
Chapter 11

Digital Terrain

Modeling

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11.1 Objectives

- Understand Digital Terrain Models (DTM's)
- Learn how to analyze a digital terrain model

11.2 Definitions

A **Digital Terrain Model (DTM)** represents the topography of a project in the form of a triangulation network. The DTM can be drawn in a three-dimensional file, and rotated to see the existing surface of the project area.

Digital Terrain Models can be generated from various sources including MicroStation Elements, survey data, photogrammetry data, **GEOPAK** cross-sections, and geometry data.

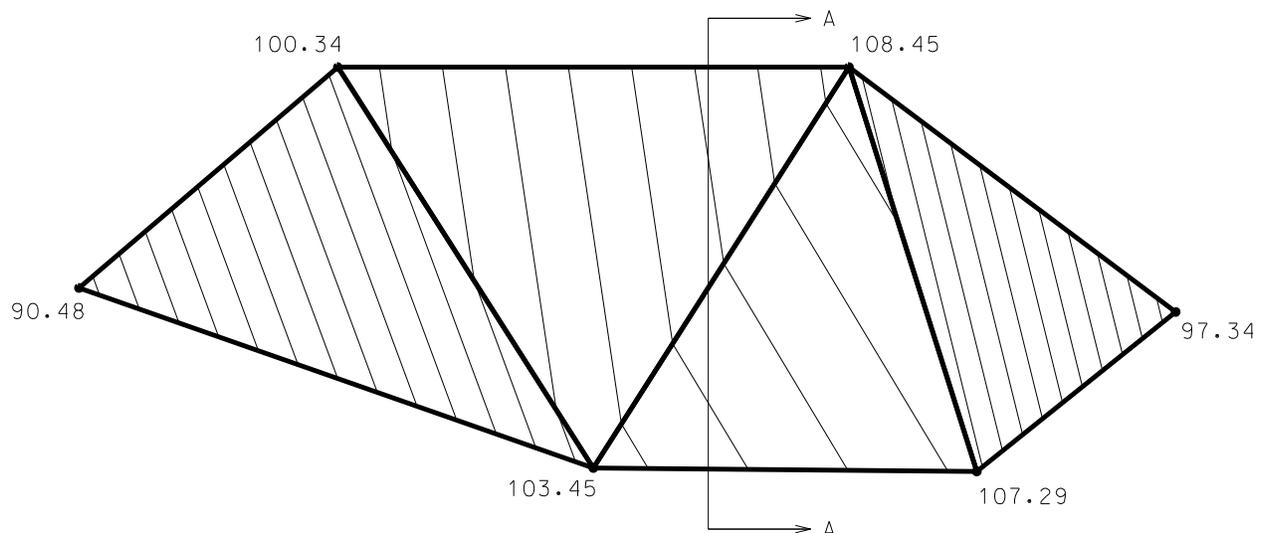
Triangulation is a mathematical process applied to stored elevation points and stored elevations along DTM break lines to create surfaces. The result of triangulations is the creation of a .tin file from which original ground profiles and original ground cross sections can be generated.

Digital Terrain Models (DTM) are made up of a network of triangles. A triangle is used because three points define a particular plane in space. This triangle then represents a slope on the existing ground passing through these three points.

The DTM is made up of several types of elements including points, breaklines, boundary, voids, and islands.

11.2.1 Points

Points represent a particular location with an X, Y, and Z coordinate. Each of these points will represent a vertex on a triangle in the digital terrain model. Below is an example of a digital terrain model made from a set of points.



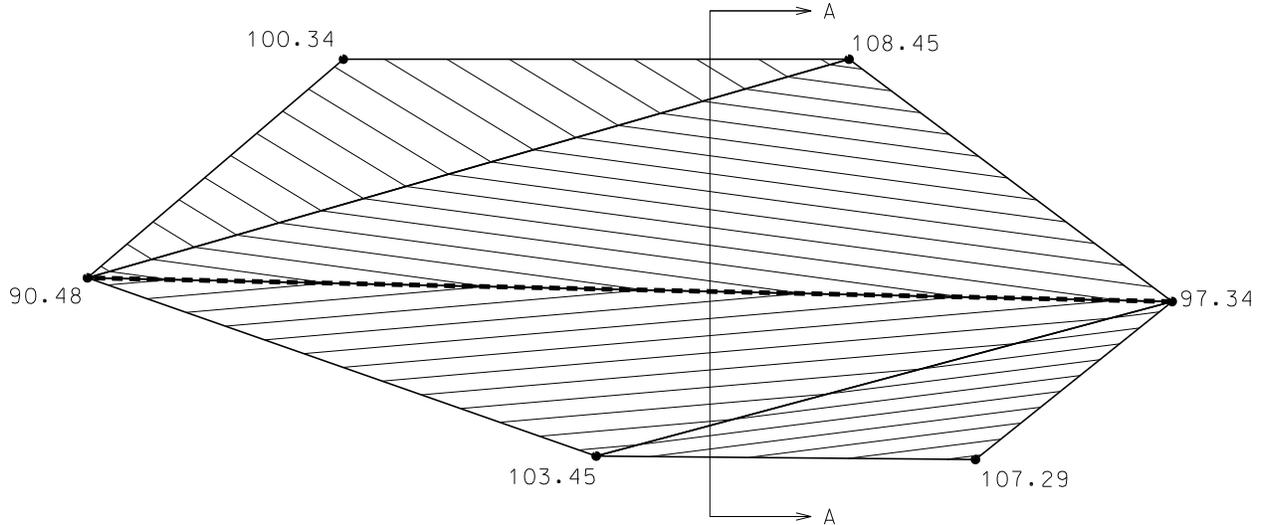
If a section is cut through this digital terrain model at the location A-A, where the elevation of the triangle leg as linearly interpolated between the triangle vertices is plotted along the distance of the section, the section would look as shown in the picture below.



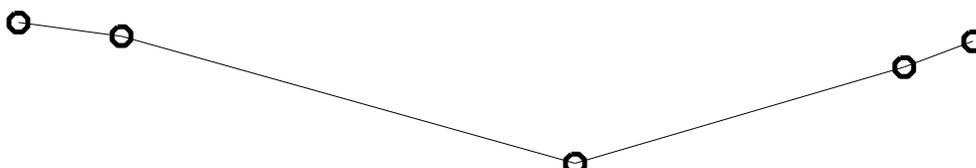
11.2.2 Break Lines

Break lines represent a line along a change in slope. Examples of breaklines may include the edge of shoulder, the toe of a slope, or the flow line of a ditch. A triangle cannot cross a breakline. If a triangle crosses a breakline, it is split into multiple triangles so that no triangle leg will cross the break line, and the triangles adjacent to the breakline will have a leg that lays on the breakline.

Adding a breakline to the same set of points used above will produce the digital terrain model as shown below.



Cutting a section at the same location will produce very different results as shown in the section below.

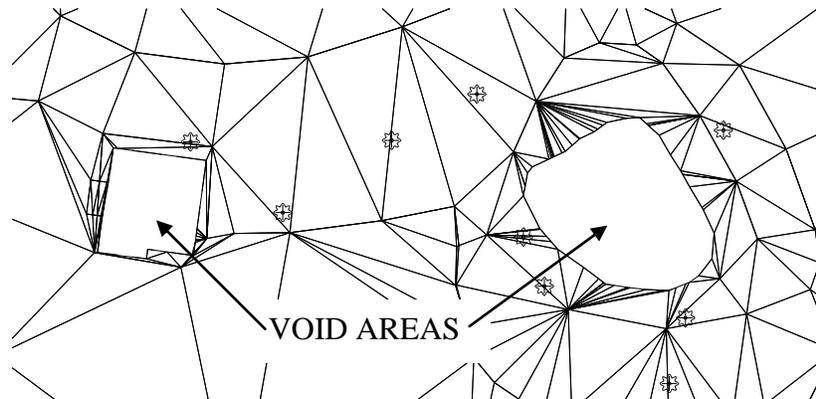


11.2.3 Boundary

A boundary is the maximum external limits a digital terrain model can extend. No triangles will be created outside of this boundary.

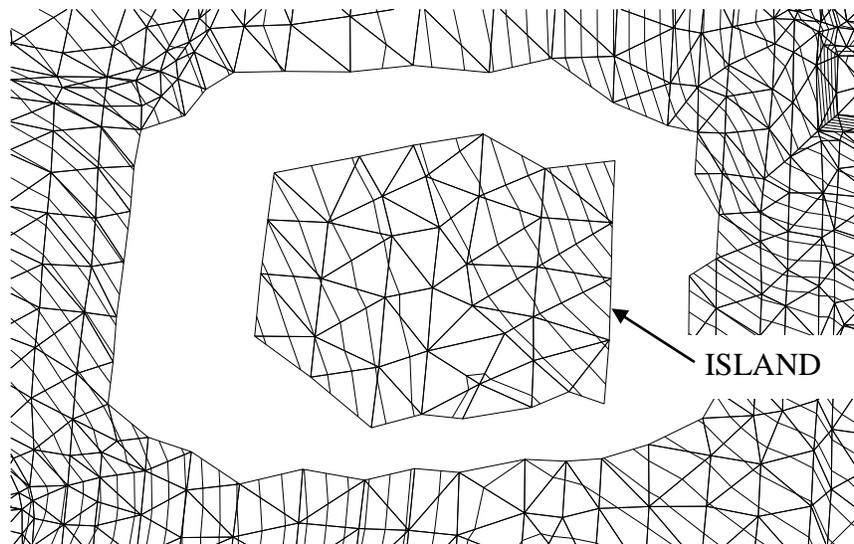
11.2.4 Voids

A void is an area where no contours can pass through. Examples of voids include ponds, lakes, buildings, concrete pads, etc.



