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An Investigation of Efficiency of Outlet Runoff Assessment Models: Navroud Watershed, Iran

H. Mojaddadi, M. Habibnejad, K. Solaimani, M.Z. Ahmadi and M.A. Hadian-Amri
Department of Watershed Management, Faculty of Natural Resources,
Agricultural and Natural Resources University of Sari, P.O. Box 737, Badeleh, Sari, Iran

Abstract: This research has been carried out for investigation and comparison of the amount of precision and correctness of SCS unit hydrograph, GRAY, G.I.U.H and Gc.I.U.H models in determination of the shape and dimensions of outlet runoff hydrograph in Navroud watershed with 266 km^2 area, located in Giulan Province of Iran and use of these models for the similar watersheds and without any data. To investigate the amount of efficiency of above-mentioned methods, first 6 equivalent rainfall-runoff events were selected and for each, hydrograph of outlet runoff were calculated. Then the models were compared with together, for peak time, base time, peak flow and volume of outlet runoff and the most efficient model in estimation of hydrograph of outlet flow for similar regions was proposed. Comparison of calculated hydrographs obtained from models under research and observed hydrographs of selected events showed that SCS unit hydrograph method had the most direct agreement in three parameters of peak time, base time and volume of direct runoff. On the other hand, the geomorphoclimatic instantaneous unit hydrograph, with the highest mean relative error of 16%, had highest harmony in estimation of peak flow direct runoff.

Key words: Rainfall-runoff model, unit hydrograph, SCS model, GRAY model, G.I.U.H model, Gc.I.U.H model

INTRODUCTION

Data and observed information are very important and basic for investigation and estimation of hydrologic events and if are recorded regularly and from old time, can be used in control structures and decrease of flood damages. Many watersheds do not have hydrometric stations, limnigraph and rain gauges (Bonta and Roa, 1991) and no data and lack of hydrological information are encountered, that is why for calculation of peak flood flow, time of concentration, peak time and watershed hydrograph, empirical formula and artificial hydrographs are used. Hydrograph is a curve which shows the variations of runoff discharge rate with respect to time and on the other hand, the dimensions of hydrograph of outlet discharge rate, shows quantitative and final responses of watershed to inlet rainfall. So, knowledge of the relationship between rainfall and runoff is one of the important issues in the hydrology (Alizadeh, 2006). One of the common methods in flood estimation is the use of unit hydrograph which not only is used in peak flow estimation, but also for creation of complicated flood hydrographs (Heshmatpour *et al*., 2002). Unit hydrograph and flood hydrograph which is obtained from rainfall and discharge rate of a watershed is used for that watershed and river only. For other points of river or watersheds having similar characteristics, artificial hydrograph method is used (Zehtabian *et al*., 2001). Among common methods for artificial unit hydrographs, Gray (1961) and NRCS/SCS (1972) models and for instantaneous unit hydrographs G.I.U.H. (Geomorphologic Instantaneous Unit Hydrograph), (1993) and Gc.I.U.H. (Geomorphoclimatic Instantaneous Unit Hydrograph), (1982) models can be cited.

About efficiency of artificial unit hydrographs and instantaneous unit hydrographs in the world and in Iran, many researches have been carried out. Bahadori Khosroshahi (1989) in Jajrood Watershed with 426 km^2 areas and Rezaee (1994) in 9 watershed of Zanjan, Guilan, Mazandaran and Tehran Provinces, studied NRCS/SCS unit hydrograph and Snyder method in determination of flood in these watersheds, concluded that NRCS/SCS method has better agreement than Snyder in construction of unit artificial hydrograph with the observed hydrograph. Shahmohammadi (1994) in Khersan Watershed in southern part of Karoon Watershed, compared observed flood hydrograph with calculated flood hydrograph and by studying three methods of unit

Corresponding Author: Karim Solaimani, RS and GIS Centre, Department of Watershed Management, Faculty of Natural Resources, Agricultural and Natural Resources University of Sari, P.O. Box 737, Badeleh, Sari, Iran Tel: +989111521858 Fax: +981512442982

