Analysis on the effect of the backbone works of the Taihu Lake

Tingting Cui¹,²*, Yuqiao Long¹,³ Leizhi Wang¹,², Meina Zhou¹,²

¹Nanjing Hydraulic Research Institute, Nanjing, Jiangsu, 210029, China
²State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Nanjing, Jiangsu, 210098, China
³Nanjing R&D Tech Group Co., Ltd., Nanjing, Jiangsu, 210029, China
*Corresponding author’s e-mail: ttcui@nhri.cn

Abstract. The Taihu Basin is one of the most important areas which contains most of the wealthy metropolis of China. The frequent floods caused by extreme rainfall always bring economic loss and property casualties to the Taihu Basin. The backbone works of the Taihu Lake (BWTL) consisted of 11 mainstay projects are aimed at the basin management and flood control. The whole works begin in 1991, and are almost completed in 2002. We compare the two rain events in 1991 and 2016, and take two typical flood events as the case to analyse the effect of the BWTL in this paper. Due to the urbanization, more flood drains into the water body around the cities and causes the water levels of the control stations are higher than that in 1991. The BWTL changes the outlets of the flood water and improves the flood regulating capability of the Taihu Basin. Under the protect of the BWTL, even the continuous rain in 2016 brings the more serious flood than 1991, the Taihu Basin experience less flood loss.

1. Introduction

The Taihu Basin with an area of 36895km² locates in the south of the Yangtze delta. The north of the Taihu Basin is the Yangtze River, the south is the Qiantang River, the east is the East China Sea, and the west is the Tianmu Mountain [1]. The Taihu Basin is divided into seven primary hydro-zones in order to serve water resources and flood management (Figure 1).

The Taihu Basin contains most of the wealthy metropolis of China and is one of the most important areas of China. Due to the fast urbanization and the climate change, the floods caused by extreme rainfall always frequently bring economic loss and property casualties to this area.

In 1991, the floods in Taihu Basin brought serious impacts on the whole basin[2]. Then China made the important decision the backbone works of the Taihu Lake were designed and constructed.

The backbone works of the Taihu Lake (BWTL) consisted of 11 mainstay projects are aimed at the basin management and flood control[3]. The BWTL could be divided into three kinds of projects. They are storage-discharge project, drainage-diversion project and district boundary project. With these projects, the flood could be drained into the Yangtze River, Huangpu River and the Hangzhou Bay, and the water could be introduced from the Yangtze River and divert into the downstream area of the Taihu Lake. The whole works begin in 1991, and are almost completed in 2002.

In order to find the effect of the BWTL, we take two typical flood events as the case to analyse the effect of the BWTL in this paper. Firstly, we introduce and compare the two rain events, to show
similarity of them. Then, we analyse the effect of the BWTL with water level at control station and the flood drainage data.

Figure 1. The distribution of different regions and rain gauges of Taihu Lake Basin

2. Typical flood event
In 1991 and 1999, two huge floods attacked the Taihu Basin. In 1991, the BWTL have not constructed, so we take the flood in 1991 (Flood A) as the background event.

The flood in 1991 could be taken as the plum rain caused flood. The max 60 days rainfall exceeds 850mm, and the return period of 30 to 90 days rainfall exceeds 170 year. As result, the whole basin experienced the serious flood that caused water level of the Taihu Lake to raised to max 4.79m after the 56 days heavy rain[2].

In 2016, another huge flood occurs in the Taihu Basin. The water level of the Taihu Lake to raised to max 4.87m. This flood (Flood B) is similar to the flood in 1991. They have almost the same rainfall, water level, occurrence date, and even the rain centre.

   (1) Areal rainfall
   Most of the rain in the Taihu Basin occurs in June and July. Figure 2 shows the 10-days rainfall of the Taihu Basin from the middle of June to the early July in 1991 and 2016. The total rainfall is 468.8mm in 1991, and it is 430mm in 2016. Though the rains have same similarity, there are still some differences. For the rain in June and July in 1991, there are 11 dry days during that time scope. So, two rains occur in that time in 1991. In 2016, the rain is continuous and last a long time.
Figure 2. The 10-days rainfall of the Taihu Basin from the middle of June to the early July in 1991 and 2016

(2) Zonal rainfall

Figure 3 shows the 10-days rainfall of different hydro-zones of the Taihu Basin in June and July in 1991 and 2016. We could find that the rain centres locate in the HUX and the WCX in both 1991 and 2016. The rain process of each hydro-zone is the same as the areal process of the Taihu Basin.

Figure 3. The 10-days rainfall of different hydro-zones of the Taihu Basin in June and July in 1991 and 2016

3. The effect of the backbone works of the Taihu Basin

The water level and flood drainage could be used to explain the effect of the backbone works of the Taihu Basin, and we will give the detail analysis as follows.

(1) The water level of the Taihu Lake

The Figure 4 shows the water level and rainfall of the Taihu Lake from April to July in 1991 and 2016. We could find that the average rainfall in May in 2016 is bigger than the average rainfall in 1991, and it causes the water level of the Taihu Lake reaches the warning water level earlier.

The total rainfall is 468.8mm in 1991, and is bigger than 430mm in 2016. But the rain process in 1991 is discontinuous, it consists of two rain processes and a 11-day dry period. The dry period is benefit for draining flood water and saving precious time for flood regulation. However, the rain...
process in 2016 is continuous, it gives more pressure for the flood control management of the Taihu Basin.

