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Flood Zoning Simulation in Steady flow With Model of one-dimensional HEC-RAS and two-dimensional CCHE-2D (Case Study: Range River Shahar Chay)

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ABSTRACT: The frequency of flood in recent decades causes that most parts of the country be exposed to destructive floods invasion and financial and life losses significantly be increased. Increase in population along with the lack of planning to exploit the land, destruction of forests and grasslands and also, development of impervious surfaces caused less water infiltration into the ground in water basins and flow faster to the downstream side. As a result, floods are more frequent, severe and sudden and inflict more damage. In this paper, a part of Brade Sur River in Urmia was selected and considering the importance of the above region, flood basins study and flood zoning in this area was selected as the necessity and objective of this study. In this study, flood capability of Brade Sur River basin in Urmia was evaluated using the techniques of GIS and HEC-HMS hydrologic model. Then, a reach of Brade Sur River in Urmia was hydraulically studied using the HEC-RAS hydraulic model and hydrographic maps were obtained for 2, 5, 10, 25, 50, 100 return periods that can be used in zoning Brade Sur River in term of structural construction.. In this research flood basin of urmiashaharchay has been studied with GIS technique and HEC-HMS hydrological model also with CCHE-MESH model, then hydrological intervals of the river was studied with the achieved results and HEC-RAS and CCHE2D hydrological models and finally the numerical values for different return periods were obtained. Due to lack of observation and field data the numerical results of these two models are compared to each other.

Keywords: Flood Zoning, hydrological models, HEC-RAS and CCHE2D

INTRODUCTION

Despite of numerous improvements, man has not been able to predict and control the flooding phenomenon completely yet. Between the years 1973 to 1996 each year on average, 66 million people have been affected by the deleterious results of flooding, according to United nations Scientific and cultural Organization (UNESCO). It has also been reported, the floods that have been occurred from 1996 to 1987 in Asia have had more than 100 billion dollars economical damage. Unfortunately our country (Iran) is among the countries that suffer from flood. 40-year flooding statistics analysis (1331-1370) has shown that each year 47 floods an average happen in Iran and unfortunately 10572 people have died during this time. So it is essential to marked research about the flood management from different points of view (Mohammad Pour *et al* 2014).

Rivers and some intervals of the rivers from the physical and general behaviors are different and we rarely can find two same rivers. Therefore morphological and hydrological studies in order to analyze the changes of the river and the impact of flood flows in soil erosion and destroy of the margins is essential. in technical discussions one of the reasons of flood increasing , is the reduction of rain or the change in the conversion of solid to liquid rainfalls due to continental changes. Population growth and forest and plains destruction also with the unpermeatable levels' expansion have cause little water permeation in soil and its fast flow to the downstream. Therefore the floods have been faster, more and more unpredictable and cause more damage. The purpose of this study is to make a two dimensional simulation with the combination of GIS with CCHE-2D software on shaharchay river basin. The results of this research have been evaluated and validated with the results of HEC-RAS model. Most of the previous studies have used MIKE11, HEC-RAS models which make a one dimensional flood flow simulation. Since two dimensional simulation is more homogenous with flood flow, so using the results of this paper can improve the process at flood flow simulation.

MATERIAL AND THE METHODS

The depth integrated two-dimensional equations are solved in CCHE2D model,
Continuity Equation:

$$\frac{\partial Z}{\partial t}+\frac{\partial(hu)}{\partial x}+\frac{\partial(hv)}{\partial y}=0$$

Momentum Equations

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial Z}{\partial x}+\frac{1}{h}\left[\frac{\partial(h\tau_{xx})}{\partial x}+\frac{\partial(h\tau_{xy})}{\partial y}\right]-\frac{\tau_{bx}}{\rho h}+fcor^{v}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial Z}{\partial y}+\frac{1}{h}\left[\frac{\partial(h\tau_{yx})}{\partial x}+\frac{\partial(h\tau_{yy})}{\partial y}\right]-\frac{\tau_{by}}{\rho h}+fcor^{u}$$

Where u and v are the depth-integrated velocity components in the x and y directions respectively; g is the gravitational acceleration; Z is the water surface elevation; ρ is water density; h is the total water depth; $fcor$ is the Coriolis parameter; τ_{xx}, τ_{xy}, τ_{yx} and τ_{yy} are the depth integrated Reynolds stresses; and τ_{bx} and τ_{by} are shear stresses on the bed surface.

Study Area. ShaharChay River is one of the major independent rivers of the Urmia plain located in the south and south west of the city of Urmia. The River is known as the Brade Sur in the upstream and the Kakre, Kouse Lou and Mirabad rivers pour into it and it is fed by the precipitations received from the West to the East. ShaharChay River is located in the category of medium-sized rivers with the catchment area located in the central part of central Silvana which is also known as the Urmia River. The area under study is 575.59 square-kilometers located in the city of Urmia. It is in 470,000 to 520,000 E and 4,128,000 to 4,160,000 N. the residential areas under study include Urmia, Noushinshahr, Silvana and Serve. The lowest height of the area is 1267 m and the maximum catchment area is 3507 m above sea level. The study area circumference is equal to 47/156 km. The geographical map of the catchments under study is presented below. The range is located outside Urmia city and within the Urmia plain before reaching lake Urmia.

