# Research on the Layout Adjustment Plan for Flood Storage and Detention Areas Near Wuhan in the Yangtze River's Middle and Lower Reaches

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**Abstract.** Given the current flood control situation and socio-economic development in the Yangtze River Basin, adjusting the layout of flood storage and detention areas is highly necessary. This paper conducts research on the layout adjustment of flood storage and detention areas near Wuhan. Through a systematic analysis of the flood control situation along the river sections near Wuhan and the regional economic development demands, the necessity and feasibility of layout adjustments are thoroughly discussed. Based on the proposed adjustment plan and a comprehensive comparison of options, a moderate adjustment plan for the layout of six flood storage and detention areas near Wuhan is recommended. The plan involves adjusting Dongxihu into a flood protection area and expanding the safety zones in three flood storage and detention areas: Xilianghu, Wuhu, and Zhangduhu. Under the new plan, the safety zone area of the flood storage and detention areas near Wuhan will be adjusted from the current 236.62 km² to 449.99 km², while the effective flood storage capacity will be adjusted from 13.568 billion m³ to 10.328 billion m³.

**Keywords:** flood storage and detention areas; layout adjustment; Wuhan river section; flood control

## 1 Introduction

Most flood storage and detention areas in the middle and lower reaches of the Yangtze River were established in the 1950s and 1960s, during a period when the flood control infrastructure in the basin was relatively weak. At that time, these areas were primarily low-lying regions focused on agricultural production. Flood storage and land reclamation allowed for the goal of maintaining agricultural production during low-water years and ensuring safety by diverting floods during high-water years, serving as a harmonious approach to human-environment interaction[1]. Since there are still many uncertain


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factors in the process of the construction of reservoirs in the upper reaches of the Yangtze River, and the changes in river erosion and river-lake relationship in the middle and lower reaches need further analysis and demonstration based on the accumulation of observation data, it is necessary to continue to conduct in-depth research on the integrated flood control and mitigation system and flood control situation in the basin, and timely adjust the layout of flood storage and detention areas. Meanwhile, given the significant changes in flood control needs and socio-economic development in the basin, it is now necessary to adjust the layout of these flood storage and detention areas in a timely manner[2-5]. This paper conducts research on the layout adjustment of flood storage and detention areas near Wuhan. Through a systematic analysis of the flood control situation along the river sections near Wuhan and the regional economic development demands, the necessity and feasibility of layout adjustments are thoroughly discussed. Based on the proposed adjustment plan and a comprehensive comparison of options, a moderate adjustment plan for the layout of flood storage and detention areas near Wuhan is recommended.

# 2 Analysis of the Necessity for Layout Adjustment of Flood Storage and Detention Areas

## 2.1 Layout Adjustment is Necessary to Implement the Overall Flood Control Strategy for the Yangtze River Basin

The 1959 report on the *Key Points for the Comprehensive Utilization of the Yangtze River Basin* proposed a three-stage overall arrangement for flood control in the basin. The first stage primarily involved appropriately raising and strengthening levees, as well as making full use of flood diversion and storage projects to eliminate the threat of ordinary floods, mitigate losses from major floods, and improve flood control standards in key areas, while constructing large reservoirs in a few tributaries to prevent catastrophic floods. The second stage, building on the first, involved the continued construction of reservoirs on main streams and tributaries and the full utilization of existing flood control facilities in the plains to further improve flood control standards, gradually achieving the goal of preventing flood damage in key areas from a recurrence of the 1954 flood. The third stage involved constructing more valley reservoirs to progressively enhance flood control capacity, with a corresponding reduction in the use and frequency of flood diversion and storage projects in the plains. With the completion of control reservoirs in the upper and middle reaches of the Yangtze River, such as the Three Gorges Reservoir, the basin's flood control efforts have entered the third stage[6]. Therefore, from the perspective of implementing the overall flood control plan for the basin, adjusting the layout of flood storage and detention areas is necessary.

### 2.2 The Progressive Improvement of the Yangtze River Flood Control System Creates Conditions for Layout Adjustment

Since the completion of control reservoirs in the upper and middle reaches of the Yangtze River, such as the Three Gorges Project, the flood control system in the basin has gradually improved. Currently, the 3,900 kilometers of main levees in the middle and lower reaches of the Yangtze River have largely met the required standards. There are 33 constructed flood control reservoirs with a total flood control capacity of 56.016 billion $m^3$. Notably, the Three Gorges Reservoir, with a flood control capacity of 22.15 billion $m^3$, effectively eliminates the threat of catastrophic flooding in the Jingjiang River section. According to planning, by 2030, 37 flood control reservoirs will be operational in the upper and middle reaches of the Yangtze River, with a total flood control capacity of 68.619 billion $m^3$, significantly enhancing the basin's flood regulation capacity. This will reduce the excess flood volume in the middle and lower reaches and lower the frequency and number of times flood storage and detention areas need to be used. Thus, the improvement of the Yangtze River flood control system has created favorable conditions for layout adjustment[7].

