第Ⅱ部門

Simplified Flood Inundation Model Integrating with Rainfall-runoff Processes

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1. Introduction

Flood hazard is one of the most harmful disasters in the world. Many more intensive rainfall events happen, which suggests flooding will become more frequent and potentially causes greater damage. As the occurrence of flood event has become common in many parts of the world, the needs to obtain reliable information on flood characteristics are increasing with the dramatically rising of people's awareness. Whilst the increase of flood damage for singular event is partly resulted by the tendency that much more people live in floodplains or low-lying areas and consequently causes that society becomes more exposed to flood damages.

Recently a shift in paradigms is observed from a technical oriented flood protection towards flood risk management, and the emphasis of disaster risk reduction has changed from an impacts-led approach to a vulnerability-led approach. Therefore it is necessary to study on regional vulnerability for flood hazard.

In order to explore the spatial distribution of flood hazard vulnerability, a grid cell based simplified flood inundation simulation integrating with rainfall runoff processes is proposed. According to the simulation result, flood characteristics can be analyzed, especially which can delineate the flood-prone area.

2. Methodology

2.1 Description of flood inundation simulation

Distributed temporal-spatial information of a flood event is of the utmost importance for flood disaster mitigation as well as for flood vulnerability assessment. A physically based flood inundation simulation model is developed in this study, which is based on simplified process representation capable of simulating dynamic flood inundation (Figure 1).

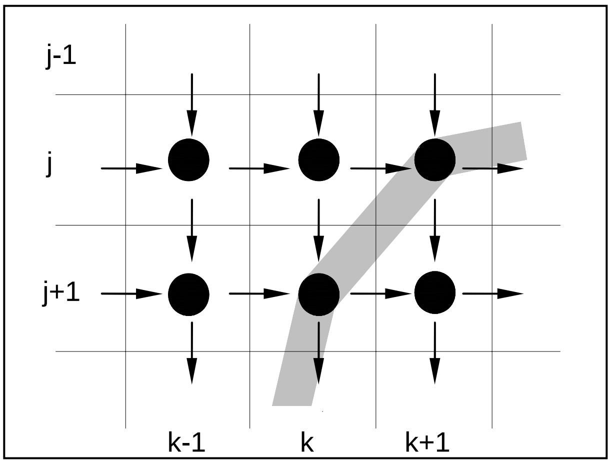

Figure 1 Schematic drawing of 2-D overland flood routing and channel routing scheme

This inundation simulation model is composed of a one-dimensional channel flow and a two-dimensional flow with unsaturated, saturated and overland flow, in which the 2-D flow model takes into account three types of flow: unsaturated flow in capillary pore, saturated flow in non-capillary pore and surface flow on soil surface, depending on the depth of flow.

The water surface elevation for river segments is calculated using the 1-D kinematic wave model solution.

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The overland surface flow routing is calculated by the 2-D Pond model, which is to treat each cell as a storage volume, and the change in cell volume over time is equal to the fluxes into and out of it, where the flow is predominantly driven by the local water surface slope. The exchange of flow between channel network and flood plain or low-lying area is simulated in response to the relative water surface elevation (Figure 2).

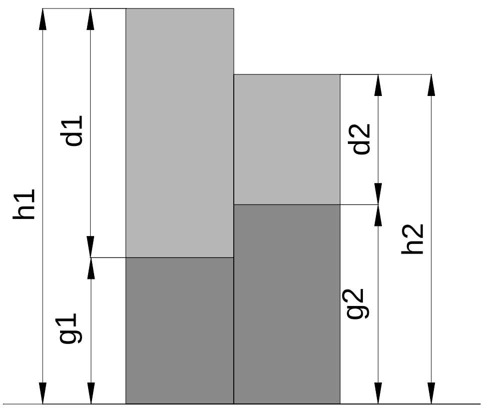

Figure 2 Flow between grid node 1 and 2 (d, depth of water in the cell; g, ground elevation; h, water surface elevation in the cell.)

2.2 Flow stage-discharge relationship equation

In this study, flow stage-discharge relationship equation for saturated-unsaturated soil layers is adopted to calculate water fluxes between grid cells, which describes the runoff yield under the consideration of soil water storage in multiple layers of soil in terms of the saturated-unsaturated flow mechanism (Figure 3) (Tachikawa et al., 2004). This relation is defined as equation (1).

$$q = \begin{cases} V_m d_m (h/d_m)^\beta & , \quad 0 \le h \le d_m \\ V_m d_m + V_a(h - d_m) & , \quad d_m < h \le d_a \\ V_m d_m + V_a(h - d_m) + \alpha(h - d_a)^m & , \quad d_a < h \end{cases} \qquad (1)$$

Where, q is the discharge per unit width [m^2/s]; h [m] is the stage; d_m [m] and d_a [m] denote the maximum water depth in the capillary pore, and the depth of water in saturated condition; V_m and V_a are flow rates from the capillary pore and non-capillary pore respectively. And β is a const that describes the reduction of hydraulic conductivity in capillary pore with the reduction of water content. When k_m and k_a are assumed as the saturated hydraulic conductivities in capillary pore and non-capillary pore respectively, V_m and V_a can be expressed as $V_m = k_m i$ and $V_a = k_a i$, in which i stands for slope. Here α is defined as $\sqrt{i}/n$, and n is roughness coefficient.

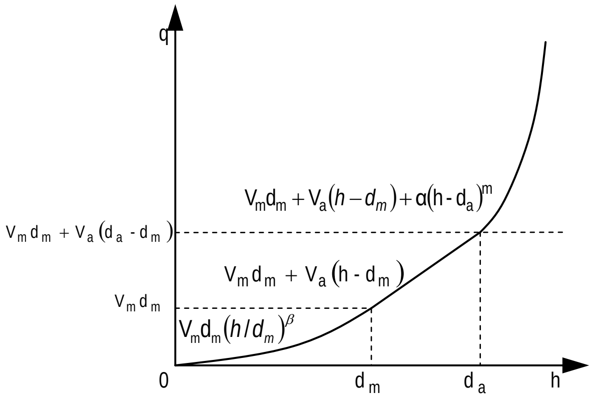

Figure 3 Flow stage-discharge relationship

3. Application

Finally through the application of the model in the Yodo River Basin in Japan, the performance of model is analyzed.

4. Conclusions

Numerical simulation is efficient to understand physical phenomenon of flood. In this paper, simplified flood inundation model integrating with rainfall-runoff processes is presented. And the simulation is of catchment flooding where the floodplain and river are coupled, which is generally used in situations where limited channel information is available and therefore only a simple treatment of the channel is incorporated.

Reference

Tachikawa, Y., et al. 2004. Development of stage-discharge relationship equation incorporating saturated-unsaturated flow mechanism (in Japanese). *Annual Journal of Hydraulic Engineering*, JSCE, 48: 7-12