

HEC-RAS 2D

Mesh Generation and Refinement

Mark Jensen, M.S.
Cameron Ackerman, P.E., D.WRE

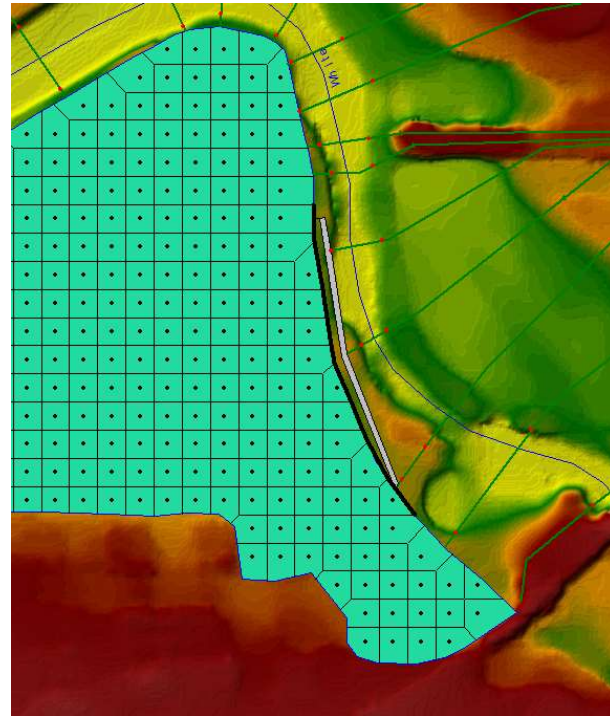
USACE, Institute for Water Resources, Hydrologic Engineering Center



A small red icon of a castle or fortress with three towers.

Overview

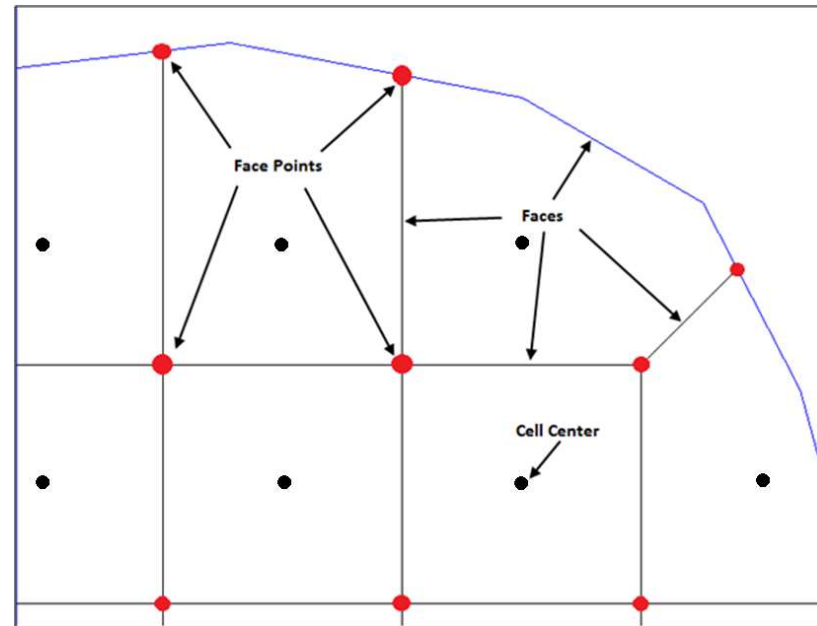
- Common Terms
- How to Create a Mesh
- Limitations
- Fixing Mesh Problems
- Hydraulic Property Tables





Finite Volume Mesh

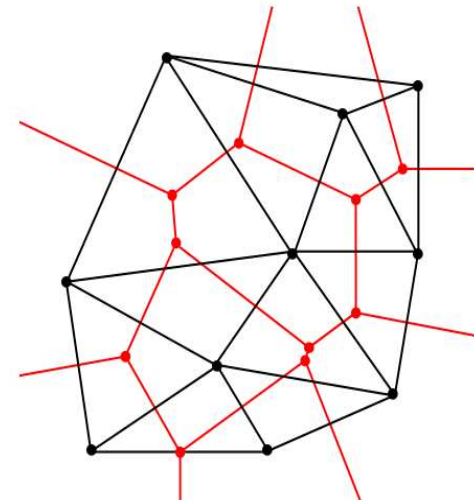
- Naming Convention
 - Cells
 - Face Points
 - Faces
 - Computation Points (center)



A small red icon of a castle or fortress with three towers.

Mesh Generation

- Define mesh boundary and triangulate Computation Points (black dots)
- Face Points (red dots) are triangle circumcircle centers
- Faces (red lines) connect face points
- Faces are also “Enforced” with internal breaklines





Create 2D Flow Area Mesh in RAS Mapper

- Meshes are generated from a set of computation points with consideration to polygons and breaklines.
- Steps/Features used to create a mesh:
 - Perimeter Polygon
 - Computation Points
 - Breaklines (Optional)
 - Refinement Regions (Optional)

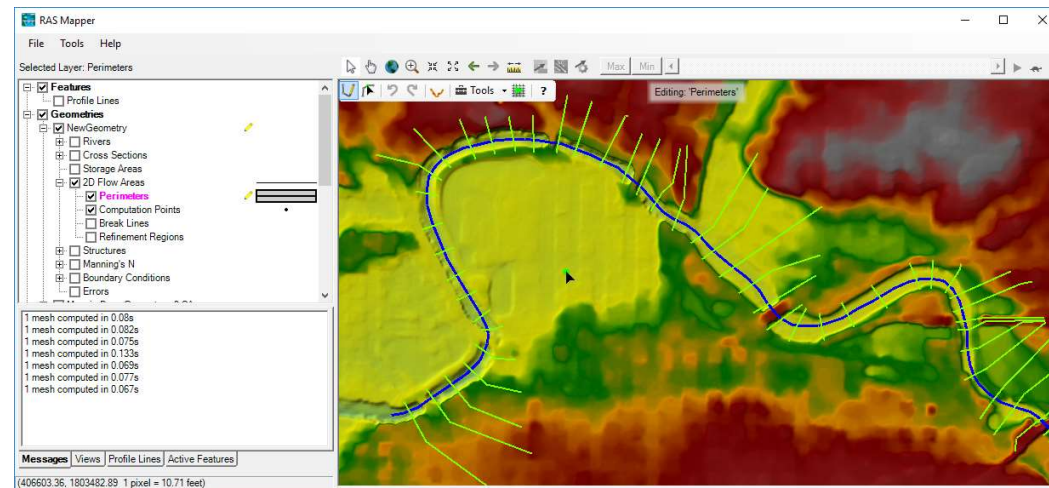
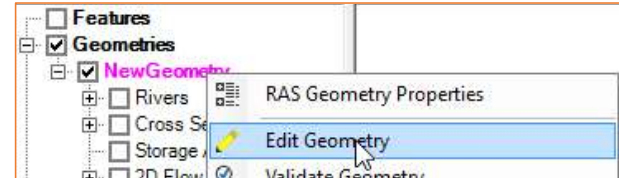
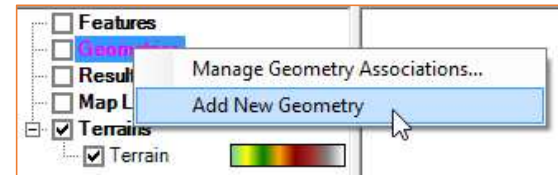


- Creating a good mesh is an iterative process!



Editor Access







- Create a New Geometry
- Edit Geometry
- Edit Toolbar
- Select Layer





Editing

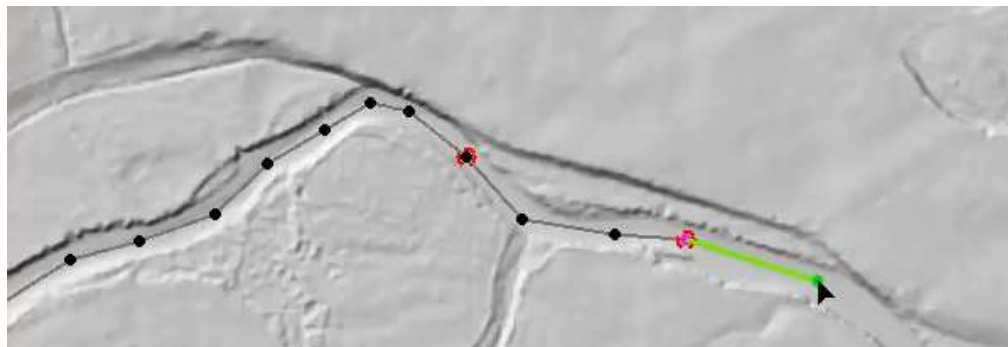


- Add New Feature 
- Select/Edit Feature 
- Undo/Redo 
- Plot Profile 
- Tools 
- Help 



Add New Feature

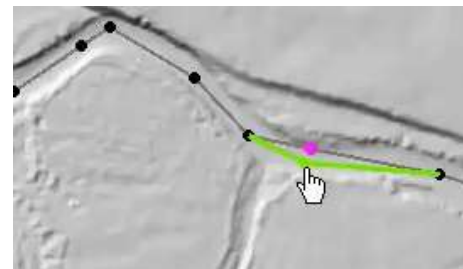
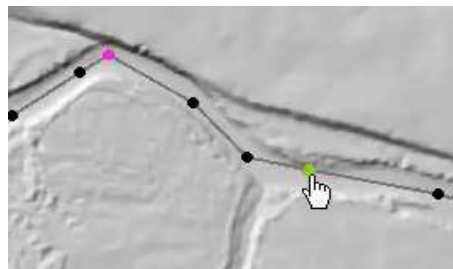
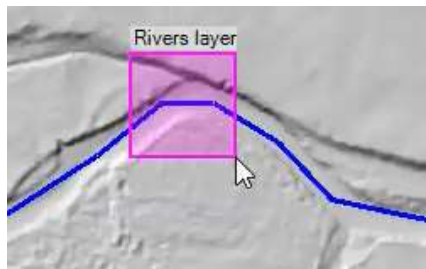
- Left-click to start adding a new point, line, or polygon
- Double-click to end a line or polygon
- Pan by switching to Pan tool, Shift key, Middle Mouse, or right-click to re-center.





