E3S Web of Conferences 350, 01020 (2022) https://doi.org/10.1051/e3sconf/202235001020
EREGCE 2022

Analysis of Rainstorm Flood Induced Flash Flood in Wende River Basin

Meihong Ma[1], *Yue* Zhou[1], *Shiyao* Bi[1], *Bingshun* He[2,*], *Qing* Li[2] and *Ting* Li[3]

[1]Tianjin Normal University, Geographical and Environmental Science Department, 300387, Tianjin, China
[2]China Institute of Water Resources and Hydropower Research, Research Center on Flood and Drought Disaster Reduction of the MWR, 100038, Beijing, China
[3]North China University of Science and Technology, College of Foreign Languages, 063210, Tangshan, Hebei, China

Abstract. Due to the joint influence of climate and topography, flash flood disasters in the Wende River Basin of Jilin Province occurred repeatedly, causing serious casualties and huge economic losses; in July 2017, three floods with large rainfall intensity and profound influence occurred in a row in the main stream of Wende River. Based on official measured data of the Wende River basin, three typical rainfall processes ("July 13", "July 20" and ","August 3 ") are selected to discuss the rainfall characteristics. The triggered characteristics, induced factors and the disaster mechanism of the basin are preliminarily explored from the aspects of rainfall weather system, temporal and spatial distribution of rainstorm and flood, geographical factors - to analyze the best countermeasures for flash flood prevention. The above will provide reference for the non-engineering measure project of flash flood prevention currently under construction.

1 Introduction

1.1 Background and significance

Flash flood disaster is a kind of flood disaster, which mainly refers to the steep flood caused by heavy rainfall in mountainous streams and ditches, as well as the induced river floods, landslides and mudflows [1]. Flood cause analysis is extremely important for the disaster study in small and medium-sized river basins. Song Qiumei, based on the rainfall and flood data of 1980-2012 in Beijing, found that the spatial and temporal distribution characteristics and intensity of rainstorm affect the flood pattern in this area [2]. Zhang Jintang and others analyzed the causes of rainstorm flood in Anhui section of the Yangtze River in 2016, and found that the cause of excessive flood on the south bank of Chaohu Lake was the uneven spatial distribution of rainfall [3].

The Wende River basin is located in the southeast of Yongji County, Jilin Province, and it is a primary tributary of the left bank of the Second Songhua River. The specific location of the Winter River basin in the study area is shown in Figure 1. The basin belongs to the northern temperate continental dry monsoon climate. It is hot and rainy in summer and cold and dry in winter. Affected by the weather system such as the North China cyclone, subtropical high rear shear and typhoon, the precipitation distribution in the river basin is not uniform, concentrated in the flood season. From July to August 2017, heavy rain hit the Wende River Basin, causing huge loss of life and wealth to Yongji County, 279800 people were affected, 31 people died or disappeared due to mountain torrents, and the total direct economic loss was 14 billion, among which "July 19-July 20" disasters and "August 2- August 3" disasters caused total direct economic losses of 3.645 billion yuan and 181 billion yuan respectively [4-7]. This paper selects the typical Wende River basin in Yongji County, Jilin Province as the research area. By analyzing the rainfall and flood characteristics of “July 13-July 14”, “July 19-July 20”, “August 2-August 3”, it initially discusses the formation mechanism of flash flood disaster, in order to analyze the optimal flash flood defense countermeasures under the new defense situation, and accumulate experience in flood disaster analysis and flood control prevention and disaster reduction.

