Development of a WCMS Groundwater Modeling Component for Underground Mine Hydrologic Impact Assessment

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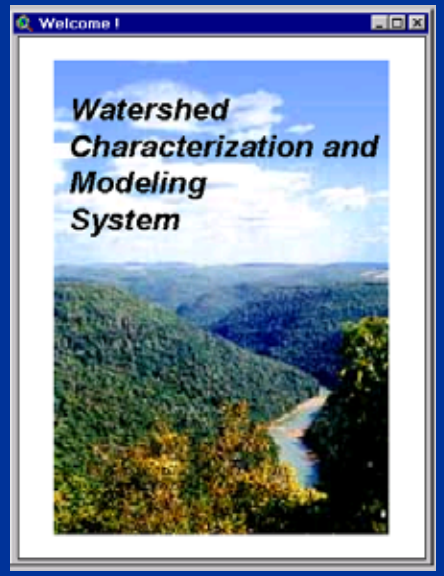


Natural Resource Analysis Center
West Virginia University
Jerald J. Fletcher, Director

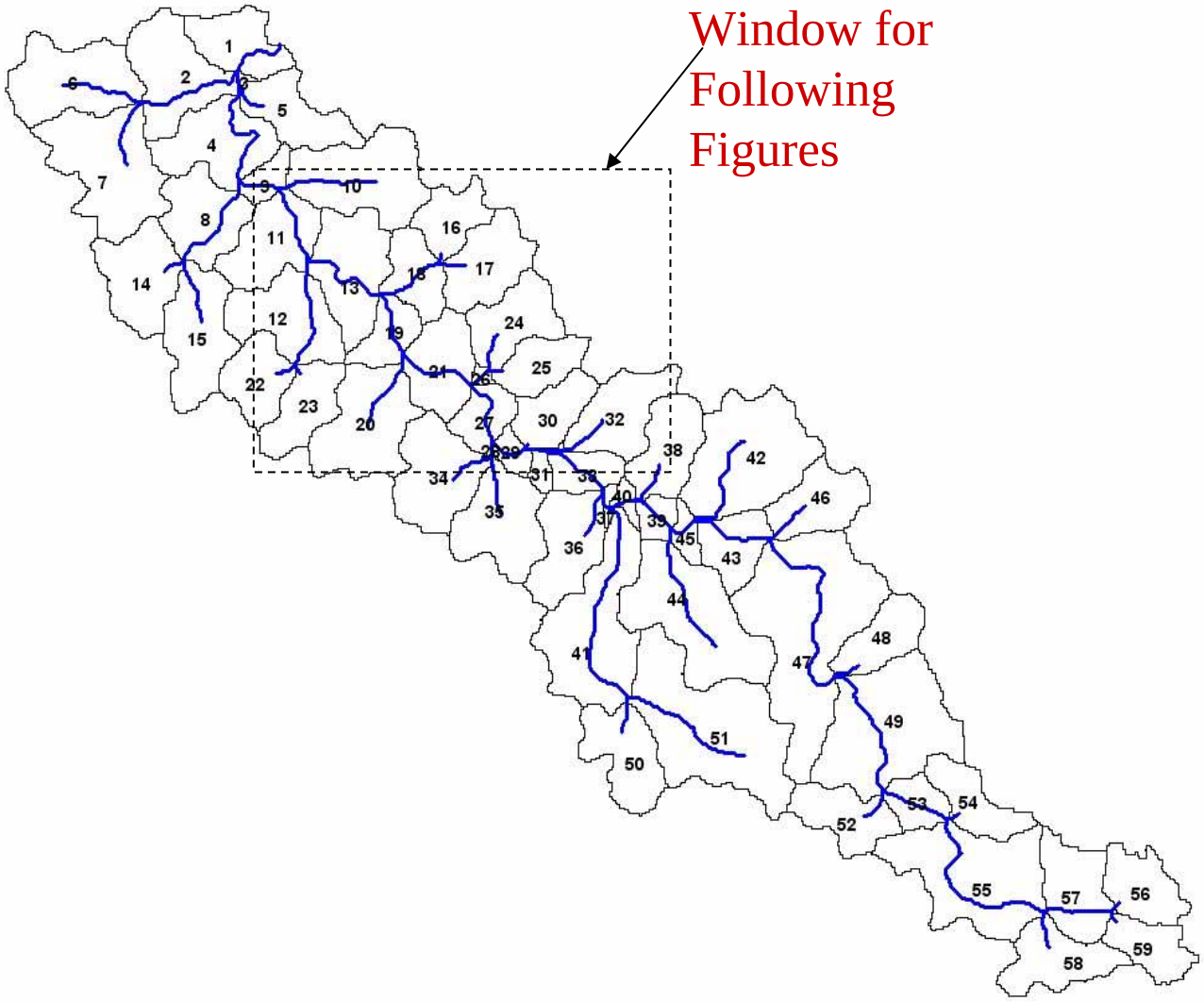
Regional Groundwater Recharge Model (RGRM) Development Goals

1. Compatibility with the Natural Resources Analysis Center (NRAC) Watershed Characterization and Modeling System (WCMS).
2. Joint application with EPA's Hydrologic Simulation Program – Fortran (HSPF), as integrated with WCMS.
3. Variable spatial resolution capability based on 1:24,000 scale National Hydrography Dataset (NHD) Segment Level Watersheds (SLW)
4. User-friendly model application toolbar for underground mine hydrologic impact assessments.

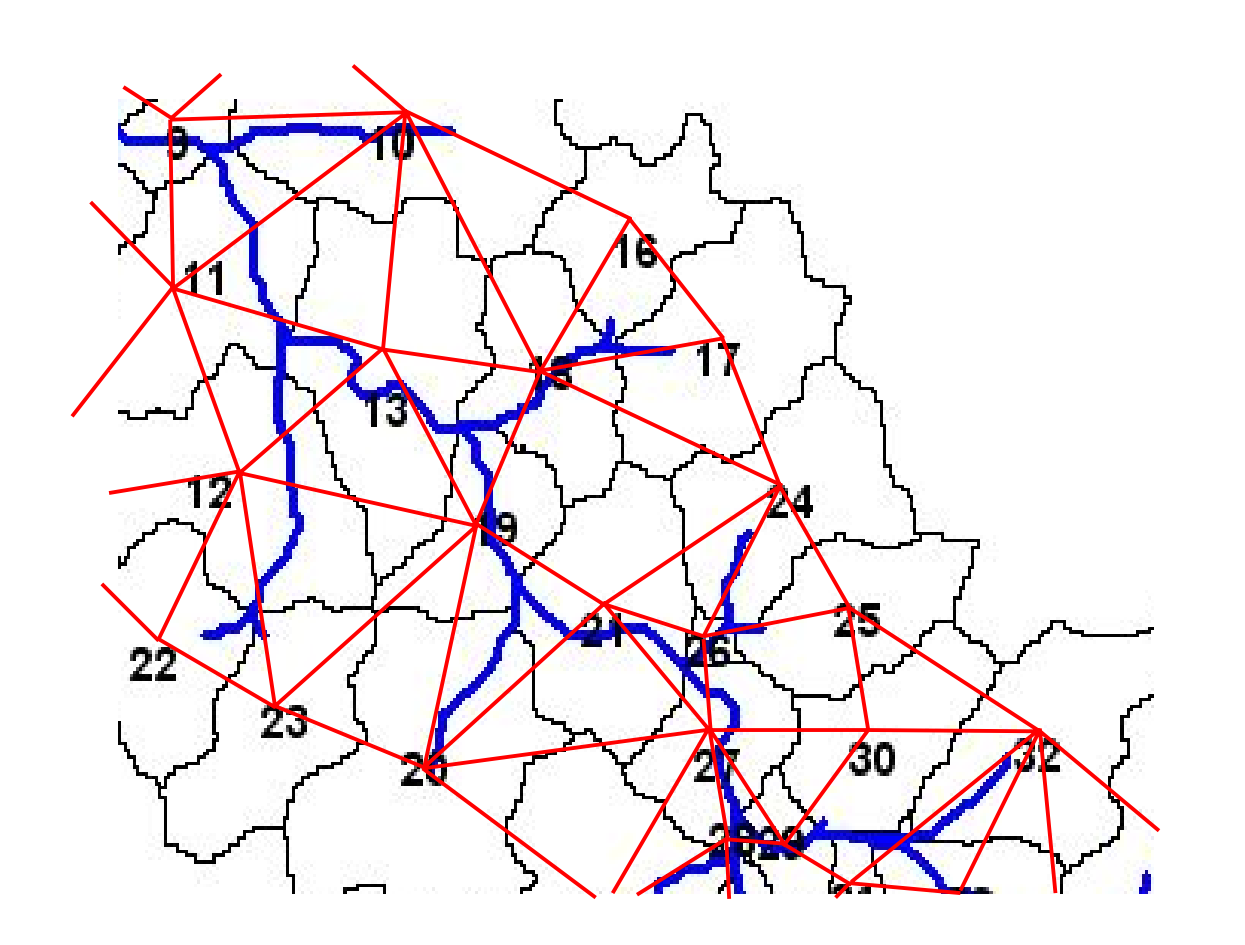
WCMS-HSPF-RGRM 3 Year Development Plan

- Year 1: OSM Applied Science Project Fiscal 2007 Funding.
  - Complete design and testing of basic model structure (30% complete).
- Year 2: OSM Applied Science Project Proposal Submitted for Fiscal 2008 Funding.
  - Add WCMS toolbar functionality to represent underground mine cavities, mine pools, aquifer dewatering, gaining and losing streamflow.
- Year 3:
  - Verification testing, user (WVDEP) training, installation of WCMS-HSPF-RGRM at WVDEP.

