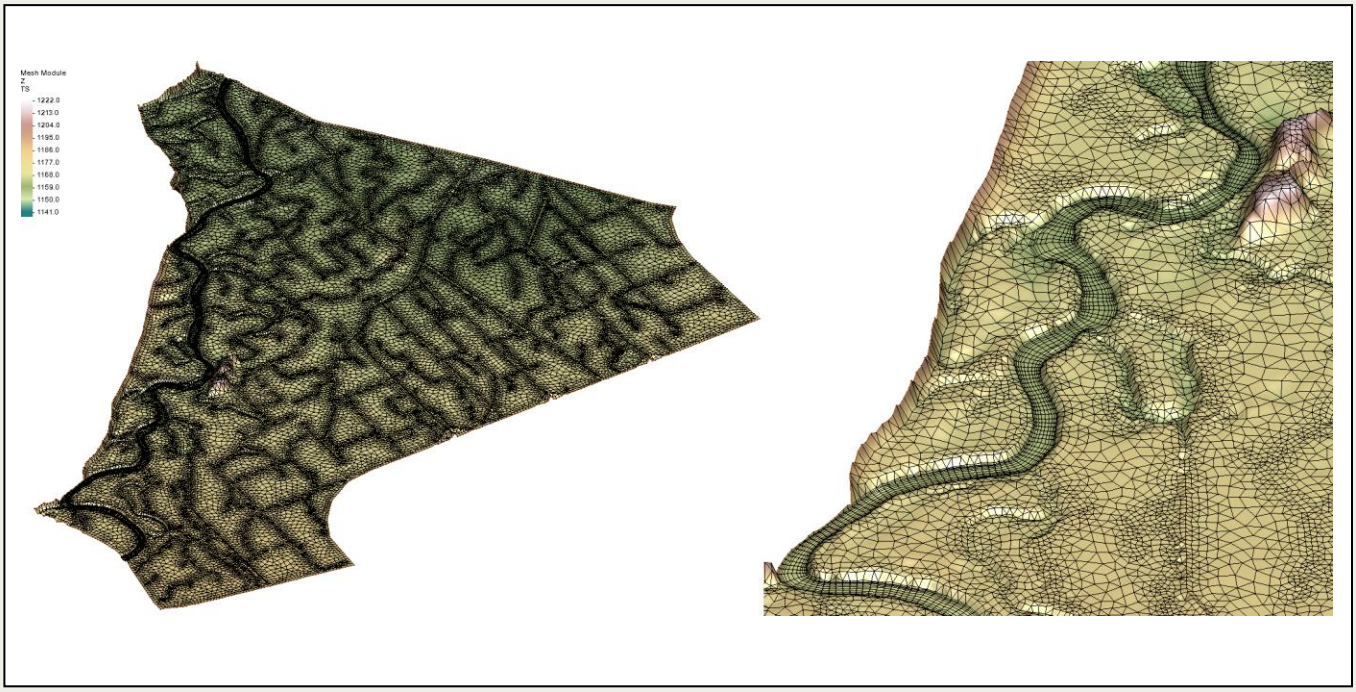
SMS 14.0 Tutorial

Mesh Generation from Extracted Features

Creating a 2D mesh from features extracted from raster data



Objectives

This tutorial demonstrates how to build a mesh that utilizes features extracted from a raster.

Prerequisite Tutorials

- Overview
- Map Module
- Raster
- Define Domain
- Feature Extraction for Mesh Generation

Required Components

- SMS Core

Time

- 15–20 minutes

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1 Introduction

This tutorial demonstrates how to use feature arcs extracted from a raster to generate a mesh for hydrodynamic analysis.

This tutorial uses a location on the Elkhorn River in Nebraska. The project begins with the slightly modified output from the “Extract Features for Mesh Generation” tutorial.

2 Getting Started

Start by importing a project file containing an existing mesh:

1. Launch the SMS application.
2. Select *File* | **Open…** to bring up the *Open* dialog.
3. Select “Project Files (*.sms)” from the *Files of type* drop-down.
4. Browse to the *data_files* folder for this tutorial and select “Elkhorn.sms”.
5. Click **Open** to import the project and exit the *Open* dialog.

The initial project should appear similar to Figure 1. The contour options have been changed for this figure to use the FHWA topography color palette.

