Detailed Bridge Modeling

Alex Sánchez, PhD

Senior Hydraulic Engineer

USACE, Institute for Water Resources, Hydrologic Engineering Center

US Army Corps of Engineers®

1

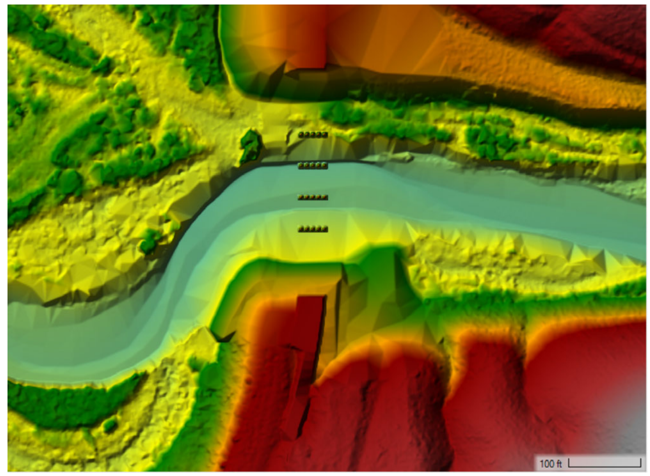
1D vs 2D Bridge Modeling

- Advantages of 2D over 1D
  - Detailed flow velocities
  - Detailed water surface elevations
  - Turbulence
  - Automatic contraction and expansion losses
  - Automatic ineffective flow areas

- Disadvantages of 2D over 1D
  - Longer run times
  - Requires more detailed terrain
  - Can be more unstable
  - Detailed 2D models can take longer to develop than 1D models

Terrain

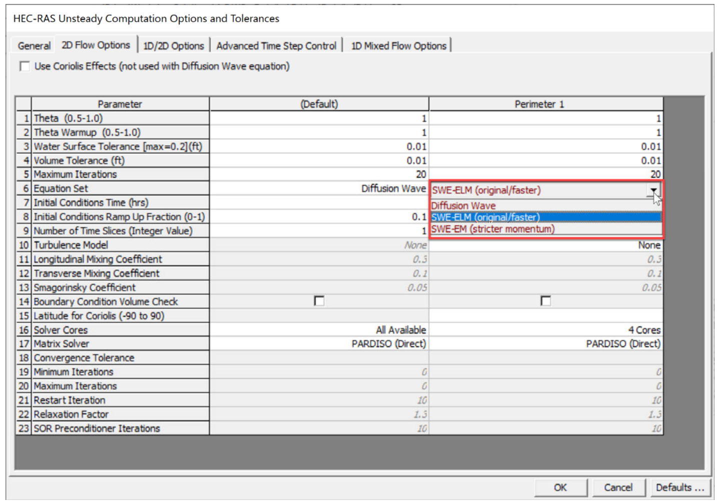
- Must be
  - High-resolution
  - High-quality
- Use Terrain Modifications for
  - Piers
  - Embankments
  - Bathymetry Modificaitons



3

Equation Set

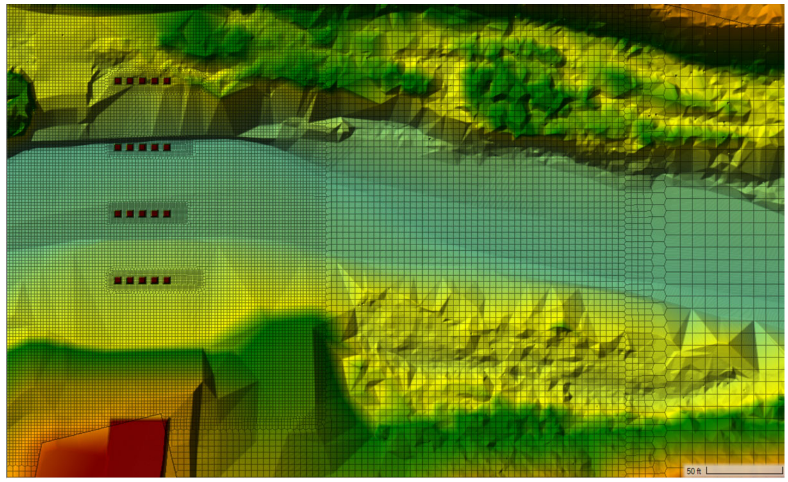
- Diffusion Wave Equation
  - For preliminary runs and/or initialization
  - Cannot simulate contraction and expansions
  - Cannot simulate mixed flow
- Shallow Water Equations
  - Production runs
  - SWE-EM preferred due to better momentum conservation



