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Simulation And Estimation Of Effective Discharge Of Annual Flood (Case Study: Jarahi River, Khuzestan, Iran)

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ABSTRACT: To calculate the amount of suspended sediment load and designing the hydraulic structures and determination of the optimal width and other hydraulic characteristics of the river, equilibrium flow or in other words, the prevailing flow should be recognized. In the present study, to investigate and recognize the effective discharge of sediment delivery in Jarahi River, three hydrometric stations located on the main branch of the river were selected. To calculate the suspended load in the studied stations, a regression relationship was established between flow rate and sediment discharge (sediment curve). Finally for each of these stations, the rate of effective discharge, dominant discharge and the discharge with a return period of 2.5 years were calculated and compared based on the normal distribution and two-parameter gamma methods. The results showed that the effective discharge rate and bankfull discharge are almost equal in stations and in the absence of data to find effective discharge, the dominant discharge (river design discharge) can be determined by river full section removal.

Keywords: bankfull discharge, effective discharge, sediment curve, hydrometric stations

1 Introduction

Rivers' behavior is very diverse and complicated so that understanding their behavior and predicting their response against the imposed changes is a major part of the river engineering branch. This understanding cannot be achieved unless sufficient knowledge and data is available about the rivers' situation and their hydraulic geometry. Certainly, the river geometrical cross section of the river from its source to the junction to other rivers or to the sea or lake is not equal and is subject to change. Geometrical changes of rivers' section result in speed changes. Since the river experience a wide range of flows, it is believed that they regulate their shape and dimensions with a dominant flow and generally rivers dimensions are subject to a certain discharge rate which is called dominant discharge. Every year, a large fund is spent to control and inhibit the flood and also, due to sediment transport in flood discharge expenses will be taken into account for sediment removal. By determining the dominant discharge which is effective in sediment transport, the flood and the amount of sediment delivered can be predicted that this is very important in designing structures that will be constructed on the river in future. The importance of calculating dominant discharge can be referred in the design of river protective structures, river overpass structures design (bridges), estimation and management of sediment transport, environmental engineering and flood control. Also the major problems we face is violating the privacy of rivers that the river stable form can be estimated by determining the dominant discharge and avoid construction and agriculture, and disrupting the morphology of the region. Until now many researchers studied the effects of flow discharge on the geometry of river. They found that any flow that transports the sediment can affect the geometrical shape of the river. Inglis [1] defined that the dominant discharge in a natural stream is a discharge, representative of a whole range of discharges that pass through the channel and that forms the channel morphology. The dominant discharge is usually defined as; i) the most effective discharge for sediment transport. Benson and Thomas [2] defined that the dominant discharge is the discharge which transports the most sediment transport in suspended load. Pickup and Warner [3] defined the dominant discharge as the discharge that transports the sediment particles as the bed load. Andrew [4] defined the dominant discharge as the discharge which transports the most sediment particles as total load. ii) The natural bankfull discharge or the discharge in a river which just fills the main channel and not overbanking the flood plains. iii) The dominant discharge is also defined as the discharge or a flood of fixed frequency such as 1-2 years flood and iv) it is defined as the discharge which exhibits the best statistical correlation with various channel morphological characteristics. Dominant discharge was also studied by many researchers; for example, Williams [5] found that the dominant discharge is a bankfull discharge of approximately 1.5 years. Keshavarzi and Erskine [6] and Erskine and Keshavarzy [7] investigated that the dominant discharge on South Creek in New South Wales, in Australia has an average recurrence interval (ARI) of 1.89 to 2.40 years on the partial series. Valentine et al. [8] studied regime theory and the stability of straight channels with bankfull. Keshavarzi and Nabavi [9] used stream flow data to predict the frequency of dominant discharge for flood plain management in Kor River. Given the importance of this issue, this study investigated and identified the effective discharge of sediment transport in Jarahi River and finally river dominant discharge is determined.

