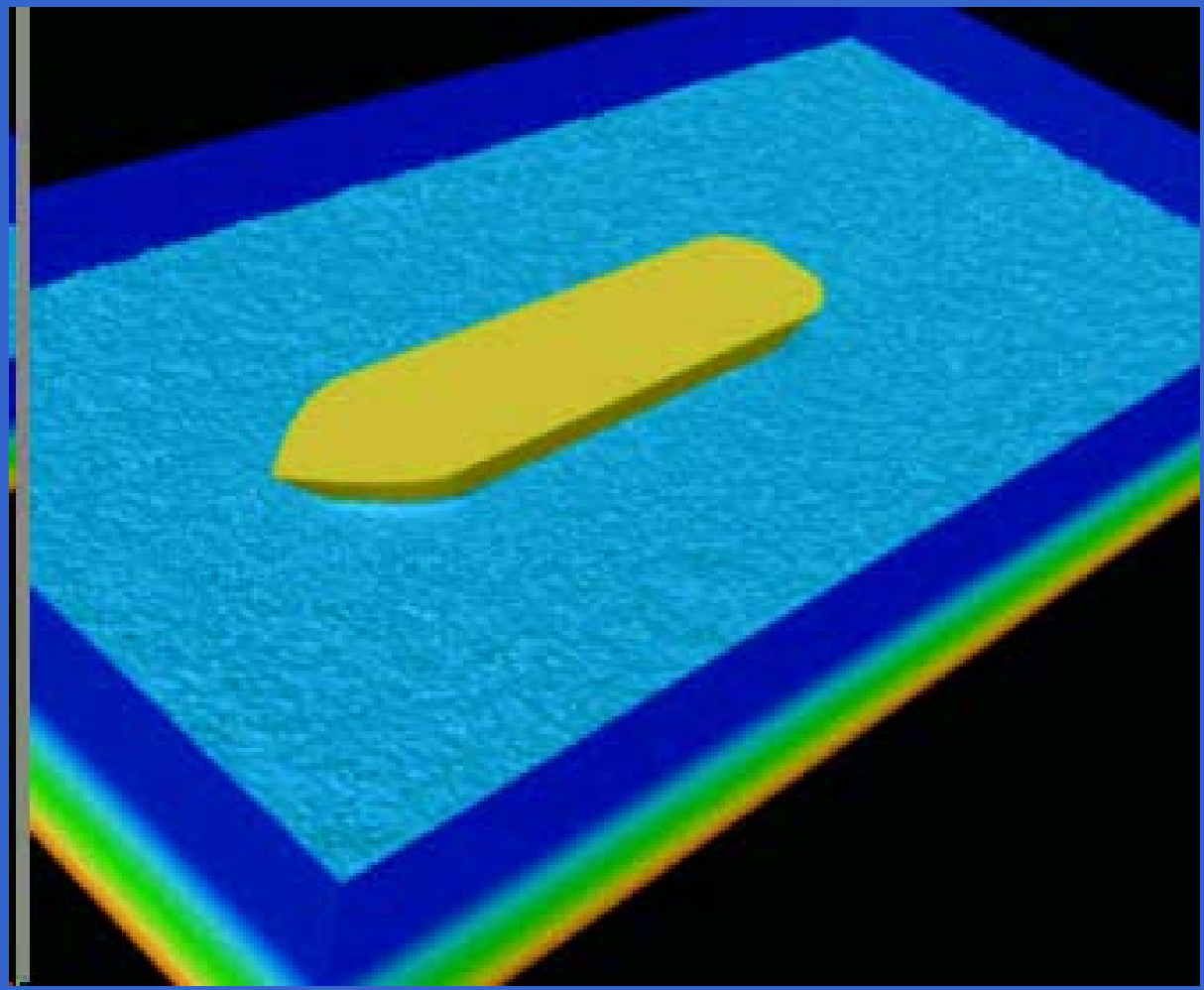
Shallow Water Modeling of Vessel Hydrodynamics

HIVEL2D and ADH

Modeling Vessel Effects

- Navier Stokes – Air/water, 3D
- Navier Stokes – single phase, 3D
- Shallow Water Equations, d/L << 1, 2D
  - Boussinesq Equations
  - St. Venant
- Shijf Equation (Bernoulli), 1D

Navier Stokes, air/water simulation



Navier Stokes – wave breaking

Shallow Water Equation Models

- $h = h_0 + h_1\sigma^2 + h_2\sigma^4 + h_3\sigma^6 + \ldots$
- $\sigma = d/L << 1$
- St. Venant, $\sigma < 1/10$
  - Conservative Form: Strong Jumps-no tuning
- Boussinesq, $\sigma < 1/3$

Model Needs
Currents and Water Surface

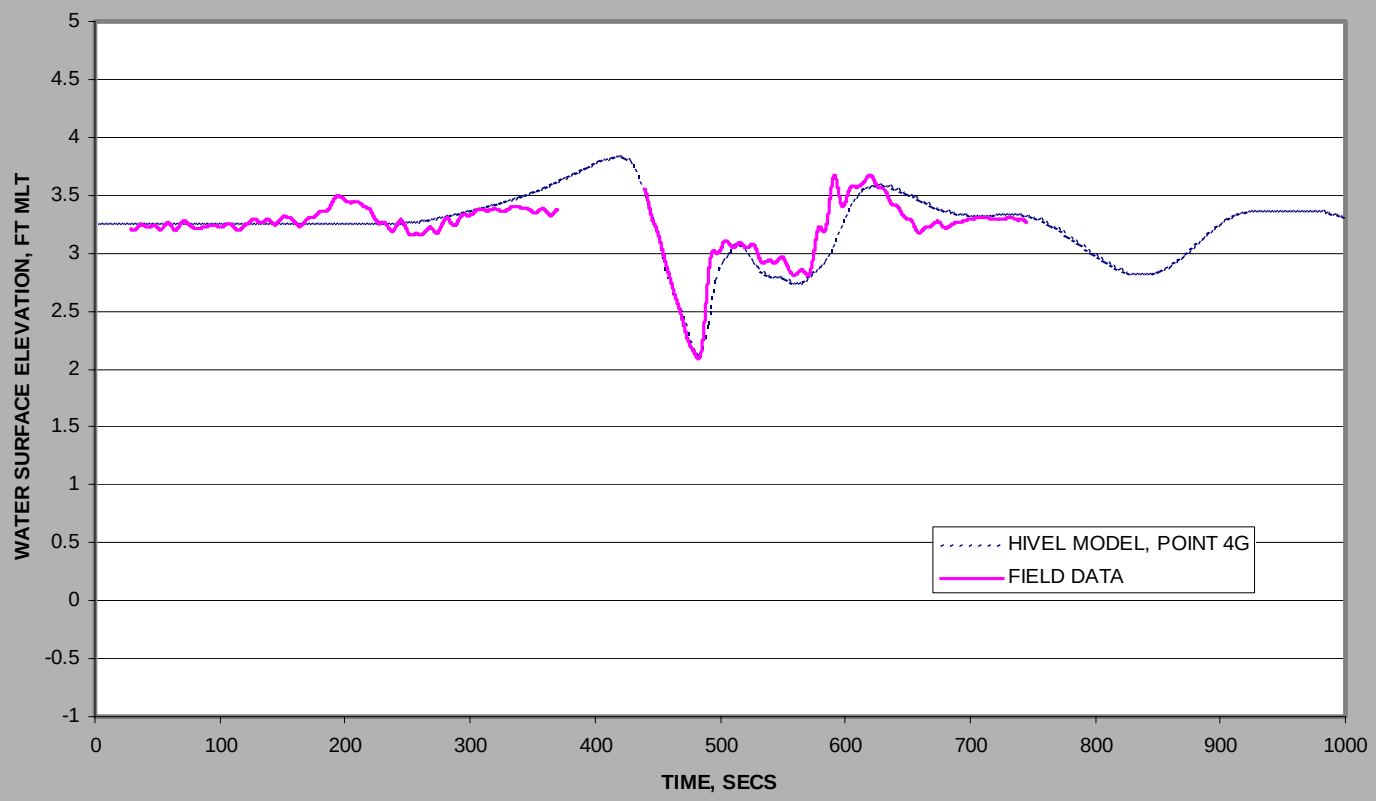
- Drawdown
- Transverse Stern Wave

Present Code
HIVEL2D

- Unstructured Grid
- Static Grid
- Vessel simulated by moving pressure field
- Conservative Form Equations – captures shocks, bores, …
- Can run two vessels at a time – transitioning to Vessel Movement Library where many vessels can be used

