Bridge Hydraulics in HEC-RAS
Workshop

1 Objective

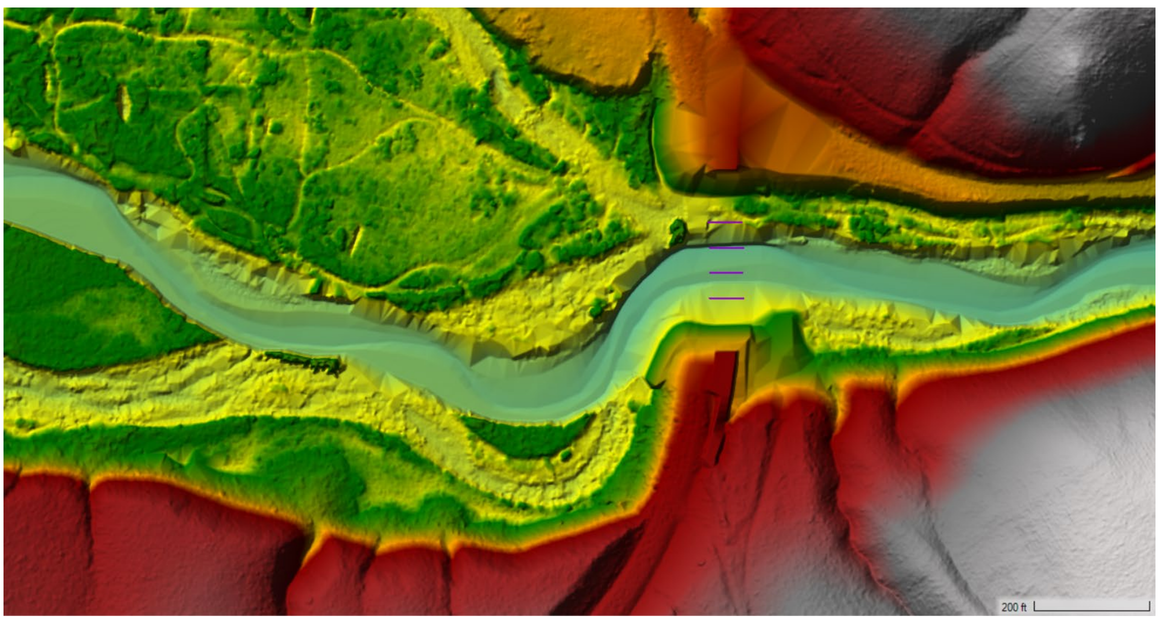
This workshop will help students learn how to use HEC-RAS to model bridges inside of a 2D flow area.

The workshop will begin by using the simplified 1D bridge solution and continue with developing detailed mesh to model the floodplain constriction. The shallow water equations (SWE) will be used. These simulations will then be compared.

2 Background

The figure below shows the terrain and bridge crossing (flow west to east). The floodplain is highly constricted at the bridge which includes four rows of piers, these piers are marked by purple lines in the view below. The square piers have 4ft sides.

The flow event modeled does not overtop the bridge or hit the low chord.

