2D Bridge Hydraulics

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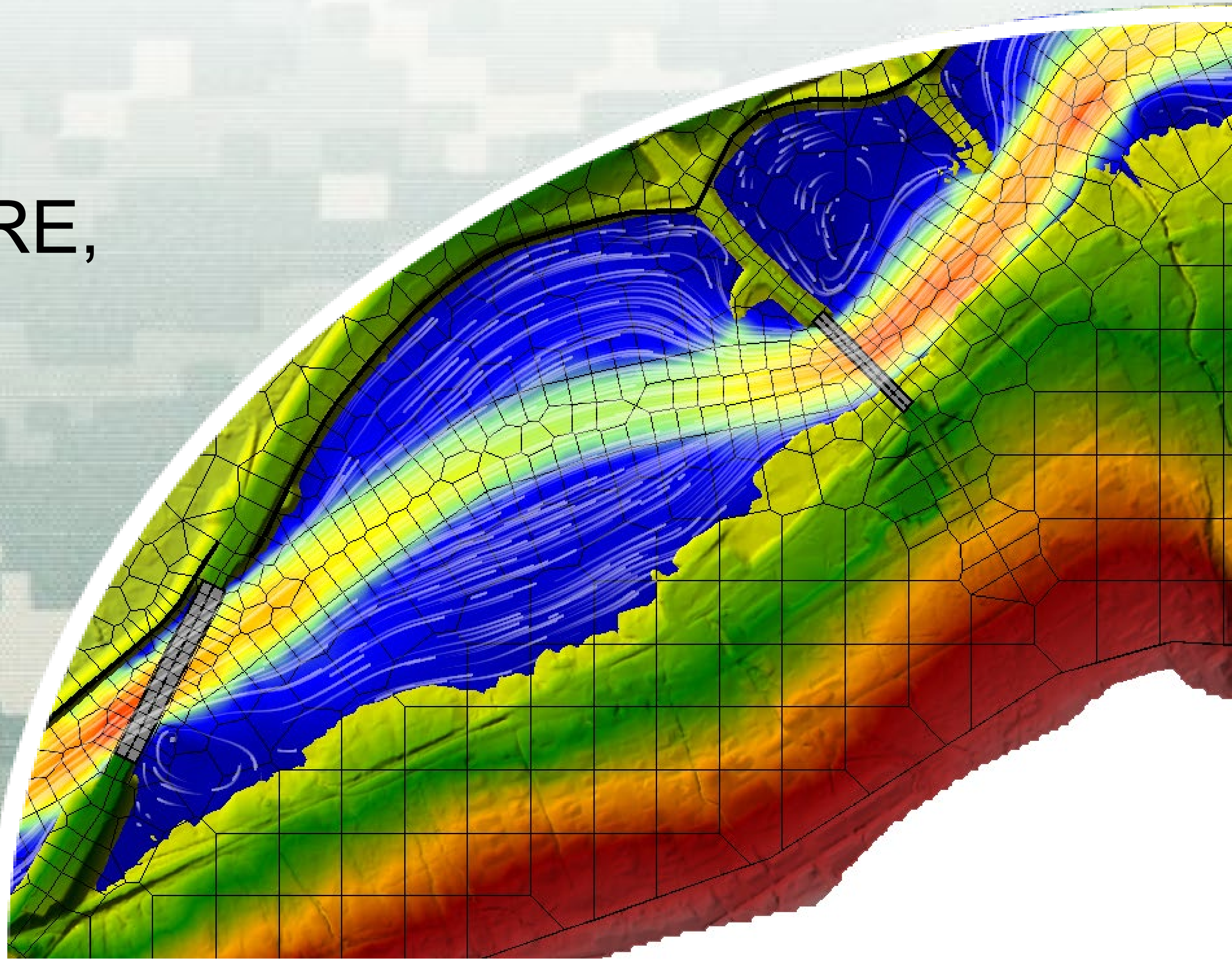
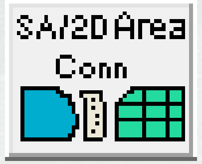


US Army Corps
of Engineers

Objectives

- Learn the details of how Bridge Hydraulics works in 2D Flow Areas.
- Learn how to enter all of the necessary data to model a bridge in a 2D Flow Area.
- Learn the differences between 1D bridge modeling and 2D.
- Review the available output for 2D Bridges



Bridge Hydraulics inside of a 2D Flow Area

- Utilizing existing HEC-RAS 1D Bridge Hydraulics methods inside of a 2D Flow Area.

- Model complete range of Bridge Hydraulic flow regimes:
  - Low flow
  - Pressure flow
  - Pressure flow and weir flow (road over topping)
  - Low flow and weir flow

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Why is it Important?

- Previous versions of HEC-RAS had no method for handling bridges inside of a 2D Flow Areas
- Modelers were forced to do 1D channels with 2D Floodplains where bridges are important.
  - 1D to 2D connections can be complicated
  - Time consuming
  - May cause instabilities
  - Less accurate for channel to floodplain flow transfers
  - More computation time to develop models and possible run times.
- The new 2D Bridge Capability has the following benefits:
  - Less need for combined 1D/2D modeling
  - Able to develop more detailed 2D models
  - Greater Modeling flexibility
  - More Stable numerical solutions
  - More accurate flow transfers from channel to floodplain
  - Possibly faster computationally (model specific)

Approach

- Use HEC-RAS 1D Bridge Geometry and Cross Section Layout (automated layout) inside of 2D Flow Area
- Develop a family of Headwater-Tailwater-Flow curves from RAS 1D bridge hydraulic calculations during geometry pre-processing
- Uses a special momentum equation that gets applied only at the 2D bridge centerline faces:
  - Friction loss, pressure differential, and convective acceleration forces are equated from the water surface difference in the bridge curves.
  - The forces are distributed across multiple faces though the bridge based on conveyance.
  - Local acceleration is calculated on the fly, as it is not a force in curves
- Bridge faces are then solved in 2D just like all other faces.
- Extremely efficient – almost no increase in computations.

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The basic steps for adding a 2D Bridge

- **Draw a centerline for the bridge opening/embankment using the SA/2D Area Conn tool.**
  - Use the Geometry editor or use the editing tools in RAS Mapper.
  - The bridge centerline must be drawn from left to right looking downstream.
- **Develop an appropriate mesh (cell size and orientation) for the bridge**
  - Use the structure mesh controls (cell size and enforcement). Some hand editing may be required depending on the bridge and what else is near the bridge (i.e. levee, another bridge, railroad tracks, road, etc…)
- **Enter the bridge data**
  - Deck/roadway; distance from upstream bridge deck to outside cross section piers; abutments; bridge modeling approach; Manning's n values for the 1D bridge cross sections; and hydraulic tables controls (HTAB) into the SA/2D Area Conn editor.
- **Pre-process the geometry in order to create the bridge curves**.
  - Review the bridge family of rating curves for hydraulic accuracy.
- **Run the model and review the results**.
  - Make any necessary changes to the data in order to improve the results.

