Detailed Modeling with 2D Flow Areas

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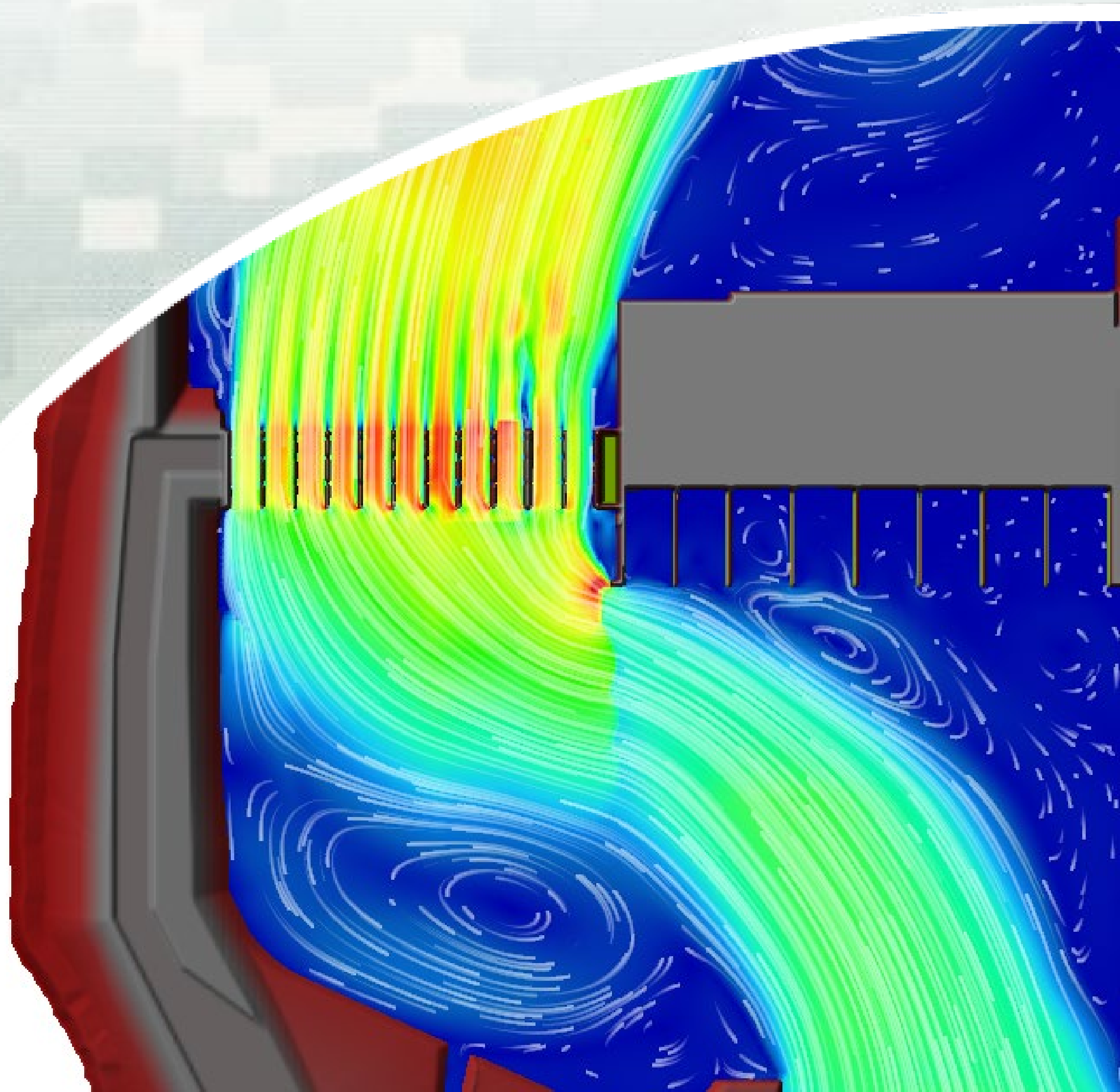


US Army Corps of Engineers

Objective

- The purpose of this lecture is to show examples of detailed 2D models that were developed with HEC-RAS, and to discuss how they were developed and the requirements to have them work correctly.

- The following examples will be shown:
  - Instantaneous Dam/Levee Breach into a building
  - Super Elevation around a Sharp Bend
  - Tidal Louisiana Example
  - Detailed Bridge Modeling
  - Elevated Structure with piers in the floodplain
  - Pump Station with Gate Openings

2D Hydraulics

- **Mass Conservation** (Continuity)

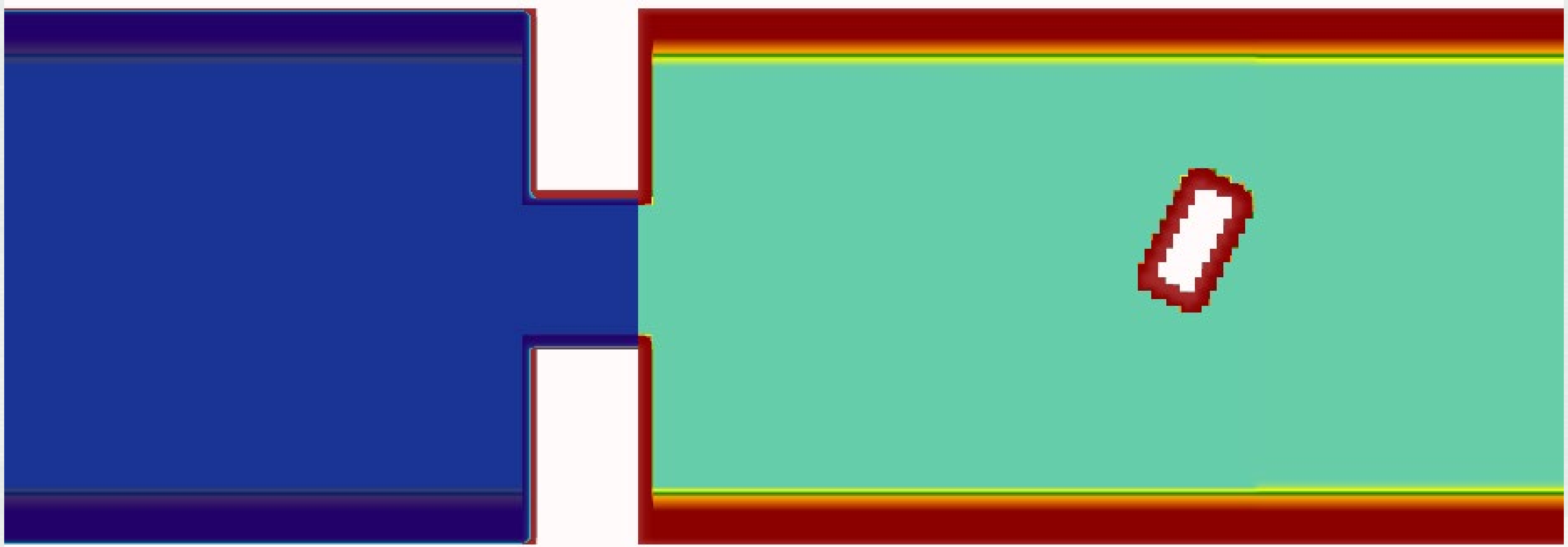
- **Full Momentum Equation** (SWE - Shallow Water Eqns.)
  - Gravity and Friction
  - Hydrostatic pressure
  - Acceleration (local and convective)
  - Turbulent eddy viscosity (optional)
  - Wind Forces (optional)
  - Coriolis term (optional)

- **Diffusion Wave Equation**
  - Gravity and Friction
  - Hydrostatic pressure

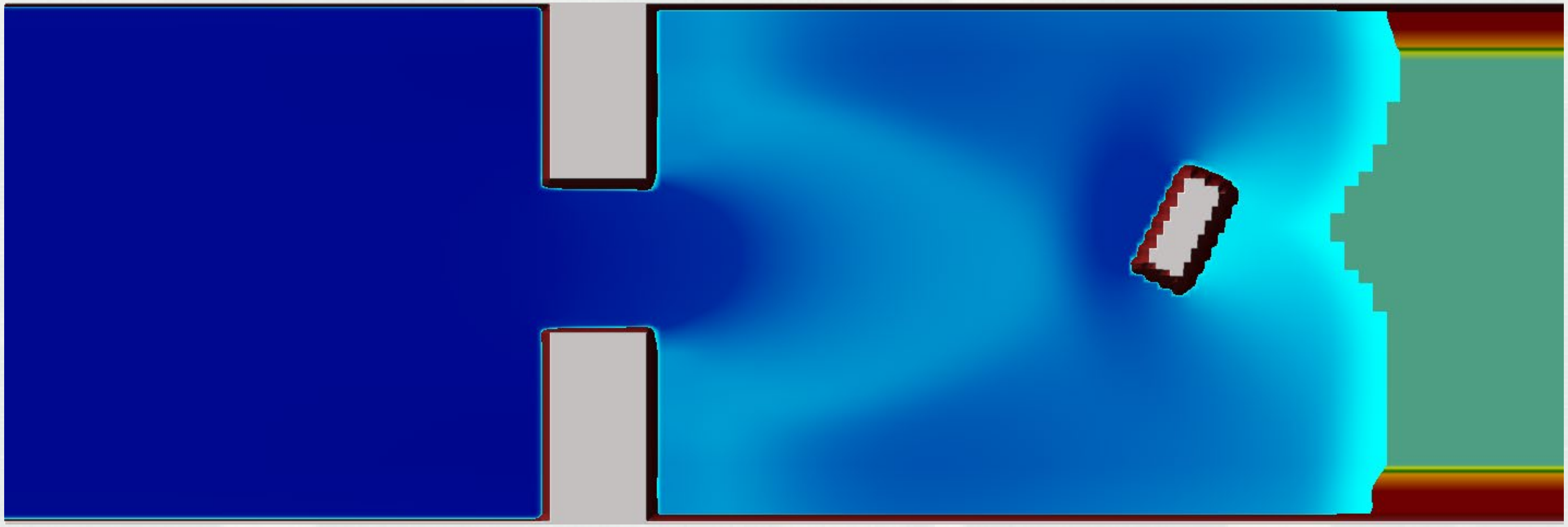
Instantaneous Dam/Levee Break

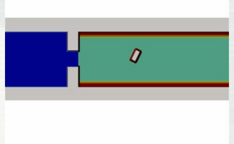
- Equation set = Full Saint Venant, SWE
- Grid Size = 2 m X 2 m (36492 cells)
- Time step = 0.5 to 2.0 variable time step
- Starting Pool Elev = 8 m (26.24 ft)
- Starting Condition = Dry downstream
- Breach Time = Instantaneous

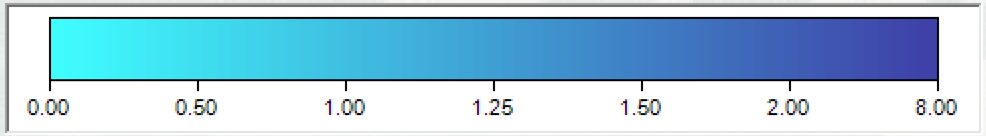
Theta = 0.8
Eddie Viscosity Coefficients D_L and D_T = 0.35
Dimensions: 75 m X 2000 m
Slope = Flat
Simulation Time Window = 30 minutes
Computational Time = 37 sec



