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Evaluating the performance of convex and corrected Att-Kin methods in operation of finding routing of flood (case study: Dalki river)

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Abstract

In this research with the use of the hydrological convex sub-methods the operation of finding flood routing was done between the Sarghanat and Kelal stations located in Dalki river. the characterstics of 26 flood was extracted as model input and then to evalute model performance and predict the output of hydrographs the Nash–Sutcliffe criteria, RMSE and relative error was used. Results of this study showed that Convex graphical sub-method can predict the outputs of hydrographs with higher precision as compared to other three methods. Moreover another result of this research is the priority of the use of 50% discharge as input discharge in model and results showed that in all sub-methods the predictiong the discharges of lower than 700 cubic meter per second had higher precision compared to discharges more than 700 cubic meter per second.

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Introduction

one of the important problem in hydrology engineering which ocuured frequerncy is the method of predicting Insurgence or refluence of flood or increasing and dectraesing the hydrograph of stream at detrmined point. This issue can be analysed using finding routing of flood. (Alizadeh, 2001). Finding Routing is used to short time prediction of flood, calculation of unit hydrograph at different point and extraction of hydrographs of artificial units (Najafi, 2002). Different method was prepared to find routing of stream and sources which these methods are divided in two groups of hydrological routing finding and hydroulic routing finding (Ghodsian, 1998). Totally all hydrological methods of routing finding for stream has beeb based on cohision equation:

(1)

$$\frac{dS}{dt} = I - Q$$

Where S is the sources or water volume, I is intensity of water input, Q is intensity of flow output, t is time and dS/dt is the intensity of sources variation. Abdolshah nejad (1996) studied the different methods of hydraulic and hydrological methods for finding flood routing in a section of Karoon stream and investigated the *Muskingum*-Cunge, *Muskingum*, Att-Kin, Convex flood routing, and hydrodynamic model of MIKE11.

Results of his study showed that time to peak and the dischrage rate were the best hydrograph of Convex and Att-Kin methods and other models are located in next stages. Abbasi zadeh (2009) in a research evaluted the performance of hydrological methods of routing finding in a section of Dez stream. Results of his study showed that Convex graphical method and *Muskingum and* Att-Kin had priority in relation to other hydrological methods. The aim of this study was evaluate the performance of Convex sub-methods in predicting the flood of river which is necessary according to the large flood of this river and the dangers threating people settlement around the river.

Materials and methods

Description of the study area

To do this study and determine the suitable period, 37.7 km of Dalki stream was selected according to the map of stream and the map of hydrometer stations of Iran. Sarghanat station as input of period with the eastern longitude of 51 17 and northern latitude of 29 28 and Kalal station with the eatern longitude of 51 06 and the northern latitude of 29 19 are as the output of pertiod which their geographical position is shown in Fig. 1.

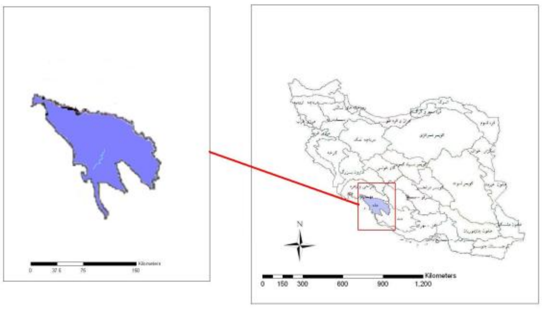


Fig. 1. The location of the study area and country.

Materials and Methods

In order to finding routing from long term statistical data of both stations the characterstics of 26 flood was extracted and then the coefficients of each method was determined using Convex flood routing methods and then the routing finding was done.

Modified Att-Kin Method

If the cohison equation is measured based on Q_2 we have:

(2)

$$Q_2 = \frac{2\Delta t}{2K + \Delta t} I_1 + \left(1 - \frac{2\Delta t}{2K + \Delta t}\right) Q_1$$

The value of $\frac{2\Delta t}{2K + \Delta t}$ was assumed C_m which is called Att-Kin. Thus:

(3)

$$Q_2 = C_m\, I_1 + (1 - C_m)\, Q_1$$

$K = \dfrac{L}{mV}$ equation was used to measure K where L is the even length of river in meter, V is the mean velocity of water in meter per second and m is the equation coefficient. In order to determine the m value based on the $(Q = A\ .\ V)$ for each segment of river it can possible to provide an equation between the cross section and discharge:

(4)

$$Q = xA^m$$

With considering Maning equation and placing $\dfrac{A}{P}$ instead of hydraulic radius and comparing to $Q = xA^m$ we have:

(5)

$$m = \frac{5}{3}\text{،}\quad x = \frac{1}{n} S^{\frac{1}{2}} P^{-\frac{2}{3}}$$

Where S is the slope of river in meter per meter, n is the stubby coefficient of Maning and P is the environmnet of moist area. At first an equation was prepared between the cross section and flow discharge $(Q = xA^m)$ and then the values of X and m is calculated. At the next stage the output discharge at different times is estimated using Att-Kin equation and the output hydrograph is provided.

