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The simulation of flood hydrograph under uncertain conditions of rainfall extreme values in different return periods: A case study on Gharesoo basin

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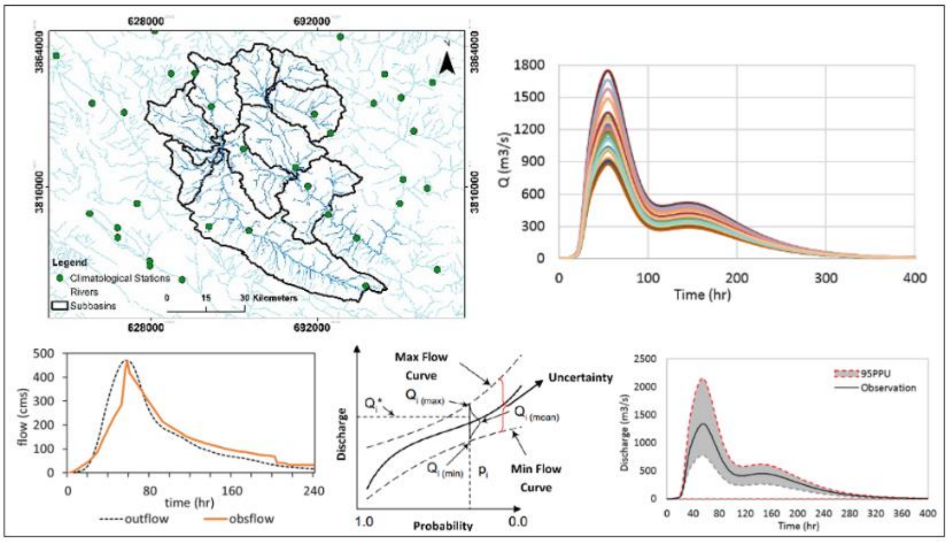
GRAPHICAL ABSTRACT



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ABSTRACT

Flood is inherently an uncertain phenomenon and the certainty and credibility of flood forecasting and warning systems will cause errors regardless of the sources of uncertainty. Extreme rainfall events are one of the most important input data to rainfall-runoff models, which always have uncertainty. Considering this issue the uncertainty of the design flood hydrograph can be investigated for different return periods. In this research first to simulate the flood hydrograph the HEC-HMS model was calibrated and validated based on the hourly flood hydrographs recorded at the basin outlet. Historical data were collected on the 24-hour maximum rainfall of Gharesoo basin stations with 30-year statistics and the affected basins were identified. Then in each station 30 series of 30 years of artificial data with a maximum 24-hour rainfall were produced. For each of these produced stochastic series the best statistical distribution was fitted and in each series extreme values with a return period of 25 50 100 and 1000 years were calculated. Finally in each return period by combining 30 different amounts of rainfall obtained from stochastic series, the uncertainty bandwidth of the flood hydrograph was obtained during this return period. The results indicated that the highest predicted peak discharge for different return periods was between 1.2 and 1.7 times the historically recorded discharge during that return period. Generally the maximum discharge of different return periods was between 1.5 and 3 times the minimum discharge.

1. Introduction

Hydrological simulation models are used as an efficient tool for better investigation and understanding of hydrological processes in the watershed. There are many rainfall-runoff models for flood prediction each of which has different capabilities and applications .Drainage basin models are classified into different categories including experimental versus physical models event-oriented versus continuous

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models and concentrated versus distributive parameter models. HEC-HMS software is a simulation-type hydrological modeling software capable of simulating precipitation-runoff processes in different basins (Goodarzi et al. 2009). Cheng et al. (2013) used the HEC-HMS hydrological model to predict severe floods in the Sheiman Basin in Tavan. Using data from three dangerous floods with a 1-90 year return period they simulated runoff from torrential rainfall in the HEC-HMS model .They concluded that HEC-HMS's hydrological calibrated and approved model is capable of predicting historical floods. Ghiasi and Roghani (2006) investigated the efficiency of the geomorphological moment unit hydrograph and compared it with Schneider, Triangular and SCS hydrographs .The results indicated that there was no difference between different methods based on statistical analysis. Karimi et al. (2011) evaluated different methods of flood hydrograph simulation using HEC-HMS software in the Chehel Gezi basin .They investigated the simulation of flood hydrograph and hydrograph characteristics including peak discharge runoff volume and peak time, using three hydrograph methods of synthetic unit SCS, Schneider and Clark .Their results showed that the SCS method is better than Clark and Schneider's methods. Rostami and Esmaili (2014) simulated the rainfall-runoff process using the HEC-HMS model according to the seasons and also changes in the use of different periods in Kordan's drainage basin .Their results showed that in case of user change and consequently changing the curve number it is necessary to prepare a separate hydrological simulator model with higher accuracy for periods with similar applications. Hosseinzadeh and Immani (2015) modeled hydrologically in the Qarchak-Rudak watershed using HEC-HMS software. The results of their model were not accepted in relation to the efficiency of the mentioned model in estimating runoff and peak flood discharge because the difference between the observational and computational peak discharges was more than 20 %.

In all the studies mentioned and also studies conducted by Rostamizad et al. (2009) and Ymani and Mehrjunejad (2011), and Hosseinzadeh and Immani (2015), despite the use of numerical models such as HEC-HMS and experimental equations the effect of uncertainty of predictions on flood hydrograph has not been seen which will cause errors in predicting future events and floods.

