Modelling the Hydrologic Impacts of the Nanting River Regulation and On-site Validation in the Mengding Urban Area, China-Myanmar

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Abstract. The Nanting River runs through China and Myanmar, which has been planned to be renovated as the urban river of Mengding City, Yunnan. In order to make the river regulation works more efficient, different river discharges are tested in the 1-D and 2-D numerical models to investigate the variation of river hydrology and local flow field profiles before and after the construction works. The results are used to validate the feasibility of designed river parameters (including the width and the depth) and assess the correlation impacts. It proves that: 1) The Nanting River is a typical southern mountain river, of which the discharge has a great difference between rainy and dry seasons. The waterscape and flood control capability of different discharges should be considered for both ecological environment and flood control safety. 2) 1-D model is benchmarked against the on-site measurement data. The results indicate that 1-D model has the capability to simulate the hydrological characteristics before and after the regulation works and represent the influence of upstream and downstream flow. The results can be used as the boundary conditions in the 2-D model. 3) The simulations of the local flow field with different flow discharges are carried out by a 2-D numerical model. Those results are used for the assessments of the project layout and the revetment protection. 4) During the implementation of the regulation works, this project experienced the extreme flood which was close to the defense limit. Moreover, an earthquake and several floods hit this region. The structures survived and maintained in good condition in the hazards which proves that this regulation project is successful and necessary and the research method is valid and efficient.

1. Introduction

The Nanting River is a tributary on the left bank of the Nujiang-Salween River (referred to “Nujiang River” in China and “Salween River” in Myanmar) which flows through China and Myanmar. Its basin area is mostly located in China. The total length of the main channel is about 264 km in China and 20 km in Myanmar. The river originates from the Linxiang District (Lincang City, Yunnan Province) and runs along the geologic fault lines to the southwest, joining the trunk stream of the Nujiang-Salween River near Kunlong Town, Myanmar, and its middle reach runs through Mengding
City. Compared with the upstream in the mountainous regions, the river in the Mengding urban area has a gentle longitudinal slope due to the plain terrain. The Nanting River is designed to be renovated as the urban centre river in Mengding city according to the master plan. Therefore, the relative department decided to carry out a river regulation project of 7.4 km long to achieve following objects: 1) ensure the flood control safety; 2) improve the ecological environment; 3) promote the urban development; 4) enhance the value of surrounding lands and 5) provide more living and leisure places. This project is helping to accelerate the progress of “first-class port” construction in Mengding City which plays a significant role in “gateway” strategy of Yunnan Province. The works of this project mainly involve building and rebuilding dikes, river dredging, building three eco-friendly sluices and afforestation on the river banks [1]. The construction of new sluices and dikes would certainly change local flow characteristics and cause some effects on both upstream and downstream. For this reason, the author uses 1-D and 2-D numerical models to simulate the flow field of the Nanting River before and after the regulation works respectively. The variation of hydrological characteristics is analysed to validate the feasibility of designed river parameters (including the width and the depth) and assess the correlation impacts. During the construction period, this project experienced an earthquake hazard and several floods while the structures still remained intact. The on-site measurement indicates that some flooding flows have been close to the defense limit, which has been predicted by the numerical models.

Figure 1. Distribution of the water system and the hydro-meteorological station network in the Nanting River Basin

2. Overview of the Nanting River Basin

2.1. The River System
The Nanting River Basin in China is located in the central part of Lincang City, Yunnan Province, and runs through six counties, i.e. Lincang, Yunxian, Yongde, Zhenkang, Gengma and Cangyuan. The southwestern part of the basin is the main stream of the Nujiang River (Salween River); the northern part contains a primary tributary (named Meng Baltic River) on the left bank of the main stream of the Nujiang River and a primary tributary (named Luozha River) on the right bank of the main stream of the Lancang River; the eastern part is a primary tributary (named Xiaohei River) on the right bank of
the main stream of the Lancang River. The geographical location of the river basin in latitude and longitude is 23°18′~24°20′ north and 98°41′~100°14′ east.

