Benefits of Automation in Hydrostratigraphic Framework Modeling - 2

Translating Geologic Framework Assignments from Solids Modeling to Flow Modeling Software

[1]Todd Kincaid Ph.D., [1]Brent Meyer, & [2]Tim Vogt
[1]GeoHydros LLC, Reno Nevada, [2]Navarro-INTERA, Las Vegas Nevada

ABSTRACT

Computer simulations of complex geologic environments are often performed with dedicated solids modeling software as opposed to conceptual modeling packages bundled with groundwater modeling programs. This approach results in more sophisticated framework models and better visualizations, however, translating the resulting framework into flow modeling software can be challenging. This has been the experience at the Nevada National Security Site (NNSS) where hydrostratigraphic framework models have been developed in EarthVision™ (EV) while the groundwater flow models have been developed in FEHM. As part of a sub-domain modeling exercise conducted in 2012, the NNSS EV modeling team developed a process that greatly reduces the time and complexity associated with the translation effort. The process leverages EV tools combined with UNIX-shell scripts and a step-wise procedure to render nodal assignments onto a pre-defined finite-element mesh. Assignments included: layer elevations; material properties characteristic of country-rock, disturbed zones around faults, and fault core zones; and boundary conditions extracted from the full-domain model. The new process requires hours as opposed to days or even weeks that have been characteristic of similar previous translation efforts. The sub-domain modeling exercise used FEFLOW but the process is adaptable to any nodal-based code such as FEHM or MODFLOW.

EXAMPLE PROCESS

1.) Identify hydrogeologic features in HFM around which the GWM grid will need to be refined to smaller node spacings.
- Example: Fault / HSU Intersections

2.) Export the X,Y coordinates & deliver to flow modelers.
- Example for FEFLOW Model:
  a) Calculated shallowest fault dip.
  b) Determined maximum GWM layer spacing that would permit vertical continuity along the simulated fault plane.
  c) Established buffer polygons for faults that define the area over which the grid needed to be refined to preserve vertical continuity along faults between GWM layers.

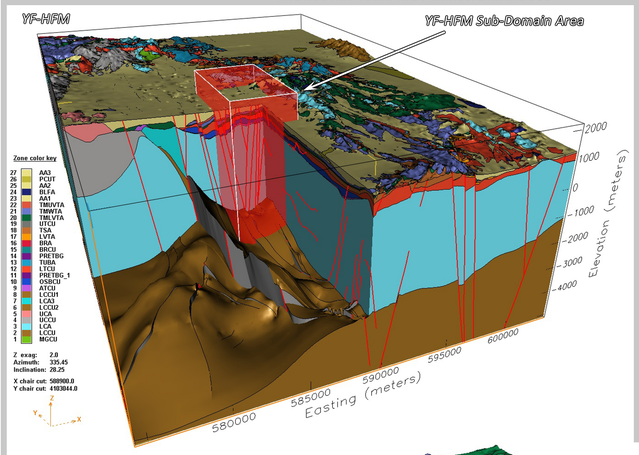
3.) Flow modelers build mesh

4.) EV modelers assign layer elevations to mesh nodes such that:
  a) all HSU surfaces are captured, and
  b) critical vertical layer spacing is preserved

5.) EV modelers label mesh nodes according to:
  a) intersections with fault planes - *core zone*
  b) inclusions within a fault zone buffer - *damage zone (if desired)*
  c) appropriate HSU outside of fault zones

6.)Hydraulic properties assigned by either EV or Flow modelers

HYDROSTRATIGRAPHIC FRAMEWORK MODEL



Objectives

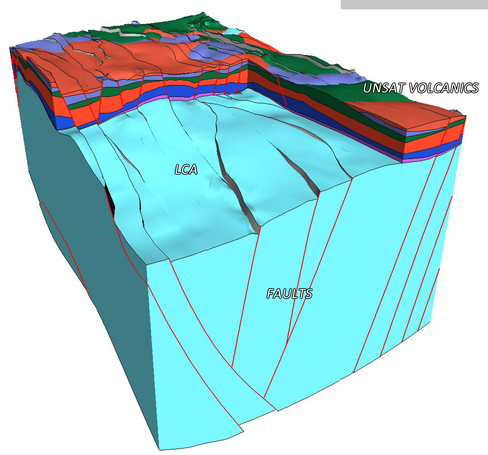
1) Develop a GWM and Transport model for a subsection of the established HFM.
2) Water table is within a single HSU.
3) Critical components of concern are therefore the HSU surface and all faults.

Requirements

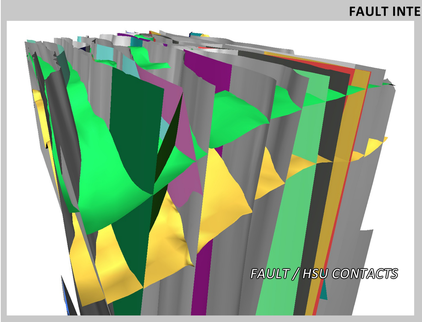
1) Establish a sub-domain model from the established HFM.
2) Translate all unit contacts and faults directly from HFM to FEFLOW.