Select / Edit

- Select / Edit tool is used to select feature(s) and then begin editing (move, add points, delete, etc).
 - Double-click to Start Editing (Open feature)
 - Double-click to End Editing (Close feature)
- Mouse hover indicates action
 - Green point indicates: Move, Insert, Delete point





2D Flow Area

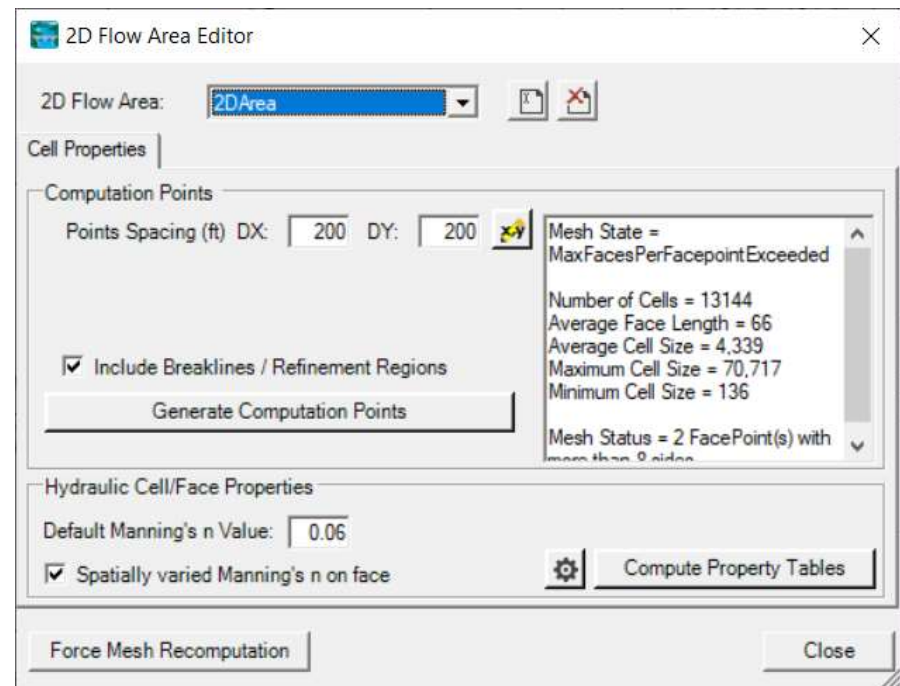
- Draw Perimeter



- 2D Flow Areas
 - Perimeters
 - Computation Points
 - Break Lines
 - Refinement Regions



- 2D Flow Area Editor





- 2D Flow Areas
- Perimeters
- Computation Points
- Break Lines
- Refinement Regions



Computation Points

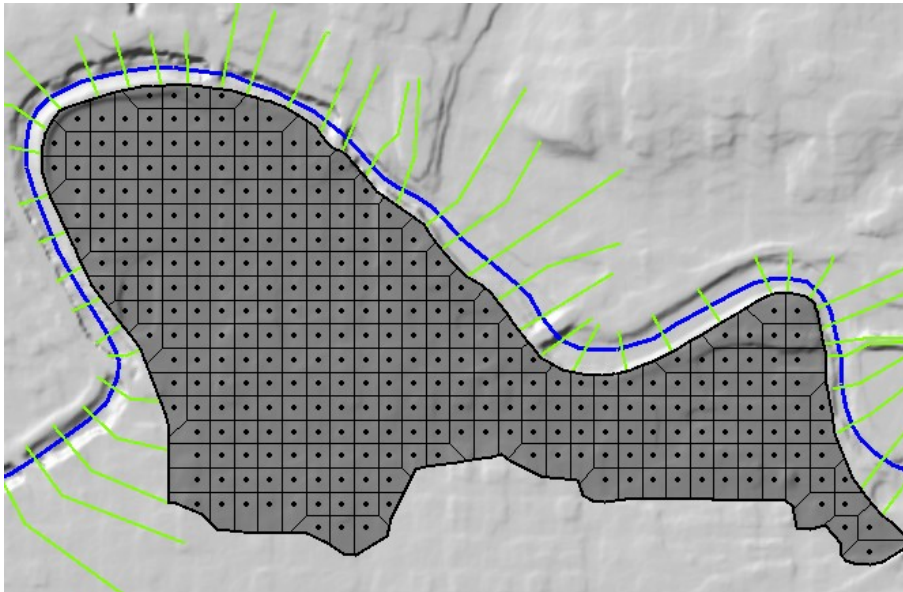
- Generate Computation Points at an even interval
 - Breaklines and Refinement Regions area enforced
- N Value (Default or Spatially Varied)
- Hydraulic Table Property Tolerances

The '2D Flow Area Editor' dialog box is shown. It features a dropdown menu for '2D Flow Area' set to '2DArea'. Under the 'Cell Properties' tab, the 'Computation Points' section has 'Points Spacing (ft) DX' and 'DY' both set to 200. A red arrow points from the first bullet point in the list to this 'Points Spacing' field. Below this, there is a checked checkbox for 'Include Breaklines / Refinement Regions' and a 'Generate Computation Points' button. To the right, a 'Mesh State' section displays statistics: 'Number of Cells = 13144', 'Average Face Length = 66', 'Average Cell Size = 4,339', 'Maximum Cell Size = 70,717', and 'Minimum Cell Size = 136'. At the bottom, the 'Hydraulic Cell/Face Properties' section shows 'Default Manning's n Value' set to 0.06 and a checked checkbox for 'Spatially varied Manning's n on face'. A red arrow points from the third bullet point in the list to the 'Compute Property Tables' button. A 'Close' button is located at the bottom right of the dialog.

The 'Hydraulic Property Table Tolerances' dialog box is shown, titled '2D_Area'. It contains several input fields for filter tolerances: 'Cell Elev-Vol Filter Tol (ft)' (0.01), 'Cell Minimum Area Fraction' (0.01), 'Face Profile Filter Tol (ft)' (0.01), 'Face Elev-Area Filter Tol (ft)' (0.01), 'Face Conveyance Tol Ratio' (0.02), and 'Face Laminar Depth (ft)' (0.2). A red arrow points from the third bullet point in the list to the 'Face Conveyance Tol Ratio' field. At the bottom, there are 'Defaults', 'OK', and 'Cancel' buttons.



Computation Points



- Mesh is generated from resultant set of computation points.

- 2D Flow Areas
- Perimeters
- Computation Points**
- Break Lines
- Refinement Regions



Edit Points

Selected Area Edits

Table Tools

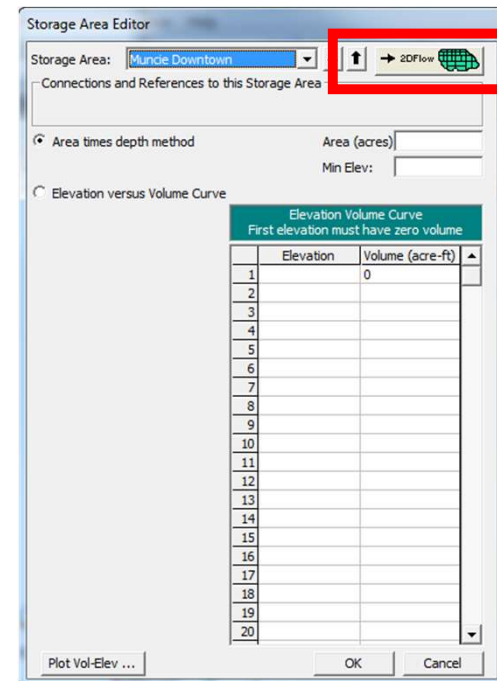
	X	Y
1	405880.1458	1804922.839
2	406080.1458	1804922.839
3	406280.1458	1804922.839
4	406480.1458	1804922.839
5	405280.1458	1804722.839
6	405480.1458	1804722.839
7	405680.1458	1804722.839
8	405880.1458	1804722.839
9	406080.1458	1804722.839
10	406280.1458	1804722.839
11	406480.1458	1804722.839
12	405080.1458	1804522.839
13	405280.1458	1804522.839
14	405480.1458	1804522.839
15	405680.1458	1804522.839
16	405880.1458	1804522.839
17	406080.1458	1804522.839
18	406280.1458	1804522.839

OK Cancel



Create 2D Flow Area Mesh from an existing Storage Area

- Converting Existing Storage Area
 - Click convert button



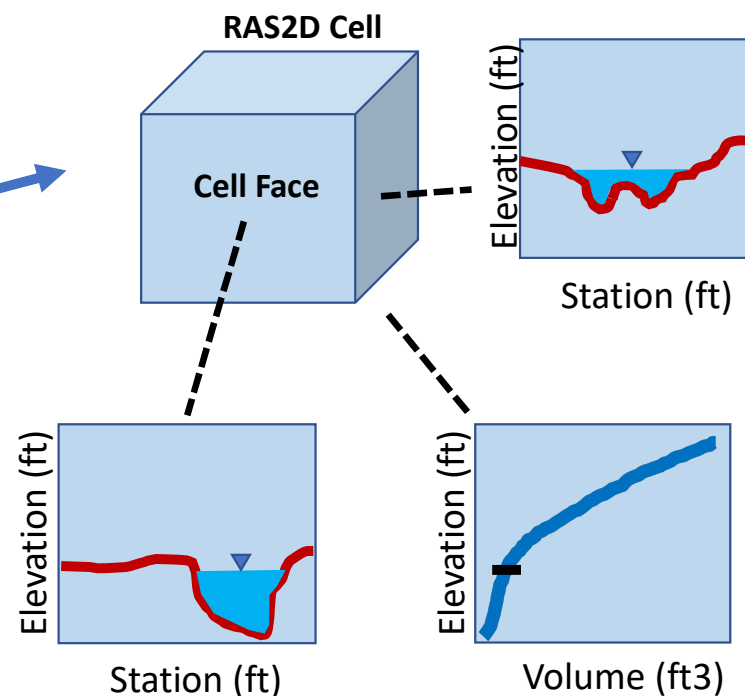
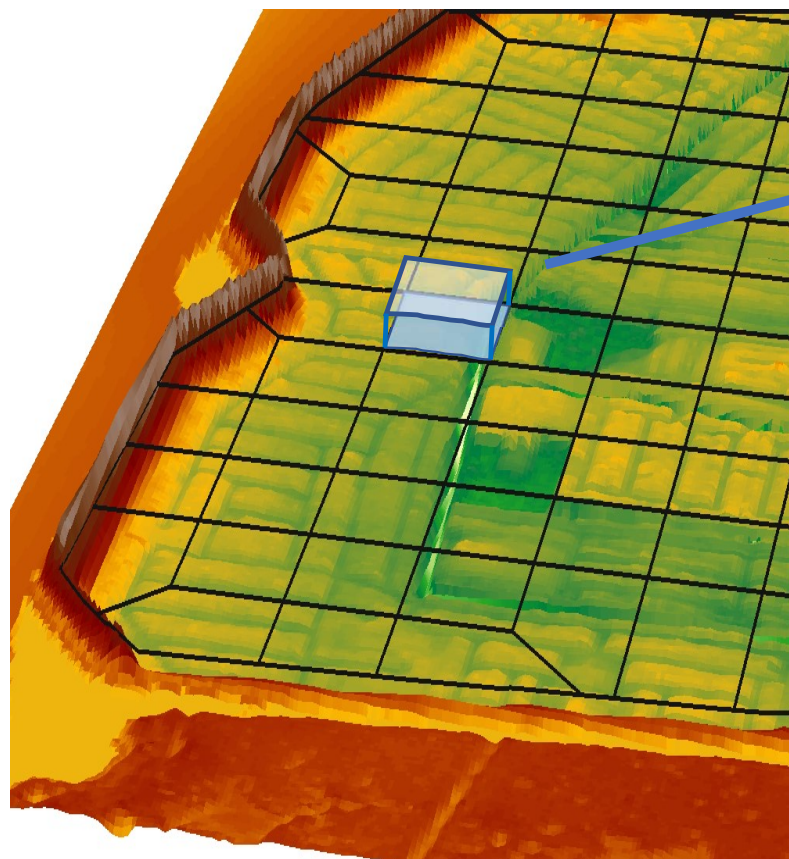
A small red icon of a castle with three towers, enclosed in a red square border.