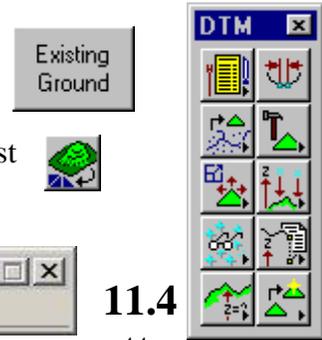
11.2.5 Islands

An island represents an area inside a void that contains contours.

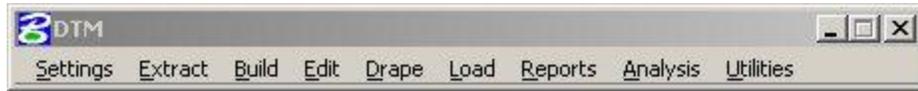


11.3 Accessing

Selecting the Existing Ground push-button from Project Manager or the DTM Tools icon, and selecting a run will bring up the tool palette shown to the right. All of the DTM tools can be accessed from the tool palette or from the DTM menu that can be accessed from the first icon in the tool palette.

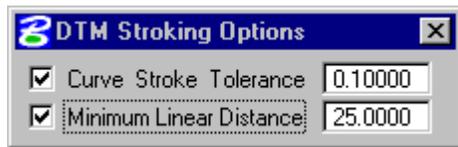


11.4
ett



ings

Two user-defined stroking values need to be defined before graphics can be extracted to create a DTM. Stroking is the process of automatically adding shots to the DTM Input file by interpolating new shots from the linear and curved sections of the data. If the source topography data is mapped in a 3D-design file, stroking may be applied. Stroking is not available if the topography data resides in a 2D-design file.

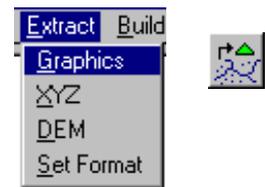


Curve Stroke Tolerance The maximum distance between the arc and the chord used to approximate the arc in the DTM.

Minimum Linear Distance If a linear segment is greater than the Minimum Linear Distance, points are interpolated and added to the segment such that the distance between the points is not greater than the Minimum Linear Distance.

11.5 Extract Graphics

The Extract Parameters tool translates MicroStation elements into DTM input data. The dialog box shown below can be accessed from the GEOPAK DTM pull down by single clicking **Extract >> Extract Graphics** or from the Extract Graphics icon in the DTM toolbox.



File Name specifies the name of the file to be created for storing the input data. If file already exists, it may be found using the **Files** button.

File Type specifies the format of the new file. Either format will produce the same results. The difference between the two is ASCII files can be viewed and edited with a text editor while Binary files process faster. For ASCII files, the number of decimal places can be chosen.

File Open indicates if you are creating a new file or appending data to an existing file.

Feature Type determines the type of feature to extract from a design file.

Spots – random survey points. Can be vertices of a line or line string.

Breaks – designate linear features such as edges of pavements, ditch bottoms, ridges, etc.

Boundary – the external boundary of the digital terrain model.

Contours – for use in extracting digitized or otherwise imported contours.

Void – closed shapes representing an area with no contours. (i.e. ponds, headwalls, concrete pads, etc.)

Islands – an area within a void that contains contours.

Graphic Triangles – for use in extracting triangles from a TIN model that has been otherwise created or imported.

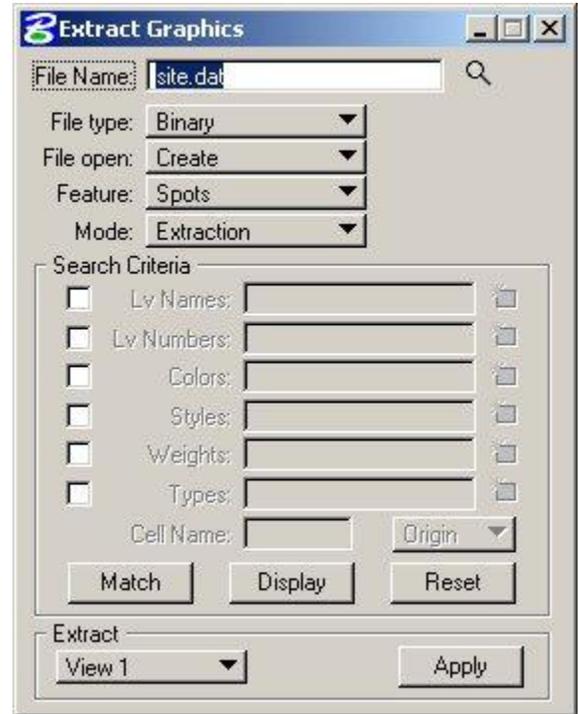
Drape Void – same as void, except uses the elevation from the triangulated model.

Break Void – same as void except edges are inserted as breaklines instead of drapelines.

Mode the extraction mode calculates XYZ data directly from the coordinate values of 3D MicroStation elements. The interpolation mode produces XYZ data by interpolating between spot elevations along linear MicroStation elements. This mode works in both 2D and 3D files.

Select Criteria provides ways to specify the features to be extracted. When an “X” is placed in the box next to Levels, the Select box is activated. You may then click the Select button to indicate only those levels you want GEOPAK to search for when extracting data. If the Levels box is not turned on, GEOPAK will search all levels. The same procedure is true for the other criteria selections. The three buttons located at the bottom of the **Select Criteria** group box **Match**, **Display**, and **Reset** will assist you in interactively defining the search criteria.

Extract there are four options for data extraction. **Complex Chain** reads those elements along adjoining MicroStation elements. **Selection Set** uses a MicroStation



Selection Set to define elements for extraction. **Fence** will extract all elements within a fence boundary. **View 1** etc. will extract all the elements displayed in the selected view.

11.6 Build



Included under the **Build** pull down and icons are options for creating, manipulating, and merging DTM models.



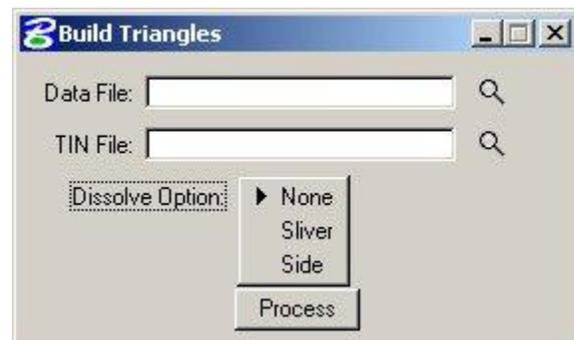
11.6.1 Build Triangles

Build > Triangles processes the information stored in a DTM input file (.dat) to create a triangulated model (.tin). The file extension represents a triangular irregular network.

Data File is the name of the DTM input file where the extracted topological features are stored.

TIN File is the name of the file in which the triangulated model will be stored in binary format.

In either of the above cases, you do not have to enter the file extension with the file name and you can always navigate to an existing file using the **magnifying glass** button.



The **Dissolve Option** eliminates external triangles that are not representative of the surface. The three options are:

None – no external triangles are dissolved.

Sliver – long, thin triangles are dissolved.

Side – external triangles whose external side is longer than a user specified length are dissolved. (Recommended Option)

11.6.2 Additional Build Options

Build > Lattice creates a grid (.lat) that can be draped over the triangulated data (.tin) to create a three dimensional visual display of the topography.

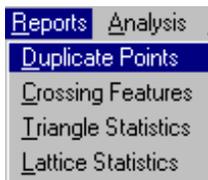
Build > Merge allows two triangulated models to be merged together as long as the boundary of one model overlaps the other. This process will create a third model (.tin) from the combination of the two existing models.

Build > Clip creates a new model (.tin) from a clipped portion of an existing model. The area is defined as internal or external to a user defined clip polygon.

Build > Pad defines a pad (such as a building slab) and integrates the pad into the existing terrain with a variety of slope options.

Build > Delta Surface creates a new model based on the difference between two other models, or a model and elevation surface. The Z value in the model that is created is equivalent to the difference between the two specified models, or model and surface.

11.7 Reports



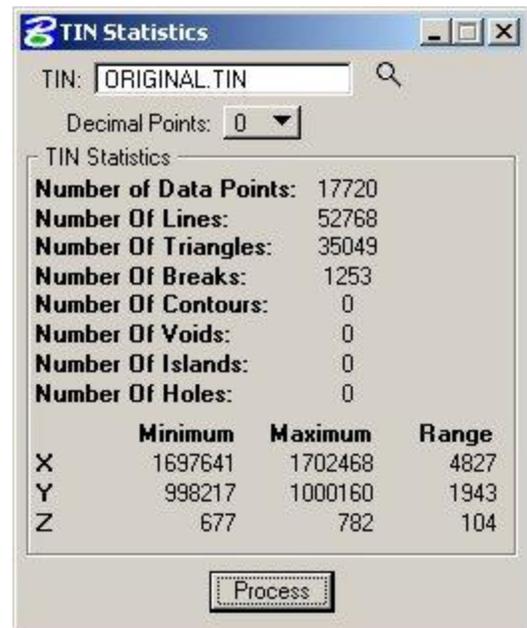
The options under the **Reports** pull down and icons include a way to check for duplicate points or crossing breaklines, and the ability to generate statistics associated with a .tin file.



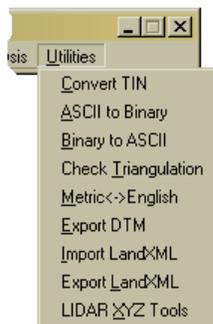
Duplicate Points – reports points with the same x and y coordinates.

Crossing Features – reports intersecting breaklines or contours.

Triangle Statistics and Lattice Statistics - displays a summary indicating the total count of each element type and minimum and maximum X, Y, Z ranges for the specified .tin or .lat file.



11.8 Utilities



Options under the **Utilities** pull down and icons include a way to check the validity of a triangulated file, converting triangulated files from previous versions of GEOPAK, converting the DTM data file between ASCII and binary format, converting the DTM from English to Metric, and exporting a TIN to Trimble DTX model or Leica GSI model.