4

Computational Mesh

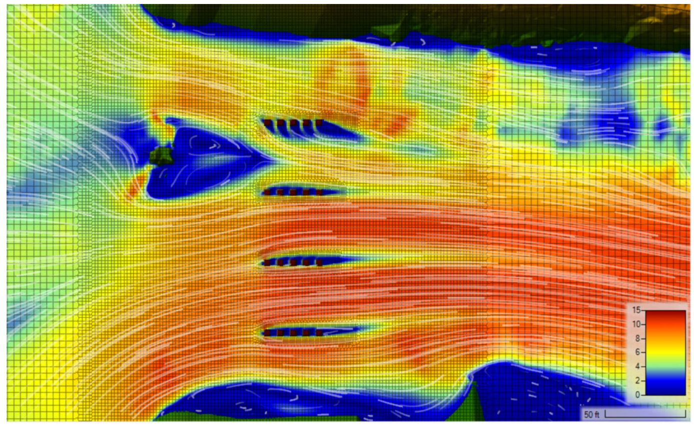
- Preliminary runs with simple coarse mesh
- Breaklines and refinement regions for high-resolution meshes
  - Minimum cell size will drive time step
- Perform grid convergence



5

Turbulence Modeling

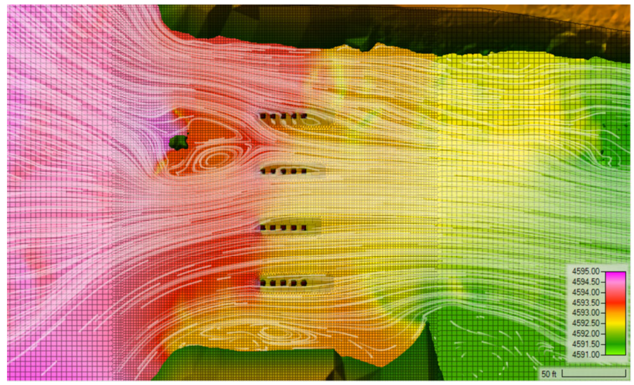
- Turbulence Model
  - Use the Conservative Formulation!
- Eddy Viscosity Model
  - Use Parabolic-Smagorisnky
  - Calibrate if possible
  - In lieu of calibration, perform sensitivity analysis



6

Bottom Roughness

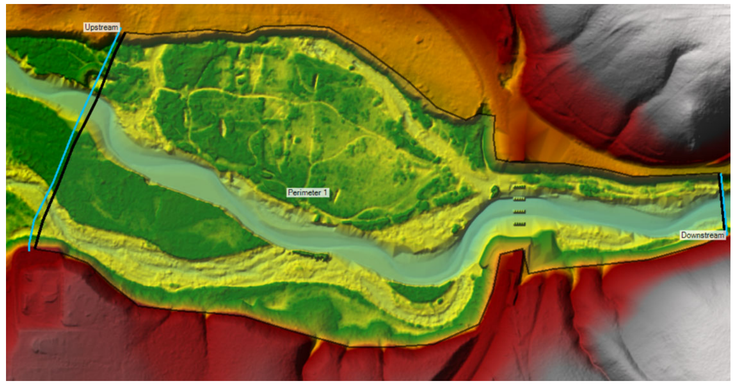
- Use spatially variable Manning's n
- Different flows may require different bottom roughness
- Compare Results Between
  - Single Manning's n per Face
  - Composite Manning's n on Faces (Beta)



