Vadose Zone Hydrological Processes

Modeling Soil and Groundwater systems using the HYDRUS and STANMOD Software Packages

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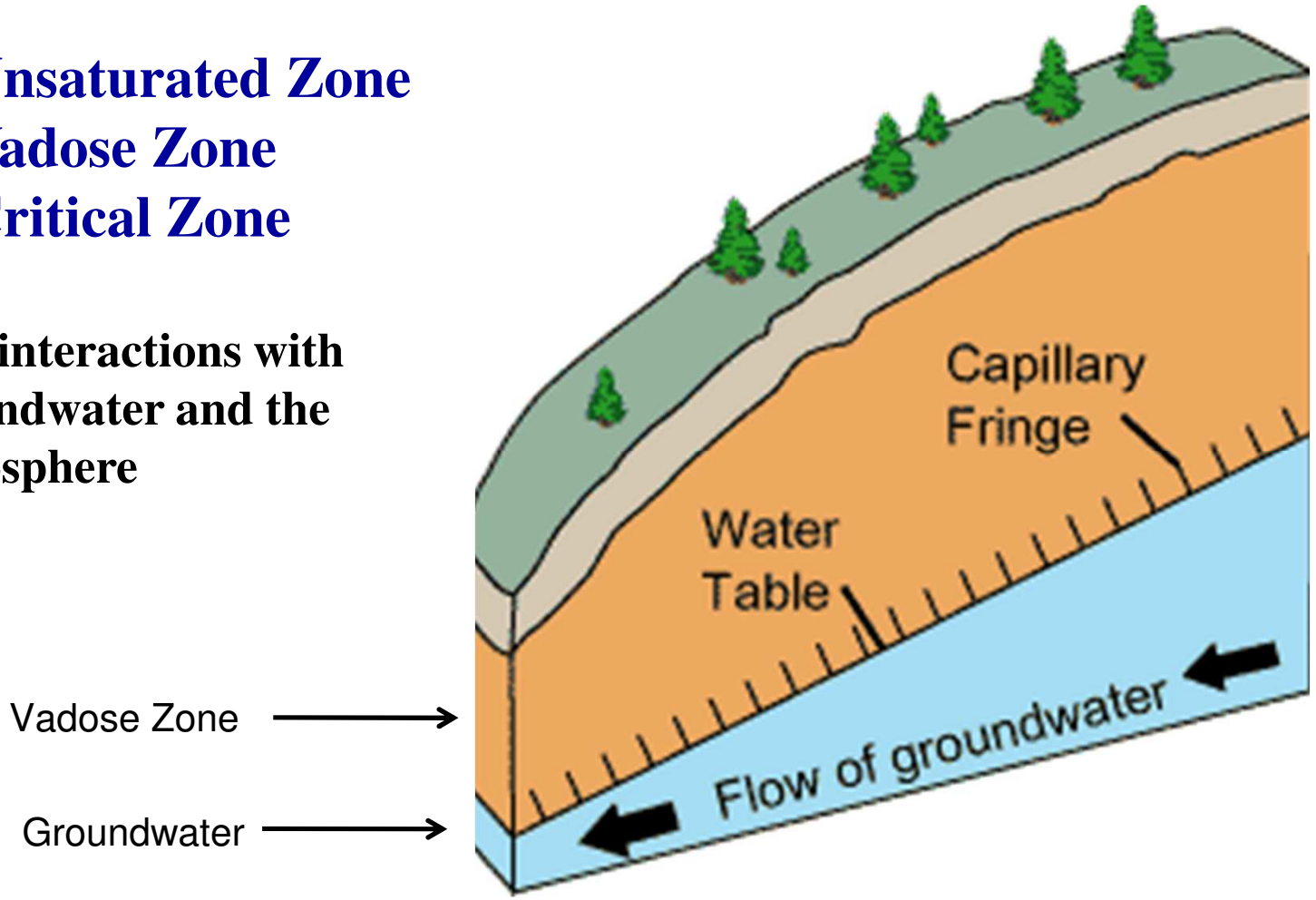
The Near-Surface Environment

- **Unsaturated Zone**
- **Vadose Zone**
- **Critical Zone**

Plus interactions with groundwater and the atmosphere



Governing Equations

Variably-Saturated Water Flow (Richards Equation)

$$\frac{\partial \theta(h)}{\partial t} = \frac{\partial}{\partial z}\left[K(h)\frac{\partial h}{\partial z} - K(h) \right] - S(h)$$

