Evaluation of Drainage Capacity in Old Urban Area of Tongshan County Based on SWMM Model

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Abstract. Scientific simulation calculation and capacity evaluation of urban drainage system can provide theoretical guidance for the adjustment and optimization of urban drainage system planning scheme. Taking the drainage system of the old urban area of Tongshan County as an example, based on the analysis of the present drainage and waterlogging prevention facilities, this paper evaluates the existing drainage network of the city by using the rainstorm runoff management model SWMM (Storm Water Management Model), analyzes the actual drainage capacity, and puts forward some suggestions for the optimization and transformation of the pipe network. The research ideas and methods in this paper are universal and can be used for reference for the evaluation of drainage capacity in other areas.

1. Introduction

With the development of society and economy, the number of cities, population and land have grown on a large scale. With the expansion of the city, the impermeable surface increases, resulting in the increase of runoff coefficient, the increase of Rain Water confluence speed, and the increasingly serious urban drainage and waterlogging prevention, which poses a great threat to the life and property safety of urban residents. The design standard of drainage network in old urban area is low, and the problem of old drainage pipe is prominent, which further aggravates the problem of urban waterlogging.

In this paper, the old urban area of Tongshan County is selected as the research object, and the SWMM (Storm Water Management Model) model is used to analyze the drainage capacity of the drainage pipeline in the ideal state and the actual state, and the measures for the optimization and transformation of the pipe network are put forward.

2. Analysis of the present situation of drainage system

The area of the old urban area of Tongshan County is 717ha, the total length of the constructed drainage pipeline is 38.48km, and the coverage rate of the drainage canal is 97.20%. The old urban area is basically all pipes made of rain and sewage, the specification is DN600~4m*4.5m. The present drainage pipe canal is distributed on both sides of Tongyang River, all of which rely on gravity to discharge into the river channel, and no drainage and drainage pumping stations are set up.

Table 1. Summary of drainage facilities.

| Area      | Total length of pipe and canal (km) | Built-up area (ha) | Planning service area (ha) | Unit area pipe length (m/ha) | Pipe and canal coverage (%) | Pipe and canal reaching standard rate (%) |
|-----------|------------------------------------|--------------------|---------------------------|------------------------------|-----------------------------|------------------------------------------|
| Old town  | 38.48                              | 717                | 1213                      | 11.79                        | 97.20                        | 59.36                                    |

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3. Model Construction and Calculus process

3.1. Current situation pipe network system arrangement
Collate the current pipe network nodes, pipe segments, divide the area of water confluence, get the research area system, and establish the topological relationship of the pipe network, as shown in figure 1.

![Figure 1. Schematic diagram of topological relationship of drainage network.](image)

3.2. Synthetic rainfall scenario
In this paper, the Chicago synthetic rainfall process line is used to simulate the present situation. The formula for designing rainfall intensity is as follows:

\[ q = \frac{2417(1 + 0.79 \log P)}{(t + 7)^{0.7655}} \]  
\[ (1) \]

In the formula: \( q \) is rainstorm intensity, \( L / (s \cdot Hm^2) \); \( P \) is designed rainfall recurrence period, year; \( t \) is rainfall duration, min.

The rainstorm process line can be divided into pre-peak rising section and post-peak descending section.

Pre-peak rising section:

\[ i_a = \frac{a}{(t_1 + rb)^n} \left(1 - \frac{nt_1}{t_1 + rb}\right) \]  
\[ (2) \]

Post-peak descending section:

\[ i_b = \frac{a}{[t_2 + (1-r)b]^n} \left[1 - \frac{nt_2}{t_2 + (1-r)b}\right] \]  
\[ (3) \]

In the formula: \( i_a, i_b \) is the instantaneous rainstorm intensity; \( a, b, n \) is the local parameter in the rainstorm intensity formula; \( t_1, t_2 \) is the time before and after the peak, \( r \) is the coefficient of rain peak (the ratio of pre-peak duration to total duration), \( r=0.4 \).
Compared with the formula of rainstorm intensity in Tongshan County, the following results are obtained:

\[ a = 2417(1 + 0.79 \log P) ; \quad b = 7 ; \quad c = 0.7655. \]

Taking \( P = 1, 2, 3, 5, 10a \) as an example, the rainfall process line of Tongshan County is synthesized, as shown in figure 2.

