Formulation of Rainfall Warning Indicators for Disaster Prevention Objects in Hilly Area Based on NAM Model

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Abstract. The rain warning indicator is an important basis for early warning of Flash Flood. In this study, a semi-distributed hydrological model for small watershed was established based on NAM. Combined with 19990811, 20080817 and 20150805, three floods and floods are used to determine the watershed. - The elevation judgment model of the residents along the line, combined with the results of the on-site investigation to locate the households with the weakest flood control capacity in the village, establishment of flood water level and height determination model for residents along the line, using the method of water level and flow back to deduce the disaster volume of disaster prevention targets; Prediction of rainfall early warning indicators based on model trial method to reach disaster level. The results show that the NAM model can better simulate the rainfall runoff process in the basin and can be applied to the early warning indicators of the basin.

1. Introduction
The early warning of mountain flood disaster in small watershed is the key link and technical difficulty in preventing mountain flood, and rainfall warning is the most widely used early warning method at home and abroad. The occurrence of mountain flood disaster is closely related to rainfall and soil water content in the initial stage during the characteristic period of the upstream basin, and there are a series of combinations of rainfall and soil water content during the characteristic period.

In the research of rainfall warning index calculation method, domestic and foreign scholars have done a lot of beneficial exploration. Zhang lei et al. conducted Flood Area simulation based on Flood Area model, and made parameter calibration according to field investigation data, so as to calculate and establish rainfall warning indicators [3]. Abroad, the United States' early warning indicator Flash Flood Guidance (FFG) is the most representative, using distributed hydrological models to calculate early warning indicators. The warning index of Japanese mountain flood disaster was determined by establishing the linear relationship between rainfall intensity and effective accumulated rainfall [2].

At present, based on the calculation of the early-warning indexes of mountain flood disaster rainfall and the regions with abundant data, the actual rainfall statistics method, the rainstorm critical curve method, the water level or flow inversion method and the comprehensive analysis method are usually
used to calculate. For areas with little or no data, interpolation and analogy methods are used [4, 7]. However, the calculation of rainfall warning index based on hydrological model is seldom applied in practice. In this paper, based on NAM hydrological model method, the water level flow back-extrapolation method is used to develop rainfall warning indexes for Luoquan and xiwanwan ditch. The research results provide reference for the development and application of the warning index.

2. NAM-based disaster prevention object basin hydrological model

2.1. Watershed overview
Luoquan village is located in the upper reaches of the middle river with a basin area of 15.923km2. The upper channel of the village is narrow with no embankment on both sides. River channel overall more straight, local bend.

Xiwanjiagou is located in the upper reaches of the Yuangong River with a basin area of 6.3km2. Residents in the village are distributed along the river, and vertical embankments are built on the left bank of the river course. The river course is relatively curved, and the bottom of the river course is mostly stone and full of weeds. The watershed details are shown in Figure 1, Figure 2.

![Figure 1. Luoquan Watershed Map](image1)

![Figure 2. Xiwanjiagou Watershed Map](image2)
2.2. Model principle
The NAM model, as a conceptual, lumped hydrological model, can simulate the change of slope flow, soil flow, base flow and soil moisture content. The process of water exchange between aquifers is carried out through parameter control: (1) when the water content of local surface aquifer is greater than the potential evaporation amount $E_p$, the evaporation amount $E$ is first provided by surface aquifer ($U$). When $U$ is not enough to satisfy potential evaporation, the water layer in the root zone will recharge the surface with an actual evaporation rate $E_a$. (2) After precipitation enters the surface aquifer, it is first used to evaporate plants and replenish the surface aquifer to store water. When the local surface storage is greater than the maximum surface storage, part of the net rainfall is used for infiltration, and the water entering the surface storage water layer forms the flow in the soil, and the other part forms the slope flow. (3) The aquifer in the root zone is located between the surface aquifer and the underground aquifer, and the change of water content in the root zone is closely related to the exchange of surface aquifer and groundwater. (4) The underground aquifer is located at the lowest level. Generally, the groundwater level is relatively stable and not easy to change [5]. The schematic is shown in Figure 3.

