



OpenRoads Survey: Terrain Models

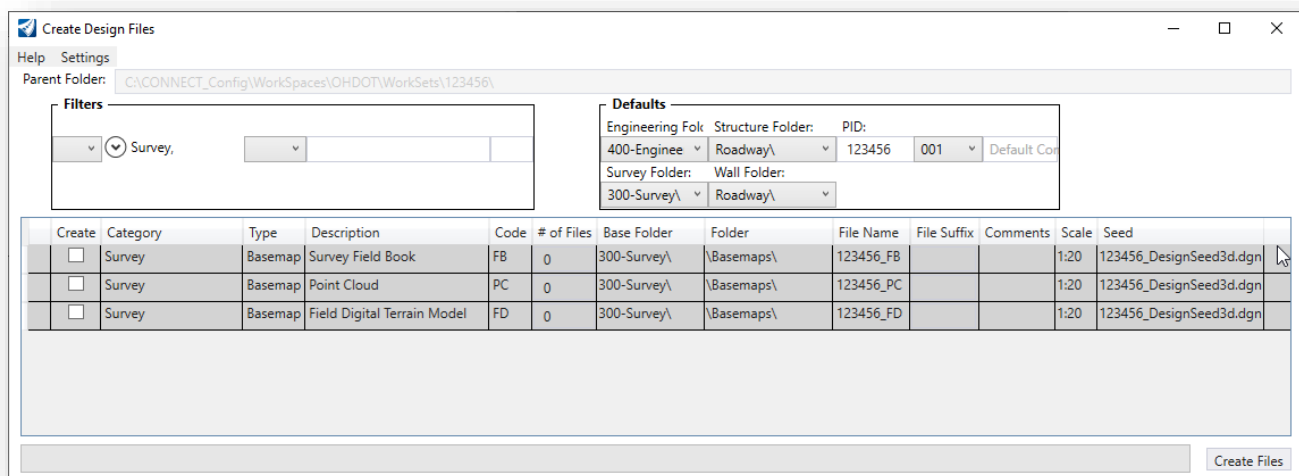
The OpenRoads tools provide functions to generate terrain models from multiple sources. Traditional topo survey, ground and aerial based LiDAR data are frequently used to generate the existing ground terrain model, and can be combined to create a single terrain model as necessary.

This document will discuss the process to create a combined complex terrain model from three sources: ground survey, ground based LiDAR data, and Aerial LiDAR data.

Design File Types for Existing Ground Terrain Models

The existing ground terrain model is usually created directly from the topo survey data in the Field Book (FB) design file. If the exiting terrain model will be combined using disparate data sources, it is best to create the combined terrain in a separate design file. The OHDOT CADD Standards include a new file type for a Field Digital Terrain Model (FD) that is used when the terrain model will be created by combining different sources.

The **OHDOT Create Design Files** application provides three design file types used for Survey processing as shown below.



If the terrain model will be generated from only the topo survey information, the best practice is to create the terrain model from the Field Book directly in the FB design file.

The Point Cloud (PC) file type is used to generate a terrain model from LiDAR information. This file type may be used for ground based or aerial based LiDAR pint cloud information.

The FD file type may be used for multiple purposes.



- Most commonly, the FD file type is used to create a combined terrain model from other sources. In this case, the other files are referenced to the FD file. The **Create Complex Terrain Model** command is used to generate the combined terrain model
- The FD file type may also be used to create a terrain model from the Survey Data using the **Create Terrain Model from Graphical Filter** command. It is possible the WorkSet will contain multiple FD design files.

Care must be taken to ensure that the design personnel understand which design file, FB or FD, contains the terrain model used for the design process.



Exercise 1: Creating a Terrain Model from the Survey Field Book

This exercise will cover the process to create a terrain model from the topo survey information that was processed in section 300 of this training guide.

Terrain models are typically generated in the Field Book (FB) design file. In some cases, it may be desirable to create the terrain model in a separate DGN file (FD) depending on the size of the project and the needs of the design personnel.

If the terrain is created in the Field Book (FB) design file, ***editing the terrain by deactivating the survey processing rules is no longer recommended.*** An alternate method will be demonstrated in this manual.

If the terrain is to be created in a separate FD design file, the process is summarized below:

1. Create a 3D Terrain Model (FD) design file
2. Attach the Field Book (FB) design file as a reference
3. Use the **Create Terrain from Graphical Filters** command to generate a terrain model from the survey data in the Terrain Model (FD) design file.

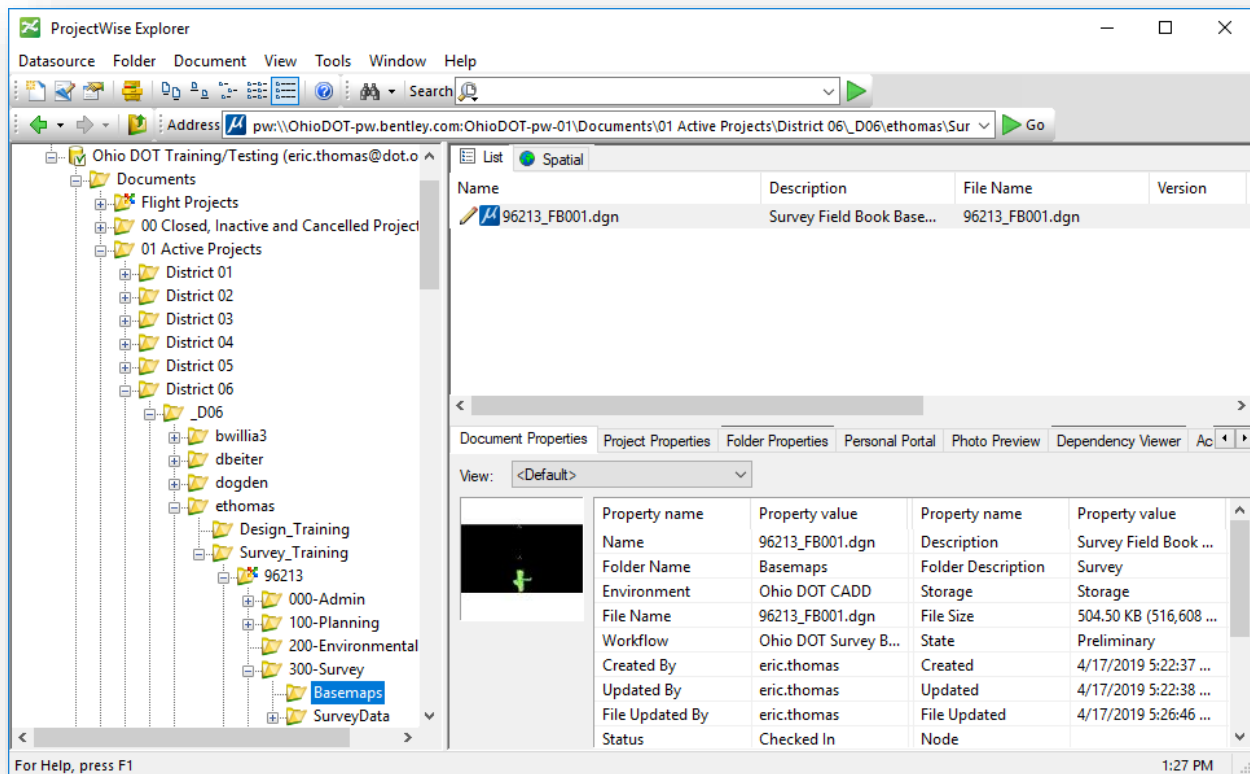
Note: At this time, we are not documenting this process since it is not typically used by ODOT's survey personnel to generate the terrain model. There are graphical filters in the OHDOT WorkSpace intended to be used for his process, however with the current release of the software graphical filters based on Survey linear features and point features are not working. A defect has been logged with Bentley.

Take the following steps to create a terrain model from the survey information that was processed in the previous chapter:

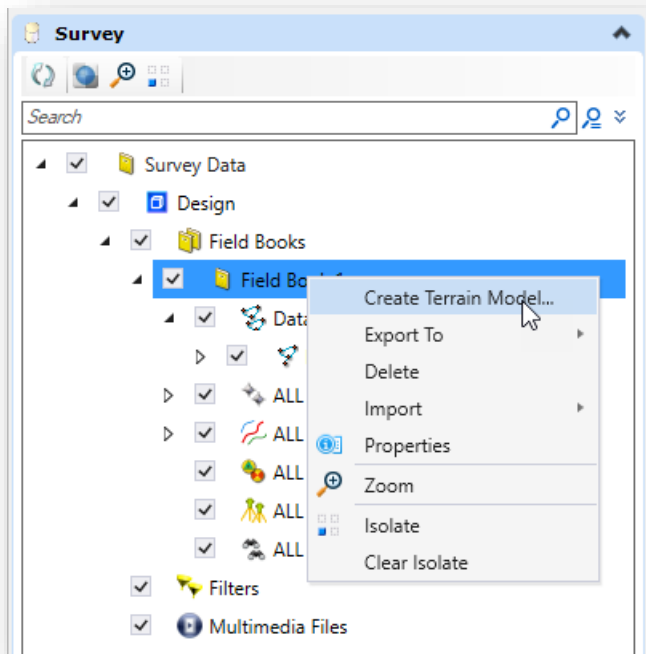
- Open **ProjectWise Explorer**



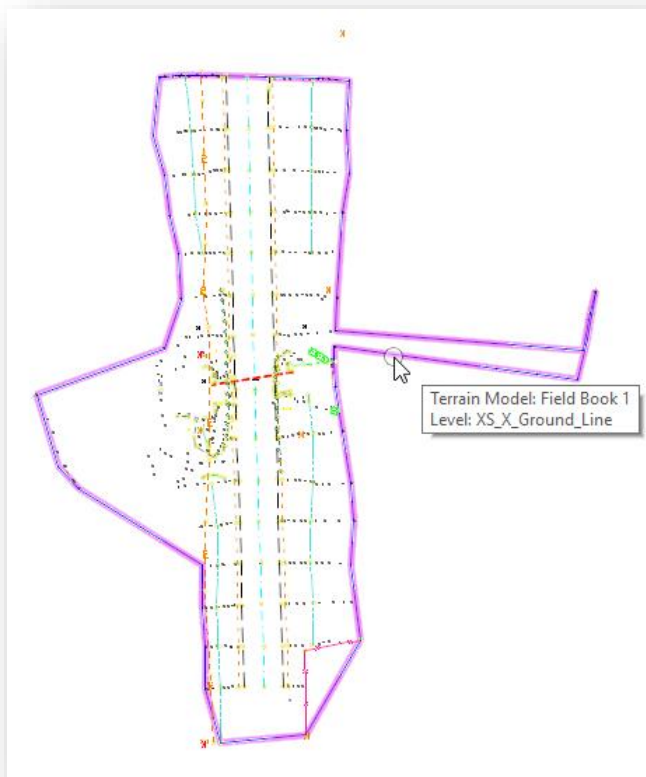
- Open the file shown below using your home District and your user name.



- Open the **Survey** tab in *Project Explorer*
- Right-click on the **Field Book** and choose the **Create Terrain Model...** option as shown below



The terrain model is created in the active file as shown below.



Notes:

The terrain model is named according to the name of the Field Book. The name can be edited in the terrain model properties dialog

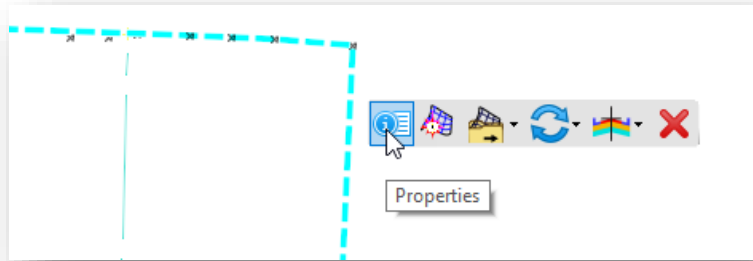
If there are multiple datasets contained in one field book, all of the datasets are combined to make one terrain model

Point and linear features are used to create the terrain model according to the Terrain Model Attribute for the field code.



Terrain Model Properties

Use the MicroStation *Element Selection* tool to select a terrain model in the design file. Allow the cursor to rest on the terrain model element for a few seconds to reveal the pop-up menu shown below.



The following commands are available:

- Properties
- Set As Active Terrain Model
- Export Terrain Model
- Update From Source
- Templates
- Delete

See the online help for more information on items not covered in this document.

The **Properties** options are shown at right.

Edge Method

In the OHDOT workspace, the default **Edge Method** has been set to **Max Triangle Length** with a **Length** value of 100. The following **Edge Method** options are available:

- None
- Slivers
- Max Triangle Length

The option to key in a **Length** value is only available when the **Edge Method** is set to **Max Triangle Length**.

Feature Name

The **Feature Name** is the name of the terrain model. This field may be edited as necessary.