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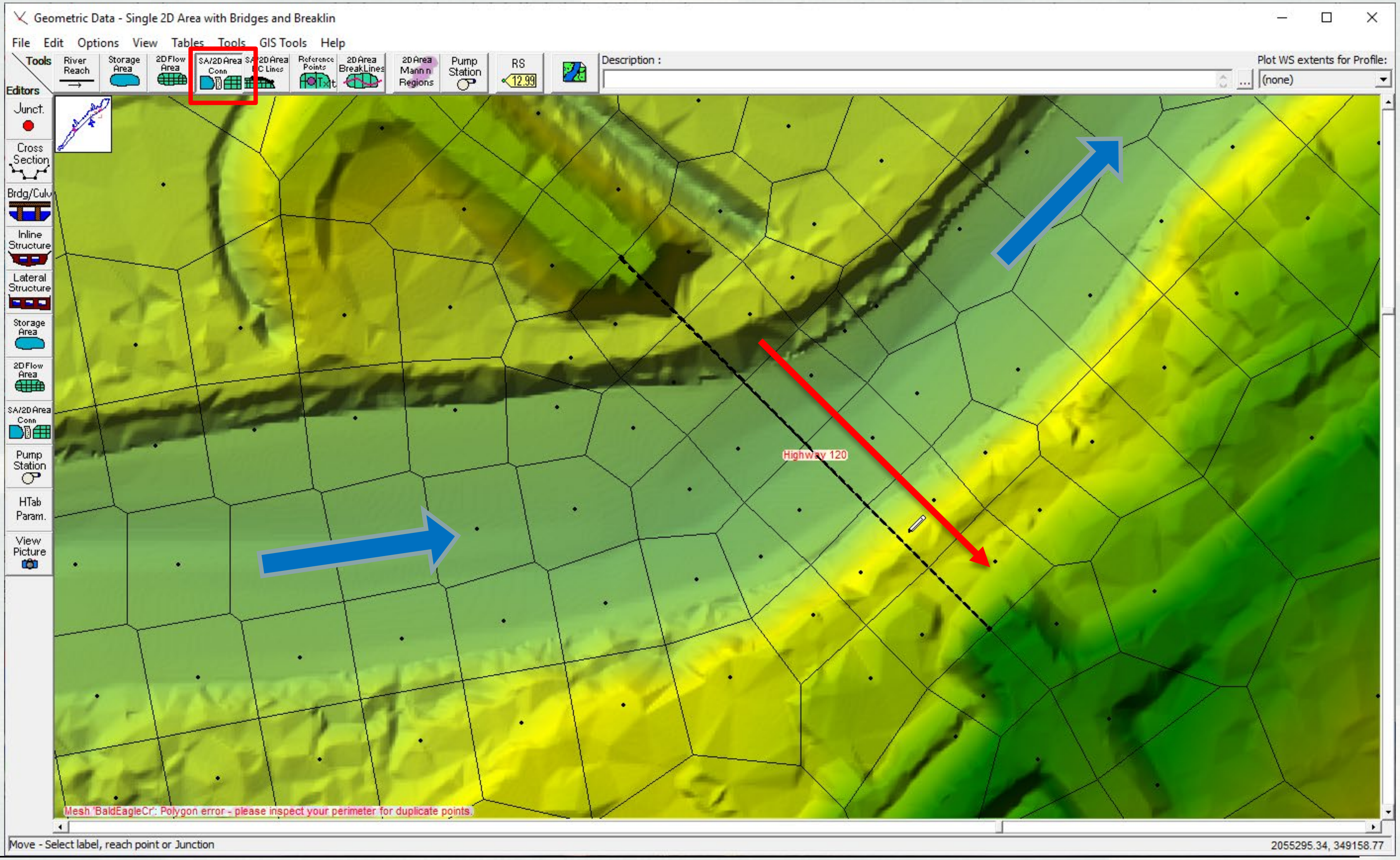
Draw the Bridge Centerline and Fix Mesh

- Select the **SA/2D Area Conn** tool and **Draw the centerline** of the bridge from left to right looking downstream
- Left click on the bridge centerline and select **Edit Internal Connection Cell Spacing.** Enter Desired Cell Spacing for across the bridge
- Left click on the centerline and select **Enforce Internal Connection as a Break Line.**



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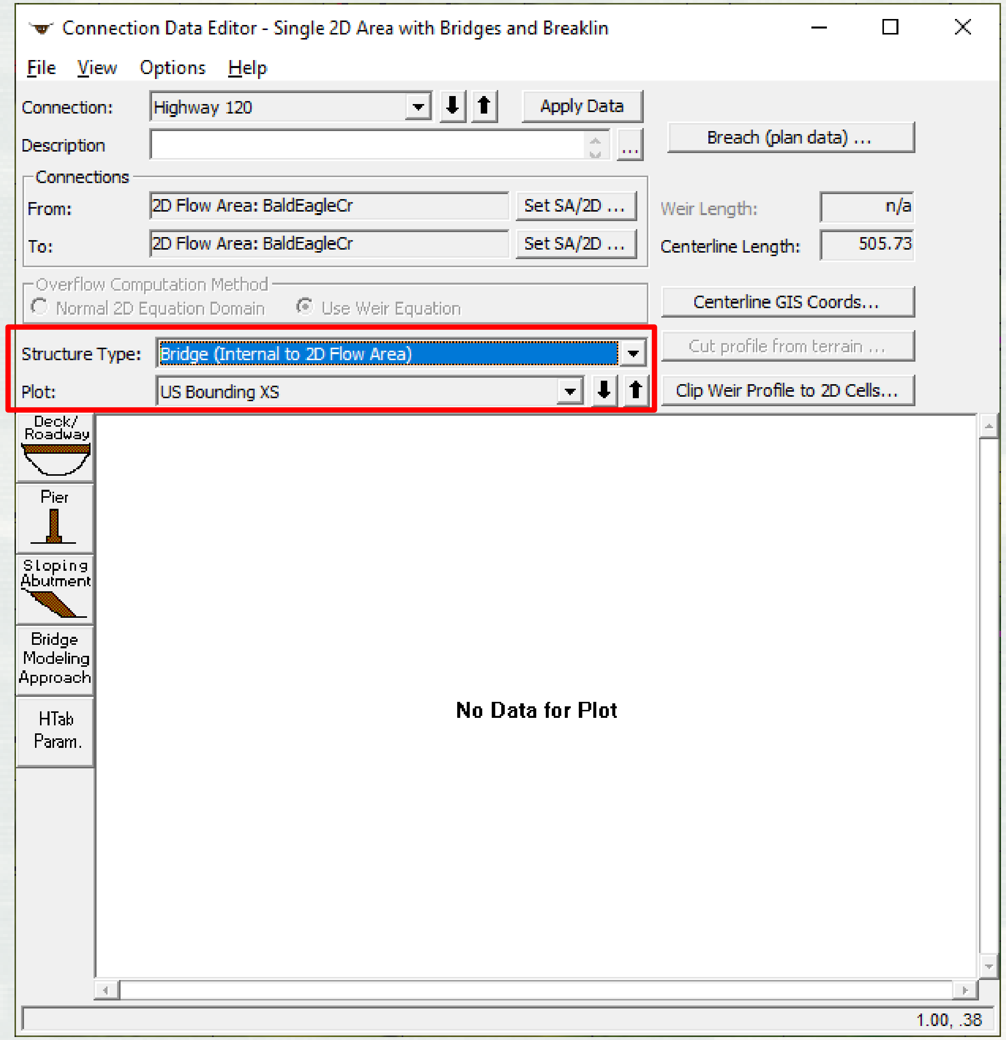
Enter the bridge Data