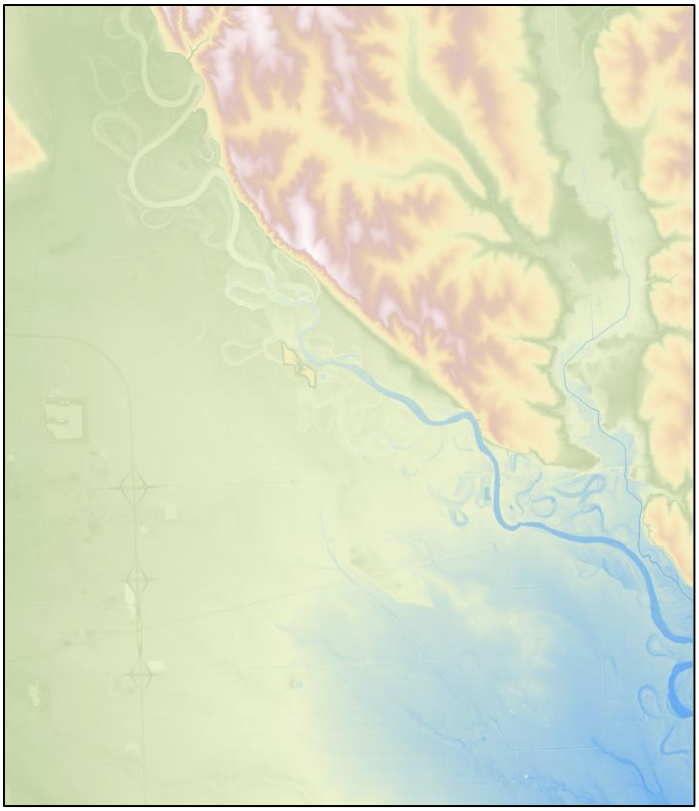

Figure 1 Initial project

3 Domain Limits

The input for this tutorial includes a polygon representing the domain extents. This polygon is in the "Domain Limits" coverage. Since the selection of the domain extents is important to the modeling process, the reasoning for this polygon will be reviewed in this tutorial. The mechanics of defining this polygon is described in the "Define Domain" tutorial.

The most subjective part of defining the domain is the positioning of the inflow and outflow boundary locations (the BCs). Best practice guidelines suggest that these locations have the following attributes:

- Positioned at a location where the flow conditions are well-behaved (close to 1D) and well-known (such as using a gaging station or other control).
- Positioned away from the area of interest. This can be taken to mean upstream or downstream by one to two floodplain widths or a full meander of the river. The distance can be reduced if the flow conditions at the boundary conditions are truly well-defined and simple. The purpose of the distance is to allow space for the flow to distribute based on physics, and for backwater at the boundary to not infringe on the study area. A few examples of an area of interest include:
    - A bridge crossing or other flow control structure.
    - A roadway segment that is being protected or redesigned.
    - A reach for which a floodplain or floodway study is being undertaken.

For this tutorial, the objective of this simulation is to define floodplain extents for a reach of the Elkhorn River near Fremont, NE. The reach is located upstream and through the Highway 30 bridge crossing.

Because this floodplain varies from roughly 2-4 miles wide, the upstream boundary was located about 6 miles upstream of the crossing where the floodplain narrows. This allows flow to distribute through the floodplain. The downstream boundary was positioned about 2 miles downstream of the crossing. Bell Creek joins the domain very close to the downstream end and is ignored.

With those guidelines, the model domain was laid out to be generally perpendicular to the floodplain and the lateral boundaries were defined to stay out of the floodplain.

4 Setting up the Main Channel

This section will illustrate how to incorporate a main channel polygon into a model domain, effectively splitting the domain into three subdomains (left floodplain, channel, and right floodplain). (Note: Just for notation purposes, in this case, the river is flowing from north to south, so the left floodplain is on the east, while the right floodplain is on the west.) Linear features such as channels or embankments should be accurately represented by the mesh because they provide the conveyance area and hydraulic controls which result in accurate simulations. Representing these structures as rectangular elements which are aligned to the feature has proven to be an efficient approach.

4.1 Adding the Channel to the Domain

To incorporate the channel into the domain:

1. Right-click on the "Domain Limits" coverage and select *Duplicate.*
2. Right-click on the new "Domain Limits (2)" coverage and select **Rename**.
3. Type "Mesh" as the new name and press *Enter.*

This will be used to generate a mesh.

4. Select and turn on the "Channel" coverage to make it active.
5. Using the **Select Feature Arc** tool, hold down the *Ctrl* key and drag an arc through the two arcs that define the channel banks.
6. Right-click and select **Copy to Coverage…** to open the *Select Coverage* dialog.
7. Select the "Mesh" coverage.
8. Click **OK** to close the *Select Coverage* dialog.
9. Turn off the display of the "Channel" coverage.

