U.S.ARMY

Adaptive Hydraulics (AdH)

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COASTAL & HYDRAULICS LABORATORY

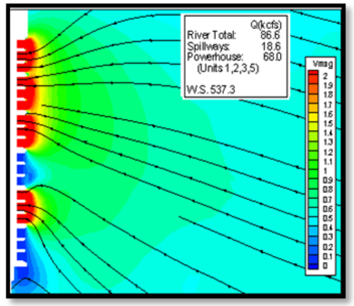
ERDC
Engineer Research and Development Center

Innovative solutions for a safer, better world

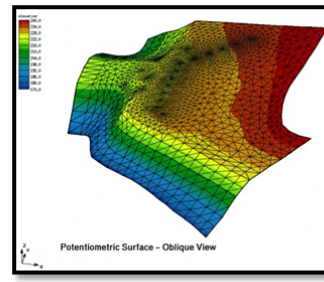
"Essentially, all models are wrong, but some are useful". -- George E. P. Box

A useful model provides meaningful insights into the behavior of the prototype.

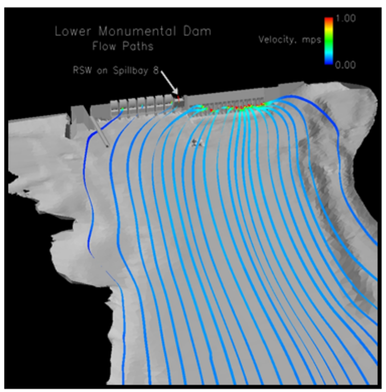
Navier-Stokes Equations

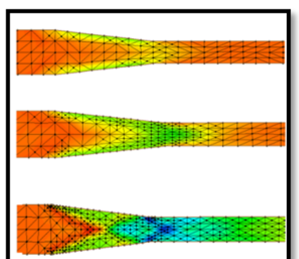


Unsaturated Groundwater Equations

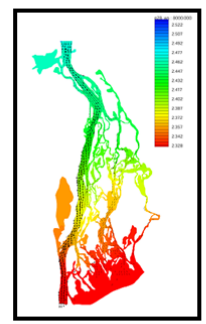


Computational Engine (FE utilities, preconditioners, solvers, I/O to xMS GUIs)