Hydraulic Property Tables

- Computation engine uses hydraulic property tables to represent the geometry of the system
- Cells
 - Elevation/Volume
- Faces
 - Elevation/Area
 - Elevation/Wetter Perimeter
 - Elevation/Manning's n
 - (all from station elevation profile)



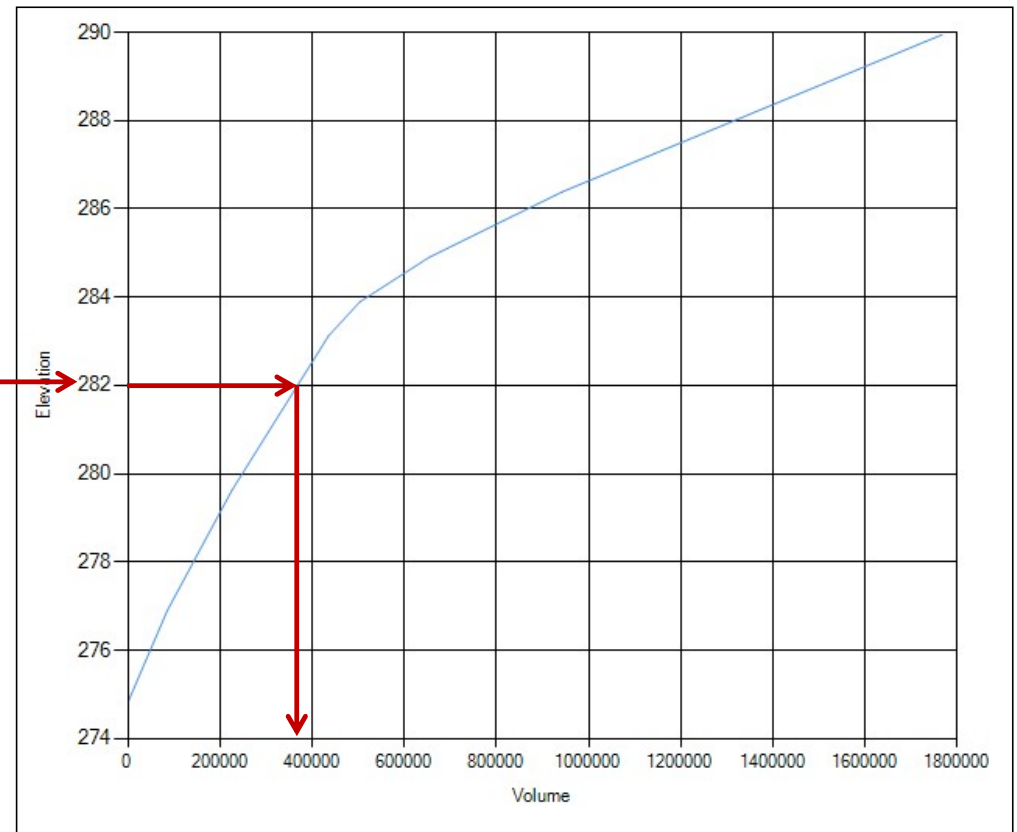
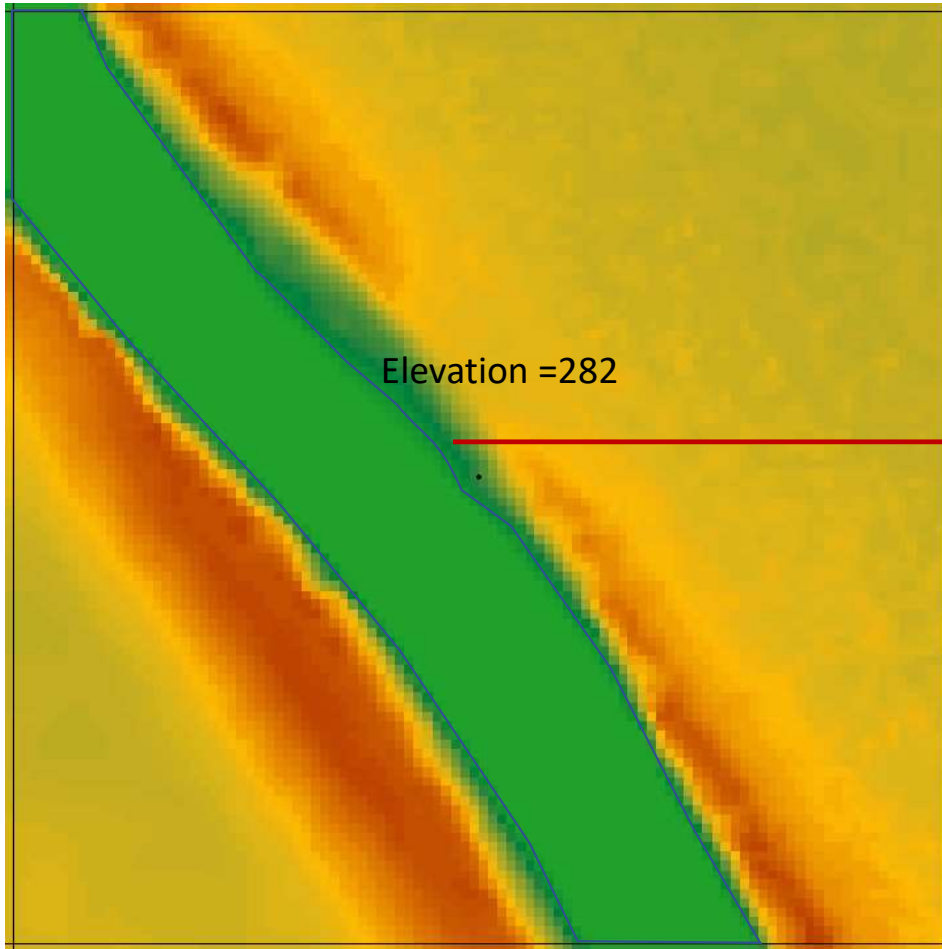
2D Computational Mesh Sub-grid Terrain



Each cell face profile and stage-volume curve is based on **hundreds to thousands topo-bathymetric data-points**, depending of resolution of underlying terrain raster. Cell approach very efficiently discretizes space including complex terrain & surface roughness.

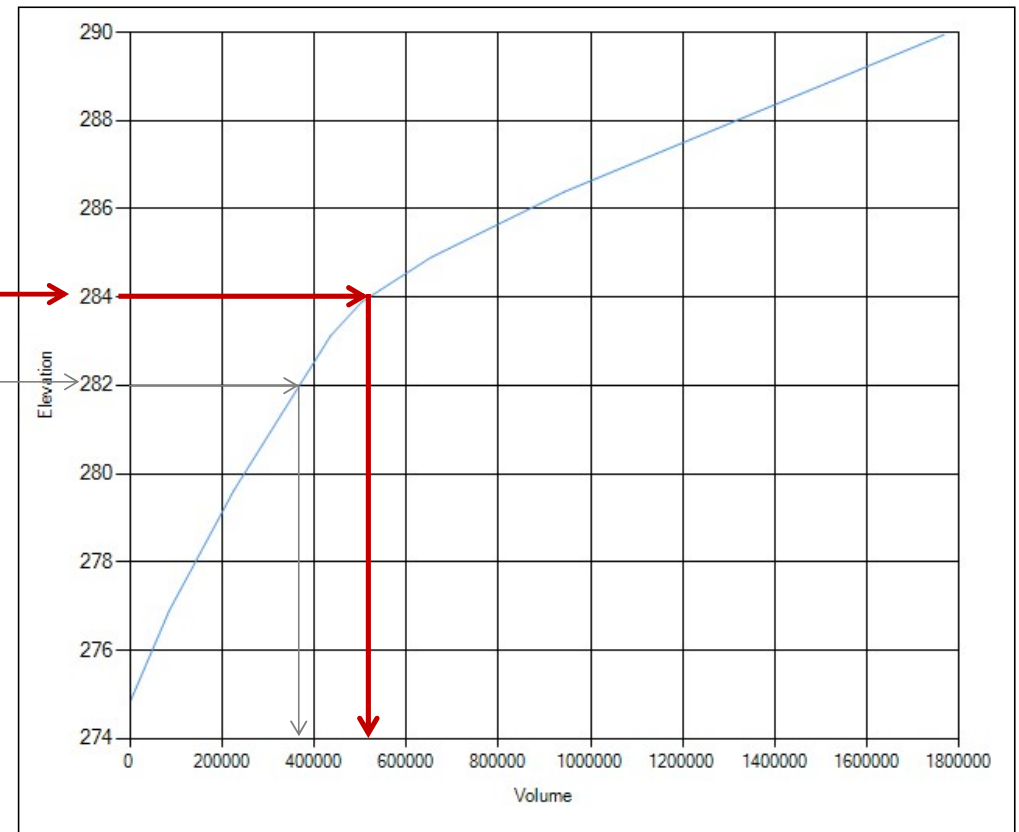
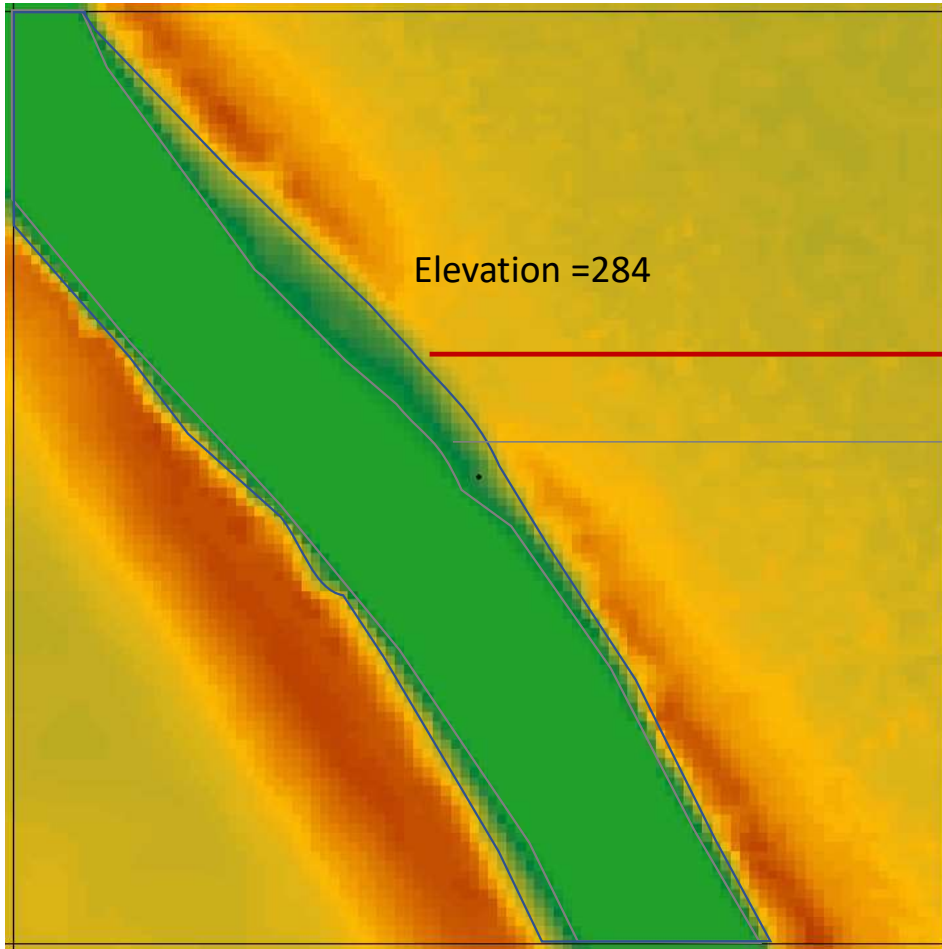


