Flood Disaster Risk Assessment of Tongren, Guizhou Based on WMS and SMS

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Abstract

This article takes the flood disaster in tongren, guizhou province as an example to understand the natural conditions and hydrogeology of the research area by consulting literatures and materials. Based on DEM data to determine the basin scope; Consult hydrological and meteorological data to analyze and simulate relevant parameters of the basin; Using the HEC-HMS module in WMS software, a combination of SCS curve method, SCS unit line method, and Muskingum method was used to establish a basin rainfall runoff model. The sensitivity of relevant parameters of the model was obtained by parameter sensitivity analysis in the study area, and then the parameters were calibrated. The parameters after the utilization rate was set were respectively used to simulate the rainfall-runoff intensity of the 24-hour rainstorm with a recurrence period of 20, 50 and 100 years. Then the simulated results of rainfall, runoff and flood peak flow in three different recurrence periods were input into SMS software for flood inundation simulation and flood disaster risk assessment during the recurrence period.

Keywords

HEC-HMS hydrological model, parameter sensitivity analysis, flood during recurrence period.

1. INTRODUCTION

China's flood disasters occur frequently, with heavy rainfall processes and high overlap. Flash flood prevention is a difficult and weak link in China's national defense flood mitigation. Therefore, the simulation of river basin flood process plays a very important role in flood forecasting, flood cause analysis, and guidance of flood control measures.

Stefan Reese and Doug Ramsay [1] deduced a vulnerability calculation formula with wide applicability according to the flood vulnerability curve; Joshua Ntajal[2] combined GIS, satellite remote sensing technology and flood risk assessment technology to draw Flood disaster risk map; Marlies H. Barendrecht et al. [3] assessed and managed flood risk by coupling a dynamic model of human activity-flood interaction;Ying Qi[4] applied the theory of dry and wet water depth to the two-dimensional flood inundation analysis model to improve the accuracy and stability of the model, and applied it to the mountain flood risk assessment in the small watershed of eastern liaoning province.Yongfei Wang et al. [5] used DEM to perform flood inundation simulation and Flood disaster risk assessment;Xingke Zang[6] used GIS software coupled with the HEC-RAS model to simulate flood evolution and assess flood disaster risk.

The lack of current regional runoff data has brought difficulties to hydrological research, which is a universal problem. Based on the historical flood in the study area, technical literature history Chad (July 1, 1995) the rainfall data in the study area, the runoff simulation with specific case floods, parameter calibration, it is concluded that the best parameters of research area, for the lack of rainfall data of flood disaster research provides a train of thought. This paper selects

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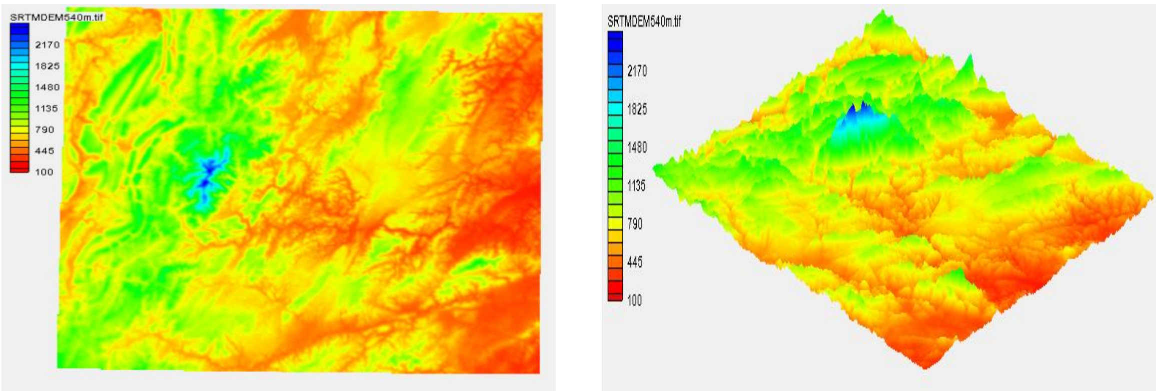
tongren city, guizhou province as the case. By using WMS and SMS software, based on the acquired DEM, land, and meteorological data of the basin, a basin hydrological model is established to simulate the flood disaster process in the area and carry out risk assessment. Flood disaster risk assessment provides reference and theoretical basis for model selection.

