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Original Research Paper

Analysis of Runoff Changes of Niqu River in Water Diversion Area of Western Route Project of South-North Water Transfer Project

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ABSTRACT

The runoff data of Zhuba Station at Niqu river in water diversion area of Western Route Project (WRP) of South-North Water Transfers Project (SNWTP) from 1961 to 2010 were applied to estimate the coefficients of variation of hydrology, the peak pattern degree, and ample flow VS low flow, climate tendency rate and so on. The results were used to analyse the effects of hydrological regime on river discharge in the water supply area of the first stage project in WRP. The results demonstrated that: The annual river discharge is increasing in Niqu River which is the water supply area in the first stage project of WRP. The cumulative increased river discharge is $0.52\times10^8 m^3$ within 50 years which is 2.6% larger than the average value. The runoff increased each year in non-flood season and decreased each year in flood season.

INTRODUCTION

South-to-North Water Transfer Project is an important ecological engineering which is formed by three lines: Western Route Project (WRP), Middle Route Project (MRP) and Eastern Route Project (ERP). These three water transfer projects connect the Yangtze River, Huaihe River, Yellow River and Haihe River which formed the general pattern for Chinese water resources development, distribution and utilization (Li 2001). The Middle Route Project and the Eastern Route Project are under construction now. Project proposal of the Western Route Project is under evaluation at present. $170\times10^8 m^3$ volume of water is scheduled to be transferred from the upper reaches of the Yangtze River, including Tongtianhe River, Yalong River and Dadu River to the Yellow River in the Western Route Project.

The studies of the WRP in the SNWTP mainly focused on the hydrological data estimation at the dam section, the runoff features analysis, water transfer volume evaluation, the effects of water transfer on the hydrological regime and ecological environment and the ecology, and water requirement in the downstream of the water transfer rivers. There is no hydrological station at the dam section. The hydrological data at the dam section needs to be derived from the data collected by the downstream stations (Gao 2001, Men 2006a).

The determination of the water diversion volume of the WRP in the SNWTP, the effects of water transfer on the ecological environment and water requirement are both related to the variation of the river runoff. Water is one of the most active factors in the ecological system. It is very important to study the runoff variation. The runoff supply source and run-off characteristics of river in south-north water transfer scheme via western route had been studied (Men 2007, Men 2009), while, there are no relationship researches about the relationship between the variation of the runoff and the climate factors at present. The runoff change of Niqu river as an example (Men 2007), is introduced in this paper. This study can supply scientific foundation to the proposal demonstration, planning and design, available water transfer amount and ecology, and water requirement of the first stage of WRP.

DATA COLLECTION

Zhuba Station is the only hydrological station in Niqu river. The monthly average runoff data from 1961 to 2010 recorded in Zhuba Hydrological Station were supplied by the National Hydrological Bureau.

ALGORITHM MODEL

The annual average runoff at Niqu Hydrologic Station, which is the water supply area in the first stage project of WRP, was estimated.

Coefficient of variation (C_v) (Men 2006b, Tang 1992): Coefficient of variation can indicate the annual runoff series deviating from the mean of runoff. In general, coefficient of variation can be calculated by equation (1).

$$Cv=\sqrt{\sum_{i=1}^{n}(K_i-1)^2/(n-1)} \quad ...(1)$$

$$K_i = Q_i/\overline{Q} \quad ...(2)$$

Where n is the number of observation years; K_i is the runoff variation of the i^{th} year; Q_i is the average runoff of the ith year; $\overline{Q}$ is the average runoff.

Residual accumulative curve (Men et al. 2006b): Standardized $(K_i-1)/Cv$ was applied to indicate the variation of runoff in order to minimize the effect of unit of annual runoff, precipitation and C_v. The Residual accumulative curve was calculated to show the variation of the runoff periodically with $\sum(K_i-1)/Cv$ as the Y-axis.

