Estimation of Surface Runoff for Sub-watershed of Rajkot District, Gujarat, India using SCS – Curve Number with Integrated Geo-Spatial Technique

Fenil R. Gandhi, Jayantilal N. Patel

***Abstract:** Catchment area of Rajkot District has described as a "water Scares" area, with constrained new water supplies, and is relied upon to be under water stress constantly. Along these lines, it is critical to building up any available means to supply water to maintain human life, for example, overflow gathering approach. The present paper carries the study of SCS CN methods of runoff estimation. Runoff is estimated for the 20 years for Sub-basin of Rajkot district. The Sub-basin and slope are delineated with the help of ASTER DEM in ArcGIS. The Sub-basin is selected which has maximum rain gauge stations. The Curve Number (CN) is a hydrologic parameter used to depict the stormwater flood potential for Drainage territory, and it is a component of land use, soil type, and soil Moisture. With the use of GIS integration and different thematic maps (Land use/Land cover, soil map, and slope map) Runoff volume can be found out. Landsat picture was converged with land cover data to make land use and land spread (LULC) depict. Yearly overflow quantity is gathered subject to the yearly precipitation surplus and spillover coefficient per pixel using a raster calculator in ArcGIS. Weighted curve number has been resolved so as to locate a representative curve number by incorporating attributes of different topical maps like LULC and Soil in ArcGIS using the area of LULC and soil types as weighted factors. Again the result by SCS CN method is compared with the rational formula and runoff coefficient method.*

***Key Words:** Curve Number, Geo Spatial Integration, LULC, Thematic Map, HSG, Antecedent Moisture Condition (AMC)*

I. INTRODUCTION

Water, which can be and is a valuable natural treasure on our planet as well as a cardinal component for socio-economic growth of any country. On the planet, 97% of water is available still only 3% of water is fresh water. Most important reach is, it is not uniformly distributed in quality and quantity. Water crises are increasing at a drastic rate universally. Rainfall is part of the water cycle. As rainfall occurs, not the whole quantity of water will drain off, it will be loose in the environment by infiltration, evaporation, and evapotranspiration. Loses are depends on different climatic, physical and chemical parameters. After deducting the losses the remaining water flows as a runoff. Reliable assessment of water quantity and quality, which is collected in catchment helps researchers and government authorities for planning and developing water resource system which includes the flow pattern on daily and longer time steps, seasonal distribution and characteristics of peak and bottom flow, spatial and temporal variability of flows. Runoff Estimation includes the estimation of the quantity of runoff and simultaneously it leads to making flood hydrographs in relation to high discharges. An understanding of runoff types and characteristics is essential for application of the method properly in different climatic regions.

For the sustainable development and taking a view of climatic issues in mind, rain harvesting is the best alternative method of advancement of water distribution for the sustainability of water and propelled techniques for utilizing the source effectively. Presently, agriculturists are practicing the same for the more water accessibility and to save fresh water for the future. Micro water harvesting systems with an outer catchment region are working pretty much similarly.

Precipitation and surplus water are huge comprise the useful resource for Groundwater harvesting and recharge in the basin area. Other considerable resources of reviving incorporate drainage from tanks, channels, streams, and functional irrigation. To assess the water availability, it is essential to understand the rainfall and runoff phenomenon. Remote sensing and geographical information system which different hydrological and geological data can find the best ground water recharge location, dam site etc. Measure of runoff in a watershed is influenced by geomorphological components. Generally the land use change affects the volume of overflow and the release rate fundamentally. In the Present study, we have use the Curve number method in order to quantify runoff. Also another methods are used also foe the comparison purpose. Research zone area is about 3747.94 km^2 which fall in the Rajkot district. It is the largest basin in the Rajkot district. And the selected basin includes 9 rain gauge stations. Runoff coefficient is described as the part of precipitation that ends up being prompt flow in the midst of an event. The runoff coefficient can be characterized either as the proportion of the absolute profundity of runoff to a complete profundity of rainfall or as the proportion of the pinnacle rate of runoff to rainfall force for the season of fixation (Wanielista and Yousef, 1993).

Manuscript published on 30 June 2019.
***** Correspondence Author (s)
Fenil R. Gandhi, PhD Research Scholar, Civil Engineering Department, Vallabhbhai National Institute of Technology, Surat, Gujarat, India.
Dr. Jayantilal N. Patel, Professor in Civil Engineering Department, Sardar Vallabhbhai National Institute of Technology, Surat, Gujarat, India.

Runoff coefficients can be utilized in event-based derived flood frequency models (Sivapalan et al., 2005) for evaluating flood events from rainfall frequencies. The coefficients of runoff are helpful for understanding the flood frequency controls in a specific hydrologic or climatic routine. The runoff coefficient is changes with vegetation cover, runoff, geology, landuse, soil type and available moisture. The rational runoff coefficient is strongly dependent on land use land cover and up to some extent by watershed slope.

The Runoff curve number depends on the region's hydrologic soil group, land use, moisture condition and hydrologic condition. The fundamental presumption of the SCS curve number is that, for a single rainfall event, the ratio of water stored in soil after generation of runoff to potential maximum water stored in the soil should be equal to the ratio runoff to available rainfall.

