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Estimation of Runoff using SCS-CN Method for Yelahanka Region

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Abstract
Floods are among the most destructive acts of nature. . Loss of wetland and vegetation due to urbanization is the reason behind frequent floods during heavy rainfall in Bengaluru. Recalling the recent disaster occurred in Bengaluru, the South –West monsoon was supposed to wind up by the end of September, but it extended to few more days causing overflowed lakes situation and many parts of the city were inundated. Surface runoff is directly responsible for flood in an area thus, understanding the complex relationship of rainfall-runoff for a watershed is necessary Present work focuses on estimating direct runoff using Soil Conservation Service Curve Number (SCS-CN) method, one of the popular and widely used method to estimate the direct runoff from a watershed. SCS–CN method based on all the three antecedent moisture conditions (AMC I, AMC II and AMC III) were used for the present study. For the purpose of applying the SCS-CN method, Yelahanka region is selected as study area. Rainfall data for 17 years (2000-2017) was collected from the meteorological department. In addition, Land use and Land cover maps were used. This study is usefull for watershed development and planning of water resources effectively. The results reveals that SCS – CN method is a promising potential and reliable method to estimate the runoff of the Yelahanka watershed area.
Key words: Curve number, urban flood, runoff, watershed, land use and land cover.

Introduction
Water is one of the most demanded and precious natural resource. The availability of fresh water in the world is always constant when we compare with the spatial and temporal variations. Due to the rapid growth in the population the demand of water is also increasing rapidly. There are mainly certain reasons that effect insufficiency of water in certain region. Mainly the effect of drought plays a major role in decreasing the water quantity of a particular place which will ultimately increase in the demand of water in that region.[1] It is a very challenging task for human beings to delineate the causes and consequences of water stress and variability [2]. Moreover, it is the responsibility of water scientists, hydrologists and water engineers to make people understand the inherent phenomena, the prevailing ecosystem and the inter-relationship of the components. Floods are among the most destructive acts of nature. Loss of wetland and vegetation due to urbanization is the reason behind frequent floods during heavy rainfall in Bengaluru. Recalling the recent disaster occurred in Bengaluru, the South –West monsoon was supposed to wind up by the end of September, but it extended to few more days causing overflowed lakes situation and many parts of the city were inundated. Surface runoff is directly responsible for flood in an area thus, understanding the complex relationship of rainfall-runoff for a watershed is necessary. There have been many models developed in the rain-flow analysis; relation of rainfall-runoff is a discharge based approach to predict the rain that enters the watershed. Rainfall-runoff method is a mathematical method describing the rainfall-runoff relations of a watershed area [3]. Present work focuses on estimating direct runoff using Soil Conservation Service Curve Number (SCS-CN) method, one of the popular and widely used method to estimate the direct runoff from a watershed. SCS–CN method based on all the three antecedent moisture conditions (AMC I, AMC II and AMC III).The Runoff curve numbers map was obtained by combining these Empirical and SCS table. The Important source of water is rainfall and for most of the hydrological elements, rainfall is used as one of the main elements to estimate the runoff process [4]. For this purpose Yelahanka is selected as study area. Rainfall data were collected for a period of 17 years from 2000 to 2017 on monthly basis. In addition, an attempt is also made to analyze the flood frequency to predict the possibility of flood.

Study Area
Yelahanka, Bengaluru, Karnataka, India is located with the GPS coordinates of 13° 6' 27.2448" N and 77° 34' 16.3128" E. with the elevation of 907 meters above mean sea level. It lies to the north of Bengaluru, an administrative capital of Karnataka (1). Karnataka Hosing Board (KHB) developed this well planned city in the early 1980s. This township is also identified by several names like 'Yelahanka Upanagar; 'Yelahanka Satellite Town; 'Yelahanka New town' (2).
Yelahanka has several lakes surrounding it, adjoining: Old Yelahanka, Puttenahalli, Attur, Ananthapura and Allalasandra. The lake at Puttenahalli has been declared a bird sanctuary. Most of these are either dry or are in bed condition due to emptying to untreated sewerage effluents into them. The city is on the verge of being the prime real estate hub in North Bengaluru owing to its vast undeveloped areas and easy access to the Kempegowda International Airport. Yelahanka has seen remarkable developments since its inception.

