Dam Breach Analysis with 1D and 2D Areas
Workshop

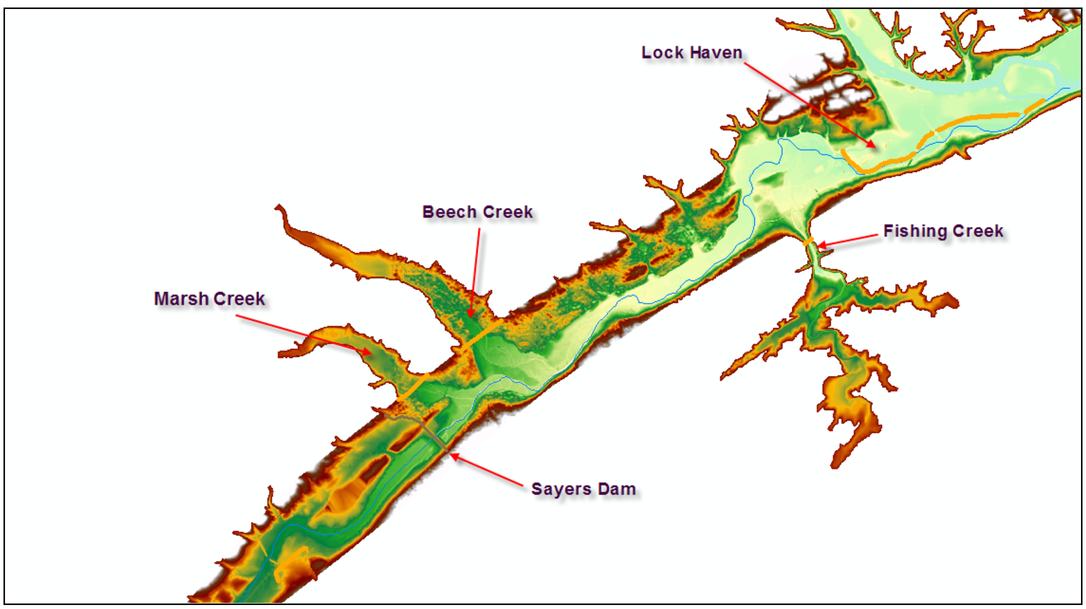
1 Objective

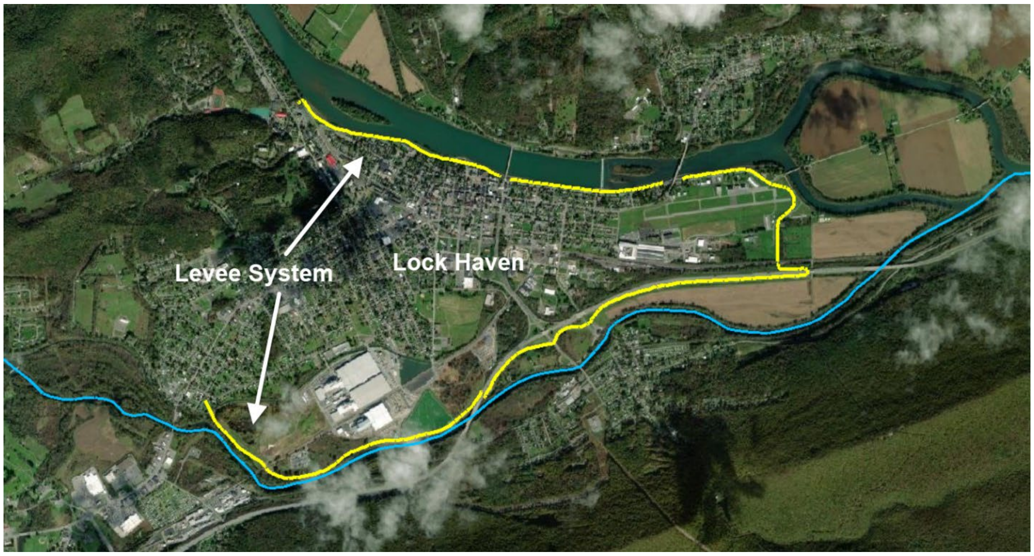
This workshop will guide students on using HEC-RAS to:

- Create a new dam breach model using 1D and 2D elements
- Connect 1D and 2D elements using SA/2D Connections
- Set a SA/2D Connection to breach
- Interpret the results of a dam breach simulation

2 Background

The town of Lock Haven is situated on the north bank of Bald Eagle Creek in central Pennsylvania. Lock Haven sits behind a levee system that was designed to provide protection for a 500-year (0.2% Chance) event. Sayers Dam, a flood control project on Bald Eagle Creek, is approximately 15 miles upstream of Lock Haven. See the figures below to become acquainted with the domain.

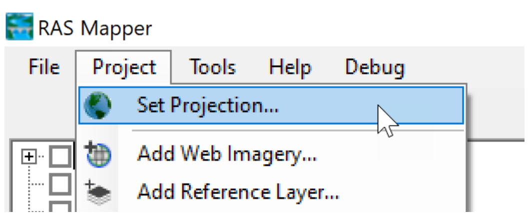




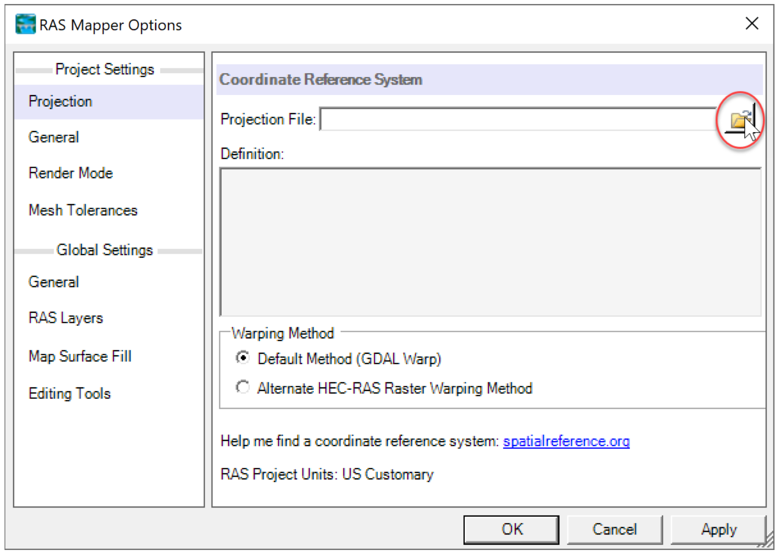
In this workshop we will be performing a dam breach analysis to determine the consequences of a failure of Sayers Dam by inputting design inflows for the reservoir and setting the Sayers Dam to breach.

3 Create the HEC-RAS Project

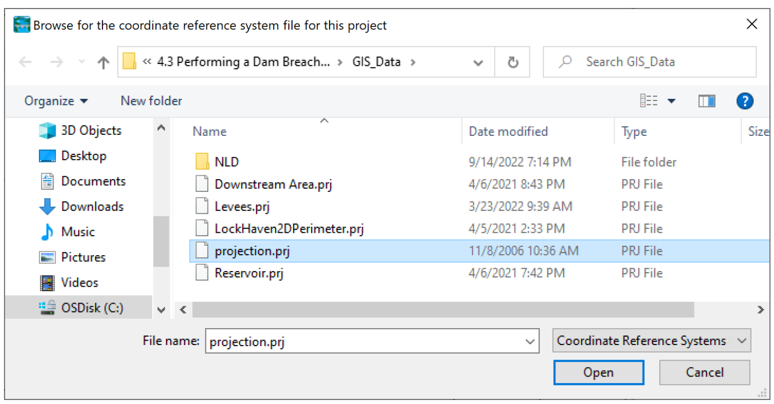
1. **Create** a new HEC-RAS project in the workshop directory containing the Terrain, Features, and GIS_Data directories. Use the title “Bald Eagle Creek Dam Breach Analysis” and name the project “BaldEagleCreekDamBreach.prj”
2. **Open RAS Mapper** by clicking on  in the main window.
3. **Set** the **projection**
   a. Click on the menu **Project** | **Set Projection**

