Analysis and Evaluation of the Flooding Capacity of the Liangshui River Channel -Locoal Model

ZHANG Cheng, IWHR/ICFM

Beijing 2024-09-24

中国水利水电科学研究院
China Institute of Water Resources and Hydropower Research

Contents

1.1 Background

- Liangshui River originates from Shijingshan District and flows through Haidian District, Xicheng District, Fengtai District, Chaoyang District, Daxing District, Tongzhou District and Yizhuang Economic Development Zone, which is one of the four major flood diversion and drainage channels in the center of Beijing.
- Flow through the area is mostly urban built-up areas,the city's sub-center and other key areas, flood control status is important.

1.1 Background

- The Liangshui River has undergone a number of comprehensive management projects, such as dredging of the river channel and ecological bank protection, which have significantly changed the pattern of the river cross-section.

1.1 Background

- The upper and middle reaches of the Liangshui River flow through the city. During the flood season, a large amount of silt from the upstream tributaries and pipeline networks enters the river and silts up in the slower sections of the main river, raising the water level of the river and leading to the situation of the service channels on both sides of the river being inundated by water, which is showing a more and more serious situation.
- In June 2023, the inundated section of the river from the right outer Guanzhang Bridge to the South Fifth Ring Road Bridge in the main stream amounted to 21 locations, totaling 11.60km in length, with a maximum depth of 40cm.

Right bank 50 meters downstream of Yangqiao Dam

Right bank downstream of Dahongmen lock

Left bank upstream of Xiaocun Bridge

1.2 Project Content

Research objectives

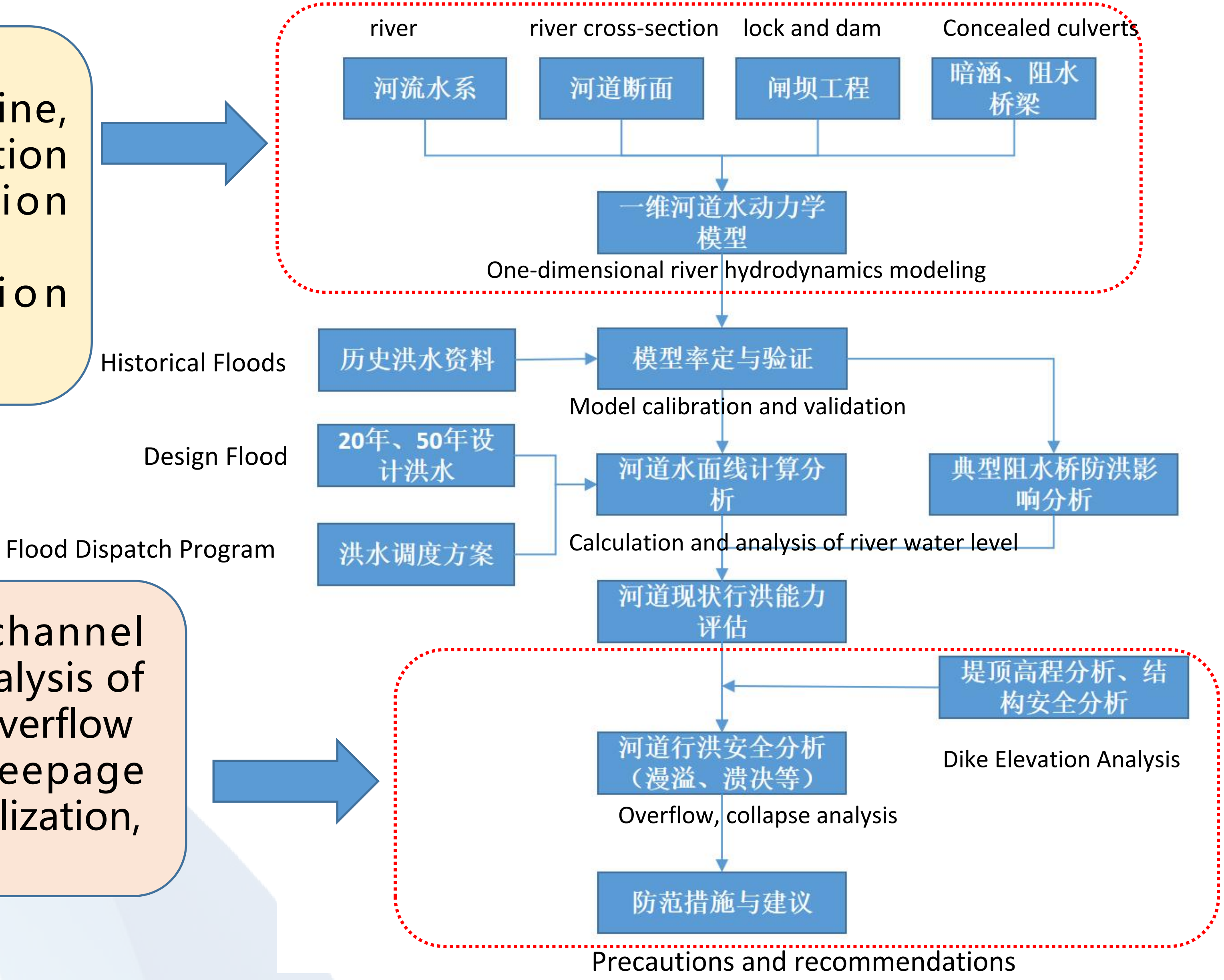
Analyze the current flood-carrying capacity of the river, assess risks at key points, and predict potential overflow or breaches. Provide early warnings and support flood management for the Liangshui River.

construct a one-dimensional river model for the main stream of the Liangshui River → Analyzing and calculating the water surface line under different frequency design flood conditions → Analyze and assess the impact of flood control on water-blocking bridges and the safety of river flooding (e.g.Tongzhou) → put forward recommendation-s for river elimination

2 General idea and technical route

Full channel water surface line, locks and dams, water retention facilities (culverts, retention bridges);
full channel cross-section measurements

Integration of current channel flooding capacity with analysis of channel flooding safety (overflow risk, structural safety (seepage damage, landslide destabilization, etc.)



3 River hydrodynamic modeling

Generalization of the river network

A one-dimensional hydrodynamic model of the mainstem channel of the Liangshui River was constructed based on MIKE11, and the river network was generalized according to the water system of the Liangshui River, the main locks and dams, the tributary confluence, and the location of the recharge outlet of the reclaimed water plant.

