第II部門

Lumped Representation of Cell-Based Distributed Sediment Runoff Model With Embedding River Channel Sediment Transport Mechanism

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1. Introduction

Total runoff and sediment loads from hillslopes to and storage in river channel reaches can disrupt aquatic habitats, impact river hydromorphology, and water quality. It is often convenient to visualize a catchment as consisting of the channel network and the contributing areas that can be described as hillslopes. The reasonableness of this characterization varies, depending upon the hydrologic systems under consideration and upon the scale of consideration (small vs. large scale). In the fact, the source area of sediment for large catchment scale is primarily the river channel bed and banks, hillslope processes only feeding material for subsequent storage lower down the slope or in the river channel. To accommodate this, the recent developments of one-dimensional model from this study are physically-based distributed sediment runoff model and its lumping with embedding river channels sediment transport mechanism.

The advantage to lump a distributed model is to produce a new lumped sediment runoff model version as interest in sediment runoff modeling extends to large catchment scale, to derive lumped model parameters keeping the physical meanings of an original distributed model without any additional calibration, and to reduce computational time respectively. Those models can be used as a modeling tool for simulating the time-dependent response of runoff and sediment transport processes at the catchment scale which facilitates the analysis: (1) total runoff and sediment loads in both hillslopes and river channel processes; (2) interacting processes of erosion sources and deposition; and (3) internal catchment behaviors.

The proposed lumped model on hillslopes is divided into two parts: lumping of the kinematic wave distributed rainfall-runoff model and lumping of the distributed sediment transportation model that takes into account soil detachment by raindrop and hydraulic detachment or deposition driven by overland flow. A kinematic wave distributed rainfall-runoff model is lumped based on the assumption of steady state conditions. Soil detachment and deposition from an entire hillslopes are simulated by the balance between the current sediment storage and the maximum sediment storage, which is estimated from a distributed sediment runoff model as a function of total surface water storage of the lumped rainfall-runoff model.

The eroded soils from hillslopes defined as wash load provided to stream networks flow with sediment transport mechanism and routing process. The total sediment load within river channels consists of the sum of the bed-material load and wash load. Sediment transport mechanism of river channels incorporates sources of bed materials load for both suspended bed material load and bed load, which are composed of grains found in the stream bed.

The principal sediment transport mechanism controlling model behaviour in the simulations are the transport capacity of overland flow and the river channels flow generation specified in terms of stream power, storage, and release of the water and sediment concentration fractions.

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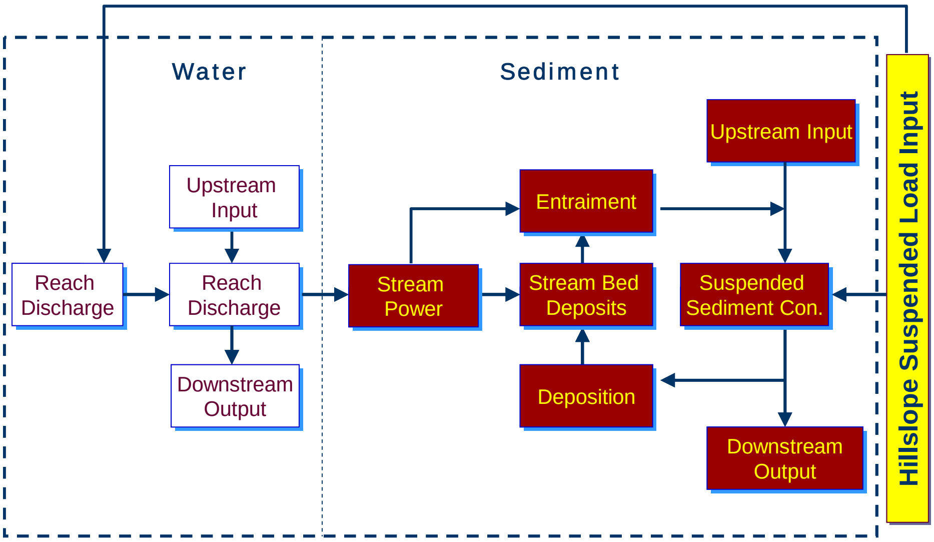

Figure 1. Schematic diagram of the sediment transport processes components and interactions in river channel.

2. In River Channel Fine Sediment Dynamics Equation

The set processes are considerably simplified relative to fine sediment transport processes models such as INCA-Sed. Given sufficient overland flow, the eroded soil material from the catchment hillslopes is transported from the land to the river channel phase of the model. Within the channel, the uniform condition flow conditions generated by the rainfall-runoff model based upon kinematic wave model [**1**] are used to represent the bulk movement of sediment within the channel (**Figure 1**).

The suspended sediment flux within the river channel can be conceptualized as having two components: lateral downstream transfer and vertical exchange with the bed material. Downstream movement can be readily linked to the total runoff flux; however the vertical exchange is much more complex, as sediment is potentially eroded, deposited, and reentrainment during its migration through river networks. In order, to accommodate this, the same idea with hillslope sediment transport model [**1**], the relative rates of erosion from and deposition to the river bed must be linked to the rainfall-runoff equation. The key variables controlling this are transport capacity of flow in terms of stream power and the grain size distribution of the sediment, and model incorporates the effect of grain size for each of five grain size classes (2, 60, 200, and 600 μm). The grain size of the eroded material to the river from the slopes is assumed to be related to the soil texture of the catchment.

In terms of lumped representation of the cell-based distributed sediment runoff model, the volume of sediment stored on the river bed s increased by the deposition from the flow and is decreased by the material erosion and reentraiment. The mass balance for the sediment in suspension within the river channel phase is function of local exchange with the bed, the suspended store in river receives sediment from hillslope phase, upstream river channel, and releases suspended sediment catchment outlet as:

$$\frac{dM_{sus}}{dt} = \left(M_{upper} + A\left(m_{erosion} - m_{dep}\right) + M_{Hillslope} - Qm_{sus}\right)$$

where M_{sus} is the total mass of sediment in suspension, $M_{hillslope}$ is the mass from hillslopes, A is area, M_{upper} is the input from upstream river, m_{sus} is the suspended sediment concentration, $m_{erosion}$ is the mass of sediment entrainment/erosion, and m_{dep} is the deposited material.

References

[1] APIP, Takahiro SAYAMA, Yasuto TACHIKAWA, and Kaoru TAKARA: Lumping of a physically-based distributed model for sediment runoff prediction in a catchment scale, Annual Journal of Hydraulic Engineering, JSCE, vol. 52, 2008, in Press.