Analysis on the Return Period of “7.26” Rainstorm and Flood in 2017 in the Wudinghe Basin

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Abstract: The return period of “7.26” rainstorm flood in 2017 in Wudinghe basin is analyzed by the method of P-III distribution. The Lijiahe and Dingjiagou stations with long rainfall observation data in the rainstorm area are selected, and the frequency curve of the annual maximum 24 hours rainfall are established, and the recurrence period of rainfall stations in rainstorm area are estimated according to the parameters determined by the curve fitting method. The frequency curve of the annual maximum peak discharge of Baijiachuan hydrological stations and so on are established, and the return period are analyzed in combination with the historical survey floods. The results show that the return period of Zhaojiabian of heavy rainfall center is about 100 years, and which of the other stations over than 200mm in Wudinghe basin is about 30~90 years; while the return period of the peak discharge of Baijiachuan and SuiDe hydrological station is about 30 and 20 years respectively.

1 Introduction

1.1 Research Area

Wudinghe is the primary tributary of the Yellow River,

locates in the southern Maowusu desert and the northern Loess Plateau, and the basin area is 30261km². The Baijiachuan hydrological station is the controlling station entering the Yellow River, the catchment area above which is 29662km²(shown in Figure 1).

Fig.1 The location of the Wudinghe basin

According to the landform and the soil erosion characteristics, the basin can be divided into three types:

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River Source Liang-Jian Region, Windy Desert Area and Loess Hilly and Gully Region. Among them, the Windy Desert Area is located in the north and northwest of the basin, occupies 54.3% of the total area (Zhang, 2003).

Dalihe is the largest primary tributary of the Wudinghe, and the basin area is 3906 km². The controlling station entering the Wudinghe is Suide hydrological station, the catchment area above which is 3893 km². The whole basin of Dalihe locates in the Loess Hilly and Gully region.

1.2 Rainstorm and Flood

The rainstorm occurred in the most of the north Shanxi-Shaanxi Region of the middle Yellow River from July 25 to July 26 in 1977, and the heavy rain occurred in the tributary of Wudinghe. The rainstorm center is mainly concentrated in the Dalihe basin. The heavy rainstorm center is Zhaojiabian of Suide County, and the rainfall is 252.3mm. There are 34 rainfall stations with cumulative rainfall over than 100mm and 10 rainfall stations over than 200mm (Tab.1 and Fig.2).

Tab.1 Rainfall over than 200mm at the stations from July 25 8:00 to July 26 8:00

No.	River	Station	Rainfall (mm)	No.	River	Station	Rainfall (mm)
1	Wudinghe	Zhaojiabian	252.3	6	Chabagou	Xinyaotai	214.2
2	Wudinghe	Sishilipu	247.3	7	Wudinghe	Mizhi	214.2
3	Dalihe	Zizhou	218.7	8	Chabagou	Caoping	212.2
4	Xiaolihe	Lijiawa	218.4	9	Chabagou	Zhujiayangwan	201.2
5	Xiaolihe	Lijiahe	214.8	10	Chabagou	Jijiajian	200.6

Fig.2 The isogram of rainfall in “7.26” rainstorm in the Wudinghe

The mean rainfall of different region from 8:00 on July 25 to 8:00 on July 26 in the Wudinghe basin is shown in Table 2. It is 63.6mm above Baijiachuan hydrological station in Wudinghe basin. It reaches

129.8mm above Suide hydrological station in Dalihe basin, which is next to 1977 and ranks the second in history. The enveloped area of the rainfall above 100mm in the Wudinghe basin is 4573km².