- Left click on the bridge centerline and choose Edit Connection, or select the **SA/2D Area Conn editor** button
- Change the **Structure Type** to a **Bridge**
- The first step is to enter the **Bridge Deck/Roadway** data



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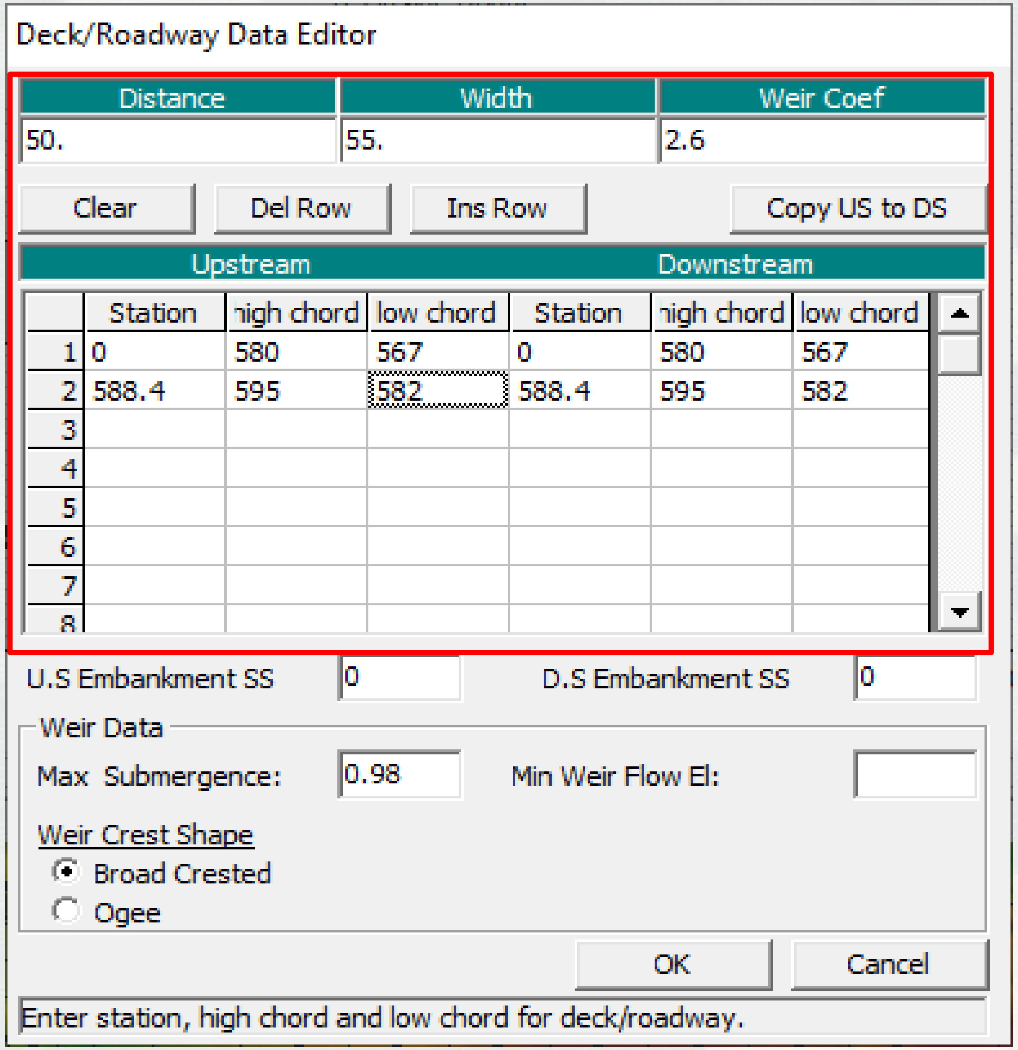
Enter the Deck and Roadway Data

- Enter the **Distance** (this is the distance from the upstream side of the bridge deck to the cross section upstream outside of the bridge, as wells as downstream outside).
- Enter the **Width** of the bridge deck in the direction of flow.
- **Weir Coefficient** for flow going over the roadway
- **Station** (distance from left to right along the bridge deck/roadway), **High Chord**, and **Low Chord** elevations for the upstream and downstream side of the bridge deck

