

1. Terrain Models

Bentley Definition:

'A terrain model is a set of three-dimensional triangles mathematically computed from point data collected on the surface being modeled. Models are used to define highly irregular surfaces, particularly the surface of the earth, but can be generated for proposed surfaces and subsurface geotechnical layers...'

- Terrain models are stored in 3D design files instead of requiring a TIN or DTM file making them easy to reference into other files.
- New Civil Tools use file referencing and active vs. inactive statuses to utilize terrain models
- Currently a survey and a TIN are provided to the designer for use. The designer will be responsible for creating the terrain model in the new workflow.

2. Terrain Model Features

Terrain models are defined by Features. There are two types of features: Source Features and Calculated Features. **Source Features** come from the source data (xml, txt, dtm, graphics, etc.) that was utilized to create the Terrain Model. **Calculated Features** are viewable characteristics derived or calculated from the source data.

- **Source Features** include break lines, boundaries, spots, voids, etc.
- **Calculated Features** include contours, triangles, flow arrows, etc.

Calculated Features Display	
Contours	On
Triangles	Off
Triangle Vertices	Off
Flow Arrows	Off
Low Points	Off
High Points	Off

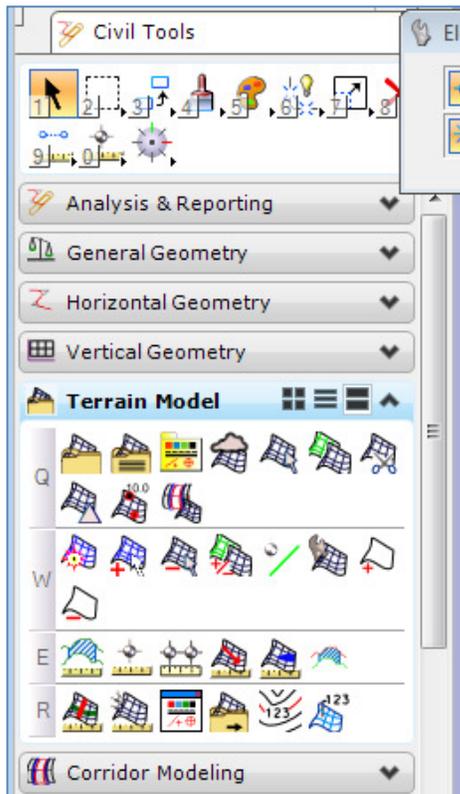
Source Features Display	
Breakline	Off
Boundary	On
Spot	Off

3. Terrain Model Feature Types

- **Spot or Spot Elevation** – Points (with X, Y, Z) that have no functional relationship to any other point. Ground shots in open terrain would be an example of random spots. [Point elements such as cell, circles and text strings are typical MicroStation elements used to graphically define spot elevations, lines, line strings and other longitudinal elements are equally valid.] The software creates a spot elevation for each vertex of each longitudinal element.
- **Break Line** – Breaks are used to designate linear features such as edges of pavement, ditch bottoms, ridges, etc. where an abrupt change of slope occurs. Any longitudinal element may be defined as a break line. Triangles will not cross a break line in the terrain model.
- **Contour** – A contour is an element or set of elements of the same elevation. Contours may be used as source data to generate a terrain model, or may be computed (drawn based on a terrain model).
- **Hole** – An area defined by a closed shape that delineates a region where the current terrain is ignored and the underlying terrain is utilized. For example, holes can be used for marking areas that you do not want to disturb during a design.
- **Boundary** – A boundary is the maximum external limits a terrain model can extend. No triangles will be created outside of this boundary. The boundary of a terrain model can be changed by deleting triangles or changing the Edge Method. A new graphic can be added, to an existing terrain model, as a boundary element.
- **Drape Boundary** – A drape boundary is a surface boundary that determines its elevations by draping on the underlying surface. For example, you may use a drape boundary to limit the extent of the triangles by drawing the boundary as an element and using the Add Features command to add the boundary to the terrain model. The new boundary would use the elevation of the underlying surface as the boundary elevations.
- **Voids** – An area defined by a closed shape that delineates a region of missing data or obscure area. No point or break data located within the void area is utilized and no triangles are created inside the void areas. The void coordinates are included in the triangulation and void lines, between successive void coordinates, are inserted as drape lines on the surface. Therefore, they do not change the slope or elevations of the surface.
- **Drape Void** – An area defined by a closed shape that delineates a region of missing data or obscure areas. No point or break data located within the void area is utilized and no triangle are created inside the void areas. In the drape void, the void coordinates are not included in the triangulation. Voids are inserted post triangulation. The void coordinates and lines are draped on the terrain model surface. Even though a user must provide an elevation for Drape Void vertices, the user elevations are changed to the elevation of the terrain model surface at the XY Drape Void coordinate position. For example, if you don't have accurate survey data for the void area, you may want to use the drape void.

4. Terrain Tools

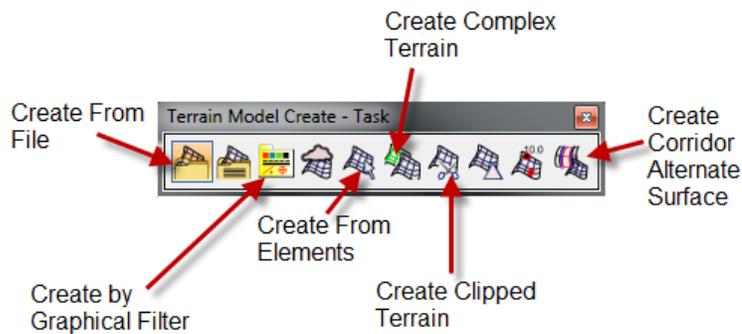
Terrain Model Tools are located on the Terrain Model tab under Civil Tools in the Task Menu.



The tools are divided into 4 groups:

- A. Terrain Model Create
- B. Terrain Model Edit
- C. Terrain Model Analysis
- D. Terrain Model Miscellaneous

A. Terrain Model Create



There are many ways to create a terrain model using several types of data.

Creating a terrain model using OpenRoads Technology tools adds a level of intelligence to the Terrain Model called Rules. The rules allow the terrain model to preserve a link to the source data so it can be updated when revisions are made to the source data. This has very powerful implications for both existing and proposed terrain models.

For terrain models created from 3D elements, the terrain model will automatically update when existing elements change. For example, additional vertices added to a break line. New elements will not be incorporated into the terrain model automatically. They must be added manually which will be discussed later in this training.

For terrain models created by importing files, the terrain model will not be updated until the source data has been manually resynchronized. For example, a change to the TIN file.

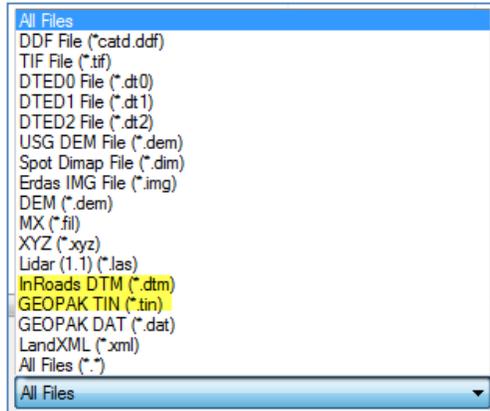
Unlike the past, when DTMs and TINs were a result of a design process, terrain models are a dynamic representation of the current source data.

All terrain creation commands allow the selection of a Feature Definition. Element Templates can only be assigned after the terrain has been created.

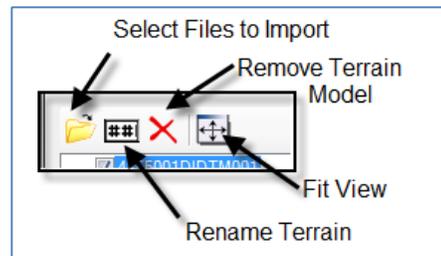
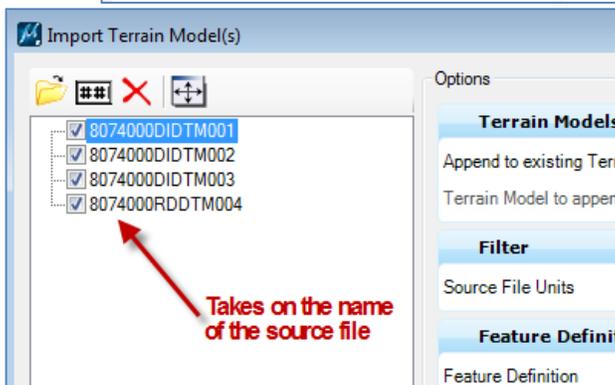
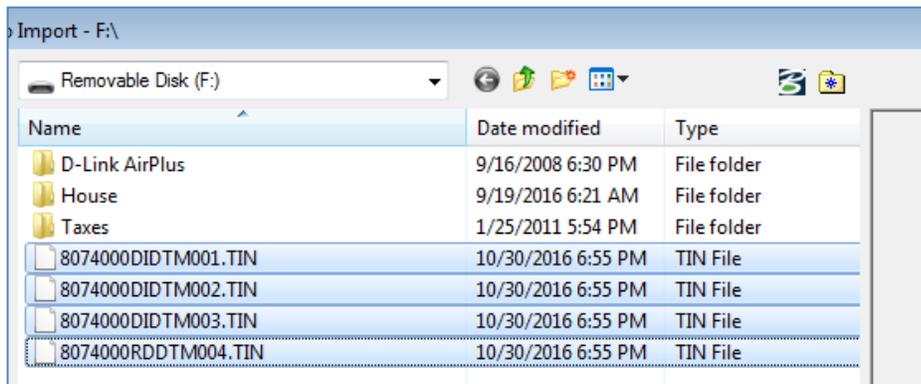


1. **Create From File**

OpenRoads Technology accepts all of the file types listed below. DTMs and TINs are the most common formats used at MDT. Lidar (LAS) is becoming more common.



A separate terrain will be created for each file selected.

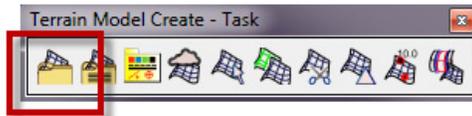


Note: Selecting **Import Features Only** or **Import Both** limits the amount of editing that can be done in a terrain model. Triangle edges cannot be switched along features, nor can vertices be deleted. Importing features *only* writes the graphics to the design file without creating a terrain. Importing both, as implied, imports both the terrain model and its features. The graphics are not tied to the terrain model.