### 2.3 Layout Adjustment Is Necessary to Support High-Quality Economic and Social Development

Most flood storage and detention areas in the middle and lower reaches of the Yangtze River are located along the river and around Dongting Lake and Poyang Lake. These regions are key areas for the development of the Yangtze River Economic Belt. However, according to laws and regulations such as the *Flood Control Law of the People's Republic of China*, industrial development within most flood storage and detention areas is restricted, leading to underdeveloped infrastructure and low-income levels among residents, making these areas a weak link in the effort to build a moderately prosperous society. In some flood storage and detention areas near cities, conflicts between economic and social development and the existing layout of flood storage and detention areas are becoming increasingly prominent. For example, in cities such as Wuhan and Yueyang, urban master plans and regional industrial development plans have generated significant demand for construction land in surrounding flood storage and detention areas such as Wuhu, Zhangduhu, and Junshanyan. The 19th National Congress of the Communist Party of China pointed out that the principal contradiction in Chinese society has evolved into the tension between the people's ever-growing needs for a better life and unbalanced and inadequate development. By 2035, China aims to achieve basic modernization, with significant reductions in disparities between urban and rural development and in residents' living standards. The Yangtze River Economic Belt Development Plan outlines a proactive approach to promoting new urbanization, encouraging the urbanization of agricultural populations, and coordinating urban-rural development. Therefore, researching layout adjustment plans for flood storage and detention areas, alongside coordinating regional strategic development with flood control and safety, is crucial for promoting high-quality economic and social development.

# 3 Feasibility Analysis of the Layout Adjustment of Flood Storage and Detention Areas

In 2017, Wuhan proposed the construction of a national-level Yangtze River New District. The planned area of this district includes the eastern part of Jiang'an District in the main urban area of Wuhan, as well as the southern portions of Huangpi District and Xinzhou District, covering approximately 500 km². A large portion of this area lies within the Wuhu flood storage and detention area, introducing new demands for its layout and construction. Therefore, under the premise of ensuring flood safety, this study analyzes the feasibility of adjusting the classification and safety zones of various flood storage and detention areas near Wuhan, taking into account socio-economic development and the needs of the Yangtze River New District.

## 3.1 Analysis of Excess Flood Volume Below Chenglingji

The 1954 flood is recognized as the largest flood since the founding of the People's Republic of China and serves as the standard for flood control in the middle and lower reaches of the Yangtze River. The 1954 flood had several key characteristics:

- Large flood volume with high peak water levels and flow rates: Major tributaries and lakes, such as the Dongting Lake and Poyang Lake systems, experienced flood volumes that exceeded or closely approached the levels seen in years of major floods. The maximum flow rate downstream of Chenglingji exceeded historical records, and the flood volume during the flood season at major stations like Yichang, Hankou, and Datong corresponded to a frequency of once every 100-200 years.
- Broad peak shape and prolonged flood duration: After the confluence of major tributaries such as the Jinsha River, Min River, Jialing River, and Wu River, a broad flood peak formed at Yichang, with the flow rate exceeding 40,000 m³/s for 45 days, marking the longest such period on record. After passing Zhicheng, the floodwaters merged with those from the Dongting and Poyang Lakes and the Han River system. Natural storage in lakes and lowlands, along with flood diversion and breaches, resulted in a broad, mound-shaped flood peak, which exceeded the flood process lines of previous major flood years. This is referred to as the historical "outer envelope."
- Coincidence of upstream, midstream, and downstream floods: In 1954, the flood in the middle and lower reaches was delayed until July, nearly a month later than usual, while upstream floods occurred earlier than expected. This overlapping of flood events in different parts of the river system contributed to the basin-wide, catastrophic flood.
- Massive flood volume in the middle and lower reaches: The total volume of floodwater diverted or released through breaches reached 102.3 billion m³.
- This study calculates the excess flood volume below Chenglingji during a repeat of the 1954 flood, considering changes in flood regulation capacity due to the construction of control reservoirs such as the Three Gorges Dam, as well as the current status of river and lake storage capacity.

(1) Excess Flood Volume under Planned Scheduling and Flood Diversion Conditions

Planned scheduling and flood diversion conditions refer to the use of control reservoirs according to established dispatch plans, with water level-flow relationships at control stations based on long-term integrated data. Flood storage and detention areas are utilized as needed, according to the flood diversion control water levels specified in the 1990 revision of the Yangtze River Basin Comprehensive Utilization Plan.

