SMS 13.3 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.

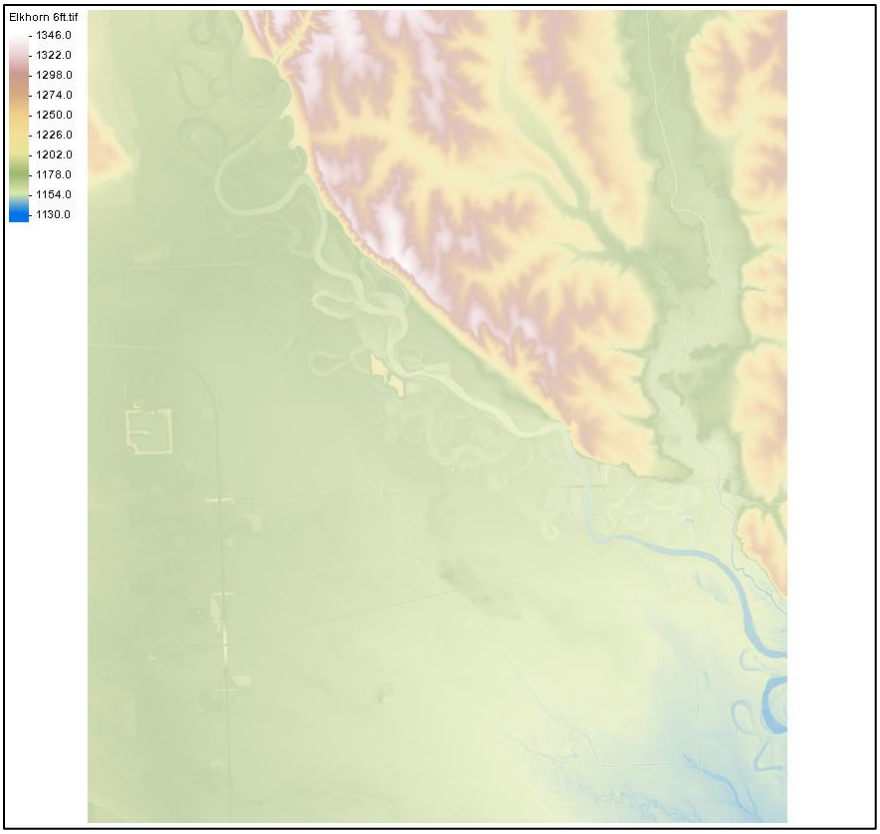

Figure 1 Initial project

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 approximately 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 1.5 to 4.5 miles wide, the upstream boundary was located about 6.3 miles upstream of the crossing to allow flow to distribute through the floodplain and 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, 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" and select *Duplicate.*
2. Right-click on the new "Domain Limits (2)" and select **Rename**.
3. Enter "Mesh" as the new name (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 *Control* 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 as the target and click **OK** to close the *Select Coverage* dialog.
8. Turn off the display of the "Channel" coverage.

