DESERT

DESERT
Online at http://jdesert.ut.ac.ir

DESERT 18 (2013) 105-111

Estimation of Instantaneous Peak Discharge Using GIUH, Snyder, SCS and Triangular Models: a Case Study of Central Alborz Watershed

H. Ahmadi[a], A.A. Mohammadi[b*], Sh. Khalighi[c], A. Salajegheh[c], S. Soltani[d]

[a] *Science and Research Branch, Islamic Azad University, Tehran, Iran*
[b] *PhD Student of Watershed Management, Science and Research Branch , Islamic Azad university, Tehran, Iran*
[c] *Faculty of Natural Resources, University of Tehran, Karaj, Iran*
[d] *Faculty of Natural Resources, Isfahan University of Technology, Isfahan, Iran*

Received: 6 February 2010; Received in revised form: 21 July 2010; Accepted: 25 July 2010

Abstract

The estimation of instantaneous peak discharge is important for watershed management because there is a insufficient climatic and hydrologic data in countries such as Iran. Researchers have been forced to link constant parameters (geomorphology) and variable parameters (hydrology) to models with minimum dependence on climatic and hydrologic data for hydrologic estimation. The present study used a synthetic unit hydrograph at three drainage basins in the central Alborz watershed (Kan, Amameh and Mehran) and compared the results with peak discharge in the study areas to derive the best model. The results of the instantaneous peak discharge estimation were similar for each drainage basin. A comparison of the models using relative mean error (RME) and root of mean square error (RMSE) for the three drainage basins showed that the mean RME for GIUH was 21.31, for Snyder was 82.25, for SCS was 227.34, and for triangular was 231.27. The mean RMSE for GIUH was 12.76, for Snyder was 17.05, for SCS was 42.84, and for triangular was 43.62. This confirms that the best estimation was produced by GIUH, followed by the Snyder, SCS and triangular models.

Key words: Peak Discharge; Model; Watershed; Hydrograph; Geomorphology

1. Introduction

The average global annual precipitation is 860 mm. Iran records an average of 240 mm and is classified as semi-arid. This amount of precipitation is insufficient for spatial agricultural needs (Alizadeh, 2000). To address the issue, water use should be modified according to annual rate of precipitation. One way to cope with drought is strategic application of available water resources (such as surface and ground water). This strategy cannot be practiced without identifying district hydrology.

Water resources must be identified to mitigate the important biological and economic problems. Better application of hydrology in Iran is also needed to control flooding throughout the country and mitigate the effects of drought. In recent years, attention to water crises has increased, but there is not enough data recorded in this regard. It is clear that, without the study of geomorphology and hydrology of drainage basins, scientific approaches for flood management cannot be developed. The study of drainage basins must consider geomorphological characteristics that affect discharge characteristics of major rivers and tributary streams, along with the sediment they generate (Ahmadi, 2006). In the absence of instrumentation to record essential data and natural unit hydrographs, other methods can be used for determining unit hydrographs.

Sherman (1932) considered the effective factors for shaping a hydrograph, including physical attributes of the drainage basin such as area, shape and slope. In many cases, that are

* Corresponding author. Tel.: +98 21 88286838, Fax: +98 21 88286838.
E-mail address: aliasgharmohammady@yahoo.com

constant results there hydrograph shape must be same for storms with same attributes (Mahdavi, 1999). Snyder (1938) proposed a method in accordance with the attributes of unit hydrographs for a drainage basin in the Appalachian Mountains (Alizadeh, 2000). Measurement was done by the US Soil Conservation Service (SCS) in different drainage basins to produce a dimensionless hydrograph (Mockus, 1957). This study showed that, if dimensions of a flood hydrograph axis are derived under different conditions, they will have similar shapes (Mahdavi, 1999).