Instantaneous Dam/Levee - Animation







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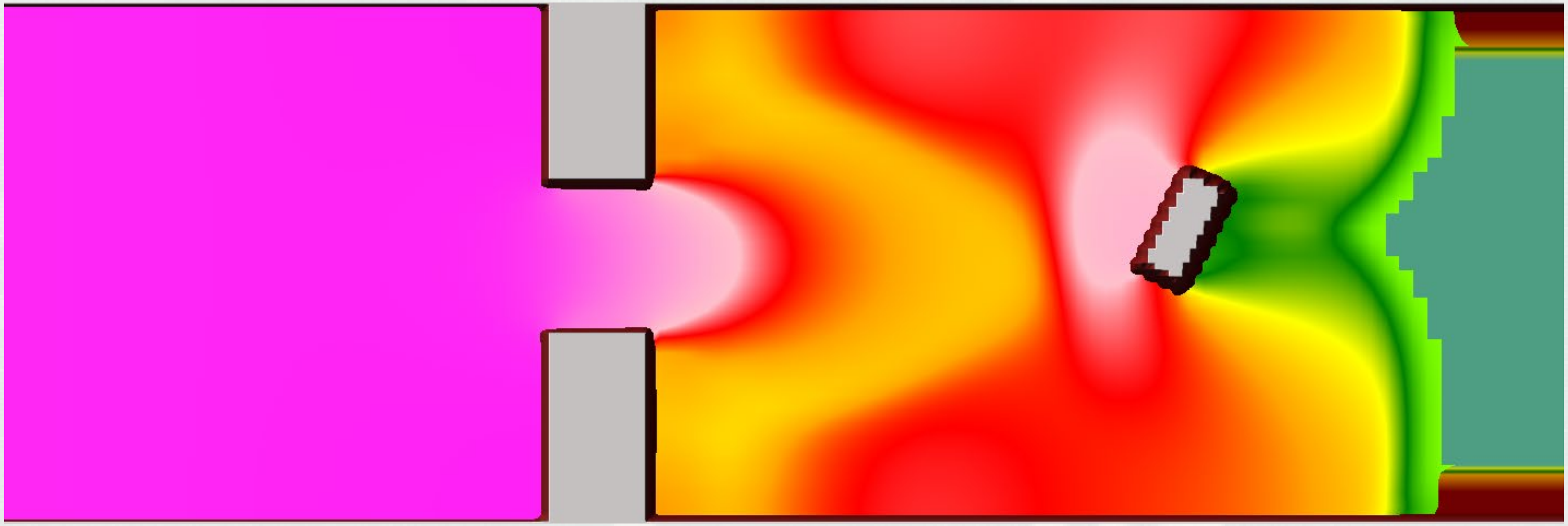
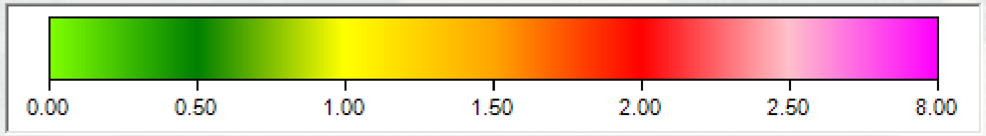
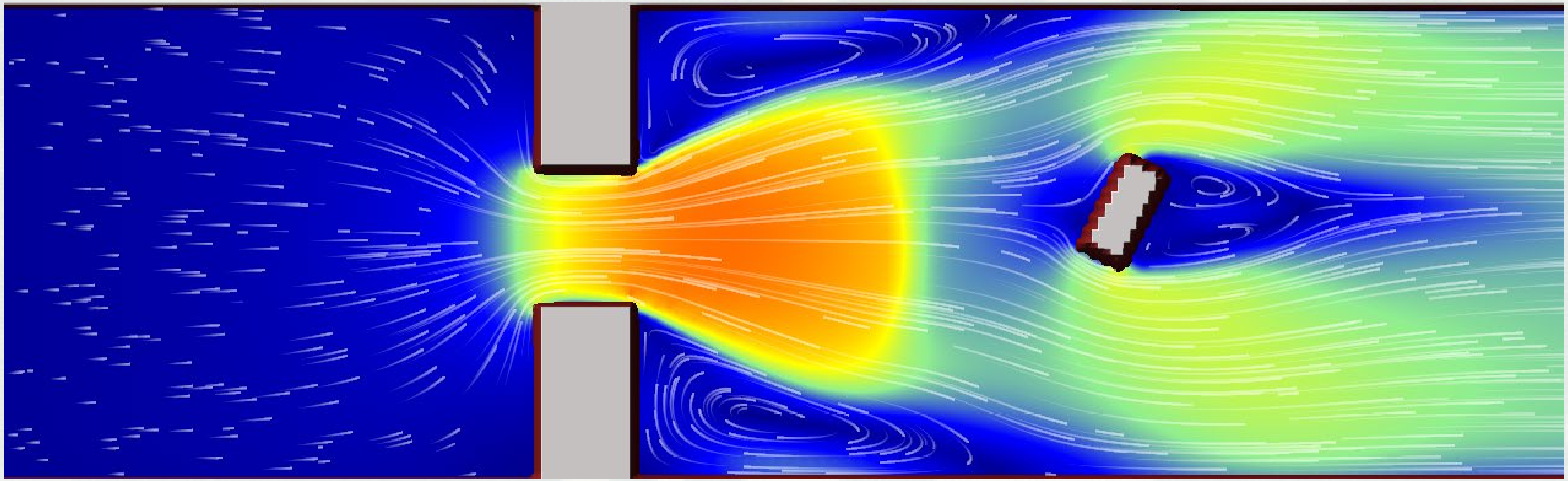
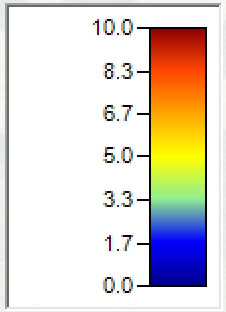
Instantaneous Dam/Levee Breach WSE Animation

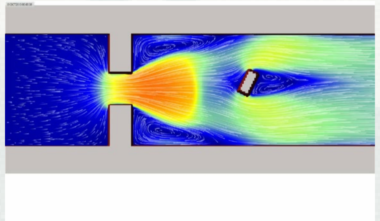




Instantaneous Dam/Levee Breach Velocity (m/s) - Animation



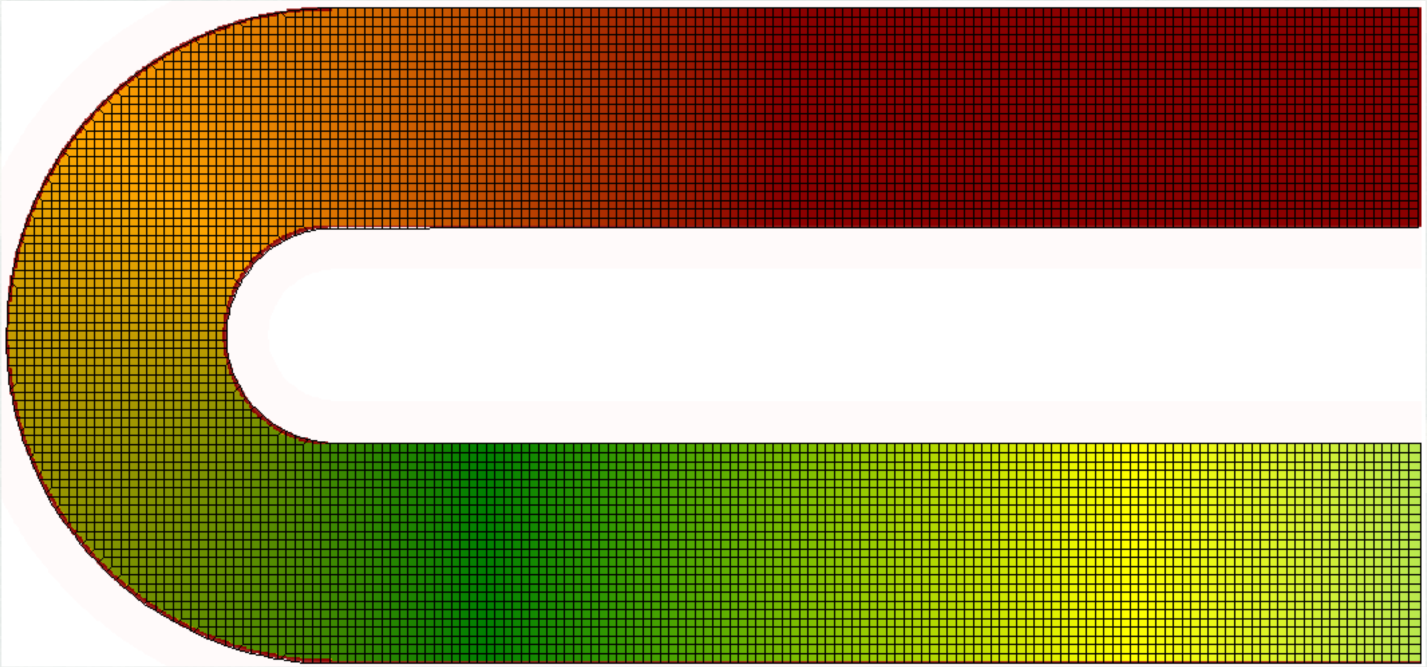




Super Elevation around a 180 Degree Bend

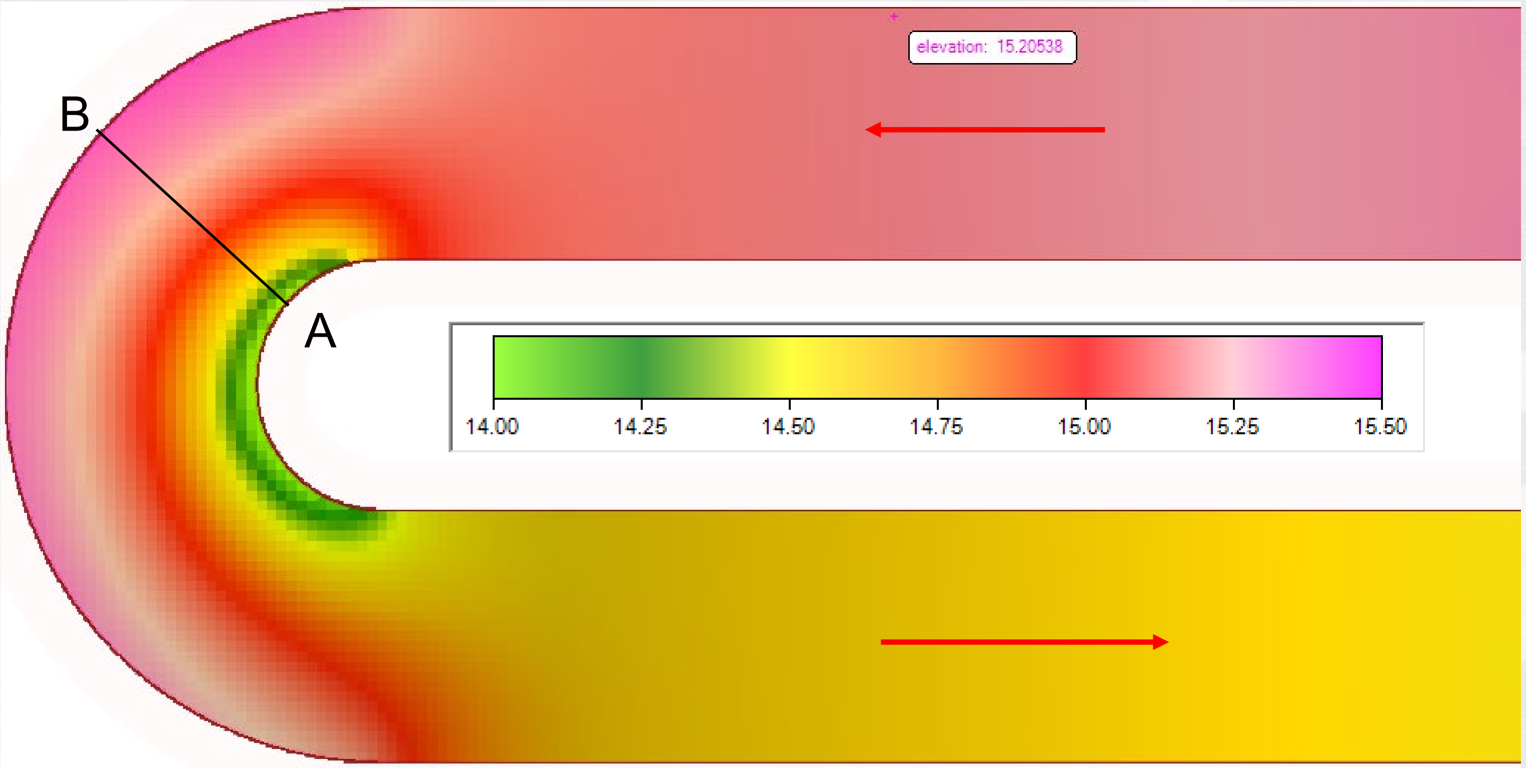
- Equation set = Full Saint Venant
- Grid Size = 4 ft X 4 ft
- No. Cells = 8177
- Time step = 0.5 seconds
- Event Duration = 4 hours
- Run Time = 6 minutes
- Theta = 0.8
- Eddie Viscosity Coefficients = 0.5

- Rectangular Channel with width = 100 ft
- Slope = 1 ft/mile
- Water Depth = around 5.0 ft
- Flow Rate = 3000 cfs

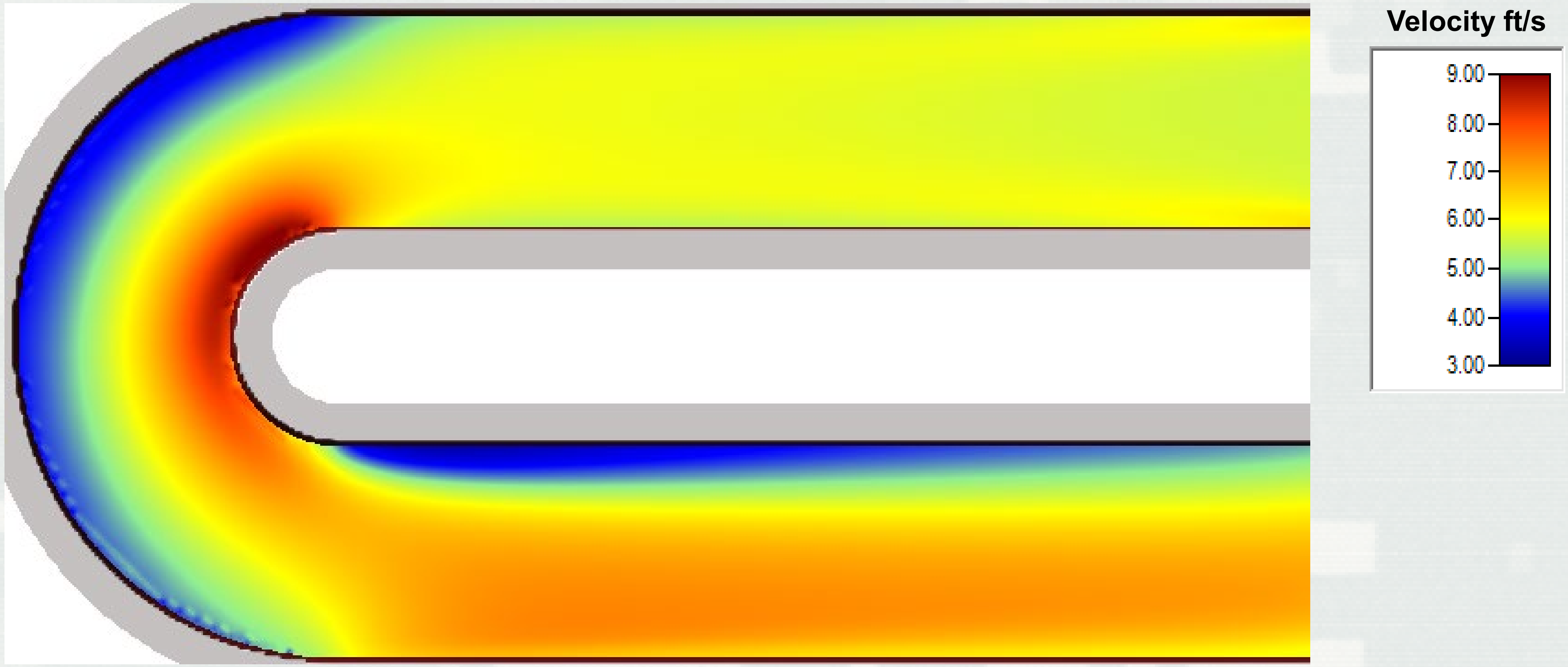


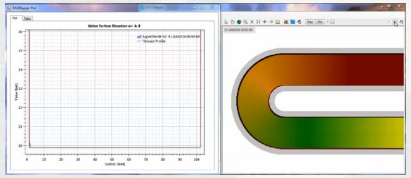
Super Elevation around a Bend - Results

- Computed Super Elevation from A to B = 1.44 ft
- Equation Predicted (Chow's Open Channel Hydraulics) = 1.5 ft
- Velocity at Approach = 6.2 ft/s
- Max Velocity on Inside of Bend at point A = 9.0 ft/s
- Min Velocity on outside of Bend at point B = 3.9 ft/s