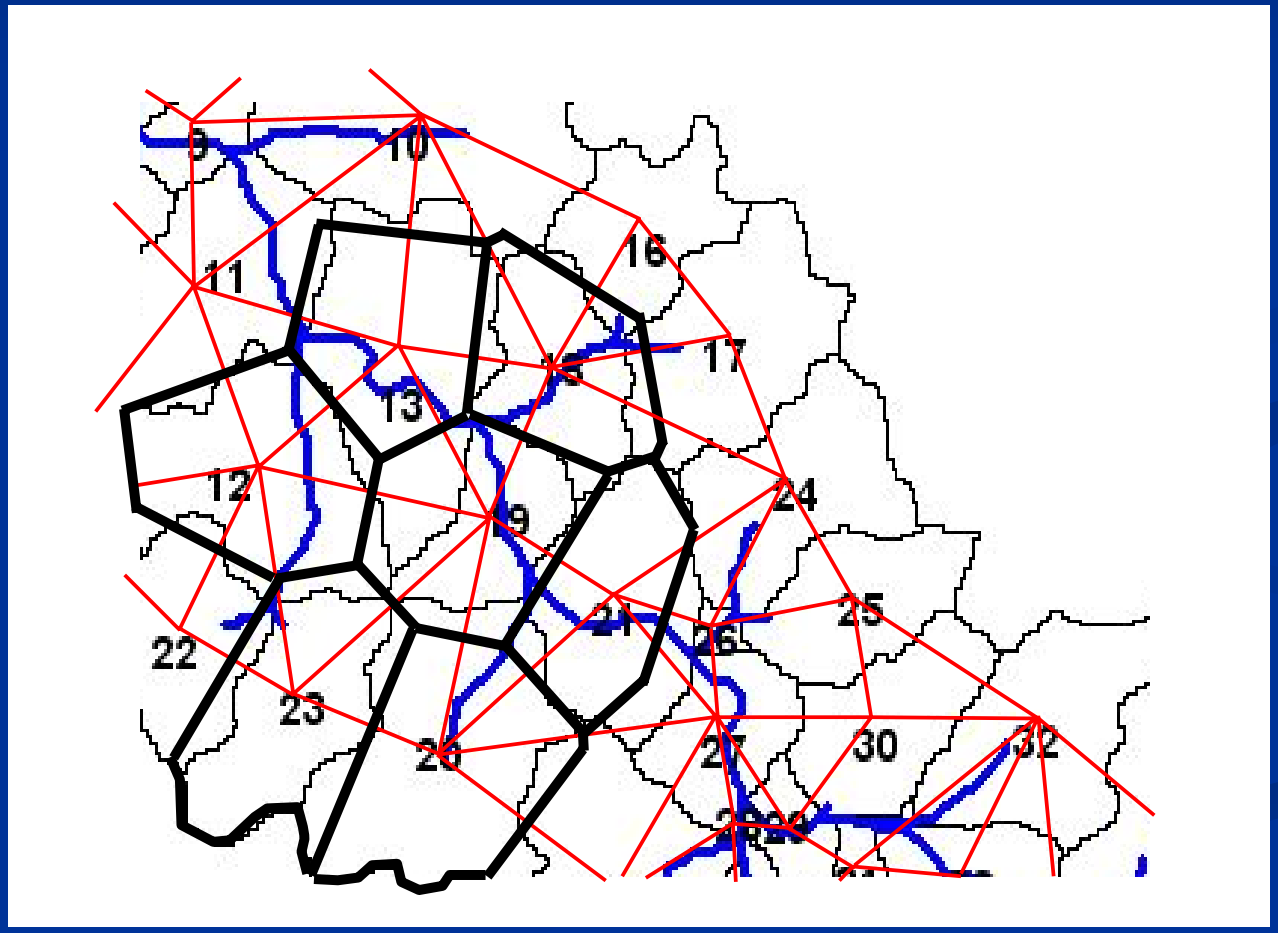
East Fork Twelvepole Creek



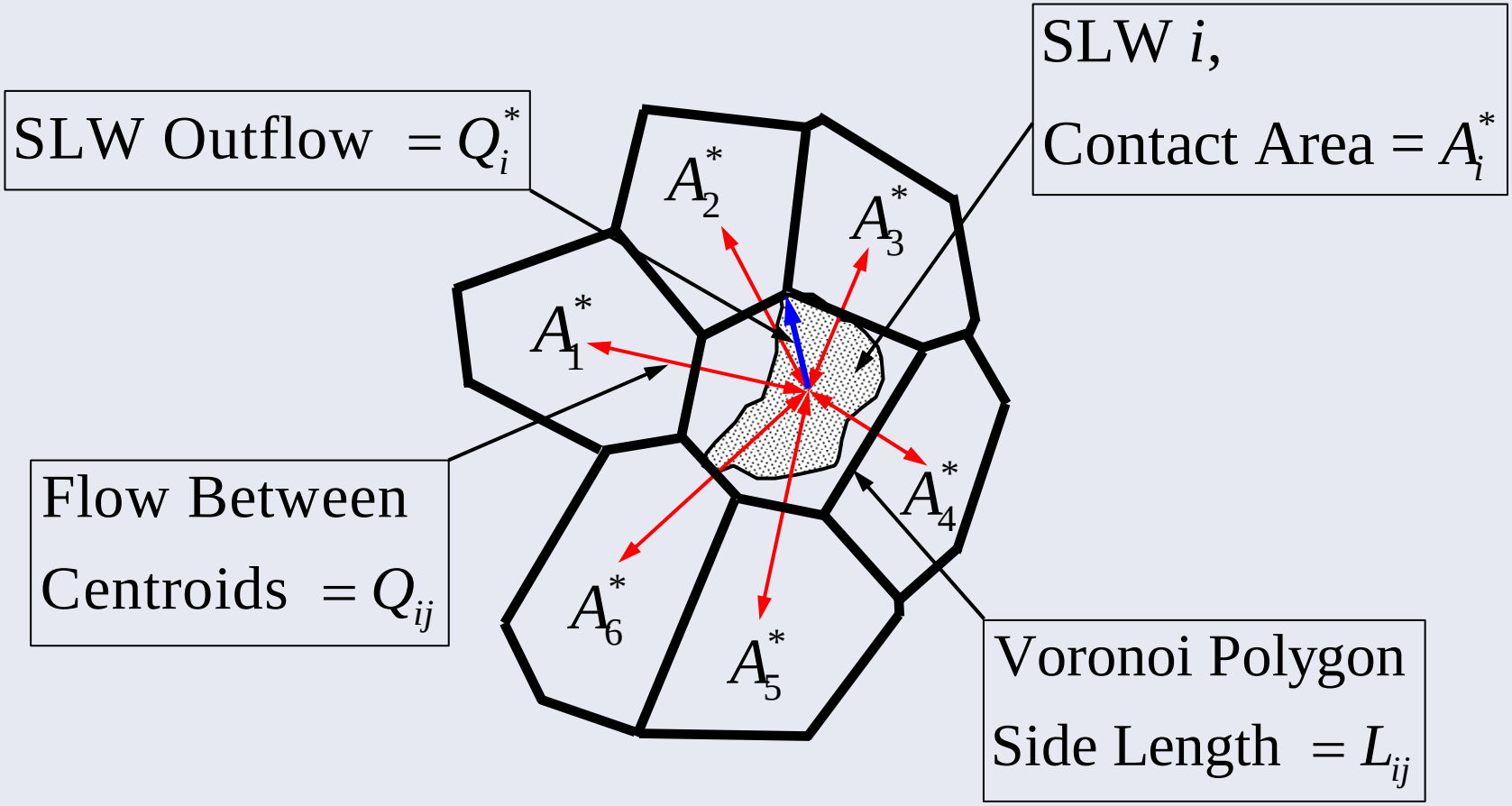
Delaunay Triangulation using SLW Centroids