The deficiencies of a geomorphologic instantaneous unit hydrograph (GIUH) were demonstrated in 1979 by Rodriguez-Iturbe. Recent progress has been made in obtaining run-off topographic data using GIUH. In the past two decades, the use of geomorphology for drainage basin attributes in run-off simulations has been of interest (Gupta, 1980; Rodriguez-Iturbe, 1982; Krishen and Bars, 1983; Troutman, 1985; Anges, 1988; Chutha and Dooge, 1990; Yen and Lee, 1997; Feldman and Kull, 1988; Olivera and Maidment, 1999; Berod, 1999; Mc Donnel and Brooks, 2000). The result is GIUH, an instantaneous unit hydrograph derived using Horton law for the construction and structure of drainage basins describing the engineering of stream networks and the resulting of geomorphology response (Karonen, 1998).

A mathematical method and its efficiency were proposed by Lee and Chin-Hsinchang (2005) in a study in northern Taiwan. The results showed that run-off primarily occurs in the lower portions of a watershed near streams. A precipitation-run-off model that considers only surface run-off was recognized as inadequate and shows that the assistance of GIUH can help derive better results. The surface-flow IUH of this study could adequately reflect the variation of surface roughness conditions. A subsurface-flow IUH could reveal different soil conditions. GIUH was utilized to calculate the influence of the channel network on the delay and the shape of the hydrograph (Karvonen, 1999).

2. Material and methods

Study area

Central Alborz watershed contains three drainage basin; Kan, Amameh and Mehran (Fig 1). These drainage basins were selected because they contain rain gauge stations and hydrometric stations at their outlets. Kan has three rain gauge stations (Rendan, Sangan, Emamzadeh Davood) and one hydrometric station to record of hour-by-hour flood discharge (Soleghan). Amameh has one rain gauge station (Amameh) and one hydrometric station (Kamarkhani). Mehran drainage basin has one gauge station (Joestan) and one hydrometric station (Joestan) (Fig. 1 and Table 1).

Methods

1. Rain and discharge data for floods

The flood discharge and rainfall statistics were provided by the Institute of Tehran Province and Organization of Water Resource Research. Of the 22 events recorded for Kan drainage basin, 11 events were deemed appropriate for the present study. Eight events were selected for Amameh and 7 events were selected for Mehran drainage basin.

2. Digital topographic map

The digital topographic map was provided by the Iranian Geographic Organization. The map provided drainage basins in the area, mean slope of drainage basin, mean weighted slope of main streams outlets, main stream length from centroid to outlet, and slope of highest streams. The bifurcation ratio (R_b), stream length ratio (L_u) and area ratio (A_u) were determined from the values provided. The bifurcation ratio (R_b) is calculated as $R_B = N_u/N_{u+1}$. The length ratio was calculated as $R_l = L_u/L_{u-1}$ and area ratio as $R_A = A_u/A_{u-1}$ where:

N_u, N_{u+1}: number of streams U and U+1
L_u, L_{u-1}: mean length of streams U and U-1
A_u, A_{u-1}: mean area of basins U and U-1

3. Flow rate

Flow velocity was determined for one specific storm using the method described by Rodriguez-Iturbe et al. (1979) (Eq. 1):

$$V_\Omega=0.665\alpha_\Omega^{0.6}(i_rA)^{0.4} \qquad \alpha_\Omega=S_\Omega^{0.5}/nB^{2/3} \qquad (1)$$

where V_Ω = flow velocity (m/s), i_r = rain intensity (cm/h); A = drainage basin area (km^2); S_Ω = slope of main river in drainage basin outlet (%); n = Mannig's roughness coefficient; and B = mean flow width in outlet of drainage basin (m).