The GIS turned into a helpful and important software in hydrological modeling because it has ability to deal with a lot of spatial and attribute data. The main objective of this research work was to determine the Surface runoff of Sub watershed of Rajkot District using the Curve Number method and Geo-Spatial integration. Also, the validation of the same method with other two methods: Runoff coefficient and rational formula.

II. Materials and Methods

A. Study Area

Rajkot district is one of the 33 regions of the Indian province of Gujarat. Situated in Saurashtra zone, Rajkot city is the authoritative central station of the region. It is the third-most exceptional district in Gujarat and the fourth most crowded. This area is encompassed by Morbi in north, Surendranagar and Botad regions in east, Amreli and Junagadh regions in south and Porbandar, Jamnagar region in the west. The region involves a region of 11203 km^2.

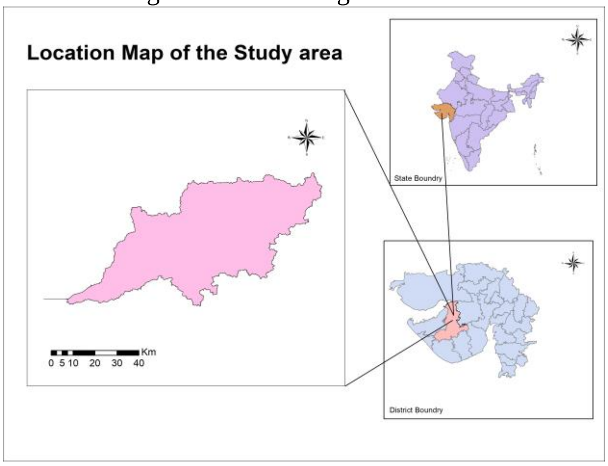

Fig 1: Location Map of Study Area

The city is located between 23°08' North scope and 20°58' North scope and 71 ° 40’ East longitudes and 70 ° 20’ East longitudes. The atmosphere does not show extremities. Normally, the summer season occurs from March to June and the temperature changes between 20 °C and 40 °C. The rainy season ranges from July to September. The average measurement of precipitation in the area is about 550 mm. The winter months are from October to February. The geography is mainly rugged and undulating because of the underlying sandstone formations. The significant waterways moving through the Rajkot are Bhadar, Aji, Machhu, Demai, and their tributaries. Some other little streams are Phulki, Jhinjhora and Ghodadro.

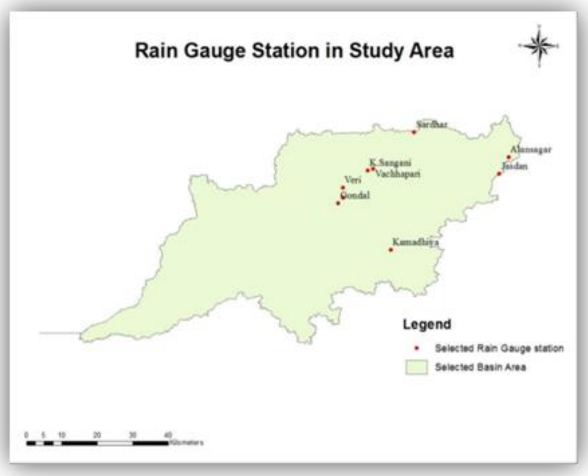

Fig 2: Rain Gauge Station in Study Area

Sub Basin is derived from the Digital Elevation Model carried out with different processes and analysis of the tools of Arc GIS software. Yearly Rainfall of this basin is 1040 mm. The Area of this basin is 3474.92 km^2. The latitude and longitude of study area basin are 70°39’39”E and 21°56’3.574”N. In this basin 9 Rain Gauge stations are covered. That includes Gondal, Gondali, Veri, Kotda Sanghani, Sadhar, Kamadhiya, vacchapari, Jasdan and Alansagar. The topography in these parts in intersected by ridges form by sandstone and intrusive dykes.

Table I: Latitude and Longitude of Rain Gauge Station in Study Area Basin

Station	Latitude	Longitude
Alansagar	22.076682	71.226183
Gondal	21.961946	70.792297
Gondali	21.975929	70.803919
Jasdan	22.035609	71.201778
K.Sangani	22.043520	70.866994
Kamadhiya	21.847503	70.926444
Sardhar	22.137973	70.985886
Vachhapari	22.047300	70.881472
Veri	22.000514	70.804160

Precipitation data of 20 years have been collected from the government authorized body. Collected data was in daily basis. Daily data is being converted in monthly data format as per the requirement of uses.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

