Improvement research of flood routing model in Aksu River basin

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Abstract. To optimize the existing flood control plan of Aksu River basin and strengthen the flood control management during the flood season, the flood routing of Aksu River is studied based on the improved Muskingum method. Firstly, to make up for the shortcomings of the traditional Muskingum method in flood routing of double tributaries, the parameters of single tributary are further improved. Then, the improved Muskingum method is used to simulate and validate the flood process of Shaliguilanke, Xiehela and Xidaqiao hydrometric stations in Aksu River from 1999 to 2016. The results show that: (a) In the main stream of Aksu River, the flood of Xidaqiao Hydrometric Station is mainly caused by the water coming from Xiehela Hydrometric Station, while the flood caused by the water coming from Shaliguilanke Hydrometric Station and two stations (Shaliguilanke Hydrometric Station and Xiehela Hydrometric Station) is less. (b) We classified the main streams of the above three situations by flood peak level, and then carried out flood routing. The calculating parameters under the same flood peak level all show strong integrity, and the fitting degree between the simulated process and the observed process is relatively high. The parameters 𝐾 and 𝑥 inversely deduced under the condition of the inflow of Xiehela Station as the main source have more physical significance.

1. Introduction
Aksu River is the largest runoff river in Tianshan Mountains, Xinjiang, and also the largest source of Tarim River. In recent years, precipitation, glacial ablation and runoff have increased continuously in Xinjiang, water level of lakes has risen significantly, and flood losses have increased dramatically [1]. However, the current flood routing method for flood control planning in Aksu River basin is too simple to meet the flood control needs of the basin under the new situation. Zhang Chuanrong [2] used the monthly runoff and annual maximum peak flow data of the two tributaries and main streams of Aksu River to analyze the flood characteristics of Aksu River, but did not carry out the flood routing calculation of the river. After comparing models, Ouyang Rulin [3] and others selected AR (p) model revised by temperature and rainfall to simulate and forecast the daily runoff of the two tributaries of Aksu River basin. However, due to the lack of representative precipitation data, the precipitation at Shankou Station is much smaller than that at high mountains, which affects the prediction accuracy. Zhu Kai [4] used climate and runoff data from 1961 to 2000 in Aksu River basin to establish BP runoff forecasting models based on influencing factors and time series, respectively. The prediction accuracy of BP runoff prediction model based on time series is higher than that of BP runoff prediction model...
based on influencing factors, but the time series is relatively simple and generally has poor accuracy, which is manifested by the obvious hysteresis phenomenon of peak flow forecast. The hydrological method based on Muskingum method has better effect on river flood routing and can effectively solve the above problems. However, the traditional Muskingum method optimizes $K$ and $x$ [5] according to the basic assumption that $W$~$Q'$ is a single straight line. The flow calculating coefficients calculated according to the $K$ and $x$ values do not necessarily minimize the fitting error between the calculated outflow and the observed outflow, and there are large errors. For this reason, Qu Guojing [6] used Lagrange multiplier method, He Hui and Zhang Jianyun [7] used least square method to calculate the optimal estimates of outflow coefficients $C_0$, $C_1$ and $C_2$. Based on the minimum sum of squares of errors in calculated outflow and actual outflow, the optimum values of flow evolution coefficients $C_0$, $C_1$ and $C_2$ are directly derived. Both methods are better mathematical methods for estimating outflow coefficients $C_0$, $C_1$ and $C_2$, which overcome the blindness of trial-and-error method. But these methods are mainly used in single tributary flood routing, and have limitations in multi-tributary application and time step. Therefore, this paper constructs a sectional improved Muskingum flood routing model for the two tributaries of the Aksu River, and uses genetic algorithm to calibrate parameters for the flood routing of the Aksu River. The results of calculation can provide scientific support for optimizing existing flood control plans and strengthening flood control management in Aksu River basin.

2. Research area and data

2.1. Research area

The two main streams, the Kumalik River and Taushgan River, converge to form the Aksu River near Wensu County (see Fig. 1). The north main stream is the Kumalik River, which originates from the Atbash Mountains and is 293 km long from the source of the river to the confluence of the two rivers. The catchment area is 12816 km$^2$, and the average annual runoff is $4.89 \times 10^9$ m$^3$. The western main stream is the Taushgan River, which originates from the Khan Tengri Peak and is 457 km from the source of the river to the confluence. The catchment area is 19166 km$^2$, and the average annual runoff is $2.83 \times 10^9$ m$^3$. The main flood season of Taushgan River, the West tributary of Aksu River, is from May to August. The main flood season of the North tributary, Kumalik River, and Aksu River is from July to August. Therefore, the flood of Kumalik River plays a more important role in the flood of Aksu River. The main types of floods in the Taushgan River are snow melting type and snow melting combined with rainstorm type. The main types of floods in the Kumalik River are snow (ice) melting type and snow (ice) melting combined with ice lake dam-break type. The mixed type is the most common type of floods in the main stream of the Aksu River, followed by snow(ice) melting type [2].