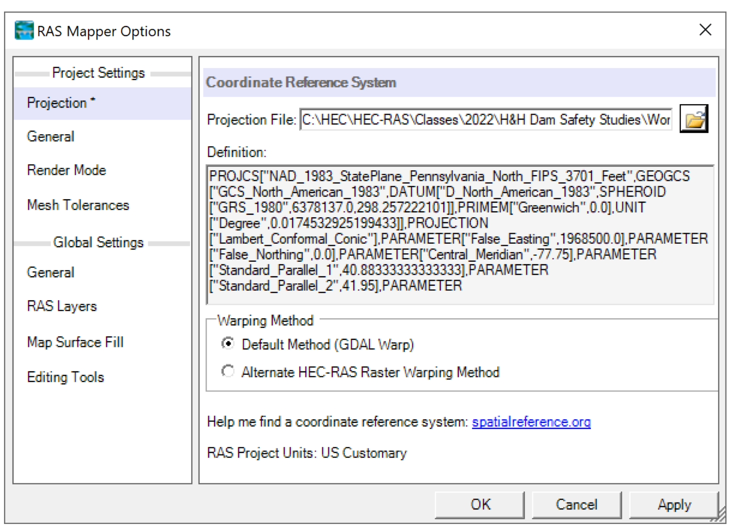
   b. In the **Projection** Section of the **RAS Mapper Options** window click on the button 



c. Select the file "projection.prj" in the "GIS_Data" directory



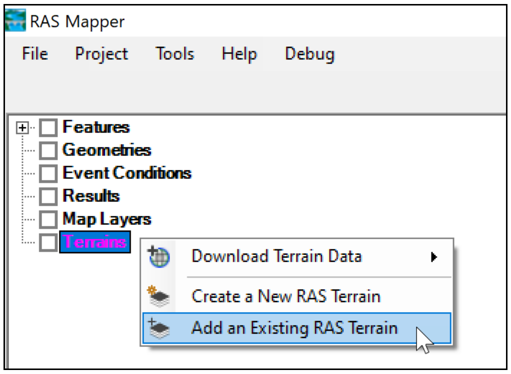
d. The RAS Mapper Options window should look like this:



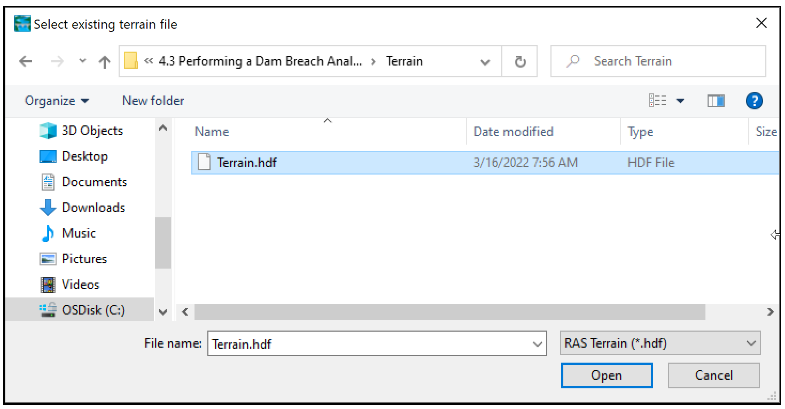
e. Click **Apply** and **OK** to exit the window.

4. **Add the Existing RAS Terrain** ("Terrain.hdf")

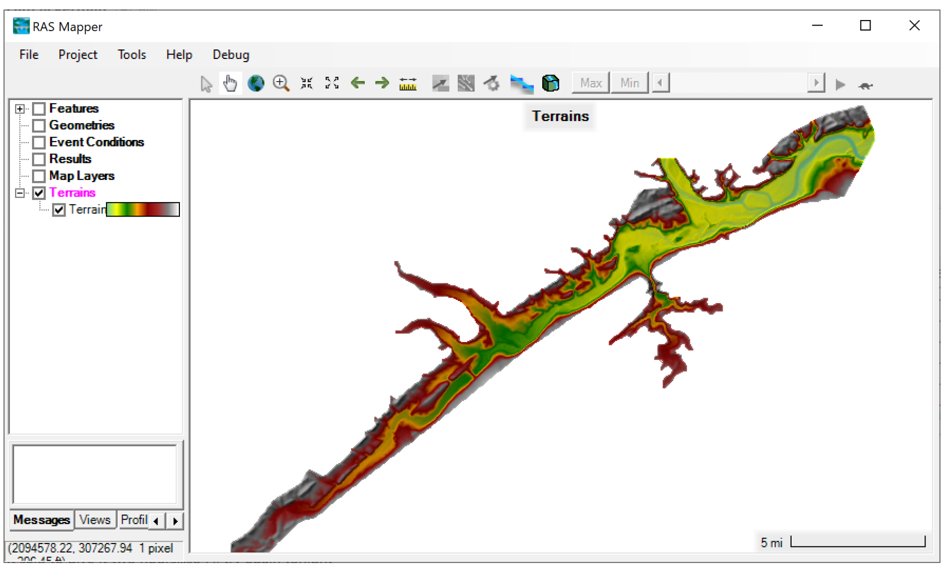
   a. **Right-click** on the Terrain node in **RAS Mapper**, and select the menu **Add an Existing RAS Terrain** as shown below



   b. Within the **Terrain** folder of the main project directory, select the RAS terrain file called "Terrain.hdf"



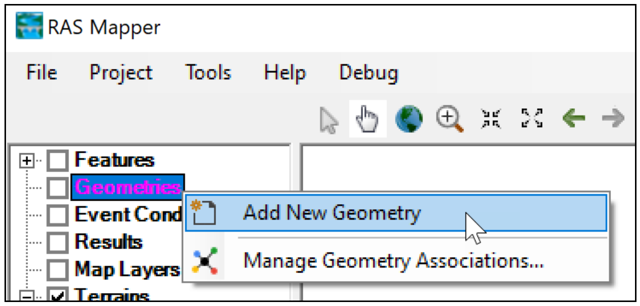
   c. The terrain should display in RAS Mapper.



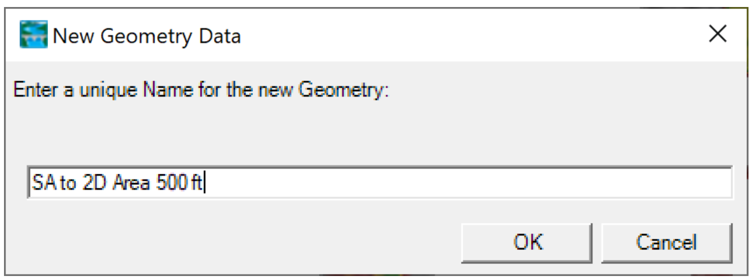
4 Create the Geometry in RAS Mapper

5. **Add** a **New Geometry**

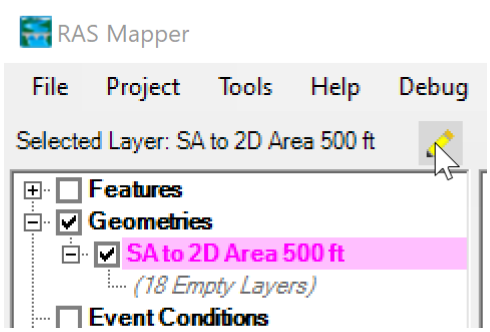
   a. **Right-click** on the **Geometries** node and select **Add New Geometry**.



