Hanford Site

Water and Energy Balance in an ET Cover with a Protective Side Slope Using the STOMP Simulator

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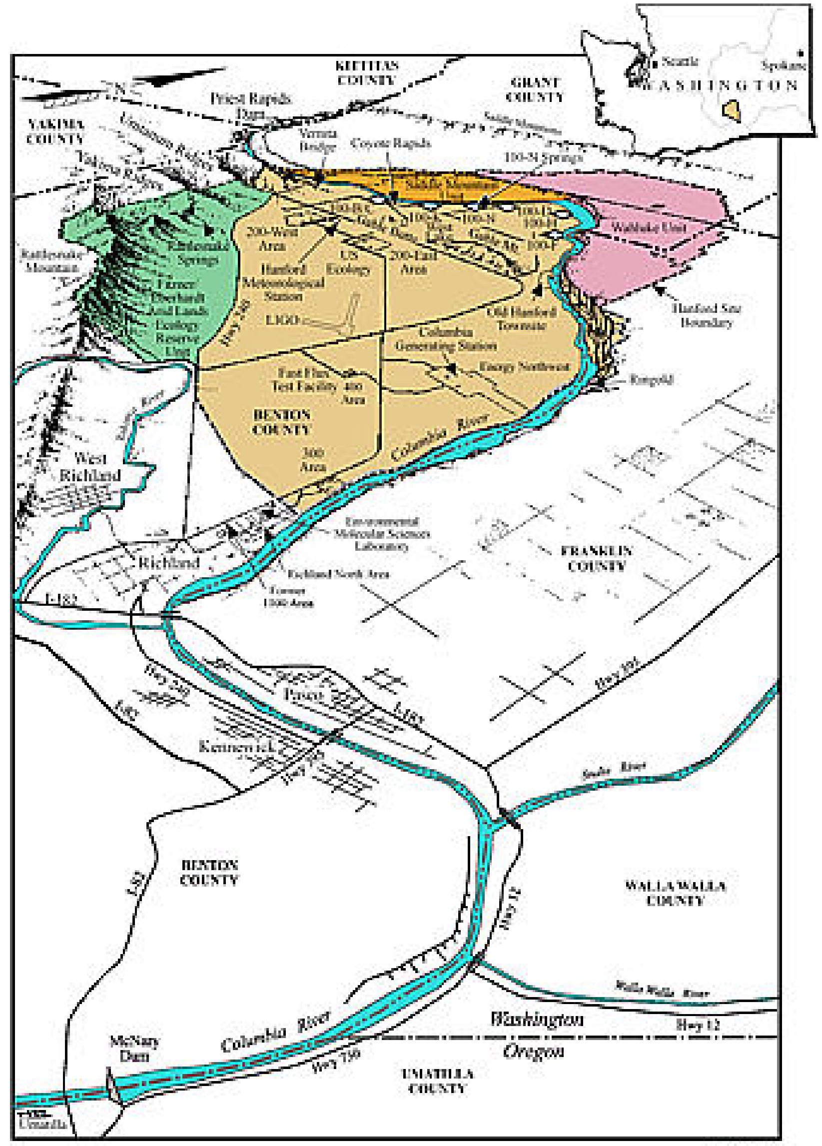
March 9-10, 2004

Background

- Surface barriers are needed for closure at most DOE sites
- At Hanford alone, over 1600 liquid and solid waste sites, including 12 tank farms
- Some 200 barriers covering ≅ 1000 acres required for waste site closure
- Barrier development is of the top four Science &Technology challenges to site clean-up