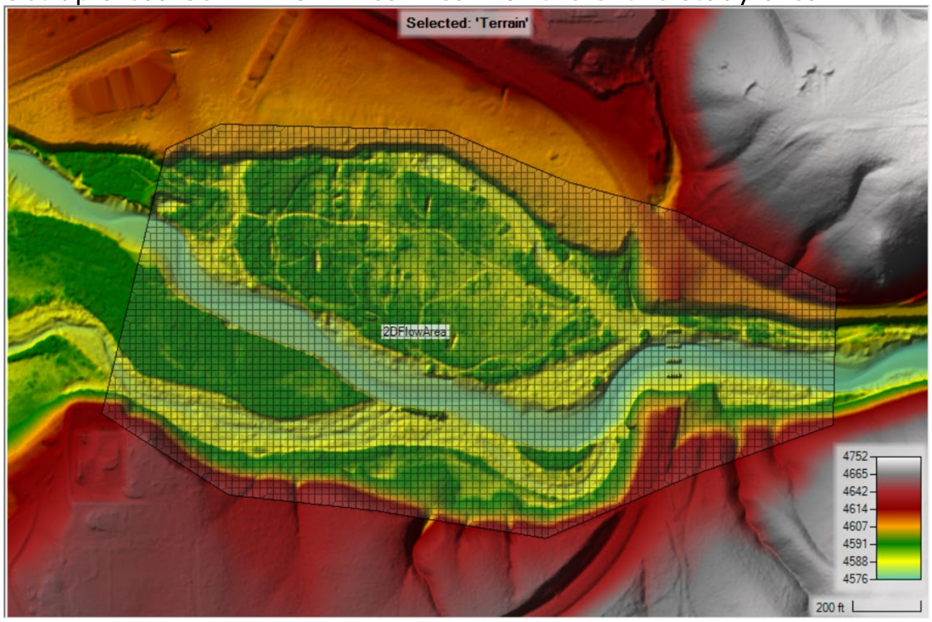


3 Part 1 – Simplified 1D Bridge Model

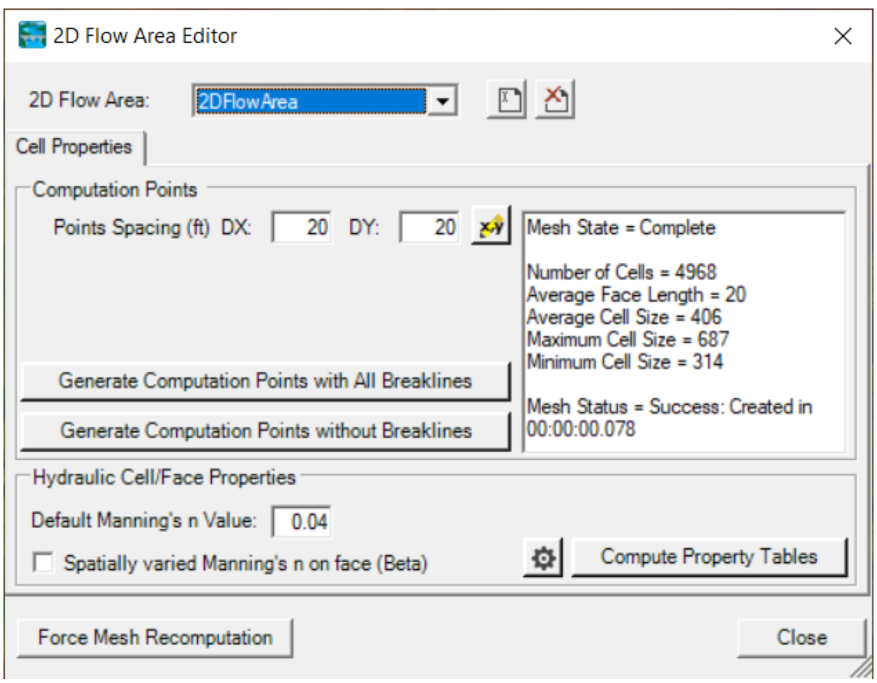
3.1 Create Initial Model Geometry

1. Open **HEC-RAS** and start a new project in the bridge modeling folder.
2. Open **RAS Mapper**
    a. Set the **projection** (“GIS_Data” folder).
    b. Add the existing **Terrain_NoPiers** from the “Terrain” folder.
    c. Add a **New Geometry** (name it “**Initial**”).

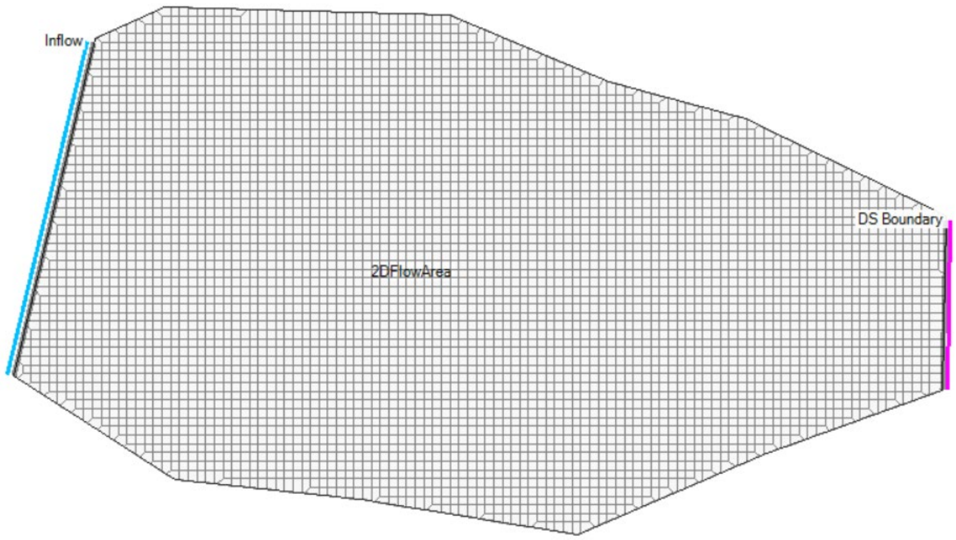
3. Set up a coarse 2D Flow Area mesh for the entire study area.



