Analysis of influence of mesh partition on Mike21 calculation in flood impact assessment

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Abstract. In order to study the impact of different grid mesh sizes on the calculation results of the model in the analysis of flood impact assessment, this paper takes the newly constructed bridge between the Niushou and Xiangyang sections of the Hanjiang River as an example. It simulates the influences of bridge construction on river flow under the six schemes of setting the bridge pier as a solid boundary, no internal mesh generation, and not participating in numerical calculation, and dividing the bridge pier local mesh size into 2m, 4m, 6m, 8m, and 10m. The results show that different grid sizes in the project have an effect on the river water level and the range of water level changes. The smaller the local grid size of the project relative to the building size, the greater the maximum water level change value, and the closer it is to the calculated value of the bridge pier as a solid boundary. By adding piers module of the model to generalize the project, the water level change in the model results is significantly smaller. Under the same water level change conditions, the larger the mesh size, the greater the scope of the project. For projects located in important river sections with significant water blocking effects, it is recommended that buildings be used as solid boundaries without participating in generating meshes or modifying local terrain to simulate the effects of water flow. The results are more in line with actual conditions.

Key words: Flood Impact Assessment; Grid Size; Mike21 Model; Piers

1. Introduction

With the acceleration of urban development, the demand for river-related projects is increasing. In order to ensure the safety of river flooding, a flood impact assessment report should be prepared before the construction of engineering facilities such as crossing river, facing river and crossing dykes. When there is an important flood prevention task in the river section where the project is located or the project construction may have a large impact on the flood control of the river section, the flood impact assessment should include model calculations.

The Mike model can simulate one-dimensional river network hydrodynamic systems and two-dimensional flood plain and coastal areas, and can realize exchange of free water bodies between one-dimensional and two-dimensional areas. It is applicable to the demonstration and evaluation of Macroscopic controlling scale of river basin, study on watershed flood dispatching, simulation of microscopic water flow.
At present, the commonly used two-dimensional flow model in flood impact assessment is Mike21. The Mike21 model is mainly for flood simulation. Its meshing types include unstructured grids such as triangular grids and non-orthogonal rectangular grids. It guaranteed high flexibility.

The Mike21 model has some achievements in practical engineering applications. Zhang Hu [1] used Mike21 to optimized the scheme for improving the water environment by establishing a two-dimensional hydrodynamic water quality model of Chaohu Lake. Chen Ping [2] analyzed the flood evolution process of the flood storage by Mike21 and provides a reference for the safety construction planning of flood storage and detention areas. Ma Xiaobing [3] adopted the joint application of one and two-dimensional hydraulic calculations to provide support for the hydraulic calculation data required for Mike21 application. Chang Di [4] compared and analyzed the calculation results of river backwater under different generalization methods of the project, which has certain guiding significance for practical engineering applications.

Yuan Xiongyan [5], Zhang Chong wei [6] and Wang Zengxin [7] respectively applied the Mike21 model to different Bridge Projects. And the simulation results have achieved high accuracy, which provided support for the river flow simulation of the newly-built bridge project.

In the calculation of flood impact assessment, grid division is an important part of building Mike21 model. The grid size is directly related to the minimum time step of the model, which has a great impact on the stability of the model and the running time [8]. The mesh division is closely related to the generalization of the terrain [9]. When the size of the engineering building is larger than or equivalent to the grid size, the height of the grid node can be directly modified to express the building. When the building size is relatively small compared to the grid size, it is not possible to express the engineering building by modifying the grid node elevation. The local mesh of the project needs to be encrypted to maximize the simulation of the building’s shape in the river. And the smaller the grid size, the longer the project running time, which is not conducive to model stability [10].

![Figure 1. Project location.](image_url)

It can be seen that creating an appropriate mesh is an important condition for the model to obtain reliable results. This article mainly analyzes the degree of influence of the locally encrypted grid size on the calculation results of Mike21 when generalizing the local terrain of the project during flood impact assessment. When a model needs to be constructed in flood impact assessment, it can provide a reference for completely generalizing engineering buildings while reducing the model's running stability time.

In order to study the impact of different grid mesh sizes on the calculation results of the model in the analysis of flood impact assessment, this paper takes the newly constructed bridge between the
Niushou - Xiangyang sections of the Hanjiang River as an example to simulates the influences of bridge construction on river flow.

2. Research methods and calculation conditions

2.1. Location of study area

The simulated bridge is located in the Niushou ~ Xiangyang section of the Hanjiang River. The center of the project is: 112°04’15.58″ east longitude and 32°02’05.41″ north latitude. The location of the project is shown in Figure 1.