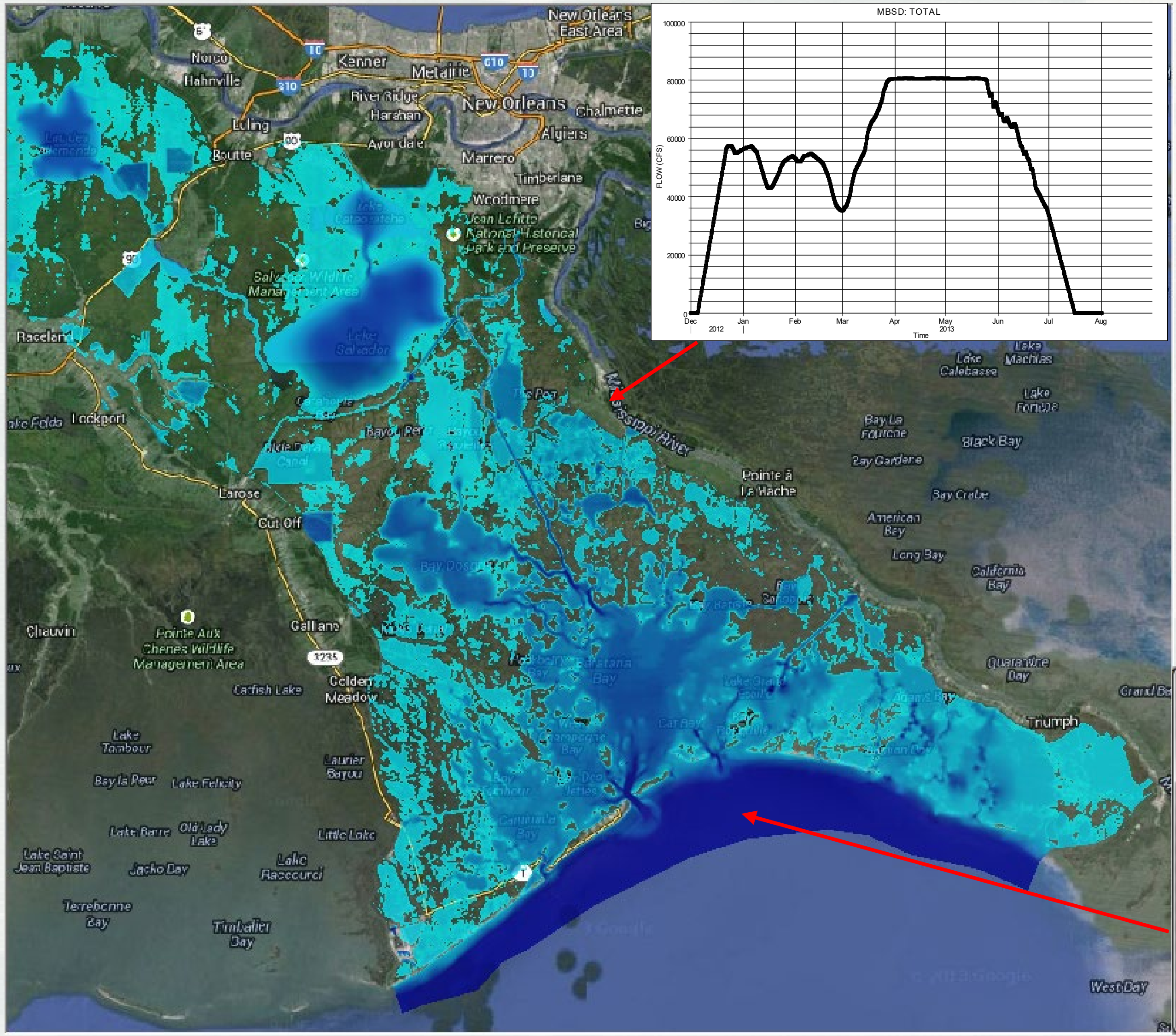


Super Elevation around a Bend - Animation





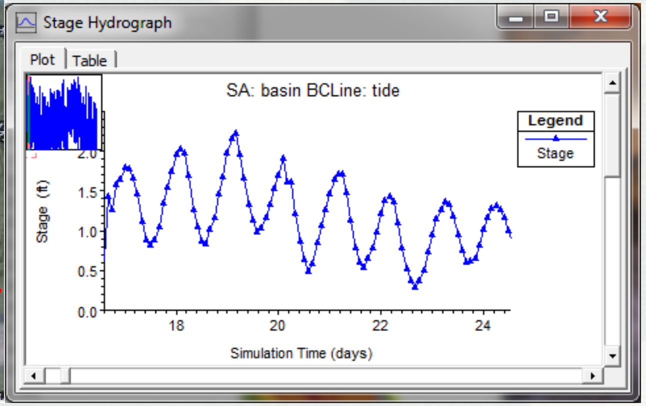
Tidal Louisiana – Boundary Conditions



Diversion Inflow Hydrograph:
Zero to 80,000 cfs

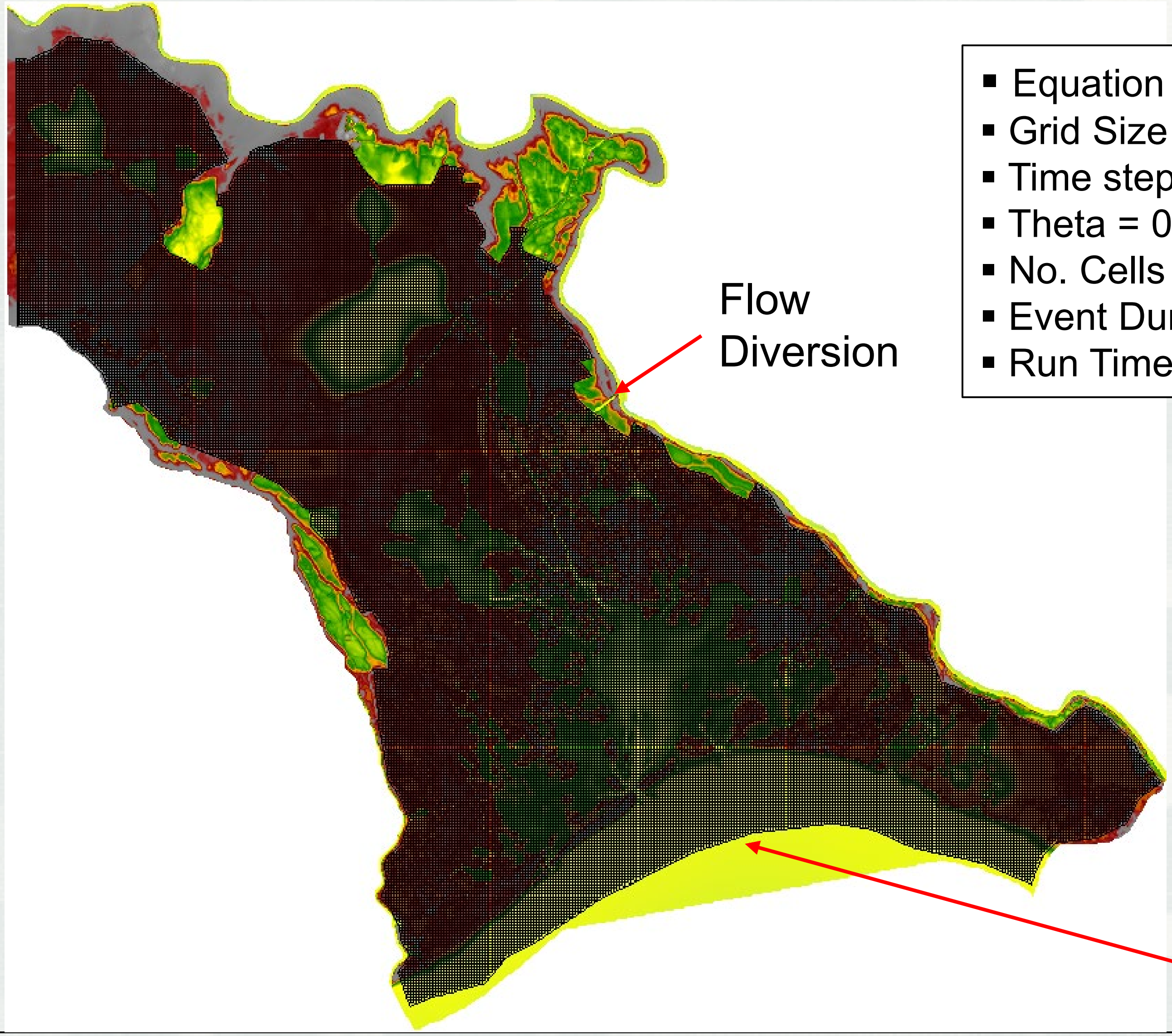
Downstream Boundary:
Measured Stage Hydrograph representing the Ocean tide

Initial Conditions:
Restart File from previous run



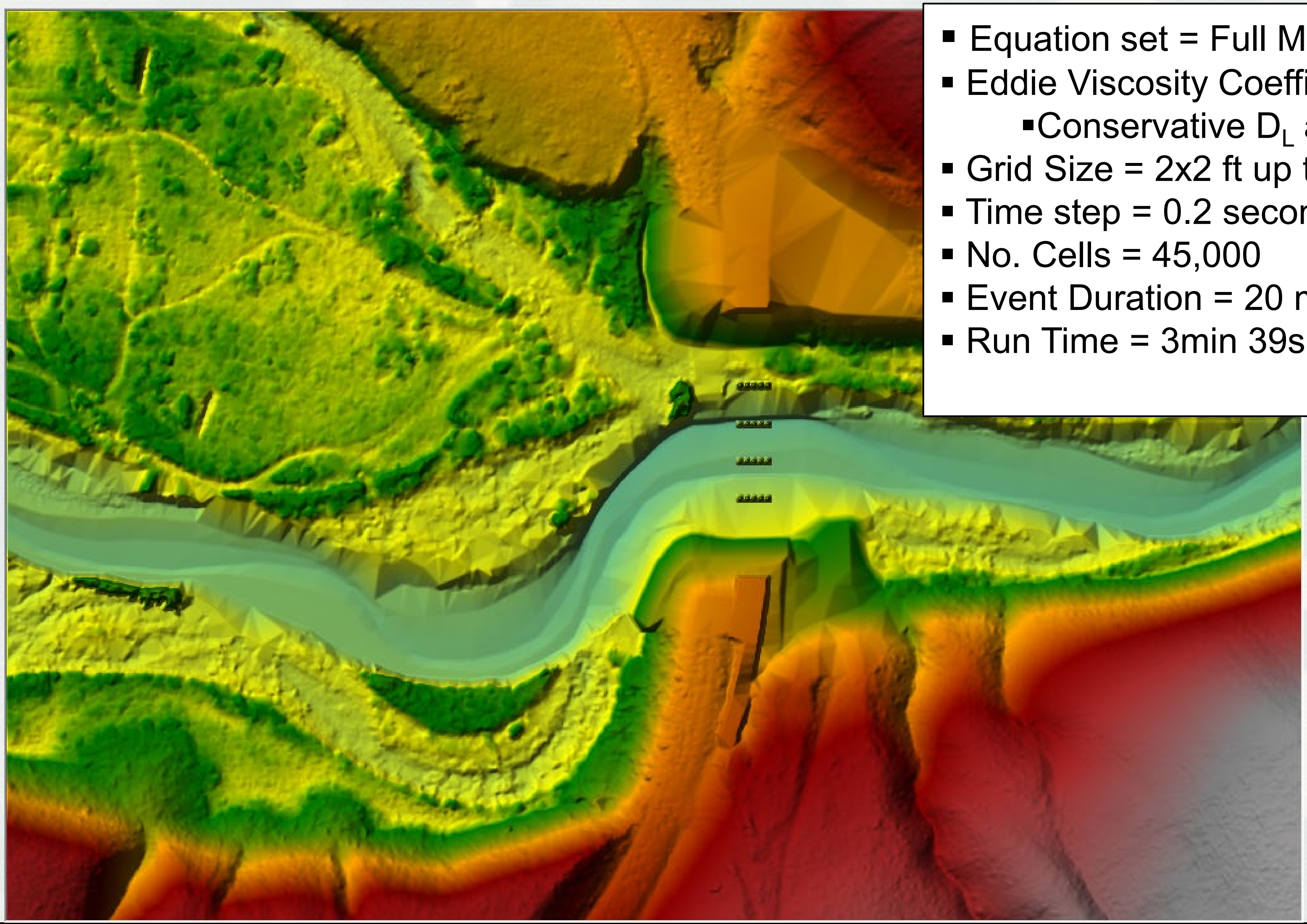
Tidal Louisiana - Numeric's

- Equation set = Full Saint Venant
- Grid Size = 500 ft X 500 ft
- Time step = 2 minutes
- Theta = 0.8
- No. Cells = 211676
- Event Duration = 7 Months (210 days)
- Run Time = 1 hours 7 minutes