Emerson et al. (2003) modeled rainfall-runoff using the HEC-HMS model. The results showed that the storage levels reduced the peak flow value for the storm event. Osama et al. (2009) analyzed the sensitivity of the HEC_HMS model to the number of sub-basins in a case study .They analyzed the sensitivity of the model in two cases with sub-basins 3 and 5 .The results showed that the number of sub-basins does not have a significant impact on the amount of discharge however increasing the number of sub-basins changes the peak discharge values .The results also showed that the HEC_HMS model is sensitive to the input slope parameter if the SCS method is used whereas this sensitivity is not present in the Green Ampet method. Ulche et al. (2010) used HEC-HMS software to predict flooding in the Misai Basin in China. They conducted their study with the aim of presenting a comprehensive program of the HEC-HMS model and investigated its application, capability and suitability for flood prediction. The results showed that the SCS hydrograph method has acceptable results in the simulation of precipitation-run off .Song et al. (2011) used the Muskingam routing method in HEC-HMS software with variable parameters k and x and physical characteristics of the basin such as slope, river length and peak flood discharge in the basin and considered the impact of flood on routing parameters .Their results showed that the combination of a hydrological model and a geographical analysis model is significant for obtaining topographic parameters of the basin and is a reliable method for flood prediction. Mandal et al. (2016) assessed the risk of flash flooding in the Tessta River basin using HEC-HMS software. They evaluated the data to estimate the maximum peak discharge and runoff volume and concluded that in real conditions based on rainfall, peak discharge time and volume are predictable for the basin. Brauer et al. (2017) used the HEC_HMS modeling continuous system for simulation in the Russian River Basin in California. Their study showed that the model had a very good performance level in all locations for runoff production. As mentioned above in many studies conducted outside Iran predictions have been considered conclusively and the bandwidth of flood hydrograph uncertainty has not been analyzed .But some new studies have examined this issue. Among Jacquier et al. (2021) investigated the uncertainty in AI-based models in flood prediction and tried to present a model considering the uncertainty caused by the model errors. Also, Muñoz et al. (2022) used the data assimilation (DA) method based on a combination of simulated data and observational data to almost reduce the uncertainty of predictions. Flooding as one of the natural hazards annually causes a lot of damage in urban areas and agricultural lands adjacent to the Gharesoo river. One of the useful strategies for flood control and management is to predict the hydrograph of some floods with different return periods in order to use it for flood zoning and also to design flood warning systems in flood zones. Due to the use of statistical methods and the use of empirical equations, flood hydrograph prediction is always associated with uncertainty. This uncertainty is especially important in rivers such as Gharesoo, part of which crosses urban boundaries and where flooding is life-threatening in addition to financial risks.

The main purpose of this study is to use historical data of 24-hour rainfall based on stochastic models of artificial rainfall series and predict the uncertainty bandwidth of extreme rainfall values in different return periods .Then, based on extreme rainfall values, the uncertainty of the designed flood hydrograph in the Gharesoo basin is analyzed, and the predictive bandwidth of the flood hydrograph with different return periods is investigated. Evaluating the HEC-HMS model in flood hydrograph prediction and its capability in estimating peak discharge and rainfall-induced flood volume as two important parameters in designing and managing catchments and water resources is another goal of this study.

2. Materials and methods

2.1. Study area

Introducing the study area: The drainage basin of Gharesoo is one of the sub-basins of Karkhe which covers about 11.4 % with an area of about 5793 square kilometers. Fig1 shows the Gharesoo Basin up to the site of the old bridge station. This basin is one of the most flooded catchments in Kermanshah province where the occurrence of destructive floods annually causes a lot of damage to urban and agricultural lands near the river.

This basin is located in Kermanshah province in terms of political divisions. The maximum height of the basin is 3351 meters and the minimum is 1300 meters. The average annual rainfall of the Gharesoo basin is 400 mm and the months of January and February have the highest, and June, July, and August have the lowest rainfall. The flow of the Gharesoo river increases from October, and it reaches its highest amount in April then the river's watering is reduced and it reaches its lowest amount in September.

Some Subbasin characteristics: In order to obtain the watershed area and differentiate the sub-basins and their physiographic characteristics, HEC-GeoHMS software extracts the characteristics of the region using a geographic information system (GIS (was used, which ultimately resulted in the extraction of 13 sub-basins. Some of the properties of the sub-criteria are listed based on Table 1.

Table 1. Some physiographic characteristics of the basin.

Sub-basin	Area, Km^2	Length of the longest waterway (m)	(%) Slope
1	228.46	35315	12.15
2	300.96	36062	10.33
3	441.595	52293	12.26
4	430.84	40270	9.1
5	2.94	3340	13.69
6	514.786	45801	11.83
7	419.277	44775	4.72
8	384.54	45229	7.72
9	0.547	2802	1.55
10	55.97	22646	4.35
11	219.44	37949	5.76
12	1463.67	115471	5.34
13	545.41	39049	10.88

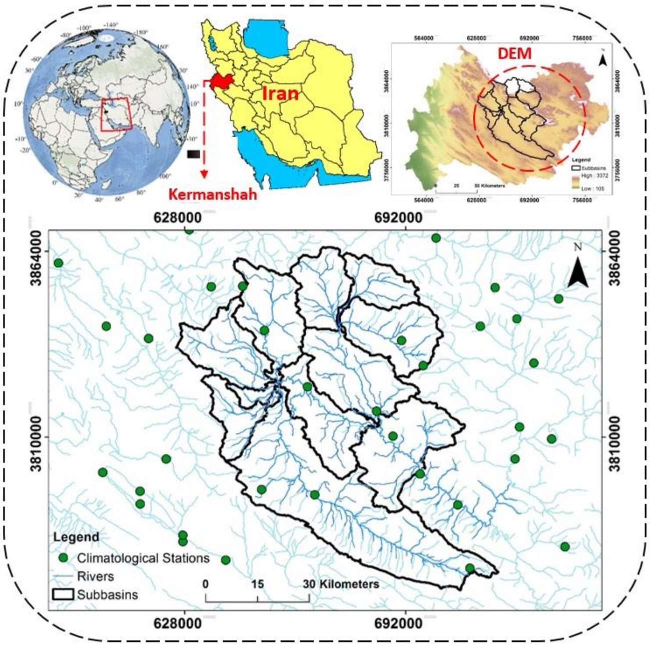


Fig. 1. Location of Gharesoo basin in Iran and Kermanshah province.