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

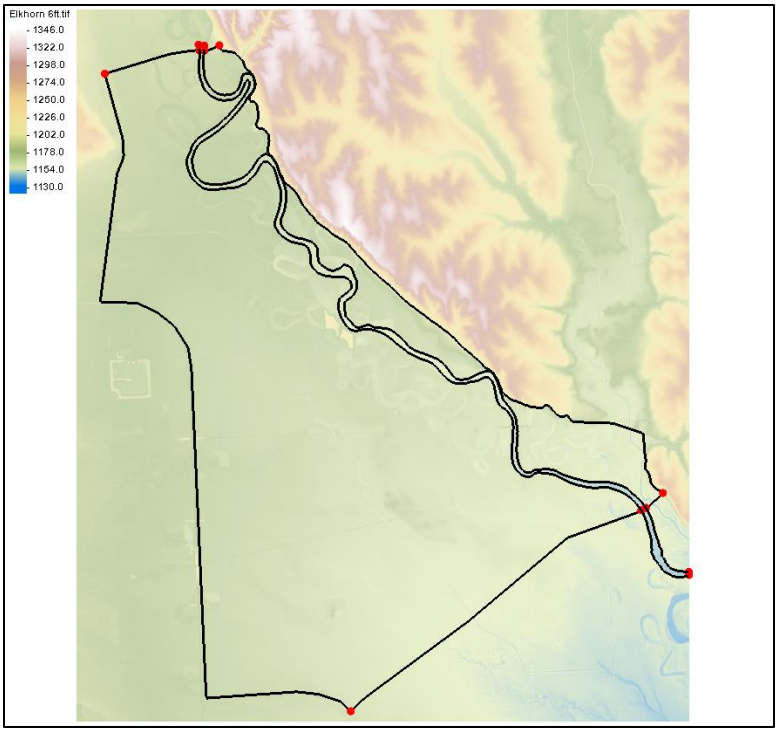

Figure 2 Domain with added bank arcs

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. Select the *All arcs* option in the *Clean coverage* section.
4. Click **OK** to close the *Clean Options* dialog.
5. Using the **Select Feature Arc** tool, select each of the arcs that extend beyond the edges of the domain.
6. Press the *Delete* key and 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 to select both sides of the channel using the *Control* key to drag an arrow through both.
2. Right-click and select **Blend Arcs** to create a new arc down the center of the channel that is the average of the two banks.
3. Use the **Select Feature Arc** tool, select the new blended arc and note the arc ID at the bottom of the screen.

4. Right-click and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
5. Set *Specify* to “Specified spacing” and set *Average spacing* to “100” ft.
6. Click **OK** to close the *Redistribute Vertices* dialog.
7. Using the **Select Feature Arc** tool, select the centerline arc and hold down the *Shift* key to select one of the bank arcs.
8. Right-click and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
9. Set *Specify* to “Source Arc” and make sure the *Source Arc* is set to be the arc ID of the centerline arc noted in step 3 above.
10. Click **OK** to close the *Redistribute Vertices* dialog.
11. If a message that some nodes distributed parametrically, click **OK**.
12. Repeat steps 8–11 to redistribute with the other bank arc.
13. Using the **Select Feature Arc** tool, select the centerline tool and press *Delete*. This arc is no longer needed.
14. Click **Yes** in the warning dialog to confirm deleting the centerline arc.

4.4 Distributing Vertices on the Channel Ends

Now to distribute the vertices across the channel by doing the following:

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

4.5 Distributing Vertices on the Other Domain Boundaries

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

1. Using the **Select Feature Arc** tool with the *Shift* key, select the six arcs that forms the boundary (excluding the channel ends).
2. Right-click and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
3. Set *Specify* to “Specified spacing” and set *Average spacing* to “200”.
4. Set the *Bias* to “1”.
5. Turn off the *2nd Bias*.

6. Click **OK** to close the *Redistribute Vertices* dialog.

4.6 Assigning Attributes

Now to assign the channel polygon attributes and perform final manual cleanup on the arcs. Normally it is recommended to minimize the amount of manual cleanup, because it is not reproducible and can be inconsistent. However, due to the complex geometry of nature, some cleanup is expected. To do this:

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

Element quality could be improved by manually editing the position of the vertices around the sharp bends in the channel. This is not required in this case but should be considered if element quality is low due to tight meanders.

5 Trim the Networks

For this demonstration, the two 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. Processing these networks will result in a better and more efficient mesh. This example requires performing multiple operations including:

- 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 resolguion.
- 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. Select the “ 2,000,000 sq ft (0.25%) Streams” and then use the *Shift* key to select “ 4,000,000 sq ft (0.5%) Ridges” coverage as well.
2. Right-click and select **Merge Coverages**.
3. Click **No** on the query asking to delete the old coverage.
4. Right-click on the new “ Merge coverage” and select **Rename**.
5. Enter “All Features” as the new name.