As shown in Table 1, under the current 155 m scheme, during a 1954-level flood, control reservoirs in the upper reaches of the Yangtze River are projected to store 20.66 billion m$^3$ of floodwater, while the excess flood volume downstream of Chenglingji would be 35 billion m$^3$. Of this, the Chenglingji section accounts for 25.5 billion m$^3$, the Wuhan section for 5.5 billion m$^3$, and the Hukou section for 4 billion m$^3$. Compared to the period immediately after the completion of the Three Gorges Reservoir, when upstream reservoirs stored an additional 5.55 billion m$^3$, excess flood volume has decreased by 5.1 billion m$^3$. Specifically, excess flood volume in the Chenglingji section has decreased by 5 billion m$^3$, while the excess in the Wuhan section has decreased by 100 million m$^3$, with no change in the Hukou section. Under the 158 m scheme, upstream control reservoirs would store 23.26 billion m$^3$ of floodwater, an increase of 2.6 billion m$^3$ compared to the 155 m scheme. Excess flood volume downstream of Chenglingji would total 32.5 billion m$^3$, a reduction of 2.5 billion m$^3$ compared to the 155 m scheme.

**Table 1.** Changes in Excess Flood Volume in the River Section Below Chenglingji During the 1954 Flood Under Current Conditions

| **Scenario** | **Excess Flood Volume (billion m$^3$)** | | | | |
|---|---|---|---|---|---|
| | Jingjiang | Chenglingji | Wuhan | Hokou | Total |
| Initial Stage after the Completion of the Three Gorges Dam | 0 | 30.5 | 5.6 | 4.0 | 40.1 |
| Current Scenario (155 m Scheme) | 0 | 25.5 | 5.5 | 4.0 | 35.0 |
| Current Scenario (158 m Scheme) | 0 | 23.3 | 5.3 | 3.9 | 32.5 |

The above excess flood volumes are based on calculations under planned scheduling and flood diversion conditions. Actual excess volumes may vary due to factors such as flood forecasting accuracy, reservoir scheduling, the status of flood storage and detention areas, and special hydrological conditions. The following analysis uses the Three Gorges Reservoir 155 m scheme as a baseline for calculations.

(2) Impact of Chenglingji Operating Water Levels on Excess Flood Volume

This study calculates excess flood volume under the current conditions during a 1954-level flood, considering different operating water levels at Chenglingji, as shown in Table 2. The results indicate that as the operating water level at Chenglingji increases, the total excess flood volume in the middle and lower reaches of the Yangtze decreases. The excess flood volume near Chenglingji decreases, while the excess volume near Wuhan increases. The flexible operation of water levels at Chenglingji should ensure that flood safety is not compromised for upstream and downstream sections, such as Wuhan, and should only be implemented when conditions in these sections permit. However, it should be noted that during actual scheduling, complex flood conditions, forecast errors, and operational challenges may cause the water level at Chenglingji to exceed the designed level of 34.4 m, increasing excess flood volume near Wuhan beyond what is anticipated under planned flood diversion conditions.

**Table 2.** Impact of Different Chenglingji Operating Water Levels on Excess Flood Volume During the 1954 Flood Under Current Conditions

| **Chenglingji Operating Water Level (m)** | **Excess Flood Volume (billion m³)** | | | | |
|---|---|---|---|---|---|
| | Jingjiang | Chenglingji | Wuhan | Hokou | Total |
| 34.40 | 0 | 25.5 | 5.5 | 4.0 | 35.0 |
| 34.50 | 0 | 23.6 | 6.8 | 4.0 | 34.4 |
| 34.60 | 0 | 21.5 | 8.4 | 4.0 | 33.9 |
| 34.70 | 0 | 19.4 | 10.2 | 4.0 | 33.6 |
| 34.80 | 0 | 17.7 | 11.6 | 4.0 | 33.3 |
| 34.90 | 0 | 16.1 | 13.0 | 4.0 | 33.1 |

(3) Analysis of the Impact of Luoshan StationStation Impact of Luoshan Station-olume Durin

The impact of Luoshan Station's discharge capacity on excess flood volume was analyzed using both current composite data and data from the 1960s–1970s, as shown in Table 3. The calculations show that if Luoshan Station's discharge capacity increases to 65,000 $m^3/s$, while the other lake and river storage and discharge capacities remain unchanged, the excess flood volume in the middle and lower reaches of the Yangtze River during a 1954-like flood will decrease to 33.8 billion $m^3$. Specifically, the excess flood volume in the Chenglingji area will reduce to 22.2 billion $m^3$, but it will increase to 7.7 billion $m^3$ in the Wuhan area.

