

Retraction

Retracted: Flood Simulation Analysis of the Biliu River Basin Based on the MIKE Model

Complexity

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] Q. Liu, D. Wang, Y. Zhang, and L. Wang, "Flood Simulation Analysis of the Biliu River Basin Based on the MIKE Model," *Complexity*, vol. 2021, Article ID 8827046, 10 pages, 2021.

Research Article

Flood Simulation Analysis of the Biliu River Basin Based on the MIKE Model

Qi Liu ^{1,2}, Dianwu Wang ³, Yulong Zhang,¹ and Li Wang⁴

¹Shenyang Agriculture University, College of the Land and the Environment, Shenyang, Liaoning 110866, China

²Liaoning Agricultural College, Yingkou, Liaoning 115009, China

³Liaoning Provincial Water Resources Department, Shenyang, Liaoning 110003, China

⁴Fushun Vocational Technology Institute, Department of Chemical Engineering, Fushun, Liaoning 113122, China

Correspondence should be addressed to Dianwu Wang; 20131104@stu.syau.edu.cn

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The Biliu River is the largest river in Dalian. The occurrence of floods and droughts in this basin has extremely important impacts on local industry, agriculture, and urban development. For a long time, the annual distribution of precipitation in the Biliu River Basin is extremely uneven, the river runoff varies greatly from year to year and season to year, floods and droughts occur frequently, and serious soil erosion results in fragile ecological environment and severe shortage of water resources. In this paper, the spatial and temporal changes of rainfall and runoff in the Biliu River Basin are studied through the coupling of the MIKE 11 model and the MIKE SHE model. The hydrological changes in the Biliu River Basin are simulated. The coupled model is verified by monthly runoff data from 1996 to 2015, and the simulation values are found to be true. The values match well. Based on the cyclical pattern of precipitation and runoff in the Biliu River Basin, the rainfall and runoff data in the Biliu River Basin from 2016 to 2030 are derived. The MIKE SHE/MIKE 11 coupling model is used to predict the Biliu River from 2016 to 2030. The results show that flood disasters are expected to occur in August 2020, July 2025, and July 2030, which can provide a basis for hydrological management in the Biliu River Basin.

1. Introduction

The Biliu River is the largest river in the south of Liaoning Province. The basin runs through Yingkou and Dalian. The flood and drought conditions in the basin directly affect the industrial and agricultural development and economic growth of the people in the two places. The Cocoon Hydrological Station is located in Taudaoling Village, Guiyunhua Township, Zhuanghe City, Liaoning Province. It has a longitude of 122° 33'E and a latitude of 40° 02'N. It was established in 1958. It is the longest station in the river basin and has the longest statistical period. The comprehensive hydrological monitoring station with the longest and most complete hydrological and meteorological data is the only provincial hydrological monitoring point in the Biliu River Basin. The Biliu Hydrological Station is located in Shuangta Town, Pulandian City, Liaoning Province, with 122° 28' east

longitude and 39° 49' north latitude. The station was established in 1986. The total length of 42 km from Cocoa Field Station to Biliu Reservoir is a relatively concentrated area for catchment of water in the upper and upper reaches of the Biliu River Basin. The rainfall during the flood season at each station exceeds 70% of the annual rainfall [1, 2]. The hydrological conditions of Hehe Reservoir can well reflect the flood and waterlogging rules of the Biliu River, which is of great significance to the flood forecasting of the Biliu River Basin [3].

With the deepening of research on natural phenomena, accurate description and scientific disclosure of rainfall-runoff patterns in the natural world through mathematical methods can help people better understand and predict the water cycle in nature and rationally and scientifically allocate and use water resources. This has become a hotspot in hydrology research [4–6]. The distributed hydrological

model is to digitize rainfall, evaporation, and runoff data through elevation to show the hydrological change process of runoff and sink, which has higher requirements for the accuracy of the data [7]. In terms of professional software, the Danish Institute of Water Resources and Water Environment has been a world leader [8]. The company's software has been verified in actual engineering and has been widely recognized in water resources research. The functions of the software cover production, sink, and flow, including land, rivers, lakes, and oceans. The spatial scope ranges from one dimension to three dimensions. The research area ranges from water environment to hydrodynamics, and the research business ranges from water resource assessment and management to surface water and groundwater [9, 10]. In combination, one-dimensional river networks, two-dimensional estuaries, and three-dimensional deep seas are involved. The Danish Institute of Water Resources and Water Environment is a professional research department dedicated to water resources and the water environment [11]. Their technology has always been a leader in the world [12]. Hydrology in France, the United Kingdom, and Denmark has developed the first hydrological model for small watersheds, SHE [13]. In order to solve the calculation relationship between different hydrological processes and the values of different processes at the same time, the ASHE Association splits and combines the components that make up the SHE model and initially realizes the coupling [14]. The Danish Institute of Water Resources (DHI) uses the same code to port all the important coupled components. Relevant scholars improved the MIKE SHE model through the techniques of MODFLOW and OPENMI [15, 16]. MIKE 11 is a widely used one-dimensional river canal hydrodynamic model. Related scholars used the MIKE 11 modeling system to manage water resources in Strymonas River and Kerkini Lake and achieved good results [17, 18]. MIKE SHE is widely used in various runoff simulations. The researchers took the Saliberta Basin in the middle of the Mahanadi River Basin as the research object and focused on the application of the physical-based distributed modeling system MIKE SHE with good results [19]. Relevant scholars use the spatial distribution model MIKE SHE SWET to analyze the impact of afforestation and tree species on hydrology in different watersheds and use MIKE 11/MIKE SHE to study regional water resources management [20, 21].