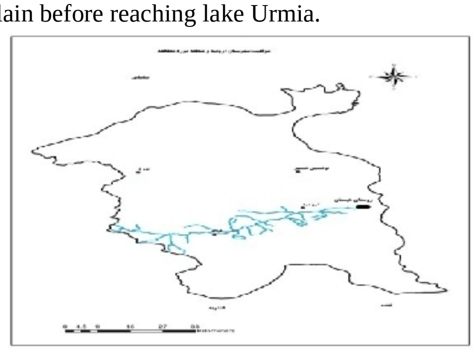

Fig. 1. Location of the city of Urmia and study area.

This range is about 100m below the Keshtiban Dam in coordinates 518, 274 and 4,156,881 and has a length of 1200 meters, within this range the river passes through the Haspestan, Poshtgol and Darghalu villages. perimeter of basin is 156.47 kilometers.

In this paper first we obtained the topographic map of the area with 1:50000 scales from the mapping organization of the country and then using the map the contour lines were drowned and the required revisions were made visually. Also the waterways and network of streams of the basins were formed and the GIS model was completed. The software can conduct physical calculations of the basin and the required parameters after the completion of the basin model. This is easily done on GIS. The following figure presents the basin model in the GIS software.

To obtain every single slope of the waterways the drainage basin slope maps of the area produced by Arc GIS software are used. The upstream waterway have higher slope than the rest of areas indicating the mountainous basins in the area. From the maps of the slope it can be inferred that the highest area is within the class of 0.02-8% slope.

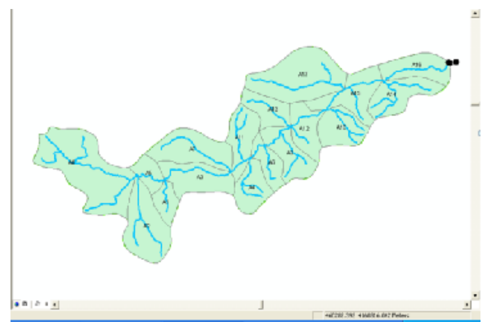

Fig. 2. Formation of the basin and sub-basin operation in ARC GIS software.

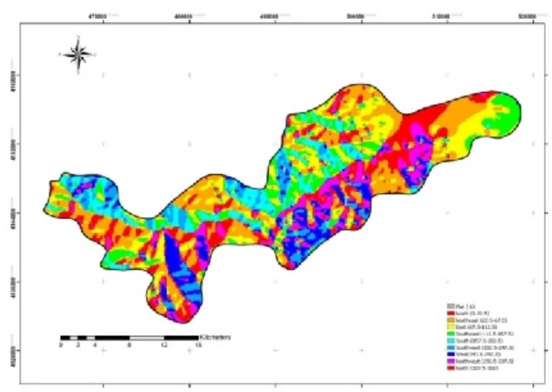

Fig. 3. Map of the slope in the study area.

Maximum 24-hour rainfall. Maximum 24-hour rainfall is the amount of rain which has fallen down during 24 hours, and the highest amount of rainfall during a year (365 days) is chosen. We have used the maximum 24-hour rainfall data of shaharchay basin for the statistical period of time from 1366-1365 to 1389- 1388.

Table 1: Physical characteristics of the studied basins in the study area Shahar Chay.

Raw	Sub field No	Area	Perimeter	Main Stream length	Average Slope	Maximum height	Minimum height	Average height	Gravelius coefficient	Equivalentcircle diameter	Concentration Time	Equivalent Rectangle Length	Equivalent Rectangle Width	Shape Factor	X	Y
		(Km²)	(Km)	(Km)	Percent	(m)	(m)	(m)		(Km)	(h)	(Km)	(Km)			
1	A1	12.86	15.06	4.59	40.8	3119	1801	2556	1.2	4.0	1.0	4.9	2.6	0.5	480644	4139022
2	A2	44.27	28.12	11.54	27.3	3126	1872	2543	1.2	7.5	2.5	9.3	4.8	0.5	478196	4136158
3	A3	32.62	27.33	10.11	26.8	2836	1575	1902	1.3	6.4	2.2	10.6	3.1	0.3	484669	4142230
4	A4	23.01	19.40	7.14	9.5	1855	1573	1669	1.1	5.4	2.0	5.6	4.1	0.7	492364	4141105
5	A5	12.81	14.52	5.21	40.4	2800	1774	2129	1.1	4.0	1.2	4.2	3.0	0.7	478165	4142937
6	A6	16.72	19.85	5.32	17.2	2202	1473	1800	1.4	4.6	1.4	7.8	2.2	0.3	494304	4143604
7	A7	39.23	28.82	11.65	13.5	2767	1577	1846	1.3	7.1	2.9	10.8	3.6	0.3	483660	4146219
8	A8	83.85	43.23	14.69	31.7	3507	1870	2632	1.3	10.3	2.9	16.5	5.1	0.3	469872	4138048
9	A9	27.57	24.75	8.78	17.6	2224	1453	1835	1.3	5.9	2.1	9.5	2.9	0.3	497039	4145132
10	A10	26.62	20.70	6.66	10.8	2129	1400	1578	1.1	5.8	1.8	5.6	4.8	0.9	504331	4148742
11	A11	26.51	24.52	8.30	12.2	2206	1570	1791	1.3	5.8	2.2	9.5	2.8	0.3	490935	4147113
12	A12	23.52	22.31	8.49	19.2	2208	1383	1700	1.3	5.5	2.1	8.3	2.8	0.3	499607	4148066
13	A13	20.60	20.95	7.48	15.5	2213	1450	1825	1.3	5.1	1.9	7.9	2.6	0.3	493964	4150552
14	A14	30.45	26.18	7.05	4.0	1675	1269	1362	1.3	6.2	2.3	10.1	3.0	0.3	512729	4153191
15	A15	32.89	31.84	9.35	4.5	1713	1332	1418	1.6	6.5	3.0	13.5	2.4	0.2	504224	4152347
16	A16	26.52	23.90	9.48	1.0	1360	1267	1307	1.3	5.8	4.2	9.0	2.9	0.3	513714	4156508
17	A17	63.20	33.37	13.37	8.8	2109	1352	1604	1.2	9.0	3.5	10.9	5.8	0.5	497981	4155190