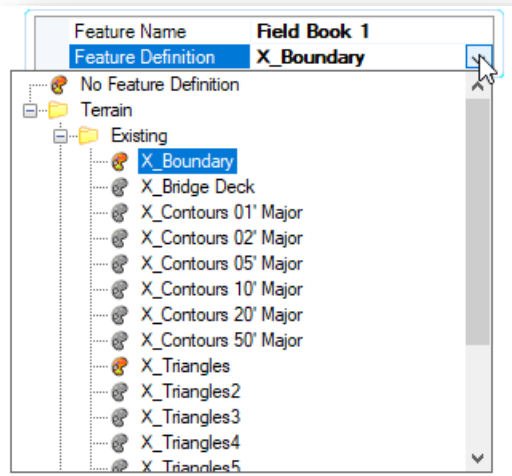
Terrain Model: Field Book	
Number of Points	633
Number of Point Featu	404
Number of Islands	0
Number of Voids	0
Number of Features	424
Number of Contours	0
Number of Breaklines	19
Number of Triangles	1,223
Edge Method	Max Edge Length
Length	100.000'
Major Contours	Off
Minor Contours	Off
Triangles	Off
Spots	Off
Flow Arrows	Off
Low Points	Off
High Points	Off
Breaklines	Off
Boundary	Off
Imported Contours	Off
Islands	Off
Holes	Off
Voids	Off
Feature Spots	Off
Feature Name	Field Book 1
Feature Definition	X_Boundary



Feature Definition

The **Feature Definition** item is used to select the surface feature that will be used to control the terrain model display. Surface feature definitions are defined in **OHDOT_Feature_Definitions.dgnlib**. When using the OHDOT workspace, the surface feature **X_Boundary** is the default. This feature has been configured to display the terrain model boundary.

Various feature definitions have been configured for ODOT projects. The Feature Definition is selected from the drop-down list as show below.



- Change the **Length** parameter for the **Edge Method** to a value of 25.
 - Note the changes to the terrain boundary. Are there triangles missing that you would like to see included in the terrain model?
 - Try changing to a value of 50.
- Change the feature definition to use one of the options that draws contour lines. Which contour interval works best for this dataset?
- Change back to the X_Boundary feature definition when complete.

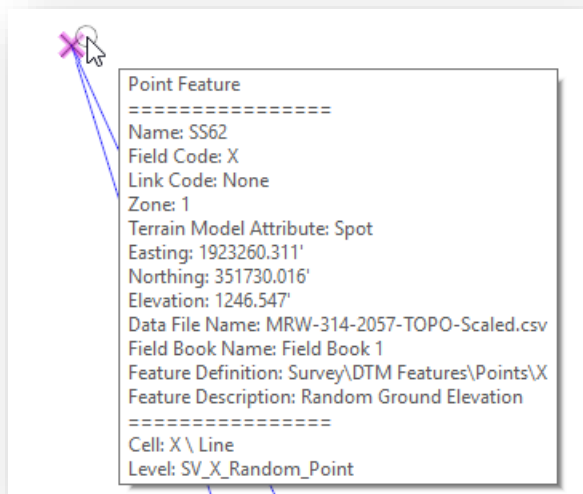


Terrain Model Editing

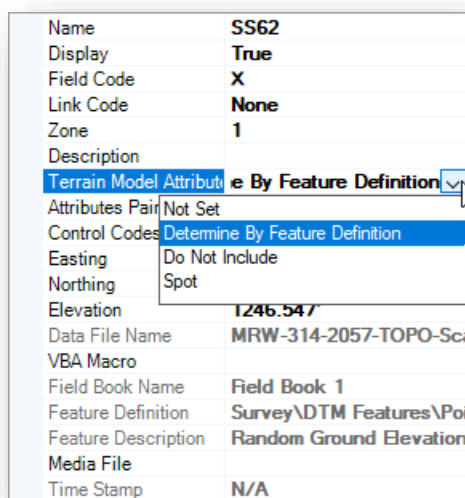
The terrain model is dynamically linked to the survey points and lines. Edits made to the points and linear features that comprise the terrain model are immediately and dynamically reflected in the terrain model.

On the left and right side of the terrain model there are survey points included in the terrain that are located far enough away from the main portion of the survey that probably should not be included in the terrain. These points can be removed from the terrain by changing the Terrain Model Attribute value.

- From the **Survey Workflow Home** tab, select the MicroStation **Element Selection** tool. Floating the cursor over a point or a linear feature will reveal the survey attributes as shown below



- Select the point and allow the cursor to rest until the pop-up menu appears. Select the **Properties** icon

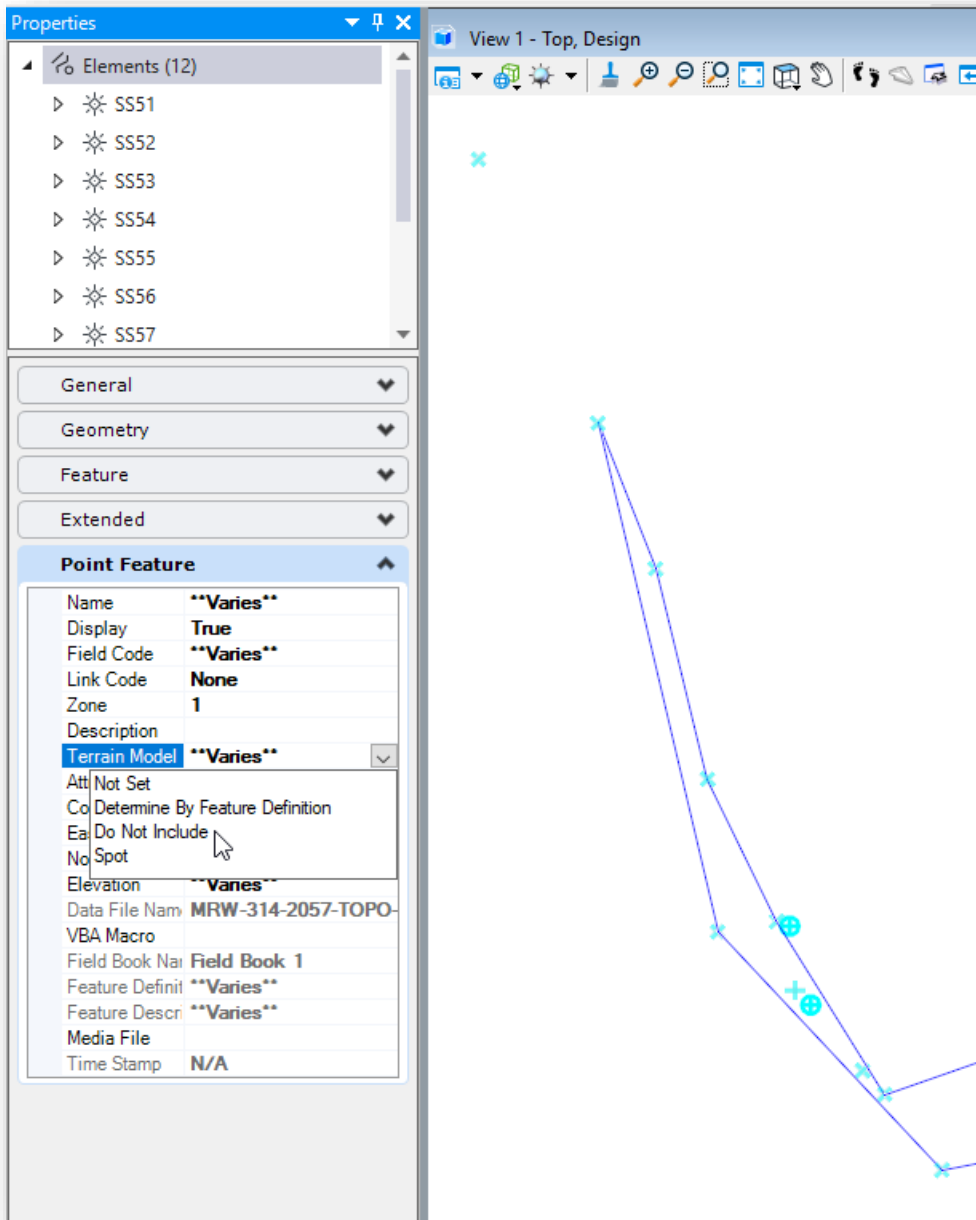


- Change the **Terrain Model Attribute** value to **Do Not Include**. The point is immediately removed from the terrain model



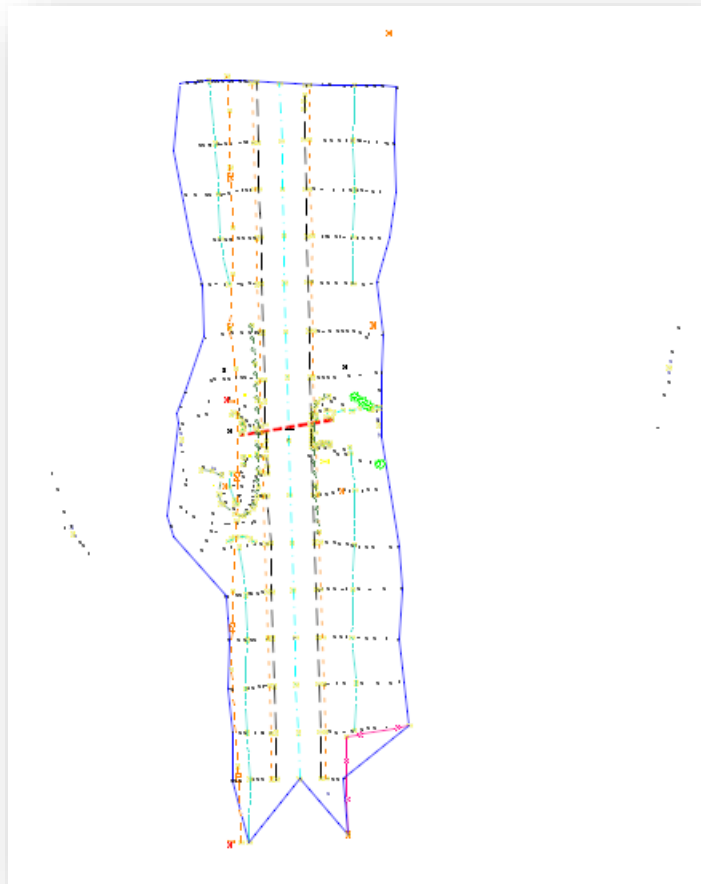
Multiple elements can be removed from the terrain model by selecting the elements, and then changing the **Terrain Model Attribute** in the *Properties* dialog

- Use the **Element Selection** tool to select all the points to the left of the terrain model
- In the *Properties* dialog, change the **Terrain Model Attribute** value for the selected elements to **Do Not Include**. All the selected elements are immediately removed from the terrain model





- Repeat this process for the points on the right side of the terrain model. The edited terrain model should look like the example below

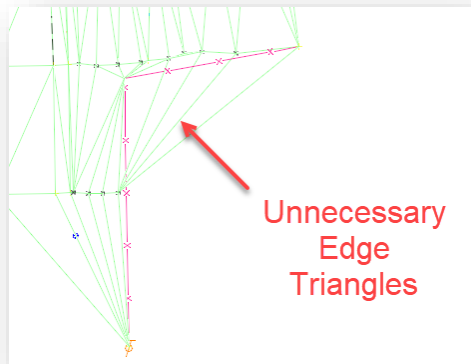




Removing Edge Triangles

After survey processing and editing is complete, it may be necessary to delete some of the terrain model edge triangles that are formed in areas along the boundary of the terrain.

The example below shows several triangles that are formed across an area where no survey data was collected



Setting the terrain model's **Edge Method** to **Max Triangle Length** with a shorter value can eliminate some of these triangles, however it may still be desirable to manually remove some of these triangles.

Terrain models are “ruled” by the survey points and chains. Changes made to the survey points and chains are dynamically reflected in the terrain model.

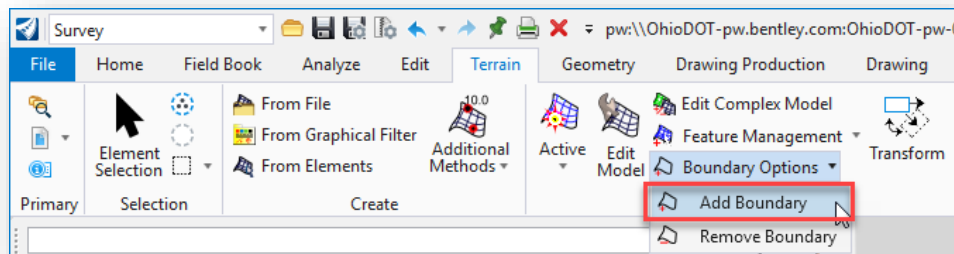
Previously, we had recommended deactivating the **Survey Processing Rules** to allow editing the terrain model directly. *That workflow is no longer recommended.*

Deactivating the processing rules means that you cannot add any additional survey information to the design file without reactivating the processing rules. For example, if you are returning to an area previously surveyed to collect additional data, and that data will be processed as a new dataset in the same design file that has had the survey processing rules deactivated, the linework for any linear features will not be drawn since this function required that the survey processing rules are activated to generate the linework.

