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Evaluation of Synthetic Unit Hydrograph (SCS) and Rational Methods in Peak Flow Estimation (Case Study: Khoshehaye Zarrin Watershed, Iran)

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Abstract The leakage of statistic and data of hydrometry gages is the one of basic difficulties in peak flow estimation with different return periods, because of this estimation of peak flow in these gages are more importance. Khoshehaye Zarrin watershed did not have any hydrometry gages So, the present research is conducted with goal of determining amount of peak flow with two methods that mentioned in the title, firstly we calculated the run-off coefficient and rainfall intensity in each sub basin with Rational method, then with calculating of run-off height by curve number, peak flow was calculated for each sub basin and according to this, the dimensionless unit hydrograph was drawn. For assessment of accuracy of these two methods, we compared their results with nearest gage. The results showed that SCS method has accurate estimation than Rational method and it can be used for peak flow estimation in the similar condition watersheds.

Keywords Peak Flow, Synthetic Unit Hydrograph, Rational, Khoshehaye Zarrin Watershed, Iran

1. Introduction

Nowadays peak flow estimation from storms in small basins and no-statistics especially is very important for hydrologists[4]. Peak estimation from precipitation is always one of the basic problems of the watershed and it causes that many of implemented projects are encountered with numerous problems[2,9]. Therefore using of peak flow estimation methods is very important in no-gage watersheds and selection of the most accurate estimation seems necessary with use of available statistics[16]. Several researches have conducted about evaluation of peak flow estimation methods[10,12,14,17,1]. Shahmohammadi studied peak flow estimation with use of SCS, Triangular dimensional and Snyder's unit hydrographs methods in Khorasan watershed, Iran. The results showed that SCS unit hydrograph method estimated peak flows with less error than the others methods[19]. Barkhordai et al studied Clark, SCS, Triangular dimensional and Snyder's unit hydrographs methods evaluation in peak flow estimation in Sikhoran watershed, Iran. Their results showed that for selecting unit hydrograph method in no-statistics watersheds, SCS and Triangular dimensional methods for low-slope watersheds and Clark and Snyder's mountainous watersheds show the best estimation[3]. methods for Cheng; Cheng et al and Taguas et al have used Rational method in peak flow estimation in small watersheds and they have determined direct run-off coefficient between 0.8-1 and also their resulted showed that there are not difference between observation and estimated discharges[5,6,20]. Considering Khoshehaye Zarrin watershed has no hydrometry gage and peak flow measurements have not done, therefore we have used valid and acceptable empirical methods for peak flow estimation in this research.

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2. Data and Methodology

2.1. Study Area

Khoshehaye Zarrin watershed is located in Arak province, Iran, between 50° 08' 52" to 50° 15' 42.85" E and 35° 37' 33.4" to 35° 54' 30" N. Its area is 8362 hectares and it has been divided to 6 hydrological units based on drainage pattern. Its maximum elevation is 1380 m and its minimum elevation is 1100 m in the watershed outlet. The mean annual rainfall is 197.5 mm and its general slope is northwest to southeast. Khoshehaye Zarrin watershed has two permanent rivers that these rivers are the most important source of irrigation of Khoshehaye Zarrin region. Figure (1) shows Khoshehaye Zarrin watershed location and table (1) shows some physiographic characteristics of its sub-basins.