模拟范围

从凉水河干流人民渠至凉水河入北运河口，桩号0-66+639。

边界条件

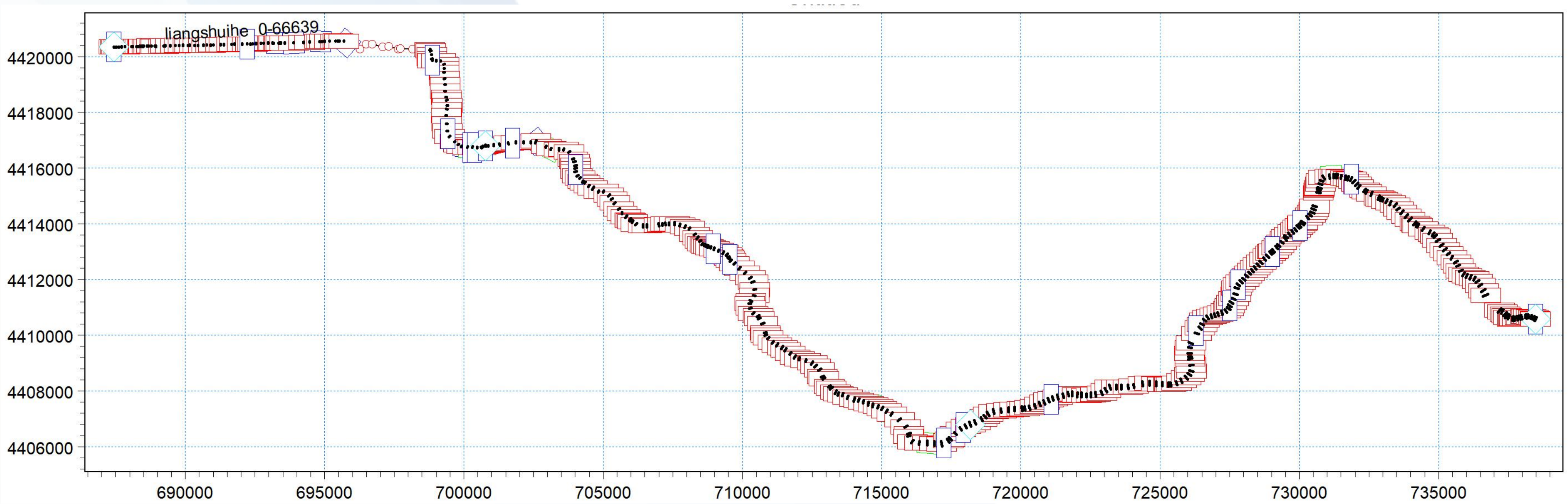
上游以人民渠为入流边界；

下游以凉水河入北运河断面水位流量关系为边界。

区间汇入

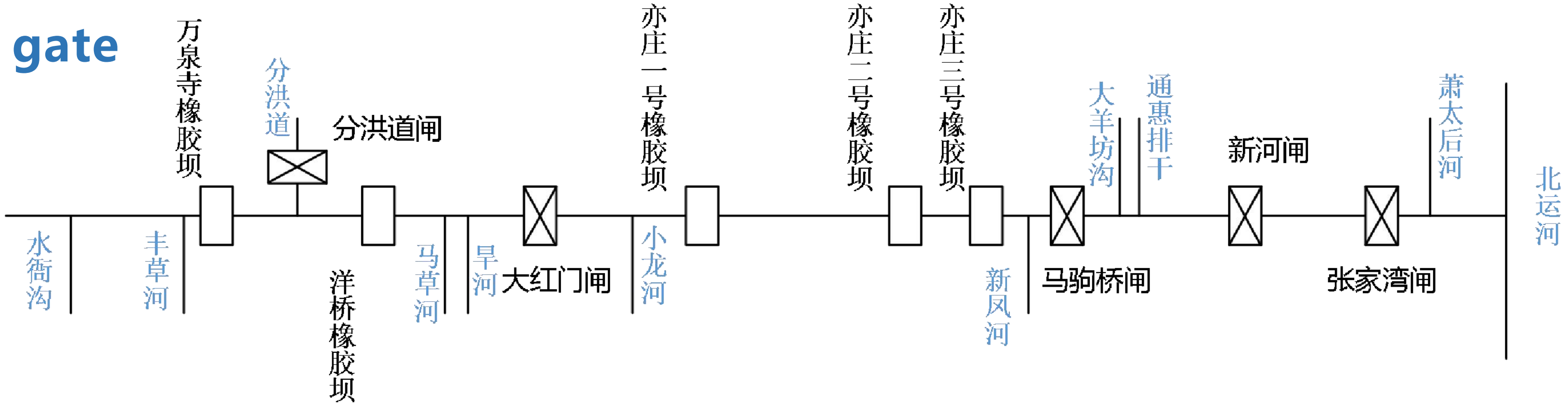
区间考虑水衙沟、新丰草河、马草河、小龙河、新凤河、大羊坊沟、通惠西排干、萧太后河等主要支流汇入，以及吴家村、槐房、卢沟桥、高碑店、小红门等主要再生水厂补水等

River generalization map

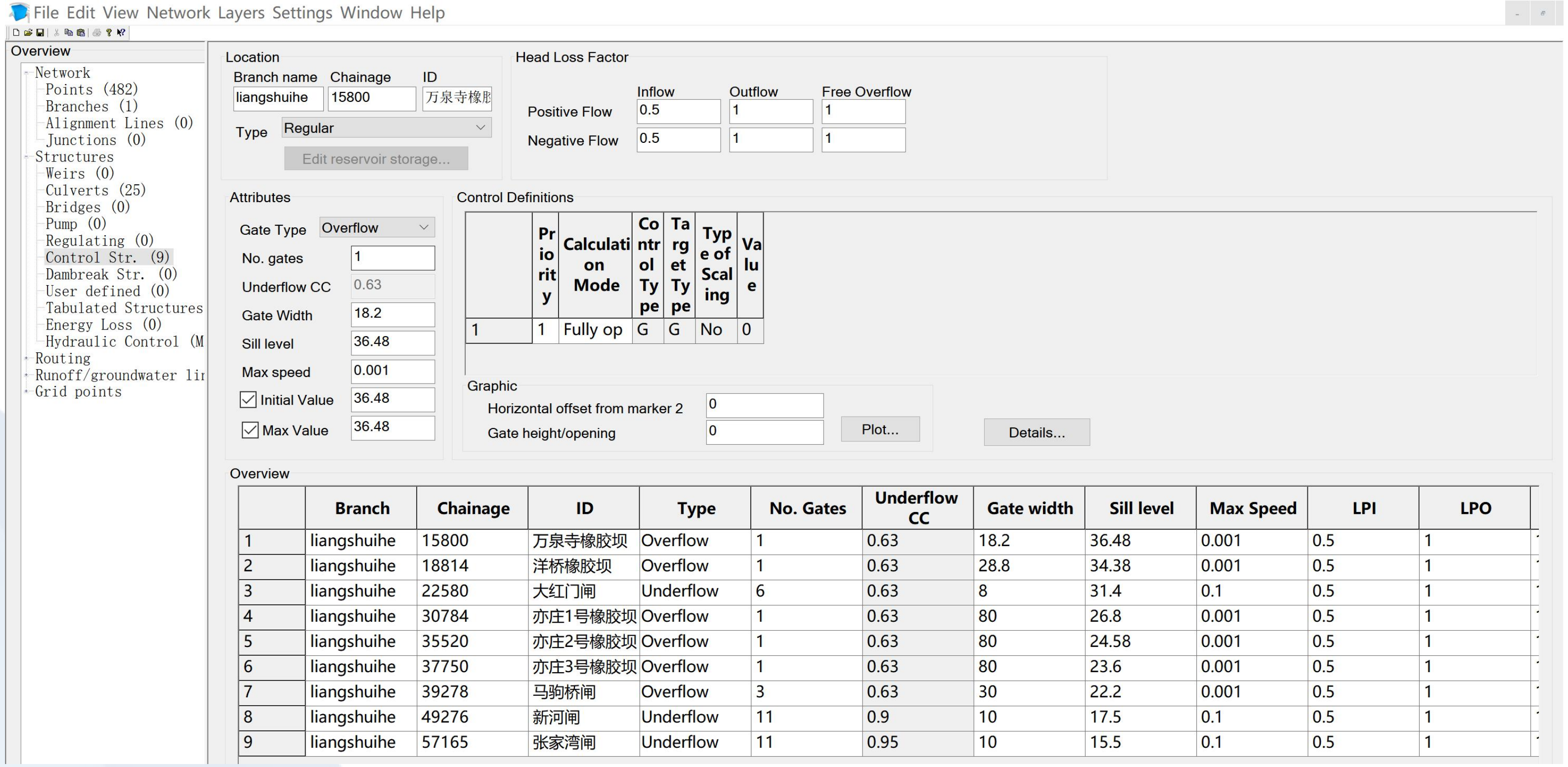


3 River hydrodynamic modeling

River network generalization - gate and dam settings



Set the gate and dam parameters according to the location of the gate and dam in the river, and the engineering information.