The recommended procedure to remove edge triangles is as follows:

- Add a **Ruled Boundary** to the terrain. This is a physical element that can be edited with the element manipulation tools.
- Use the element manipulation tools, such as Inset Vertex, or Remove Vertex, to redefine the boundary and eliminate unnecessary edge triangles.

The **Add Boundary** command is selected from **Terrain > Edit > Boundary Options** as shown below.





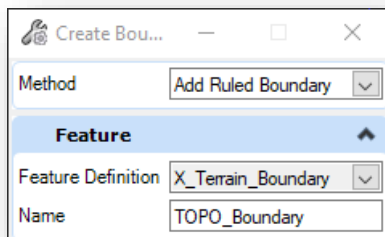
The tool has three methods:

- **Extract Graphic** - extracts the current boundary for the triangulation to an editable 3D linestring.
- **Add Boundary** - extracts the current boundary for the triangulation as an explicit boundary in the terrain element - ie locked boundary.
- **Add Ruled Boundary** - extracts the current boundary for the current triangulation to an editable ruled draped boundary element. Deleting this element will remove the boundary from the terrain.

Use the **Add Ruled Boundary** method to add a fixed boundary to the selected terrain model. This boundary element is ruled to the terrain. Edits to the boundary are automatically applied to the terrain model.

Take the following steps to create a ruled terrain boundary

- Choose the **Add Boundary** command
- Set the **Method** to **Add Ruled Boundary**
- Choose the **Linear > Survey Office Use > Terrain Editing > X_Terrain_Boundary** feature definition as shown at right
- Enter a **Name** for the boundary element

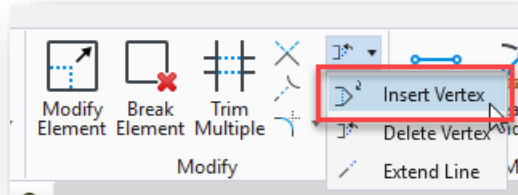


- Select the terrain model to add the boundary

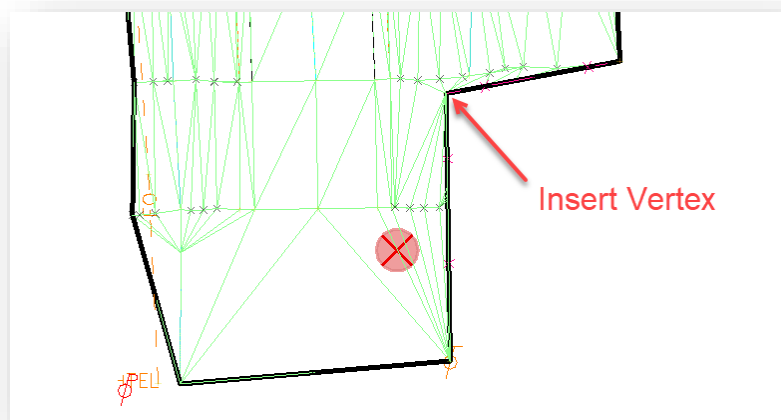


After adding the ruled boundary, unnecessary edge triangles can be eliminated by editing the boundary element.

- Change the triangle model feature definition to **X_Triangles**
- From the **Drawing** tab, select the **Modify > Insert Vertex** command



- Inset a vertex in the terrain boundary to eliminate unnecessary triangles in the lower right corner of the triangle model, as shown below.



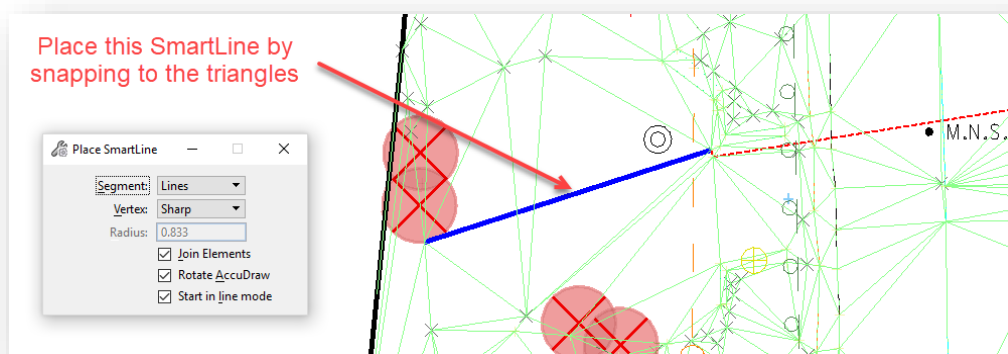
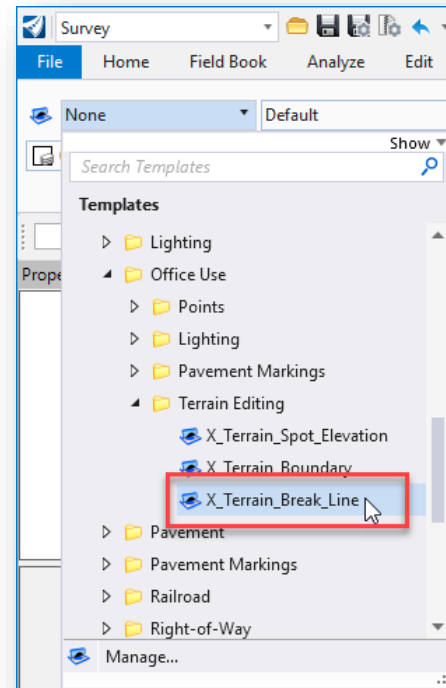


Swap Line

Another common triangle model edit is swapping triangle lines. This can be accomplished by graphically drawing a line in the file representing the new triangle leg, and then adding the line to the terrain as a break line.

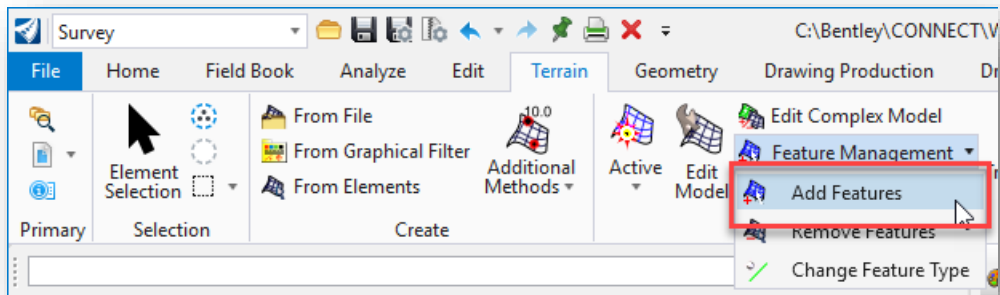
Take the following steps to add a break line to flip the triangulation lines:

- Select the **Survey > Office Use > Terrain Editing > X_Terrain_Break_Line** element template as shown at right. The element template defines the active symbology settings.
- Draw a SmartLine as shown below
- Be sure to snap to the triangle vertices, or the Survey points so the elevation is defined for the SmartLine element

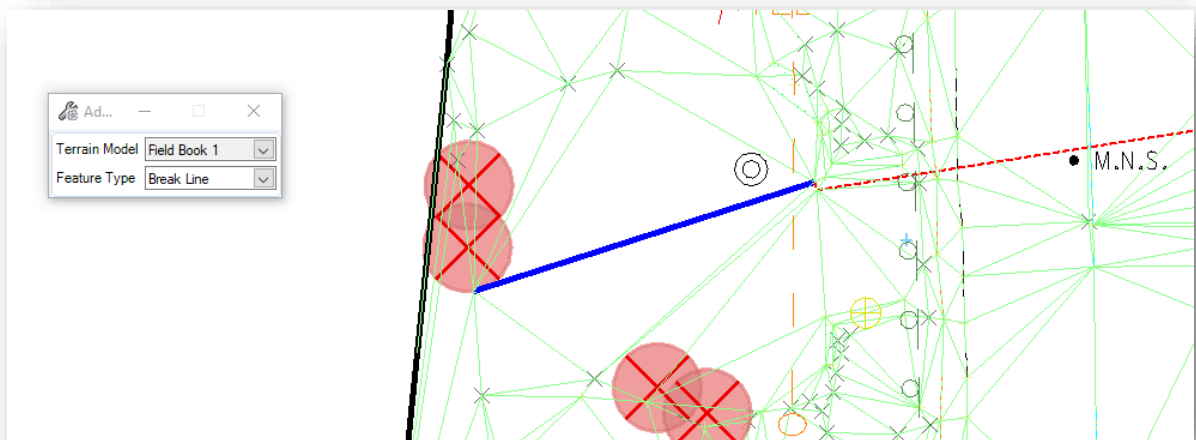




- Select the **Add Features** command from the **Terrain > Edit** group.



- Add the SmartLine as a **Break Line** to the terrain. The triangles are swapped as shown below.



Note: The triangles can be reverted by deleting the SmartLine element.



Exercise 2: Terrain Models from Point Cloud Data

LiDAR data in LAS format from terrestrial scans or aerial sources is often incorporated with traditional ground survey information to create a combined terrain model for the project. This information can be imported directly from the LAS file to create the terrain model, or optionally imported as a Point Cloud in POD format in order to visualize the data in the design file. The POD file can be used to generate a terrain model for the point cloud. The terrain model can then be merged with the ground survey terrain information.

When creating complex terrain models, the best practice is to use a separate design file for each data source rather than importing the data into the FB design file. This eliminates confusion over which terrain model should be used that can occur when there are multiple terrain models contained in one design file.

In this exercise, we will generate two terrain models. The first is from a ground based terrestrial scan of the pavement surface in LAS format. The second is from aerial mapping in XYZ format. Each terrain model will be created in its own design file

Part 1: Creating a Terrain Model from LAS Data

The process to import LAS data into the Point Cloud (PC) design file is summarized below:

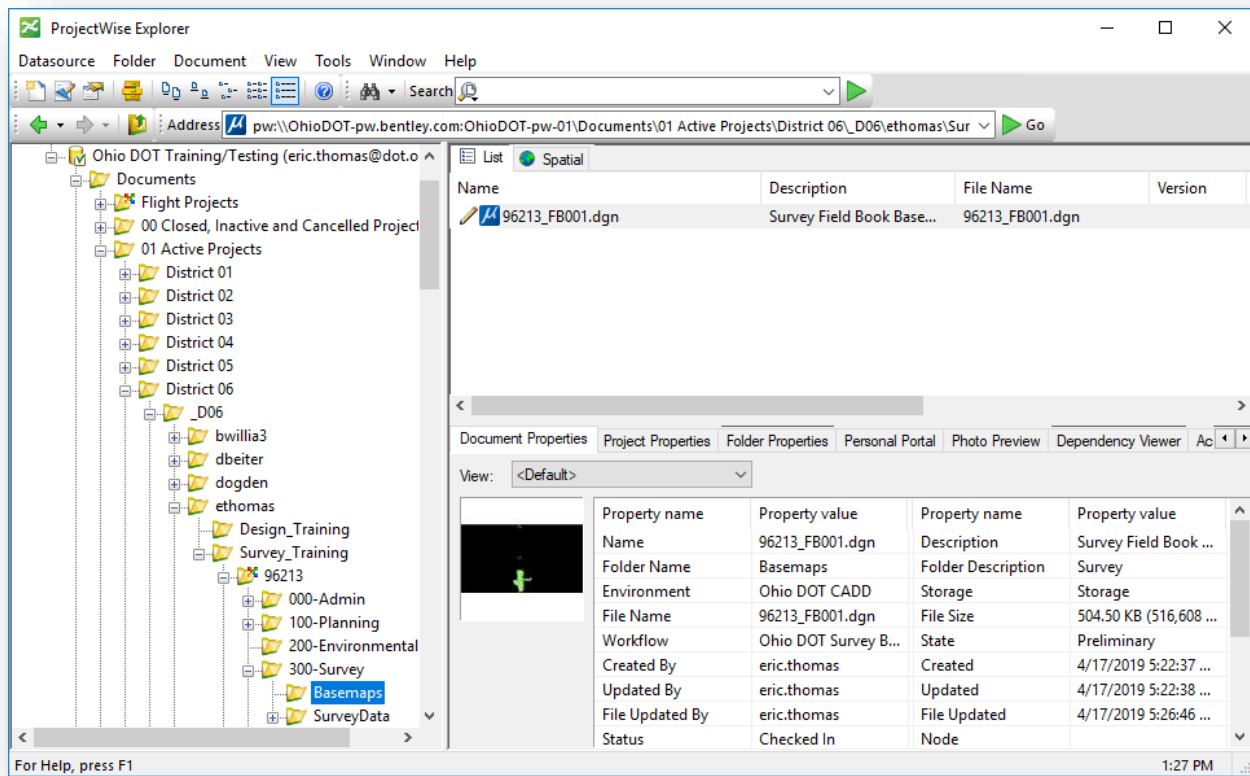
1. Create a 3D Point cloud (PC) design file
2. Optional: Use the Point Cloud tools to attach the LAS file and save a POD file
3. Use the **Create Terrain From Point Cloud** tool to create the terrain model