The "Mesh" coverage should contain both the domain arcs and the channel arcs (Figure 2).

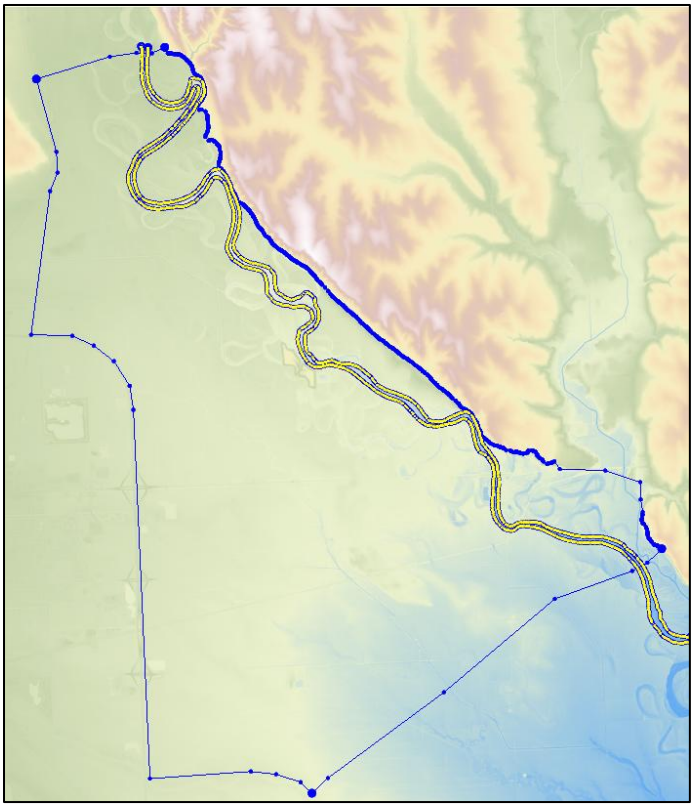

Figure 2 Domain with added bank arcs

4.2 Intersecting the Channel with the Domain Limits

To incorporate the channel into the domain limits, the arcs must intersect rather than just cross. To do this:

1. Select and turn on the "Mesh" coverage to make it active.
2. Click on the **Clean** macro to open the *Clean Options* dialog.
3. Set *Snap distance* to "0.1"
4. Click **OK** to execute the clean command.

Note: This command merges nodes and vertices that are within the specified distance from each other and intersects all arcs in the coverage. More information on the clean options can be found in the wiki.

5. Using the **Select Feature Arc** tool, hold down the *Shift* key and click on each arc that extends beyond the edges of the domain.
6. Press the *Delete* key
7. Click **Yes** to confirm deletion of these arcs.

4.3 Distributing Vertices on the Channel Banks

This example will use a patch (quadrilateral elements) to represent the channel. This requires uniform distribution of vertices from one bank to the other. To do this:

1. Use the **Select Feature Arc** tool, hold down the *Ctrl* key and drag a line through both arcs of the channel.
2. Right-click and select **Blend Arcs**.

This creates a new arc down the center of the channel that is the average of the two banks.

3. **Zoom** in until all three arcs can be seen in the channel.
4. Using the **Select Feature Arc** tool, select the new blended arc and note the arc ID at the bottom of the screen for step 12.
5. Right-click and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
6. Set *Specify* to “Specified spacing”
7. Set *Average spacing* to “100”.
8. Click **OK** to execute the *Redistribute Vertices* command and close the dialog.
9. Using the **Select Feature Arc** tool, select the centerline arc.
10. Hold down the *Shift* key and select one of the bank arcs.
11. Right-click and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
12. Set *Specify* to “Source Arc”.
13. Set *Source Arc* to be the arc ID of the centerline arc noted in step 3 above.
14. Click **OK** to execute the *Redistribute Vertices* command and close the dialog.
15. If a message that some nodes distributed parametrically, click **OK**.
16. Repeat steps 9–14 to redistribute vertices with the other bank arc.
17. Using the **Select Feature Arc** tool, select the centerline arc.
18. Press *Delete,* as arc is no longer needed.
19. Click **Yes** in the warning dialog to confirm the deletion of the centerline arc.

