2D Hydraulic modelling of the main urban area of Chongqing, Part 2: model validation and application

Hua Ge, Chunyan Deng
Changjiang River Scientific Research Institute, Wuhan 430010, China
gh-102@126.com

Abstract. The main urban area of Chongqing reach is located at the fluctuating backwater area of the Three Gorges reservoir. The operation of the reservoir has a significant impact on the erosion and deposition of this reach, not only the total amount and scope, but also the period in one year. In this paper, a two-dimensional hydraulic mathematical model was built in order to simulate the sediment deposition in this reach. The calibration was carried out by using some series of field data to provide the accurate parameters, such as roughness, sediment capacity. And values of roughness, coefficient and index of sediment carrying capacity, saturation coefficient of deposition and erosion are suggested after the calibration.

1. Introduction
The sediment from the Yangtze River is mainly concentrated in the flood season. In the process of flood detention operation of the reservoir for medium and small floods, the sediment from the upstream is also deposited in the reservoir. It is very necessary to make a timely and reasonable sediment operation plan and properly solve the sediment problem in the process of flood operation to do a good job of sediment prediction and prediction of the Three Gorges reservoir. This has also attracted widespread attention [1-8]. In this paper, using the established two-dimensional mathematical model of water and sediment, the typical flood process is selected for erosion and deposition simulation test, and the characteristics of water and sediment movement and riverbed erosion and deposition in the short-term flood process are simulated and analysed.

2. Model validation

2.1. Water level and velocity validation

2.1.1. Calculation conditions. The filed data measured in 2012 were used to carry out the water level and velocity validation. The field data includes 6 measurements. The number of cross-sections measured each time is 10, and the measurement covers different periods, including flood, middle and dry seasons. The maximum flow of Cuntan station of the Yangtze River is 35100m$^3$/s and the minimum flow is 3890m$^3$/s, the details of the measurement was shown in table 1. The results of fitting curve in Part 1 are used for the roughness of river reach.
Table 1. Information of the measurements in 2012.

| No | Date         | Jiling River | Upstream of Chaotianmen | Downstream of Chaotianmen |
|----|--------------|--------------|-------------------------|--------------------------|
| 1  | 2012-03-23   | 287          | 3420                    | 3890                     |
| 2  | 2012-04-11   | 1040         | 3310                    | 4280                     |
| 3  | 2012-05-18   | 1630         | 5320                    | 7780                     |
| 4  | 2012-07-29   | 5450         | 29600                   | 35100                    |
| 5  | 2012-09-18   | 2790         | 17800                   | 20200                    |
| 6  | 2012-10-26   | 1430         | 9330                    | 10300                    |

2.1.2. Results of water level validation. Figure 1 shows the calculation results of water level verification. It can be seen that, except for the measurement on July 29, 2012, the error between the calculated water level and the measured water level is relatively small, and the average error is generally within 0.06m. The main reason for the large measurement error on July 29, 2012 is that the maximum discharge of Cuntan station in the main stream of the Yangtze River is only 22400 m³/s, and there is no calibration result when the discharge is greater than this discharge. On July 29, 2012, Cuntan discharge measured was about 35100 m³/s. according to the roughness curve, the roughness was only 0.023, so the calculated water level of Luozi and Egongyan was significantly lower than the measured water level.

![Figure 1](image1.png)

2.1.3. Results of flow velocity validation. Figure 2 is the result of flow velocity distribution validation. It can be seen from the calculation results that the calculated velocity distribution is basically consistent.

![Figure 2](image2.png)
with the measured value, and the accuracy of the model is good. Figure 3 gives two flow field
distribution on 2015-05-18 and 2012-07-29. It can be seen that the main flow direction is consistent with
the river regime, which conforms to the general law of flow movement. In general, the model can better
reflect the flow characteristics of the reach.

2.2. Bed evolution validation

2.2.1. Calculation conditions. The flow and sediment concentration conditions are generalized based
on the daily measured average data. The Jialing River inlet flow is measured at Beibei Station, the
Yangtze River inlet flow is measured at Zhutuo Station, and the downstream water level is measured at
Tongluoxia. The sediment grading of each import uses the monthly average grading data of the
corresponding station. The calculation period is from November 2009 to December 2013. The starting
terrain was measured in November 2009. The values of coefficient and index of sediment carrying
capacity, saturation coefficient of deposition and erosion were taken as 0.24, 0.98, 0.1 and 0.05,
respectively, as suggested in part 1.
2.2.2. **Results of bed evolution validation.** The measured erosion and deposition analysis shows that during the calculation period, the main urban area of Chongqing reach showed a tendency of cumulative deposition. The average sedimentation volume in the period from 2011 to 2013 was about 1.4 million m$^3$, about 90% was taken place during the flood season.

Figure 4 is the calculated cumulative erosion and deposition. It can be seen that deposition plays a key role during the flood period. After that, a weak erosion occurred. During the calculation period, the cumulative sedimentation of Jialing River, up and down stream of Chaotianmen is about 0.66, 2.89, and 1.5 million m$^3$, respectively. The total cumulative sedimentation amount of the whole river is about 5.05 million m$^3$. The average annual deposition amount is about 1.21 million m$^3$. From the comparison between the calculated and measured, the calculated is smaller than the measured. This has a certain relationship with sand extraction in the river. According to the relevant analysis report, a large amount of sediment will deposit in the sand extraction area, which will play a role in promoting sediment deposition to a certain extent. This promoting effect was not taken into account. As a result, it is reasonable that the calculated amount is less than the measured amount.
3. Model application during flood processes

3.1. Information of the flood processes
Three processes, July 12 to 18, 2014, August 3 to 12, 2014, and September 11 to 19, 2014 were selected to carry out the calculation in order to analyze the river bed evolution characteristics during a flood process. The daily average sediment concentration process of each process is shown in Figure 5.

![Figure 5. Sediment concentration during the flood process.](image)

3.2. Sediment deposition during the flood
Table 1 shows the accumulated deposition in the three flood processes. The calculation shows that: the sediment deposition is mainly distributed in the deep channel and backwater area, such as Tongluoxia, Baishatuo and Lijiatuo in main Yangtze River. The deposition in the Jialing River is mainly distributed in the concave bank of the bend, coincident with the sand mining area. The siltation thickness of the main stream is generally within 0.1m.

The scouring and silting characteristics during the three flood processes are basically consistent with the analysis results of the measured data and the calibration and verification calculation results, both of which show an obvious deposition during the flood seasons. The three periods are about 26 days in total, accounting for about 28% of the days from July to September with an amount of about 0.343 million m$^3$ deposition. Based on this situation, the total deposition during the whole flood season is estimated to be about 1.2 million m$^3$.

Table 2. Statistics of the water level error in calibration calculation.

| Period                | Deposition |
|-----------------------|------------|
|                       | Jialing River | Upstream Chaotianmen | Downstream Chaotianmen | All the reach |
| July 12 to 18, 2014   | 0.3         | 5                      | 3                      | 7             |
| August 3 to 12, 2014  | 0.1         | 7.3                    | 2.9                    | 10.3          |
| September 11 to 19, 2014 | 6.1     | 7.4                    | 3.7                    | 17.2          |

4. Conclusion
The filed data measured in 2012, and the daily averaged data from November 2009 to December 2013 were used to carry out the water level, velocity and bed evolution validation. The results shows a good reflection of the flow and sediment deposition characteristics of the reach. Then three flood processes data were used to analyze the sediment deposition characteristics during the flood seasons. The results has shown amount of about 1.2 million m$^3$ deposition during a flood season.

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