hydrograph (Snyder, NRCS/SCS and triangular), proposed the NRCS/SCS method for this watershed. Rahimian and Zare (1995) in Paskoohak Watershed in Shiraz concluded that Geomorphologic method had more agreement than SCS, Snyder and triangular methods with observed hydrograph. Ghahraman (1995), based on his studies on Kasilian and Emameh Representative Watersheds, concluded that for estimation of flood hydrograph, the Geomorphoclimatic instantaneous unit hydrographs are better than Geomorphologic artificial unit hydrograph. Ghiasi (1996) in Emameh Watershed, 6 rainfall-runoff events considered 6 tantamount rainfall-runoff events with Geomorphologic, NRCS/SCS, Snyder and triangular methods and concluded that efficiency of Geomorphologic method is similar to NRCS/SCS method and is less than that of Snyder method. Erfanian (1998) concluded in Jezin Watershed of Semnan by comparison of statistical indices of sum of squares errors that the percentage of efficiency of Geomorphologic model with respect to Geomorphoclimatic, Roso, Nash and NRCS/SCS methods were 134.2, 160.6, 295.18 and 210.2, respectively. Also, the efficiency percentage of Geomorphoclimatic method with respect to Roso, Nash and NRCS/SCS methods are 119.7, 294.7, 156.5%, respectively. Heshmatpour *et al*. (2002) after carrying research in Kasilian Watershed and comparison by statistical indices of sum of squares errors, that efficiency percentage of Geomorphologic model with respect to Geomorphoclimatic, Nash, Roso and NRCS/SCS methods were 106.56, 171.12, 106.79 and 112.64, respectively. Also, the efficiency percentage of Geomorphoclimatic method with respect to Nash, Roso and SCS methods are 160.57, 100.21, 105.69%, respectively. Barkhirdari (2006), concluded that in Sikhoran Watershed of Hormozgan Province to determine ability and efficiency of artificial unit hydrograph (Snyder, triangular and Clark), including determination of natural and artificial unit hydrographs using morphologic, rainfall and hydrometric data and comparison of four methods of construction of artificial and observed (natural) unit hydrographs, Snyder method in mountainous steep watersheds and NRCS/SCS and triangular methods in plain and low slope watersheds had better estimation. Gary (1961) concluded in his research called artificial unit hydrograph for small watersheds that Gray unit artificial hydrograph in watershed with 243.5 km^2 areas in Iowa, Illinois, Wisconsin, Nebraska and Missouri with specific local coefficients, had acceptable results. Zeiazinski (1986), in his research by expressing this case that theory of Geomorphologic unit hydrograph to estimate parameters of 2 conceptual models of cascade Liner and model of the type Laurenson, using the two models for flood control, expressed Geomorphologic unit instantaneous hydrograph for Vistola Watershed of Poland. Ghioto (1991), in a research compared NRCS/SCS, Snyder and Santa barba hydrographs and showed that in big watersheds, NRCS/SCS model has better estimation. Bonta and Roa (1991) by using four statistical distributions of Gamma, Beta, Weibul and K^2 and three artificial unit hydrographs of Snyder, NRCS/SCS and Gray, compared the shapes of hydrographs in two sub-watersheds with 114 and 350 km^2 in India. Among methods of estimation of unit artificial hydrographs, the percentage of relative error in time to peak and peak discharge rate of hydrographs obtained from NRCS/SCS method had 20 and 3% and standard error of 2.95% which shows that this method is suitable for watersheds of without data.

MATERIALS AND METHODS

Study area: Navrood representative watershed (Table 1) is located between 48° 36'-48°36' E and 48°36'-48° 36' N and located between Gorganrood Watershed from north, Khale-Sara Watershed from east, Arpachay Watershed from west and Dinachal Watershed from south. About 83% of the Watershed is as forest and the rest is as rangeland and bare land. Figure 1 shows some morphometric characters of Navrood Watershed. This study was conducted in Winter (June) 2008.

Data and methods: To reach the aims of this research, the following should be carried out:

- Physiographic parameters of watershed are prepared (Table 1)
- Data and information of equivalent rainfall-runoff events in non-melting season of snow are collected from graphs

Table 1: Physiographic parameters of Navrood watershed region

Parameters	Values	Parameters	Values
Area (km^2)	266	Length of watershed (m)	27.5
Circumference (km)	84	Min. height of watershed (m)	130
Horton shape coefficient	0.3517	Max. height of watershed (m)	3016
Gravelius shape coefficient	1.442	Average slope (%)	5.1
Miller shape coefficient	0.4737	Extent of channel	1.27
Schume shape coefficient	0.669	Drainage density (km km^{-2})	1.1344
Weighted average height (m)	1393.91	Division of ratio	3.834
Length of main channel (km)	32.5	Area of ratio	4.7185
Length with highest order (km)	20.9	Lenth of ratio	1.9246