2.2. Research methods

The Mike21 model is a hydraulic business software developed by DHI of Denmark, with a module for hydraulic calculations. The simulation calculation principle is as follows:

The two-dimensional shallow water equation in the Cartesian coordinate system includes the continuous flow equation and the momentum conservation equations in the x and y directions. The specific forms are as follows:

$$\frac{\partial h}{\partial t} + \frac{\partial hu}{\partial x} + \frac{\partial hv}{\partial y} = 0$$

(1)

$$\frac{\partial hu}{\partial t} + \frac{\partial hu^2}{\partial x} + \frac{\partial hvu}{\partial y} = \frac{\partial}{\partial x}\left(h\Gamma \frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left(h\Gamma \frac{\partial u}{\partial y}\right) - g\left(\frac{\partial z}{\partial x} + s_f x\right)$$

(2)

$$\frac{\partial hv}{\partial t} + \frac{\partial huv}{\partial x} + \frac{\partial hv^2}{\partial y} = \frac{\partial}{\partial x}\left(h\Gamma \frac{\partial v}{\partial x}\right) + \frac{\partial}{\partial y}\left(h\Gamma \frac{\partial v}{\partial y}\right) - g\left(\frac{\partial z}{\partial y} + s_f y\right)$$

(3)

In the above formula, $u$ and $v$ are the velocity in the x and y directions; $h$ is the depth of the water; $b$ is the elevation of the river bed; $z = h + b$ is the water level; $g$ is the acceleration of gravity; $n$ is the roughness coefficient; $s_{fx}$ and $s_{fy}$ are x and y Directional resistance which is determined by the Manning formula.

$$s_{fx} = \frac{n^2 u \sqrt{u^2 + v^2}}{h^{4/3}}, s_{fy} = \frac{n^2 v \sqrt{u^2 + v^2}}{h^{4/3}}$$

(4)

$\Gamma$ is the turbulent diffusion coefficient and is calculated by the following formula:

$$\Gamma = kU^* h/6$$

(5)

$k$ is the von Karman constant which is usually taken as 0.4. $U^*$ is the frictional flow rate and is determined by the following formula:

$$U^* = \sqrt{gn^2 (u^2 + v^2) / h^{1/3}}$$

(6)

2.3. Calculation conditions

Considering the unity and intuitiveness of bridge pier sluice in Mike21 calculation results, this paper takes a circular pier as an example to conduct a comparative analysis of the results.

(1) Overview of river course

The river section of the project is selected from the Niushou ~ Xiangyang section of the Hanjiang River. The reach is a curved channel. There are three large river cores in the channel. The river width in this section varies greatly. The width above Changhong Bridge is generally 1500 ~ 5000m. The river beaches are covered during dry season. There are many branches and the flow is disordered which formed a wandering river section.

(2) Model boundary conditions

The model calculation area starts from Baijiawan Water Level Station (2.4km upstream of the project) and ends at Changhong Bridge (6.5km downstream of the project). The total length of the river reaches 8.9km. Inlet flow is 18700m$^3$/s and outlet water level is 66.70m.

(3) Bridge pier arrangement and generalization
The width of the river at the project location is about 1.3km. In order to ensure the representativeness and intuitiveness of the calculation results, the bridge piers are arranged on the main channel. Three circular bridge piers are arranged in the directions of sedimentary flow. And the diameter of the bridge pier is 10m. In order to ensure that the models before and after the project are calculated and compared based on the same set of grids, the generalization of the bridge piers was selected using the method of adding building bridge piers in Mike21 hydrodynamic parameters. The layout of bridge piers is shown in Figure 2.

![Figure 2. Layout of river section and bridge pier where the project is located.](image)

(4) Schemes design

Based on the basic computer configuration and daily production needs in actual work, the local minimum mesh size of the model constructed in this paper is 2m. The grid of the river section in the model changes gradually from small to large. The local grid size of the project is different, and the grids of other river sections are the same in different schemes.

This paper mainly simulates the water level changes before and after the project construction under different grid division schemes.

1) The local grid sizes of the project are 2m, 4m, 6m, 8m and 10m respectively.
2) Set the piers as solid boundary. No mesh is generated inside the pier and it does not participate in numerical calculation. This scheme is closest to the actual situation of the project. But due to the influence of computer configuration and the model's own convergence, this scheme is rarely used in actual production practice. In practical applications, most of the models have modules to add structures (piers). This paper uses such a scheme as a truth reference.