Flood estimate by SCS method

It is necessary to specify the flood discharge and its hydrograph for the return period of the design in order to make awarness and present the damages of flood and its sediments and also in order to make a hydro-structure in downstream basin. HEC-HMS model in the study board, has been used to estimate the flood hydrograph. This case study has been divided into 17 sub-basins, considering this point in HEC-HMS model this division has been made to do two processes in a multi-basin and semi-distributed model. First is to follow the flood routine and second process is to estimate the flood hydrograph in every sub-basin output. SCS is the method that has been used in this model due to the lack of field and observations data in making the base hydrograph. The essential parameters are 1- the area of basin 2- curve number 3- delay time 4- the rainfall of design.In order to calculate the delay time, we have used so many empirical relations. Here in order to estimate delay time according to the caculated CN for each sub-catchment we have used the proposed SCS relation.

Y: the average slop percentage of basin
L: the length of the longest river in foot
S: water storage index within the basin in inch
T_lag: the delay time of basin in hour

Hydraulical characteristics. The case study is outside of urmia (urmia plain) before the joint point of the river with urmia lake. theinterval is 100 meters down the kashtiban dam with the coordinates of 518274 and 4156881 and with the length of 1200 meters.

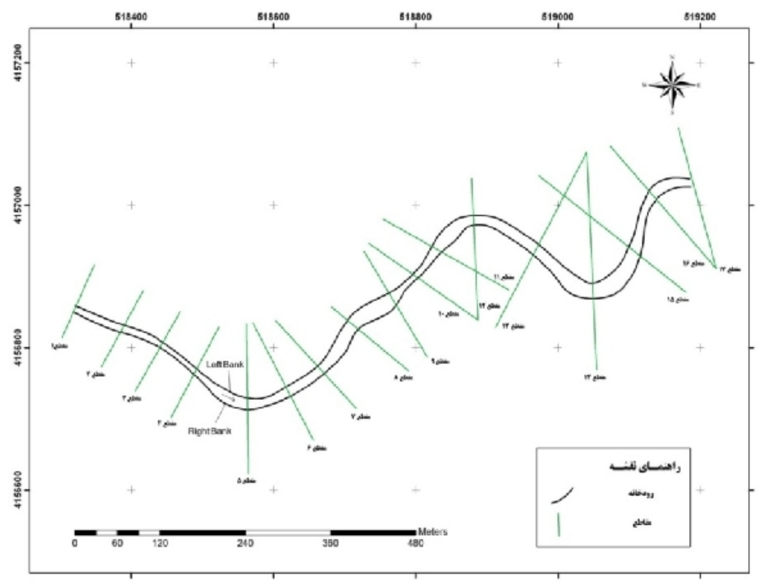

Fig. 4. Used sections' position in this case – study.

Table 2: Cross sections characteristics in shaharchay intervals.

Cross-Section	Cont/Exp Coefficients		Main Channel Bank Station		Maning's n Values			Downstream Reach Lengths		
	Contraction	Expansion	Right Bank	Left Bank	ROB	Channel	LOB	Right Rob	Main Channel	Right Lob
1	0.3	0.1	84.8	47.9	0.035	0.035	0.035	75	73	70
2	0.3	0.1	69.2	40.6	0.035	0.035	0.035	60	59	58
3	0.3	0.1	68	43.4	0.035	0.035	0.035	58	59	61
4	0.3	0.1	93.5	61.9	0.035	0.035	0.035	67	90	115
5	0.3	0.1	132.4	105.8	0.035	0.035	0.035	46	62	88
6	0.3	0.1	76.1	50.5	0.035	0.035	0.035	48	59	70
7	0.3	0.1	77.2	55.4	0.035	0.035	0.035	74	79	83
8	0.3	0.1	82	0	0.035	0.035	0.035	76	65	51
9	0.3	0.1	118.6	31.7	0.035	0.035	0.035	35	50	63
10	0.3	0.1	117.9	54.1	0.035	0.035	0.035	43	47	52
11	0.3	0.1	78.4	54.8	0.035	0.035	0.035	95	50	5
12	0.3	0.1	81.3	42.2	0.035	0.035	0.035	112	92	71
13	0.3	0.1	163.6	122.5	0.035	0.035	0.035	57	92	122
14	0.3	0.1	177.8	145.3	0.035	0.035	0.035	23	80	136
15	0.3	0.1	213.5	174.2	0.035	0.035	0.035	76	68	60
16	0.3	0.1	124.7	68.5	0.035	0.035	0.035	65	52	31
17	0.3	0.1	96.4	61	0.035	0.035	0.035	0	0	0

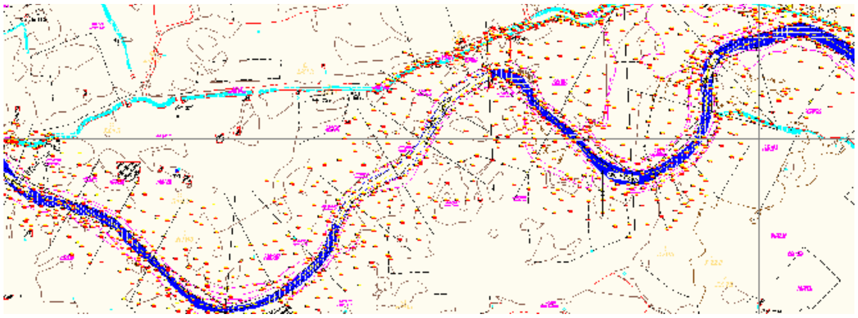

Fig. 5. The topographic map of shaharchay river range.