2. ENGINEERING GEOLOGICAL CONDITIONS AND MODEL ESTABLISHMENT

2.1. Project Overview

The Jinjiang River Basin in Tongren City, Guizhou Province is the second largest river in Tongren City. It belongs to the subtropical rain-source river. The river runoff is replenished by rainfall [7].It has a total length of 117km, a drainage area of 4157km2, a drop of 652m, an average drop of 4.1‰, an average river width of 105m, a water depth of 10-30m, and an annual average flow of 180m3/s.. Among them, the hydrometeorological data used in the research are from the yearbook records, and the characteristic parameters are based on the DEM data of the study area, and the relevant parameter values are extracted using Arcgis software.



(a)Flat DEM (b) Three-dimensional DEM

Fig 1. DEM elevation data model of Tongren section in Jinjiang River Basin

Tab 1. Values of characteristic parameters of watersheds in the study area

Parameter	Full basin	Sub-basin1B	Sub-basin2B	Sub-basin3B
Drainage area/ km^2	3565.9	1175.5	1930.4	460
Watershed length/m	5968.59	5966.36	5963.99	6462.31
Watershed slope/(m/m)	0.097	0.084	0.129	0.067
Runoff distance/m	116103.15	61314.42	102808.30	39466.32
Runoff gradient/(m/m)	0.015	0.011	0.017	0.014
Max river length/m	98019.80	45338.83	86077.65	16929.15
Max river slope/(m/m)	0.004	0.004	0.006	0.007
Initial CN value	79.6	79	79	80
Initial lag time/hr	11.994	7.896	9.621	6.019

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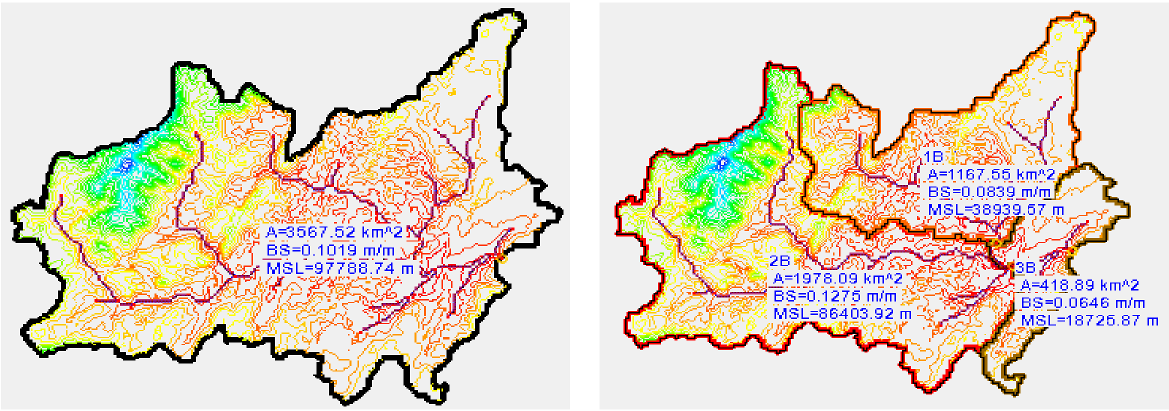
2.2. Building A Computational Model

Based on the original DEM data, set the threshold of the minimum catchment area, establish a river network with a defined flow direction and catchment area, and generate a basin boundary to determine the study area basin and its sub-basin Fig 3.



(a) Study area watershed (b) Study area sub-basin

Fig 2. Study area map in WMS

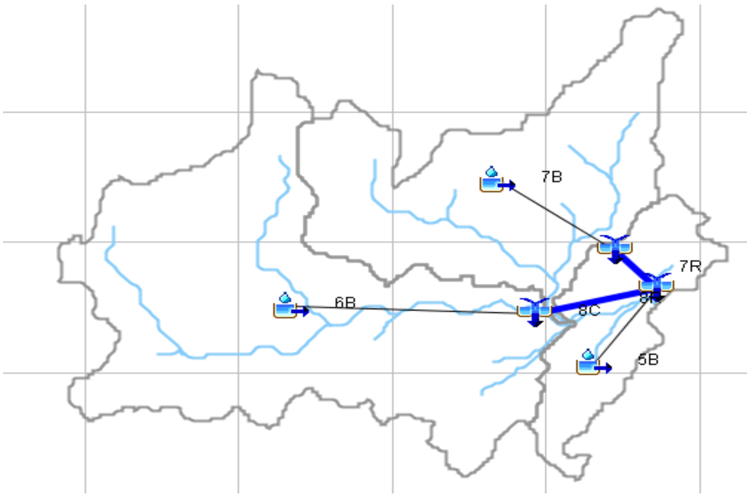


Fig 3. Structure of Tongren section of the Jinjiang River Basin

2.3. Parameter Sensitivity Analysis

This article uses sensitivity to determine sensitive parameters. The formula for calculating sensitivity is as follows:

$$S = \left| \frac{I}{r} \right|$$

Among them: S is the sensitivity; I is the target value change rate; r is the parameter change rate[8]. Parameter sensitivity classification is shown in Table 2 below.