![Figure 1. Diagram of Aksu River system and hydrometric stations](image)
2.2. Research data
The data used in this paper are daily flow data of Shaliguilanke, Xiwhela and Xidaqiao hydrometric stations from 1999 to 2016 (18 years in total). The time intervals are mostly 6 hours or 8 hours. In order to prevent missing of maximum peak flow, the interval of measurement near peak current time is 1 h or 0.5 h. For most of the time, the flow of Xiwhela Hydrometric Station is larger than that of Shaliguilanke Hydrometric Station. It is preliminarily judged that the flood of Xidaqiao Hydrometric Station in the main stream of Aksu River is dominated by the inflow of Xiwhela Hydrometric Station.

3. Research method
The basic principle of Muskingum method is described by the water balance equation expressed by the continuity equation and the momentum equation replaced by the storage equation, which is:

\[
\begin{cases}
\frac{dw}{dt} = I - Q \\
W = K \left[ xI + (1 - x)Q \right] = KQ'
\end{cases}
\]  

(2-1)

Where: \( I \) is the inflow of upper section, \( m^3/s \); \( Q \) is the outflow of lower section, \( m^3/s \); \( Q' \) is the storage flow, \( m^3/s \); \( W \) is the storage capacity of river reach, \( m^3/s \); \( x \) is the flow specific gravity factor; \( K \) is the storage coefficient, \( h \). In a physical sense, \( K \) value is equal to the propagation time of the stable flow state under the water storage \( W \), and \( x \) is the flow specific gravity factor, reflecting the shape of the water surface curve and the regulation and storage effect of the river reach [9].

When the flow process of the upper section of the reach is known, the flow of the lower section is decomposed into the following equation by the difference obtained from (2-1):

\[
Q_2 = C_0 I_1 + C_1 I_2 + C_2 Q_1
\]

(2-2)

\[
C_0 = \frac{0.5 \Delta t - Kx}{0.5 \Delta t + K - Kx}
C_1 = \frac{0.5 \Delta t + K - Kx}{0.5 \Delta t + K - Kx}
C_2 = \frac{-0.5 \Delta t + K - Kx}{0.5 \Delta t + K - Kx}
\]

(2-3)

And satisfy:

\[C_0 + C_1 + C_2 = 1\]

(2-4)

Where: \( I_1 \) and \( I_2 \) are the upper section inflow of the beginning and end of the period, \( m^3/s \), \( Q_1 \) and \( Q_2 \) are the lower section outflow of the beginning and end of the period, \( m^3/s \), and \( \Delta t \) is the length of the calculation period, h.

It can be seen from (2-2) (2-3) that if the three parameters \( C_0, C_1 \) and \( C_2 \) are calculated, the lower flow of the river can be calculated from the upper flow of the reach. Therefore, the key of Muskingum’s algorithm lies in the calibration of the calculating parameters \( C_0, C_1 \) and \( C_2 \) or \( K, x \).

The optimized model established in this paper takes \( C_0, C_1 \) and \( C_2 \) as parameters, the fitting degree of calculated flow and observed flow as optimization criterion function, and the calculating parameters are directly optimized by the results of optimization criterion function. That is to say, based on the minimum sum of squares of errors between calculated and observed outflows, the optimal estimates of flow evolution coefficients \( C_0, C_1 \) and \( C_2 \) are directly derived, and then the parameters \( K \) and \( x \) are inversely calculated. Because there are tributaries in this reach, this paper uses the method of “first calculating respectively then combining together” to deal with the tributaries. The objective function is as follows when water from a single station is dominant:

\[
\min \ E = \sum_{i=1}^{N} \left( C_i I_i + C_1 I_{i+1} + C_2 O_{i+1} - O_i \right)^2
\]

(2-5)

Where: \( i \) is the number of periods, \( E \) is the sum of squares of deviation of single station, and \( N \) is the number of observed flow points. The objective function of water coming from two stations is as follows:
\[ \min E^2 = \sum_{i=2}^{N} \left( C_i I_i^1 + C_i I_i^1 + C_i I_i^2 + C_i I_i^2 + C_i I_i - O_i \right)^2 \] 

(2-6)

Where: \( i \) is the number of periods, \( E^2 \) is the sum of squares of deviation of two stations, \( N \) is the number of observed flow points, \( C_i \) is the evolution coefficient of tributary \( k \), \( j \) is 1, 2, 3; \( I_i \) is the inflow of tributary \( k \) at time \( j \).

