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# Working with Digital Terrain Models

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## 1 Objectives

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

## 2 Definitions

A **Digital Terrain Model (DTM)** represents the topography of a project in the form of a triangulation network or lattice model. 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 triangulation is the creation of a .TIN file from which original ground profiles and original ground cross-sections can be generated.

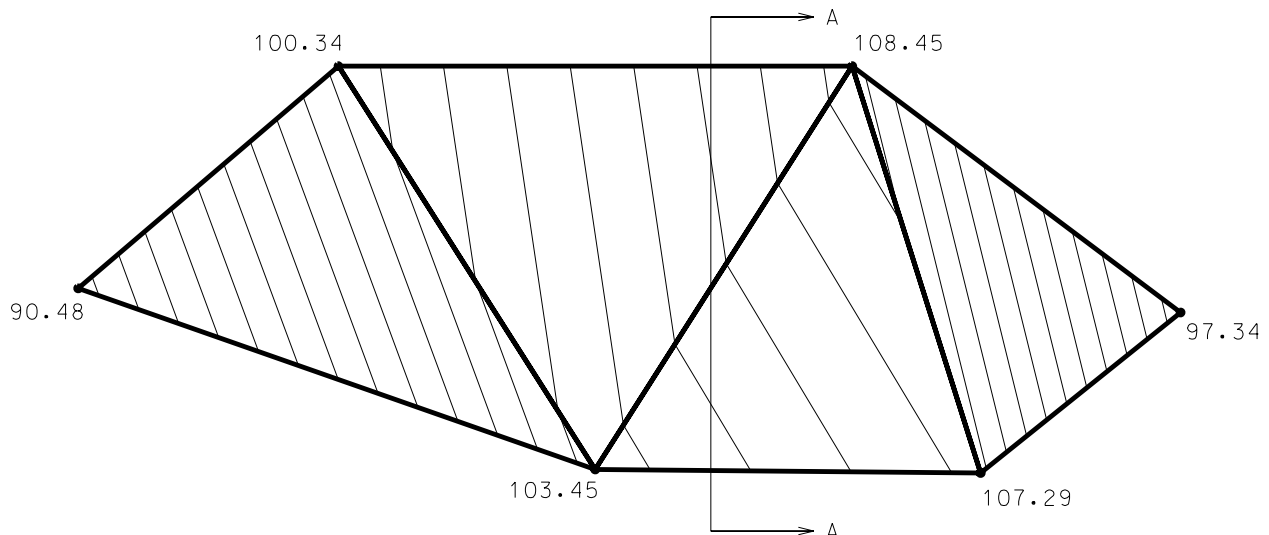
### 2.1 Triangular Digital Terrain Models