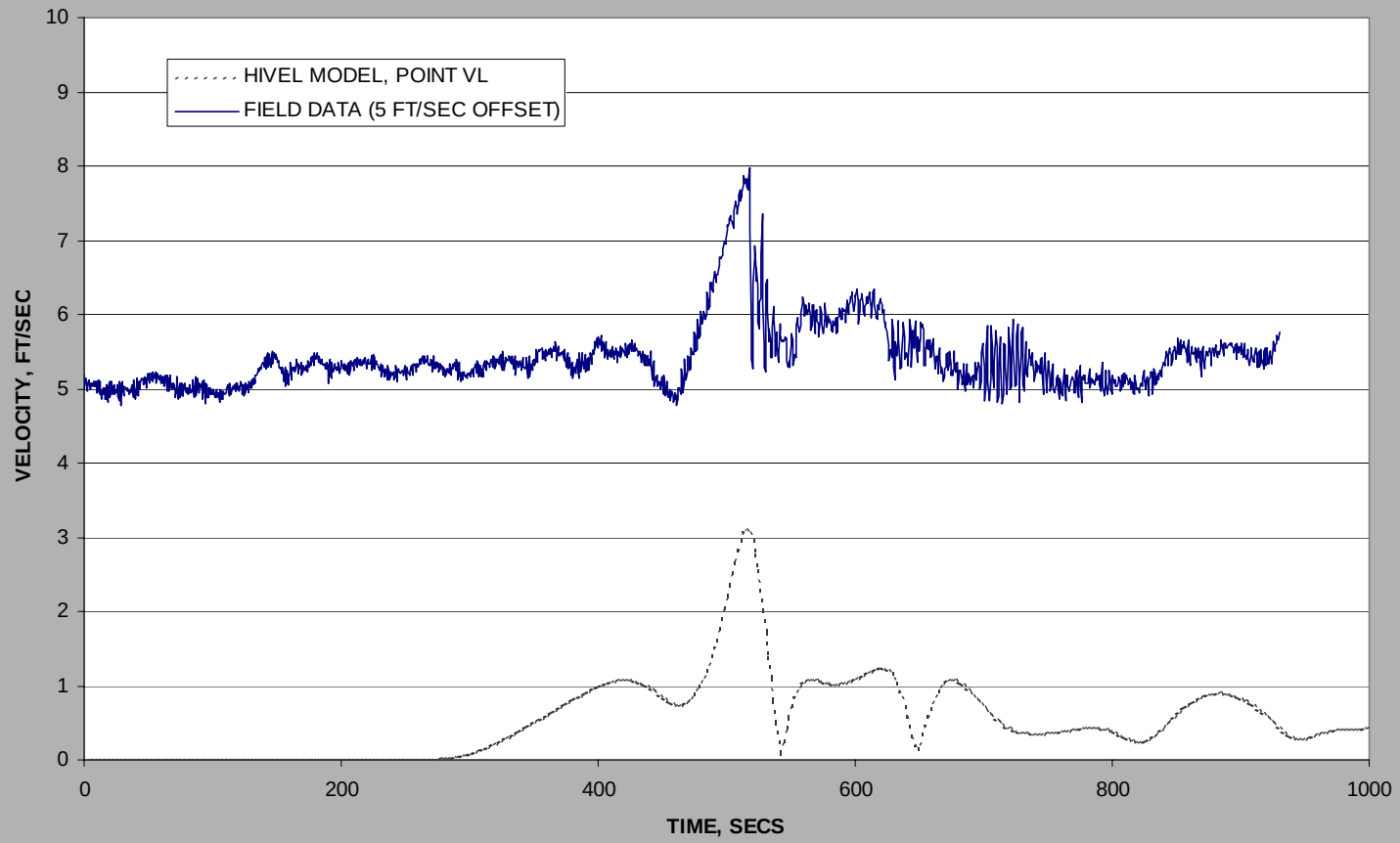
Water Surface Comparison with Field Data