* Corresponding author: hebss@163.com

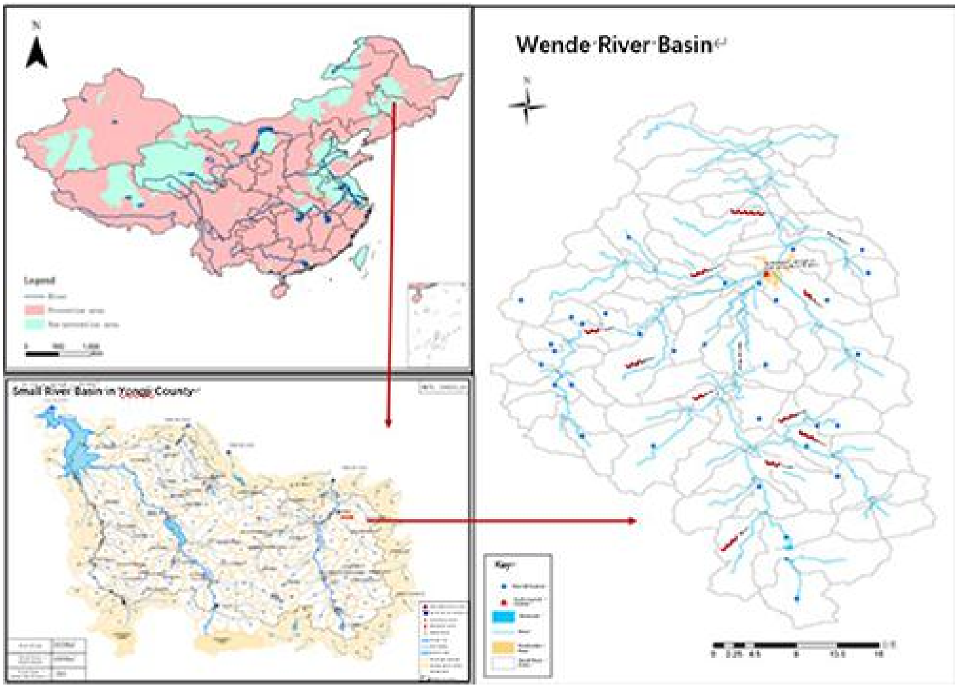

Fig. 1. Schematic Geographic Location of Wende River Basin, Yongji County, Jilin Province

2 Data introduction

The data are mainly obtained from the China Institute of Water Resources and Hydropower Sciences, mainly including DEM data, rainfall data, flood data in Wender River Basin, Yongji County, Jilin Province; both rainfall data and flood data are measured data. The rainfall data mainly includes the duration, rainfall, rainfall intensity and flood peak flow of the three rainfall events in Wende River Basin in 2017, which mainly come from the measured rainfall data of the hydrological station in front of the estuary and the measured rainfall data of 43 rainfall stations in the basin. At the same time, the data of 13 rainfall monitoring stations built by the hydrological department are also considered.

According to the division of precipitation data, the precipitation accumulation period is from 08:00 of the previous day to 08:00 of the current day. Based on the rainfall level adopting the meteorological definition of China, the daily rainfall is divided into three types: weak precipitation (0-25mm, light rain and moderate rain), general intensity precipitation (25-50mm, heavy rain), heavy precipitation (>50mm, rainstorm, heavy rainstorm and severe rainstorm); rainfall times is mainly defined by Taiwan RIT method, which means a rainfall starts when the rainfall is more than 4mm, and ends when the rainfall is less than 4mm for 6h.

3 Analysis of rainfall characteristic

In late July, the subtropical high stabilized and moved less. Jointly affected by the North China cyclone northward and the subtropical high [5-7], the Winter River basin suffered three flash floods from July 13 – July 14, July 19 – July 20, and August 3 – August 4, 2017. In “July 13”, the maximum rainfall strength is 93mm, and the average rainfall is the highest rainfall in the three floods, up to 181.5mm. In “July 20”, from 17:00 on 19th to 15:00 on 20th, there were two obvious rainfall processes: in the first round of rainfall, the rotation direction of the rainstorm centering along the watershed is clockwise; the new round of rainfall from 02:00 on the 20th has greater intensity and wider range. In "August 3", from 20:00 on August 2 to 21:00 on August 3, the third rainstorm with relatively small rainfall occurred in Yongji County, with average rainfall of 127.4mm. Specific precipitation of the three floods is shown in Table 1.