Take the following steps to import the point cloud information:

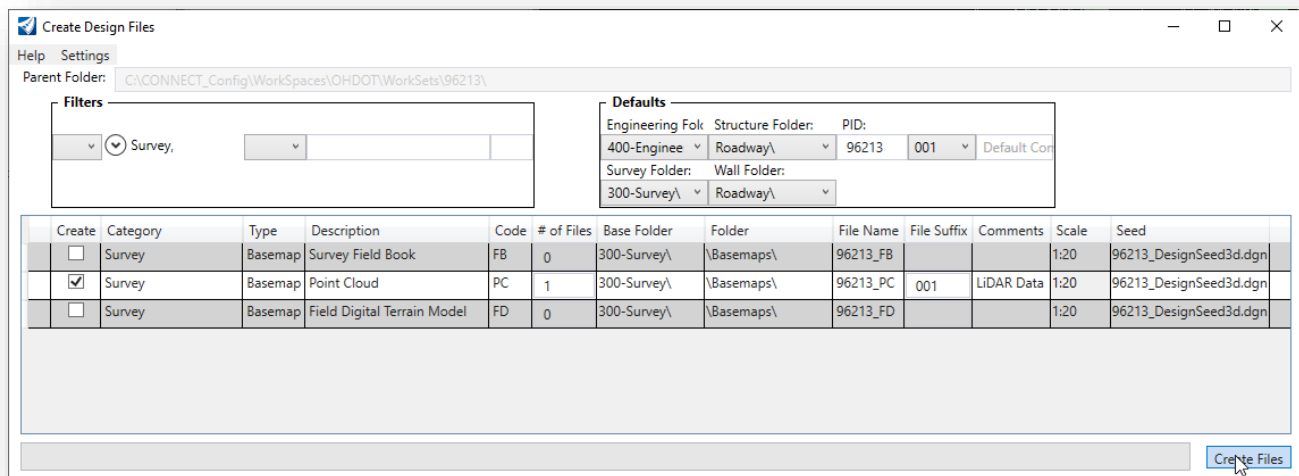
- Open **ProjectWise Explorer**



- Open the Field Book design file (FB) as shown below using your home District and your user name.



- Create a Point Cloud design file for the LiDAR data using the **Ohio DOT > Apps > OHDOT Create Design Files** application



- Open the newly created PC design file

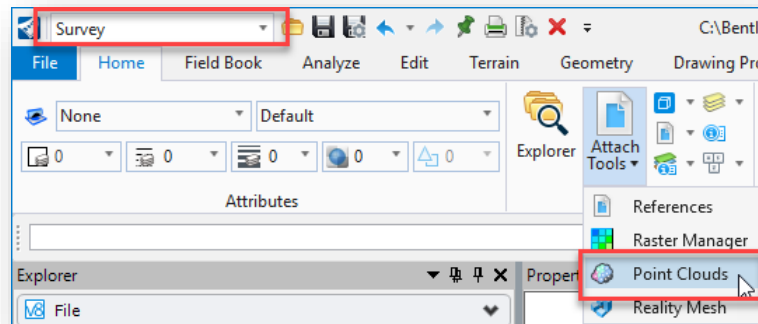


Optional: Create a POD File

Bentley products use the POD file format for point cloud data. A POD file is not required to create the terrain model from the point cloud data, but can be useful if you want to visualize the point cloud data in ORD.

Take the following steps create the POD file:

- From the **Survey** workflow **Home** tab, select **Attach Tools > Point Clouds** as show below

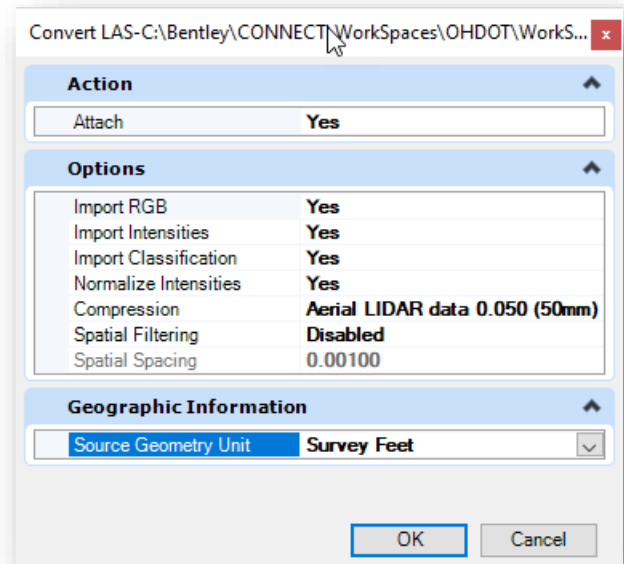


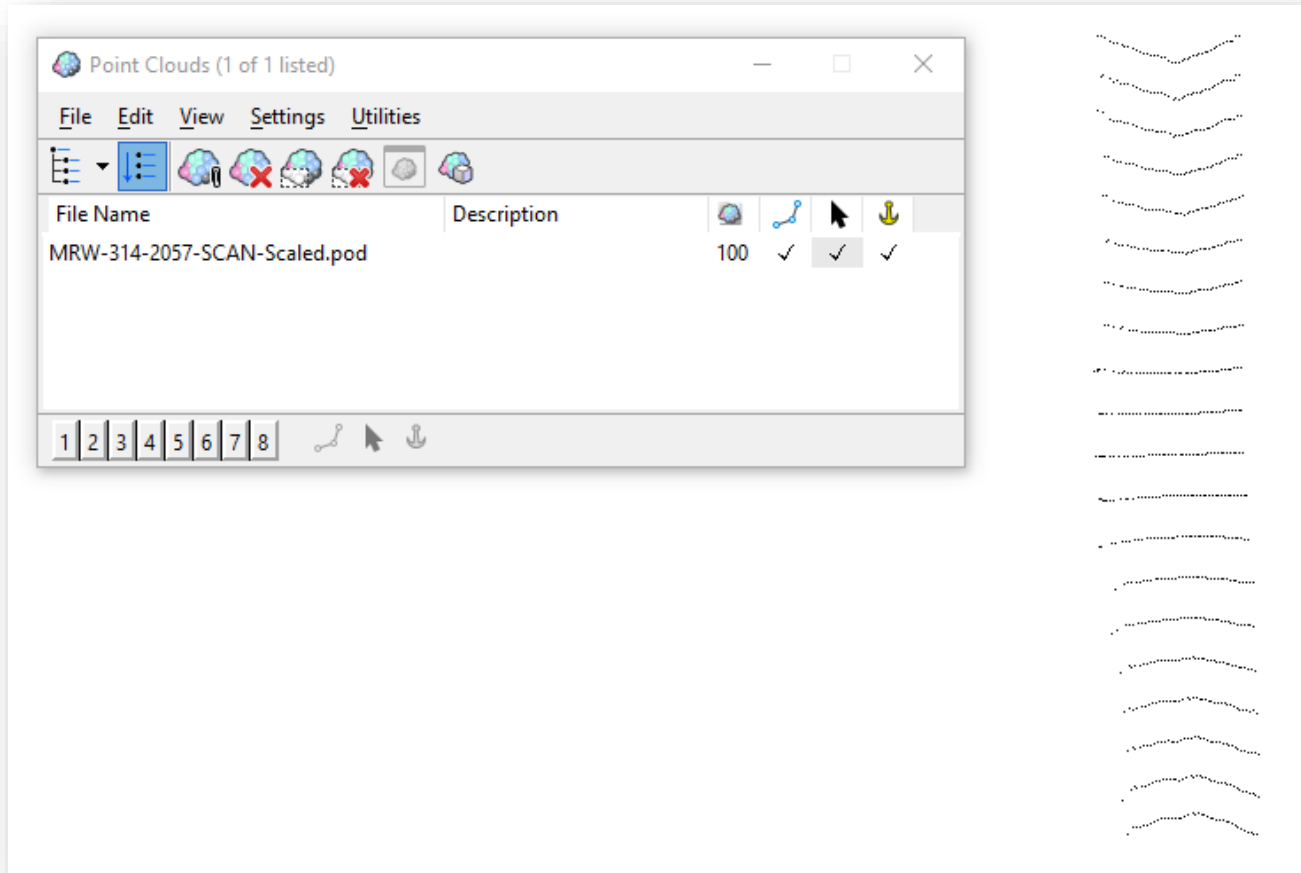
- From the **Point Clouds** dialog, select **File > Attach**.
 - Change the Filter to **LAS (*.las)** to attach the following file:
300-Survey\SurveyData\FieldData\MRW-314-2057-SCAN-Scaled.las

- The **Convert LAS** dialog is opened. Change the **Source Geometry Unit** to **Survey Feet**. Select **OK** to initiate the process

- The **Specify new pod file** dialog is opened. Save the new POD file to the **300-Survey\SurveyData\FieldData** folder.

The point cloud is created in the file and displayed as show below.



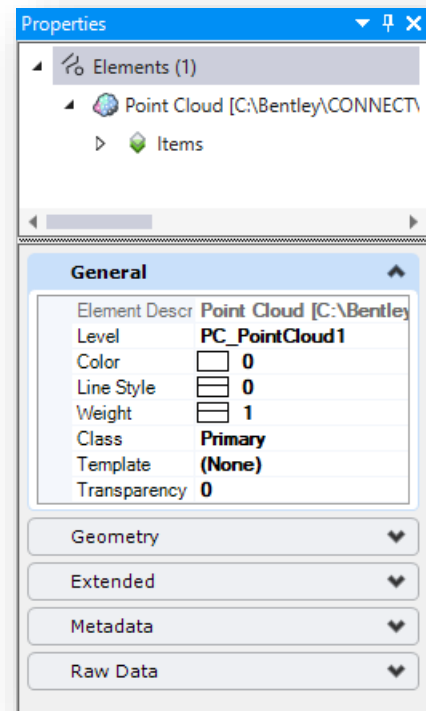


- Use the **Element Selection** tool to select the point cloud in the design file. The properties for the point cloud are displayed in the **Properties** dialog as shown below.



Change the **Level** for the point cloud to **PC_PointCloud1** as shown at right

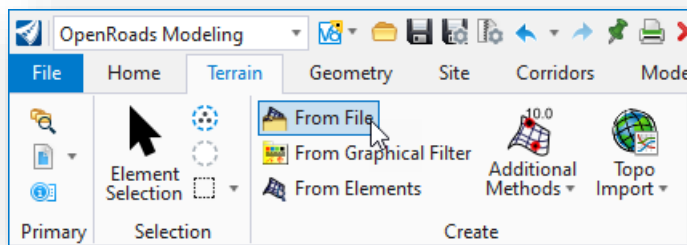
- If desired, change the **Weight** to **1**. This will display the individual points a little bolder in the design file



Create the Terrain Model

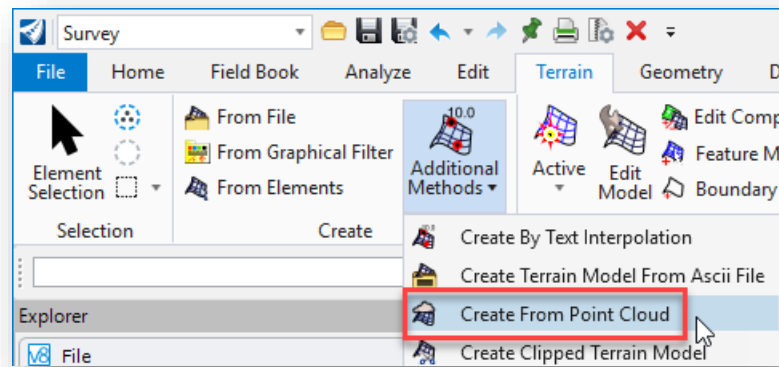
The terrain model can be generated from the POD file, or directly from the LAS file.

To create a terrain model directly from the LAS file, from the **Survey** workflow **Terrain** tab, select the **From File** option as shown below. Choose the LAS file type from the **Select Files to Import** dialog.

