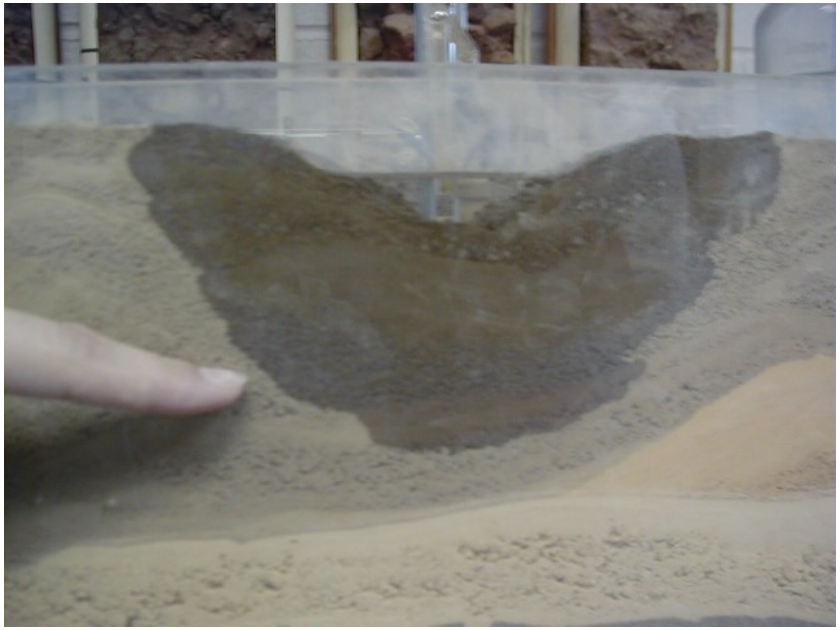
Simulating Infiltration in GSSHA

Discussion Topics

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

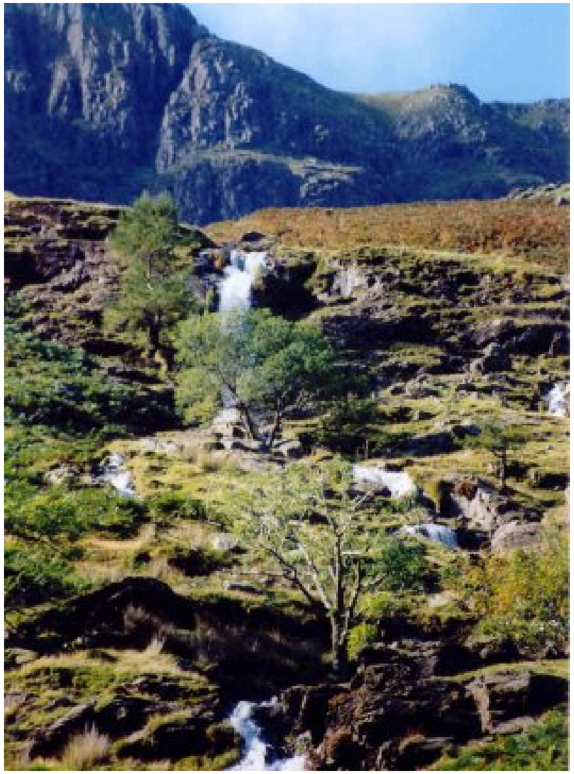
Infiltration

- 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



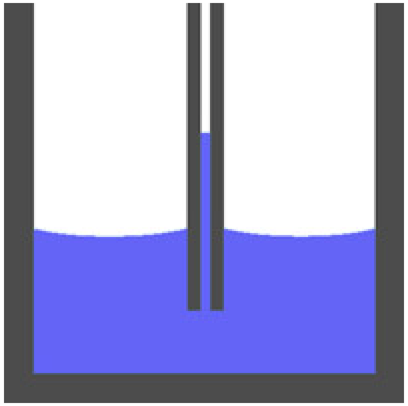
Gravity

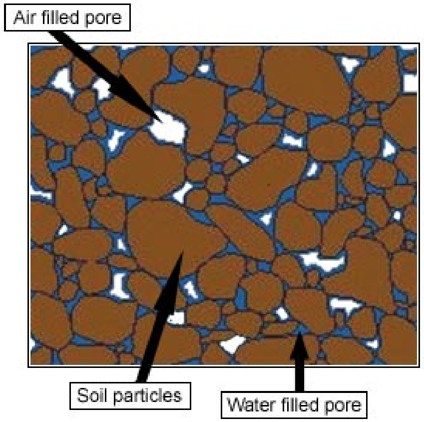
- Potential energy of water at higher elevation results in downward movement.