Voronoi Polygons Created from Delaunay Triangulation Define RGRM Integrated Finite Difference Elements



Groundwater Flow Exchange Between SLW's



SLW Continuity Equation at Each Node:

$$\sum_j Q_{ij} - Q_i^* + I_i A_i^* = \frac{dS_i}{dt} = \frac{d\left(h_i A_i^* \eta_i\right)}{dt} = A_i^* \eta_i \frac{dh_i}{dt}$$

where:

$Q_{ij} =$ inflow to node i from adjacent node j $\left[m^3 / d \right]$

$Q_i^* =$ outflow to SLW i stream segment $\left[m^3 / d \right]$

$I_i =$ recharge rate in SLW i $\left[m / d \right]$

$A_i^* =$ SLW i planform area $\left[m^2 \right]$

$S_i = h_i A_i^* \eta_i =$ SLW i groundwater storage volume $\left[m^3 \right]$

$h_i =$ aquifer saturated thickness in SLW i $\left[m \right]$

$\eta_i =$ drainable porosity in SLW i

$t =$ time $\left[d \right]$

Darcy's Law Along Connecting Links

$$Q_{ij} = K_{ij} A_{ij} \frac{d\phi_{ij}}{dl_{ij}}$$

where:

$Q_{ij} =$ flow from node j to node i $\left[m^3 / d \right]$

$K_{ij} =$ hydraulic conductivity along link ij $\left[m / d \right]$

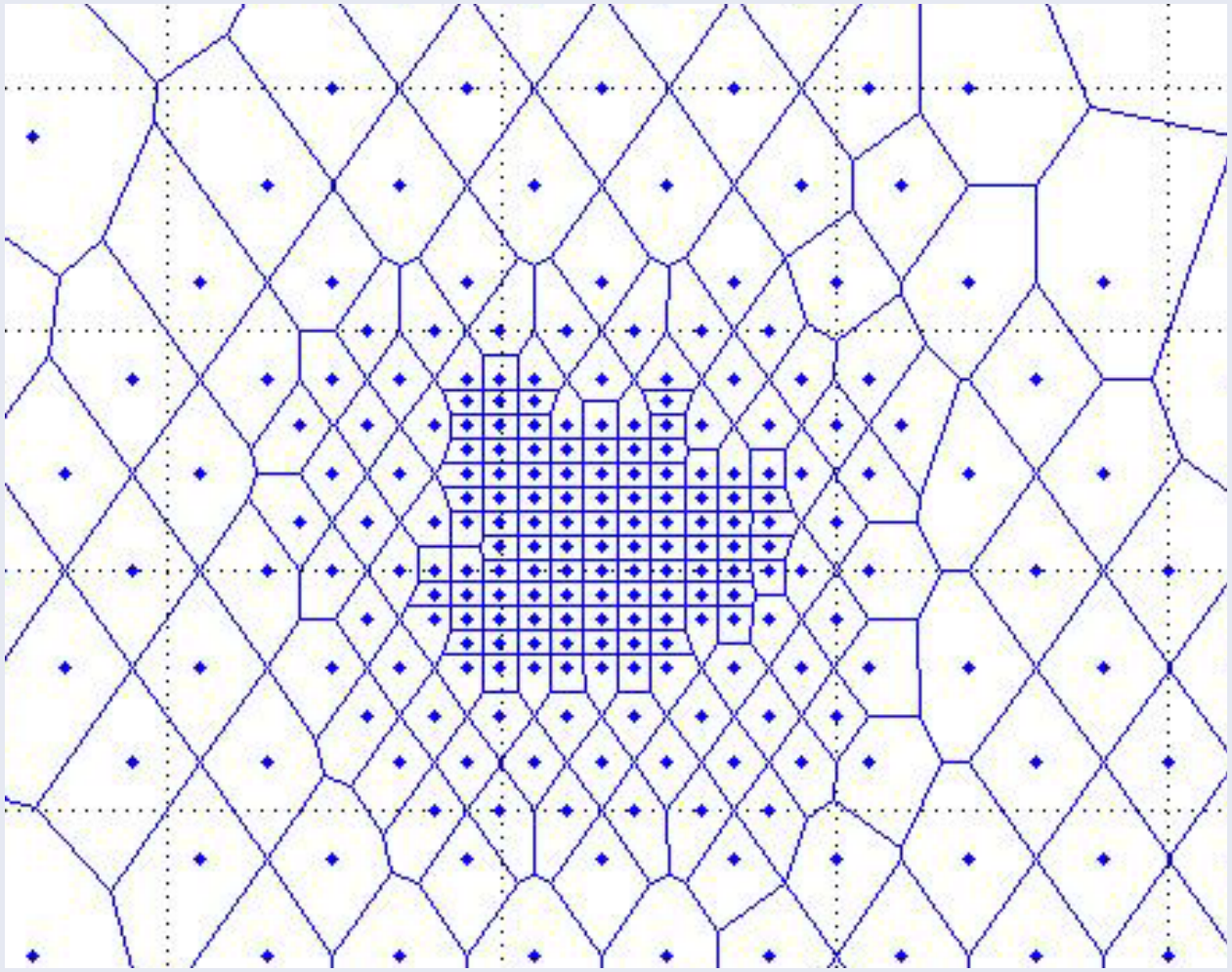
$A_{ij} =$ flow cross section area along link ij $\left[m^2 \right]$

$\phi_{ij} =$ piezometric level along link ij $\left[m \right]$

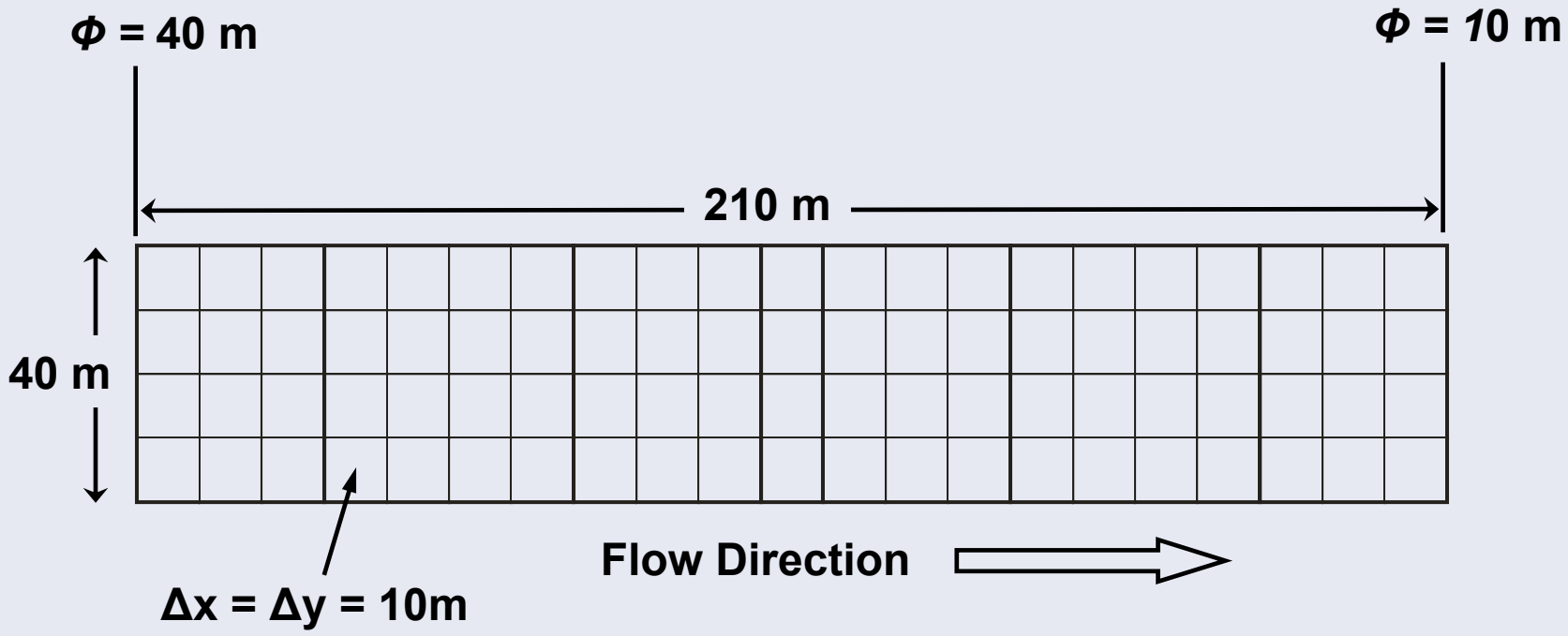
$\frac{d\phi_{ij}}{dl_{ij}} =$ piezometric gradient from node i to node j along link ij