**Table 3.** Impact of Luoshan StationSs Discharge Capacity on Excess Flood Volume During the 1954 Flood (Unit: Billion m³)

| Luoshan Discharge Capacity | Excess Flood Volume | | | | |
|---|---|---|---|---|---|
| | Jingjiang | Chenglingji | Wuhan | Hokou | Total |
| 64000 $m^3/s$ | 0 | 25.5 | 5.5 | 4.0 | 35.0 |
| 65000 $m^3/s$ | 0 | 22.2 | 7.7 | 3.9 | 33.8 |

Currently, the joint operation of the upstream control reservoirs is still being optimized, and changes in the riverbed erosion and lake-river dynamics in the middle and lower reaches need further analysis based on accumulated observation data. Thus, the excess flood volume in the middle and lower reaches of the Yangtze River requires continued in-depth research. Given the complexity of the factors influencing excess flood volume and the importance of critical flood protection areas such as Wuhan, the adjustment of the storage and detention area layout must fully account for the impact of factors such as Chenglingji's operating water level and changes in Luoshan's discharge capacity, leaving sufficient margins for safety.

(4) Analysis of Excess Flood Volume in the Chenglingji and Downstream Sections under the 2030 Scenario

As shown in Table 4, by 2030, with the construction of additional upstream reservoirs, the capacity of the Three Gorges Reservoir to compensate for Chenglingji's flood control will be enhanced. Under the condition of a compensatory reservoir water level of 158 m at Chenglingji, the excess flood volume in the middle and lower reaches will further decrease to 25.3 billion m³. Specifically, the excess flood volume in the Chenglingji area will reduce to 16.3 billion m³, while that in the Hukou area will decrease to 3.5 billion m³. Due to the increase in Luoshan's discharge capacity, the excess flood volume in the Wuhan area will be 5.5 billion m³, remaining the same as under current conditions.

**Table 4.** Changes in Excess Flood Volume in the Middle and Lower Yangtze River under Different Scenarios during the 1954 Flood

| Scenario | Excess Flood Volume (Billion m³) | | | | |
|---|---|---|---|---|---|
| | Jingjiang | Chenglingji | Wuhan | Hokou | Total |
| Current Scenario (Three Gorges 155 m Scheme) | 0 | 25.5 | 5.5 | 4.0 | 35.0 |
| Current Scenario (Three Gorges 158 m Scheme) | 0 | 23.3 | 5.3 | 3.9 | 32.5 |
| 2030 Reservoir, Current Storage and Discharge (Three Gorges 155 m Scheme) | 0 | 19.8 | 5.3 | 3.6 | 28.7 |
| 2030 Reservoir, Current Storage and Discharge (Three Gorges 158 m Scheme) | 0 | 18.7 | 4.9 | 3.6 | 27.2 |
| 2030 Scenario (Three Gorges 155 m Scheme) | 0 | 17.8 | 6.0 | 3.6 | 27.4 |
| 2030 Scenario (Three Gorges 158 m Scheme) | 0 | 16.3 | 5.5 | 3.5 | 25.3 |

## 3.2 Current Layout of the Flood Storage and Detention Areas in Wuhan

In the vicinity of Wuhan, six flood storage and detention areas have been designated: Dujiatai, Xiliang Lake, Wuhu Lake, Zhangdu Lake, Baitan Lake, and Dongxi Lake. The total area of these flood storage zones is 3,136.49 km², with an effective flood storage capacity of 13.568 billion m³. Among them, Dujiatai is classified as an important flood storage area, Dongxi Lake as a reserve flood storage area, and the remaining four are general flood storage areas. According to data from 2020, the total population within the flood storage areas near Wuhan is 2.193 million, with 1.603 million acres of farmland. The industrial output is valued at 321.68 billion yuan, agricultural output at 24.05 billion yuan, and total fixed assets at 122.57 billion yuan.

### 3.3 Feasibility of Adjusting the Flood Storage Layout near Wuhan

After the construction of upstream control reservoirs on the Yangtze River, the excess flood volume in the Wuhan area has decreased under the 1954 flood conditions, assuming planned scheduling and flood diversion operations. However, due to factors such as variations in the operating water level of Chenglingji, changes in Luoshan's discharge capacity, and the operation of the drainage systems along the river during actual flood management, a significant amount of excess flood volume still needs to be properly managed in the Wuhan area. Therefore, the study continues to explore adjustment plans for the flood storage zones near Wuhan, based on the originally planned 6.8 billion $m^3$ of excess flood volume, while allowing for additional flood capacity beyond the design standard.