FIGURE 17. OUINNISIAN NAVIGATOR, WATER SURFACE ELEVATION, WITHOUT ISLAND, HIVEL MODEL VERSUS FIELD DATA

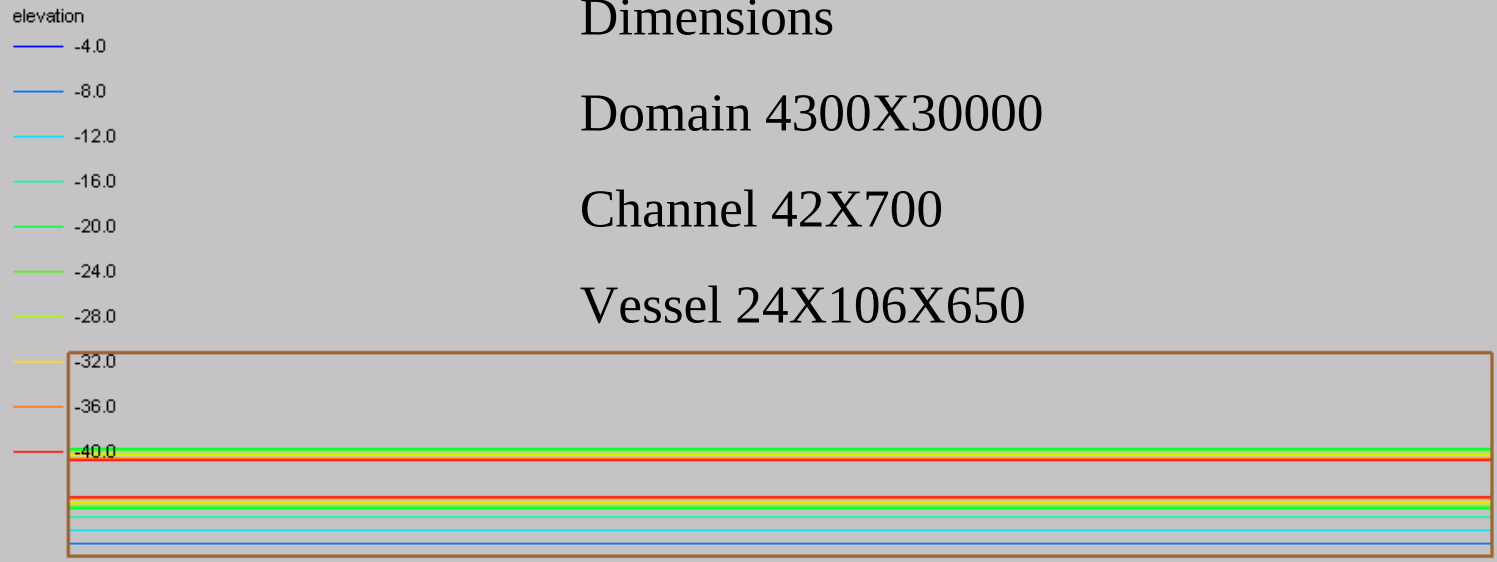


Velocity Comparison with Field Data

FIGURE 18. OUINNISIAN NAVIGATOR, VELOCITY, WITHOUT ISLAND, HIVEL MODEL VERSUS FIELD DATA



Vessel Example