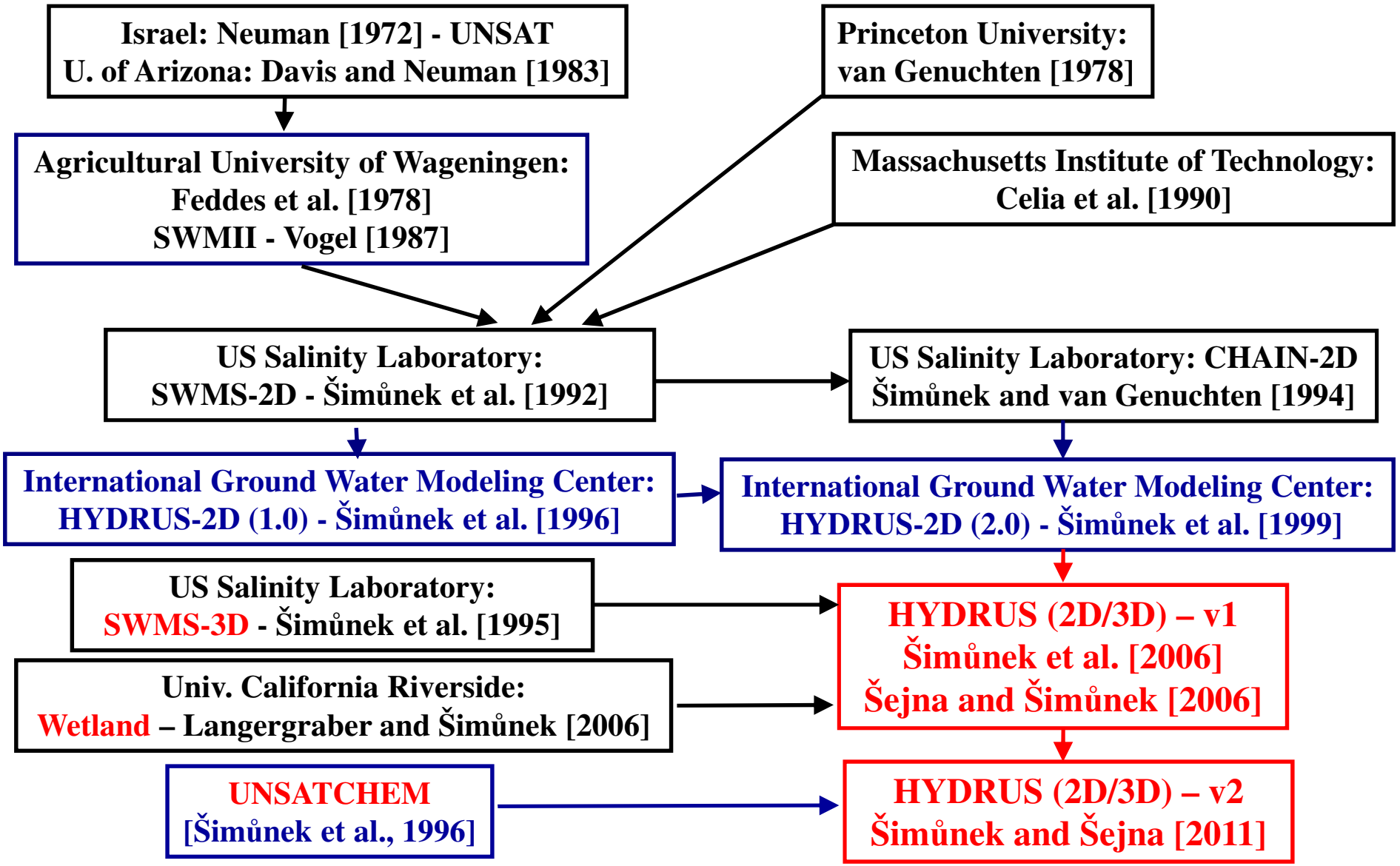
Solute Transport (Advection-Dispersion Equation)

$$\frac{\partial(\rho s)}{\partial t} + \frac{\partial(\theta c)}{\partial t} = \frac{\partial}{\partial z}\left(\theta D \frac{\partial c}{\partial z} - qc \right) - \phi$$

Heat Movement

$$\frac{\partial C_p(\theta)T}{\partial t} = \frac{\partial}{\partial z}\left[\lambda(\theta)\frac{\partial T}{\partial z} \right] - C_w \frac{\partial qT}{\partial z} - C_w ST$$

