

Simulating Infiltration in GSSHA



- Infiltration process
- Mathematical description of infiltration
- Infiltration models
 - Richards' equation
 - Green and Ampt
- Assignment of Green and Ampt parameters



- Infiltration is the process of water penetrating from the ground surface into the soil.
- Infiltration occurs due to two forces
 - gravity
 - capillary pressure in the soils

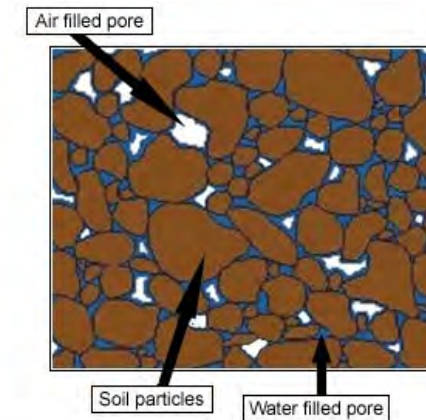
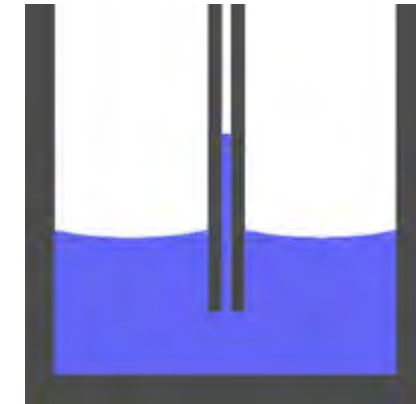


- Potential energy of water at higher elevation results in downward movement.



Capillary Pressure

- Negative pressure in the soil matrix due to the capillary effect of voids.
- Higher negative pressure in drier soils results in water movement from wetter to dryer soils.
- During rainfall events, soils near the soil surface become wet, or even saturated. Drier soils beneath continue to exert a suction on this water resulting in continued downward movement.