7

Boundary Conditions

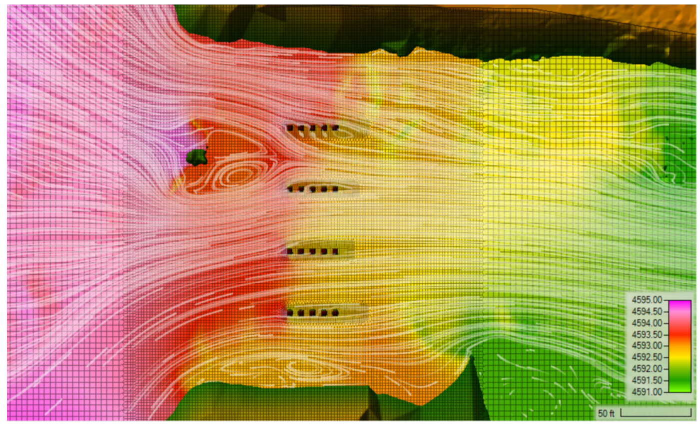
- Tempting to place them very close to the bridge but don't
- Perform sensitivity on boundary placement and boundary values (such as friction slope)
- Place boundaries in areas with 1D flow (i.e. no recirculation, or sharp contracts and expansions)
- Precipitation, Infiltration, Wind, etc.



8

Advanced Computational Parameters and Options

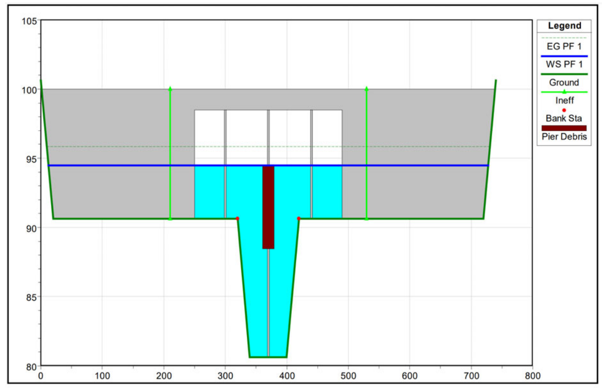
- Time Step
  - Variable time step algorithm
  - Hand calculations of Courant
  - Model stability
- Implicit Weighting Factor
  - 1.0 for preliminary runs
  - 0.5-0.6 for production unsteady flow runs
  - Not important for steady flow
- Coriolis not important
- Mobile Bed (2D Sediment Transport)