Computational Cells - Elevation vs. Volume





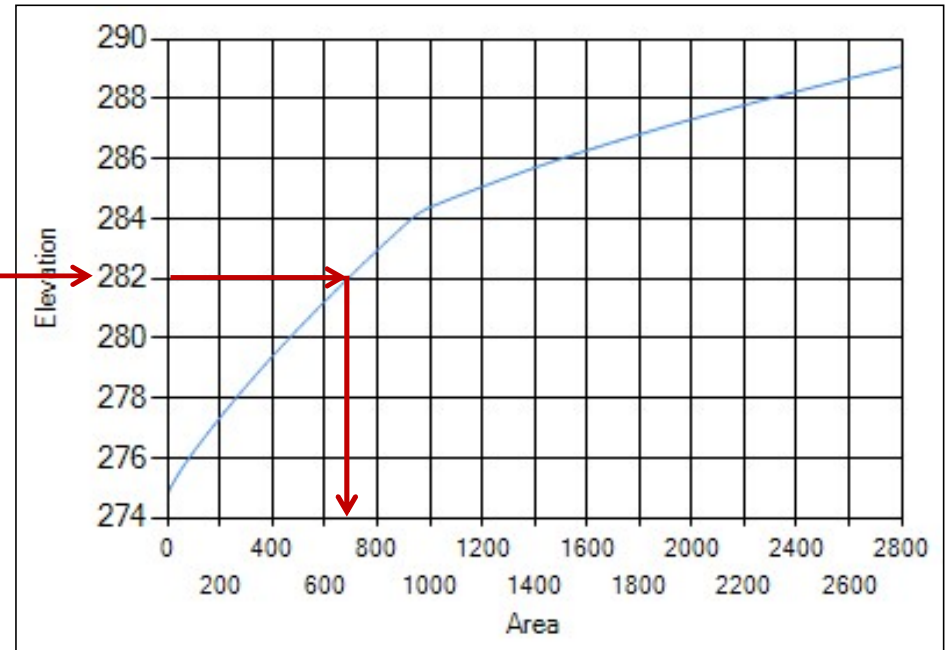
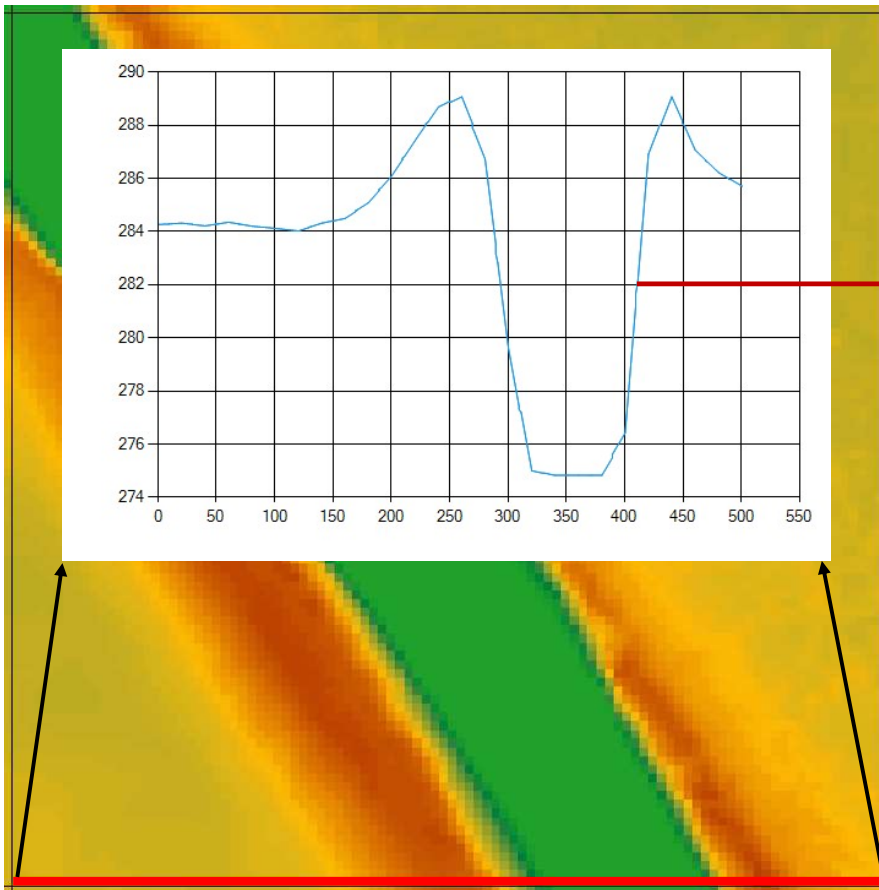
Computational Cells - Elevation vs. Volume



Subgrid = Higher fidelity cell volume tracking ¹⁷



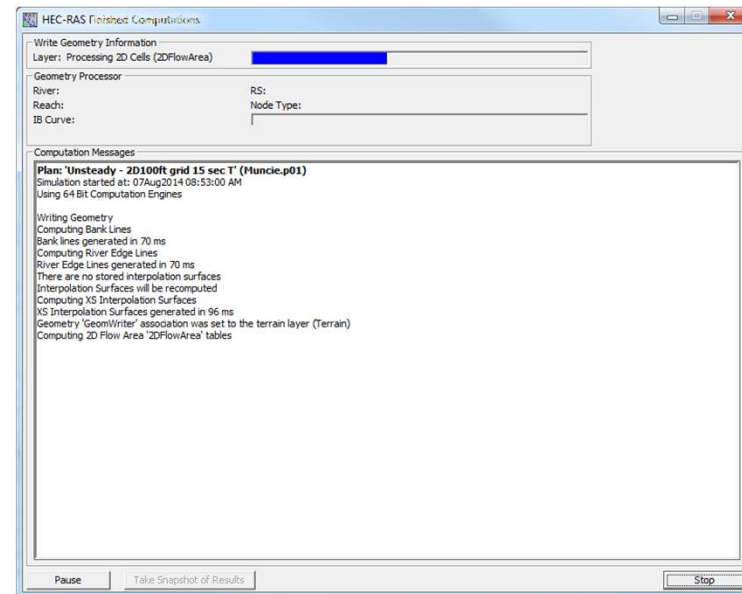
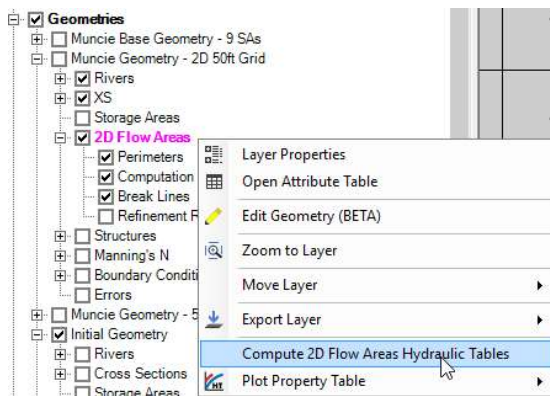
Computational Faces - Elevation vs. Area



Faces = Control flow into and out of cell
Can model small channels in with large cells

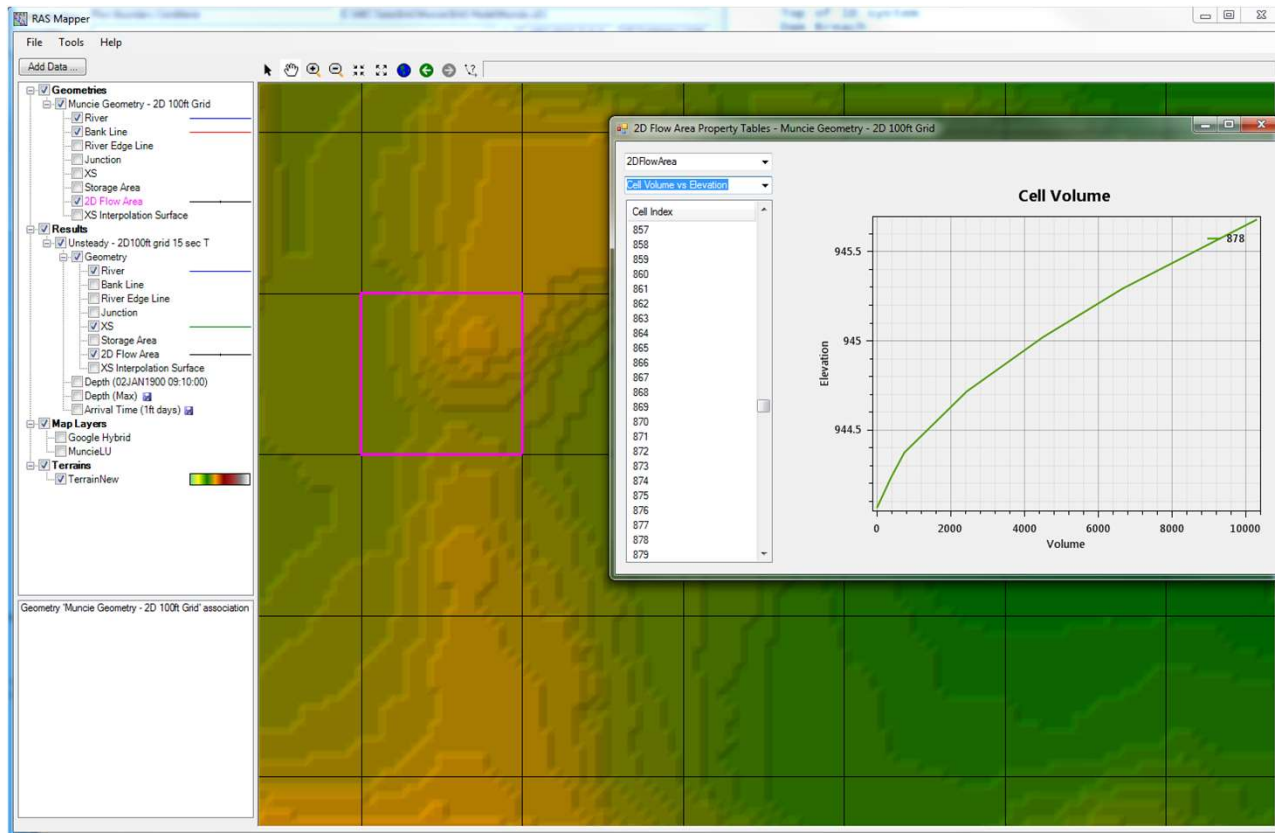
Hydraulic Property Tables

- Computed (once and stored in geometry *.hdf)
 - From RAS Mapper
 - Before unsteady-flow simulation