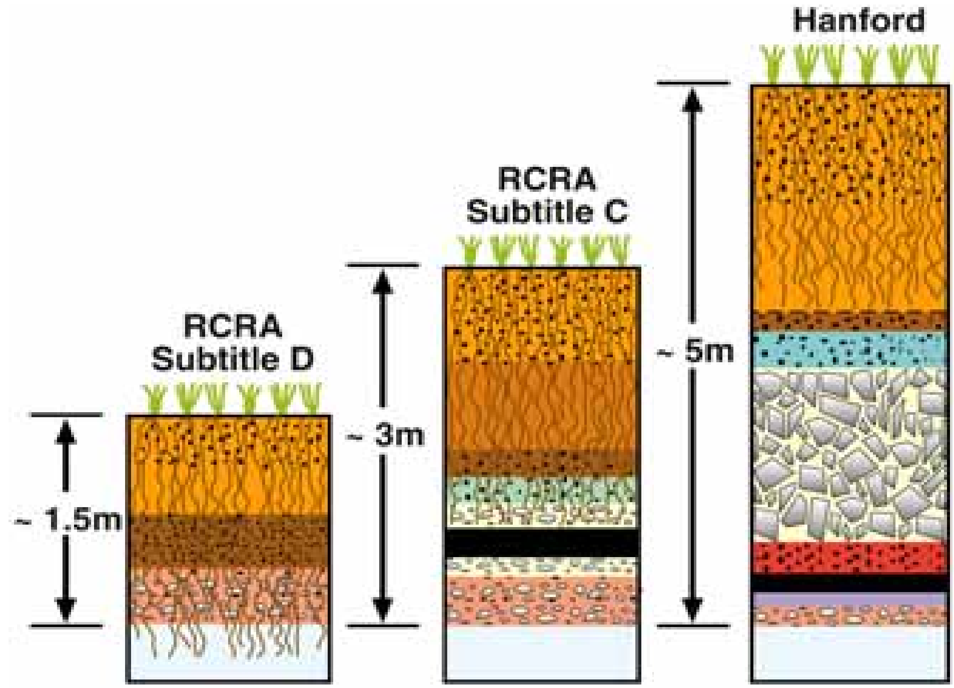


Challenges to Barrier Deployment

- Multidimensional design problem
  - raised sloped surfaces
  - minimize footprint; underflow
- Protective side slopes
  - no design standard
- Important components of field-scale transport
  - subsurface heterogeneity
  - strong anisotropy
  - reactive transport (radiological and hazardous wastes)
- Limitations in design tools
  - not all are physically based
  - semi-empirical climate coupling
  - mass and energy not coupled
  - not suited to sparse canopies typical of arid environments

Objective

- Develop a tool to support design and performance evaluation of candidate barriers for the Hanford Site
- STOMP already includes many of the features needed of a barrier design tool
- Routinely used to predict soil water dynamics
  - Multidimensional
  - nonisothermal
  - Multiphase
  - unsaturated
- develop a module for soil-plant-atmosphere dynamics



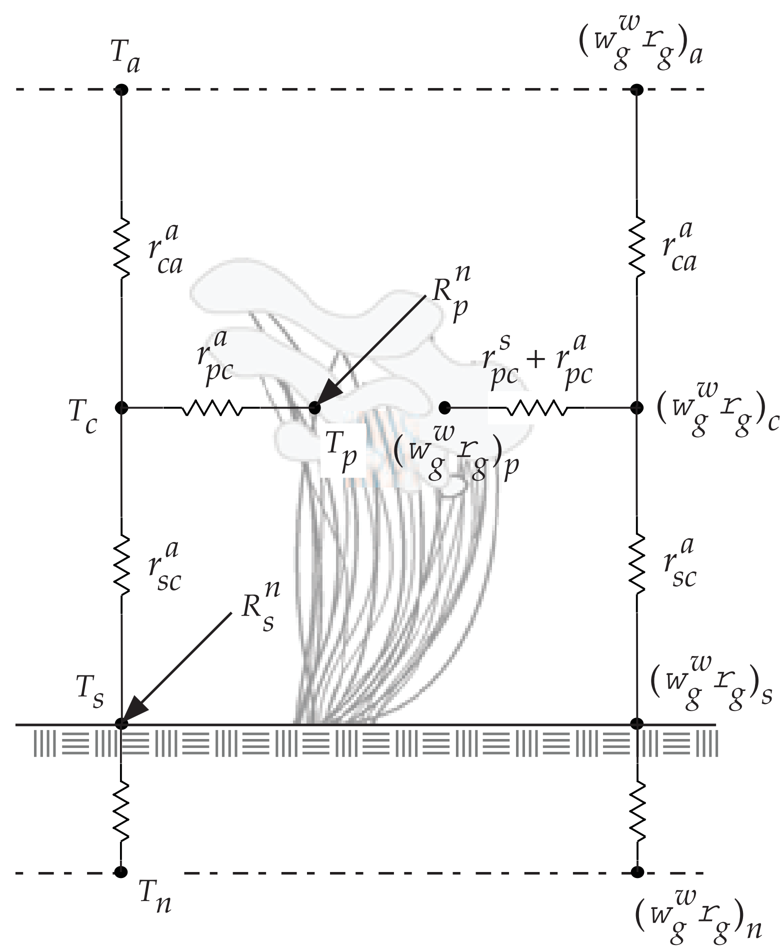
STOMP
Subsurface Transport Over Multiple Phases
www.pnl.gov/etd/STOMP