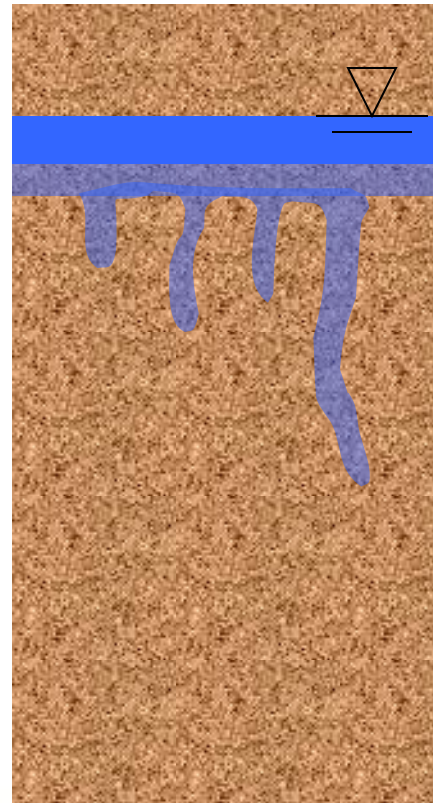


Types of Porous Media Flow

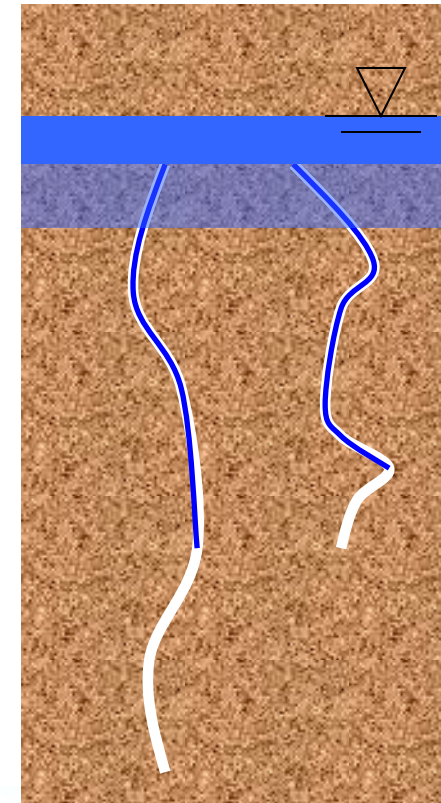
Capillary Driven



Gravity Driven



Macropores



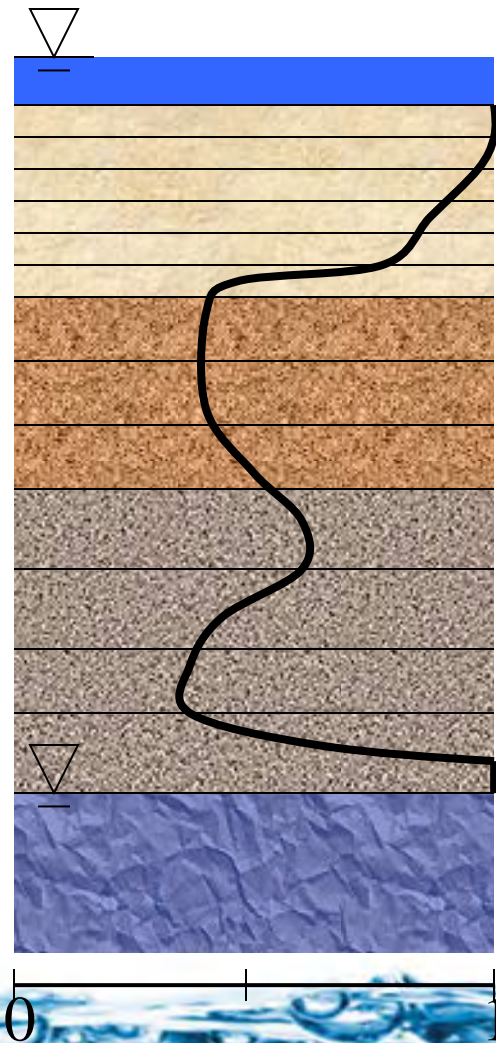
Infiltration Methods in GSSHA

- Richards' Equation – numerical solution of flow equations through layered system.
- Green and Ampt – simplification of soil column and flow equations – no layering, piston flow.
- Multi-layer Green and Ampt – Green and Ampt solution in a multiple layered soil column.
- Green and Ampt with Redistribution – Simple Green and Ampt representation of soil column with redistribution of soil moisture during rainfall hiatus.