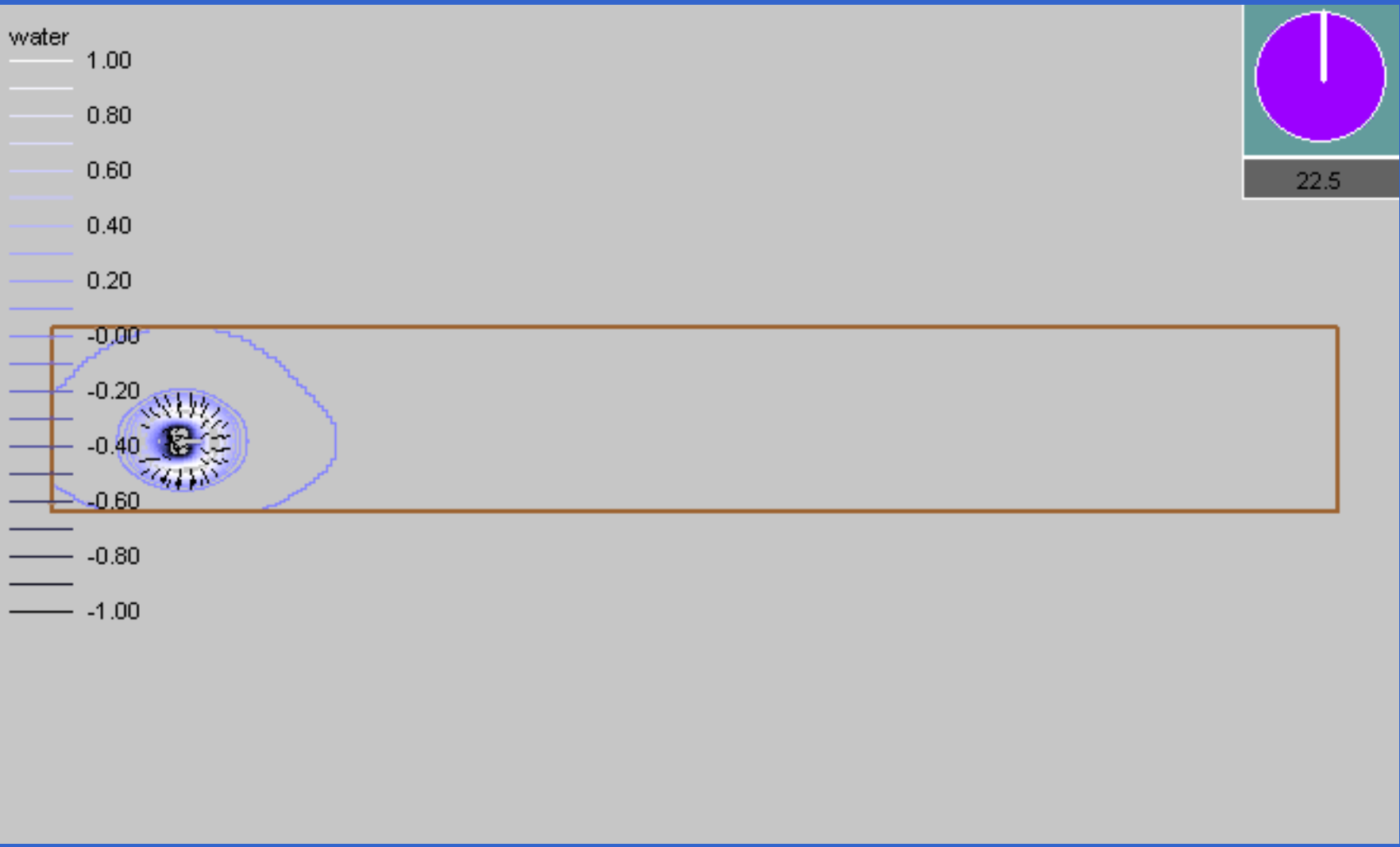


Dimensions

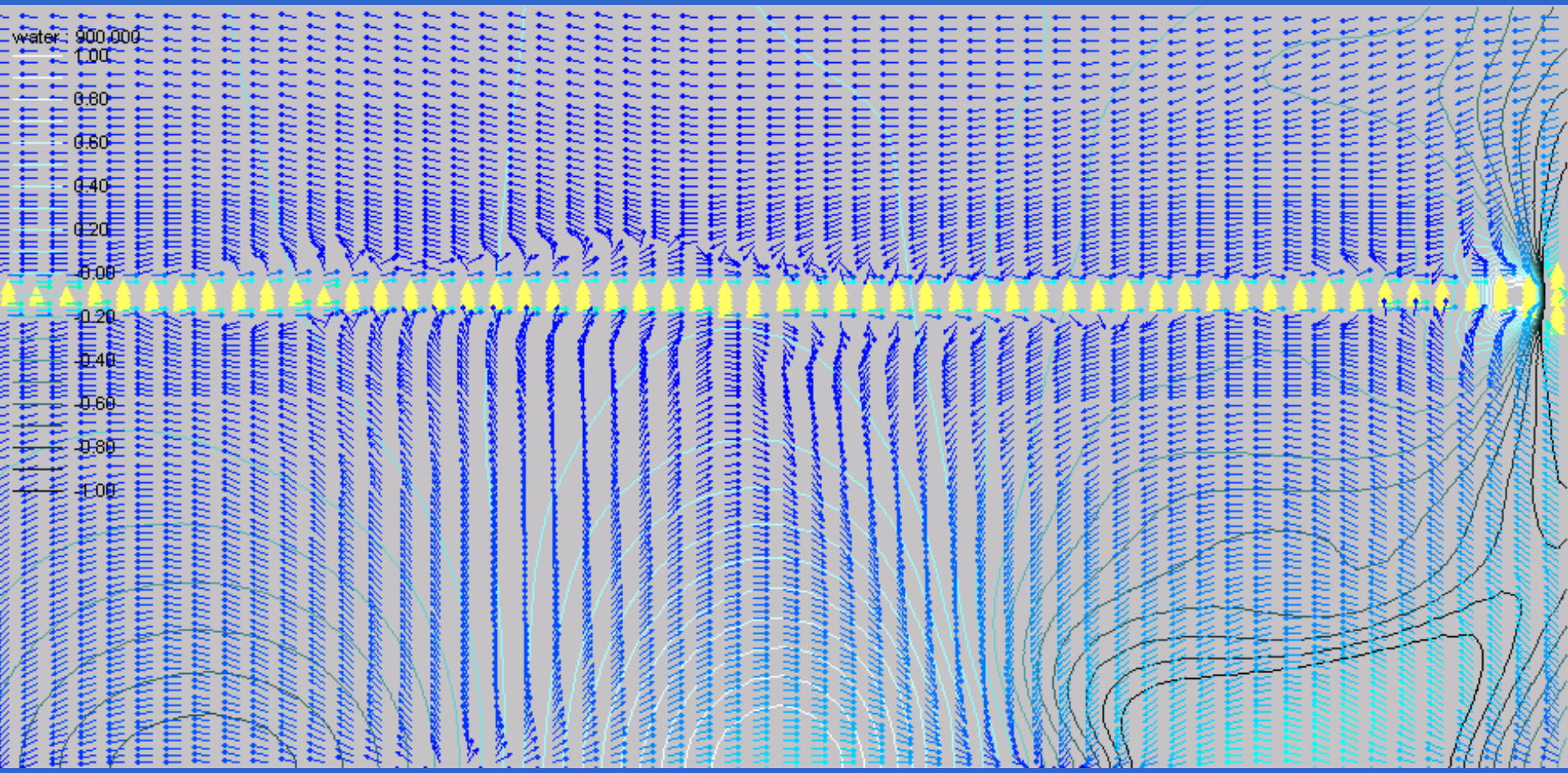
Domain 4300X30000

Channel 42X700

Vessel 24X106X650


water
1.00
0.80
0.60
0.40
0.20
-0.00
-0.20
-0.40
-0.60
-0.80
-1.00
22.5

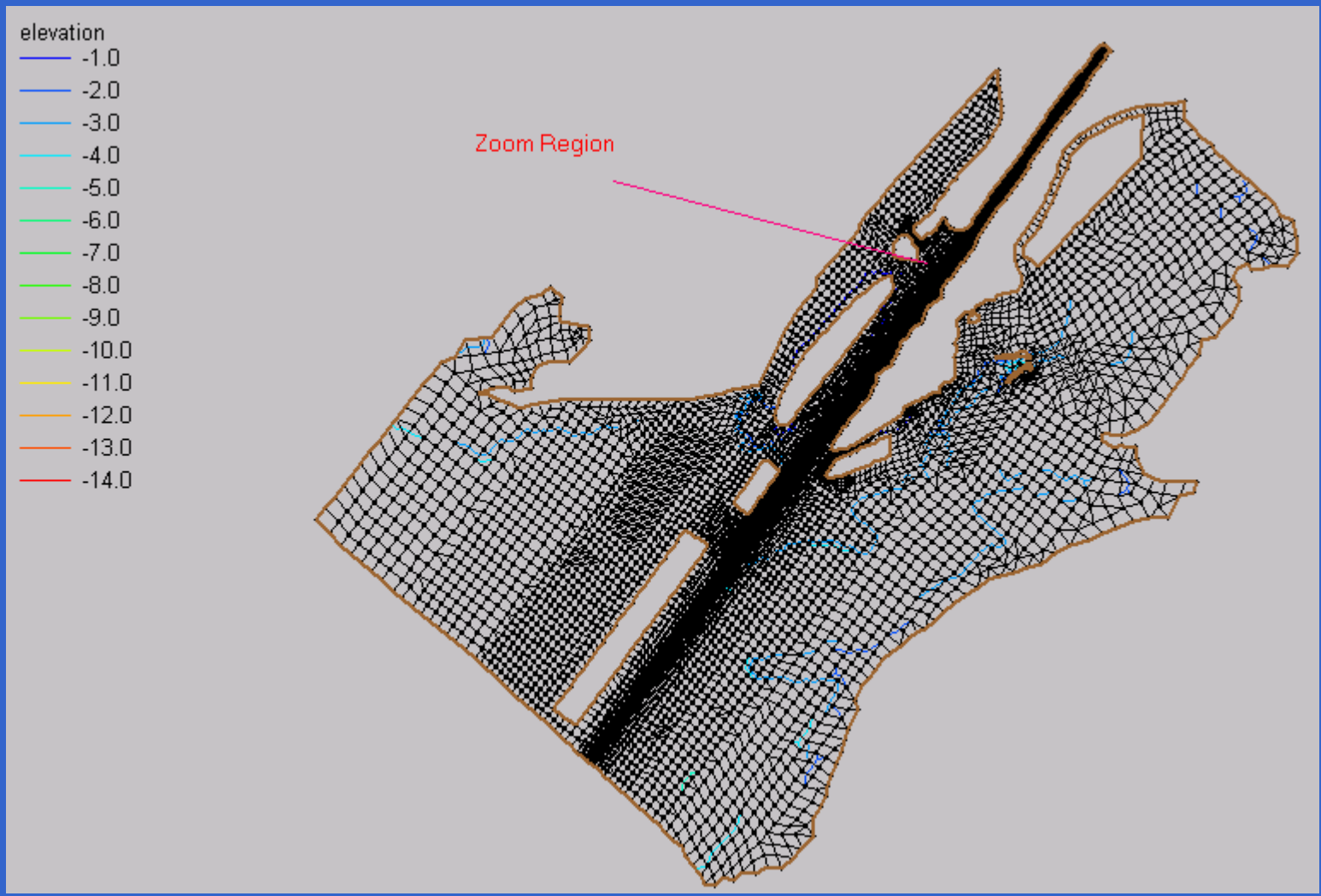
Vessel Example
Water Surface and Velocity