This paper uses the hydrometeorological data from southern Liaoning from 1978 to 2016, based on an in-depth analysis of the occurrence of rainfall, evaporation, and runoff and its impact on floods and droughts. The dynamic process of runoff drainage is numerically simulated, the characteristics of floods and droughts in the Biliu River Basin are systematically studied, and related mechanisms are discussed. Local suggestions for controlling natural disasters such as floods and droughts and strengthening ecological construction are proposed.

The rest of this article is organized as follows. Section 2 analyzes the collection and processing of data. The model is established in Section 3, and the model is verified and predicted in Section 4. Finally, Section 5 summarizes the full text.

2. Data Collection and Processing

According to the actual conditions of the Biliu River Basin, the channel conditions in the simulated section, and the ultimate goal of the study, several modules such as river runoff (OC), slope flow (OL), and unsaturated flow (UZ) were selected in the MIKE 11 model.

For all hydrological processes and selected modules of the MIKE 11 model, we collate the collected data, summarize the model range, terrain, rainfall, vegetation, and other data, establish SHE parameters, and fully prepare for the modeling. The range of the Biliu River Basin is shown in Figure 1.

2.1. Terrain. The topographic data come from the topographic map with elevation data downloaded from Ovi Map, including the water system map of the simulated watershed. The elevation data come from the geographic and national conditions monitoring cloud platform; through the adjustment of the coordinate system and the rasterization of ArcGIS, the corresponding topographic water system map is generated.

2.2. Land Cover/Use. The land cover/use data is from the historical statistics of the Ministry of Agriculture. The land cover type, soil type, and vegetation classification are all extracted from the observation data with a resolution of 500 m. The data projection is converted and merged with the MODIS Reprojection Tool (MRT). Based on this, a commonly used Gauss Kruger format is formed, which can facilitate data synchronization processing.

There are multiple classification systems for land cover. This study uses a common vegetation classification scheme for agriculture. Most of the Biliu River Basin is a rural area, and the land use has not changed much between 1978 and 2016, and it is relatively stable. Therefore, the land use type in 1999 was used for treatment and it was divided into forest land (coniferous forest, broad-leaved forest, and shrubs) accounted for 45.41%, arable land (all agricultural land) accounted for 42.45%, residential and industrial land accounted for 7.07%, garden land accounted for 1.66%, unused land accounted for 0.02%, and water area accounted for 3.39%. The land-use types in the Biliu River Basin are shown in Table 1.

2.3. Soil Types. Based on the local soil data query, the soil types and their parameters in the Biliu River Basin are shown in Table 2. It can be found from Table 2 that the saturated hydraulic conductivity of brown earth soil is the highest; the saturated moisture content of meadow soil is the highest; the field water holding capacity of paddy soil is the largest; in addition, the withered moisture content of paddy soil is also the biggest.

2.4. Plant Foliar Index. The leaf surface index (LAI) of each coverage type in this research process can be determined based on actual measurement results, and the relevant results are shown in Table 3.

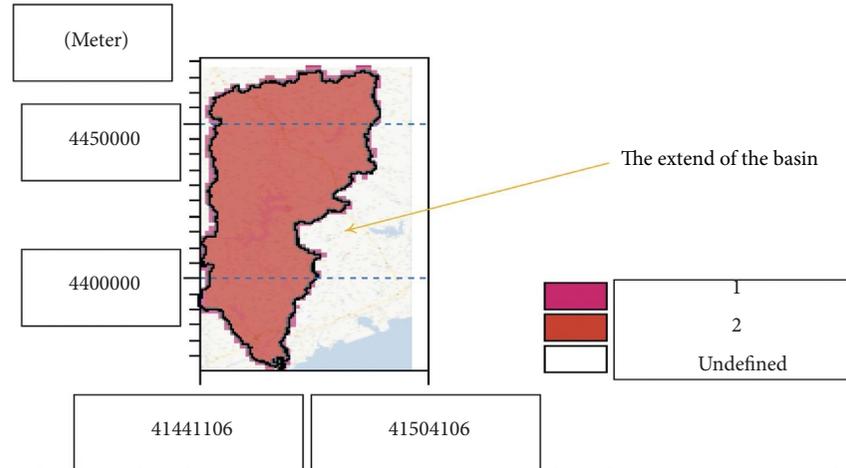


FIGURE 1: The extent of the Biliu River Basin.

TABLE 1: Land-use types in the Biliu River Basin.

Soil use type	Proportion (%)
Woodland	45.41
Arable land	42.45
Garden	1.66
Waters	3.39
Urban and industrial land	7.07
Unused land	0.02
Total	100

2.5. *Others.* The four hydrological stations of the Biliu River are cocoon field, Xiaosongjiatun, Biliu Reservoir, and a tributary Yushi Reservoir. The annual average runoff is 612 million m^3 .