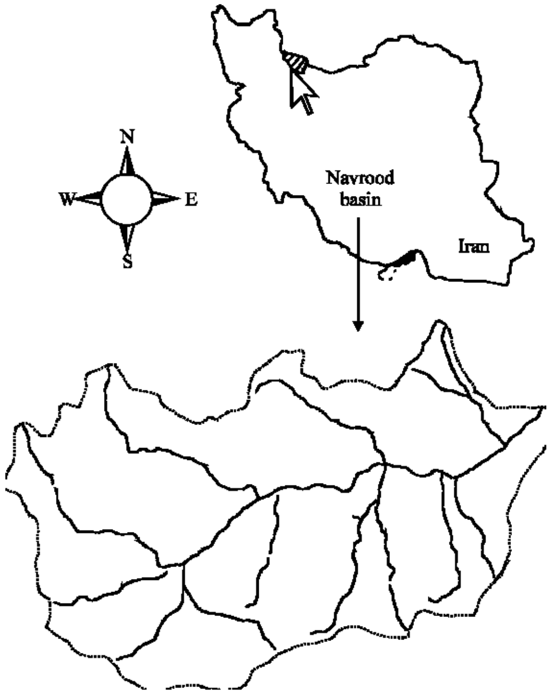

Fig. 1: Navroud Watershed, North of Iran

- After selection of events, the 1 h rainfall and then cumulative rainfall of each duration from rainfall recording gages are obtained. The base flow of each flood is obtained from different methods (Chow *et al.*, 1988; Viessman and Lewis, 2003). Here, the direct line method is used which is usually used in most hydrologic works (Mahdavi, 2005; Alizadeh, 2006). After separation of base flow and calculation of under curve area, the direct runoff is obtained by dividing it by watershed area. The excess rainfall for 1 h is obtained which is NRCS/SCS method which is a model of one-event (Karvonen, 1999; Chow, 1964; USACE, 2000; Mahdavi, 2005; Alizadeh, 2006)
- Preparation of unit hydrograph and instantaneous unit hydrograph with different models:

NRCS/SCS unit hydrograph: In this method it is sufficient to calculate the time to peak and the amount of peak flow. The coordinate of unit hydrograph is obtained from a table (Mahdavi, 2005; Alizadeh, 2006). The relationships in NRCS/SCS hydrograph are 1-4:

$$Q_p = \frac{2.08A}{t_p} \quad (1)$$

$$t_p = \frac{D}{2} + t_l \quad (2)$$

$$t_l = 0.6t_c \quad (3)$$

$$D = 0.133t_c \quad (4)$$

where, Q_p is peak of flow ($m^3\ sec^{-1}$), A is area (km^2), t_p is time to peak flow (h), D is effective time of rainfall (h), t_l is lag time (h) and t_c is time of concentration (the time needed to reach out let) (h).

To solve equation of dimensionless unit hydrograph, calculation of t_c of watershed is necessary. In this research t_c is 11 h (equal to 660 min) based on observed hydrographs. As the rainfall-runoff data dose not exist in watersheds of without hydrometric stations, t_c is estimated by other characters and compared with its real value. Based on existing parameters of watershed 11 relationships are used to calculate t_c (Mobaraki, 2006). In this research among these methods, Espy-Vintslo, time of concentration (601 min) with relative error of 8.95% is acceptable.

Gray unit hydrograph: Gray (1961) found the relationship 5 for t/P_R:

$$Q_t / p_R = \frac{25\gamma^q}{\Gamma(q)}\left(\frac{t}{P_R}\right)^{q-1} \exp\left(-\frac{\gamma t}{P_R}\right) \quad (5)$$

So, that Q_t/P_R, flow percentage in $0.25P_R$, for t/P_R, q and γ are shape parameter and scale, Γ, gama function q equal to (q-1)! (! = factorial), P_R is peak time of natural unit hydrograph of 1 h to minute and t is time in minute (Singh, 2000).

Instantaneous unit hydrograph G.I.U.H: The hydrologic function of Navrood representation watershed, order based on 5 based on Strahler classification, is given by the following relationship 6:

$$\begin{aligned} GIUH(t) = {} & \theta 1(o)\frac{d\phi 17(t)}{dt} + \theta 2(o)\frac{d\phi 27(t)}{dt} + \theta 3(o)\frac{d\phi 37(t)}{dt} \\ & + \theta 4(o)\frac{d\phi 47(t)}{dt} + \theta 5(o)\frac{d\phi 57(t)}{dt} \end{aligned} \quad (6)$$

where, GIUH(t) is ordinate instantaneous unit hydrograph in time t, θ1(o) to θ5(o) are probability of primary conditions, dϕ17(t)/dt to dϕ57(t)/dt are the variations of probability of transfer of time interval. Knowing velocity of flow and the average length of channels, the inverse of time of expectance (γ) is determined and having this criterion probability of transfer to (dϕ/dt) is obtained. Having (dϕ/dt) and probability of initial condition θi(o), the coordinate of instantaneous unit hydrograph is determined (Bhaskar, 1996; Ganjkhanlou, 2002). In theory of G.I.U.H., the discharge rate, peak time and base time are calculated from relationships 7-9, (Rodriguez-Iturbe and Valders, 1979; Erfanian, 1998).

$$Q_p = \frac{1.31 R_L^{0.43}}{L_\Omega} \times V \tag{7}$$

$$T_p = \frac{0.44 L_\Omega R_B^{0.55}}{R_A^{0.55} R_L^{0.38} V} \tag{8}$$

$$Q_p.T_b = 2 \tag{9}$$

where, Q_p is peak discharge rate ($m^3\ sec^{-1}$), T_p is peak time (h), $L_Ù$ is length of channel of highest order (km), R_B is branch ratio, R_L is length ratio, V is maximum velocity ($m\ sec^{-1}$) and T_b is base flow time (h). So, the presence of flow velocity as an important factor in determining peak discharge and time to peak flow causes that for each rainfall, unit instantaneous hydrograph is different.

