# Combined 1D/2D Modeling in HEC-RAS

Workshop

# Objective

In this workshop, students will use HEC-RAS to:

- Model areas behind levees with 2D Flow Areas
- Attach 2D Flow Areas to 1D Cross Sections using a Lateral Structure
- Compare and understand differences between 1D and 2D approaches

# 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 analyze how the levees perform for a 1000-year event and compare difference in results between 1D and 2D approaches for modeling the protected area.





#### **Review 1D Results**

- 1. Open the Project and Run the 1D Plan called "Existing Conditions 1D 1000 yr Event".
- 2. Review the model results. Specifically, look at the water surface profiles and hydrographs to see what is happening around the town of Lock Haven.

## **Replace 1D Elements with 2D Flow Area**

3. Go to **RAS Mapper** and make a copy of the current Geometry data using the **Save Geometry As** option.



4. <u>Name the new geometry something like: "Existing – 2D Levee Area"</u>

| 🚟 Save Data As                            |    | ×      |
|---|----|--------|
| Enter a unique Name for the new Geometry: |    |        |
| 5 0D I A                                  |    |        |
| Existing - 2D Levee Area                  |    |        |
|   | OK | Cancel |

5. **Start Editing** the geometry

6. **Storage Areas** layer - **Delete** the Storage Areas labeled **191 and 192** (the two upstream).



- 7. **SA/2D Connections** layer **Delete** the **hydraulic connection** that was between storage areas 191 and 192
- 8. Import the new 2D Flow Area perimeter

| Computatio   | Layer Properties   |   |
|--|--|---|
| Breaklines   | Stop Editing   |   |
| Bridges/Culver Inline Structure Lateral Structur SA/2D Connect | Edit 2D Area Properties<br>Generate Computation Points with Breaklines for All Meshes<br>Try to Fix All Meshes |   |
| Pump Stations Boundary Conc  Initial Condition                 | Zoom to Layer<br>Move Layer  | • |
|  | Import Features From Shapefile   |   |

 a. Click the browse icon, navigate into the "GIS\_Data" folder and select "LockHaven2DPerimeter.shp". You should see your perimeter now in the Importer.



- b. Click **Import**, and your 2D perimeter will load into the geometry.
- 9. Create a mesh for the new 2D Flow Area

a. Right-click on the "Perimeters" layer in the map window and select Edit 2D Area Properties

| D 2D Flow Areas    |  |
|--------------------|--|
| Perimeters         | /  |
| Computation        | Layer Properties   |
|                    | Open Attribute Table                                       |
|                    | Stop Editing   |
| E Lateral Structur | Edit 2D Area Properties                                    |
| E. SA/2D Connecti  | Generate Computation Points with Breaklines for All Meshes |

 b. Create the 2D Mesh with **100**ft cell spacing and Manning's n value of **0.06**.

| 2D Flow Area: Lockhaven 💌                       | <u> </u>  |
|---|---|
| ell Properties                                  |   |
| Computation Points                              |   |
| Points Spacing (ft) DX: 100 DY: 100             | Mesh State = UnknownError   |
| Generate Computation Points with All Breaklines | Number of Cells = 0<br>Average Face Length = 0<br>Average Cell Size = 0<br>Maximum Cell Size = 0<br>Minimum Cell Size = 0 |
| Generate Computation Points without Breaklines  | Mesh Status = Mesh not created  |
| Hydraulic Cell/Face Properties                  | · ,   |
| Default Manning's n Value: 0.06                 |   |
| Spatially varied Manning's n on face (Beta)     | Compute Property Tables   |

- c. Select Generate Computation Points with Breaklines
- d. Check to make sure the cells around the outside of the mesh are all formed correctly and there are no mesh generation mistakes
- e. Stop Editing and select Yes when asked to save the edits
- 10. In RAS Mapper, **associate** the **Terrain** and **Manning's n** layers with the geometry.

| Ι |               | TTUILE LITES   |                                   |         |   |             |   |             |
|---|---------------|----------------|-----------------------------------|---------|---|-------------|---|-------------|
| - | <b>⊻</b><br>€ | 🗌 Existing     | Add New Geometry                  |         |   |             |   |             |
|   | <u>:</u>      | Existing       | Manage Geometry Associations      |         |   |             |   |             |
|   | Ν             | Manage Layer A | ssociations                       |         |   |             |   | ×           |
|   |               |                |                                   |         |   |             |   |             |
|   |               | Туре           | RAS Geometry Layers               | Terrain |   | Manning's n |   | Infiltratio |
| 1 |               | Geometry       | Existing Conditions Geometry - 1D | Terrain | • | LandCover   | - | (None)      |
|   |               | Geometry       | Existing - 2D Levee Area          | Terrain | - | LandCover   | - | (None)      |
|   |               | Results        | Exist-1D-1000 yr                  | Terrain | - | (None)      |   | (None)      |
|   |               | [              |                                   |         |   |             |   |             |

- 190 Lockhaven Mannings
- 11. Turn on the **Land Cover** Layer to see what range of n values to expect.