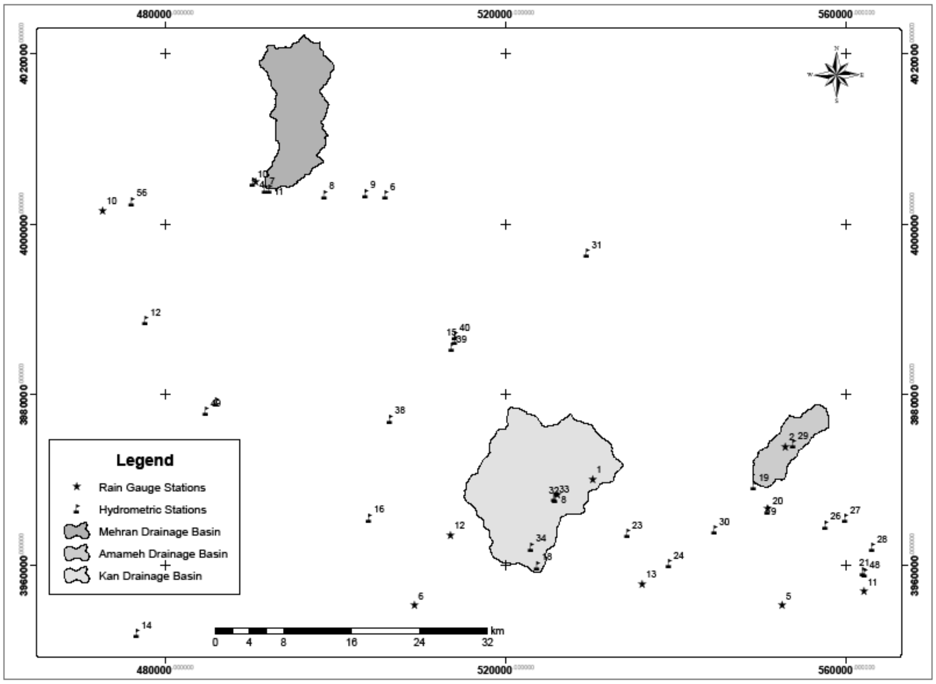

Fig. 1. Location of drainage basins, rain gauge stations and hydrometric stations

Table 1. Attributes of drainage basins, rain gauge stations, and hydrometric stations

ID	X	Y	hydrometric station	ID	X	Y	hydrometric station
1	51.945	35.921	Sefid Ab- Sefid Ab	37	51.929	35.738	Ah- Roodehen
2	51.993	35.918	Delichay- Delichay	38	51.071	35.939	Haftcheshme- Aradan
3	52.057	35.855	Lar- Plour	39	51.151	36.014	Morood- Pole Khab
4	52.076	35.837	Haraz- Ghable Cheshme	40	51.156	36.027	Glokan- Siera
5	52.088	35.857	Haraz- Baede Cheshme	41	51.872	35.731	Siahrood- Bomehen
6	51.065	36.175	Gatedeh- Gatedeh	42	52.174	35.514	Jamabrood- Kilan
7	50.908	36.182	Shahrood- Joestan	43	50.401	35.810	Khoroji Kordan- Najmabad
8	50.986	36.176	Narian- Narian	44	51.354	35.503	Kan- Jahan abad
9	51.039	36.177	Dehdar- Dehdar	45	51.340	35.502	Kanal Navab Safavi- Kashanak
10	50.892	36.189	Elizan- Joestan	46	51.469	35.478	Nahre Firoozabad- Nazarabad
11	50.913	36.182	Mehran- Joestan	47	51.467	35.583	Koroji Shemiranat- Taghiabad
12	50.752	36.043	Fashand- Fashand	48	51.688	35.774	Nahr Latian- Latian
13	50.844	35.957	Kordan- Deh Someh	49	50.831	35.946	Nahre Kordan- Kordan Dehe Some
14	50.742	35.711	Shor- Asefaldole	50	50.951	35.453	Shor- Pole Save
15	51.156	36.022	Karaj- Siera	51	51.232	35.450	Karaj- Fashfoe
16	51.044	35.834	Karaj- Bileghan	52	52.504	35.522	Dilichae- Simindasht
17	50.147	36.019	Nashtrood- Pole Khab	53	52.771	35.748	Hablerood- Firoozkoh
18	51.262	35.784	Kan- Soleghan	54	52.663	35.721	Namrood- Namrood
19	51.544	35.867	Amameh- Glokan Kamarkhani	55	52.517	35.521	Hablerood- Simindasht
20	51.562	35.841	Jajerood- Roodak	56	50.734	36.169	Shahrood- Glinak
21	51.685	35.776	Jajerood- Latian				
22	51.534	35.233	Jajerood- Sharif Abad				
23	51.379	35.817	Darake- Haft Hooz	ID	X	Y	Rain Gauge Station
24	51.433	35.785	Darband- Maghsood Beik	1	530199	3970103	Emamzade Davood
25	51.883	35.919	Lar- Goozal Dare	2	552827	3973921	Amameh
26	51.637	35.825	Galandook- Najar Kola	3	560611	3909708	Ab Varamin
27	51.663	35.831	Narvan- Afje	4	490631	4005022	Joestan
28	51.698	35.801	Lavarak- Ali abad	5	552465	3955261	Daneshgah Abaspour
29	51.596	35.911	Amameh- Bagh Tange	6	509277	3955261	Sade Karaj
30	51.493	35.820	Dar abad- Ghalak	7	491342	3762106	Sangan
31	51.328	36.113	Velayatrood- Gachsar	8	526051	3968295	Rendan
32	51.286	35.854	Kiga- Kiga	9	550717	3966557	Roodak
33	51.284	35.855	Redan- Rendan	10	472653	4001552	Zidasht
34	51.254	35.803	Kashar- Kashar	11	562043	3956914	Latian
35	51.884	35.623	Damavand- Zere Dare	12	513500	3963506	Niavaran
36	52.069	35.710	Damavand- Targhazi	13	536000	3957750	Yousef Abad