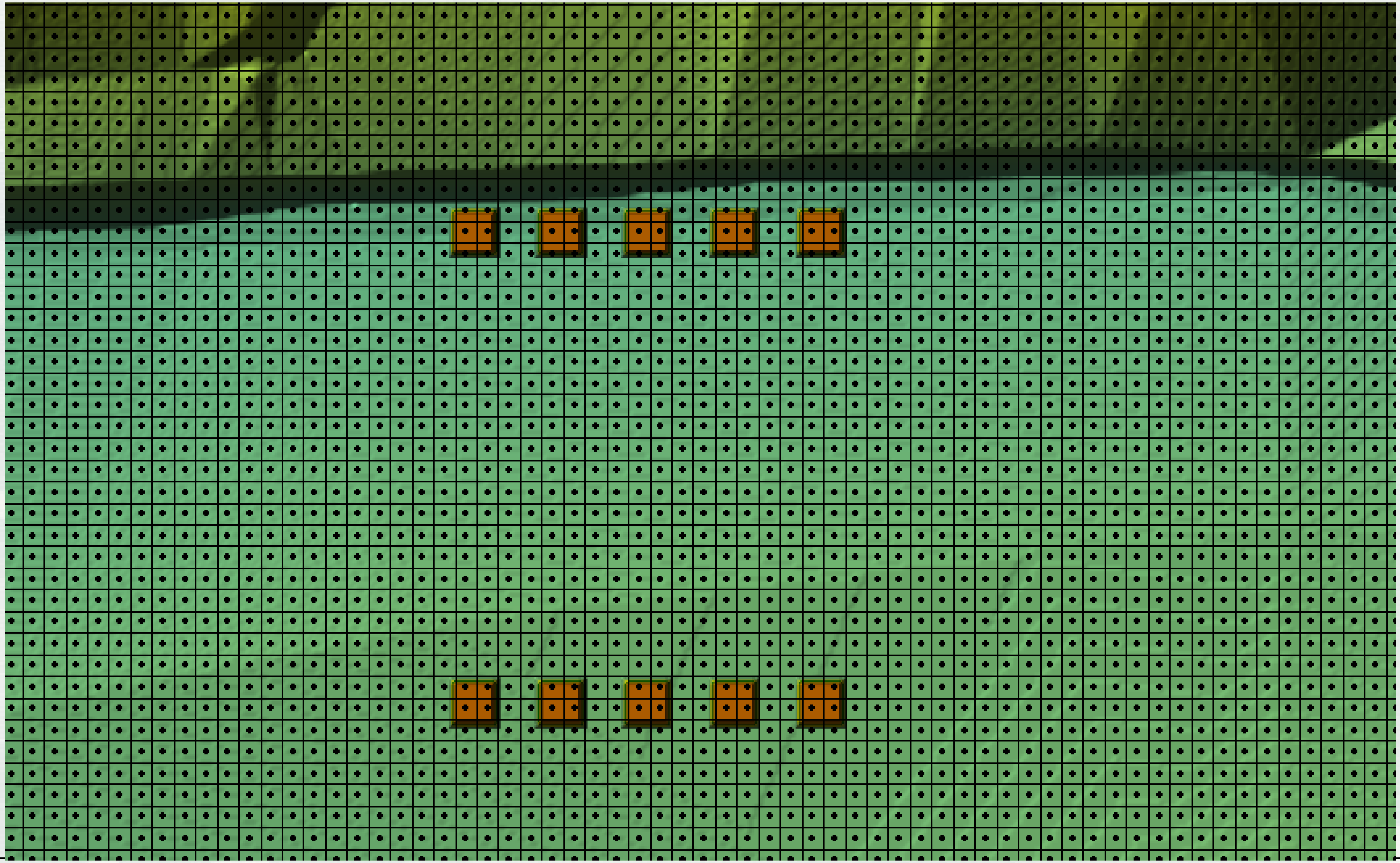
Tidal Louisiana – Animation Water Surface Elevation

Detailed Bridge Modeling

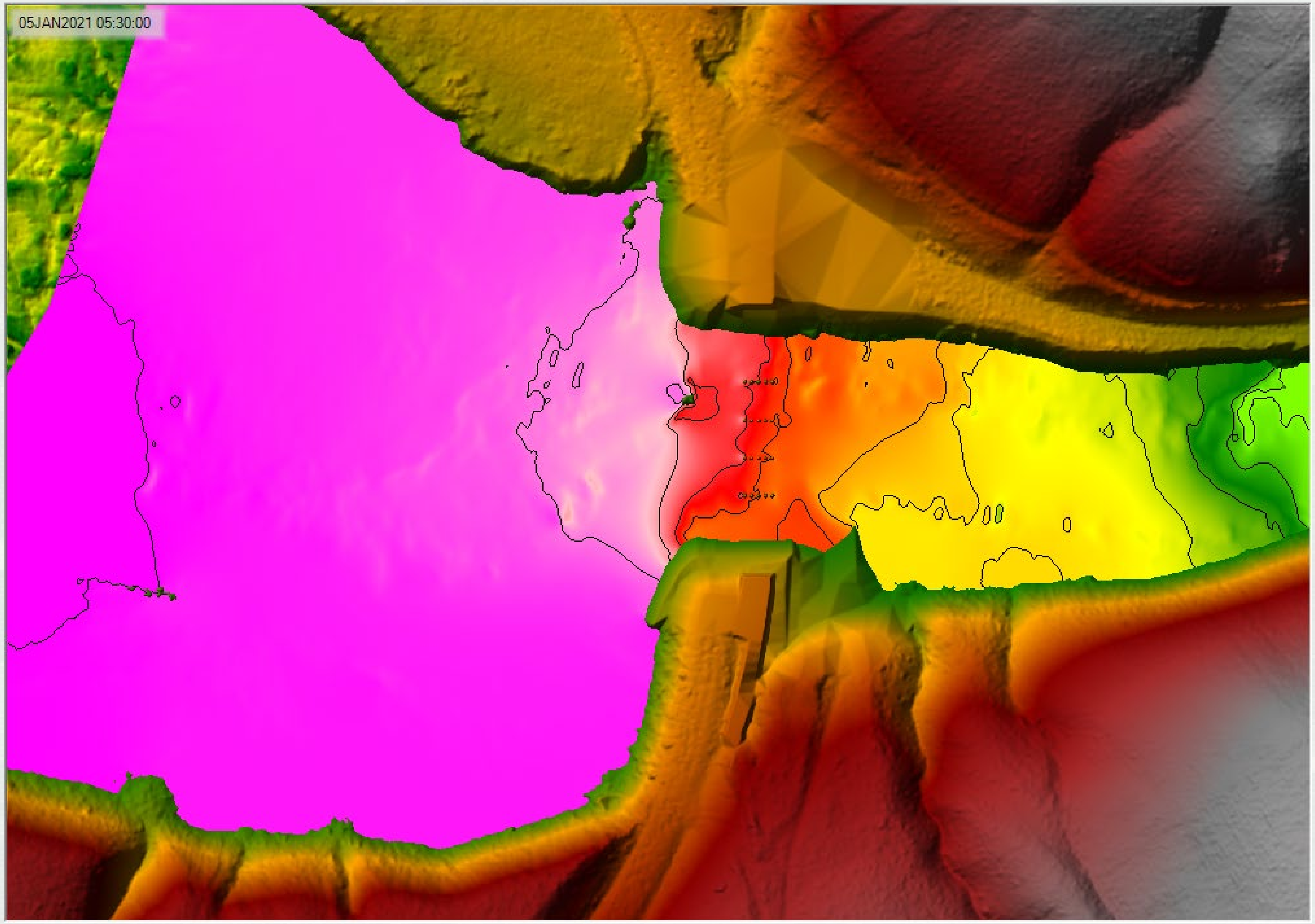


- Equation set = Full Momentum
- Eddie Viscosity Coefficient
  - Conservative D_L and D_T = 0.5
- Grid Size = 2x2 ft up to 8x8 ft
- Time step = 0.2 seconds
- No. Cells = 45,000
- Event Duration = 20 min. Steady Flow
- Run Time = 3min 39s

