Multiple Processor Numerical Flow Modeling Using Cellular Automata Techniques

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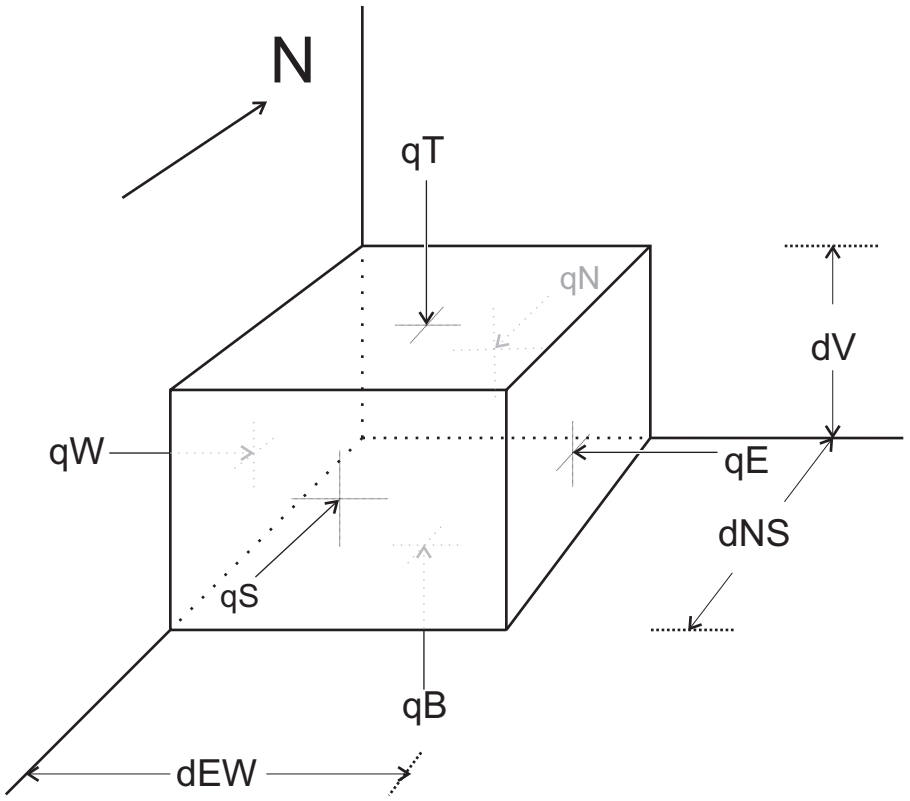
Why Cellular Automata?

- Traditional Modeling
  - Start With Phenomenological Relationships for Small Volume
  - Shrink to Infinitesimal Volume to Get Differential Equations
  - Homogeneous: Sometimes Can Get Analytical Solution
  - Heterogeneous: No Analytical Solution - Must Expand Infinitesimals to Finite Volumes to Solve

- Cellular Automata
  - If System Is Heterogeneous, No Need to Use Differential Equations
  - Use Original Phenomenological Relationships Directly

Model “Interior” Cell

Dimensions and Flows



For Incompressible Flow, the Sum of the Flows Must be Zero:

$$qN + qS + qE + qW + qT + qB = 0.$$

Cell Calculation Scheme

- ”Interior” and “Boundary” Cells
- Every Interior Cell Surrounded by Interior or Boundary Cells
- Cells Have Properties and Methods to Implement All Calculations
- Flow and Groundwater Potential Related by Darcy’s Law
- Cell Methods Interact Only With the Six Adjacent Cells
- Boundary Cells Determine Flow From Boundary
- Flow Potential Throughout the Model Calculated From Conductivities and Boundary Conditions

Multi-Processor Strategy

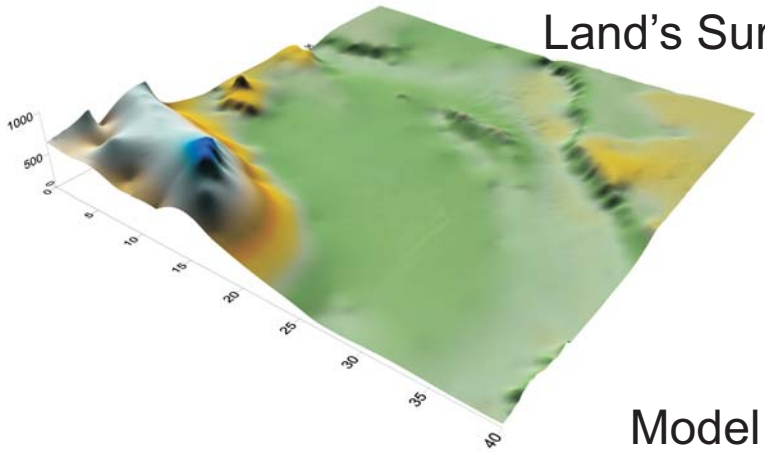
- Build Model Using Microsoft Windows Graphical User Interface
- Save Model in ASCII Text File
- Build Multi-Processor Program to Read Model and Execute Cell Methods
- Save Results in ASCII Text File
- Display Results Using Graphical User Interface