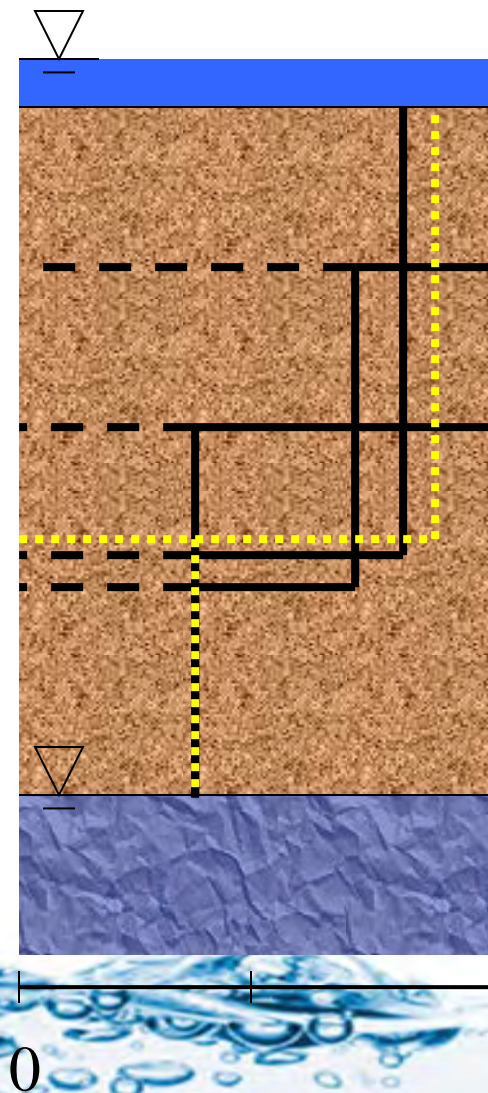


Representations of Infiltration

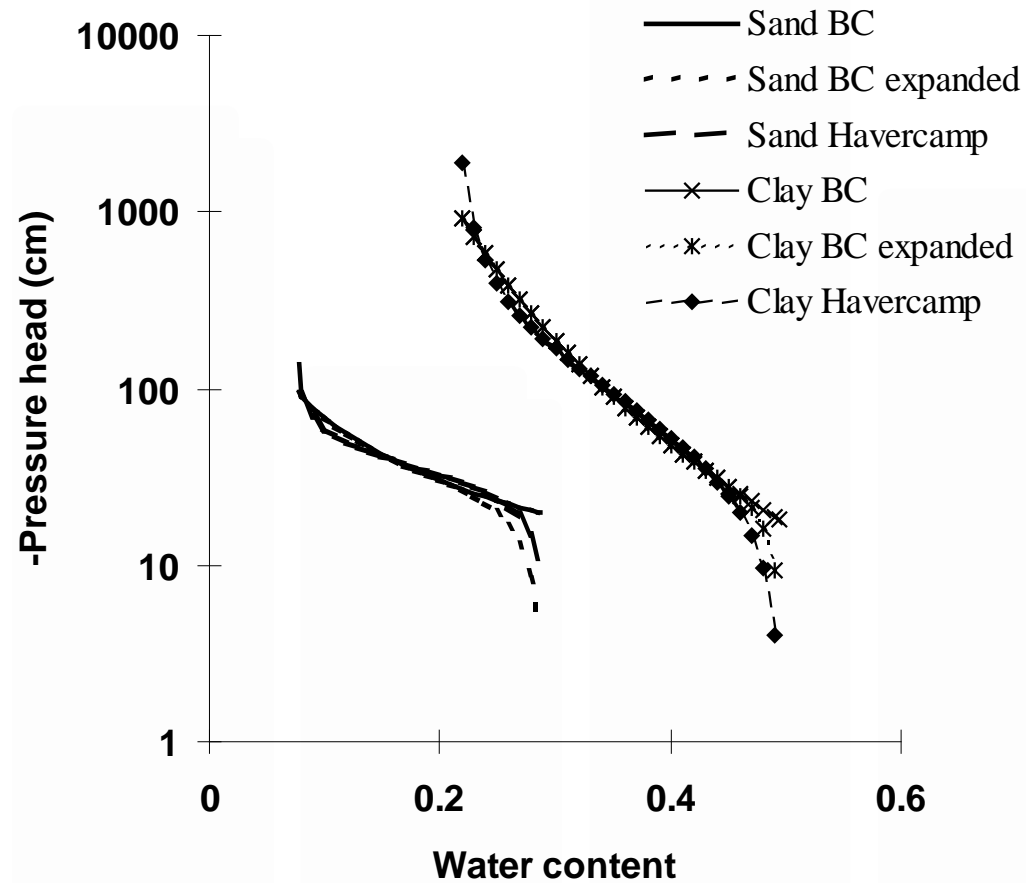