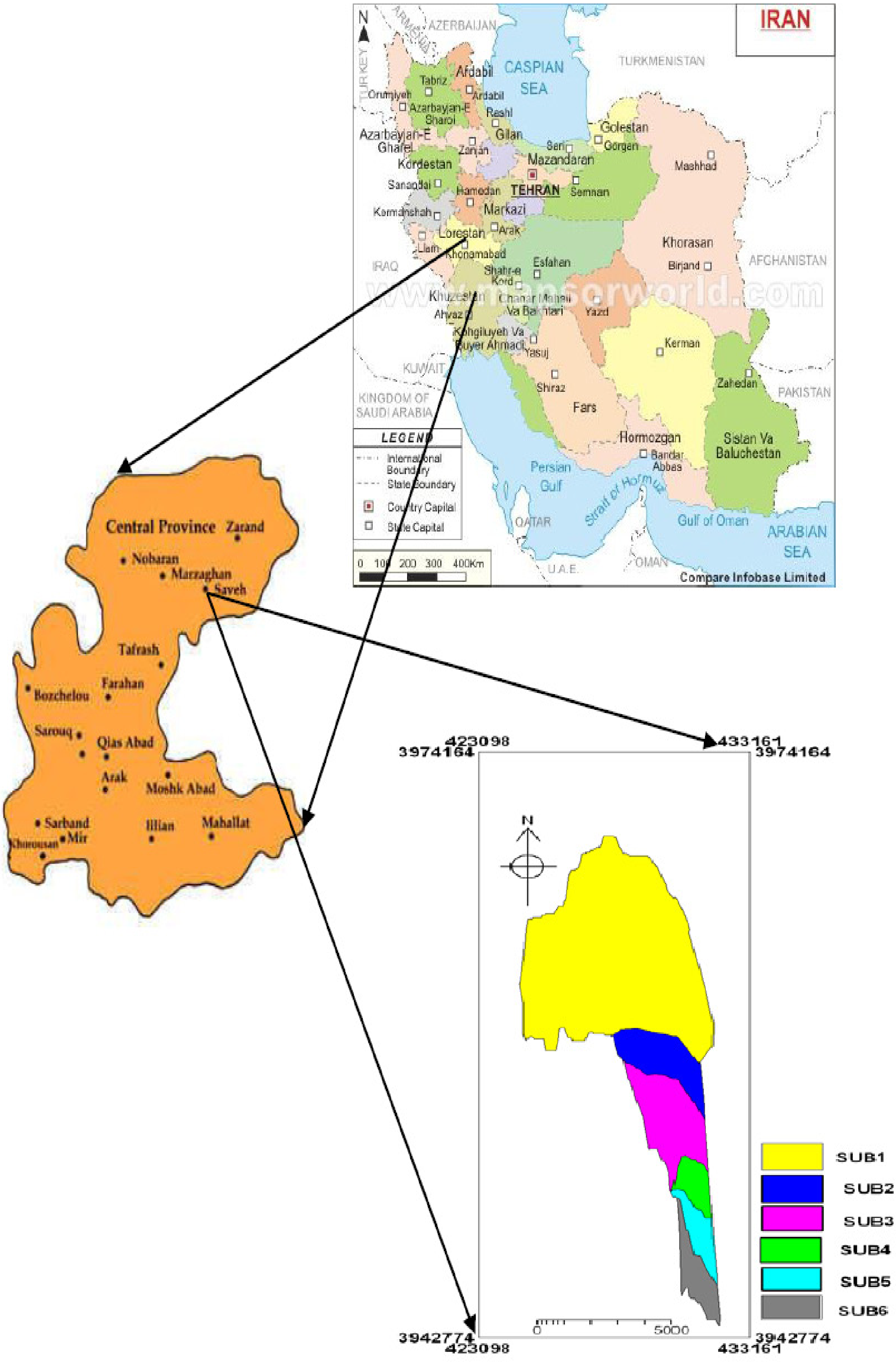

Figure 1. Khoshehaye Zarrin watershed location

Table 1. Some physiographic characteristics of Khoshehaye Zarrin watershed

Sub-basins	Area (km^2)	Perimeter (km)	Time of concentration (hr)	Main channel length (km)
Sub 1	55.94	37.98	2.31	23.2
Sub 2	7.08	13.91	0.57	6.6
Sub 3	10.16	18.89	0.42	5.34
Sub 4	3.08	11.78	0.18	2.54
Sub 5	2.88	8.5	0.16	2.31
Sub 6	4.12	15.86	0.43	5.39

2.2. Study Method

We have used rainfall data and field studies for analysing in Khoshehaye Zarrin watershed. Then following empirical methods used for estimating of flood discharges in the study area due to high relative accuracy:

2.2.1. Rational Method

This method uses for small watersheds (about 1000 till 5000 hectares) and therein is assumed that rainfall falls with constant intensity and uniform in all basins. The major defect of this method is ignoring the factors such as soil moisture and temperature but ease of its use caused to be used widely[13]. This method is given by following equation (1).

$$Q = 1/360\ CIA \quad (1)$$

Where Q is maximum peak discharge with return period equal with storm return period (m^3/s), C is coefficient that depends on slope, vegetation, land use, soil and return period and it is variable between 0-1, I is rainfall intensity (mm/hr) and A is area (hec).