The parameters \( K \) and \( x \) are inversely deduced by:

\[ K = \frac{C_i + C_j}{C_i + C_j} \times \Delta t \] 

(2-7)

\[ x = \frac{C_0 + C_1}{2(C_i + C_j)} + \frac{C_0}{C_0 - 1} \] 

(2-8)

4. Results and discussion

The flood characteristics of each hydrometric station are analyzed. The peak flow more than 600 m³/s of Xidaqiao Station in the main stream is taken as the research object. When the main inflow is from Shaliguilanke Station, the peak flow of the main stream is small, the number of events is less, and the occurrence time is from April to September; when the main inflow is from Xiehela Station, the peak flow is large, the number of events is the largest, and the occurrence time is from June to August; when the main inflow is from two stations, the peak flow appears the maximum, the peak flow event is in the middle, and the occurrence time is from June to August, and also appears in September. Most of the floods are mainly from the inflow of Xiehela Station. (If the peak flow of tributary A > the peak flow of tributary B and the ratio of the peak flow of tributary B to the peak flow of tributary A is more than 50%, it is determined that the two stations will co-dominate the formation of flood, otherwise the tributary A will be the dominant the formation.)

According to statistics, the propagation time of flood peak of the two river reaches can be obtained by eliminating the abnormal values, as shown in Table 1 below.

| River reach                | Propagation time of flood peak (h) |
|----------------------------|-----------------------------------|
| Xiehela~ Xidaqiao          | 4~35.35                           |
| Shaliguilanke~ Xidaqiao    | 4~40.83                           |

4.1. The inflow of Xiehela Hydrometric Station as the main source

When the inflow of Xiehela Station is the main water source, Shaliguilanke Station has a weaker water supply. It can be considered as a single tributary flood routing from Xiehela Station to Xidaqiao Station. At this time, Shaliguilanke Station is regarded as the basic flow of Xidaqiao Station. Thirty eligible floods are selected as the research object. This paper intends to use the leave-one-out-cross-validation method. One of the 30 floods is randomly selected for validation and the other 29 for calibration. In this way, on the one hand, we can get as much effective information as possible from the limited data because of the small number of flood events selected; on the other hand, we can evaluate the prediction performance of the model, especially the performance of the trained model on the new data, which can avoid over-fitting to a certain extent. Muskingum's method is based on constant flow. Different flow has different parameters. Usually, only one set of parameters is used in hydrological prediction. In order to make the simulation results more accurate and avoid the errors caused by different flood levels as far as possible, this study uses parameter calibration and validation of flood classification. That is to say,
different parameters are given under different flood levels, and then parameter validation is carried out separately under different flood levels.

The calibration of parameters can be seen in Table 2 below. From Table 2, it can be seen intuitively that the values of parameters of the same level are not very different and have integrity. On the other hand, from the point of view of parameter $K$, the result of parameter calibration accords with the fact that the larger the peak flow is, the shorter the propagation time is. However, compared with the actual flood propagation time, it shows a rather large situation. The reason may be that the flow of Xidaoqiao Station is the result of the co-evolution of two tributaries (Xihela Station and Shaligulianke Station), but the partial flow evolution of Shaligulianke Station is neglected in flood routing under this condition. From the point of view of parameter $x$, the coefficient increases with the increase of flow as a whole.

Table 2. Parameter calibration results of inflow of Xiehela Station

| Flood peak level | $C_0$ | $C_1$ | $C_2$ | $K$ | $x$ |
|------------------|-------|-------|-------|-----|-----|
| 1000~1500        | 0.015 | 0.043 | 0.942 | 17.00 | 0.014 |
| 600~1000         | 0.006 | 0.048 | 0.945 | 18.37 | 0.022 |
| 1000~1500        | 0.015 | 0.041 | 0.944 | 17.65 | 0.013 |
| $>1500$          | 0.014 | 0.047 | 0.939 | 16.22 | 0.017 |
| 1000~1500        | 0.015 | 0.043 | 0.941 | 16.96 | 0.014 |
| 1000~1500        | 0.015 | 0.043 | 0.941 | 16.87 | 0.014 |
| $>1500$          | 0.010 | 0.041 | 0.943 | 17.47 | 0.013 |

Note: The unit of flood peak level is m/s, and the unit of $K$ is h. The same below.