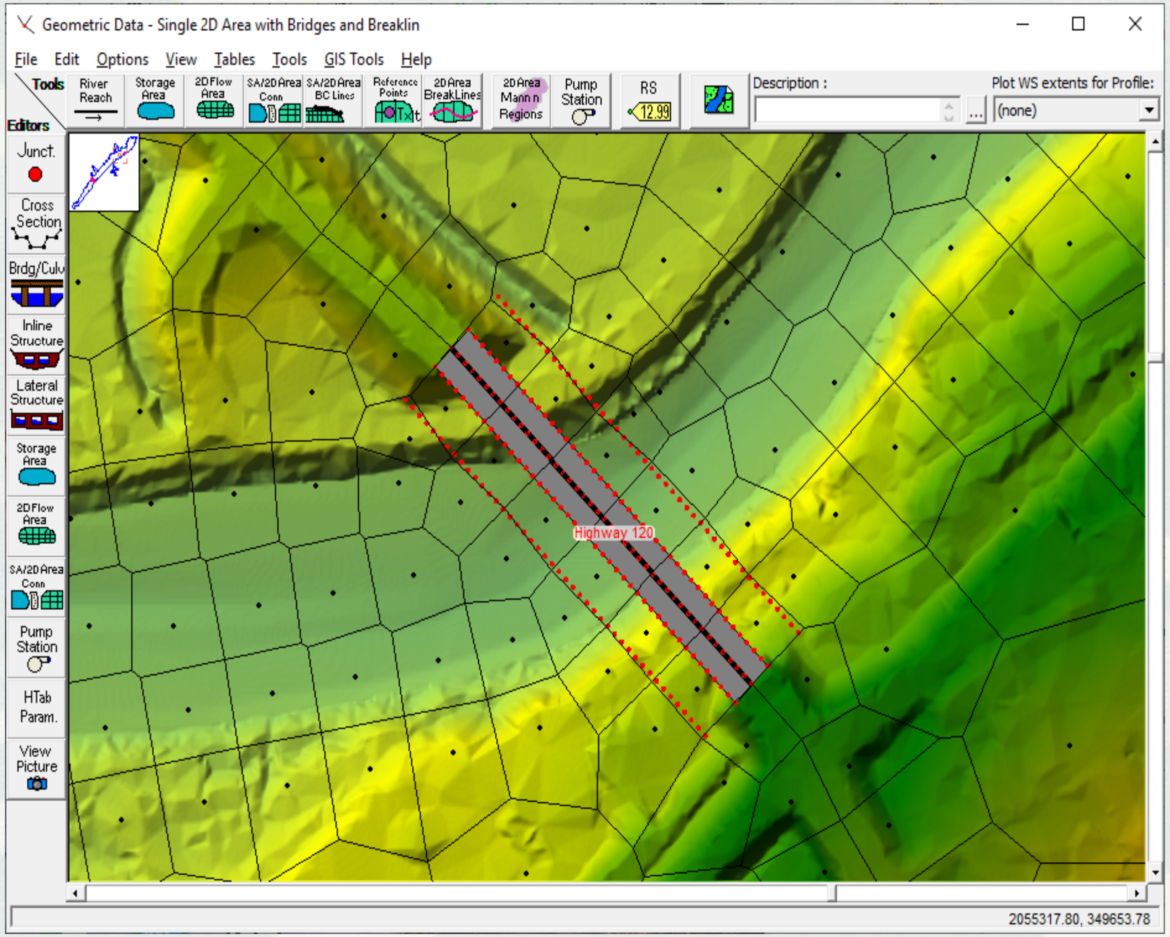


Automated 1D Cross Sections

- HEC-RAS will automatically create the four needed cross sections for pre-processing the bridge hydraulics into a family of curves.

- These four locations are:

  1. **Upstream just outside the bridge deck**, normally at the toe of the upstream embankment. This cross section is automatically generated upstream of the bridge deck based on the user entered **Distance** field.
  2. **Upstream just inside the bridge deck/roadway**.
  3. **Downstream just inside the bridge deck/roadway**.
  4. **Downstream outside of the bridge deck/roadway**, normally at the toe of the downstream embankment. This cross section is automatically generated downstream of the bridge deck a distance equal to what the user entered for the upstream **Distance** field.



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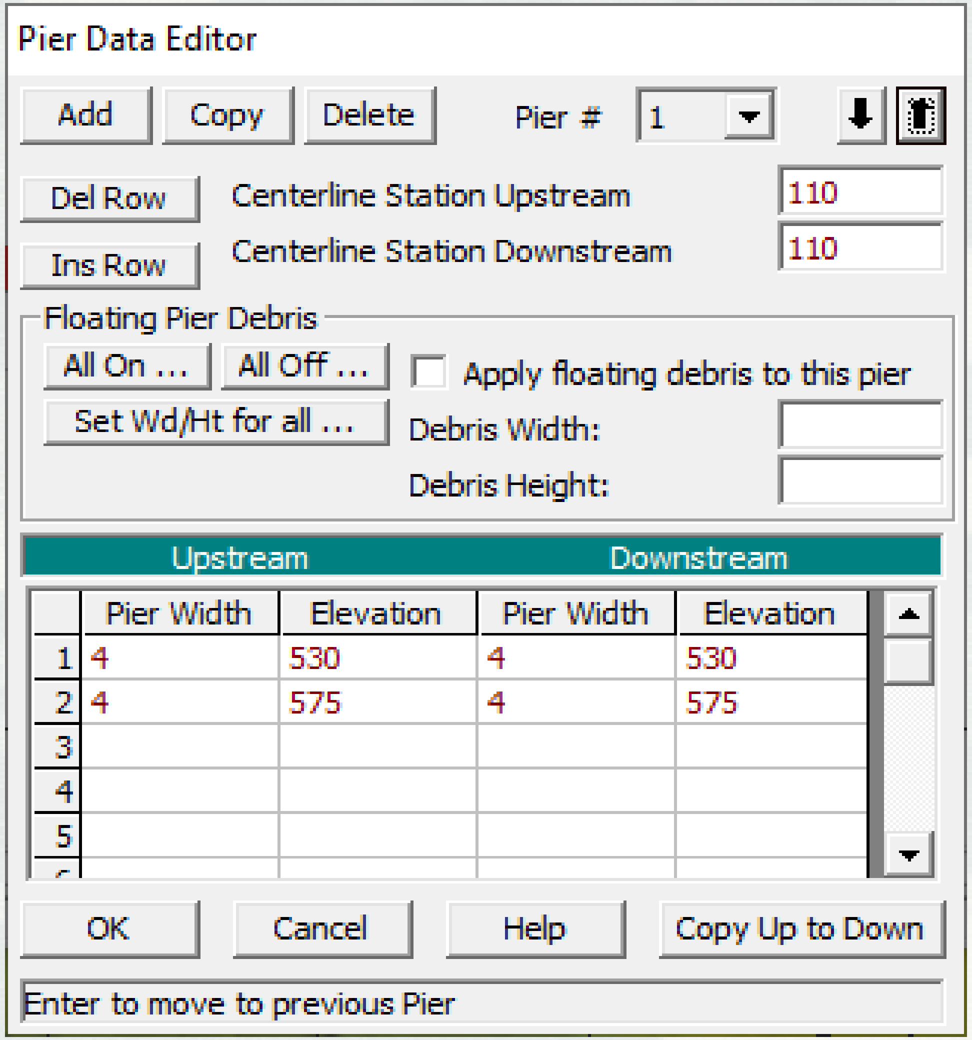
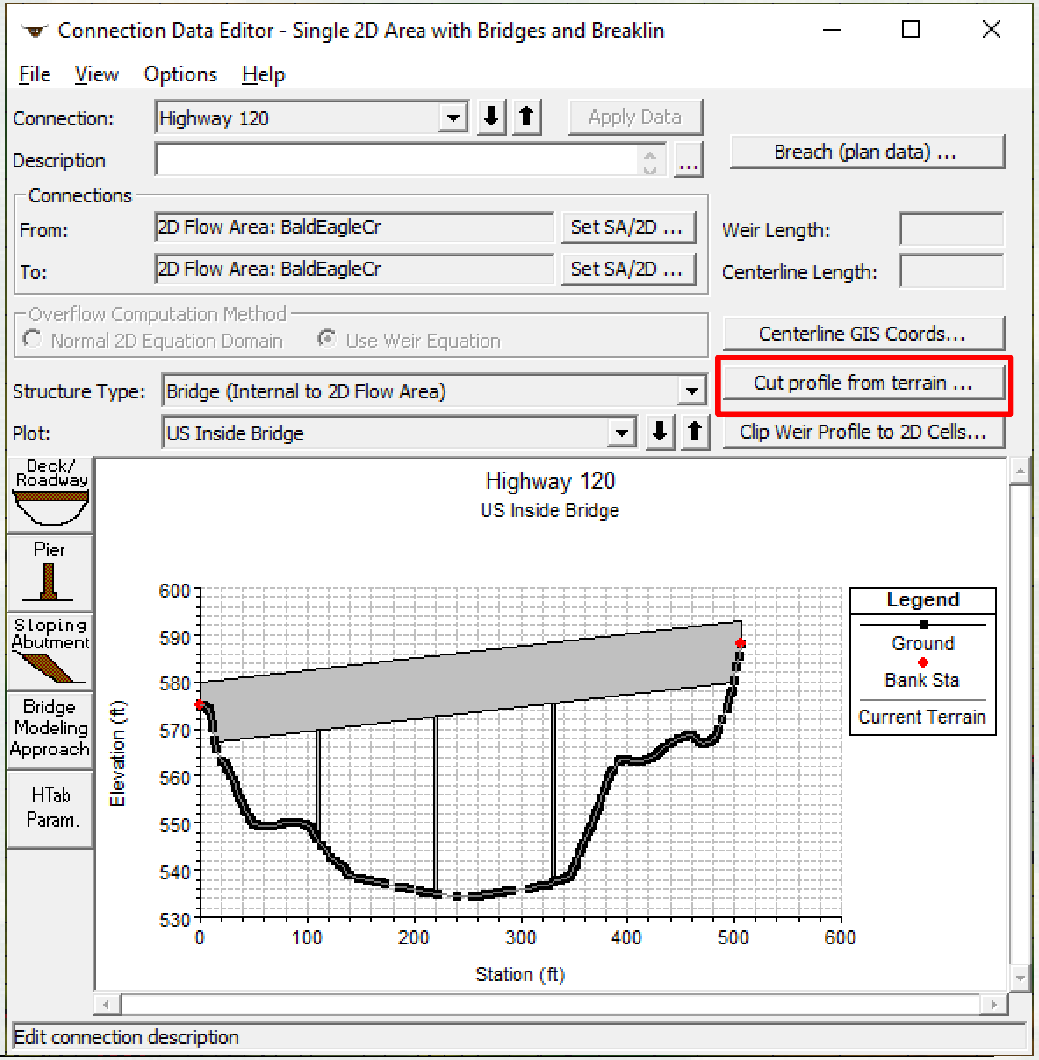
Enter any Piers and Abutment Data