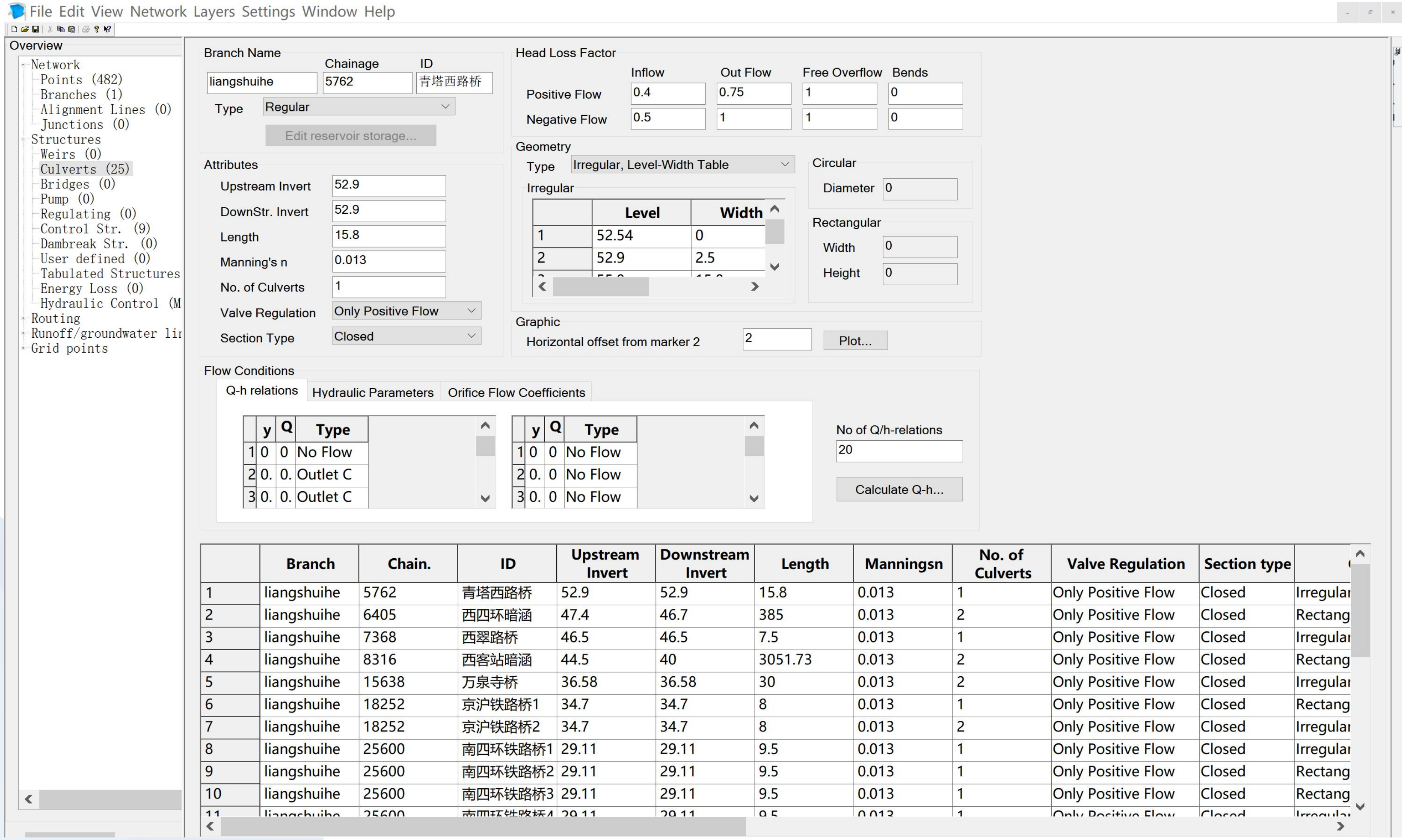


	Branch	Chainage	ID	Type	No. Gates	Underflow CC	Gate width	Sill level	Max Speed	LPI	LPO
1	liangshuihe	15800	万泉寺橡胶坝	Overflow	1	0.63	18.2	36.48	0.001	0.5	1
2	liangshuihe	18814	洋桥橡胶坝	Overflow	1	0.63	28.8	34.38	0.001	0.5	1
3	liangshuihe	22580	大红门闸	Underflow	6	0.63	8	31.4	0.1	0.5	1
4	liangshuihe	30784	亦庄1号橡胶坝	Overflow	1	0.63	80	26.8	0.001	0.5	1
5	liangshuihe	35520	亦庄2号橡胶坝	Overflow	1	0.63	80	24.58	0.001	0.5	1
6	liangshuihe	37750	亦庄3号橡胶坝	Overflow	1	0.63	80	23.6	0.001	0.5	1
7	liangshuihe	39278	马驹桥闸	Overflow	3	0.63	30	22.2	0.001	0.5	1
8	liangshuihe	49276	新河闸	Underflow	11	0.9	10	17.5	0.1	0.5	1
9	liangshuihe	57165	张家湾闸	Underflow	11	0.95	10	15.5	0.1	0.5	1

3 River hydrodynamic modeling

River network generalization - water-blocking bridge treatment

The 11 water-resistant bridge areas were generalized into 23 box culverts.



3 River hydrodynamic modeling

Boundary conditions

Typical Storm Floods
2012.7.21 Flood
2016.7.20 Flood

→ Flood Scene

Process of the 7.21 Flood and 7.20 Flood in Dahongmen

20-year and 50-year design flood flow of each control section of the main stream of the Liangshui River