Instantaneous unit hydrograph Gc.U.I.H: Theory of Geomorphoclimatic Instantaneous Unit Hydrograph was submitted by Rodriguez-Iturbe and Bars (1982) by accepting bases of Geomorphologic instantaneous unit hydrograph and accepting the results of there studies about velocity, based on the fact that peak velocity is a function of excess rain intensity and kinetic wave. They used the relationship 10-13:

$$Q_p = 1.971(\Pi_i)^{-0.4} \tag{10}$$

$$T_p = 0.2587(1.971\Pi_i)^{0.4} \tag{11}$$

$$\Pi_i = \frac{(L_\Omega)^{2.5}}{i_r A_\Omega R_L (\alpha_\Omega)^{1.5}} \tag{12}$$

$$Q_p.T_b = 2 \tag{13}$$

The formulas 14 and 15 were used from the same researches:

$$Q_p = 5.475\left(\frac{A_\Omega i_r t_r}{(\Pi_i)^{0.4}}\right)\left(1 - \frac{0.4927 t_r}{(\Pi_i)^{0.4}}\right) \tag{14}$$

$$T_p = 0.2587(\Pi_i)^{0.4} + 0.75 t_r \tag{15}$$

where, Q_p is peak discharge rate ($m^3\ sec^{-1}$), T_p is peak time (h), A_Ω is catchment area (km^2), L_Ω is length of channel of highest order of drainage (km), i_r is mean of effective rainfall intensity ($m\ sec^{-1}$) calculated from hyetograph, R_L is length ratio, α_Ω kinetic wave parameter with dimension $L^{2/3}$, t_r is travel time (h) and T_b is base flow time (h). So, the presence of flow velocity as an important factor in determining peak discharge and time to peak flow causes that for each rainfall, unit instantaneous hydrograph is different.

Extraction of unit hydrograph from instantaneous unit hydrograph: The dimensions of 1 h instantaneous unit hydrograph of Geomorphologic and Geomorphoclimatic in terms of inverse of time (h^{-1}) in terms of one unit excess water for selected storms were calculated. If the aim is the extraction of 1 h unit hydrograph from P_e units of excess water, one should obtain extracted instantaneous unit hydrograph from models that are obtained from inverse of time (h^{-1}) and should be expressed in $m^3\ sec^{-1}$ based on relationship 16:

$$u_t = (IUH_{(t)})(P_e)(A_\Omega) \tag{16}$$

where, $IUH_{(t)}$ is dimensions of instantaneous unit hydrograph in t (h) and P_e is excess water (m).

Extraction of outlet hydrograph from selected events: To calculate dimension of outlet hydrograph of selected events for different methods under research, due to non uniformity of time distribution of rain in hydrograph of each storm and allocation of different excess rainfall in different time periods, the matrix method and simultaneous solution of equations are used (Heshmatpour *et al*., 2002).

Determination and assessment of outlet hydrograph dimensions of watershed by comparison of calculated and observed hydrographs and by Mean Relative Error (MRE) and Mean Square Error (MSE) based on relationship 17-20, (Zehtabian *et al*., 2001; Erfanian, 1998; Nash, 1958; Smith *et al*., 2004; Sadeghi *et al*., 2005).

$$MRE = 1/n \sum_{i=1}^{n} RE_i \tag{17}$$

$$RE\ (\%) = \left|\frac{O - P}{O}\right| \times 100 \tag{18}$$

$$MSE = 1/n \sum_{i=1}^{n} SE_i \tag{19}$$

$$SE_i = [(Q_{oi} - Q_{ci}) / Q_{oi}]^2 \tag{20}$$

where, MRE is mean relative error percentage, n is number of estimation, RE (%) is the percentage of relative error in estimation of the related parameter (here 4 parameters of peak time, base time, peak volume and discharge rate of flood have been considered). O is the observed values, P is the calculated values, MSE is mean of power 2 error, Se_i is sum of squares of errors between observed and calculated hydrographs in each time interval, Q_{oi} is dimension of observed hydrograph and Q_{ci} is dimensions of calculated hydrograph.