According to the water Organization measurements, the roughness coefficient at the mentioned river is 0.035.

This section according to collected data, is prepared and transmitted to the model respectively.

1. The preparation of topographic map of shaharchay river.
2. Map preparation with DEM format by topographic map with ARC-GIS software.
3. Mesh creation with CCHE-MESH software.

Smaller meshes creation need smaller time steps in order to solve the model or to find an acceptable answer from model. In this study, due to long time of simulation, the number of meshes, in direction of X (I=300) and in direction of Y(G=100), have been chosen in respect of river geometry.

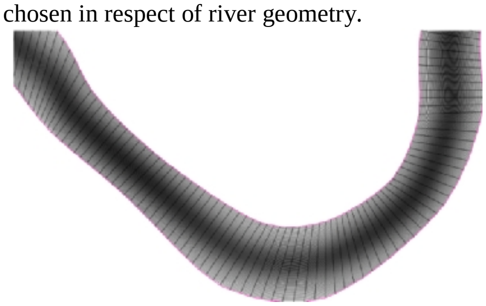

Fig. 6. A part of river mesh by CCHE-MESH software.

4. Mesh map transmission to CCHE- GUI model

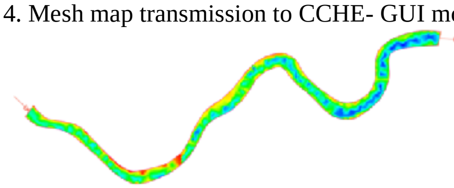

Fig. 7. Transmitted topographical mapto CCHE-GUI model.

We need to set the input stream boundary conditions to input boundary conditions. The total discharge number use for the different return periods is computed with HEC-HMS software and for output boundary conditions, we use the amount of initial water level which is one of the parameters of HEC-RAS model. In following tables you can see the amounts of discharge number and initial water level.

Considering that the maximum instantaneous flow was estimated using HEC-HMS software for the mentioned basin, thus, flood hydrograph for different frequency can be achieved by having the unit hydrograph. For this purpose, it is necessary to multiply the dimensions of the unit hydrograph in the designed discharge rate on the maximum flow rate of the unit hydrograph.

Table 3: Initial water levels for return periods of 2,5,10,25,50,100 from the HEC-RAS model.

Return Periods	section 1	section 2	section 3	section 4	section 5	section 6	section 7	section 8
2 Years	1288.84	1288.83	1288.82	1288.67	1288.74	1288.72	1288.72	1288.53
5 Years	1289.22	1289.2	1289.16	1288.92	1289	1288.95	1288.97	1288.78
10 Years	1289.57	1289.53	1289.45	1289.09	1289.2	1289.12	1289.15	1288.89
25 Years	1289.76	1289.69	1289.58	1289.29	1289.35	1289.25	1289.29	1288.97
50 Years	1289.93	1289.84	1289.7	1289.45	1289.48	1289.37	1289.41	1289.05
100 Years	1290.08	1289.97	1289.8	1289.62	1289.62	1289.49	1289.53	1289.12

section 9	section 10	section 11	section 12	section 13	section 14	section 15	section 16	section 17
1285.89	1285.59	1285.73	1285.69	1285.66	1285.64	1285.63	1285.62	1285.58
1286.54	1286.34	1286.41	1286.34	1286.32	1286.29	1286.28	1286.27	1286.21
1287.09	1286.91	1286.98	1286.88	1286.86	1286.83	1286.82	1286.8	1286.73
1287.47	1287.29	1287.35	1287.23	1287.22	1287.19	1287.17	1287.16	1287.07
1287.8	1287.62	1287.68	1287.54	1287.53	1287.51	1287.49	1287.47	1287.38
1288.07	1287.89	1287.94	1287.77	1287.78	1287.77	1287.73	1287.72	1287.62

Table 4: The total discharges for return periods of 2, 5,10,25,50,100 obtained from HEC-HMS software.

Return Periods	**Q** total
2 Years	59.2
5 Years	113.5
10 Years	175
25 Years	225.6
50 Years	277.8
100 Years	331.5

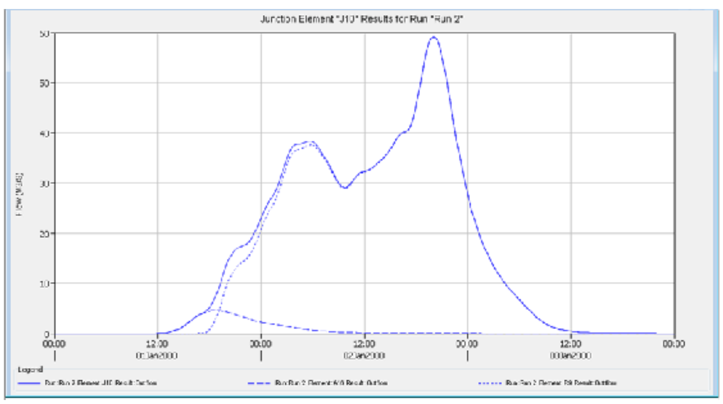

Fig. 8. Flood hydrograph for a 2-year return period obtained from HEC-HMS software.