The Nanting River System belongs to the Nujiang-Salween River basin. Its main stream originates from a 2,480m-high mountain named Liangshan which is located in the southwest of Yongquan Village (at Boshang Town, Linxiang District)[2]. From the riverhead, the main stream flows from south to north, passing through Boshang Town, Linxiang District, Mayidui Township and Yangtouyan in sequence. It joins the Toudaoshui River at Yangtouyan and then turns to northeast-southwest direction, passing through the alpine and gorge regions, including Xingfu Town in Yun County, Snow Mountain in Yongde County and Chonggang Town in Yongde County, etc. After leaving the gorge regions, it enters into two large alluvial plains, i.e. Mengjia Township in Zhenkang County and Mengding Town in Gengma County. Then it goes into gorge regions again and exits from China and enters into Myanmar at the Qingshui River Gate (Mengding Town, Gengma County). It runs about 20 km and finally joins the Salween River in Kunkong, Myanmar. It has a total length of 264 km and a basin area of 8,097 km² (Figure. 1) in China, overall falling 2,090 m with an average slope of about 4‰. The characteristics of the main stream and the tributaries are shown in Table 1.

2.2. The Meteorology
The elevation of the Nanting River Basin ranges from 450 m to 3,504 m. The local climate has great differences at different altitudes due to the complex topography. In the area around the watershed line and the Yongde Mountains, the temperature is low and it gets cold in winter and cool in summer. However the areas of river valley and basin plain with low altitude are pretty warm. In general, the Nanting River Basin, as a median mountainous region, has a typical humid, three-dimensional subtropical climate, with distinct wet and dry seasons. The basin area has an average annual temperature of 17-22 °C, daylight time of 1,900-2,200 h and average annual evaporation of 1,500-2,000 mm. The distribution of the annual precipitation in the basin decreases from southwest to northeast but increases in all regions as the elevation increases. The average annual precipitation is between 1,100 mm and 2,700 mm. Affected by the topography, the precipitation in the rainy season (May to November) accounts for 90% of the total annual precipitation. The spatial and temporal distribution of precipitation is extremely uneven in a year but the inter-annual variation is small. Mengding Town, located near the Tropic of Cancer, has a subtropical monsoon climate with long sunshine time, four summer-like seasons, frost free all year round, and an average annual temperature of 21.7 °C.

2.3. The Hydrology
The runoff in the Nanting River Basin is mainly supplied by the southwest warm and humid airflow from the Bay of Bengal on the Indian Ocean (atmospheric precipitation of the water vapor). The basin has an average annual runoff of 5.68 billion m³, average annual runoff depth of 701 mm and runoff
yield modulus of 700,000 m$^3$/km$^2$. The inter-annual variation of the runoff is stable, with the variation coefficient of about 0.20-0.26.

Heavy rains play significant roles in the flooding of the Nanting River Basin. The floods in the downstream mainly come from the Nanpeng River on the right bank and the Xiaohei River on the left bank. The floods in the upstream of the Mengding Dam are mainly from the tributaries on the left bank, and the upstream river (Toudaoshui River) (Table 2). According to the measurement data of the hydrological stations in the basin, floods usually appear from June to November. Among them, the flood occurrence frequency of the main stream is about 72.3% from July to August, and that of the Nanpeng River is 80% from July to August approximately. In the upstream river (Mengpeng River), and other tributaries, most floods occurred between June and September. The corresponding modulus of flood peak is small due to the low probability of heavy rains covering large area in the basin. The Gulao River Hydrological Station is the main station on the Nanting River, located in the boundary of the middle and lower reach. It has a controlled drainage area of 4,185 km$^2$, which accounts for 52% of the total drainage area of the Nanting River [2]. In the historical record, The Gulao River Hydrological Station had a maximum flow rate of 1,220 m$^3$/s in 1953.