Richard's Equation



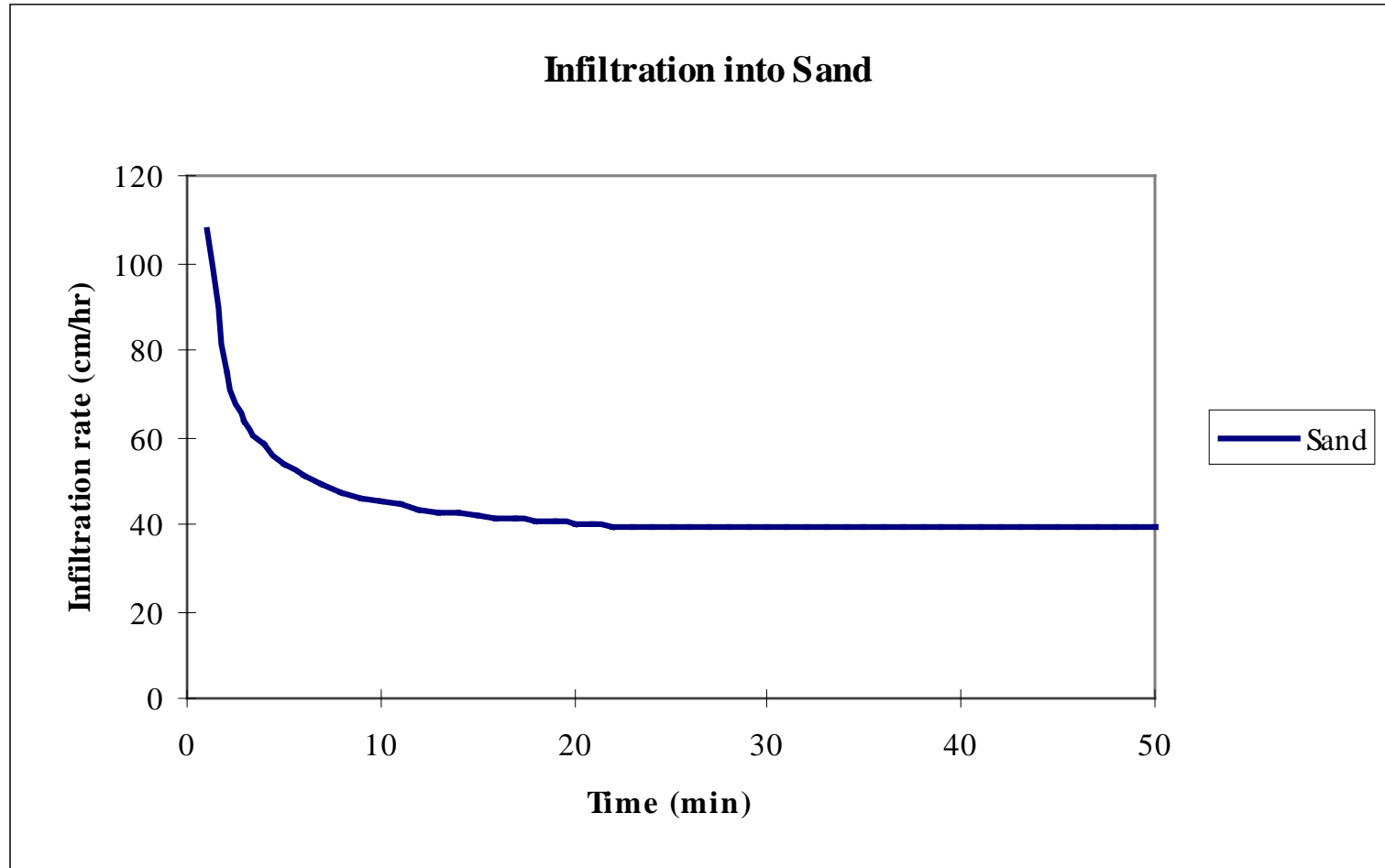
Green & Ampt w/ Soil Moisture Redistribution