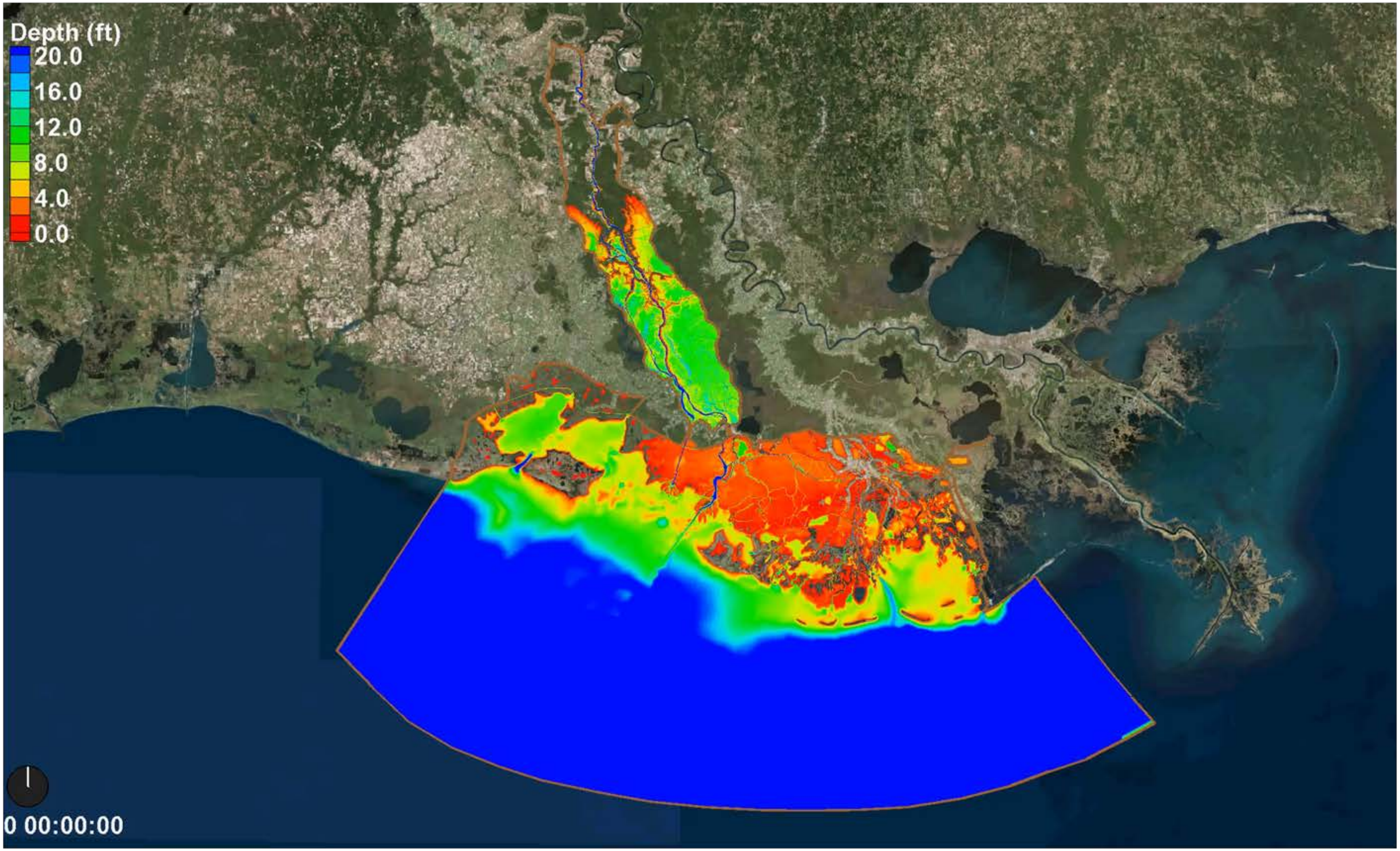


Shallow Water Equations

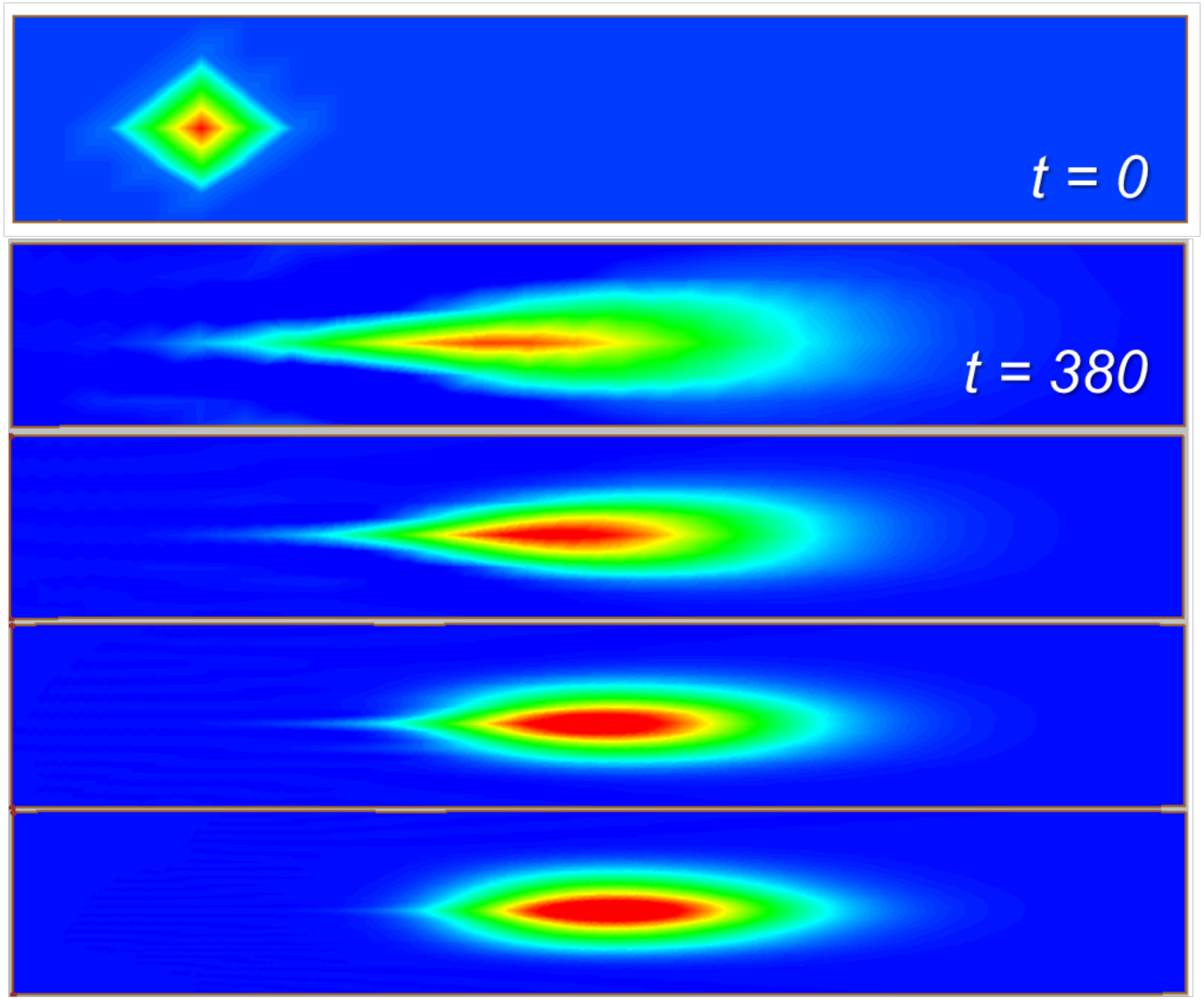


AdH

Parallel scaling

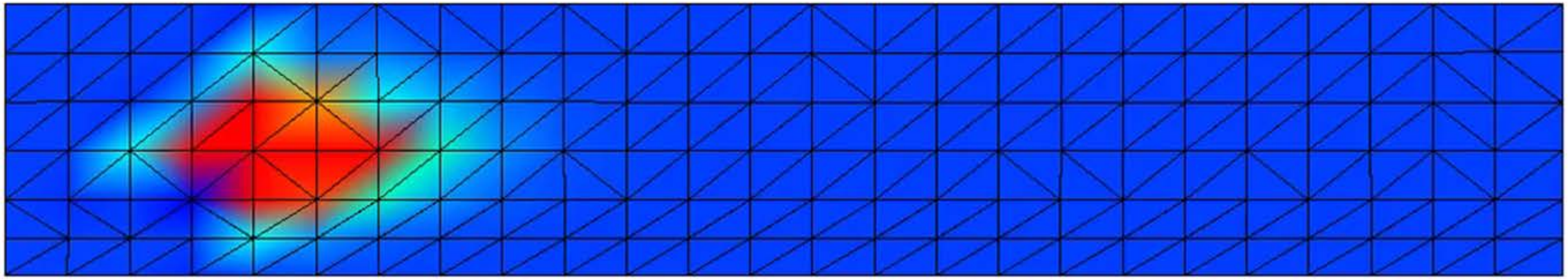


Mesh resolution effects on transport



Nodes/Elements
182 / 300
663 / 1,200
2,525 / 4,800
9,849 / 19,200

Adaptive Mesh Refinement



Initial mesh only needs to resolve geometry.

Adapt mesh to reduce residual error.

Mesh convergence: Increase adaption until changes are insignificant.

AdH 2D Free Surface Hydraulics

- Two-dimensional, depth-averaged shallow water equations + vorticity transport