HYDRUS - History of Development



HYDRUS – Main Processes

Water Flow:

- **Richards equation for variably-saturated water flow**
- **Various models of soil hydraulic properties**
- **Hysteresis**
- **Sink term to account for water uptake by plant roots** (uncompensated and compensated, reduced due to osmotic and pressure stress)
- **Isothermal and thermal liquid and vapor flow**
- **Preferential flow**

Heat Transport:

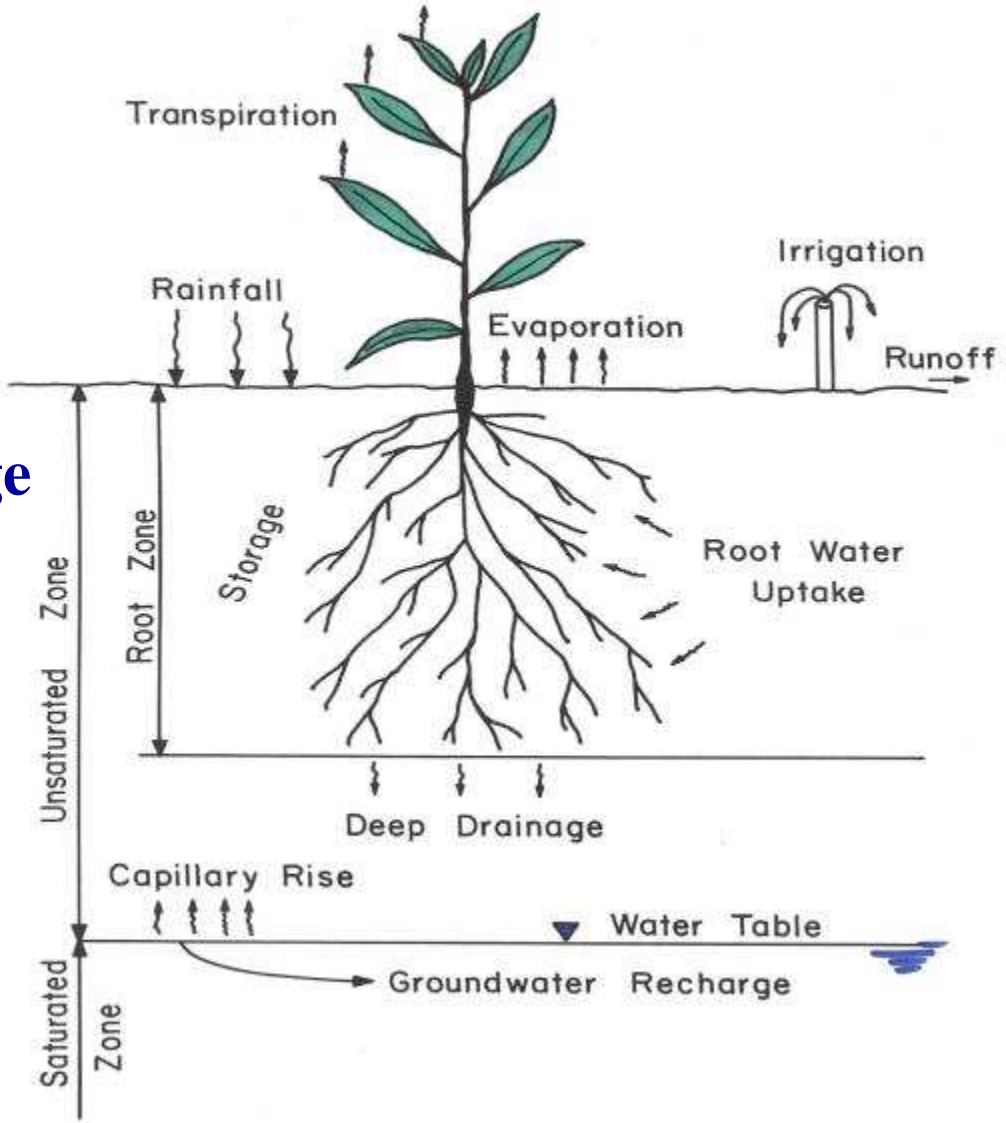
- **Conduction and convection with flowing water (transport of latent heat)**

Solute Transport:

- **Advective-dispersive transport in the liquid phase**
- **Diffusion in the gaseous phase**
- **Linear and nonlinear reactions between the solid and liquid phases**
- **Linear equilibrium reactions between the liquid and gaseous phases**
- **Zero-order production; First-order degradation**
- **Physical nonequilibrium solute transport**
- **Chemical nonequilibrium solute transport**
- **Sink term to account for** (active and passive) **nutrient uptake by plant roots**