Peak-pattern degree and ample flow Vs low flow (Li 2004): Peak-pattern degree *a* and ample flow Vs low flow *b* were applied to analyse the runoff distribution within the year. The peak-pattern degree *a* reflected the ratio of the seasonal snow melt water to the mountain snow melt water plus rainfall of the river runoff. The ample flow Vs low flow reflected the ratio of the runoff in the flood season to that in the non-flood season, which indicated the ratio of the increment of groundwater to the annual runoff.

$$a = Q_{5-7}/Q_{8-10} \quad ...(3)$$

$$b = Q_{5-10}/Q_{11-4} \quad ...(4)$$

where Q_{5-7} is the total river discharge from May to July each year; Q_{8-10} is the total river discharge from August to October each year; Q_{5-10} is the total river discharge from May to October each year; Q_{11-4} is the total river discharge from November to next April each year.

Climate tendency rate: It fluctuates with time and showed certain tendency with large time scale. The climate tendency reflected the variation of climate factors with time.

If one element array data was assumed to be a time array, the data can be expressed as X_1, X_2, X_3,……, X_n, which can be presented as a polynomial:

$$\hat{X}(t)=a_0+a_1t+a_2t^2+\cdots+a_pt^p \quad ...(5)$$

Where t is time with year as the unit which is usually expressed as *a*.

Generally, the climate tendency of one element can be simulated with curvilinear equation, parabolic equation or straight line equation. The tendency rate can be given as:

$$\frac{\mathrm{d}\hat{X}(t)}{\mathrm{d}t}=a_1 \quad ...(6)$$

a_1 can be determined using least square method or orthogonal polynomial with $10a_1$ as the climate tendency rate.

$$\sum_{t=1}^{n}\left[X(t)-\hat{X}(t)\right]^2=\min \quad ...(7)$$

VARIATION FEATURES OF RUNOFF IN NIQU RIVER

The variation of the surface water resources in the water supply area of the first stage of WRP is related to the exploration of the water resources (available water transfer amount) and the water supply of the river discharge. This can influence the reliability of the water supply in the water intake area directly.

C_v of the Niqu river: Generally, the discharge of some rivers varied seasonally because of the seasonally changing water supply. This usually happens to the rivers with seasonal snow melt water or precipitation as the water supply. The coefficient of variation of these rivers is very large. The discharges of rivers are relatively stable with mountain ice melt water mixing with rainfall as the water supply because these two kinds of water supply can complement each other and minimize the seasonal effects. The coefficients of variation of these rivers are relatively small. The C_v is about 0.10-0.12 for rivers with mountain ice melt water as the water supply; the C_v is around 0.12-0.20 for rivers with mountain

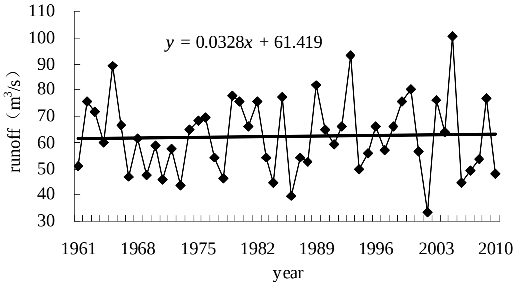

Fig. 1: Variation curve of annual mean flow in Niqu River.

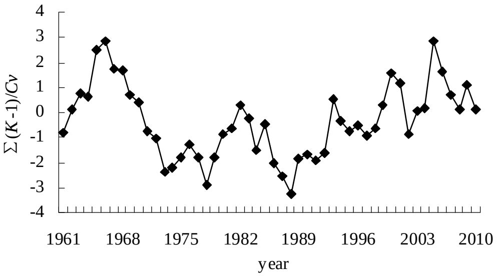

Fig. 2: Difference-integral curve of annual mean flow in Niqu River.