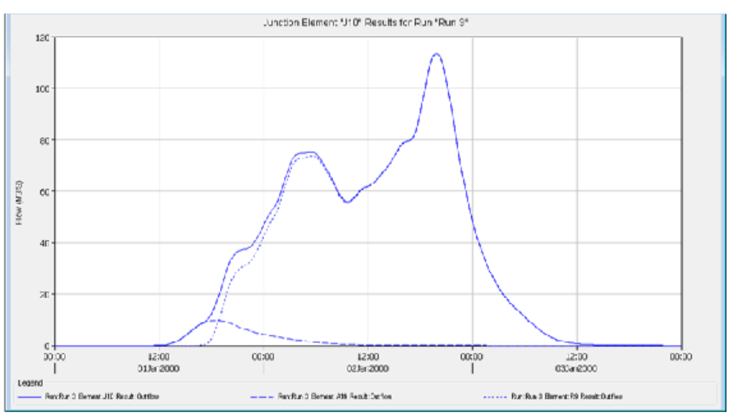

Fig. 9. Flood hydrograph for a 5-year return period obtained from HEC-HMS software.

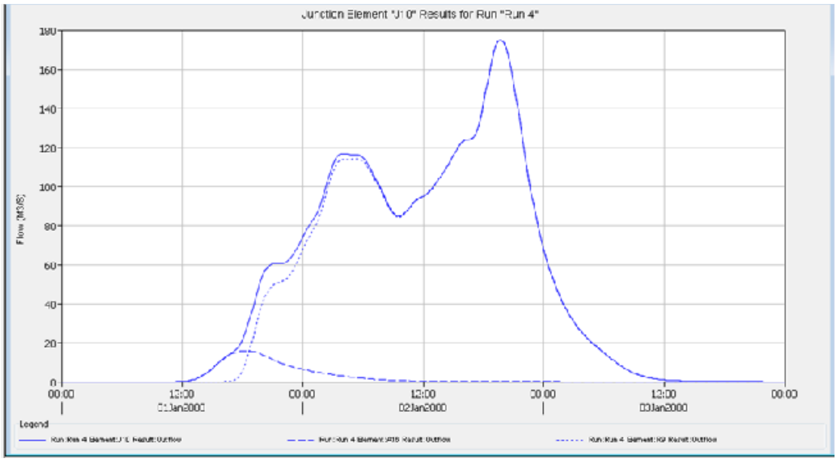

Fig. 10. Flood hydrograph for a 10-year return period obtained from HEC-HMS software.

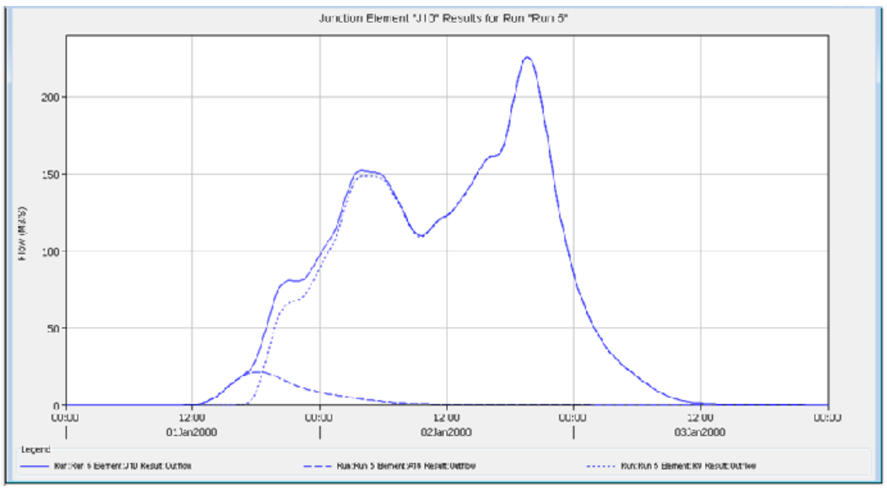

Fig. 11. Flood hydrograph for a 25-year return period obtained from HEC-HMS software.

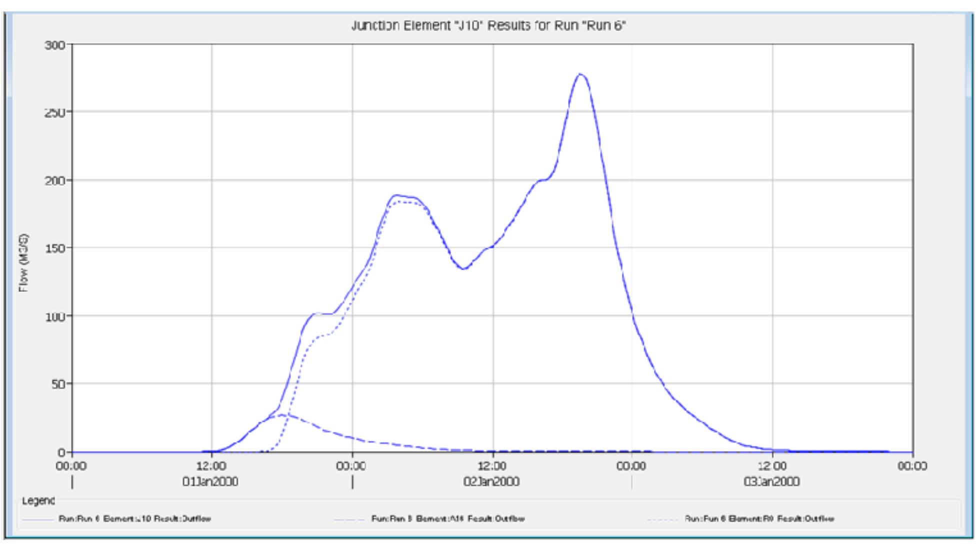

Fig. 12. Flood hydrograph for a 50-year return period obtained from HEC-HMS software.