Model Structure

- Single-plant-temperature boundary
- Multiple-plant-temperature boundary
- 5 coupled conservation equations
  - water mass at the ground surface
  - thermal energy at the ground surface
  - thermal energy at the plant leaves
  - water mass at the canopy height
  - thermal energy at canopy height
- Primary unknowns
  - aqueous pressure (soil surface)
  - temperature (soil surface)
  - plant leaf temperature
  - water-vapor partial pressure
  - temperature at the canopy height

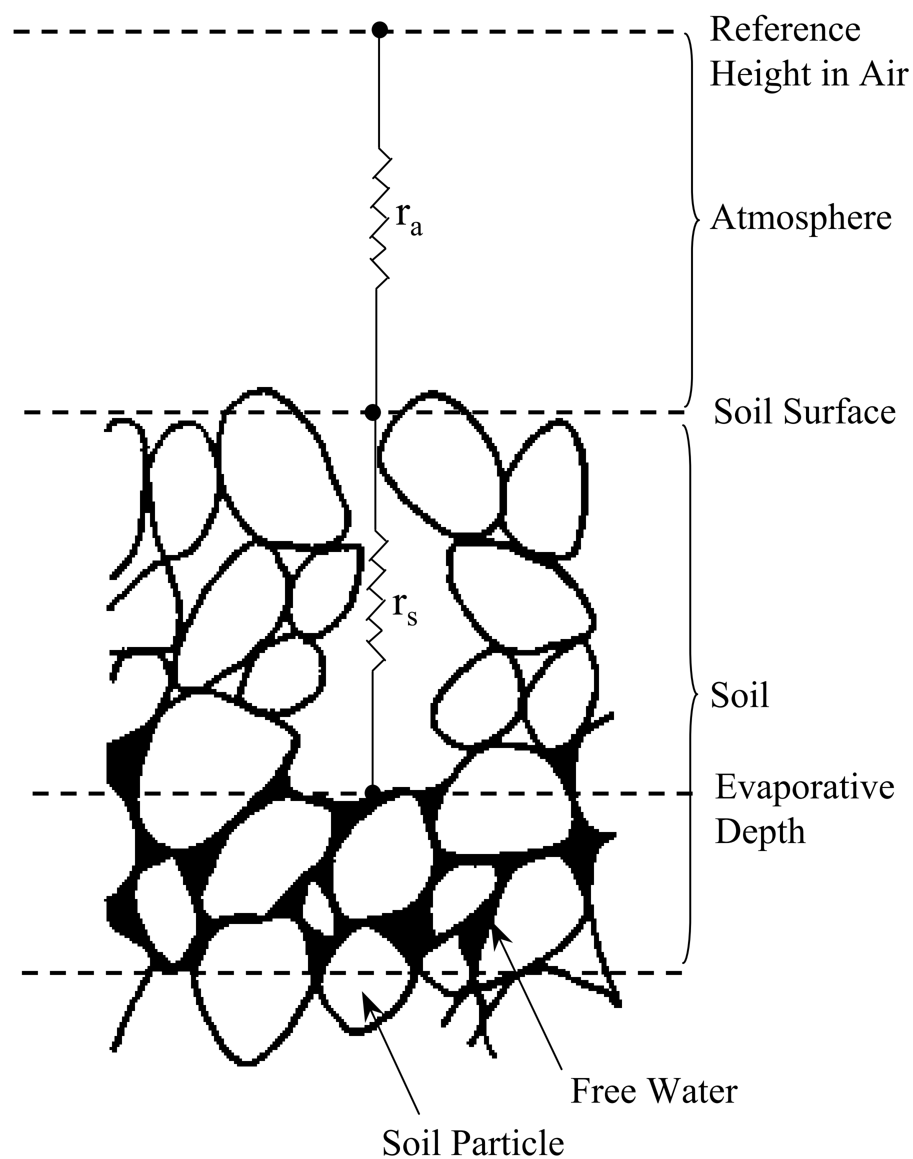
Potential Evapotranspiration

- Priestly-Taylor model best for ample soil water and minimal advection
- Penman-Monteith model best for full canopy ground coverage
- For sparse canopies, typical of arid ecosystems, Shuttleworth-Wallace [1985] is best
  - Single species transpiration and soil evaporation model extended to multiple species in multiple dimensions