Table 1. Details of three floods

Rainfall time	Total rainfall duration (h)	Average Rainfall (mm)	Maximum Rainfall Strength (mm)
July 13	17	181.5	93
July 20	23	153	103
August 3	25	127.4	53.5

In terms of cumulative rainfall, the maximum rainfall is mainly concentrated in the northwest corner of the river basin, and the rainfall is relatively small in the southeast corner. The cumulative rainfall maximum increased from 100mm to 306.5mm. the largest accumulated rainfall in each period of rainfall is located in the upstream tributaries of Chundeng River (except Jinye Reservoir at 1 and 2 o'clock on the 20th), and those of the other periods are located near the Hongshiling Reservoir on Chundeng River. The southwest of the mouth basin is seriously affected by the rainstorm, while the main stream of Wende River is relatively less affected. The maximum 24-h accumulated rainfall of the three floods is shown in Figure 2.

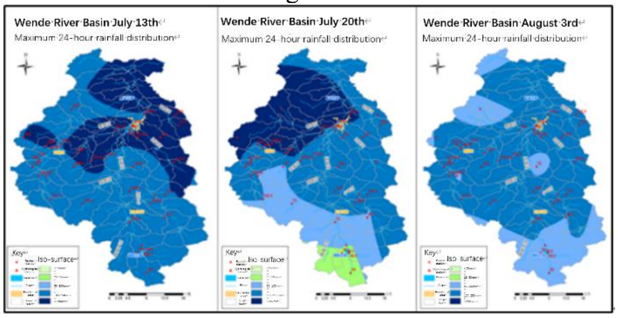

Fig. 2. Cumulative rainfall in three floods (maximum 24h)

4. Analysis of rainstorm and flood characteristics

4.1 Typical rainstorm and flood characteristics

4.1.1 "July 13" rainstorm and flood

Wende River in Yongji County is located in mountainous areas. Rising and falling rivers generally form fast yield and confluence, which often has the characteristics of fast formation, high intensity and short duration. On 13 July 2017, the average rainfall on the Winter River watershed reached 181.5mm. The water level of the front station began to rise at 17:00 on July 13th, and the water level began to overflow the top of the embankment at 21:25 on July 13th, reaching 260mm. At 0:00 on the 14th, there is a flood peak with an estimated discharge of 3350mm^3/s at the hydrological station in front of the mouth, with water level up to 228.05mm. The flood caused 90% of the town covered with water of 2-3 meters. The measured results of rainfall and flow on July 13 in Wende River Basin are shown in Figure 3. The entire rainfall center is near the outlet and the flood moves along the river from upstream to downstream.

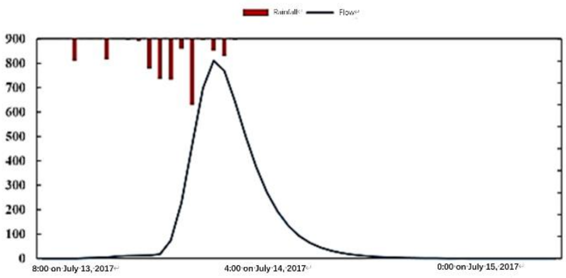

Fig. 3. Results of rainfall and flow on July 13 in Wende River

4.1.2 "July .20" rainstorm and flood

Basin

From 17:00 on July 19 to 15:00 on July 20, Yongji County was hit by the second heavy rain, with the average rainfall, maximum 1h rain intensity and maximum rainfall 153.0mm, 103mm/h, 339.5mm respectively. The rainstorm center is mainly distributed in the higher northwest of the basin and moves along the upstream of the river. The rainfall had two obvious processes about which the center of the first round turning clockwise around the Winter River basin and the second was more intensity and wider range; the station began to fall at 5:15 on 20th after the 226.8mm, peak of 2480mm^3 /s. The measured results of rainfall and flow of Wende River Basin July 20 are shown in Figure 4. The flood caused about 70 percent of the Yongji County city to drown, at a depth of 0.6m-2m.