Cells

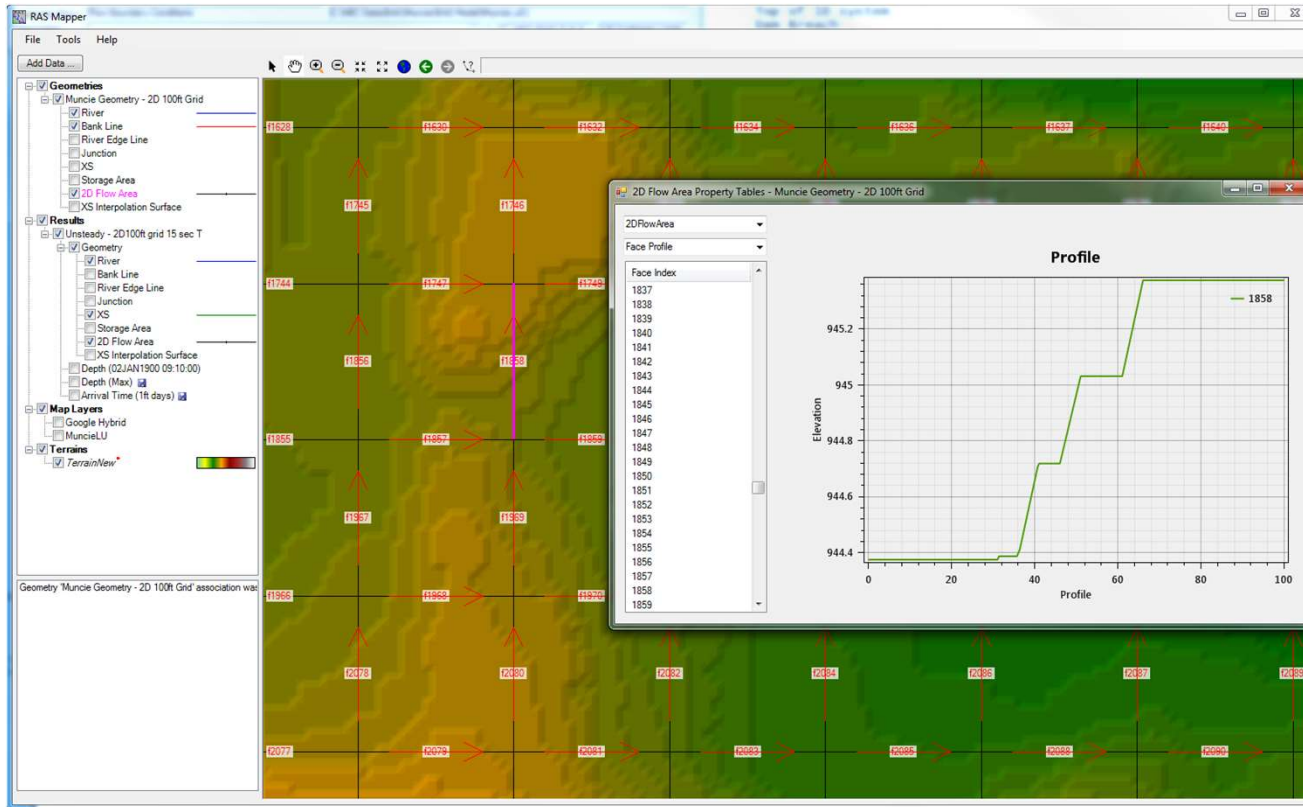




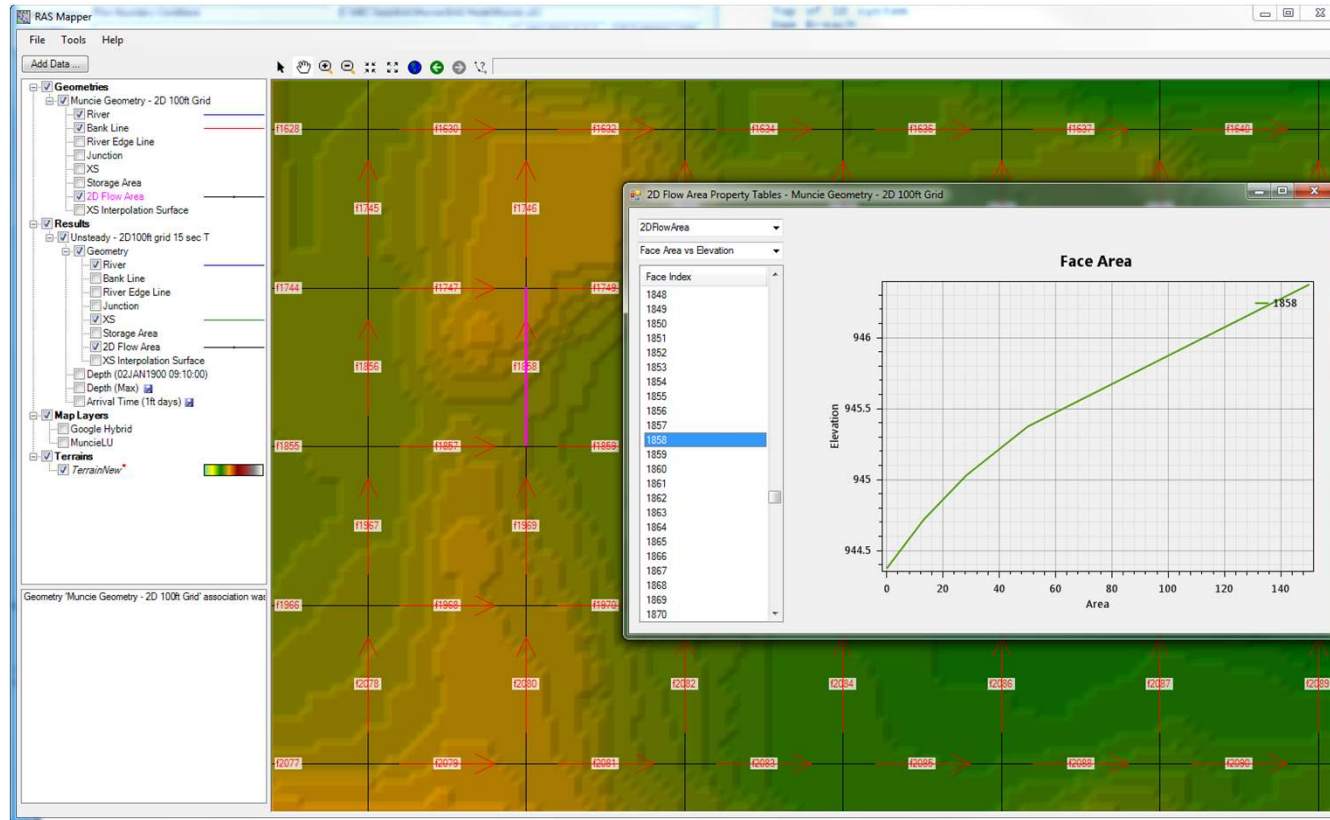
Faces

The screenshot shows the RAS Mapper interface. The main window displays a 2D flow area mesh with a grid of cells. Each cell is labeled with a face ID (e.g., F1628, F1630, F1632, F1634, F1636, F1637, F1640, F1744, F1747, F1749, F1750, F1850, F1857, F1859, F1960, F1963, F2070, F2073, F2081, F2083, F2085, F2087, F2089, F2077, F2079, F2081, F2083, F2085, F2087, F2089). The mesh is overlaid on a terrain map. The left sidebar shows the project structure, including Geometries, Results, Map Layers, and Terrains. The right sidebar shows the '2D Flow Area - Layer Properties' dialog box, which is currently open. This dialog box has tabs for 'Visualization and Information' and 'Features'. The 'Features' tab is active, showing options for 'Point Symbol', 'Line Style', and 'Fill Style'. The 'Additional Options' section includes checkboxes for 'Mesh Edges', 'Mesh Cell Numbers', 'Mesh Face Numbers' (which is checked), 'Mesh Face Point Numbers', and 'Mesh Dual TIN'. The 'Source File' path is displayed as 'C:\HEC Data\RAS\Muncie\RAS Model\Muncie.g01.hdf'.

Face Profile



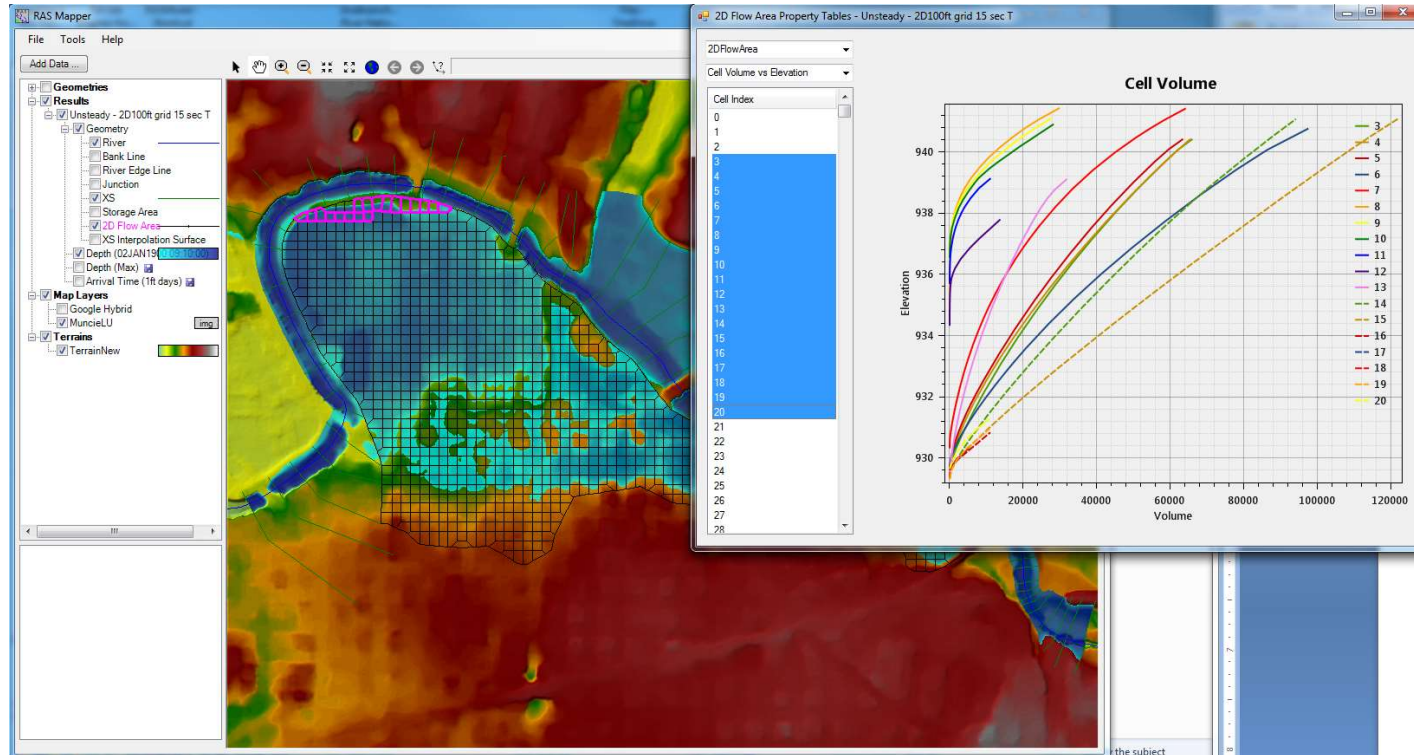
Face Elevation vs Area





Hydraulic Property Tables

- View from RAS Mapper - '2DFlow Area' in 'Geometry' or 'Results'





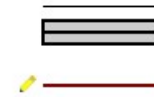
Mesh Limitations

- One face between cells – even on perimeter
- Only one boundary condition per Face
- Except for Lateral structures
 - Lateral structures can stop and start on the same 2D external Face, when connecting 1D reach to a 2D area.

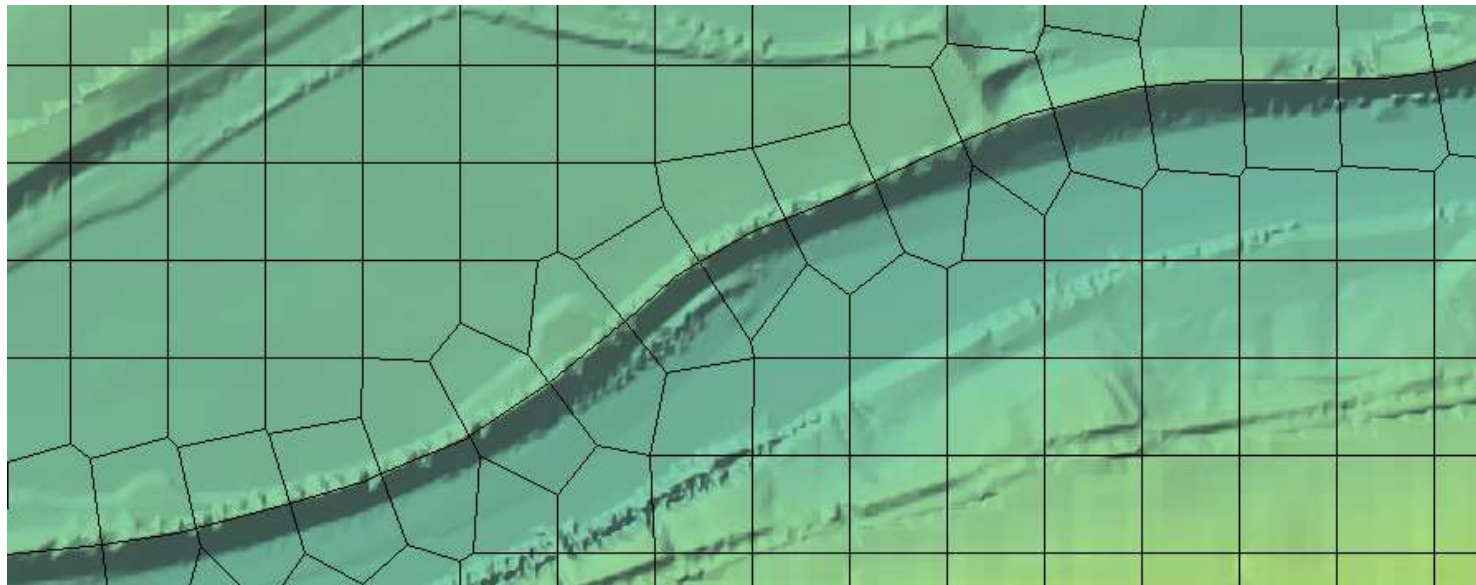


Breaklines

- 2D Flow Areas
- Perimeters
- Computation Points
- Break Lines
- Refinement Regions