- Unstructured, triangular finite element mesh
- Implicit solution scheme
- Wetting and drying
- Convergence controlled time step reduction
- Subcritical and supercritical flow
- Vessel generated currents

Houston Ship Channel

AdH/SEDLIB
Sediment Transport Library

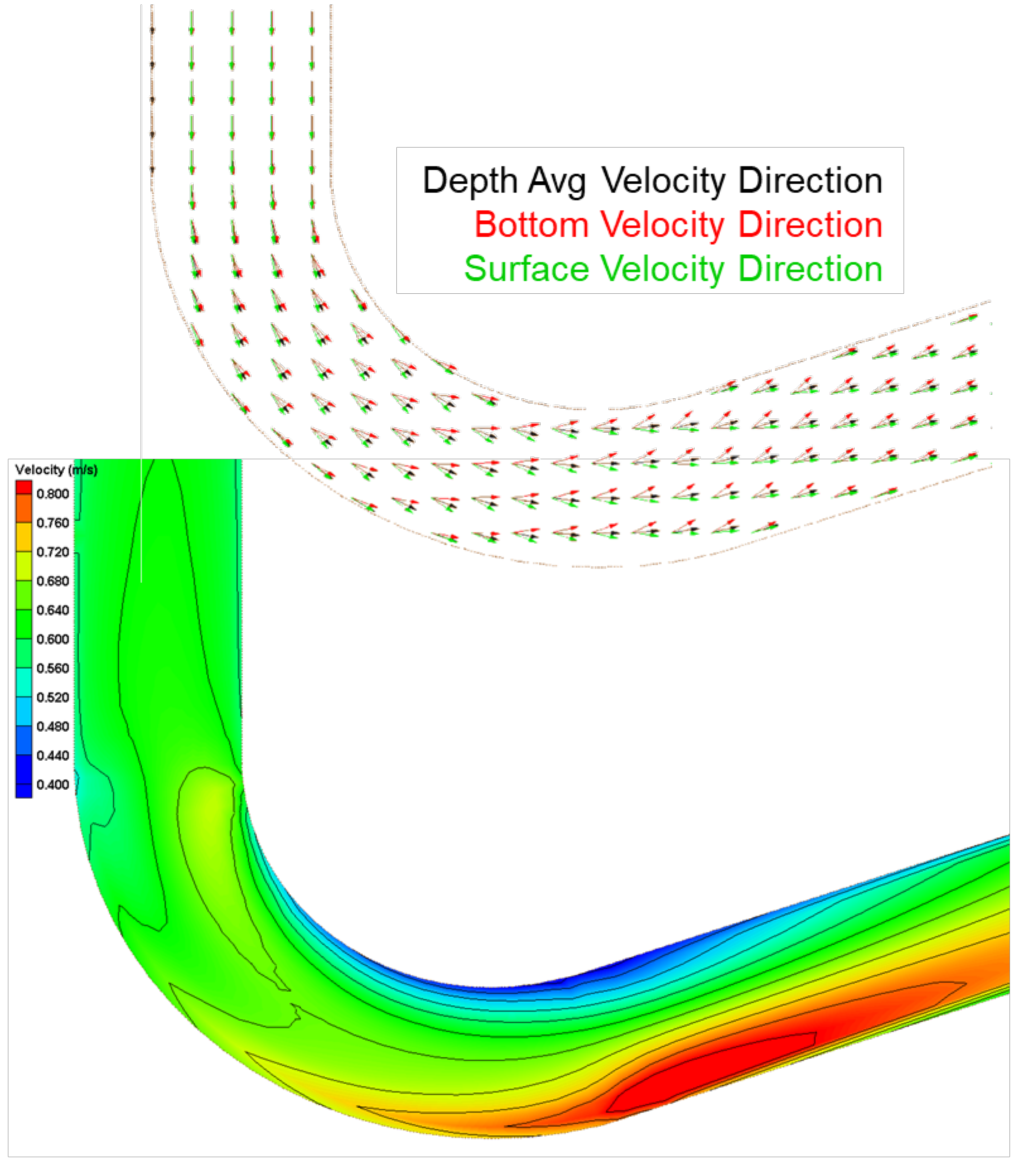
- Multiple user-defined grain sizes
- Cohesive and noncohesive sediments
- Bedload and suspended load
- Multiple bed layers (for storing strata)
- Quasi-3D transport
- Based on CH3D fundamental logic (Brown, 2012)