To determine percentage of superiority of the models under research in estimation of outlet hydrograph dimensions in the watershed under study, the mean of power 2 of error of each model with respect to other model have been used based on the relationship 21, (Erfanian, 1998; Sadeghi *et al*., 2005).

$$(MSE_2/MSE_1)\times 100 = \text{Ratio of estimating (1) percentage efficiency of estimating (2)} \quad (21)$$

RESULTS

Dimensions of calculated outlet hydrographs by different methods were compared with observed hydrograph in 1 h time duration and have been shown in Fig. 2-7.

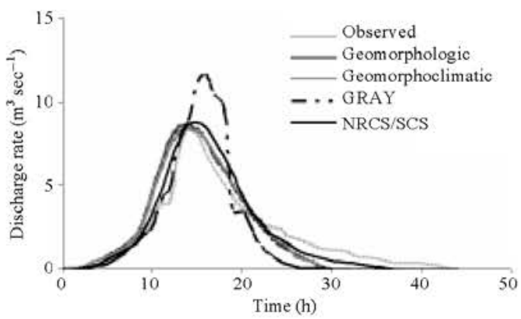

Fig. 2: Comparison of observed and calculated hydrographs of different models for storm 14th Oct. 1994

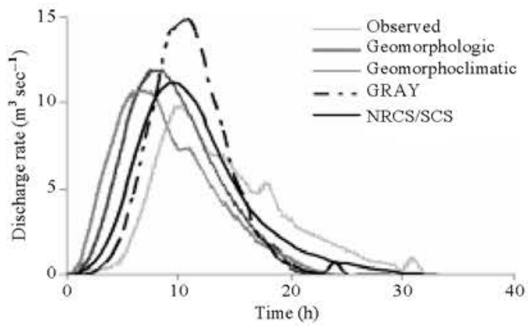

Fig. 3: Comparison of observed and calculated hydrographs of different models for storm 21st Oct. 1994

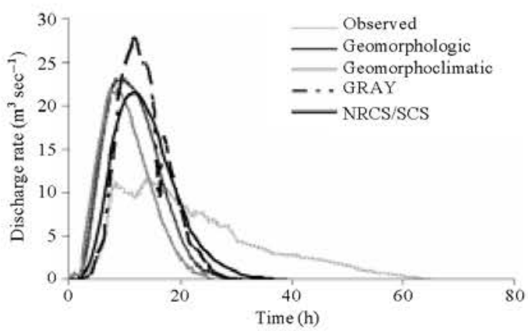

Fig. 4: Comparison of observed and calculated hydrographs of different models for storm 23rd Apr. 1995

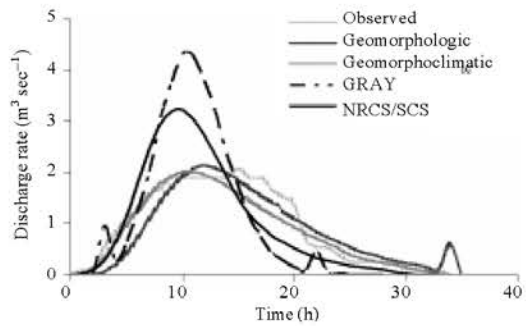

Fig. 5: Comparison of observed and calculated hydrographs of different models for storm 21st Jun 1995

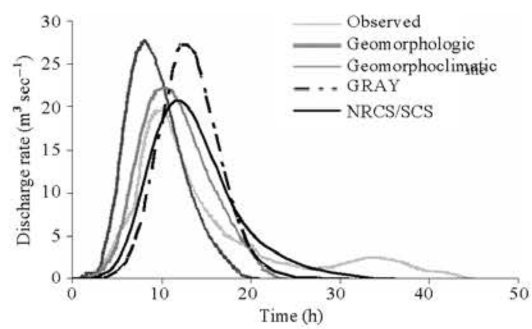

Fig. 6: Comparison of observed and calculated hydrographs of different models for storm 13th Aug. 1995

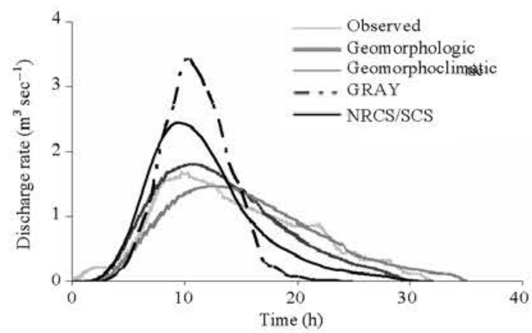

Fig. 7: Comparison of observed and calculated hydrographs of different models for storm 10th Nov. 1998

The results show the efficiency of extracted hydrographs in different methods by two indices of MRE and MSE. Table 2-5 show amounts of peak time, base time, peak flow and peak discharge rate, estimated runoff volume of out let runoff, percentage of their differences with observed values and mean error (MRE) of these characters in different methods for selective events.

Table 6 shows observed amounts of characters and Table 7 shows MSE in different methods for different events.