2.2. HEC-HMS software

HEC-HMS software has been produced by the U.S. Army Hydrological Engineering Center which has replaced HEC-1 software in the field of rainfall-runoff simulation and flood hydrology. HEC-HMS is more advanced in computer programming and hydrology engineering than HEC-1 software. HEC-HMS model has several models for analyzing the rainfall-runoff process loss calculation and routing. This study prepared the necessary information to estimate runoff and simulate flood hydrograph. For this purpose, rainfall data recorded in Doab Marg hydrometric stations, research center, old bridge, Ravansar and Soleimanabad were used .To investigate the performance of the model for simulation of a flood hydrograph, recorded data in old Bridge Station which was considered a basin outlet, related to flood events from 1998.3.7 to 1998.3.26 were used. In HEC-HMS software, the curve number method of soil conservation service (SCS Curve Number) was used to calculate rainfall losses .This method essentially implies total penetration during a precipitation event. By selecting this method three parameters should be introduced to the model including primary penetration, curve number, and percentage of the impenetrable surface area of the basin .Initial penetration indicates the amount of precipitation to land on earth before surface runoff is created. The experimental estimation of this parameter is done using Eq. 2.

$$S = (25400/CN) - 254 \quad (1)$$

$$Ia = 0.2S \quad (2)$$

Concerning (1), CN is a dimensionless number and varies from zero to 100. In relation to (2), Ia, the initial penetration is in millimeters and S is the amount of soil surface storage in millimeters .The curve number (CN) in different parts of a basin can vary according to the basin's type of soil and land use .Therefore, in this section, a curve number indicating the outcome of soil type and total land use under the basin was introduced to the model .In the conversion of precipitation to runoff, the hydrograph method of the SCS unit was used. The latency parameter should be introduced to the model by selecting this method. Latency is the time interval between the center of gravity of the precipitation hitograph and the peak time of the hydrograph corresponding to that precipitation, which is obtained from the relation (3).

$$t_{lag} = \frac{l^{0.8} * (s+1)^{0.7}}{1900 y^{0.5}} \quad (3)$$

$$S = (1000/CN) - 10$$

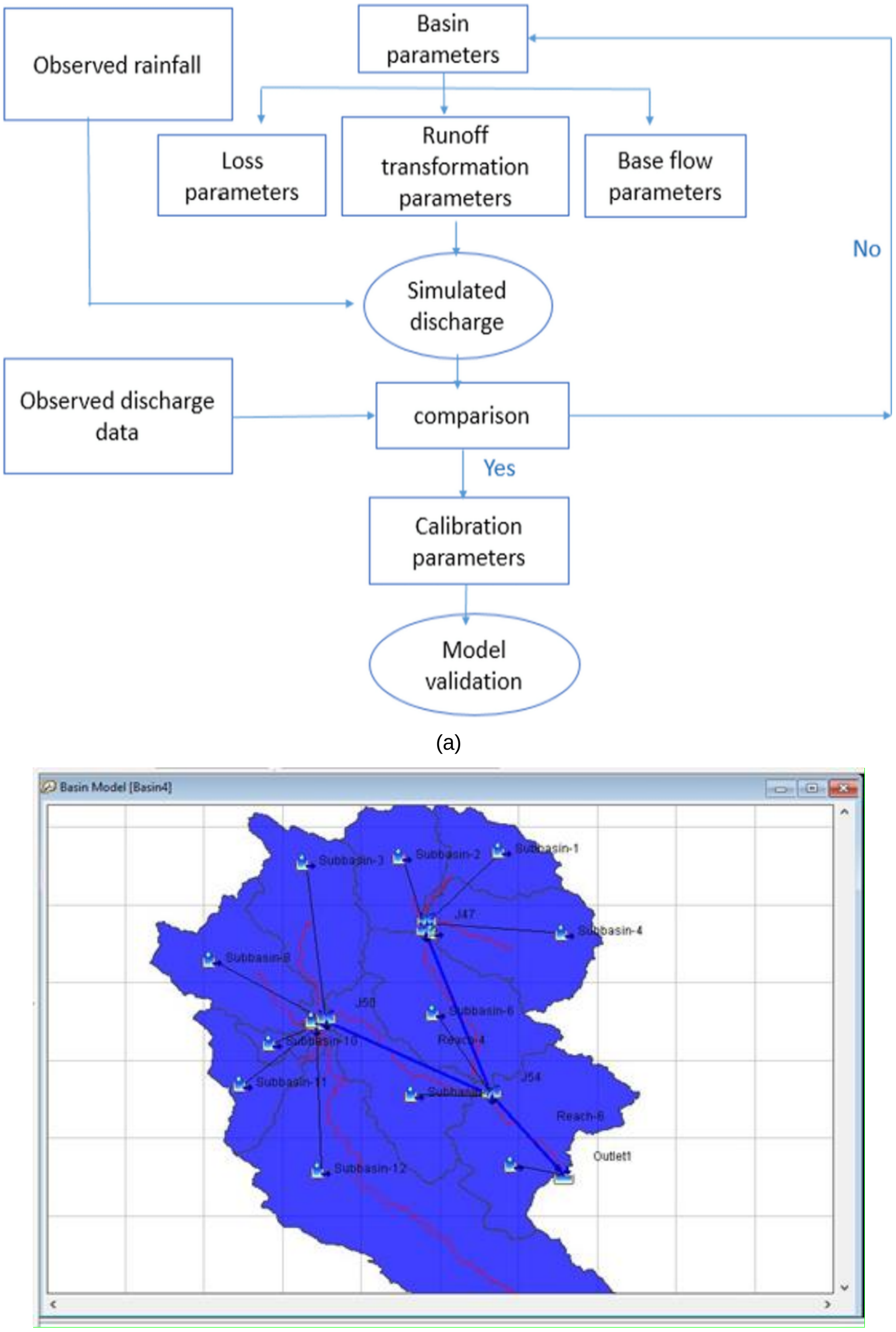
In this regard, L is the length of the main river in terms of feet, y is the average slope of the basin in percentage, CN curve number and t-lag. The latency is in hours. In the drainage basin meteorological model that prepares the weather conditions affecting the basin during the simulation period, the defined hitograph method was used.