Parameters related to rainfall, evaporation, and runoff were determined according to the statistics of the Hydrological Bureau. The meteorological data used in the calculation and analysis came from the Liaoning Meteorological Bureau. The location of the Biliu River Basin is shown in Figure 2.

There are obvious similarities between the average rainfall and annual rainfall distribution in the river basin during the flood season. The entire river basin gradually decreases from Dajiangtun in the north to Kuangdonggou in the southwest and Chengzitan in the south. All areas are gradually decreasing from the northeast to the southwest. The areas with increased rainfall are located in Dongsandaogou and Taipingzhuang in the northeast. The rainfall is greater than 560 mm, while the areas with lower rainfall are located in Bangladesh, in which the rainfall is less than 500 mm.

3. Model Establishment

3.1. *The Basis of the Model.* The runoff depth of each station does not change with time. The runoff depth of the Yushi Reservoir site has become smaller due to the commissioning of the Yushi Reservoir in 2003. At the same time, the Yushi Reservoir also affects the runoff depth of the mainstream cocoon field of the Biliu River and Xiaosongjiatun. Xiaosongjiatun Station is located in the lower

reaches of the Biliu River, and its runoff is greatly affected by the Biliu River Reservoir. In addition, the gradual decrease in rainfall over time is also the main reason for the depth of runoff. The blockage of river channels and the interception of vegetation will cause a decrease in runoff depth.

In the process of hydrological research, it is generally believed that a high-water year is a year when the flow is greater than the normal flow, while the opposite is true for a low-water year. The results of this paper show that the Biliu Reservoir has had more wet years than dry years in the past 40 years, while the results of other sites are opposite. The overall analysis shows that the ratio of the wet year to the dry year of the Biliu Reservoir is about 3 : 2, and the flood season is basically in line with the annual average, which shows that the regulation effect of the Biliu Reservoir is obvious.

The modeling process adopts the section from the mainstream cocoon field in the Biliu River Basin to the Biliu Reservoir. This section of the river has a large runoff and frequent floods. It plays a very important role in preventing floods in the Biliu River Basin. During the simulation, MIKE SHE was used to simulate the runoff, rainfall, and evapotranspiration fitting conditions at the cocoon field station, and MIKE 11 was used to simulate the water level change of the Biliu Reservoir.

Combined with the design data of the reservoir, the flood prevention alert water level is set. In this study, the Biliu Reservoir warning line 69.8 m designed by Liaoning Province Water Conservancy Survey and Design Institute in 1982 was used as an indicator of flood occurrence, and the maximum safe water level was 68.1 m. If the Biliu Reservoir water level reaches or exceeds the warning level, floods will occur and the reservoirs need to be flooded.

There are many factors that affect runoff changes, but rainfall is the most important factor. Analyzing the relationship between rainfall and runoff at various stations in the Biliu River Basin, it is found that the overall trend of annual runoff and rainfall is consistent. Secondly, the completion and commissioning of the Yushi Reservoir in 2003 greatly improved the hidden flood hazards and runoff conditions in

TABLE 2: Calculation of soil parameters.

Numbering	Withering water content (% vol)	Tianwen water holding capacity (% vol)	Saturated water content (% vol)	Saturated hydraulic conductivity (10 ⁻⁶ m/s)	Note
Brown soil	14.3	27.1	43.8	3.72	Calibration parameters
Brown soil	14.8	26.5	36.5	4.13	
Paddy soil	30.8	43.1	42.3	2.8	Calibration parameters
Coastal saline soil	14.8	28.3	45.6	3.68	
Meadow soil	12.6	28.5	46.1	3.78	Calibration parameters

TABLE 3: Vegetation leaf area index in the Biliu River Basin.

Types	January	February	March	April	May	June
Arable land	0	0	0	0	1.5	2.0
Woodland	0	0	0	0	3	6
Garden land	0	0	0	0	0.25	0.50
Waters city and industry unused	0	0	0	0	0	0
	0.5	0.5	0.5	0.5	0.5	0.5
Types	July	August	September	October	November	December
Arable land	3.5	4.6	4.5	3	0	0
Woodland	6	6	6	3	0	0
Garden land	2	2	2	2	0	0
Waters city and industry unused	0	0	0	0	0	0
	0.5	0.5	0.5	0.5	0.5	0.5

the Biliu River Basin, and the design standards of the Biliu Reservoir have been continuously improved. Third, the improvement of the river course reduces the leakage loss of the river course, so that the impact of runoff is not obvious when the annual rainfall continues to decrease.

There is a total of 42 km from the cocoon field to the Biliu Reservoir. During the modeling process, sections were established at Cocoon Station, 40.5 km from Cocoon Station, 41.99 km from Cocoon Station, and 42 km from Cocoon Station to ease the water flow. A weir was established at 41.999 km from the cocoon field station to control the water level. When the water level exceeds 89.2 m, the weir will automatically prevent flooding until it reaches a safe water level of 68.1 m.