$l_{ij} =$ link ij length $\left[m \right]$

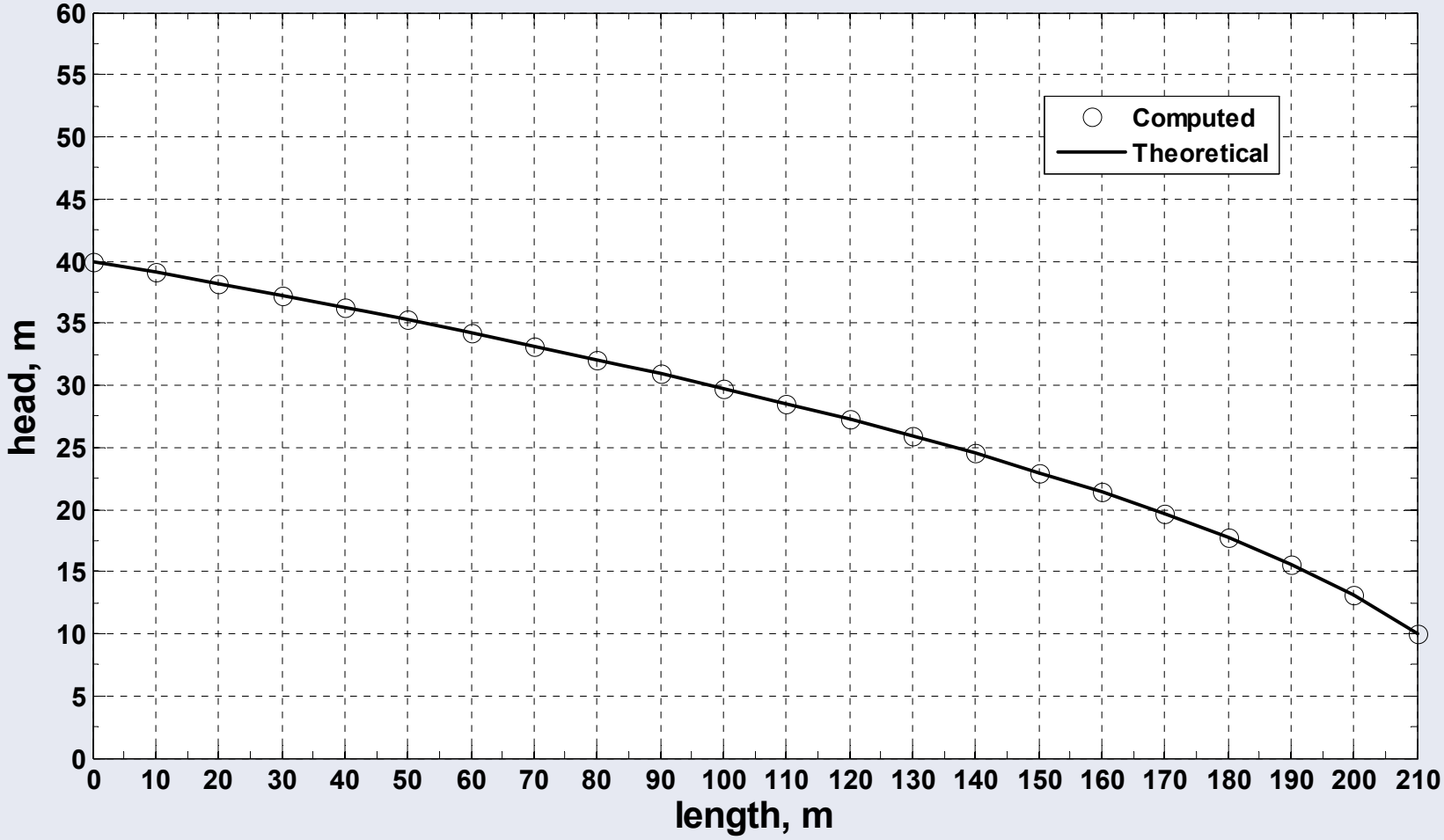
Control Point Spacing Determines Voronoi Polygon Shape and Size.



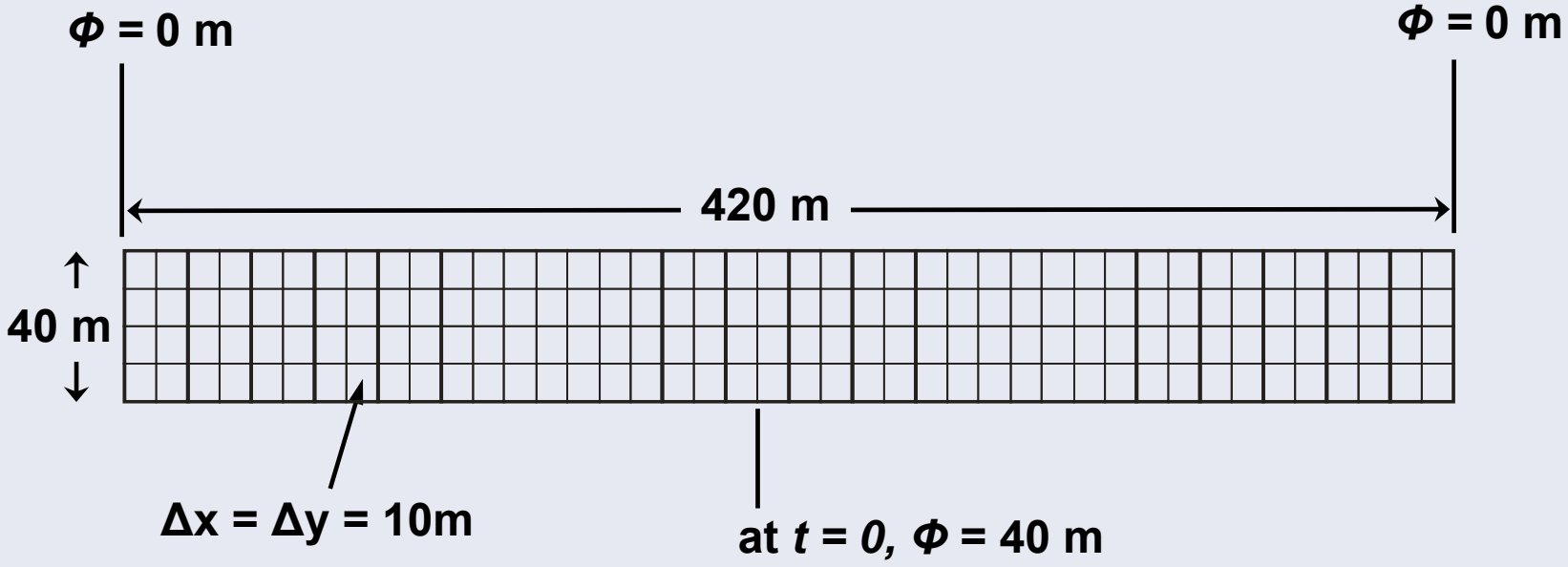
Steady State Solution Verification Grid – Unconfined Flow Between Two Reservoirs