Tab.2 The mean rainfall of different region from July 25 8:00 to July 26 8:00 in Wudinghe basin

Region	The enveloped area of different rainfall (km ²)								Area /km ²	Mean rainfall (mm)
	20	25	50	75	100	150	200	250		
	-	-	-	-	-	-	-	-		
Above Caoping	0	0	0	0	5.6	158.1	23.3	0	187	177.8
Above Lijiahe	0	35.0	94.9	289.4	141.6	113.1	133.1	0	807	121.4
Above Qingyangcha	0	83.2	319.9	226.5	624.0	6.3	0	0	1260	97.2
Above Suide	0	118.2	414.8	606.5	1549	715.2	489.2	0	3893	129.8
Above Dinggou	3971	11497	4759	1847	562.7	409.1	334.9	41.2	23422	51.3
Above Baijiachuan	3987	11988	6256	2858	2560	1148	824.1	41.2	29662	63.6

The flood occurred in the trunk stream and tributary of Wudinghe in succession due to the rainfall. The peak discharge of Suide hydrological station in Dalihe is 3290m³/s, which occurred at 5:05 on July 26, the largest flood since the establishment of the station in 1959. The peak discharge of Dingjiagou hydrological station in Wudinghe is 1660m³/s, the largest flood since 1994. The peak discharge of Baijiachuan hydrological station is

4480m³/s, occurred at 9:42 on July 26, the largest flood since 1975, and ranks the second in the history.

The composition diagram of “7.26” flood in Baijiachuan hydrological station is given in Figure 3. The total water volume of “7.26” flood in Baijiachuan hydrological station is 166.62 million cubic meter, about 30% comes from the main stream and about 70% comes from the tributary of the Dalihe.

Fig.3 The composition diagram of “7.26” flood at Baijiachuan station

peak discharge in Baijiachuan hydrological station and so on were analyzed.

1.3 The proposal of the problem

The government and public have paid great attention to the rainstorm and flood, especially the recurrence period of heavy rain and flood.

The recurrence period refers to an average of hydrological event can occur in a number of years during long periods (Zhuang, 1995). It is a design standard widely used in the planning programming, operation and management of water conservancy and hydropower projects and civil engineering. It is mainly determined by the importance of engineering and the result of the damage to the project of hydrological events (Jin, 1964; Huang, 2011).

The rainfall of Lijiahe and Dingjiagou station with long rainfall observation data in the “7.26” rainstorm area were selected, the field survey was combined, the return period of the maximum 24 hours rainfall in rainstorm center stations, and the return period of the

2 Method

The ultimate aim of hydrological frequency calculation is to determine the design values corresponding to the given design frequency. It stipulates that the line type of frequency curve generally adopts P-III distribution in *Regulation for Calculating Design Flood of Water Resources and Hydropower Projects* (Wang, 2006).

The P-III curve is an unsymmetrical single peak and positive partial curve with infinite end at one end. The probability density function is (Zhan, 2010; Guo, 1992):

$$f(x) = \frac{\beta^\alpha}{\Gamma(\alpha)} (x - a_0)^{\alpha-1} e^{-\beta(x-a_0)} dx \quad (1)$$

Where: $\Gamma(\alpha)$, Gamma Function; α, β and a_0 , the shape, scale and position parameter of the P-III type distribution, $\alpha > 0, \beta > 0$.

After the integration, standardized transformation and simplification for formula (1), the equation for calculating the design value of the given design frequency can be deduced:

$$x_p = \bar{x}(1 + C_v \Phi_p) = \bar{x} \left(1 + \frac{C_s^2 \times C_s / C_v \times \text{Gammainv}(1-p, \alpha, \beta)}{2} - \frac{2}{C_s / C_v} \right) \quad (2)$$

Where:

$$\Phi_p = C_s / 2 \times T_p - 2 / C_s \quad (3)$$

$$T_p = \text{Gammainv}(1 - P, \alpha, \beta) \quad (4)$$

$$\alpha = 4 / C_s^2, \quad \beta = 1 \quad (5)$$

Using macro command programming in Excel to find out the mean value $\bar{x}$, variation coefficient C_v , coefficient of skew C_s and Gammainv ($1-p$, alpha and beta) of series x_i ($i=1,2,\dots, n$), and draw P-III frequency curves of series (p, X_p). The parameters of mean, C_v and C_s/C_v are determined by the estimation of the fitting line method. According to the formula (2), the frequency corresponding to the rainfall or peak discharge is calculated.