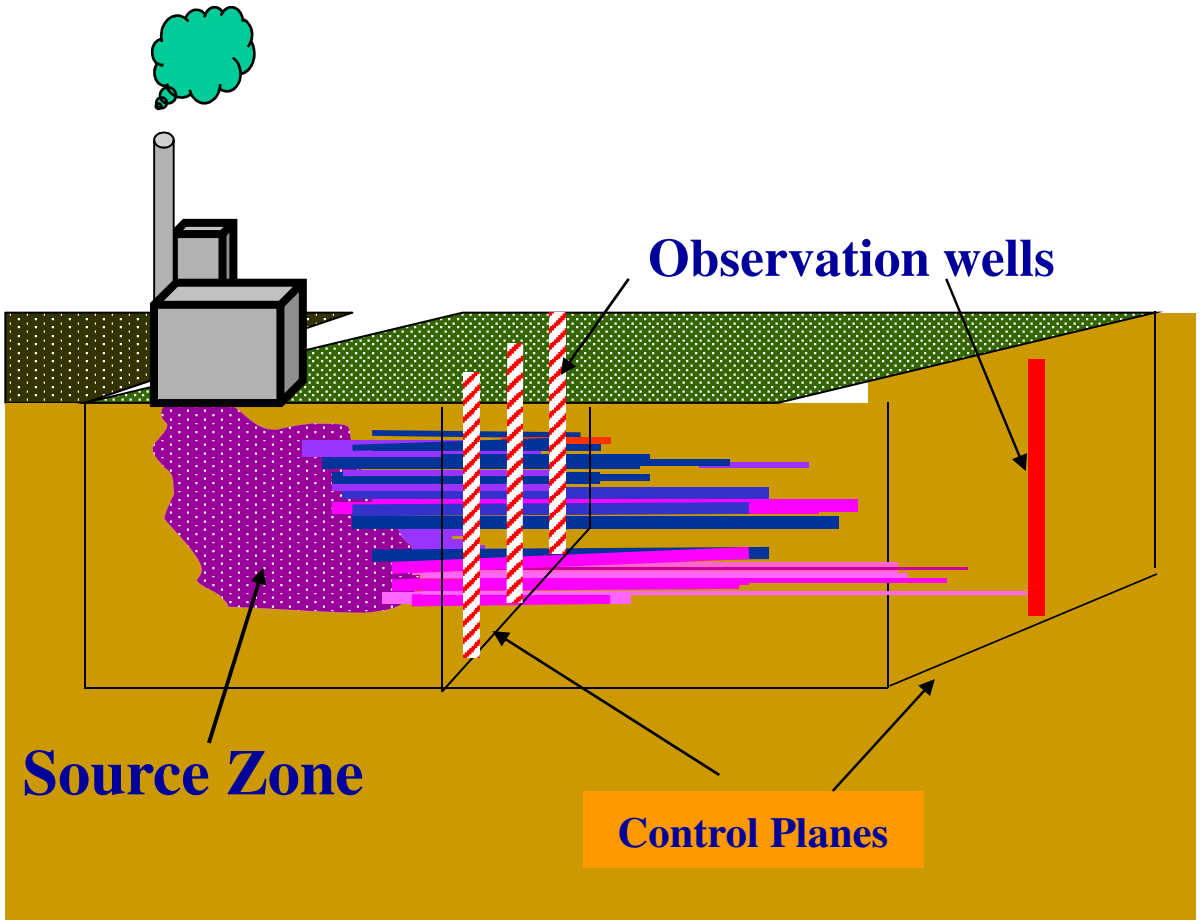
Agricultural Applications

- Precipitation
- Irrigation
- Runoff
- Evaporation
- Transpiration
- Root Water Uptake
- Capillary Rise, Drainage
- Salinity
- Nutrients
- Pesticides
- Fumigants
- Colloids
- Pathogens
- Nanoparticles
- …