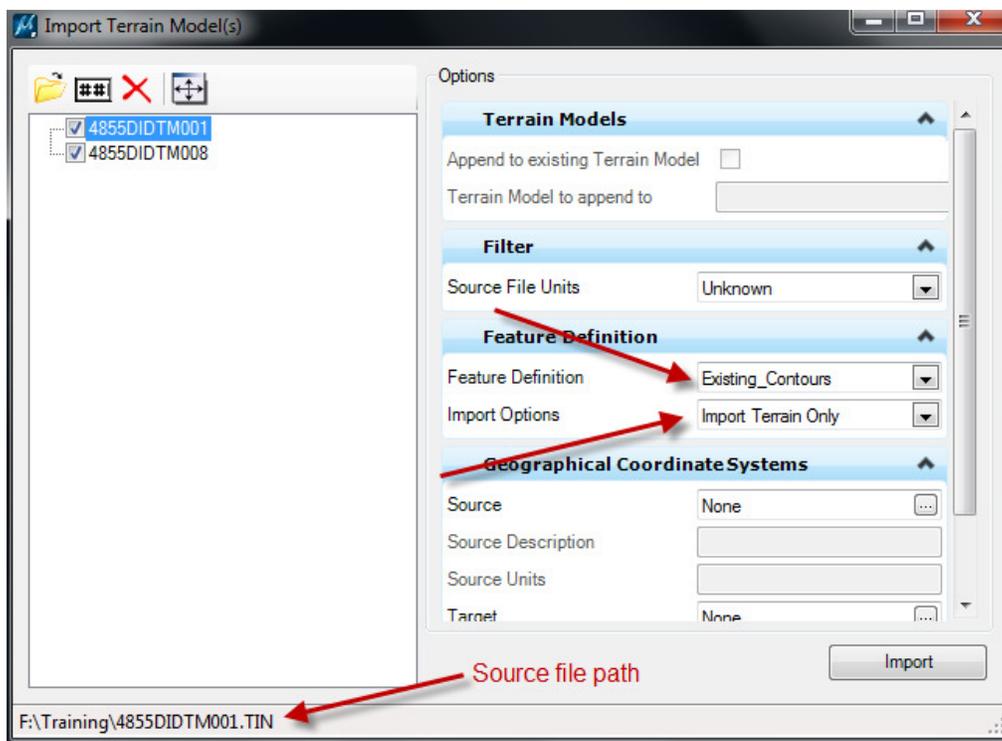
MDT Best Practice is to import the terrain only.

Exercise 1: Creating a Terrain from a TIN file

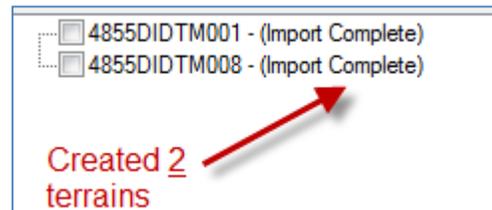
1. **Start OpenRoads using the Enhanced Workspace**
2. **Open file *From_File.dgn* (usually the ETR)**
3. **Select *Create Terrain from File***

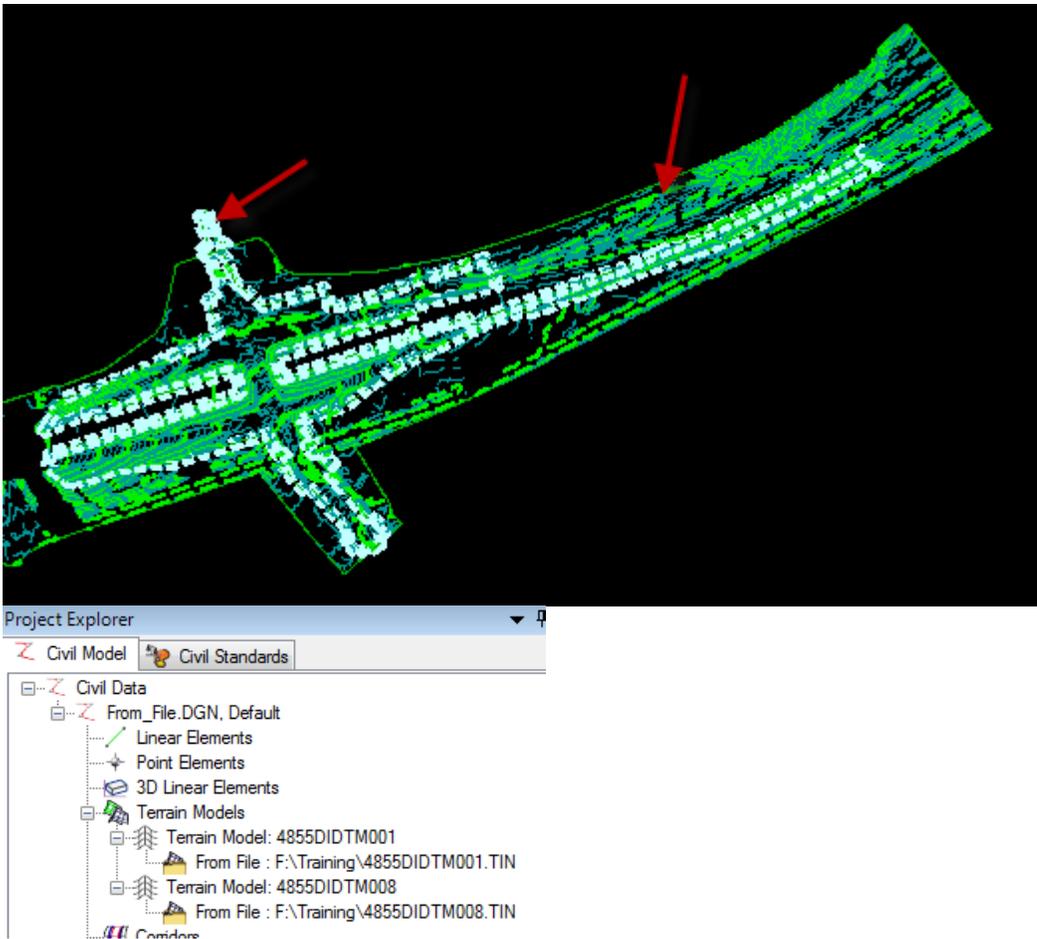


4. **Select *4855DIDTM001.TIN* and *4855DIDTM008.TIN***
5. **Set Import Options to *Import Terrain Only***

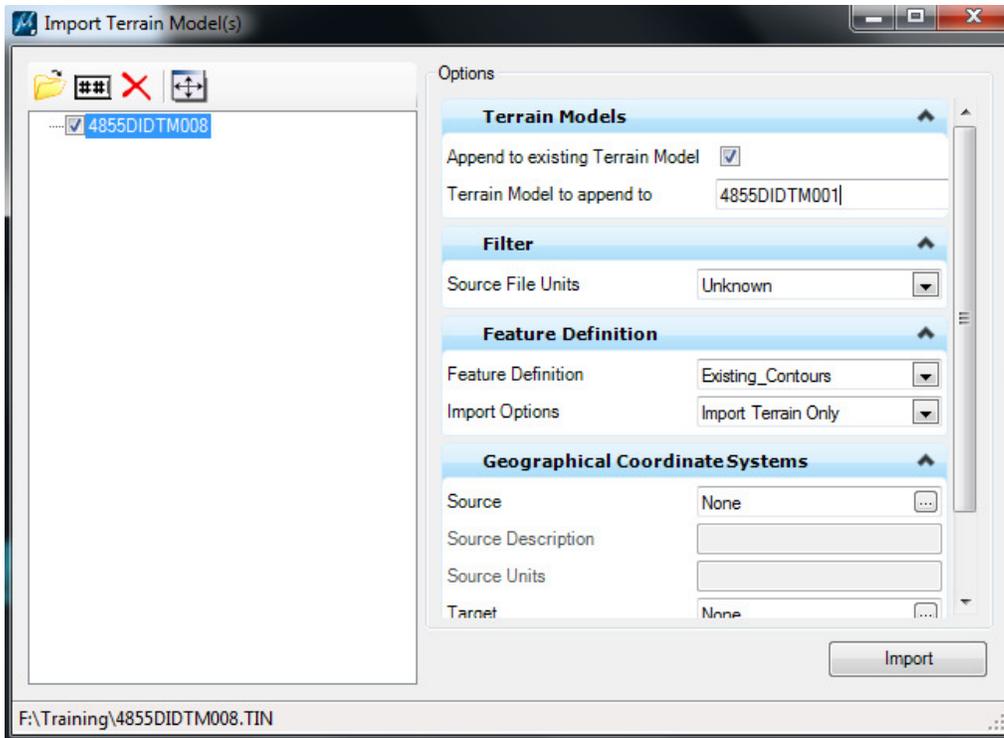


6. **Click Import**

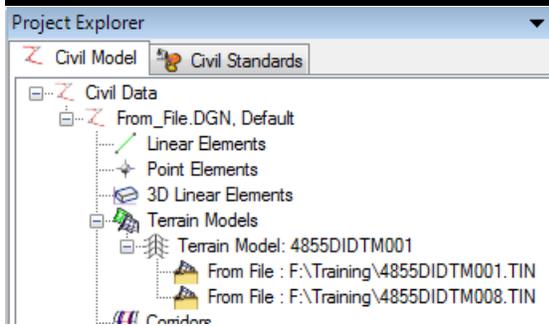
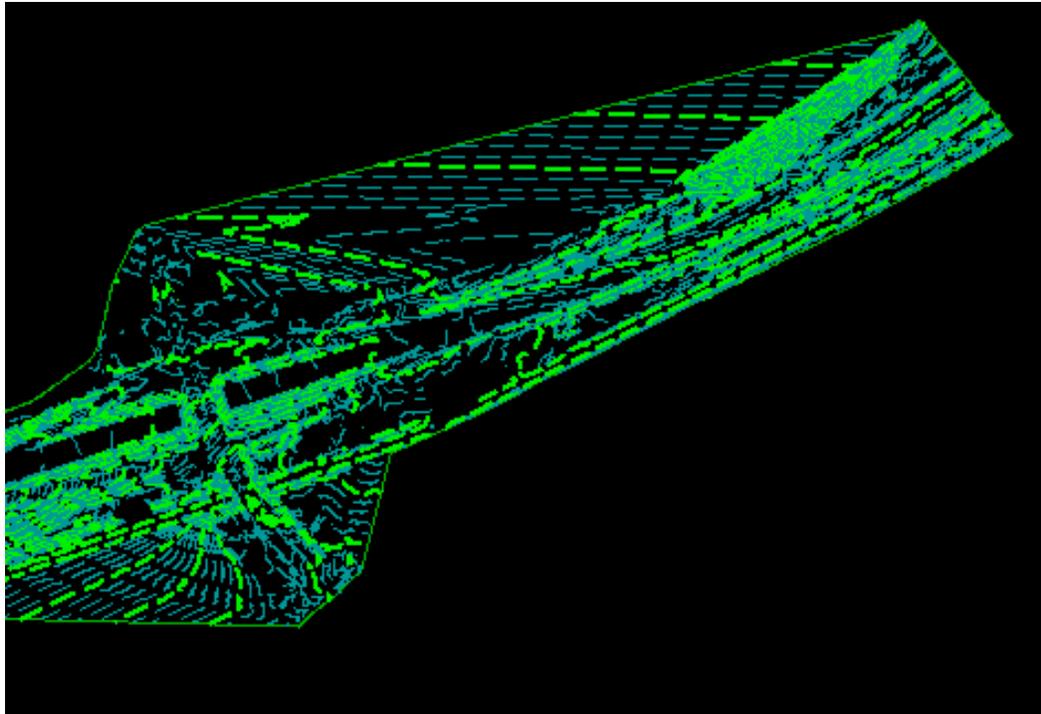