2 MATERIALS AND METHODS

2.1 Location Of The Study Area

Jarahi River is originated from Zagros Mountains 2300 meters height by branches as Saqaveh, Lurab, Shour, Charou and Saaq that the basin of the mentioned river is in Khuzestan and Kohgiluyeh and Boyer Ahmad and with an area of approximately 2,750 square kilometers is measured at Idanak Hydrometric station [10]. Then, on its way after connecting to the Qalat River and several sub-branches, its discharge will be controlled and recorded in Behbahan Hydrometric station with an area of 3820 square kilometers. Jarahi Impounding Dam site is approximately located in the upstream of Behbahan hydrometric station. Jarahi River in Behbahan station has 325 meters height and its length from the source to the station is

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160 km. The river has several sub-branches in its right and left sides, that the largest of which is Qalat River. The hydrometric calculations are only done in three stations as Idanak, Behabahan and Cham Nezam. Cham Nezam Hydrometric station is the last one on Jarahi River located approximately 40 km downstream of Behbahan [10]. Idanak hydrometric station is located about 40 km upstream of the site of Jarahi impounding dam and upstream of the Idanak village bridge in geographic profile -57✈ 30💣 North latitude and 28✈ -50💣 East longitude. The station was destroyed in the floods in water year 1986-87 but it was immediately rebuilt on the same site and has already been recorded (Figure 1). Behbahan hydrometric station with s short distance from the downstream of Jarahi Impounding Dam is located near Tang-Takab village and in the geographical coordinates ✈ -41 31💣 North latitude and -28✈50💣 East longitude. The station was built in 1951 and has already been recorded. Cham Nezam hydrometric station with geographical coordinates of 55✈ -49💣 North latitude and 45✈ -30💣 Eastern longitude with 190 meters elevation. The station was established in 1976 and since then, it is well recorded. (Fig. 2).

Fig. 1. *hydrometric stations of Idanak*

Fig. 2. *Cham Nezam hydrometric station*

2.2 Physiographic characteristics of the basin

Physiographic characteristics of the basin refer to a set the physical parameters whose values are relatively constant for each basin and represent the appearance of the basin. These parameters are important because a relationship exist between them and basin runoff that can be used to measure and estimate the flood and discharge in areas without statistics. The physiographic specifications of hydrometric stations of Jarahi River are shown in Table (1). Also, to investigate the annual river discharge regime of Maroon, the annual statistics of Behbahan station were considered. The results of calculation of annual average of the desired station during water years 1993-1994 to 2012-2013 in 19 continuous observations after calculation is given in Table 2.

TABLE 1
JARAHI RIVER PHYSIOGRAPHIC CHARACTERISTICS

Row	Basin characteristics	Idanak	Behbahan	Cham Nezam
1	Basin Area (km²)	2761	3802	5376
2	Basin ambient (km)	291.4	377	458.4
3	Maximum height of the Basin (m)	3124	3124	3124
4	Basin average height (m)	1980	1030	1280
5	basin mean height (m)	1882	1644	1340
6	Minimum height of the basin (m)	560	280	190
7	Compactness coefficient	1.55	1.71	1.75
8	Equivalent rectangle length (km)	123	165.5	202.7
9	Equivalent rectangle width (km)	22.4	23	26.5
10	The river main branch length (km)	105.8	151.6	213.7
11	The main branch pure slope (percent)	1.87	1.29	0.83
12	Average basin slope (percent)	4.9	4.6	4
13	Concentration time (hours)	9.8	14.2	20.9
14	Delay time (hours)	41.6	16.4	92.5

TABLE2
THE AVERAGE AND MAXIMUM RATE OF JARAHI RIVER DIS-CHARGE IN STUDIED STATIONS (M3/S)

3

	Idanak Station		Behbahan Station		Cham Nezam Station	
Year	Average annual	Maximum	Average annual	Maximum	Average annual	Maximum
1994	95	1394	0.90	2174	71	631
1995	83	874	5.60	1039	42	630
1996	45	408	8.38	300	36	550
1997	74	1805	4.68	2276	32	136
1998	44	1196	9.47	1269	42	563
1999	73	1637	3.91	1444	86	1298
2000	127	2573	6.113	2097	74	1177
2001	57	482	4.78	1587	33	640
2003	74	1373	5.70	663	85	1544
2004	61	926	3.37	400	24	438
2005	52	731	1.90	1495	21	168
2006	87	1273	4.41	741	92	1268
2007	4	300	5.19	79/7	55	1208
2008	79	1228	7.77	660	70	1042
2009	78	330	6.47	108	127	628
2010	250	330	6.276	531	20	168
2011	110	310	7.62	278	35	170
2012	85	300	8.51	160	22	120
2013	50	190	1.34	84 / 8	19	99

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Results And Discussiomn

After selecting Idanak, Behbahan and Cham Nezam stations on the Jarahi River, the effective, and bankfull discharge and the average annual flood were calculated and then by specifying return period of the effective and bankfull discharges and comparing them with the average annual flood with a return period of 2 years, the discharge with more reasonable trend is introduced as the dominant discharge or river regime (equilibrium).