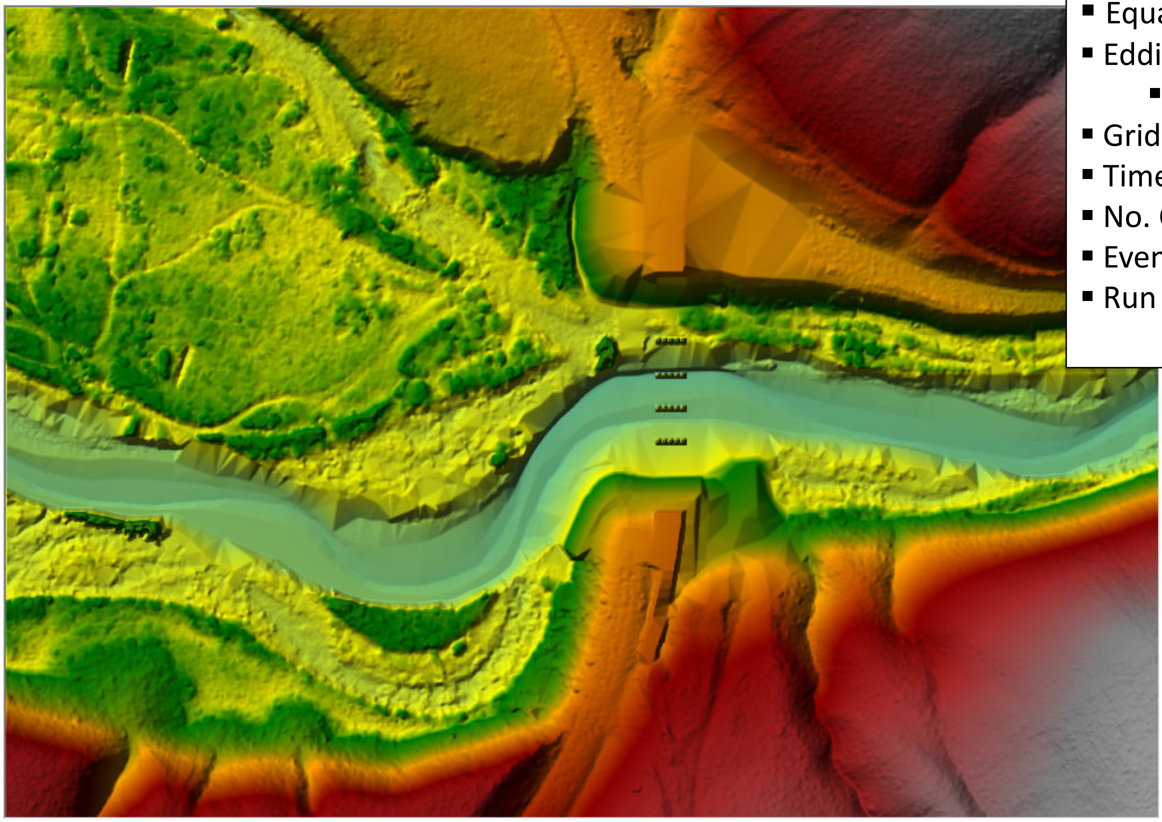
9

Limitations

- Flow must be below bridge deck
  - No pressured flow
  - No flow overtopping
- 2D Flow Assumption
  - Breaks down when cell resolution is much finer than depth
- Hydrostatic Pressure Assumption
- Cannot simulate
  - Bridge openings such as culverts
  - Debris (can be done in 1D)
  - Ice (can be done in 1D)
  - Waves