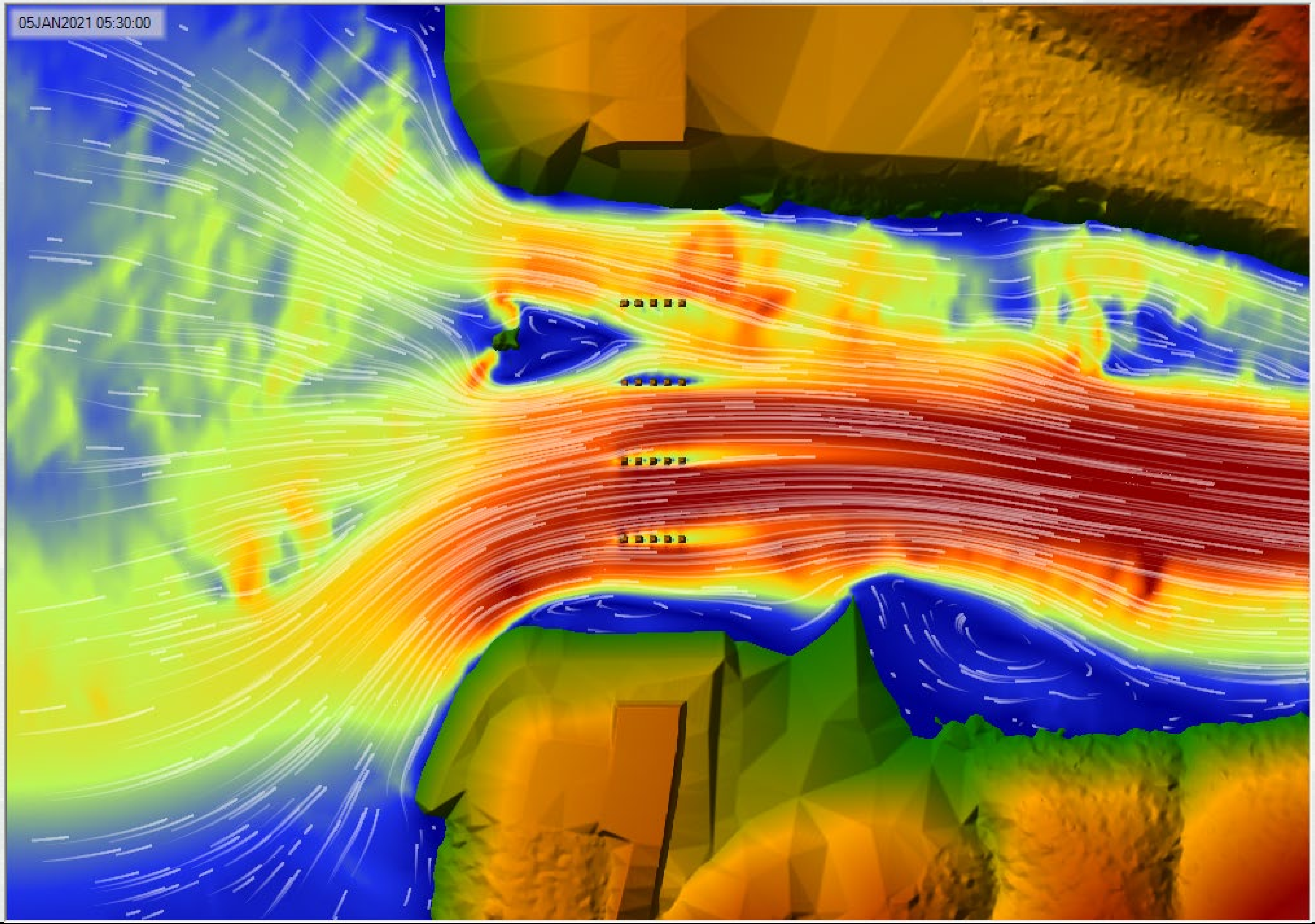
Detailed Bridge Modeling

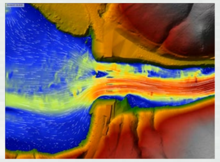


Detailed Bridge Modeling

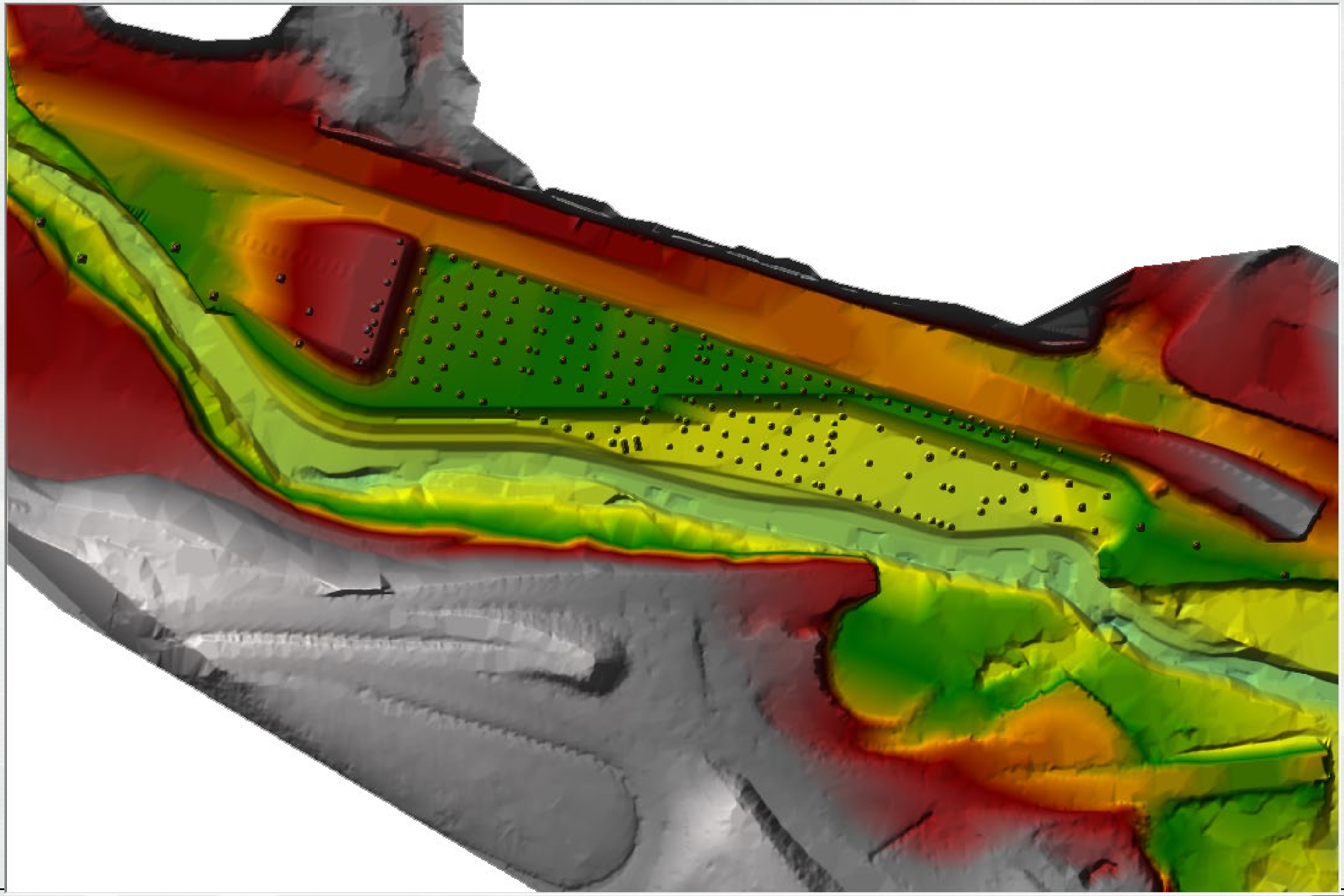


Detailed Bridge Animation

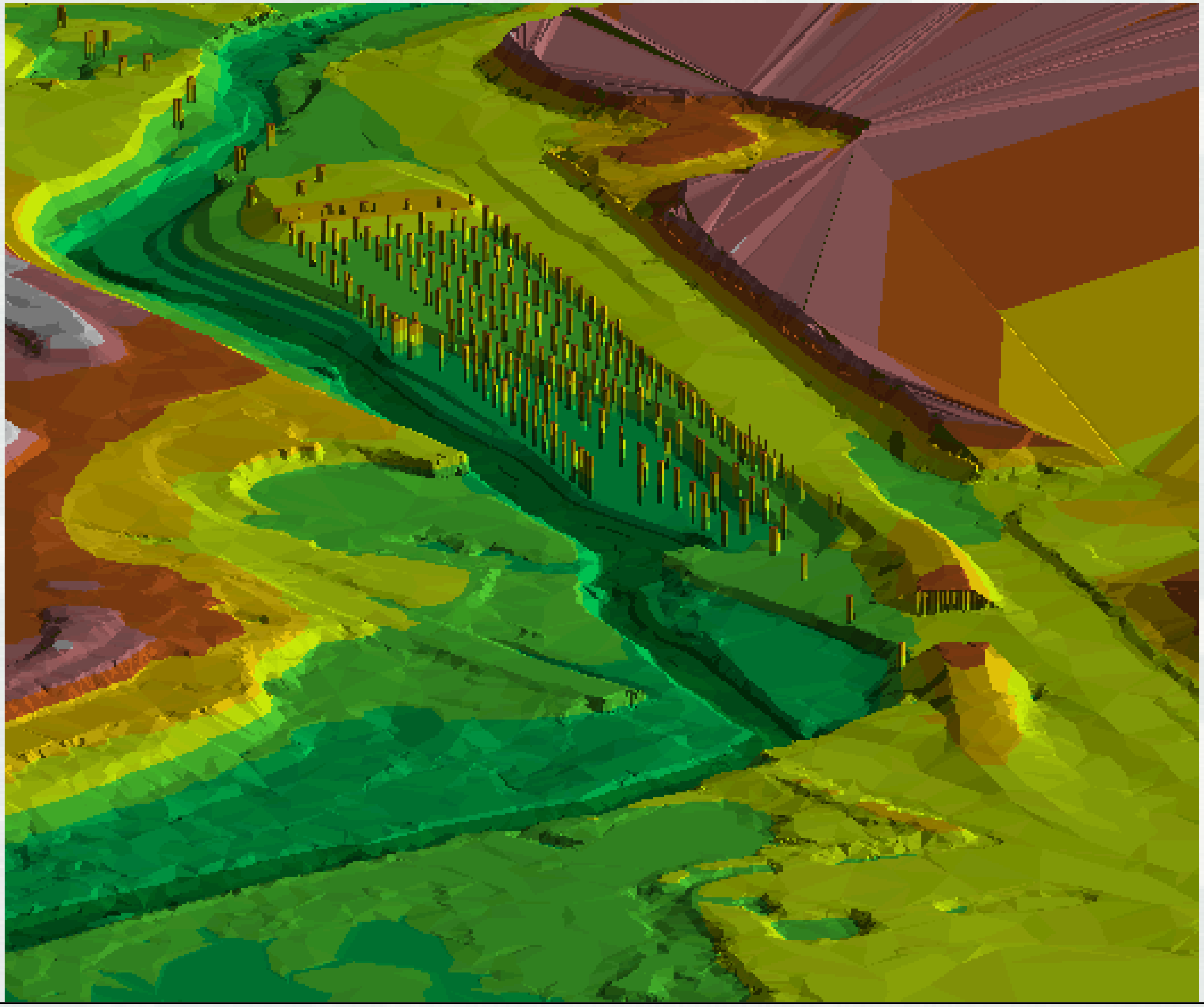




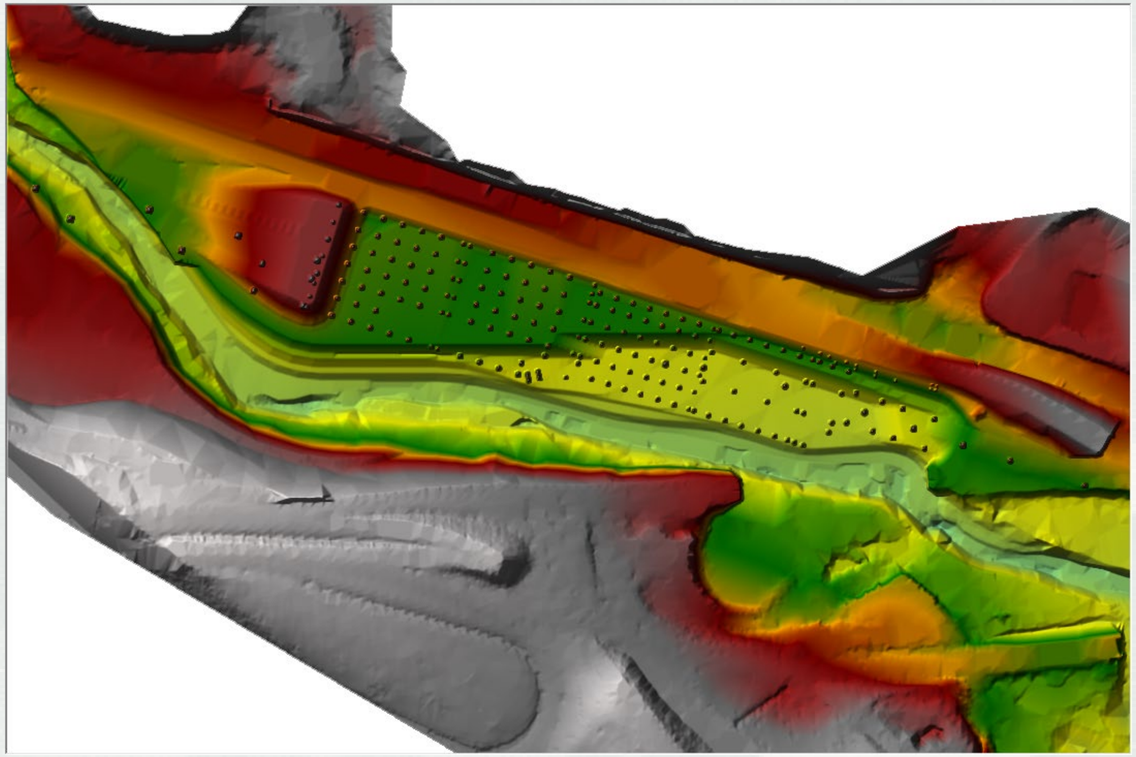
Detailed 2D Flow Area Model of Proposed Structure with Piers in Floodplain