3.1 Calculation Of The Effective Discharge

To find the effective discharges, daily discharges of each station are classified in different classes and their frequency histogram is drawn. Then, having suspended sediment discharge (Q_s) and its corresponding flow (Q_w) by establishing correlation between them, the coefficients a and b the equation $Q_s = a.Q_w{}^b$ is obtained. Having coefficients, fitted suspended sediment discharge is achieved and by bringing Q_w values on X axis and primary and fitted Q_s on Y axis, the suspended sediment curve is plotted. In Figure (3) Jarahi river suspended sediment curve is typically plotted in Behbahan station. Finally, by multiplying the suspended sediment curve in the discharges frequency histogram, the total suspended sediment curve is obtained. The peak of the curve is the effective discharge and corresponding to it the maximum suspended sediment of the desired station. (Figure 4)

TABLE 3

RESULTS OF THE CALCULATION OF THE EFFECTIVE DISCHARGE AND CORRESPONDING SEDIMENT OF JARAHI RIVER

River	Station	Effective discharge	Return Period	Corresponding sediment to effective discharge (tons)	Annual mean sediment (tons)
Maroon	Idanak	275	2.25	914641	476244
Maroon	Behbahan	425	1.7	336617	90549
Maroon	Cham Nezam	350	1.8	456125	127199

Table 3 shows the results of the calculation of discharge and total sediment and its corresponding sediment in different stations.

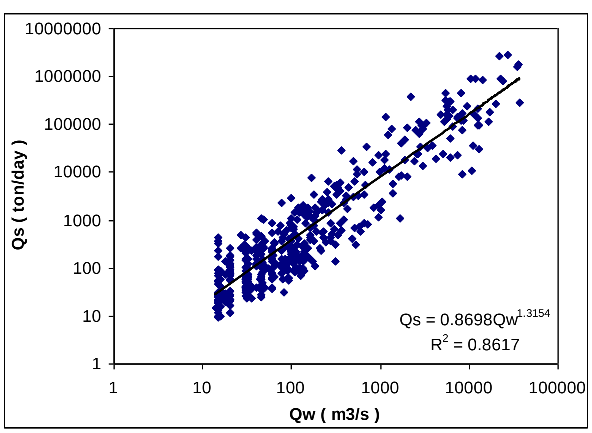

Fig. 3. *Suspended sediment curve at Jarahi river Behbahan station*

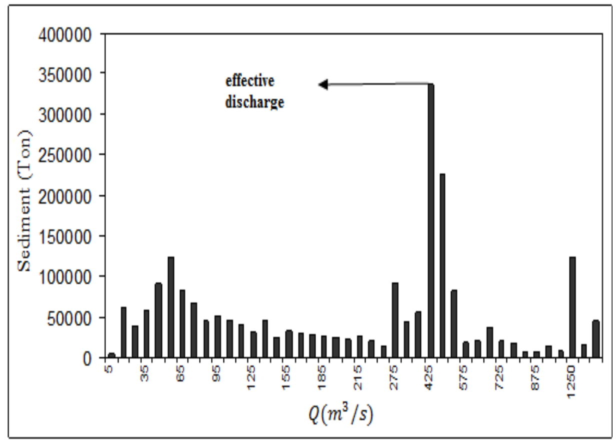

Fig. 4. *Histogram of average discharge - Jarahi River total sediment transport to Behbahan Station*

3.2 Bankfull Discharge Calculation

To determine the bankfull discharge, river cross section should be available. Then with the help of it, the bankfull section or any section corresponding to the bankfull or overflow discharge can be determined. To determine the bankfull discharge, width to depth parameter is used. For this purpose, according to the form of each station section, water surface width (w) and flow depth (d) are measured at different levels and then by placing d on axis X and $\frac{w}{d}$ on the axis Y its minimum point will be the bankfull border and increasing the curve to the right above, there is the section plain flood and using stage-discharge curves using a bankfull discharge is calculated [11]. Table (4) shows a bankfull discharge and their corresponding heights for each station and (Figure 5) shows transverse section of river and Figure (6) shows the test for determination of full section for example Behbahan station.