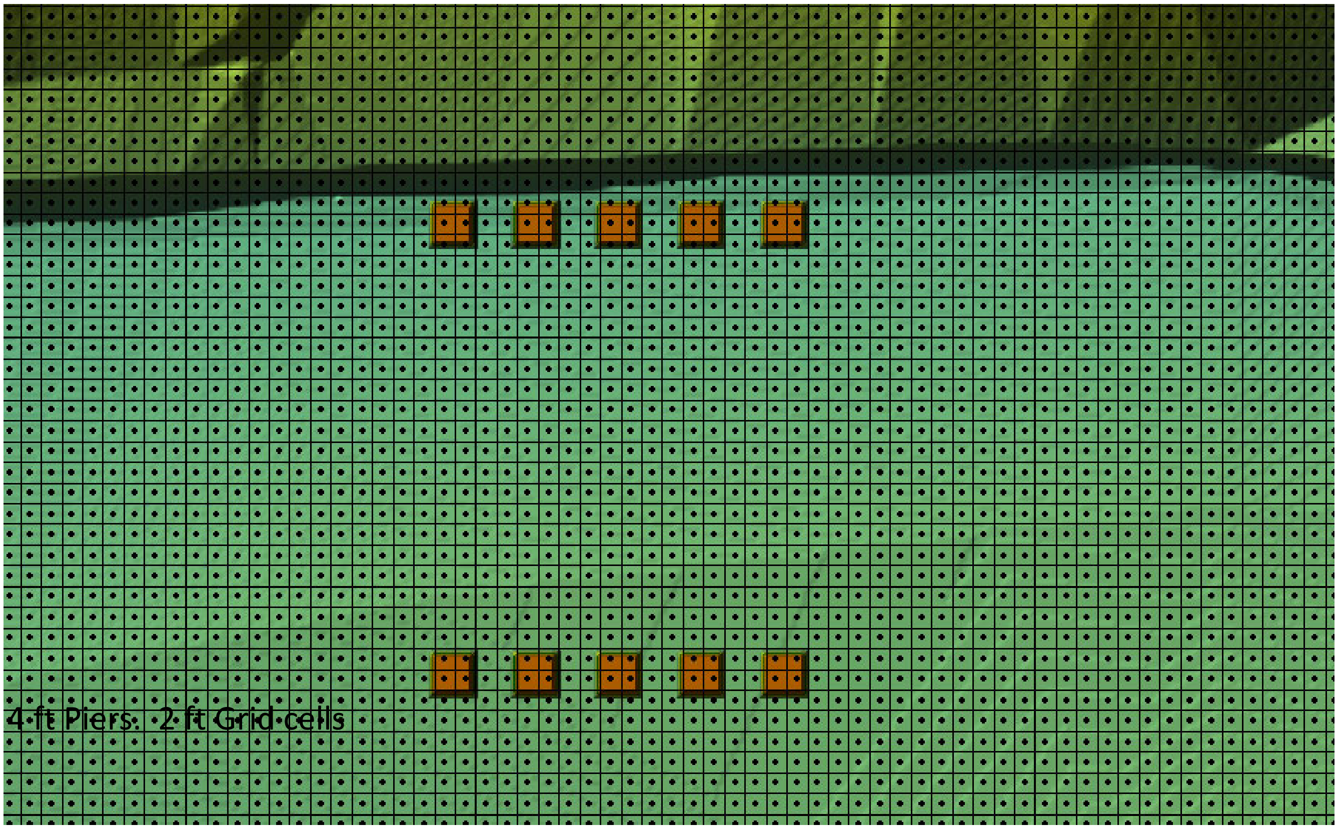
Detailed Bridge Modeling



- Equation set = SWE-ELM
- 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
- Run Time = 3min 39s