Effect of Soil Moisture on Capillary Pressure



Effect of Soil Moisture on Infiltration Rate

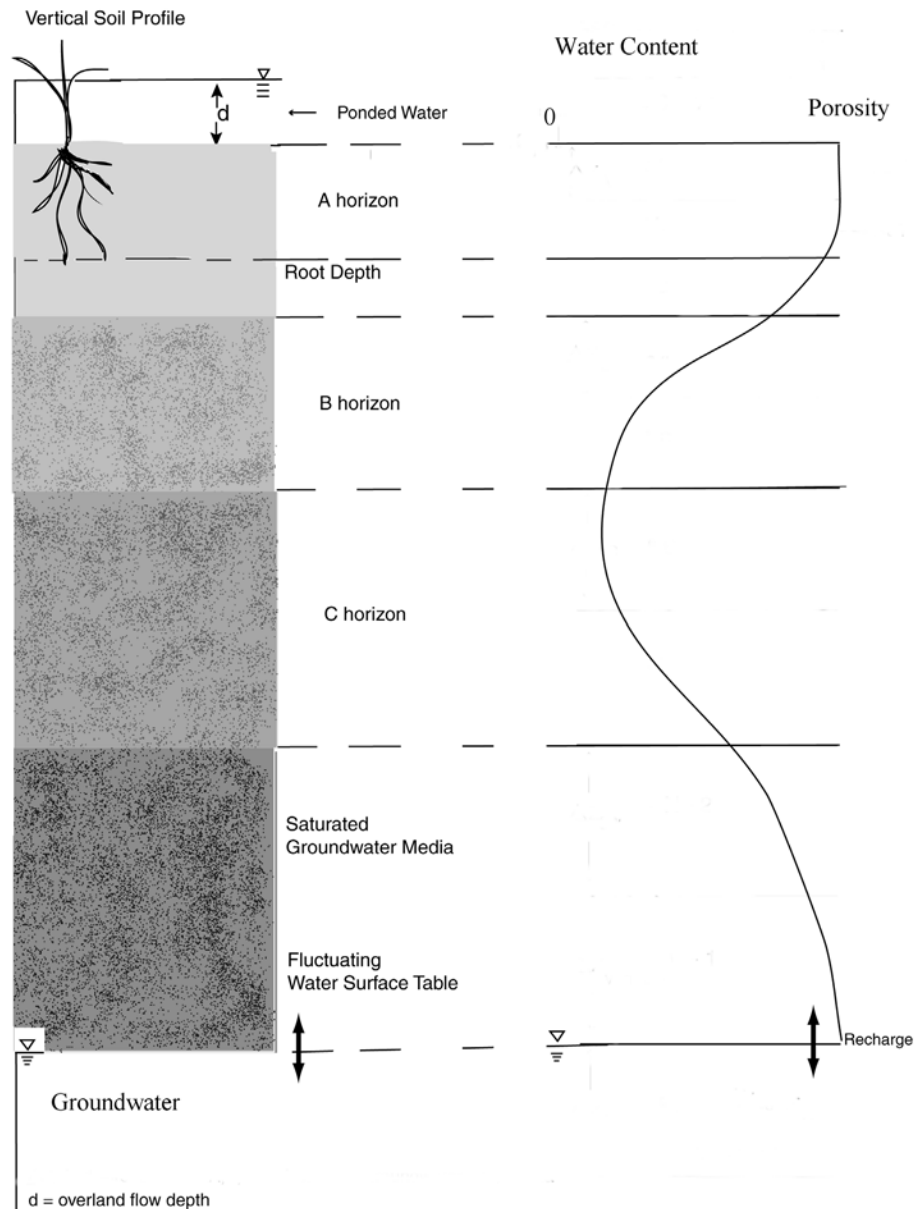


Factors That Affect Infiltration

- Soil texture
- Initial soil moisture
- Soil layering
- Vegetation
- Macro-pores
- Location of the water table