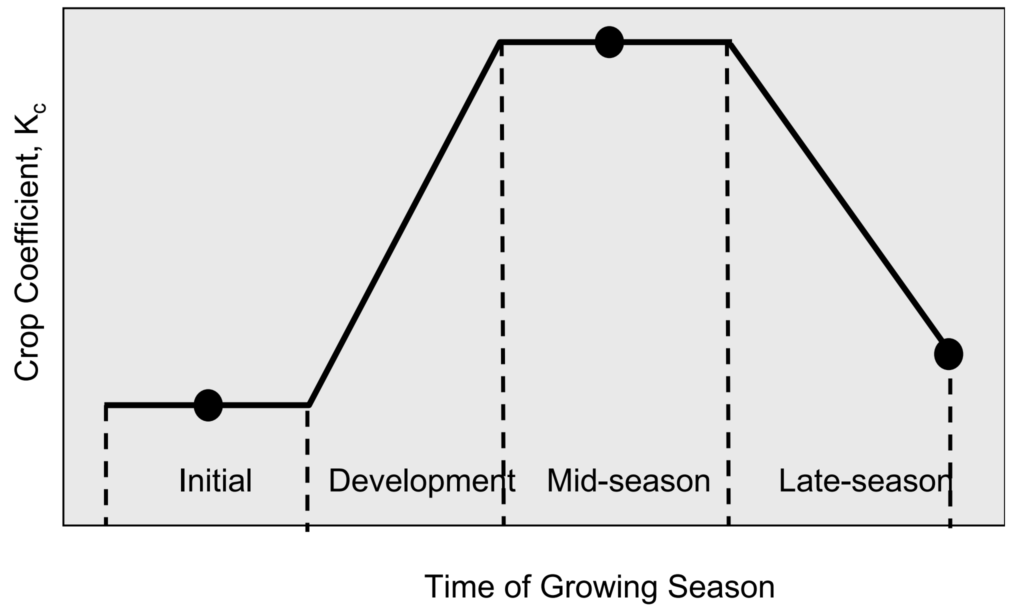
Soil Evaporation

- The evaporative depth is determined implicitly for each time step
- A departure from specification of evaporative depth
  - Eliminates arbitrary definition
  - Cannot vary evaporative depth to dictate barrier performance
- Required modifications of $\theta(\psi)$ and $K(\psi)$ for dry conditions