4. Try **20ft** cells with a Manning's n value of **0.04**.



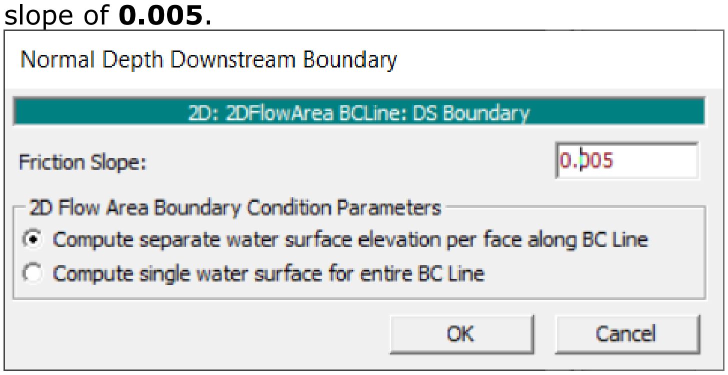
5. Set up boundary condition lines
    a. Inflow
    b. DS Boundary



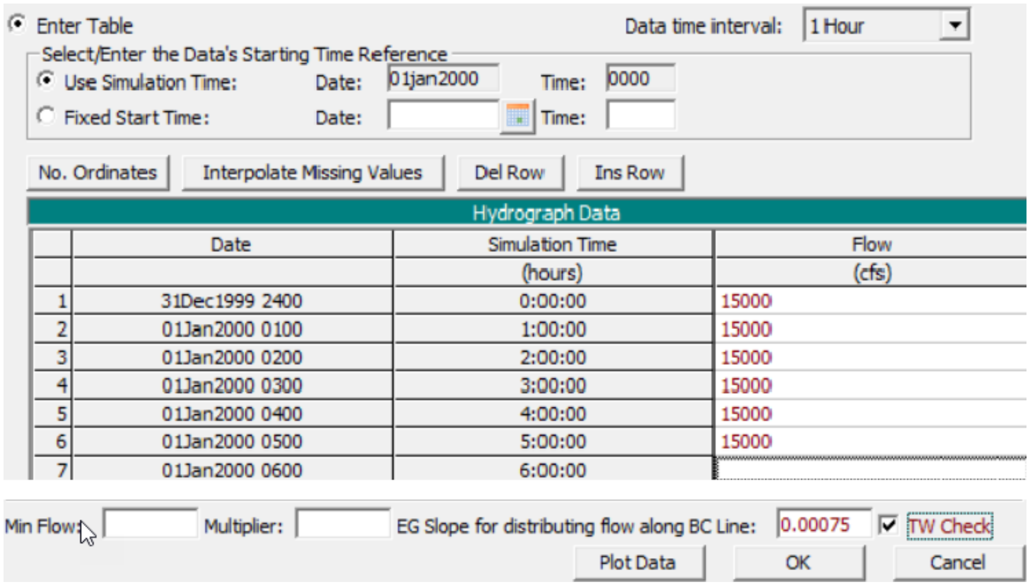
6. Stop **Editing** in RAS Mapper.
7. Close **RAS Mapper**
8. Open the **Geometric Data** editor.
    a. Open the geometry **Initial** and inspect it.
    b. Close the **Geometric Data** editor.

3.2 Enter Flow Data and Boundary Conditions

9. Open the **Unsteady Flow Data** editor.
10. Set the downstream boundary condition to **Normal Depth** with a friction slope of **0.005**.