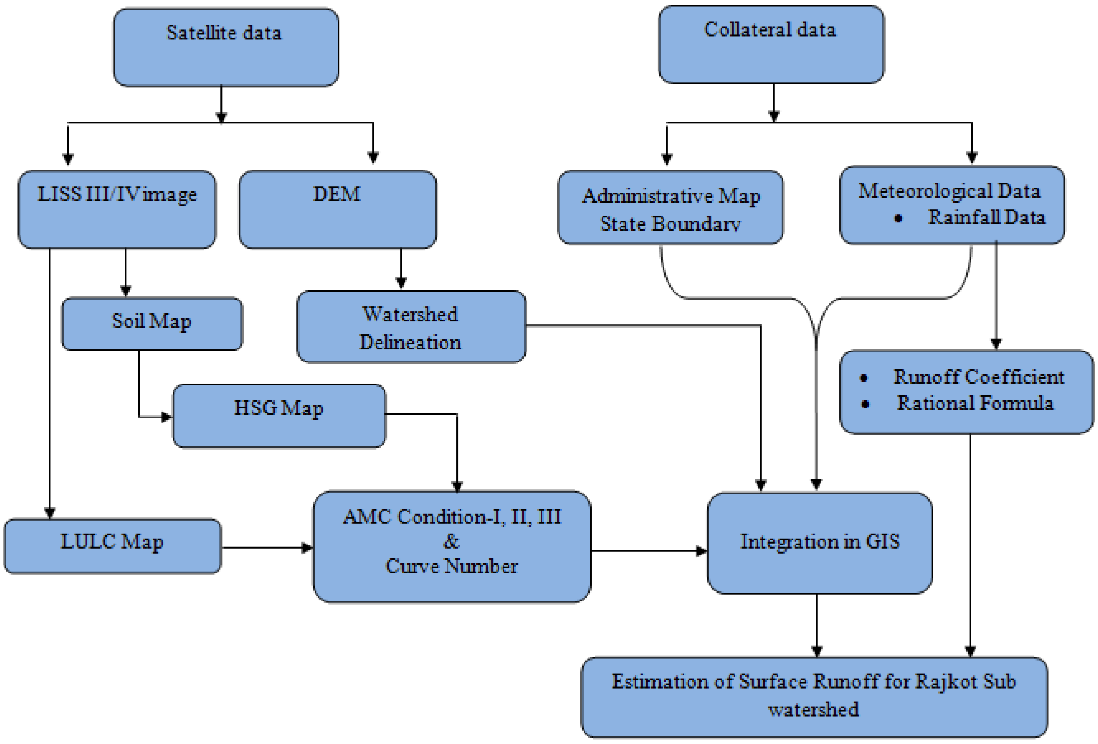

Fig 3: Flowchart showing the methodology used in present study

B. GIS-based layer configuration

Digital elevation model, impervious surface map, soil profile and landuse cover is introduced in a GIS to generate curve numbers.

Land use land cover map was created from the investigation of Landsat unsupervised classification. The land use land cover map of the research zone is shown in Fig 4 and summarized in Table II. Land use/land cover map of the research area reveals that there are eight noteworthy typess of LULC class, namely Agriculture (84.97%), Built-up (0.92%), forest (0.05%), Grass Land (0.09%), Wastelands (11.19%), Water Bodies (2.00%), Wetland (0.02%) and others (0.72%). Land use of any watershed impacts the overflow and evapotranspiration. Surface with vegetation cover will become hurdle for the runoff and it leads to infiltrate water in downward direction. This will be subjected to lower run-off coefficients (Chowdary et al. 2009; Jasrotia et al. 2009; Neil & Devi 2011; Nayak et al. 2012).

Generally soil texture allows surface water to infiltrate and storage in the same. Usually, texture of soil plays important role for water retention, as medium to fine soil have more carrying capacity of water and minerals. A soil which contain more silt with clay particles has more water retension capacities. In the present study, the soil map discloses that the region has for types of soil classes viz. clay, clay skeletal, fine and loamy. The major portion of the research zone is occupied by clay and fine soil (50.07% and 45.62%), which is spread in the central and north eastern portions of the selected research zone (Fig 5) encompassing an area of 3360.33 km^2, which is 36.95% of the total area. The high value of CN number indicates the low infiltration and high run-off..

Fig. 6 shows the hydrological soil group of research zone. From the map it can be said that major area of the research zone is covered with hydrological soil group C & D. The group D exists in the Central part of the study area encompassing an area of about 1894 km^2, Group C exists in the North-eastern and South-Western part of the study area covered 1466 km^2 and Group A exists in a small patch in the middle part of the study area.

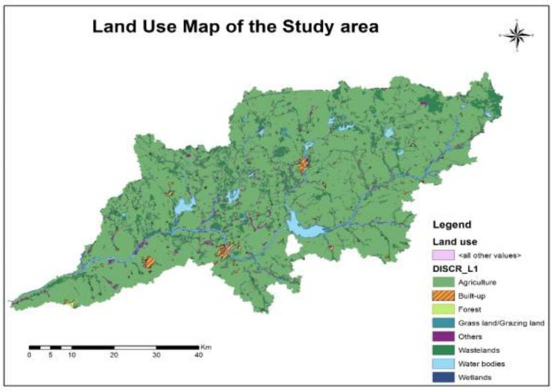

Fig 4: Land use map of the study area

Table II : Land use/Land cover Classification

Sr. No	LULC Classification	Area (%)
1	Agriculture	84.97662
2	Built-up	0.928344
3	Forest	0.058431