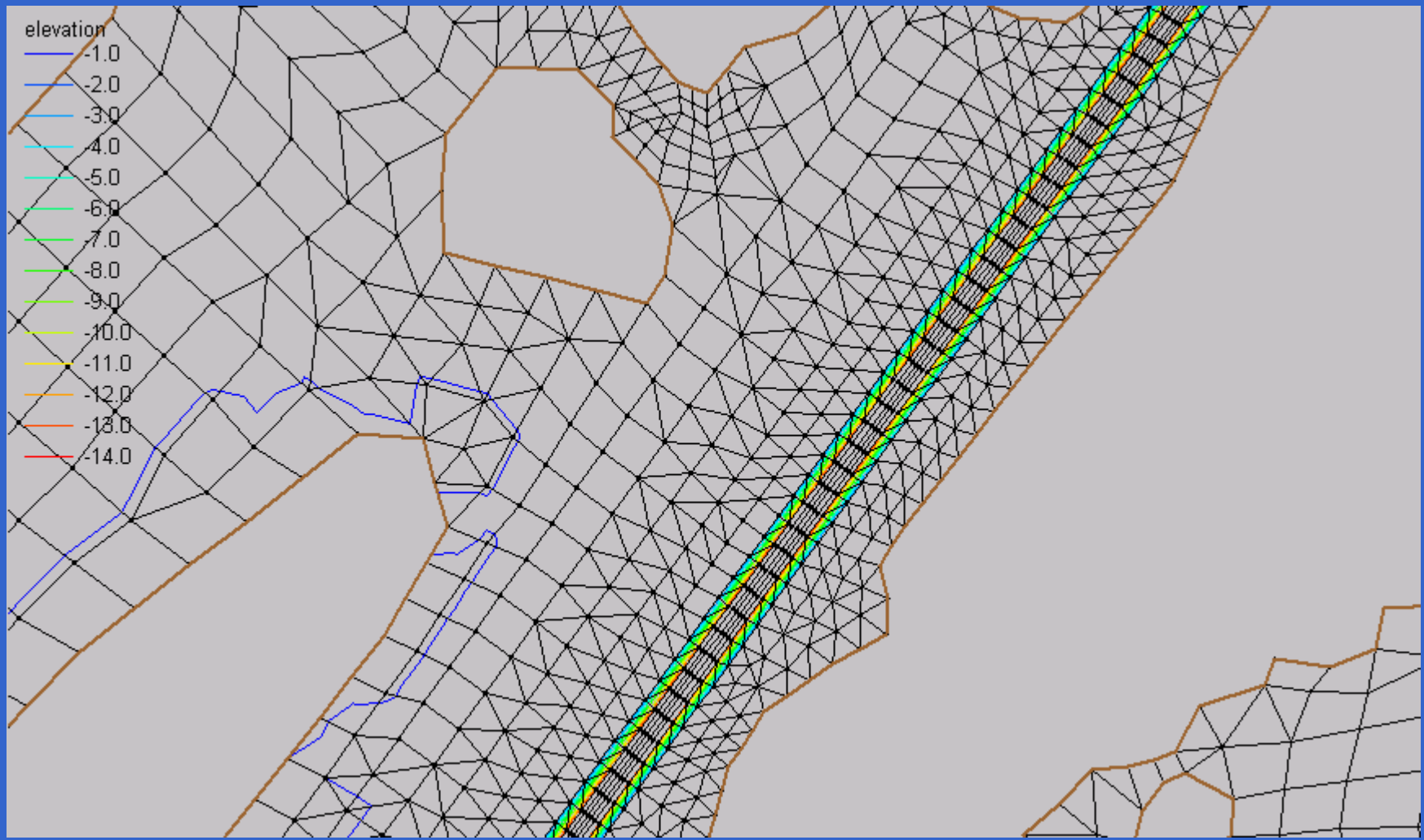
Grid Requirements

- Capture Blockage Area
- Capture Wavelength
- Capture hydrodynamics in nearby areas
- About 6 elements across width
- 15 or more elements along length
- Transition resolution into surroundings

Aransas Grid



Aransas –Zoom Grid



Future Direction

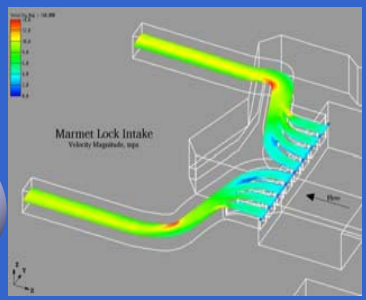
Add vessel feature to the ADH code and include sedimentation processes associated with vessel entrainment.

Major Features

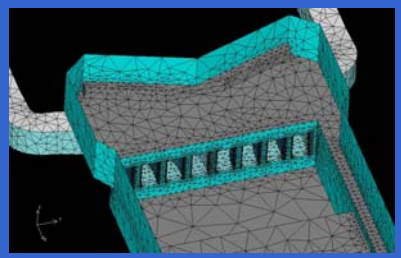
- Multi-processor
- Adaption – refinement and coarsening
- Portability – T3E, O2/3k, IBM-SP, Unix workstations
- Multi-physics

ADH Philosophy

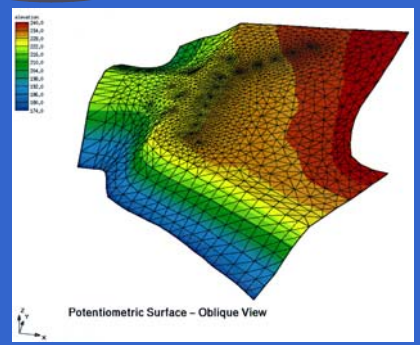
Navier-Stokes Equations



Unsaturated Groundwater Equations

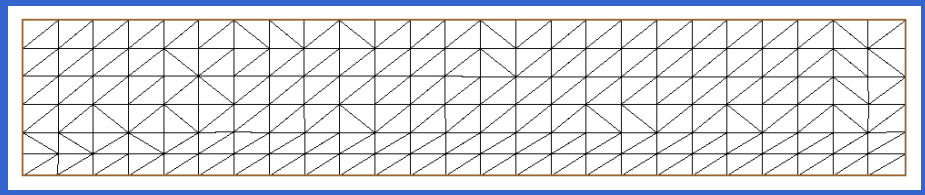


Computational Engine (FE utilities, preconditioners, solvers, I/O to xMS GUIs)



Shallow Water Equations

How important is grid resolution?