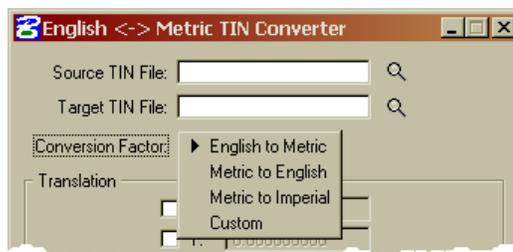


Convert TIN – permits the conversion of a triangulated file from a previous version of GEOPAK to a GEOPAK 98 format.

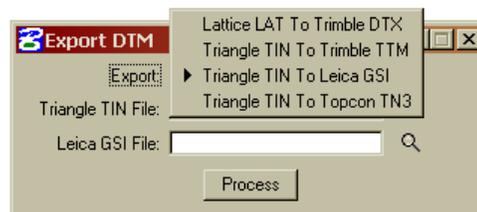
ASCII to Binary and **Binary to ASCII** - permits conversion of the DTM input file (.dat)

Check Triangulation - starts an internal process that verifies the integrity of the triangulated file. A message will appear indicating "Triangulation Valid".

Metric <-> English – converts a file from English to Metric units, or from Metric to English or Imperial units. A custom scale factor can also be used. The DTM can also be translated or rotated. If translation or rotation is desired without scaling, a Custom scale of 1.0 can be used. This process will create a new DTM file.



Export DTM – uses a LAT or TIN to create files suitable for GPS controlled construction equipment. This tool supports both Trimble and Leica file format.



Import LandXML - uses a LandXML file to create a DAT readable by the various DTM tools.

Export LandXML – uses a TIN file to create (or append to) a LandXML file, suitable for import into external programs



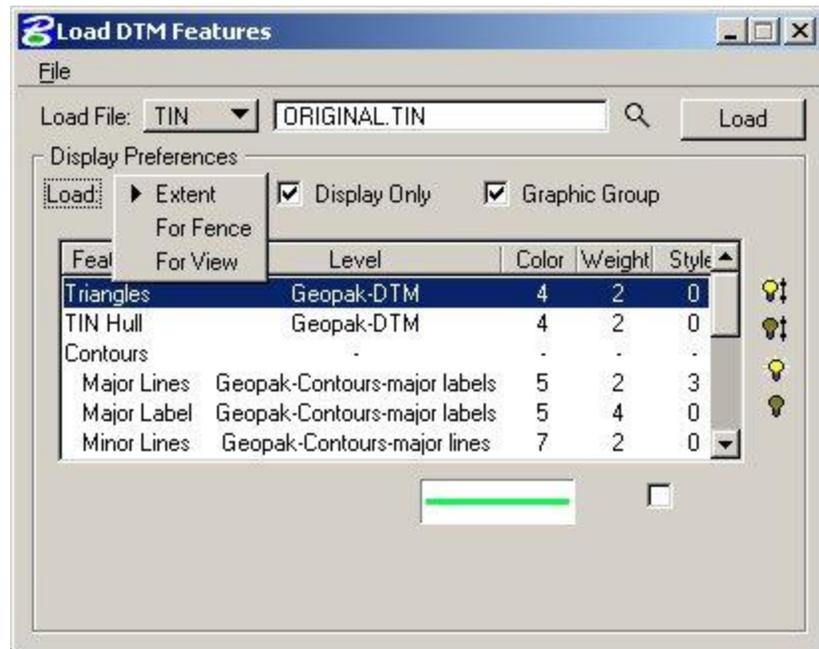
11.9 Load



Load is the process by which we can visualize the DTM data, the TIN model, the lattice model, and the contours. By clicking on **Load >> DTM Feature**, or by clicking on the icon, the following dialog will appear.



The user can choose to load the DTM data (.dat), the TIN file (.tin), or the lattice file (.lat). Each of these files can be loaded for the model extents, within a fence, or within a window.



Toggling on **Display Only** will allow the user to view the elements without writing them to the MicroStation file. Conversely, toggling **Display Only** off will store the viewed elements as MicroStation elements. If **Display Only** is on, updating the active screen will clear the display of these elements. When **Display Only** is off, the elements can be placed as a graphic group using the **Graphic Group** toggle.

The user can set what data to visualize, the symbology, and the contour interval (if **Contours** is turned on).

The default MoDOT symbology to visualize DTM items is stored in a preference file. To load the file into dialog box, go to **File >> Open** and navigate to **t:\gpk_std\DTM\ MoDOT.lpf**.

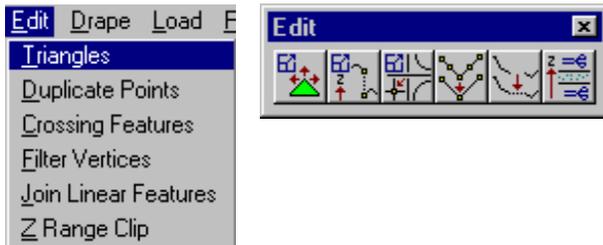


- Will turn on all items.
- Will turn off all items.
- Will turn on only the selected item.
- Will turn off only the selected item.

11.10 Other Pull Down Menus

11.10.1 Edit

The **Edit** pull down provides the ability to edit the digital terrain model.



Triangles - Allows the user to add, delete, or modify triangle vertices, triangle legs, and breaklines.

Duplicate Points – Reports and allows interactive editing of points in a survey data file with the same X and Y coordinates.

Crossing Features – Reports and allows the correction of crossing breaklines.

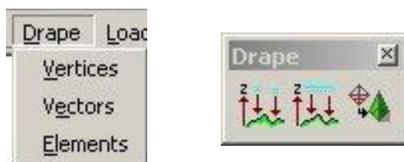
Filter Vertices – Reduces the amount of vertices by deleting the vertices based on a user specified distance.

Join Linear Features – Allows the user join two linear features into one feature.

Z Range Clip – Deletes information from the survey data file (**.dat**) based on given elevation information.

11.10.2 Drape

GEOPAK provides three tools for draping MicroStation elements onto a triangulated model, vertices, vectors and elements.



Volumes – Will calculate the volume between two TIN models, the volume between a TIN model and a plane, or the cut and fill totals between two TIN models.

Elevation Differences – Will display the elevation difference, or the amount of cut and fill between two TIN models, or a TIN model and a plane.

Slope Area – Displays the slope area of a TIN model, or a portion of a TIN model.

Themes – Displays the digital terrain model based on different user definable themes such as, elevation ranges, slope percentage, slope degree, or aspect.

Drainage Tools – Allows a user to display and analyze drainage patterns with in a TIN model. Tools include delineating watersheds, drawing flow arrows, determining upstream and downstream traces, and finding high and low points.

Visibility – Displays lines of sight (which triangles can and cannot be seen), or what is visible between two specified points.

Trace Slope Path –Traces a path along a TIN file, or if site modeler is active, a site model or object.

Trench Volumes – Using pipes from a Drainage project and / or Water Sewer project, this tool uses a TIN file (and optional offset) to compute trench and bedding volumes.

For more information on these items, see the *GEOPAK Help Applications > GEOPAK Road > Help*.

Camera – Supports a wide variety of tools and options to view Digital Terrain models within a MicroStation 3D file.



Once a 3D model has been created in Geopak, the *DTM Camera Tools* shown to the left can be used to create a drive or fly through of the project.



Before a fly through can be created, the camera and targets must be set using the **Locate Camera and Target Tools**. This is done by setting two data points, the location of the camera and the target view. Once both the camera and targets are set, the next two tools in the pallet can be used to adjust them individually.