   b. Name the Geometry “SA to 2D Area 500 ft” and click **OK**

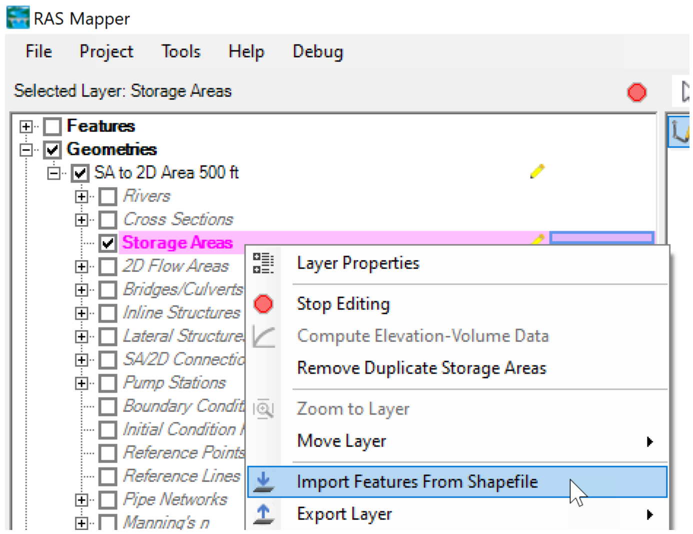


6. **Start Editing** the by selecting the Geometry clicking on the Pencil

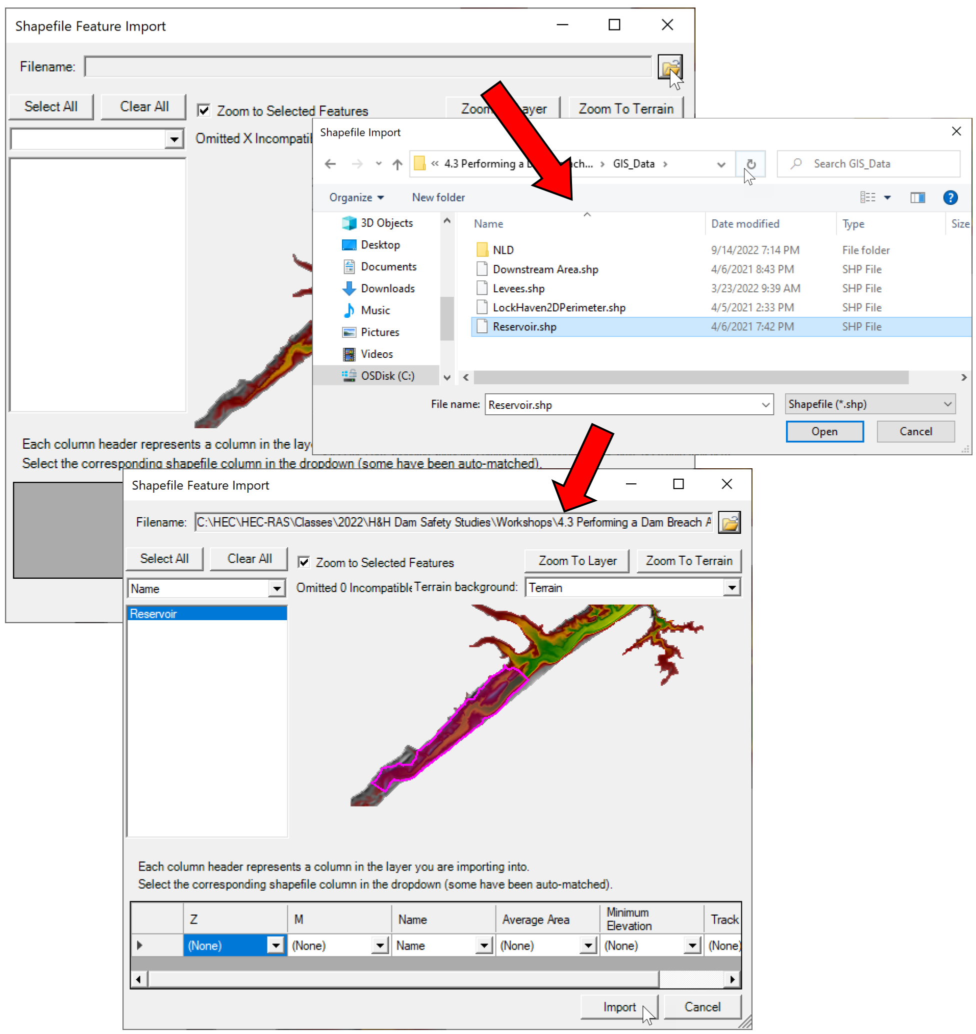


7. **Create the Reservoir** behind Sayers Dam

   a. **Right-click** on the **Storage Areas** layer, and select the menu **Import Features from Shapefile** as shown below



b. Import the "**Reservoir**" shapefile (GIS_Data folder)

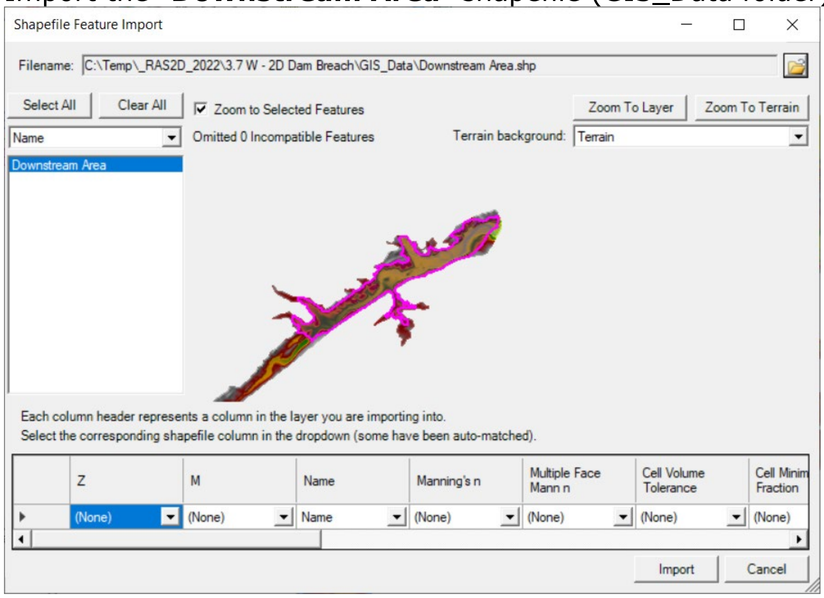


8. **Create the 2D Flow Area**

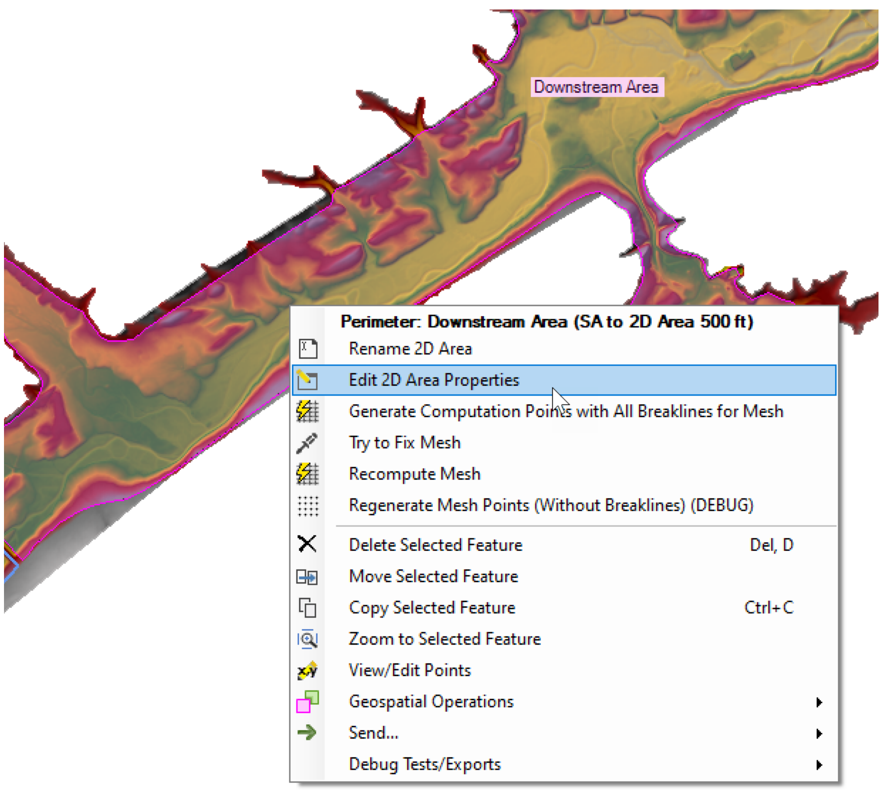
a. Expand the **2D Flow Areas** layer

b. Select the **Perimeters** layer

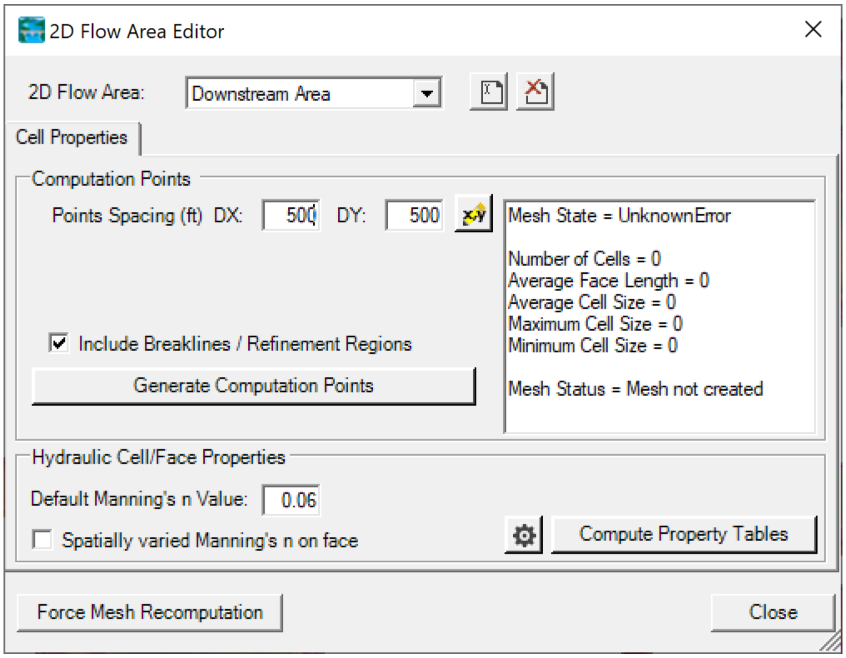
c. Import the "**Downstream Area**" shapefile (GIS_Data folder)