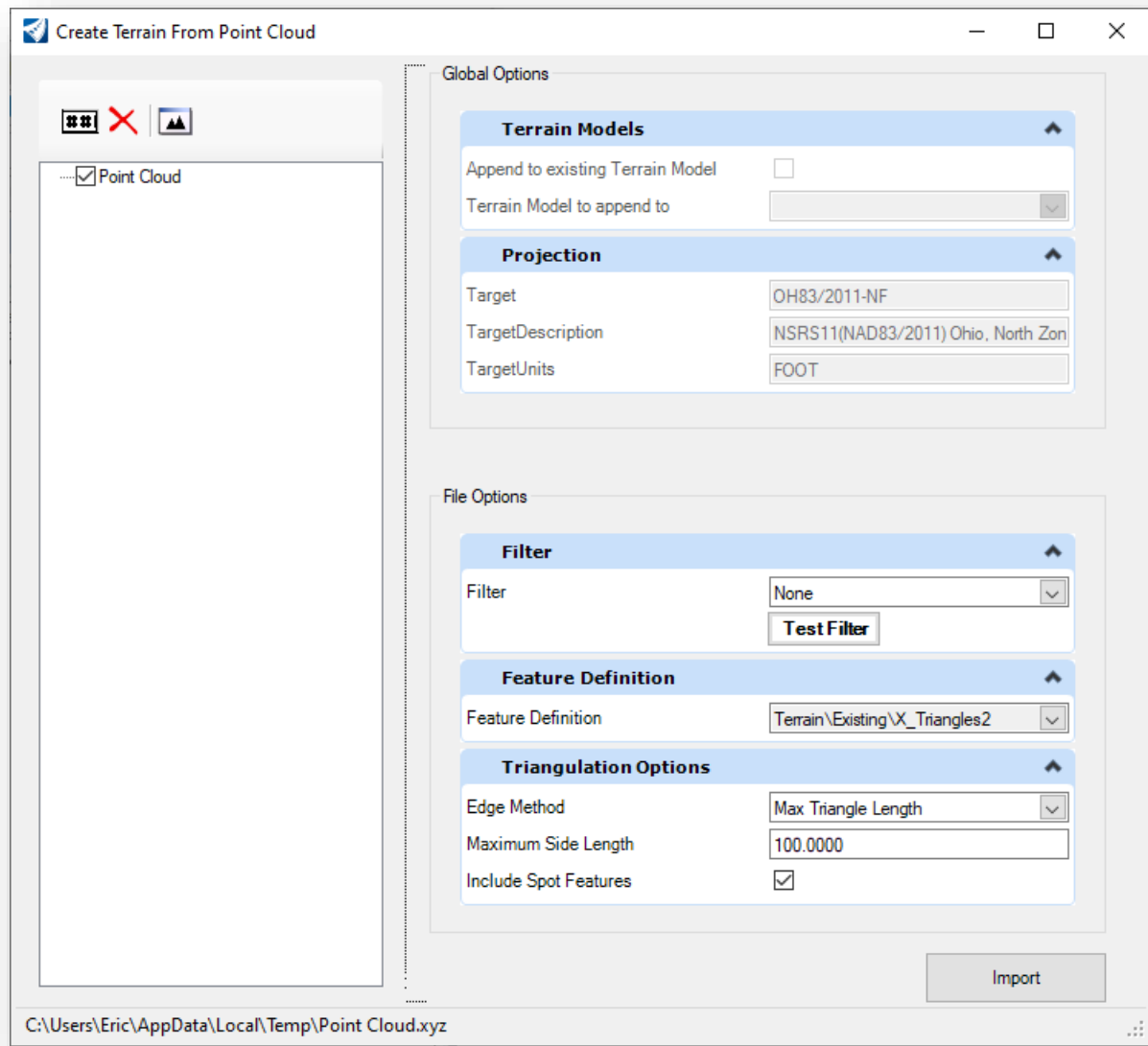


In this exercise, we will create the terrain model from the POD file. Take the following steps to generate a terrain model from the point cloud POD file:

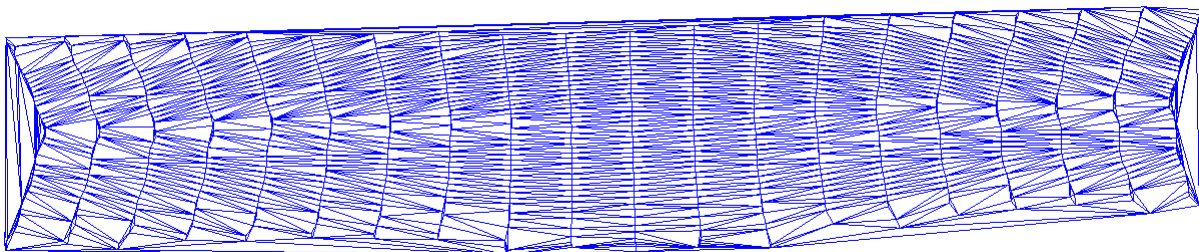
- From the **Survey** workflow **Terrain** tab, select the **Additional Methods > Create From Point Cloud** command



- Create the terrain using the settings shown below. The **Feature Definition** is set to **Terrain > Existing > X_Triangles2** in this example



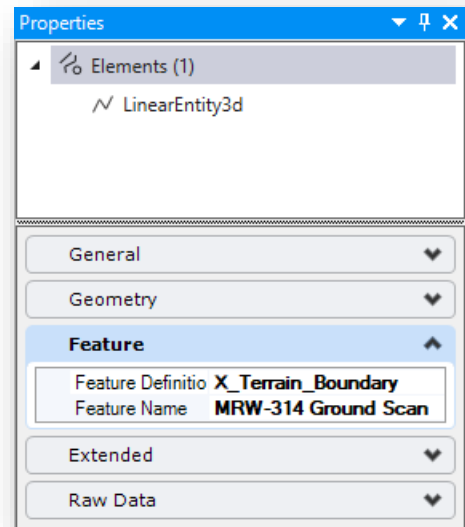
The terrain is created as shown below. **Note:** The image has been rotated 90 degrees to show the terrain horizontally on the page.





Take the following steps to rename the terrain model:

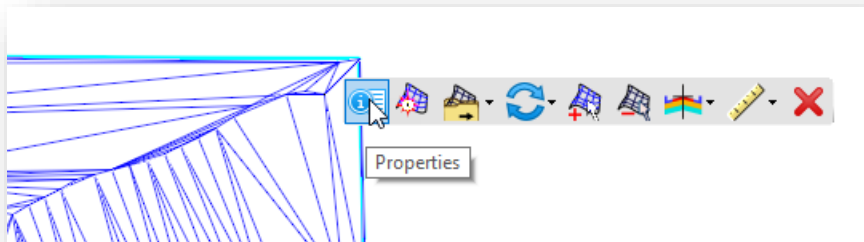
- Select the terrain model with the MicroStation **Element Selection** tool
- In the **Properties** dialog, change the **Feature Name** parameter to **MRW-314 Ground Scan** as shown at right



In some cases, it may be desirable to define a boundary for the terrain to eliminate triangles that span across areas where no data was collected. In the example above, the triangles formed at each end of the terrain model are crossing across the pavement surface and do not accurately represent the cross slope of the pavement. The best way to eliminate these triangles is to define a boundary for the terrain model.

Take the following steps to generate a boundary for the terrain:

- Review the terrain model **Properties** to refine the **Edge Method** parameter. Use the **Element Selection** tool to select the terrain model. Let the cursor rest in place for a second until the pop-up menu appears. Select the **Properties** option



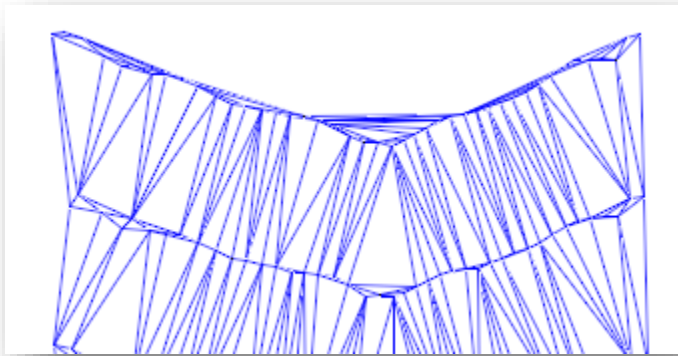
A portion of the terrain model properties dialog is shown at right.

- Set the **Edge Method** to **Max Edge Length**. Experiment with different values for the Length. Be sure to review the entire terrain model to see how the value is applied to the surface. Values that are too short will result in eliminating some triangles that you may wish to keep.

Terrain Model: Point Cloud	
Name	
Number of Points	830
Number of Point Featu	1
Number of Islands	0
Number of Voids	0
Number of Features	1
Number of Contours	0
Number of Breaklines	0
Number of Triangles	1,622
Edge Method	Max Edge Length
Length	15.000'

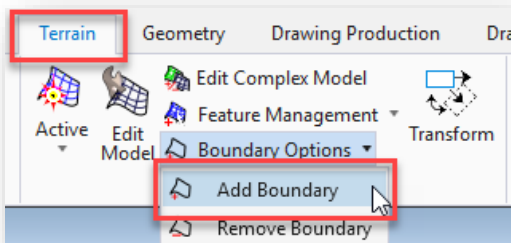


- With the **Edge Method** set, the northern end of the terrain should look like the example below

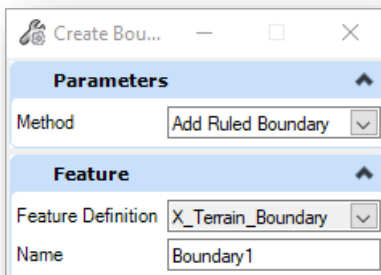


Note that there are some triangles formed that still cross over the pavement crown. A boundary element can be defined to further constrain the formation of triangles as described below

- From the **Survey** workflow's **Terrain** tab, select the **Add Boundary** command



- Add a boundary to the terrain using the following settings:



Set the **Method** parameter to use the **Add Ruled Boundary** option.

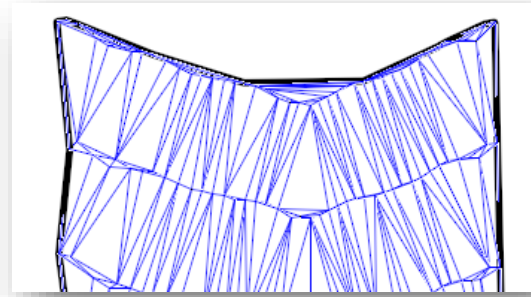
Use the following **Feature Definition**:

Linear > Survey Office Use > Terrain Editing > X_Terrain_Boundary

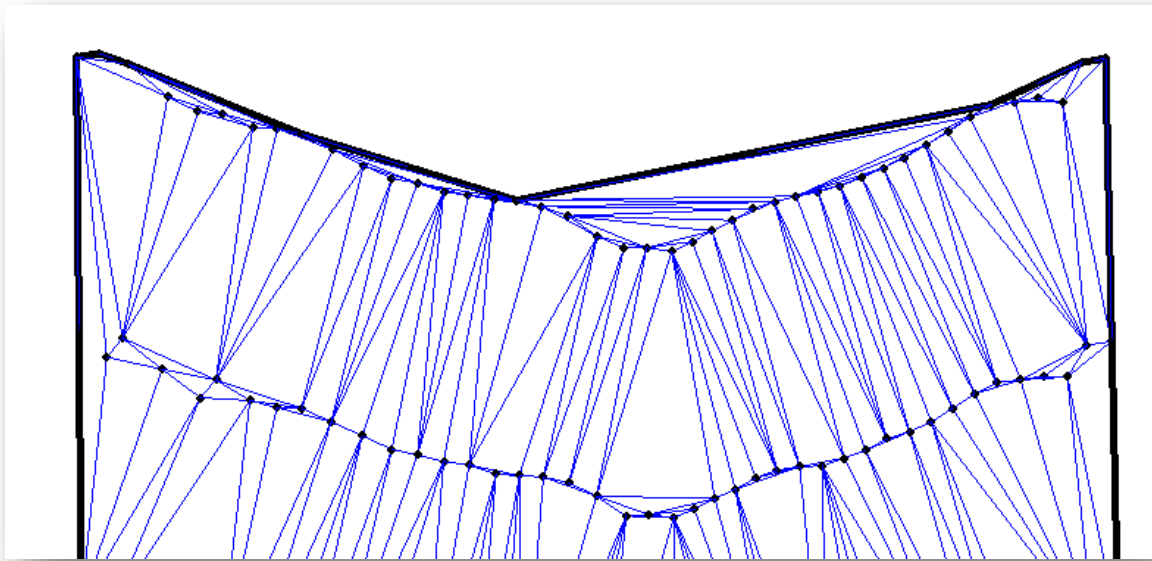
- The boundary element is drawn around the external limits of the terrain model. This element can be modified as necessary to constrain the triangles.