Convex method

This method is based on this hypothesis that output flow in each time of t is depend on output of Q, input of I and beginig of the themporal distance of Δt. If C is fixed and $0 \le c \le 1$ we can have:

(6)

$$Q_{t+\Delta t} = cI_t + (1-c)Q_t$$

For this hypothesis it is necessary for ascendant hydrograph arm: if $I_t \ge Q_t$ the $I_t \le Q_{\Delta t} \le Q_t$ and for the descent hydrograph arm: if $I_t \ge Q_t$ the $I_t \le Q_{\Delta t} \le Q_t$. Therefore if Δt has been selected correctlly the $Q_{t+\Delta t}$ is equal to I_t or Q_t or between them no more or less. It can be shown that the value of Q_t, I_t and $Q_{t+\Delta t}$ are the members of a convex collection which is shown in Fig. 2. So this method is shown as this name. Equation 6 can be writed as:

(7)

$$c = \frac{Q_{t+\Delta t} - Q_t}{I_t - Q_t}$$

According to Figure 1 it can show that:

(8)

$$\frac{Q_{t+\Delta t} - Q_t}{\Delta t} = \frac{I_t - Q_t}{k}$$

A parameter which must be calculated. So:

(9)

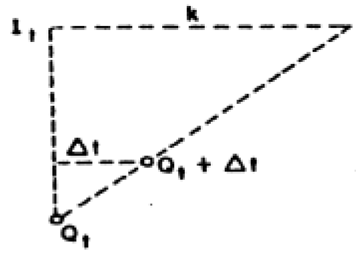
$$\frac{\Delta t}{k} = \frac{Q_{t+\Delta t} - Q_t}{I_t - Q_t}$$

following equation is achieved with comparing the equation 9 and 7:

(10)

$$c = \frac{\Delta t}{k} \quad or \quad \Delta t = ck$$

Convex method is a result of a two parameter method about the finding routing of flood in river. The benefit of this method is that $I_{t+\Delta t}$ don't interface in calculation of $Q_{t+\Delta t}$. Therefore it can be used in prediction. If the temporal distance of routing finding be one day and the input and output is appeared we can predict the output of tomorrow without information about today input.



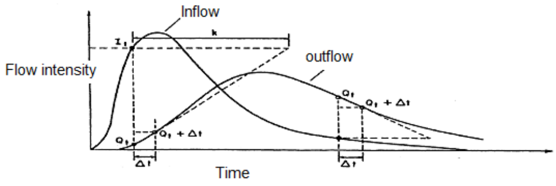


Fig. 2. Construction of three angular shape for Convex method.

Sub-methods of the calculation of Convex coefficient

Different methods are used to calculate the coefficient of C which the most important is:

A) Sing (1988) recommended the following equation to calculate the Convex parameter (Sing equation):

(11)

$$C = \frac{\bar{V}}{1.7 + \bar{V}}$$

B) American soil conservation organization (1985) recommended the following equation to calculate C coeffficient where V is the mean velocity of water in mentioned period in meter per second (SCS equation):

(12)

$$C = \frac{\bar{V}}{\bar{V} + 0.518}$$

C) One of the most accurate method of calculating C value is comparison of the input and output hydrographs. In this method Convex equation can be shown as:

(13)

$$Q_2 - Q_1 = C(I_1 - Q_1)$$

This equation is simmilar to linear equation which passes from the corrdinate offset $(y = bx)$ and its angle coefficient is $\left(b = \frac{\sum XY}{\sum X^2}\right)$. Therefore:

(14)

$$C = \frac{\sum[(Q_2 - Q_1)(I_1 - Q_1)]}{\sum\left[(I_1 - Q_1)^2\right]}$$

Evaluating the performance of models using statistical index

In this research following statistical index were used to evaluate the performance of models:

(15)

$$R.M.S.E = \sqrt{\frac{\sum_1^n (Qo - Qe_e)^2}{n}}$$

$RMSE$: Is the root of mean square error (cubic meters per second) Qo, Qe: Are the calculated and observed discharge hydrograph at the moment t.

n: is the number of discharge

(16)

$$CE = 1 - \frac{\Sigma(Qo - Qe)^2}{\Sigma(Qo - \overline{Qo})^2}$$

CE: is the preformance coefficient which in some of resources is shown E or EI and is called ***Nash***–Sutcliffe coefficient. Other parameter are simmilar to previus criteria.

(17)

$$\mathrm{Re}Q_p = \left|\frac{Qpo - Qpe}{Qpo}\right|$$

(18)

$$\mathrm{Re}Tp = \left|\frac{Tpo - Tpe}{Tpo}\right|$$

(19)

$$ReV = \left| \frac{Vo - Ve}{Vo} \right|$$

ReQ_p, ReT_p and ReV are relative error of the peak of discharge, relative error of the time to peak and relative error of the hydrograph volume, respectively. $Q_p o, Q_p e$ are discharge peak of calculated and observed hydrograph, respectively. $T_p o, T_p e$ are the time to peak for the calculated and observed hydrograph, respectively. Vo, Ve are the observed and calculted hydrograph of flood volume, respectively.