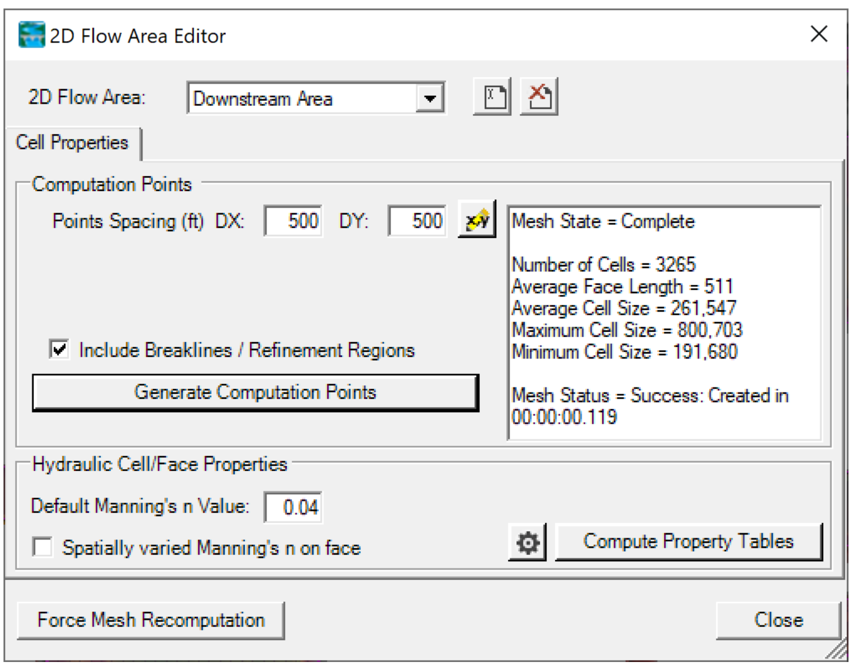
d. **Right-click** on the perimeter and choose **Edit 2D Area Properties**



e. Set the **Points Spacing** (i.e. cell size) to **500 ft,** the **Manning's n value** to **0.04** as shown below. The 500-ft spacing is quite coarse for a dam break simulation. However, this is a good start which will allow the model to run fast and mesh refinements can be done later.



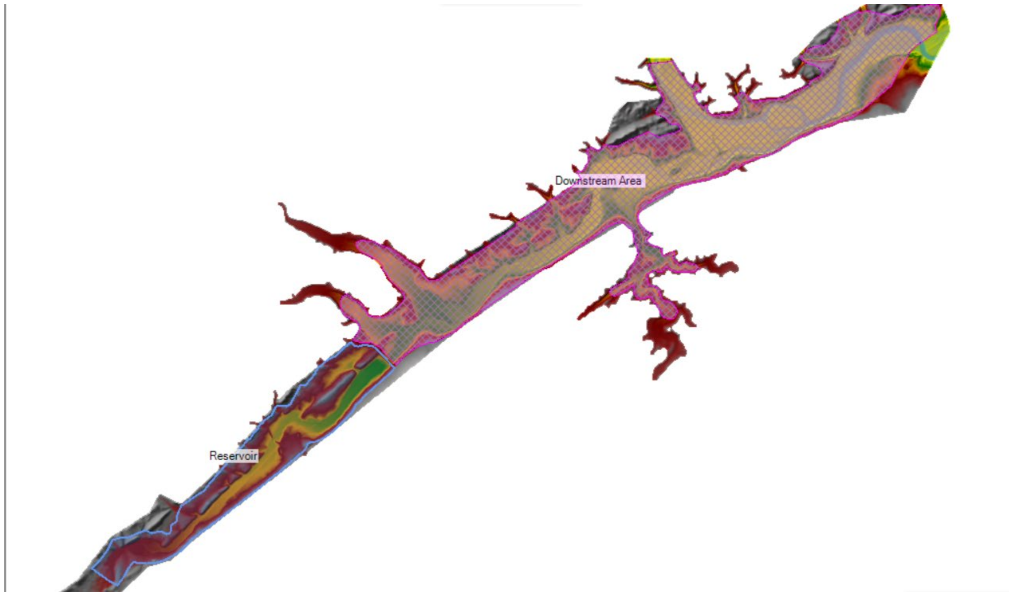
f. **Click** on **Generate computation points** for the 2D Flow Area.



g. **Close the 2D Flow Area Editor.**

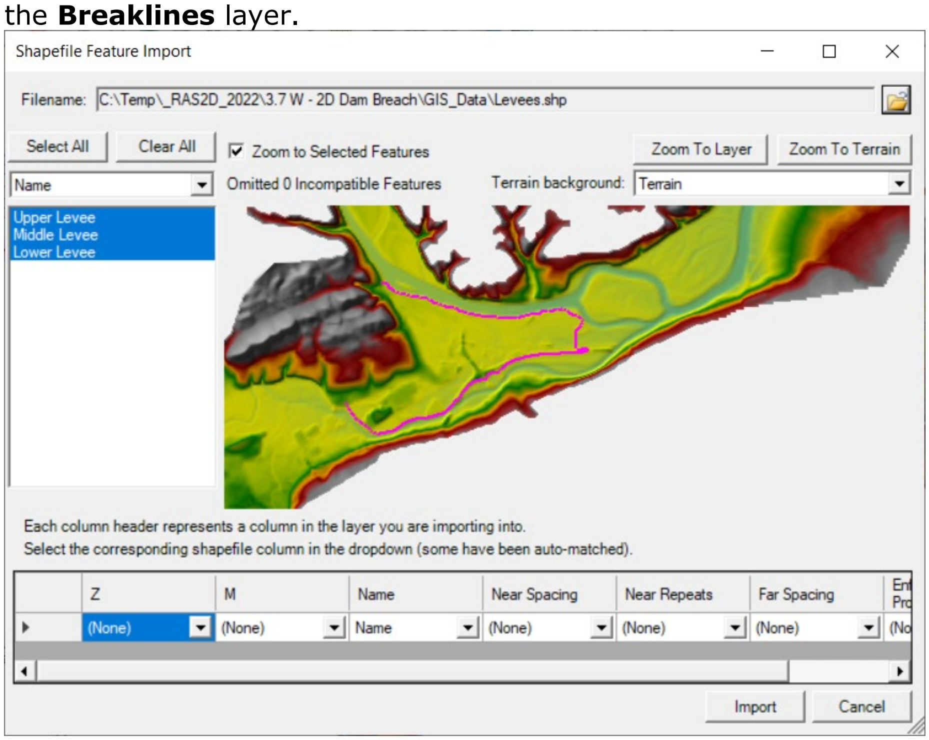
h. **Inspect** the mesh for bad cells. Look for any red dots on the mesh and fix any problems with the mesh.

At this point you should have a Storage Area and a Mesh, as shown below.