Model Geometry Creation

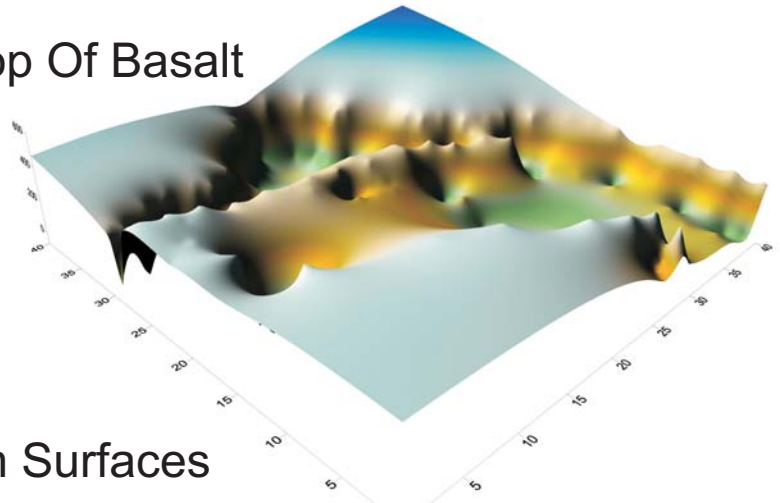
- Either Directly Assign Cell Types or Import Surface Files
- Properties, Cell Types, and Hydro-geologic Units Shown With Color
- Iterative Calculation in Separate Thread for Windows Application
- Model Cells Divided into Groups for Multi-Processor Application

