Research and Simulation of Flood Forecasting Model in Coastal Plain Area Based on Antecedent Precipitation Index Algorithm

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Abstract. This paper presents a simulation model for flood warning and sluice dispatch in complex coastal plain water area. We propose an improved "semi-diurnal water production" Antecedent Precipitation Index (API) algorithm for computational modeling and simulation. By analyzing a large number of historical flood data and applying multiple curve fitting method, the quantitative function curve of the rainfall rainfall, runoff, and pre-rainfall index was established. The comparison between simulation data and historical data shows that the experimental results have high reliability, can effectively predict and warn the flood flow, and provide important data reference for the sluice scheduling in the area.

1. Introduction

Water plays a decisive role in the development of human society. The plains on the coastal plains are magnanimous and the water flow is slow, which makes the river nets poor in self-purification [1]. At the same time, in order to continuously meet the demand for water brought about by social and economic development, a large number of sluice gates, pump stations and other water conservancy projects have been built on the river network. The existence of these water conservancy engineering measures has brought about convenience. However, it has changed the natural state of rivers, weakened the ability of water bodies to self-repair, made river network pollution, ecological deterioration, and prone to flooding [2]. Moreover, the coastal plain river network itself is affected by tides in the open sea, which results in short flood discharge times and weaken the flood discharge capacity.

The coastal plain area has a high population density and a high level of economic and social development. It has relatively high requirements for the quality and quantity of water resources in the region. Due to the densely populated river network in the area, the water system crisscrosses and the water surface is smaller than the water flow rate. The flow velocity of the water is slow, which is not conducive to the self-purification of the water body and affects the healthy development of the river [3]. Once heavy rain hits and the water flow is not smooth, it is extremely prone to floods and damage to the lives and property of the people around them.

In order to minimize the disaster caused by floods to neighboring cities, it is of great significance to timely and reasonably estimate the amount of water generated by heavy rain after a rainstorm has fallen, and it is also a prerequisite for the realization of floodgate group scheduling. In addition, unlike the inland areas, the sluice scheduling in the coastal plain area is not only related to the amount of water in the area, but also closely related to the changes in the tidal level of the downstream estuary. Based on the Antecedent Precipitation Index (API) algorithm model [4], this paper puts forward the concept of "half diurnal water production" and simulates the water production in the half-day tide in order to realize effective flood forecasting and warning.

2. Algorithm model establishment and main index calculation

The API (Antecedent Precipitation Index) model, also known as the pre-influenced rainfall model, is based on the physical mechanism of rainfall and runoff in river basins, which uses the main influencing factors as reference variables to establish a quantitative correlation between rainfall and production. Calculating the net rain using the correlation map, together with the empirical unit line method to calculate convergence, this method is simple and easy to operate and is widely used in actual production projects of flood forecasting in Chinese waters.

The commonly used parameters in the API model include the previous rainfall index, season, rainfall duration, and rainfall intensity. In production practice, their relationship is usually simplified two-phase correlation equation for ease of use, i.e.

$$\mathrm{R} = f(P + Pa) \tag{1}$$

Where P is the rainfall, Pa is the previous rainfall index, and R is the water runoff. According to this formula, the key to making correlation maps for rainfall and runoff is to calculate the pre-rainfall index Pa and runoff of floods R during the field. The following parts introduce the corresponding calculation methods.

2.1 Pre-rainfall index Pa calculation

The pre-rainfall index reflects the degree of dryness and humidity of the soil before the start of floods. Generally calculated using the following empirical formula.

$$P_{a,t} = kP_{t-1} + k^2 P_{t-2} + \cdots + k^n P_{t-n} \tag{2}$$

Among them, Pa,t represents the early rainfall index at 8 am; n is the number of days before the impact on the current runoff; which is normally about 30 days; k is the conversion coefficient, and its approximate constant is about 0.85, considering the monthly evaporation conditions. Taking into account the difference in evaporation conditions and evaporation capacity in each month, this paper adopts an improved calculation method. The conversion coefficient changes monthly, but takes the same value within the month.

