Numerical study on the sedimentation at intake of the new water supply project in the LaoYeMiao area of Poyang lake

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Abstract. The water intake of a new water supply project of Lushan City is located on the opposite side of the LaoYeMiao in Poyang Lake. Dredging is required between the shore and the deep trough to allow water to be introduced into the intake during low water season. Based on the intake dredging project, this study established a numerical model of water and sediment transport of the research area. The model is verified in terms of water level, flow velocity, erosion-deposition rate using hydrological and topographical data. The characteristics of water flow and erosion-deposition, before and after the implementation of different dredging schemes, are studied and the influence by dredging project are analyzed from the hydrodynamics perspective. The simulation results show that the water level and flow velocity change before and after the dredging project is less than 0.002m and 0.1m/s. The dredging area before and after the project shows deposition, and the average deposition rate changed by 0.01m/year. research shows that the dredging project only affects the erosion and deposition of the dredging area. The adjustment of the dredging scheme will not have a significant impact on the deposition rate and distribution of the area. The research results can provide a scientific basis for the argumentation and optimization of the water intake dredging scheme.

1. Introduction
In recent years, the water level of Poyang Lake has been decreasing continually [1; 2]. However, the water demand of Lushan City is increasing day by day, and the original water intake pumping station has gradually become unsuitable for the needs of life, production water consumption and water quality. Therefore, Lushan City has put forward a new water supply project with a total designed water supply scale of 80,000m³/d. As shown in Figure 1, the newly-built water intake is located on the opposite of Laoyemiao, 3km upstream of Dujiu Expressway, and the water source is Poyang Lake. The scheme is designed to carry out excavation and dredging between the shore water intake and the deep trough of the lake area to ensure the water supply under extreme low water conditions. Existing data and studies [3] show that the sediment deposition in the dredging project area may affect the overflow capacity of the dredging project within the guaranteed period. So further research to checkout and optimize of the water intake dredging program is needed.

Scholars have carried out a large number of numerical simulation studies on water and sediment transport, evolution of erosion-deposition in Poyang Lake. Yao [4] studied the hydrodynamic changes of Poyang Lake under different sand mining conditions. Zhang Pengfei [5] simulated the process of water and sediment exchange in Poyang Lake by using a two-dimensional mathematical model based on quadrilateral grid and finite volume method. Zhang Peng [6] and Li Haijun [7] established the suspended sediment transport model of Poyang Lake, with the aid of remote sensing data, and
completed the simulation of suspended sediment transport process of Poyang Lake under different hydrology and sand mining conditions. Wang [8] determined the critical starting shear stress of sediment in flood season and dry season through flume experiment, and then studied the transport law of suspended load under different flow conditions by numerical simulation. In summary, the current simulation of water and sediment transport in Poyang Lake mainly focuses on the suspended load in the macro-level of the Poyang Lake, and sediment transport in local areas remains to be further studied.

Based on the dredging project of the new water supply project in Lushan City, the mathematical model of water and sediment transport in the project area is established in this thesis. Based on the measured water and sediment data and topographic data, the flow characteristics and sedimentation of different dredging programs under the continuous water and sediment process are simulated and analyzed, which provides a scientific basis for argumentation and optimization of the dredging programs.

2. Modeling and verification

In this study, the unstructured grid flow model MIKE21 FM [9-12] with non-viscous Sand Transport Module (ST) [13-15] is used to simulate the water and suspended load movement in the project area.

2.1. Establishment of the model

As shown in Figure 1, the research range of the model is 5 km upstream to 4 km downstream of the dredging project, and the upper and lower boundary of the model is perpendicular to the deep trough of the lake. The model have an inflow boundary in the south, an outflow boundary in the north and wall boundary in the east and west. The triangular grid is used to divide the research area, with special refined in dredging engineering area. The research area is divided into 6689 grids and 3505 nodes with the grid size ranging from 900m² to 6000m². The grid is interpolated by using the lake terrain in 2010 with resolution 50m × 50m.