Runoff concentration is to synthesize the monthly runoff by the vector method, and the ratio of the resulting composite amount to the annual runoff can be used to describe the concentration level of the runoff during the year. The concentration period refers to the orientation of this composite vector, which describes the month corresponding to the center of gravity of the annual runoff concentration. In the process of mathematical analysis, it is generally described by the tangent angle of the ratio of the component sum.

For the convenience of research, the Biliu Reservoir was generalized into a part of the river during the research. The river below the reservoir was set at a constant water level of 30 m and the natural slope drop ratio of the river was 2‰.

In this study, the 5-year moving average method was used to select typical stations on the Biliu River, namely, the cocoon site, Biliu Reservoir, Xiaosongjiatun, and Yushi Reservoir, to analyze the change trend of its runoff. Then, the MK method was used to analyze the cocoon site and Biliu River. The MK method is used to test the sudden change of the rainfall trend. The MK method is a nonparametric test method. It does not need to analyze the distribution of the sample. The impact of abnormal values is very small. It does not need to be considered. It has high applicability to various types of variables. The accuracy of the result obtained is high, and the calculation is simple. The M-K method is widely used in hydrological research and meteorological research trend checking.

For the climate sequence x_i , at time i , $i = 1, 2, \dots, n-1$, there are

$$m_j = \begin{cases} 1, & x_j > x_i, \\ 0, & \text{others,} \end{cases} \quad (1)$$

$$r_i = \sum_{j=i+1}^n m_j, \quad (2)$$

$$Z = \frac{4 \sum_{i=1}^{n-1} r_i}{n(n-1)} - 1. \quad (3)$$

We set the significance level to $\alpha = 0.05$, and then the criterion is

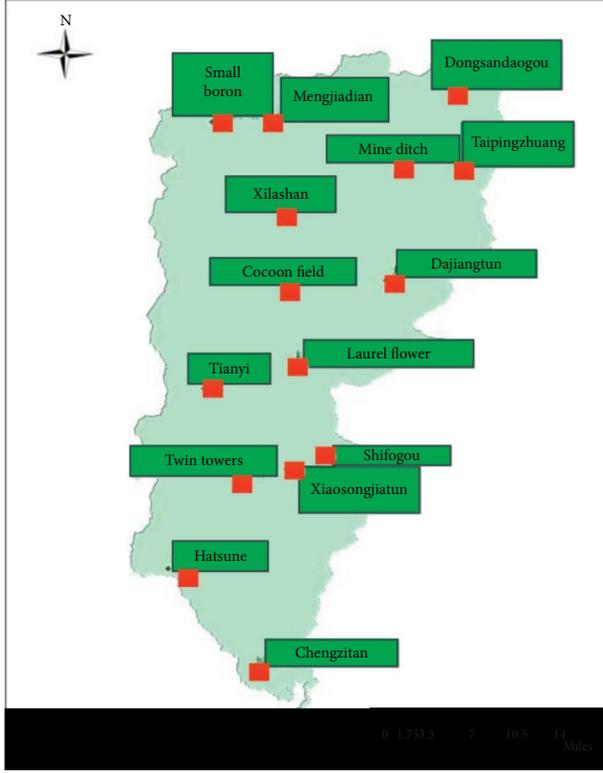


FIGURE 2: Survey station map of the Biliu River Basin.

$$Z_{\alpha} = 1.96 \times \left[\frac{4n + 10}{9n(n-1)} \right]^{(1/2)}. \quad (4)$$

Suppose that the sequence is x_1, x_2, \dots, x_n , S_k represents the cumulative number of the i -th sample $x_i > x_j$ ($1 \leq j \leq i$), and the defined statistics are

$$S_k = \sum_{i=1}^k r_i, r_j = \begin{cases} 1, & x_i > x_j, \\ 0, & x_i \leq x_j. \end{cases} \quad (5)$$

3.2. Model Establishment. The MIKE SHE model runoff simulation is performed by the Saint-Venant equations, where the momentum equation is simulated by the following equations:

$$\frac{\partial h}{\partial t} + \frac{\partial(uh)}{\partial x_i} + \frac{\partial(vh)}{\partial x_j} = q, \quad (6)$$

$$\frac{\partial(h)}{\partial x_i} = S_{oxi} - S_{fxi}, \quad (7)$$

$$\frac{\partial(h)}{\partial x_j} = S_{oxj} - S_{fxj}. \quad (8)$$

In the formula, $h(x_i, y_j)$ represents the surface water depth (m), (x_i, y_j) represents the space coordinates, t is time (s), u and v represent the surface runoff velocity (m/s), and q represents the horizontal direction of the source-sink term

of inflow per unit area ($\text{m}^3/\text{s m}^2$), S_{oi} and $S_{oj}(x_i, y_j)$ represent the ground slope in the directions of x_i and y_j , and S_{fi} and $S_{fj}(x_i, y_j)$ represent downhill in the directions of x_i and y_j .

The rainfall and runoff of the Biliu River Basin were simulated, and MIKE 11 and MIKE SHE were coupled for flood forecast research.