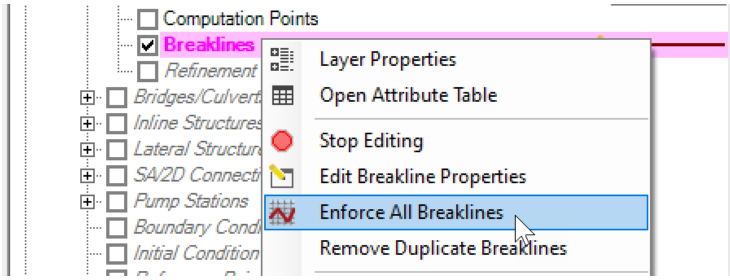


9. **Create Breaklines** along the levees

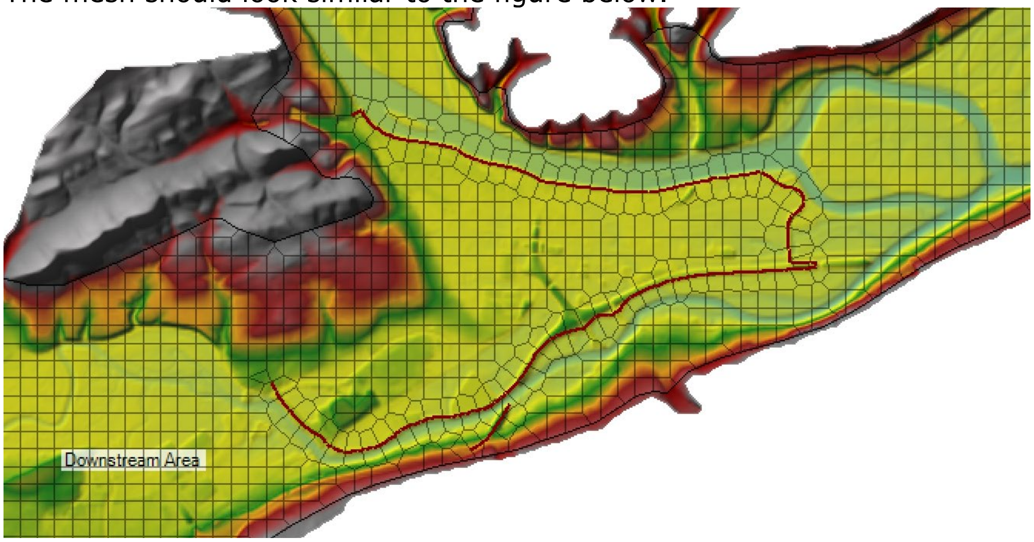
   a. Import the **Levee** shapefile for the upper, middle, and lower levee to the **Breaklines** layer.



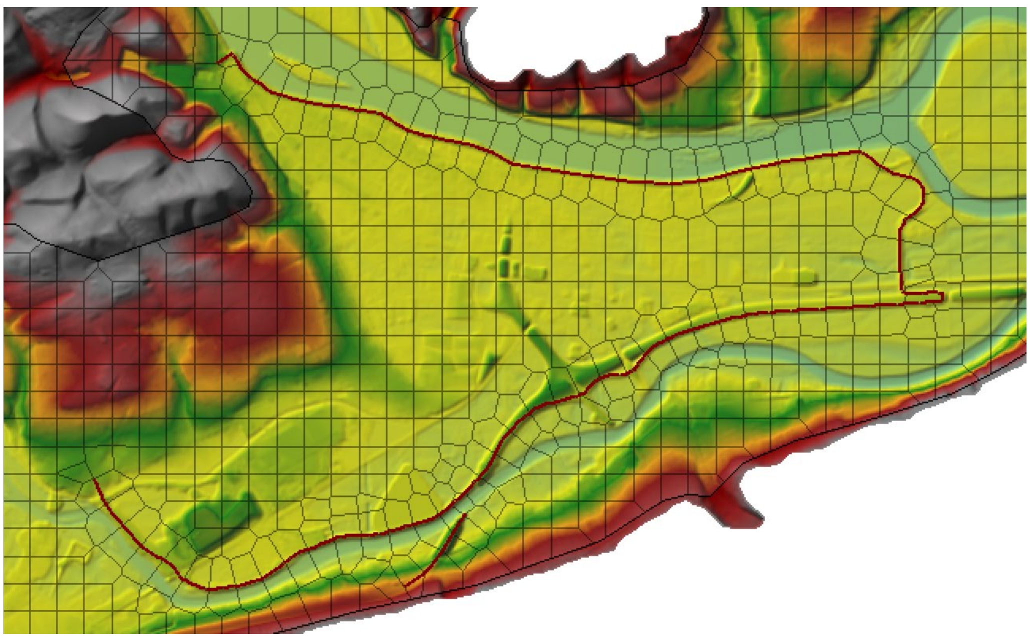
   b. **Right-click** on the **Breaklines** layer and choose **Enforce All Breaklines** to modify the mesh.



The mesh should look similar to the figure below.



c. **Fix** any problems with the mesh quality, especially around sharp bends and transition areas. An example mesh is shown below.

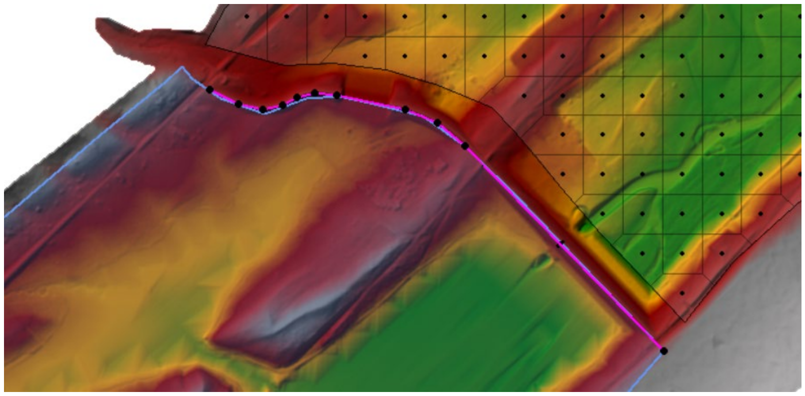


10. **Create the Dam**

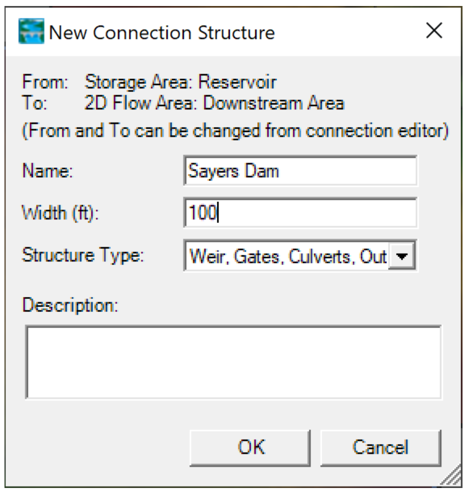
a. **Zoom** to the Dam location.

b. **Select** the **SA/2D Connections** layer.

c. **Draw the structure** along the top of the dam, left-to-right when looking downstream. (We will override the weir elevations later). **Double-click** to end the connection.

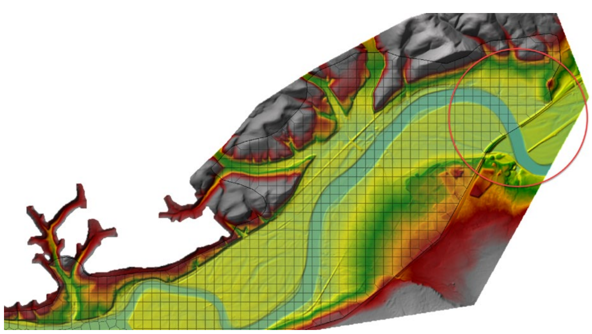


d. **Enter** the **SA/2D Connection** parameters shown below.



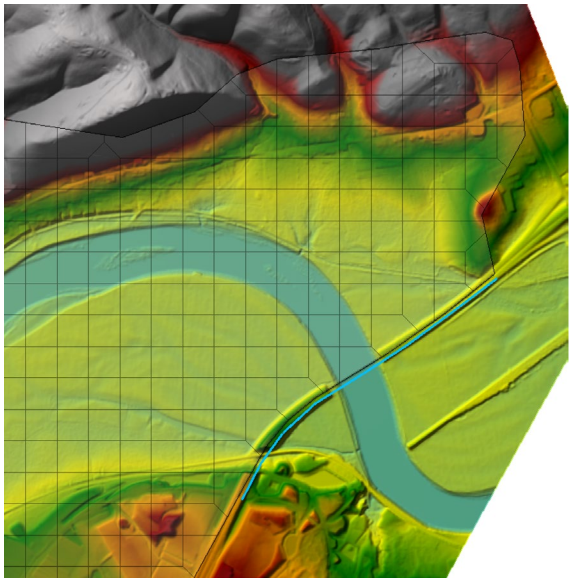
11. **Create** the **Downstream Boundary**

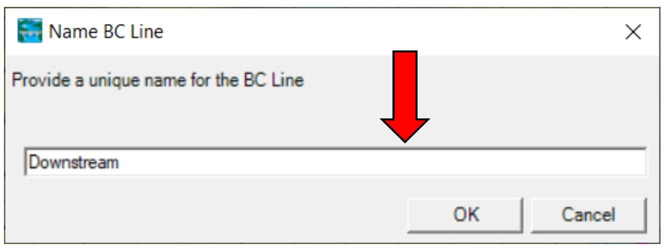
a. **Zoom** to the lower end of the model.