| Name of Stations | Monthly Occurrence Frequency | P (%) | Total |
|------------------|-----------------------------|-------|-------|
|                  | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Σ    |
| Gulao River      | 0   | 9.1  | 34.1 | 43.3 | 4.5  | 4.5  | 4.5  | 0    | 100  |
| Xuanlai          | 0   | 0    | 44.0 | 56.0 | 0    | 0    | 0    | 0    | 100  |
| Dawen            | 0   | 14.3 | 38.1 | 28.6 | 11.9 | 4.7  | 2.4  | 0    | 100  |
| Fengwei          | 0   | 11.5 | 31.4 | 31.4 | 11.4 | 8.6  | 5.7  | 0    | 100  |
| Xihe             | 0   | 19.4 | 29.0 | 25.8 | 16.1 | 3.2  | 6.5  | 0    | 100  |
| Mengpeng         | 0   | 30.8 | 7.7  | 30.8 | 23.1 | 7.7  | 0    | 0    | 100  |
| Toudaoshui       | 0   | 21.7 | 26.1 | 30.4 | 13.1 | 8.7  | 0    | 0    | 100  |

2.4. The Sediment
The Nanting River Basin contains various types of soil erosion. They are widely distributed and some of them are in dangerous conditions, especially in the upper and middle reaches. The main soil erosion types can be found including stratified erosion, gully erosion, landslide, collapse, mudslide, etc [3,4]. Based on the measurement of the river bed elevation at the Gulao River Station and the Dawen Station in recent years, the sediment in the upstream of the Dawen Station tends to decline by years while the sediment transportation between two stations increases every year.

According to the measurement of the suspension and bed loads distribution with different water levels in the Gulao River Station, the local sediment is mainly composed of fine, coarse clay grains, sands, and gravels (some pebbles). The size of the suspension load is among 0.002 mm and 0.08 mm, and that of the bed load is between 0.077 mm and 50.0 mm.

3. River Regulations

3.1. Status of the Nanting River in the Mengding Urban Area
The Nanting River in the Mengding urban area has a typical wandering riverbed. The river width is about 125-350 m. A large number of areas of mudflat are distributed in both sides of the river. While the water surface remains low, sand islands can be found in the main channel. On the river edges, the scarp of the mudflat is steep due to the erosion effect. The river bank is protected by the earth dike, with a crest width ranged from 3m to 5m which can defense flooding in 1-in-10 year event. An emergency rescue project was carried out in the reach between the Nanmusuan Bridge and the Hehai Bridge in the first half of 2012. The newly built dike have a flood control capacity of 1-in-20 year event. The width of the local river is about 200 m and the alluvial islands are distributed randomly due to the wandering river flow.
3.2. Regulation Schemes
To get a better urban waterscape and increase the flood control safety, several objects had been considered including building eco-friendly dikes [4] along the Nanting River in the urban area, restoration of the mudflat which has been seriously eroded, building three sluices with great looking design base on the river assessment. Moreover, in order to settle down the river channel, it was proposed to construct a division dike between the Nanmusuan Bridge and the Hehai Bridge where the river bank had been newly protected, and reserve a buffer land with a certain width at the dike feet.

The locations of the three sluices were selected by considering river flow conditions, surrounding water system and waterscape [1]. The Xincun Road Sluice is near the upstream boundary of the city. The Hehai Sluice is located at the downstream of the Hehai Bridge by comparing with the upstream location plan. The Xincheng Avenue Sluice is near the downstream boundary of the city (figure 2). All three sluices were constructed in the main channel, designed with 3x30m underwater plain gate [5-6]. When the river discharge is less than the average, the sluice gates are applied to impound the water thus the area of water surface can be increased for a better scenery view. When the river discharge is over the average, the gates will lie down on the river bed for the flooding. The crest height of the sluice was determined by calculating the interaction of river branches and the antiscour capability.

