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Modeling Infiltration and Redistribution for Multistorm Runoff Events

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ABSTRACT

Infiltration and water flow in the upper soil layer of a deep water table aquifer are modeled for multistorm runoff events. The infiltration process is developed using the sharp wetting front model of Green and Ampt, and the following redistribution process is modeled using the gravity drained rectangular approximation. The Brooks-Corey model [*Brooks and Corey*, 1966] is adopted to relate the effective soil saturation, the tension head, and the unsaturated hydraulic conductivity. Firstly, the infiltration and redistribution model is developed for a single storm runoff event. Then a couple of events combined for multistorm runoff events. In the later case, infiltration rate of the second rainfall is strongly influenced by the length of the rainfall hiatus and soil moisture profile.

Key words : infiltration, redistribution, multistorm, soil moisture, Green-Ampt model.

1. Introduction

To describe the infiltration and redistribution process in the unsaturated zone is essential to understand the hydrogeological evironment in vadoze zone. However, the solution to the problem of unsaturated flow for infiltration and redistribution in a homogeneous soil column is in itself quite difficult because of the strong nonlinearity of the flow differential equation [*Dagan and Bresler*, 1983].

The approximation of the ponded infiltration as a moving rectangular block was introduced by *Green and Ampt* [1911] and acquire a firm physical basis by *Philip* [1954]. The approximation method has been widely used by many researchers for its simplicity and applicability. However, the approximation process is usually applied to single storm runoff event to predict infiltration for its rather limited conditions. This limit could be overcome by combining appropriate redistribution process. Redistribution process can also be approximated using rectangular block assumption likewise. The combination make it possible to describe the consecutive processes of infiltration and redistribution in multistorm runoff events.

2. Single Storm Runoff Event

A simple equation proposed by *Green and Ampt* [1911] describing infiltration process on ponding condition can be written as (see Figure 1)

$$i = K_s \cdot \left[\frac{(\theta_s - \theta_i)(\psi_s - \psi_w)}{I} + 1 \right] \tag{E.1}$$

where i is infiltration capacity (L/T), K_s is saturated hydraulic conductivi- ty, θ_i is initial moisture content, θ_s is saturated moisture content, ψ_w is capillary suction head at the wetting front (L), and $I=(\theta_s-\theta_i)\cdot L$ is cumulative infiltration from the beginning of the event (L). Explicit expression for the Equation 1 can be found in *Salvucci and Entekhabi* [1994].

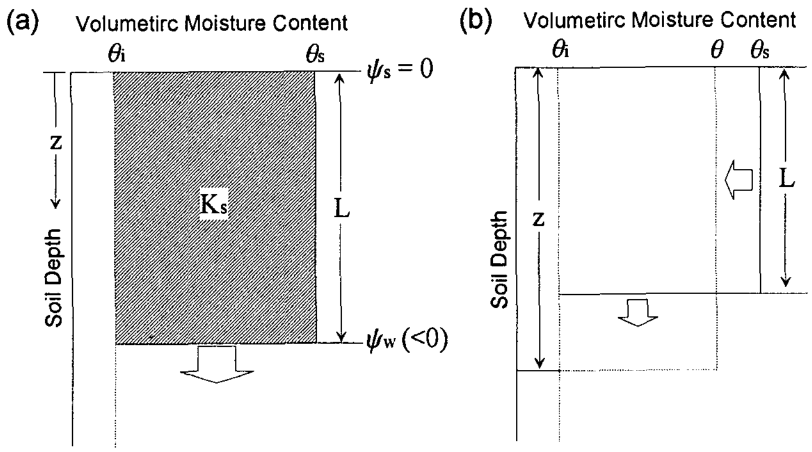

Figure 1. The rectangular approximation to (a) the infiltration and (b) the redistribution processes.

Redistribution process during a rainfall hiatus can also be approximated with the rectangular block assumption (see Figure 1). Using Brooks-Corey model

[*Brooks and Corey*, 1966] (see Appendix), the effective soil saturati- on s at time t during the rainfall hiatus can be written as

$$s(t) = \left(\frac{1}{K_s \cdot (\theta_s - \theta_r) \cdot c}\right)^{1/c} \cdot \left(t + \frac{L}{K_s \cdot (\theta_s - \theta_r) \cdot c}\right)^{-1/c} \quad \text{(E.2)}$$

where $s(t) = (\theta(t) - \theta_r)/(\theta_s - \theta_r)$, c is the pore disconnectedness index, and θ_r is the residual moisture content.

3. Multistorm Runoff Event

In case of multiple ponding infiltration, the later infiltration is influenced by the previous redistribution status. Let the soil moisture content at the beginning of the second storm $\theta(t_1)$ and the time from the beginning of the first redistribution t_1, then the infiltration rate of the second storm can be written as (see Figure 2)

$$i)\ z_1 > z_2 :\ i = K_s \cdot \left[\frac{(\theta_s - \theta(t_1))(\psi_s - \psi_{w2})}{I} + 1\right] \text{ where } I = (\theta_s - \theta(t_1)) \cdot z_2 \quad \text{(E.3)}$$

$$ii)\ z_1 = z_2 :\ i = K_s \cdot \left[\frac{(\theta_s - \theta_i)(\psi_s - \psi_{w1})}{I} + 1\right] \text{ where } I = (\theta_s - \theta_i) \cdot z_1 \quad \text{(E.4)}$$

z_1, z_2, and $\theta(t_1)$ can be obtained from the Equations 1 and 2.

4. Conclusion

Using rectangular block assumption of Green and Ampt, the infiltration and the follwing redistribution processes can simply be approximated. After a rainfall hiatus, simultaneous process of infiltration and redistribution can also be described by combining the above approximation methods of infiltration and redistribution. It is known from the resulted equations that the infiltratin rate of the second storm event is strongly influenced by the the length of the rainfall hiatus and soil moisture profile at the beginning of the event.

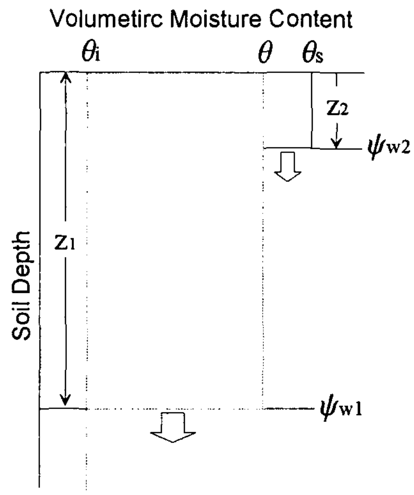

Figure 2. The simultaneous infiltration and redistribution process during the multistorm event.

5. Appendix: Brooks-Corey Model

The Brooks-Corey model [*Brooks and Corey*, 1966] relates the effecive soil saturation (s), the suction head (ψ) and K_s by the following relationships:

$$s(\psi)=(\psi/\psi_s)^{-m} \quad \psi \leq \psi_s \tag{A.1}$$

$$s(\psi)=1 \quad \psi \geq \psi_s \tag{A.2}$$

$$K(s)=K_s s^c \tag{A.3}$$

where ψ_s is the bubbling pressure head, m is the pore size distribution index, and the pore diconnectedness index c is related with m by $c=(2+3m)/m$.

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