b. **Select** the **Boundary Condition Lines** Layer.

c. **Draw** the **Downstream Boundary** line and provide a **Name**

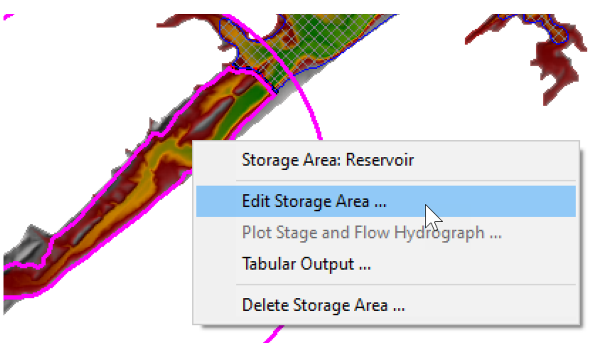




12. **Stop Editing** and **Save** the edits.
13. **Save** and **Close RAS Mapper.**

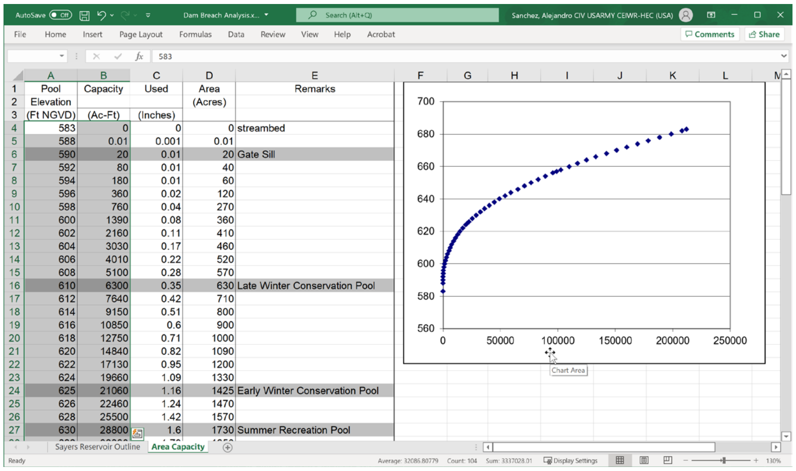
5 Edit the Reservoir Volume-Elevation Curve

14. **Open** the **Geometric Data** editor by clicking on the icon in the main HEC-RAS window.
15. **Open** the **Geometry** "SA to 2D Area 500 ft"
16. **Edit** the **Storage Area**



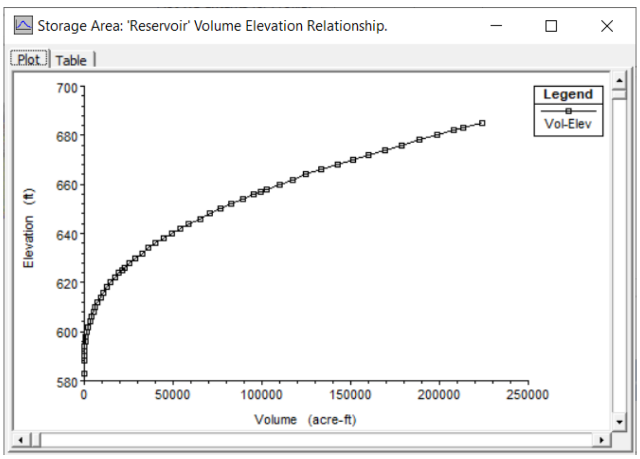
Note that there are already Volume-Elevation data provided. These data were extracted from the terrain model, but we need to replace with more accurate data.

17. **Enter the Elevation-Volume Relationship** – this data is in the Excel spreadsheet provided.



Pool Elevation (Ft NGVD)	Capacity (Ac-Ft)	Used (Inches)	Area (Acres)	Remarks
583	0	0	0	streambed
588	0.01	0.001	0.01	
590	20	0.01	20	Gate Sill
592	80	0.01	40	
594	180	0.01	60	
596	360	0.02	120	
598	760	0.04	270	
600	1390	0.08	360	
602	2160	0.11	410	
604	3030	0.17	460	
606	4010	0.22	520	
608	5100	0.28	570	
610	6300	0.35	630	Late Winter Conservation Pool
612	7640	0.42	710	
614	9150	0.51	800	
616	10850	0.6	900	
618	12750	0.71	1000	
620	14840	0.82	1090	
622	17130	0.95	1200	
624	19660	1.09	1330	
625	21060	1.16	1425	Early Winter Conservation Pool
626	22460	1.24	1470	
628	25500	1.42	1570	
630	28800	1.6	1730	Summer Recreation Pool

18. **Plot** the SA Volume-Elevation curve to confirm it has been entered correctly.



6 Complete the Dam Data (Weir Profile and Gates)

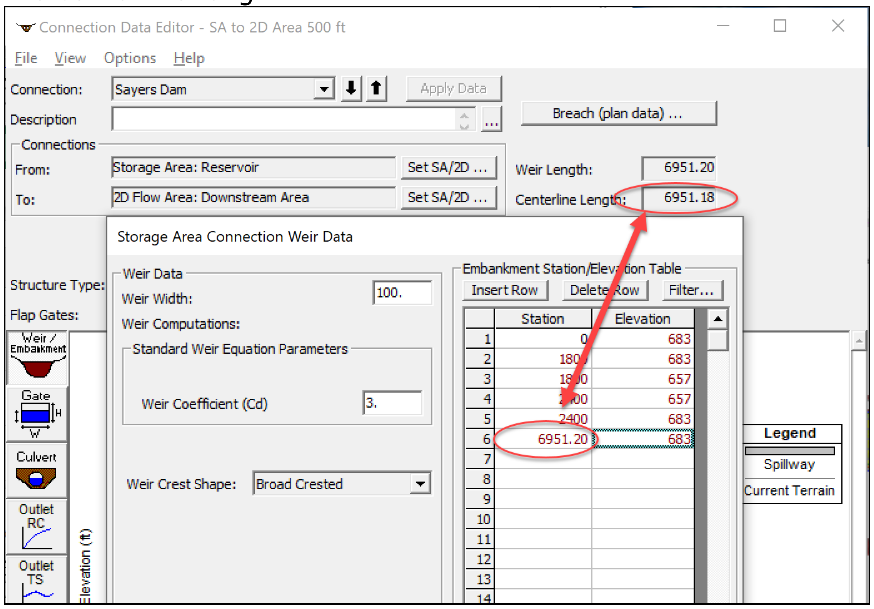
19. **Edit** the **SA/2D Area Connection** by clicking on the  button on the left panel of the **Geometric Data** editor.

20. **Verify** the **From** and **To** connection

21. **Replace the Weir/Embankment profile** from the terrain (see below)

    a. Click on the Weir/Embankment profile button 

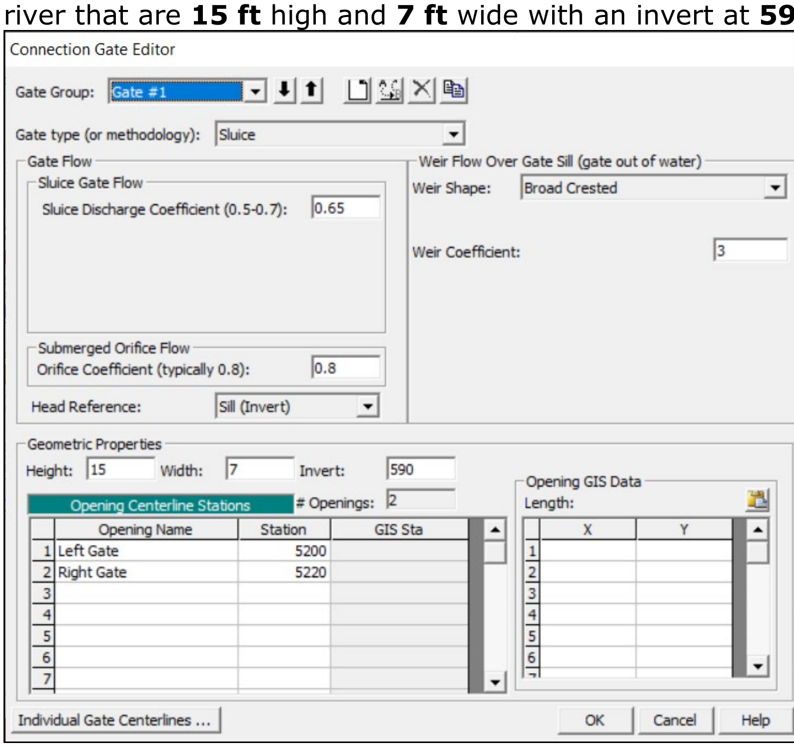
b. The top of dam is **683 ft**, top of spillway is **657 ft** and the auxiliary spillway is **600 ft** wide. You will need to match the weir width with the centerline length.