After re-examining the research, it was determined that, after excluding the safety zones in Dujiatai according to the feasibility study and in the general flood storage areas according to the original plan, the effective flood storage capacity of the areas near Wuhan is 13.568 billion $m^3$. Of this, the effective flood storage capacity in the important and general flood storage areas is 11.369 billion $m^3$, which exceeds the required excess flood volume under the 1954 flood scenario, indicating room for adjustments.

## 4 Recommendations for Adjusting the Layout of the Flood Storage and Detention Areas Near Wuhan

According to the specific situation of the flood storage area near Wuhan, the adjustment plan is drawn up.

### 4.1 Adjustment Plan Formulation

(1) Dujiatai Flood Storage and Detention Area

Given that Dujiatai is frequently used and plays a significant role in flood control for both the lower reaches of the Han River and the Yangtze River, it is recommended that no changes be made to its classification. The safety zone plan should maintain the results of the feasibility study, with an effective flood storage capacity of 2.864 billion $m^3$, as per the feasibility phase.

(2) Xiliang Lake Flood Storage and Detention Area

Xiliang Lake is located upstream of Wuhan, and its flood diversion greatly reduces water levels at the Hankou Station, with a large storage capacity. It is crucial for flood defense, especially under conditions similar to the 1954 flood. Therefore, its classification as a general flood storage area remains unchanged. The effective flood storage capacity of Xiliang Lake is 4.224 billion $m^3$.

(3) Wuhu and Zhangdu Lake Flood Storage and Detention Areas

Wuhu's current classification is a general flood storage and detention area, with an originally planned area of 277.9 $km^2$ and an effective flood storage capacity of 1.81 billion $m^3$. The initial plan included two safety zones, Sanli and Wuhu, with a combined area of 10.56 $km^2$. After re-examination, the flood storage area increased to 305.15 $km^2$.

When the volume occupied by the safety zones is deducted, the effective flood storage capacity is 1.499 billion $m^3$.

Zhangdu Lake's current classification is also general, with an originally planned flood storage area of 309 $km^2$ and an effective capacity of 1 billion $m^3$. The initial plan included four safety zones—Shuangliu, Wangji, Zhangdu Lake, and Kongbu—covering a total of 29.35 $km^2$. After re-examination, the flood storage area increased to 438.32 $km^2$. After deducting for safety zones, the effective flood storage capacity is 1.817 billion $m^3$.

The changes in area and capacity for Wuhu and Zhangdu Lake are primarily due to differences in the precision of topographic data. This study used 1:10,000 topographic maps from the 2014 Ministry of Water Resources' project for re-surveying flood storage areas along the Yangtze River Basin, while the original plan relied on 1:50,000 topographic maps from the 1970s and 1980s.

Given that both Wuhu and Zhangdu Lake are located downstream of Wuhan, flood diversion under special hydrological conditions significantly lowers water levels at Hankou Station, making them effective in flood control. Therefore, both areas will maintain their classification as general flood storage areas.

Considering the proximity of Wuhu and Zhangdu Lake, and the re-examined results showing a decrease in Wuhu's capacity and an increase in Zhangdu Lake's, a coordinated approach is recommended for adjusting their safety zones. This approach balances flood control safety with socio-economic development needs.

Before any safety zone construction begins, the re-examined flood storage capacity for Wuhu is 1.546 billion $m^3$. To address the resettlement needs of local residents and accommodate land-use demands for the Yangtze River New District in Wuhan, a preliminary adjustment plan for Wuhu was developed. This plan includes two safety zones, Wuhu and Yangluo, covering a total area of 98 $km^2$. After deducting the volume occupied by the safety zones, the effective flood storage capacity of Wuhu is 1.021 billion $m^3$. The Wuhu safety zone is expanded to 82 $km^2$ from its originally planned size, while a new Yangluo safety zone, covering 16 $km^2$, is located in the southeastern part of Wuhu. This area currently hosts the Yangluo Development Zone and Wuhan Bioengineering Institute.

Before safety zone construction at Zhangdu Lake, the re-examined flood storage capacity is 1.918 billion $m^3$. To meet the resettlement needs of local residents and align with the development goals for the Xinzhou District outlined in Wuhan's master plan for 2030, a preliminary adjustment plan for Zhangdu Lake was also proposed. This plan includes new safety zones totaling 95.42 $km^2$, reducing the effective flood storage capacity to 1.531 billion $m^3$. A new Zhucheng safety zone, covering 15 $km^2$, is located on the west bank of the Jushui River, where there are existing communities and schools.