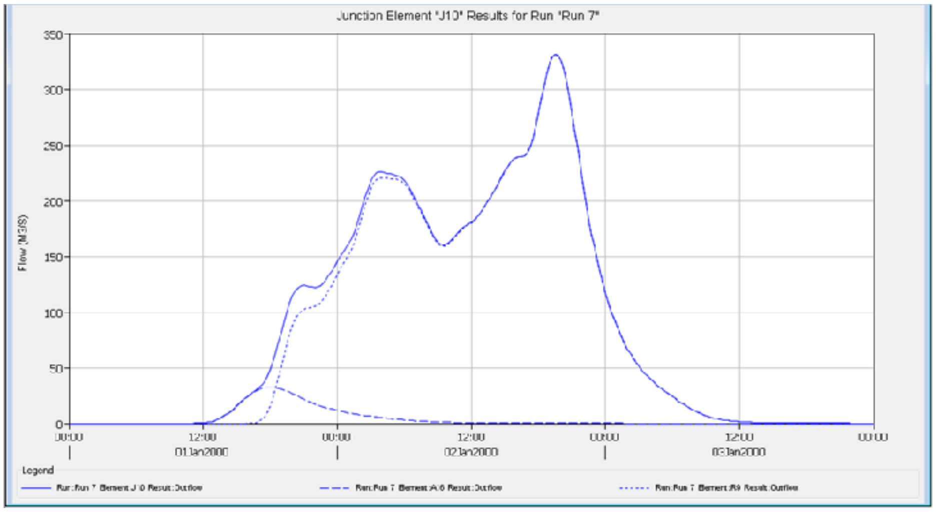

Fig. 13. Flood hydrograph for a 100-year return period obtained from HEC-HMS software.

The calibration of results and errors estimation. The computed numerical results about the depth by two models in river with the different return periods can be seen in following tables. According to the numerous results and 17 cross sections we decided to analyze 5 section for each return period. (sections3,5,12,14,16 were analyzed and in figure 4 you can see cross sections conditions.

Table 5: Water depth for a 2 year return period.

Cross section	HEC-RAS	CCHE2D
3	1.01	1.26
5	1.1	1.28
12	0.7	0.96
14	0.65	0.9
16	0.8	1.18

Table 6: Water depth for a 5 year return period.

Cross section	HEC-RAS	CCHE2D
3	1.12	1.29
5	1.18	1.32
12	0.9	1.21
14	0.83	1.2
16	1	1.25

Table 7: Water depth for a 10 year return period.

Cross section	HEC-RAS	CCHE2D
3	1.21	1.37
5	1.24	1.41
12	1.06	1.24
14	1.05	1.23
16	1.16	1.31

Table 8: Water depth for a 25 year return period.

Cross section	HEC-RAS	CCHE2D
3	1.24	1.41
5	1.28	1.51
12	1.16	1.31
14	1.11	1.28
16	1.27	1.49

Table9.Water depth for a 50 year return period

Cross section	HEC-RAS	CCHE2D
3	1.28	1.5
5	1.32	1.52
12	1.26	1.48
14	1.21	1.37
16	1.36	1.57

Table 10: Water depth for a 100 year return period.

Cross section	HEC-RAS	CCHE2D
3	1.31	1.58
5	1.36	1.61
12	1.33	1.54
14	1.28	1.49
16	1.44	1.67

Obtained datas have statistically errors that these errors should be computed. Despite the lack of observations and field data that can be based on observation data, obtained errors. in this study linear regression method was used to estimate the error. Computed error for 5 section for return periods of 2,5,10,25,50 years explain in following tables:

For 2 years return period:

$y = 0.4067 + 0.8325X$

$\sigma^2_{ras} = 0.03827$ $\sigma^2_{cche} = 0.0306$ $\bar{X} = 0.852$ $\bar{Y} = 1.116$

Table11: The amount of errors for a 2 year return period.

sections	HEC-RAS	CCHE2D	Error value
3	1.01	1.26	0.01246407
5	1.1	1.28	0.04246146
12	0.7	0.96	0.02945911
14	0.65	0.9	0.04783381
16	0.8	1.18	0.10729031

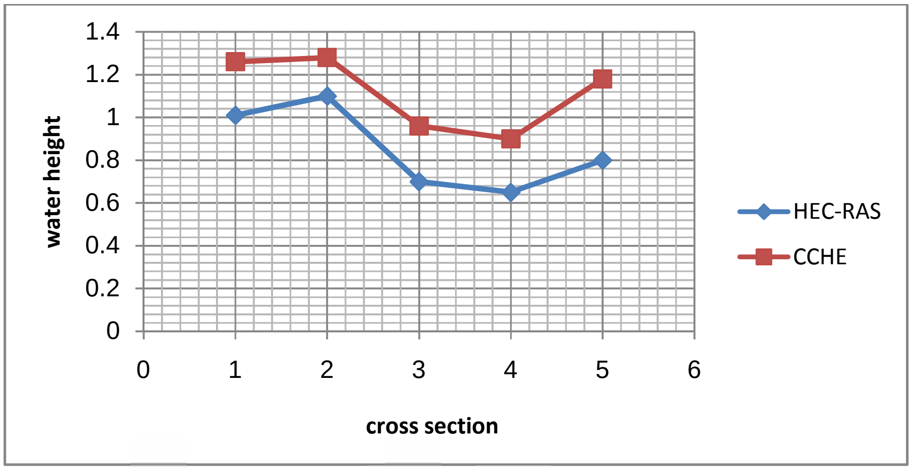

Fig. 13. Water height for 2 year.

