

Detailed Bridge Modeling

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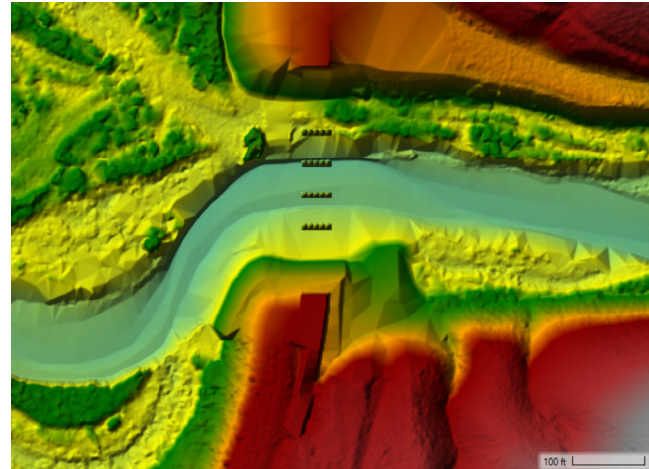
1D vs 2D Bridge Modeling

- 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





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

HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | 1D Mixed Flow Options

Use Coriolis Effects (not used with Diffusion Wave equation)

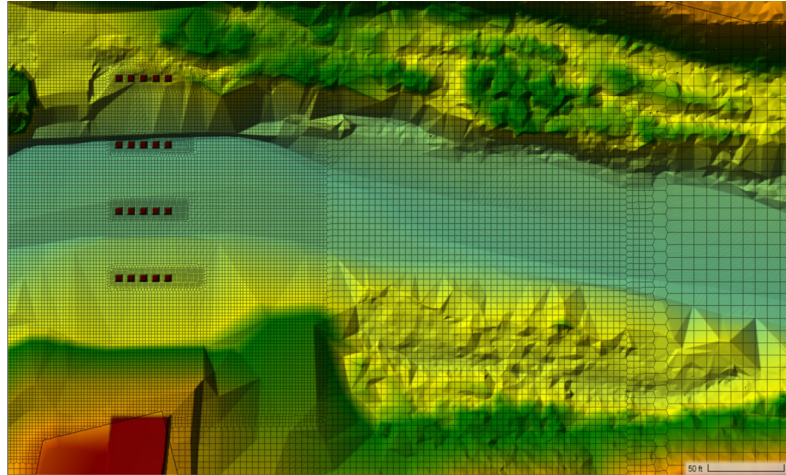
Parameter	(Default)	Perimeter 1
1 Theta (0.5-1.0)	1	1
2 Theta Warmup (0.5-1.0)	1	1
3 Water Surface Tolerance (max=0.2)(ft)	0.01	0.01
4 Volume Tolerance (ft)	0.01	0.01
5 Maximum Iterations	20	20
6 Equation Set	Diffusion Wave	SWE-ELM (original/faster)
7 Initial Conditions Time (hrs)		Diffusion Wave
8 Initial Conditions Ramp Up Fraction (0-1)	0.1	SWE-EM (original/faster)
9 Number of Time Slices (Integer Value)	1	SWE-EM (strict momentum)
10 Turbulence Model	None	None
11 Longitudinal Mixing Coefficient	0.3	0.3
12 Transverse Mixing Coefficient	0.2	0.2
13 Smagorinsky Coefficient	0.05	0.05
14 Boundary Condition Volume Check	<input type="checkbox"/>	<input type="checkbox"/>
15 Latitude for Coriolis (-90 to 90)		
16 Solver Cores	All Available	4 Cores
17 Matrix Solver	PARDISO (Direct)	PARDISO (Direct)
18 Convergence Tolerance		
19 Minimum Iterations	0	0
20 Maximum Iterations	0	0
21 Restart Iteration	10	10
22 Relaxation Factor	1.3	1.3
23 SOR Preconditioner Iterations	10	10

OK Cancel Defaults ...