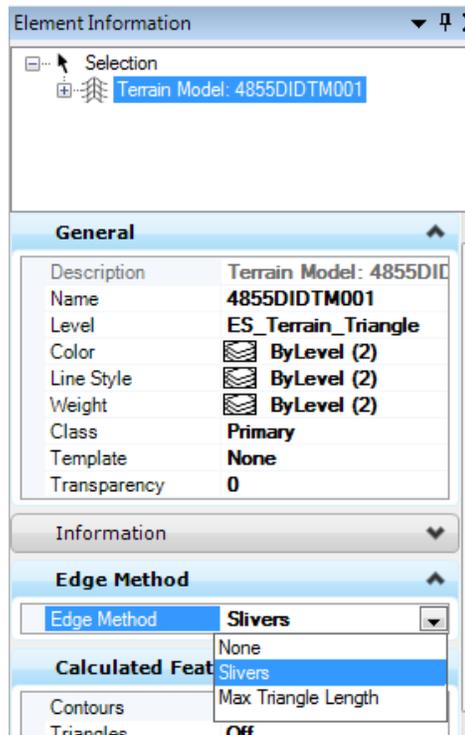
- 7. Select terrain both terrains in the Project Explorer, right click and delete.**
- 8. Select Create Terrain from File**
- 9. Select 4855DIDTM001.TIN**
- 10. Import using the same settings as above.**
- 11. Select Create Terrain from File**
- 12. Select 4855DIDTM008.TIN**
- 13. Toggle on Append to existing Terrain Model**
- 14. Click Import**



15. Click **Import**



16. Select the terrain and in the Element Information Dialog change the Edge Method to Max Triangle Length and set to 50.



17. Close the file

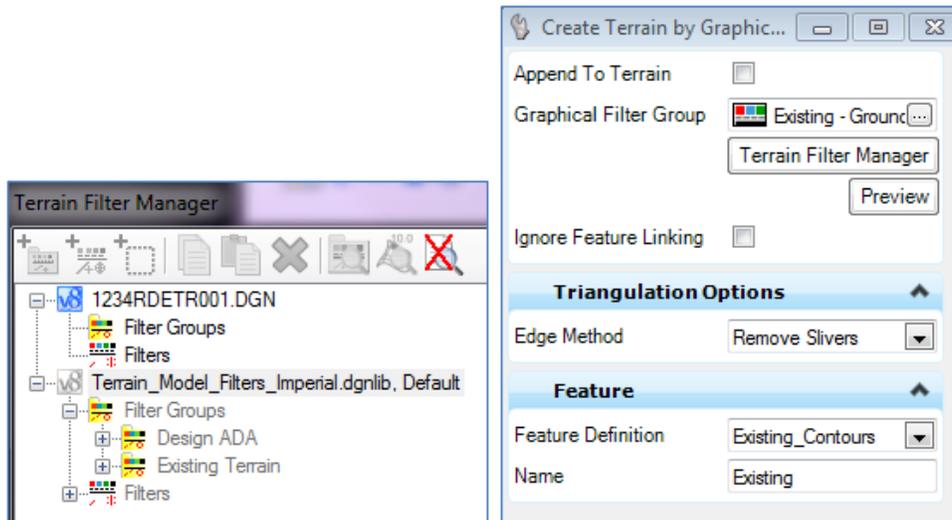


2. Create Terrain Model By Graphical Filter

Uses predefined graphic element search settings to simplify the **Create from Elements** command

Uses settings stored by the **Graphical Filter Manager*** to create the terrain.
Two parts to the **Graphical Filter Manager**:

- a. **Filters** – define feature type and selection criteria
 - Feature Type: break line, spot, void, etc.
 - Selection Criteria: color, level, element type, line style, line weights, cell names, feature name, transparency, element template and elevations.
 - i. A minimum of one selection criteria must be defined
- b. **Filter Groups** – combination of individual filters that will be processed in a single **Create Terrain** operation.

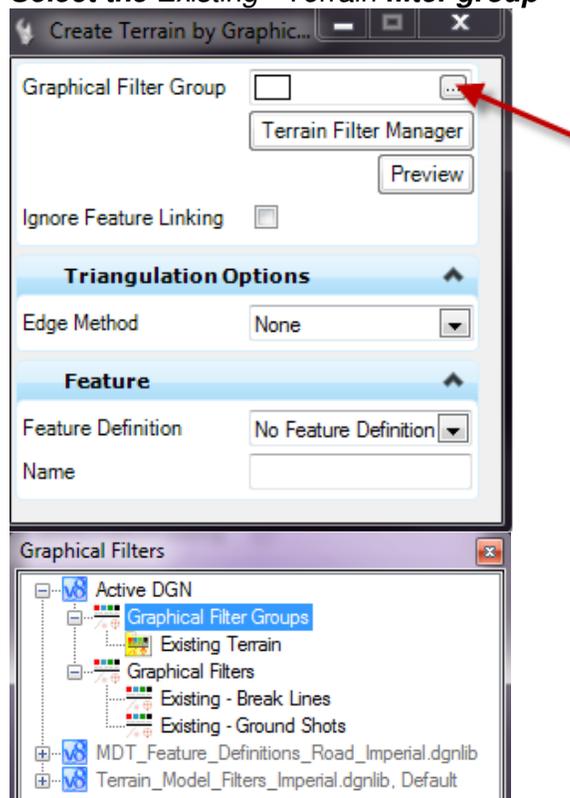


Exercise 2: Creating a Terrain using a Graphical Filter

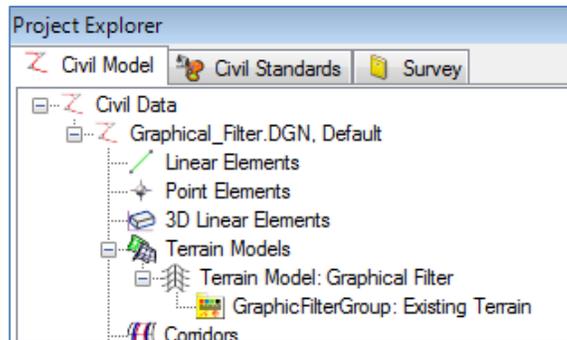
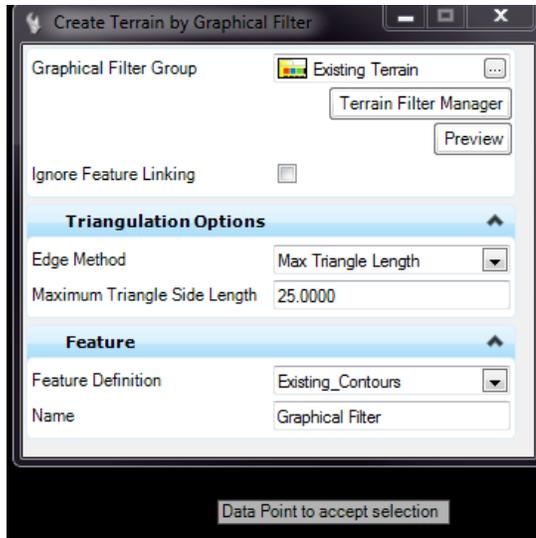
1. **Open file *Graphical_Filter.dgn* (ETR file with *EFF* referenced, or *PTR* file with *CRR* file(s) referenced)**
2. **Select *Create Terrain By Graphical Filter***



3. **Select the *Existing - Terrain filter group***



4. **Set Edge Method to *Max Triangle Length of 25***
5. **Set Feature Definition to *Existing Contours***
6. **Name Terrain: *Graphical Filter***
7. **Click through the prompts to create the terrain**





3. Create From Elements

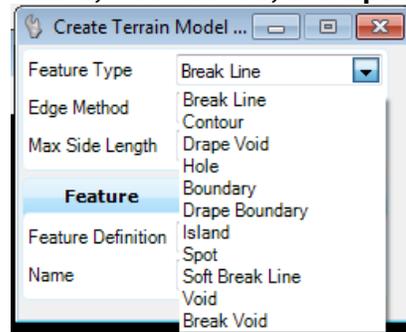
Uses user selected 3D graphical elements. Using this method results in a relationship between the terrain and its source elements (graphical 3D elements).

This command can be utilized with a pre-selected (highlighted) element set before the command is activated or individual elements can be selected 1 at a time once the command is active. (Instructor suggestion is option #1!!!!)

Note: MDT Best Practice is to create terrain models in a file separate from their source data. For example, referencing the Existing Features File (RDEFF) into the existing ground terrain file (RDETR) and creating the existing terrain in the RDETR from the elements in the RDEFF.

****CAUTION: DETACHING REFERENCE FILES BREAKS THE RELATIONSHIP****

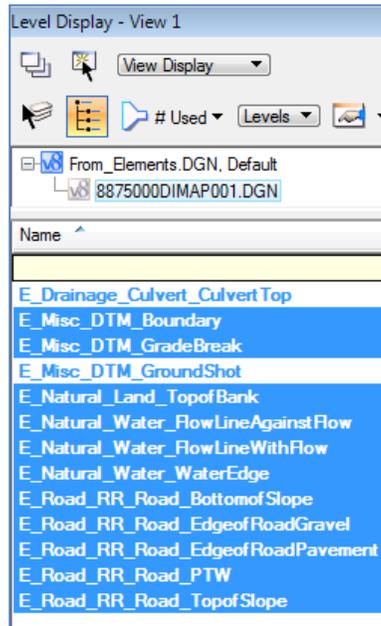
All the feature types defined in Section 4 are available. The most commonly used feature types are: **Break Lines, Contours, Boundaries, and Spots.**



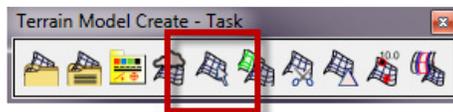
A terrain created with elements has a relationship with the elements. As long as the reference file remains attached, the terrain will dynamically update if the included elements are modified. This is incredibly useful when creating a terrain model from proposed 3D models.