3.2.1. MIKE 11 Model. We establish a river network file based on the DEM data in the Biliu River Basin as required. The cross-section data are converted into a .shp file and entered into the MIKE 11 model to adjust the hydrodynamic parameter data.

The cross-section data simulated by the MIKE 11 model are derived from the generalization of the reservoir channel design and actual topographical data. The amount of water comes from the runoff generated by rainfall at the confluence of the cocoon field station. The cocoon field station is located 59 km from the river source; the lower boundary is 101 km from the river source. The river basin in this section is located in the middle of the Biliu River Basin. The concentrations of river runoff and large drop are of great significance for studying the drought and flood laws and forecasting in the Biliu River Basin. The height difference between the upper and lower boundaries will be calculated from the average ratio of the river channel and the actual relative height difference. Hydrodynamic parameters are set by default.

3.2.2. MIKE SHE Model. In the model calculation area, the mainstream of the Biliu River Basin was selected. When the grid was set, the grid size was determined to be 1 km. The target area was divided to determine 50×100 units. In the course of this research, for the convenience of preprocessing and supplementation, all of them were uniformly transformed into the Xi'an 80 coordinate system. The rainfall data can be processed and determined based on the measured values of various stations in this area. The obtained results are processed appropriately to form the corresponding time series file (* .dfs0); the evaporation data is determined according to local meteorological statistics. The Penman formula is calculated on the obtained raw data, and the resulting ET0 value is used to generate a * .dfs0 file. In the model, the rainfall data and evaporation data are set separately by Tyson polygons. Thiessen polygon is a set of continuous polygons composed of vertical bisectors connecting two adjacent points. The distance from any point in a Thiessen polygon to the control points constituting the polygon is less than the distance to the control points of other polygons.

3.2.3. Coupling of MIKE SHE/MIKE 11. The water movement module of MIKE SHE covers the main processes of the hydrological cycle. It can study the hydrological cycle processes at different scales. It describes the hydrological cycle process of the runoff through evapotranspiration, slope flow, rivers and lakes, unsaturated flow, and saturated flow: evapotranspiration (ET) related factors mainly include

interception, soil, and water surface evaporation; surface runoff is described according to slope flow (OL), etc.; rivers and lakes (OC) are obtained by MIKE simulation analysis; and the correlation of reservoirs and dams is also calculated. However, the simulation of the hydrodynamic part of the MIKE SHE channel is insufficient and needs to be coupled with MIKE 11. Building a comprehensive MIKE SHE/MIKE 11 model includes the following basic steps.

First, we set the corresponding MIKE 11 hydrodynamic independent model and then test and analyze, under the possible conditions through the specified flow-related parameters to make a preliminary determination. Then, we establish the NIKE SHE model, the modules of which mainly include surface flow and saturated band, unsaturated band, and so on. Hydrodynamic simulation (1) and hydrodynamic simulation (2) are shown in Figures 3 and 4, respectively.

The branch river is defined as the connection between the two models, and the two are coupled. The lake submodule OC is used to import the simulation files related to the previous model. In this simulation system, the two models are simultaneously simulated and analyzed, and the data of the two is processed by the switch based on the shared storage space. MIKE 11 calculated the corresponding runoff water level, transferred the results to the latter model, and then compared the analysis results with the surface terrain information stored in the model to determine the remaining water volume. It can be inferred that the influential factors of water exchange between the two are mainly the corresponding evaporation and infiltration of surface water and the corresponding river exchange. Finally, the calculated water flow is exchanged with the first model through the sink source term of the Saint-Venant equation.

During the MIKE SHE model input process, the corresponding input data content is determined based on the corresponding modules and problem-solving requirements of the simulated hydrological process. The basic parameters include the model range, terrain, and rainfall. These data are indispensable in various MIKE SHE models. Based on the research area, a grid size of 1 km was set during the research in this paper. The target area was partitioned to determine 50×100 cells. In the course of this research, for the convenience of preprocessing and supplementation, all data were converted and uniformly converted to the Xi'an 80 coordinate system.

We use MIKE 11 to simulate the river from the cocoon field in the Biliu River Basin to the Biliu Reservoir. According to the needs, the DEM data in the Biliu River Basin is used to create a river network file, and the cross-section data are converted into a .shp file to enter the MIKE 11 model to adjust the hydrodynamic parameter data.

The cross-section data simulated by the MIKE 11 model are derived from the generalization of the reservoir

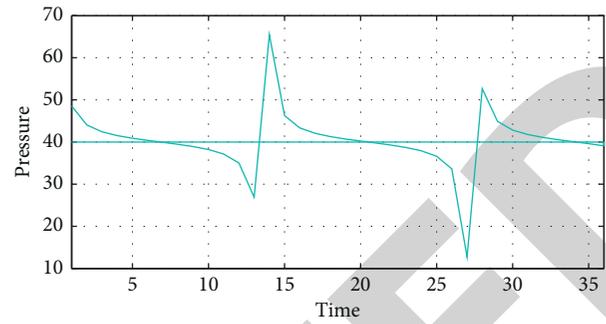


FIGURE 3: Hydrodynamic simulation (1).