Capillary Pressure

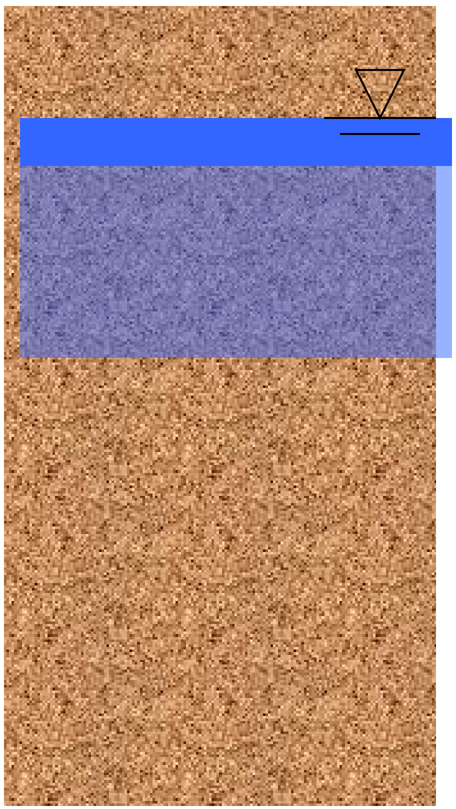
- Negative pressure in the soil matrix due to the capillary effect of voids.
- Higher negative pressure in drier soils results in water movement from wetter to dryer soils.
- During rainfall events, soils near the soil surface become wet, or even saturated. Drier soils beneath continue to exert a suction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