6. Select the "All Features" coverage to make it active.

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 allow 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 and select the *Trim Coverage* tool.
3. Click the **Run Tool** button to open the *Trim Coverage* tool dialog.
4. For the *Input coverage containing arcs to be trimmed option*, select "Map Data/All Features".
5. For the *Input coverage containing polygons to trim by*, select "Map Data/Domain Limits".
6. Make certain the *Trimming option* is set to "Trim to inside".
7. Set the *Trimming buffer distance* to "200.0". This is to give transition space.
8. For the *Output coverage*, enter "Domain Features".
9. Click **OK** to run the *Trim Coverage* tool.
10. When the tool execution completes, click **OK** to close the *Trim Coverage* dialog.
11. Select the new "Domain Features" coverage created by the *Trim Coverage* tool to make it active.

Compare "Domain Features" coverage (Figure 3) with the "All Features" coverage.

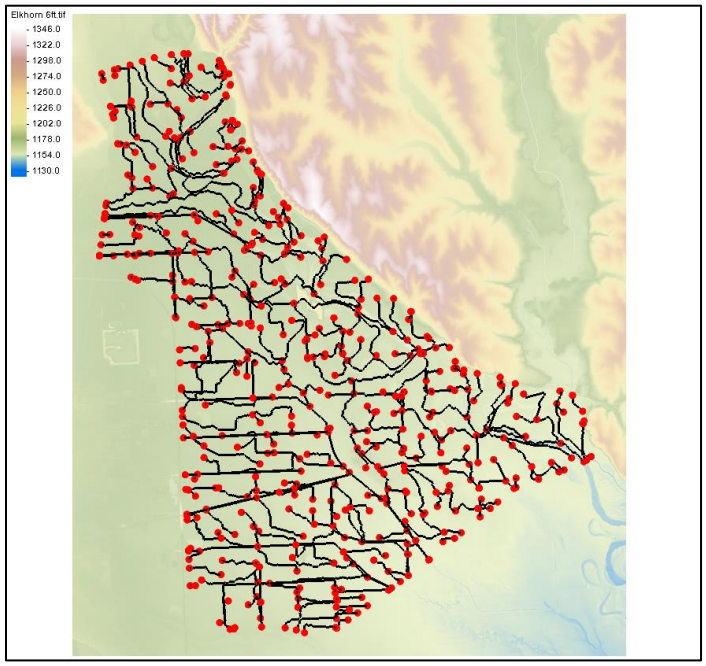

Figure 3 The domain features coverage

5.3 Trimming to the Channel

Just as some of the features extended 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. Click the **Toolbox** macro to open the *Toolbox* dialog.
2. Expand the *Coverages* folder and select the *Trim Coverage* tool.
3. Click the **Run Tool** button to open the *Trim Coverage* tool dialog.
4. For the *Input coverage containing arcs to be trimmed option*, select “Map Data/Domain Features”.
5. For the *Input coverage containing polygons to trim by*, select “Map Data/Channel”.
6. Make certain the *Trimming option* is set to “Trim to outside”.
7. Set the *Trimming buffer distance* to “100.0”. This is to give transition space.
8. For the *Output coverage*, enter “Floodplain Features”.
9. Click **OK** to run the *Trim Coverage* tool.
10. When the tool execution completes, click **OK** to close the *Trim Coverage* dialog.