- A **Centerline Station** is required for both the upstream and downstream side of the bridge pier.
- The pier is formed by entering **pairs of elevations vs widths**, starting below the ground and going up past the low chord of the bridge deck.
- This must be done for both the **upstream side and downstream side** of the bridge,
- If they are the same, then just fill in the upstream side, then use the **Copy Up to Down button** to copy the data downstream.



Final Bridge Geometry

- For the **two cross sections inside the bridge**, they follow the edges of the deck/roadway.
- The **outside cross section locations** are automated by simply creating cross sections that are parallel to the inside cross sections, and the distance upstream and downstream from the bridge deck is based on what the user entered for the **Distance field in the Deck/Roadway editor**.
- **Note:** If the user changes the Deck/roadway data (Bridge width or distance field), then the location of the 1D cross sections will change.
- The user can view each of the four cross sections, as well as the centerline from the **plot by selecting the location to view**.
- **If the bridge data is changes**, the user will see that the terrain under the current 1D cross section line is different than what they currently have entered. The user can recut any of the 1D cross sections by simply pressing the **Cut profile from terrain button** while viewing a specific cross section.



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Enter the Manning's n Data for the XS's

- To enter Manning's n values for the 1D cross sections, go to the **Options menu** and select **External and Internal Bridge Cross Sections**…

Bridge Cross Sections

Upstream Outside

Main Channel Bank Stations	
Left Bank Sta	Right Bank Sta
0	505.73

Cross Section X-Y Coordinates

	Station	Elevation	Mann n
1	0	552.78	0.04
2	2.08	552.43	
3	3.49	552.07	
4	5.61	551.46	
5	6.34	551.22	
6	9.11	550.12	
7	9.85	549.97	
8	11.97	549.62	
9	13.33	549.41	
10	16.22	549.21	
11	17.55	549.09	
12	21.77	548.59	

Upstream Inside

Main Channel Bank Stations	
Left Bank Sta	Right Bank Sta
0	505.73

Cross Section X-Y Coordinates

	Station	Elevation	Mann n
1	0	575.09	0.04
2	1.13	575.08	
3	3.25	574.95	
4	3.74	574.9	
5	5.37	574.65	
6	7.02	574.32	
7	7.49	574.17	
8	7.96	573.91	
9	9.61	572.74	
10	11.28	570.87	
11	11.74	570.25	
12	13.86	567.6	

Downstream Inside

Main Channel Bank Stations	
Left Bank Sta	Right Bank Sta
0	505.73

Cross Section X-Y Coordinates

	Station	Elevation	Mann n
1	0	573.08	0.04
2	0.87	573.13	
3	3.32	573.38	
4	5.11	573.66	
5	6.91	574.04	
6	7.55	574.11	
7	9.35	574.17	
8	11.18	574.33	
9	13.6	574.28	
10	15.44	574.34	
11	15.99	574.33	
12	17.84	574.18	