3 Return period of rainfall

3.1 Basic Data

(1) Rainfall of the annual maximum 24 hour. The

establishment year of the two hydrology stations for Lijiahe and Dingjiagou is 1959, thus the rainfall of the annual maximum 24 hour from 1960 to 2017 are selected. The rainfall of the annual maximum 24 hour is 214.8mm of Lijiahe station on July 26 in 2017, ranks the first in the series. While in Dingjiagou station it is 139.2mm, ranks the third in the series.

(2) Transplant of Zhaojiabian rainfall

According to the transplant principle of rainstorm, the rainstorm in adjacent area should be transplanted into the series of frequency analysis, under the similar weather background, water vapor source and underlying surface conditions.

Zhaojiabian locates about 33km and 12km from Lijiahe and dingjiagou station. The rainfall of 252.3mm in Zhao Jiabian is the heavy rain measured by Yulin Meteorological Bureau in 2017. It should be transplanted into the rainfall series of Lijiahe and Dingjiagou station to establish the frequency curve.

3.2 Results and Discussion

The frequency curves of the maximum 24 hours rainfall of the series from 1960 to 2017 and the transplantation value in Lijiahe and Dingjiagou station are given in Figure 4 and Figure 5. The value of C_s/C_v is 3.5, according to the *Atlas of the Statistical Parameters of China's Rainstorm* (Wang, 2006).

Fig.4 The rainfall frequency curve of the maximum 24h in 1960-2017 in Lijiahe station

Fig.5 The rainfall frequency curve of the maximum 24h in 1960-2017 in Dingjiagou station

The recurrence period of the rainfall stations above 200mm of the "7.26" rainstorm in Wudinghe basin are estimated, according to the parameters of the frequency curve of Lijiahe and Dingjiagou station. Among them, the rainfall stations in the Dalihe basin are used the frequency curve of Lijiahe station, Zhaojiabian and

Sishilipu stations near the main stream of the Wudinghe are used the frequency curve of the Dingjiagou station. Therefore, the return period of the maximum 24 hours rainfall of the stations greater than 200mm in Wudinghe basin is about 30~100 years (Table 3).

Tab.3 The recurrence period of "7.26" rainstorm greater than 200mm in Wudinghe basin

No.	Station	Rainfall /mm	Return period	No.	Station	Rainfall /mm	Return period
1	Zhaojiabian	252.3	96.9	6	Xinyaotai	214.2	36.4
2	Sishilipu	247.3	88.5	7	Mizhi	214.2	36.4
3	Zizhou	218.7	38.8	8	Caoping	212.2	35.3
4	Lijiawa	218.4	38.6	9	Zhujiayangwan	201.2	30.1
5	Lijiahe	214.8	36.7	10	Jijiajian	200.6	29.9

Similarly, through calculating and analysis, we can get that the range of return period of the maximum 24 hours rainfall of the "7.26" rainstorm in the rainfall

stations of the Dalihe basin is about 3~40 years (Table 4).

Tab.4 The recurrence period of all the "7.26" rainstorm station in Dalihe basin

Region	Rainfall station	Rainfall /mm	Return period/a	Region	Rainfall station	Rainfall /mm	Return period/a
Above Caoping station in Chabagou basin	Xinyaotai	214.2	36.4	Above Lijiahe in Xiaolihe basin	Lijiawa	218.4	38.6
	Caoping	212.2	35.3		Lijiahe	214.8	36.7
	Zhujiayangwan	201.2	30.1		Lixiaohe	179.8	22.0
	Jijiajian	200.6	29.9		Liujiawa	162.6	17.0
	Xiaoji	199.6	29.4		Gaozhen	113	7.8
	Taoyuanshan	188	24.8		Aihaomao	87.2	5.1
	Wangjiayan	183.2	23.1		Dalumaotai	68.8	3.6
	Wanjiayan	183	23.0	Above Qingyangcha in Dalihe	Shiyaogou	52.2	2.6
	Niuxuegou	181.2	22.5		Linwangetuo	39.2	1.9
	Lijiayan	168.8	18.7		Yangkelangwan	79	4.4
	Dujiashan	158.4	15.9		Qingyangcha	161.2	16.6
	Mahuyan	150	14.0	Ungauged region	Shiwan	141.3	12.3
	Heminyan	126.8	9.8		Zhuanmiao	113.4	7.9
					Zizhou	218.7	38.8