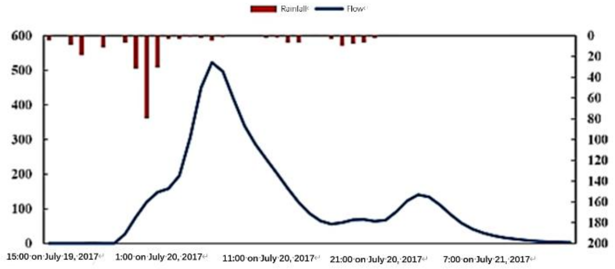

Fig. 4. Measured data of the rainfall and flow on July 20 in

4.1.3 "August 3" rainstorm and flood

Wende River Basin

From 20:00 on August 2 to 21:00 on August 3, the third rainstorm occurred in Yongji County, with the maximum average rainfall up to 127.4mm, 1h rain intensity up to 53.5mm, and the maximum rainfall reached to 180mm, but precipitation is smaller compared with the previous two. The rainstorm center is mainly distributed in the middle and lower reaches of the basin with relatively low terrain. The movement direction of the precipitation front is the same as that of the "July 13" and "July 20" floods, moving from the upstream to the downstream. At the front water level station in the Winter River basin, the water level rose from 01:00 on August 3. About seven hours later the water level reached the highest value of 224.98mm, 0.98mm higher than the warning water level (224mm), and the corresponding flow was 942mm^3/s. After that, the water level fell rapidly. At 14:00 on the 3rd, the water level fell to 221.36mm, 1.64mm lower than the warning water level.

4.2 Flood characteristics

At present, the warning water level of Wende river basin is 223mm and the dam crest elevation is 226mm; Characteristics of three rainstorm floods in 2017 are as follows:

In the "July 13" precipitation, the highest flood water level exceeds the dam crest elevation, and the rising flow is 8mm3/ s, peak flow is 3350mm^3/s. The highest peak level reaches 228.05mm, belonging to single peak flood. Compared with the July 28 flood in 2010 (peak flow of 3120mm^3/s), this flood peak flow was higher, becoming the maximum of the watershed. In the "July 20" precipitation, the highest flood level exceeds the dam crest elevation, with the 226.8mm. The peak flow is 2480mm^3/s and the rising flow is as high as 50mm^3/s. It belongs to multi peak flood, in which the peak modulus is 2.99. In the "August 3" precipitation, the highest flood level exceeds the dam crest elevation and warning water level. The peak flow is 943 mm^3/s, and the rising flow i stands in the middle of the three, which is 36mm^3/s, belonging to single peak flood.

4.3 Cause of flood investigation

The Wende River basin belongs to the continental dry-cold monsoon climate area in the northern temperate zone. The spatial and temporal distribution of precipitation is uneven, mostly concentrated in summer. The flood season rainfall can account for 70-80% of the annual rainfall, and the flood season mostly has southeast wind, and the warm and humid air flows northward, which results in heavy rain in the basin.

Main reasons: (1) affected by low altitude shear and warm and humidity flow, the precipitation intensity and range are large, the precipitation is concentrated, and the peak flow is heavy; (2) main rain experienced short rainfall time, the precipitation yield is large, and almost all of them produce runoff; (3) the superposition of flood peaks leads to large contribution of flood volume and rise of water level.

5 Preliminary disaster causing mechanism in drainage basin

5.1 Weather system triggering rainfall

The Wende River basin belongs to the northern temperate continental dry-cold monsoon climate zone. Under the joint influence of shear and warm and humid air flow, the subtropical high is stable and less dynamic, caused by the northward movement of the North China cyclone and the subtropical high. Due to the influence of high-altitude low vortex and shear at the back of subtropical high on the 20th-21st, the precipitation distribution on the 24th-25th was uneven, which means the low vortex system and shear precipitation are easy to cause severe rainstorm. At the same time, the rainfall front moves along the river direction, with the center of gravity moving from north to south.