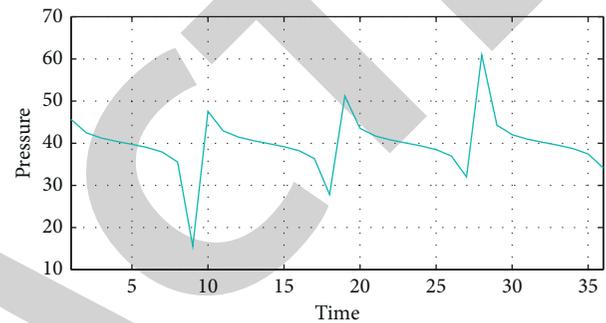


FIGURE 4: Hydrodynamic simulation (2).

channel design and actual topographical data. The amount of water comes from the runoff generated by rainfall at the confluence of the cocoon field station. The cocoon field station is located 59 km from the river source; the lower boundary is located 101 km from the river source; the river basin in this section is located in the middle of the Biliu River Basin. The concentrations of river runoff and large drop are of great significance for studying the drought and flood laws and forecasting in the Biliu River Basin. The height difference between the upper and lower boundaries will be calculated from the average ratio of the river channel and the actual relative height difference. Hydrodynamic parameters are set by default. The coupling between MIKE SHE and MIKE 11 is shown in Figure 5.

4. Model Verification and Prediction

In order to verify the model effect, the adjustment of MIKE SHE model parameters should be as small as possible. In the MIKE SHE/MIKE 11 coupling model, the setting of parameters affects both the MIKE SHE and MIKE 11 models, and they are uniform in the river network. The correlation level between the measured value and the simulated value is

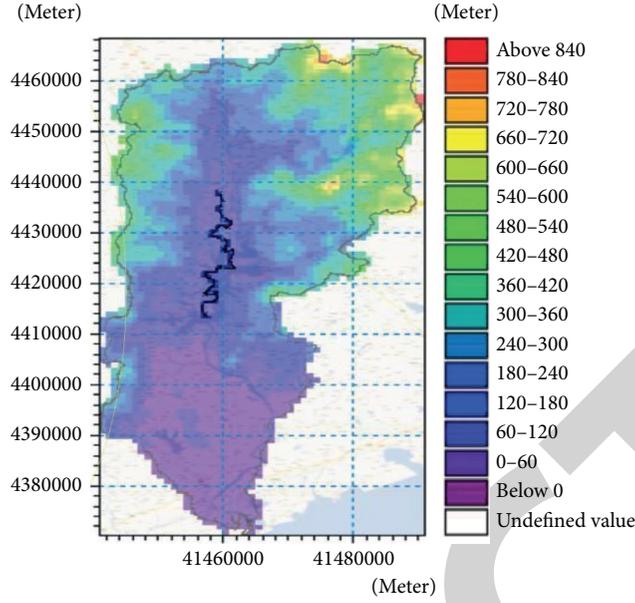


FIGURE 5: Coupled river pattern of MIKE 11/MIKE SHE.

described by the correlation coefficient, and the fitting degree of the two is evaluated by the Nash coefficient (Nse).

$$R = \frac{\sum_t (\text{Calc}_{i,t} - \overline{\text{Calc}_i}) \cdot (\text{Obs}_{i,t} - \overline{\text{Obs}_i})}{\sqrt{\sum_t (\text{Calc}_{i,t} - \overline{\text{Calc}_i})^2 \cdot \sum_t (\text{Obs}_{i,t} - \overline{\text{Obs}_i})^2}} \quad (9)$$

$$Nse = 1 - \frac{\sum_t (\text{Obs}_{i,t} - \text{Calc}_{i,t})^2}{\sum_t (\text{Obs}_{i,t} - \overline{\text{Obs}_i})^2} \quad (10)$$

Among them, Obs_i , Calc_i , $\overline{\text{Obs}_i}$, and $\overline{\text{Calc}_i}$ are the measured and calculated values and their average values at i , respectively. The value range of Nse is negative infinity to 1. The larger the parameter is, the better the simulation effect can be judged to be, and the credibility requirements are met. If Nse is close to 0, it can reflect that the obtained result is close to the observation mean; that is, credibility is in the acceptance interval. If it is small, the model is untrustworthy. Relevant experience shows that if Nse is greater than 0.75, the simulation effect can be judged to be good; within the range of 0.36 to 0.75, it can be considered basically satisfactory; if it is less than 0.36, the requirements are not satisfied. Generally, when $R > 0.8$, it is considered that the level of linear correlation is high.

4.1. Calibration of Parameters. The MIKE SHE/MIKE 11 coupling model uses the data of the cocoon field from 1986 to 1995 for the parameter calibration. The calibration results are shown in Table 4. The simulation results of the runoff process before and after calibration are shown in Figures 6 and 7.

The correlation coefficient before calibration is $R = 0.751294$, and the Nash index is $Nse = 0.531545$; the correlation coefficient after calibration is $R = 0.94583$, and the Nash index is $Nse = 0.71379$. The simulated and observed values achieve a good fitting effect.