![Synthetic rainfall process lines at different recurrence periods (t=120min, r=0.4)](image)

3.3. Model parameter setting and evaluation process

In this paper, the initial value and source of parameters in hydraulic simulation with SWMM are summarized as shown in Table 2. The model parameters can be input into SWMM software and combined with different simulation processes and related simulation options can be set to simulate Rain Water pipe network dynamically, as shown in figure 3.

| Type                  | Data name          | Content                             | Acquisition method    |
|----------------------|--------------------|-------------------------------------|-----------------------|
| Data base            | Underlying surface data | Land use status, Soil property | Measured data         |
|                      | Joint (inspection well, Weir, pumping station, etc.) | Name                  | Site survey           |
|                      | Bottom of pipe, elevation | Ground level | Measured data         |
|                      | Pipe network data   | Line pipe                           | Measured data         |
|                      | Starting point      | Measured data                       |
|                      | Pipe diameter, length, buried depth | Measured data |                     |
|                      | Outfall             | Name                                | Reconnaissance trip   |
|                      | Bottom of pipe, elevation | Measured data |                     |
| Model construction data | Rainfall data     | Rainfall intensity, rainfall duration | Scenario simulation |
|                      | Adjust parameters  | Pipeline roughness coefficient, Permeability roughness coefficient, Proportion of permeable water area, Water permeable area storage capacity | Literature collection, Model manual, Rate setting tool |
4. Drainage capacity system assessment

The rainfall process lines under different recurrence periods are input into the model, and the current pipe network is simulated and analyzed. In the process of simulation, the water depth of the pipe canal and the water depth of the joint change with the change of rainfall duration. When the water depth of the pipe canal exceeds the pipe diameter or its channel depth, it is regarded as overloading, and when the water depth of the joint exceeds its well depth, it is regarded as overflow. Finally, through statistics and collation, the comprehensive drainage capacity of the pipe network in the old urban area of Tongshan County can be obtained, as shown in Table 3 and figure 4.

Table 3. Evaluation form of drainage capacity of drainage Pipe Canal in present situation.

| Area      | P<1 year (km) | 1≤P<2 years (km) | 2≤P<3 years (km) | 3≤P<5 years (km) | P>5 years (km) |
|-----------|---------------|------------------|------------------|------------------|----------------|
| Old town  | 2.15          | 8.55             | 4.94             | 11.54            | 11.30          |

Through the analysis, under the condition that the influence of mountain flood is not taken into account, that is, the facilities of flood interception ditch are perfect, when the rainfall occurs for 3 years in the recurrence period, the rate of reaching the standard of Rain Water pipe network is 54.38%.
5. Optimization and Transformation of official website

The recurrence period of urban pipe network is (P=) 1~3 years in general areas and (P=) 3~5 years in important areas. Considering the fluctuation of terrain, the economic rationality of pipe network arrangement and the difference of runoff coefficient of different plots, different rainstorm recurrence periods are adopted according to the nature of different land use. In principle, the general plot adopts the recurrence period of 2 years, the important areas such as schools, kindergartens, hospitals, commercial centers and important roads in the city, etc., and the recurrence period of 3 years is adopted. In order to meet the design standard, it is necessary to transform the current pipe network. It is analyzed that the overflow of the joint is often caused by the insufficient flow rate of the pipeline (canal). The flow rate of pipeline (canal) is closely related to the cross section area and slope of pipeline (canal). Therefore, there are two kinds of reconstruction methods for the present pipe network: one is to change the slope of the pipe section, the other is to enlarge the overcurrent area of the pipeline.

The modified pipe diameter and buried depth are re-inputted into the model until the simulation results are carried out without pipe section overload and node overflow. After software simulation and calculation and analysis, the current pipe network transformation project is shown in Table 4 and figure 5.

Table 4. Current situation pipe network reconstruction project.

| Number | Specification after revamping | Quantity (m) | Remarks |
|--------|-------------------------------|--------------|---------|
| 1      | DN800                         | 1340         | Transformation of DN600 into DN800 |
| 2      | DN1000                        | 425          | Transformation of DN600 into DN1000 |
| 3      | B*H=0.4m*0.8m                 | 165          | Reconstruction, adjustment of slope |
| 4      | B*H=0.4m*0.8m                 | 165          | Reconstruction, adjustment of slope |
| 5      | B*H=0.8m*1.5m                 | 200          | Transformation of DN800 into DN1000 |
| 6      | DN1000                        | 450          | Transformation of DN800 into DN1000 |
| 7      | B*H=2.0m*1.5m                 | 377          | Transformation of B*H=0.5m*1.2m into B*H=2.0m*1.5m |
| Total  |                               | 3122         |         |
6. Conclusion
From the above simulation process and results of urban drainage system in Tongshan County, it can be seen that SWMM model can simulate the whole process of urban drainage system, thus reflecting the hydraulic condition of pipe network under different rainfall intensities. Through the evaluation of the capacity of drainage network, the suggestions for optimization and transformation are put forward, and technical support is provided to the urban drainage system planning scheme.

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