5.2 Temporal and spatial distribution of rainstorm flood induced flash flood

5.2.1 Rainfall is the main cause

The temporal and spatial distribution of rainfall in Wende river basin is uneven and the rainfall is concentrated. Meanwhile, the rainfall front surface moves along the flow direction of the river. For example, the maximum rainfall is mainly concentrated in the northwest corner of the basin, while the relatively small rainfall is in the southeast corner. In addition, the areas with large precipitation, large precipitation intensity and the rainstorm center near the basin exit all induce the generation of flood.

5.2.2 Large flow

From 22:00 on the 13th to 0:00 on the 14th in the “July 13” flood, because of the large flow of the Bahu River, the water level of Wende River was raised, increasing the inundation loss suffered by the town in front of the river mouth.

5.2.3 The flood volume has a large contribution

Under the influence of rainstorm center distribution, the contribution ratio of each period and river reach to flood at different scales will be different. In "July 13" flood, rainfall impact is the same, and the flood contribution is mainly equivalent to the proportion of area. In the "July 19" flood, because the flood affected the spring reach, the flood volume contribution is twice that of the corresponding index.

5.3 Impact of geographical environment

The hydrological Station in front of the river mouth is located in the lower Wende River. Sijian River and Bahu River are tributaries of the Wende River. In the two floods of "July 20" and "August 3", the flood peaks of Wende River and Sijian River are superimposed in the section of Kouqian Town, while the flood of BAHU river is discharged, resulting in serious disasters. In the “July 13” flood, Wende River and Sijian River jointly superimposed flood peaks in Kouqian Town, and the disaster in kouqian town was further aggravated due to the large peak flow of BAHU river.

In addition, the terrain of Wende River basin is hilly, tilts from southeast to northwest, and the slope changes obviously; the main land use are woodland (97.5%), grassland (98%) and farmland (97.9%), and most of the surface is rough and exposed, the basin soil is mainly clay and pink loam, fine texture, resulting in slow infiltration rate. All of the above factors induced the occurrence of flash floods.

6 Analysis of countermeasures for optimizing flash flood prevention

According to the current situation that Wende River Basin often encounters heavy rainfall and concentrated rainfall, which is easy to induce flood disasters, this paper mainly puts forward the following suggestions:

(1) Strengthening the study on the rainfall and flow relationship of flash flood disasters. At present the early warning indicators are mainly rainfall or water level. We should strengthen the analysis of rainfall and runoff in the basin and the impact of flood on tributaries and tributaries, and study the transformation mechanism and causes of flood disasters

(2) Strengthening the construction of an intelligent

and automatic emergency defense system for falsh flood defense. Applying modern information technology such as artificial intelligence technology in pre-disaster, during-disaster and post-disaster defense emergency management; With the help of virtual scene to prevent flood, and clarify the relationship between multi factors that induce flash flood disaster, we should emphasize the importance of analyzing the main influencing factors, and building a passive to active flash flood disaster prevention system.

(3) Making overall planning for river treatment and building a high standard flood control system. In view of the large number and wide coverage of small and medium-sized rivers in China, we clarifying the key points of governance and formulating a comprehensive project plan for the governance of small and medium-sized rivers. At the same time, introducing foreign advanced control methods, such as adopting ecological methods to conserve water and soil and prevent water and soil loss.

(4) Improving the non-engineering flood control measures. Establishing and improving the flood control and rescue command system. The automatic measuring and reporting system should be used to timely and accurately grasp the rain and water conditions, preparing a reasonable long-term prediction scheme, and dispatching the water conditions step by step as planned. At the same time, research the flash flood risk system, and explore ways for appropriate flood defense and relief.