For 5 years return period: $y = 0.90368 + 0.34822X$

$$\sigma^2_{cche} = 0.002\bar{X} = 1.006\bar{Y} = \quad \sigma^2_{ras} = 0.02138$$

Table 12: The amount of errors for a 5 year return period.

sections	HEC-RAS	CCHE2D	Error value
3	1.12	1.29	0.00369738
5	1.18	1.32	0.00540926
12	0.9	1.21	0.0070884
14	0.83	1.2	0.00728718
16	1	1.25	0.00191066

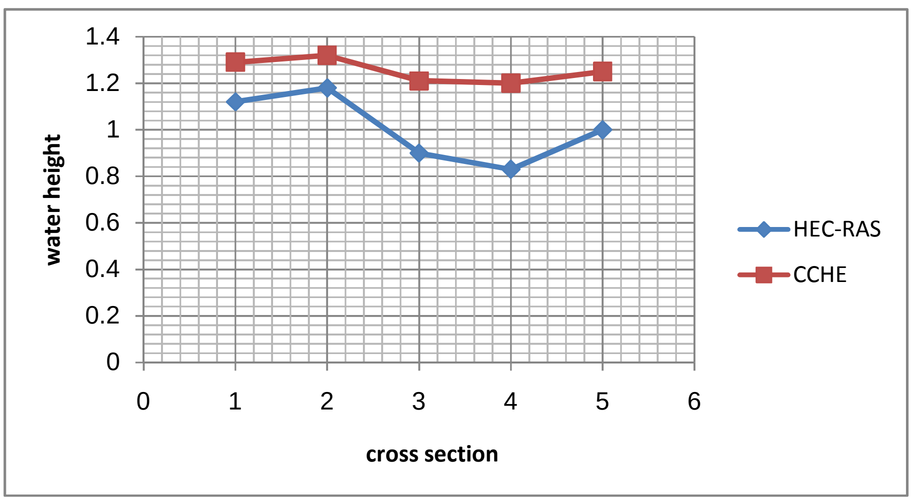

Fig. 14. Water height for 5 year.

For 10 years return period:

$$y = 0.27424 + 0.9071X$$
$$\sigma^2_{cche} = 0.00622\bar{X} = 1.144\bar{Y} = 1.312 \quad \sigma^2_{ras} = 0.00743$$

Table13: The amount of errors for a 10 year return period.

sections	HEC-RAS	CCHE2D	Error value
3	1.21	1.37	0.00187079
5	1.24	1.41	0.01091521
12	1.06	1.24	0.00419919
14	1.05	1.23	0.00327052
16	1.16	1.31	0.01651413

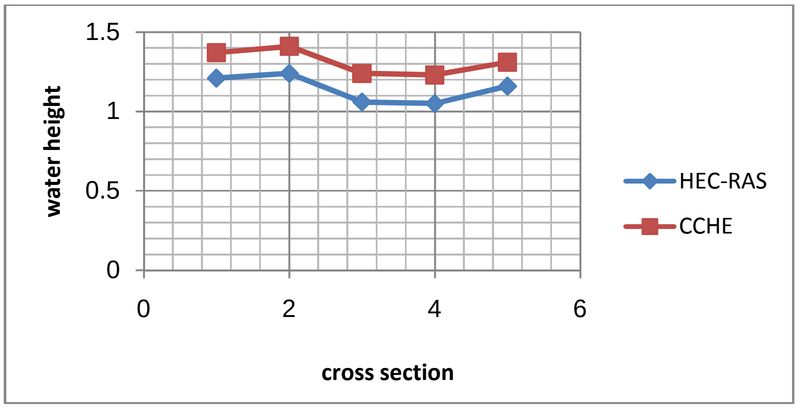

Fig. 15. Water height for 10 year.

For 25 years return period:

$y = -0.25625 + 1.3665$

$$\sigma^2_{ras} = 0.00547 \sigma^2_{cche} = 0.0107 \bar{X} = 1.212 \bar{Y} = 1.4$$

Table14.The amount of errors for a 25 year return period

sections	HEC-RAS	CCHE2D	Error value
3	1.24	1.41	0.02826325
5	1.28	1.51	0.01707495
12	1.16	1.31	0.01893967
14	1.11	1.28	0.01938757
16	1.27	1.49	0.0107404

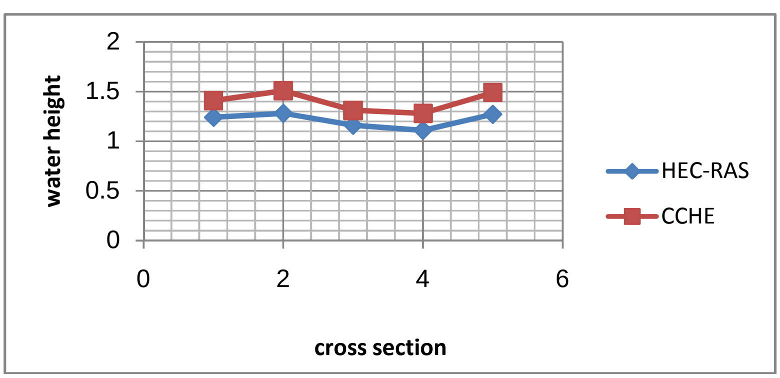

Fig. 16. Water height for 25 year.