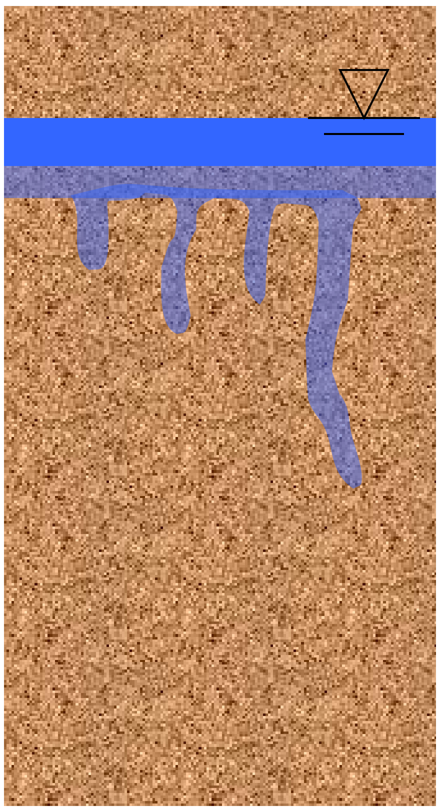


Types of Porous Media Flow

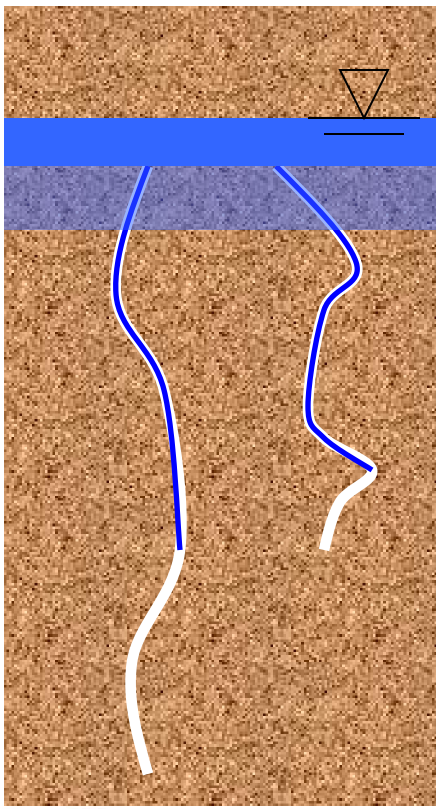
Capillary Driven