Vorticity transport

Corrects velocity distribution in river bends (Bernard, 1992)

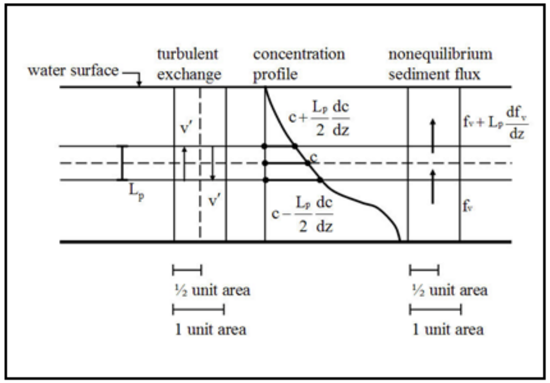
May be used to imply differences in surface and bottom current direction.

Computed suspended sediment transport is adjusted for quasi-3D velocity profile. (Brown, 2012)

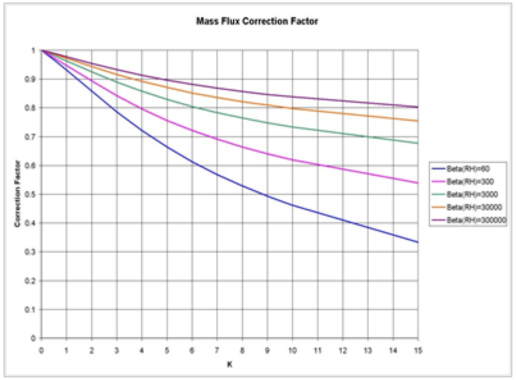


SEDLIB Quasi 3D Capability

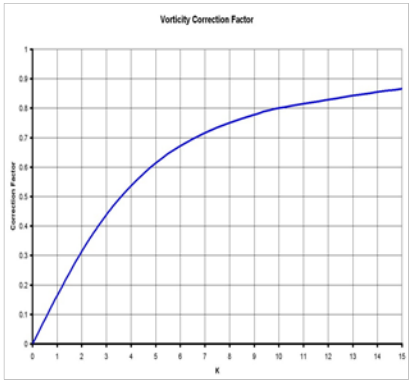
SEDLIB is equipped with methods to approximate 3D sediment transport behavior. This permits modeling of sediment processes in rivers for many commonly observed conditions.



Nonequilibrium sediment profile (Brown, 2008)