Geometry From Surfaces

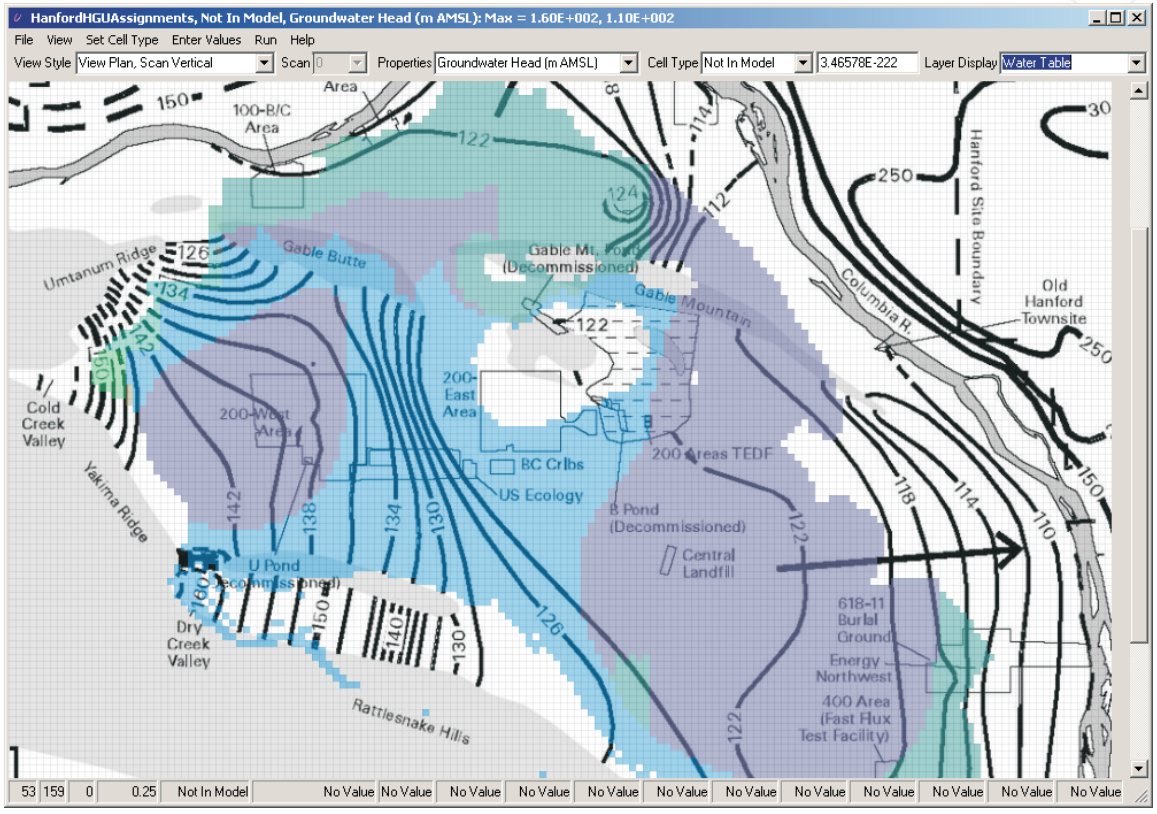
Land's Surface



Top Of Basalt



Model Geometry from Surfaces



Water Table Determination

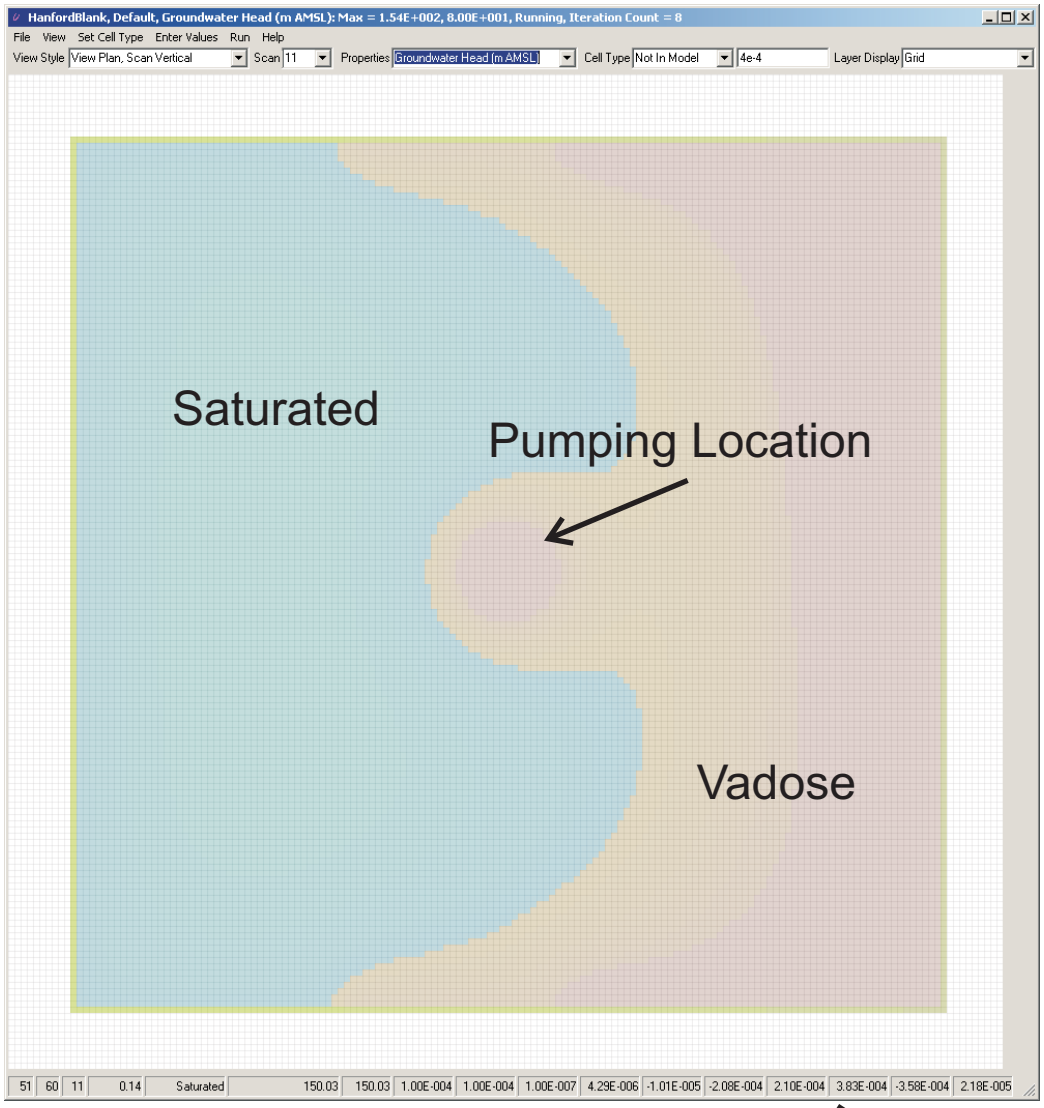
- Each Interior Cell Has Both Head and Elevation
- If Head > Elevation Then Cell is Saturated, Otherwise Vadose
- Recharge Passed Down Directly Through Vadose Cells