Gravity Driven



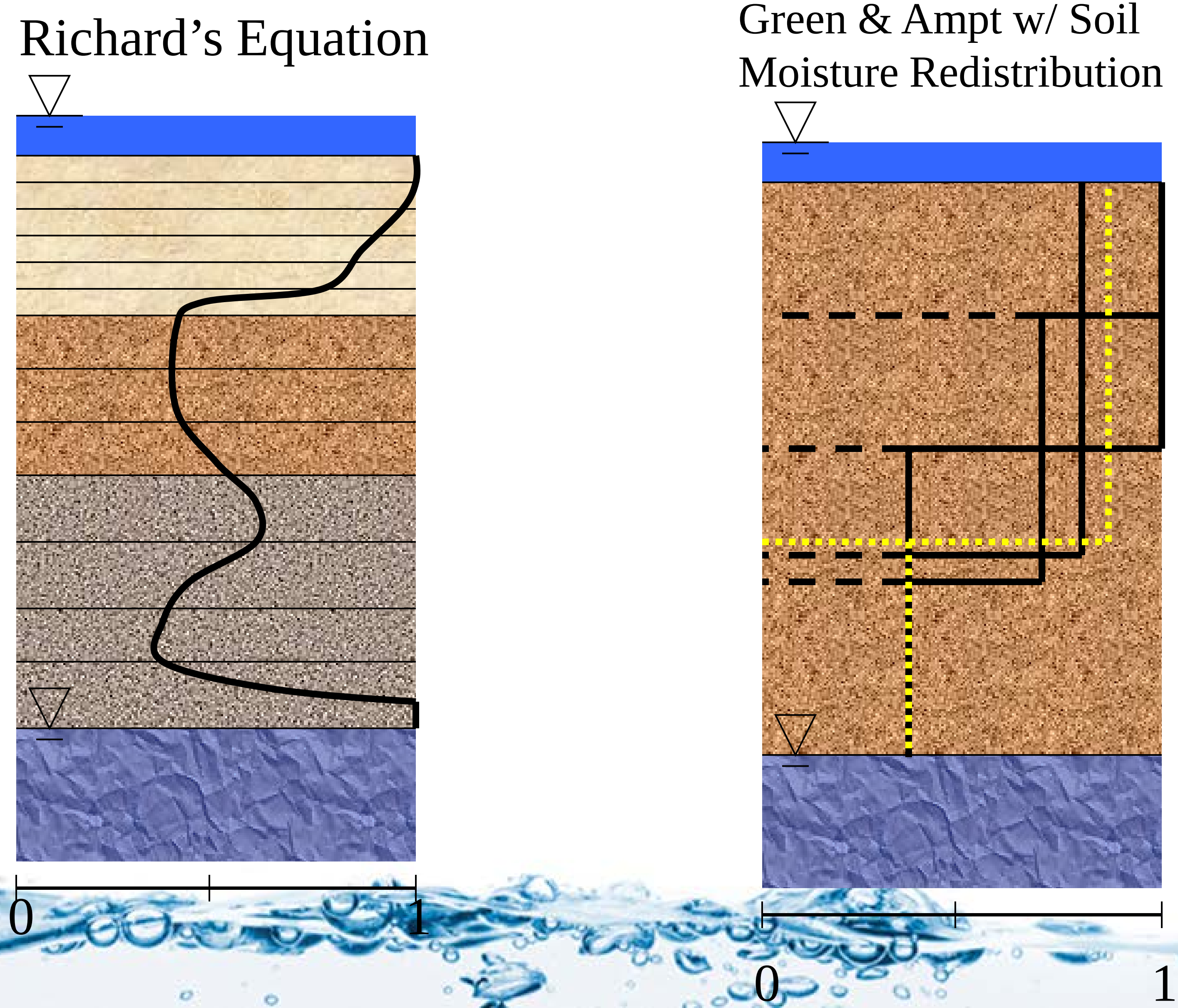
Macropores



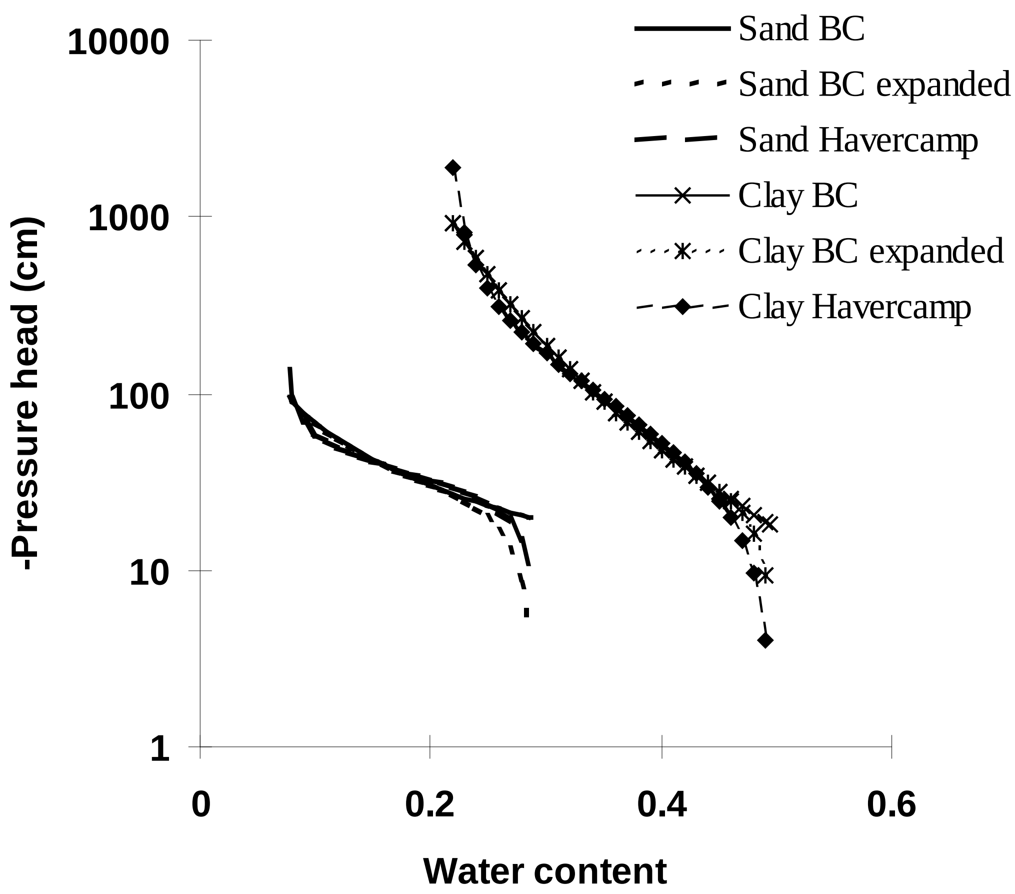