Exercise 3: Creating an Existing Ground Terrain using Graphical Elements

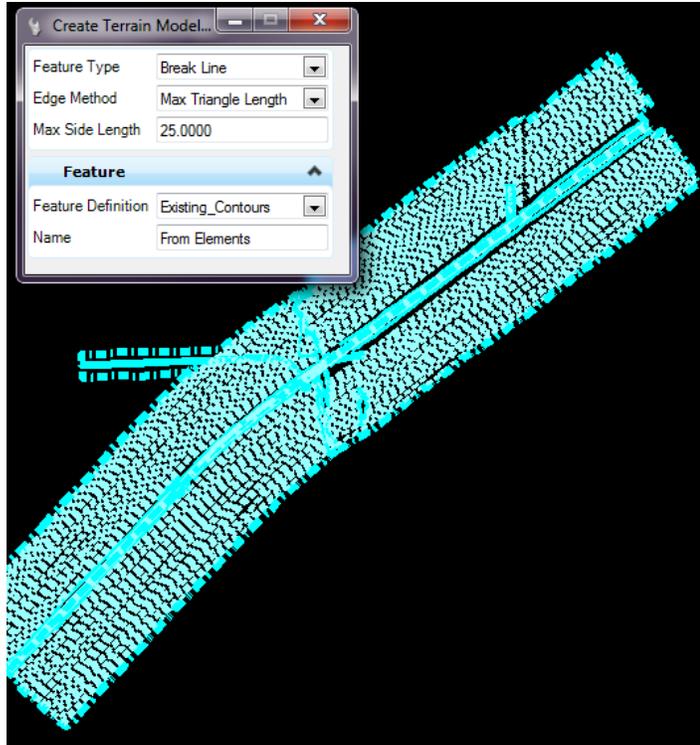
1. ***Open file From_Elements.dgn (ETR with EFF referenced)***
2. ***In the Level Display dialog turn off all non-break line levels in reference file 8875000DIMAP001.***



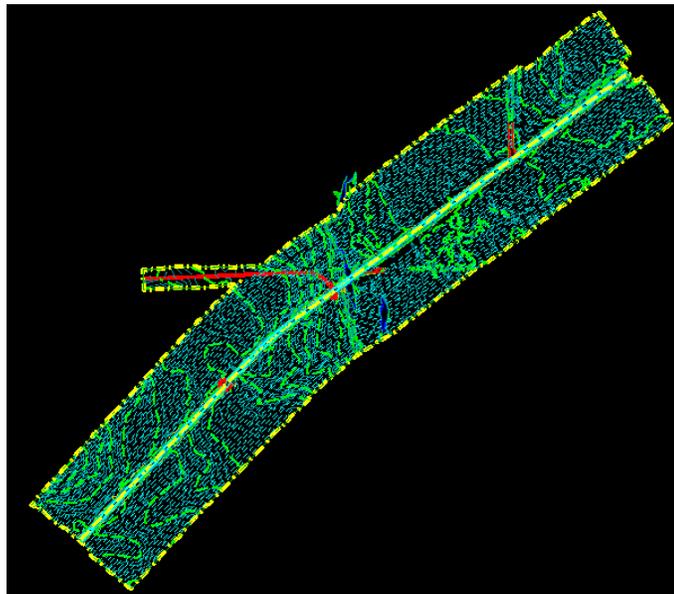
3. ***Zoom extents and select all visible graphics***
4. ***Select Create From Elements***



5. ***Set Feature Type to Break Line***
6. ***Set Edge Method to Max Triangle Length and Max Side Length to 25***
7. ***Set Feature Definition to Existing_Contours***
8. ***Name Terrain: From Elements***



9. Data Point through the prompts



10. Close the file



4. Create Complex Terrain Model

The **Create Complex Terrain Model** tool is used to merge or append multiple terrain models into one. Order is important as the models are processed in the order listed. It is also crucial to specify append or merge as appropriate for the project, as the results may be dramatically different.

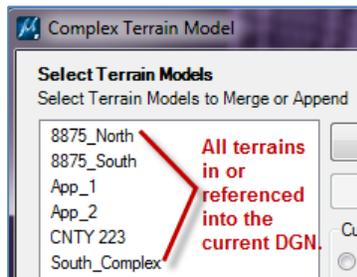
Any two terrain models can be complexed together as long as they overlap at a minimum of one point. A warning message is displayed if there is no overlap, and no processing occurs.

Merge or Append

Both merging and appending combines the data contained in multiple (two or more) models. However, they are not the same process and yield different results. Please note, the resultant terrain is dynamic and will change based on alterations to the original terrains.

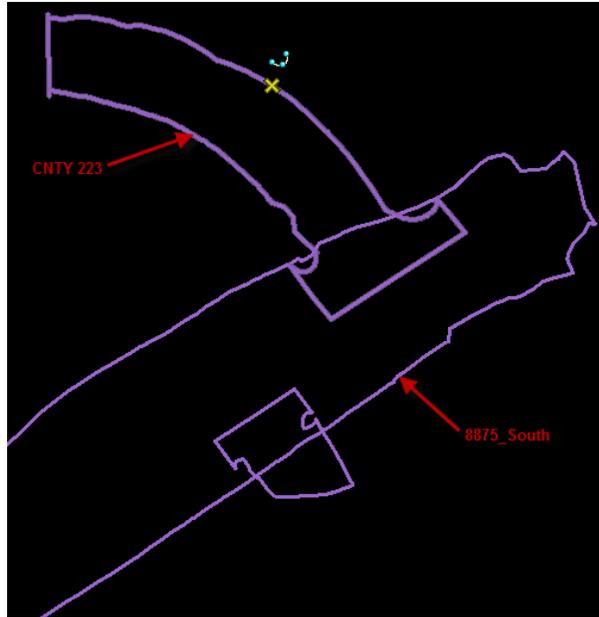
When **Appending**, the software triangulates the combined data from the two terrain models using all data from both models and ignoring none. The two models may overlap or be adjacent to one another. If there is data in both models in a shared area, it is all utilized for triangulation.

When **Merging**, the software triangulates the combined data from the two terrain models in areas where they do not overlap. If there is data in both models in a shared area (overlap), the data from the primary model is discarded, and only the data from the merging model is used. Therefore, **order is critical.**

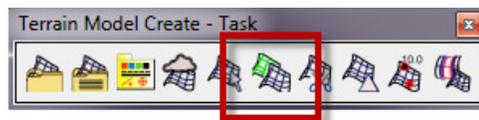


Exercise 4: Creating a Complex Terrain

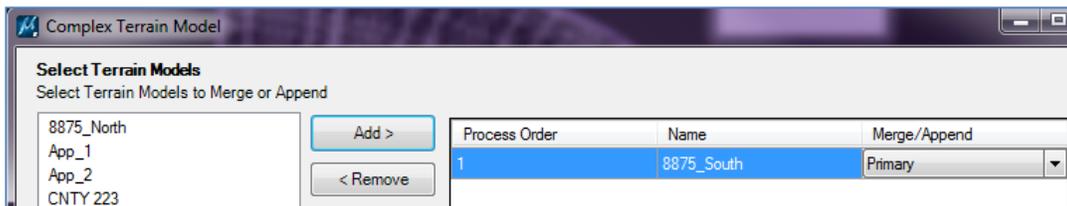
1. **Open file Complex.dgn (a 2nd separate ETR or PTR with the initial terrains referenced in)**



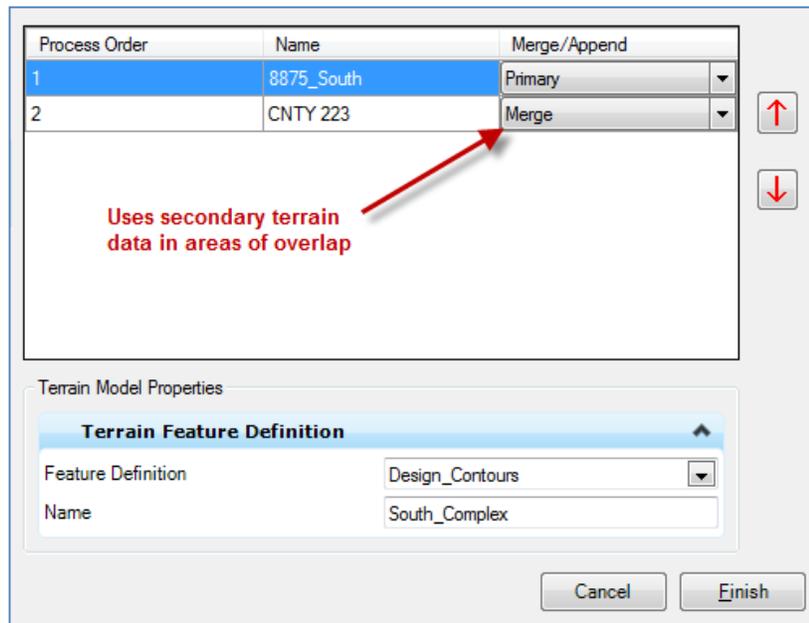
2. **Select Create Complex Terrain Model**



3. **Add terrain 8875_South as the primary terrain.**



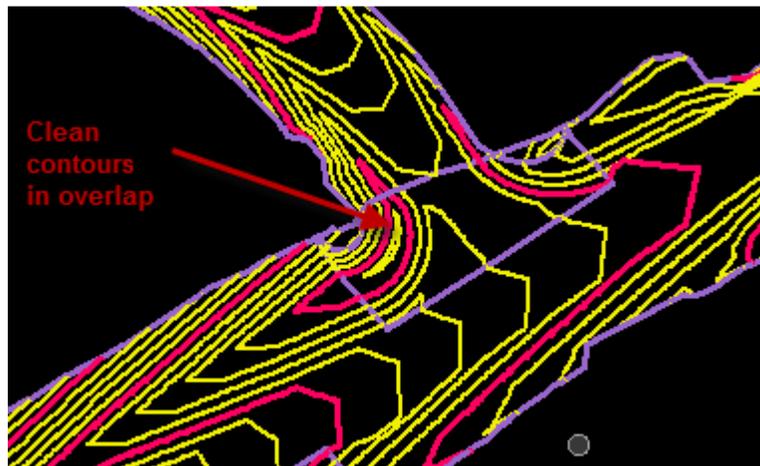
4. Add terrain CNTY 223 with the Merge option

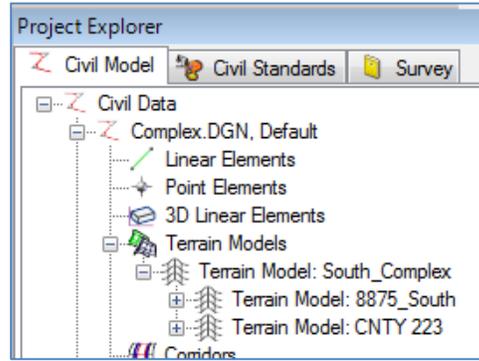


5. Set the Feature Definition to Design_Contours

6. Name the terrain South_Complex

7. Click Finish





8. Close file



Create Clipped Terrain Model

Creates a new terrain model by clipping an existing terrain model. Clipping boundaries can be any type of closed area, including other terrains. The boundary does not have to be entirely contained within the reference terrain.