4. Instantaneous peak discharge estimation

Using GIUH and the relation presented by Rodriguez-Iturbe et al. (1979) (Eq. 2):

$$q_p=1.31/L_{\Omega}[R_L^{0.43}V] \quad (2)$$

where L_{Ω} = length of main river (km); V = flow velocity (m/s);, q_p = peak discharge in (hr^{-1}) (Eq. 3).

$$Q_p/Q_e=t_r*q_p(1-t_r*q_p/4) \quad Q_e=i_r*A\rightarrow t_b>=t_r \quad (3)$$

where Q_p = exited peak discharge of hydrograph (m^3/s) Q_e = effective discharge (m^3/s); q_p = peak discharge of GIUH (hr^{-1}); t_r = time of effective precipitation (h); i_r = rain intensity (cm/h); A = drainage basin area (km^2).

5. Peak discharge estimation

The Snyder, SCS and triangular models used the relation presented in Mahdavi (1999) and Alizadeh (2000).

3. Results

1. The results of rain and discharge coincidence extractions are presented in Table 2
2. The geomorphologic parameters calculated for extraction from each drainage basin are shown in Tables 3, 4 and 5

Table 2. Numbers and dates of events in each drainage basin Table (2): Numbers and dates of events in each of study drainage basin

Mehran drainage basin		Amameh drainage basin		Kan drainage basin	
Date of events	Events Num.	Date of events	Events Num.	Date of events	Events Num.
20,21 Apr 2003	7	8, 9 Dec 2002	8	12 Dec 2000	11
29 May 2003		6, 7 Mar 2002		18,19 Nov 2001	
4 Oct 2003		25, 26 Mar 2003		7, 8 Jan 2001	
24, 25 Apr 2004		21,22,23 Apr2003		2, 3 Apr 2002	
26, 27 Apr 2005		13 Jan 2003		12, 13 Apr 2002	
7, 8 Nov 2006		15, 16 Feb 2003		17,18,19,20 Apr 2002	
		2,3 Apr 2004		26, 27, 28 Mar 2003	
		5,6 Apr 2004		16, 17 Apr 2003	
				22 Apr 2003	
				15, 16 Apr 2005	
27, 28 Apr 2007				26, 27 Apr 2007	