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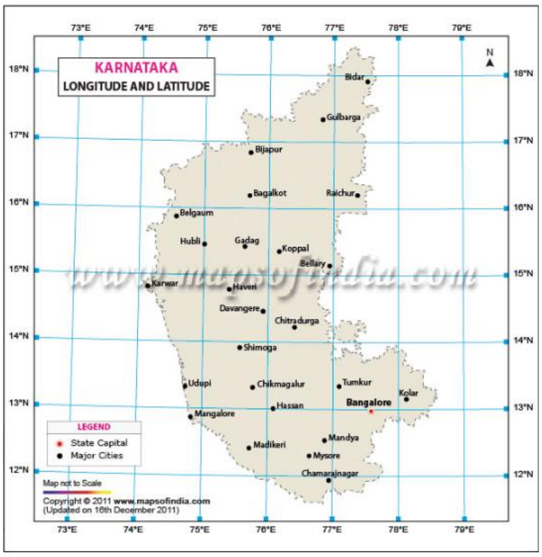

Figure1: Map of Karnataka (Source: Maps of India)

Figure 2: Study area; Yelahanka (Source: Compare Infobase Ltd.)

Methodology and Data

Since 1969, SCS-CN method has explored many research study applied widely in the analysis of flood.SCS-CN technique and its capabilities can be summed up as follows: [5]

i. Simple and robust method supported by empirical data estimates the surface runoff based on rainfall depth.

ii. Relies only on one parameter, Curve Number (CN). CN can have a hypothetical rang of 0-100 but in practice it is more likely fall within the range of 40-98.

iii. Features of SCS_CN can be readily captured and reasonably documented.

iv. Well established and widely accepted method worldwide.

The adopted methodology for this work is shown in the form of flowchart in 3. Land use and Land cover details with soil details were extracted from Survey of India toposheet and satellite image LISS III. Daily rainfall data for Yelahanka watershed were used/collected with the courtesy of Karnataka State Natural Disaster Monitoring Centre, Yelahanka, Bengaluru.

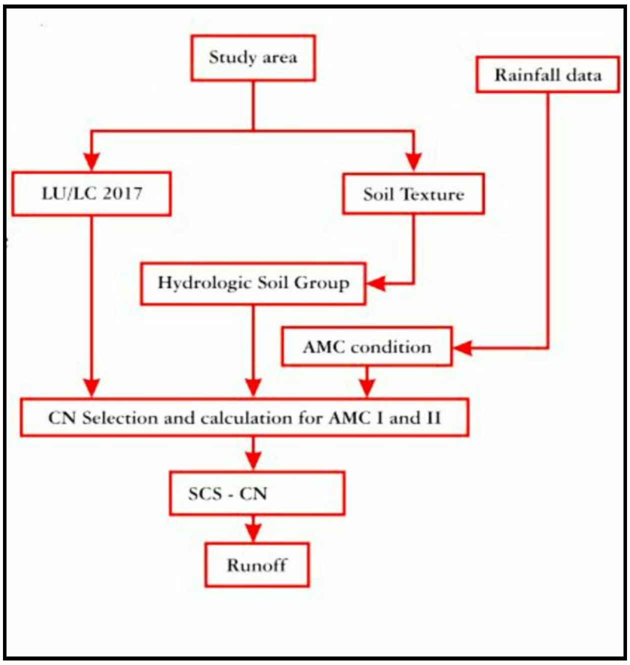

Figure3: Work flow chart for SCS-CN method

SCS-CN Equation for Indian Condition

Values of λ varying in the range of $0.1 \leq \lambda \leq 0.4$ have been documented in a number f studies from various geographical locations .For Indian conditions λ=0.1 and 0.3 subjected to certain constraints of soil type and AMC type has been recommended as below;

$Q=(P-0.1S)^2/P+0.9S$ for $P > 0.1S$, valid for Black soils under AMC of Types 2 and 3

$Q=(P-0.3S)^2/P+0.7S$ for $P>0.3S$, valid for Black soils under AMC of type 1 and for all other soils having AMC of types 1,2 and 3 [6].