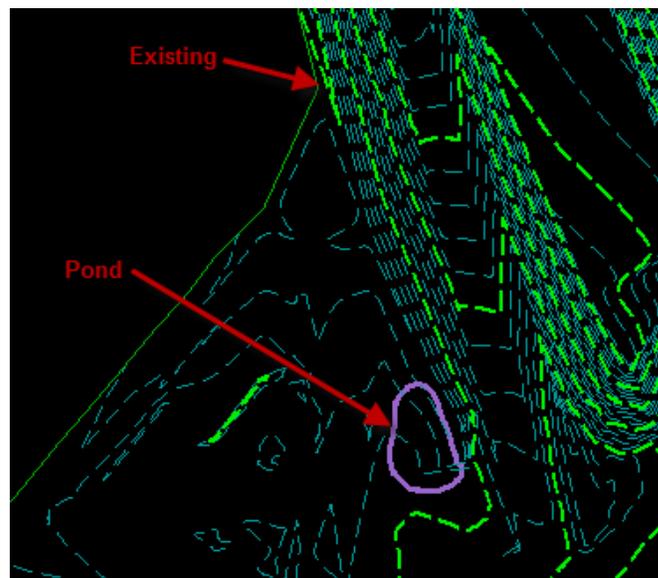
Clipping Method:

Internal – Creates a terrain model with a void within the clipping boundary.

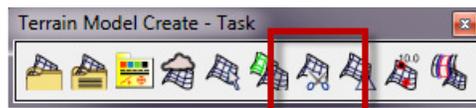
External - Clips all data outside of the clipping limits with the clipping polygon being the boundary of the resultant terrain model.

Exercise 5: Creating an Internal Clipped Terrain

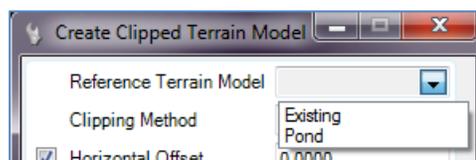
1. **Open file CLIP_INT.dgn (a 2nd ETR or PTR with the initial terrain file referenced in)**



2. **Select Create Clipped Terrain Model**

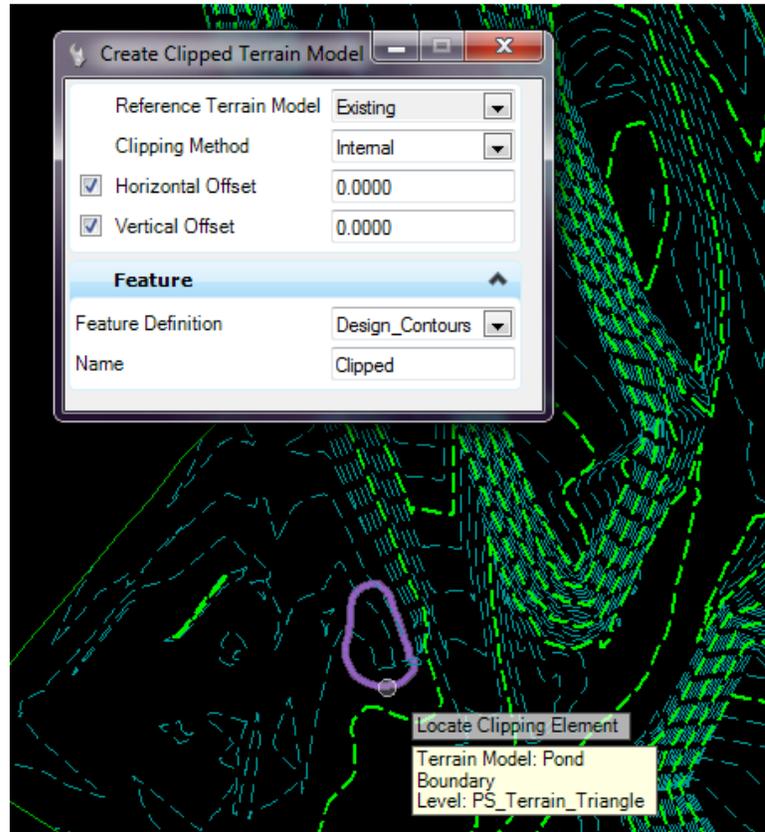


3. **Select Existing as the reference terrain model**

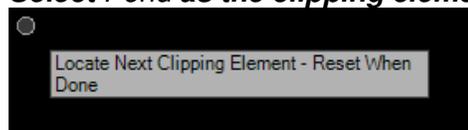


4. **Set Clipping Method to Internal**

5. **Set Horizontal and Vertical Offsets set to 0 and Feature Definition to Design_Contours**

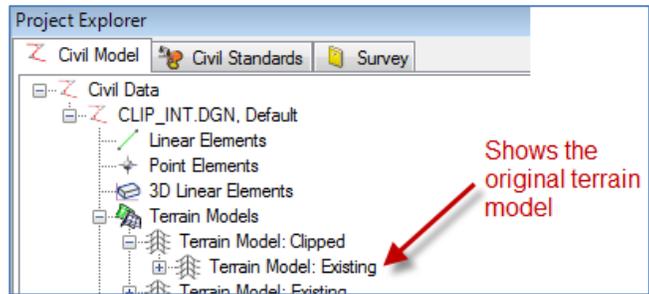
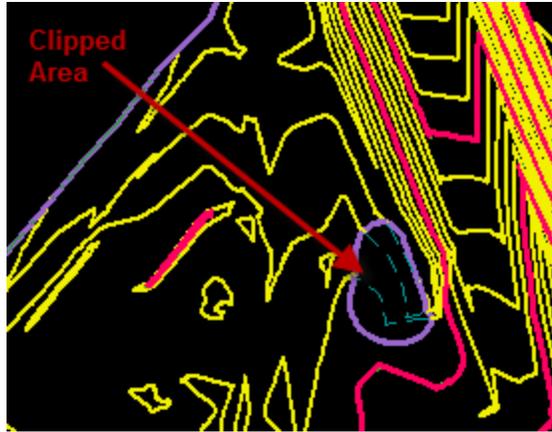