Computational Mesh

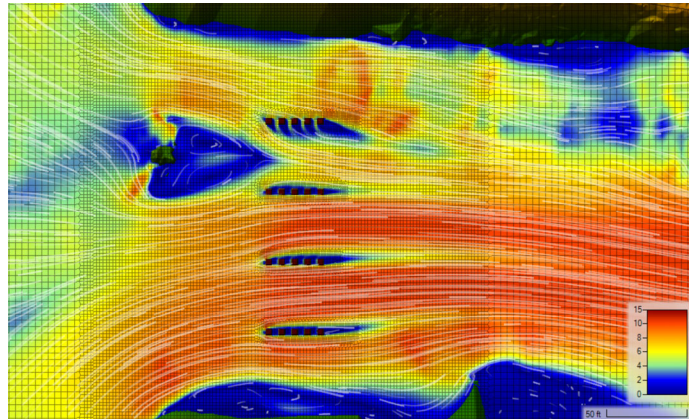
- Preliminary runs with simple coarse mesh
- Breaklines and refinement regions for high-resolution meshes
 - Minimum cell size will drive time step
- Perform grid convergence





Turbulence Modeling

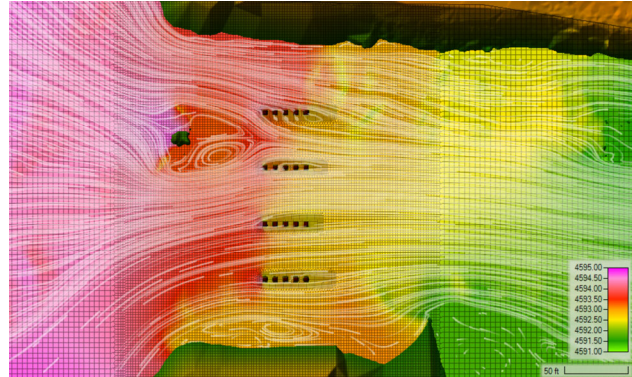
- Turbulence Model
 - Use the Conservative Formulation!
- Eddy Viscosity Model
 - Use Parabolic-Smagorinsky
 - Calibrate if possible
 - In lieu of calibration, perform sensitivity analysis





Bottom Roughness

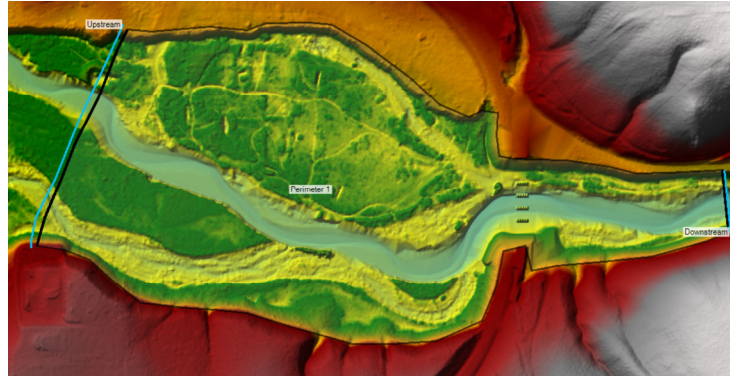
- Use spatially variable Manning's n
- Different flows may require different bottom roughness
- Compare Results Between
 - Single Manning's n per Face
 - Composite Manning's n on Faces (Beta)





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.

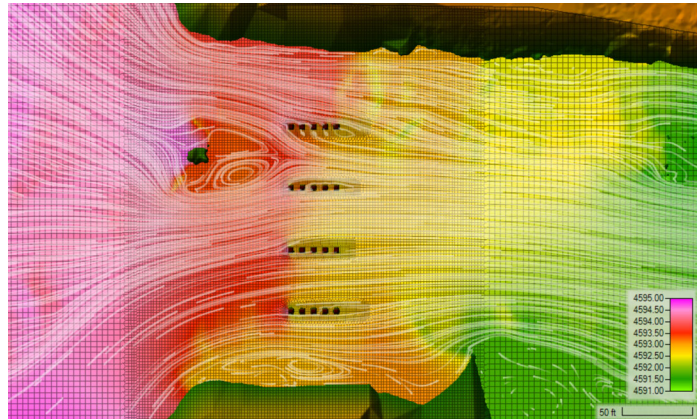




Advanced Computational Parameters and Options



- 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)