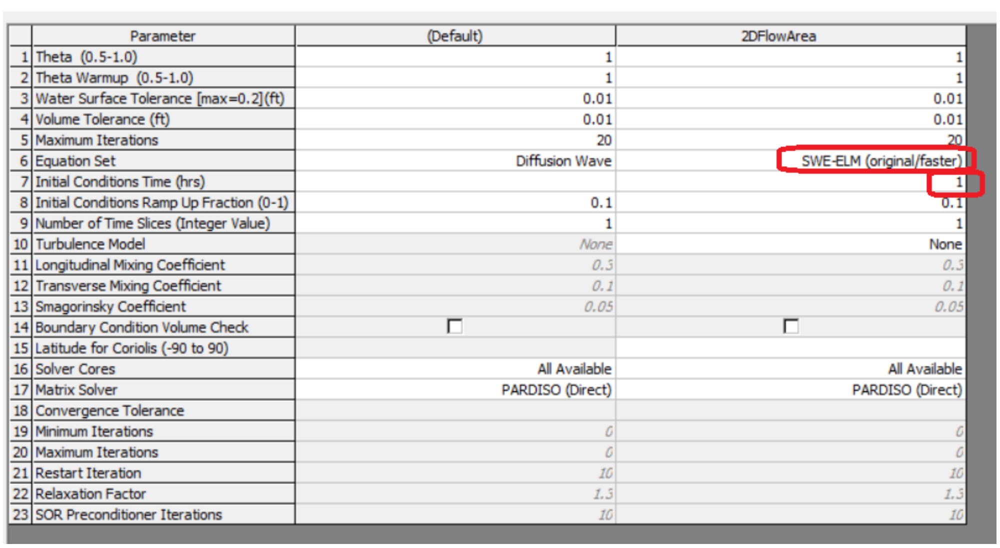
11. Set the inflow boundary to **Flow Hydrograph**.
Use a constant flow of **15,000 cfs**. Set the EG Slope to **0.00075**, and turn on the **TW Check**.



12. **Save** the flow data.

3.3 Create a Plan and Simulate

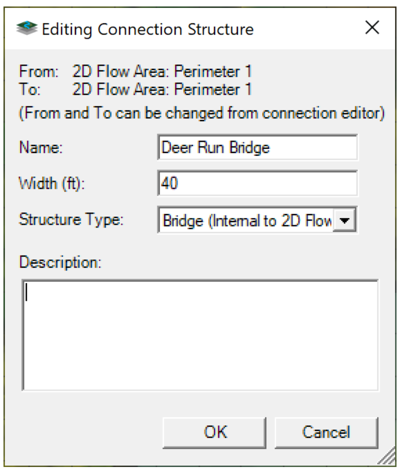
13. Open the **Unsteady Flow Analysis** window.
14. Set up the time window, time step, and mapping output interval.
15. Set the **Computation Options**
    a. Set the Equation Set to **SWE-ELM (original/faster)** and the **Initial Conditions Time** as shown in the figure below.



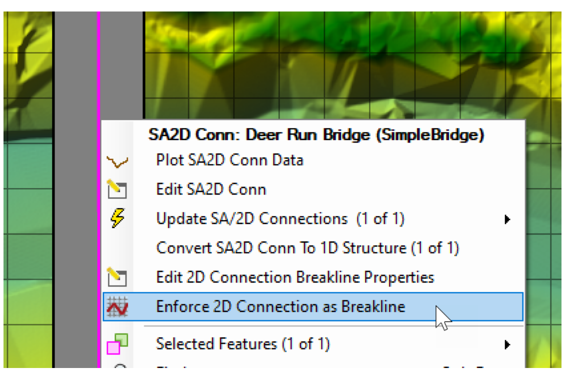
16. **Save** the plan data as "Base Plan".
17. **Compute**
18. **Computation Time Step Check** ensure solution is smooth and stable, pick a new time step and re-run if necessary.

3.4 Create new Geometry and Plan with 1D Bridge

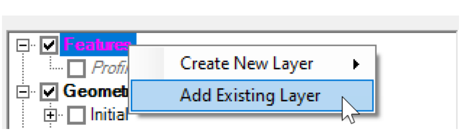
19. In **RAS Mapper** window use the "**Save Geometry as** …" menu option to copy the base geometry to a new one.
20. Name the new geometry "**Simple Bridge**".
21. Start editing and draw a centerline for the bridge deck (draw from left to right looking downstream, which will be top to bottom in this case). For best results start and end the bridge at or near mesh nodes. Set the structure **Name** to "Deer Run Bridge", the **Width** to **40 ft**, and the **Structure Type** to "Bridge (Inline to 2D Flow Area)".