Table 3. Geomorphologic parameters calculated for Kan drainage basin

Streams order	Number of streams	Length of streams (km)	Mean Length of streams (km)	Upstream drainage basin area (ha)	Mean Upstream drainage basin area (ha)	Mean stream length from upstream to outlet (km)	Main stream distance from outlet to centroid of drainage basin (km)	Mean slope of drainage basin (m/m)	Mean slope of main stream in outlet of drainage basin (m/m)
1	359	232.54	0.647	13785.3	38.39	23.00	12.181	0.473	0.02
2	64	69.29	1.08	11453.0	178.95				
3	13	30.649	2.235	9992.81	768.67				
4	4	28.519	7.13	14134.2	3533.55				
5	1	12.295	12.29	20478.8	20478.8				

Table 4. Geomorphologic parameters calculated for Amameh drainage basin

Streams order	Number of streams	Length of streams (km)	Mean Length of streams (km)	Upstream drainage basin area (ha)	Mean Upstream drainage basin area (ha)	Mean stream length from upstream to outlet (km)	Main stream distance from outlet to centroid of drainage basin (km)	Mean slope of drainage basin (m/m)	Mean slope of main stream in outlet of drainage basin (m/m)
1	234	109.01	0.465	2535.33	10.83	13.76	67.56	0.59	0.0654
2	45	30.078	0.668	2390.84	53.13				
3	10	10.640	1.064	2450.51	245.05				
4	1	11.869	11.869	3763.19	3763.19				

Table 5. Geomorphologic parameters calculated for Mehran drainage basin

Streams order	Number of streams	Length of streams (km)	Mean Length of streams (km)	Upstream drainage basin area (ha)	Mean Upstream drainage basin area (ha)	Mean stream length from upstream to outlet (km)	Main stream distance from outlet to centroid of drainage basin (km)	Mean slope of drainage basin (m/m)	Mean slope of main stream in outlet of drainage basin (m/m)
1	598	286.21	0.4786	6767.44	11.3168	22.07	11.749	0.244	0.01955
2	120	72.330	0.6027	5928.74	49.406				
3	27	36.998	1.3703	6599.67	244.432				
4	5	9.352	1.8704	4853.50	970.700				
5	1	16.548	16.548	9971.29	9971.29				

3. The results of measurements and parameters calculated for flow velocity from the kinematic wave parameters are presented in Table 6.
4. The estimated peak discharge estimation of the study models are shown in Tables 7,8 and 9.
5. The comparison of RME and RMSE for calculated peak discharge of the 4 models and observed peak discharge are shown in Table 10.

Table 6. Parameters for flow velocity from cinematic wave parameters

Drainage basin	Mannig's roughness coefficient (n)	Slope of main river in drainage basin outlet S_Ω (%)	drainage basin area (km^2)	rain intensity I_r (cm/h)	mean flow width in Outlet of drainage basin B (m)
Kan	0.52	2.36	20478.85	It's different for any events in drainage basin	10.04
Amameh	0.0229	6.54	3763.19		1.367
Mehran	0.0382	1.95	9971.46		7.089

Table 7. Dates and peak discharge estimation (m^3/s) from 4 models in Kan drainage basin
(Qp(o) = observed peak discharge; Qp(Tri) = peak discharge for triangular model; Qp(SCS) = peak discharge for SCS model; Qp(Sny) = peak discharge for Snyder model; Qp(GIUH) = peak discharge for GIUH model