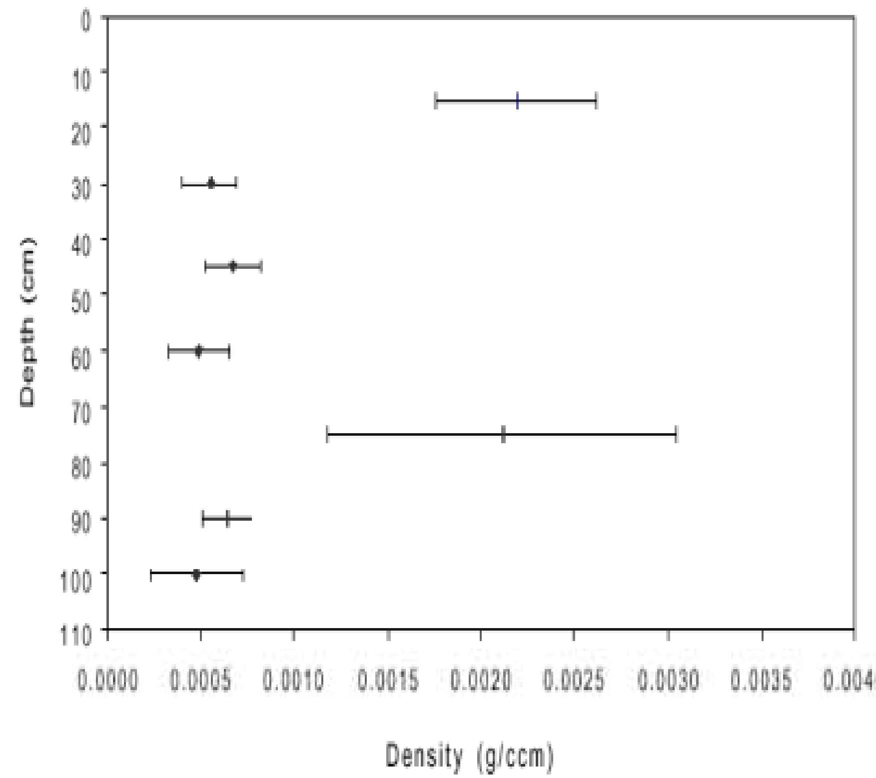
Crop Coefficient

- Used to scale ET_0 to ET_a, for the plant species of interest
- For $K_c < 1$, plant uses less water than ET_0 ; when $K_c > 1$, plant uses more water
- Defined using 5 points in development stage
- Linear interpolation between points
- Allows values to vary over life of barrier



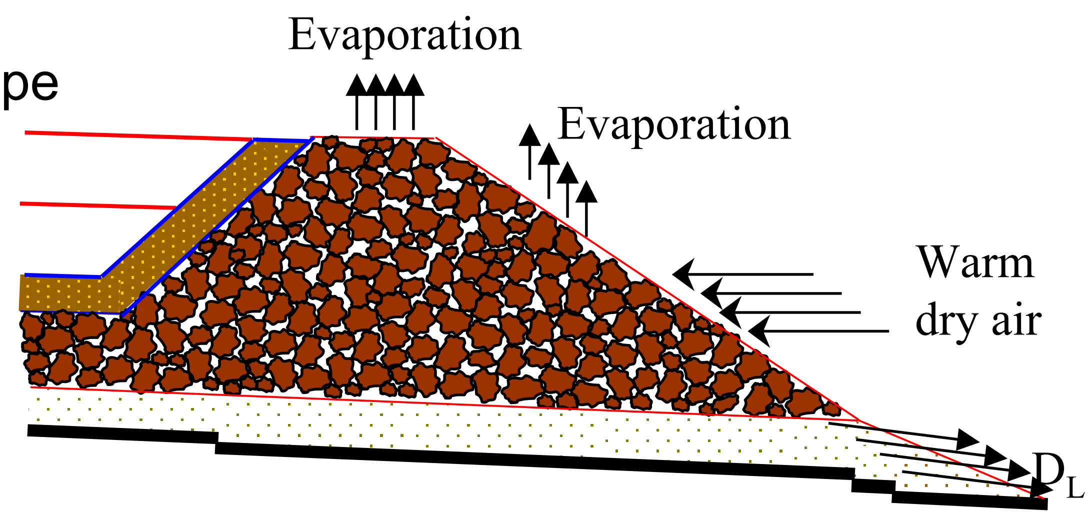
Root Water Uptake

- root water uptake, S, based on Vrugt [2001] model
- Modified to handle multi-layered soils in which root length density do not decrease exponentially with depth
- Water uptake, S, depends on ψ, max root lengths (x_m, y_m, z_m), and T_0,