Infiltration Methods in GSSHA

- 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



Effect of Soil Moisture on Capillary Pressure



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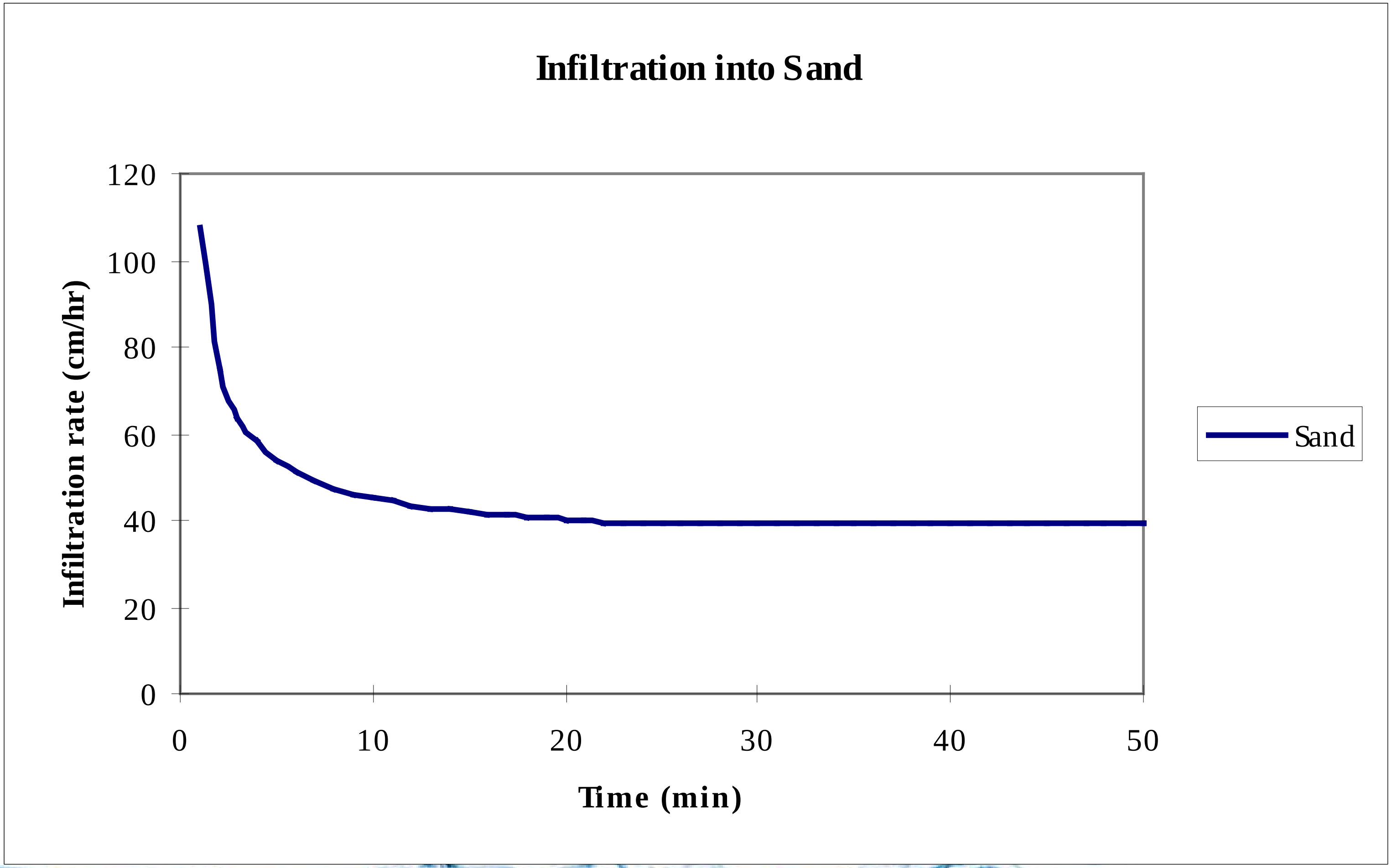
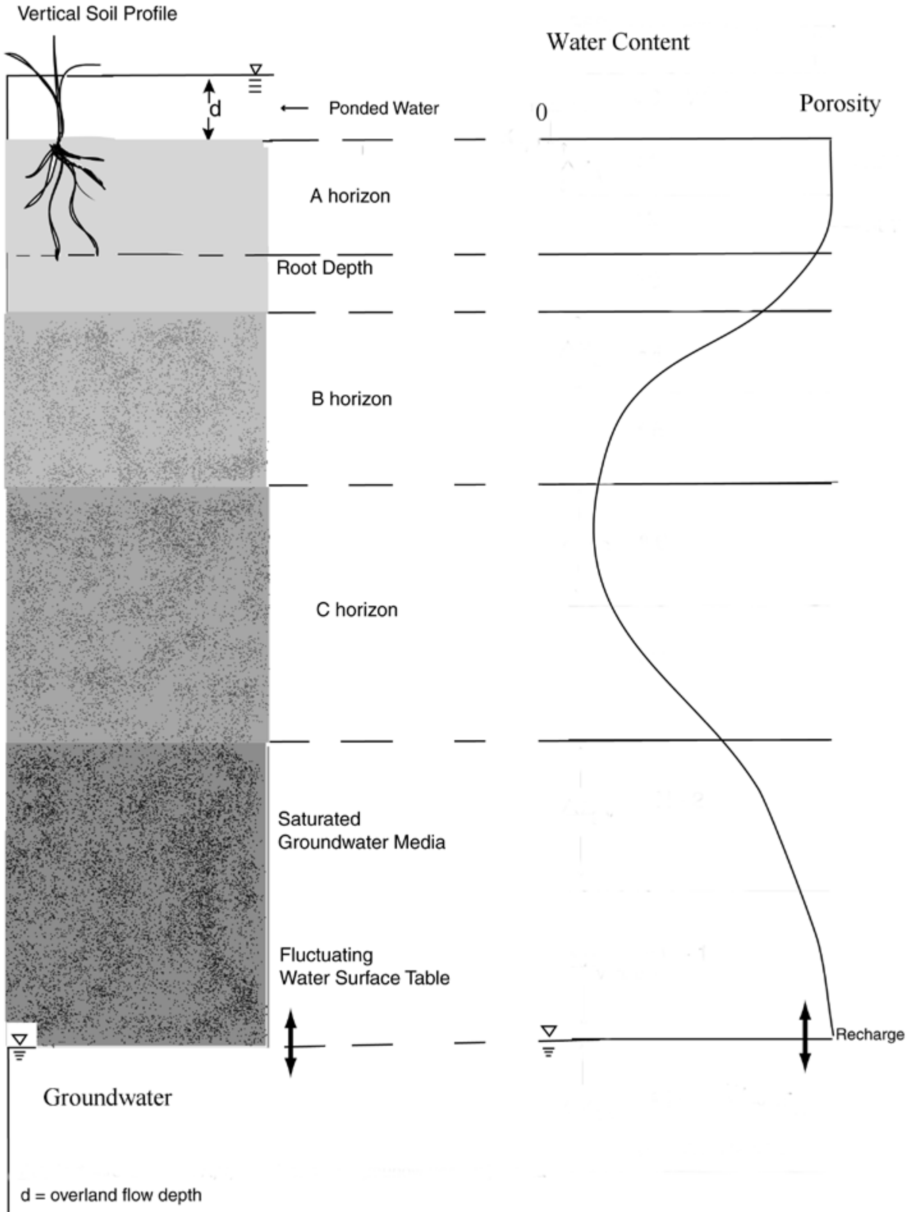