2.3. Implementation of the model for the studied basin

First the drainage basin derived from ARCGIS software in which sub-basins, rivers and outlet points are defined was called in the HEC-HMS software environment and input information of each sub-basin including curve number, initial losses, latency and initial losses of runoff were calculated and the model was implemented. The objective function considered to evaluate the performance of the model in flood simulation works in such a way as to simultaneously minimize the difference between the estimated peak discharge and the estimated flood volume in the simulation hydrograph with the observed hydrograph. So that the difference in peak discharge reaches less than 10 % and the difference in flood volume reaches less than 20%. Fig. 2 shows the flowchart of the work steps and the basin model in the HEC-HMS software.

Runoff estimation using the HEC-HMS model for calibration of the model, after feeding the information about the meteorological model of the basin, adjusting the time series data and control characteristics, the HEC-HMS model was implemented using rainfall data of 5 meteorological stations to simulate the flood occurring on 1998.3.7**.** Parameters of curve number (CN), impenetrable surface percentage, latency and weight parameter of input current effect on storage in the waterway (X) were optimized, and a simulated hydrograph was obtained for basin output (old bridge station).

The simulated hydrograph is shown in Fig. 3 observed and simulated peak discharge values in Table 2 and some parameters optimized for each sub-basin in Table 3. As can be seen, the difference between observed and simulated hydrographs in peak discharge is 0.7 m/s, i.e. less than 1 % and in the amount of flood volume (the area below the flood hydrograph diagram) is 12.5 million cubic meters, i.e., about 12 % (less than 20 %), which is acceptable amounts for predicting flood hydrograph. To evaluate the results of the model calibration and their evaluation, observational storms were used on March 29, 1998, and March 11, 2005, and the optimized parameters were introduced to the model and the model was implemented to investigate how to fit the observed and computational hydrograph (Fig. 4). The results of peak discharge difference and perceived and simulated flood volume difference are shown in Table 3.



(a)

(b)

Fig. 2. Flowchart of the work steps and the basin model in the HEC-HMS software.

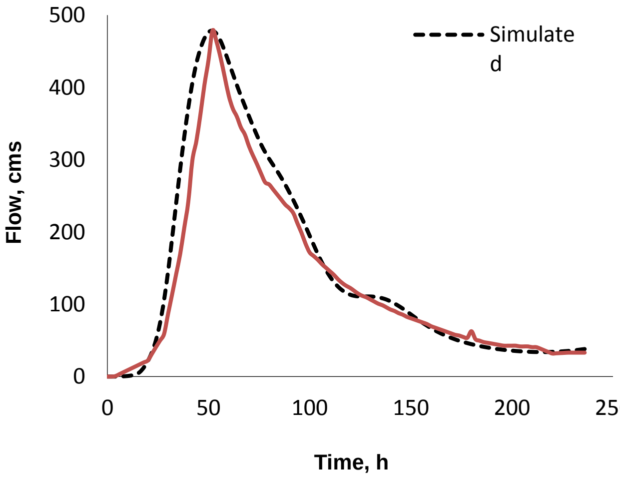


Fig. 3. Observational and simulated hydrograph at the site of old bridge station-calibration stage.

Table 2. Peak discharge and observed and simulated flood volume in the output of the Gharesoo watershed in the calibration stage.

Observational and computational differences	Computational	Observational hydrograph	Parameter
0.6	473.1	472.4	Peak discharge, m^3/s
12.3	90	112.6	Flood volume (MCM)