Kan drainage basin					
Events Date	Qp(o.)	Qp(Tri.)	Qp(SCS)	Qp(Sny.)	Qp(GIUH)
12 Dec 2000	49.00	119.77	118.38	67.175	48.58
18,19 Nov 2001	56.71	93.733	92.549	72.415	54.41
7, 8 Jan 2001	69.86	111.97	110.69	65.59	48.58
2, 3 Apr 2002	79.71	139.14	137.492	70.58	83.91
12, 13 Apr 2002	51.81	99.07	97.96	62.64	42.66
17,18,19,20 Apr 2002	44.41	151.39	149.56	72.41	47.865
26, 27, 28 Mar 2003	95.89	99.075	97.96	62.64	54.41
16, 17 Apr 2003	70.10	166.00	163.95	74.348	72.46
22 Apr 2003	35.08	151.39	149.56	72.415	34.59
15, 16 Apr 2005	30.02	151.39	149.561	72.145	30.143
26, 27 Apr 2007	22.74	84.522	83.480	68.835	41.735

Table 8. Dates and peak discharge estimation (m^3/s) from 4 models in Amameh drainage basin

Amameh drainage basin					
Events Date	Qp(o.)	Qp(Tri.)	Qp(SCS)	Qp(Sny.)	Qp(GIUH)
8, 9 Dec 2002	19.29	30.9	30.55	17.507	3.07
6, 7 Mar 2002	7.61	26.180	25.86	18.79	7.63
25, 26 Mar 2003	23.02	31.377	30.97	20.28	17.63
21,22,23 Apr2003	2.78	50.74	50.12	20.28	3.08
13 Jan 2003	19.33	50.74	50.123	20.28	11.54
15, 16 Feb 2003	6.31	25.86	26.180	18.79	5.92
2,3 Apr 2004	8.73	38.41	37.96	18.793	5.65
5,6 Apr 2004	12.308	43.72	43.206	19.509	12.788

Table 9. Dates and peak discharge estimations (m^3/s) from 4 models in Mehran drainage basin

Mehran Drainage basin					
Events Date	Qp(o.)	Qp(Tri.)	Qp(SCS)	Qp(Sny.)	Qp(GIUH)
20,21 Apr 2003	55.46	48.483	47.893	21.39	18.73
29 May 2003	23.51	54.83	54.145	22.09	23.366
4 Oct 2003	34.054	32.77	32.35	22.1	12.59
24, 25 Apr 2004	8.97	58.67	57.92	22.45	9.052
26, 27 Apr 2005	18.54	33.66	34.108	22.45	16.94
7, 8 Nov 2006	22.57	31.136	31.54	21.73	22.83
27, 28 Apr 2007	22.35	51.46	50.827	21.73	21.803

Table 10. Comparison of RME and RMSE for 4 models

Study models	Mehran Drainage basin		Amameh Drainage basin		Kan Drainage basin	
	RMSE	RME	RMSE	RME	RMSE	RME
GIUH	16.089	20.43	6.73	25.52	15.46	17.99
Snyder	14.65	40.062	9.69	146.75	26.82	59.66
SCS	25.371	133.082	27.165	386.323	76.002	162.631
Triangular	25.828	135.722	27.61	392.284	77.444	165.821

4. Discussion and Conclusions

Table 10 shows that the best estimations were obtain from (in order) the GIUH, Snyder, SCS, and triangular models. Tables 7, 8, 9 and 10 indicat that the GIUH and Snyder models produced similar results. A study in Paskohak drainage basin by Rahimian and Zare (1995) was used for comparison of the results of the 4 methods results. It showed that GIUH was most similar to the observed hydrograph.

Ghiassi (2004) compared the GIUH and GCIUH methods for the hydrographs of Kassilianh and Lighvan basins and compared them to other synthetic methods (Snyder, SCS, triangular SCS). He found that the GIUH by ROSSO method also acquired. No significant difference was observed. He also found that peak discharge estimation for the GIUH, triangular, SCS and Snyder hydrographs gave, in order, the best estimations. Ghiassi's results for GIUH matched the results of the present study, but results for the other methods did not coincide.