- Breaklines enforce Cell Faces inside of the Mesh.
- Place along linear features that control water movement



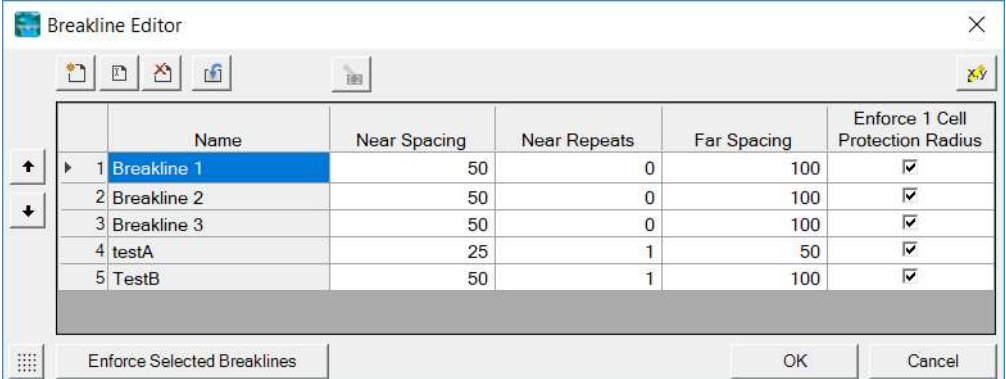
A small red icon of a castle with three towers, enclosed in a red square border.

Breaklines

- “Snapping” is part of mesh generation
 - Faces snap to breaklines if they are close enough
- “Enforcing” changes the cell points around a breakline
 - Improves the snapping of the 2D faces to the breaklines
 - Not perfect, might require tighter cell spacing and/or hand graphical editing

Breakline Properties

- Near Spacing – Initial cell size (approx.) along the breakline.
 - Default value is 2D Area point spacing
- Near Repeats – Repeats cell insertion using Near Spacing a multiple away from the breakline.
- Far Spacing – Max cell size (approx.) of newly added cells.
 - Default value is 2D Area point spacing
- Enforce 1 Cell Protection Radius – Once enforced cells near to the breakline will not be removed through the enforcement of additional breaklines.
 - Include cells added/edited by hand.



The screenshot shows the 'Breakline Editor' dialog box with a table of breakline properties. The table has five columns: Name, Near Spacing, Near Repeats, Far Spacing, and Enforce 1 Cell Protection Radius. There are five rows of data, with 'Breakline 1' selected.

	Name	Near Spacing	Near Repeats	Far Spacing	Enforce 1 Cell Protection Radius
▶	1 Breakline 1	50	0	100	<input checked="" type="checkbox"/>
	2 Breakline 2	50	0	100	<input checked="" type="checkbox"/>
	3 Breakline 3	50	0	100	<input checked="" type="checkbox"/>
	4 testA	25	1	50	<input checked="" type="checkbox"/>
	5 TestB	50	1	100	<input checked="" type="checkbox"/>

Buttons at the bottom: Enforce Selected Breaklines, OK, Cancel.



Breakline Process

- All points within a computed buffer are removed.
- Cells are added uniformly along the side of breakline.
- Buffer for point removal is computed as:
Near Spacing * Near Repeats
+ Double Near Spacing size n times until reach Far Spacing size
(However, take 75% of last cell size so as to not delete too far)

	Name	Near Spacing	Near Repeats	Far Spacing	Enforce 1 Cell Protection Radius
1	Breakline 1	50	0	100	<input checked="" type="checkbox"/>
2	Breakline 2	50	0	100	<input checked="" type="checkbox"/>
3	Breakline 3	50	0	100	<input checked="" type="checkbox"/>
4	testA	25	1	50	<input checked="" type="checkbox"/>
5	TestB	50	1	100	<input checked="" type="checkbox"/>

- A breaklines' area of influence is stopped by a neighboring breakline (will not proceed to opposite side).



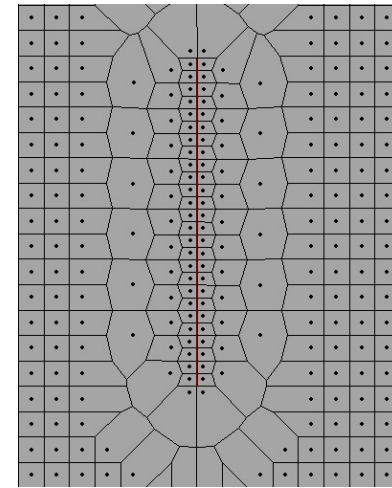
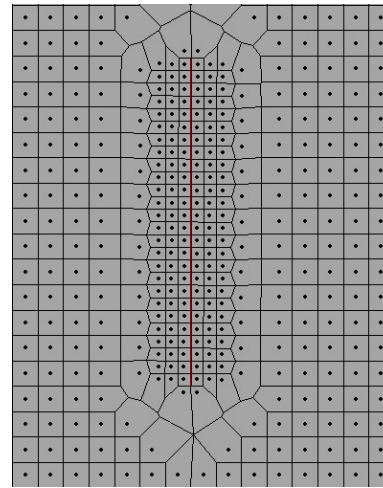
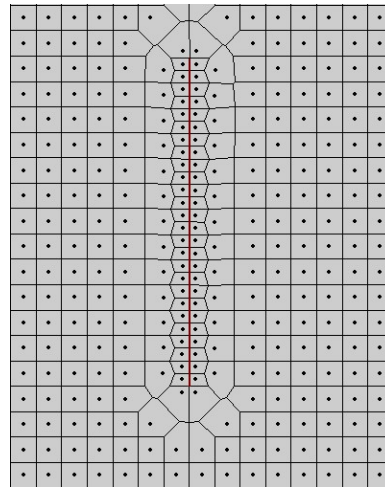
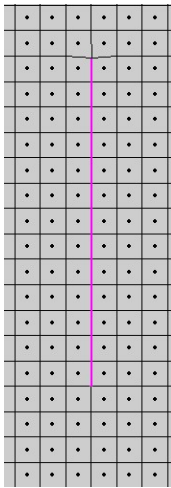
Breakline Examples

- Grid spacing = 100

Near Spacing	Near Repeats	Far Spacing
50		

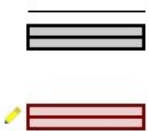
Near Spacing	Near Repeats	Far Spacing
50	2	

Near Spacing	Near Repeats	Far Spacing
50		200





- 2D Flow Areas
 - Perimeters
 - Computation Points
 - Break Lines
 - Refinement Regions



Refinement Regions

- Cell Size X,Y – Internal cell size dimension
- Perimeter is treated like a breakline
 - Perimeter Spacing, Near Repeats, Far Spacing, Cell Protection same as for breaklines
- Internal cell size used for perimeter spacing, if not defined

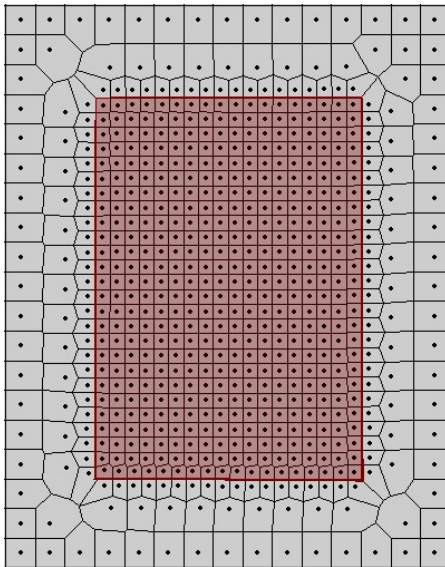
Name	Cell Size X	Cell Size Y	Perimeter Spacing	Near Repeats	Far Spacing	Enforce 1 Cell Protection Radius
1 Region 1	50	50	100			<input checked="" type="checkbox"/>



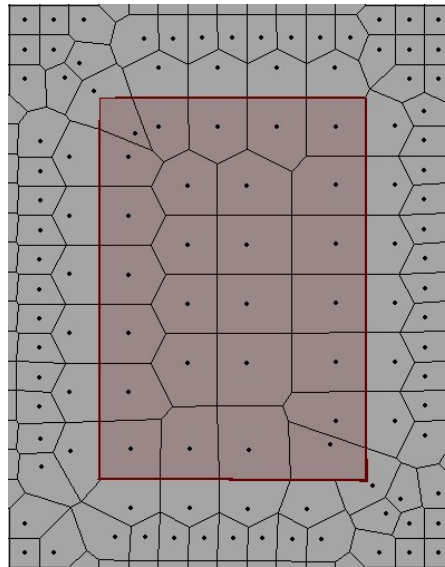
Refinement Examples

- Grid spacing = 100

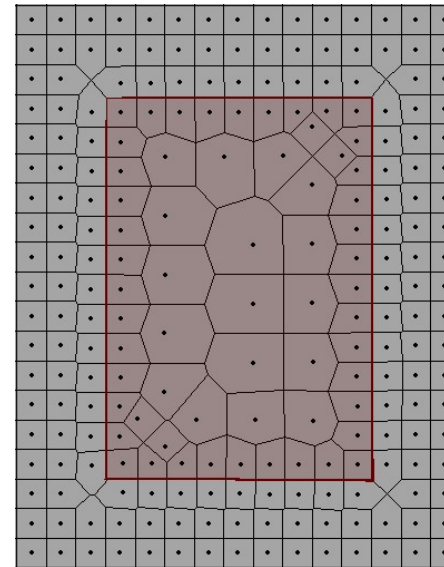
Cell Size X	Cell Size Y	Perimeter Spacing
50	50	



