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Analysis of Forecast and Early Warning of Flood in Medium and Small Rivers

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Abstract: Flooding of small and medium rivers is caused by environmental factors like rainfall and soil loosening. With the development and application of technologies such as the Internet of Things and big data, the disaster supervision and management of large river basins in China has improved over the years. However, due to the frequent floods in small and medium-sized rivers in our country, the current prediction and early warning of small and medium-sized rivers is not accurate enough; it is difficult to realize real-time monitoring of small and medium-sized rivers, and it is also impossible to obtain corresponding data and information in time. Therefore, the construction and application of small and medium-sized river prediction and early warning systems should be further improved. This paper presents an analysis and discussion on flood forecasting and early warning systems for small and medium-sized rivers in detail, and corresponding strategies to improve the effect of forecasting and early warning systems are proposed.

Keywords: Medium and small rivers; Flood forecast and early warning; Flood disaster

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1. Introduction

In recent years, frequent floods in small and medium-sized rivers not only contribute to the most economic loss among all types of floods, but it also a great representation of the disconnection between the flood control and disaster reduction system. The prevention, control, and management of small and medium rivers require accurate forecasting, timely early warning, scientific scheduling, and efficient processing. At present, flood control and disaster reduction cannot be carried out efficiently due to poor forecasting of sudden rainstorms in small and medium-sized watersheds, incomprehensive forecasting and early warning of short-term rainstorms, poor flood control, and weak emergency response system for sudden rainstorms and other emergencies. Due to the large differences in flow yield and confluence in different hydrometeorological divisions in the basin, drastic changes in the underlying surface caused by human activities, and the lack of real-time information, the prediction of small and medium-sized watersheds are inaccurate, which makes to job of the control room more difficult.

2. Status of flood disasters in small and medium rivers

According to the latest information of our country's water conservancy census, more than 45,000 are prone to floods, of which the number of small and medium-sized rivers is about 12,000, and the total area of the basin is between 2000 km^3 and 3000 km^3. Most of the small and medium-sized rivers cover urban and rural areas. More reservoirs or pond and dams have been constructed on small and medium-sized rivers, which are mainly used for effective monitoring and regulation of water flow and water volume in the basin. However, floods still occur frequently in small and medium-sized rivers, most of which are flashfloods, and most of them are caused by rain. This is also an important problem in flood disaster management, accounting for 70% of the total floods in the country. In 2021, warning have been issued in more than 2,600 small and medium-sized rivers in the Pearl River Basin, with 22 having warning messages. For flashfloods in small and medium-sized rivers caused by rain, it is necessary to carry out real-time monitoring and evaluation, and provide early warning by using big data, cloud computing, and other technologies. Besides, flood-control infrastructure should be constructed to improve prevention and control of floods. Floods in small and medium-sized rivers in China are mostly sudden, widely distributed, and difficult to control [1] .

3. Characteristics of floods in small and medium rivers

Compared to floods in large rivers, floods in small and medium-sized rivers in our country are significantly different in terms of temporal and spatial distribution, causes, and process of formation, which can be manifested in different ways. (1) In terms of spatial distribution, small and medium-sized rivers are widely distributed and high in number, the physical geography and climate characteristics of each basin are also relatively complex. There are also huge differences in hydrology and meteorology of different rivers. (2) In terms of time distribution, floods in small and medium-sized rivers are seasonal and sudden: In some areas floods occur frequently in summer, and local heavy rains in the rainy season cause floods in small and medium-sized rivers; in other areas floods occur more frequently in spring or autumn. (3) The causes of floods in small and medium rivers can be divided into two aspects: natural and man-made. Natural causes include heavy rain and steep terrain of the catchment area. Man-made causes include improper development of small and medium-sized watershed, which led to a decline in forest vegetation coverage, soil erosion, and deterioration of the natural environment. In addition, river encroachment, river blockage, and barriers have led to shrinkage of the river. These factors will further cause or aggravate flood hazards. (4) The intensity of floods in small to medium-sized rivers is high, with fast flow velocity, and the duration of flood is short, usually no more than 6 hours. (5) In terms of impact, floods in small and medium watersheds are highly destructive and harmful, and the degree of impact depends on the volume of rainfall. Especially in hilly areas, floods are often accompanied by mudslides and landslides [2].