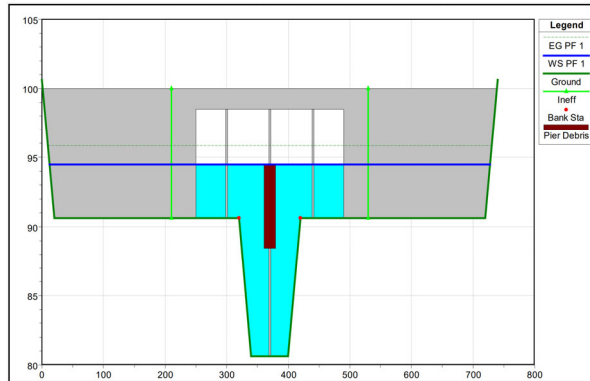




Limitations

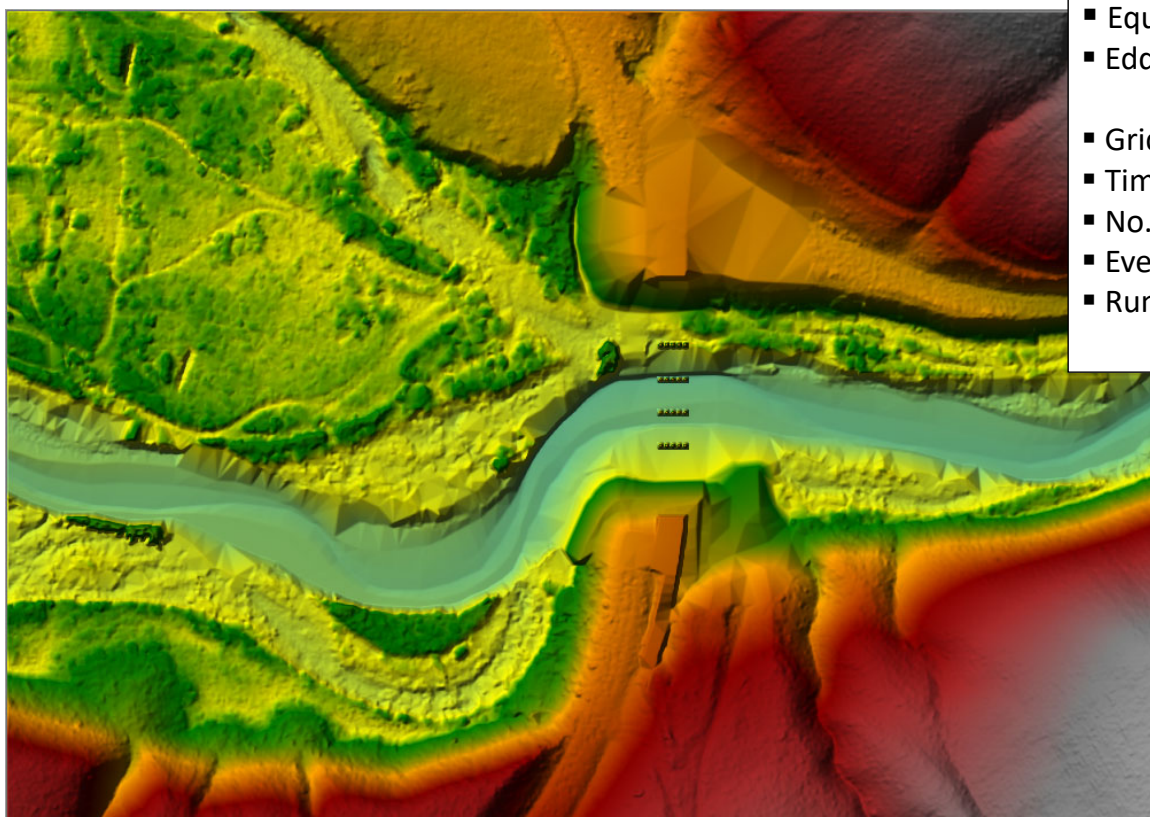


- Flow must be below bridge deck
 - No pressured flow
 - No flow overtopping
- 2D Flow Assumption
 - Breaks down when cell resolution is much finer than depth
- Hydrostatic Pressure Assumption
- Cannot simulate
 - Bridge openings such as culverts
 - Debris (can be done in 1D)
 - Ice (can be done in 1D)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