## **Connect 2D Flow Area to Cross Section with Existing Lateral Structures**

- 13. Close RAS Mapper and open the Geometry Editor
- 14. Open the new Geometry "Existing 2D Levee Area"
- 15. Using the Lateral Structure Editor, connect all the Lateral Structures to the new LockHaven 2D Flow Area. This includes 23100, 21200, 14800, and 11950.



a. Notice that the plot displays the cell faces and the minimum cell elevation that the weir is connected to (you may have to switch the plot after hooking up the LS to LockHaven



16. Rename the SA/2D Area Conn labeled "SA191to190" to "LockhavenTo190" using the "Edit|Change Name" option in the Geometric Data Editor



17. Using the **SA/2D Area Conn.** editor, connect the renamed connection to the the 2D Flow Area

| Connection: | LockHavenTo 190         | • I I | Apply Data  |                    |         |
|-------------|-------------------------|-------|-------------|--------------------|---------|
| Description |                         |       | ÷           | Breach (plan da    | ata)    |
| Connections |                         |       |             |                    |         |
| From:       | 2D Flow Area: Lockhaven |       | [Set SA/2D] | Weir Length:       | 2303.25 |
| To:         | Storage Area: 190       |       | Set SA/2D   | Centerline Length: | 2303.25 |

18. **SAVE the Geometry Data.** Then close the geometry editor.

### Make a New Plan for the 2D Flow Area Geometry

19. Open the Unsteady Flow Analysis window and open the existing 1D Plan "Existing Conditions 1D -1000 yr event"



20. Make a new Plan file using the **Save Plan As** option from the **File** menu and call it **\*Existing 2D Levee – 1000yr**. Give the Plan a relevant short ID, **\*Exist-2D-1000yr** 

21. **Select** the new 2D Geometry File for the new plan.

| 上 Unsteady Flow Analysis          |                          |                           | ×  |
|-----------------------------------|--------------------------|---------------------------|----|
| File Options Help                 |                          |                           |    |
| Plan: Existing 2D - 1000 yr event | Sh                       | nort ID: Exist-2D-1000 yr |    |
| Geometry File:                    | Existing - 2D Levee Area |                           | ×1 |
| Unsteady Flow File:               | 1000 yr Event from HMS   |                           | •  |
| Programs to Run                   | Plan Description         |                           |    |
| Geometry Preprocessor             |                          |                           | ^  |

#### Perform Computations and Review Model Output

22. **Run** the new 2D Plan. When the model has finished running, compare the 1D model to the 2D Model with the Profile Plot, Hydrograph plots, and RAS Mapper

<u>*Question:*</u> What are the differences you see in the model output when comparing the 1D and 2D model runs? Why do you think they are different?

<u>Question</u>: There is a Point Shape file loaded under the Features Layer called PointsOfInterest that has three locations of interest. Turn on the layer and describe the differences in terms of time at which the streets got wet, peak stage, and time to peak using the table below What is the maximum velocity on the toe of the Lock Haven side of the levee?

| Model Type       | Arrival Time | Peak Stage | Time of Peak |
|------------------|--------------|------------|--------------|
| 1D Storage Areas |              |            |              |
| 2D Flow Area     |              |            |              |

Table 1. Intersection of Main St, Mill St

Table 2. Intersection of Church St. and Washington St.

| Model Type       | Arrival Time | Peak Stage | Time of Peak |
|------------------|--------------|------------|--------------|
| 1D Storage Areas |              |            |              |
| 2D Flow Area     |              |            |              |

Table 3. Intersection of Park St. and Prospect St.

| Model Type       | Arrival Time | Peak Stage | Time of Peak |
|------------------|--------------|------------|--------------|
| 1D Storage Areas |              |            |              |
| 2D Flow Area     |              |            |              |

*Question:* Are these differences significant? Which answer do you think is more correct?

<u>Question</u>: Do you think that the cell size of 100 X 100 ft is adequate for this problem? If not why?

<u>*Question:*</u> What computational time Step did you use for the 2D Model run? Is this time step appropriate?

<u>Question</u>: Is the Terrain data adequate for this area? If not why?