Table 8 shows the percentage of efficiency of models compared to each other in estimating dimensions of outflow in Navrood Watershed. For this purpose MSE of each model was used.

Table 2: Estimated amounts of characters in NRCS/SCS method for selective events and percentage of their differences with observed values and mean error (MRE) of them

Method	Parameter	14th Oct. 1994	21st Oct. 1994	23rd Apr. 1995	21st Jun. 1995	13th Aug. 1995	10th Nov. 1997	MRE
NRCS/SCS	Qp	8.741	11.140	21.524	3.216	20.791	2.423	-
	RE-Qp (%)	4.062	14.139	87.165	56.117	5.807	46.848	35.690
	Tp	15	10	12	10	12	10	-
	RE-Tp (%)	7.142	0	14.286	33.333	20	0	12.460
	Tb	38	33	39	33	36	32	-
	RE-Tb (%)	15.556	3.125	40	5.714	18.182	5.882	14.743
	V	348446.3	420806.36	1019320.08	119946.5	789654.5	88231.03	-
	RE-V (%)	3.686	0.684	0.46	0.897	0.594	0.158	1.080

Table 3: Estimated amounts of characters in GRAY method for selective events and percentage of their differences with observed values and mean error (MRE) of them

Method	Parameter	14th Oct. 1994	21st Oct. 1994	23rd Apr 1995	21st Jun. 1995	13th Aug. 1995	10th Nov. 1997	MRE
GRAY	Qp	11.656	14.761	27.757	4.345	27.095	3.398	-
	RE-Qp (%)	38.750	51.239	141.360	110.920	37.888	105.939	81.016
	Tp	16	11	12	10	12	10	-
	RE-Tp (%)	14.29	10	14.29	33.33	20	0	15.318
	Tb	33	29	34	28	31	27	-
	RE-Tb (%)	26.67	9.38	4.69	20	29.55	20.59	25.647
	V	353408	426791	1033829	120580	709291	89494	-
	RE-V (%)	5.16	0.765	1.893	0.37	10.71	1.59	3.415

Table 4: Estimated amounts of characters in GIUH method for selective events and percentage of their differences with observed values and mean error (MRE) of them

Met hod	Parameter	14th Oct. 1994	21st Oct. 1994	23rd Apr. 1995	21st Jun. 1995	13th Aug. 1995	10th Nov. 1997	MRE
GIUH	Qp	8.663	11.879	29.989	2.147	27.510	1.803	-
	RE-Qp (%)	3.136	21.700	99.904	4.199	39.954	9.261	29.692
	Tp	14	8	9	13	8	11	-
	RE-Tp (%)	0	20	35.72	13.33	20	10	16.508
	Tb	30	24	28	36	21	30	-
	RE-Tb (%)	33.33	25	56.92	2.86	52.27	11.77	30.358
	V	342230	413602	926374	118593	750946	86588	-
	RE-V (%)	1.836	2.35	8.700	2.02	5.47	1.71	3.681

Table 5: Estimated amounts of characters in Gc.I.U.H method for selective events and percentage of their differences with observed values and mean error (MRE) of them

Method	Parameter	14th Oct. 1994	21st Oct. 1994	23rd Apr. 1995	21st Jun. 1995	13th Aug. 1995	10th Nov. 1997	MRE
Gc.I.U.H	Qp	8.402	10.652	21.484	2.024	22.311	1.466	-
	RE-Qp (%)	0.024	9.139	86.791	1.747	13.541	11.145	20.398
	Tp	14	7	7	11	10	14	-
	RE-Tp (%)	0	30	50	26.67	0	40	24.445
	Tb	32	23	29	36	24	36	-
	RE-Tb (%)	28.89	28.12	55.38	2.86	45.46	5.88	27.765
	V	362040	396149	917950	117707	764317	86701	-
	RE-V (%)	7.725	6.47	53.9	2.747	3.78	1.58	5.3053

Table 6: Observed amounts of parameters

Method	Parameter	14th Oct. 1994	21st Oct. 1994	23rd Apr. 1995	21st Jun. 1995	13th Aug. 1995	10th Nov. 1997	MRE
Observed	Qp	8.4	9.76	11.5	2.06	19.65	1.65	-
	Tp	14	10	14	15	10	10	-
	Tb	45	32	65	35	44	34	-
	V	336060	423551	1014624	121032	794376	88092	-

Table 7: MSE in different methods for different events

Model	SEi 14th Oct. 1994	21st Oct. 1994	23rd Apr. 1995	21st Jun. 1995	13th Aug. 1995	10th Nov. 1998	MSE
NRCS/SCS	0.5969	3.0093	26.3997	0.2841	11.7255	0.1709	7.0476
GRAY	0.4330	6.8487	31.2369	0.9006	15.0389	2.4901	9.4914
G.I.U.H	0.9980	9.7219	28.9552	0.0702	21.2337	0.0296	10.1681
Gc.I.U.H	0.8172	12.7021	27.6781	0.0299	3.8534	0.0595	7.5234