Side-slope Hydrologic Performance

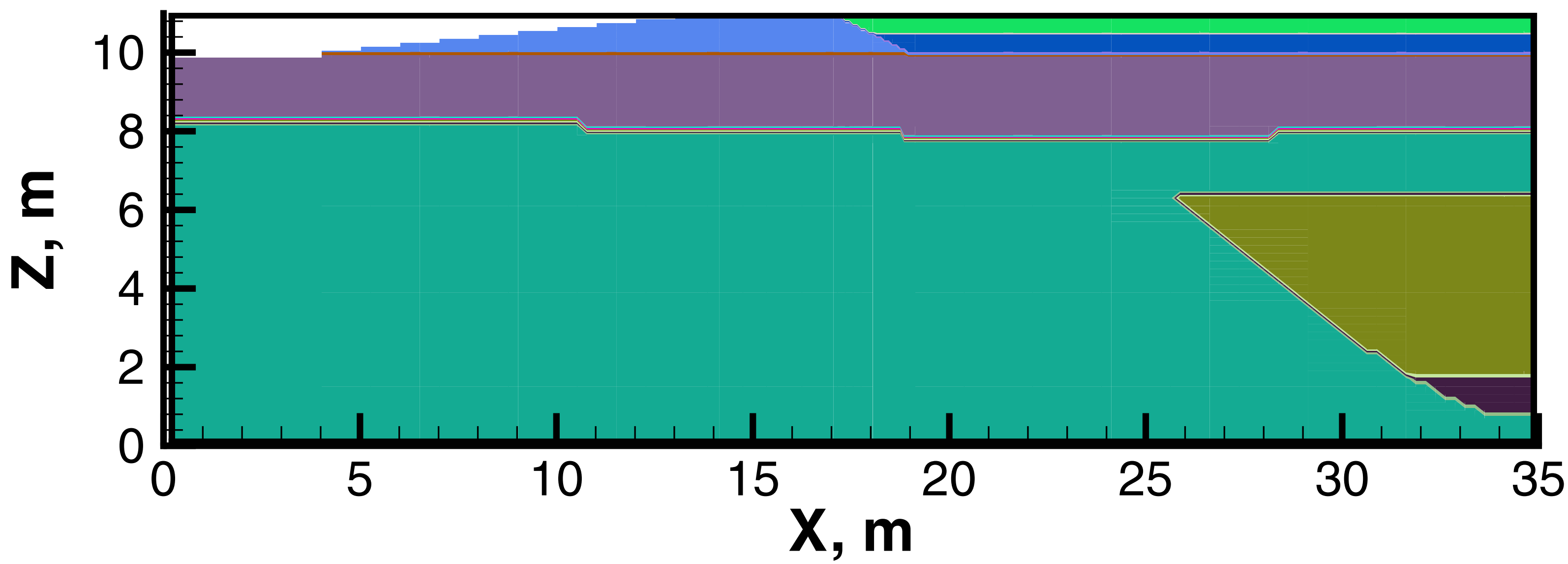
- Allows for simulation with a bare or vegetated surface
  - Time-dependent plant density
- Solving for aqueous and gas phase flows
  - wind pumping in side slope
  - advective drying
  - Reduced recharge



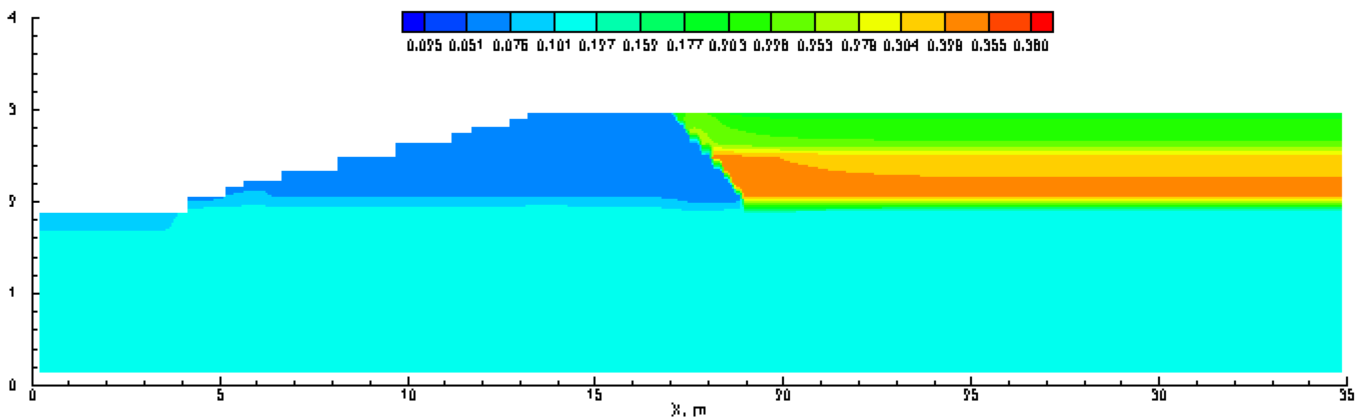
Model Calibration

- Several parameters and variables
  - Field data
  - Literature values
  - Estimated
- Calibration can be a complex task
  - several forward runs while changing parameters in search for the best output
- Iterative procedure facilitated with UCODE