4.4 Adjust the Channel Ends

Where flow enters the domain of a 2D hydraulic simulation, it is assumed to enter perpendicular to the boundary. As a general rule, good practice suggests all “open boundaries” (where flow enters or leaves the domain), be perpendicular to the flow direction. Since the flow direction is not known until a simulation has been run, a valid assumption is that the flow will move parallel to the channel and floodplain. Therefore, defining open boundaries perpendicular to the channel is a common practice.

To adjust the open boundaries to be perpendicular to the channel:

1. Click on **Display Options** to open the *Display Options* dialog.
2. Click on “Map” to view map options.
3. Turn on *Vertex.*
4. Click **OK** to accept changes and close the *Display Options dialog.*
5. Turn off “ ElkhornRiver.tif” for easier viewing of vertices.

6. **Zoom** in on the upstream end of the channel (left side of Figure 3).

The channel is almost perpendicular to the domain. No change is needed here.

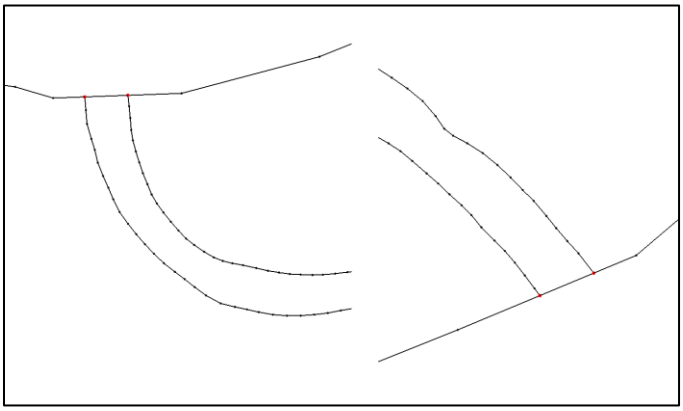

Figure 3 Intersection of the channel with the open boundaries.

7. Now **Zoom** in on the downstream end of the channel (right side of Figure 3).

Note that the two end segments of the channel are not the same length. This is an indication that the boundary is not perpendicular.

8. Using the **Select Objects** tool drag the two nodes to make the segments approximately the same length (Figure 4).

The length of the other segments in the channel can be a reference. (The lengths do not need to be precise.)

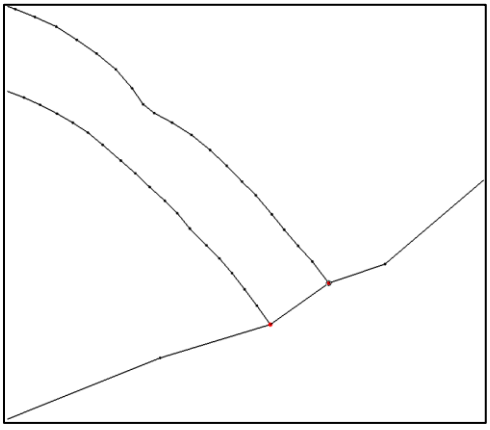

Figure 4 Adjusted outflow boundary.

4.5 Trimming the Domain to the Channel

In this simulation, the channel is positioned very close to the left domain boundary in two places. Trying to mesh between the channel and the boundary when the space is so small would probably result in poorly shaped elements. For this reason, in these areas we will merge the domain boundary to the channel. To do this:

1. **Zoom** into one of the locations on the left floodplain where the channel approaches the domain boundary as shown in Figure 5.