6. **Select Pond as the clipping element.**



7. **Reset**

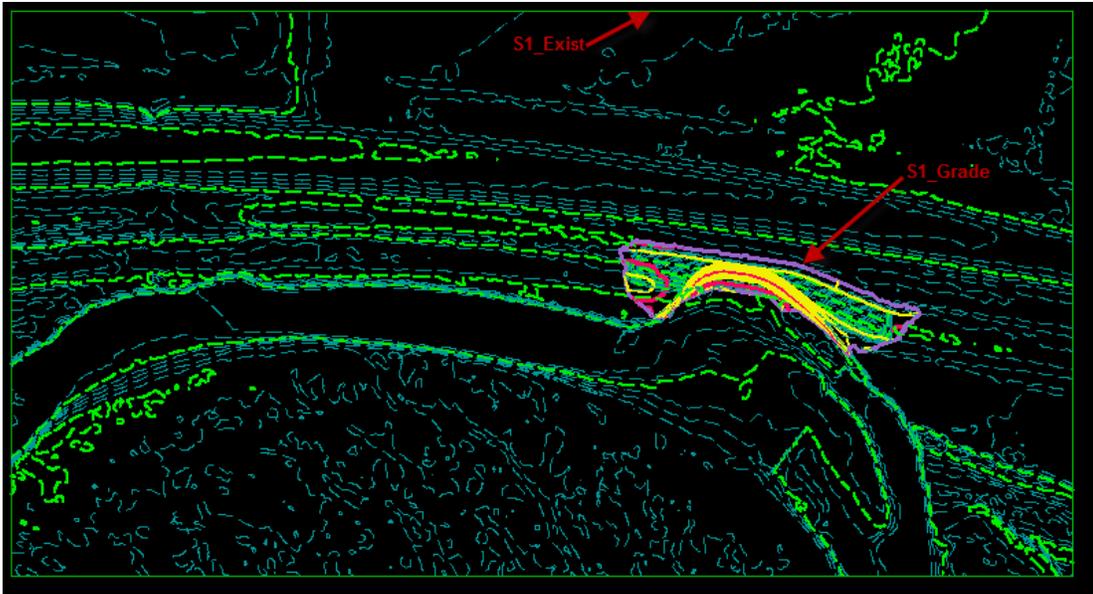
8. **Name the terrain Clipped**



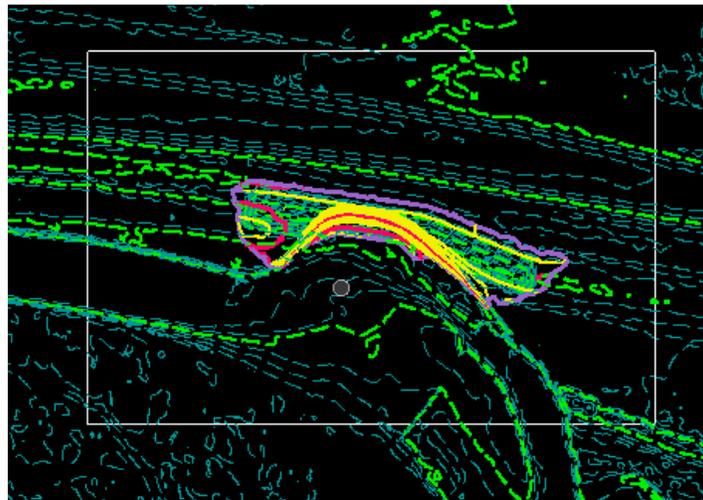
9. Close the file

Exercise 6: Creating an External Clipped Terrain

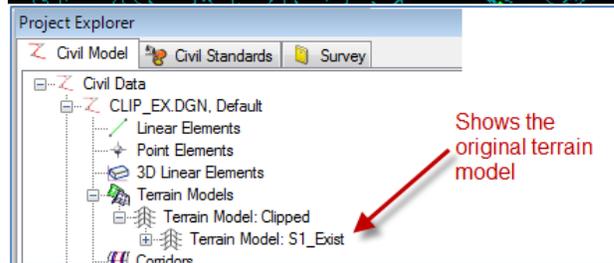
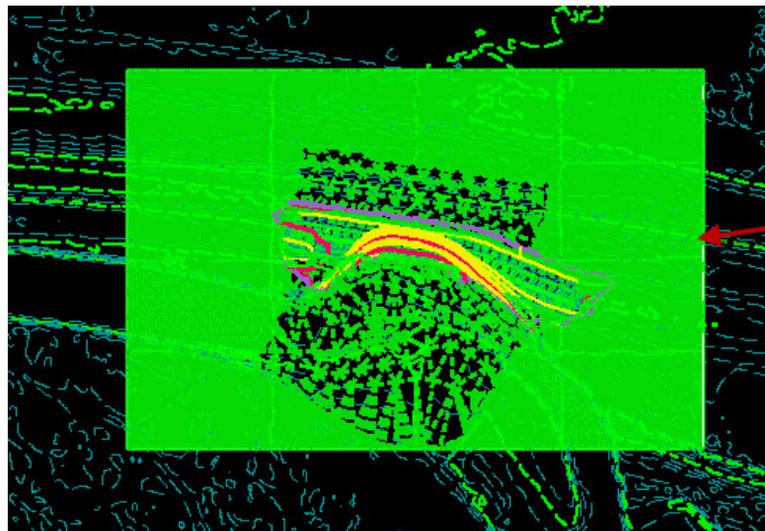
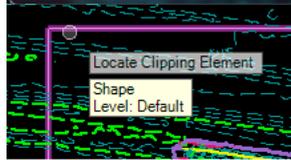
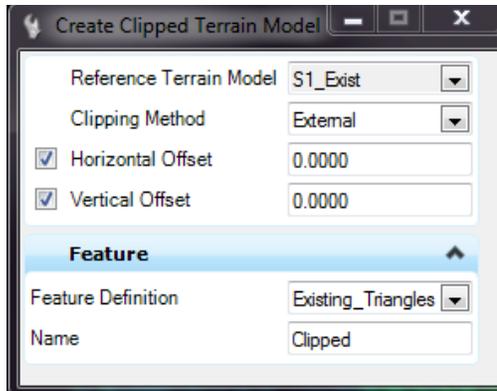
1. ***Open file CLIP_EX.dgn (a 2nd ETR or PTR with the initial terrain file referenced in)***



2. ***Place a block around S1_Grade.***



3. ***Select Create Clipped Terrain Model***



4. Close file



5. Create Corridor Alternate Surfaces

Creates a terrain based on the 3D break lines of the corridor created by the Template Point Feature Definitions.

Point Properties

Name: SH2_L Apply

Use Feature Name Override: SH2_L Close

Feature Definition: Road_Subgrade < Previous Next >

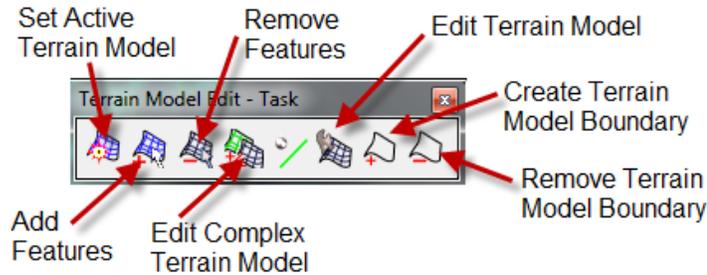
Superelevation Flag

Alternate Surface: Subgrade Help

Member of:
Cr Ann

This command will be discussed in detail in the Corridors training.

B. Terrain Model Edit



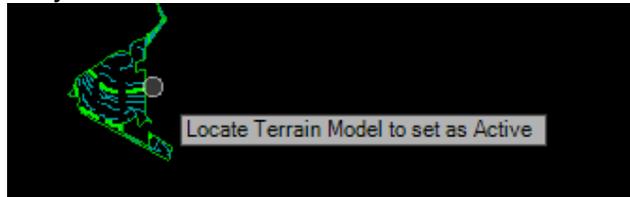
Overriding Symbology was discussed in Section 3. This section focuses on edits to how the terrain model composition calculates instead of its visual properties



1. Set Active Terrain Model

The active terrain model is displayed by default in profile and cross section models and is the default target for Corridor Modeler. Commonly, the existing ground terrain is set to Active.

Only **one** terrain can be active at a time. This includes referenced terrains.



2. Add Features

Additional source elements can be incorporated into a terrain model. The original creation method does not matter. Only graphical elements can be added using this command. Elements must either be 3-dimensional elements or a horizontal element with an active profile.



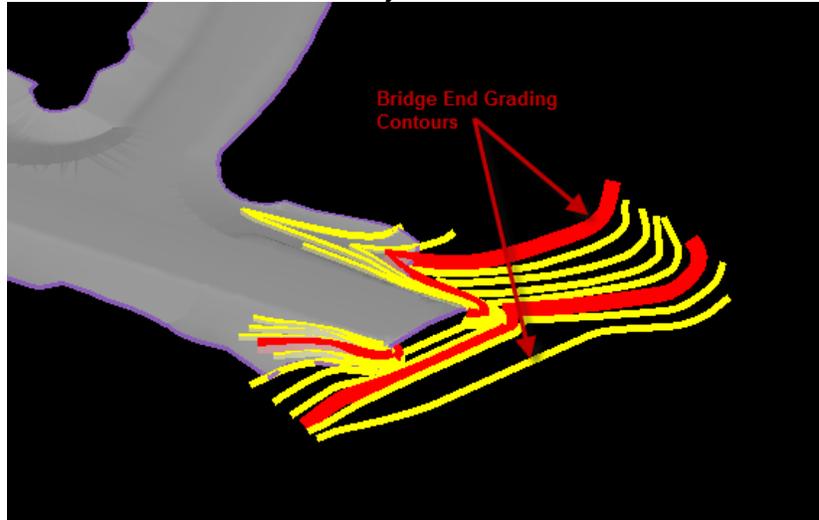
3. Remove Features

Source elements can also be removed from a terrain model **as long as the relationship between them has not been broken.**

Elements can be added and removed singly or by pre-selecting a group. Pre-selecting is a faster process and is less likely to cause the program to crash.

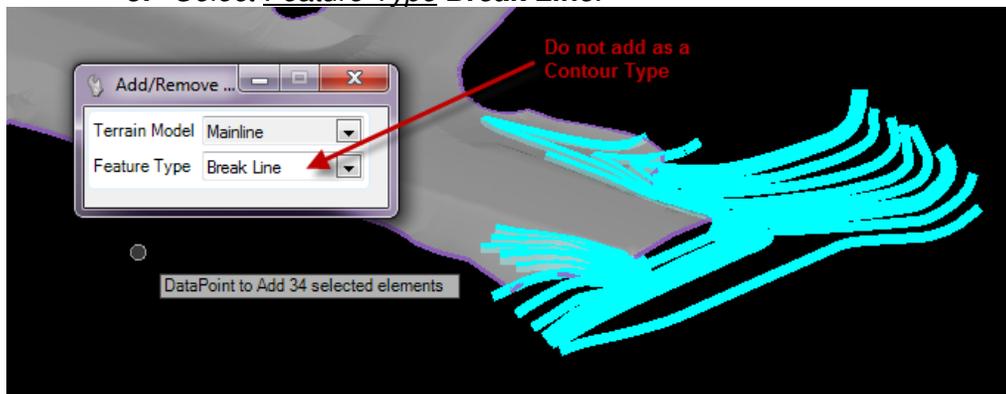
Exercise 7: Adding & Removing Features From a Terrain

1. **Open file Add_Remove.dgn (must be the file that the terrain lives in)**
2. **Select all the red and yellow contour lines**

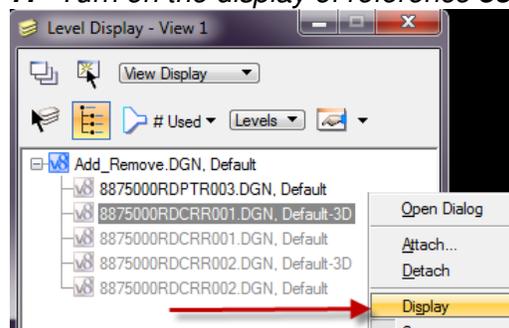


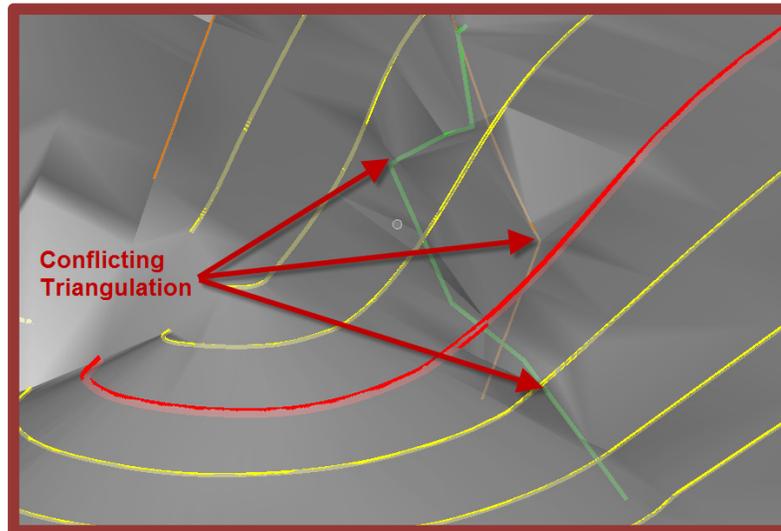
3. **Click Add Features**
4. **Select Terrain Model Mainline. BE PATIENT!**

5. **Select Feature Type Break Line.**

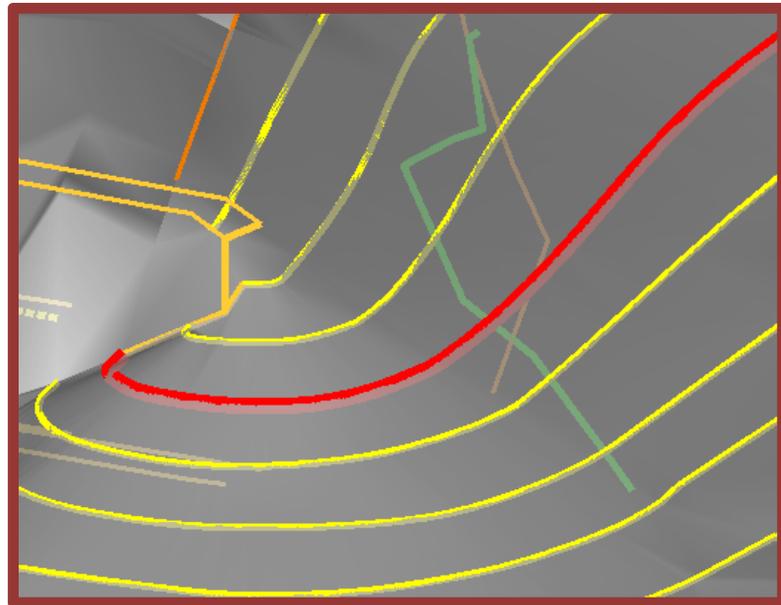


6. **Data Point**
7. **Turn on the display of reference 8875000RDCRR001.DGN, Default-3D.**