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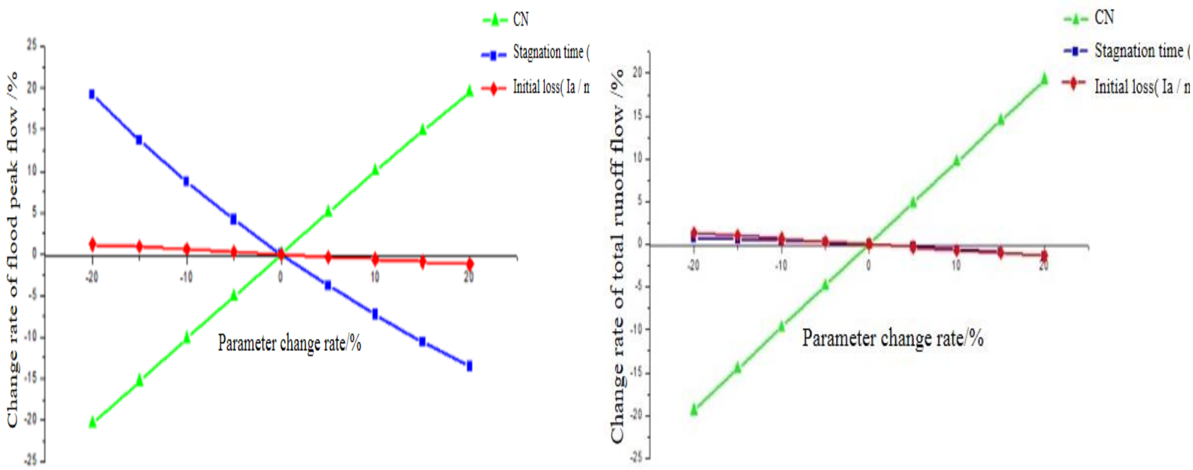
Tab 2. Parameter sensitivity classification

Grade	Sensitivity range	Sensitivity
I	$0 \le \lvert S \rvert < 0.05$	Not
II	$0.05 \le \lvert S \rvert < 0.2$	Moderately
III	$0.2 \le \lvert S \rvert < 1$	Normally
IV	$\lvert S \rvert \ge 1$	Highly

Taking Tongren 19950701 flood disaster as a model, the sensitivity of relevant parameters in the model was analyzed based on the runoff simulation results of the initial parameters. Each parameter varies between -20% ~ 20% of the initial value, and the range of each change is 5%, and finally the corresponding change rate of flood peak flow and total runoff is calculated. It can be seen from Figure 4 that the CN value is most sensitive to the flood peak flow and the total runoff, so the CN value is used as the main calibration parameter for adjustment in this paper.



(a)Change rate of flood peak flow (b) Change rate of total runoff

Fig 4. Change rate of flood peak flow and total runoff when related parameters change

2.4. Calibration of Model Parameters

The common methods of model parameter calibration include trial and error method and objective function method. The trial-and-error method (also known as manual parameter adjustment method) means that the error between the simulated value and the actual value can be reduced by constantly correcting the parameters manually. The objective function method automatically optimizes the simulation results by setting an objective function. The advantage of this method is that the calibration speed is fast, while the disadvantage is that the physical significance of relevant parameters may be ignored. In this paper, the manual parameter adjustment method is used for parameter calibration. Through continuous trial and error, the best parameters are determined. According to the parameter sensitivity analysis, the CN value is the most sensitive. Therefore, the CN value is used as the main calibration parameter to adjust. The parameter values after calibration are shown in Table 3.