4. Difficulties in flood forecasting of small and medium rivers

There are many kinds of hydrological predictions and forecasting methods at home and abroad. However, these methods cannot predict floods in small and medium-sized rivers accurately. At present, the flood forecasting of small and medium-sized rivers in our country is lacking and inaccurate. In our country, the flood forecasting of small and medium rivers has become an important restricting factor of the improvement of hydrological forecasting of our country, but there is no set of forecast accuracy evaluation standards suitable for small and medium rivers in our country. The characteristics of floods in small and medium-sized rivers make their forecasting different from that of large rivers. (1) The hydrological data of small and medium-sized rivers are scarce. (2) There are not many observation stations, and the density of the station network is low. Even in catchment areas where rainfall stations are densely distributed, the representativeness of the stations and the calculation of surface precipitation are insufficient. The intensity and magnitude of the rainstorm in the precipitation area did not meet the requirements, and the weather forecast is inaccurate. (3) Due to the inhomogeneity of rainstorm space and time, the flood of small and medium rivers often starts from a small tributary rather than from the mouth of the basin, making it difficult to predict. In addition, the period of flood peak in small and medium-sized rivers is generally short, and it is difficult to achieve effective forecasting through the conventional 6-hour flood reporting method. (4) It is difficult to satisfy both the complexity of stormwater response and the simplicity of operational forecasting. The commonly used simple correlation maps and statistical models highly depend on the experience of forecasters, and it is difficult to make further breakthroughs in technology and be popularized in practical applications. However, there are problems such as insufficient pertinence, inability to adapt to flood characteristics, prediction time, and prediction accuracy in the flood prediction of small and medium-sized rivers by adopting the centralized model or the existing general hydrological model [3].

5. Flood forecasting and early warning strategies for small and medium rivers

5.1. Three-dimensional monitoring of information

In the flood forecasting and early warning of small and medium rivers in our country, the data used is diversified, and there are inaccuracies in the monitoring information of the current forecasting software. Therefore, we should make better use of modern technology, integrate ground sensing technology, radar scanning technology, satellite positioning technology, etc. to carry out real-time monitoring of disasters and relevant data feedback. With the invention and application of various technologies, relevant information of small and medium-sized rivers can be monitored in a three-dimensional manner, so that the whole process of flooding in the entire basin can be monitored, and refined management can be carried out [4]. Remote sensing technology, Internet of Things, and perception technology can be used on the ground, and wireless bandwidth technology and satellite technology can be used to build an integrated smart network. In this way, an integrated smart network can be constructed, so that relevant data in small and medium-sized river basins can be effectively obtained and monitored. After collecting the relevant data, an early warning system can be established. Digital technology and data mining can then be used to identify the signs of flood disasters in small and medium rivers, so that early warning and processing can be carried out. The collected data can be stored in the corresponding instrument and compared and analyzed with past data, thereby improving the accuracy of flood prediction and early warnings.

5.2. Construction of hydrological website system

In view of the existing problems of long data transmission time and low transmission accuracy in terms of forecasting and early warning of small and medium-sized rivers, it is necessary to expand the hydrological monitoring network, use modern technology to make up for the shortcomings of the hydrological station network, and improve the accuracy of precipitation data. The detection and prediction capabilities of the system enable multi-scale, high-temporal-scale precipitation analysis and forecasting. When improving and optimizing the hydrological station network system, the upper reaches of small and medium-sized rivers should be prioritized. After the hydrological station is constructed, the precipitation and runoff patterns can then be predicted and analyzed in combination with field data collection and rainfall analysis [5]. Taking the Huaihe River region as an example, 235 water network observation stations have been set up since 1956. As of the first half of 2022, there were 1,348 water network observation stations. At the same time, the coverage of the hydrological station network was further improved, and the exchange and transmission of data was realized. Many newly established stations in the hydrological station network can now meet the requirements of modernization technically, but many hydrological stations still operate using traditional technologies and methods. Therefore, these stations must be optimized and updated, and big data technology, intelligent technology, sensing technology, etc. should be integrated into the layout and coverage of hydrological websites, so that the accuracy and timeliness of data transmission can be improved.