Results

According to the equations 7 to 10 and with the use of the characteristics of river sections the coefficients of each sub-method was determined to measure the Convex coefficient. Then the values of K, dt and Convex coefficient was determined which the value of coefficients for each sub-method and some of floods has been illustrated in Table 1. The routing of input hydrograph was found for 26 flood. Results of the observed and achieved hydrograph were compared using the equation of statistical index 15 to 19 where results is shown in Table 2 to 5, moreover the predicted hydrographs by Convex and Att-kins methods is shown in Fig. 3 and 4.

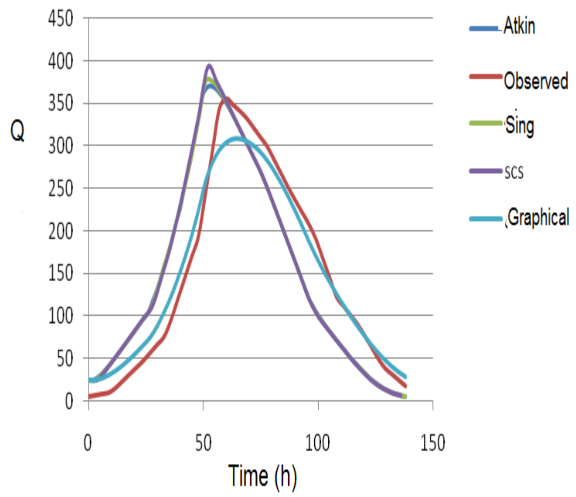


Fig. 3. Observed and estimated hydrographs using the Convex sub-methods for flood of 14.

Table 1. Coefficients of Convex and Att-kins methods for the some of floods.

Flood number	Coefficients of Sing method		Coefficients of SCS method		Coefficient of Graphical method		Coefficients of Att-Kin method	
	Q_P	$0.5\,Q_P$	Q_P	$0.5\,Q_P$	Q_P	$0.5\,Q_P$	Q_P	$0.5\,Q_P$
1	0.58	0.52	0.82	0.78	0.198	-	0.37	0.29
2	0.68	0.61	0.87	0.84	0.225	-	0.50	0.41
3	0.58	0.51	0.82	0.77	0.297	-	0.37	0.29

Table 2. The values of mean errors of Att-Kin method.

Statistical index	Q_P	$0.5\,Q_P$
RMSE	78.50	70.16
EI	0.66	0.73
REQ_p	0.104	0.079
RET_p	0.11	0.1
REV	0.003	0.005

Table 3. The values of mean errors of Sing method.

Statistical index	Q_P	$0.5\,Q_P$
RMSE	81.40	77.87
EI	0.64	0.68
REQ_p	0.15	0.13
RET_p	0.14	0.13
REV	0	0.01

Table 4. The values of mean errors of Americal soil conservation organization method.

Statistical index	Q_P	$0.5\,Q_P$
RMSE	80.88	79.30
EI	0.636	0.651
REQ_p	0.195	0.185
RET_p	0.143	0.143
REV	0.0065	0.0069

Table 5. The values of mean errors of graphical method.

Statistical index	Q_P
RMSE	21.36
EI	0.96
REQ_p	0.077
RET_p	0.041
REV	0.0076

Table 6. Comparison of the statistical parameters for selecting most suitable estimation methods of Convex and Att-kins coefficient.

Statistical index	SCS method	Sing method	Att-Kin	Graphical method
RMSE	80.88	81.40	78.50	21.36
EI	0.636	0.64	0.66	0.96
REQ_p	0.195	0.15	0.104	0.077
RET_p	0.143	0.14	0.11	0.041
REV	0.0065	0	0.003	0.0076

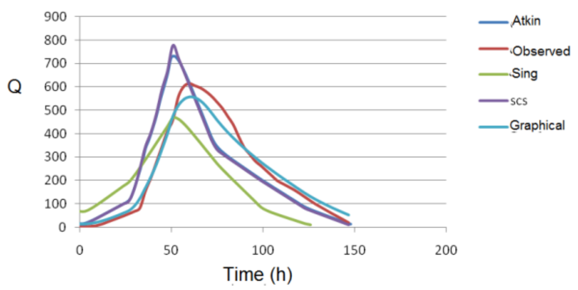


Fig. 4. Observed and estimated hydrographs using the Convex sub-methods for flood of 15.

Conclusions

According to the Table 6 and besed on the means of RMSE, performance coefficient, relative error of volume, peak time and peak of discharge and emperical comparison showed that graphical sub-method can find routing of flood in Dalki river with higher precision as compared to Sing, SCS and Att-Kin method. As all predicted hydrographs by graphical sub-method had higher precision as compared to other three methods. Moreover another result of this research is the priority of the use of 50% discharge as input discharge in model and results showed that in all sub-methods the predictiong the discharges of lower than 700 cubic meter per second had higher precision compared to discharges more than 700 cubic meter per second. Among the statistical index, RMSE and EI were most suitable index to find flood routing.

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