(5) Strengthening community disaster management and the dissemination of early warning information. Improving people's awareness of flood risk, and gradually improve the mass testing and prevention organization with Chinese characteristics. Using social software APP, combined with 5G technology to share disaster situations in real time.

7 Conclusion

This paper analyzes the process of three rainstorm floods in Wende River Basin in terms of rainfall characteristics, rainstorm causes and disaster factors to explore the causal mechanism of flood.

First, rainfall is the main factor; the three precipitations have large rainfall, large intensity, short duration and rainfall front moving along the river direction. Secondly, the flood peaks are superimposed and the contribution of the flood volume is large. During the "July 13" flood，the rainfall concentration periods of the three river sections are basically the same. At the same time, the proportion of flood volume contribution is large; Especially in the "July 19" precipitation, the proportion of flood contribution is twice that of the area. In addition, the geographical environment has also aggravated the disaster. The Bahu River is in the upper reaches and has a relatively large flow, leading to the rise of the Wende River water level, and the obvious slope, sparse vegetation and low soil infiltration rate all provide favorable conditions for the flood.

Based on the above situation, this paper proposes to further optimize flash flood prevention measures, such as comprehensive planning and control engineering, improving non-engineering flood control measures, strengthening group measurement and group prevention and advanced scientific measures, strengthening flood disaster prevention and providing reference for the ongoing flash flood disaster prevention work.

Acknowledgements

This work was supported by Deep learning-based research on the inducing factors and early warning of flash floods (42101086), Research on Key Technologies of Flash Flood Prevention Based on Multi-machine Learning Model (2019KJ086), Huaneng Lancang River Hydropower Co., Ltd.: Research on the Integrated Forecast System of Meteorology and Hydrology in the Lancang River Basin (Phase I) (JK2021/D02), Inspur Software Group Co., Ltd. entrusted project: Hainan Province Smart Water Network Information Platform (Phase I) Project(202109161126CGYRK03), National Key R&D Program of China(2021YFC3000202), China Three Gorges Corporation Scientific Research Project(0704183), Hainan Provincial Academician Innovation Platform Research Project (YSPTZX202142), State Key Laboratory of Hydrology, Water Resources and Hydraulic Engineering Science "The Belt and Road" Water and Sustainable Development Science and Technology Fund Key Project(021490311), and Independent exploration project of the State Key Laboratory of Water Cycle Simulation and Regulation in the Basin(SKL2020TS01). The authors wish to thank the anonymous reviewers for their comments and suggestions.

References

1. Y. Hong, P. Adhikari and J.J. Gourley, Flash flood. In Encyclopedia of Natural Hazards, Springer Netherlands, 324-325 (2013)
2. Q.M. Song, B. Zhu, D. Ma, etal, Analysis of rainstorm and flood in typical flash flood basin in Beijing, Hydrology, **037(003)**, 91-94,90 (2017)
3. J.T. Zhang, B.B. Li, Fang Hong, etal. Analysis of 2016 in Anhui section of Yangtze River Basin, Hydrology, **2017(37)**, 96 (2017)
4. Z.L. Xu and K.N. Yan, Study on the technical capability of flood control and flood fighting projects, Water conservancy and hydropower technology,(2017)
5. L.X. Chen, Y. Feng, M. Xue and X. Zhou, Analysis of 7 · 13 rainstorm and flood in Wende River[J].Northeast Water Resources and Hydropower Project, 2018 (2): 2-2.
6. P.L Qu, Y.L. Wang, L.Q. Han, J.X. Dong, M. Zhang and Z.H. Zhou, Analysis of storm flood in “2010 · 07” in Windriver River Basin, Hydrology, **2012 (02)**, 93-96 (2012)

7. F.C. Zhao, Analysis of 2017 flooding in Yongji County [J].Water Conservancy Planning and Design, **2018(9)**, 3-3 (2018)