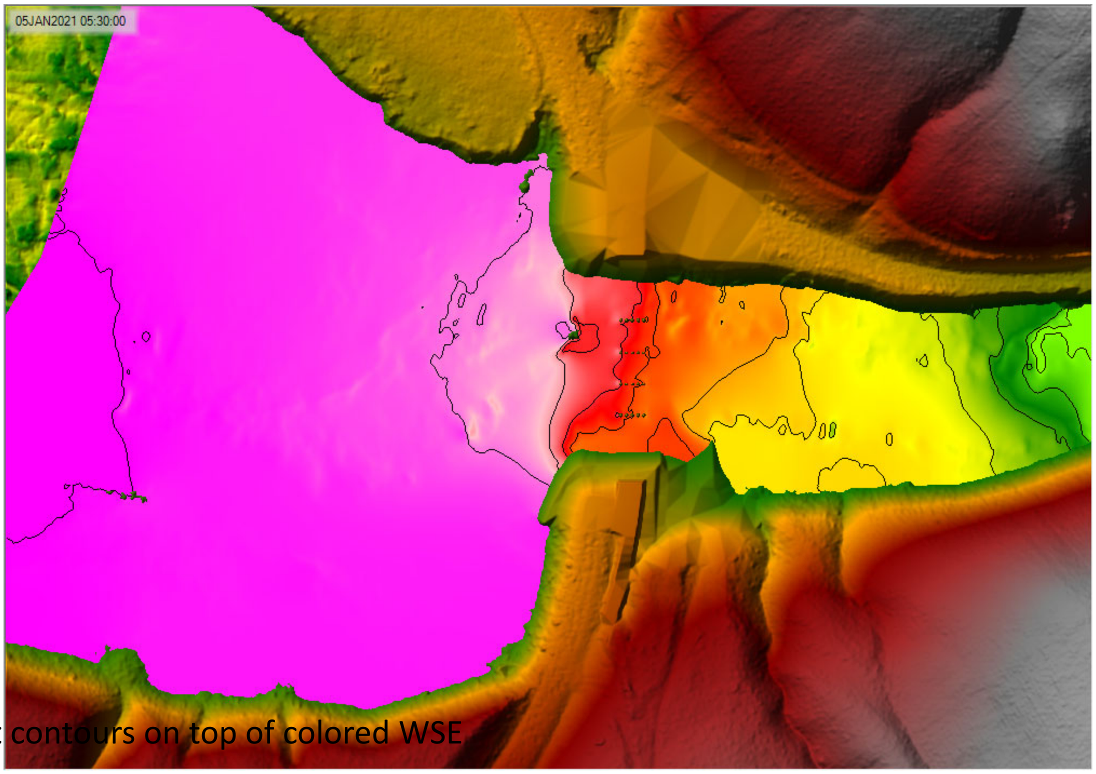
11

Detailed Bridge Modeling



12

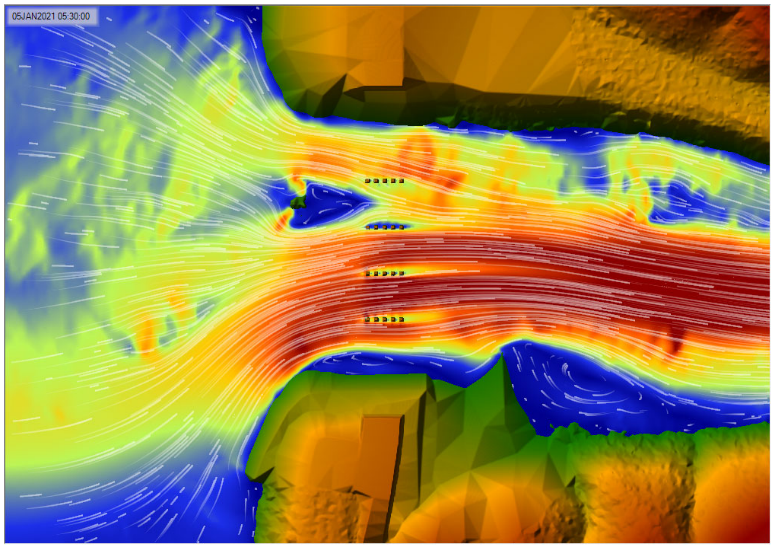
Detailed Bridge Modeling

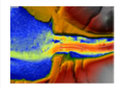


0.5 ft contours on top of colored WSE

13

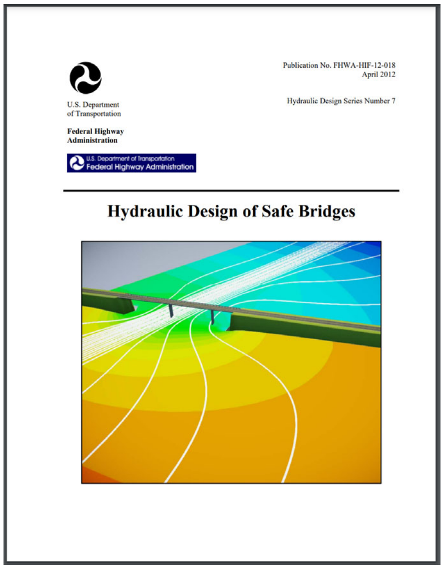
Detailed Bridge Animation





14

Resources


Publication No. FHWA-HIF-12-018
April 2012

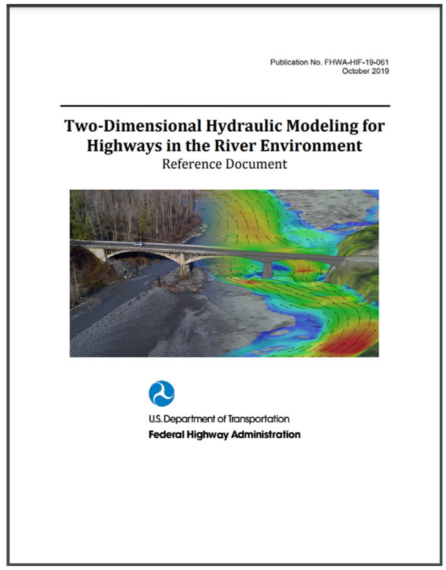
Hydraulic Design Series Number 7

U.S. Department of Transportation

Federal Highway Administration

U.S. Department of Transportation Federal Highway Administration

Hydraulic Design of Safe Bridges


Publication No. FHWA-HIF-19-061
October 2019

Two-Dimensional Hydraulic Modeling for Highways in the River Environment

Reference Document

U.S. Department of Transportation

Federal Highway Administration

Thank You!

HEC-RAS Website:
https://www.hec.usace.army.mil/software/hec-ras/

Online Documentation:
https://www.hec.usace.army.mil/confluence/rasdocs

US Army Corps of Engineers®