Locate Camera Tool

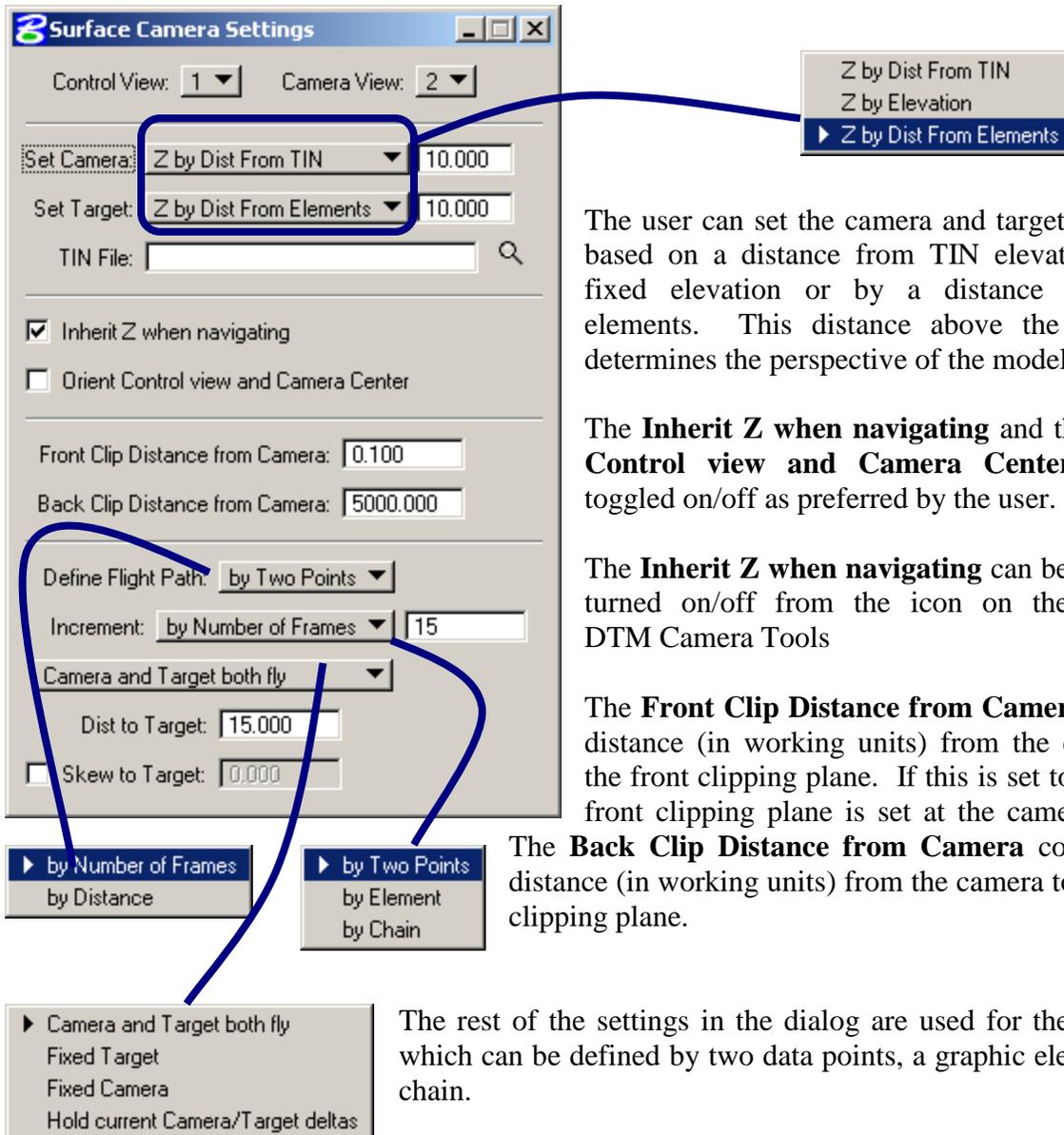


Locate Target Tool

The **Fly Path Tool**  allows the user to start the fly through once all the **Surface Camera Settings**  are defined.

The **Surface Camera Settings** dialog is shown below.

Control View and Camera Views should be set to MicroStation view 1 and view 2 respectively. The Control View is typically a top view, which is used to define the camera and target locations



The screenshot shows the **Surface Camera Settings** dialog box with the following settings and callouts:

- Control View:** 1
- Camera View:** 2
- Set Camera:** Z by Dist From TIN (10.000)
- Set Target:** Z by Dist From Elements (10.000)
- TIN File:** [Empty field]
- Inherit Z when navigating**
- Orient Control view and Camera Center**
- Front Clip Distance from Camera:** 0.100
- Back Clip Distance from Camera:** 5000.000
- Define Flight Path:** by Two Points
- Increment:** by Number of Frames (15)
- Camera and Target both fly** (selected)
- Dist to Target:** 15.000
- Skew to Target:** 0.000

Callouts from the dialog box:

- Set Camera:** Z by Dist From TIN, Z by Elevation, Z by Dist From Elements
- Define Flight Path:** by Number of Frames, by Distance, by Two Points, by Element, by Chain
- Camera and Target both fly:** Camera and Target both fly, Fixed Target, Fixed Camera, Hold current Camera/Target deltas

The user can set the camera and target elevation based on a distance from TIN elevation, by a fixed elevation or by a distance from the elements. This distance above the elements determines the perspective of the model.

The **Inherit Z when navigating** and the **Orient Control view and Camera Center** can be toggled on/off as preferred by the user.

The **Inherit Z when navigating** can be turned on/off from the icon on the DTM Camera Tools 

The **Front Clip Distance from Camera** sets the distance (in working units) from the camera to the front clipping plane. If this is set to zero, the front clipping plane is set at the camera origin.

The **Back Clip Distance from Camera** controls the distance (in working units) from the camera to the back clipping plane.

The rest of the settings in the dialog are used for the fly path, which can be defined by two data points, a graphic element or a chain.

The increment determines the distance between each step of the flight along the flight path.

The last options shown to the left determine whether the camera and target are stationary or moving during the flight.

The Skew to Target toggle can be turned on or off.

The last four icons on the tool bar are used for camera navigation. The icons are listed below.



Navigate camera



Zoom Camera Out



Zoom Camera In



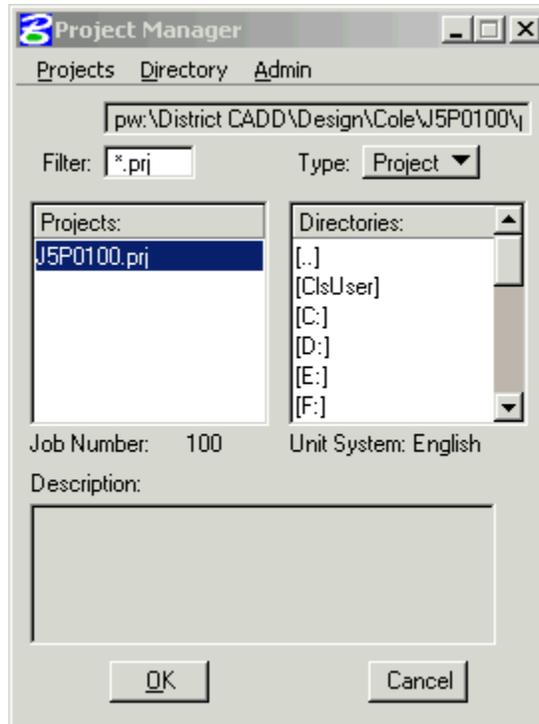
Display More Camera Settings

11.11 Group Exercise: J5P0100 Project DTM

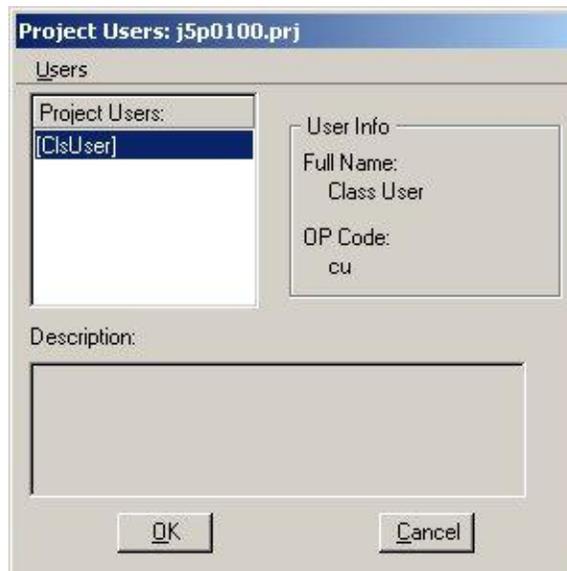
1. Open the following MicroStation file:

pw:\District CADD\Design\Cole\J5P0100\data\topo_J5P0100.dgn

2. Open the project **j5p0100.prj**.



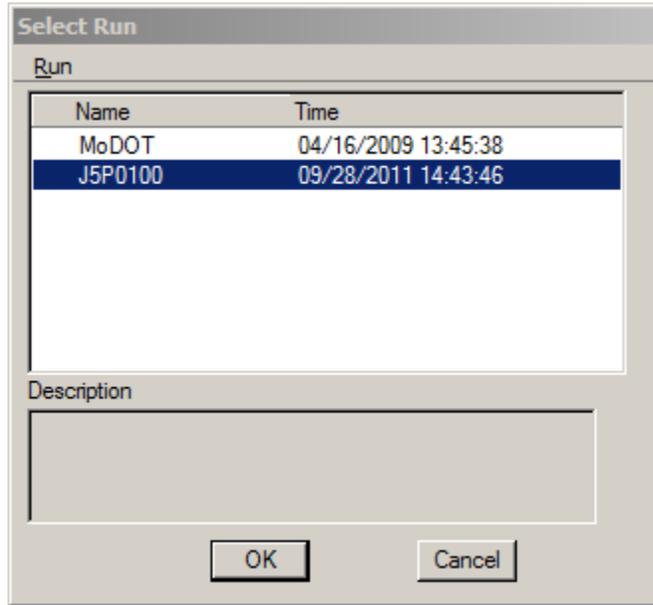
3. Select the user **ClsUser**.



4. Select the **Existing Ground**.



Copy the MoDOT run to **J5P0100**, and open the **J5P0100** run.



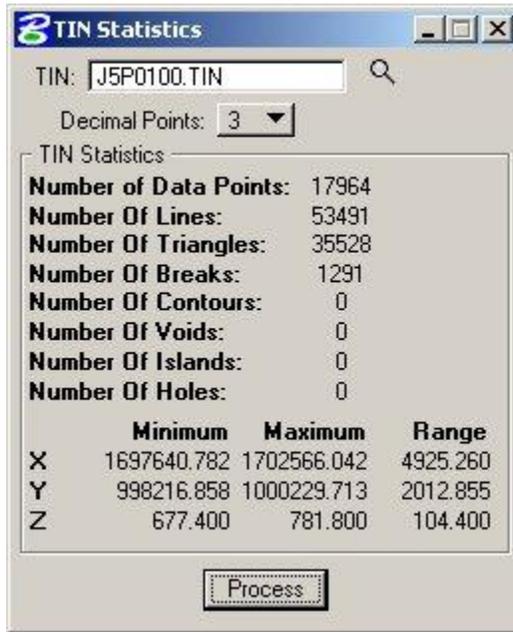
5. Use the **Build > Merge TINs** tool to merge the **25857dm.tin** with the **Original.tin**.

Select the **Original.tin** as the **Old Tin** and the **25857dm.tin** as the **Mrg Tin**.