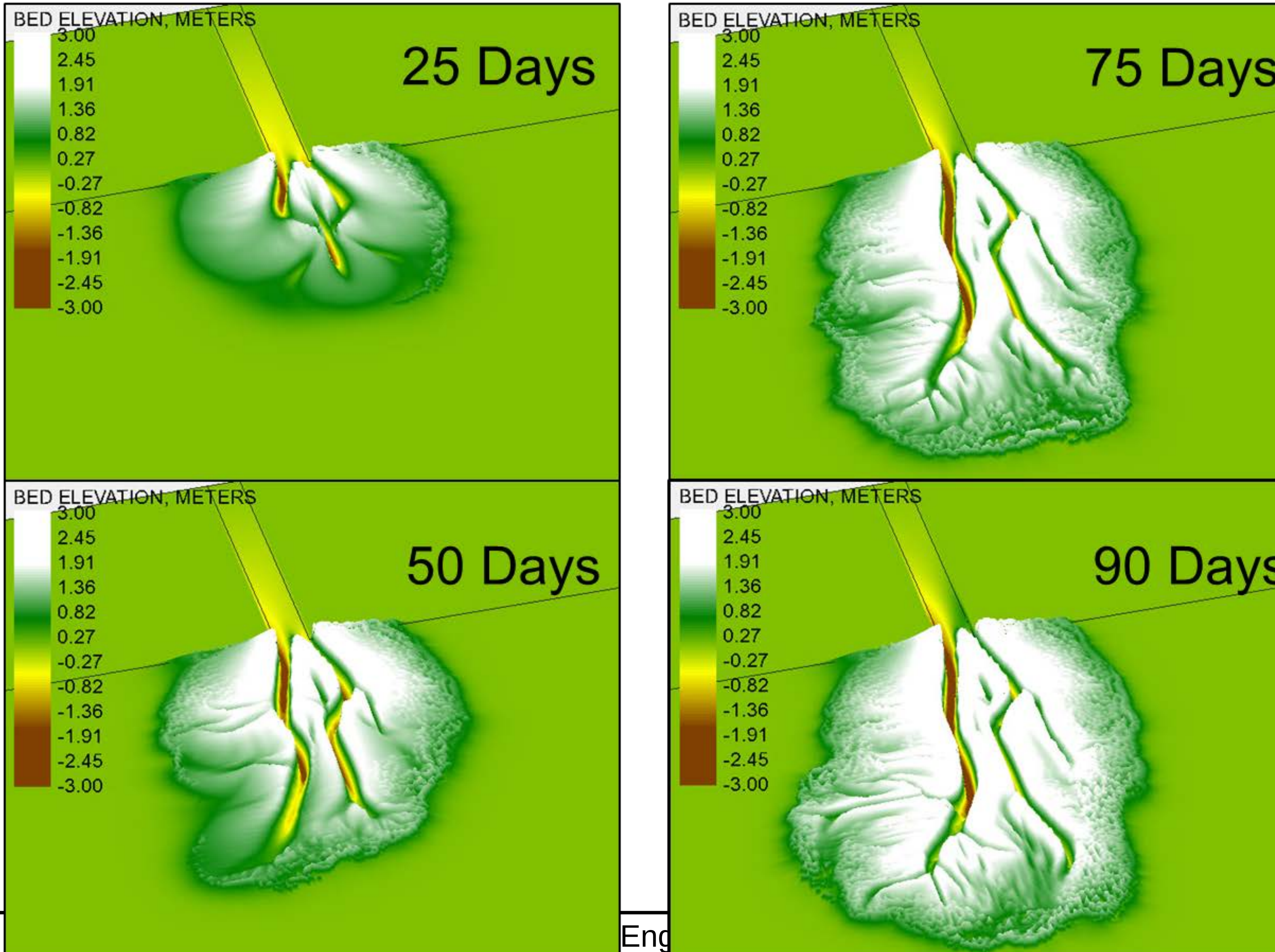


Horizontal mass flux correction (Brown, 2012)