2.2 Water runoff index R calculation

The depth of runoff of a flood is the net rain generated by the rainfall, which is numerically equal to the area enclosed by ABCDEF in Fig. 1. Among them, the CD segment is derived from the extension of the average drainage curve of the basin. This paper uses the flat cut method to calculate runoff.
In order to simplify the calculation, this algorithm selects floods that have similar flow rates for two adjacent rises. If the epitaxy is needed, suitable artificial extensions can be made according to the trend of water withdrawal. Referring to Fig. 1, the area surrounded by ABCDEF is used as the runoff depth of this flood, which can be expressed by Eq. 3.

$$R = \sum_{i=1}^{n-1} 3.6 Q_i \Delta t \,/\, A \tag{3}$$

Where, A indicates the drainage area in km^2.

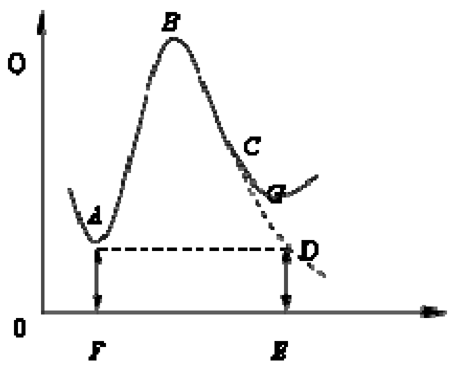

Fig. 1. The schema of water runoff calculation.

3. Computational simulation and test results

The daily rainfall, daily evaporation, and daily flow data for a total of 18 years from 1991 to 2008 were used to adjust the model parameters. The remaining 4 years of data were used for inspection. The model identification section required the use of flood data for flood seasons, while the original data was only for annual floods. Excerpts, data sessions vary in length. Therefore, prior to model parameter identification, the original data must be properly reorganized. In order to overcome the shortcomings of time-consuming and large errors caused by manual sorting, this project compiles the data compilation work into a sub-module, nested into the main program, and is specifically used to extract rainfall, traffic, etc. from the flood excerpt data during the same period. Evaporation and other information. Using this procedure, after the corresponding year is selected, the corresponding floods of the flooding stage can be selected by using the mouse in the annual runoff process line to obtain the results of the flood rectification. For example, the curve of the 1992 watershed flow process automatically extracted from the program is shown in Fig. 2.

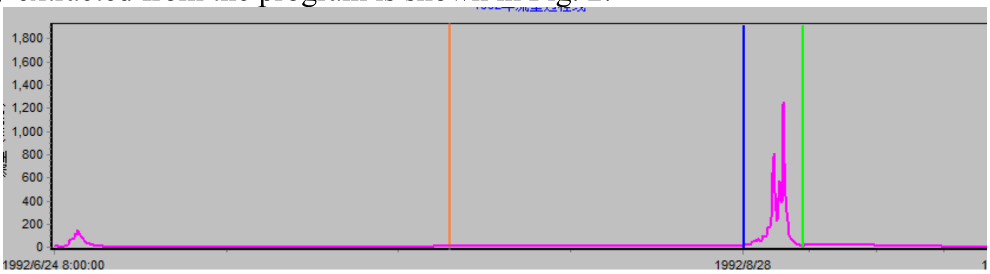

Fig. 2. The flow process curve in 1992 of the research water area.

By using the 66 flood data extracted from the 22-year annual runoff data, a P + Pa - R relationship diagram can be obtained through computational calculations. And their scatter plots diagram is shown in Fig. 3.