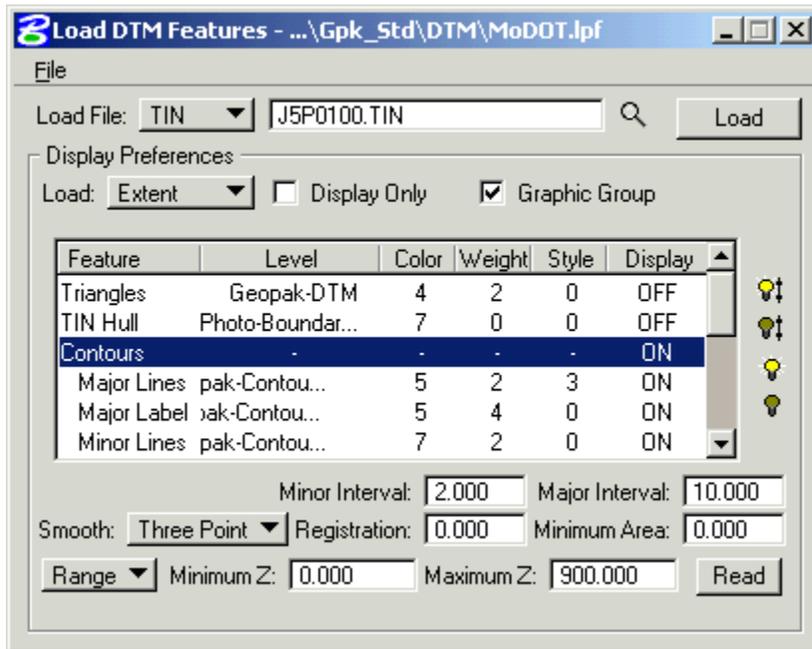
For the “New Tin” type **J5P0100.TIN**



6. Check the **Triangle Statistics** of the tin file **J5P0100.tin**.

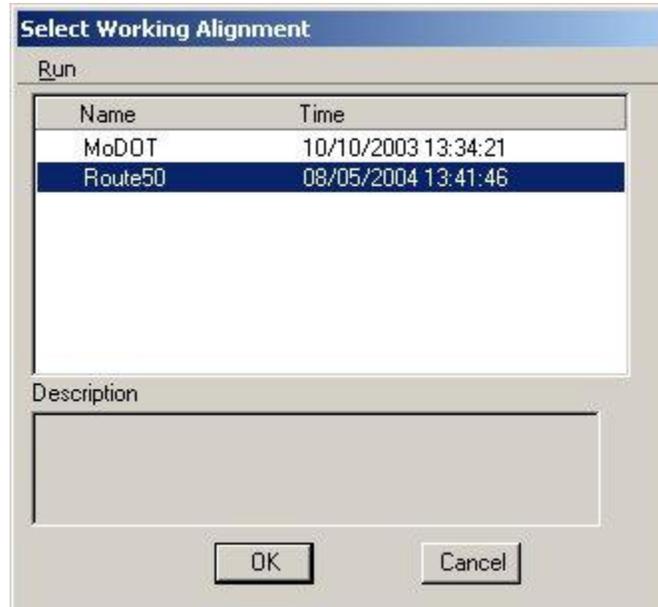


7. Load the contours into the file. Do this turning on the display for Contours, Major Lines, Major Label, and Minor Lines. Set the contour settings as shown below. For the Major Labels, set the **Distance Between Labels**: to **500** and **Th: & Tw:** to 6. Load them as permanent elements as a **Graphic Group**.



8. Choose the **Select** button to create a new **Working Alignment**.

Copy the **MoDOT** Working Alignment to **Route50**, and select the **Route50** working alignment.

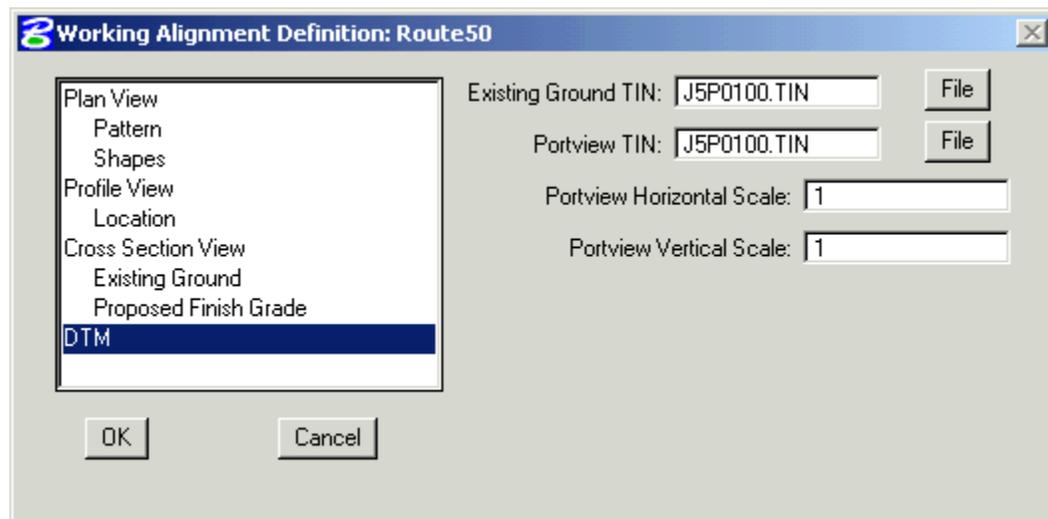


9. Set the **DTM** section of the **Working Alignment Definition** (Define button)

Set the **Existing Ground TIN** and **Portview TIN** to the following:

pw:\District CADD\Design\Cole\J5P0100\data\J5P0100.TIN

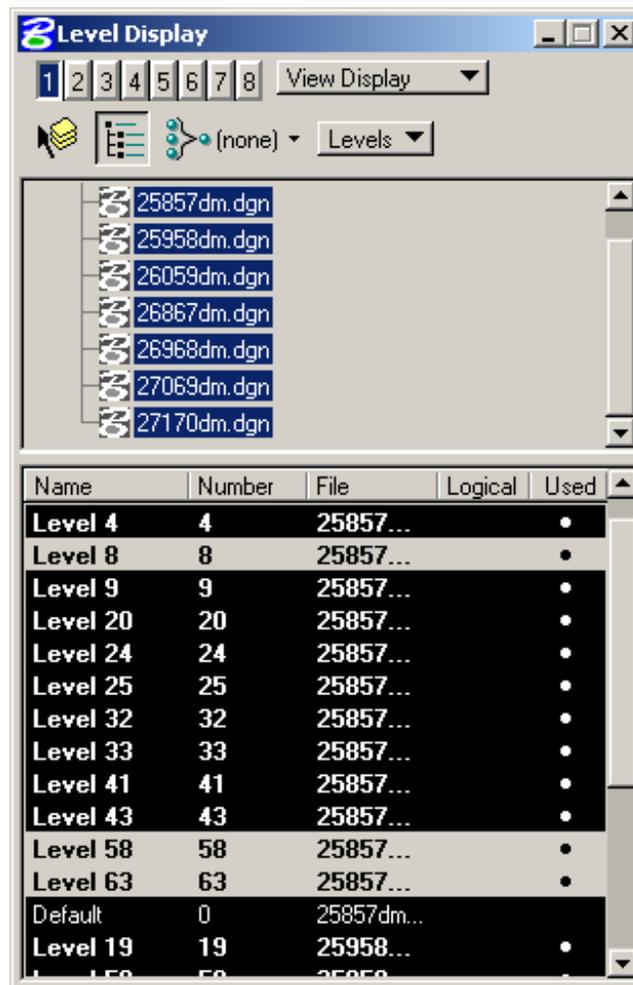
Set the **Portview Horizontal** and **Vertical Scales** to **1**.



10. Reference the photogrammetric files to **topo_j5p0100.dgn**:

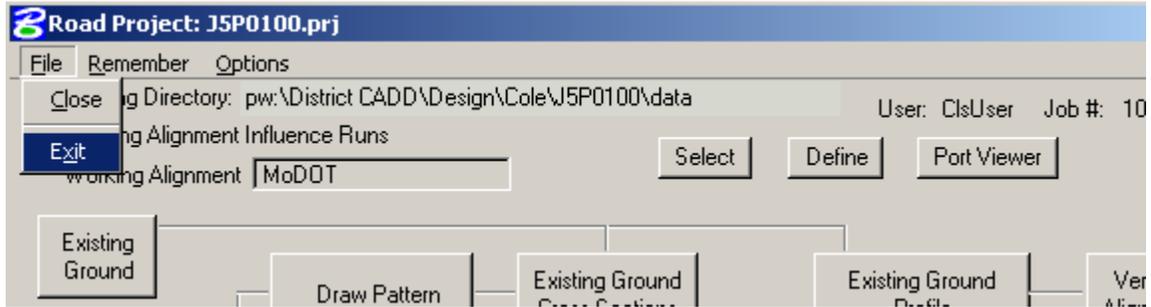
- 25857dm.dgn
- 25958dm.dgn
- 26059dm.dgn
- 26867dm.dgn
- 26968dm.dgn
- 27069dm.dgn
- 27170dm.dgn

Open the **MicroStation Level Display**; highlight the attached reference files; and **turn of** Level 8, Level 58, and Level 63 as shown below.



Save the changes to the MicroStation file.