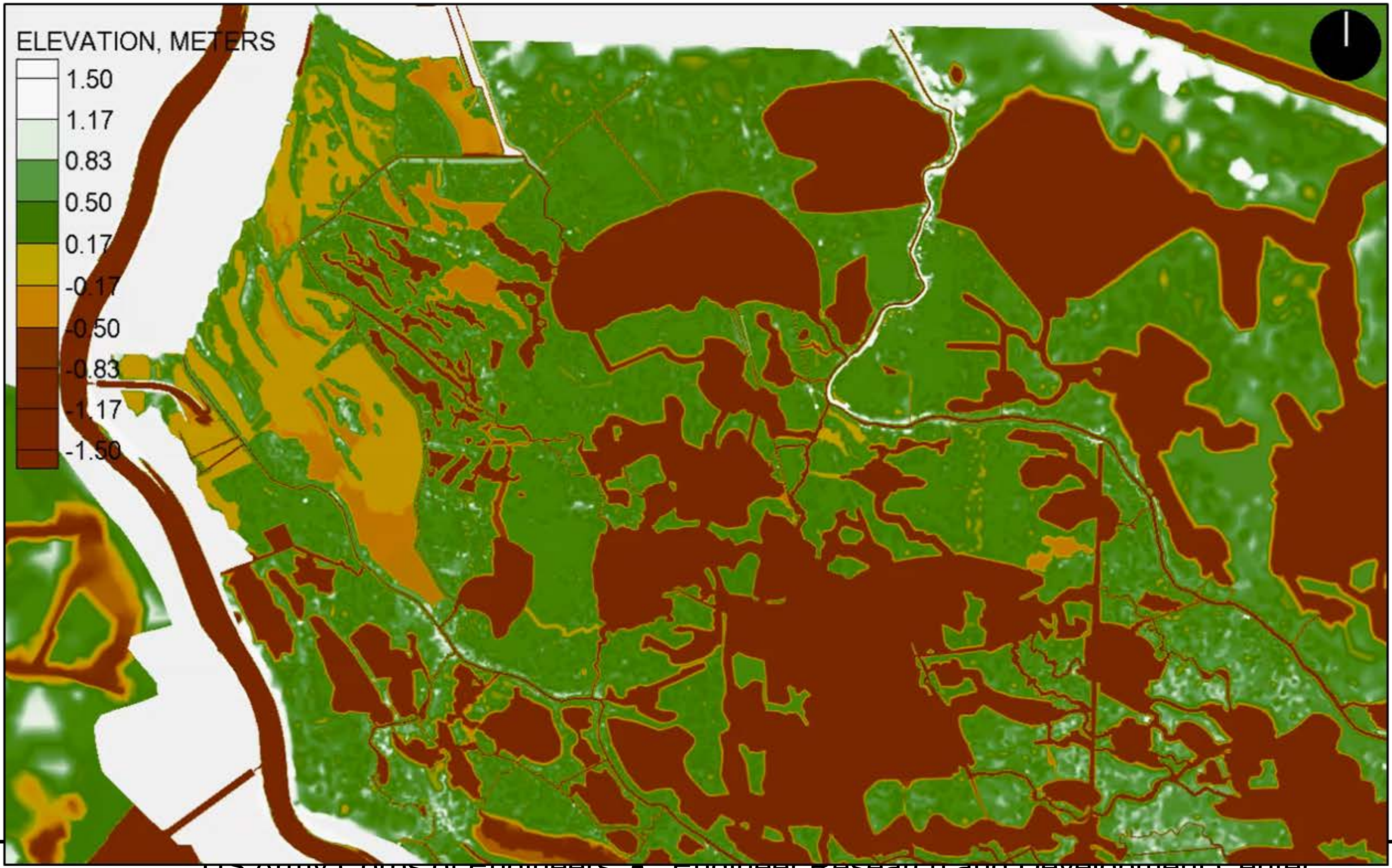


Bendway mass flux correction (Brown, 2012)