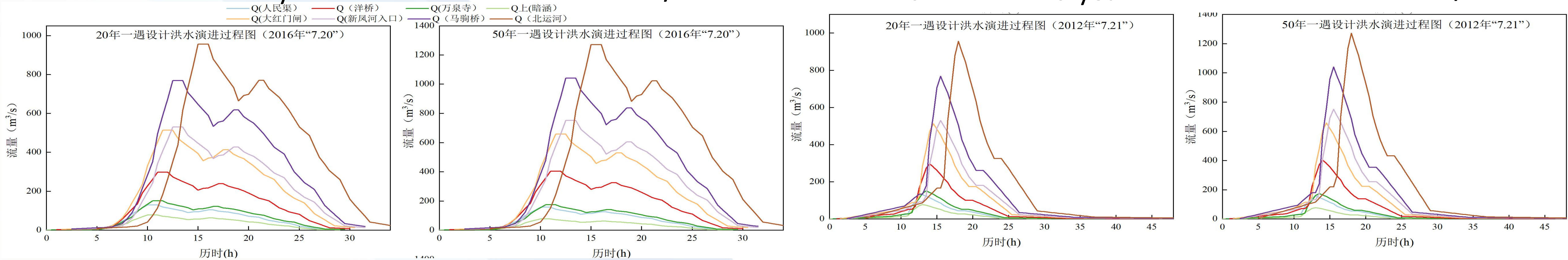
isomorphic amplification →

20-year and 50-year design flood process for each cross section

Flood processes in the tributaries according to the Muskingum method

→ Model hydrologic boundary conditions

2016.7.20---20-year 2016.7.20---50-year 2012.7.21---20-year 2012.7.21---50-year

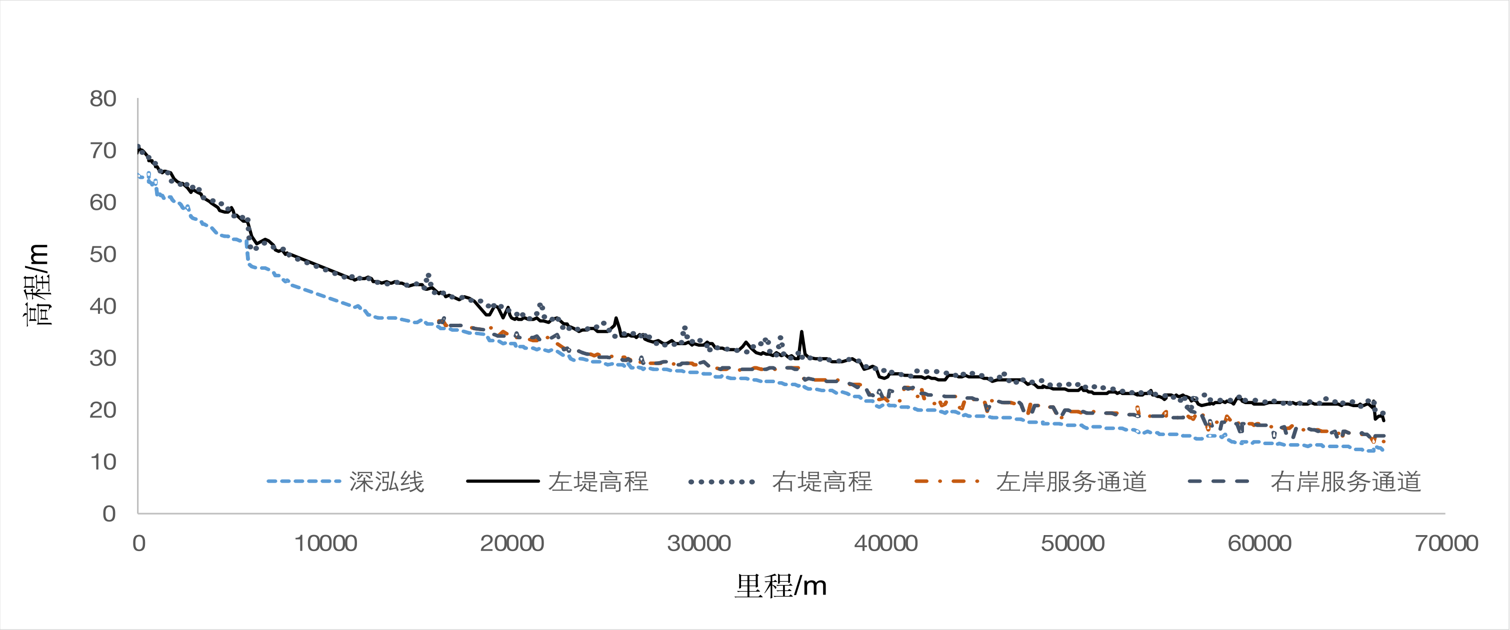


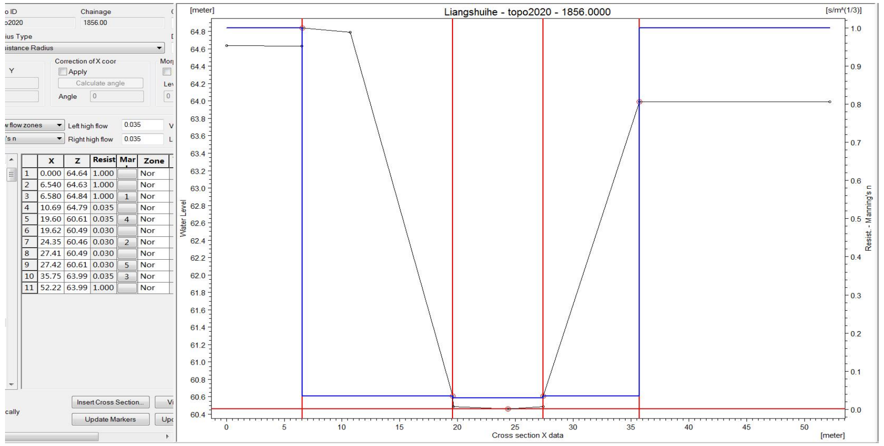
Typical flood process of “7.20” and “7.21” in the main control section of the main stream of the Liangshui River (20-year, 50-year design flood)

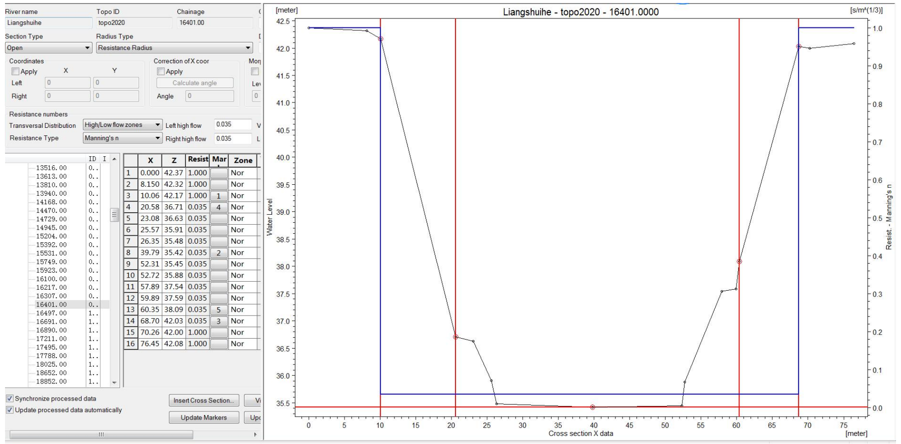
3 River hydrodynamic modeling

River cross-section

In 2020, actual measurements were taken to obtain information from 413 cross-sections at 100-200m intervals along the main stream.
In 2023, 40 cross-sections with severe sedimentation in the section from some bridges were re-surveyed. The basic cross-sections used for this river channel are based on the field measurement results from 2020, and corrections have been made to the cross-sections according to the actual conditions surveyed in 2023, resulting in a file of river cross-sections under the current sedimentation conditions.





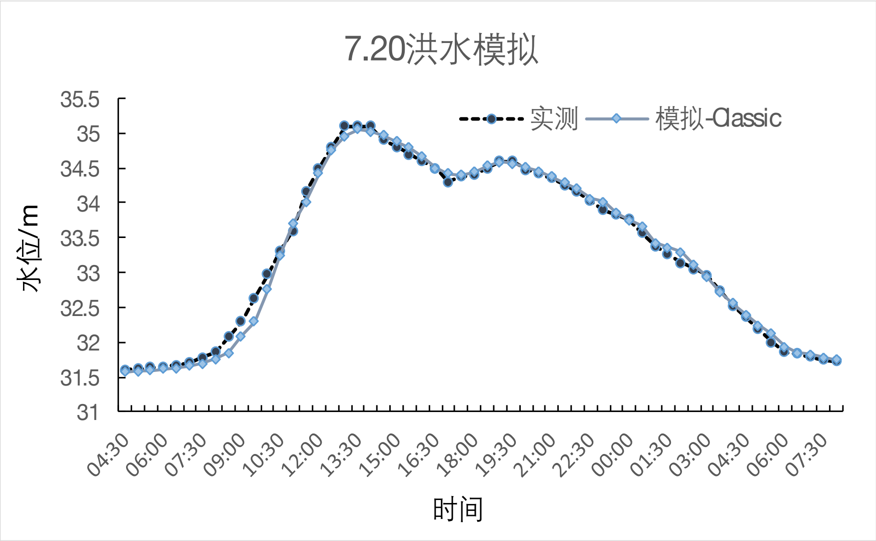


3 River hydrodynamic modeling

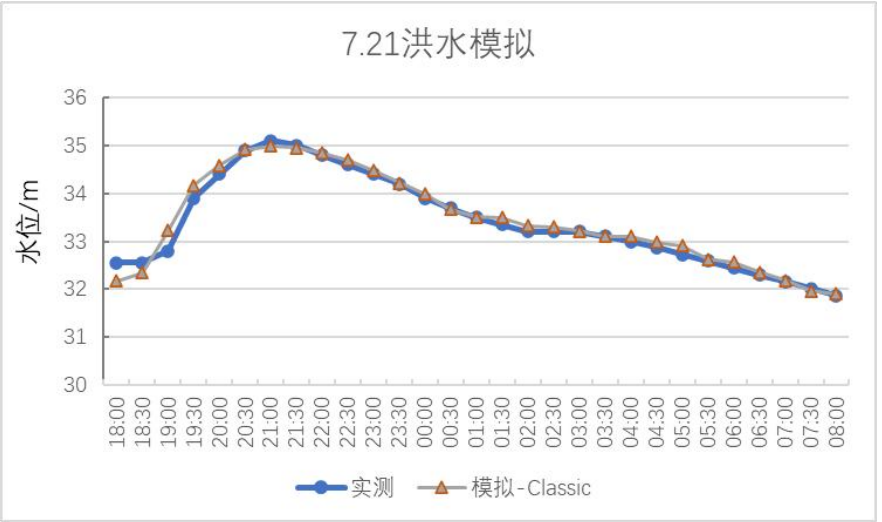
Model validations

Using the Classic computation mode of MIKE11, the water level changes at the Dahongmen sluice during the "7.21" flood in 2012 and the "7.20" flood in 2016 were simulated, with the typical representative being the Dahongmen sluice.

The simulated highest water level for the "7.20" flood was 35.06m, while the actual highest water level was 35.10m, resulting in an absolute error of -0.04m, which is 0.11% lower than the actual value. For the "7.21" flood, the simulated highest water level was 0.31% lower than the actual value. The simulation accuracy meets the specification requirements, and the flood process line fits well with the actual flood process line.