Results and discussions

Table No.1 presents the calculation of surface runoff using SCS-CN method for 17 years of rainfall data (2000-2017). An exercise was carried out converting these data from daily to monthly time scale. Relevant SCS-CN equations sequentially with rainfall data following surface runoff is derived on monthly time scale. It is important to note that the surface runoff obtained from 2005 year onwards is typically high and the reason may be due to change in the land use/land cover pattern on account of urbanization. However, this had no sever impact on this watershed area.

Table: 1a. Calculation of runoff by SCS-CN method (Jan to Jun)
(P-Rainfall; R-Runoff; meteorological data in 'mm')

YEAR		JUL	AUG	SEP	OCT	NOV	DEC
2000	P	78.9	178.7	222.7	168	0	0.5
	R	42.7	134.3	176.7	124	0	1.97
2001	P	112	83.6	246	156	35	7.6
	R	71.8	46.67	199.4	113	9.58	0.04
2002	P	36.5	45.5	94.8	173	38	4.9
	R	15.2	24.0	38.5	69.2	11.2	1.2
2003	P	96.2	139	77.4	208	27	2.6
	R	57.7	96.76	41.39	163	5.19	1.05
2004	P	285	74.6	269	153	26	0
	R	303	93.57	287.2	171	47	0
2005	P	163	229	181	606	61	9.1
	R	119	182.9	136.5	555	28	0
2006	P	46.3	50.3	45.3	50	42	0.3
	R	17	19.86	16.29	19.6	14	2.07
2007	P	217	229	271	156	36	42
	R	171	182.9	223.8	113	10.2	14
2008	P	283	310	139	194	66	0.9
	R	236	262.1	96.76	149	32	1.77
2009	P	33.3	127.1	259.8	41.3	64.9	10.6
	R	8.58	85.69	212.9	13.6	31.1	0.06
2010	P	157	108	137.5	166	145	10.5
	R	114	68.23	95.36	122	102	0.05
2011	P	49.5	236.1	125.5	163.0	51.5	5.0
	R	19.3	189.8	84.22	119	20.7	0.38
2012	P	77.0	148.5	52.5	19.0	12.0	23.5
	R	41.1	105.7	21.48	1.84	0.19	3.57
2013	P	134.0	107.0	268.0	82.0	143.0	0.0
	R	92.1	67.32	220.9	45.3	101	0
2014	P	106.5	40.5	196.0	292.0	23.0	1.5
	R	66.9	13.05	150.9	244	3.36	1.49
2015	P	75.5	104.5	254.0	143.5	232.0	3.5
	R	39.8	65.07	207.2	101	186	0.76
2016	P	204	28.71	62.46	30.6	4.94	68
	R	158	6.053	29.14	7.03	0.39	33.6
2017	P	38.5	199	287.5	267	12	9.5
	R	11.8	153.8	240	220	0.19	0.01

Table: 1b. Calculation of runoff by SCS-CN method (Jul to Dec)

