Analysis and Determination of early warning index for Mountain Flood Disasters—A Case Study of Yalin River Small Watershed

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Abstract: Determination of the critical rainfall is very important for the influence by mountain torrents with disaster prevention and reduction in significance, which is the priority among priorities of mountain flood early warning work. In this paper, the small watershed of Yalin River as the example, has carried on the analysis and the calculation of flood disaster early warning index. The results show that, the using method is simple and practical, with the certain reference value to the mountain torrent disaster warning.

1. Introduction
Zhejiang Province is mountainous, with hilly area accounting for more than 70% of the province's land area. Mountain flood caused by hard rainfall is suddenly, and it has become one of the major disasters causing casualties in flood disasters. Mountain flood is natural disaster caused by persistent heavy rainstorms in mountainous areas. It seriously threatens the safety of people's lives and property because of its wide range, sudden strong and destructive power[1].

This paper chooses Yalin River Basin in Xiangshan County to study the mountainous flood disaster prevention. Through calculation and analysis, the critical rainfall and critical water level are determined, which can provide some reference for the prevention of mountain torrent disasters.

2. Watershed General Situation
Yalin river rise in Shejian Mountain, and flows northwest from Southeast through the village of Huxiaopu, Yalin river and Andong. Yalin River Basin covers an area of 6.68 km² and the main stream is 5.02 km long, with ratio descending of 13.4%.

The topography of the basin is mainly low mountains and hills. The mountain elevation is generally between 300~ 600 m, and the peak is 545m. The terrain inclines from southwest to north. Yalin river is steeper, and the source is short and the current is fast. The watershed has good vegetation and soil and water conservation. The main soils are red clay and loess.

Yalin river is located in the subtropical monsoon climate. The general climate characteristics are as follows: significant alternations of winter and summer monsoon, abundant distinct rainfall in four seasons, and uneven distribution of precipitation in a year. The flood of this river basin is caused by heavy rain. The flood in April to June is Mei-xun rain, and the flood in July to October is caused by...
typhoon and heavy rain.

3. Hydrological Calculation

3.1 Design rainstorm

(1) Design rainstorm calculation

There are no rainfall gauging stations in Yalin river watershed, so the design rainstorm is calculated by referring-to-diagram method. According to the usage regulation of "Short-duration Rainstorm in Zhejiang Province", the average point rainfall and Cv values of 10 min, 1 h, 6 h and 24 h were obtained by mapping the geographical location of Yalin river watershed, and then the Kp value was calculated from the parameters of each duration rainstorm using line fitting method (Cs/Cv=3.5). After conversion of the point-surface coefficients, the design rainstorm of each duration and frequency in Yalin river watershed was obtained.

(2) Design rain pattern

Designed rainstorm process distribution includes daytime distribution and hourtime distribution, and they are determined according to "Short-duration Rainstorm in Zhejiang Province".

Daytime distribution: The maximum rainfall day is the second day, the rainfall of the first day is 60% of \( H_{3d} - H_{24h} \) and the rainfall of the third day is 40% of \( H_{3d} - H_{24h} \), as shown in table 1.

| Table 1. Daytime Distribution of Designed Rainstorm |
|-----------------------------------------------|
| Daytime distribution | First day | Second day | Third day |
| Percentage of \( H_{3d} - H_{24h} \) | 60 |
| Percentage of \( H_{24h} \) | 100 |
| Percentage of \( H_{3d} - H_{24h} \) | 40 |

Hourtime distribution: The design rainstorm in each period is calculated according to the rainstorm formulas. The formulas for calculating the design rainstorm \( (H_i) \) and the rainstorm attenuation index \( (n_i) \) in each period are as follows:

\[
H_i = H_{10} \times \left( \frac{t_i}{10} \right)^{1-n_{10,60}} \times \frac{1}{H_{60}} = 1 + 1.285 \times \lg \left( \frac{H_{10}}{H_{10,60}} \right) \times \frac{H_{60}}{H_{60}}
\]

\[
H_i = H_{6} \times \left( \frac{t_i}{6} \right)^{1-n_{6,16}} \times \frac{1}{H_{16}} = 1 + 1.285 \times \lg \left( \frac{H_{6}}{H_{6,16}} \right) \times \frac{H_{16}}{H_{16}}
\]

\[
H_i = H_{24} \times \left( \frac{t_i}{24} \right)^{1-n_{24,624}} \times \frac{1}{H_{624}} = 1 + 1.661 \times \lg \left( \frac{H_{24}}{H_{24,624}} \right) \times \frac{H_{624}}{H_{624}}
\]