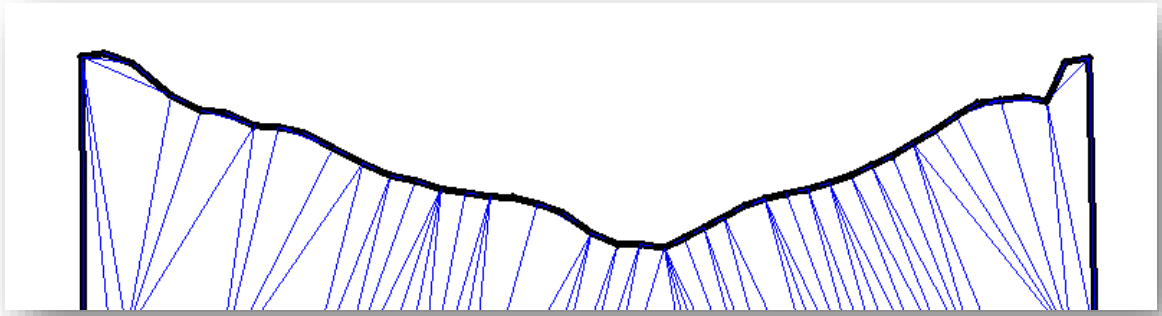
The triangles at both the north and south ends of the point cloud cross over the crown of the pavement. These triangles do not accurately represent the pavement slope and can be removed by establishing a new boundary. The northern end of the point cloud is shown at right.



- Use the **Survey > Drawing > Manipulate > Insert Vertex** command to add vertices to the boundary element. Before starting to insert vertices, it is useful to set the Point Cloud weight to a value of 5 to see the points while editing (Use the **Element Selection** tool to select the Point cloud element and change the **Weight** parameter to a value of 5).



Add vertices corresponding to the point locations. This will dynamically clip the terrain model to the boundary as edits are made. When complete, the terrain model boundary at the north end of the project should appear like the example as shown below



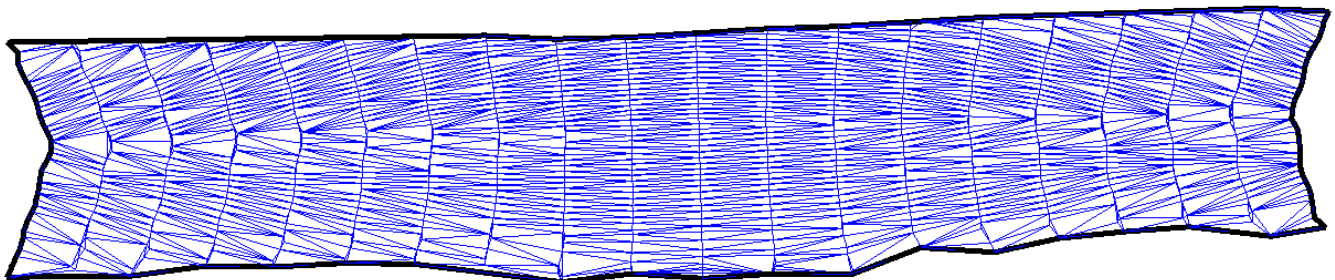
The **Delete Vertex** command also useful to edit the terrain boundary element.

- Repeat this process to define a new boundary for the southern end of the terrain
- Be sure to review the triangles along the edges of the terrain model. Are there areas on the sides that you would like to constrain to a new boundary?

When complete, the terrain model should appear similar to the example below.

Notes:

- The example below has been rotated 90 degrees for display on this page.
- The Point Cloud **Weight** parameter was changed to a value of 0 after editing.







Part 2: Creating a Terrain Model from Aerial Point Cloud Data

The process to create a terrain model from Aerial point clouds is like the above example to create a point cloud from a terrestrial scan with one notable exception:

- The aerial point cloud data is not in ground coordinates, nor does it have a sister file to define the coordinate system. It is necessary to set the design file to use the appropriate State Plane coordinate system for the point cloud data.

The process to import LAS data into the Point Cloud (PC) design file is summarized below:

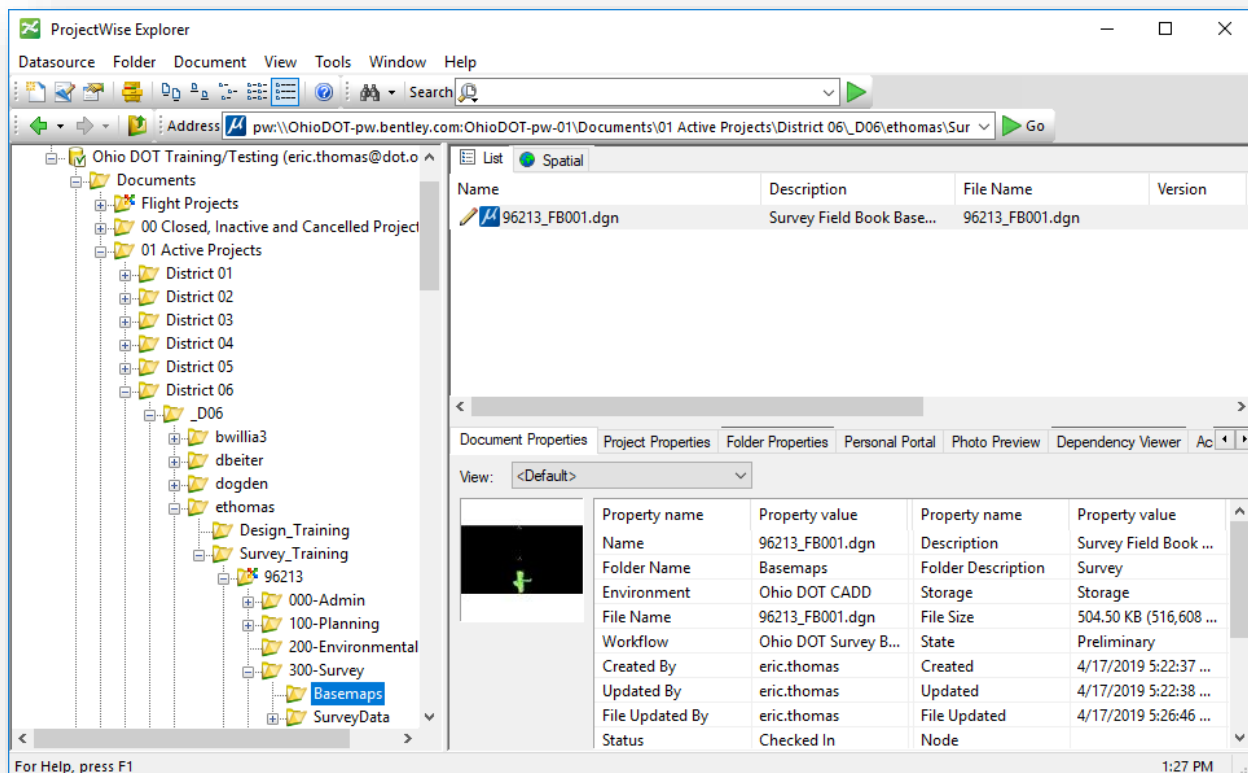
1. Create a 3D Point cloud (PC) design file
2. Optional: Use the Point Cloud tools to attach the LAS file and save a POD file
3. Use the **Create Terrain From Point Cloud** tool to create the terrain model

Take the following steps to create a terrain model for the aerial point cloud data:

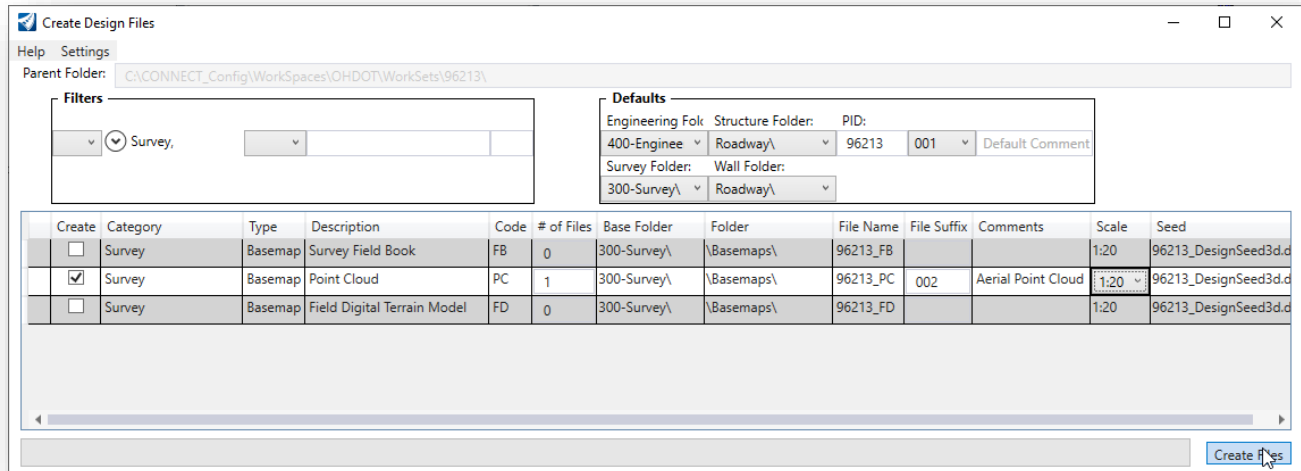
- Open **ProjectWise Explorer**



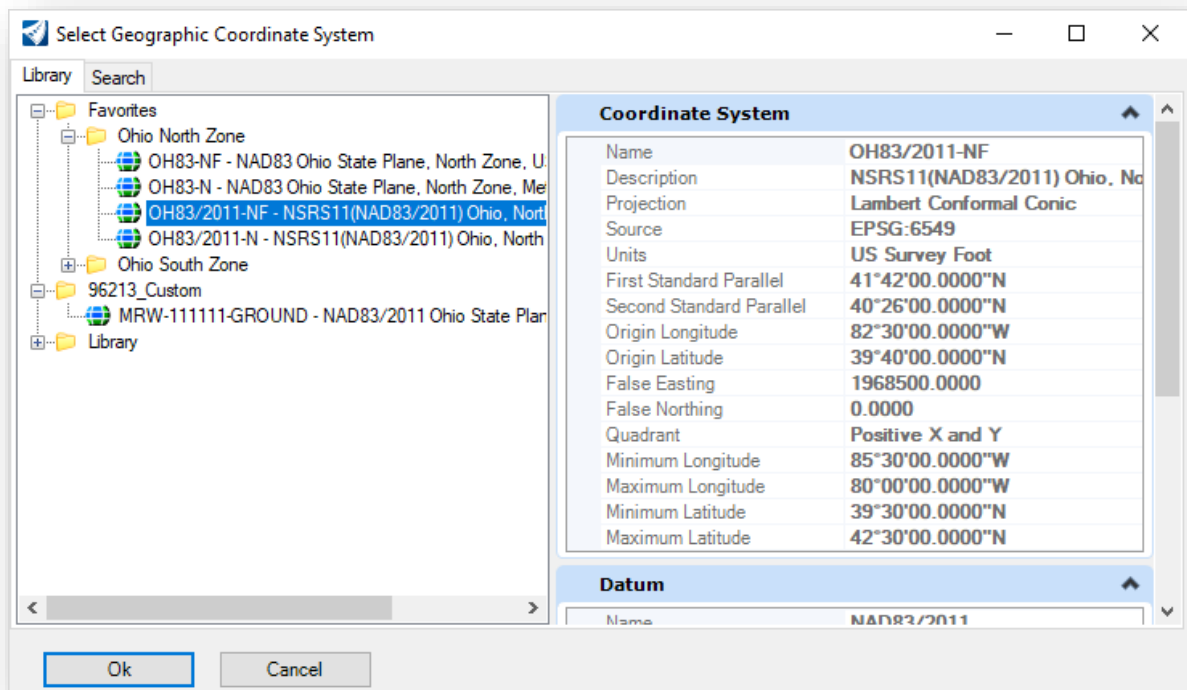
- Open the file shown below using your home District and your user name.



- Create a Point Cloud design file for the LiDAR data using the **Ohio DOT > Apps > OHDOT Create Design Files** application



- Open the new design file
- From the **Drawing** workflow, choose **Utilities > Geographic > Coordinate System**
- Change the point cloud to the appropriate coordinate system. Marrow County is in the **OH83/2011-NF** coordinate system



- Select the **OK** button to apply the coordinate system definition to the file

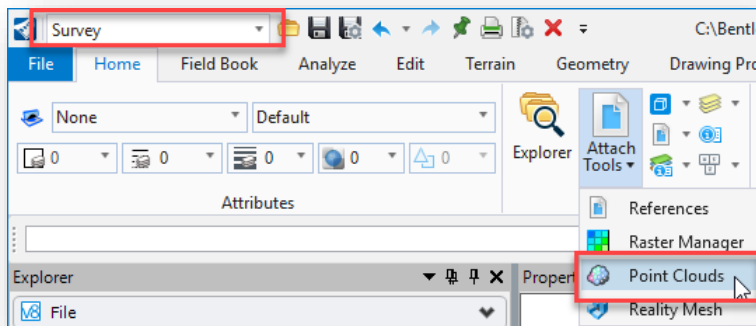


Optional: Create a POD File

Bentley products use the POD file format for point cloud data. A POD file is not required to create the terrain model from the point cloud data, but can be useful if you want to visualize the point cloud data in ORD.