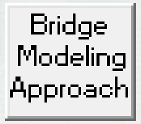
Downstream Outside

Main Channel Bank Stations	
Left Bank Sta	Right Bank Sta
0	505.73

Cross Section X-Y Coordinates

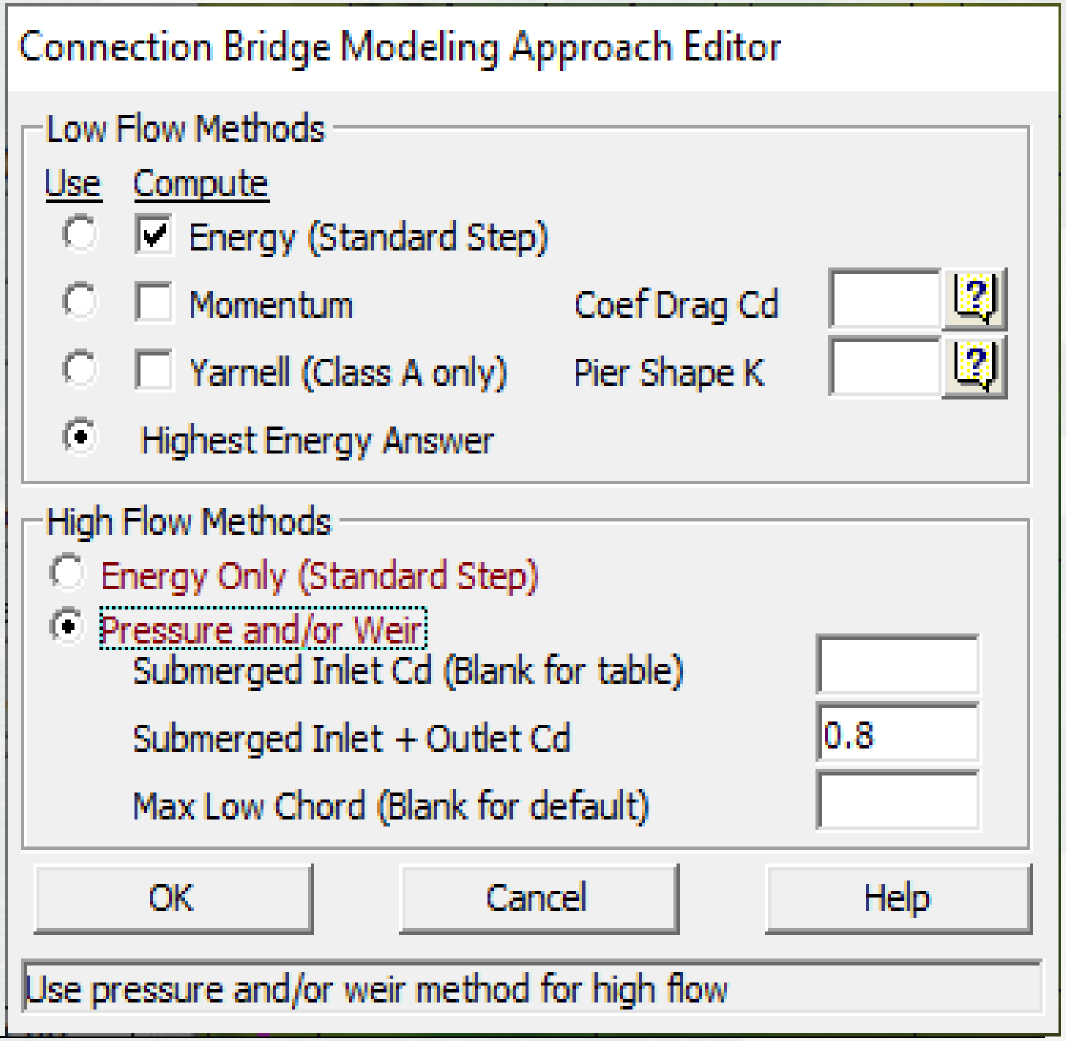
	Station	Elevation	Mann n
1	0	547.16	0.04
2	2.18	547.32	
3	2.75	547.29	
4	4.87	547.29	
5	7.59	547.46	
6	9.12	547.51	
7	11.85	547.68	
8	13.36	547.73	
9	14.85	547.84	
10	17.6	547.93	
11	19.07	548	
12	19.72	548.02	