<u>Question</u>: By Default the Diffusion Wave equation set was used in the model. Do you think this is adequate for this model, or should the Full Shallow Water Equations be used? How can you test this out?

# **Bonus - Levee Breaching**

As time allows...

- 23. Save the Plan File as a new Plan, using the **SAVE AS** option.
- 24. Add a levee breach into the Lateral Structure at River Station 23100.
- 25. Add in the breach with the following information, using the **"Levee (Lateral Structure) Breach**" option under the Unsteady Flow Analysis **Options** menu

| Lateral Structure Bald Eagle | Cr. Lock Haven | 23100       | - I t              | Delete this Bread | h   C   | elete all Breach | es                    | _                            |         |
|------------------------------|----------------|-------------|--------------------|-------------------|---------|------------------|-----------------------|------------------------------|---------|
| Breach This Struct           | ure            |             |                    |                   |         |                  |                       |                              |         |
| Breach Method:               |                | Breach Plot | Breach Progression | Simplified Phys   | ical Ph | ysical Breaching | (DLBreach) Parameter  | Calculator Breach Repair (or | tional) |
| Simplified Physical          | •              | Overtopping | Downcutting        |                   | Widen   | ing Relationship |                       |                              |         |
| a i au                       | 750            | Velocity    | (ft/s) Downcutting | Rate (ft/hr)      |         | Velocity (ft/s)  | Widening Rate (ft/hr) |                              |         |
| Center Station:              | 750            | 1           | 0                  | 0                 | 1       | 0                | 0                     |                              |         |
| Max Possible Bottom Width:   | 1000           | 2           | 1                  | 0                 | 2       | 1                | 0                     |                              |         |
| Min Possible Bottom Elev:    | 566            | 3           | 2                  | 1                 | 3       | 2                | 1                     |                              |         |
|                              |                | 4           | 3                  | 5                 | 4       | 3                | 10                    |                              |         |
| Left Side Slope:             | 0.1            | 5           | 5                  | 10                | 5       | 5                | 50                    |                              |         |
| Right Side Slope:            | 0.1            | 0           | 10                 | 25                | 0       | 10               | 100                   |                              |         |
| Breach Weir Coef             | 2              | 8           | 20                 | 100               | 8       | 20               | 200                   |                              |         |
| breach wei coch              | -              | 9           |                    |                   | 9       |                  |                       |                              |         |
| Breach Formation Time (hrs): |                | 10          |                    |                   | 10      |                  |                       |                              |         |
| Failure Mode: Overt          | opping 👻       | 11          |                    |                   | 11      |                  |                       |                              |         |
| Dining Coefficients          | 0.5            | 12          |                    |                   | 12      |                  |                       |                              |         |
| Hping Coemdents              | 0.5            | 13          |                    |                   | 13      |                  |                       |                              |         |
| Initial Piping Elev:         |                | 14          |                    |                   | 14      |                  |                       |                              |         |
| Starting Notch Width:        |                | 15          |                    |                   | 15      |                  |                       |                              |         |
|                              | 1              | 16          |                    |                   | 16      |                  |                       |                              |         |
| Mass wasting Feature:        |                | 17          |                    |                   | 17      |                  |                       |                              |         |
| Trigger Failure at: WS Ele   | ev+Duration 💌  | 18          |                    |                   | 18      |                  |                       |                              |         |
| Threshold WS                 | 577.6          | 20          |                    |                   | 20      |                  |                       |                              |         |
| Duration Above Threshold(hr  | s) 1           | 21          |                    |                   | 21      |                  |                       |                              |         |
| Immediate Initiation WC      |                | 22          |                    |                   | 22      |                  |                       |                              |         |
| Immediate Initiation WS      | 580.6          | 23          |                    |                   | 23      |                  |                       |                              |         |
| Accumulate Duration          |                | 24          |                    |                   | 24      |                  |                       |                              |         |
|                              |                | 25          |                    |                   | 25      |                  |                       |                              |         |
|                              |                |             |                    |                   |         |                  |                       |                              |         |
|                              |                |             |                    |                   | -       |                  |                       |                              |         |
|                              |                |             |                    |                   |         |                  |                       | OK                           | Cancel  |

#### 26. Run the plan

<u>Question</u>: How much more water went into the Lock Haven area due to the levee breach vs. the just overtopping Plan? Compare the hydrographs for that Levee?

<u>*Question:*</u> What difference did it make to the inundated area and the resulting water surface elevations in downtown Lock Haven?

*Question*: What were the final Breach dimensions through the levee?

second run compare to the 20 second run?