TABLE 4

BANKFULL DISCHARGE RESULTS AND THEIR CORRESPONDING HEIGHT FOR EACH STATION

River	Station	Bankfull discharge (cubic meters/second)	Equivalent Height (m)	Return Period (years)
Maroon	Idanak	621	7	Three
Maroon	Behbahan	558	4	2.3
Maroon	Cham Nezam	400	2	1.6

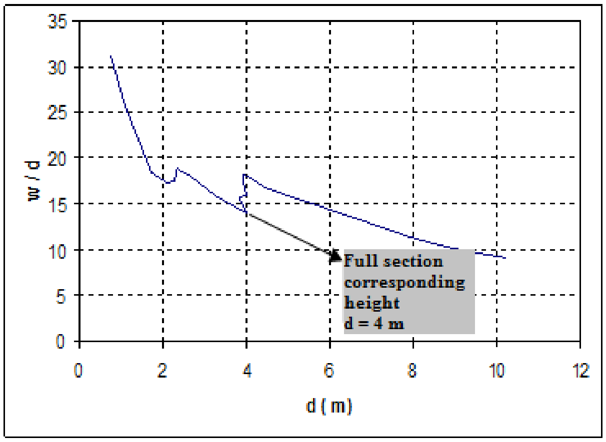

Fig. 6.*Determination of full section of Jarahi River in Behbahan Station*

3.3 Calculation of the mean discharge of the annual flood

To evaluate the flood of maximum moment recorded discharges during the statistics in three studied stations were collected. For Idanak stations during water year 1981-1982 to 2003-2004 and for Behbahan station during the water year 1985-1986 to 2007-2008 and Cham Nezam station during the water year 1981-1982 to 2006-2007, the statistics were studied. Using these observations and applying different methods of statistical distribution, the data were analyzed. After the Chi square test X2, examining skewness and squared standard error of each method, it was determined that for two stations of Behbahan and Cham Nezam the two-parameter gamma distribution using the method of Moment and for Idanak station, two-parameter gamma distribution by Max likelihoods offer better results. In Table (5) the results of the above calculations are presented for studied hydrometric stations.

4 CONCUSIONS

Great care should be taken in studies of determining the effective and bankfull discharges and identifying them. Because in definition, the type of river is important and theory of the effective flow may not be honest under certain circumstances. For example, in mountainous rivers, banks are rocky (the bank material is not the alluvium) and erosion invariably takes place from the floor. So the definition of flat plain flood for this river is very difficult. In Hydrometric stations of Behbahan and Cham-Nezam, values and the results obtained are closer to each other which is due to the fact that Idanak Hydrometric station is located upstream of the Jarahi Impounding Dam, so the effective discharge of this station due to sediment trapping by dams has less value than two other stations. In fact, the presence of impounding dam affect the dominant discharge of the downstream and upstream stations and increase the return period of dominant discharge in the downstream stations. In the case study of each of the three stations, it can be concluded that the rate of effective and bankfull discharges in two stations of Behbahan and Cham-Nezam were almost equal and in the absence of statistics to find the effective discharge, river design discharge return interval (dominant discharge) can be found by removing the full section, and in contrast, when statistics are available but width cross is not available, the effective flow can be found by analysis and consider it as bankfull discharge and use it for designs of river engineering. However, about the Idanak station with the probability that the data are less consistent with the two other stations, the presence of Jarahi Dam can be referred, which will certainly impact on the dominant discharge. In previous studies it was observed that the effective discharge values in all three stations was separately equal to the flood discharge with 1.5 to 2-year return period and these values can be used as the dominant discharge of the river in the interval related to each station. In fact, in the Jarahi River, the rate of dominant discharge is more likely to be close to the effective discharge of the river, but about the bankfull discharge, an interval or a specific station should be investigated locally and as case study to achieve more accurate results.

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