Figure 1. Location of dredging project.
2.2. Verification of the model

The hydrodynamic characteristics of the model are validated by 36-month water level and flow processes from January 2010 to December 2012. Then, the erosion-deposition characteristics of the model are verified by 24-month flow and sediment processes from January 2010 to January 2012.

There are no measured hydrological data at the model exit boundary, but there are Duchang hydrological station and Xingzi hydrological station at the upper and lower reaches of the exit boundary. The model outlet boundary is located in the lake area with small water surface slope. According to the measured water level process of the upstream and downstream hydrological stations, the model outlet boundary water level process is interpolated according to the distance. The downstream Hukou station flow process is approximated as the model upstream inflow boundary process. The sediment concentration boundary conditions of the model is approximated by the process of Hukou.

In the hydrodynamic model, the riverbed resistance is expressed by Manning number, which ranges from 32 to 50 m$^{1/3}$/s. Manning number of deep channel is larger than the shoal area. In the hydrodynamic model, the relative density $\rho_s / \rho$ of sediment is 2.65; Median diameter $d_{50}$ is 0.01 mm; The Manning number of bed surface is 58.2m$^{1/3}$/s.

The hydrodynamic verifying section M1, mentioned in Figure 1, is about 8km upstream of Xingzi station. Because of the small slope of water surface and the gentle change of water level in the lake area, the verifying section water level change should be synchronized with the water level change of Xingzi station. The verification results are shown in Figure 2 and Figure 3, and the water level matches well with the Xingzi station.

In order to verify the velocity distribution of the model, the measured cross-sectional velocity in low water period on November 13th, 2011 and high water period on May 12th, 2012 are compared with the simulation results. As shown in Figure 3, the numerical data of cross-sectional velocity coincide with the measured data.

As Figure 1 shows, the location of erosion-deposition verification section M2 is from Taozifa in Xingzi County ($116°01′03"; 29°23′26") to Xishan in Duchang County ($116°03′42"; 29°23′26")$. From 2010 to 2015, the section is mainly silting, and the topography of the section is undulating due to the influence of sand mining, so the deposition rate of the section is used as the verification index, as shown in Table 1. From 2010 to 2015, the measured average deposition thickness and deposition rate of M2 section are 0.85m and 0.14m/year. The simulation results show that the average deposition thickness and deposition velocity are 0.30m and 0.15m/year, which are larger and more conservative than the measured results. In addition, the study of Ouyang[1] showed that the Taozifa is a concentrated area of sedimentation, and the sedimentation rate is 0.16 m/year, which is very close to the calculated value of the model in this paper. In conclusion, the model can reflect the flow characteristics and the overall erosion-deposition law of the project area.

### Table 1. Siltation rate verification.

| Data form other paper | Numerical data | Measured data |
|-----------------------|----------------|---------------|
| Deposition rate (m/year) | 0.15 | 0.14 | 0.16 |

3. simulation analysis

Considering to reduce excavation, the optimization scheme proposes to narrow the bottom width of dredging channel on the basis of the original design. The main design parameters of the dredging scheme are shown in Table 2.

### Table 2. Main parameters of dredging schemes.

| scheme | side slope grade | bottom width (m) | Relative quantity ($10^4$ m$^3$) |
|--------|-----------------|------------------|-------------------------------|
| Original scheme | 1:6             | 70               | /                             |
| Optimization scheme | 1:6            | 40               | -41.18                        |
The flow and sediment process from January 1st, 2010 to January 1st, 2012 is simulated to analyze the erosion-deposition law in the project area. Then 10 monitoring points are arranged along the dredging project, as shown in Figure 1.