3D View of Proposed Structure Piers

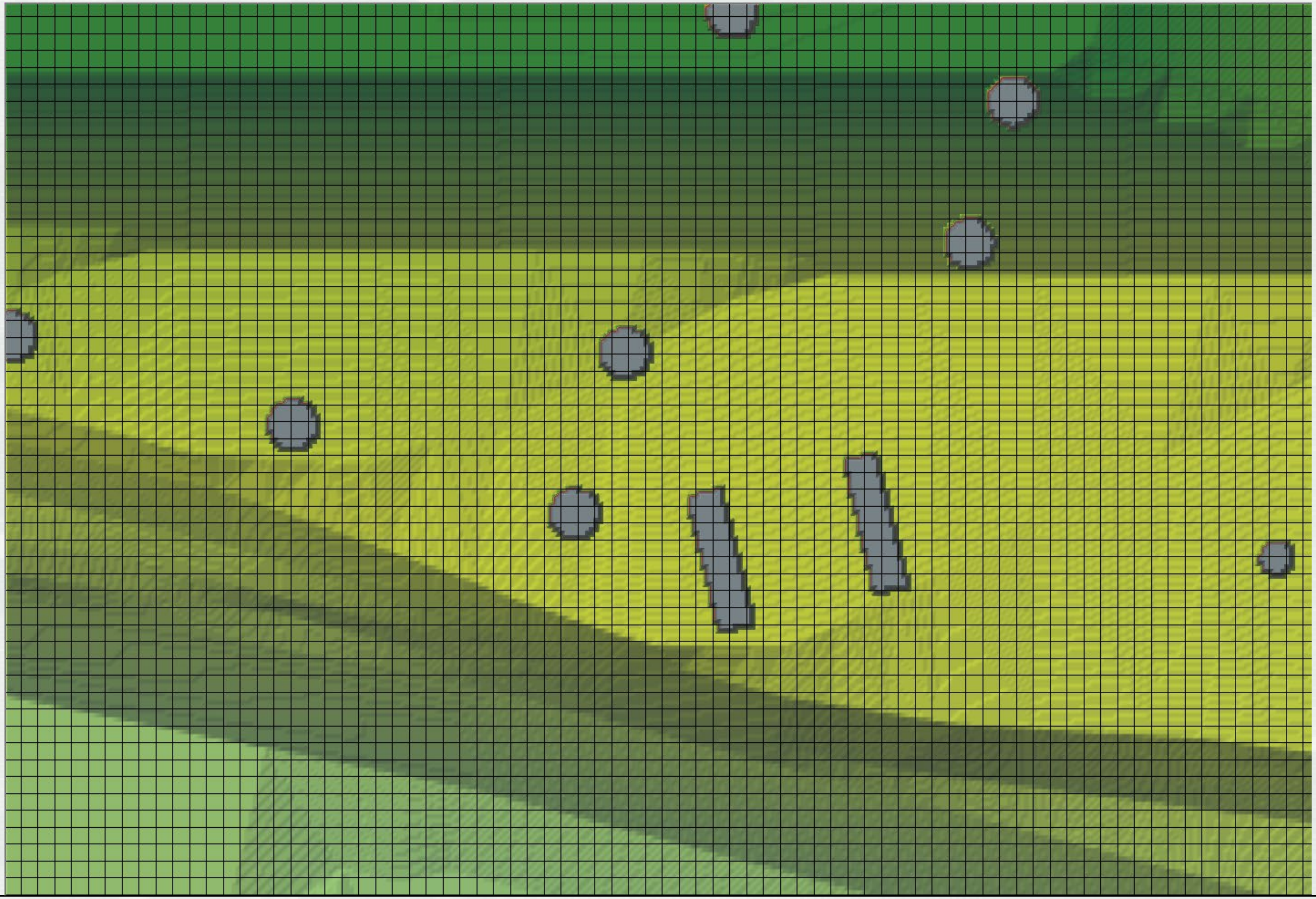


Proposed Structure with Piers - Continued

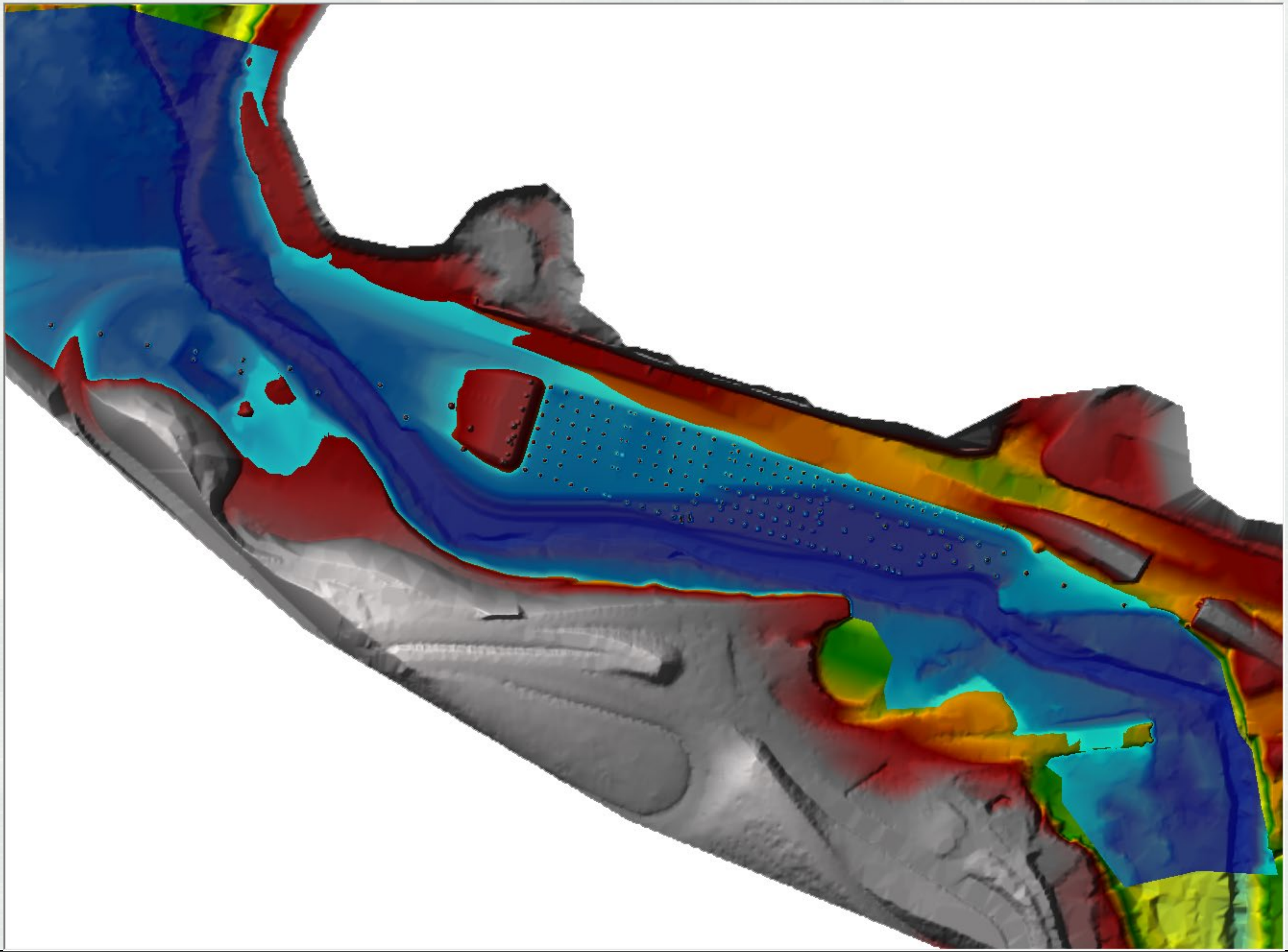


- Equations = Full Saint Venant
- Grid Size = 2 ft X 2 ft
- Time step = 0.2 second
- Turbulence – Conservative
  - D_L and D_T = 0.2
- No. Cells = 454,603
- Event Duration = 12 hours
- Run Time = 6 hours 54 minutes

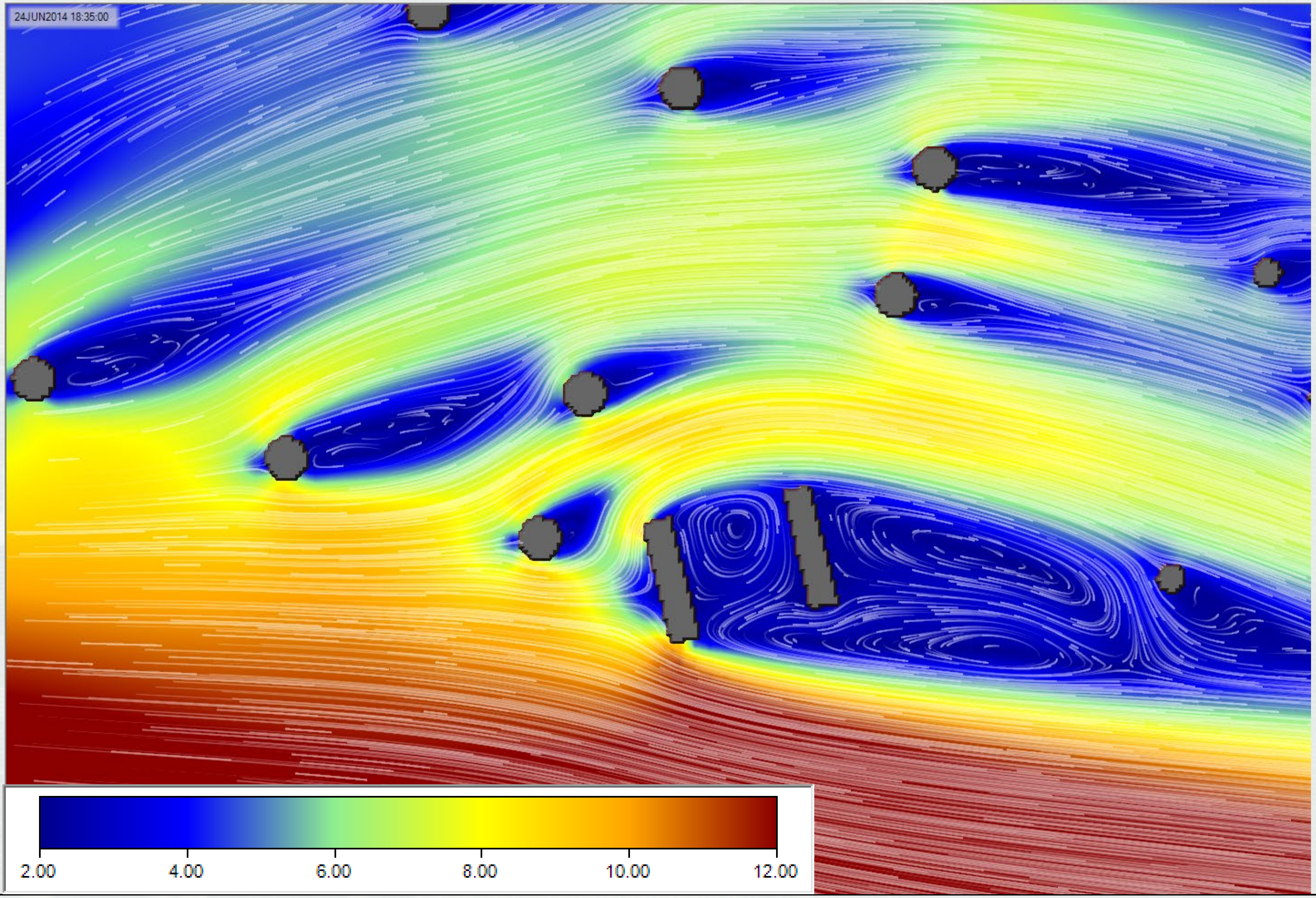
Pier/Mesh Details



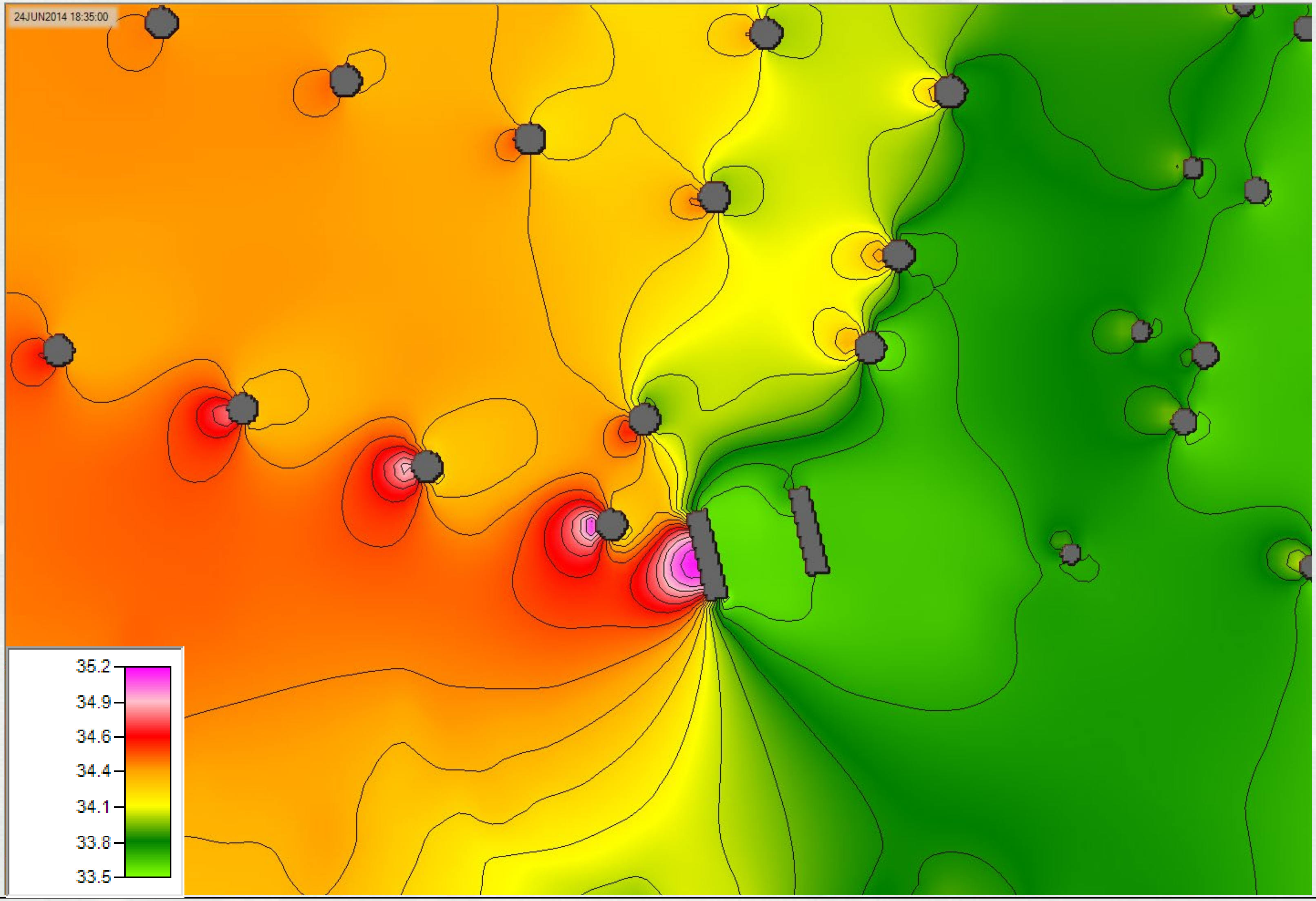
Proposed Structure with Piers - Animation