Cell Size X	Cell Size Y	Perimeter Spacing
200	200	

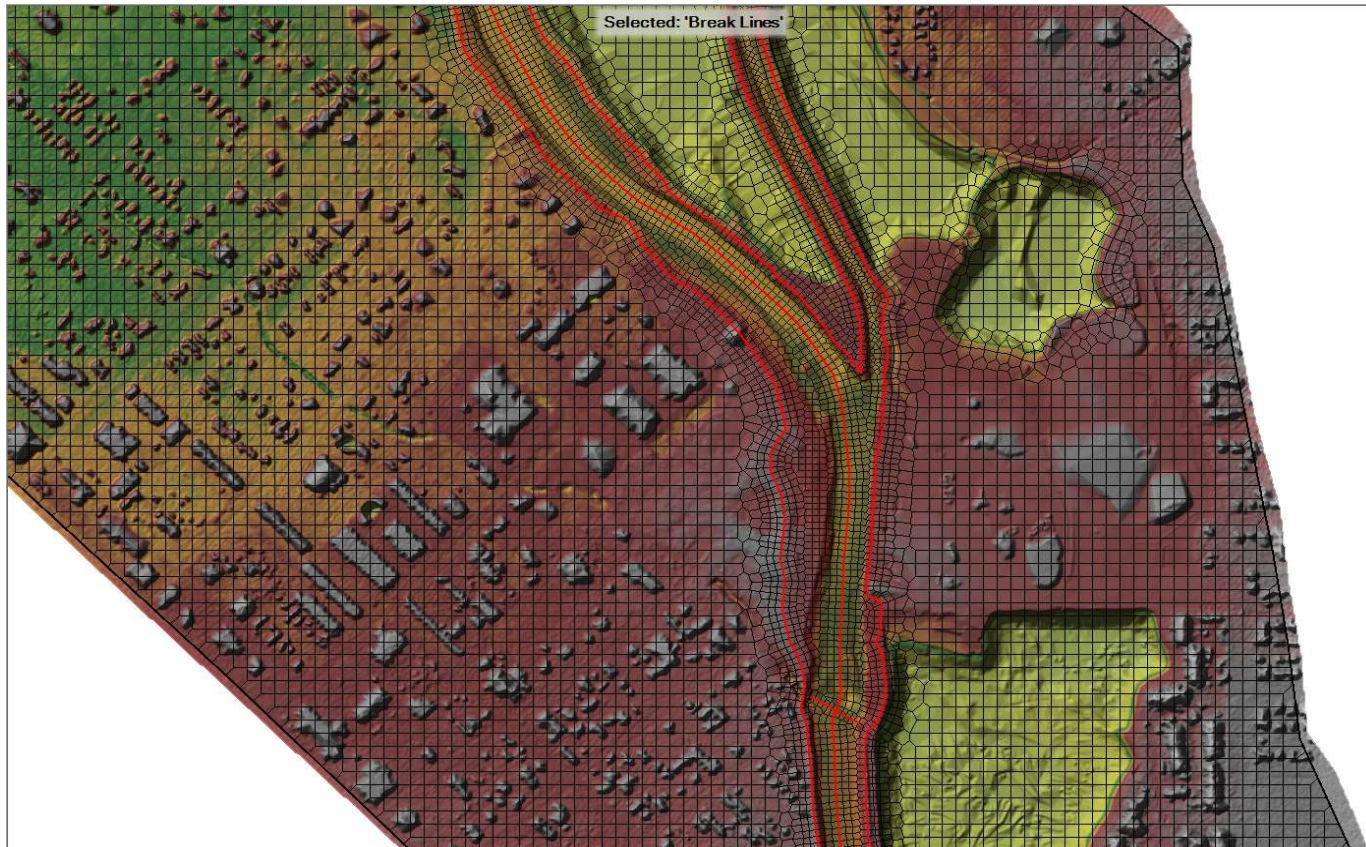


Cell Size X	Cell Size Y	Perimeter Spacing
200	200	100





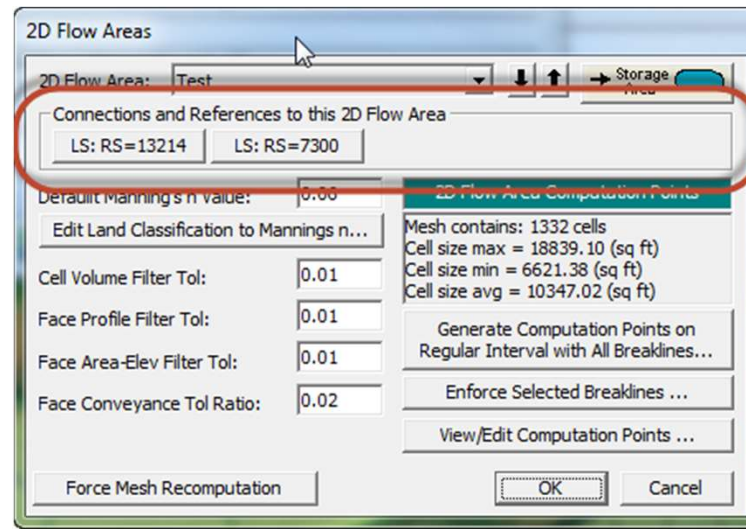
Refinement Regions and Break Lines to Align Channel Cells





2D Flow Area Editor Geometry Editor

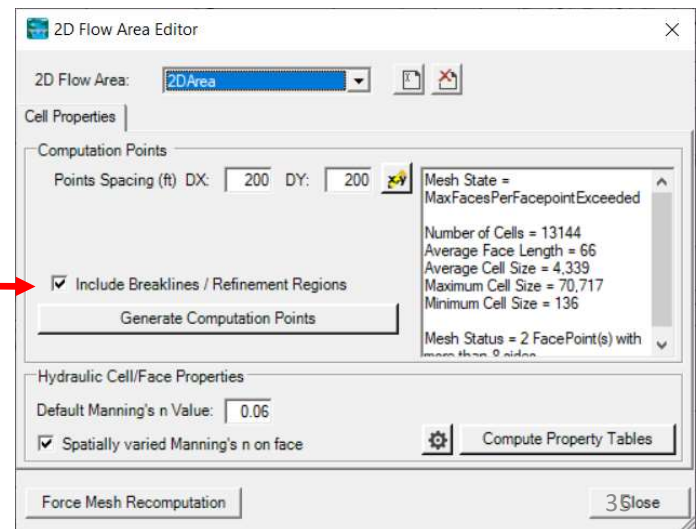
- Connections
 - Similar to Storage Area
 - Quick Link to Connections





Computation Points

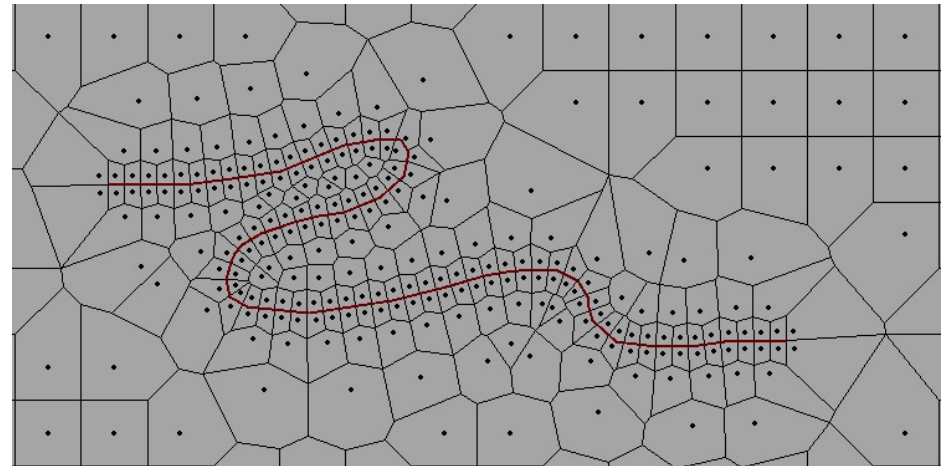
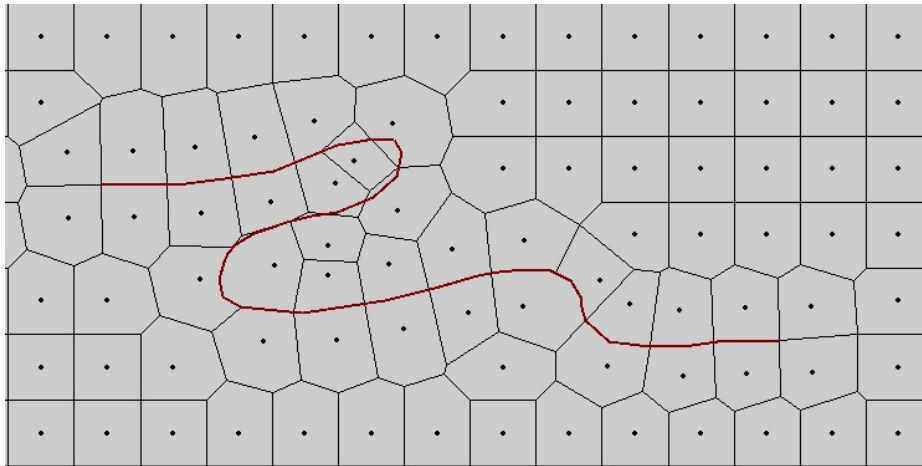
- Final mesh is based on final computation point set.
- Enforcement of Breaklines and Refinement Regions modifies existing computation points.
- Can enforce a breakline once, change parameters and enforce again.
 - Each iteration modifies the previous points.
- Point Regeneration will automatically use Breaklines and Refinement Regions (if included).





Fixing Problems

- If cell spacing is too large, cell faces may not be enforced

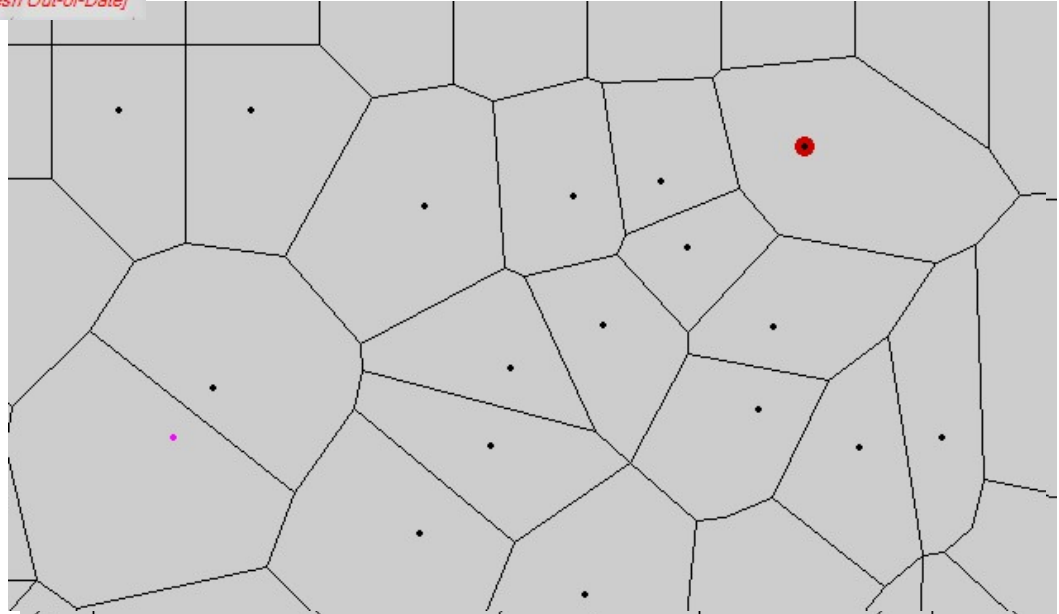


Fixing Problems

- More than 8 sides on a cell.