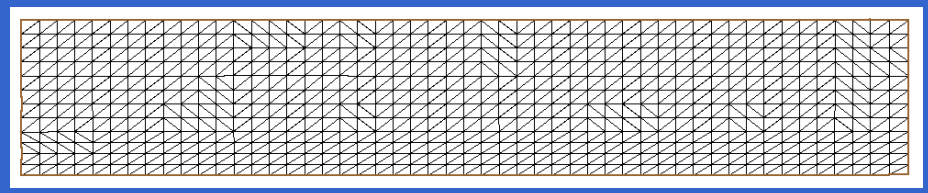


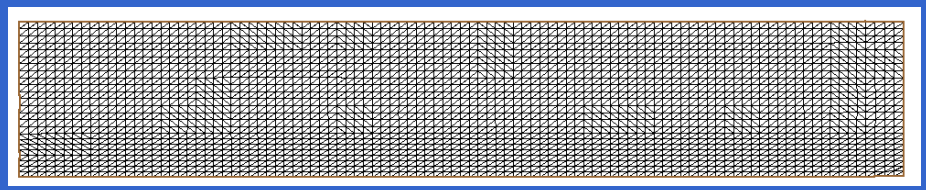
Coarse Mesh

182 nodes/300 elements

Refined Mesh #1

663 nodes/1200 elements



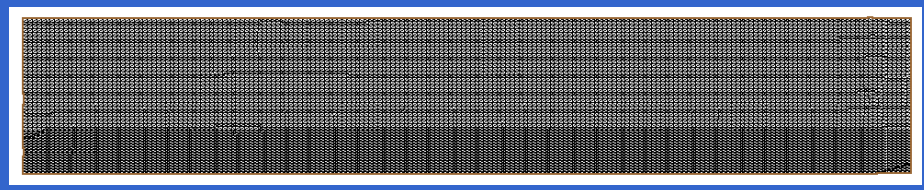


Refined Mesh #2

2525 nodes/4800 elements

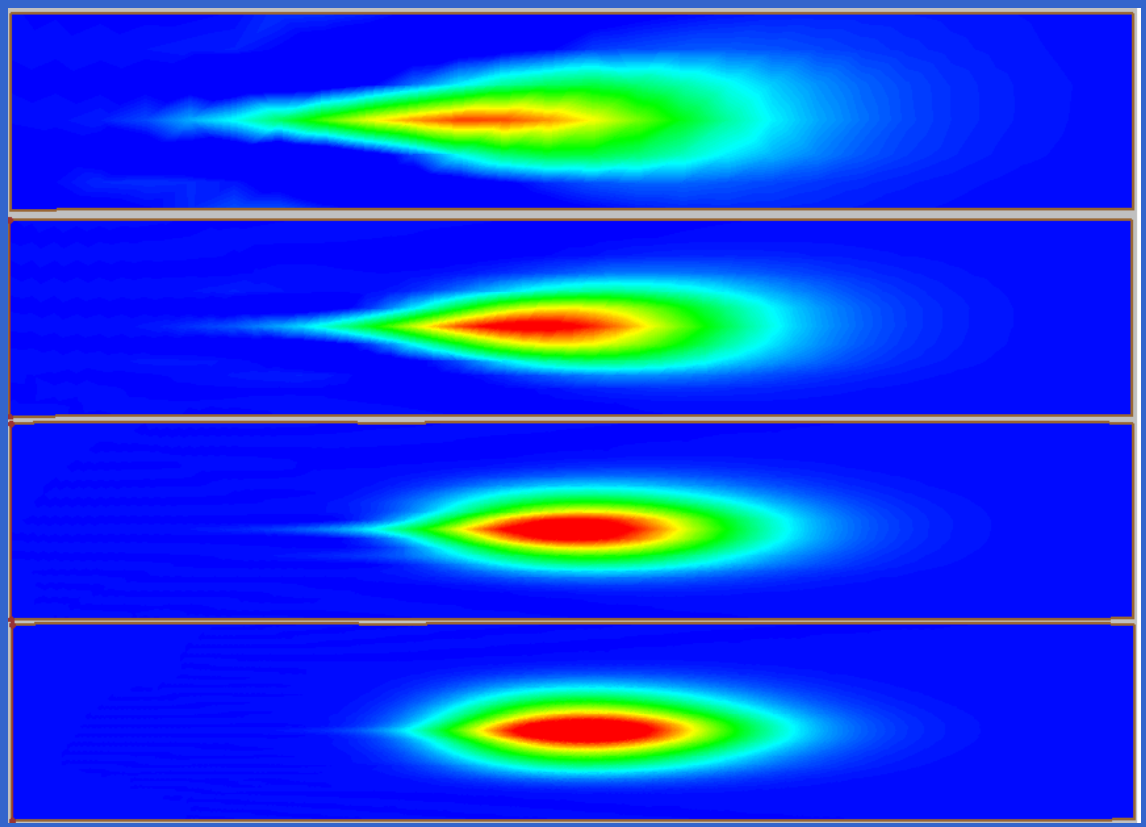
Refined Mesh #3

9849 nodes/19200 elements



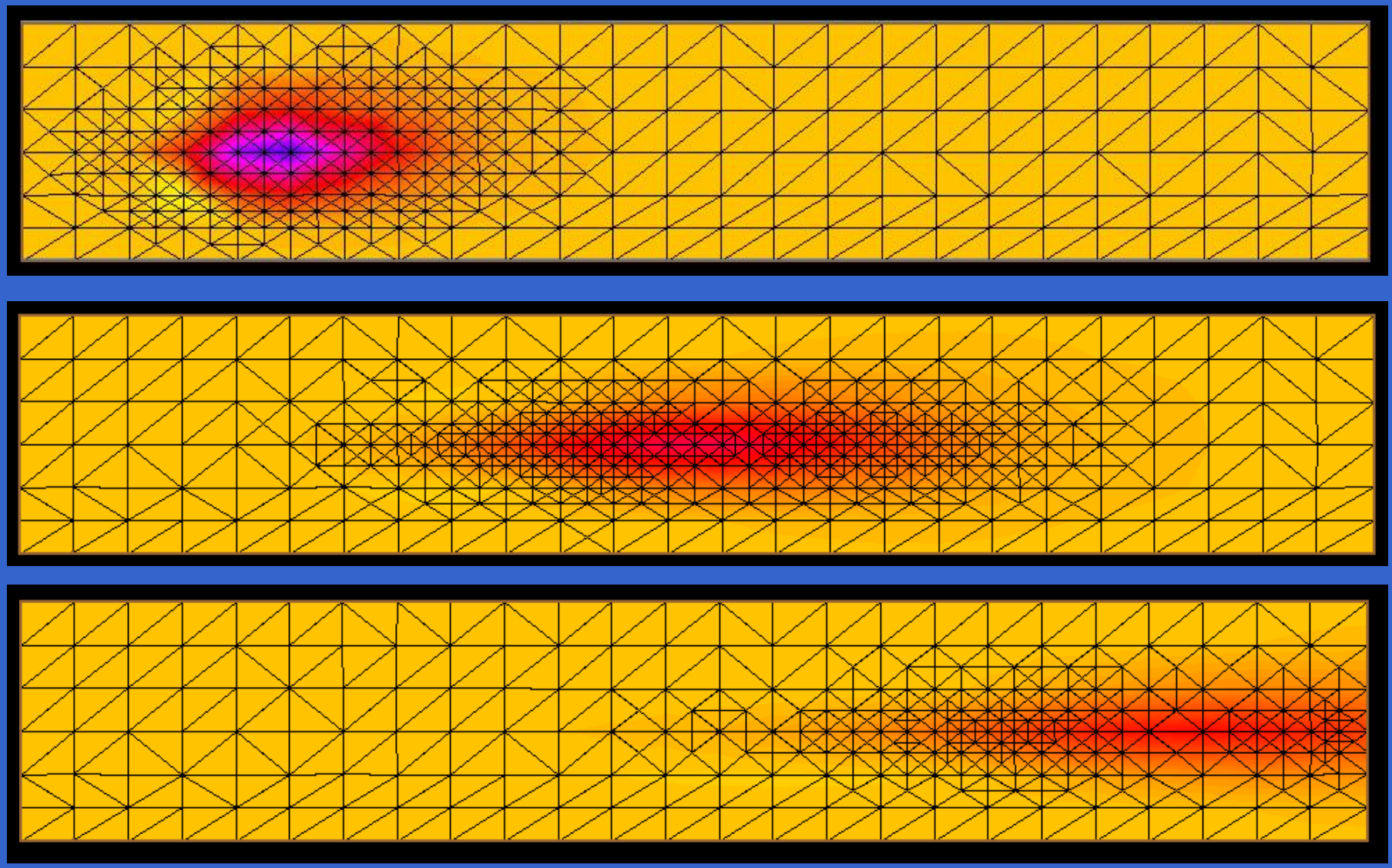
Initial Concentration Cloud

Grid Resolution Results…

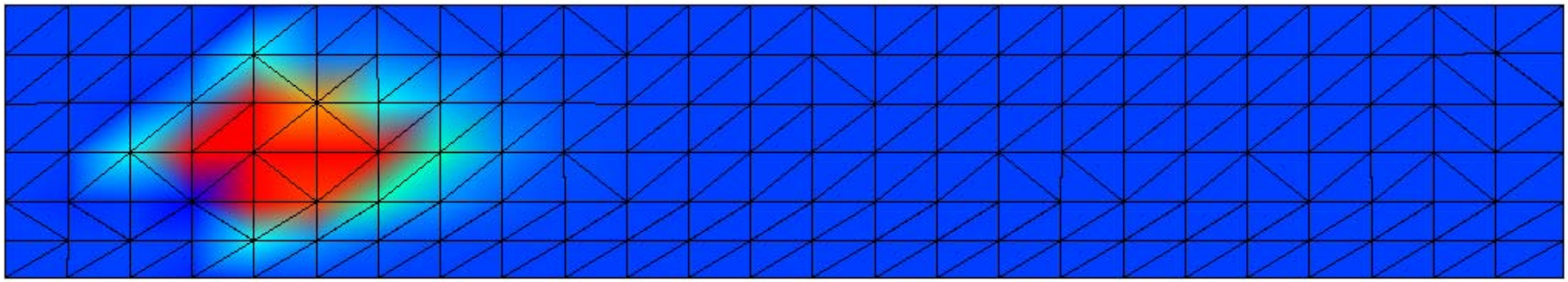


at timestep = 380 seconds

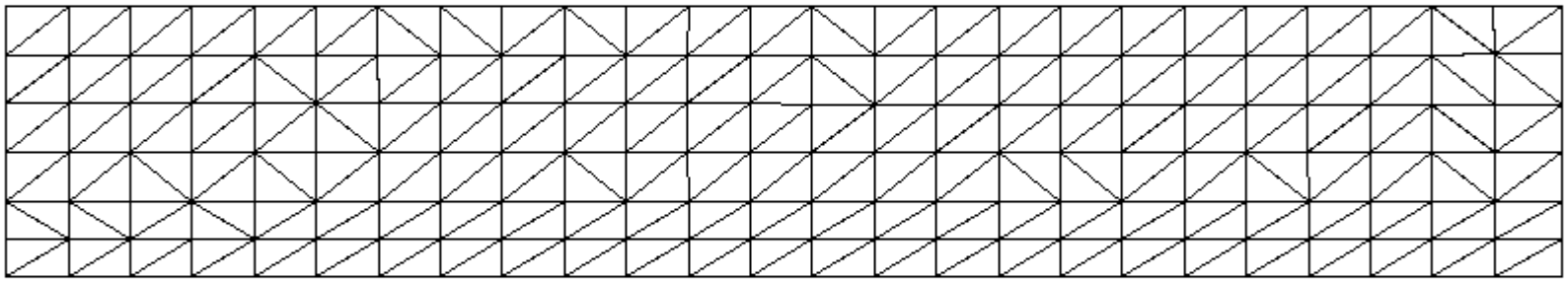
Concentration Field and Adapted Mesh using ADH