11. Exit Project Manager by going to the Road Project pull down menu **File > Exit**.

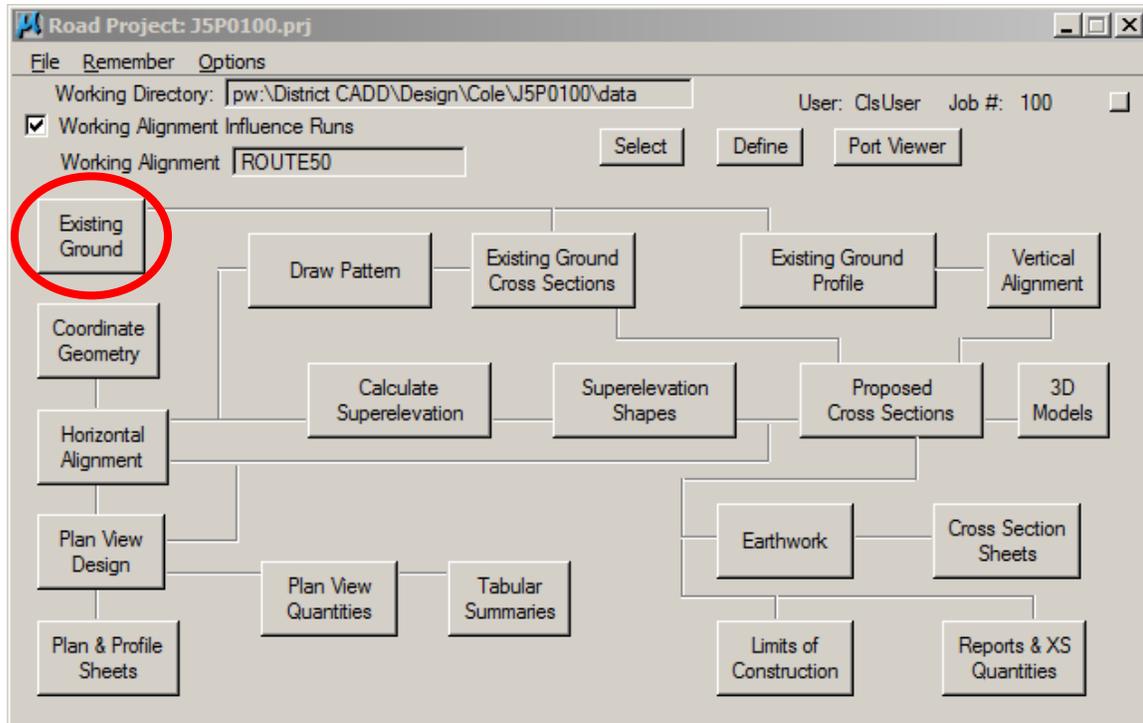


11.12 Group Exercise: Merge DTM

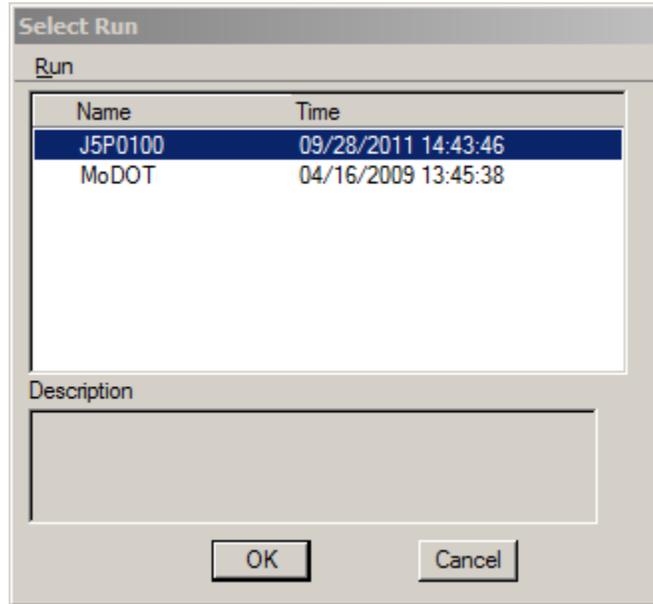
1. Open the Microstation file

pw:\District CADD\Design\Cole\J5P0100\data\dtm_J5P0100.dgn.

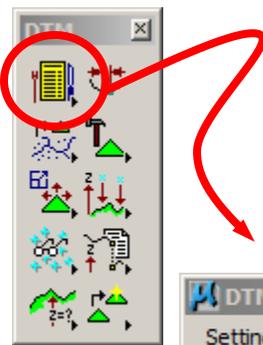
4. From the flow chart select **Existing Ground**



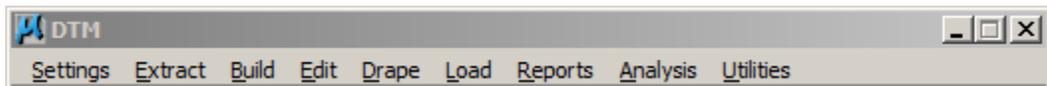
2. Open the **J5P0100** run.



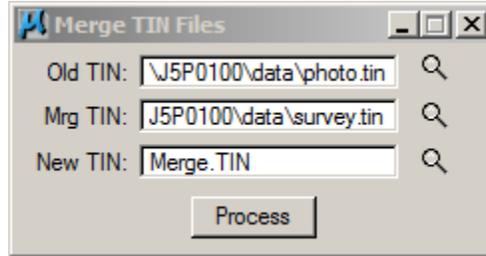
The DTM toolbar is enabled.



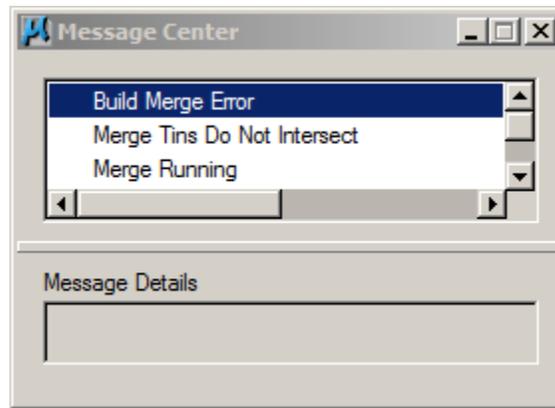
Click the “menu” icon to open the DTM pull down bar.



- Use the **Merge TINs** tool (**DTM Menu: Build > Merge**) to merge the (Mrg Tin:) **survey.tin** into the (Old Tin:) **photo.tin** to create the (New Tin:) **J2P0200.tin**. The Files button can be used to select the first two tins; but the name of the new tin needs to be typed because it does not exist yet.



You should get the following error in the **MicroStation Message Center**:



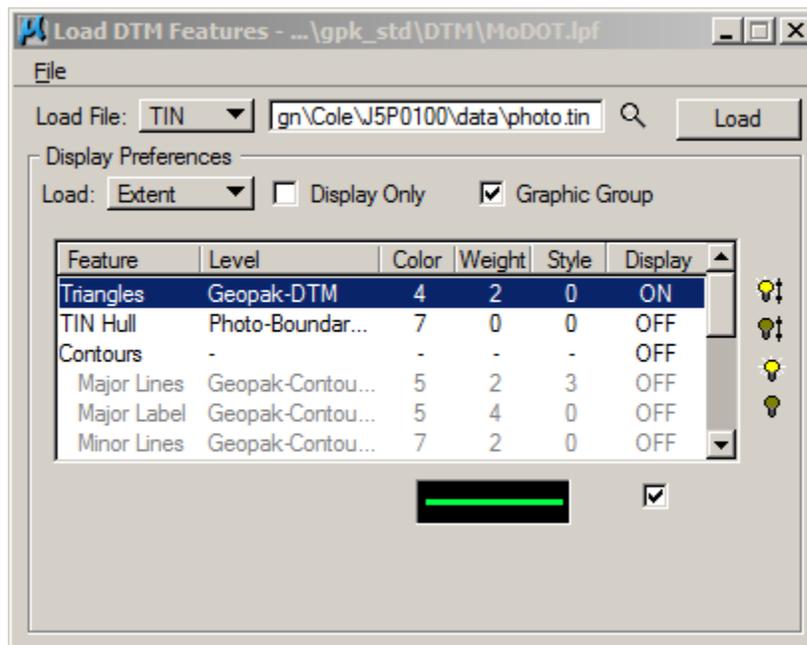
4. To see the reason for the error, plot the two existing tins using the DTM Menu.

Load > DTM Features tool

Uncheck Display Only, and Check **Graphic Group**

Turn **ON** Triangles

Select the **photo.tin** file



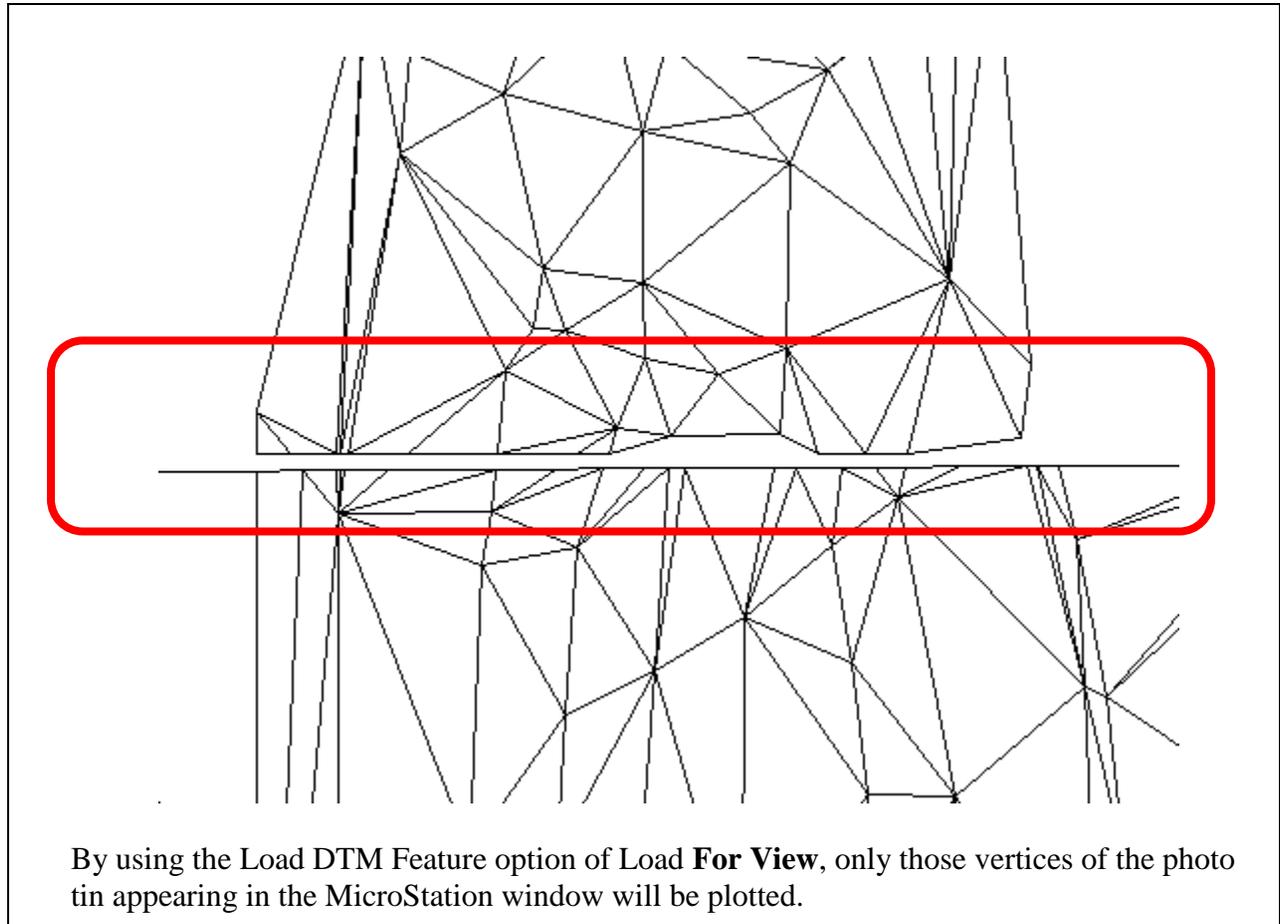
Click on the **Load** button to plot the triangles. Select the MicroStation **Fit View**. Switch the tin to the **survey tin** and load its triangles using the same settings.