22. **Add** Gates

a. Click on the **Gate** button  in the **Connection Data Editor**.

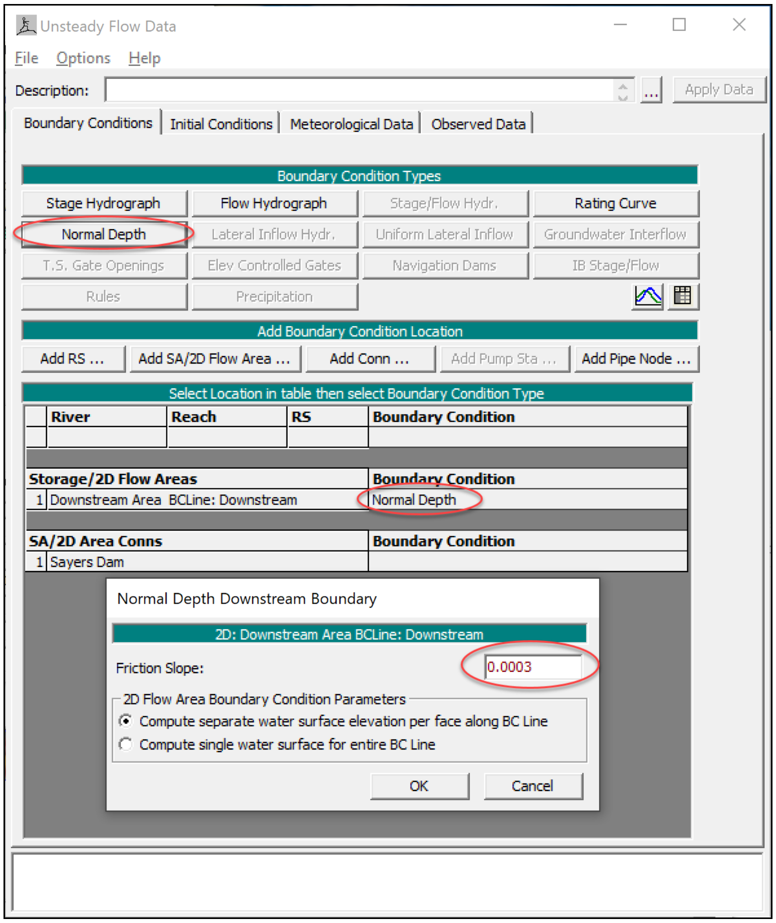
b. Gate information is provided below. Two gates (that line up with the river that are **15 ft** high and **7 ft** wide with an invert at **590 ft**.



23. **Save** the **Geometry**

7 Enter Flow Data and Boundary Conditions

24. **Open** the **Unsteady Flow Data** editor .
25. **Save** the **Unsteady Flow Data** as "PMF Flow".
26. **Specify** a **Normal Depth** BC for the **Downstream** boundary with **S=0.0003**



27. **Set** the **Gate Opening Time Series**
    a. For **Sayers Dam**, set the boundary type to **Time Series of Gate Opening**.
    b. Set the opening to a time series with a constant value of **2 ft**
28. **Add** a **Flow Hydrograph** for inflow into the **Reservoir.**
    a. Click **Add SA/2D Flow Area** button
    b. Select the **Reservoir**
    c. **Add a Lateral Inflow Hydrograph** to the Reservoir
    d. **Increase the number of points** in the table to **200** using the No. Ordinates button
    e. **Copy-paste** the **Lateral Inflow Hydrograph** tab of the Excel sheet

29. Set the **Initial Conditions** for the Reservoir Pool
    a. Click on the **Initial Conditions** tab
    b. Set the initial elevation of the Reservoir to **630 ft**.

	Storage Area/2D Flow Area	Initial Elevation
1	2D: Downstream Area	
2	SA: Reservoir	630

    c. Leave the 2D Flow Area blank. It will start dry.
30. **Save** the flow data

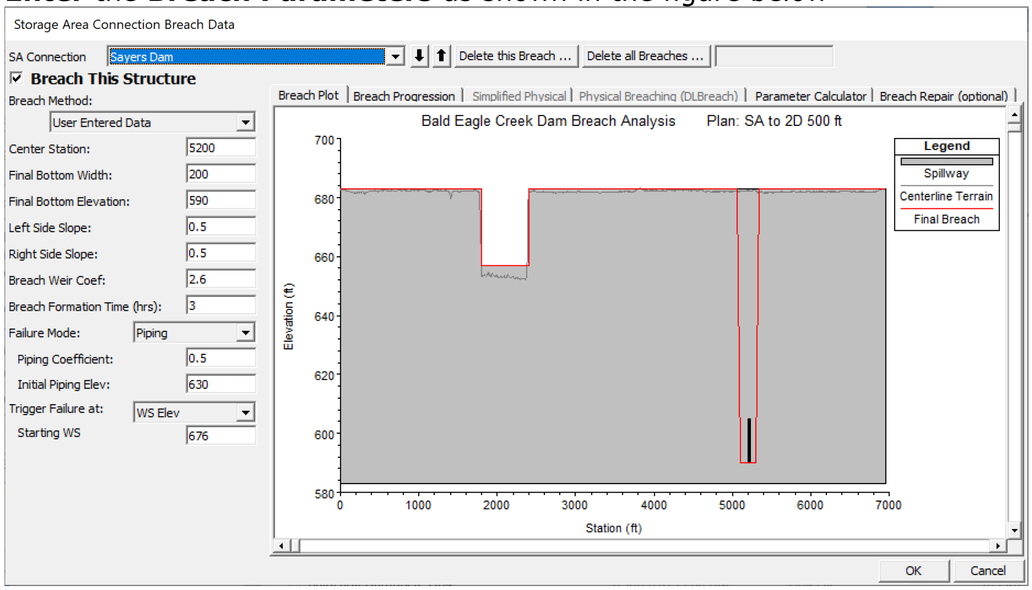
8 Create a Plan with Breach and Simulate

31. **Open** the **Unsteady Flow Analysis** editor .
32. **Save** the plan with a title "SA to 2D 500 ft" and Short ID "SA2D500ft".
33. **Check** the boxes for the **Geometry Preprocessor** and **Unsteady Flow Simulation**.
34. **Set** the **Mapping Output Interval**, **Hydrograph Output Interval**, and **Detailed Output Interval** to **5 min**.
35. **Set** a **5-day** simulation window.
36. **Set** a "reasonable" **time step** (i.e. Computation Interval) to start.
37. **Click** on the menu **Options | Computation Options and Tolerances**, select the **2D Flow Options** tab, and set the **Initial Conditions Time** for the 2D area to **2 hrs.**

	Parameter	(Default)	Downstream Area
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)		2
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1

38. **Click** on the menu **Options | SA Connection Breach.**

39. **Enter** the **Breach Parameters** as shown in the figure below



40. **Check** the box for **Breach This Structure**.
41. In the **Beach Progression** tab **Select Sine Wave**.
42. **Save** the Plan Data.
43. **Compute** the results. The simulation should take about 30 seconds.

9 Review Results

After running the model, review the output and answer some questions.

Question: What is the Peak Outflow coming out of the Dam from the PMF event and the breach?

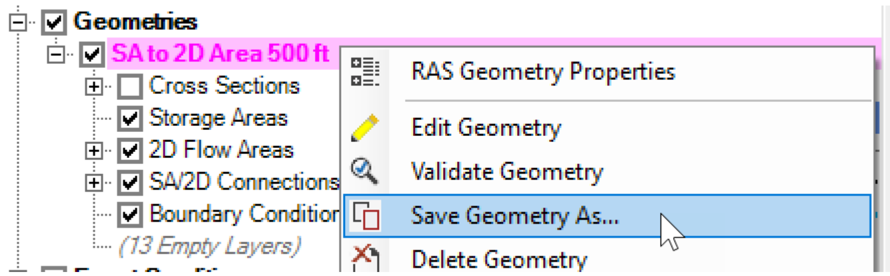
Question: What is the peak flow coming out of the 2D Flow Area for the downstream Normal Depth boundary condition outlet? Does this flow make sense given the upstream inflow from the Dam breach, the terrain data, and the computational mesh used?