Outcome

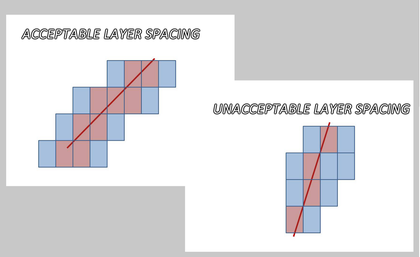
1) Developed process for translating HFM components to any nodal based flow models (FEFLOW).
2) Created GWM with identical flow field as large-scale GWM.
3) Developed transport model to simulate H^3 and I^{129} movement from source terms.
4) Developed process for visualizing transport results in EarthVision such that transport can be evaluated relative to the hydrogeologic framework.



FAULT INTERSECTIONS



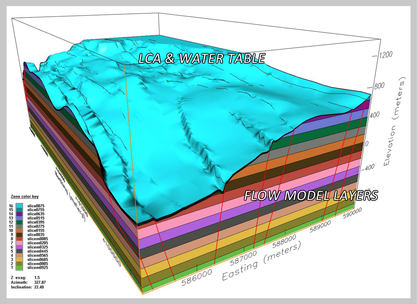
1) Use EV to identify fault dips and fault / HSU intersections.
2) Create fault buffer polyons that flow modelers can use to define areas in which mesh needs to be fine-scale.
3) Detemine optimal layer spacing to insure that vertical continuity is preserved along faults in GWM.



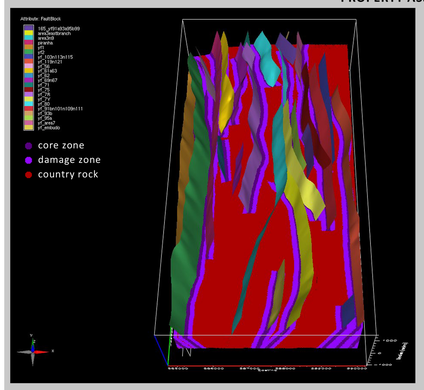
MESH DESIGN AND LAYER CONSTRUCTION

1) Mesh created in FEFLOW using fault buffer polygons extracted from HFM using EV.
2) Layer elevation assigned to mesh using EV such that layers intersect the HSU surfaces and preserve an optimal vertical spacing that preserves vertical continuity along fault planes.

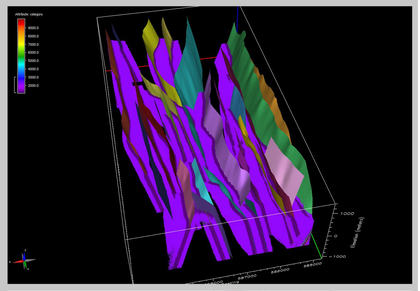
There was ony one critical HSU in this model because the water table was within the LCA. The process will handle multiple (many) HSUs if necessary.



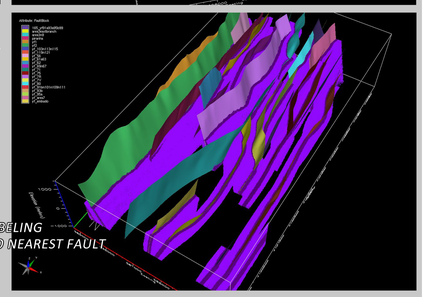
PROPERTY ASSIGNMENT

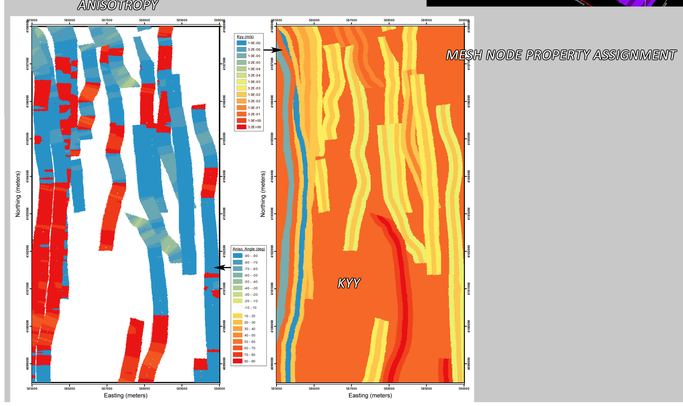


1) Distance to closest fault at every node in the 3D in the 3D mesh is assigned using EV and the HFM.
2) Distance then used to label each node as:
   - fault core zone
   - fault damage zone
   - country rock