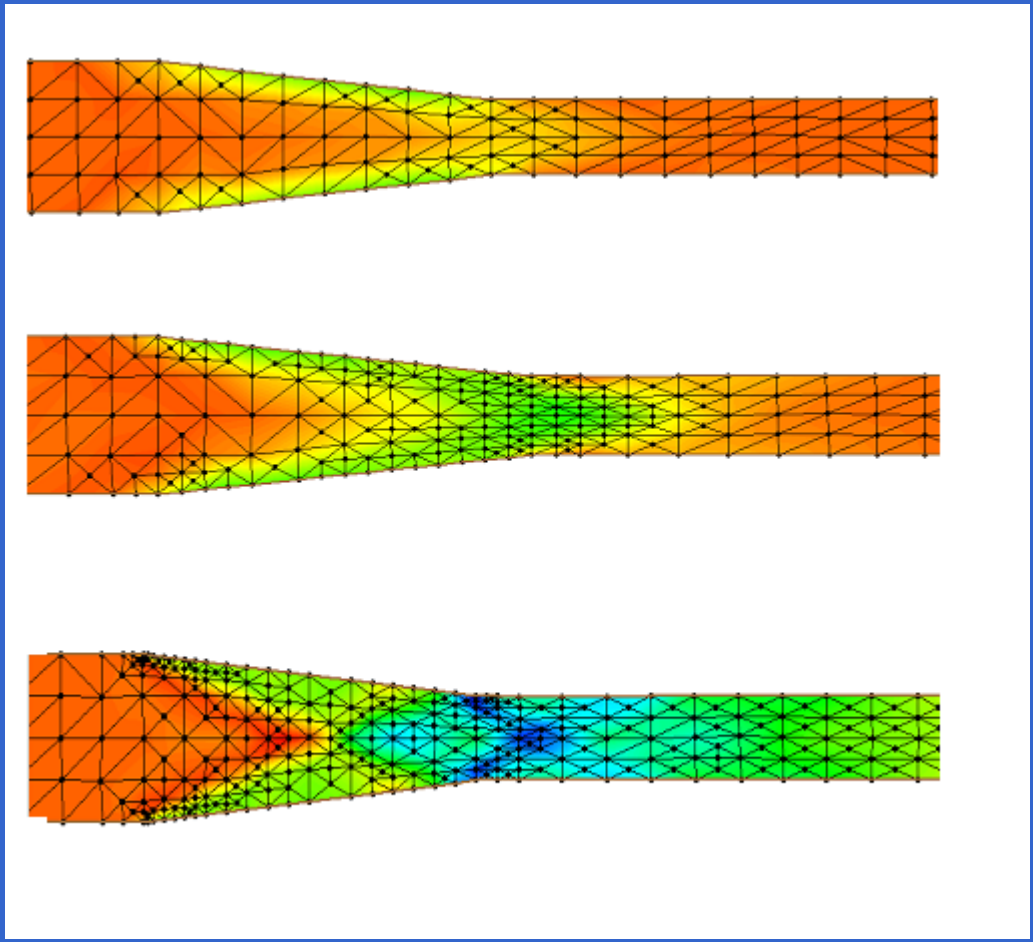
Adaption Grid and Concentration



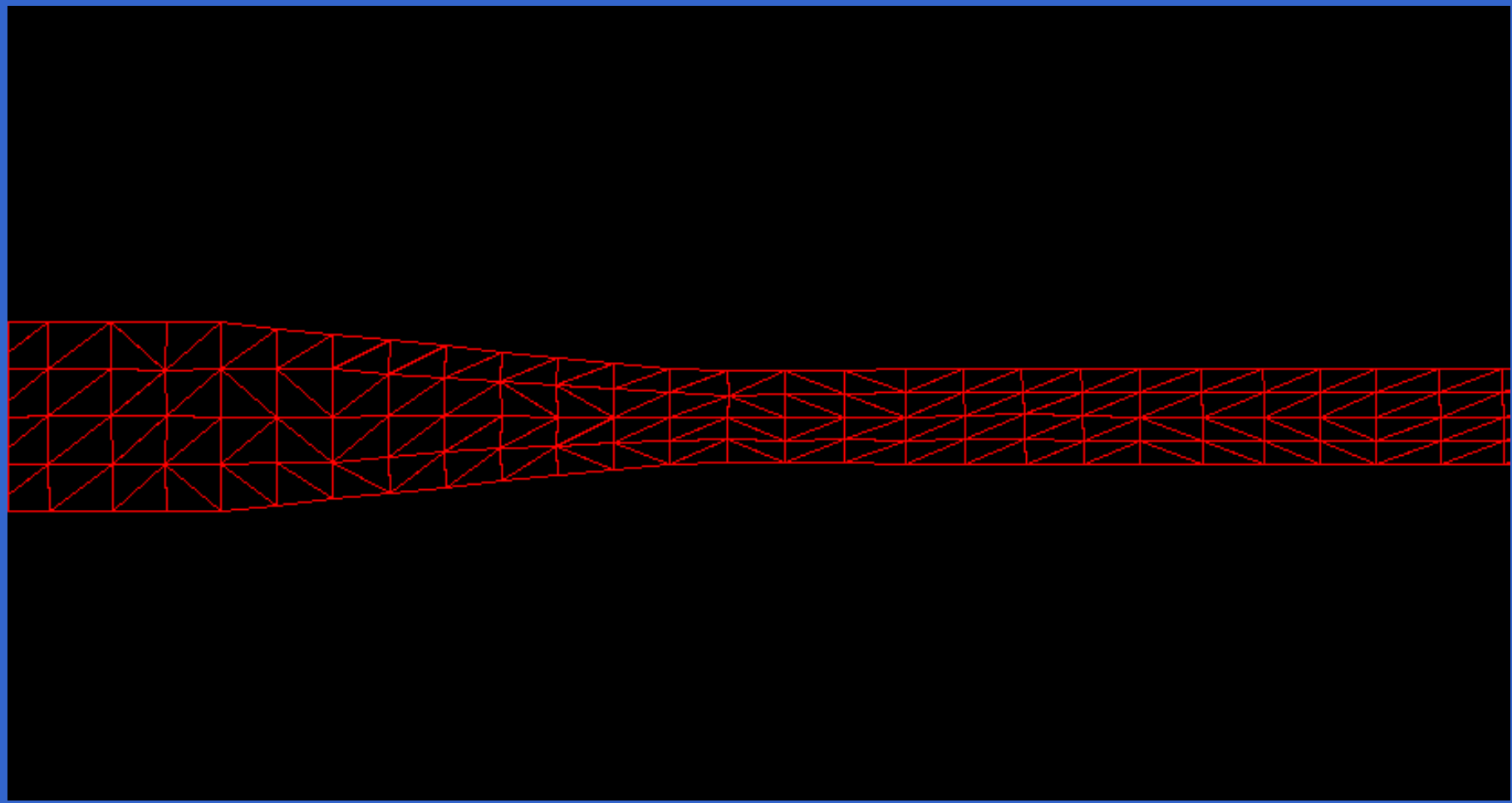
Grid Alone



Supercritical Transition Water Depth

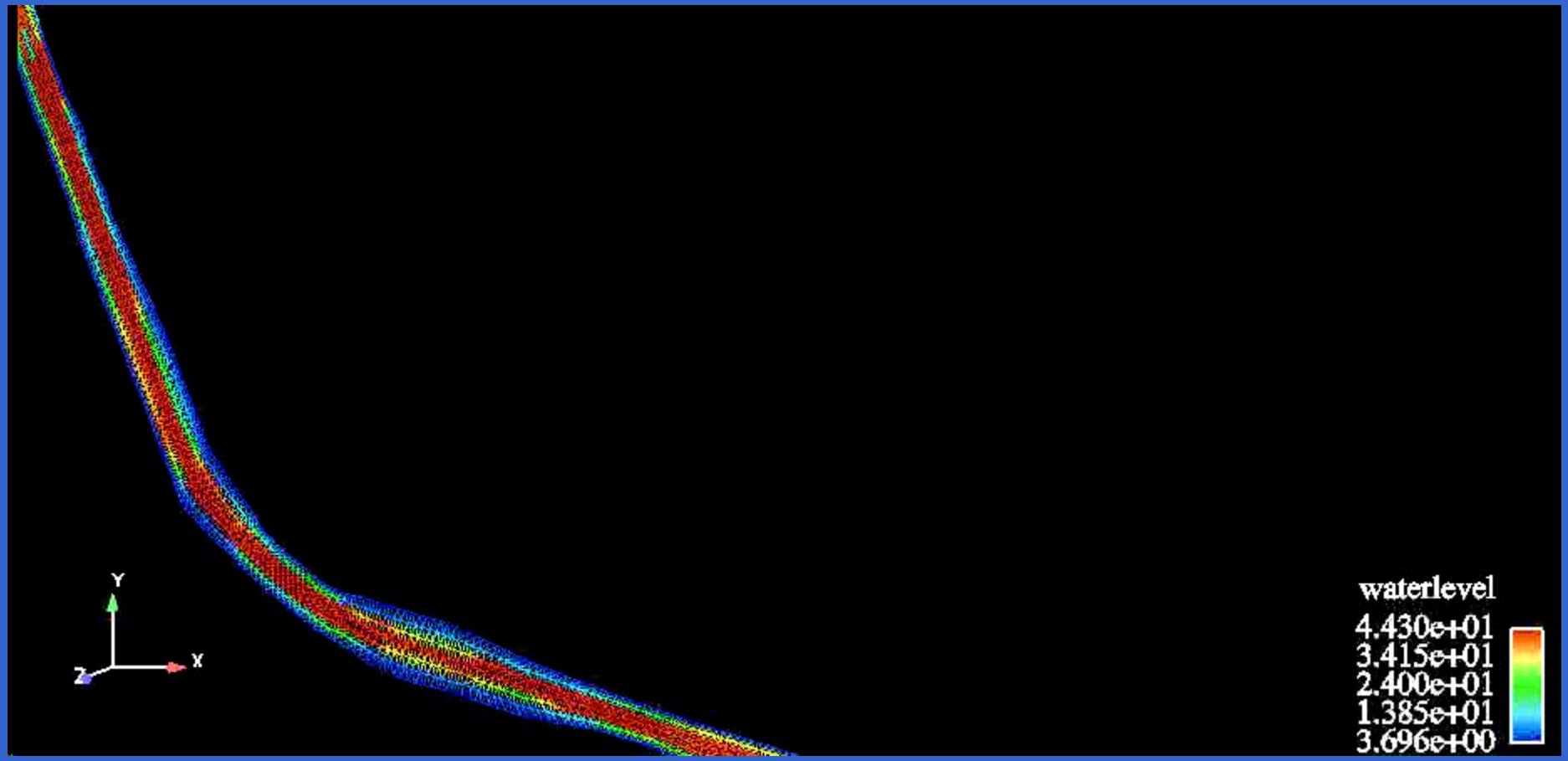


Supercritical Contraction

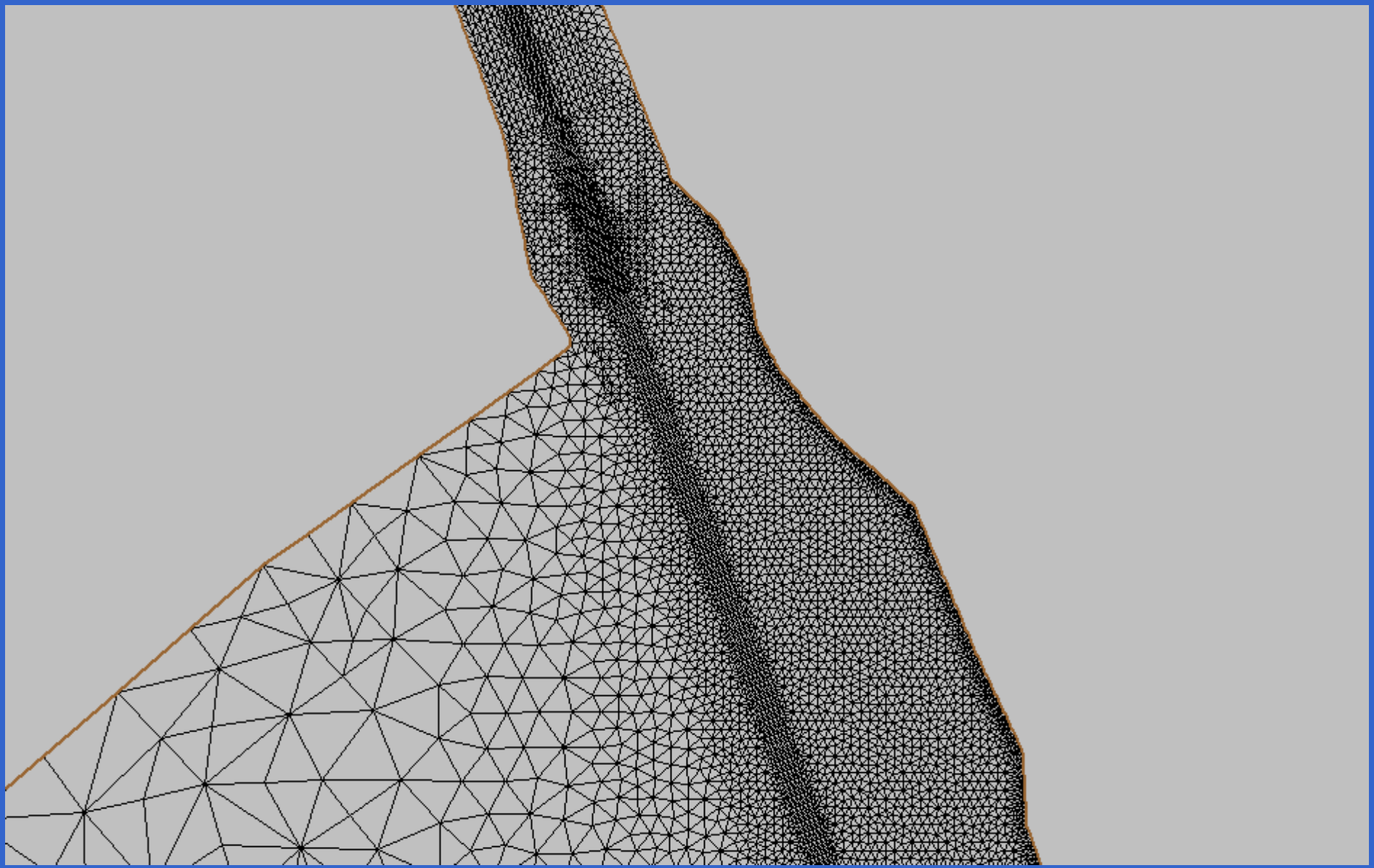


VML and ADH Test

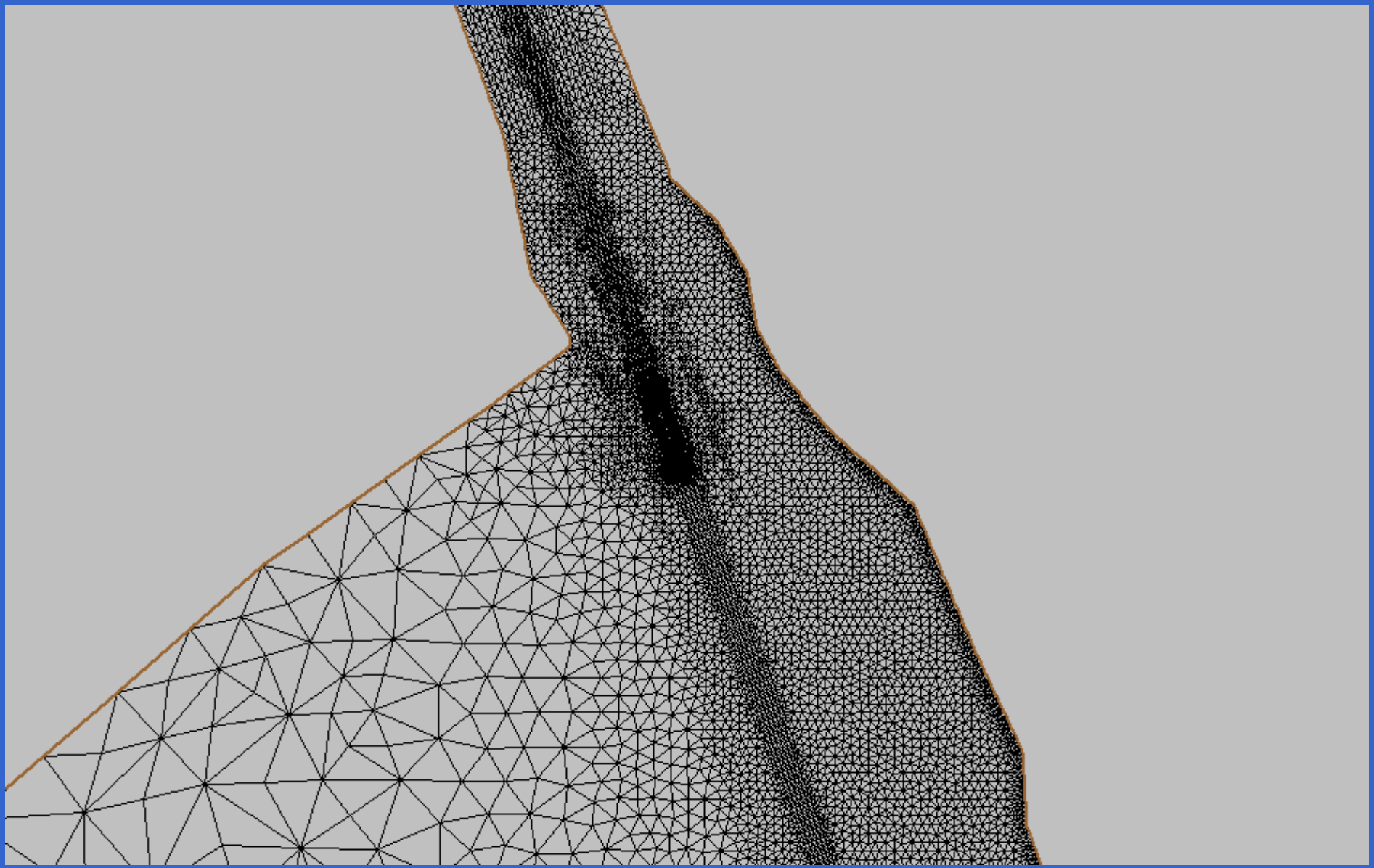
Sabine-Neches Waterway



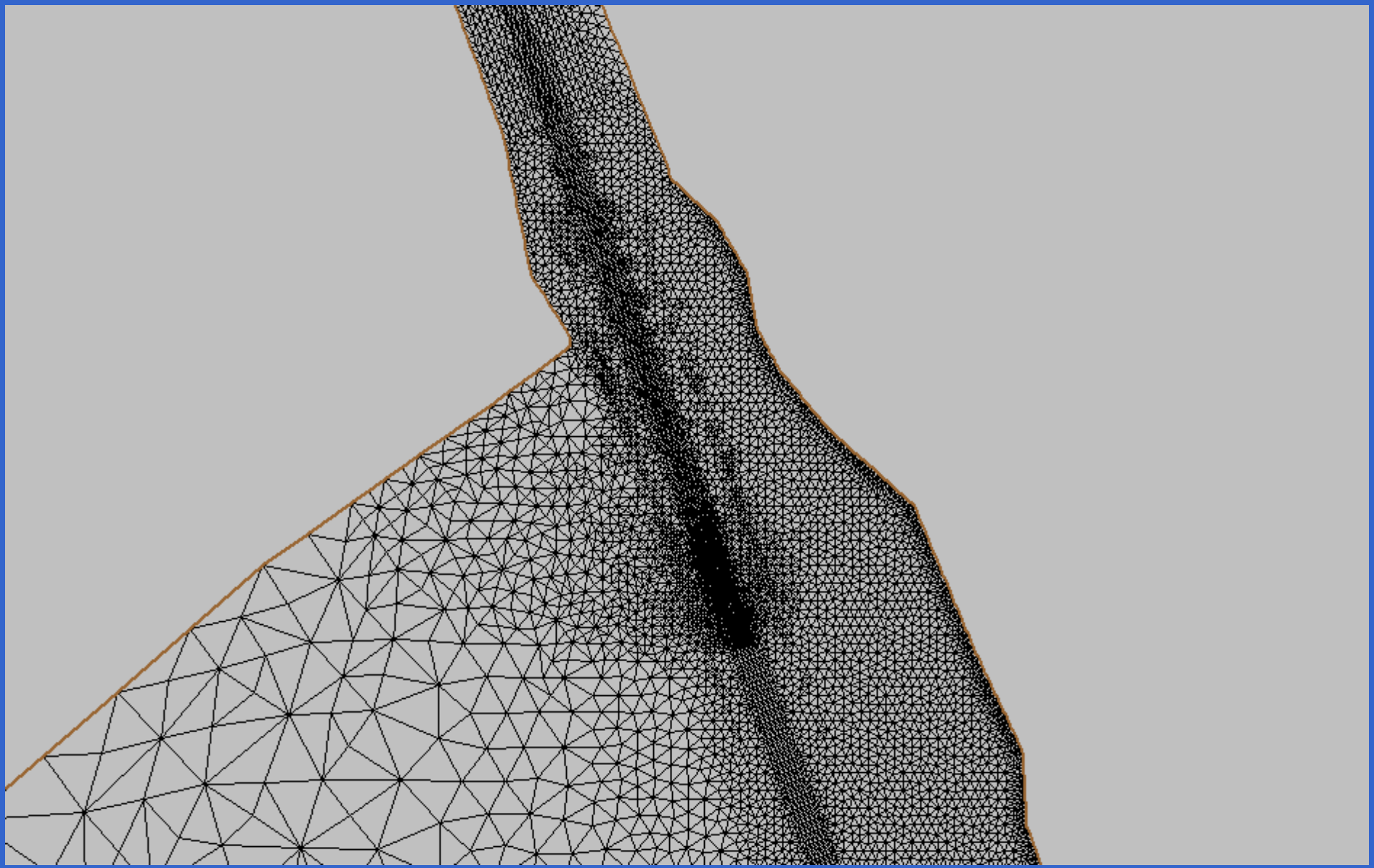
Adaption 1



Adaption 2



Adaption 3



Needed Features

- Add moving pressure fields - VML
- Error Indicators for Adaption
- Sediment entrainment under vessel

Summary

- Standard shallow water equations appropriate for drawdown and transverse stern wave estimates
- Represents strong bores/jumps correctly, but treats undular bores and weak jumps as if they were strong
- Hivel2D unstructured, static grid, model of hydrodynamics
- ADH unstructured, adaptive grid, parallel, model of hydrodynamics and sedimentation
- VML moves multiple pressure fields and available for any hydrodynamic model.