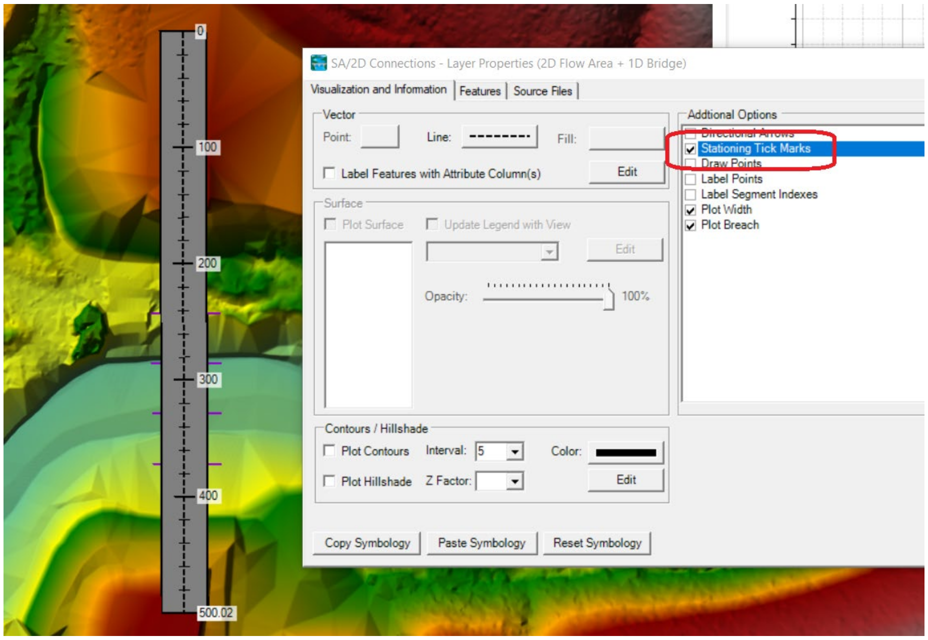
22. Enforce the 2D cell spacing around the centerline as appropriate.



23. Add the Pier Centerline shapefile (in the GIS Data folder) by right-clicking on **Features** at the top of the project tree, and selecting Add Existing Layer.



24. Turn on the stationing tick marks on the bridge centerline.



25. Note the bridge centerline stations where the piers cross it, you will need these stations when entering the pier data.

26. Go the main **Geometry Schematic** and open the **2D Connection Data Editor**.

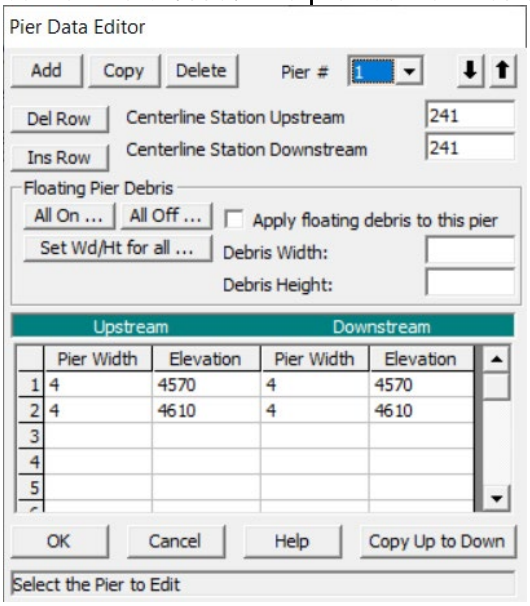
27. Ensure the structure type is modeled as Bridge (Internal to 2D Flow Area).

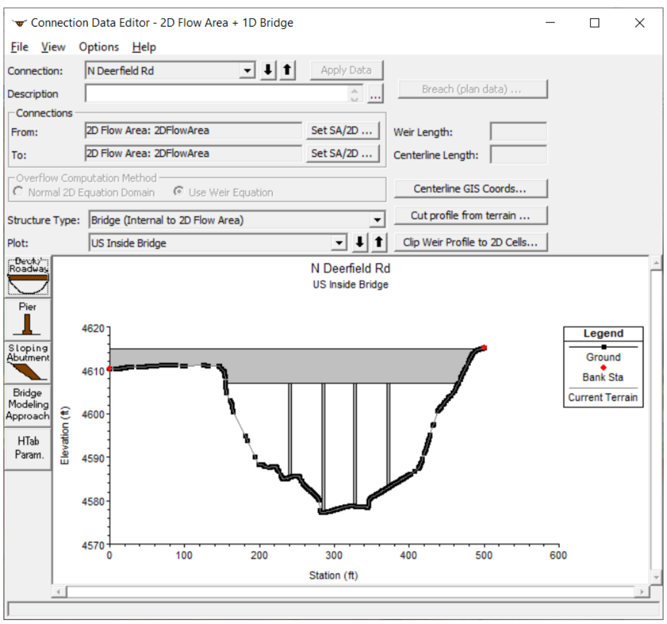
28. Add a deck roadway that spans the full range width of the XS's with a flat top roadway at an elevation of **4615** and a low chord at **4607 ft**.