Model Validation Simulation

West to East Gradient, Pumping Well in Center, Plan View

200 mm/yr
Recharge

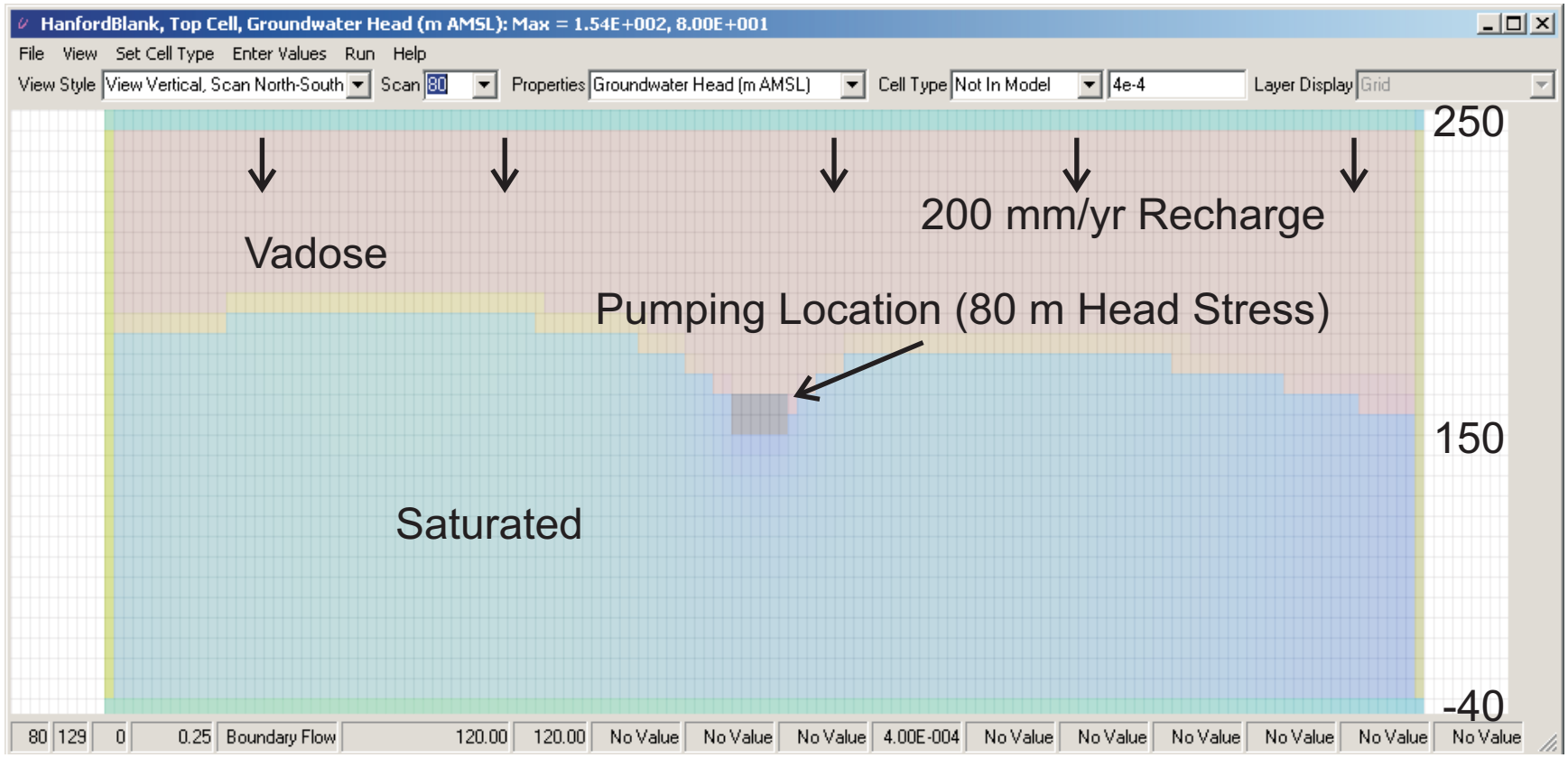
140 m
Above Sea Level



Groundwater Potential Gradient

Model Validation Simulation

West to East Gradient, Pumping Well in Center, Cross Section



Groundwater Potential Gradient: West to East
(140 m on West Boundary, 100 m on East Boundary)

Elevation
(m Above Sea Level)