Factors That Affect Infiltration

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

Soil Moisture Profile During Infiltration



Mathematical Description

- Continuity

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

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

Mathematical Description

- Momentum - Buckingham-Darcy flux law

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

ψ - soil capillary pressure

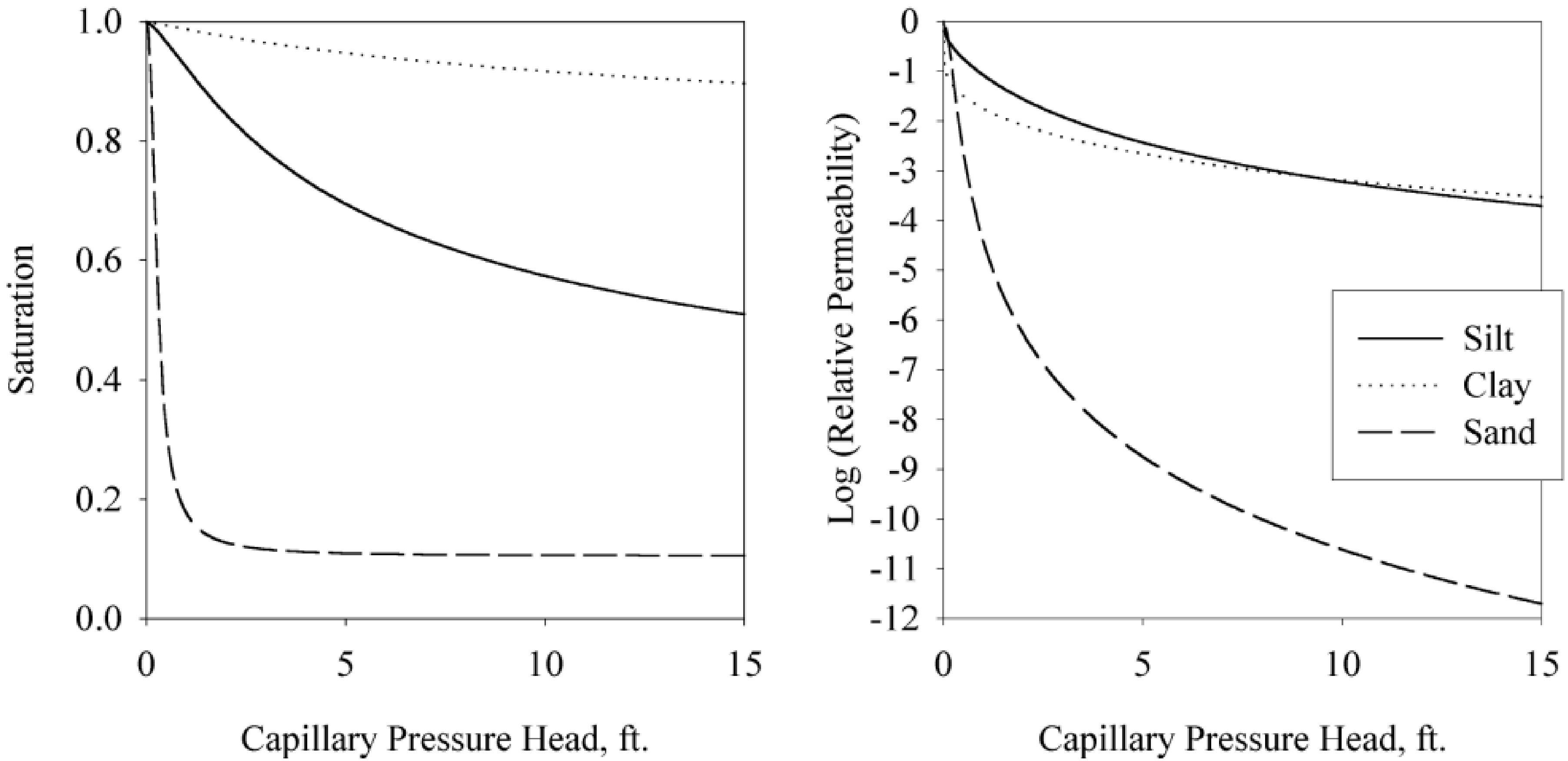
$K(\psi)$ - hydraulic conductivity at pressure ψ

Richards' Equation

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

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).