![Figure 2. Water system and sluice locations in the Mengding City area](image1)

![Figure 3. Simulation domain of the 1-D hydrodynamic Model](image2)

3.3. Regulation Standards and Parameters
According to the Master Plan of Mengding City and “Standard for flood control (GB50201-94)”, the city is ranked as Class IV and the urban flood control standard is 1-in-20 year event. The flood control capability was calculated based on the long-term floods records of the hydrological station located in the Gulao River (the main stream of the Nanting River) and by the regional comprehensive formula method. The flood occurred in 1953 ($Q_{m}=1220$ m$^3$/s) was treated as an extraordinary value. According to the on-site measurements, the region where the Xincun Road Sluice is located has an average annual runoff of 102 m$^3$/s, average peak flooding rate of 690 m$^3$/s. In the 1-in-5 year and 1-in-20 year event, the flooding discharges are about 878 m$^3$/s and 1,230 m$^3$/s respectively. The region where the Xincheng Avenue Sluice is located has an average peak flooding rate of 718 m$^3$/s. The flooding discharges in 1-in-5 year and 1-in-20 year event are 914 m$^3$/s and 1,230 m$^3$/s.

The river width was determined by giving considerations to the urban development, flooding discharge and mudflat utilization. The Master Plan of Mengding City shows that the population of the central urban area will increase year by year, hence the demand for the urban land will increase greatly. However the city is surrounded by mountains, that the available land is limited. Therefore, the relative department pointed out that the layout of the river regulation works should base on the following objects: 1) In the reach from the Nanmusuan Bridge to the Hehai Bridge, the layout of new dikes should follow the current river banks; 2) In the rest of the reach, the width of the river should be retained more than 150m in general, the minimum width should be more than 125m.
The elevation of the river bottom and its longitudinal slope were designed based on the current river state, partially adjusted. The longitudinal slope of the reach upstream of Nanmusuan Bridge was set at 1:850. In the reach from the Nanmusuan Bridge to the Hehai Bridge, and the downstream of the Hehai Bridge, the slope gradient was set at 1:600 and 1:1000 correspondently. The width and depth of the main channel were designed based on the prescribed flood control capability, channel hydrology, flow discharge, riverbed roughness and current longitudinal slope. The width of main channel was initially set at about 100m. The average flooding discharge was used as the designed mean flow rate in the main channel. By taking the current elevation of the mudflat into account, the water surface profile of the prescribed flooding was defined. The height of the dike was increased to meet the desired flood control capability.

4. Research Method

In order to simulate the river flow before and after the regulation works more precisely, a coupled 1-D and 2-D hydrodynamic model is applied in this research [7-9]. In which, the simulation domain of the 1-D model ranges from the Gulao River Hydrologic Station in upstream to the Dawan River Hydrological Station in downstream. A 2-D numerical model is implemented to provide flow field details in the Mengding urban area. The results obtained from 1-D model are used as the boundary conditions of the 2-D model.

4.1. 1-D Hydrodynamic Model

The equation of the 1-D hydrodynamic model is written as:

\[
\frac{\partial Q}{\partial t} + \frac{\partial A}{\partial t} = q
\]

where \(Q\) is the discharge, m\(^3\)/s; \(A\) is the flow area, m\(^2\); \(q\) is the lateral inflow, m\(^3\)/s; \(h\) is the stage above datum, m; \(C\) is the Chezy resistance coefficient, m\(^{1/2}\)/s; \(R\) is the hydraulic or resistance radius, m; \(\alpha\) is the momentum distribution coefficient.

The simulation covers the region from the Gulao River Hydrologic Station in upstream to the Dawan River Hydrologic Station in downstream. The total length of the Nanting River is about 38km, including following branches: Nanwang River, Nanwen River, Nandi River, Nanwa River, Xiaohei River and Nanpeng River (Figure 3). The local head losses due to the lakes, bridges, barrages and sluices have been taken into account to ensure the numerical simulation close to the realistic conditions.