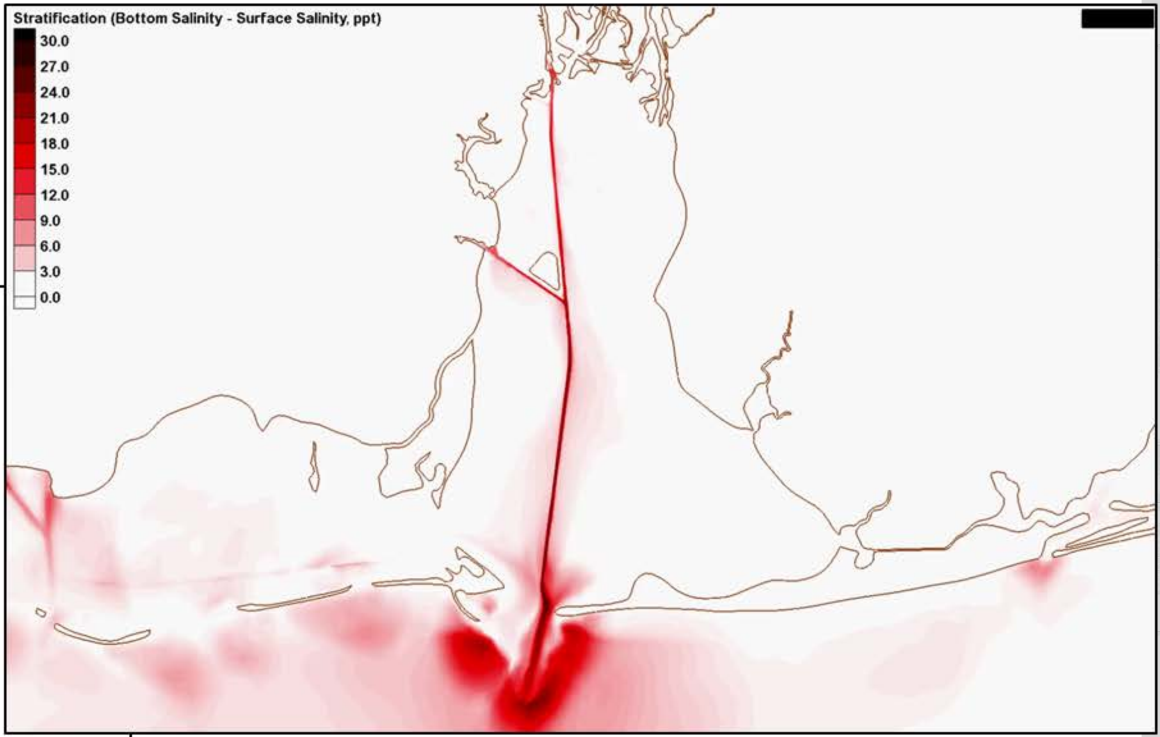
Evolution of Delta with AdH/SEDLIB

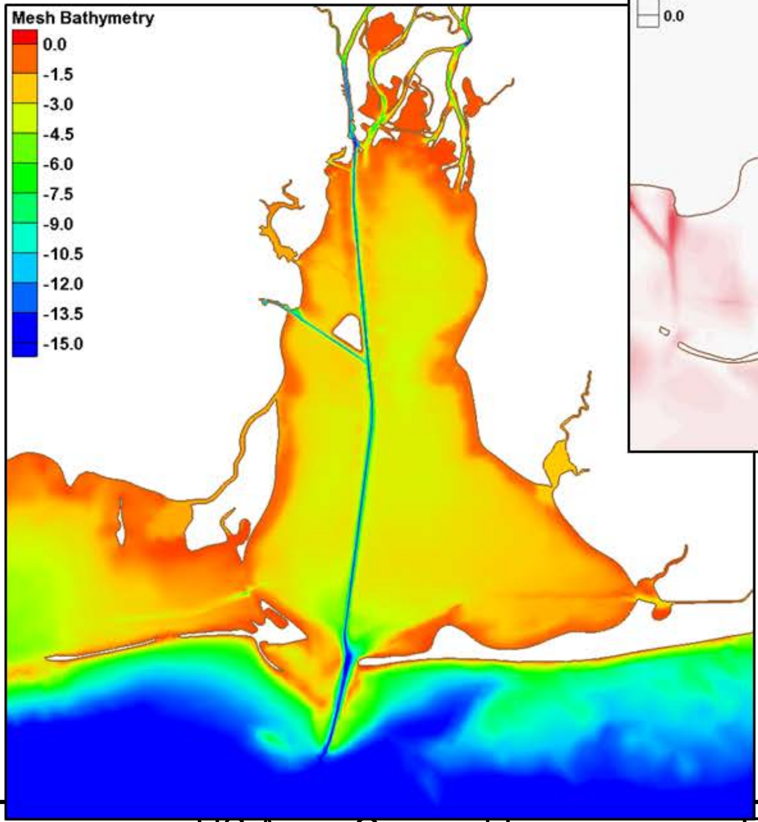


Mississippi River Sediment Diversions Marsh Building in Southern Louisiana



AdH 3D: Mobile Bay Stratification





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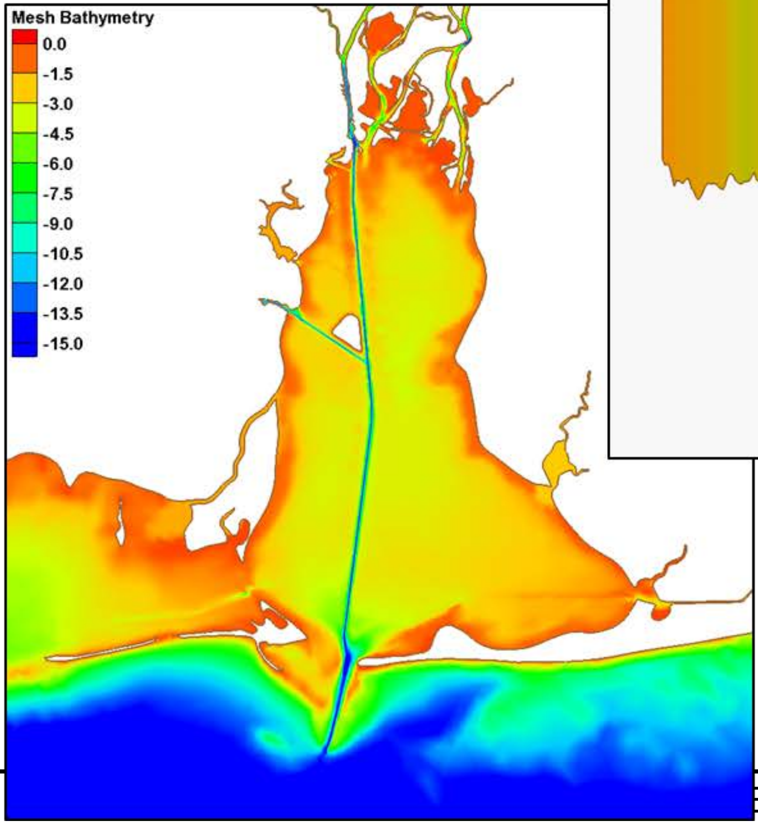
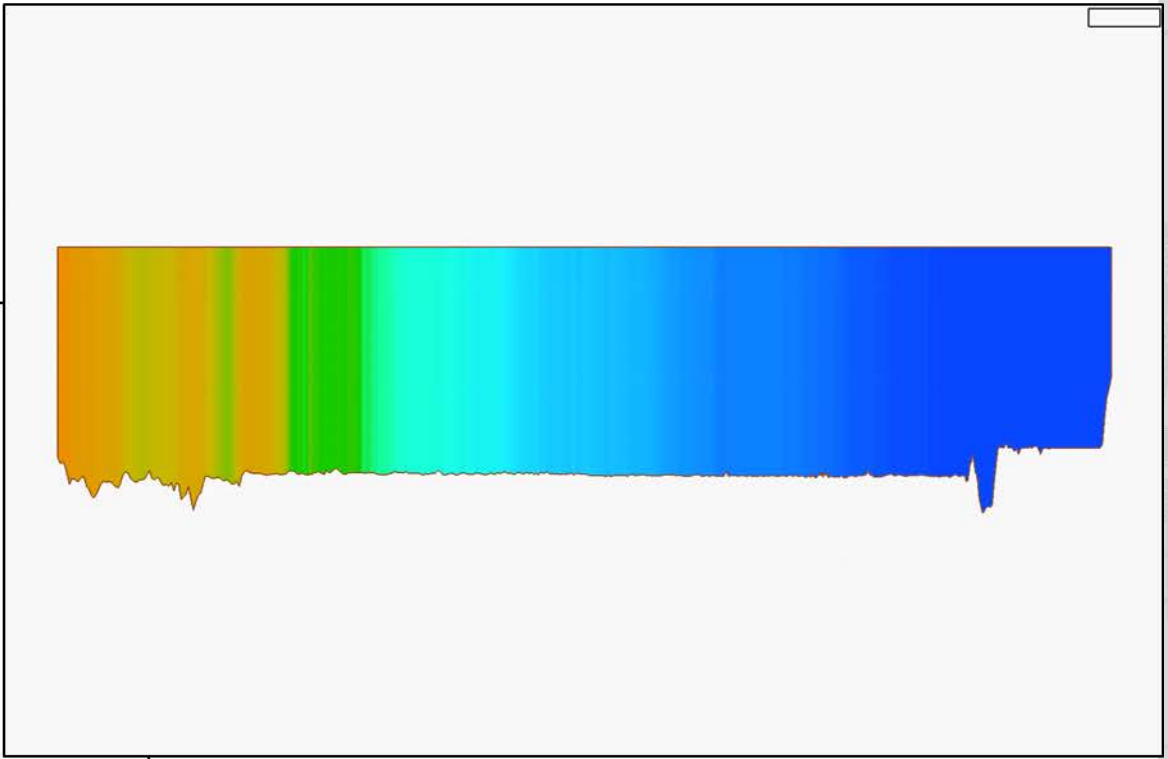