29. Set the upstream distance to **5 ft**.

30. Select appropriate **Weir Coefficient** for this structure.

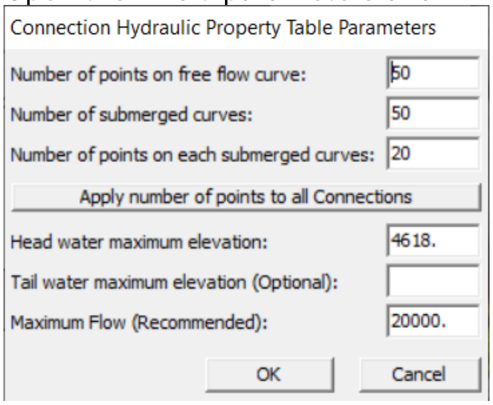
31. Add **4 Piers** that are **4 ft** wide at the stations you noted earlier where the centerline crossed the pier centerlines shapefile.



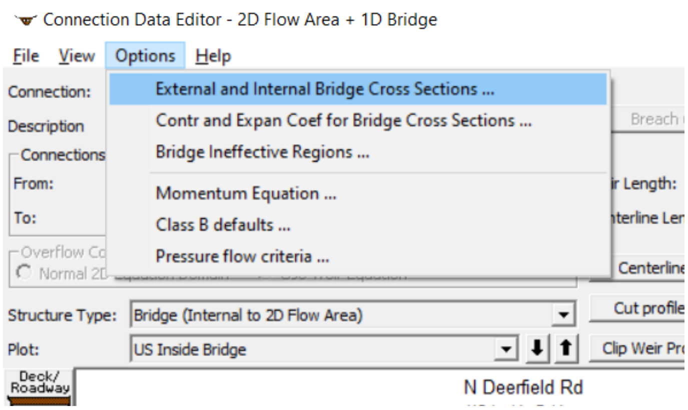


32. Open the **Bridge Modeling Approach** and turn on the **Momentum** method and select an appropriate drag coefficient **Cd** for square nosed piers.

33. Open the **HTab** parameters and limit the curves for this simulation.



34. Open the **External and Internal Bridge Cross Section** dialog.



35. Set the Manning's values for the 4 XS's for this structure to use a value or **0.04**.

36. Save geometry file.

37. **Save Plan As**, to create another plan with this geometry.

38. **Compute**

3.5 Compare Results

39. Create a **Profile Line** for the river centerline. (turn on Plot Tick Marks to help find where the bridge is in the profile)

40. **Plot the WSE** and compare the results.

Question: What is the difference in WS between the Initial and Simple Bridge plans at the bridge?

Question: Look at the family of bridge curves and for the flow through the bridge track back the HW to find the prescribed TW and try to verify the loses were applied correctly.

Question: Is the cell size adequate for modeling the terrain, bridge, piers, etc.?

4 Part 2 – Detailed Mesh at Roadway

4.6 Create Initial Model Geometry

1. In RAS Mapper window use the "**Save Geometry as** …" menu option to copy the "Initial" base geometry to start.
2. Name the Geometry "Detailed Mesh".
3. Add an existing **Terrain - "Terrain"** ("Terrain" folder)
   (You should see piers in the terrain at the road crossing.)
4. **Associate** the detailed Terrain with the Detailed Geometry.
5. Close **RAS Mapper.**

4.7 DW - Create a Plan and Simulate

6. Open the **Unsteady Flow Analysis** window.
7. Select the Geometry and Flow files.
8. Set up the time window, time step, and mapping output interval.
9. Set the **Computation Options**
   a. Set the Equation Set to **Diffusion Wave**.