2.2.2. SCS Unit Hydrograph Method

A unit hydrograph is expressed as direct run-off due to one inch of rainfall excess and its figure is characteristic function of basin[7]. Unit hydrograph can be used synthetically and using physical factors of Basin in cases there is no hydrometry gage. Mockus (1957) showed a dimensionless unit hydrograph with the study of accomplished measurement by USA Soil Conservation Service that it has T/Tp and q/qp axis. For determining of synthetic unit hydrograph in this method, time to peak (Tp) and peak flow (qp) must be calculated. Equations (2) and (3) are used for determining (Tp) and (qp)[13].

$$q_p = 2.083\ Q.A/t_p \quad (2)$$

$$T_p = 0.6\ T_c + \sqrt{T_c} \quad (3)$$

Where q_p is peak flow *(m^3/s)*, A is area *(km^2)*, t_p and T_p is time to peak *(hr and min respectively)*, T_c is time of concentration *(min)*, Q is run-off height *(cm)* that it obtained from Curve Number (CN) method. The reason of choosing this method is increase of its accuracy in estimating run-off than the other methods[18]. Run-off height due to rainfall in CN method is calculated by following equation:

$$Q = (P-0.2S)^2/P+0.8S,\ P>0.2S \quad (4)$$

Where P is height of 24-hours precipitation (mm) and S is surface detention that it is calculated by following equation in metric system:

$$S = 25400/CN-254 \quad (5)$$

Where Curve Number is determined with regard to soil profile, land use and hydrologic soil groups and then it is modified based on Antecedent Moisture Condition (A.M.C). And finally unit hydrograph coordinates obtained from table of dimensionless chart that it has been provided for this purpose[13].

3. Results and Discussion

With regard to no record of rain recorder data with appropriate statistical period in Khoshehaye Zarrin watershed, rainfall intensity in time of concentration with different return periods estimated by Ghahraman and Abkhezr's equation[8]. Rainfall intensity in time of concentration in study watershed is shown in table (2).

Table 2. Rainfall intensity in time of concentration in Khoshehaye Zarrin watershed

T(year)/I (mm/h)	I_{tc1}	I_{tc2}	I_{tc3}	I_{tc4}	I_{tc5}	I_{tc6}
2	7.25	20.17	14.9	6.34	5.67	15.13
5	10.65	30.31	22.5	9.53	8.52	22.74
10	13.05	37.31	27.5	11.68	10.4	27.86
25	16.01	45.55	33.7	14.33	12.8	34.18
50	18.18	51.74	38.3	16.27	14.5	38.83
100	20.36	57.92	42.9	18.12	16.3	43.46

We did not obtain complete information about flood in study watershed with regard to the references that we did to the flood relevant organizations in region. Basin drainage waterways were seasonal and there was no flood measurement equipment in region. Considering the results of physiography, agrology, geology, vegetation and field studies together with adjusted maps in different parts, we estimated run-off coefficient and curve number (CN) in six sub-basins and estimated peak flow with use of Rational method. With the mention of this point that Rational method uses for 10-50 km^2 areas, so it can't be used for sub-basin 1 but can be used for the other sub-basins. Table (3) is shown maximum peak discharges of sub-basins. Curve number, surface detention and run-off height in average moisture condition are given in table (4). After estimating the run-off height, peak discharge and time to peak estimated for each sub-basin (table 5). Then, unit hydrograph dimensions calculated for each sub-basin with regard to Mockus's table[13]. Tables (6) and (7) are shown unit hydrograph dimensions for sub-basins 1 and 4 as example and also dimensionless unit hydrographs calculated for each sub-basin that figures (2) and (3) are shown for sub-basins 1 and 4 as example.

Table 3. Peak discharges of sub-basins to Rational method in Khoshehaye Zarrin watershed

T(year)	Sub1	Sub2	Sub3	Sub4	Sub5	Sub6
2	-	19.8	21.1	2.71	2.27	8.6
5	-	29.8	31.7	7.04	3.41	12.96
10	-	36.7	38.8	4.99	4.18	15.88
25	-	44.8	47.5	6.13	5.12	19.5
50	-	50.79	54.1	6.95	5.8	22.13
100	-	56.81	60.5	7.75	6.51	24.76

Table 4. Determination of CN, Surface detention and Run-off height

	CN	Surface detention*(mm)*	Run-off height*(mm)*
Sub1	79	6.75	16.94
Sub2	79	6.75	16.94
Sub3	69	11.4	35.02
Sub4	79	6.75	16.94
Sub5	79	6.75	16.94
Sub6	69	11.4	35.02