Question: Is the Computational Time Step appropriate for the selected 2D Flow Area cell size and the floodwave being routed through it?

Question: Is the Computational cell size in the 2D Flow Area adequate for modeling the terrain, levees, and roads in this area? If not, briefly describe why not?

10 Change 2D Cell Size and Re-Run

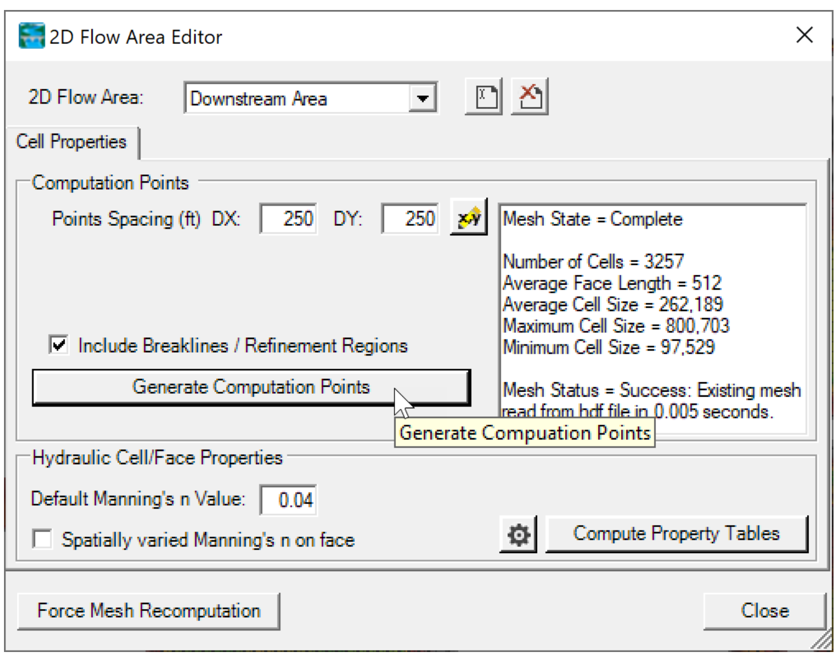
44. In **RAS Mapper**, **Save Geometry As** and provide a new name ("SA to 2D Area 250 ft")

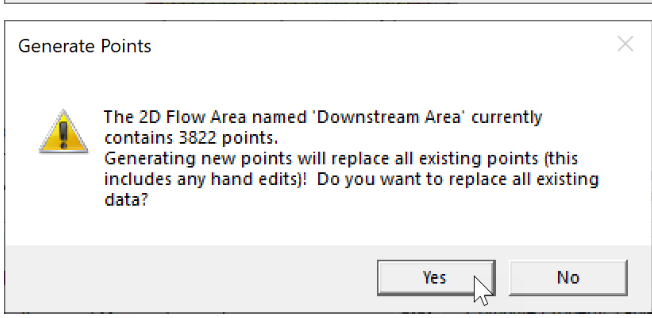


45. **Start Editing** the mesh by clicking on the  .

46. **Click** on the **Edit Mesh Properties** button in the toolbar

47. Change the **cell size** to **250 ft** and **Generate Computation Points** with **Include Breaklines**.checked. A menu will appear. Select **Yes** to generate the new points.





48. **Close** the **2D Flow Editor**.
49. **Inspect** the mesh and **edit** any areas with poor mesh quality manually.
50. **Stop** editing the **Geometry.**
51. **Save** the base **Plan** to a new plan with the title "SA to 2D Area 250 ft" and Short ID "SA2D250ft"
52. **Select** the **new Geometry** for the Plan.
53. **Select** an appropriate **time step**
54. **Compute**
55. Review the following questions

Question: Is the peak outflow from the dam any different than the previous run done with 500ft mesh?

Question: Has the Peak outflow coming out of the 2D Flow Area changed? If so, why?

Question: Are there any differences in the inundation mapping between the two runs? Look at the Max Depth inundation, as well as different time steps during the event in order to answer this question. It will also be helpful to change the color of one of the plans to something other than Blue. I changed my 250 ft Plan to Red/green, and moved it to be the top layer, which made it easier to see differences between the two plans.

Question: Does the smaller cell size better represent the downstream terrain and the levee system protecting Lock Haven? Is it detailed enough with this cell size? If not, what are the options you could use to model the Lock Haven levee system more accurately than it is currently represented in this model?

Question: Do you think it is appropriate to use the Diffusion Wave equations or the Full Shallow Water equations for this Dam Breach analysis in the Bald Eagle system? Why or why not?

11 Change Governing Equations and Re-Run

56. **Create** a new plan with the 500-ft resolution mesh and **Save** it with the Title "SA to 2D 500 ft ELM" and Short ID "SA2D500ftELM"
57. In the **Unsteady Flow Analysis** editor, select on the menu **Options | Computation Options and Tolerances** and select the **2D Flow Options** tab.
58. Set the **Equation Set** on line 6 to **SWE-ELM (original/faster)**. This is the Eulerian-Lagrangian Solver of the Shallow Water Equations.
59. **Select** an appropriate **time step** for the SWE-ELM solver.
60. **Save** the Plan Data.
61. **Compute** the results.

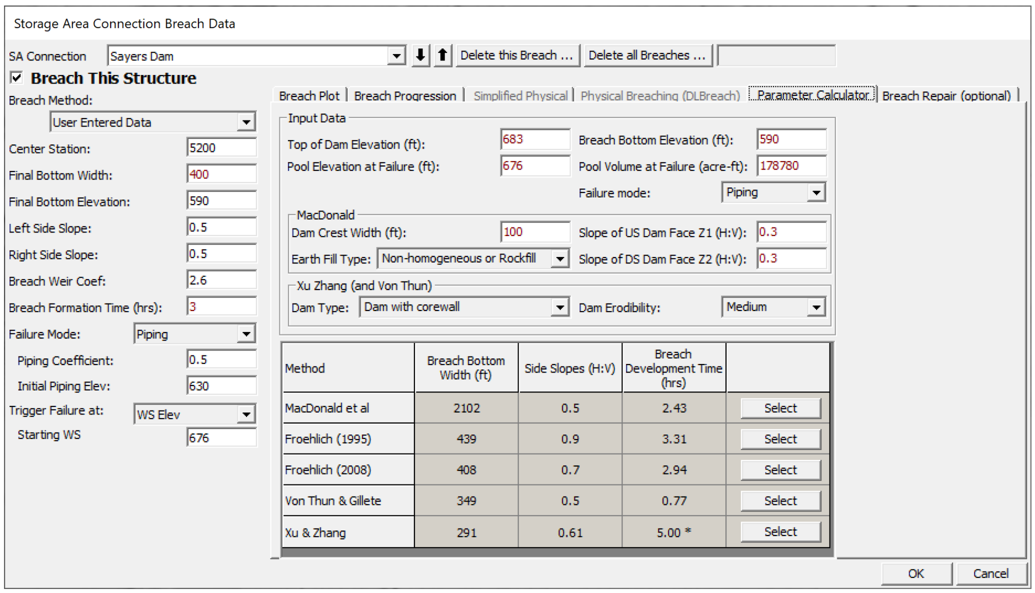
Question: Generally, are the results from the SWE solver very different from the Diffusion Wave (DWE) solver?

Question: Where are the largest differences expected between the SWE and DWE solvers and why?

Question: How can you tell if you used an appropriate time step? What variables or model output would you look at to determine if the time step is appropriate?

12 Use the Breach Parameter Calculator and Change the Breach Width

62. **Create** a new with plan the 500-ft resolution mesh, SWE-ELM solver, and Save it with the Title “SA to 2D 500 ft ELM Mod” and Short ID “SA2D500ftELMMod”.
63. In the **Unsteady Flow Data** editor, select the menu **Options | SA Connection Breach**.
64. **Select** the tab **Parameter Calculator**, and enter the parameters as shown below



65. **Set** the Breach **Final Bottom Width** to **400 ft.**
66. **Save** the Plan Data.
67. **Compute** the results.

Question: Plot time series of water levels near the dam and near the city of Loch Haven. How different are the water levels at these two locations?

Question: Did changing the Final Breach Width affect the model stability? If so why would it do that?