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Tab 3. Model parameter calibration table

Subcatchment	Parameter	Initial value	Calibration range	Parameter value after calibration
Subbasin-1	CN	79	0-100	50
Subbasin-2	CN	79	0-100	55
Subbasin-3	CN	80	0-100	60

In order to verify the reliability of the parameter calibration and determine whether the calibrated model can be used for rainfall runoff simulationin the recurrence period of the study area, an accuracy analysis of the calibrated model is required. In this paper, the relative error of flood peak flow (REp) is used to analyze the accuracy of the model simulation results. According to “the Hydrological Information Forecasting Specification” SL250-2000 , 20% of the measured discharge is used as the tolerable error in the flood forecast. The smaller the absolute value of the relative error in the flood forecast, the better the simulation result. The relevant calculation formula is as follows:

$$R_{Ep} = \frac{(q_s - q_0)}{q_0} \times 100\%$$

Among them: REp is the relative error value of the flood peak flow; qs and q0 are the simulated and actual values of the peak flow. Through the above formula, the accuracy evaluation of the HEC-HMS model is performed, as shown in Table 4 below.

Tab 4. Accuracy of simulation results during the verification period

Flood number	Peak traffic(m3/s)	Peak actual traffic(m3/s)	Relative error
19950701	8168.8	8170	-0.0147%
20140715	6488.7	6500	-0.174%

From the simulation results during the verification period, the simulation values are slightly smaller than the actual measured values, and the relative error is far less than the tolerance error of 20%. Therefore, from the results of the accuracy analysis, the runoff simulation during the verification period is qualified and reliable. Therefore, the rainfall runoff simulation can be performed with the parameters determined in the recurrence period.

3. FLOOD DISASTER RISK ASSESSMENT IN TONGREN AREA

The flood recurrence period is a method to measure the magnitude of the flood. For any river, there is a characteristic peak discharge and water level corresponding to each flood recurrence period. If a flood of a certain magnitude has a recurrence period of 100 years, it is called a once-in-a-century flood; a recurrence period of 10 years is said to be a 10-year flood. The longer the recurrence period, the larger the magnitude of the flood and the more rare it is; otherwise, the smaller the magnitude of the flood, the more common.

In this paper, the rainfall intensity formula is used to design the rainfall during the return period. According to the "National Rainstorm Intensity Formula", the rainstorm intensity formula of Tongren City was obtained.

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$$q = \frac{2022(1 + 0.674 \lg P)}{(t + 9.58P^{0.044})^{0.733}}$$

Among them: i is the rain intensity in mm / min.

In this study, 24 hours (1440 minutes) of heavy rain at three recurrence periods of P = 20, P = 50, and P = 100 were selected as the design rainfall. The calculation results are shown in Table 4-11 below.

Tab 5. Rainfall under different recurring periods

Recurrence period	20	50	100
24 hours rainfall(mm)	157.54	180.01	197.00

3.1. Rainfall Runoff Simulation During the Recurrence Period

In this paper, the calculated rainfall intensity (157.54mm) for 20 years, 50 years, and 100 years is input into the corrected model, and the simulation results of rainstorm runoff for three recurring periods are obtained. According to the simulation results, under the 24-hour heavy rain intensity once in 20 years, the maximum flood peak flow in the basin is 2465.9m3/s, and the maximum flood peak flows in sub-watershed 1B and sub-watershed 2B are 729m3/s and 1397.9m3/s, respectively. Under the 24-hour heavy rain intensity once in 50 years, the maximum flood peak discharge of the basin is 3348.4m3/s, and the maximum flood peak discharges of sub-basin 1B and sub-basin 2B are 1021.2m3/s and 1881.2m3/s, respectively. Under the 24-hour rainstorm intensity once in 100 years, the maximum flood peak discharge of the basin is 4069.2m3/s, and the maximum flood peak discharges of sub-basin 1B and sub-basin 2B are 1264.3m3/s and 2273.9m3/s, respectively. Figures 5 and 6 show the simulation results of the rainstorm runoff once in a century.