After the proposed adjustments, the combined effective flood storage capacity of Wuhu and Zhangdu Lake is 2.552 billion $m^3$, slightly lower than the originally planned 2.81 billion $m^3$. To compensate, this study proposes converting the original diversion channels into floodgates to improve flood diversion efficiency. This approach, prioritizing quality over quantity, aims to achieve the goals of "diverting effectively, storing safely, and discharging efficiently," improving the reliability and flexibility of flood management near Wuhan. Preliminary mathematical model analyses suggest that, although the effective storage capacity slightly decreases, using floodgates for controlled diversion offers better control over water levels at Hankou Station than the original diversion channel plan.

(4) Baitan Lake Flood Storage and Detention Area

Baitan Lake is currently classified as a general flood storage and detention area. The original planned effective flood storage capacity was 880 million $m^3$. After re-examination, accounting for the volume occupied by safety zones in the original plan, the effective storage capacity is reduced to 688 million $m^3$. At present, all dikes surrounding the area have been upgraded to the required standard, except for the eastern dike along the Jushui River. There are no plans to change the classification of Baitan Lake.

(5) Dongxihu Flood Storage and Detention Area

Dongxihu is currently designated as a reserved flood storage and detention area. The originally planned effective flood storage capacity was 2 billion $m^3$, with no safety zones designated in the original plan. After re-examination, the effective flood storage capacity has increased to 2.199 billion $m^3$, with all surrounding dikes now meeting the required standards.

In recent years, Dongxihu has experienced rapid economic and social development. Since the establishment of the Wujia Mountain Economic and Technological Development Zone in 1992, Dongxihu has grown significantly. In 1993, it was approved by the Wuhan municipal government as the Wujia Mountain Taiwan Investment Zone, and by 2000, it was elevated to a provincial-level economic development zone. In 2010, Dongxihu was officially recognized as a national-level economic development zone, and it has since established several important industrial parks, including the Cross-Strait Science and Technology Industry Development Park, the Wuhan Food Industrial Processing Zone, and the High-Tech Entrepreneurship Service Center. It was also selected as one of the first national pilot parks for circular economy initiatives. As of the end of 2019, Dongxihu housed over 2,000 companies, including 13 Fortune 500 firms, with a population of 601,300 and a GDP of ¥135.164 billion. Based on an analysis of the potential economic losses from flood diversion in Dongxihu, these losses far exceed those of other flood storage areas along the Wuhan section of the Yangtze River. Considering the flood control needs of the areas near Wuhan and the socio-economic development of Dongxihu, this study will conduct an in-depth analysis to explore the feasibility of entirely removing Dongxihu from its current designation as a flood storage and detention area.

### 4.2 Comparison of Schemes

Based on the previous analysis, two adjustment schemes are proposed regarding whether or not to cancel the Dongxihu flood storage and detention area. Hydrodynamic model is an effective method for simulating flood evolution. Therefore, based on the hydrodynamic model simulation results, these schemes are evaluated from the perspectives of flood diversion effectiveness, flood diversion losses, and socio-economic benefits.

Scheme 1: Expanding the safety zones of Xiliang Lake, Wuhu, and Zhangdu Lake.

Scheme 2: Expanding the safety zones of Xiliang Lake, Wuhu, and Zhangdu Lake, while canceling the Dongxihu flood storage and detention area.

(1) Comparison of Flood Diversion Effectiveness

A hydrodynamic model for flood progression in the middle and lower reaches of the Yangtze River was used to simulate flood storage and detention area scheduling in key sections such as Jingjiang, Chenglingji, Wuhan, and Hukou. The model analyzed the effectiveness of each scheme for flood diversion. The 1954 flood was used as the design standard flood for the Chenglingji and downstream sections. Additionally, to evaluate the performance of flood defense systems under floods exceeding the design standard, simulations were conducted for a 1-in-300-year flood based on the 1954 event.

According to the results of the hydrodynamic model for the middle and lower reaches:

For the 1954 flood, no excess flood volume was observed in the Jingjiang section, so the flood storage areas there were not activated. In the Chenglingji section, after activating 15 important and general flood storage areas, followed by some reserved areas, the maximum water level at Chenglingji could be controlled at 34.40 meters. In the Wuhan section, four flood storage areas, excluding Baitan Lake, were activated, which allowed the maximum water level at Hankou to be controlled at 29.59 meters. As the Dongxihu flood storage area was not activated, there was no difference in flood diversion effectiveness between the schemes involving maintaining or canceling Dongxihu. In the Hukou section, after activating five important and general flood storage areas, the maximum water level at the Hukou station could be controlled at 22.54 meters. Therefore, for the 1954 actual flood, both schemes provide identical flood diversion effectiveness.