A flood is randomly selected for parameter validation, and the results are shown in Table 3 below, from which it can be seen that the qualified rate of parameter validation is 80%. The certainty coefficients of flood simulation process are greater than 0.9. The fitting degree between calculated flood process and observed flood process is high. Almost all simulated flood peak time lags behind the actual peak time, but most of the time differences are within the allowable range. This also reflects the applicability of the model.

Table 3. Validation results of flood routing of inflow of Xiehela Station

| Flood peak level | $Q_1$ | $Q_2$ | $\Delta t$ | $DC$ | $Y/N$ |
|------------------|-------|-------|------------|------|-------|
| 600~1000         | 720   | 704.8 | -72.6      | 0.926 | N     |
| 912              | 902.0 | -1.0  | 0.995      | N     | N     |
| 646              | 645.0 | -1.0  | 0.985      | N     | Y     |
| 755              | 748.2 | -1.4  | 0.988      | N     | Y     |
| 851              | 842.1 | -0.5  | 0.997      | Y     | Y     |
| 872              | 872.8 | -13.0 | 0.995      | N     | Y     |
| 678              | 671.6 | -1.0  | 0.988      | Y     | N     |
| 614              | 609.9 | -1.0  | 0.983      | Y     | N     |
| 1000             | 959.8 | -0.2  | 0.979      | Y     | N     |
| 1000~1500        | 1130  | 1110  | -6.0       | 0.999 | Y     |
| 1120             | 1121.9| -0.1  | 0.999      | N     | N     |
| 1090             | 1072.6| -1.0  | 0.987      | Y     | Y     |
| 1110             | 1160.9| -1.0  | 0.993      | Y     | Y     |
| 1120             | 1175.3| -1.8  | 0.988      | Y     | Y     |
| 1140             | 1119.7| -1.0  | 0.977      | Y     | Y     |
| 1410             | 1387.3| -1.0  | 0.984      | Y     | Y     |
Flood peak level | $Q_r$ | $Q_f$ | $\Delta t$ | DC | Y/N | Flood peak level | $Q_r$ | $Q_f$ | $\Delta t$ | DC | Y/N
---|---|---|---|---|---|---|---|---|---|---|---|---|
1010 | 1005.8 | -1.0 | 0.982 | Y | 1460 | 1437.5 | -1.1 | 0.975 | Y |
820 | 810.3 | -1.0 | 0.991 | Y | 1510 | 1474.4 | 8.0 | 0.998 | Y |
622 | 619.8 | -1.0 | 0.988 | Y | 2020 | 1978.6 | -0.5 | 0.999 | Y |
772 | 753.6 | -0.7 | 0.935 | Y | 1460 | 1462.4 | -1.7 | 0.996 | Y |
1340 | 1318.2 | -1.0 | 0.983 | Y | 1250 | 1269.3 | -1.0 | 0.995 | Y |
786 | 752.7 | -1.7 | 0.910 | Y | 1790 | 1769.6 | -0.5 | 0.989 | Y |

Note: $Q_r$ and $Q_f$ denote the observed and simulated flood peaks at Xidaqiao Station, respectively, $m^3/s$; $\Delta t$ denotes the time of observed flood peaks minus the time of simulated flood peaks, h; DC denotes the certainty coefficient of flood simulation; Y/N denotes whether the simulation is qualified or not. The same below.

A flood is extracted from different flood peak levels in the above table, and the observed flood hydrograph and the simulated flood hydrograph are drawn. It can be seen that the fitting process of the three floods is good. With the increase of peak level of Xiehela Station, the peak flow of Xidaqiao Station in the main stream is also increasing. And the peak flow of Xidaqiao Station in the main stream is in the same flood peak level as the corresponding Xiehela Station. See Figure 2:

![Figure 2. Comparison of flood routing of different levels of peak flow in Xiqiao Station in main stream (the inflow of Xiehela Hydrometric Station as the main source)](image)

4.2. The inflow of Shaliguilanke Hydrometric Station as the main source

Six eligible floods are selected as the research objects. The calibration results of parameters are shown in Table 4. Because the number of flood events is too few, and the ratio of peak flow of Xiehela Station to peak flow of Shaliguilanke Station is close to 50%, the influence of Xiehela Station is too great. It is impossible to see the specific trend of parameters varying with flow.