Window into the area between the two tins and notice that they do not touch. For two tins to be merged in GEOPAK, they must have at least one point in common.

5. To correct this error without sending the survey party back to pick up additional coverage, we will extract some graphics to make the two tins connect.

A few of the vertex elevations for the photo tin and all of the vertex elevations for the survey tin will be plotted into the 3D file **dtm_J5P0100.dgn**. Once the elevations are plotted as text, the Extract Graphics tool will store points based on the text locations.

Window in to where the two tins come together as shown below. The **photo.tin** is the one on the bottom.



6. From the **Load > DTM Features** tool set up as shown

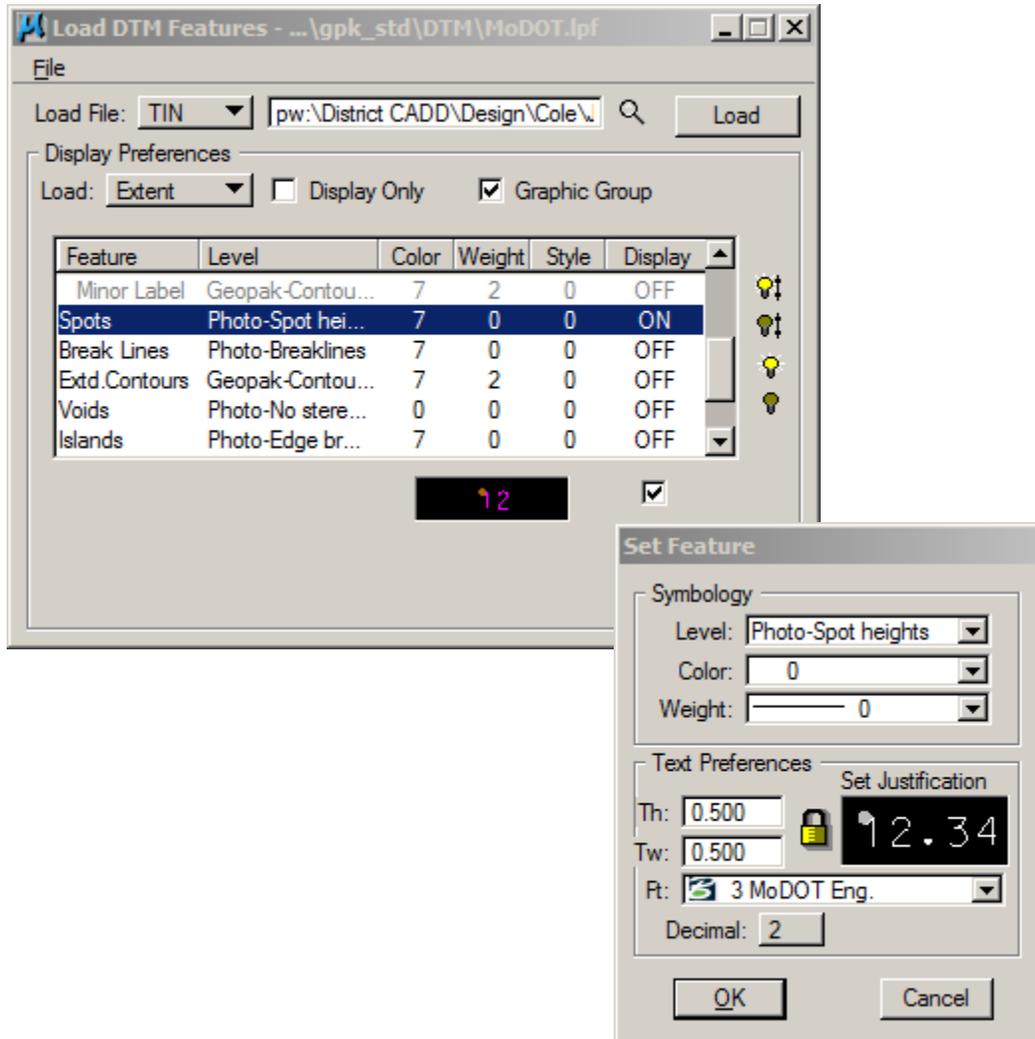
TIN: photo.tin

Load: For View or Fence

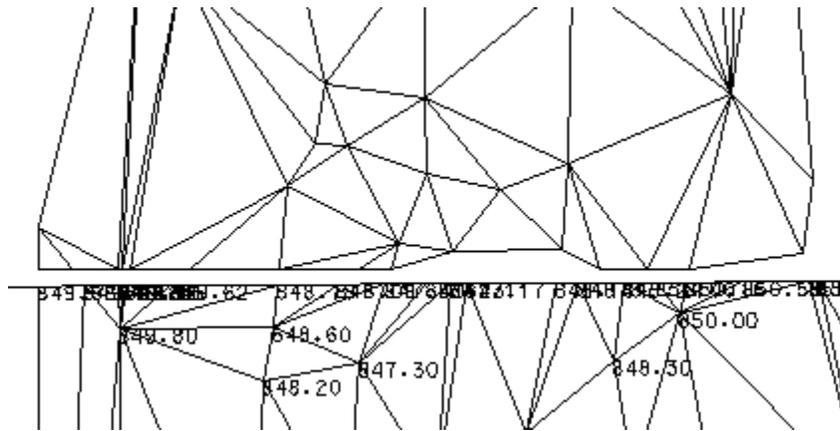
Display only is unchecked AND Graphic Group is checked.

Turn off all features except for **Spots** (Color, Style, & Weight are all 0).

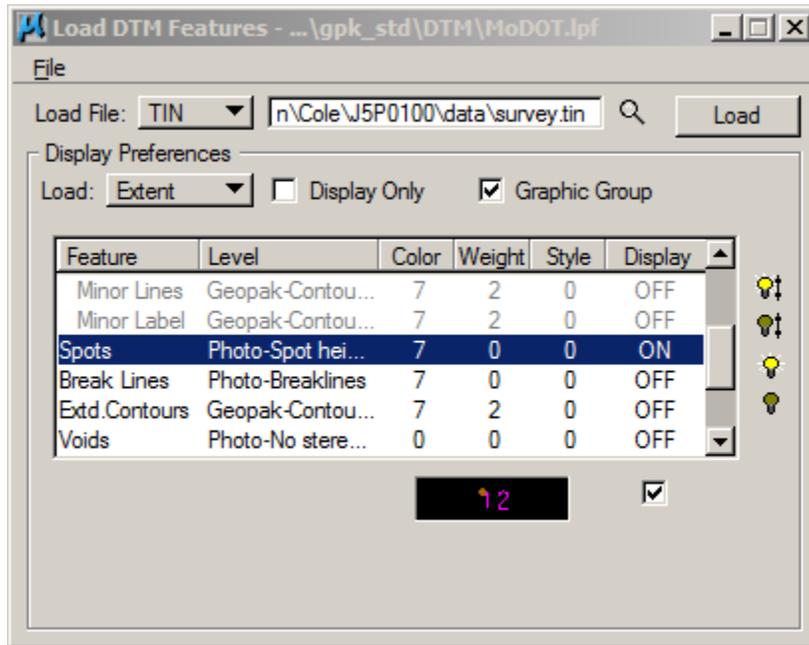
Select the **Load** button to plot the elevations for the **photo.tin**.



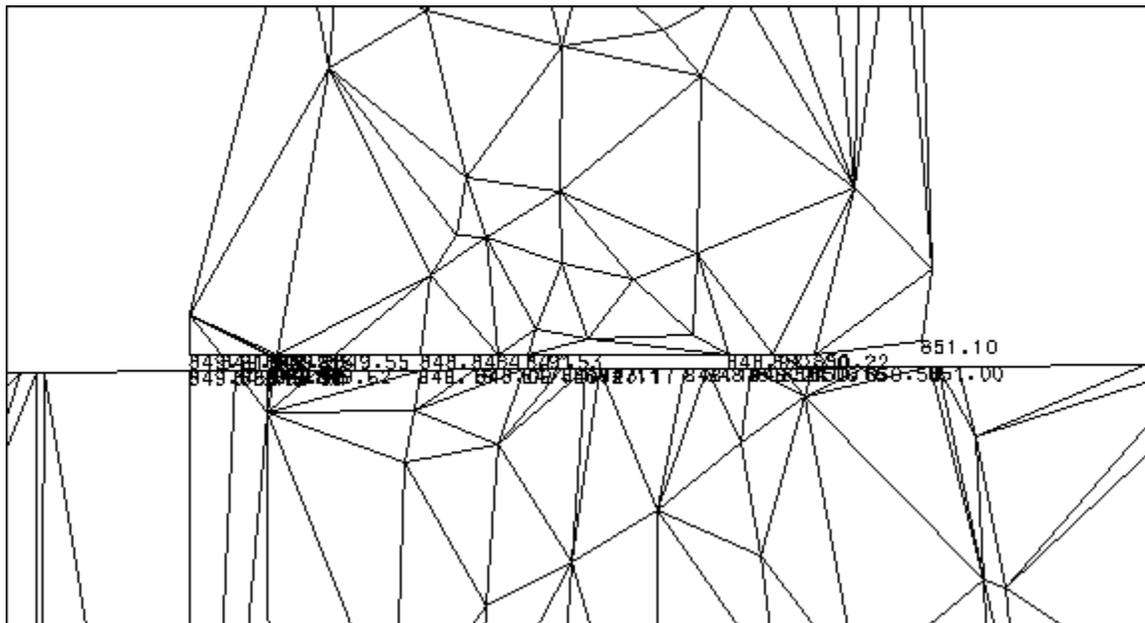
7. Adjust the MicroStation view so that only the lower edge of the survey tin is visible, as shown below.