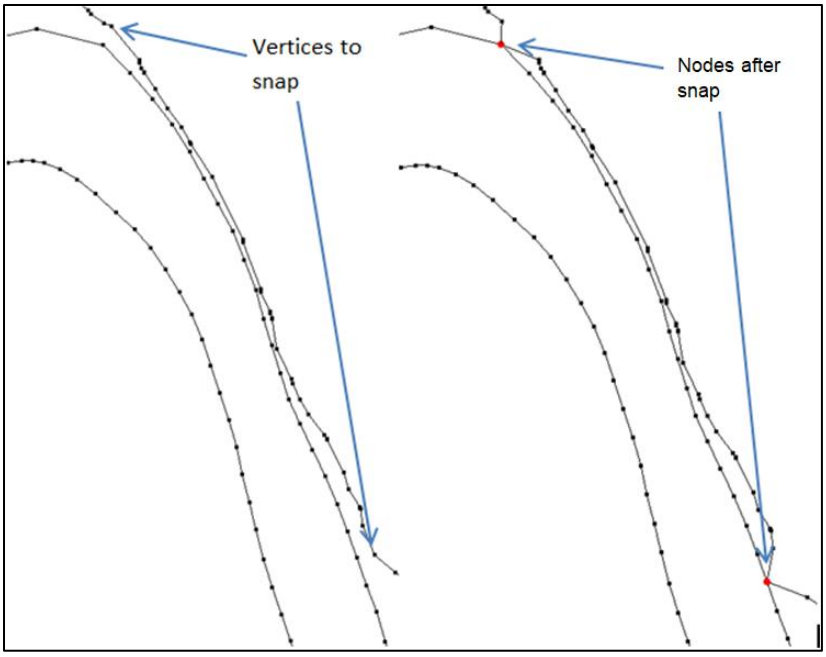

Figure 5 Snapping vertices from domain boundary to channel

2. Using the **Select Feature Object** tool, select a vertex from the domain boundary (see Figure 5).
3. Drag the vertex close to a vertex on the channel boundary so they will snap together.
4. Repeat steps 2–3 for a second vertex.

These locations will be changed to feature nodes. Exactly which vertices are selected is not important.

5. Using the **Select Feature Arc** tool, select the arc on the domain boundary between the two snapped vertices
6. Press *Delete*.
7. Click **Yes** to delete the selected arc.
8. Repeat steps 1–7 at the second location where boundaries are close.
9. Click **Build Polygons** macro.

Note: this operation should be done after the channel arcs have been redistributed (as we did above) so that the vertex distribution for the patch can be performed with a single arc for each side of the channel.

4.6 Distributing Vertices on the Domain Boundaries

Now distribute the vertices on the domain boundaries by completing the following:

1. **Frame** the project.
2. Using the **Select Feature Arc** tool.

3. Hold down the *Shift* key and select all the arcs that form the boundary, excluding the two channel boundaries that became domain boundaries in section 4.5. (There should be 14 selected.)

Note: The boundary of the channel was already distributed above to form a patch.

4. Right-click and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
5. Set *Specify* to “Specified spacing”.
6. Set *Average spacing* to “150”.
7. Click **OK** to close the *Redistribute Vertices* dialog.

4.7 Distributing Vertices on the Channel Ends

Higher resolution is desired across the channel to represent the variation of flow in the channel. To accomplish this:

1. **Zoom** in on the upstream end of the channel.
2. Using the **Select Feature Arc** tool, select the arc that forms the upstream channel boundary.
3. Right-click and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
4. Set *Specify* to “Number of Segments”.
5. Set *Number of Segments* to “12”.
6. Enter a *Bias (0.01-100.0)* of “4”.
7. Turn on *2nd Bias (0.01-100.0)*.
8. For *2nd Bias (0.01-100.0),* enter a value of “4”.
9. Click **OK** to close the *Redistribute Vertices* dialog.
10. Repeat steps 1–9 on the downstream end of the channel.

5 Trim the Networks

For this demonstration, the floodplain polygons will not be filled as patches. There are multiple options for filling these regions. Here, they will be filled as paved regions with internal features defined by the extracted networks of streams and ridges (see the “Extract Features for Mesh Generation” tutorial to see where the coverages used in this tutorial came from). Processing these networks will result in a better and more efficient mesh. This example requires performing multiple operations including:

- Merging the extracted networks.
- Trimming the features to the floodplains.
- Remove features smaller than the minimum resolution of this simulation.
- Redistribute the vertices on the features to the desired resolution.
- Remove features that are too close to each other.

5.1 Merging the Features

Feature extraction creates separate features for streams and ridges and uses the resolution of the DEM to define these features. To prepare these for the hydrodynamic solution:

1. In the Project Explorer,click on "2,000,000 sq ft (0.25%) Streams" to make it active.
2. Press and hold control while selecting "4,000,000 sq ft (0.5% Ridges). This should select both coverages.
3. Right-click and select **Merge Coverages**.
4. Click **No** on the query asking to delete the old coverages.
5. Right-click on the new "Merge coverage" and select **Rename**.
6. Type "Features" and press *Enter*.
7. Select the "Features" coverage to make it active.
8. **Frame** the project.

5.2 Trimming to the Domain

Note that many of the features are outside of the domain. These are not of interest for this project, so it is necessary to trim all features that are close to the edges of the domain. This allows the mesh generation to transition from one feature to another. To trim the features based on the domain:

1. Click the **Toolbox** macro to open the *Toolbox* dialog.
2. Expand the *Coverages* folder.
3. Select *Trim Coverage*.
4. Click **Run Tool…** to open the *Trim Coverage* dialog.
5. For the *Input coverage containing arcs to be trimmed option*, select "Map Data/Features".
6. For the *Input coverage containing polygons to trim by*, select "Map Data/Mesh".
7. Ensure *Trimming option* is set to "Trim to inside".
8. Set the *Trimming buffer distance* to "200.0".