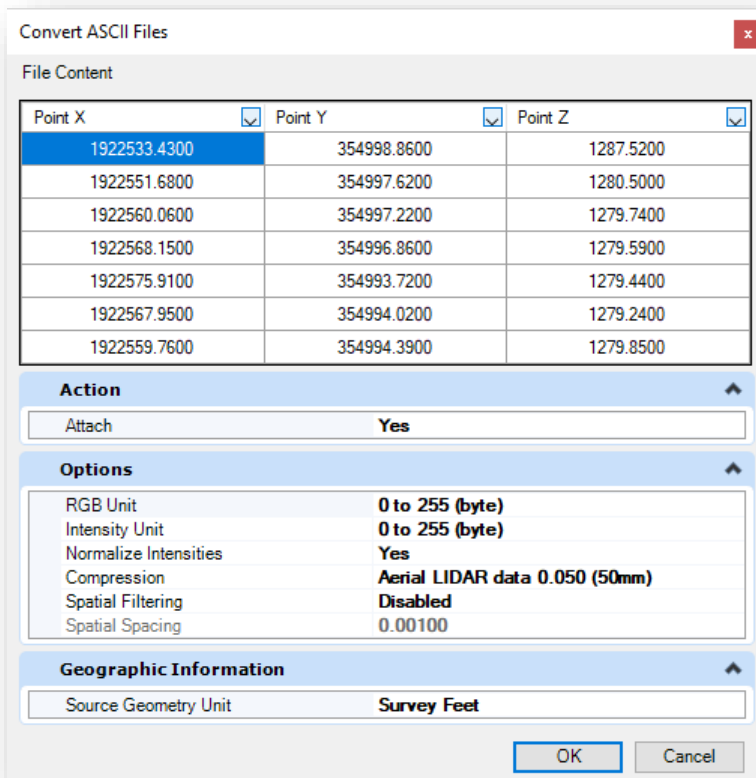
Take the following steps create the POD file:

- Select the **Attach Point Cloud** command



- Attach the following file: `\300-Survey\SurveyData\FieldData\n190350.xyz`

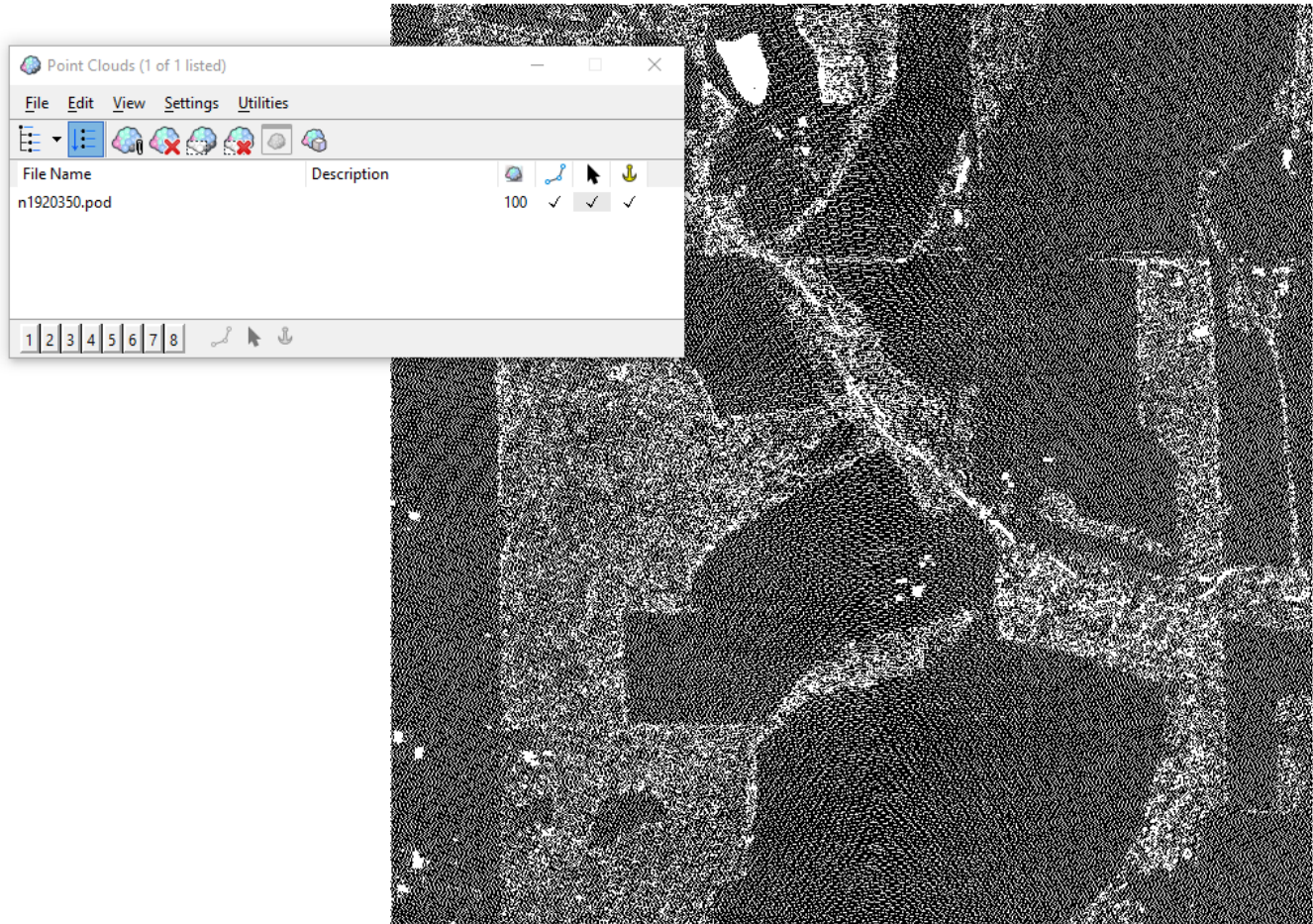
The **Convert ASCII Files** dialog is opened as shown below.





- Set the **Source Geometry Unit** appropriately for the source data. In this example, set the parameter to **Survey Feet**
- Select **OK** to convert the ASCII data to a point cloud. Save the point cloud file in the **\300-Survey\SurveyData\FieldData** folder

The point cloud data is displayed in the file like the example below.



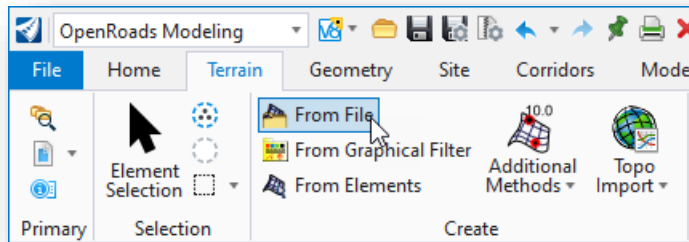
- After saving the POD file, use the MicroStation **Element Selection** tool to select the point cloud in the design file and change the level to **PC_PointCloud1**



Create the Terrain Model

The terrain model can be generated from the POD file, or directly from the LAS file.

To create a terrain model directly from the LAS file, from the **Survey** workflow **Terrain** tab, select the **From File** option as shown below. Choose the LAS file type from the **Select Files to Import** dialog.

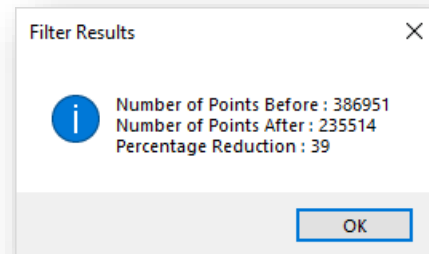
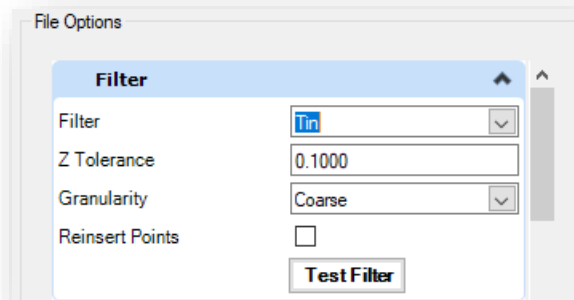


In this exercise, we will create the terrain model from the POD file.

Take the following steps to create the terrain model from the POD file:

- Use the **Survey > Terrain > Additional Methods > Create From Point Cloud** command to create a the terrain model for the point cloud using the **X_Triangles3** Feature Definition.

The **Filter** parameter may be used to thin the point cloud data. The **Test Filter** option will report the percentage of reduction as shown in the example below.

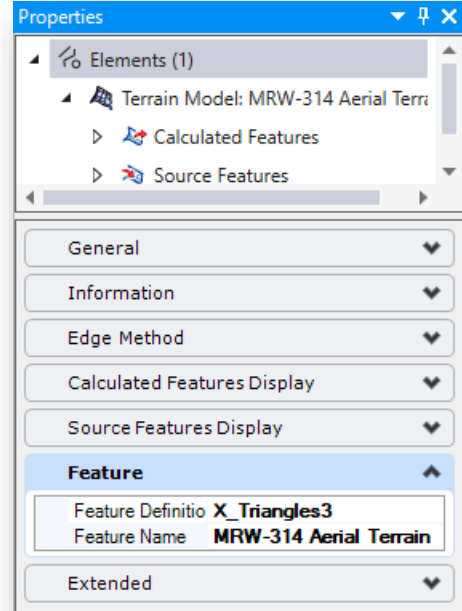


- Select the **Import** button to create the terrain model.



Take the following steps to rename the terrain model:

- Select the terrain model with the MicroStation **Element Selection** tool
- In the **Properties** dialog, change the **Feature Name** parameter to **MRW-314 Aerial Terrain** as shown at right



This completes Part 2 of the exercises.



Exercise 3: Create Complex Terrain Model

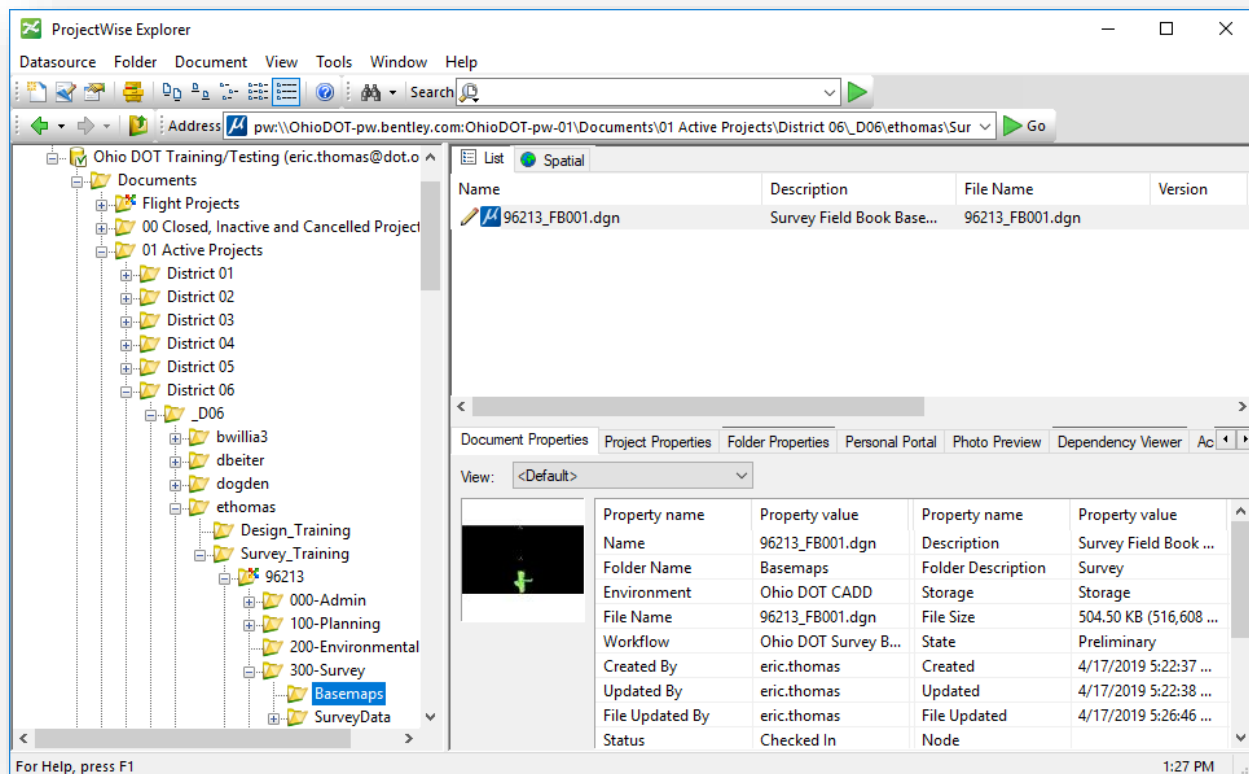
In this exercise we will create a terrain model by combining the ground survey terrain model with the terrestrial scan terrain model and an aerial terrain model.