OK Cancel Help



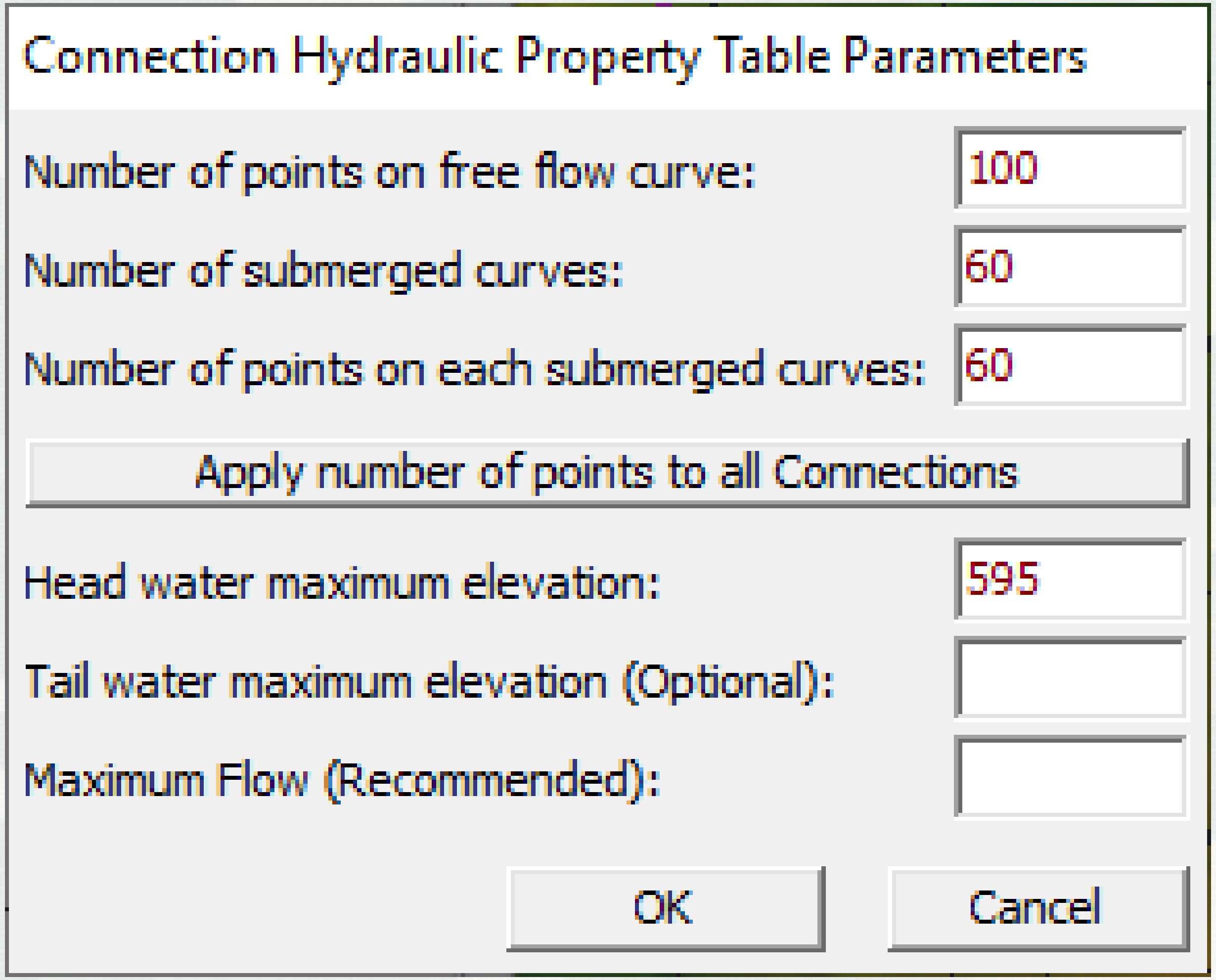
Enter the Bridge Modeling Approach

- This editor is very similar to the bridge modeling approach editor for 1D bridges.
- The user can select one or more **low flow bridge hydraulic methods**:
  - Energy
  - Momentum
  - Yarnell.
- The **high flow methods** are:
  - Energy
  - Pressure/Weir flow