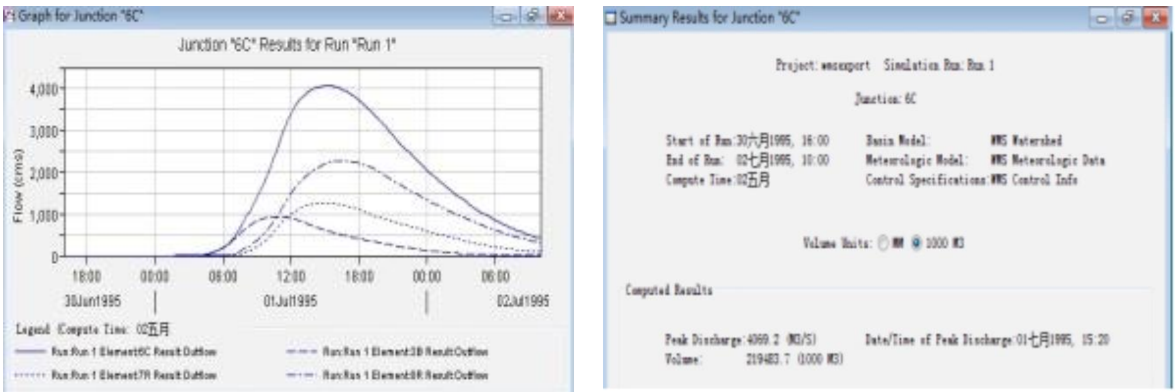

Fig 5. Simulation results of rainfall runoff in a 100-year storm

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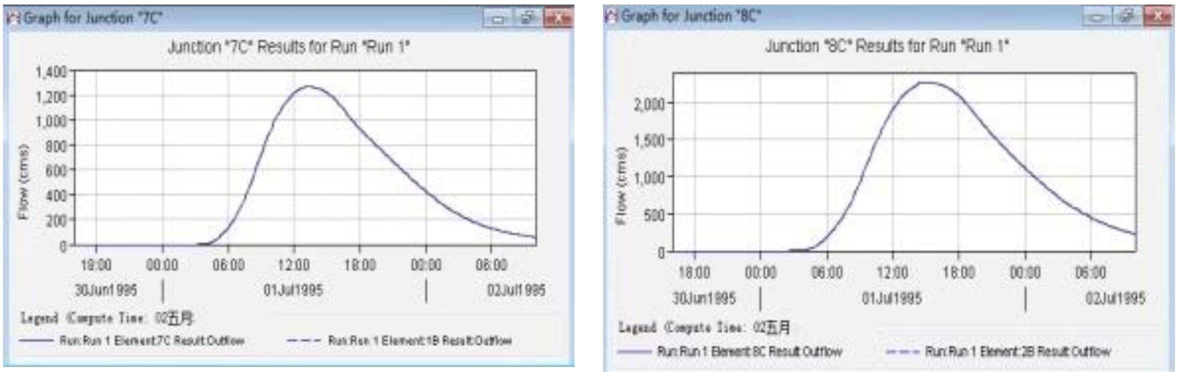
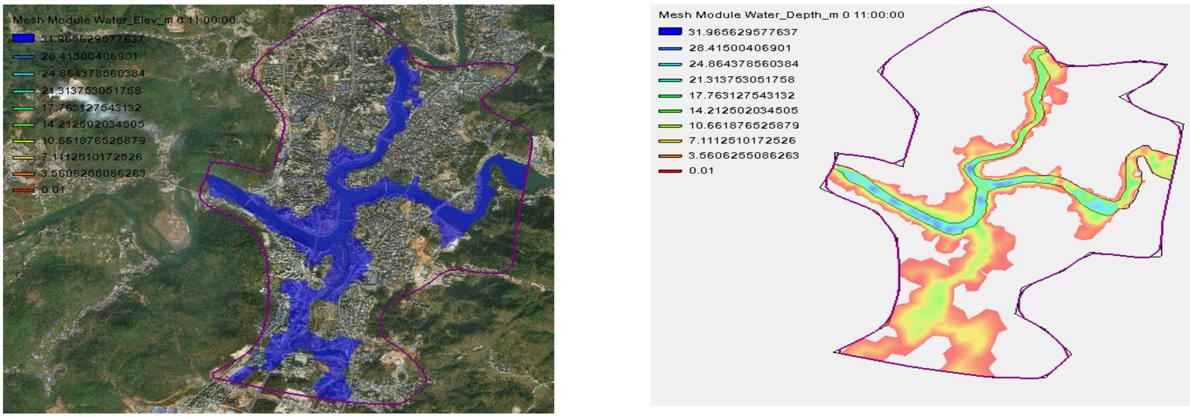


(a) Sub-basin 1B simulation flow (b) Sub-basin 2B simulation flow

Fig 6. Runoff simulation results of the sub-watershed in the case of a 100-year storm

3.2. Flood Flooding Simulation Based on SMS / SRH-2D

In this paper, the SRH-2D module is used to build a hydrodynamic model of the study area based on grid elevation scatter data and grid generation, setting of roughness and boundary conditions. Finally, the time-varying distribution of the floodplain and water depth in the research basin was simulated, and the simulation results were evaluated and analyzed. The flood inundation simulation map and the distribution of flood depth for one hundred years are shown in Figure 7.