This is to give transition space.

9. For the *Output coverage*, enter "Domain Features".
10. Click **OK** to run the *Trim Coverage* tool.
11. When it is finished, click **OK** to close the *Trim Coverage* dialog.
12. Select the new "Domain Features" coverage to make it active.

Compare the "Domain Features" coverage (Figure 6) with the "Features" coverage.

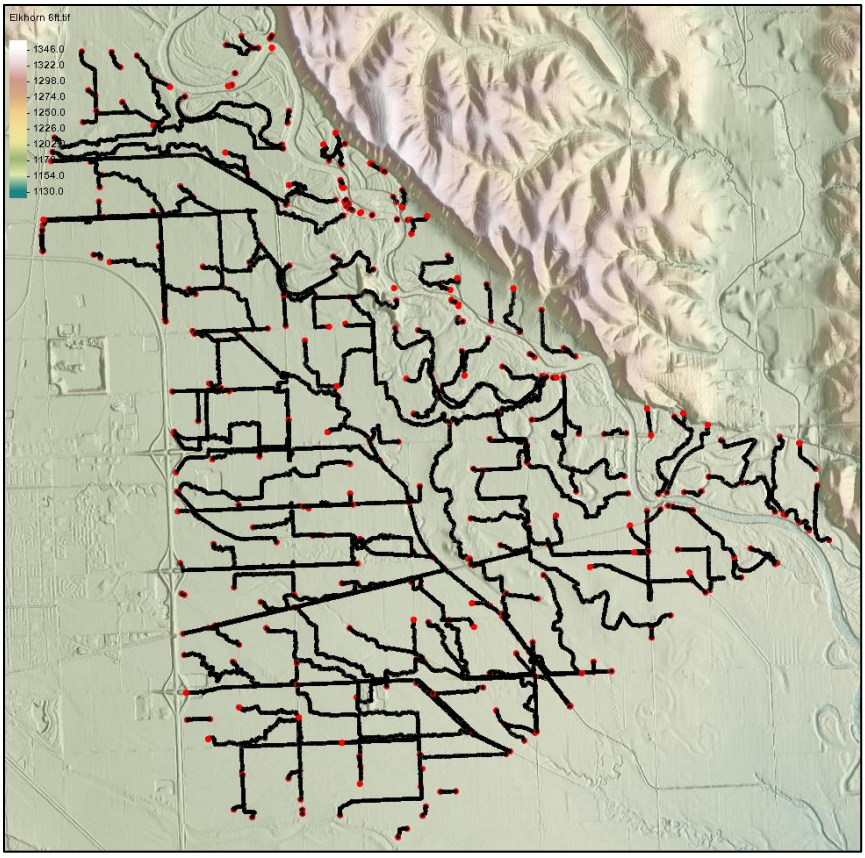

Figure 6 The Domain Features coverage

5.3 Trimming to the Channel

Just as some of the features extend outside of the domain, other features are inside the main channel. Since this example uses a polygon to represent the channel, features inside, or close to the channel are not of interest and should be trimmed. To trim the features based on the channel:

1. Select and turn on the "Channel" coverage to make it active.
2. **Zoom** into the upstream end of the channel.
3. Select the **Create Feature Arc** tool.
4. Create an arc connecting the two bank arcs by clicking on each node in turn.
5. **Zoom** into the downstream end of the channel.
6. Use the **Create Feature Arc** tool to create an arc to connect the two bank arcs by clicking on each node in turn.
7. Click the **Build Polygons** macro to build the channel polygon.

Now to trim the coverage:

8. Click the **Toolbox** macro to open the *Toolbox* dialog.
9. Expand the *Coverages* folder and select the *Trim Coverage* tool.

10. Click the **Run Tool…** button to open the *Trim Coverage* tool dialog.
11. For the *Input coverage containing arcs to be trimmed option*, select "Map Data/Domain Features".
12. For the *Input coverage containing polygons to trim by*, select "Map Data/ Channel".
13. Set *Trimming option* to "Trim to outside".
14. Set the *Trimming buffer distance* to "100.0".

This is to give transition space.

15. For the *Output coverage*, enter "Floodplain Features".
16. Click **OK** to run the *Trim Coverage* tool.
17. When complete, click **OK** to close the *Trim Coverage* dialog.