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

4	Grassland/Grazing land	0.093722
5	Others	0.722104
6	Wastelands	11.19507
7	Water bodies	2.005419
8	Wetlands	0.020294

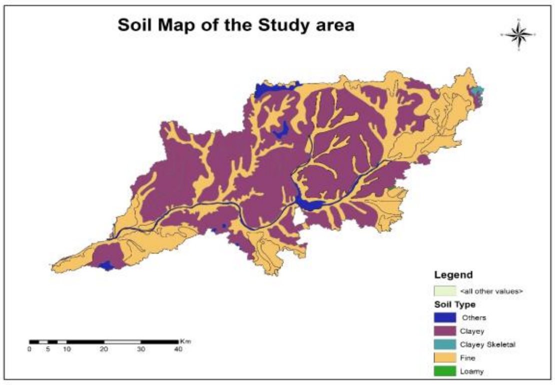

Fig 5: Soil map of the study area

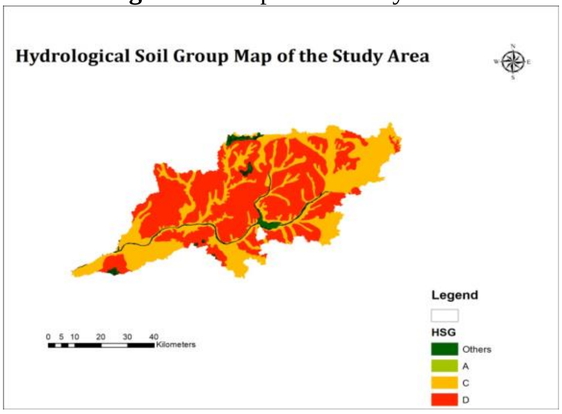

Fig 6: Hydrological soil group of the study area

C.Effects of AMC on Stormwater Runoff

The Curve Number method can be utilized to decide the measure of net runoff for the chosen sub watershed for a single-storm event. Modeling runoff from precipitation data is huge in survey the measure of water being transported by existing feasibility given the soil moisture condition (i.e., AMC I, II, or III) at the period of an rainfall event. For each expansion in AMC level, as appeared on the weighted sub-watershed Curve Number map (Figure 7), there was a comparing increment in the net runoff for a similar precipitation

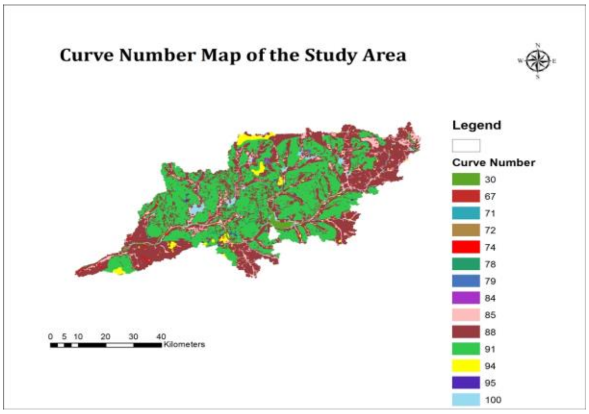

Fig 7: Curve Number map of the study area

III. Result and Discussion

A. Runoff Estimation using SCS-CN Method

Soil Conservation Service (SCS) is invented by United States Department of Agriculture (USDA) in 1975, which is very useful and reliable method for estimating runoff for small basin area.

$$\frac{Q}{P-Ia} = \frac{F}{S} \quad (1)$$

$$F = (P - Ia) - Q \quad (2)$$

Substituting eq. (2) in eq. (1) and by solving;

$$Q = \frac{P-Ia^2}{(P-Ia)+S} \quad (3)$$

Where, Q = actual runoff (mm),

P = rainfall (mm),

Ia = initial abstraction,

Which represents all the losses before the runoff begins and is given by the empirical equation

$$Ia = 0.2\,S \quad (4)$$

Substituting eq. (4) in eq. (3); the eq. (3) becomes

$$Q = \frac{(P-0.2\,S)^2}{(P+0.8\,S)}$$

$$For, P > Ia(0.2\,S) \quad (5)$$

S = the potential infiltration after the runoff begins given by following equation.

$$S = \frac{25400}{CN} - 254 \quad (6)$$

The CN is a unit less property ranging from 0 to 100. It is based on land-cover, Hydrological Soil Group, and Antecedent Moisture Condition. Hydrological Soil Group is depends on the soil infiltration rate and characterized in four groups (A,B,C,D). According to rainfall limits for dormant and growing seasons, Antecedent Moisture Condition is expressed in three levels (I, II and III). CN value can adopted from Technical release (TR-55). This method was applicable for 15 km^2 watershed area originally and afterwards the method get modified for larger watershed area and weighing curve number introduced respect to Watershed/land cover area. Equation (7) shows Weighted Curve Number.

$$CN_w = \frac{\sum CN_i * A_i}{A} \quad (7)$$

Where, CN_W = weighted curve number;

CN_i = Curve number from 1 to any number N.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