In summary, the main parameters of each aquifer in the model are sorted out, as shown in Table 1. On the basis of expounding the physical meaning, the range of values of each parameter of the NAM model is summarized [6].

![Figure 3. Schematic diagram of the model](image-url)

![Figure 4. Roadmap for Critical Rainfall Calculation](image-url)
Table 1. Physical meanings and values of model parameters

| Parameter | Meaning                                                                 | Range   |
|-----------|--------------------------------------------------------------------------|---------|
| Umax      | Umax indicates that the layer contains water volume such as river basin vegetation interception, sloping water storage and upper layer soil storage. | 10-25mm |
| Lmax      | Lmax represents the maximum water content that can be achieved by the root layer soil that provides the moisture required for the evapotranspiration of the plant. | 50-250mm|
| CQOF      | The surface runoff coefficient determines the distribution of the remaining rainfall into the surface runoff or becomes the infiltration amount. | 0-1     |
| CKIF      | The effluent flow time in the soil determines the parameters of the amount of soil flow in the surface water storage volume U. | 500-1000hr |
| CK1, CK2  | The surface runoff and soil midstream convergence models are two series linear reservoir models with the same time constant. | 3-50hr  |
| TOF       | Surface runoff calculation threshold, generated only when the relative water content of the shallow aquifer is greater than TOF. | 0-1     |
| TIF       | The threshold in the middle of the soil is calculated only when the relative water content of the shallow aquifer exceeds TIF. | 0-1     |
| TG        | The underground runoff calculation threshold is generated when the relative water content of the plant root zone exceeds TG. | 0-1     |
| CKBF      | The underground runoff convergence time, the base flow from the aquifer, is generated by a linear reservoir model with a time constant of CKBF. | 500-1000hr |

2.3. model rate

Since there are no hydrological stations at the exits of the two small watersheds in Luoquan and Xiawanjiaogou, it is impossible to use the measured flow data to accurately determine the parameters of the two small watersheds. This study used the field surveys of 19990811, 20080817 and 20150805. The flood peaks of the flood seasons are used to determine the peak rate of the two small watersheds, and the watershed hydrological model of the disaster prevention objects is established according to the rate parameters.

Table 2. Model Rate Table

| Parameter | Umax | Lmax | CQOF | CKIF | CK1 | TOF | TIF | TG | CKBF |
|-----------|------|------|------|------|-----|-----|-----|----|------|
| Luoquan   | 10.04| 200.66| 1    | 444.51| 10  | 0   | 0.79| 0.08| 1835.74 |
| Xiawanjiaogou | 10 | 100 | 1 | 690.25| 10  | 0   | 0.84| 0.89| 2784.78 |

3. Disaster water level and disaster flow calculation

3.1. into the disaster water level calculation

This study proposed by water level method based on the water surface slope, households took along the water - flood elevation decision model is established, combined with field investigation results orientation within the village flood control ability the most vulnerable households, all households took along the river section elevation according to the slope into the flood control, on the basis of the final by water level, water flow backstepping method is used to calculate flow of plague disaster prevention objects.

(1) Judgment model of the height of residential houses along the flood water surface

1) Draw water surface lines with different frequencies. Control section water level as the center, water surface (flood mark) as a water surface line.

2) Projection of residents along the river to the longitudinal section of the river
3) Draw the vertical cross-section starting distance -- resident elevation \ water surface elevation map, determine the relationship between the water surface line of different frequencies and the height of residential households along the river, and draw the water-level – population relationship of the control cross-section based on water surface gradient.

(2) Counter calculation of flood water level

By comparing the flood mark and longitudinal section, all residential households are projected to the control section to obtain the flood level of all residential households along the river relative to the control end surface. The minimum value is selected to control the disaster-forming water level in the section.

(3) Integrated determination of flood water level in villages along the river

Comprehensive analysis of the height distribution of village residents along the river, eliminate the impact of low-lying residents in the village and far from the river, and comprehensively determine the disaster water level in the control section of the whole village.

