IP3 3rd Annual Workshop, 12-15 November 2008, Whitehorse, Yukon

Improved Processes & Parameterisation for Prediction in Cold Regions

Update on IP3 Soil Water Budget: Progress towards an Analytical Solution for Shallow Aquifers

E.D. Soulis, G. Liu, and J. Craig
Civil and Environmental Engineering University of Waterloo
Email: rsoulis@uwaterloo.ca

University of Waterloo

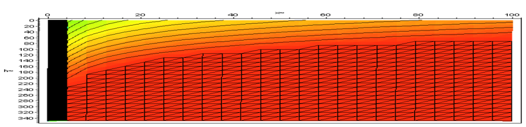
Introduction

- Soil moisture is critically important in near-surface water balance; A simple, fast, and robust soil moisture parameterization scheme is needed
- A consistent soil moisture parameterization scheme (WATDRAIN) was found for shallow aquifers by solving a modified Richards Equation analytically.
- However, the suction gradient is ignored in WATDRAIN , therefore there is no naturally retained water. The approach works well in regions with wet soils but not suitable for regions that are dry for long periods.
- Field capacity was introduced as a temporary measure to enforce water retention
- A modified WATDRAIN is being developed to deal with the problem

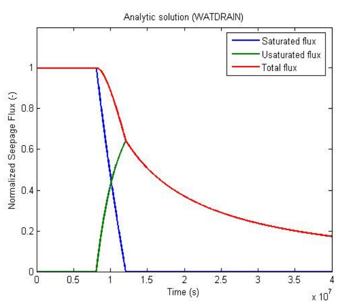
Previous Analytical Solution

$$S = \min\left[1, \left(\frac{\theta_S\sqrt{1+\Lambda^2}}{cK_S\Lambda}\cdot\frac{x}{t}\right)^{\frac{1}{c-1}}\right] \qquad (1)$$

where S is the saturation, θ_s is the porosity, Λ is the slope, c is a soil index, x is the axis along the slope, K_s is the saturated hydraulic conductivity and t is time.

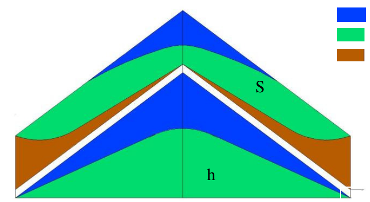


Saturation VS depth for a given time



Revised Concept

- Parameters needed:
  - Slope- Λ
  - Length- L
  - Thickness- H
  - Hydraulic conductivity- K_s
  - Air entry pressure- ψ_0
  - Porosity- ϕ
  - Soil index-b



Initial state
Transition state
Steady state

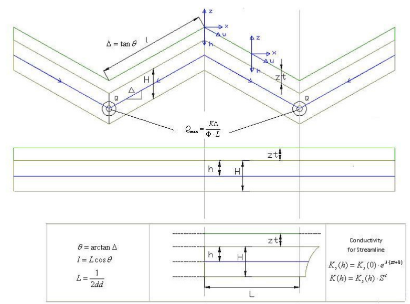
Upper- Saturation
Middle- Streamline
Lower- Total head

Development

WATDRAIN Co-ordinate System

Corresponding Land Surface Scheme Co-ordinate System

Streamline Relationships (no flow B.C. at x=0.0)



Initial state, gravity dominated flow
Transition state, the linear combination
Steady state, field capacity

Assumed form of the solution (compared to equation (1))

$$S = \left(\frac{x+\varepsilon}{x_s+\varepsilon}\right)^{\frac{\left(1-x/x_s\right)^2}{c-1}} \qquad \psi = \psi_0 S^{-b}$$

$$\left.\frac{\partial\psi}{\partial x}\right|_{x=0.0,t} = \Lambda \Rightarrow \varepsilon(t) \qquad \int_0^{x_s} S\,dx = K_s\Lambda t \Rightarrow x_s(t)$$

Boundary Condition solved for $\varepsilon(t)$ Mass Balance solved for $x_s(t)$

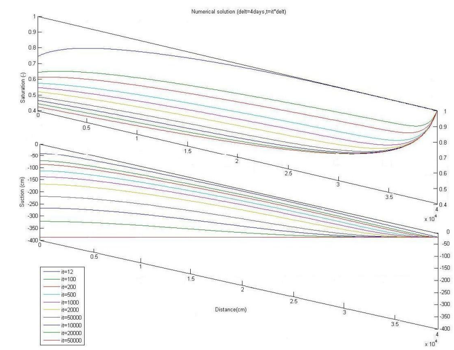
Initial state and transition state

$$\psi = \psi_0 - \Lambda(L - x)$$

Steady state

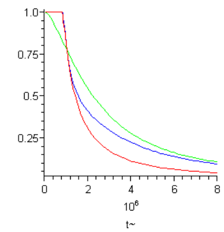
Interpretation

- Initial soil suction is equal to air entry pressure everywhere
- Drying front progresses downslope until time ts, when streamline is totally unsaturated
- Drying front location-xs stops at time ts, when it reaches the bottom of the slope
- Flow continues with water from behind drying front until suction gradient equals slope



Application

Recession Curves



Red-a typical gravity dominated curve.

Green-corresponding suction dominated solution.

Blue-New analytical solution

Summary

- Both old and new solutions work well in nearly saturated soil
- Modified WATDRAIN is capable of simulating the water movement in wet and dry soil