3. Results analysis and discussion

It can be seen from Tables 1 and 2 and Figures 3 to 5 that when the local mesh size of the project is different, the maximum water level change value and the range of influence under a certain water level change are different, which are specifically reflected in the following aspects:
Table 1. Maximum change in water level at piers of different grid sizes (Unit: m).

| Grid size | Maximum water level change | 1# | 2# | 3# |
|-----------|----------------------------|-----|----|----|
| 2m        |                            | 0.036 | 0.048 | 0.060 |
| 4m        |                            | 0.028 | 0.032 | 0.035 |
| 6m        |                            | 0.016 | 0.020 | 0.023 |
| 8m        |                            | 0.012 | 0.018 | 0.018 |
| 10m       |                            | 0.011 | 0.016 | 0.016 |
| gtbj*     |                            | 0.100 | 0.150 | 0.160 |

*: gtbj refers to setting the pier as a solid boundary

(1) As the size of the local mesh of the project increases, the maximum change in water level at the same bridge pier location gradually decreases. When the local grid size of the project is increased from 2m to 10m, the maximum value of the water level at the positions of the three piers decreased by 0.025m, 0.032m, and 0.044m respectively, and the maximum reduction is up to 73.3%. When the grid size is increased from 2m to 6m, the maximum amplitude of the water level change fluctuates around 0.01m, which is a large proportion compared with the change value itself. When the grid size is 6m, 8m or 10m, the maximum water level change is basically the same.

Table 2. Statistical table of the same water level variation range at different grid size piers (Unit: m).

| piers | water level change | 2m | 4m | 6m | 8m | 10m | Influence distance |
|-------|--------------------|-----|----|----|----|-----|-------------------|
| 1#    | 0.002              | 158.4 | 996.2 | 1443.0 | 1034.1 | 1376.9 |
|       | 0.005              | 25.9  | 39.0  | 23.2  | 28.7  | 36.8  |
| 2#    | 0.002              | 183.4 | 1016.6 | 1445.0 | 1258.0 | 1388.4 |
|       | 0.005              | 30.9  | 48.7  | 36.6  | 42.9  | 54.9  |
| 3#    | 0.002              | 154.6 | 934.8 | 1480.0 | 1326.4 | 1363.0 |
|       | 0.005              | 37.4  | 54.1  | 42.9  | 51.1  | 63.3  |

*Figure 3. Variation of 2mm water level at the position of bridge pier corresponding to different grid sizes.*
(2) With different grid sizes of the project, the results of the river surface curve calculated by the model are basically the same. The mesh division has a small impact on the results of the model calculation of the water surface curve.

![Figure 4](image1)

Figure 4: Variation of 5mm water level at the position of bridge pier corresponding to different grid sizes.

![Figure 5](image2)

Figure 5: Different mesh size models to simulate the results of the water level.

(3) With the increase of the local mesh size of the project, the overall scope of its influence appears to increase under the same water level changes. When the grid size is increased from 2m to 4m, the range of influence increases multiplied. When the grid size is greater than 4m, the range of influence under the same water level is basically close.

(4) It can be known from Table 1 that by adding piers to simulate the change of river water level, the value of the change is much smaller than that when the pier is set to a solid boundary condition. The reason is that when building the model, the method of adding pier is mainly to increase the drag force in the unit where the pier is located to simulate the water blocking effect of the pier. It can be seen from the flow field diagram after the project that the grid unit at the bridge pier still has a flow...
velocity. It means that there is still water flowing through the bridge pier, which is inconsistent with the actual water blocking effect of the bridge pier in practice. In the case of setting the bridge pier as a solid boundary solution, no grid is generated at the position of the bridge pier, and it does not participate in the numerical calculation, which is more in line with the actual situation. Therefore, by adding bridge piers to simulate the impact of the project on the flow, the simulation result is too small.

4. Conclusion
This paper mainly analyzes the influence of the local encryption grid size on the calculation result of Mike21 by adding the bridge pier in the natural river. The conclusion is as follows:

(1) The smaller the local grid size of the project relative to the building size, the larger the maximum water level change value and the closer it is to the calculated value of the bridge pier as a solid boundary.

(2) The local mesh size of the project has a small impact on the water surface line of the model calculation.

(3) The larger the local grid size of the project, the larger the range of influence under the same water level changes. When the grid size is increased from 2m to 4m, the range of influence increases multiplied. When the grid size is larger than 4m, its influence range is basically close.

(4) By adding building pier in the Mike21 model to simulate the water level effect after the project, the result is too small. For projects located in important river sections with significant water blocking effects, it is recommended that buildings be used as solid boundaries without participating in generating meshes or modifying local terrain to simulate the effects of water flow. The results are more in line with actual conditions.

This paper summarizes the circular pier by adding piers, and analyzes the influence of the local mesh size of the project on the calculation of Mike21 model. In the future, the simulation results of the Mike21 model can be further studied for different engineering types, different engineering generalization methods, and changes in different parameters.

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