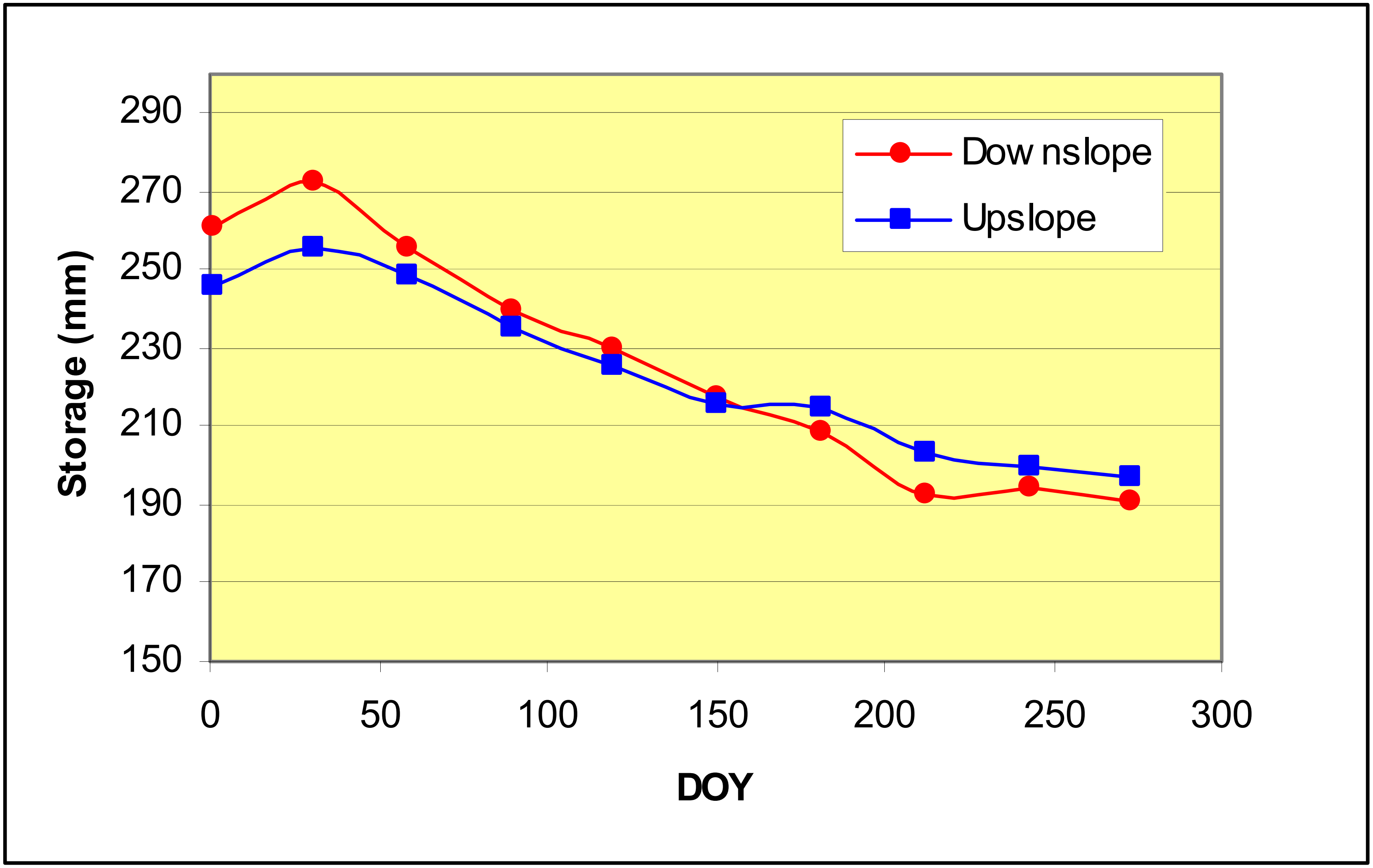
Example Simulation
Prototype ET Cover over Existing Crib



Simulated Water Content in ET Cover Jan - Oct 1995 (Daily Output)



Water Storage



Summary

- Barrier design is a multidimensional problem
- Performance controlled by coupled processes
- Available tools for barrier design not always applicable
- STOMP used extensively at DOE sites for subsurface flow and Transport
- Soil-Plant-Atmosphere module added
  - physically based
  - full climate coupling
  - fully coupled mass and energy
  - Well suited to sparse canopies typical of arid environments

Interactive Processes Governing Performance