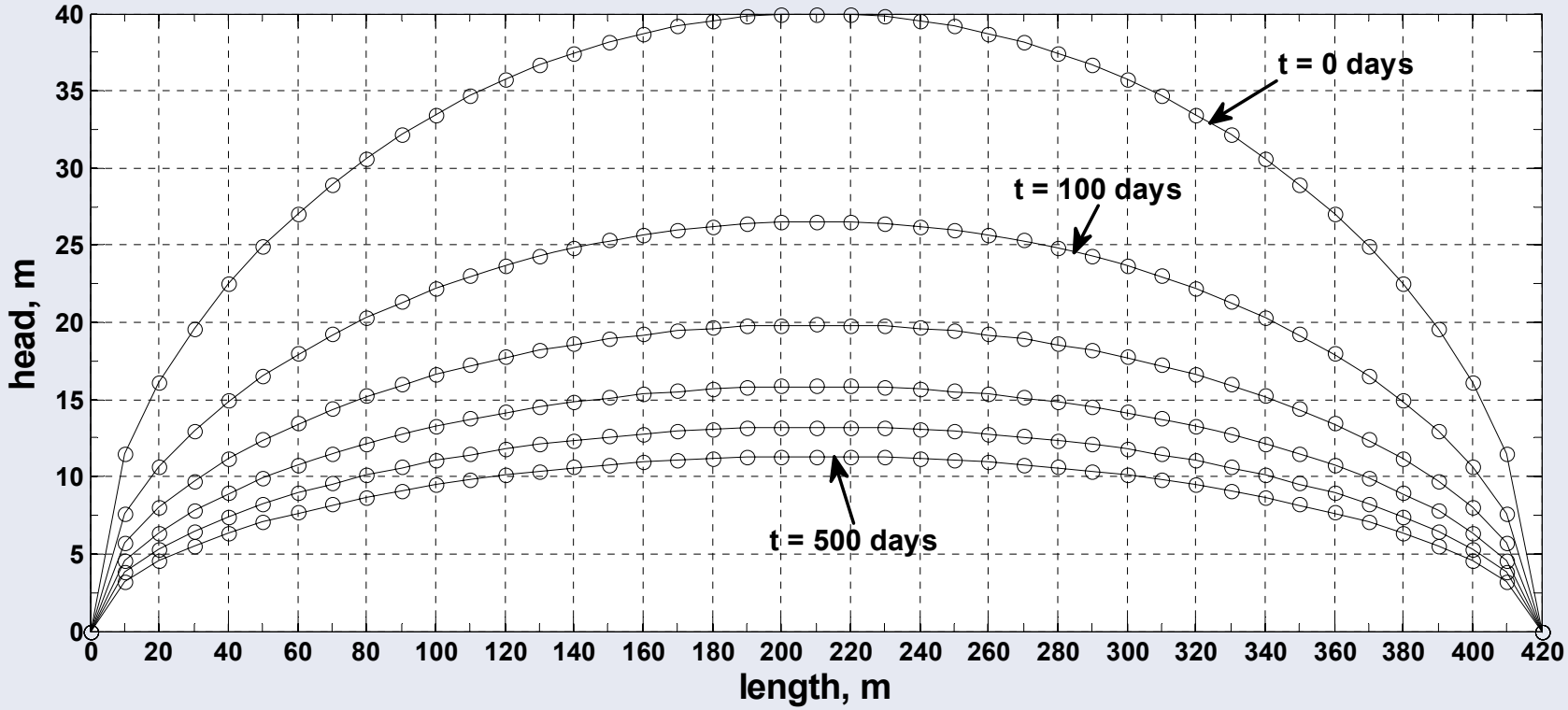
Steady Unconfined Flow Between Two Reservoirs



UnSteady Solution Verification Grid – Unconfined Flow Between Parallel Drains



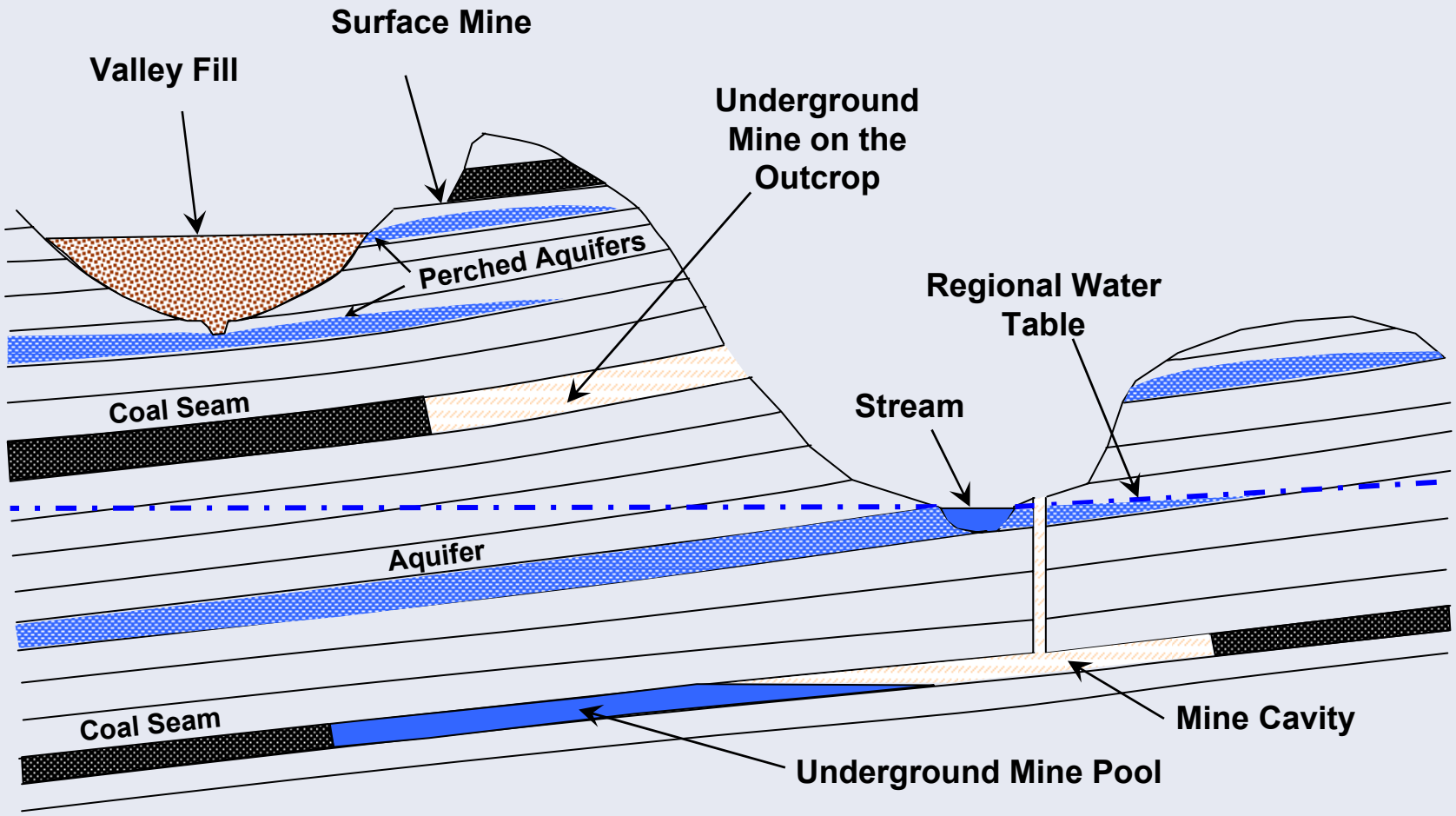
Declining Piezometric Head Between Two Drains, Numerical (Points) Versus Analytical (Line)



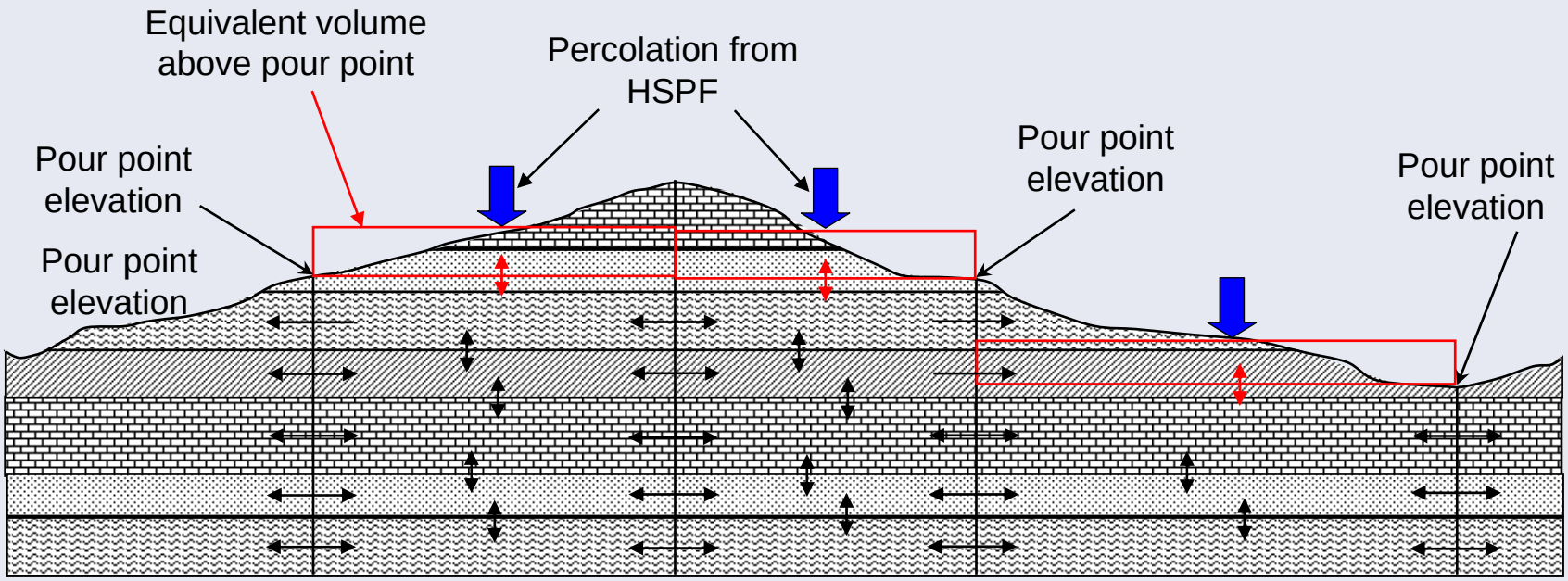
Declining Head RMS Errors

- 100 days, rms = 0.02489 m
- 200 days, rms = 0.02777 m
- 300 days, rms = 0.02757 m
- 400 days, rms = 0.02634 m
- 500 days, rms = 0.02484 m