4.2. Model Verification. The MIKE SHE/MIKE 11 coupling model was verified using two consecutive 10-year rainfall and runoff data from the cocoon field from 1996 to 2005 and 2006 to 2015. The results are shown in Figures 8 and 9, respectively. Time series verification results are from 1996 to 2005, correlation coefficient is $R = 0.98818$, and Nash index is $Nse = 0.918427$; time series verification results are from 2006 to 2015, correlation coefficient is $R = 0.964802$, and Nash index is $Nse = 0.895926$. It shows that the simulated values and observed values of the two periods are in good agreement whether from the peak flow or the observation time.

Figures 10 and 11 show the changes in the water level at the Biliu Reservoir Station for two consecutive years (1996–2005 and 2006–2015). It can be found that, in the 20 consecutive years from 1996 to 2015, the water level of the Biliu Reservoir exceeded the warning level by 69.8 m: July 1995, July 1996, August 1997, August 1998, and August 2001, July 2005, August 2006, August 2010, August 2011, July 2012, and July 2013, these time nodes coincide with the historical changes in the water level of the Biliu Reservoir, indicating that the water level simulation results of the river reservoir can well reflect the real water level change of the reservoir. At this time, the reservoir needs to be discharged to prevent floods.

4.3. Application of the Model and Flood Disaster Prediction. The MIKE SHE/MIKE 11 coupling model was calibrated and verified by the rainfall, evaporation, and runoff data from the cocoon field from 1985 to 2015. It is found that the verification model is in good agreement with the real effect, and the water level changes of the Biliu Reservoir obtained from the simulation are basically consistent with the historical data of the Biliu Reservoir. This shows that the application of this model to predict flood disasters in the Biliu River Basin has a good effect.

TABLE 4: Parameter rate determination result.

Parameter name	Calibration results	Parameter unit
Evapotranspiration (ET)	1.665	mm/d
Slope roughness (M)	5.0	$m^{1/3}s^{-1}$
Initial water depth	-0.5	m
Channel roughness (RM)	5.0	$m^{1/3}s^{-1}$
<i>Saturated hydraulic conductivity</i>		
Brown soils	4.13×10^{-6}	ms^{-1}
Brown earth	3.72×10^{-6}	ms^{-1}
Coastal solonchaks	3.68×10^{-6}	ms^{-1}
Meadow soils	4.68×10^{-6}	ms^{-1}
Paddy soils	2.80×10^{-6}	ms^{-1}

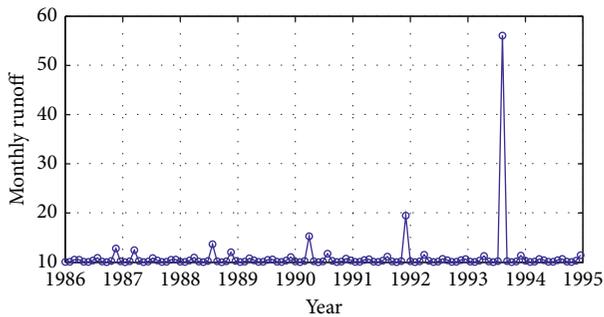


FIGURE 6: Simulation results of monthly runoff in Jianchang field (1986~1995).

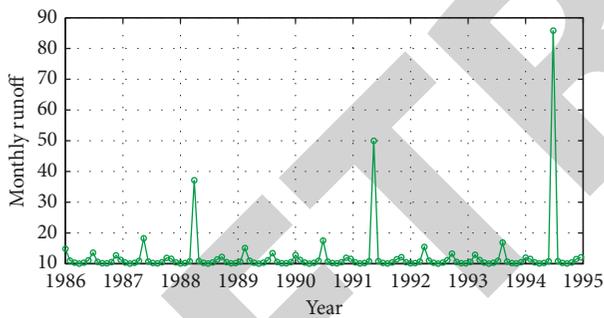


FIGURE 7: Simulated results of monthly runoff in the cocoon field after calibration (1986~1995).

Based on the cyclical pattern of precipitation and runoff in the Biliu River Basin from time to time, the precipitation and runoff data of the Biliu River Basin from 2016 to 2030 are derived. The MIKE SHE/MIKE 11 coupling model was used to predict flood disasters in the Biliu River Basin from 2016 to 2030.

Figure 12 shows the results of the monthly runoff simulation through the cocoon field. It can be seen that the correlation coefficient of the correlation coefficient between the derived value and the simulated value is $R = 0.965588$, the Nash index is $Nse = 0.920947$, and the fitting effect is very good. Figure 13 shows the water level change of the Biliu Reservoir. It can be seen that flood disasters are expected to occur in August 2020, July 2025, and July 2030.

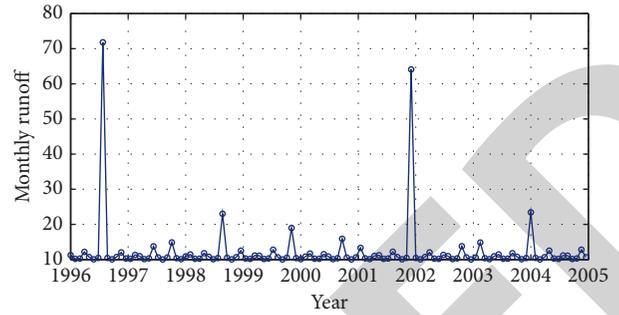


FIGURE 8: Simulation results of monthly runoff in Jianchang field (1996~2005).