(a) Flooding simulation in 100 years (b) Water depth distribution in case of flood in 100 years

Fig 7. Flood inundation simulation and water depth distribution in 100 years

Combining the inundation simulation map and the inundation water depth distribution map, it was found that under a flood in 100 years, the water body in the river began to overflow to the shore as a whole, resulting in a large area of flooding. The confluence of the three rivers (Sanjiang Park) was the most severe flood disaster Serious, the maximum water depth can reach 11 meters. Therefore, the flood once in 100 years will bring a great risk of flood disaster to Bijiang District.

Through the analysis of the simulation results, it can be concluded that under the flood conditions with a recurrence period of 20, 50 and 100 years, different degrees of flood disaster will occur in bijiang district of tongren city. Among them, the flood disaster at the confluence of three rivers (Sanjiang Park) is the most serious with the deepest water depth, while the flood area of the southern tributary is the largest.

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3.3. Causes and Countermeasures of Flood Disasters in Tongren Area

The main factors of flood disaster include climate and rainfall, topography, water system, land use, soil type, insufficient capacity of urban drainage system, and other human factors[9].

The torrential rains in the Jinjiang River Basin are mainly cold peak low troughs and two high-shear types, which are compounded under the influence of surrounding mountains, so the probability of torrential rains increases. The upstream basin of Tongren has a fan shape, and the floods converge quickly. It has the obvious characteristics of steep rises and falls of mountain rivers. It usually takes only 9 to 12 hours from rise to flood peak. Therefore, as long as heavy rainfall occurs once in 10 years, it will be enough to cause disasters in some areas[10].

The Jinjiang River Basin is the second largest river in Tongren City, with a total of 55 tributaries in the territory. The river network is dense, rivers are rich in runoff, and surface water is easy to gather. It is a water-rich area in the Jinjiang River Basin. The soil types distributed in the basin are mainly red soil, yellow soil, paddy soil, etc. Among them, red soil is the most, accounting for 49.97%. Red soil is poor in water and fertilizer retention, which easily leads to flood disasters [11]. If the stagnant water generated by heavy rainfall cannot be eliminated in time, stagnant water will form in the city, which will cause urban waterlogging.

Based on the analysis of the results of the flood disaster risk assessment in Tongren, the author puts forward the following suggestions on urban flooding caused by heavy rainfall in Tongren:

①Reducing the imperviousness of the underlying surface can reduce flood runoff at the source and alleviate urban waterlogging problems.②Establish a perfect flood prevention mechanism and emergency response mechanism. Make timely arrangements for flood prevention work based on the early warning results.③Strengthen land use management, avoid excessive and uncontrolled land development and utilization, and leave enough space for urban rain and flood regulation.④Strengthen rainstorm forecast and flood warning. Hydrological measurement stations can be added to record the hydrological data in the river basin in detail, establish a complete hydrological historical database, and provide support for the formation of a scientific and effective early warning system.⑤Actively implement the concept of a sponge city and establish sustainable stormwater management.

4. CONCLUSIONS

(1) In this study, the HEC-HMS hydrological model was selected, and the combination of production and sink schemes using the SCS curve method, SCS unit line method, and Muskingum method was used. The parameter CN value is a parameter that has an important effect on the simulation results of the model and determines the runoff. Total amount and peak flow; the stagnation time affects the peak flow and the peak arrival time of the flood; in addition, the breakthrough of the initial loss amount has a certain effect on the arrival time of the flood peak.

(2) Based on the accuracy analysis of the two rainfall runoff simulation results of the model verification period "19950701" and "20140715", it is concluded that the HEC-HMS hydrological model is suitable for rainfall runoff simulation in the study area, and the results of the two runoff rainfall runoff simulations and The relative errors of actual data comparison are -0.0147% and -0.174%, respectively, and the accuracy is far less than the tolerance of 20%.

(3) By using SMS / SRH-2D to simulate flood inundation in Bijiang District of Tongren City, it is concluded that the flood during the 20-year recurrence period will cause partial drainage difficulties in Bijiang District, resulting in a small amount of waterlogging; 50 years Floods in the return period will cause severe flooding disasters in Bijiang District; floods in the 100-year return period will cause severe flooding disasters in Bijiang District.

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