Table III: Computation of Curve Number using soil map and land use

Sr.No.	Different Classes	Soil Type	HSG	Area Sq. M	% Area	CN	A*CN	WCN
1	**Agriculture**	Clayey	D	405091468.43	14.73	91	1340.4	
		Clayey Skeletal	C	343213952.89	12.48	88	1098.2	
		Fine	C	434792675.9	15.81	88	1391.3	
		Loamy	A	508770683.37	18.5	72	1332	
		Other		1058243021.41	38.48	30	1154.4	
		Total		**2750111802.00**				
2	**Built up**	Clayey	D	212662.19	17.47	95	1659.7	
		Clayey Skeletal	C	0.00	0	94	0	
		Fine	C	167743.842	13.78	94	1295.3	
		Loamy	A	0.00	0	89	0	
		Other		836893.26	68.75	30	2062.5	
		Total		**1217299.29**		90		
3	**Forest**	Clayey	D	937278.50	40.12	67	2688	
		Clayey Skeletal	C	0.00	0	64	0	
		Fine	C	0	0	64	0	
		Loamy	A	0.00	0	33	0	
		Other		1398909.19	59.88	30	1796.4	
		Total		**2336187.70**				
4	**Grass land/Grazing land**	Clayey	D	4184.51	23.66	84	1987.4	
		Clayey Skeletal	C	0.00	0	79	0	
		Fine	C	13501.4924	76.34	79	6030.9	
		Loamy	A	0.00	0	49	0	
		Other		0.00	0	30	0	
		Total		**17686.00**		79	0	68.065
5	**Wastelands**	Clayey	D	4716202500.00	8.95	88	787.6	
		Clayey Skeletal	C	6539449500.00	12.41	85	1054.9	
		Fine	C	9785461500.00	18.57	85	1578.5	
		Loamy	A	11318886000.00	21.48	71	1525.1	
		Other		20335000500.00	38.59	30	1157.7	
		Total		**52695000000.00**		83	0	
6	**Water bodies**	Clayey	D	14719967.78	24.43	100	2443	
		Clayey Skeletal	C	0.00	0	100	0	
		Fine	C	29265199.97	48.57	100	4857	
		Loamy	A	0.00	0	100	0	
		Other		16268486.70	27	30	810	
		Total		**60253654.45**		0	0	
7	**Wetlands**	Clayey	D	141913.23	45.49	100	4549	
		Clayey Skeletal	C	0.00	0	100	0	
		Fine	C	978547.26	18.49	100	1849	
		Loamy	A	0.00	0	100	0	
		Other		135520.4371	27	30	810	
		Total		**610263215.87**				
8	**Others**	Clayey	D	133916376.20	34.17	78	2665.3	
		Clayey Skeletal	C	0.00	0	74	0	

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

		Fine	C	88101847.73	22.48	74	1663.5	
		Loamy	A	0.00	0	73	0	
		Other		**169893910.1**	43.35	30	1300.5	
		Total		**3474962134.05**				

Table IV shows the calculation of weighted curve number, which is 68.065. Here for the study AMC II is considered. Also the table 6 shows the calculation of runoff as well Infiltration. From the figure 8, it can be seen that maximum runoff generates in July month, as precipitation is also higher in July month.

Table IV: Computation of direct runoff using SCS-CN method for year 1990-2010

Month (1990-2010)	Total R.F.(P) mm	CN (mm)	S(mm)	Ia(mm)	P-Ia (mm)	P - Ia + S (mm)	Q= (P-Ia)^2/(P-Ia+S) (mm)	(P-Q) Infiltration (mm)
June	134.05	68.06	119.20	23.84	110.21	229.41	52.95	81.11
July	212.90	68.06	119.20	23.84	189.06	308.26	115.95	96.95
August	136.97	68.06	119.20	23.84	113.13	232.33	55.08	81.88
September	96.26	68.06	119.20	23.84	72.42	191.62	27.37	68.89
October	16.20	68.06	119.20	23.84	-7.64	111.56	0.52	15.67

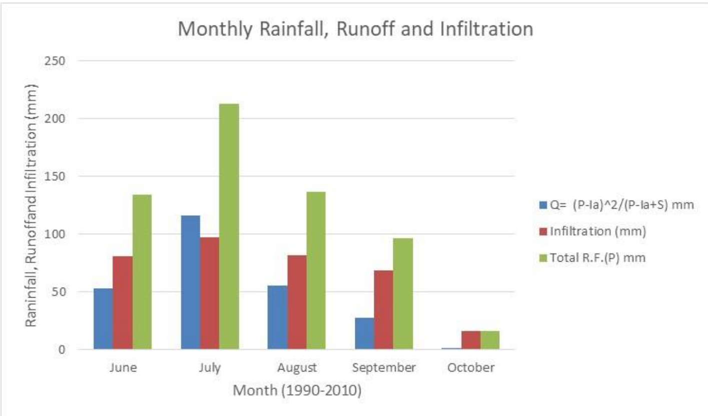

Fig 8: Month wise Rainfall Runoff and Infiltration of the Study Area

B. Runoff Estimation using Rational Method

The Rational equation is easiest method to obtain peak runoff from watershed. It is not much precise method as the SCS TR-55 method, but is the most common and quick method to estimate runoff.

Rational Equation: Q= CIA (8)

Where, Q = Peak discharge, cfs

C = Runoff coefficient (Rational method)

I = Rainfall intensity, mm/hour

A = Drainage area

As the equation shows, the rational method runoff coefficient (c) can be defined as a function parameters soil and drain slope. The Rainfall intensity can be found from Intensity/Duration/Frequency bends for precipitation occasions in the topographical district of sub basin. The duration is commonly same as the season of centralization of the seepage territory. The precipitation frequency is expressed by nearby governing bodies relying upon the impact of the development. A 10-yr, 25-yr, 50-yr, 75 yr, or 100-yr might be indicated.