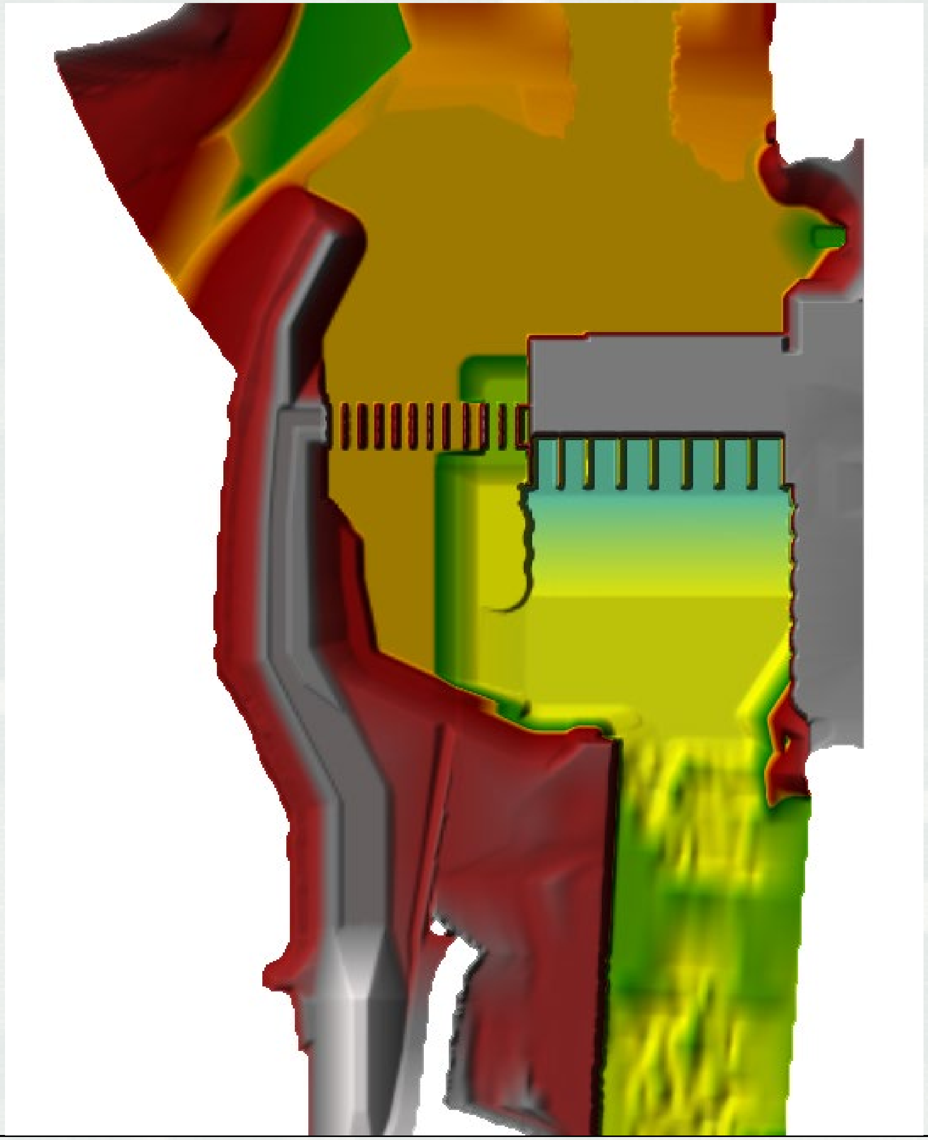
Velocity Tracking and Colored Grids



Water Surface Elevation with Contours



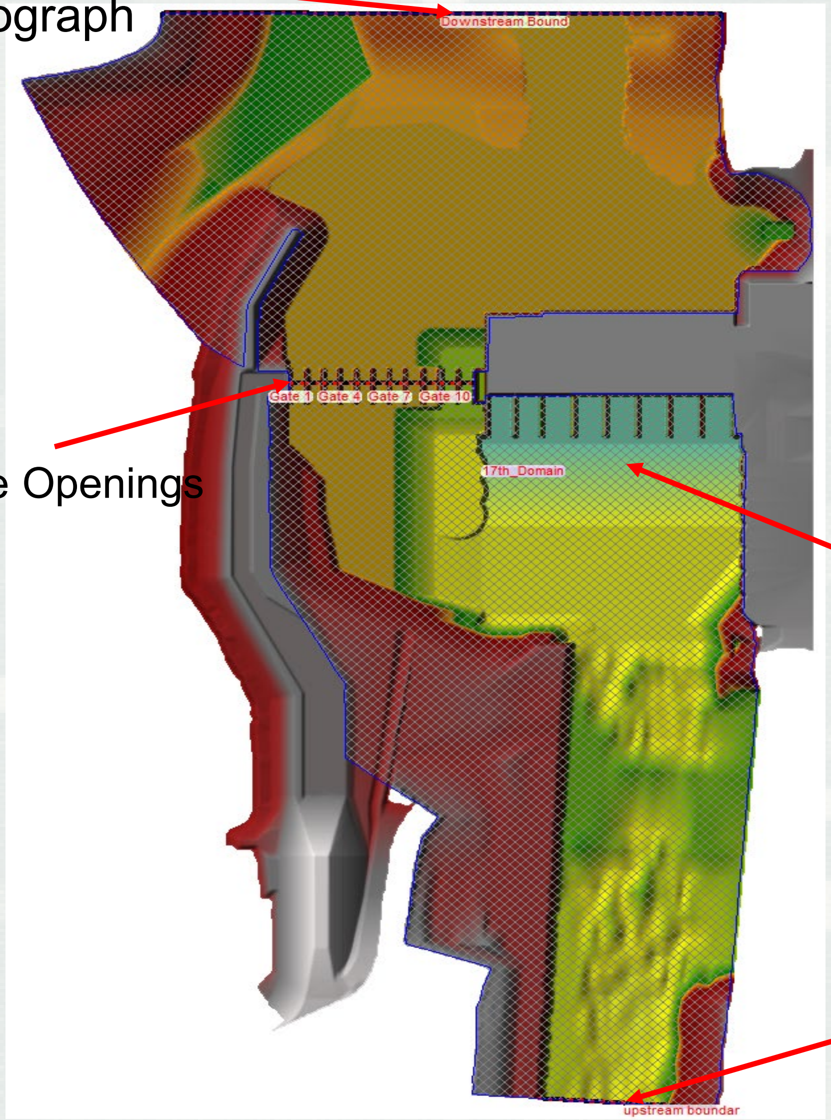
17th St. Pump Station with Gate Openings



- Equation set = Full Momentum
- Grid Size = 1x1 ft up to 4x4 ft cells
- Time step = 0.1 seconds
- Eddie Viscosity Coefficient = 0.5
- No. Cells = 104197
- Steady Flow 12500 cfs
- Event Duration = 20 minutes
- Run Time = 17 minute 4 seconds

Boundary Conditions

Downstream Stage Hydrograph



11 Gate Openings

Pump Station

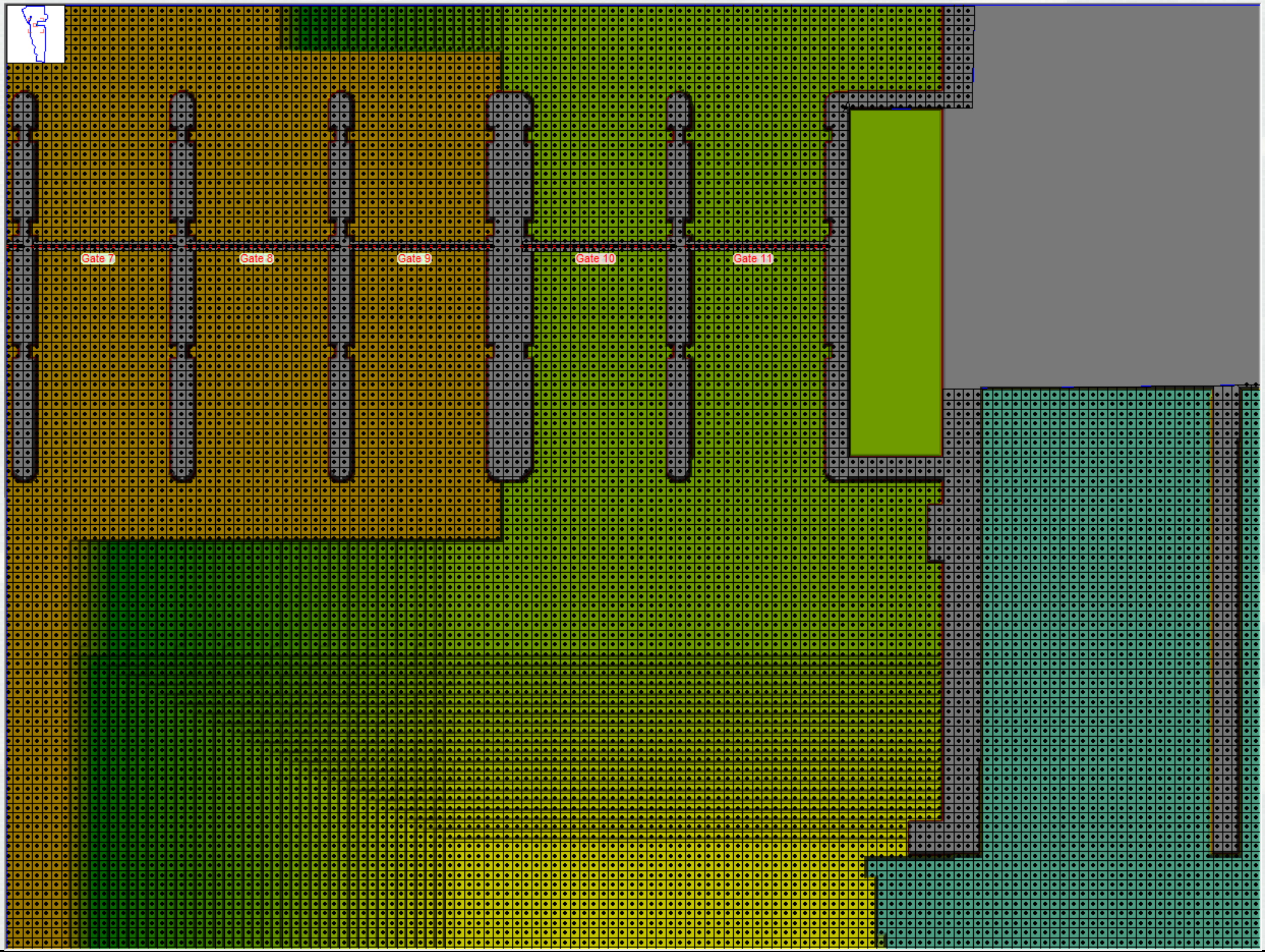
Upstream Flow Hydrograph

Upstream Flow Hydrograph:
0 to 12500 cfs over 5 minutes

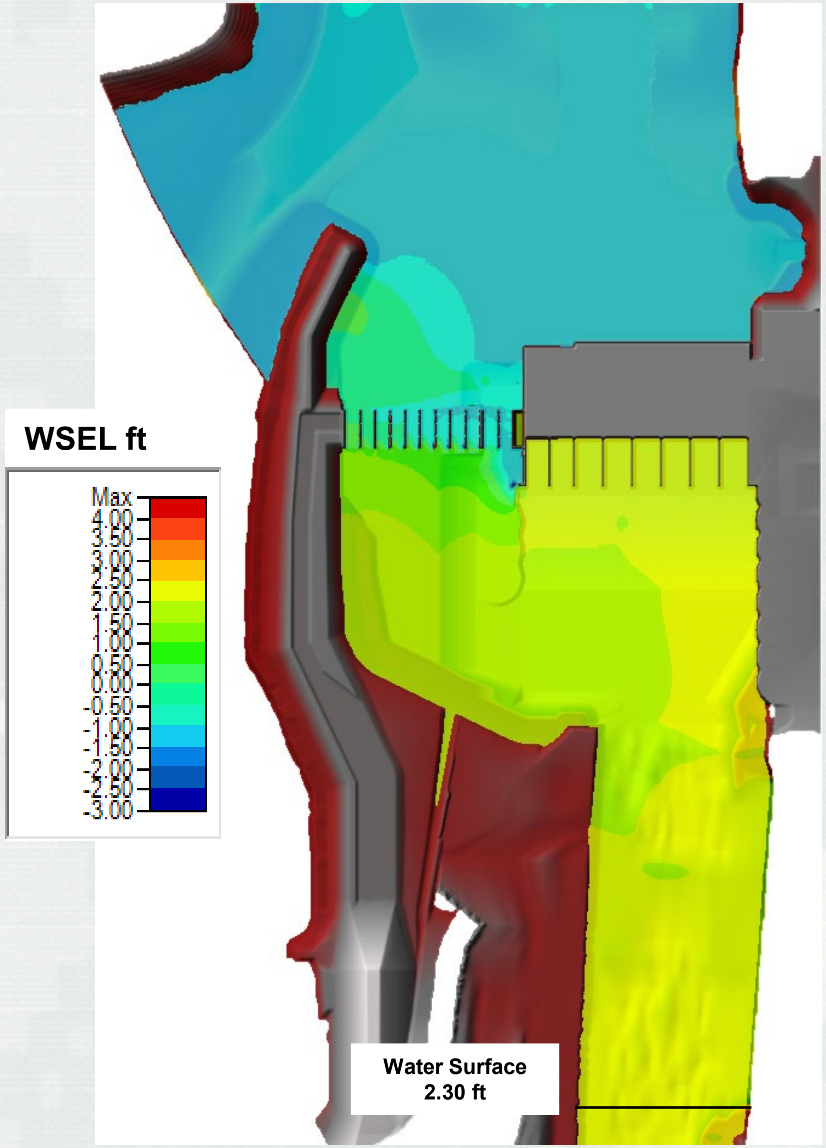
Downstream Boundaries:
Stage Hydrograph = -1.0 feet

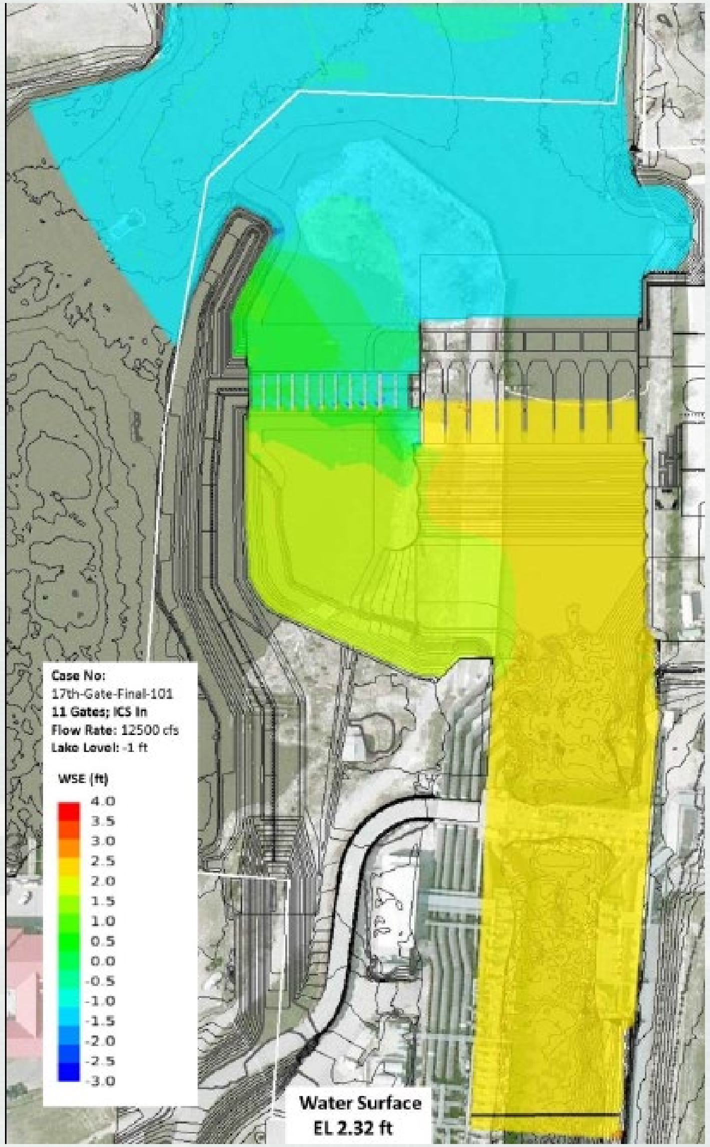
Initial Conditions:
Flat water surface at -1.0 feet