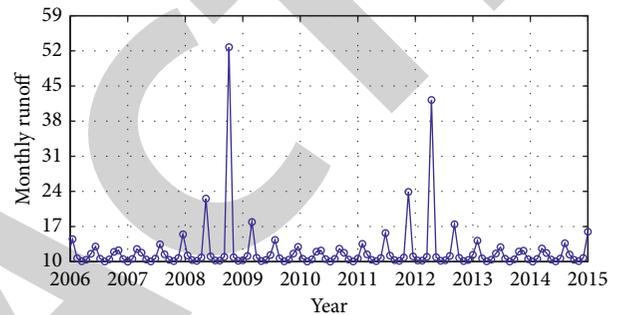


FIGURE 9: Simulation results of monthly runoff in Jianchang field (2006~2015).

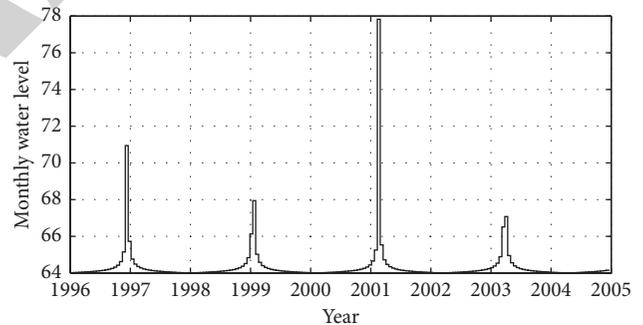


FIGURE 10: Simulation results of monthly water level in the Biliu River Reservoir (1996~2005).

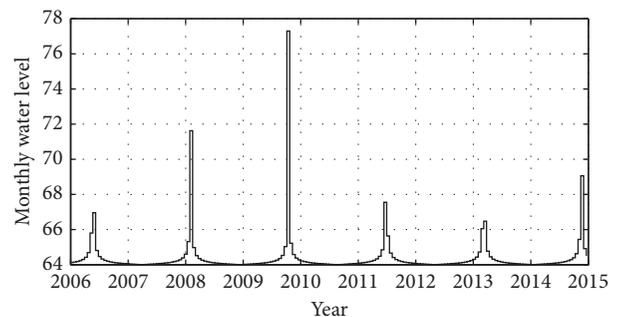


FIGURE 11: Simulation results of monthly water level in the Biliu River Reservoir (2006~2015).

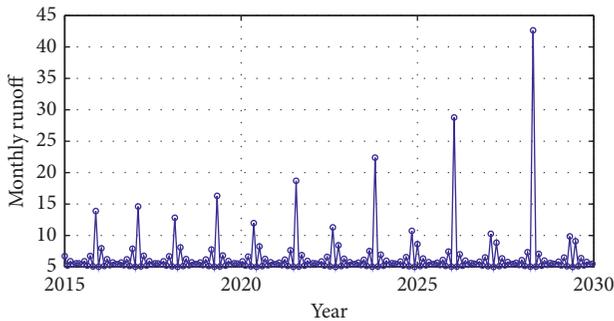


FIGURE 12: Simulation results of monthly runoff in Jianchang field (2005~2015).

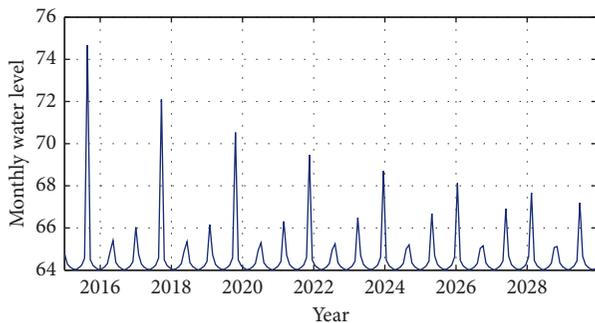


FIGURE 13: Simulation results of monthly water level in the Biliu Reservoir (2005~2015).

5. Conclusion

For the section of the Biliu River Basin from the cocoon field to the Biliu Reservoir, this paper uses the MIKE 11 model to create a one-dimensional hydrodynamic model. Through various terrain indicators, the MIKE SHE model is established. The coupling of MIKE 11 model and MIKE SHE model is used to study the temporal and spatial changes of rainfall and runoff in this basin and to simulate the hydrological changes in Biliu River Basin. Based on the monthly runoff data of Biliu River Basin from 1986 to 1995, the parameters were calibrated, and the model was given a reasonable parameter scheme. The model was verified through monthly runoff data from 1996 to 2015, and the simulation values were found to be in good agreement with the real values, which ensured the applicability of the model in the study area. Based on the cyclical pattern of precipitation and runoff in the Biliu River Basin from time to time, the precipitation and runoff data of the Biliu River Basin from 2016 to 2030 are derived. The MIKE SHE/MIKE 11 coupling model was used to predict flood disasters in the Biliu River Basin from 2016 to 2030. The results show that flood disasters are expected in August 2020, July 2025, and July 2030.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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