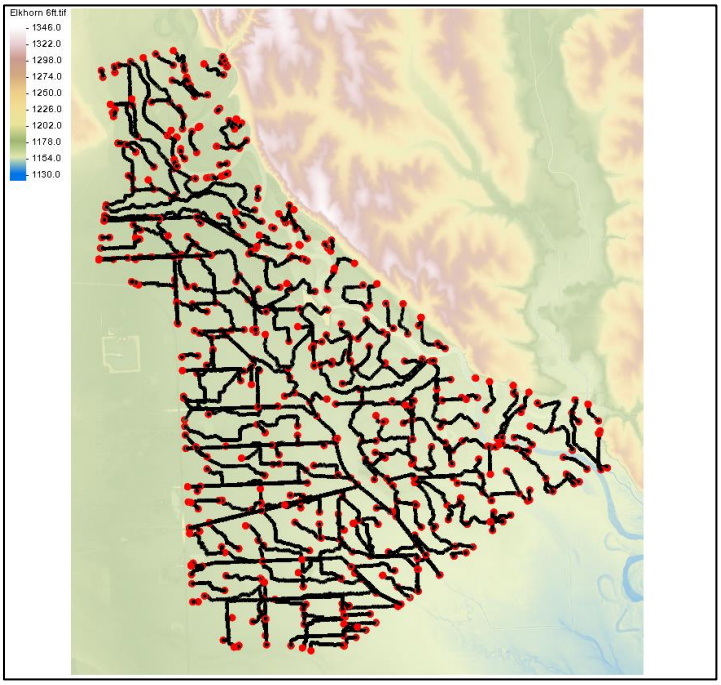

Figure 4 The Floodplain Features coverage

5.4 Removing Small Features

It’s 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 elimination of 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 issue the *Edit* | *Select By* | **Length…** command to open the *Select by Length* dialog.
3. Enable the *Less Than* option and enter "100" as the length parameter.
4. Click **OK** to close the *Select by Length* dialog.

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

5. Press the *Delete* key and click **Yes** to confirm 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 we want in 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 and select **Redistribute Vertices…** to open the *Redistribute Vertices* dialog.
3. Set *Specify* to "Specified spacing" and set *Average spacing* to "100" ft.
4. Click **OK** to close the *Redistribute Vertices* 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 that are too close to each other:

1. Click on the **Clean** macro to open the *Clean Options* dialog.
2. Enter a *Distance* of "50" in the C*lean coverage* section. The *All arcs* option should be selected from the last time the dialog was opened.
3. Click **OK** to close the *Clean Options* dialog and merge arcs that are within 50 ft of each other.
4. Using the **Select Feature Point** tool, right-click and choose **Select all**.
5. At the bottom of the interface, note how many points are selected.
6. Right click again and select **Nodes** ↔ **Vertices**.
7. Repeat steps 1–6 until the number of selected nodes quits changing (about 4–5 times).

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. With the "Floodplain Features" coverage active, and using the **Select Feature Arc** tool, right-click in the Graphics Window and choose **Select All**.
2. Right-click and select **Copy to Coverage…** to open the *Select Coverage* dialog.
3. Select the "Mesh" coverage as the target and click **OK** to close the *Select Coverage* dialog.

6 Specify Floodplain Meshing

The floodplain now needs to be given meshing parameters.

6.1 Assigning attributes

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

1. Select the "Mesh" coverage to make it active.
2. Use the **Build Polygon** macro to build the polygons of the domain.

Note there are now more polygons because features closed into polygons.)

3. Using the **Select Feature Polygon** tool, right-click and choose **Select all…**
4. Hold down the *Shift* key and click in the channel to deselect that polygon.
5. Right-click and select **Polygon Attributes…** to open the *2D Mesh Multiple Polygon Properties* dialog.
6. Turn on *Mesh type* and set it to "Constant Paving (triangles)"
7. Set *Size* set to "300".
8. Turn on *Elevation (bathy/topo) type* and set it 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.

7.1 Triangle Based Mesh Generation

To generate the mesh:

1. Clear all the selections by clicking in the background or changing tools.
2. Right-click on the "Mesh" coverage and select *Convert* | **Map → 2D Mesh** to open the *Mesh Name* dialog.
3. Enter "Tri Mesh" for the name.
4. Click **OK** to close the *Mesh Name* dialog.
5. Click the **Display Options** to open the *Display Options* dialog.
6. Turn on the *Elements* option.

7. Click **OK** to close the *Display Options* dialog.

The generated mesh should appear similar to Figure 5.

Figure 5 Generated mesh

7.2 Merge Triangles

A common method of reducing the number of elements in a mesh is to merge triangles that form good quadrilaterals.

1. Right-click on "Tri Mesh" and select **Duplicate**….
2. Right-click on "Triangle Mesh (2)" and select **Rename**.
3. Enter "Quad Mesh" as the new name.
4. Select "Quad Mesh" to make this mesh active.
5. Select *Elements* | **Merge Triangles**.
6. Click **Yes** when asked if this should apply to all elements.

There are now two meshes for this domain. One mesh represents the floodplain with triangles, and one has quadrilaterals when that results in well-shaped elements.

7.3 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.

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 *Control* 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.