**Triangular 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.

### 2.2 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

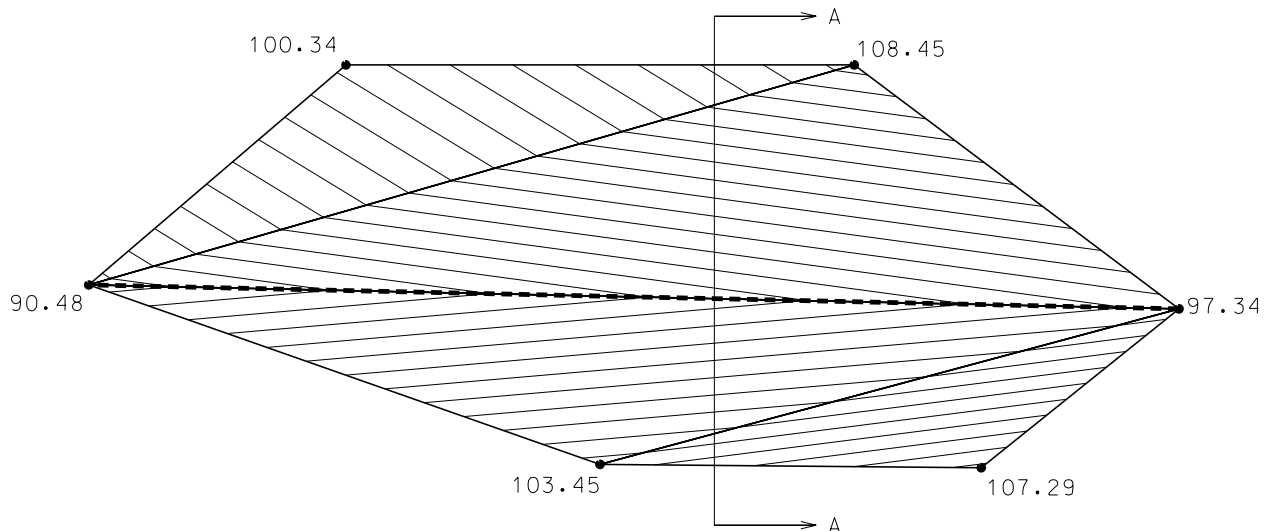


of the section, the section would look as shown in the picture below.

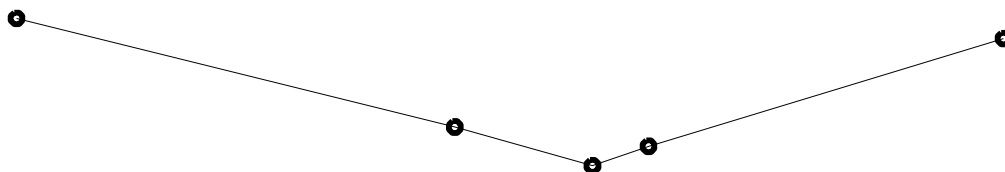
### 2.3 Breaks

Breaks represent a line along a change in slope. Examples of breaklines may include the edge of a 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 breakline, 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.