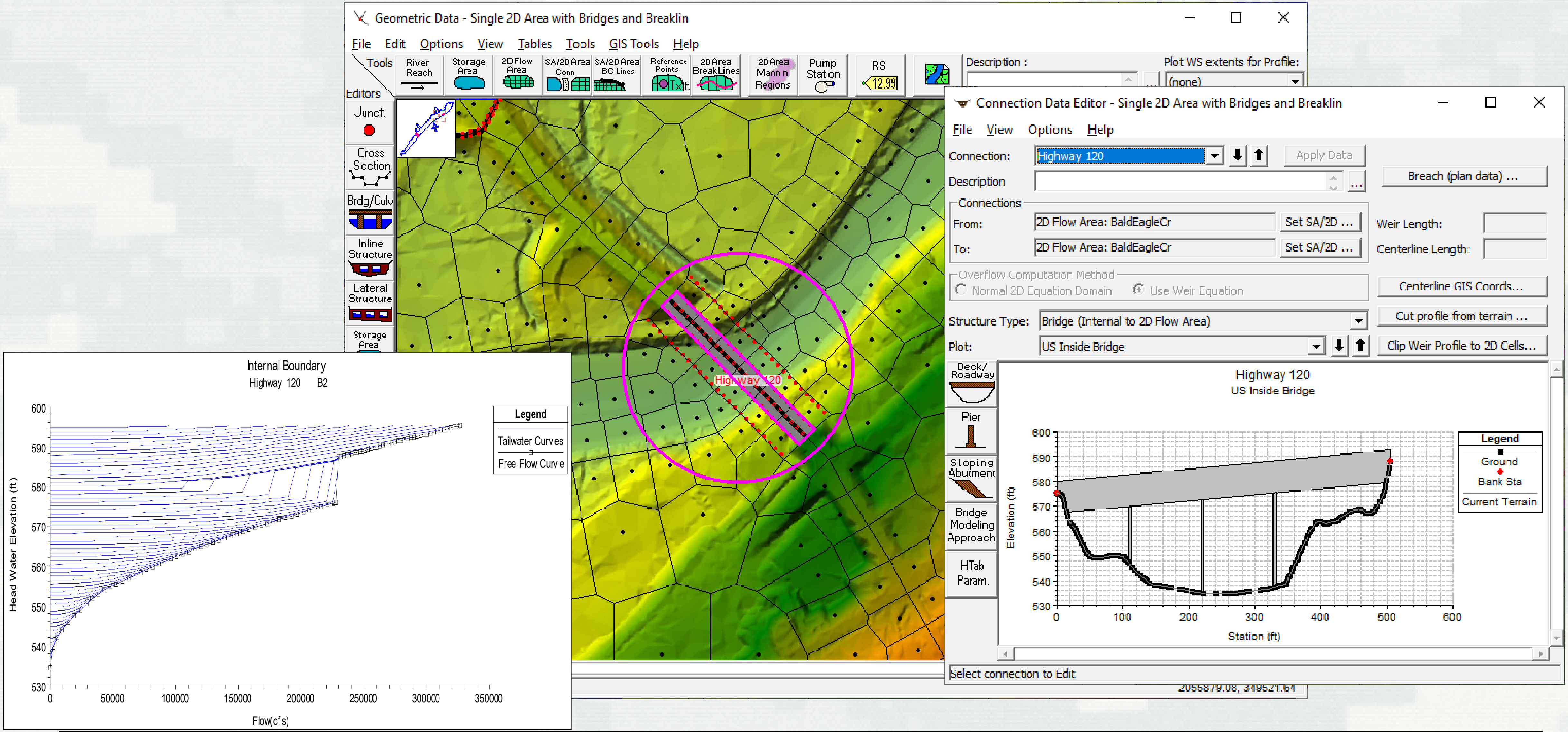


Define the Hydraulic Table Parameters

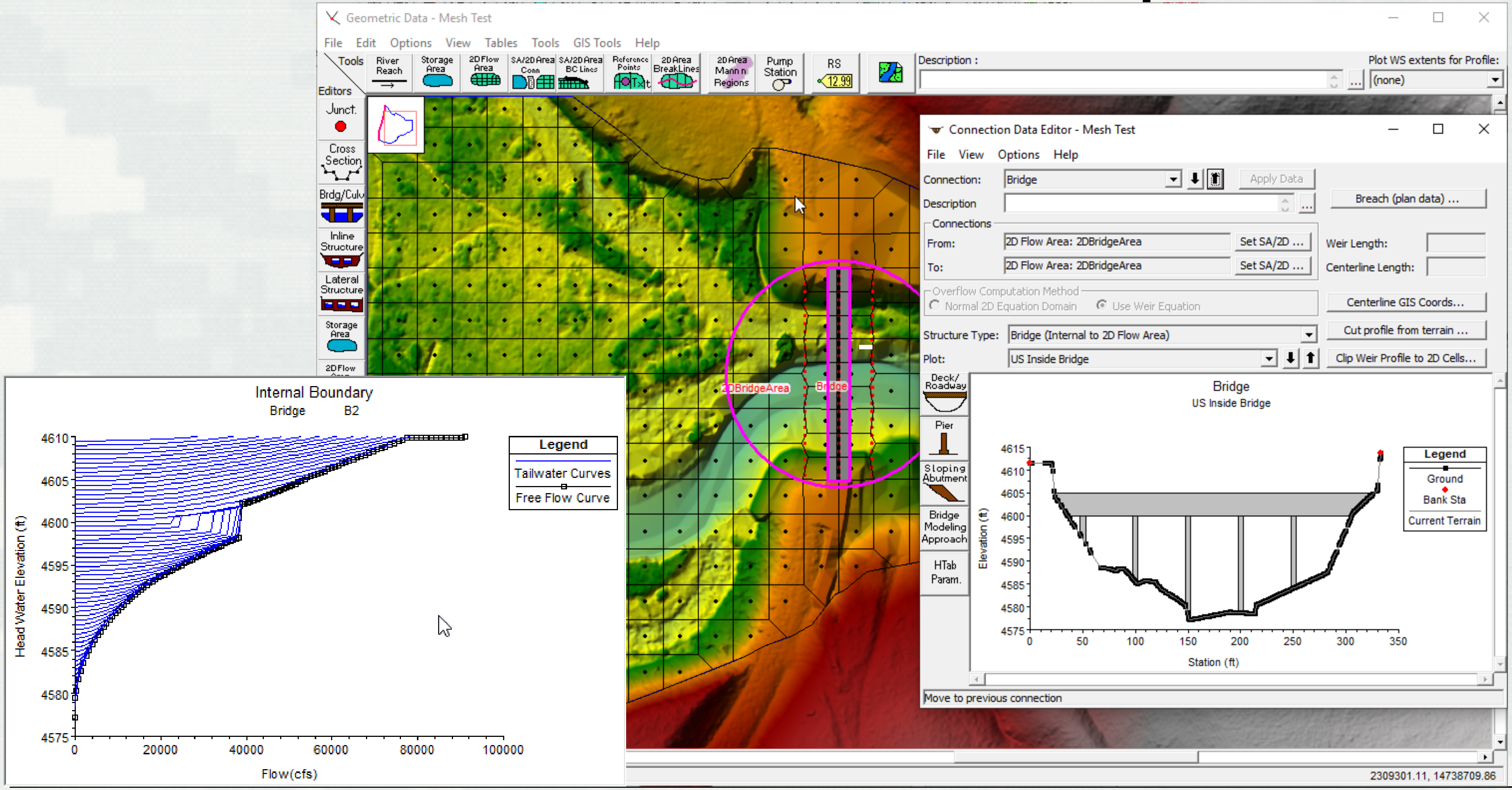
- **Number of points on free flow curve** (maximum is 100)
- **Number of submerged curves** (maximum is 60)
- **Number of points on each submerged curve** (maximum is 60)
- **Head water maximum elevation**.
- The Tail water maximum **elevation** is optional, as is the Maximum Flow.



Pre-processing – Family of Bridge Curves



Results
1D vs 2D Model Comparison



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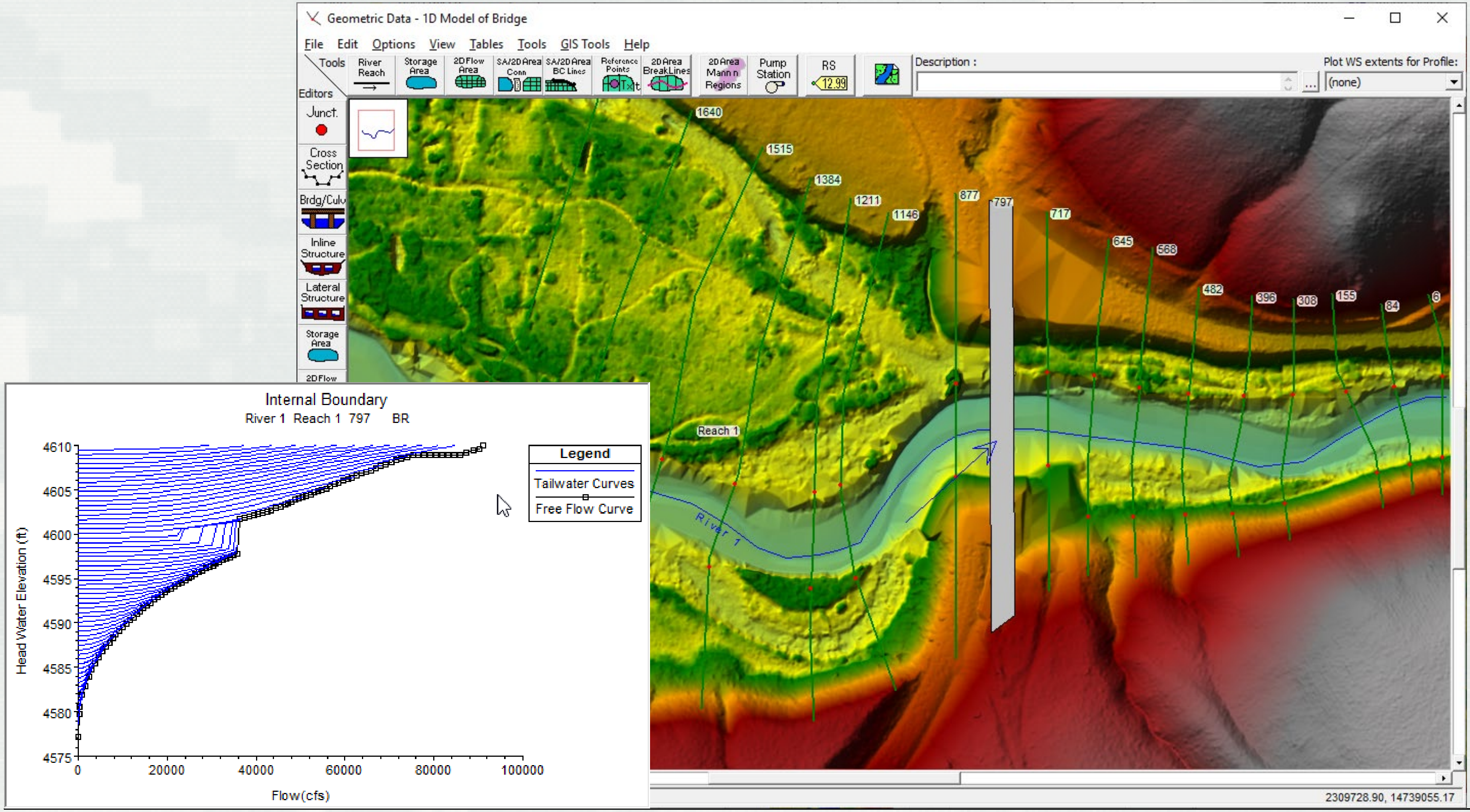
1D Model of Same Area



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1D and 2D Comparison Animation

Velocity Tracers

Questions?