Table V: Calculation of Value 'C'

Land Use	Area	Value of C	Area* C	Final Value of C
Agriculture	2750.11	0.0605	166.382	0.06
Built-up	46.25	0.0625	2.89063	
Forest	2.336	0.15	0.3504	
Grass land/Grazing land	5.14	0.0175	0.08995	
Wastelands	526.95	0.05	26.3475	
Water bodies	103.81	0.095	9.86195	
Wet lands	1.11	0.9	0.999	
Other	39.19	0.2	7.838	
Total	3474.89		214.759	

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

Table VI shows the calculation of rational method runoff coefficient, which is 0.06. Also the Table VI shows the calculation of runoff from the rational formula. From the fig 9 it can be seen that maximum runoff generates in July month, as precipitation is also higher in same month.

Table VI: Calculation of Runoff from Rational Formula

Month	Average Rainfall of all station (mm)	Average Intensity of Rainfall (mm)	Area (Km^2)	Q= CIA (mm)
June	134.054	0.335	3474.92	69.874
July	212.897	0.515		107.390
August	136.965	0.331		69.0885
September	96.261	0.240		50.175
October	16.193	0.039		8.1697

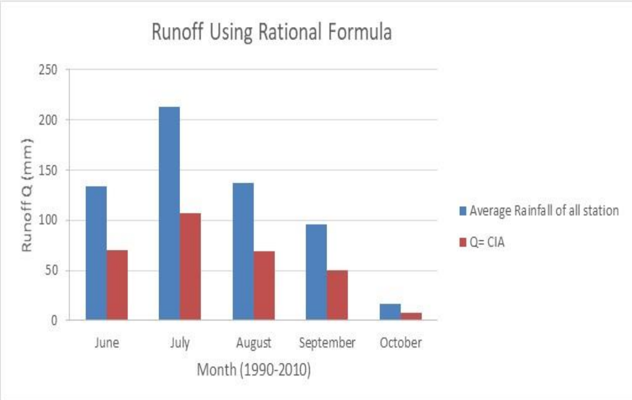

Fig 9: Runoff using Rational method

C.Estimation of Runoff using Runoff Coefficient

Above-mentioned method can be a site-specific method, because it does not consider physical condition of catchment area. It is difficult to find homogeneous conditions in whole watershed region. Even at the small level there may be different varieties of slopes, soil conditions, vegetation covers etc.

Runoff = K x Rainfall depth (in mm) (9)

In rural area, there may be no or small parts of the area are impervious. The Coefficient K described as the percentage of runoff resulting from a rainfall. Value of K is not a constant as it highly depends on catchment-specific factors and on the rainfall characteristics.

All the way, the runoff coefficients for larger area of watersheds cannot be utilising for smaller catchment areas.

$$K = \frac{Runoff\ (mm)}{Rainfall\ (mm)} \quad (10)$$

Initially, for the estimation of runoff data certain amount of rainfall is needed before occurance of runoff, which is known as threshold rainfall which represents the initial abstractions, evaporation, infiltration etc.

S. No.	Type of area	Value of K: Flat land 0 to 5% slope	Rolling land 5% to 10% slope	Hilly land 10% to 30% slope
(a)	Urban areas			
	30% area impervious (paved)	0.40	0.50	—
	50% area impervious (paved)	0.55	0.65	—
	70% area impervious (paved)	0.65	0.80	—
(b)	Single family residence in urban areas	0.3		
2.	*Cultivated Areas*			
	Open Sandy Loam	0.30	0.40	0.52
	Clay and Silt Loam	0.50	0.60	0.72
	Tight Clay	0.60	0.70	0.82
3.	*Pastures*			
	Open Sandy Loam	0.10	0.16	0.22
	Clay and Silt Loam	0.30	0.36	0.42
	Tight Clay	0.40	0.55	0.60
4.	*Wooded land or Forested Areas*			
	Open Sandy Loam	0.10	0.25	0.30
	Clay and Silt Loam	0.30	0.35	0.50
	Tight Clay	0.40	0.50	0.60

Fig 10: Runoff Coefficient, K
(Source: S.K.Garg, Hydrology and water Resources Engineering)

Table VII: Calculation of Runoff coefficient, K

Land Use	Area (km^2)	Value of Coefficient K	Area X Value of K	Coefficient K
Agriculture	2750.11	0.6	1650.07	0.590
Built-up	46.25	0.65	30.0625	
Forest	2.336	0.35	0.8176	
Grass land/Grazing land	5.14	0.6	1.799	
Wastelands	526.95	0.36	316.17	
Water bodies	103.81	0.35	37.37	
Wet lands	1.11	0.35	0.38	
Other	39.19	0.25	13.72	
Total	3474.89		2050.39	

Table VII shows the calculation of rational method runoff coefficient, which is 0.06. Also the table VIII shows the calculation of runoff from the rational formula. From the fig 11, it can be seen that maximum runoff generates in July month, as precipitation is also higher in July month