Table 8: Relative efficiency (1) with respect to estimator (2) in estimating runoff in Navrood representative watershed

Model	Estimator 2 SCS	GRAY	G.I.U.H	Gc.I.U.H
Estimator 1				
NRCS/SCS	100.00000	134.67460	144.2770	106.75060
GRAY	74.25303	100.00000	107.1300	79.26556
G.I.U.H	69.31113	93.34451	100.0000	73.99006
Gc.I.U.H	93.67627	126.15820	135.1533	100.00000

DISCUSSION

An investigation of the obtained results, showed high agreement of NRCS/SCS, GRAY, G.I.U.H and Gc.I.U.H methods with observed hydrograph in three parameters of peak time, runoff volume and outlet runoff. This is in agreement results obtained later (Barkhirdari, 2006; Bahadori Khosroshahi, 1989). But these methods show higher peak discharge rate than that observed values which is due to influencing factors on the shape of hydrograph in the watershed under study like vegetation (dense forest) and long watershed (Habibnejad *et al*., 2004). Overall, the comparison of obtained results of the methods under study shows that efficiency of NRCS/SCS method is more efficient than GRAY, Geomorphologic and Geomorphoclimatic methods by 134.6746, 144.277 and 106.7506%, respectively. As a result, NRCS/SCS is more efficient than other method, the difference with Geomorphoclimatic is sight and one can say that the two methods have similar efficiencies. This is in agreement results obtained later (Heshmatpour *et al*., 2002). As the Geomorphoclimatic method can not estimate peak and base times precisely, its MSE becomes higher, so that the efficiency of model has been reduced. But as Table 3-6 show the MRE of peak flow in this method is higher with respect to other models and these show a high precision in estimation of peak flow of outlet runoff. Ghahraman (1995) and Heshmatpour (1999) got same results in their researches.

It is suggested that in this research two models of NRCS/SCS and Geomorphoclimatic methods have similar efficiencies, due to lower number of parameters required in NRCS/SCS model and simplicity of calculation of this method with respect to other methods in flood estimation and also in cases lower risk in designs is important, this method can be used for watersheds of no data. Also, in case for a specific region with respect available data, all types of models should be evaluated, one can obtain safer and more reliable results. Increase on number of events, calculation of excess water with more efficient methods which can calculate rain loss as a function of time and in case of using SCS model for excess rain estimation, calculation of precise CN of the region, calibration of time of concentration (t_c) formula and peak flow coefficients for the region under study, etc. is a factor of increase in precision in NRCS/SCS unit hydrograph, whose result is the more precise of dimensions of outlet runoff.

In general, this research is in agreement with the results of Bahadori Khosroshahi (1989), Rezaee (1994), Shahmohammadi (1994), Ghiasi (1996), Heshmatpour (1999) and Barkhirdari (2006) but differs from the results of Rahimian and Zare (1995) and Erfanian (1998).

REFERENCES

Alizadeh, A., 2006. Principle of Applied Hydrology. 20th Edn., Emam Reza University Publications, Mashhad, Iran, pp: 808.

Bahadori Khosroshahi, F., 1989. An investigation of using unit hydrograph in flood determination. Proceedings of 1st Hydrology Conference, September 6-7, University of Tehran, pp: 206-229.

Barkhirdari, J., 2006. An investigation of using and evaluation of the methods of preparation of artificial unit hydrograph for flood estimation in Sikhoran Watershed of Hormozgan Province. J. Pajohesh Sazandegi., 71: 56-65.

Bhaskar, P.N., 1996. Flood estimation for ungauged catchments using the GIUH. J. Water Resour. Planning Manage., 123: 228-238.

Bonta, J.V. and R.A. Roa, 1991. Estimating peak flow small agriculture watershed. J. Irrig. Drain. Eng., 118: 28-36.

Chow, V.T., 1964. Handbook of Applied Hydrology. 1st Edn. Mc. Graw-Hill, New York.

Chow, V.T., D.R. Maidment and L.W. Mays, 1988. Applied Hydrology. 2nd Edn., McGraw Hill Publishing Company, New York, pp: 572.

Erfanian, M., 1998. An investigation of geomorphologic and geomorphoclimatic instantaneous unit hydrograph in dergezin watershed of semnan. M.Sc. Thesis. University of Gorgan, pp: 123.

Ganjkhanlou, 2002. Study of efficiency of geomorphologic and geomorphoclimatic instantaneous unit hydrograph and gray unit hydrograph. M.Sc. Thesis. College of Natural Resources, University of Mazandaran, pp: 75.