5.4 Removing Small Features

It is necessary to make some additional adjustments to the floodplain features. Specifically, remove small arcs that resulted from the trimming process, redistribute the vertices on the arcs for better representation in the mesh, and eliminate features that are too close to each other. To get rid of these:

1. Select the "  Floodplain Features" coverage to make it active.
2. Select the **Select Feature Arc**  tool and click *Edit* | *Select By* | **Length…** to open the *Select by Length* dialog.
3. Enable the *Less Than* option.
4. Enter "100" as the length parameter.
5. Click **OK** to close the *Select by Length* dialog.

SMS will select all arcs that are shorter than the specified threshold.

6. Press the *Delete* key.
7. Click **Yes** to confirm the deletion of these arcs.

5.5 Redistributing Features

The features were extracted from the DEM at the resolution of the DEM. This means that there are too many vertices, which would result in elements that are smaller than is desirable for the simulation. To get rid of these extra vertices:

1. Using the **Select Feature Arc**  tool, right-click in the Graphics Window and select **Select All**.
2. Right-click again and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
3. Set *Specify* to "Specified spacing".
4. Set *Average spacing* to "100" ft.
5. Set the *Bias (0.01-100.0)* factor to "1.0".
6. Turn off the *2nd bias (0.01-100.0)* factor.
7. Click **OK** to execute the *Redistribute Vertices* command and close the dialog.

5.6 Removing Features That Are Too Close

This case illustrates situations where extracted features (ridges and streams) are very close to each other. If these are major features, they would be represented as specific polygons, as was done with the main channel. For minor features, when they get too close together, they can interfere with each other resulting in a lower quality mesh. To get rid of features too close to each other:

1. Using the **Select Feature Arc** tool, right-click in the Graphics Window and select **Select All**.
2. Click on the **Clean** macro to open the *Clean Options* dialog.
3. For *Snap distance,* enter "50".
4. Click **OK** to close the *Clean Options* dialog and merge arcs that are within 50 ft of each other.
5. Using the **Select Feature Point** tool, right-click in the Graphics Window and choose **Select All**.
6. At the bottom of the interface, note how many points are selected.
7. Right-click again and select **Nodes** ↔ **Vertices**.

Note: Remember that the arcs in this coverage represent channels or ridges that should be included in the mesh to maintain integrity with the existing topography. Additional edits such as smoothing, adjusting individual arcs, or adding/deleting specific features can still be done based on experience with the domain.

5.7 Adding the Trimmed Network to the Mesh Generator Coverage

Now add the trimmed network to the mesh generator coverage. To do this:

1. Click on the "Floodplain Features" to make the coverage active.
2. Select the **Select Feature Arc** tool, then right-click in the Graphics Window and choose **Select All**.
3. Right-click and select **Copy to Coverage…** to open the *Select Coverage* dialog.
4. Select the "Mesh" coverage.
5. Click **OK** to close the *Select Coverage* dialog.
6. Click on the "Mesh" coverage to make it active.
7. Use the **Build Polygons** macro to build the polygons of the domain.

Adding all the interior features to the coverage can make the polygons invalid.

6 Specify Meshing Attributes

The polygons now need to be given meshing parameters.

6.1 Assigning Channel Attributes

To assign the channel polygon attributes and perform final manual cleanup on the arcs. To do this:

1. Using the **Select Feature Polygon** tool, double-click on the channel polygon to bring up the *2D Mesh Polygon Properties* dialog.
2. Set *Mesh Type* to “Patch (quadrilaterals)”.
3. Set *Elevation (bathy/topo) type* to “Raster”.
4. Click the **Preview Mesh** button.
5. After reviewing the full length of the channel, click **OK** to close the *2D Mesh Polygon Properties* dialog.

6.2 Assigning Floodplain Attributes

The last step before generating the mesh is to specify the polygon attributes for the floodplain polygons. To do this:

1. Using the **Select Feature Polygon** tool, right-click in the Graphics Window and choose **Invert Selection**.
2. Right-click again and select **Polygon Attributes…** to open the *2D Mesh Multiple Polygon Properties* dialog.
3. Turn on *Mesh type.*
4. Change the drop-down to “Constant Paving (triangles)”.
5. Set *Bias (0.01-100.0)* to “0.2”.
6. Set *Size* to “300”.
7. Turn on *Elevation (bathy/topo) type.*
8. Set *Elevation (bathy/topo) type* to “Raster”.
9. Click **OK** to close the *2D Mesh Multiple Polygon Properties* dialog.

7 Generate the Mesh

The example is now ready to generate the computational mesh.