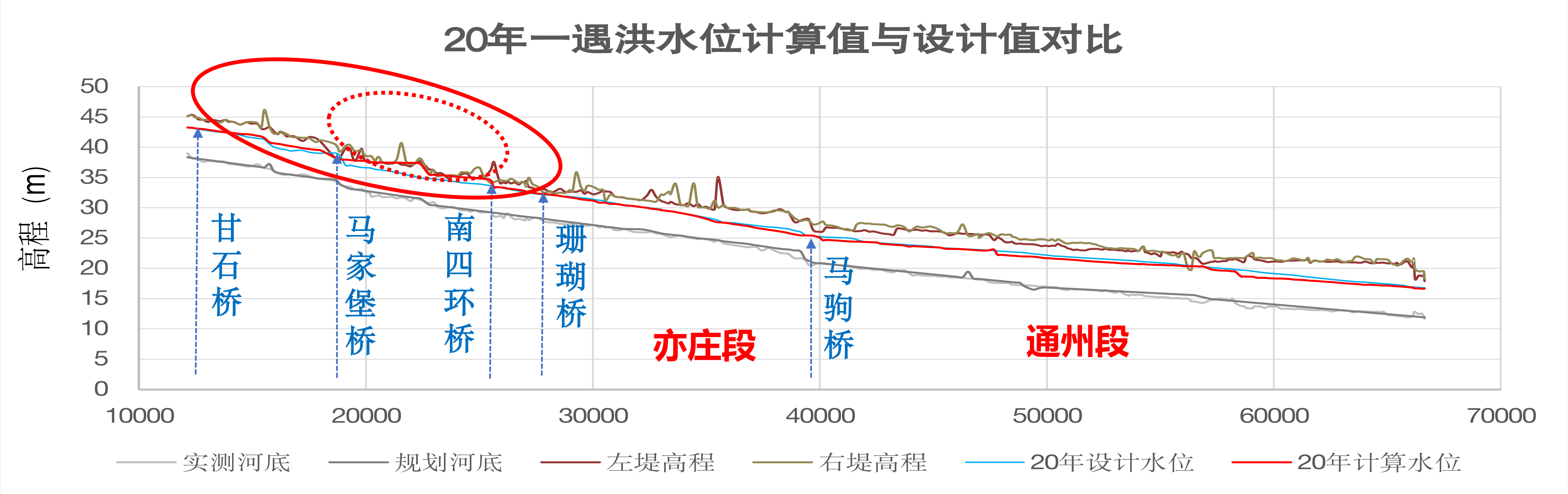
“7.20”实测和模拟的洪水过程对比



“7.21”实测和模拟的洪水过程对比

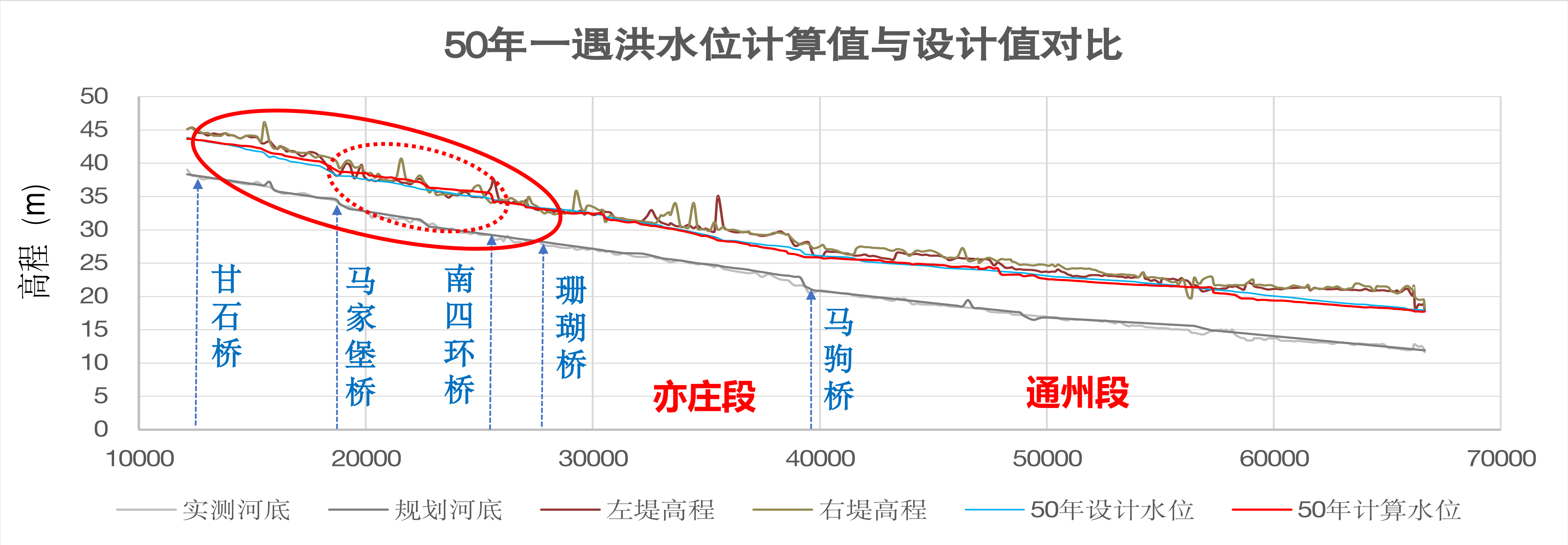
4 Analysis of River Flooding Capacity and Flood Control Safety

4.1 The variation of water surface profile



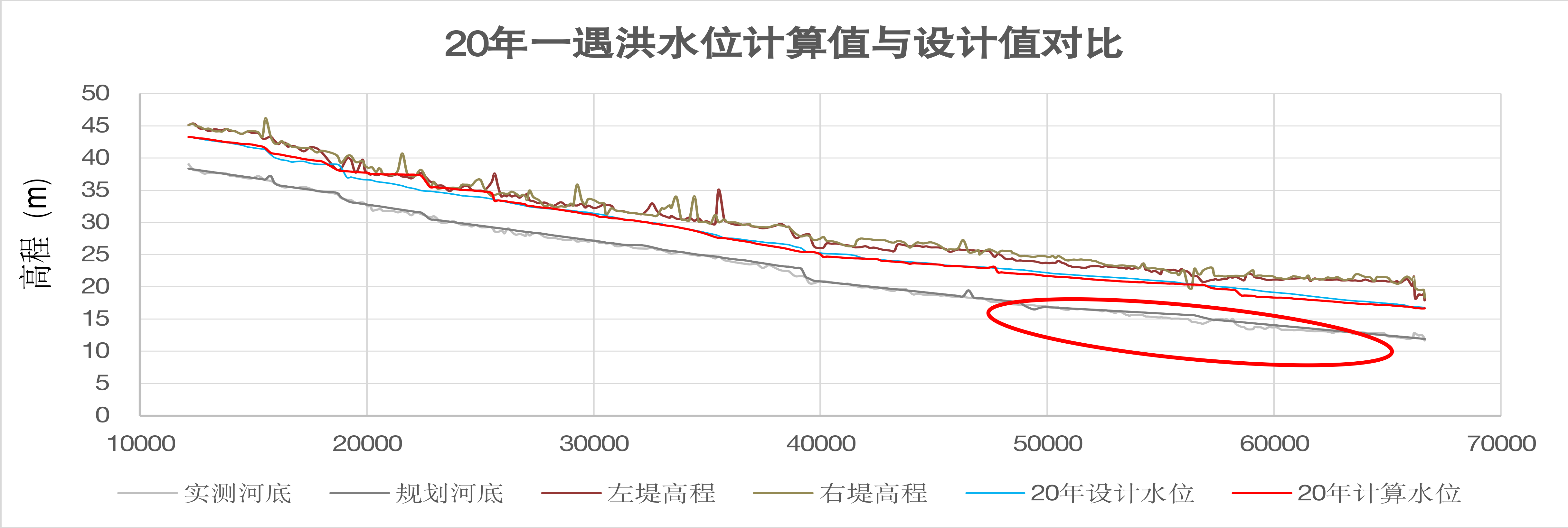
The river section from Gan Shi Bridge to Shan Hu Bridge has seen a significant increase in the water levels for the 20-year and 50-year flood events compared to the design values, with an average increase of 0.60m and 0.58m, respectively. In particular, the flood conveyance capacity of the river section from Ma Jia Pu Bridge to Nan Si Huan Bridge has noticeably decreased, with the average increase in water levels for the 20-year and 50-year flood events being 1.14m and 0.70m, respectively.