For the 1-in-300-year flood, there was no excess flood volume in the Jingjiang section, and flood storage areas were not needed. In the Chenglingji section, all flood storage areas needed to be activated, resulting in a maximum water level of 34.65 meters at Chenglingji, assuming the use of the Junshanyuan flood storage area. As the embankments along the Chenglingji section have already been raised and reinforced with an additional 0.5 meters beyond the 1990 revisions to the Yangtze River Basin Comprehensive Utilization Plan, the water level at Hankou station in the Wuhan section can be controlled below 29.73 meters without using the Dongxihu flood storage area. Consequently, there is no difference in flood diversion effectiveness between maintaining or canceling the Dongxihu flood storage area. In the Hukou section, all flood storage areas need to be activated, and the maximum water level at the Hukou station can be controlled at 22.58 meters. For this 1-in-300-year flood scenario, the difference in flood diversion effectiveness between the two schemes is minimal. By slightly raising the operational water levels and utilizing the extra height of the embankments, the floodwaters can be effectively managed.

In summary, the flood diversion effectiveness of both schemes shows no significant difference.

(2) Comparison of Flood Diversion Losses

Using the 2011 industrial and agricultural output values as a basis, the flood diversion losses for each scheme were calculated based on the simulated flood diversion operations under different flood scenarios. For both the 1954 flood and the 1-in-300-

year flood based on the 1954 event, the results from the hydrodynamic model show that the Dongxihu flood storage and detention area was not activated. Therefore, the flood diversion losses are identical across all schemes.

(3) Comparison of Other Socio-Economic Benefits

In addition to reducing flood diversion losses, the adjustment schemes, which involve removing the “flood storage” designation for some areas and expanding safety zones, can bring other socio-economic benefits. These include a reduction in flood storage areas, a decrease in the amount of farmland and population within flood-prone regions, and other developmental opportunities. Among the schemes, the cancellation of the Dongxihu flood storage area offers the greatest socio-economic benefits.

(4) Overall Scheme Evaluation

When comparing flood storage and detention area adjustment schemes, the primary consideration must be flood safety at both basin and regional scales. From the perspective of flood safety, the differences between the schemes are minimal. However, in terms of reducing flood diversion losses and enhancing socio-economic benefits, the scheme that cancels the Dongxihu flood storage area is the most advantageous.

Therefore, the recommended scheme is to expand the safety zones of Xiliang Lake, Wuhu, and Zhangdu Lake, and cancel the Dongxihu flood storage area.

### 4.3 Layout Adjustment Plan for Flood Storage and Detention Areas Near Wuhan

The current layout of the flood storage and detention areas in the middle and lower reaches of the Yangtze River was determined by the Yangtze River Basin Flood Control Plan, as shown in Figure 1. The Comprehensive Plan for the Yangtze River Basin (2012–2030), based on this framework, only made minor adjustments: elevating the status of the Jingjiang Flood Diversion Area from important to critical, adjusting Dongxihu from general to reserved, and clarifying Huayang River’s effective flood storage capacity as 2.5 billion $m^3$. The total planned effective flood storage capacity for the middle and lower reaches of the Yangtze River was adjusted to 58.97 billion $m^3$. The excess flood volume calculated under the condition of a single Three Gorges Reservoir in the Comprehensive Plan for the Yangtze River Basin (2012–2030) was higher than that in the Yangtze River Basin Flood Control Plan. However, it was anticipated that after the completion of upstream control reservoirs, the excess flood volume in the middle and lower reaches, especially near Chenglingji, would decrease, so no major adjustments were made to the flood storage and detention area layout. To some extent, the current flood storage and detention area layout is still based on the excess flood volume calculated during the Yangtze River Basin Flood Control Plan phase.

Compared to the Yangtze River Basin Flood Control Plan, a number of upstream control reservoirs have been built to enhance flood control in the middle and lower reaches. However, changes in the Three Gorges Reservoir’s scheduling scheme, particularly its reduced capacity to compensate for Chenglingji, and changes in the flood retention and discharge capacities of the middle and lower reaches, especially the reduced safe discharge capacity near Chenglingji, have resulted in a slight increase in excess flood volume near Chenglingji. In other regions, the changes in excess flood volume have been minimal. The verification results of the flood storage capacity show little change in the Jingjiang and Hukou areas, with a slight decrease near Chenglingji and an increase near Wuhan. Moreover, the impact of flood storage engineering construction on flood retention efficiency suggests that the effective flood storage capacity should maintain a buffer relative to the calculated excess flood volume. Some flood storage and detention areas not only serve the main stream of the Yangtze River but also provide flood control for tributaries. For instance, the flood storage areas in the Dongting and Poyang Lakes accommodate floodwaters from their respective lake basins, and the Dujia Tai flood storage area near Wuhan has the task of diverting and storing floodwaters from the Han River. Therefore, the effective flood storage capacity needs to account not only for the excess flood volume from the Yangtze's main stream but also leave room for tributary flood control.