Soil Moisture Profile During Infiltration



- Continuity

$$\frac{\partial \theta}{\partial t} + \frac{\partial q}{\partial z} = 0$$

- θ - water content
- q - flux
- t - time
- z - vertical direction



- Momentum - Buckingham-Darcy flux law

$$q = -K(\psi) \frac{\partial}{\partial z} (\psi + z)$$

ψ - soil capillary pressure

$K(\psi)$ - hydraulic conductivity at pressure ψ



$$C(\psi) \frac{\partial \psi}{\partial t} - \frac{\partial}{\partial z} \left[K(\psi) \left(\frac{\partial \psi}{\partial z} - 1 \right) \right] - W = 0$$

C - specific moisture capacity

ψ - soil capillary head (cm)

z - vertical coordinate (downward positive)

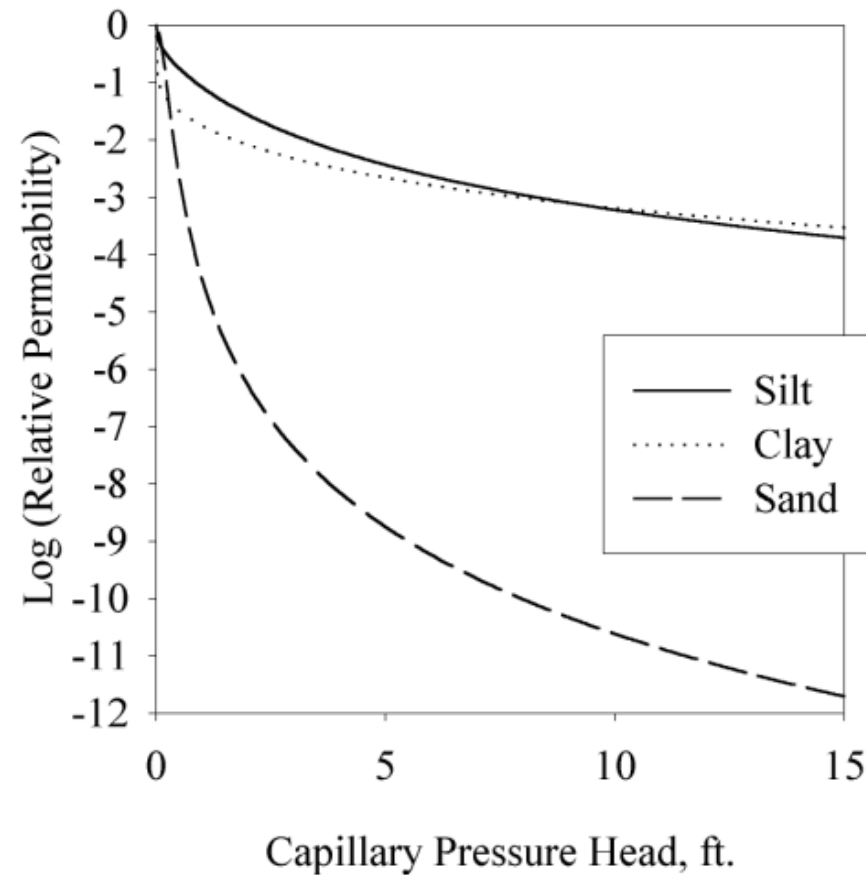
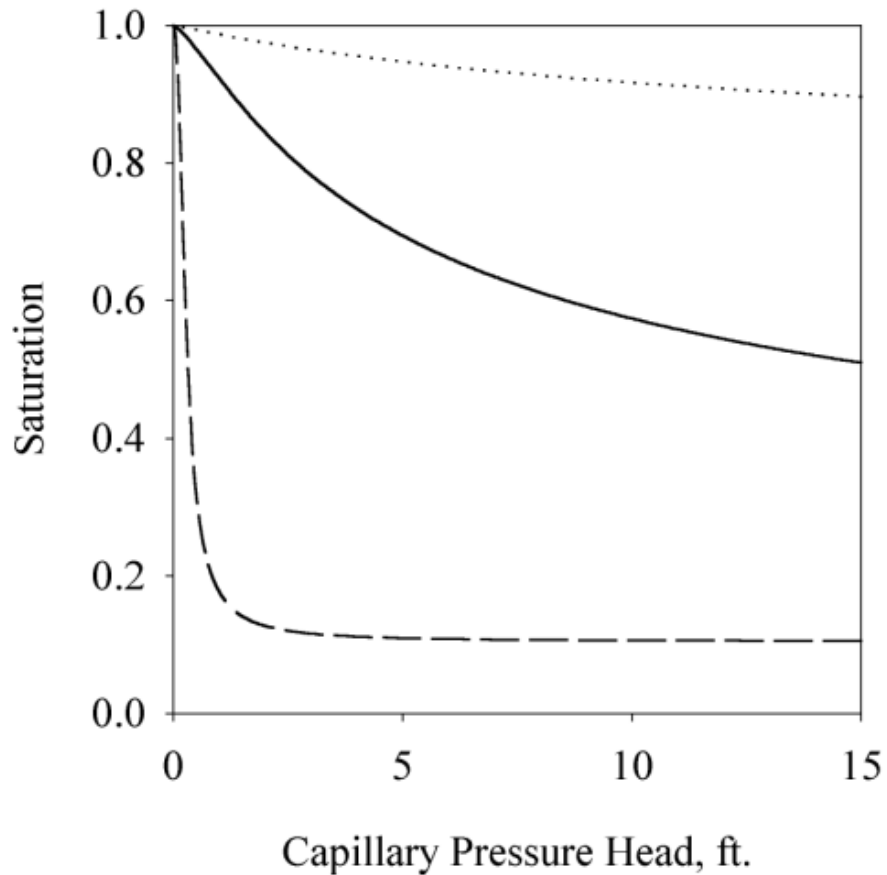
t - time (hr),