4.1 The variation of water surface profile



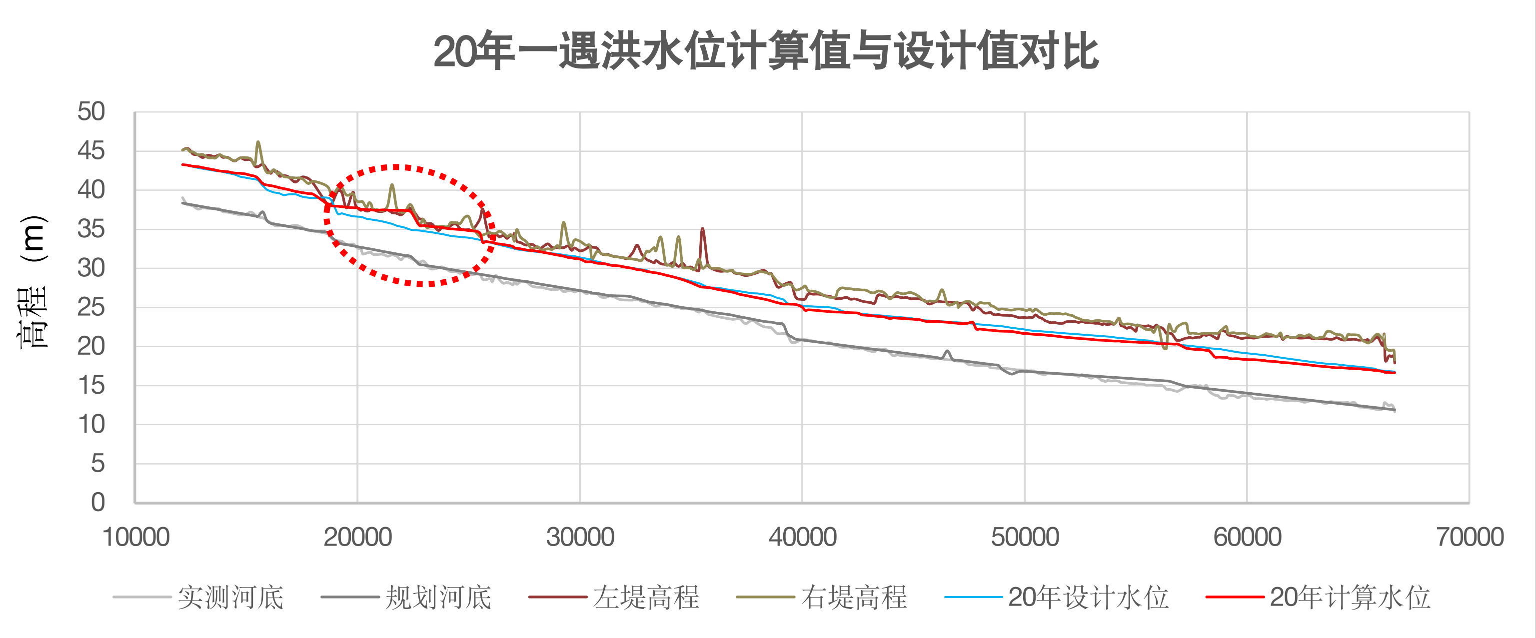
In addition to the average increase of 0.27m in the 50-year flood level for the river section downstream of Jinghai Road Bridge to the downstream of Yangtian Bridge, and the average increase of 0.07m in the 50-year flood level for the river section 1300m upstream of Zhangjiawan Sluice Bridge, the flood conveyance capacity of other river sections meets the planning requirements, and the average levels of the 20-year and 50-year flood levels have decreased by 0.37m and 0.41m, respectively.

4.1 The variation of water surface profile



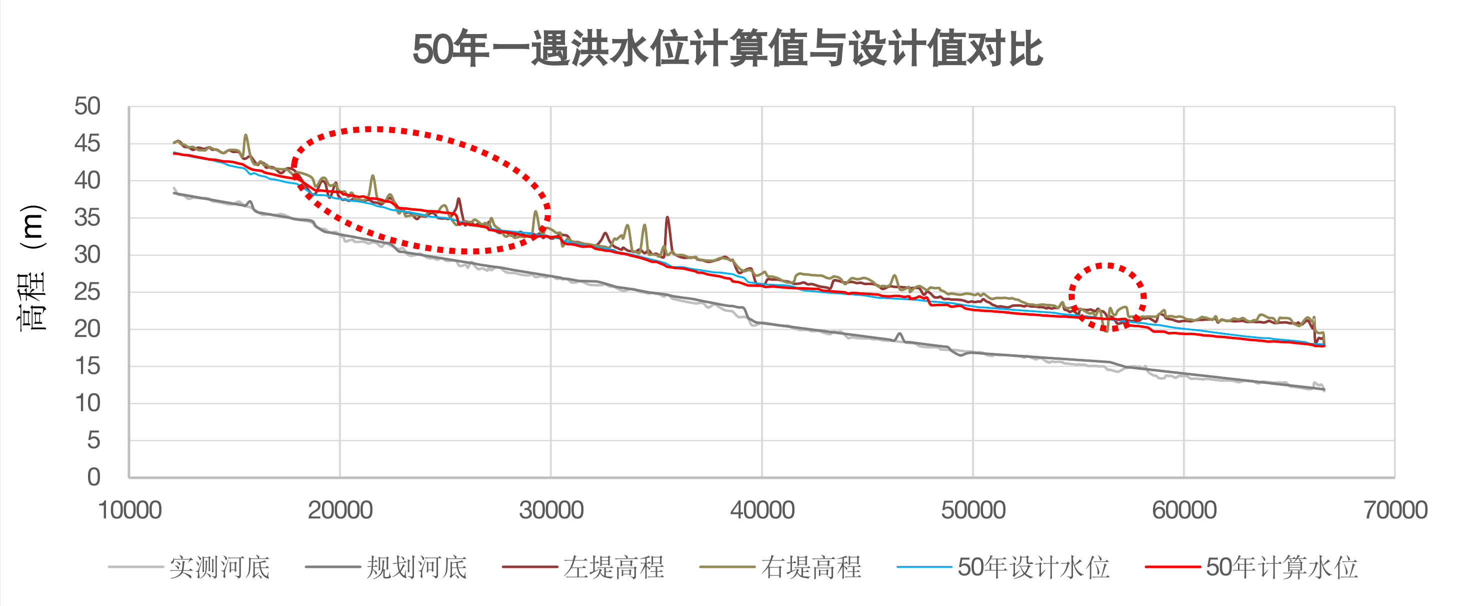
- After the completion of the Liangshui River water environment comprehensive governance project maintenance in 2020, no further work related to river dredging has been carried out, resulting in severe sedimentation in the river section from Youwaiguanxiang Bridge to Nanwuhu Bridge of the Liangshui River;
- In the Tongzhou section, the elevation of the riverbed at most cross-sections is lower than the planned design value. Therefore, except for some sections, the current flood levels of the river for 20-year and 50-year events are reduced compared to the designed values.