	Parameter	(Default)	2DFlowArea
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	Diffusion Wave
7	Initial Conditions Time (hrs)		
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1
9	Number of Time Slices (Integer Value)	1	1

10. **Save** the plan data.
11. **Compute**

4.8 SWE - Create a Plan and Simulate

12. Open the **Unsteady Flow Analysis** window
13. **Save Plan As**, to create another plan.
14. Set the **Computation Options**
    a. Set the Equation Set to the **SWE-ELM**

	Parameter	(Default)	2DFlowArea
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)		
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1
9	Number of Time Slices (Integer Value)	1	1

15. Set the **time step** to something more appropriate for **SWE**.
16. **Save** the plan
17. **Compute**

4.9 Compare DW and SWE Results

18. Use the **Profile Line** for the river centerline to **Plot the WSE** and compare the results.

<u>Question</u>: Is there a difference between DW and SWE, why would there be a difference, and what does this tell us about the model?

<u>Question</u>: What is the change in water surface through the bridge constriction?

<u>Question</u>: Is the cell size adequate for modeling the terrain, bridge, piers, etc?

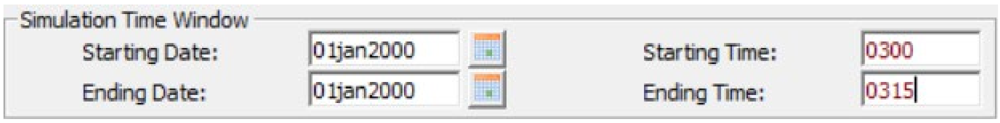
4.10 Refine the 2D Bridge Model

Now that we have some understanding of the model, let's start to improve the runs.

19. Create a copy of the initial geometry using the **Save Geometry As** option in **RAS Mapper**.
20. Use your knowledge of the contraction and expansion zone through the bridge to add a **Refinement Region**, using a smaller cell size (**5 ft**).
21. Create a new **Unsteady Flow Data** file with modified initial conditions.
    a. Click on **File | Unsteady Flow Data As** and name it "Flow with WSE"
    b. On the **Initial Conditions** tab, choose **Prior WS Filename**
    c. Select the results file from the SWE run (***.p04.hdf**)
    d. **Choose** the last profile

e. **Save**

22. **Save** the SWE to a new Plan (**SWE-5ft**)
23. **Select** the new **Geometry**.
24. **Set** an appropriate **time step**.
25. Go back to the **Unsteady Flow Analysis** window.
26. **Re-save** the Plan.
27. Set the **Time Window**.



28. **Run the new plan.**

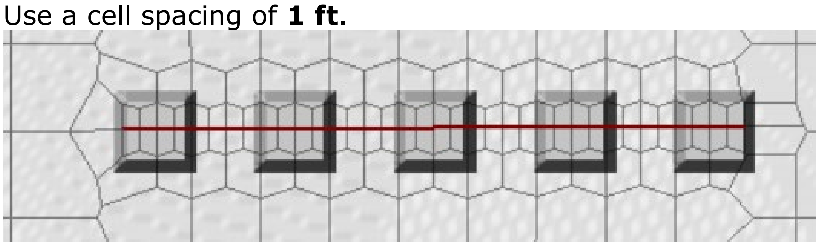
<u>Question</u>: How does the Refined Plan compare with the Initial SWE results?

<u>Question</u>: How does the Refined Plan velocity field look?

4.11 Refine Mesh Around Piers

Continue to improve the model.

29. Create a copy of the refined geometry using the **Save Geometry As** option in **RAS Mapper**.
30. Refine the area around the Piers using **breaklines** to create smaller cells. Use a cell spacing of **1 ft**.



31. **Save As** a new plan called "SWE-Piers".
32. Select the new **Geometry**.
33. Set an appropriate **time step**.
34. **Compute.**

<u>Question</u>: How does the Refined Pier Plan compare with other results?

<u>Question</u>: How else can the mesh around the piers be refined besides breaklines?

4.12 Turbulence Modeling

Add Turbulence to the model and review.

35. Save the "SWE-Piers" Plan to a new Plan called "SWE-Turbulence".
36. **Turn on Turbulence Modeling.**

	Parameter	(Default)	2DFlowArea
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)	0.02	0.02
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)		
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1
9	Number of Time Slices (Integer Value)	1	1
10	Turbulence Model	None	Conservative
11	Longitudinal Mixing Coefficient	0.3	0.3
12	Transverse Mixing Coefficient	0.1	0.1
13	Smagorinsky Coefficient	0.05	0.05

37. **Compute** results.

<u>Question</u>: How does the Refined model with Piers and Turbulence compare with other results? Which run is the better run?