Representative Geologic Section

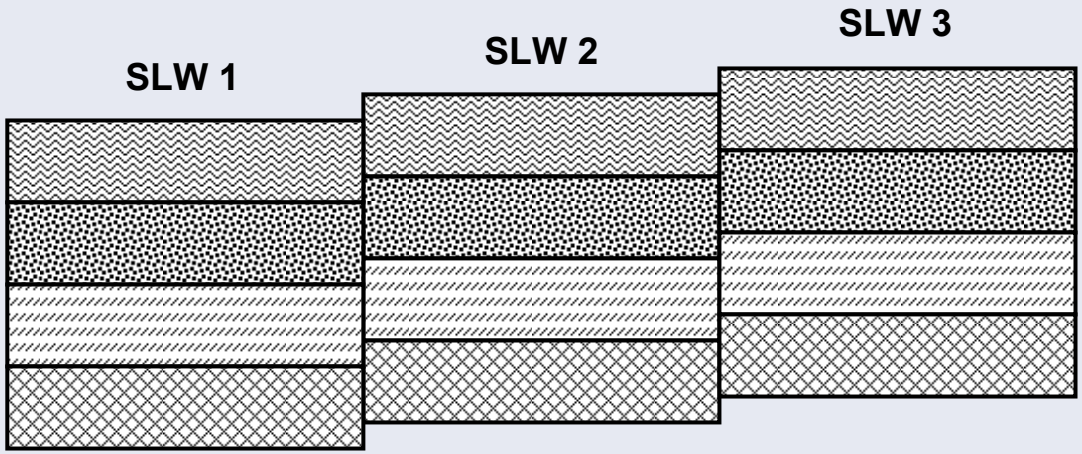


Vertical Cut Through Adjacent SLW's

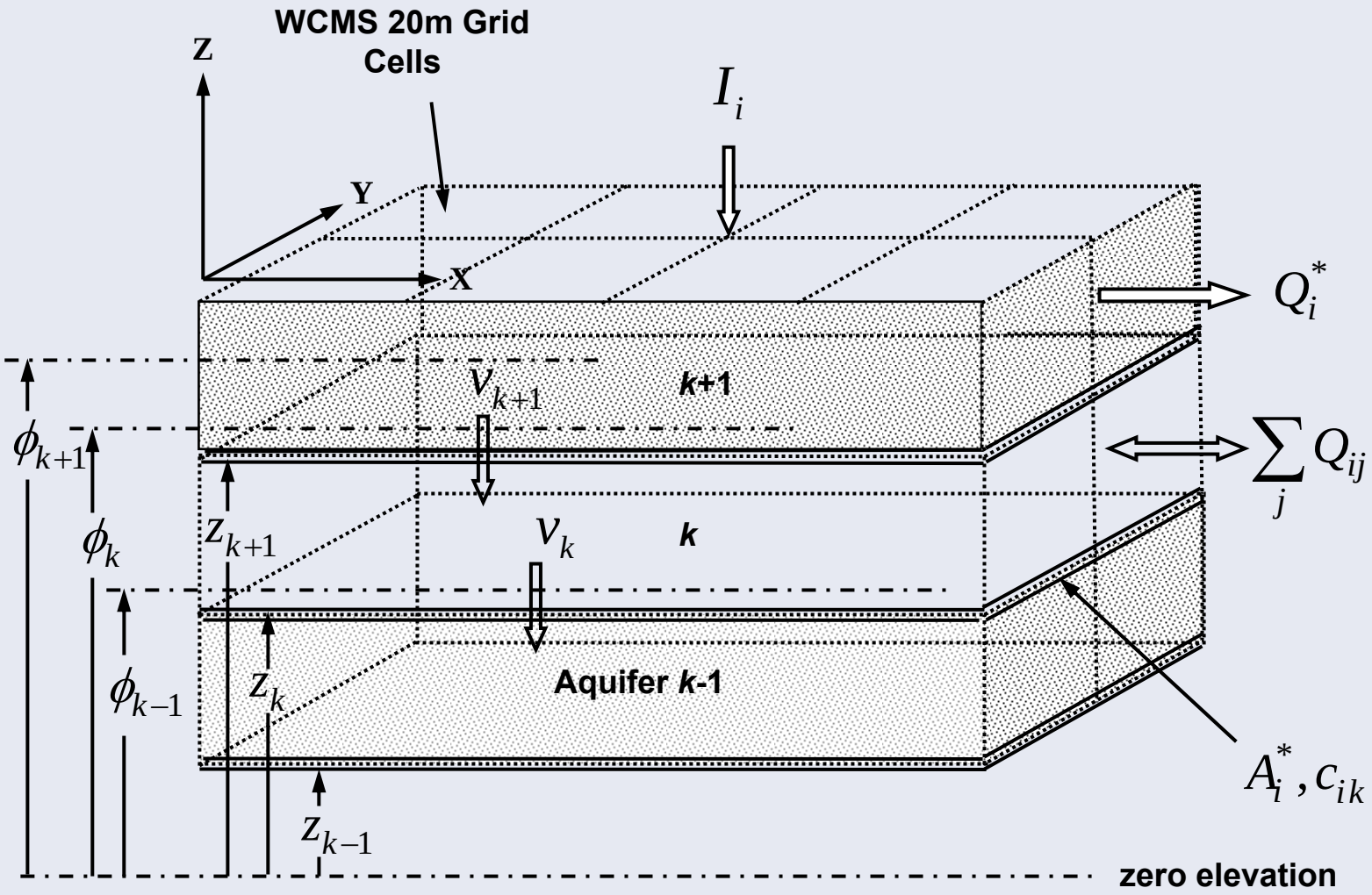


1. Volume of material above SLW pour point treated as an equivalent drainable volume.
2. Bi-directional lateral flow allowed between adjacent SLW's within non-outcropping layers.
3. Unidirectional flow between adjacent SLW's with one layer outcropping.
4. No flow between adjacent SLW's with both layers outcropping.