Detailed Bridge Modeling

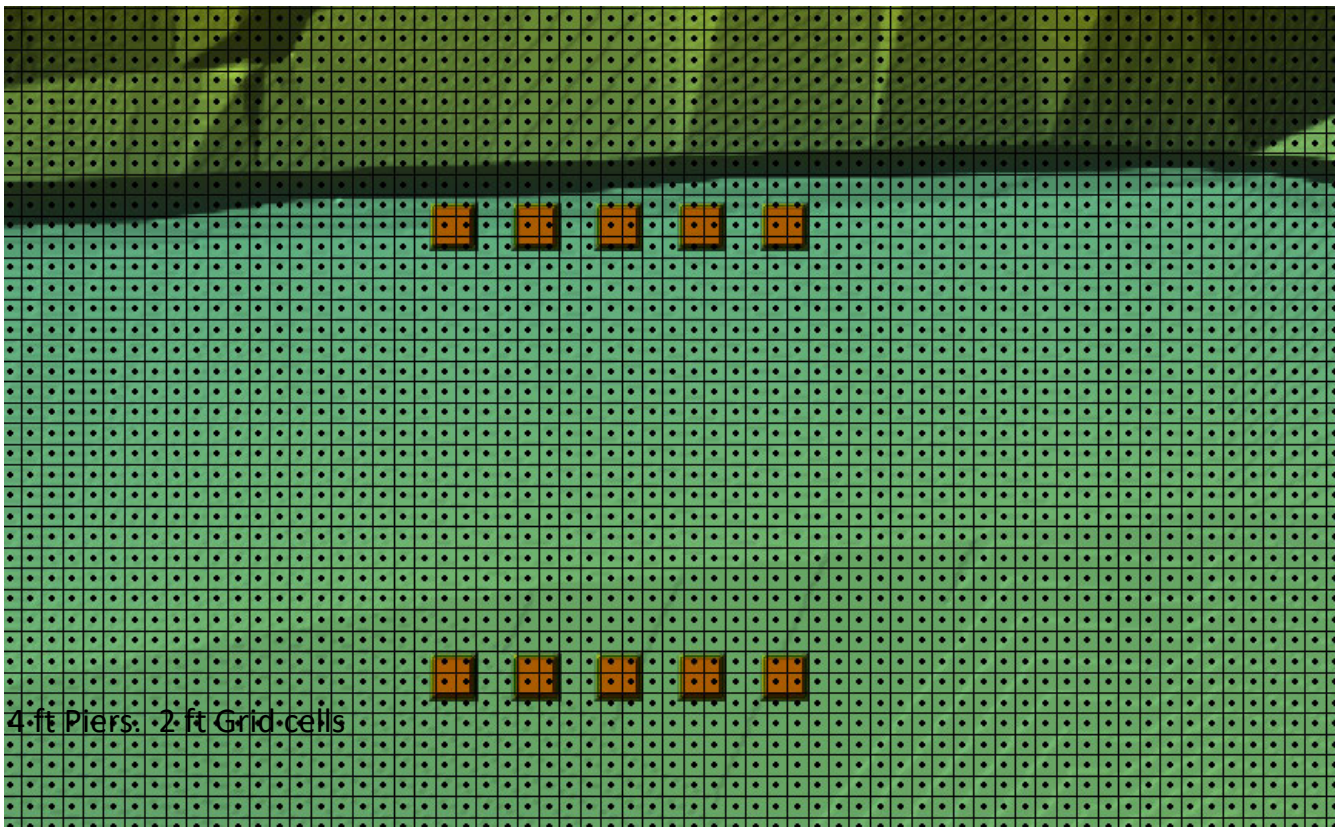


- Equation set = SWE-ELM
- Eddy Viscosity Coefficient
 - Conservative D_L and $D_T = 0.5$
- Grid Size = 2x2 ft up to 8x8 ft
- Time step = 0.2 seconds
- No. Cells = 45,000
- Event Duration = 20 min. Steady
- Run Time = 3min 39s