For 50 years return period:

$$y = -0.1057 + 1.2393X$$

Table 15: The amount of errors for a 50 year return period.

sections	HEC-RAS	CCHE2D	Error value
3	1.28	1.5	0.01943598
5	1.32	1.52	0.0101372
12	1.26	1.48	0.02422256
14	1.21	1.37	0.02381098
16	1.36	1.57	0.00971037

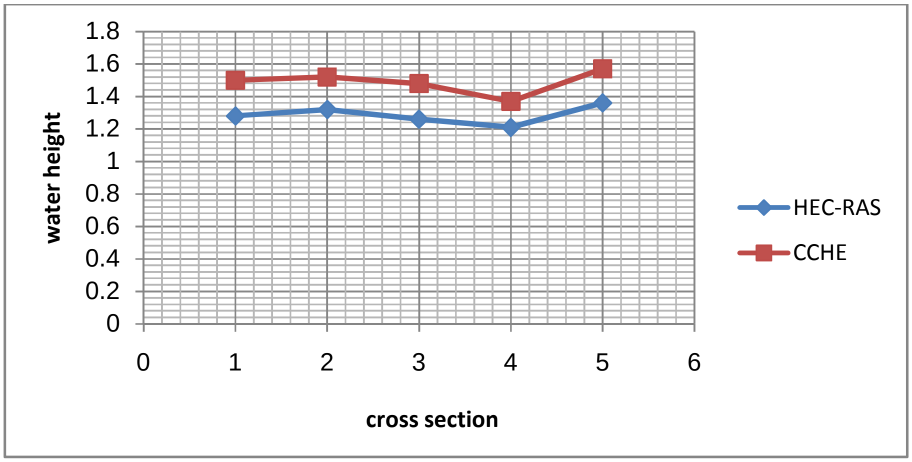

Fig.17. Water height for 50 years.

For 100 years return period:

$$y = 1.034 + 0.1871X$$

Table16: The amount of errors for a 100 year return period.

sections	HEC-RAS	CCHE2D	Error value
3	1.31	1.58	0.03718499
5	1.36	1.61	0.01544236
12	1.33	1.54	0.02351206
14	1.28	1.49	0.02176944
16	1.44	1.67	0.00734584

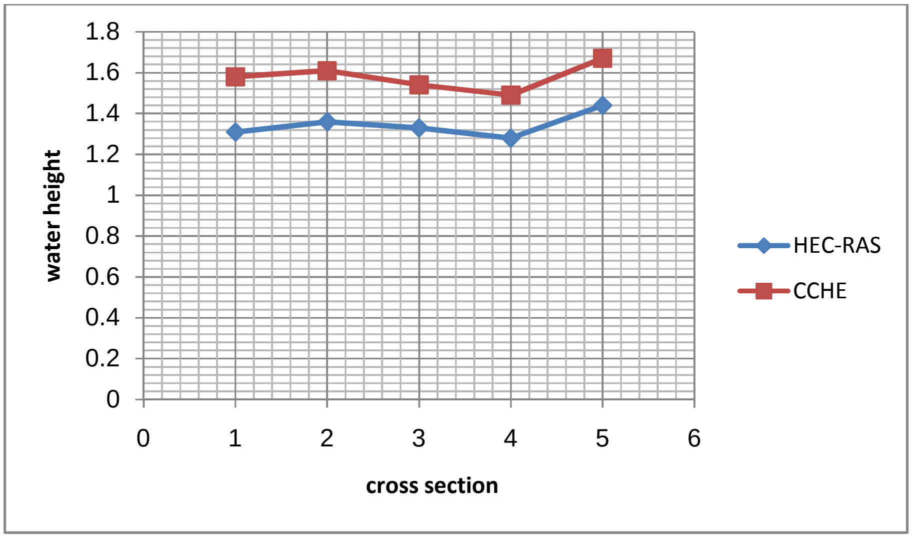

Fig. 18. Water height for 100 year

FINDINGS AND RECOMMENDATIONS

In this project, ARC GIS software was used to evaluate the sub-basins of Brade Sur River in Urmia overlooking the studied period. This software has a high capability to calculate the physical properties of the basin and the used parameters in HEC-HMS software. The studied area is divided into 17 sub-basins by this software.

HEC-HMS and SCS software were used to estimate discharge with different return periods. This model attempts to draw a flood hydrograph for each of its sub-basins using the physical characteristics of the study area and therainfall data. Two land use map and also soil groups hydrologic map were integrated in ARC-GIS software to estimate CN.

CCHE-2D and HEC-RAS softwares is used in order to flood zoning. In the way that the obtained cross sections were entered in these softwares by mapping operation and then, flood discharge values has been entered into these softwares for different return periods obtained from HEC-HMS software.

The achieved results from HEC-RAS model are in a great accordance with observed data. Because of this reason HEC-RAS method has gained great fame in our country and all the professors and organizations have accepted and corroborated this model. Most of the engineering projects in river use this model. On the other hand CCHE-2D model is not known in my country and it need to be paid attention. Since the output parameters and information of this model are complete, then we can use it easily.

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