The roughness coefficient “\(n\)” of the river bed is related to the soil texture, lining condition, surface roughness, water depth and water temperature. According to the on-site investigation and construction experience, and by the reference “Natural Riverbed Roughness Table of Yunnan Province”, the roughness of the main channel is set as 0.025 and that of the mudflat is set as 0.032–0.045.

The prescribed flow rate is given in the inlet boundary and the outlet boundary considers both flow velocity and surface level. The confluences of each river branch are also taken into account in this work. The measured topography and water surface level from November to December of 2011 are used to calibrate and verify the model (Figure 4). The results show good agreement comparing with the measurement data.

4.2. 2-D Hydrodynamic Model

In this work, a 2-D hydrodynamic model is applied which solves simplified Navier-Stokes equations based on the Boussinesq assumption. By integrating the equations in vertical direction, average 2-D velocities and surface level can be obtained from the continuity equation and momentum equations.
Finite volume method is used to discretize the equations on the topographic grids. Such 2-D model has been widely used in the academic fields [10,11].

\[
\frac{\partial h}{\partial t} + \frac{\partial h u}{\partial x} + \frac{\partial h v}{\partial y} = h S
\]

(3)

\[
\frac{\partial h u}{\partial t} + \frac{\partial h u^2}{\partial x} + \frac{\partial h u v}{\partial y} = \frac{1}{\rho_0} \frac{\partial}{\partial x} \left( \frac{\partial s_{xx}}{\partial x} + \frac{\partial s_{xy}}{\partial y} \right) + \frac{\partial}{\partial x} \left( hT_u \right) + \frac{\partial}{\partial y} \left( hT_y \right) + h u_S
\]

(4)

\[
\frac{\partial h v}{\partial t} + \frac{\partial h u v}{\partial x} + \frac{\partial h v^2}{\partial y} = \frac{1}{\rho_0} \frac{\partial}{\partial x} \left( \frac{\partial s_{yx}}{\partial x} + \frac{\partial s_{yy}}{\partial y} \right) + \frac{\partial}{\partial x} \left( hT_y \right) + \frac{\partial}{\partial y} \left( hT_{yy} \right) + h u_S
\]

(5)

where \( t \) is the time, \( x \) and \( y \) are the Cartesian co-ordinates, \( m; \eta \) is the surface elevation, \( m; d \) is the still water depth, \( m; h=\eta+d \) is the total water depth, \( m; u \) and \( v \) are the velocity components in the \( x \) and \( y \) direction, \( m/s; f=2\Omega \sin \phi \) is the Coriolis parameter (\( \Omega \) is the angular rate of revolution and \( \phi \) is the geographic latitude), \( 1/s; g \) is the gravitational acceleration, \( m/s^2; \rho \) is the density of water, \( kg/m^3; \rho_0 \) is the reference density of water, \( kg/m^3; s_{xx}, s_{xy}, s_{yy} \) and \( s_{yx} \) are components of the radiation stress tensor, \( kg/s^2; (\tau_{xx}, \tau_{yy}) \) is the surface stress, \( kg/s^2*m; \) (\( \tau_{xx}, \tau_{yy} \)) is the bottom stress, \( kg/s^2*m; S \) is the magnitude of the discharge due to point sources, \( 1/s; (u_x, v_y) \) is the velocity by which the water is discharged into the ambient water, \( m/s; T_{xx}, T_{xy}, T_{yy} \) is the lateral stress, \( m^2/s^2 \),they are estimated using an eddy viscosity formulation based on the depth average velocity gradients:

\[
T_{xx} = 2A \frac{\partial \overline{u}}{\partial x}, \quad T_{xy} = A \left( \frac{\partial \overline{u}}{\partial y} + \frac{\partial \overline{v}}{\partial x} \right), \quad T_{yy} = 2A \frac{\partial \overline{v}}{\partial y}
\]

(6)

\[
A = c_l^2 l^2 \sqrt{2S} S, \quad S_{ij} = \frac{1}{2} \left( \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) (i,j=1,2)
\]

(7)
where $A$ is the horizontal eddy viscosity, m$^2$/s; $c_s$ is a constant, should be chosen in the interval of 0.25 to 1.0; $l$ is a characteristic length, m.