Given these considerations, this study proposes moderate adjustments to the layout of the flood storage and detention areas. The planned effective flood storage capacity near Wuhan is relatively surplus. Considering both the flood control needs of the Wuhan region and local economic development requirements, it is recommended to cancel the reserved status of the Dongxihu flood storage area, redesignating it as a flood protection zone. The safety zones of Xiliang Lake, Wuhu, and Zhangdu Lake flood storage areas should be expanded. This would reduce the number of flood storage areas near Wuhan from six to five, decrease the total area from 3,136.49 km² to 2,704.89 km², and increase the total safety zone area from 236.62 km² to 449.99 km². The effective flood storage capacity would be reduced from 13.568 billion m³ to 10.328 billion m³.

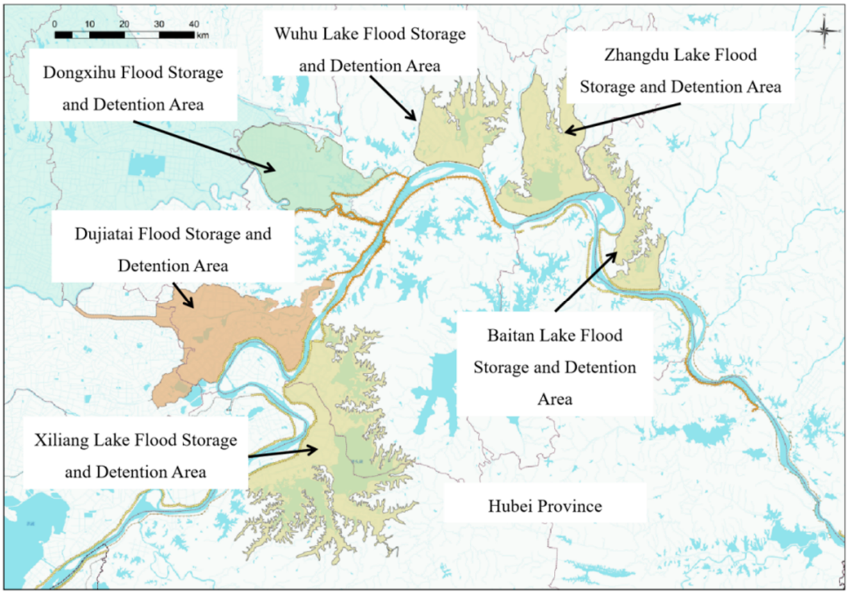


**Fig. 1.** Schematic Diagram of the Layout Adjustment Plan for Flood Storage and Detention Areas near Wuhan

## 5 Conclusion

Given the current flood control situation and socio-economic development in the Yangtze River Basin, adjusting the layout of the flood storage and detention areas is highly necessary. This study focuses on the adjustment of flood storage areas near Wuhan, addressing the necessity and feasibility of such adjustments and proposing specific recommendations. After a thorough analysis of the flood control situation in the Wuhan River segment and the region's economic development needs, the study recommends moderate adjustments to the layout of the six flood storage areas near Wuhan. The proposed adjustment plan includes the reclassification of the Dongxihu flood storage area into a flood protection zone and the expansion of the safety zones in the Xiliang Lake, Wuhu, and Zhangdu Lake flood storage areas. The total safety zone area will increase from 236.62 $km^2$ to 449.99 $km^2$, while the effective flood storage capacity will be reduced from 13.568 billion $m^3$ to 10.328 billion $m^3$.

The layout adjustment plan of flood storage area near Wuhan proposed in this study can guarantee the flood control safety of the river section near Wuhan, and meet the needs of high quality economic and social development of Wuhan. The results of the flood volume surplus were calculated based on the planned upstream reservoir construction timeline, existing research on joint scheduling of control reservoir groups, and the analysis and prediction of flood retention and discharge capacities in the middle and lower reaches of the Yangtze River. With the accumulation of reservoir operation practice and river lake relationship observation data, the joint optimal operation scheme of reservoir groups and the changes of flood retention and discharge capacities in the middle and lower reaches can be further studied, so as to carry out in-depth study on the layout adjustment of flood storage areas.

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