8. Select **Remove Features**
9. Select Terrain Model: **Mainline**
10. Remove the 2 break lines shown above.



11. Turn on level **PS_Struc_WallHoriz** in reference **8875000RDPTR003.dgn**
12. Experiment adding and/or removing the bridge bent break lines
13. Close the file



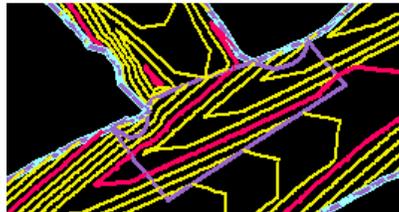
4. **Edit Complex Terrain Model**

Uses the same dialog as the **Create Complex Terrain Model** tool, but it can only manipulate previously defined complex terrain models

Exercise 8: Editing a Complex Terrain Model

1. **Open file** *Complex.dgn*
2. **Select** *Edit Complex Terrain Model*
3. **Click on terrain model:** *South_Complex*
4. **Data Point to accept**
5. **Change** *CNTY_223 to Primary.*

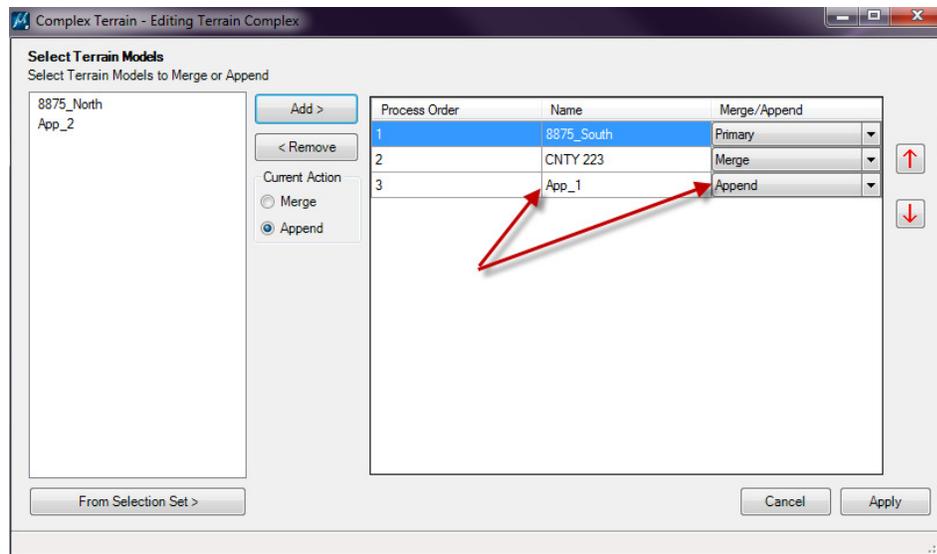
Process Order	Name	Merge/Append
1	8875_South	Primary
2	CNTY 223	Merge
		Merge
		Append
		Primary



Now the triangles from **8875_South** are used in the overlap area

Order Matters!

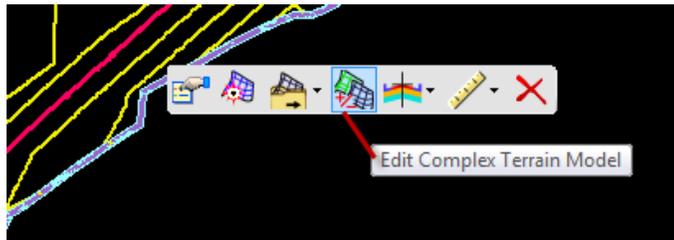
6. **Change** *8875_South back to the primary terrain.*
7. **Add terrain** *App_1 using the Append option*



8. **Apply**



9. **Click on the Complex terrain model and select Edit Complex Terrain Model from the context sensitive menu bar.**



10. **Change App_1 to Merge.**

Process Order	Name	Merge/Append
1	8875_South	Primary
2	CNTY 223	Merge
3	App_1	Append
		Merge
		Append
		Primary

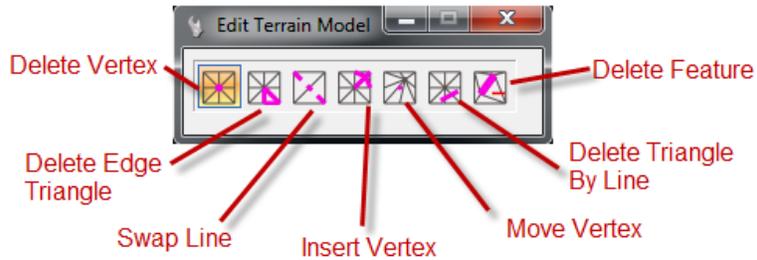
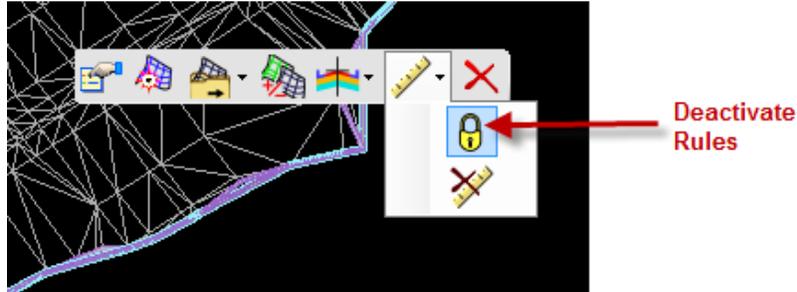
11. **Close the file**



5. Edit Terrain Model

The Edit Terrain Model tools are very similar to the Edit Triangle tool on the GEOPAK DTM Tools toolbar. The major difference is that editing a terrain model is a dynamic process. You can see the effect of the changes as you make them.

Terrains can only be edited in the 3D model of the file they were created in. And the terrain rules must be deactivated.



These tools can be used on terrains created in any of the ways discussed in **Section A**.

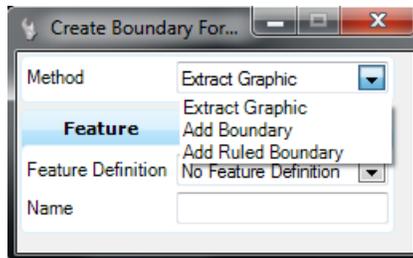


6. Create Terrain Model Boundary

Extracts implied or stored boundaries from terrains. The boundary can then be edited or ruled.

Once a boundary is added to a terrain, it becomes the edge method. **Slivers** and **Max Side Length** are no longer options.

There are three ways to create boundaries:



- **Extract Graphic:** Extracts the current boundary of the terrain triangulation to an editable 3D line string. The line string has no relationship to the terrain.
- **Add Boundary:** Extracts the current boundary of the terrain triangulation as an explicit boundary in the terrain element. Changes the Edge Method to Boundary and locks it.
- **Add Ruled Boundary:** Extracts the current boundary of the terrain triangulation to an editable, ruled, draped boundary. Combination of the **Extract Graphic** command and the **Add Feature: Boundary** command.

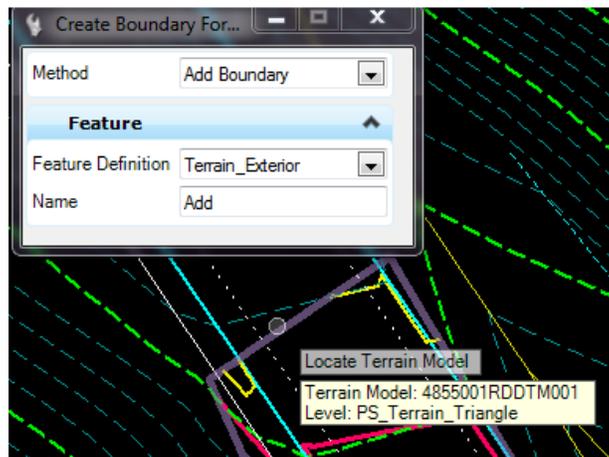


7. Remove Terrain Model Boundary

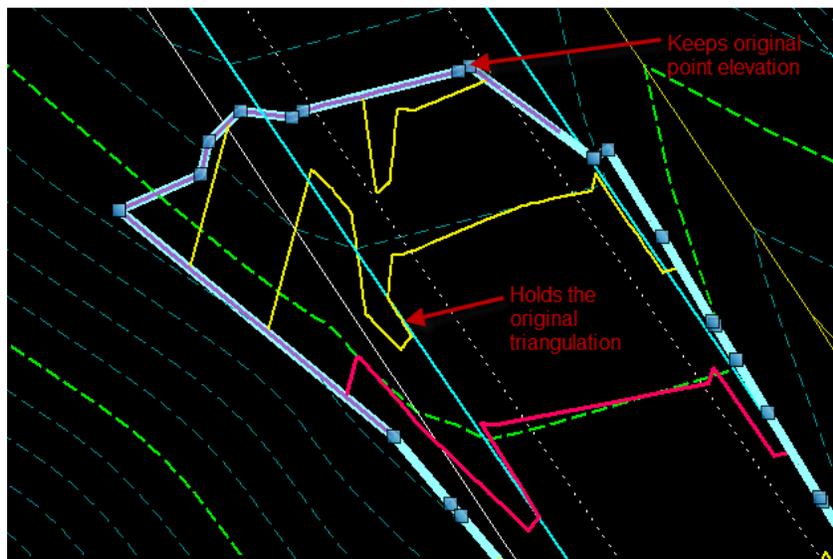
Removes a source boundary from the terrain

Exercise 9: Creating and Removing Terrain Model Boundaries

1. **Open file Boundaries.dgn (boundaries can be extracted into any file, although generally it should be extracted into the file that the terrain lives in)**
2. **Click Create Terrain Model Boundary**
3. **Select Add Terrain Model Boundary**
4. **Select Add Ruled Boundary**
5. **Select Terrain Model 4855001RDDTM001**

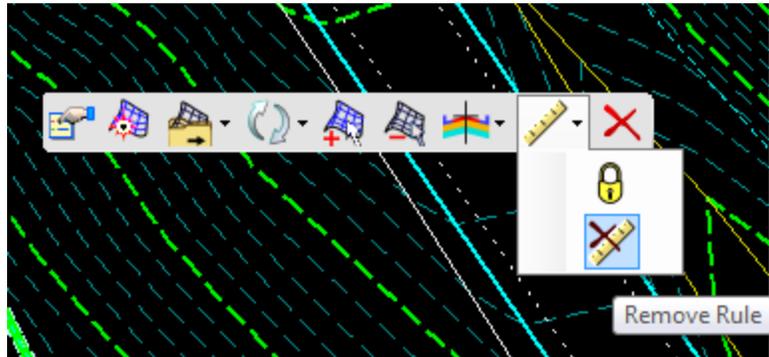


6. **Select the boundary and move one of the vertices**



7. Select Terrain Model 4855001RDDTM001

8. Click Remove Rule



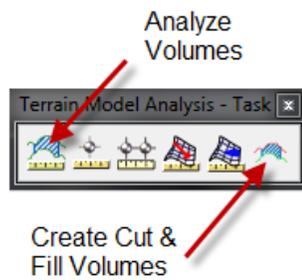
9. Click Remove Boundary

10. Select Terrain Model 4855001RDDTM001

11. Data point to accept

The result is the same whether the boundary is converted to a break line or not.