Table 4. Parameter calibration results of inflow of Shaliguilanke Hydrometric Station as the main source from 1999 to 2016

| Flood peak level | $C_0$ | $C_1$ | $C_2$ | $K$ | $x$ | Flood peak level | $C_0$ | $C_1$ | $C_2$ | $K$ | $x$ |
---|---|---|---|---|---|---|---|---|---|---|---|---|
400~1000 | 0.003 | 0.011 | 0.987 | 71.29 | 0.004 | 400~1000 | 0.003 | 0.011 | 0.987 | 71.29 | 0.004 |
0.004 | 0.001 | 0.996 | 199.40 | -0.002 | | 0.018 | 0.000 | 0.983 | 54.61 | -0.009 |
0.000 | 0.011 | 0.990 | 91.00 | 0.005 | | 0.001 | 0.007 | 0.993 | 125.00 | 0.003 |

The validation results are shown in Table 5 below. The qualified rate of parameters validation is 100%. The certainty coefficients of flood simulation process are greater than 0.95. The fitting degree between calculated flood process and observed flood process is relatively high. Most simulated flood peak time lags behind the actual peak time, but the time difference is within the allowable range of peak time difference. This also reflects the applicability of the model, but the parameters $K$ and $x$ at this time
have no physical significance, which may be due to the excessive diversion of water for oasis irrigation in Shaliguilanke Station.

Table 5. Flood routing result of inflow of Shaliguilanke Hydrometric Station as the main source from 1999 to 2016

| Flood peak level | $Q_r$ | $Q_f$ | $\Delta t$ | DC | Y/N |
|------------------|-------|-------|------------|-----|-----|
| 400~1000         | 915   | 907.8 | -1.0       | 0.962 | Y |
| 1160             | 1151.2 | -1.0  | 0.995      | Y |
| 937              | 926.2 | -1.2  | 0.985      | Y |
| 400~1000         | 700   | 699.2 | -1.0       | 0.992 | Y |
| >1000            | 2190  | 2173.5| 0.0        | 1.000 | Y |

A flood is extracted from different flood peak levels in the above table, and the observed flood hydrograph and the simulated flood hydrograph are drawn. It can be seen that the fitting process of the two floods is good. With the increase of peak level of Shaliguilanke Station, the peak flow of Xidaqiao Station in the main stream is also increasing. However, the peak flow of Xidaqiao Station in the main stream is obviously larger than that of the corresponding Shaliguilanke Station. See Figure 3:

Figure 3. Comparison of flood routing of different levels of peak flow in Xiqiao Station in main stream (the inflow of Shaliguilanke Hydrometric Station as the main source)

4.3. The inflow of two stations (Shaliguilanke and Xiehela hydrometric stations) together as the main source

Twenty-two eligible floods are selected. Because the principle of choosing flood when the two stations jointly dominate the inflow is that the ratio of peak flow (small flow/large flow) of two stations is more than 50%, there will be a situation that the peak flow of two tributaries is not in the same level in a flood. According to the actual situation, the results of parameter calibration are shown in Table 6 below. From Table 6, it is also intuitive to see that the parameter values of the same level have integrity. On the other hand, due to the parameters $K$ and $x$ inversely deduced and the actual peak propagation time are too different, there is no physical significance. The parameters $K$ and $x$ are not listed here for analysis and discussion.

Table 6. Parameter calibration results of inflow of two stations together as the main source from 1999 to 2016

| Type and level of flood peak | $C_0$ | $C_1^1$ | $C_1^2$ | $C_2^1$ | $C_2^2$ |
|-----------------------------|------|---------|---------|---------|---------|
| The level of both Shaliguilanke and Xiehela stations less than 600 | 0.005 | 0.013 | 0.009 | 0.009 | 0.983 |
| The level of Shaliguilanke Station less than 600 | 0.004 | 0.004 | 0.005 | 0.002 | 0.993 |
| The level of Shaliguilanke Station between 600~1000 | 0.010 | 0.007 | 0.003 | 0.015 | 0.982 |

| Type and level of flood peak | $C_0$ | $C_1^1$ | $C_1^2$ | $C_2^1$ | $C_2^2$ |
|-----------------------------|------|---------|---------|---------|---------|
| The level of both Shaliguilanke and Xiehela stations between 600~1000 | 0.007 | 0.003 | 0.005 | 0.005 | 0.989 |
| The level of Shaliguilanke and Xiehela stations between 600~1000 | 0.008 | 0.004 | 0.005 | 0.007 | 0.987 |
The level of Xiehela Station less than 600, The level of Shaliguilanke Station larger than 1000, The level of both Shaliguilanke and Xiehela stations larger than 1000.