Take the following steps to create a terrain model for the aerial point cloud data:

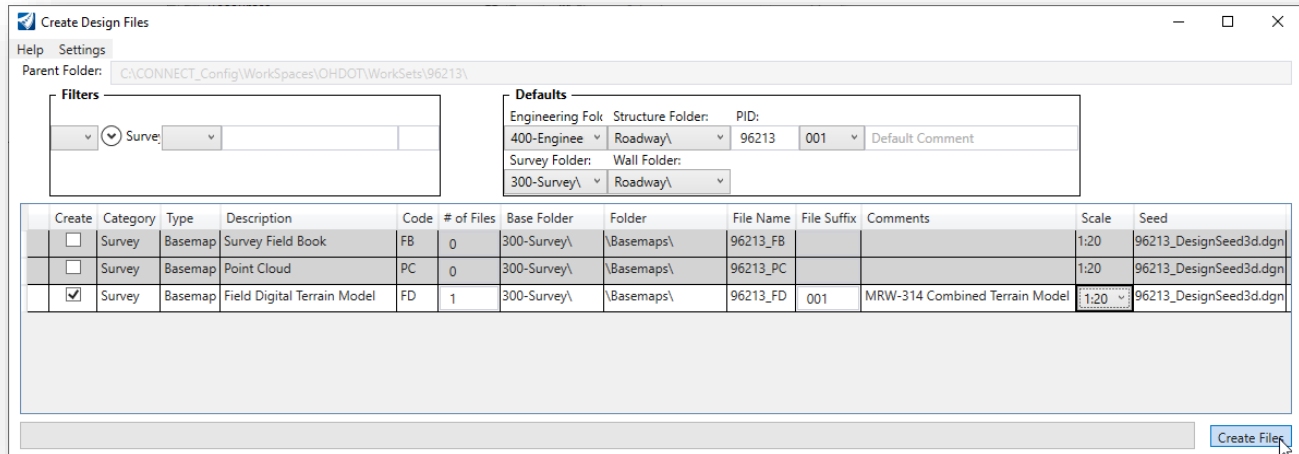
- Open **ProjectWise Explorer**



- Open the file shown below using your home District and your user name.

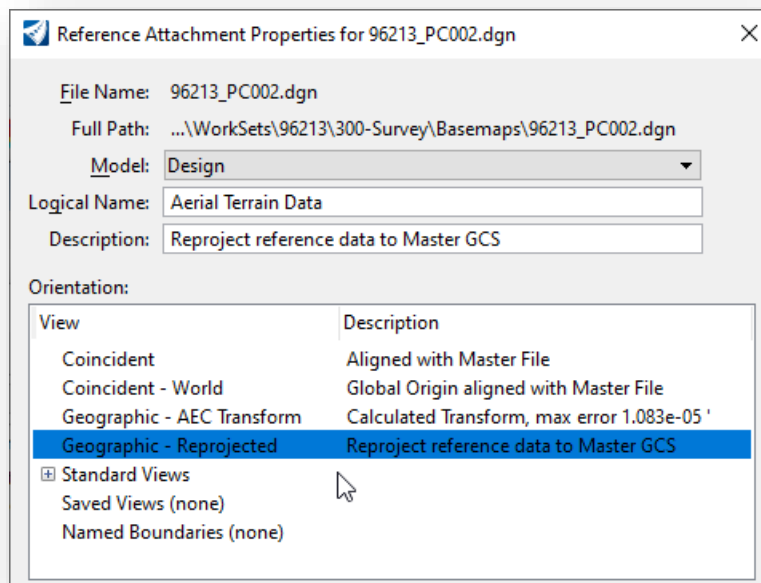


- Use the **OHDOT Create Design Files** application to create a Digital Terrain Model (FD) design file. This file is created in the 300-Survey\Basemaps folder



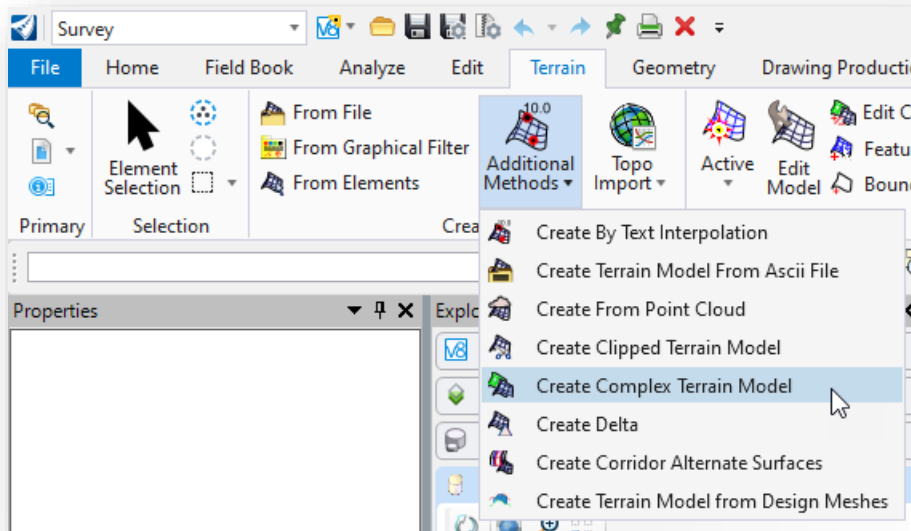
- Open the newly created design file
- Use the **Attach References** command to attach the design files that will be used to create the combined terrain model, listed below
 - 300-Survey\Basemaps\96213_FB001.dgn
 - 300-Survey\Basemaps\96213_PC001.dgn
 - 300-Survey\Basemaps\96213_PC002.dgn

When attaching the PC002 design file containing the Aerial information, be sure to set the **Orientation** to use the **Geographic - Reprojected** option.

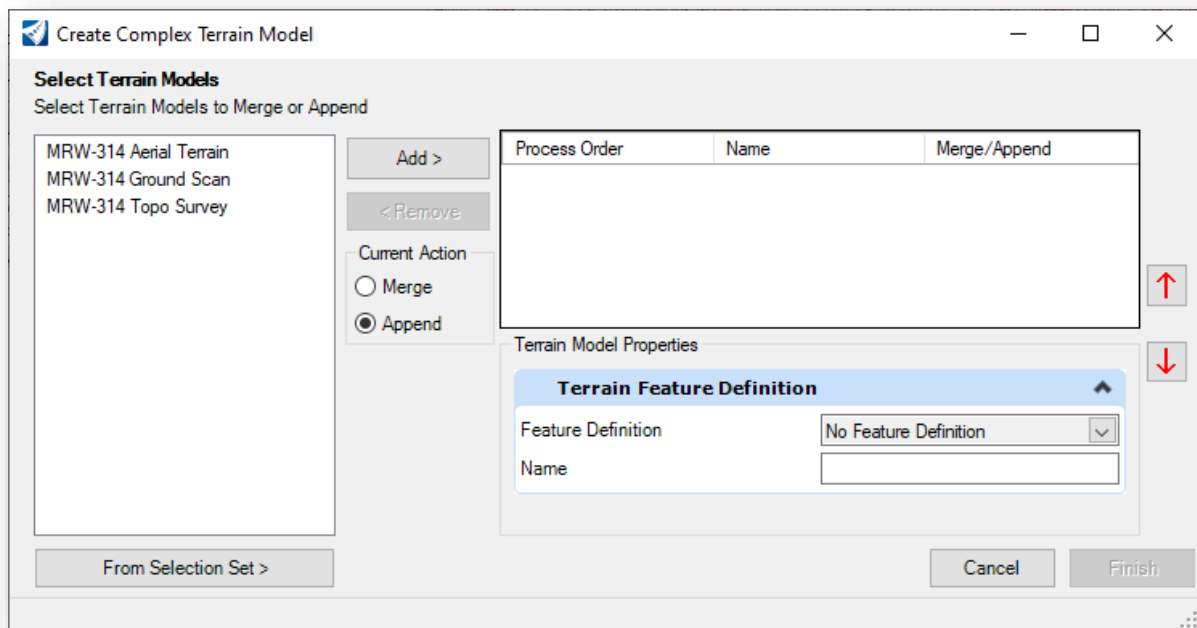




- Select the **Create Complex Terrain Model** command



The **Create Complex Terrain Model** dialog is opened like the example below.



The available terrain models from the active design file and references are listed at left.

- Select the base terrain model from the left and choose the **Add** button to add it to the list on the right.
- Select additional terrain models in the left one at a time. Select either the **Merge** or **Append** option (described below) and then click **Add**.



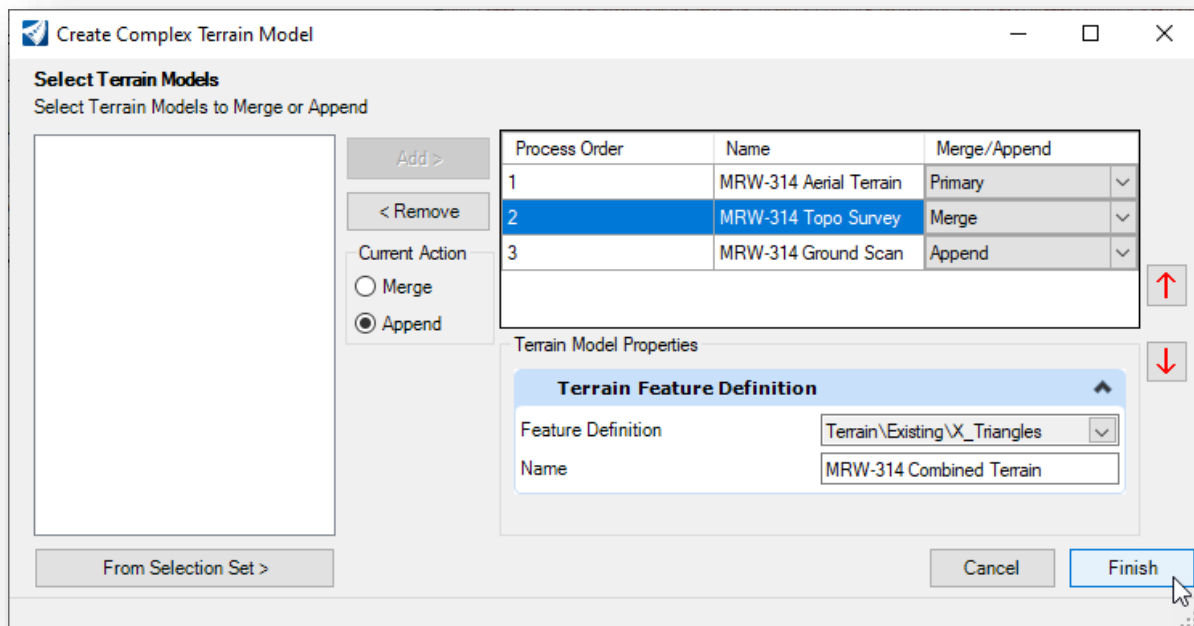
Append

When appending, the software triangulates the combined data from the two terrain models using all data from both models and ignoring none. The two models may overlap or be adjacent to one another. If there is data in both models in a common area, it is all utilized for triangulation.

Merge

When merging, the software triangulates the combined data from the two terrain models in areas where they do not overlap. The two models must overlap at least one point. If there is data in both models in a common area (overlap), the data from the primary model is discarded, and only the data from the merging model is used. Therefore, order is critical.

- The **Process Order** and the **Merge/ Append** options are critical. Add the data to the dialog as shown in the example below.



- Set the **Feature Definition** for combined terrain model using one of the Terrain\Existing\ feature definitions.
- Key in the **Name** for combined terrain model. **MRW-314 Combined Terrain** is used in the example above.
- Select **Finish** to initiate the command. The combined terrain model is created in the active design file.

This concludes this exercise. **Save Settings** and exit OpenRoads Designer when complete.



OpenRoads Software Version

This document was prepared using the following software version:

OpenRoads Designer CONNECT Edition – 2020 Release 3 - Update 9 – Version 10.09.00.91

Contacts

For any questions, suggestions, or problems with this document please contact the ODOT Office of CADD and Mapping Services by use of the following form on the ODOT website:

https://odot.formstack.com/forms/cadd_servicerequest