Ghahraman, B., 1995. Geomorphoclimatic instantaneous unit hydrograph. Ferdosi Univ. Mashhad. Eng. J., 7: 38-56.

Ghiasi, N., 1996. Calibration of geomorphologic and geomorphoclimatic unit hydrograph in emameh watershed. M.Sc. Thesis. College of Natural Resources, University of Tehran, pp: 143.

Ghioto, R.D., 1991. Runoff hydrograph computation methods. A Paper for Storm Water Management.

Gray, D.M., 1961. Synthetic unit hydrographs for small drainage areas. J. Hydraul. Div, ASCE, 87: 33-54.

Habibnejad, M., M.Z. Ahmadi and H. Ganjkhanloo, 2004. An investigation of efficiency of instantaneous unit hydrograph using Geomorphologic, Geomorphoclimatic and Gray models in watersheds. J. Natural Resour., 57: 379-390 (In Persian).

Heshmatpour, A., 1999. An investigation of efficiency of instantaneous Geomorphologic and Geomorphoclimatic unit hydrograph in Kasilian Watershed. M.Sc. Thesis. University of Agricultural Sciences and Natural Resources of Gorgan, pp: 134.

Heshmatpour, A., M. Saravi, A. Saaddin and M. Erfanian, 2002. An investigation of efficiency of Geomorphologic and Geomorphoclimatic instantaneous unit hydrograph in estimation of flood discharge rate. Iran. J. Nat. Resourc., 55: 3-22.

Karvonen, T., 1999. A hydrological model for predicting runoff from different land use areas. J. Hydrol., 217: 253-265.

Mahdavi, M., 2005. Applied Hydrology. 2nd Volume. 4th Edn., University of Tehran, Publications, Iran, pp: 441.

Mobaraki, J., 2006. An investigation of the amount of precision of empirical relationships in estimation of time of concentration and time to peak of hydrographs (case study: Tehran Province). M.Sc. Thesis. University of Tehran, pp: 97.

Nash, J.E., 1958. Determining runoff from rainfall. Proc. Inst. Civil Eng. Ireland, 10: 163-184.

NRCS, 1972. National Engineering Handbook, Section 4. 1st Edn., USDA, Washington, DC.

Rahimian, M. and M. Zare, 1995. Use of geomorphologic and geomorphoclimatic instantaneous unit hydrograph model to investigate in no data watersheds. Proceeding of 3rd Hydrology Seminar on Ministry of Energy, 1995 University of Tehran, Iran, pp: 203-227.

Rezaee, A., 1994. Agreement between synthetic (artificial unit hydrograph and natural hydrograph in number of small watersheds. M.Sc. Thesis. University of Tehran, pp: 167.

Rodriguez-Iturbe, I. and J.B. Valdes, 1979. The geomorphologic structure of hydrology response. Water Resour. Res., 15: 1409-1420.

Rodriguez-Iturbe, I., G. Deveto and J.B. Valders, 1979. Discharge response analysis and hydrologic similarity, the interrelation between the geomorphological IUH and storm characteristic. Water Resour. Res., 15: 1435-1444.

Rodriguez-Iturbe, I. and R.L. Bars, 1982. A geomorphoclimatic theory of the instantaneous unit hydrograph. Water Resour. Res., 18: 887-886.

Sadeghi, H.R., H.R. Moradi, M. Mozayan and M. Vafakhah, 2005. Efficiency of different methods of statistical analysis of rainfall-runoff modeling (Case study: Kasilian catchment). J. Agric. Sci. Natural Resour., 12: 81-90.

Shahmohammadi, Z., 1994. Comparison of hydrograph of observed flood with hydrograph of calculated floods in Khersan Watershed. M.Sc. Thesis. Tarbiat Modarres University, pp: 186

Singh, S.K., 2000. Transmuting synthetic unit hydrographs into gama distribution. J. Hydrol. Eng., 112: 380-385.

Smith, M.B., V.I. Koren, Z. Zhang, S.M. Reed, J.J. Pan and F. Moreda, 2004. Runoff response to spatial variability in precipitation: An analysis of observed data. J. Hydrol., 298: 267-282.

USACE, 2000. HEC-HMS Users Manual Hydrologic Engineering Center. 1st Edn., US Army of Crops Engineers, Davis, CA., pp: 187.

Viessman, W. and G.L. Lewis, 2003. Introduction to Hydrology. 5th Edn., Prentice Hall, Englewood Cliffs, New Jersey, pp: 612.

Zehtabian, Gh., A. Alipour Tomaj and M. Vafakhah, 2001. An investigation of the use of artificial unit hydrograph in analysis of flood of northern Iran watersheds. Iran. J. Natural Resour., 54: 331-344.

Zeiazinski, J., 1986. Application of the geomorphological instantaneous unit hydrograph theory to development of forecasting models in Poland. Hydrol. Sci. J., 31: 261-561.