Mesh Details – Gate Openings

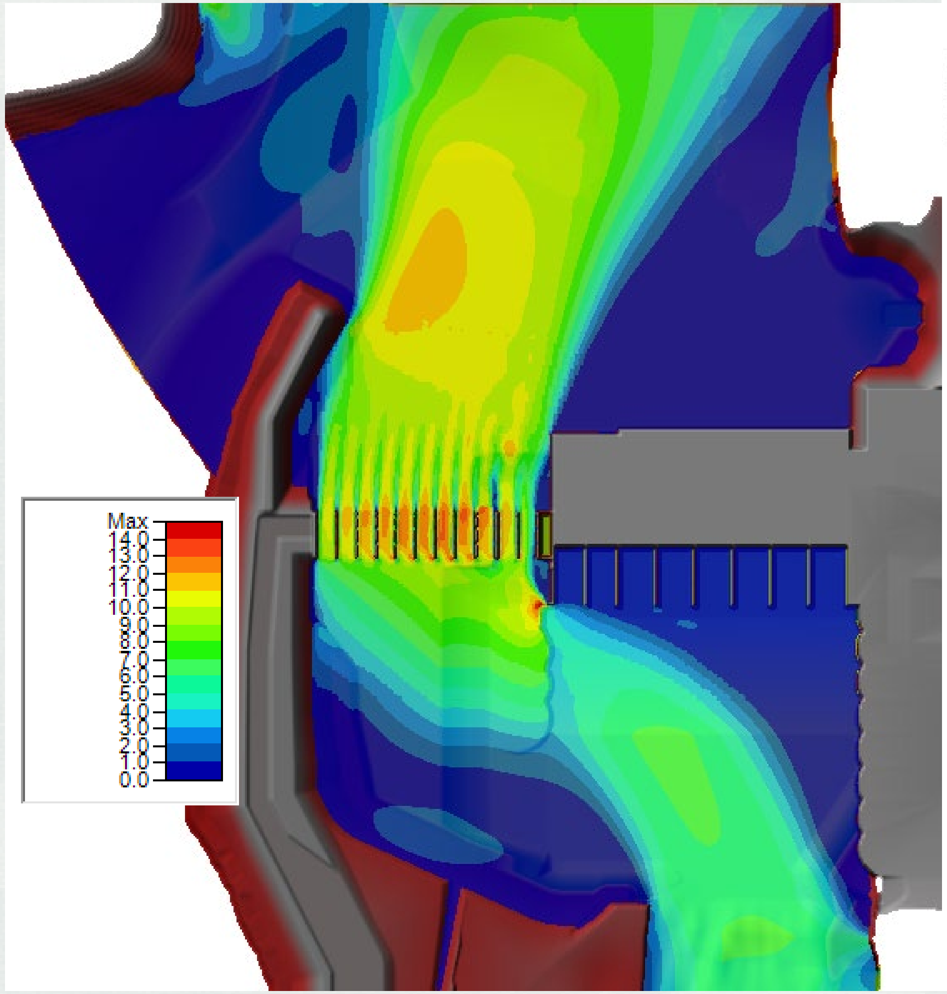


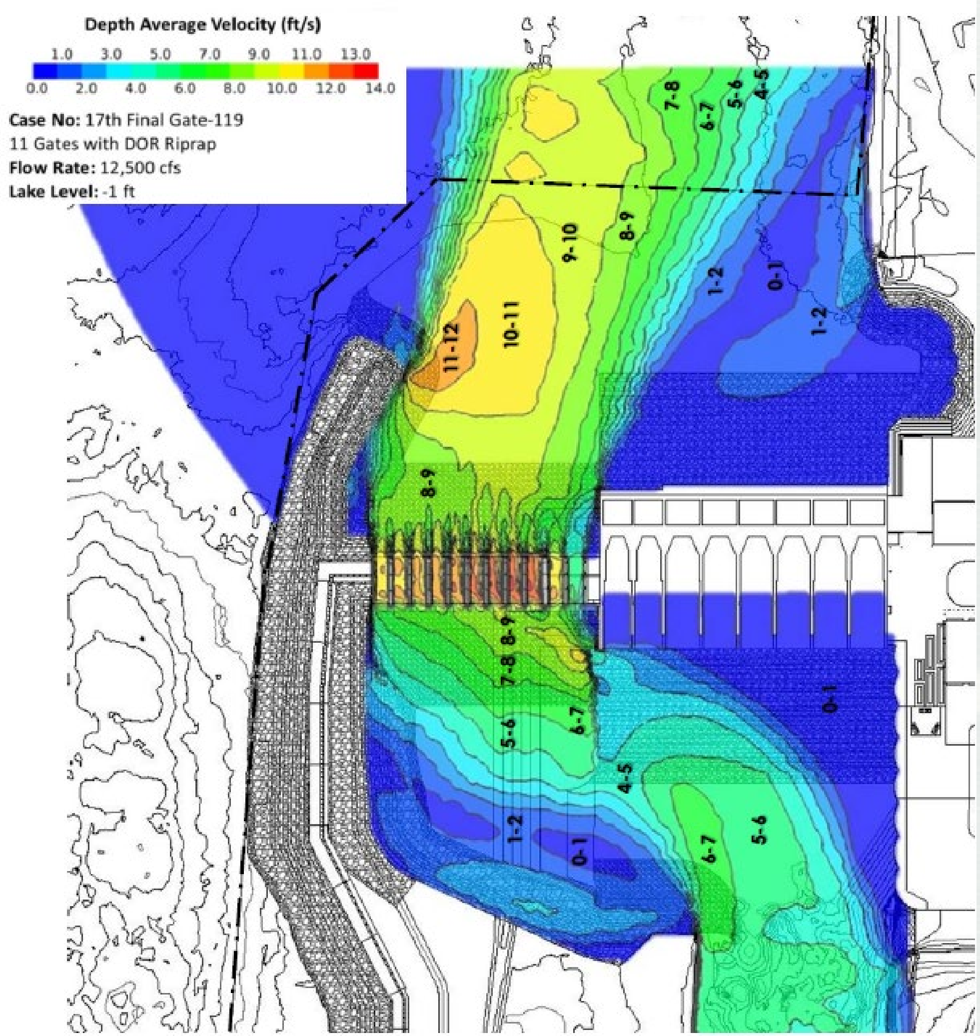
WSE HEC-RAS 2D and Fluent 3D



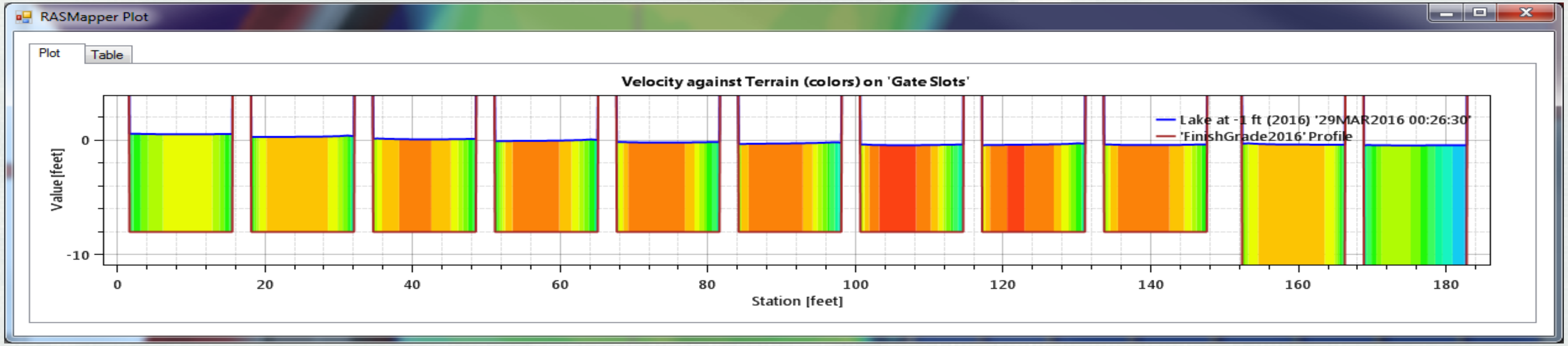


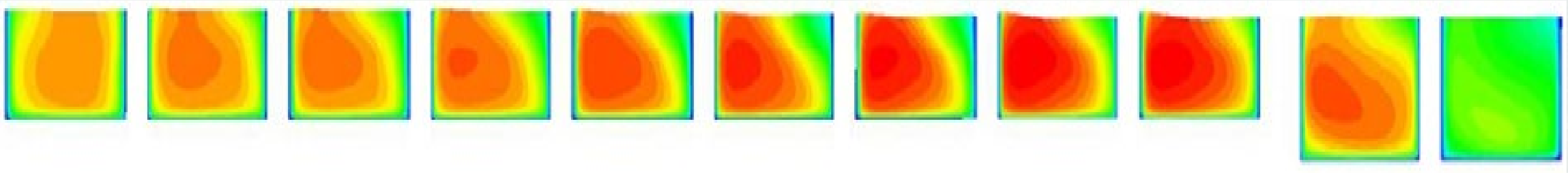
Velocity HEC-RAS 2D and Fluent 3D

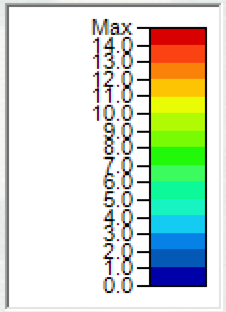




Velocity Plotting RAS 2D and Fluent 3D



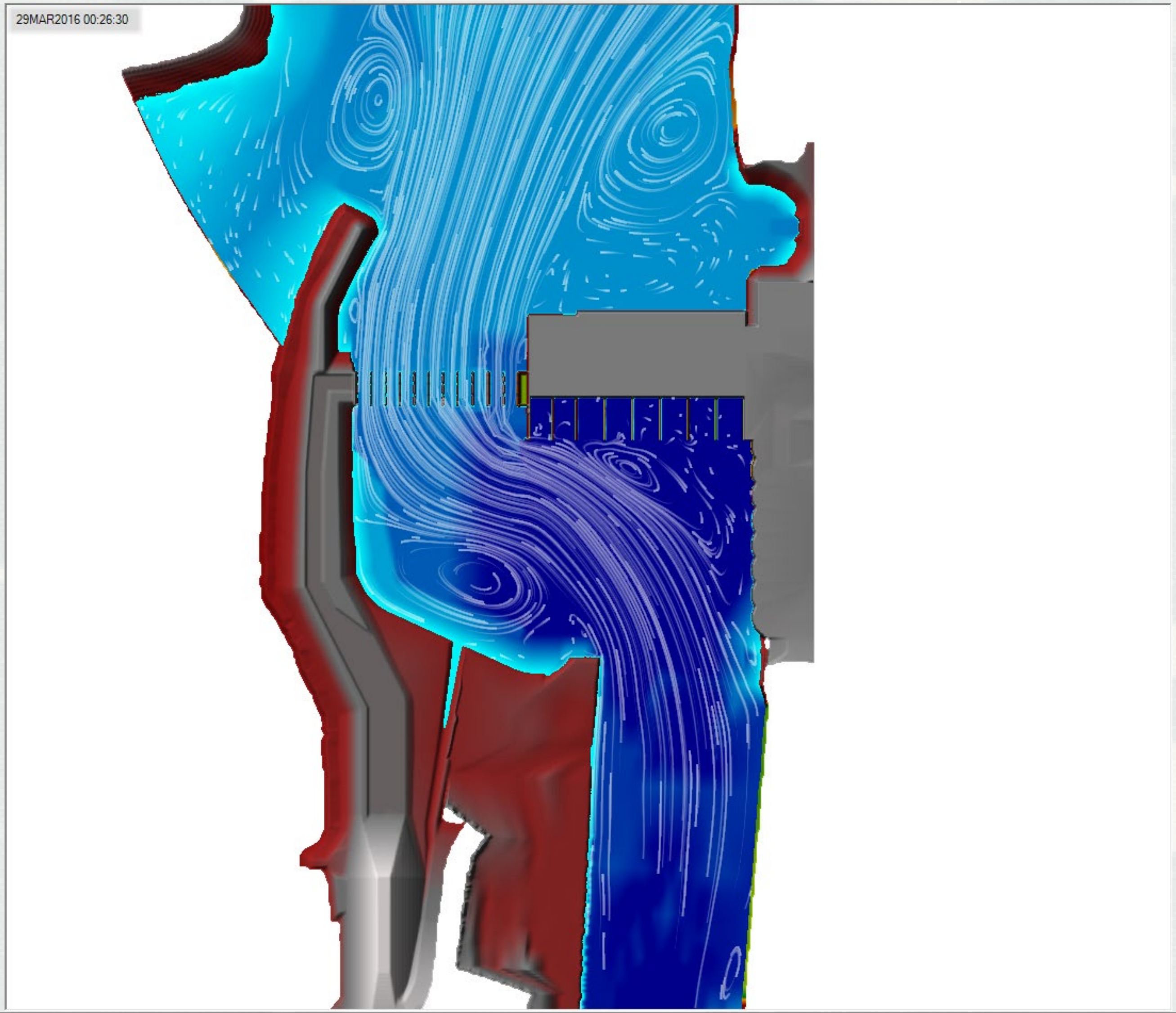


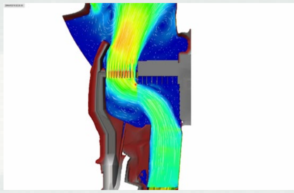


Flow and Velocity Comparison

Gate #	1	2	3	4	5	6	7	8	9	10	11
Flow RAS	1034	1135	1164	1154	1149	1120	1131	1148	1122	1466	988
Flow FLUENT	1091	1124	1110	1110	1102	1083	1099	1132	1144	1491	984
Ave. Velocity RAS	9.24	9.91	10.28	10.30	10.63	10.40	10.77	11.2	11.13	10.34	6.13
Ave. Velocity FLUENT	9.70	9.92	9.82	9.90	10.00	10.00	10.35	10.79	10.99	10.25	6.78

Velocity Animation





Detailed Modeling Summary

- Detailed modeling requires the following:
  - **Selecting the Correct Equations for the problem**:
    - Full Momentum (SWE, Saint Venant Equations)
    - Diffusion Wave (No acceleration terms)
  - **The correct computational mesh for the problem**
    - May need to use variable grid shapes and sizes, break lines and refinement regions.
  - **The right time step given the grid size and velocity**
    - Use the Courant Condition Guidelines provided.
  - **Turbulence Modeling** - Use Eddie Viscosity coefficients if needed (Calibration parameter)
  - **Possibly use Theta less than 1.0** (0.6 to 1.0 should be tested)
    - Definitely needed for tidal boundary conditions

Detailed Modeling Summary-Continued

- The Full Momentum Equation SWE is required for:
  - **Rapidly rising and falling flood waves** (dam break, etc..)
  - **Detailed water surface elevations and velocities around an object**. Including wave run-up in front of and around an object.
  - **Detailed mixed flow regime**: sub to supercritical flow transitions, and hydraulic jumps (super to subcritical)
  - **Tidal boundary conditions** (wave propagation upstream)
  - **Super elevation around bends**
  - **Abrupt contractions and expansions** of the flow with high velocities, as well as flow approaching structures on an angle.

Questions?