2D_Area: 2 Error(s) - Maximum 8 Faces per Cell [Displaying Local Mesh] [Full Mesh Out-of-Date]

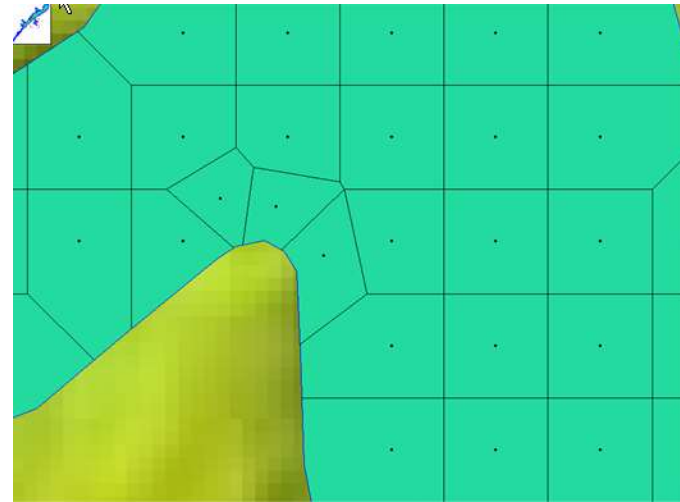
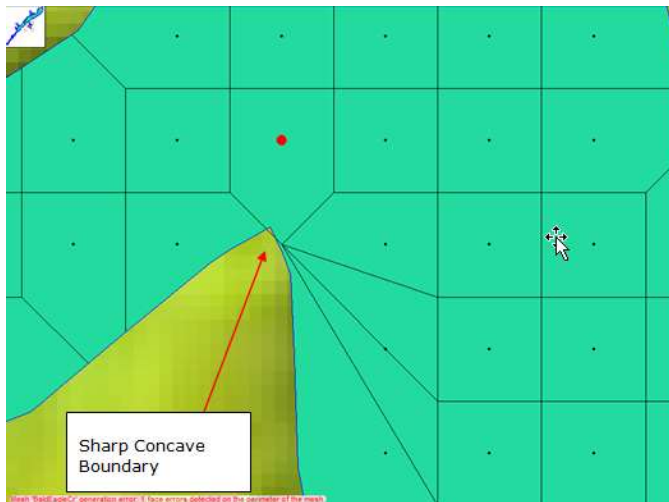
- Fix by Hand
- Auto “Try Fix” menu option





Fixing Problems

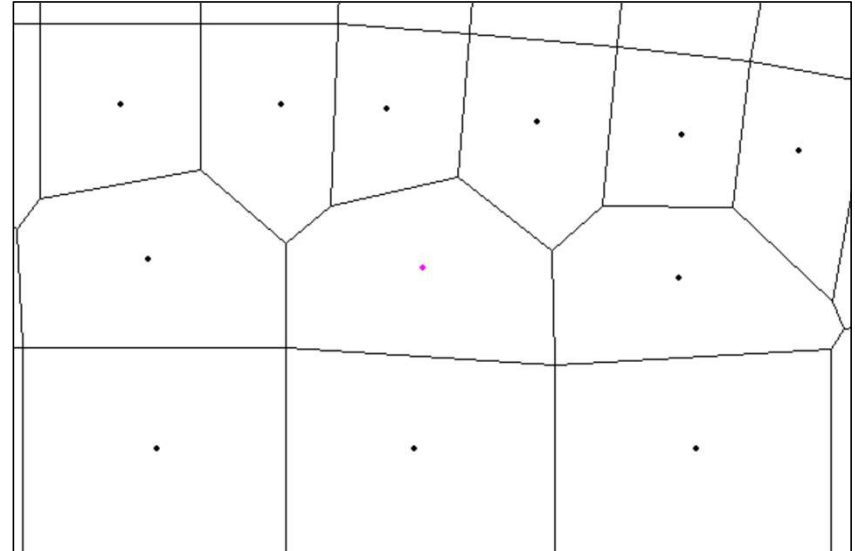
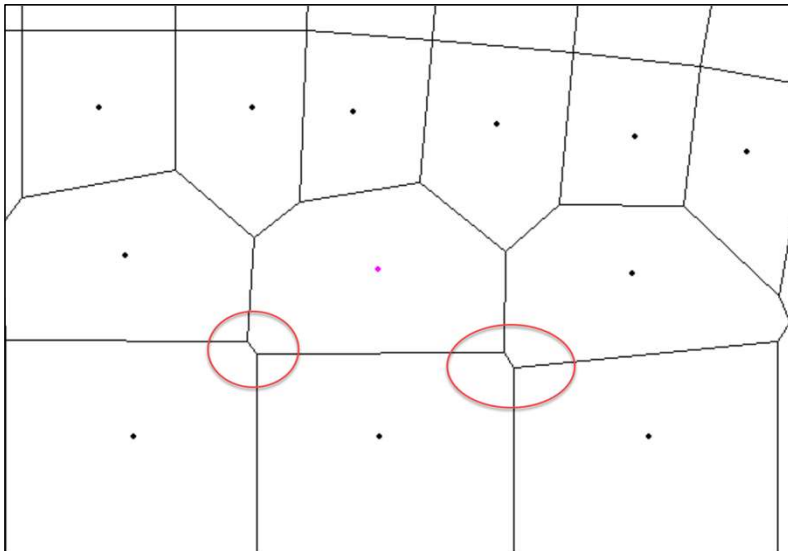
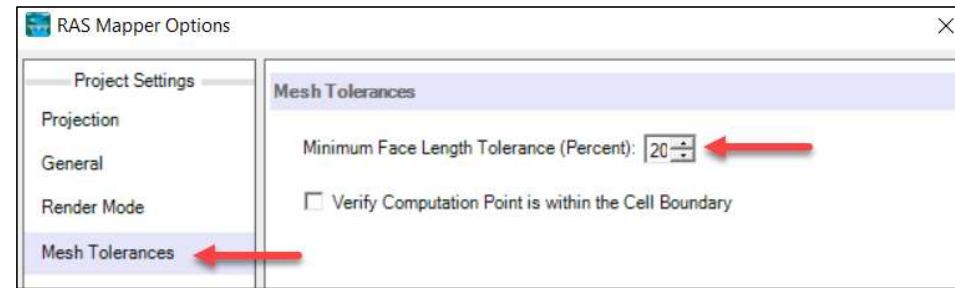
- Cells need to have exactly one Computation Point (Black Dot)
- Fix graphically by adding more points and/or moving points near perimeter





Mesh Tolerances

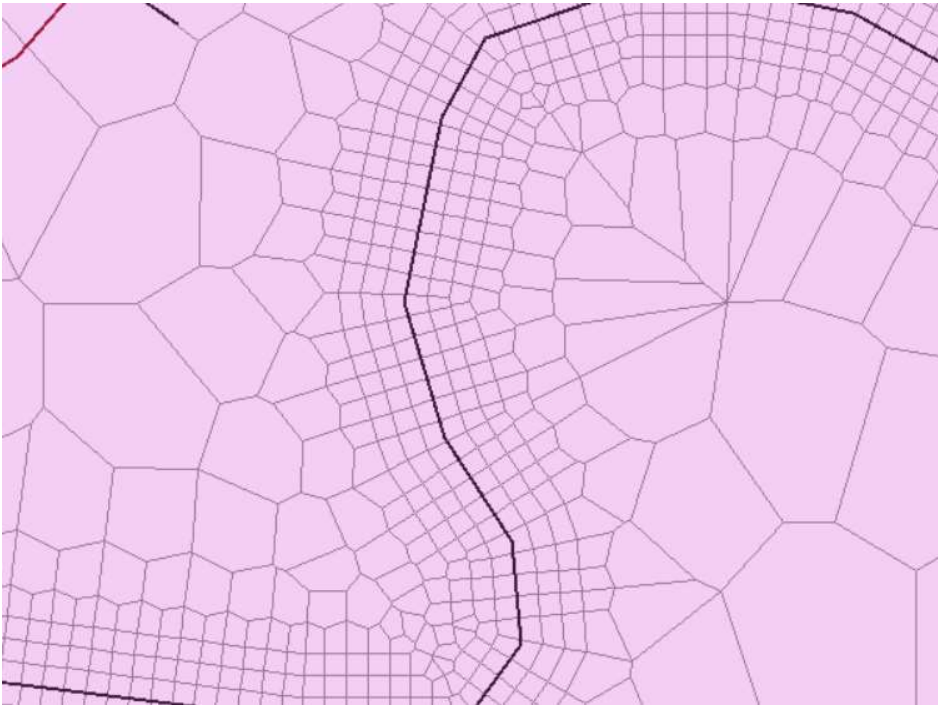
- Minimum Face Length (%)
 - 5% is Default, Recommend increasing





Face Tolerance

- Small Face Tolerance



- Larger Face Tolerance

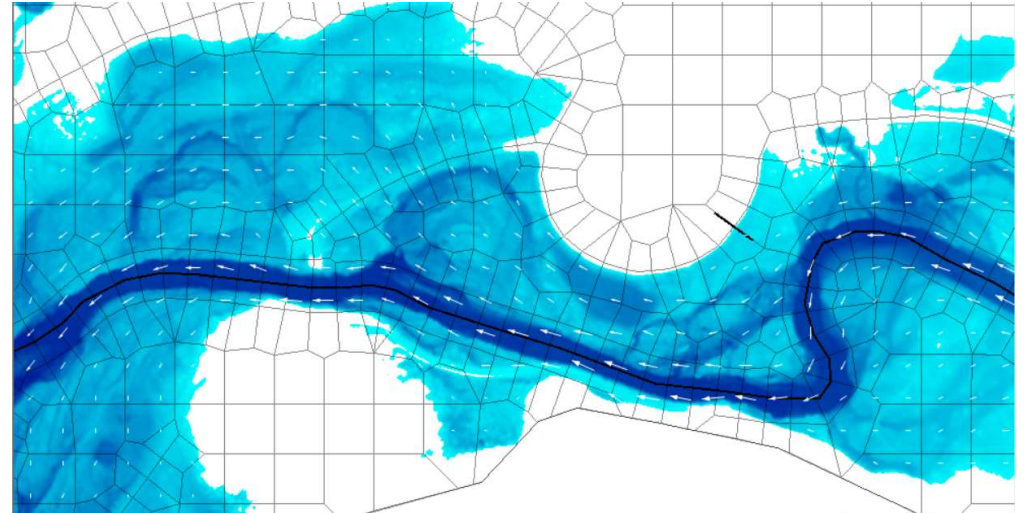
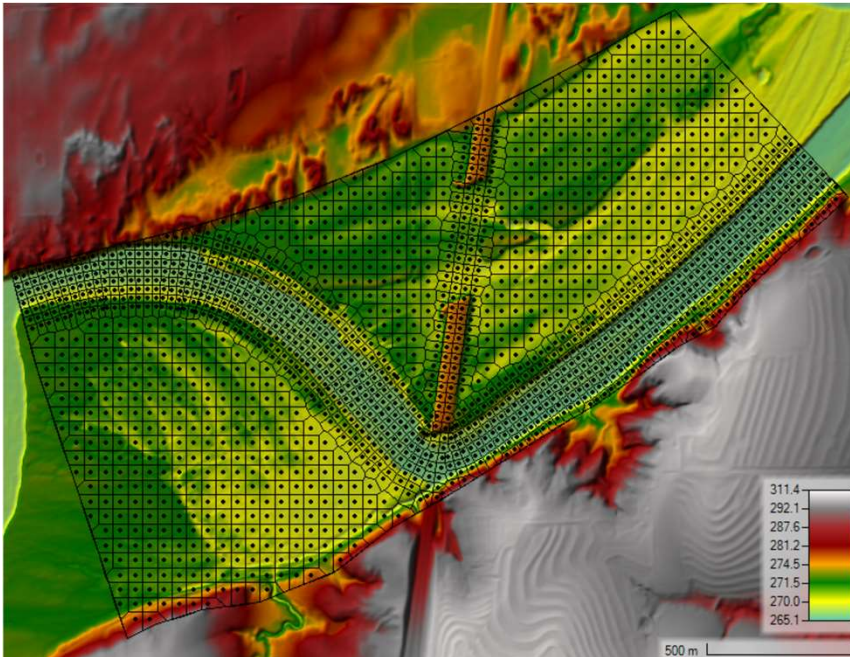


- Fewer faces faster models (less cell face computations).



Face Alignment

- Normal velocities are computed at every face. Tangential velocities are interpolated; therefore, aligning faces with flow more accurate.





Mesh Evaluation



- Additional Options
- Disable Mesh Edges
 - Mesh Cell Numbers
 - Mesh Face Numbers
 - Mesh Face Minimum Elevation
 - Mesh Face Point Numbers
 - Plot n Values

Questions?