5.3. Establishment of forecast and early warning indicators

A strong scientific forecasting and early warning system can be constructed on the basis of the existing flood forecasting and early warning system, and the early warning indicators were determined. The warning level and flood control value of the river can be analyzed using these indicators, and the water receiving capacity and flood discharge capacity of the reservoir can be scientifically determined. The early warning index can then be determined and divided into specific management responsibilities. This lays a solid foundation for flood prediction and early warning of small and medium rivers. Taking Jiang, Huai, Si and other small and medium-sized rivers in Jiangsu Province as the research objects, more than 2 million km^3 of floods pass through their upper reaches every year, and finally flow into the sea. The average annual precipitation in Jiangsu Province is about 1000 mm. A total of 220 small and medium-sized rivers and 215 sections of early warning indicator data were gathered. With sufficient preliminary investigation, the relationship between stations within the watershed was analyzed. In the process of amending and reviewing the process of flood warnings, a early warning index was constructed, and the value of the warning level was finally determined. In the process of establishing forecasting, early warning, and monitoring systems, the responsibilities of each department can be clarified, and corresponding emergency plans can be formulated [6].

5.4. Establishment of flood coupling forecasting model

On this basis, data from meteorological and hydrological observations can be collected to construct a hydrological observation model, and this model can be used to accurately predict rainfall in small and medium-sized watersheds. On this basis, remote sensing technologies, digital technology, and other means can be used to establish a high-precision and high-spatial-resolution forecast and early warning system to provide a scientific basis for floods in small and medium-sized river basins. The risks can then be classified according to the forecast results, and the probability of risk occurrence can be calculated accurately. This study intends to select the Huaihe River Basin as the research area. Through the identification of different types of precipitation, a prediction and early warning model for four levels of precipitation is constructed, namely 20–200 mm, 200–500 mm, 500–1000 mm, and more than 1000 mm. The degree of risk of flood disasters was then classified based on the forecasted rainfall period and rainfall intensity. On this basis, a refined and hierarchical forecasting model was established to provide a scientific basis for the forecast and early warning of floods in small and medium-sized rivers.

6. Application of key technologies

6.1. Forecast field technology

Information from multiple sources like remote sensing, satellites, atmospheric monitoring, and radar scanning can be integrated and optimized to achieve gridded, refined monitoring, and analysis of actual precipitation data. Then, precipitation forecast within two hours can be provided using weather forecast technologies [7]. On this basis, atmospheric water-liquid coupling technology was integrated in this research, and the numerical simulation method was used to realize the effective combination of precipitation and flood forecasting, improve the accuracy of precipitation forecasting, and extend the forecasting time to 12 hours. This technology was widely used in flood forecasting and early warning in 2021 to further improve the rainstorm forecasting system, and then combine it with the smart grid rainfall system in the early stages of the rainy season [8].

6.2. Intelligent forecasting

After constructing a smart platform, the watershed can be intelligently regulated according to the simulation results before flood disasters occur [9]. In addition, the monitoring results of flow and water level at various regional points can also be used for forecasting and early warning. The construction of the smart scheduling platform was based on the micro-service structure and was completed in a modular manner, including the establishment of models such as forecast models, rainfall models, scheduling models, and risk models. Complete regional scheduling and management was carried out using distributed computing, in which can also real-time data analysis could also be performed [10]. On this basis, information such as atmospheric precipitation forecast, soil permeability and initial conditions of the watershed can be used to carry out emergency response during a flood. This technology can achieve an 8-hour prediction, with a prediction accuracy of more than 95%, and it has strong real-time prediction ability, which can realize early warning before major floods occur in small and medium rivers.

7. Conclusion

The problem of forecasting and early warning of floods in small and medium rivers has always been highlighted in water conservancy departments and related departments. However, it is also a highly difficult problem. Using this forecasting system, it is possible to collect data related to precipitation, temperature, humidity, water velocity, etc. of small and medium-sized rivers. The data can also be visually transmitted, and the site conditions can be evaluated in real time, which is helpful in predicting the possibility and time of floods and other data, and guiding maintenance and repair. Therefore, it is necessary to strengthen the network of hydrological stations and the construction of information technology. Subsequently, a hydrological forecasting model can be built, and an integrated hydrological monitoring and early warning system can be constructed.

Disclosure statement

The authors declare no conflict of interest.

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