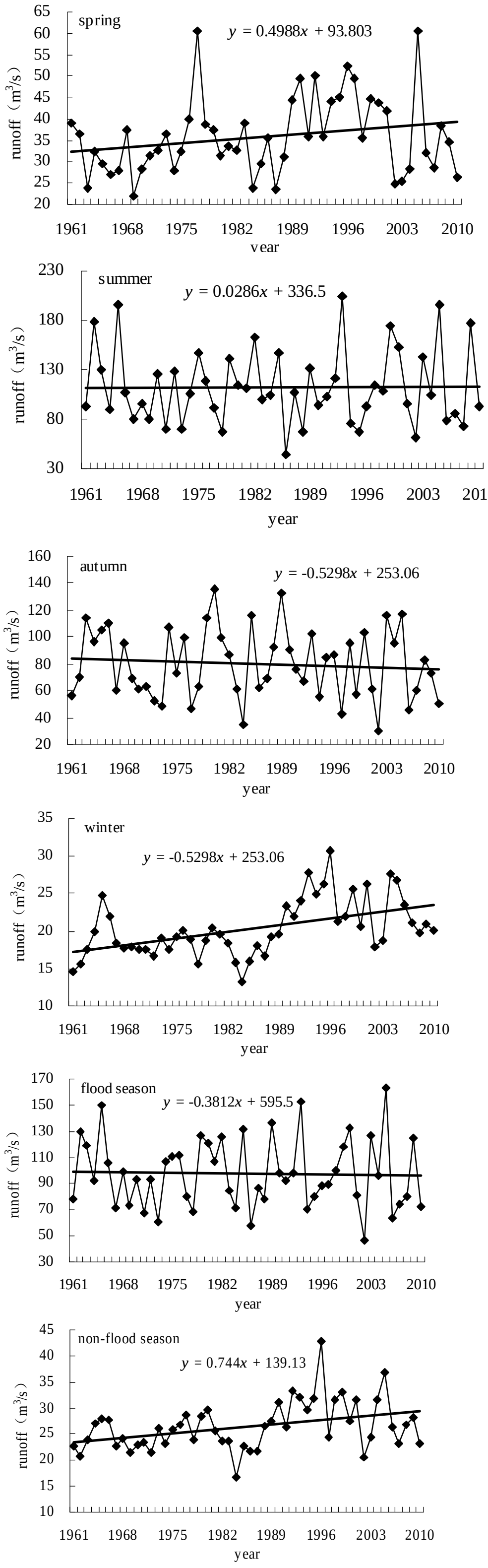

Fig. 3: Variation curve of annual mean flow in four seasons, flood season and non-flood season in Niqu River.

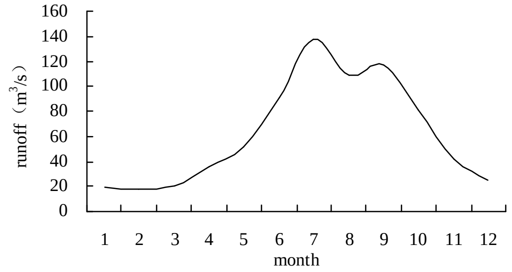

Fig. 4: Monthly variation curve of flow at Zhuba station in Niqu River.

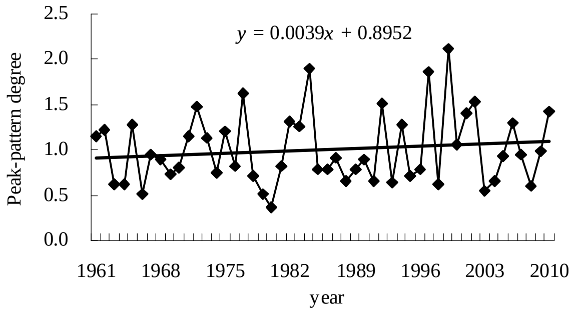

Fig. 5: Annual variation curve of peak-pattern degree in Niqu River.

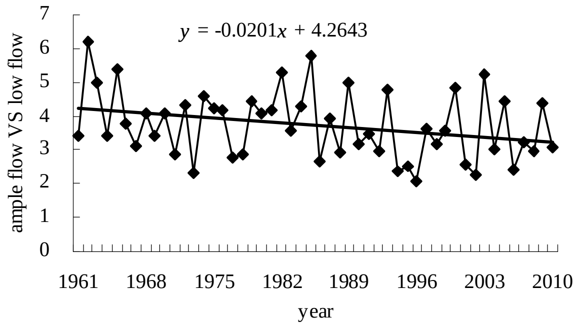

Fig. 6: Annual ample flow Vs low flow in Niqu River.

ice melt water and rainfall as the water supply; and the C_v is about 0.25-0.45 for rivers with seasonal snow melt water or rainfall as the water supply. The coefficient of variation of Niqu river was calculated with Eqs. (1) and (2) as 0.23. The river discharge of the flood season from May to October takes 80% of the total annual river discharge which means that the mixture mountain snow melt water, seasonal snow melt water and rainfall is the main water source to Niqu river.