To generate the mesh:

1. Click the **Toolbox** macro to open the *Toolbox* dialog.
2. Expand the *2D Mesh* folder.
3. Select the *2D Mesh from Coverage* tool.
4. Click **Run Tool…** to open the *2D Mesh from Coverage* dialog.
5. For *Coverage*, select “Map Data/Mesh”.
6. Toggle on the *Merge triangles* option.

This instructs SMS to merge triangles to quadrilaterals after the mesh is generated.

7. Set the *Name of the output mesh* to “Mesh”.

8. Click **OK** to run the tool.
9. Click on **Display Options** to open the *Display Options* dialog.
10. Click on “2D Mesh” to view 2D Mesh options.
11. Turn on *Elements*.
12. Click **OK** to accept changes and close the *Display Options dialog*

The generated mesh should appear similar to Figure 7.

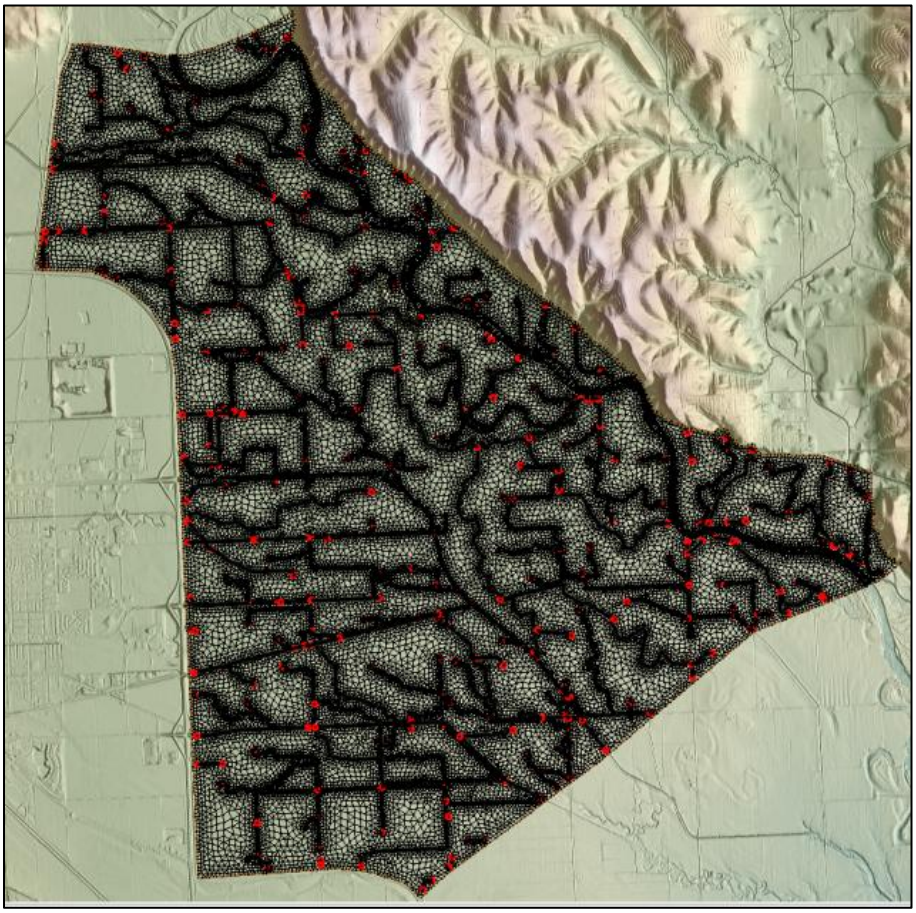

Figure 7 Generated mesh

7.1 Visual Inspection

Inspection of the mesh can be done using the tools provided, such as the **Zoom**, **Pan**, and **Rotate** tools, to manually inspect each mesh.

Use the ARR plot and other methods to evaluate element quality.

Refer to the “Observation”, “Observation Data”, and “Data Visualization” tutorials for more information on how to visualize the data.

8 Conclusion

This concludes the “Mesh Generation from Extracted Features” tutorial. Several features have been demonstrated including:

- Arc redistribution
  - Using source/target
  - Using double biasing
  - Using constant spacing
- Arc blending
- Arc selection
  - Using the *Ctrl* key to drag a line through multiple arcs
  - Using the option to select connected arcs end to end
- Arc offsetting
- Constant paving density

The steps presented here do not need to be followed in precise order. Try experimenting with using the sections in different orders to gain more understanding of the funcionality.