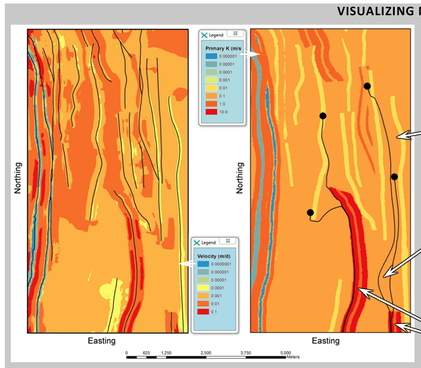


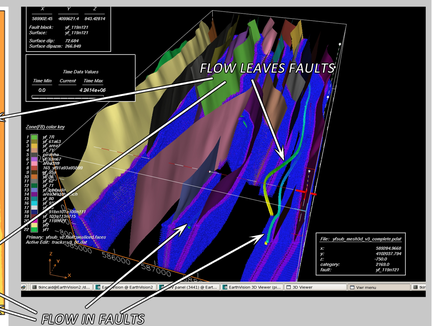
3) Nodes also labeled with closest fault.
4) Hydraulic properties (Kxx, Kyy, Kzz) assigned according to nodel label.
5) Fault core and damage zones can be varied according to the fault that they buffer.
6) Country Rock properties can be varied according to the HSU that they fall within.
7) EV used to determine the strike of each fault at every mesh node assigned as either fault-core or fault-damage zone.
8) Nodes then assigned an anisotropy value that reflects the strike direction of the faults.



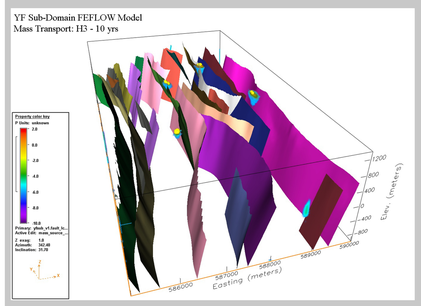


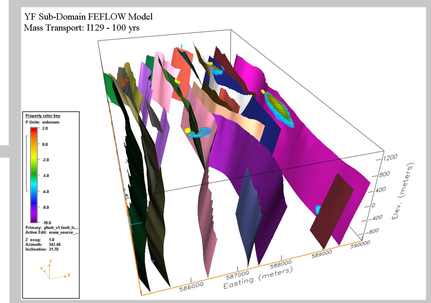
VISUALIZING MODEL RESULTS

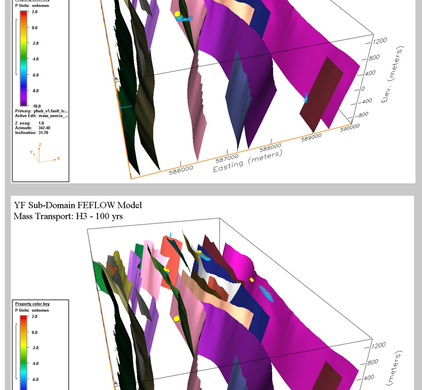


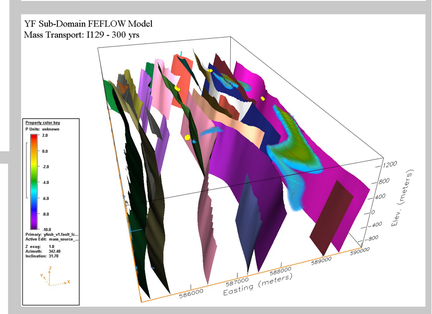


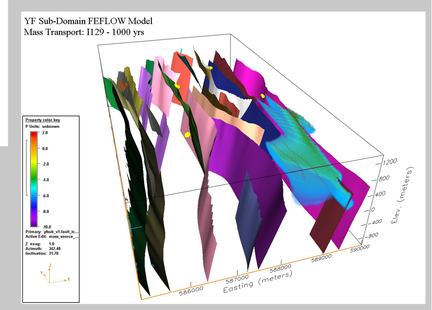
1) Nodes colored by head or velocity and viewed in 2D or 3D relative to HFM comonents.
2) Particle tracks exported from FEFLOW and viewed in 3D relative to faults zones to determine the spatial extent of fault control on flow.
3) Particle track points can be colored by elevation, velocity, of the HFM zone (fault zone or HSU0 in which they exist.
4) Transport results imported by timestep to evaluate plume movement in 3D, identify the extent to which transport ids fault controled, and to identify which HSUs are impactd and when.











SUMMARY

Processes have been developed using EarthVision for the rapid articulation of hydrostratigraphic and fault surfaces defined in an HFM onto a non-uniformly spaced mesh nodes. After the processes were developed, the complete transformation of the HFM structure into the flow modeling software including mesh node property assignments took just a few days - compared to weeks or months that had been previously necessary using more manual methods.

This process can be scaled-up easily to address any number of HSUs and faults over any size model domain, and can be adapted to any nodally-based flow code.

Processes were also developed for the automation of the 3D visualization of mass transport results, which were exported from FEFLOW in ASCII x,y,z,p format. The processes included formatting of the output files for EarthVision input, development of 3D grids, compilation of 3D and 2D views that incorporate basemaps and data files, and the export of the views to images and animations. These processes are also scalable to larger model domains and are adaptable to any flow and transport software that will produce spatially projected ASCII output.