Inter-annual variation of runoff: The variation curve and residual accumulative curve of the annual average runoff from 1961 to 2010 at Zhuba Station in Niqu is presented in Fig. 1 and Fig. 2 correspondingly.

As shown in Fig. 1 and Fig. 2, the runoff of Niqu changed from high level to low level frequently with 5 circulations. The runoff increased slightly during these 50 years. The absolute value of the runoff anomaly percent within 20% is assumed to be normal year. The value larger and smaller than 20% is assumed to be high and low level years. According to these assumptions, there are 26 normal years out of totally 50 years which take about 50%. The high level and low level years are 13 and 11 years correspondingly which takes 25% each. There are 3 high level years before 80's. There are 5 low level years between 60 and 70's which took 50% of the total low level years.

The river discharge increased gradually before 60's of 20 century and reached the maximum value in 1966. It decreased afterwards and reached the minimum value at the end of 70's. The value increased slowly after 80's and reached the maximum in 2005. According to the calculated climate tendency rate, the river discharge increased at speed of 0.33 $m^3/(s.10\ a)$. The cumulative increased runoff is $0.52 \times 10^8 m^3$ within 50 years which is 2.6% larger than the average value.

The river discharge of the flood and non-flood seasons increased or decreased at speed of +4.99, +0.29, -5.30, +4.07, -3.81, +7.44 $m^3/(s.10\ a)$ in spring, summer, autumn and winter correspondingly (Fig. 3). The increment in spring is the most significant. The decrement in summer is the most significant as well.

The variation of the average annual discharge within the year from 1961 to 2010 at Zhuba station in Niqu river is shown in Fig. 4. The distribution of the discharge within the year in Niqu is doublet shape. The river discharges from January to February were the lowest and increased slowly from March to April. The value increased greatly from May to June and reached maximum in July. It decreased slightly in August and reached the second peak value in September. It decreased obviously after October and reached the minimum in December which is still larger than that from January to February. This means that the water discharge during the flood season from May to October takes 80% of the total annual discharge which is 5 times larger than that during the non-flood season. These features demonstrated that the water supply of the river in Niqu river is mainly from rainfall. As shown in Fig. 4, the first peak value is closely related to the rainfall of this area in July. The peak value in September may be caused by the mountain ice melt water which may result in glacier lake breaking.

The Peak-pattern degree of the runoff decreased slightly each year despite the normal variation as shown in Fig. 5. This means that the ratio of the seasonal melt water to the sum of mountain ice melt water and rainfall is decreasing gradually. The ample flow Vs low flow (Fig. 6.) decreased gradually as well which means that the ratio of the flood season to that of the non-flood season is decreasing. The ratio of the runoff within the flood season to the total value is decreasing as well. This means that the water supply from rainfall within this area is increasing. Accordingly, the water supply from the snow melt water is decreasing. This may be related to the global warming and shrinking of the glacier.

CONCLUSIONS

The annual river discharge increased 0.33 $m^3/(s.10a)$ in Niqu river which is the water supply area in the first stage project of WRP. The cumulative increased river discharge is $0.52{\times}10^8 m^3$ within 50 years which is 2.6% larger than the average value. The river discharge increased or decreased at the rate of +4.99, +0.29, -5.30, +4.07, -3.81, +7.44$m^3/(s.10a)$ in spring, summer, autumn, winter, flood season and non-flood season correspondingly. The increase in spring is the most significant. The decrease of runoff in autumn is the most significant as well. The variation of the runoff in flood and non-flood season is positive. The runoff increased each year in non-flood season and decreased each year in flood season.

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