4.1 The variation of water surface profile

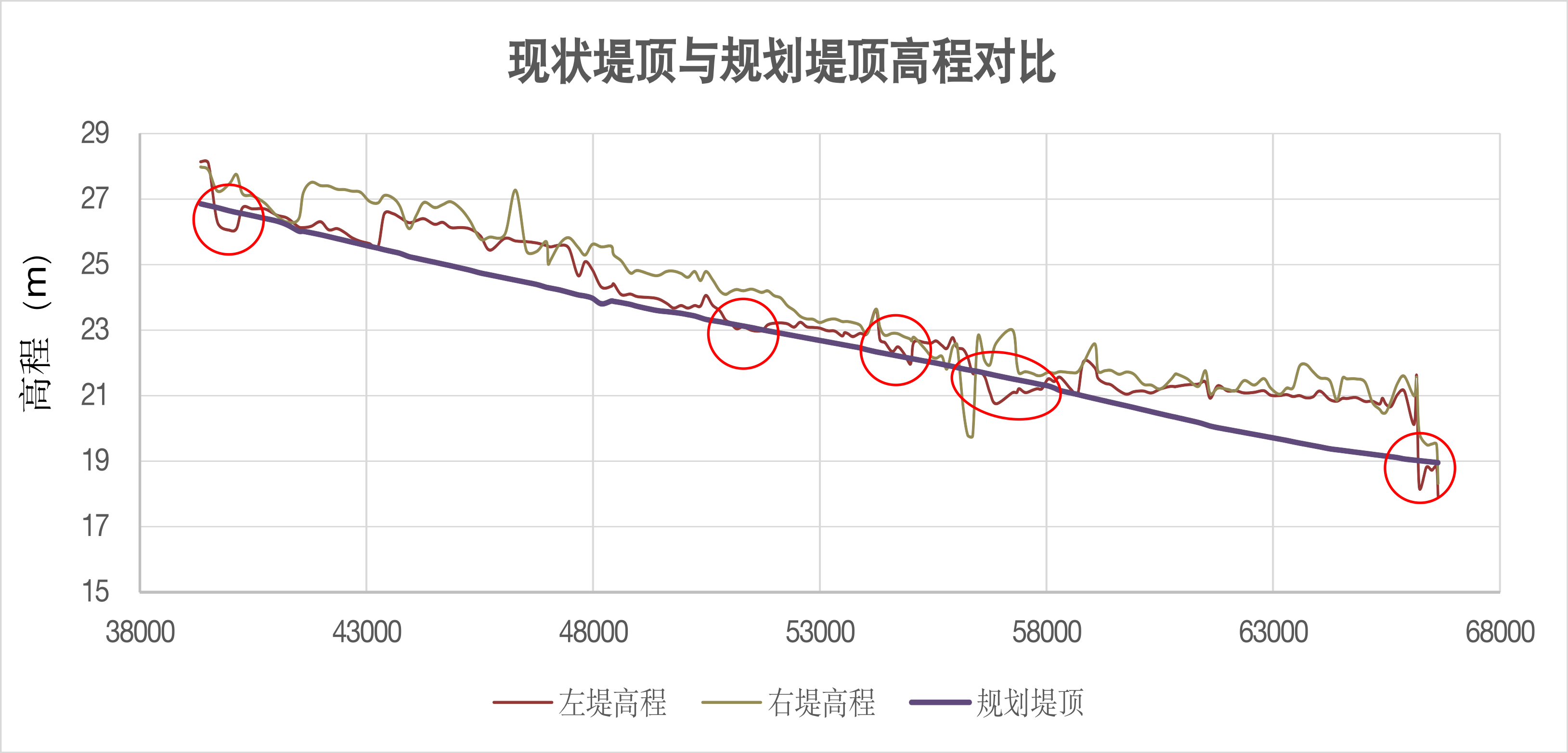


- The reduction in the flood conveyance capacity of the river has led to overflows occurring during 20-year flood events at sections downstream of the Majiapu East Road Bridge to the downstream of the Guangcai Bridge, and downstream of the Nan Si Huan Bridge.

- Overflows occur during the 50-year flood events at sections of the river downstream of the Yangqiao Dam to the downstream of the Nan Si Huan Bridge, downstream of the Shanhu Bridge to the upstream of the Jiugong Bridge, and at parts of the river upstream and downstream of the Lingxiu Bridge, as well as at parts of the river upstream of the Zhangjiawan Sluice Bridge.



4.2 Levee Top Elevation Analysis



- Six levee segments have insufficient top elevations.
- In the Tongzhou section, there are six levee segments where the top elevation has not reached the design elevation, with a total length of 3160 meters.

4.3 Structural Safety Analysis of Levees

序号	位置			规划	现状
	堤段	起始桩号	终止桩号		
1	回民公墓段	56+620	58+400	新筑左岸堤防，规划堤顶高程**21.83**~21.34m，堤顶宽度10m，背水坡设计边坡1：2	**未实施筑堤**，现状堤顶高程**21.48**~21.34m，现状边坡比约1：1
2	紧邻沟渠段	47+350	48+350	新筑左岸堤防，堤顶宽度10m，背水坡设计边坡1：2	河道堤外坡**未放坡**，现状边坡比约1：1
		49+150	49+800		
3	民俗博物馆段	47+050	47+350	新筑左岸堤防，堤顶宽度10m，背水坡设计边坡比1：2	河道堤外坡**未放坡**，现状边坡比约1：1

4.3 Structural Safety Analysis of Levees

Calculation of operating conditions and the minimum safety factor permitted by the Simplified Bishop's method

计算工况	运行条件		
	正常运用条件	非常运用条件I	非常运用条件II
最小安全系数	1.35	1.25	1.15

桩号	水位条件（m）	安全系数（括号内为规范要求最小值）
47+500	常水位 22.00	1.503（1.35）（安全裕度 1.11）
	20 年水位 23.11	1.492（1.35）（安全裕度 1.10）
	50 年水位 24.05	1.479（1.35）（安全裕度 1.09）
58+400	常水位 16.50	1.483（1.35）（安全裕度 1.09）
	20 年水位 19.95	1.473（1.35）（安全裕度 1.09）
	50 年水位 20.87	1.472（1.35）（安全裕度 1.09）

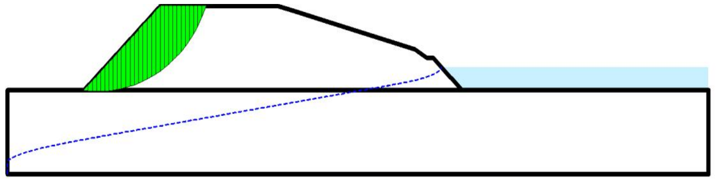


图 2.3-4　58+400 断面常水位下堤防外侧边坡临界滑面位置

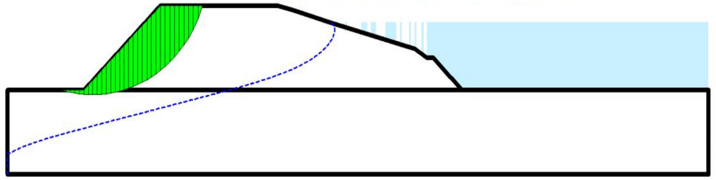


图 2.3-5　58+400 断面 20 年水位下堤防外侧边坡临界滑面位置

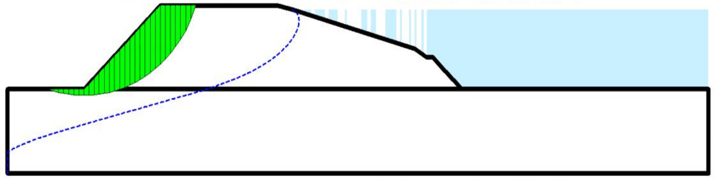


图 2.3-6　58+400 断面 50 年水位下堤防外侧边坡临界滑面位置

- Under each calculated working condition, the stability safety coefficient of the embankment slope against sliding meets the specification requirements. However, considering the frequent occurrence of extreme weather in recent years, it is conservatively estimated that under an actual slope ratio of 1:1, the safety margin of the stability safety coefficient for the dam slope is relatively low (with a maximum of only 1.11), indicating a risk of slope instability in extreme scenarios.

4.4 Impact Analysis of Water-blocking Structures Water-blocking Bridge

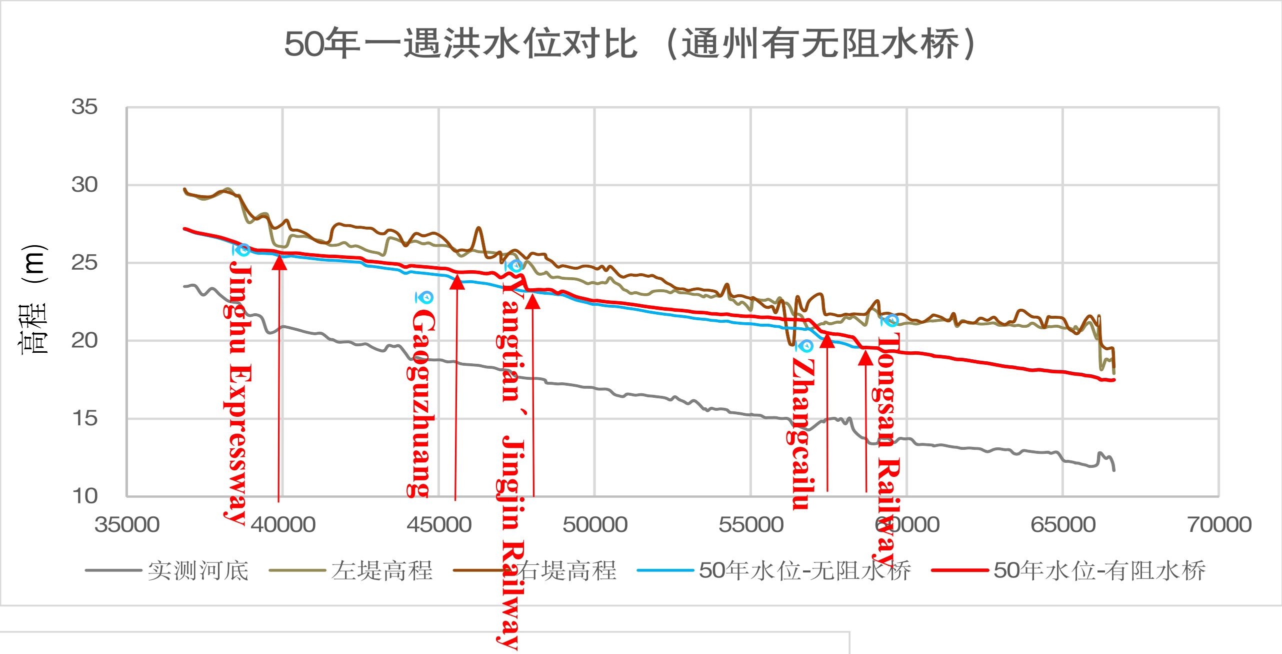
The actual over-water cross-sectional area of six bridges has been reduced by 15.5% to 43.2% compared to their design values, with the Tongsan Railway Bridge experiencing the most significant narrowing at 43.2%. Additionally, there is a large earth mound on the left bank upstream of the bridge, creating a continuous water-blocking structure.