YEAR		JAN	FEB	MAR	APR	MAY	JUN
2000	P	0	72.8	0	59.8	93.2	116.7
	R	0	37.5	0	27.05	55	76.13
2001	P	0.6	0	1.2	332	58.6	27.4
	R	1.915	0	1.62	283.7	26.1	5.386
2002	P	0	0	0	8.8	184	181
	R	0	0	0	2.4	48.5	82.5
2003	P	0	1.8	3.3	84.1	1.3	86
	R	0	1.36	0.82	47.1	1.58	48.74
2004	P	5	1.6	1.2	51.3	208	70
	R	38.92	69.6	85.9	70.76	226	89.04
2005	P	0.6	7.7	0.2	80.3	150	108
	R	1.915	0.04	2.13	43.85	107	68.23
2006	P	0.5	0	89	37.8	164	156
	R	1.967	0	51.3	11.31	120	112.7
2007	P	0	0	0	133	120	47.7
	R	0	0	0	91.16	79.2	17.98
2008	P	0	20	60	12.2	89.8	117
	R	0	2.19	27.2	0.22	52	76.41
2009	P	0	0	14.6	54.4	150	52.7
	R	0	0	0.63	22.9	107	21.63
2010	P	5.4	0	0	75.1	125	83.2
	R	0.306	0	0	39.46	83.5	46.33
2011	P	0.0	22.5	0.5	140.0	126.0	40.0
	R	0	3.15	1.97	97.69	84.7	12.72
2012	P	2.0	0.0	0.5	10.0	107.5	23.0
	R	1.278	0	1.97	0.024	67.8	3.357
2013	P	0.0	4.5	2.5	6.5	131.0	192.0
	R	0	0.49	1.09	0.142	89.3	147.1
2014	P	0.0	0.0	2.5	5.5	53.5	111.5
	R	0	0	1.09	0.288	22.2	71.4
2015	P	11	0.0	22.5	168.5	220.0	116.0
	R	0.09	0	3.15	124.6	174	75.49
2016	P	4.7	0.04	4.15	10.44	118	144.6
	R	0.446	2.22	0.58	0.048	77.1	102
2017	P	0	0	8.5	9	280	59
	R	0	0	0	0	232	26.42

(P-Rainfall; R-Runoff; meteorological data in 'mm')

Flood Frequency Analysis

Floods as discussed are exceedingly complex natural events and are very difficult to model analytically. Statistical method of frequency analysis is an important approach for the prediction of flood flows. For this case the hydrological data series are arranged in the decreasing order of magnitude and the probability (p) of each event is calculated by the plotting position formula as:

$$p = m/(N+1)$$

Where, m=order number of the event and N= total number of events in the data.

The return period, T is calculated as:

$$T = 1/p$$

Table 2: Flood Frequency Analysis

Year	Rainfall	Runoff	Rank	Probability (%)	Return period (years)
2005	606	599.395722	1	0.0526	19.0
2008	310	302.673797	2	0.1053	9.5
2014	292	286.652406	3	0.1579	6.3
2017	287.5	279.771123	4	0.2105	4.8
2004	285	277.513369	5	0.2632	3.8
2007	271	263.727273	6	0.3158	3.2
2013	268	260.513369	7	0.3684	2.7
2009	259.8	251.885561	8	0.4211	2.4
2015	254	247.235294	9	0.4737	2.1
2001	246	238.780749	10	0.5263	1.9
2011	236.1	229.335294	11	0.5789	1.7
2000	222.7	215.213369	12	0.6316	1.6
2003	208	200.807487	13	0.6842	1.5
2016	203.69	196.256845	14	0.7368	1.4
2002	184	175.97861	15	0.7895	1.3
2010	166	158.486631	16	0.8421	1.2
2006	164	156.245989	17	0.8947	1.1
2012	148.5	141.441176	18	0.9474	1.1

(Meteorological data in 'mm')

Conclusion

Flood frequency analysis of rainfall computed for Yelahanka region revealed that, maximum and minimum rainfall occurred in the year 2005 and 2012 respectively with the return period of 19 years and 1.1 year. The possibility of occurrence of flood during heavy rainfall event was experimented using SCS-CN method. It is learnt that, conducting study on account of possibility of changes in the Land use & Land cover and checking the return period of the peak runoff would help in taking measure for the safety of the crops and properties of the adjacent land. Further, study has also revealed about the improper maintenance of public utility such as roads and drainage may likely trigger the possibility of the occurrence of flood. Hence every measure shall be taken to cease the urbanization and encourage for sustainable development.

This study also helps the stake holders for effective planning as listed below.

i. Watershed management for conserving Soil and Water.
ii. Flood management and mitigation
iii. Rain Water Harvesting & recharging methods for flood mitigation
iv. Methods for improving the ability of land to hold water.

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