Table VIII: Calculation of Runoff using Runoff Coefficient

. Month	Average Rainfall of all station	Value of K	Q=K*P
June	134.0547619	0.59	79.09
July	212.8971958		125.61
August	136.965291		80.81
September	96.2615873		56.79
October	16.1962963		9.55

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

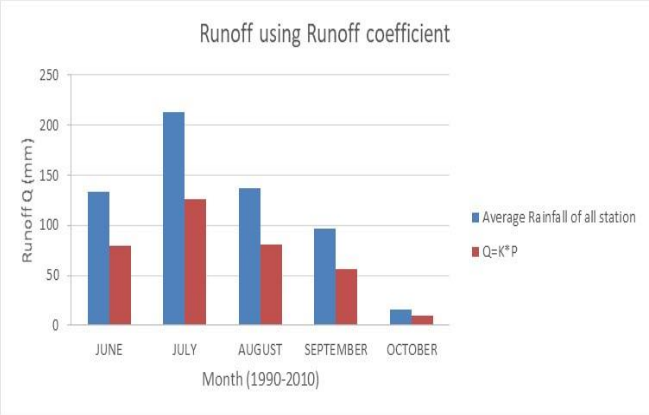

Fig 11: Runoff using Runoff Coefficient

D.Comparison of Different Runoff Estimation method

Table XI shows that in July month there is maximum rainfall intensity found that is 0.77 if we consider average rainfall occurring time 12 hr. Also it is found that in all three methods maximum discharge found in month of July. And also the minimum rainfall occurs in October month.

Table XI: Comparison of Runoff by different methods

Year/Month	Avg. Rainfall (mm)	Avg. Intensity of Rainfall	Q = CIA (mm)	Q=K X P (mm)	Q (SCS-CN) (mm)
June	134.05	0.50	69.87	79.09	52.95
July	212.89	0.77	107.390	125.61	115.95
August	136.96	0.49	69.08	80.81	55.08
Sept.	96.26	0.36	50.17	56.79	27.37
Oct.	16.19	0.058	8.17	9.55	0.52

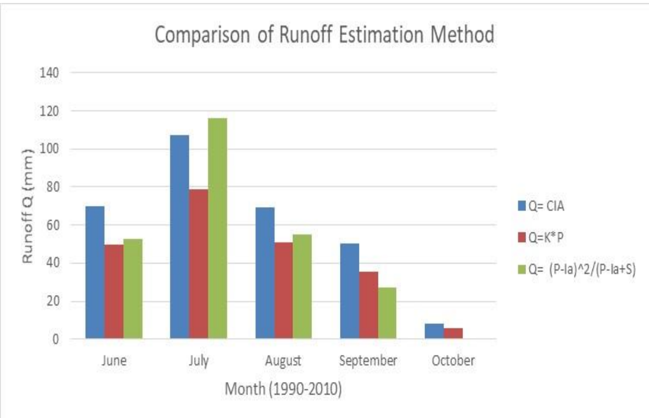

Fig 11: Runoff using Runoff Coefficient

IV. CONCLUSION

Present paper shows the estimation of runoff with the use of SCS Curve Number methods. For the study Rajkot district is selected. With the use of different maps and GIS data the numbers of watersheds found in Rajkot district. But the watershed is selected which have maximum rain gauge stations.

From the study it can be said that, the runoff coefficient equation cannot be rational, because the runoff not only depends upon the precipitation, but also depends upon the recharge of the basin. But the equation gives good results, as the imperviousness of drainage area increases and the value of K tends to approach unity. This formula is frequently used in the design of storm water drains and small water projects, especially the urban area, where the percentage of imperviousness is higher. Also this method should be avoided for rural areas and major storm analysis

In this study the Curve Number model is utilized for study of different thematic maps like, land use map and soil map which is described in ArcGIS, as input. The methodology for the tenacity of runoff utilizing GIS and curve number approach can be applied in another watershed of Rajkot district also.

In Curve number method Antecedent moisture condition of the soil plays a very meaningful role because the CN number varies according to the soil types i.e., clayey, Clayey skeletal, Loamy, fine and that is useful for runoff depth.

For a given study area watershed CN number is calculated equals to 68.06 for AMC –II.

As a closing comment, it tends to be demonstrated that Curve Number method is demonstrated as a better for estimation of surface runoff. It facilitates to handle large amount of extensive data set as well as a larger environmental area to identify site selection of artificial recharge structures and dam location too.