Beside coping with the water level, the drainage capability is enhanced notably with the BWTL. We could find the water level goes down quickly in Figure 4. The water level descending speed is 2.8 cm/d in 1991, and it increases to 3.6 cm/d in 2016. That benefits from the drainage projects of Wangyu River and Taipu River which belong to the BWTL.

![Figure 4. The water level and rainfall of the Taihu Lake from April to July in 1991 and 2016](image)

(2) Water level of the zonal control station

The water level of HUX and WCX in 2016 is higher than that in 1991. Firstly, the continuous rain brings enough water for high water level. Then, the land surface changes with the urbanization which caused more flood drainage into the water body around the cities[4]. Though the water level is higher, no serious flood occurs in the Taihu Basin in 2016.

| Hydro-zone | Control station | Safety level (m) | 1991 | 2016 |
|------------|-----------------|-----------------|------|------|
|            |                 | Max lever (m)   | Max lever (m) |
| HUX        | Wangmuguan      | 5.6             | 6.12 | 6.53 |
|            | Changzhou       | 4.8             | 5.53 | 6.29 |
| WCX        | Wuxi            | 4.53            | 4.88 | 5.25 |
|            | Qingyang        | 4.85            | 5.12 | 5.33 |
| YCD        | Suzhou          | 4.2             | 4.31 | 4.7  |
|            | Xiangcheng      | 4.00            | 4.19 | 3.98 |
|            | Chenmu          | 4.00            | 3.77 | 3.84 |
| HJH        | Wangjiangjing   | 3.55            | 3.77 | 3.86 |
|            | Jiaxing         | 3.7             | 4.05 | 3.79 |

(3) Flood drainage
The HUX and ZHX contribute most of the water which flows into the Taihu Lake. In 1991, 87.1% water converging into the Taihu Lake comes from the HUX and ZHX, and the ratio increases to 96.4% in 2016. From May to July in 2016, the volume of the water flowing into the Taihu Lake increases 1700 million m³ than that in 1991[5].

In 1991, the Wangyuhe project is not completed. The local government have to open the Taipu water-gate and the East Taihu water-gate to drain the flood out of the lake area. However, the Taipu River and Wangyu River have been the main outlet for the flood water in 2016. From May to July in 2016, the two river drain 5100 million m³ flood water which is about 80% of the flood water of the Taihu Lake.

The flood drainage of the whole Taihu Basin is also improved a lot. In 1991, the north entrance along the Huangpu River is the main outlet for flood drainage. It drains 5971 million m³ flood water from May to July, while the south Hangjiahu entrance drains 884 million m³ flood water. In 2016, the north entrance drains 3416 million m³ flood water from May to July, while the south Hangjiahu entrance drains 2020 million m³ flood water. With the Hangjiahu drainage project, more flood water can be diverted out of the Taihu Basin from the south entrance, and it reduces the flood water of the north entrance[6].

![Figure 5. The result of K-S test](image)

4. Conclusion
We compare the two rain events in 1991 and 2016. The similarity and difference of them are analysed. Then, the water level at control station and the flood drainage data are used to explain the effects of the BWTL.

(1) The total rainfalls caused the flood in the Taihu Basin in 1991 and 2016 are similar, and the total raining days are almost the same. But the rain process in 2016 is continuous, it gives more pressure for the flood control management of the Taihu Basin than the rain process in 1991.

(2) Because of the urbanization, more flood drains into the water body around the cities. It causes the water levels of the control stations are higher than that in 1991.

(3) With the help of the backbone works of the Taihu Lake, the outlets of the flood water have changed and the flood regulating capability is improved. Even the continuous rain in 2016 brings the more serious flood than 1991, the Taihu Basin experience less flood loss.

Acknowledgments
This study is financially supported by National Key Research and Development Program of China (No. 2017YFC1502705, 2016YFC0401508), the National Natural Science Foundation of China (Grant No. 51509157), the Technical Demonstration Project of Ministry of Water Resources (Grant No. SF-201706), the Commonwealth Science Research Project of Ministry of water resources, China (Grant No.201501014), the Jiangsu Water Science and Technology Project(Grant No. 2017038, 2017022) , the National Non-profit Institute Basic Research Foundation funded special project (Grant No. Y516034, Y517007).
References
[1] National Bureau of Statistics 2016 *Statistical yearbook of provinces and cities in Taihu basin in 2016* (Beijing: China Statistics Press).
[2] Wu H, Xu H, Zhang Y 2009 Defense of Taihu Lake extraordinary flood in 1999: a review of experiences and lessons learned *China Water Resources* 19 35-38.
[3] Kulejiang D, Liu J, Liu X, Li P 2016 Effect of west bank control engineering on flood control in west area of Wangyu river *Journal of Water Resources & Water Engineering* 27 166-170.
[4] Dong G, Yang Z, Yu Y 2013 Research Progress on Effects of Variations of Underlying Surface on Runoff Yield and Concentration in the River Basin *South-to North Water Transfers and Water Science & Technology* 11 111-117.
[5] Wang L, Hu Q, Dai J, Wang Y, Ge H, Li L 2017 Research on multi-objective joint operation of Taipu River oriented to water supply safety of Jinze Reservoir *Water Resources Protection* 33 61-68.
[6] Zhong G, Liu S, Hu Z, Zhang X 2017 Analysis of influence on region flood control due to polder waterlogging drainage in Yangcheng and Dianmao area *Yangtze River* 48 9-14.