The difference value between rainfall at adjacent periods \( t_i \) is the interval rainfall from bigness to smallness. The rain pattern of 24 hours in the maximum rainfall day is arranged according to the following rules: the maximum hourly rainfall is at 21:00, and the second maximum rainfall is on the left of the maximum hourly rainfall. The remaining items ranged from large to small odd Numbers on the left and even Numbers on the right. After 24:00 on the right, the remaining periods of rainfall ranged from large to small on the left. The other two days are arranged according to the 24-hour rain pattern of the maximum rainfall day.

3.2 Design flood

(1) Runoff yield calculation

Zhejiang Province belongs to humid areas in the south China. The main pattern of runoff yield is stored-full runoff, which is mean that the rainfall first satisfies the shortage of soil water, and after the soil is full (the soil moisture content reaches the field capacity), the surplus rainfall will produce runoff. The calculation of net rain is based on the simple deduction method, i.e. the initial loss is 25 mm, the later loss is 1 mm/h during the maximum rainfall day, and the loss is 0.5 mm/h in the remaining two days.

(2) Confluence calculation
Analyzing the watershed characters by one-thousandth topographic map. The calculation of design flood uses the rational formula method. The calculation results are shown in table 2.

Table 2. Design Flood Calculation Results

| River Basin Control Section                  | Flood factor | Design flood values at different frequencies (m³/s) |
|---------------------------------------------|--------------|-----------------------------------------------------|
| Control Section of Yalin river small Watershed | Flood peak discharge | H₁%   | H₂%   | H₅%   | H₁₀%  | H₂₀%  |
|                                             | Flood level  | 139   | 119   | 92    | 73    | 54    |
|                                             |              | 17.13 | 16.89 | 16.55 | 16.27 | 15.93 |

4. Determination of Early Warning Index

The critical rainfall is determined by the "water level-discharge backstepping method". According to the specific conditions of river embankments in small watershed, select appropriate number of control sections, analyse critical water levels of each section, determine the discharge of control section under critical water level by hydraulic calculation. Using hydrological calculation and iteration method to solve the problem, there must be a rainfall to match flood peak formed after runoff yielding and confluence, at which time the rainfall is the critical rainfall. Then, on the basis of critical rainfall, the flood warning index is synthetically determined by considering the river section shape, flood rising and submergence speed[2]. The results of early warning index determination are shown in table 3.

Table 3. Results of Early Warning Index Calculation

| Administrative area       | Small watershed category | soil moisture content | time interval (h) | Early warning index (mm) | Ready to transfer of index | Immediate transfer of index |
|---------------------------|--------------------------|----------------------|-------------------|--------------------------|---------------------------|---------------------------|
| Yalinxi Village           | Yalin river watershed   | rainfall             | 1                 | 78                       | 91                        |                           |
| Daxu Town                 |                          |                      | 2                 | 84                       | 101                       |                           |
|                           |                          |                      | 2.5               | 86                       | 105                       |                           |
|                           |                          |                      | 1                 | 63                       | 77                        |                           |
|                           |                          |                      | 2                 | 70                       | 88                        |                           |
|                           |                          |                      | 2.5               | 72                       | 92                        |                           |

Based on the basic theory of hydrostatistics, the method of water level-discharge backstepping is used to determine the critical rainfall in this paper. The data used in this method are relatively complete, and the calculated index has a scientific basis, but there are also some weaknesses. The main points are as follows: (1) there is often a shortage of hydrological data in flood-prone areas, which can not meet the calculation requirements[3]; (2) rainfall station layout density in mountainous areas is too small to affect the accuracy of calculation; (3) The index determination requires a lot of investigation and review work. It is suggested that different methods for determining index should be adopted in practical work, such as analogy method and interpolation method[4]. Meanwhile, the conversion between critical rainfall and critical water level should be further explored so as to calculate and analyze early warning index of mountain torrents more conveniently.

5. Conclusions

This paper takes Yalin river small watershed in Xiangshan County as an example, analyses and calculates the early warning index of mountain flood, which has certain reference value for areas with mountain torrent prevention tasks. The preliminary early warning index need to be revised according to the actual rainfall and disaster situation in the future, so as to make the initial value closer to the true
value, in order to provide more scientific and technical reference for decision makers in the future mountain flood prevention work.

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