Manning’s roughness $n$ is taken as $n=0.025$ for main channel, and $n=0.033$ for beach land, consistent with the 1D model.

The model verifies the change of the river boundary by recognizing the wet and the dry zones. If the water depth is less than 0.005m, where the mesh will be considered as the dry zone and will not be treated in the calculations. If the water depth is larger than 0.1m, the domain will be re-taken into account as the wet zone and calculated by the model.

The inlet boundary of the 2-D model is 2 km away from the starting point of the Nanting River Regulation Works and the outlet boundary is about 5km away. The total length of the simulated channel is 3km, covering the entire reach of the old dike reconstruction area (Figure 5). The water surface profile gained from 1-D model is used as the boundary conditions in the 2-D model. The simulation domain is generated by mixed triangular and curved quadrilateral cells, with a total number of 16,986 cells, and 11,185 nodes. The minimum size of the cell is about 1.5 m which is able to accurately represent the river banks and dikes (Figure 6).

The flow rate provided by the 1-D model is used in the inlet boundary, and prescribed water surface level is applied in the outlet boundary. The result of the 1-D water surface profile with a flow rate of 102 m$^3$/s are compared with the result of the 2-D model and good agreement is found.

![Figure 5. 2-D hydrodynamic model scope and verification point](image1)

![Figure 6. Topography and generalization net near the lock](image2)

5. Results and Analysis

Simulations are carried out by three different flow rate of 102 m$^3$/s, 690 m$^3$/s and 1,230 m$^3$/s respectively to investigate the change of the hydrological characteristics and the local flow field profiles before and after the regulation works. When the flow rate is 102 m$^3$/s, the sluice gates are closed and when the flow rate is 690 m$^3$/s or 1,230 m$^3$/s, the gates remain opened.

5.1. Water Level Along the River

The simulation result of the average annual flow rate condition (Figure 7) shows that after the implementation of the regulation works, the water surface in the downstream of the dikes has a general decrease due to the hammed water in the upstream. The water surface at 1.5 km upstream of the construction area increases about 0.23 m and at 0.5 km downstream of the construction area it decreases slightly by about 0.07m.

At the 1-in-20 year flooding condition, the region of the hammed water in the upstream expands to 2.5 km, however the maximum water level only increases 0.09m after the construction work. The effects at the downstream is insensitive while the water level at 0.2 km downstream of the dike has a slight decrease due to the dredging work. In general, the results of numerical model indicate that the
proposed width and depth of the river are basically feasible and the dike constructions have no effect on the flood control.

\[ Q = 102 \text{ m}^3/\text{s} \]  
\[ Q = 1230 \text{ m}^3/\text{s} \]

Figure 7. Water level along the river with different flow rates before and after the regulation works

\[ (a) \] Q=102 m$^3$/s  
\[ (b) \] Q=1230 m$^3$/s

Figure 8. Velocity profiles of the construction region with different flow rates Q