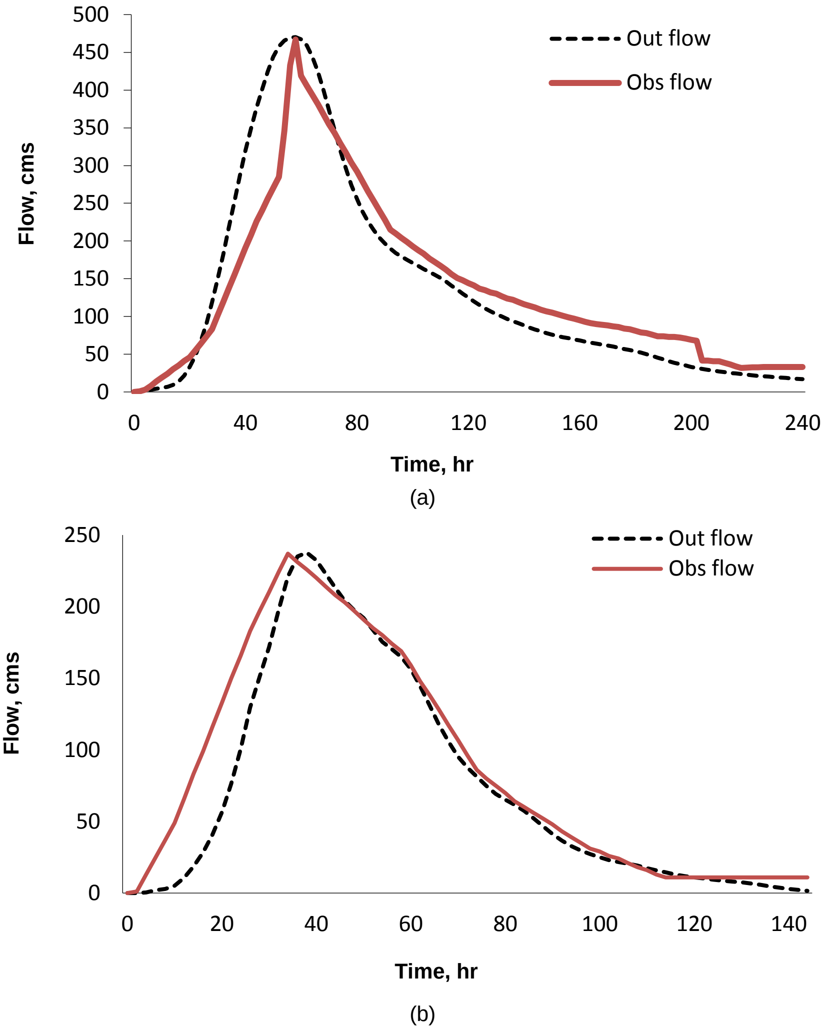


Fig. 4. Observational and computational hydrograph of the station on (a) 29/04/1998, and (b) 20/03/2005.

Table 3. Peak discharge values and observational and computational flood volume.

Date of storm	**Peak observational discharge, m^3/s**	**Computational peak discharge, m^3/s**	**The difference in observational and computational peak discharge, %**	**Observational flood volume, million cubic meters**	**Computational flood volume, million cubic meters**	**NRMSE**
1998/3/29	237	237.7	0.29	45.66	39.03	0.21
2005/3/10	467	470.2	0.68	119.68	118.67	0.28

According to this Table the difference between peak discharge in both selected incidents is less than 1 %. The difference in flood volume is less than 20 %, indicating the appropriate accuracy of the model in flood hydrograph simulation. Optimal values of effective parameters in flood hydrograph in each sub-studies are presented in Table4 As it is clear from this table the value of the penetration curve number in most sub-rivers was about 50 and less than that which indicates the slow reaction of these sub-basins' direct conversion of precipitation to runoff.
On the other hand in different stages of calibration and after many repetitions to achieve the best flood hydrograph prediction, it was found that the latency of most sub-basins is high and runoff resulting from high delay rainfall reaches the output of each sub-basin and finally to the output of the whole basin. This is because the geological structure of these sub-basins consists of karst formations, including limestone and gypsum marls which cause high infiltration of rainwater which flows with a long delay downstream as springs.

2.4. Generating of synthetic rainfall data and fitting probability distribution

In order to examine the planned flood hydrograph's uncertainty in the Gharesoo basin, artificial data of maximum 24-hour loading at the site of meteorological stations of the basin were produced based on stochastic models. SAMS software was used to produce artificial data. Historical data of maximum 24-hour loading of stations were selected as software inputs .Different models in SAMS software were tested for artificial rainfall data generation. Among mentioned models, ARMA (2, 0) model was chosen because for this model, the lowest values were seen in the AICC and SIC test statistics .Using the ARMA model (2, 0), 30 synthetic data series of maximum 24-hour rainfall during 30 years were generated statistically. Additionally, this strategy avoids producing static and repeating data by including a random element in the data generation process .Consequently, fluctuations and extreme amounts of discharge are also considered during the production time series. Than evaluate the efficiency of the model in the production of artificial data, the statistical characteristics of the produced series, such as mean, standard deviation, coefficient of variation, and skewness of the produced series, were compared with the recorded (observational) values. Regarding these criteria, the produced series should be in reasonably close vicinity to the observation series in order to maintain the characteristics of genuine data and be closely related to reality. Using Easy-fit software, various distributions were fitted to each created series, and the optimal statistical distribution for each series was chosen based on the Chi-square test. Then in each synthetic statistical series, flood discharges with return periods of 25, 50, 100 and 1000 years were estimated according to the appropriate distribution of that series.

Table 4. Some parameters optimized for the basin.

Sub-basin.	Curved number (CN)	Impenetrable surface, %	Waterway	X Coefficient
1	52	5	1	0.2
2	43	6		
3	49	5	2	0.36
4	53	4		
5	58	5	3	0.3
6	44	0.1		
7	40	0.1	4	0.3
8	58	2		
9	65	6	5	0.36
10	60	3		
11	40	0.1	6	0.3
12	45	0.1		
13	44.4	0.1		

2.5. Analysis of uncertainty of flood hydrograph design

In each of the selected meteorological stations in the basin, based on the production series of 24-hour rainfall by the stochastic model (30 series of 30 years of 24-hour rainfall) 30 different amounts of 24-hour rainfall hyetograph were obtained for each return period. The rainfall series generated from the stochastic model for each return period was entered as input to the HEC-HMS model, and different flood hydrographs (30 hydrographs) were obtained for each return period. These hydrographs were combined into one graph to determine the width of flood uncertainty within the 95 % confidence interval for each return period.