4 Return period of flood

4.1 Historical Survey Flood

The observed flood data of Baijiachuan hydrological station is from 1956 to 2017, and the series length is 62 years. The number of historical survey flood is 1, which occurred in August 6, 1919, and the peak discharge is 6950m³/s. The length of the data series is 99 years when considering the historical investigation flood.

The observed flood data of Dingjiagou hydrological station is from 1959 to 2017, and the series length is 59 years. The number of historical survey flood is 1, which occurred in August 9, 1932, and the peak discharge is 6180m³/s. The length of the data series is 86 years when considering the historical investigation flood.

The observed flood data of Suide hydrological station is from 1960 to 2017, and the series length is 58 years. There are four times of the historical survey flood, occurred in the year of 1864, 1919, 1932 and 1933(Luo, 2006). The peak flow is 7140, 9210, 4400 and 3700m³/s respectively. The length of the data series is 154 years when considering the historical investigation flood.

4.2 Results and Discussion

The frequency curve of the annual maximum peak discharge of Baijiachuan, Dingjiagou and Suide hydrological station in Wudinghe basin is shown in Figure 6~Figure 8. The parameters determined by the curve fitting method and the designed flood value are shown in Table 5.

Tab.5 The designed flood result of three hydrological stations in Wudinghe basin unit: mean: m³/s

Station	Catchment (km ²)	Variable/year			Parameter			Designed flood value (m ³ /s)				
		<i>N</i>	<i>n</i>	<i>a</i>	mean	<i>Cv</i>	<i>Cs/Cv</i>	<i>P</i> =1%	<i>P</i> =2%	<i>P</i> =3.3%	<i>P</i> =5%	<i>P</i> =10%
Baijiachuan	29662	99	62	1	1300	0.98	3	6430	5300	4500	3860	2810
Dingjiagou	23422	86	59	1	820	1.30	3	5450	4300	3510	2880	1910
Suide	3893	154	58	4	906	1.70	3	7000	5390	4290	3420	2130

Fig.6 The frequency curve of the annual maximum peak discharge in Baijiachuan station

Fig.7 The frequency curve of the annual maximum peak discharge in Dingjiagou station

Fig.8 The frequency curve of the annual maximum peak discharge in Suide station

According to the formula (2) and the designed flood value, the frequency and the return period corresponding to the peak discharge are calculated. The return period of peak discharge in Baijiachuan, Dingjiagou and Suide is about 30, 10 and 20 years respectively, shown in Table 6.

Tab.6 The recurrence period of three hydrological stations in Wudinghe basin

Station	Peak discharge (m ³ /s)	Series	Frequency (%)	Recurrence period (year)
Baijiachuan	4480	1956~2017 + historical survey flood	3.35	29.9
Dingjiagou	1660	1959~2017 + historical survey flood	12.1	8.3
Suide	3290	1960~2017 + historical survey flood	5.35	18.7

5 Conclusions

The rainfall return period of Zhaojiabian of heavy rainfall center is about 100 years, and which of the other stations over than 200mm in Wudinghe basin is about 30~90 years.

The return period of the peak discharge of 4480m³/s in Baijiachuan hydrological station is about 30 years. The return period of the peak discharge of 3290m³/s in Suide hydrological station is about 20 years. The return period of the peak discharge of 1660m³/s in Dingjiagou hydrological station is about 10 years.

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