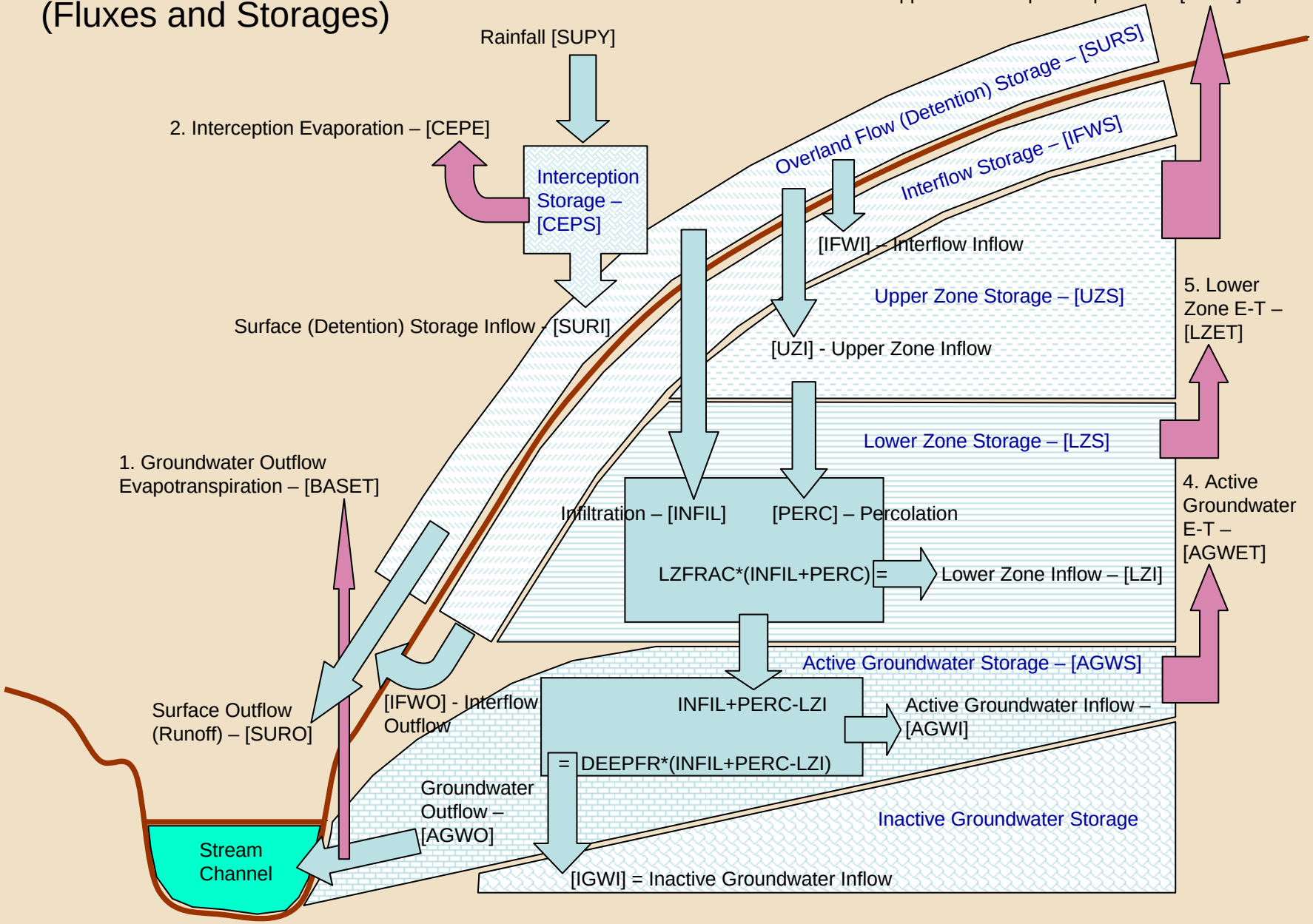
Simulation of Dip in SLW Stratigraphy



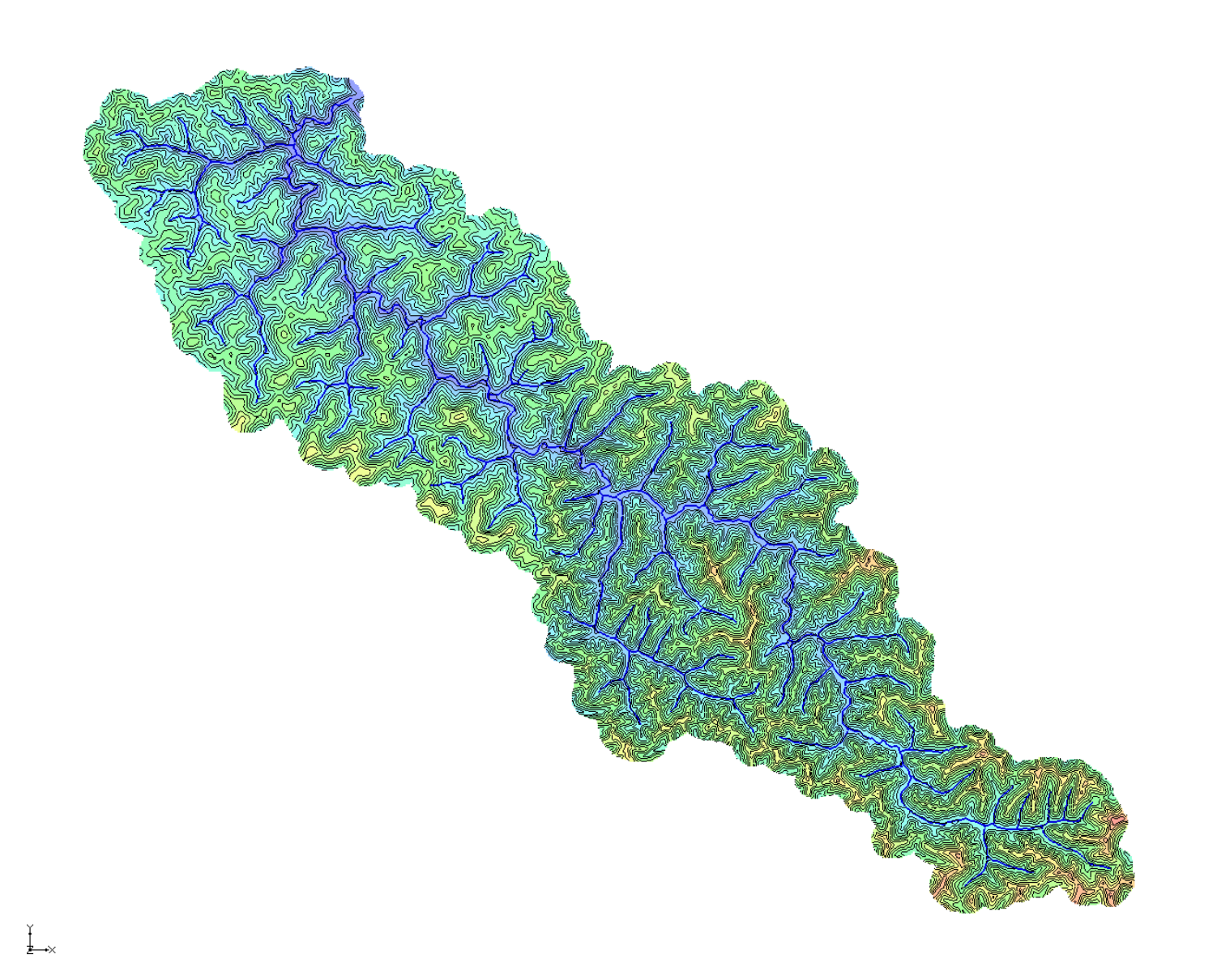
Quasi-3-Dimensional Layered Model Configuration



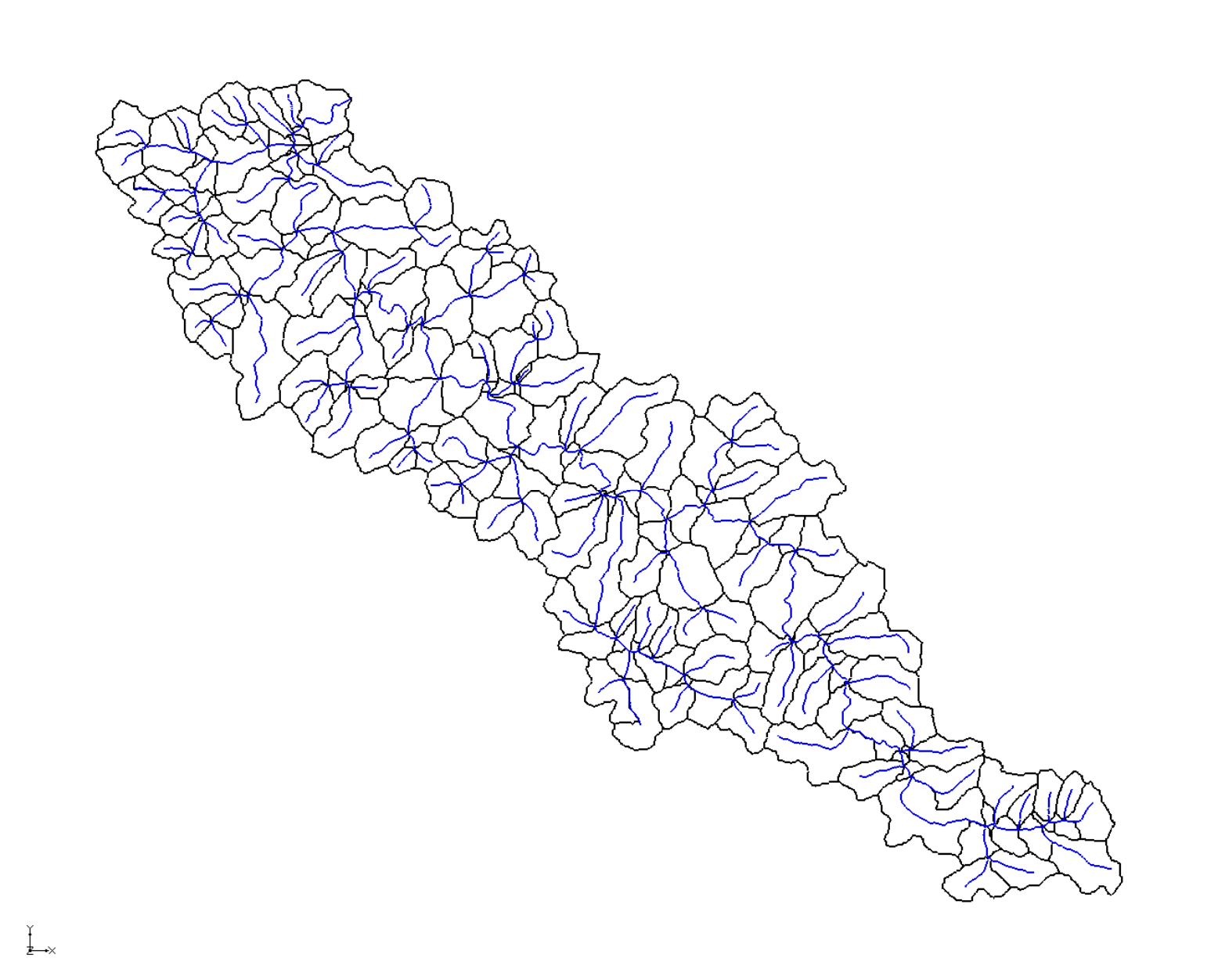
HSPF PERLND Module Water Budget (Fluxes and Storages)