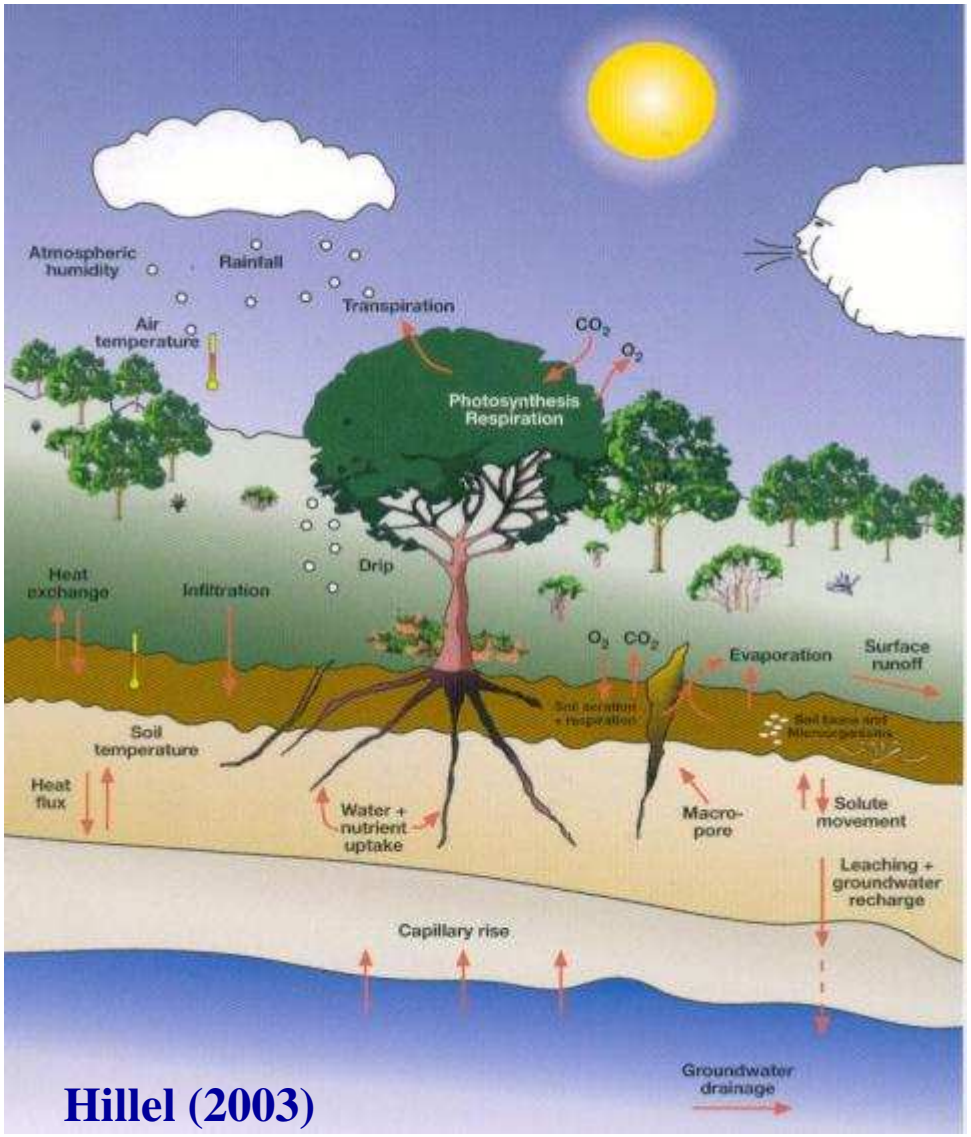
Industrial Applications

- Industrial Pollution
- Municipal Pollution
- Landfill Covers
- Waste Repositories
- Radioactive Waste Disposal Sites
- Remediation
- Brine Releases
- Contaminant Plumes
- Seepage of Wastewater from Land Treatment Systems



Environmental Applications

- Ecological Applications
- Carbon Storage and Fluxes
- Heat Exchange and Fluxes
- Nutrient Transport
- Soil Respiration
- Microbiological Processes
- Effects of Climate Change
- Riparian Systems
- Stream-Aquifer Interactions
- …



Hillel (2003)

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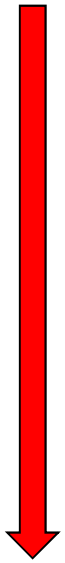
Practical Courses

HYDRUS-1D



- Infiltration into 1D profile (water flow, solute transport)
- Flow and Transport in a multilayered soils profile
- PCE decay chain transport: PCE→TCE → DCE → VC → E
- Inverse problems

Linear sorption, constant unidirectional flow,
homogeneous profile → 1,2,3D ADE analytical solutions

STANMOD

- Equilibrium and nonequilibrium contaminant transport
- Inverse problems (BTCs)

www.PC-Progress.com

www.HYDRUS2D.com

HYDRUS-1D

STANMOD

RETC