3. Results and discussion

The results showed that the most sensitive parameters in the calibration and verification stages were CN, lag time and K parameters, respectively. CN parameter had the greatest impact on the peak discharge. Lag time and K parameters had the greatest impact on the width of the hydrograph and flood volume. Different models were tested in SAMS software to generate synthetic peak flow data. Based on the results of the AICC and SIC tests, the best 5 models are ranked in Table 5. Therefore, the ARMA model (2,0), which was utilized to create artificial data, was the best model for producing synthetic data of flood peak discharge due to the lower AICC and SIC values.

After generating the synthetic series, the accuracy of the generated series was investigated by comparing the statistical indicators of mean, standard deviation, coefficient of variation, skewness, minimum and maximum of synthetic data and recorded observational data. The values of these indicators are shown in table (6) for each of the generated and historical data. Table 6 shows that among the presented models, the model ARMA (2, 0) preserves the statistical characteristics of historical data and at the same time has the ability to produce more dry and wetter data than historical data. Also ARMA (2, 0) has memorized data originality in the generating of synthetic data.

Table 5. Shown the ranking of top model for artificial data production.

Rating	Model type	AICC criteria	SIC criteria
1	ARMA (2,0)	10.2	10.1
2	ARMA (2,1)	10.23	10.16
3	ARMA (1,1)	10.45	10.37
4	ARMA (1,0)	12.55	13.5
5	ARMA(0,1)	12.6	13.5

The Chi-square test was used to determine the optimum statistical distribution for each series. Likewise, in each artificial statistical series, according to the appropriate distribution of that series, the maximum 24-hour rainfall with estimated return periods of 25, 50, 100 and 1000 years was estimated. Additionally, based on synthetic data, an estimate of the maximum 24-hour rainfall for the return period of 30 was made. Table 7 provides the estimated values' mean, maximum, minimum, and standard deviation values. The difference in estimated values demonstrates that these precipitations were assessed with a certain level of uncertainty. After extracting the hyetograph of each of these precipitations based on the time pattern of precipitation and entering it into the Hec Hms model, the flood hydrograph of these precipitations was simulated and the peak discharge rate of each hydrograph was obtained. In order to determine the uncertainty threshold for each return period and to build the discharge-probability curve, these values were employed, as shown in Fig. 6. This threshold shows the occurrence of discharge changes in every probability. In principle, using only a series of statistics and a distribution for estimating peak floods with each return period has uncertainty. For predict future condition we cannot easily use it, structural design and calculations related to the flood zone.

Table 6. Comparison of statistical indicators of artificial production data and observational data of maximum 24-hour rainfall.

Statistical Indicator	Recorded historical data	ARMA (0,2)	ARMA (0,1)	ARMA (1,0)	ARMA (1,1)	ARMA (2,1)
Mean	43.3	43.4	44.3	44.0	43.6	43.5
St Dew	13.1	13.7	13.8	13.8	14.0	13.8
CV	0.30	0.31	0.31	0.31	0.32	0.32
Skew	1.11	1.84	1.87	1.88	1.98	1.84
Min	24.8	22.0	23.2	23.2	22.8	22.1
Max	80.0	152.8	142.1	138.3	137.5	145.2

Table 7. Data of the discharge curve-probability in different return periods (probabilities).

Standard deviation	Mean	Q_{min}, m^3/s	$Q_{max,}$ m^3/s	Return period, year
8.8	72.7	54.5	94.8	25
11.5	81.5	58.8	109.2	50
14.9	90.4	63.0	123.6	100
34.1	123.2	77.0	202.3	1000

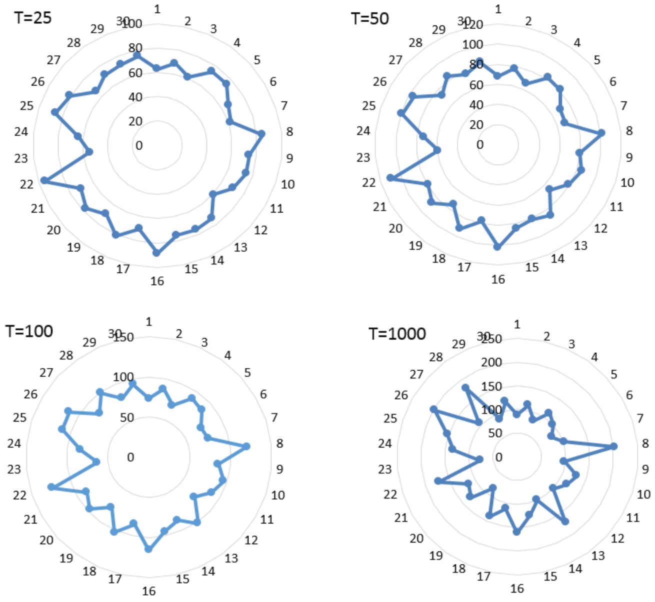


Fig. 5. Surface dispersion of maximum 24-hour rainfall by the selected stochastic model in each return period.

The purpose of this study was to acquire flood hydrograph bandwidth with various return durations. The uncertainty threshold of computational discharges according to artificial data and discharge changes in each probability based on historical data in the discharge-probability curve is illustrated in the Fig. 6.