It is calculated that the flood water level in Luoquan is 200.775m, and the water level in the Xiawanjiagou is 213.747m. See Figure 5 and Figure 6.

Figure 5. The water level of the control section of the Xiawanjiagou

![Figure 5](image1.png)

Figure 6. The water level of the control section of Luoquan

![Figure 6](image2.png)
3.2. Disaster Flow Calculation
Using the Manning formula, ratio reduction, roughness and other parameters to calculate the relationship between water level and flow, the disaster-causing water level is transformed into disaster-causing flow: the disaster-causing flow in Luoquan is 41.41 m$^3$/s, and the disaster-causing flow in the Xiawanjiagou is 31.5 m$^3$/s. See Figure 7 and Figure 8.

4. Early warning rainfall estimation and verification

4.1. method of estimation
In this study, based on hydrological and hydraulic methods, model trial algorithm was used to calculate the rainfall warning index when reaching the disaster-prone water level.

1) Assume that the characteristic storm value in the remittance period is assigned to the schedule;
2) Assume that different soil water content and utilization rate are determined by the production flow model;
3) Comparison of critical flow rates corresponding to the flood level;
4) If they are not equal, re-assume that the critical rainfall is finally calculated.

As shown in figure 4.
4.2. Calculation of rainfall indicators for typical disaster prevention objects
The basin-based hydrological model based on the disaster prevention object calculates the critical rainfall during the confluence time in the small watershed of Luoquan and the lower watershed of the Xiawanjiagou. The critical rainfall of the two small watersheds during the confluence time is calculated as follows. The table shows.

| Table 3. Results Table of Early Warning Indicators for Disaster Prevention Objects |
|---------------------------------|-----|-----|-----|-----|
| Object  | Time/h | 0.2 | 0.5 | 0.8 |
| Xiawanjiagou  | 1   | 29  | 20  | 15  |
| 2       | 62  | 54  | 46  |
| 6       | 92  | 79  | 73  |
| Luoquan  | 1   | 48  | 33  | 28  |
| 3       | 95  | 78  | 65  |
| 6       | 130 | 98  | 78  |

5. Conclusions and prospects
In this study, a semi-distributed hydrological model for small watershed was established based on NAM.

(1). NAM based hydrological model for disaster prevention. Based on the principle of rainfall-runoff model, the evapotranspiration calculation, runoff generation calculation and confluence calculation were conducted by simulating the changes of slope flow, soil flow, base flow and soil moisture content, so as to establish the hydrological model. As the flood flow of the two flood prevention objects was not measured in the river basin, parameters of the hydrological model of the basin were determined respectively by combining the flood mark of the three flood in 19990811, 20080817 and 20150805, so as to establish the hydrological model of the flood prevention objects.

(2). Calculation of disaster-generating water level and disaster-generating flow. This study is to precisely locate the residential households with the weakest flood control capacity in the village, establish the judgment model of residential height along the flood surface and the line, comprehensively determine the disaster-causing water level of the two disaster prevention objects, and establish the relationship of water level and flow rate according to the manning formula, and deduce the disaster-causing flow.

(3). Early-warning rainfall deduction. Based on the hydrological and hydraulic method, it is assumed that the characteristic rainstorm quantity value within the confluence period, the time interval distribution is carried out, the soil moisture content is assumed to be different, and the early warning rainfall is calculated by the model trial algorithm.

Outlook:
This study based on backstepping critical rainfall model test algorithm, by assuming that confluence time rainstorm quantity, soil moisture content in different trial critical rainfall, including the schedule allocation is a typical watershed hydrological figure concentrated distribution of the schedule, application in the small watershed has certain error, a certain influence on critical rainfall volume of small watershed, the future still need further study.

Acknowledgments
This work was financially supported by the Water Conservancy Scientific Research and Technology Promotion Projects of Shandong Province (No. SDSLK201808, SDSLK201705).

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