K - effective hydraulic conductivity (cm/hr)

W - flux term added for sources and sinks (cm/hr).



Non-linear Coefficients Depend on Water Content

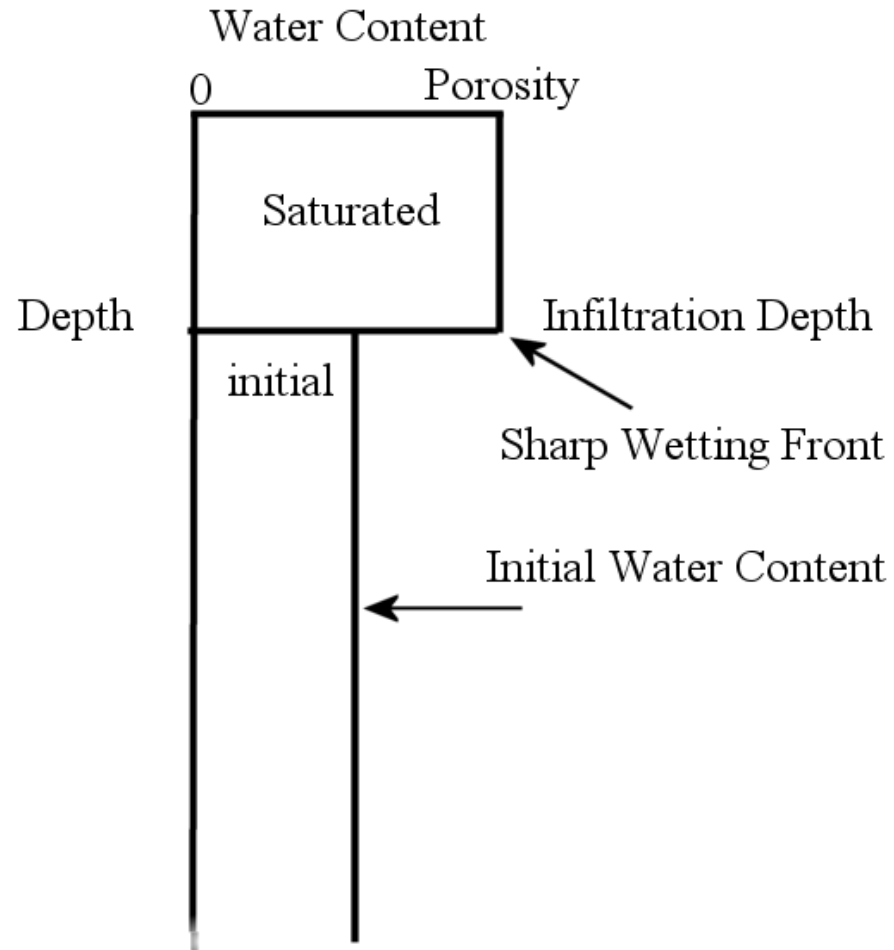


Green and Ampt Model Simplifying Assumptions

- Sharp wetting front
- Unlimited infiltration capacity
- Uniform soils
- Uniform initial moisture
- No effect of water table



Green and Ampt Model of Infiltration



- Hydraulic conductivity at the wetting front is a constant effective value
 - $K = K_d/2.0$
- The capillary effect can be expressed as the effective wetting front soil suction head
 - S_f



- Cumulative Infiltration (cm)

$$F(t) - S_f (\theta_s - \theta_i) \ln \left(1 + \frac{F(t)}{S_f (\theta_s - \theta_i)} \right) = Kt$$

- Infiltration Rate (cm/hr)

$$f(t) = K \left(\frac{S_f (\theta_s - \theta_i)}{F(t)} + 1 \right)$$

- Iterative solution - Newton method



Green and Ampt Parameters

- S_f - wetting front suction head (cm)
- n - effective porosity
- K - effective hydraulic conductivity (cm/hr)