- In the Load DTM Features dialog, switch the tin to the **survey tin**, leaving all of the other settings the same. Click on Load to plot the desired elevations for the **survey.tin**. Close the Load DTM Features tool and **save** the changes to the MicroStation drawing.



Window out once and delete any elevations that are not on the boundaries between the two tins, as shown below. You will need to either override or turn of t he Graphic Group lock to keep from deleting all of the elevations.

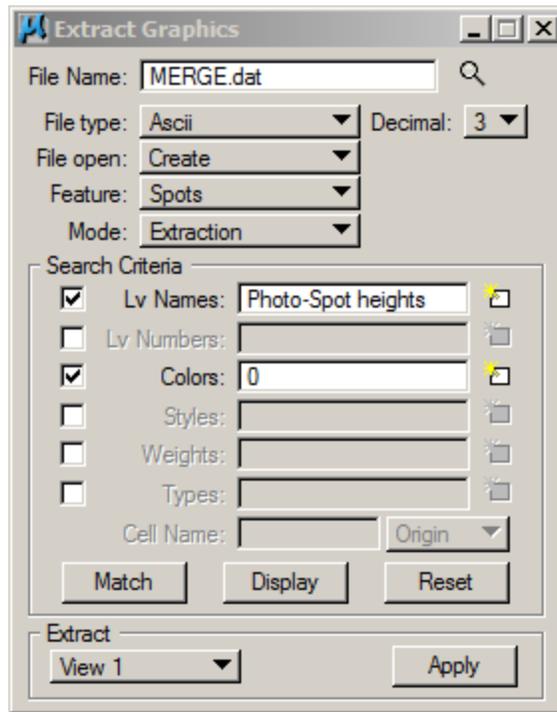


Save the changes to the MicroStation drawing.

9. From the DTM menu, select **Extract > Graphics**

Set up the dialog as shown below.

File type: **Ascii**
 File open: **Create**
 Feature: **Spots**
 Mode: **Extraction**
 Decimal: **3**



In the **Select Criteria** section of the dialog, check **Levels** and **Colors**. Click on the **Match** button and DP (data point) on the white text.

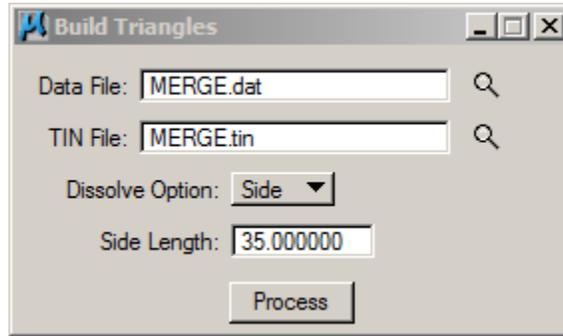
Click on **Apply** to create the data file. Because an ASCII file was created, the results can be viewed in Ultra Edit or another text editor. The file should consist of a series of lines, each one giving the X, Y, and Z coordinate of a spot point. A portion is shown below:

```

1 1676361.022 1262516.635 849.881
1 1676367.934 1262516.676 849.884
1 1676372.907 1262516.705 849.882
1 1676373.330 1262516.708 849.895
1 1676374.122 1262516.713 849.847
1 1676380.538 1262516.751 849.618
1 1676396.368 1262516.844 848.780
1 1676405.170 1262516.896 848.091
1 1676412.311 1262516.938 847.497
    
```

10. Use the Build Triangles tool (**DTM Menu: Build > Triangles**) to create the **TIN file: merge.tin** from the **Data File: merge.dat**. (Since the file merge.tin does not exist yet, its name needs to be typed into the TIN File field.)

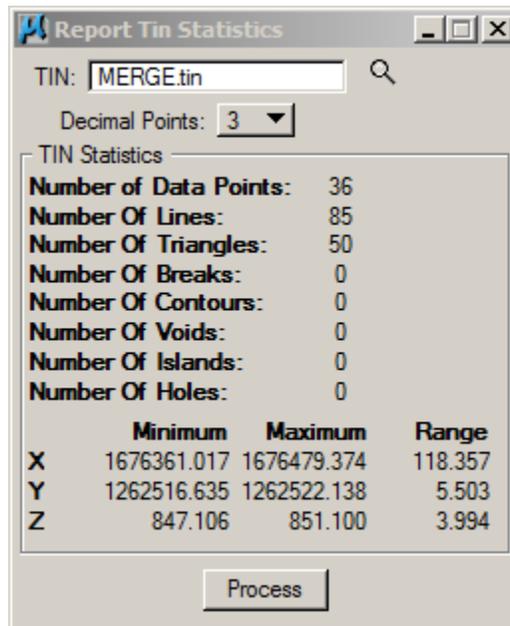
Set the Dissolve Option to **Side** and the Side Length to **35**. Click on Process to create the TIN.



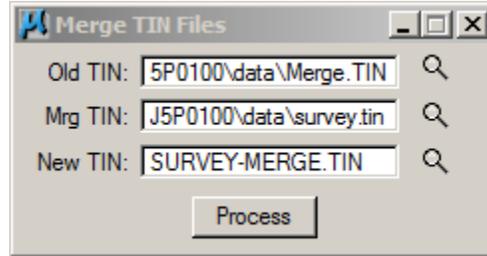
You will get the following notice in the message center:



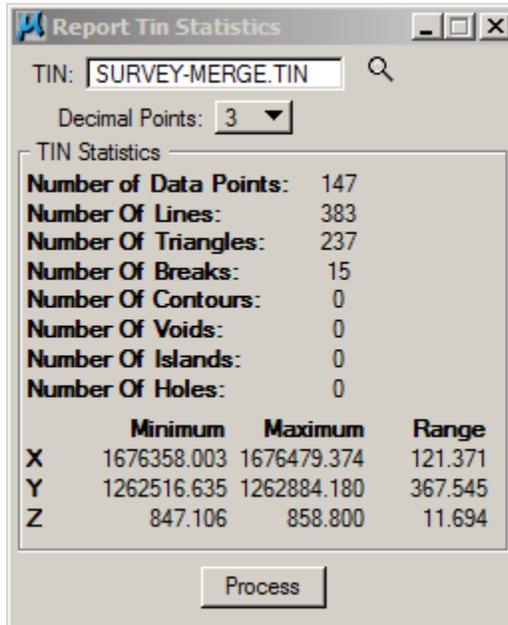
11. Check the **Triangle Statistics (DTM Menu: Reports > Triangle Statistics)** of the tin file **merge.tin**



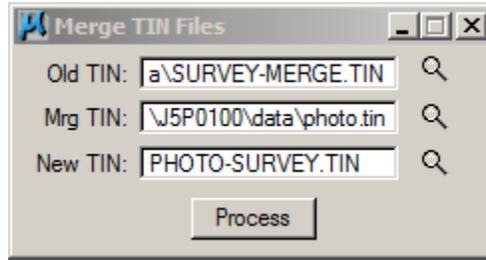
12. Use the **Merge TIN** tool (**DTM Menu: Build > Merge**) to create a new TIN from **merge.tin** (Old Tin) and **survey.tin** (Mgr Tin). Call the new TIN **Survey-Merge.tin**. (Note: the survey tin is used as the merge tin because it contains data actually collected in the field.)



Check the statistics for the new tin.

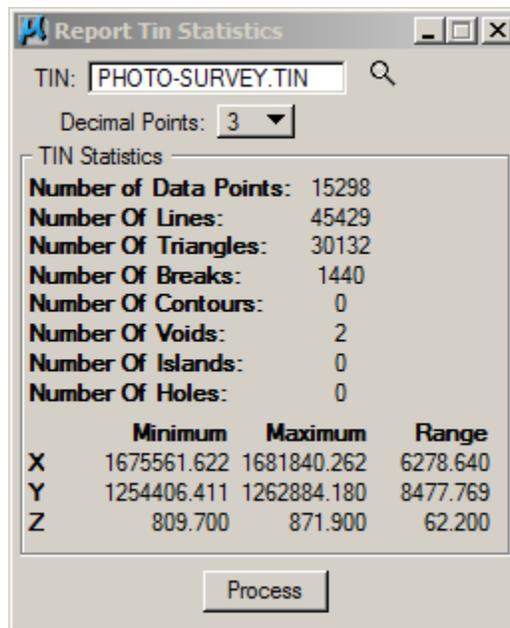


13. Create the **PHOTO-SURVEY.TIN** using **SURVEY-MERGE.TIN** as the Old Tin. This time use **photo.tin** as the Mrg Tin.



You should now get the following in the MicroStation Status bar: **Build Merge Completed**

14. Check the **Triangle Statistics** of the tin file **PHOTO-SURVEY.TIN**



Exit all DTM tools, toolboxes, and menu.