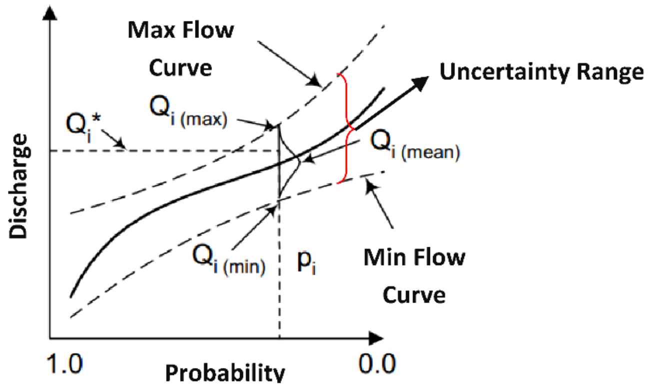
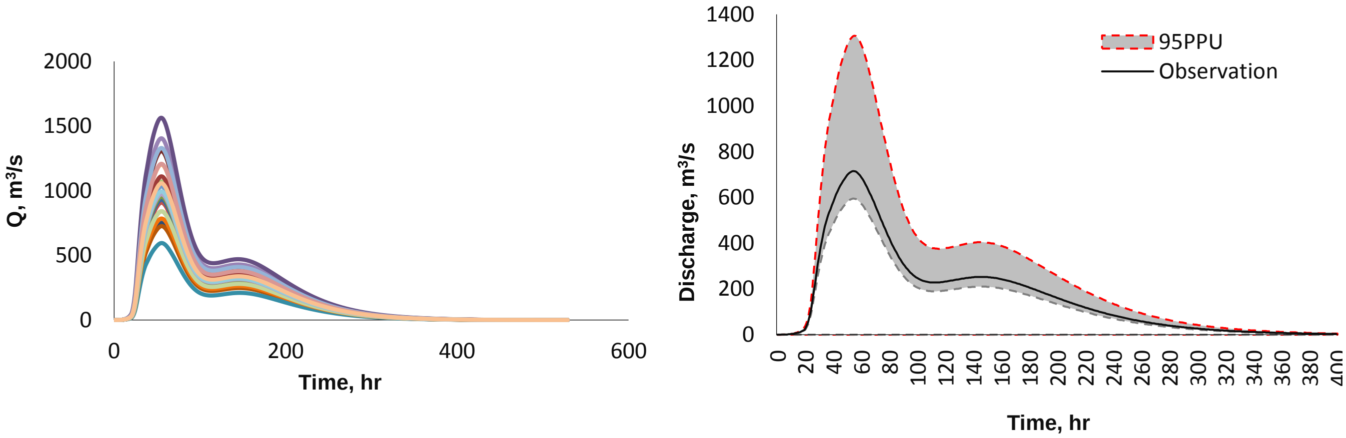


Fig. 6. Discharge curve-probability considering the uncertainty threshold of artificial peak discharges.

The probability of flood hydrograph uncertainty bandwidth was obtained by drawing the discharge curve in each return period, indicated in Fig. 4. These hydrographs are drawn after a fraction of base discharge from the total hydrograph and the flood section of the hydrograph .This bandwidth in each return period was related to the confidence range of 95 %, which was obtained by deleting 5 % of the data at the high and low threshold of estimated discharges. Also, to investigate the range of uncertainty, the flood hydrograph in every reversal period based on historical data is also presented in Fig. 7. This bandwidth suggests that more than 95 % of the possible flood hydrographs for each time are placed in this period.



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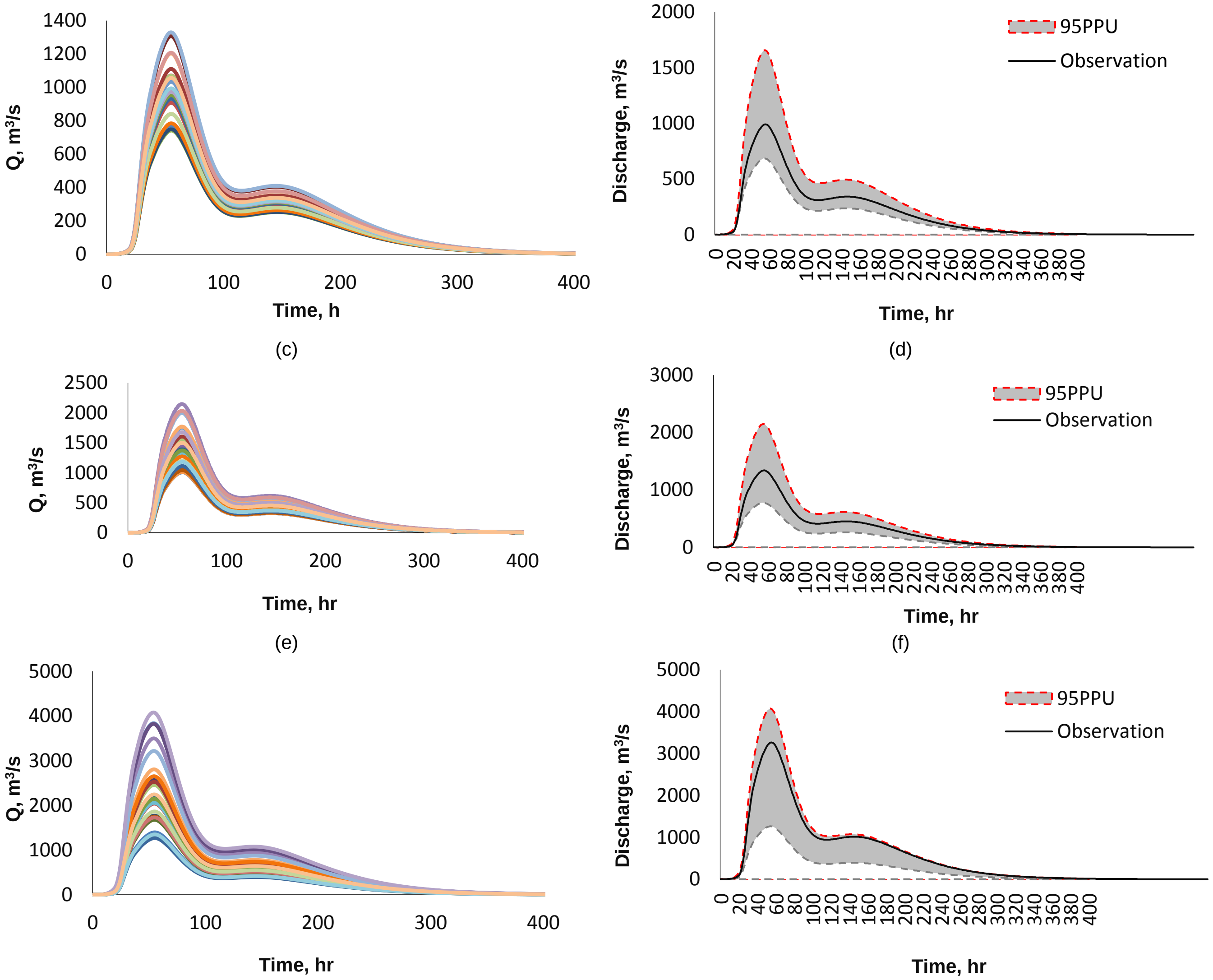