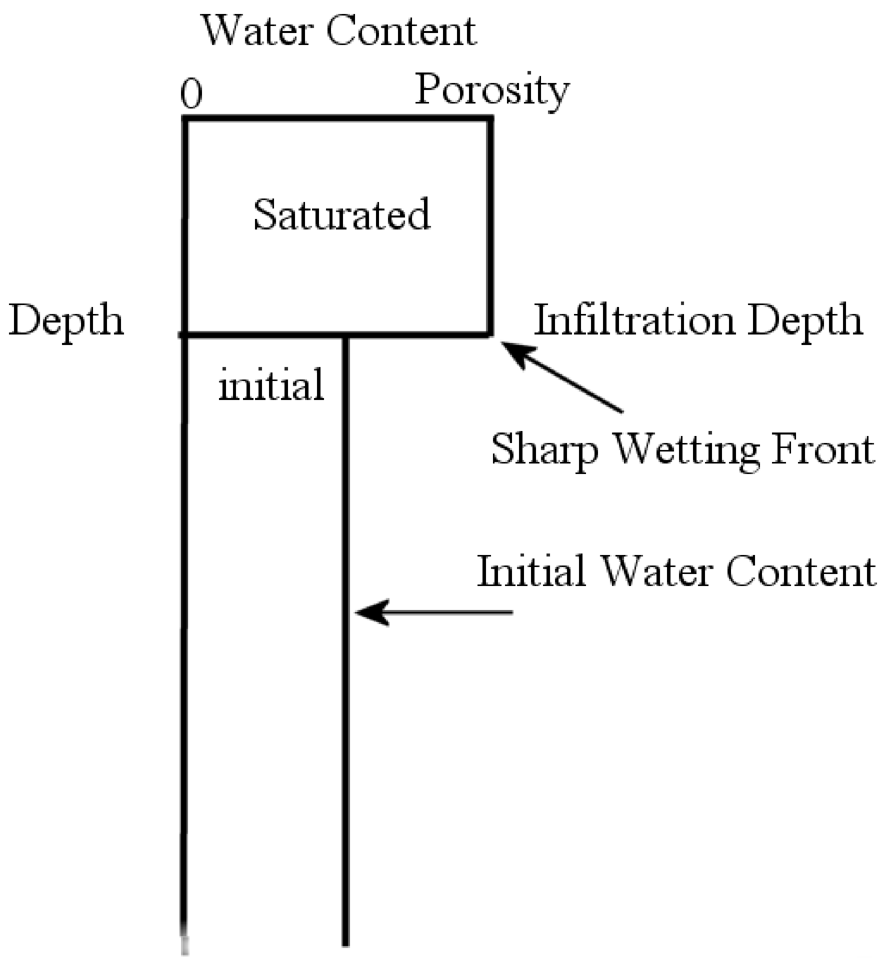
Non-linear Coefficients Depend on Water Content



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



Further Assumptions

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

Green and Ampt Model

- 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

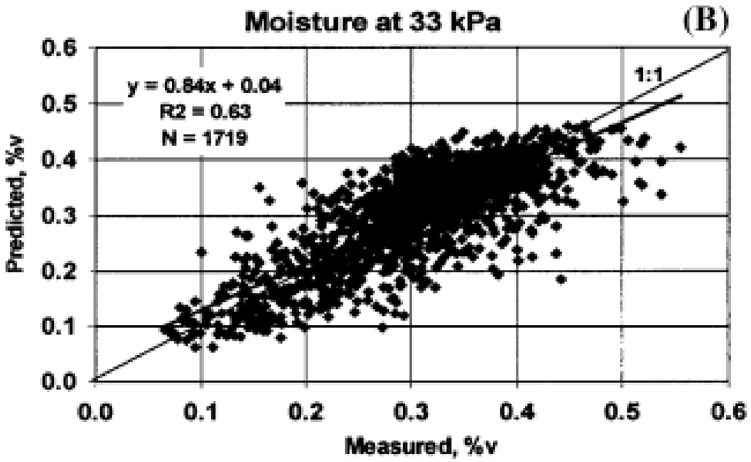
Assignment of Green and Ampt Parameters

- 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.

Saxton and Rawls, 2006

Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions

- 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