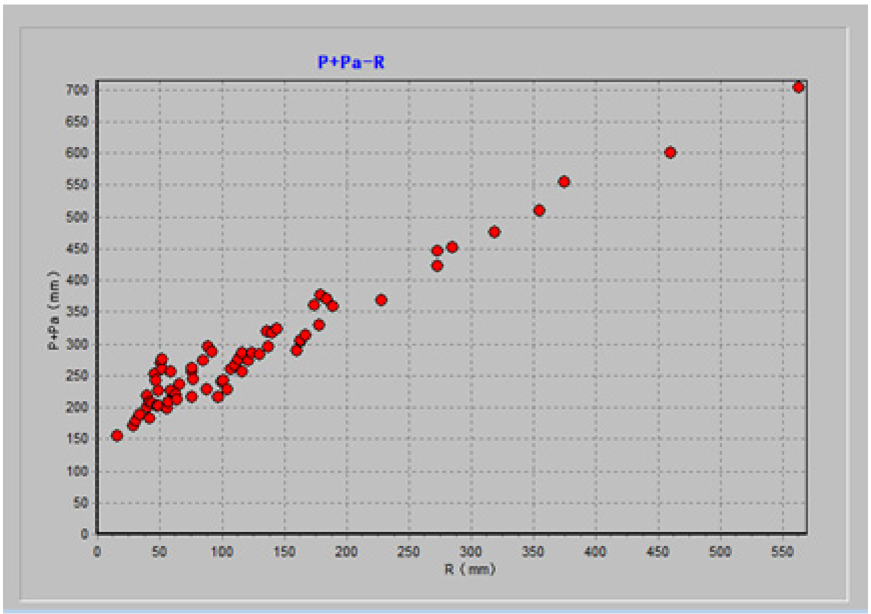

Fig. 3. The scatter plots diagram of P + Pa - R.

Assume that the lower part of the curve is an exponential function, the equation is $Y = AX^2$, the upper part is a straight line, and the equation is $Y = KX + C$. In the program interface, the corresponding parameters are continuously adjusted and the qualification rate of curve fitting is calculated. Based on the finalized fitting parameters, the only rainfall runoff curve can be determined for flood flow forecasting and warning. The curve fitting result is shown in Fig. 4.

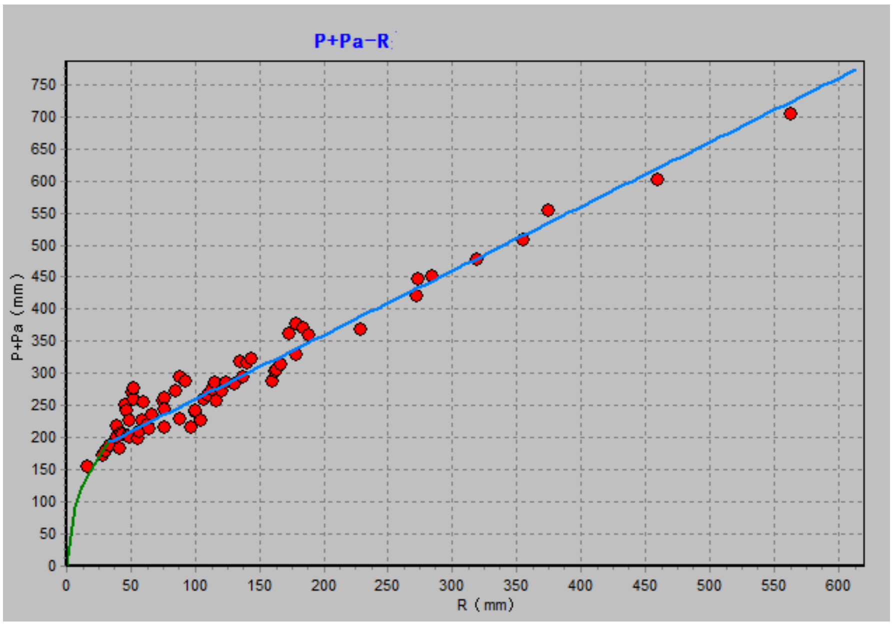

Fig. 4. The curve fitting result of P + Pa - R.

4. Conclusions

This paper introduces a method for calculating the amount of floodwater produced during the half-day tide interval based on the API model. We use the APT based algorithm to compile the corresponding computer program for simulation. The model debugging of the 22 years of data from 1991 to 2012 in the Hongjia water area was carried out: the first 18 years were used for simulation, and the last 4 years were used for testing. The research results of this paper provide strong technical support for the water scheduling of the sluice gate group, and have positive significance for flood prevention and risk warning in the coastal environment.

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