(c) (d) (e) (f)

Fig. 7. Uncertainty bandwidth of flood hydrographs in each return period.

Diagrams in Fig. 7 demonstrate that the flood hydrograph uncertainty bandwidth grows with increasing flood return duration and that the peak discharge is when the flood discharge uncertainty is highest. One of the likely coming floods during the research period is shown by the observational flood hydrograph, which falls between the uncertainty strips in all return periods. In many studies the effect of forecast uncertainty on flood hydrograph has not been seen (Rezaie Moghadam et al. 2018; Mohammadi et al. 2019; and Nguyen and Bae. 2020). This can lead to incorrect estimates of flood zones in flooded areas. New research has been presented to investigate the effect of uncertainty on flood prediction. Munoz et al. (2022) used the Data Assimilation (DA) method to reduce the uncertainty of forecasts. In Munoz et al., the initial simulation conditions in the numerical model used to predict floods were modified using a combination of simulated and observational data. Investigation and analysis of uncertainties in the estimation of rainfall with different return periods used in the design of hydraulic structures is essential. Without analyzing and examining these uncertainties, the possibility of unfavorable circumstances that interfere with the program's objectives it is not far from expected. Since uncertainty is a fundamental component of hydrological and hydraulic models, it is important to properly assess the width of the uncertainty band in these models in order to avoid making risky decisions or incurring excessive costs during the design of structures or during the life cycle of products. Experts should also take it into consideration Jokar et al. (2021) also used the same method to extract the uncertainty band of the Seymareh river floodplain. Instead of using rainfall, they used the information of floods recorded in the upstream of the basin.

However in this study the combined effect of flood data uncertainty on the model and the uncertainty of the parameters of the statistical model used on flood hydrograph were investigated to obtain the flood hydrograph's uncertainty band during several return times. The upper and lower extremes of the uncertainty band can be used to analyze many structural designs and hydraulic calculations and the prediction of the flood zone and damage estimation in each return period. Knowing this planners and designers can make better decisions to enforcement their projects, particularly in development conditions. They can reduce the number of technical errors and defects of the design by mastering and familiarizing themselves with uncertain resources and identifying and predicting the risk sources of each project . Failure to pay attention to this issue can cause mistakes in determining the boundaries of riverbeds and as a result, flooding of settlements adjacent to the river or agricultural lands around the river.

4. Conclusions

Comparing observed and simulated flood hydrograph values of the region showed that the model predicts the peak discharge with good accuracy and with a difference of about 0.7 m3/s (less than 1%) and the amount of flood volume (the area below the flood hydrograph diagram) with a difference of about 12%, which the performance of the model is highly satisfactory. Also, the peak occurrence time and hydrograph base time (the distance between the start and end of the flood) were predicted with appropriate accuracy. This study produced a stochastic series of 24-hour rainfall using 30-year statistics. Using the appropriate fit distribution on each series, 24-hour rainfall values were obtained in different return periods. In fact, these values defined the uncertainty threshold for rainfall in each return period. Using the time precipitation pattern in the region, these values were converted to rainfall hectograph and entered the HecHms model as productive precipitation. A flood hydrograph was obtained for different return periods due to each of these precipitations. The uncertainty bandwidth of flood estimation was determined for each reversal phase while accounting for the 95 % confidence interval. According to the findings, the greatest peak discharge for different return periods was between 1.2 and 1.7 times the historically recorded discharge during that return period. Generally, the maximum discharge of different return periods was 1.5 and 3 times the minimum discharge. According to the existing conditions and the obtained results, the amount of damage caused by floods with different return periods in the obtained bandwidth can be calculated for the design flood hydrograph. It is also possible to calculate the minimum and maximum damage caused by floods for different return periods. The approach used in this research can be used in the analysis of the role of climate change in the design of hydraulic structures. In many forecast scenarios in climate change models, rainfall will decrease in future periods. In this case, by predicting daily rainfall (24 h rainfall) in the coming years and using different statistical distributions, under the effects of climate change, it is possible to obtain the amount of rainfall in different return periods. In this instance, it is possible to explore how climate change may affect the peak flood outputs and finally it can be possible to It examined the hydraulic structures designed in the region to pass these discharges or gave recommendations for revising the design of hydraulic structures in the coming years based on climate change criteria. This study needs rainfall data with a statistical length of at least 30 years to be able to properly examine the uncertainties. In the absence of sufficient data or defects in the data, the results of the research will be affected and it does not have enough accuracy in estimating the uncertainty band.

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