Heshmatpour (2002), compared GIUH, GCIUH, Nash, ROSSO and SCS in the Kassilian watershed. They found that GIUH was more efficient than GCIUH, Nash, ROSSO and SCS methods by 106.56%, 171.12%, 106.79%, and 112.64%, respectively. They also found GCIUH to be more efficient than Nash, ROSSO and SCS methods by 160.57%, 100.21% and 105.09%, respectively. Heshmatpour's results for GIUH are similar to the results of the present study.

Montazeri et al. (2004) used the Clarck method and GIS technique in Kardeh dam drainage basin. They found that the GIS technique for extraction required parameters from the Clarck synthetic hydrograph. They compared the observed hydrograph for the outlet of drainage basin and found good compatibility between the observed hydrograph data and the Clarck synthetic unit hydrograph. The present study also used this technique.

Recommendations

Many of the drainage basins in Iran do not have hydrometric stations or have incomplete statistics. It is recommended that, if rain gauge stations do exist, the GIUH method be used because this model provides minute estimation. If one drainage basin does not have hydrometric and gauge rain stations, the Snyder model is recommended.

Under the same kinematical conditions, the effect of size or scale in the IUH is not provided by the area of the basin, but by the length of the storms (L_Ω). Two basins may be considered hydrologically similar when they have identical $R_L^{0.43}/L_\Omega$ values, which controls q_p and $L_\Omega(R_B/R_A)^{0.55}$ $R_L^{-0.38}$ and t_p. Since the values for R_L occur in nature, it may be assumed that $R_L^{0.43} \approx R_L^{0.38}$ for two basins will be similar when they have equal $R_L^{0.43}/ L_\Omega$ and R_B/R_A. L_Ω should be expressed in km when comparing different values of $R_L^{0.43}/L_\Omega$ (Rodriguez-Iturbe and Valdes, 1979). It is recommended that the GIUH model be further tested as a suitable method for other drainage basins in Iran.

References

Ahmadi, H., 2006. Quantities Geomorphology, document of Ph.D course of Watershed management, 220pp (In Farsi).

Alizade, A., 2000. Principles of applied hydrology, 12th publication, Emam Reza Univercity Press, 622pp (In Farsi)

Chutta, P. and J.C.I. Dooge, 1990. The shape parameters of the geomorphologic unit hydrograph. J. Hydrology, 117: 81-97.

Ghiassi, N., 2004. Application of geomorphologic instantaneous unit hydrograph in Kasilian& Lighvan basins. Final report of research plan, Soil Conservation and Watershed Management Institute, 170pp (In Farsi)

Heshmatpour, A., 2002. The efficiency study of Geomorphologic and Geomorphoclimatic instantaneous unit hydrograph in Kasilian watershed. MSc thesis, Agricultural and Natural Resources University of Gorgan, 137pp.

Lee K.T. and C.H. Chang, 2005. Incorporating subsurface-flow mechanism into geomorphology-based IUH modeling. Journal of Hydrology, pp. 91-105.

Mahdavi, M., 1999. Applied hydrology, Volume 2, Edition 2, University of Tehran Press, 401pp (In Farsi).

Montazeri, S., M. Rahnama and A. Akbarpour, 2004. Instantaneous unit hydrograph determination with using Clarck method and GIS technique in Karde dam drainage basin. International Conference of Watershed Management, Water Resources and Soil Management. Keraman, Iran, 12pp (In Farsi).

Rahimian, R and M. Zare, 1995. Application of geomorphologic instantaneous unit hydrograph for synthetic hydrograph in UN gauged drainage basin. Collection of article; third conference of hydrology, Ministry of energy: 203-227 (In Farsi).

Rodriguez- Iturbe, I., I. Devoto and G. Valdes, 1979. Discharge response and hydrologic similarity: the interrelation between the geomorphologic IUH and storm characteristic. Water Resource Research 15(6): 1435-1444.

T. Karvonen, H. Koivusalo, M. Jauhiainen, J. Palko and K. Weppling, 1999. A hydrological model for predicting runoff from different land use areas. Journal of Hydrology, 217: 253-265.