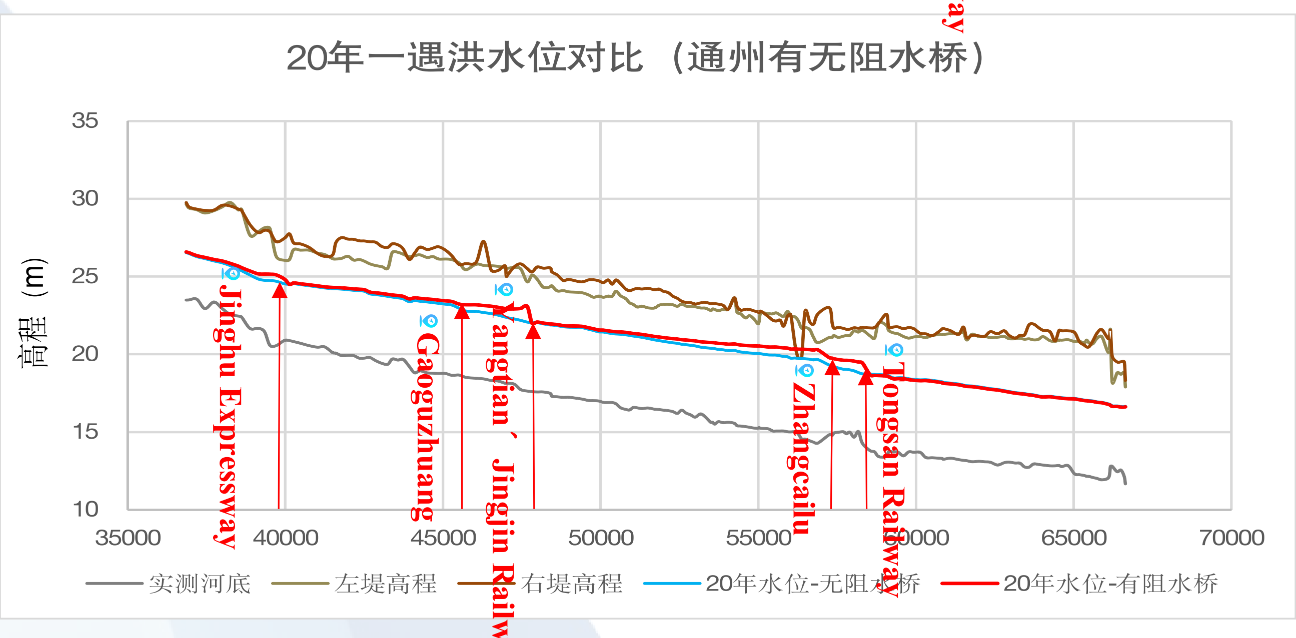
No.	Bridge	Location				Change in Cross-Section		
		Stake	Region	Longitude	Latitude	Design (m^2)	Existing (m^2)	amplitude
1	Tongsan railway	58+440.2	Zhangjiawan	116°43′07″	39°50′25″	851	484	-43.2%
2	Haiziwa Bridge	61+754.2	Zaolinzhuang	116°44′59″	39°49′23″	774	1004	29.7%
3	Zhangcai Road	57+014.7	Kuanjie	116°41′59″	39°50′12″	855	612	-28.3%
4	Yangtian	47+778.8	Yangtian	116°38′37″	39°46′49″	849	651	-23.3%
5	Jingjin Railway	47+608.1	Yangtian	116°38′31″	39°46′47″	847	644	-23.9%
6	Gaoguzhuang	45+642.6	Gaoguzhuang	116°37′10″	39°46′41″	830	701	-15.5%
7	Jinghu Expressway	40+023.1	Beimenkou	116°33′25″	39°46′07″	740	579	-21.8%

4.4 Impact Analysis of Water-blocking Structures Water-blocking Bridge

Impact of water blockage in six bridge areas and stacked gate areas

- Maju bridge：stake 39278
- Xinhe gate：stake 49276
- Zhangjiawan Gate：stake 57165





Analysis of changes in river flood conveyance capacity

- The current water levels in the downstream section of the river from Ganshi Bridge to Shanhu Bridge for the 20-year and 50-year flood events have significantly exceeded the design values, with average increases of 0.60 m and 0.58 m, respectively. In particular, the flood conveyance capacity of the river channel from Majiapu Bridge to the South Fourth Ring Road Bridge has been notably reduced, with average water level increases of 1.14 m and 0.70 m for the 20-year and 50-year events.
- The flood conveyance capacity of the Yizhuang section of the river has increased, and the water levels for the 20-year and 50-year flood events have been reduced by an average of 0.20 m and 0.24 m.
- In the Tongzhou section, except for the downstream of Jinghai Road Bridge to the downstream of Yangtian Bridge, where the average water level for the 50-year flood event has increased by 0.27 m, and the upstream 1300 m section of Zhangjiawan Gate Bridge, where the average increase for the 50-year flood event is 0.07 m, the flood conveyance capacity of other river sections meets the planning requirements. Additionally, the water levels for the 20-year and 50-year flood events have been reduced by an average of 0.37 m and 0.41 m.

5.1 Conclusions

Flood Overflow Risk

- During the 20-year flood event, there will be a risk of overflow in some sections of the river from the downstream of Majiapu East Road Bridge to the downstream of Guangcai Bridge, as well as downstream of the South Fourth Ring Road Bridge.
- In the event of a 50-year flood, there will be a risk of overflow in sections of the river from the downstream of the Yangqiao Rubber Dam to the downstream of the South Fourth Ring Bridge, from the downstream of the Coral Bridge to the upstream of the Old Palace Bridge, in some sections upstream and downstream of the Lingxiu Bridge, as well as in some sections upstream of the Zhangjiawan Gate Bridge.
- The left bank of the bridge area of the Beijing-Shanghai Expressway and six levee sections around the Zhangjiawan Gate Bridge, where the measured levee elevations have not reached the design specifications, are also at risk of overflow.

5.1 Conclusions

Impact Analysis of Water-Blocking Facilities

- The actual cross-sectional areas of water flow at the six bridges have been reduced by 15.5% to 43.2% compared to the planned sections, with the most significant reduction occurring at the Tongsan Railway Bridge, where the cross-section has narrowed by 43.2%. Additionally, there is a large earth mound on the left bank upstream of the bridge, creating a continuous water-blocking structure.
- The current 20-year water level upstream of the six water-resistant bridges has increased by 0.052 m to 0.788m compared to the design value, while the 50-year water level has increased by 0.233 m to 1.026 m. Notably, the bottom clearance of the Tongsan Railway Bridge is less than 1 m (only 0.7 m), which severely affects flood safety.

5.2 Recommendations

With regard to river sections currently exceeding the design water levels for 20-year and 50-year floods, river inspections will be intensified during the flood season, particularly in the section from Majiapu Bridge to the South Fourth Ring Road Bridge. Emergency personnel and materials will be deployed, and measures will be taken in advance to address the potential risk of overflow from larger floods.

For the substandard embankments in the Tongzhou section, it is recommended to strengthen monitoring of the sections that do not conform to the design slope, and to implement engineering measures if necessary. Additionally, coordinate with the property rights unit to expedite the completion of requisition and relocation to realize the designed river section as soon as possible.

It is recommended to expedite dredging work for key river sections, including those upstream and downstream of the Guangcai Bridge and five deep pools. Regular monitoring of river siltation changes will be conducted before and after the annual flood season, along with ongoing desilting efforts.

Thank your

中国水利水电科学研究院
China Institute of Water Resources and Hydropower Research