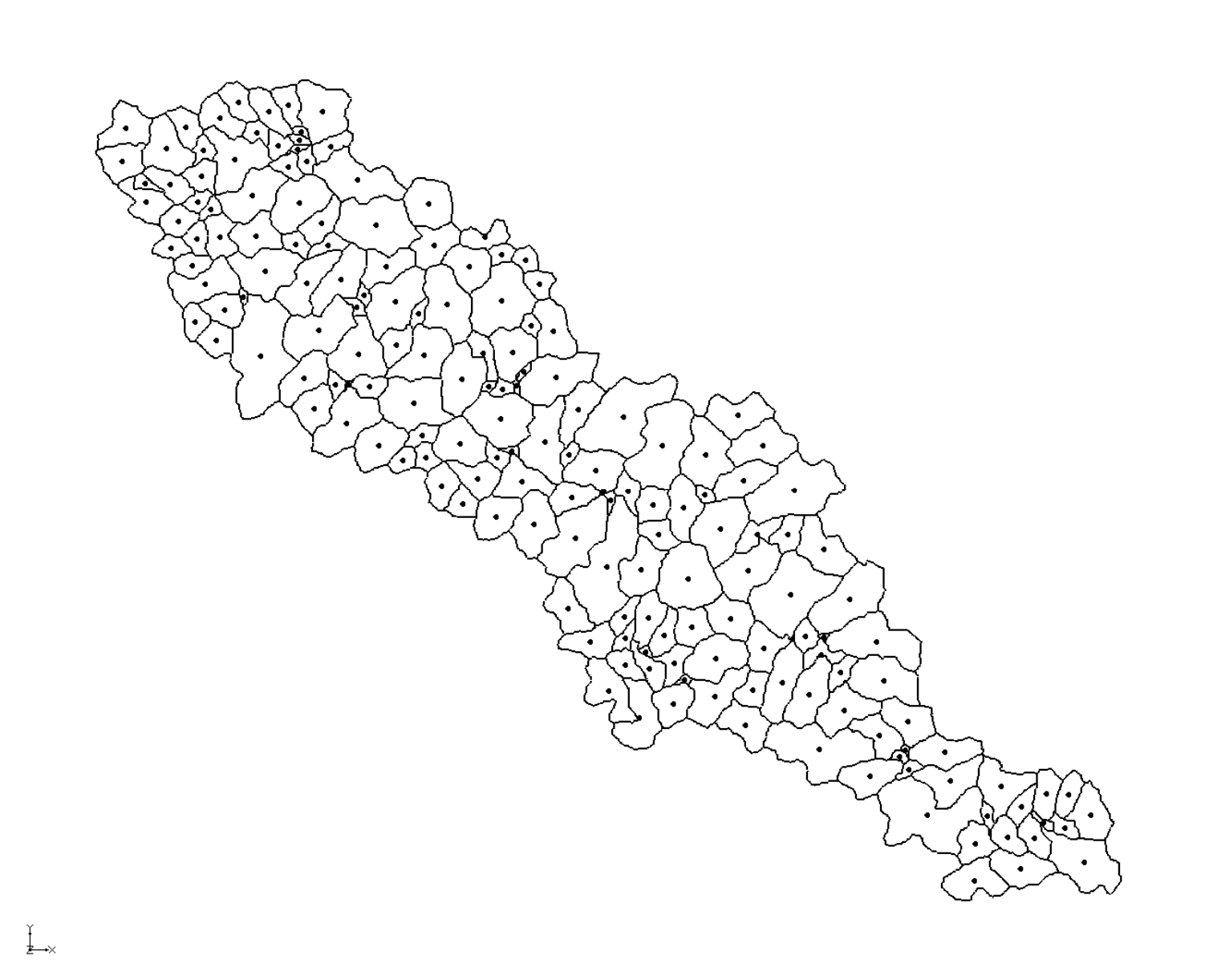
East Fork Twelve Pole Creek above Dunlow, WV



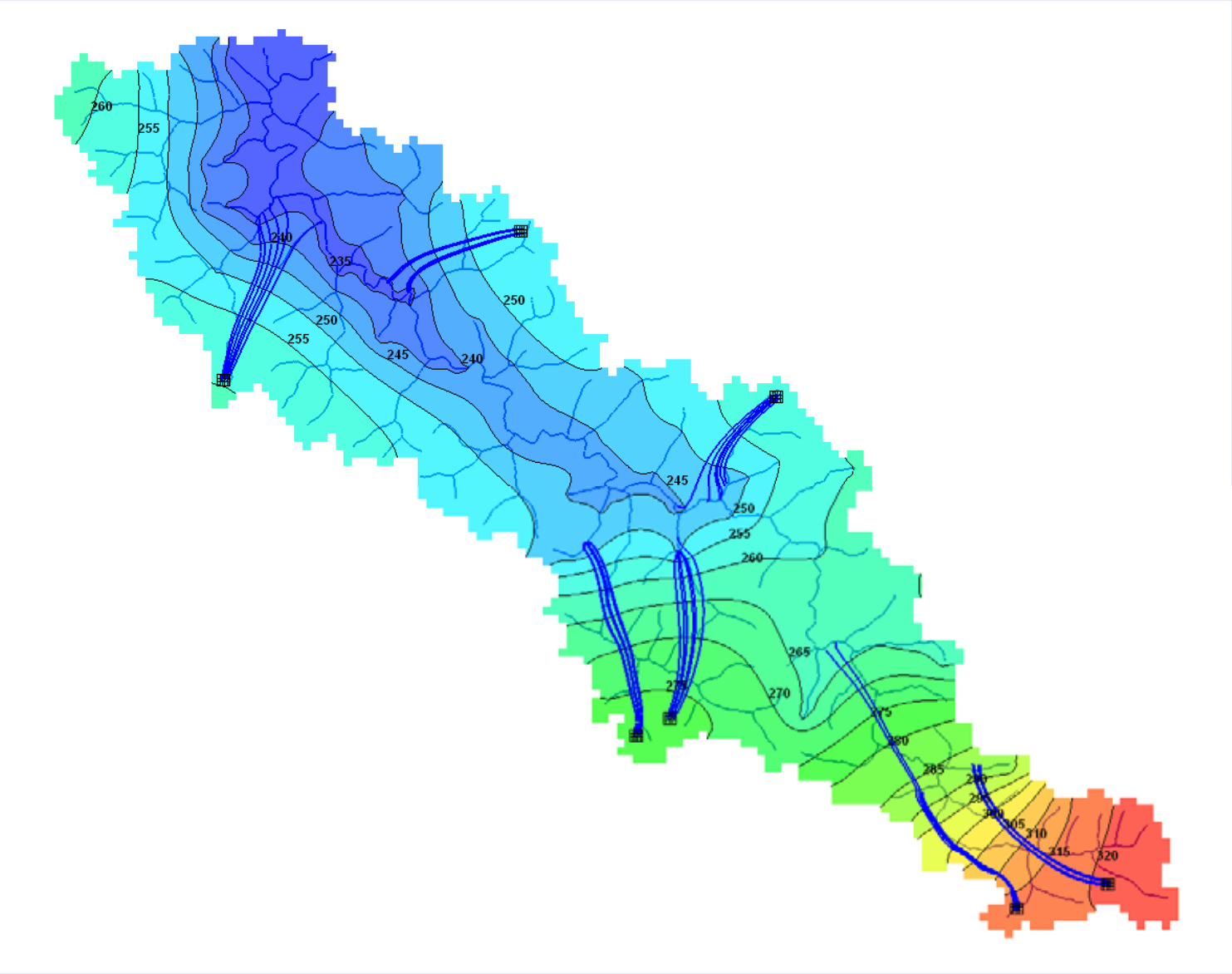
1:24,000 NHD Stream Network and Segment Level Watersheds (SLW's)



1:24,000 NHD SLW's and SLW Centroids



MODFLOW Single Layer Simulation with Example Particle Pathlines, (554 by 688 grid, 381152 cells)



Future Directions

- Complete Quasi-3-Dimensional Layered Model Structure.
  - Verification testing against standardized model results.
- Conduct Performance Tests Using OSM mine pool study dataset.
  - Compare RGRM results to MODFLOW solution.
- Develop RGRM – HSPF Interface.
  - Evaluate recharge – baseflow mass balance.
  - Design HSPF-RGRM calibration procedure.
- Develop Underground Mine Tools.
  - Underground mine cavities and mine pool hydraulics.
  - Subsidence effects – fractures, stream dewatering, etc.