Table 5. Determination of peak discharges and time to peak for each sub-basin

	Peak discharges *(m^3/s)*	Time to peak *(hr)*
Sub1	125.02	1.58
Sub2	57.08	0.44
Sub3	219.88	0.34
Sub4	67.11	0.16
Sub5	69.13	0.15
Sub6	88.46	0.34

Table 6. Unit hydrograph dimensions for sub-basin 1

T/T_p	q/q_p	T/T_p	q/q_p
0	0	2.68	57.5
0.15	3.75	2.84	48.7
0.31	12.5	3	41.3
0.47	23.75	3.15	35
0.63	38.75	3.47	25.9
0.78	58.7	3.78	18.4
0.95	82.5	4.1	13.4
1.1	102.5	4.4	9.9
1.26	116.26	4.73	6.87
1.42	123.76	5.05	5
1.57	125.02	5.4	3.62
1.73	123.76	5.68	2.62
1.89	116.26	6	1.87
2.05	107.5	6.31	1.37
2.21	97.5	7.1	0.62
2.36	85.01	7.89	0
2.52	70.01		

Table 7. Unit hydrograph dimensions for sub-basin 4

T/T_p	q/q_p	T/T_p	q/q_p
0	0	0.27	30.8
0.01	2.01	0.29	26.2
0.03	6.71	0.31	22.2
0.05	12.75	0.33	18.8
0.06	20.8	0.36	13.9
0.08	31.5	0.39	9.86
0.09	44.3	0.42	7.18
0.11	55.02	0.45	5.16
0.13	62.41	0.48	3.69
0.14	66.43	0.52	2.68
0.16	67.11	0.55	1.95
0.17	66.43	0.58	1.4
0.19	62.41	0.61	1
0.21	57.71	0.64	0.74
0.22	52.34	0.73	0.33
0.24	45.63	0.81	0
0.26	37.58		

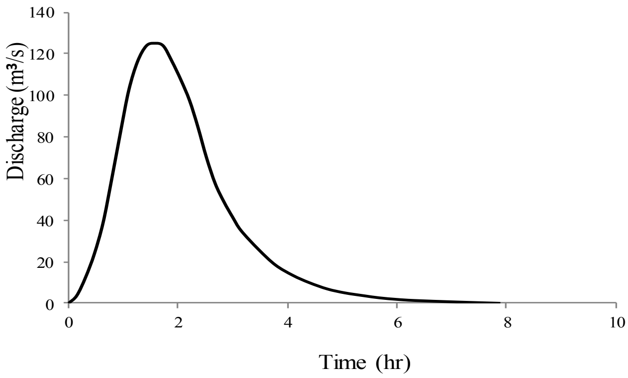

Figure 2. Dimensionless unit hydrograph for sub-basin 1

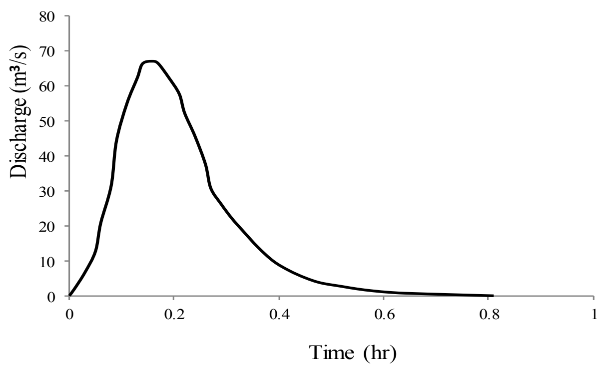

Figure 3. Dimensionless unit hydrograph for sub-basin 4

4. Conclusions

With regard to this point that Khoshehaye Zarrin watershed has no hydrometry gage and peak flow measurements have not done, so we used the nearest data of hydrometry gage to study watershed for evaluating accuracy. This research results showed that Synthetic Unit Hydrograph (SCS) method has more accurate estimate than

Rational method and also this method estimated watershed flood hydrographs with less error than Rational method and so it can be used for peak flow estimation in the similar condition watersheds. This research results correspond with results of studies such as Khosroshahi[11] and Musavi[15]. Meanwhile, the study watershed has intense rains and high flooding so that sub-basin 3 with 220 (m^3/s) is the most flooding and versus sub-basin 2 with 57 (m^3/s) is the least flooding that their reason is hydrological and physiographic conditions of sub-basins 3 and 2 and we suggest that sub-basin 3 should be considered in first priority of flood control.

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