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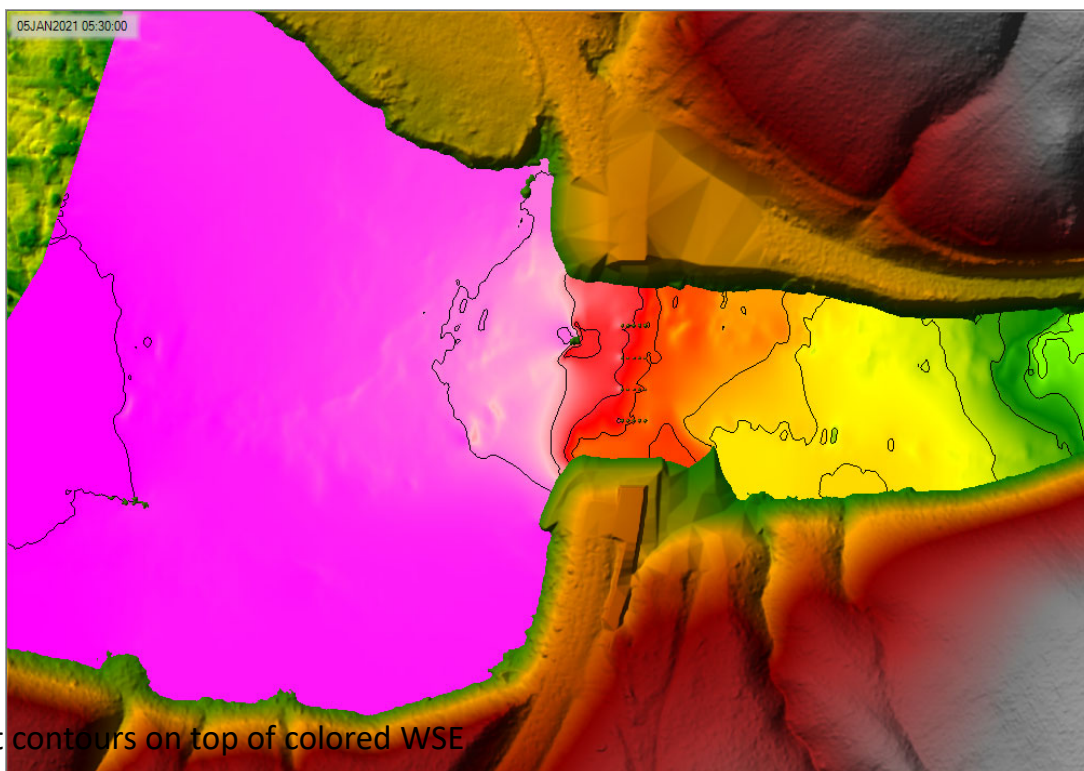


Detailed Bridge Modeling





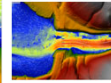
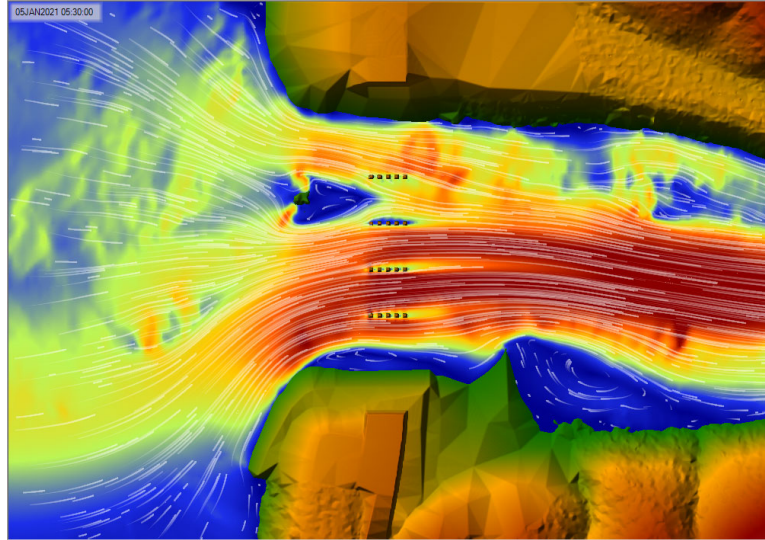
Detailed Bridge Modeling



0.5 ft contours on top of colored WSE



Detailed Bridge Animation





Resources

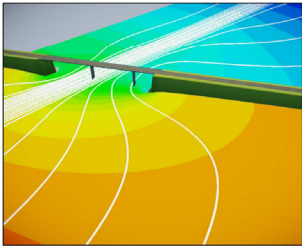


U.S. Department of Transportation
Federal Highway Administration

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

Hydraulic Design Series Number 7

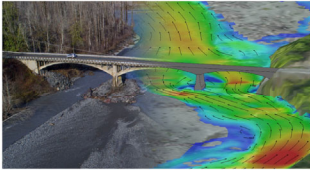
Hydraulic Design of Safe Bridges



U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-HIF-19-001
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/hecras/>

Online Documentation:

<https://www.hec.usace.army.mil/confluence/rasdocs>



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