The results of leave-one-out-cross-validation of the same type of flood are shown in Table 7. It can be seen from Table 7 that the qualified rate of parameter validation is 77%. The certainty coefficient of flood simulation process is greater than 0.95. The fitting degree between calculated flood process and observed flood process is relatively high. Most simulated flood peak time lags behind the actual peak time, but the time difference is mostly within the allowable range of peak time difference. This also reflects the applicability of the model, but the parameters \(K\) and \(x\) at this time have no physical significance.

Table 7. Flood routing result of inflow of two stations together as the main source from 1999 to 2016

| Type and level of flood peak | \(Q_r\) | \(Q_f\) | \(\Delta t\) | \(DC\) | Y/N |
|-----------------------------|--------|--------|-----------|-------|-----|
| The level of both Shaliguilanke and Xiehela stations less than 600 | 692 | 695.0 | -1.0 | 0.999 | Y |
| | 757 | 750.3 | -1.0 | 0.995 | Y |
| | 791 | 787.9 | -1.0 | 0.983 | Y |
| The level of Shaliguilanke Station less than 600 and The level of Xiehela Station between 600~1000 | 1000 | 999.5 | -1.0 | 0.970 | Y |
| | 1010 | 1005.9 | 3.0 | 0.973 | Y |
| | 725 | 782.6 | 23.0 | 0.991 | N |
| | 1140 | 1137.7 | -1.0 | 0.993 | Y |
| | 804 | 802.5 | -1.0 | 0.969 | Y |
| The level of Xiehela Station less than 600, The level of Shaliguilanke Station larger than 1000 | 732 | 732.4 | -1.0 | 0.993 | Y |
| | 740 | 757.2 | 25.0 | 0.993 | N |
| The level of Shaliguilanke Station less than 600, The level of Xiehela Station between 600~1000 | 920 | 919.2 | 0.0 | 0.996 | Y |

A flood is extracted from different flood peak levels in the above table, and the observed flood hydrograph and the simulated flood hydrograph are drawn. The fitting process of the six floods is good. Taking the last two large flood peak levels as examples, it is shown in Fig. 4.

It can be seen that when the flow of Shaliguilanke Station is larger than 1000 m\(^3\)/s, the flow of Xiehela Station increases from 600 m\(^3\)/s to 1000 m\(^3\)/s, and the flow of Xidaqiao Station in the downstream main stream is also increasing. Combined with the other four cases, the peak flow of Xidaqiao Station in the
downstream main stream will also increase when peak level of either or both the control stations of two upstream tributaries increases.

Figure 4. Comparison of flood routing of different levels of peak flow in Xiqiao Station in main stream (the inflow of two stations together as the main source)

5. Conclusion
From 1999 to 2016, the flow data series of the two upstream tributaries -- Shaliguilanke and Xiehela stations, and the downstream one-- Xidaqiao Station are used to analyze the flood peak characteristics and composition of Xidaqiao Station under different inflow conditions. Then, based on different inflow conditions, the Muskingum method is adopted to perform classified flood routing according to different flood peak level of Xidaqiao Station in the main stream. The main research conclusions are as follows:

(1) In the flood routing, considering that the length of the river reach is long, this paper adopts the piecewise Muskingum continuous algorithm; and considering the inflow of two stations, this paper adopts the method of “first calculating respectively then combining together”, and then carries out parameter calibration by combining the classification of flood level. The results show that the simulated flood process is in good agreement with the observed flood process with higher certainty coefficient and applicability of the method. In the process of parameter validation, the observed peak lags behind the simulated peak, while in the process of parameter calibration, the simulated peak can occur in advance, lag or at the same time with the observed peak. After parameter validation, it is more stable than the simulation value, tends to a certain constant, and there is no phenomenon of larger or smaller.

(2) According to the analysis of calculation results, the parameters $K$ and $x$ inversely deduced have more physical significance and are close to the actual time of flood peak propagation under the condition of the inflow of Xiehela Station as the main source. When the inflow of Xiehela Station as the main source or two stations together as the main source, the parameters $K$ and $x$ inversely deduced appear unreasonable values. The reason is that the Shaliguilanke station may have more loss of diversion irrigation or more infiltration.

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