C. Terrain Model Analysis



1. **Analyze Volumes**

Calculates volume between two terrain models or a terrain model and plane (elevation). It is capable of processing in one area (fence) or in multiple areas and computing the volumes over a range of elevations.

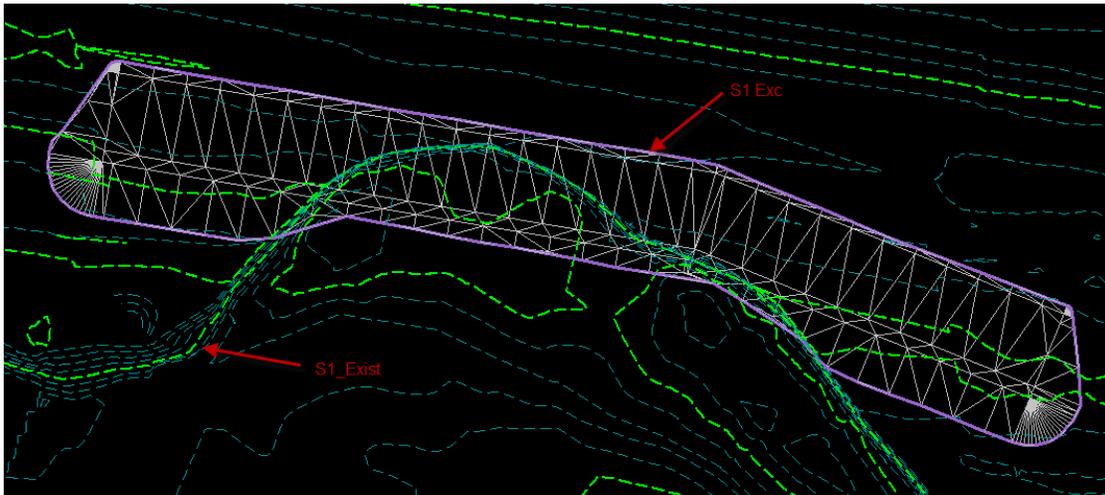
From Object is typically the existing ground terrain
To Object is the design object.

NOTE: This is not the method MDT uses for calculating earthwork. It is an excellent method of determining quantities where the average end area method does not give an accurate representation of volume.

CAUTION: Cut and Fill factors are related to, but not the same, as shrink and swell factors as applied by MDT. It is Best Practice to leave the cut and fill factors equal to one and handle shrink/swell adjustments elsewhere. (See RDM 13.3)

Exercise 10: Analyzing Terrain Model Volumes

1. **Open file** *Analyze.dgn*
2. **Click** *Analyze Volumes*
3. **Select** *Terrain Model* to *Terrain Model Volume*
4. **Choose terrain** *S1_Exist* as the **From Terrain Model**
5. **Choose terrain** *S1 Exc* as the **To Terrain Model**



6. Leave **Cut** and **Fill** factors at 1
7. **Reset** for no boundary

Note: At this point, the volumes have been calculated, and are displayed in the dialog.

Property	Value
Volume Method	Terrain Model To Terrain Model Volume
From Terrain Model	S1_Exist
To Terrain Model	S1 Exc
Cut Factor	1.000
Fill Factor	1.000
Cut	77490.733
Fill	404.816
Balance	-77085.916
Save Result	<input checked="" type="checkbox"/>

8. **Select Yes** to save the result
9. **Data point** to place the result text

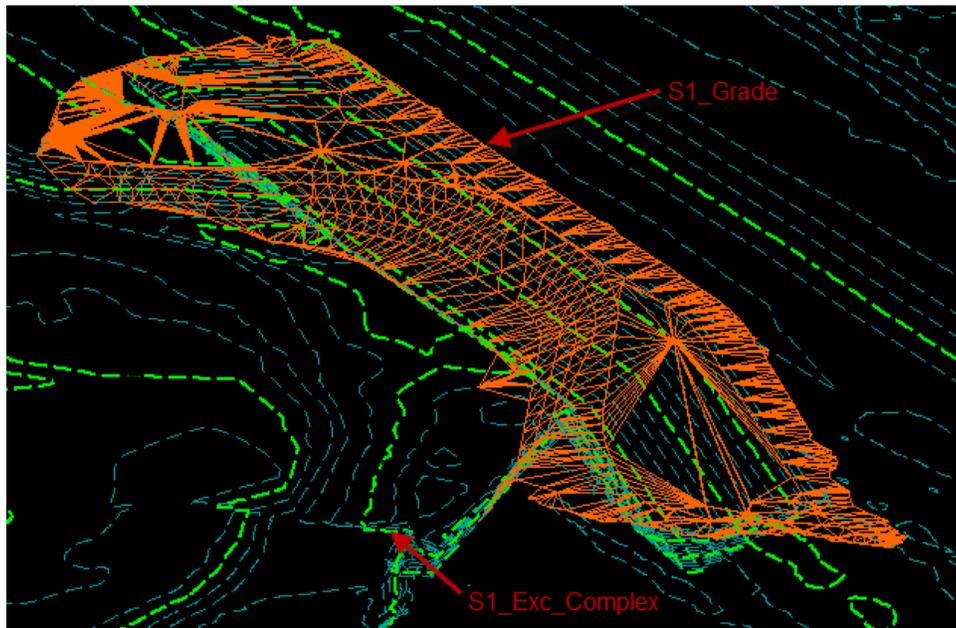
```
Terrain to Terrain Volume
-----
Terrain S1_Exist To Terrain S1_Exc
Cut Factor = 1.000
Fill Factor = 1.000
Cut = 77490.733 ft3
Fill = 404,816 ft3
Balance = -77085.916 ft3
```

10. Turn off levels PS_Terrain_Triangle and Level 12

11. Turn on levels ES_Terrain_Triangle and Level 24

12. Click Analyze Volumes

13. Repeat steps 3 – 9 using S1_Exc_Complex as the From Terrain Model and S1_Grade as the To Terrain Model



14. Close the file

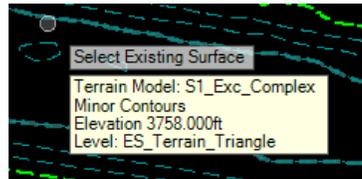


2. Create Cut & Fill Volumes

Calculates cut and fill volumes between two surfaces, usually a terrain and a second surface (terrain or mesh) and creates a 3D mesh solid for cut, and another for fill.

Exercise 11: Creating Cut and Fill Volumes

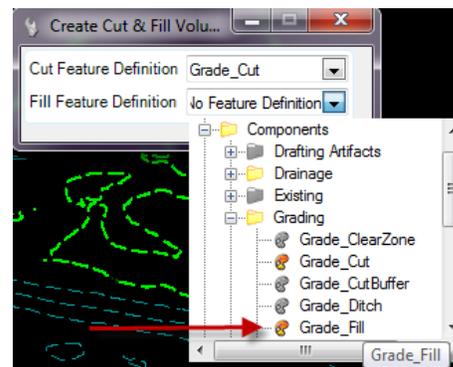
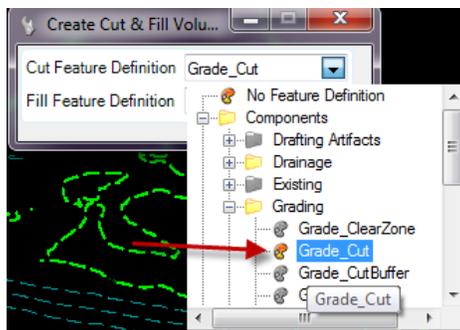
1. ***Open file Analyze.dgn***
2. ***Select Create Cut & Fill Volumes***
3. ***Select Terrain Model S1_Exc_Complex as the Existing Surface***



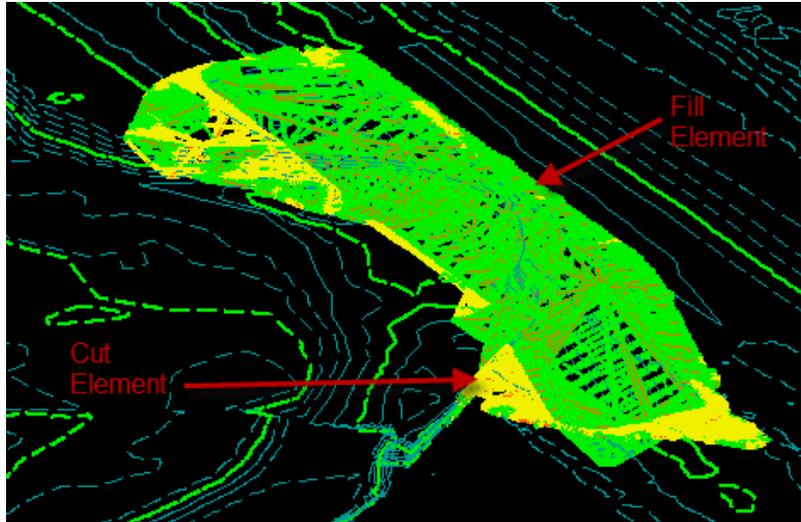
4. ***Select Terrain Model S1_Grade as the Design Surface***



5. ***Set Cut Feature Definition to Grade_Cut and Fill Feature Definition to Grade_Fill***

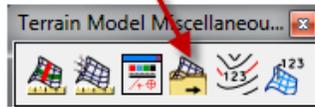


6. ***Data Point to accept***



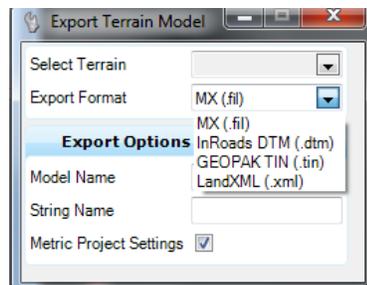
D. Terrain Model Miscellaneous

Export to File



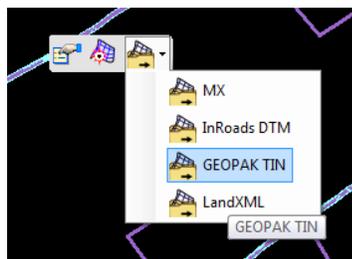
1. **Export to File**

Exports terrain to an external data type. Since MDT has no current workflow for using terrains outside of design, the terrains must be converted back to a format useful for Construction.



Workflow:

1. **Select the terrain**
2. **Select Export to File from the context sensitive toolbar.**
3. **Choose GEOPAK TIN from the drop-down menu.**



4. **Choose a location, name the TIN, and save.**