REFERENCE

1. Ajmal, Muhammad, et al. "Investigation of SCS-CN and its inspired modified models for runoff estimation in South Korean watersheds." Journal of hydro-environment research 9.4 (2015): 592-603.
2. Bo, X. I. A. O., et al. "Application of the SCS-CN model to runoff estimation in a small watershed with high spatial heterogeneity." Pedosphere 21.6 (2011): 738-749.
3. Bo, X. I. A. O., et al. "Application of the SCS-CN model to runoff estimation in a small watershed with high spatial heterogeneity." Pedosphere 21.6 (2011): 738-749.
4. Chen, Ying, et al. "Uncertainty in simulation of land-use change impacts on catchment runoff with multi-timescales based on the comparison of the HSPF and SWAT models." Journal of Hydrology (2019).
5. El Osta, M. M., and M. H. Masoud. "Implementation of a hydrologic model and GIS for estimating Wadi runoff in Dernah area, Al Jabal Al Akhadar, NE Libya." Journal of African Earth Sciences 107 (2015): 36-56.
6. Kayet, Narayan, et al. "Evaluation of soil loss estimation using the RUSLE model and SCS-CN method in hillslope mining areas." International Soil and Water Conservation Research6.1 (2018): 31-42.
7. Lal, Mohan, S. K. Mishra, and Mukesh Kumar. "Reverification of antecedent moisture condition dependent runoff curve number formulae using experimental data of Indian watersheds." Catena 173 (2019): 48-58.
8. Patil, J. P., et al. "Evaluation of modified CN methods for watershed runoff estimation using a GIS-based interface." Biosystems engineering 100.1 (2008): 137-146.
9. Petroselli, A., S. Grimaldi, and N. Romano. "Curve-Number/Green-Ampt mixed procedure for net rainfall estimation: a case study of the Mignone watershed, IT." Procedia Environmental Sciences 19 (2013): 113-121.
10. Reshmidevi, T. V., R. Jana, and T. I. Eldho. "Geospatial estimation of soil moisture in rain-fed paddy fields using SCS-CN-based model." Agricultural water management 95.4 (2008): 447-457.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

11.Rico, M., Gerardo Benito, and A. Barnolas. "Combined palaeoflood and rainfall–runoff assessment of mountain floods (Spanish Pyrenees)." Journal of Hydrology 245.1-4 (2001): 59-72.
12.Sahu, R. K., S. K. Mishra, and T. I. Eldho. "Comparative evaluation of SCS-CN-inspired models in applications to classified datasets." Agricultural water management 97.5 (2010): 749-756.
13.Sahu, R. K., S. K. Mishra, and T. I. Eldho. "Comparative evaluation of SCS-CN-inspired models in applications to classified datasets." Agricultural water management 97.5 (2010): 749-756.
14.Shadeed, Sameer, and Mohammad Almasri. "Application of GIS-based SCS-CN method in West Bank catchments, Palestine." Water Science and Engineering 3.1 (2010): 1-13.
15.Shadeed, Sameer, and Mohammad Almasri. "Application of GIS-based SCS-CN method in West Bank catchments, Palestine." Water Science and Engineering 3.1 (2010): 1-13.
16.Singh, Vishal, and Manish Kumar Goyal. "Curve number modifications and parameterization sensitivity analysis for reducing model uncertainty in simulated and projected streamflows in a Himalayan catchment." Ecological engineering 108 (2017): 17-29.
17.Tasdighi, Ali, Mazdak Arabi, and Daren Harmel. "A probabilistic appraisal of rainfall-runoff modeling approaches within SWAT in mixed land use watersheds." Journal of hydrology 564 (2018): 476-489.
18.Uwizeyimana, Dieudonne, et al. "Modelling surface runoff using the soil conservation service-curve number method in a drought prone agro-ecological zone in Rwanda." International Soil and Water Conservation Research 7.1 (2019): 9-17.\
19.Viji, R., P. Rajesh Prasanna, and R. Ilangovan. "Modified SCS-CN and Green-Ampt methods in surface runoff modelling for the kundahpallam watershed, nilgiris, western ghats, india." Aquatic Procedia 4 (2015): 677-684.
20.Viji, R., P. Rajesh Prasanna, and R. Ilangovan. "Modified SCS-CN and Green-Ampt methods in surface runoff modelling for the kundahpallam watershed, nilgiris, western ghats, india." Aquatic Procedia 4 (2015): 677-684.
21.Walega, Andrzej, and Tomasz Salata. "Influence of land cover data sources on estimation of direct runoff according to SCS-CN and modified SME methods." Catena 172 (2019): 232-242.
22.Zhan, Xiaoyong, and Min-Lang Huang. "ArcCN-Runoff: an ArcGIS tool for generating curve number and runoff maps." Environmental modelling & software 19.10 (2004): 875-879.

AUTHORS PROFILE

Mr. Fenil R. Gandhi, I have completed Bachelor degree in Civil Engineering from Gujarat Technological University and post graduation in Water resources engineering from The M .S. University of Baroda. Presently working as PhD research scholar at S.V. National Institute of Technology, Surat, India. Total 3 years of experience including field and academics. Published 6 research paper in national and international conferences and journal. More than 3 memberships in nation and international societies. Also working as a reviewer in international journal.

Dr. Jayantilal N. Patel, Presently working as Professor of Civil Engineering at S.V. National Institute of Technology, Surat, India since 32 years. Area of research is Water Resources Engineering, Geospatial Technologies and Computational techniques. Total Experience of more than 34 years. Also acted as Head of Civil Engineering Department as well as Applied Physics Department at the same Institute. Also acting at present as Dean (Alumni and Resource Generation) at the same Institute. Published more than 150 research papers and 06 books. Completed 05 research projects and 50 consultancy projects. Acting as reviewer / member of editorial board of 18 International journals. Guided / guiding 14 Ph.D. students. Received 08 awards. Member of 10 technical societies. Delivered 70 expert

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)