Through the analysis of simulation results, the design scheme and optimization scheme have little influence on the water level and velocity in this area. The variation range of water level before and after the project is less than 0.002m, and the variation range of velocity is less than 0.1m/s. This is because the lake level changes gently, the velocity of flow is small, and the dredging work quantity can be neglected relative to the lake volume. The change of flow direction before and after the project is mainly in the dredging project area, which shows that the dredging project will lead the flow from deep channel to shore, during the low water season, as shown in Figure 4 (A). With the rising of water level in flood season, and the submerging of dredging works and surrounding beach, the influence of on flow direction is gradually not obvious, as shown in Figure 4 (B).

Based on the analysis of the influence of dredging project on water level and flow field, it is concluded that the project has no obvious influence on the velocity and depth in the surrounding area. Combining with the equation of critical sediment transport rate, the erosion-deposition characteristics of the surrounding area will not change significantly. The erosion-deposition distribution before and after the dredging project is shown in Figure 5. The implementation of original scheme and optimization scheme only affect the erosion-deposition in the dredging area. The erosion-deposition at monitoring points are extracted as shown in Table 3.

The simulation results show that the sedimentation in the dredging area after the project is increased compared with that before the project. On the one hand, the dredging increases the water depth and decreases the velocity, which leads to the decrease of sediment carrying capacity in this area. However, in the region near the deep trough, where the water depth changes little before and after the project, the deposition rate changes little. On the other hand, when dredging project lead the flow from...
deep trough to the edge beach, it also carries sediment, which will deposit in the dredging channel with the decrease of the flow velocity.

![Figure 5. Simulation results of erosion-deposition.](image)

**Table 3. Siltation rate before and after the project.**

| Monitoring point | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | Average value |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---------------|
| Original scheme  | 0.00| 0.05| 0.07| 0.12| 0.26| 0.3 | 0.34| 0.37|     |     | 0.17          |
| Optimization scheme | 0.01| 0.05| 0.07| 0.12| 0.26| 0.3 | 0.33| 0.37|     |     | 0.17          |
| Nature condition | 0.02| 0.03| 0.09| 0.18| 0.23| 0.28| 0.33| 0.37|     |     | 0.16          |

The distribution rules of erosion-deposition at each monitoring point of the two schemes are the same, and the average deposition rate of the two schemes is 0.17 m/year. The dredging has little influence on the erosion-deposition of the project area, and the average deposition rate before the project is 0.16 m/year, which is 0.01 m/year less than that after the project. Point 10 has the highest deposition rate and is located in the deep trough area outside the dredging channel. The overall performance of the project area is deposition, with the maximum deposition rate occurring at monitoring point 9, in which the deposition rate of Original scheme is 0.34 m/year, and that of Optimization scheme is 0.33 m/year. The reason for the deposition rate of Original scheme slightly higher than that of Optimization scheme, is that the deposition time is affected by the settling velocity, and a certain time is required for the sediment deposition. The deposition time of the sediment is also more abundant in the more width channel, and the deposition rate is even greater.

### 4. Conclusion

Based on the analysis of the existing data and numerical simulation, the flow characteristic and sediment deposition law of dredging project in Lushan City are studied, which provides a scientific basis for the argumentation and optimization of the water intake dredging schemes. The conclusions are as follows.

1) A water and sediment transport model is established. The model can reflect the characteristics of water flow and erosion-deposition law in the project area after the verification.

2) According to the simulation results, the variation amplitude of water level and average velocity is less than 0.002 m and 0.1 m/s, before and after the project. Therefore, the implementation of the dredging project will not have a significant impact on the flow characteristics of the region.

3) The results of critical sediment transport rate analysis and numerical simulation show that the project only affects the erosion-deposition of the dredging area. Both before and after the project the
area are mainly sedimentation, the average deposition rate is 0.16 m/year and 0.17 m/year, the maximum deposition rate is 0.33 m/year and 0.34 m/year. Comparing to original scheme, the optimized scheme have no obvious influence on the sediment erosion-deposition rate and distribution law in this area.

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