Morphological System Modeling Approach

- Watershed Models
  - Gridded Surface & Subsurface Hydraulic Analysis (GSSHA)
  - Hydrologic Modeling System (HEC-HMS)
- Sediment Impact Assessment Model (SIAM)
- HEC-RAS and HEC-6T (1D)
- Adaptive Hydraulics (AdH/SEDLIB)

Sedimentation Modeling Framework

- Sedimentation Modeling should be thought of as a framework that has tools with a range of fidelities that can be applied at a range of scales (both spatial and temporal)
  - 1-D: Relatively fast and efficient, can be applied at regional scales over long time periods (many decades).
  - 2-D: More complex and computationally expensive, typically applied at project scale but can be applied regionally if super computing assets are employed.
  - 3-D: Computationally expensive, typically applied at the very local project scale.

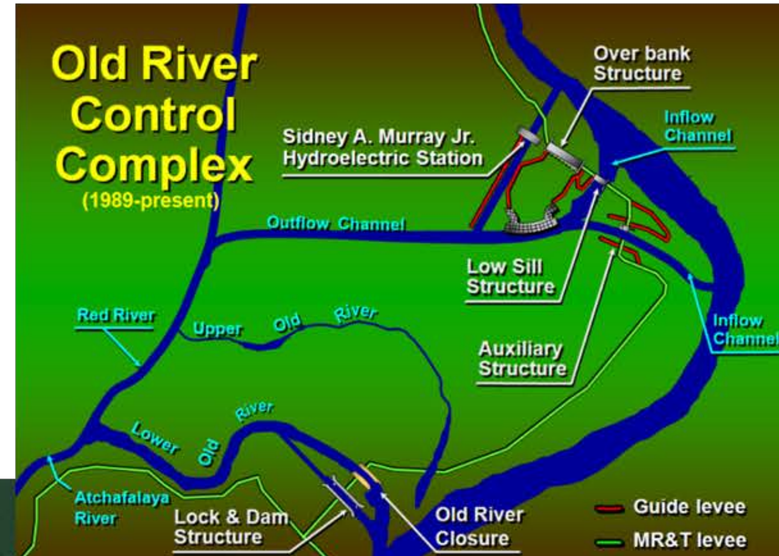
Example Framework Application

- Old River Control Complex

- 3D model – steady state simulations to compute sediment diversion coefficients of each of the ORCC diversion structures under a range of flow conditions

- 2D model – multi-year simulations under various operation scenarios to maximize sediment diversion efficiency of entire complex

- 1D model(s) – Estimate long-term impacts (50+ years) to both the Atchafalaya River and Mississippi River due to changes in ORCC flow and sediment diversions.



References:

Documentation and Windows executables:

- https://chl.erdc.dren.mil/adh/main/index.html

- Bernard, B., (1992) "Depth-Average Numerical Modeling for Curved Channels" Technical Report HL-92-9, U.S. Army Corps of Engineers, Engineering Research and Development Center, Vicksburg, MS.
- Brown, G.L. (2008) "Approximate Profile for Nonequilibrium Suspended Sediment" Journal of Hydraulic Engineering. 134, 1010 (2008), DOI:10.1061/(ASCE)0733-9429(2008)134:7(1010)
- Brown, G.L. (2012) "Modification of the Bed Sediment Equations of Spasojevic and Holly (1993) to Account for Variable Porosity, Variable Grain Specific Gravity, and Nonerodable Boundaries" IIHR Third International Symposium on Shallow Flows, Iowa City, IA, June 4-6 2012.
- Brown, G.L. (2012) "A Quasi-3D Suspended Sediment Model Using a Set of Correction Factors Applied to a Depth Averaged Advection Diffusion Equation" IIHR Third International Symposium on Shallow Flows, Iowa City, IA, June 4-6 2012.