\[ (a) \] Q=102 m$^3$/s  
\[ (b) \] Q=690m$^3$/s  
\[ (c) \] Q=1230 m$^3$/s

5.2. Flow Field Profiles

The changes of the flow field profile are mainly found in the region between the Nannusuan Bridge and the Hehai Sluice. Figure 8 illustrates that in the main area of the regulation works, the upstream flow is split up by the division dike and the barrage, while most of the water runs into the main channel on the right hand side and the rest flows into a tranquil lake on the left hand side. At Hehai sluice, overflow only occurs on the top of the gate when the flow rate is 102 m$^3$/s. The flow velocity in the main channel reduces with a maximum speed of 1.05 m/s and a minimum speed of 0.10 m/s and the flow in the lake can be only found at the entrance. In the situation of that the flow rate increases to
690 m³/s, the sluice gate will fall down on the riverbed, thus the river runs through the sluice and the barrage. The average flow velocities in the main channel and the lake are 2.36 m/s and 1.10 m/s respectively, and the maximum speed reaches to 3.33 m/s. When the flow rate turns to 1230 m³/s, the division dike and the sluice are all submerged in the flooding. The average flow velocity in the main channel decreases to 2.11 m/s however that in the lake rises to 2.78 m/s with a maximum speed of 3.74 m/s. In the region around the Nanmusuan Bridge, the flow velocities are considerably large on account of the reduction of the river width and it’s bending effect.

6. On-site Validation

6.1. Flooding Hazards
During the construction period, in 18th -20th July of 2014, the Nanting river basin experienced heavy rainstorms caused by Typhoon Rammasun [12]. The river surface increased rapidly in a very short period. According to the measurement data of the Gulao hydrologic station, the maximum flooding discharge is about 1250 m³/s, which has exceed the designed flood control capability (1-in 20 year event). The flooding lasted for 7 days. Before the flooding occurs, the construction of dike crest heightening and main channel revetment reinforcement had been just finished, however the banks on the mudflat were not protected yet. At the upstream and downstream of the construction site, the flood destroyed the dikes which are below standards, and the farm fields behind (Figure 9). In the construction region, the river banks on the mudflat were seriously eroded. However, the flooding was still kept in the range of the river and the revetment of the main channel were well protected (Figure 10).

Figure 9. Upstream river state after the flooding
Figure 10. Details of the dike structure after the flooding

6.2. Regulation Work Achievements
The river regulation project has achieved the aims of both flood defense and ecological friendly strategy and has been verified by several floods in the rainy season (Figure 12). At 18:24, 1st of March, 2015, a 5.5-magnitude earthquake hit Mangka Town (99.0 degree east and 23.5 degree north). The focal depth is about 11 km and 20 km away from the regulation domain [13]. Based on the “5.5-magnitude earthquake distribution in Cangyuan, Yunnan Province” provided by Yunnan Seismological Bureau, the maximum seismic intensity in the earthquake stricken area is level VII and covers about 200 km² region which including Mending Town in Gengma County and Mangka Town in Cangyuan County[14], which means the regulation domain is also in this area. However according to the on-site investigation after the earthquake, the main structure of the dike is maintained in good conditions. Only a few cracks are found in the structure of which the maximum width is less than 2cm.
7. Summaries
The Nanting River is a typical southern mountain river, of which the flow rate has a big difference between dry and rainy seasons. It has been designed to be renovated as the urban centre river of Mengding City, therefore the regulation works should consider both flood control capability and waterscape. The hydrology of the river basin is investigated to determine the reasonable mean water level and maximum high-water level in the domain. In order to enhance the waterscape during the dry seasons, sluice gates are implemented to impound the upstream water, meanwhile the flooding safety is secured. The flow velocity of flooding is quite large due to the steep longitude slope which may cause serious erosion damage to the river channel, so the revetments of the river need well protection. To ensure the regulation works are environment friendly, the ecological structure for the revetment protection are selected.

1-D hydrodynamic model is applied to simulate the hydrology of the Nanting River. The variation of the hydrology before and after the regulation works is well represented. The results indicate that the width and depth of the river regulation are well designed which can adapt different flow discharge conditions. The results are also used in the assessments of the river regulation impacts. A 2-D hydrodynamic model is implemented to simulate the local flow field in the construction region by using 1-D model results as the boundary conditions. The results are used as the reference of the project layout assessment and revetment protection. A 5.5-magnitude earthquake and a number of floods struck the construction structures during the implementation of the project and those structures are still maintained in good conditions, which is benefit to the society, economy and environment.

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