 - $K = Ks/2.0$
- θ_i - initial water content

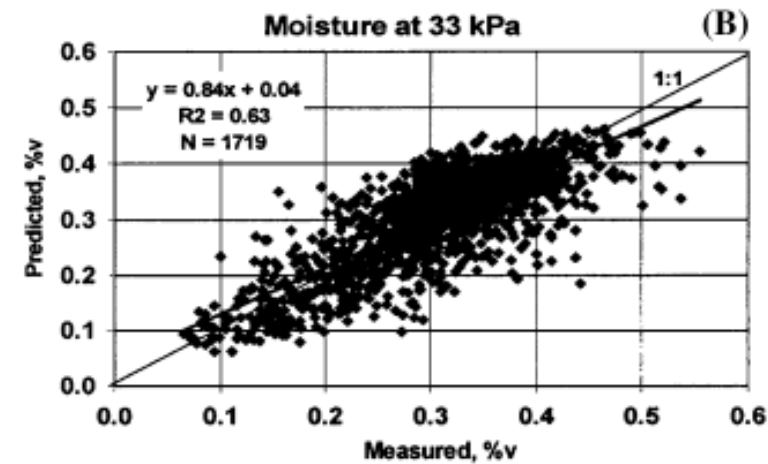


Assignment of Green and Ampt Parameters

- Derived from soil texture index map or combination soil texture land use index map
- Assigned with mapping table
- Initial values can be taken as average values from Rawls et al. 1983.
- Derived from soil texture using Saxton and Rawls, 2006.
- Calibrated values are constrained within limits from Rawls et al. 1983, Saxton and Rawls, 2006.



- Soil hydraulic properties derived from soil properties
 - Texture
 - Organic matter
 - Structure
- From statistical analysis of measured field data
- Paper and spreadsheet in your materials
 - Data Processing folder



Valid Method for the Following:

- Hortonian runoff (infiltration excess)
 - high intensity rainfall
 - fine textured soils
 - arid to semi-arid regions
- Deep homogeneous soils
 - Multi-layer model
- Water table far from the soil surface
 - Couple to saturated groundwater model