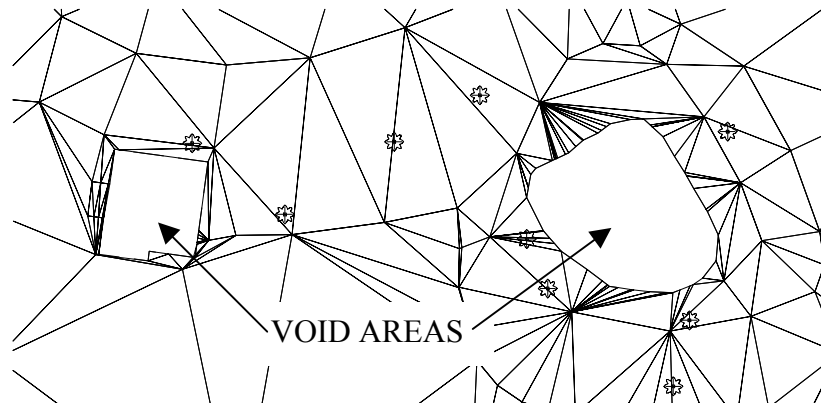


## 2.4 Boundary

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

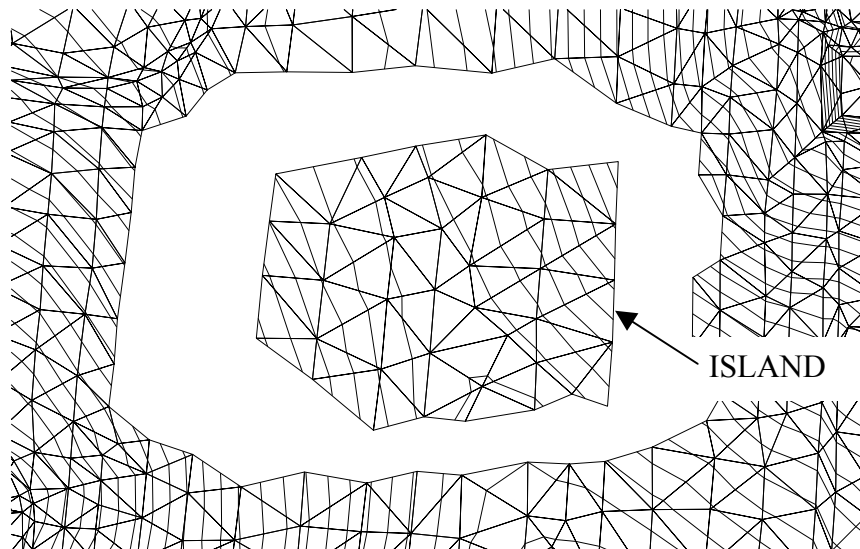
## 2.5 Voids

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



## 2.6 Islands

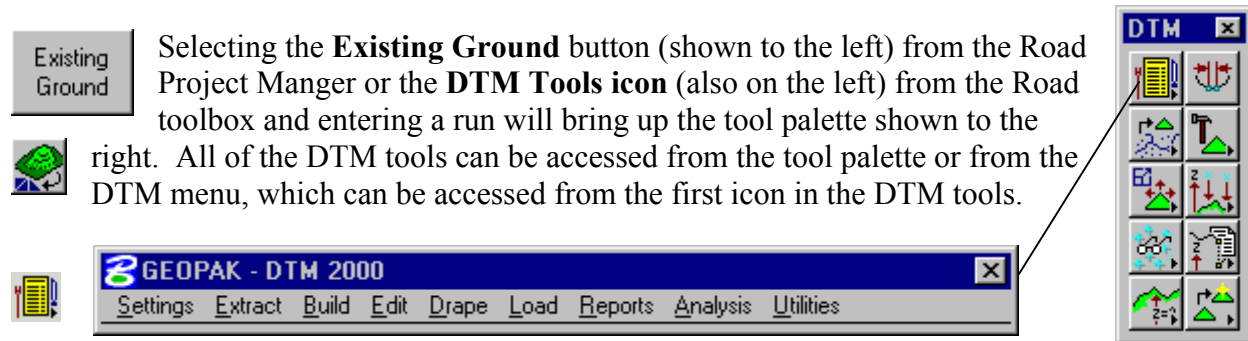
An island represents an area inside a void that contains contours.



### 3 Accessing

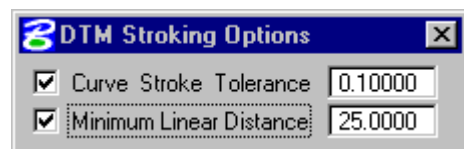
Existing Ground

Selecting the **Existing Ground** button (shown to the left) from the Road Project Manger or the **DTM Tools icon** (also on the left) from the Road toolbox and entering 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, which can be accessed from the first icon in the DTM tools.



### 4 Settings

Two user-defined stroking values need to be defined before extracting graphics 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.



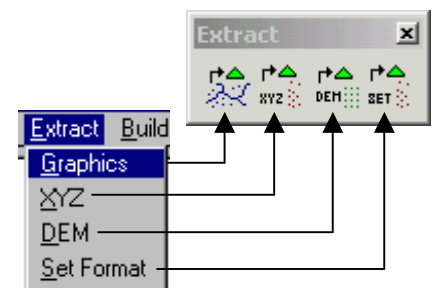
**Curve Stroke Tolerance** The maximum distance between the arc and the chord used to approximate the arc in the DTM.

**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.

### 5 Extract

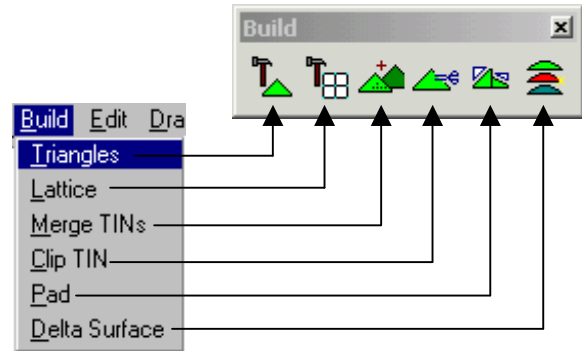
The Extract Tools allows the user to create a DTM data file from various sources. Supported sources are:

- Graphics** MicroStation graphic data is used to create a DTM source input file.
- XYZ** Information from an ASCII text file serves as the source with the user determining how to interpret the data.
- DEM** Digital Elevation Models are used. A variety of different DEM formats are supported.
- Set Format** Uses data in a variety of formats output by other software program. Supported modes are TEX, THD, RT40, and CAiCE.



## 6 Build

Included under the **Build** pull down and icons are options for creating, manipulating, and merging DTM models. The menu and the location of the corresponding tools are shown to the right.



### 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.

**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 **Files** button.

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

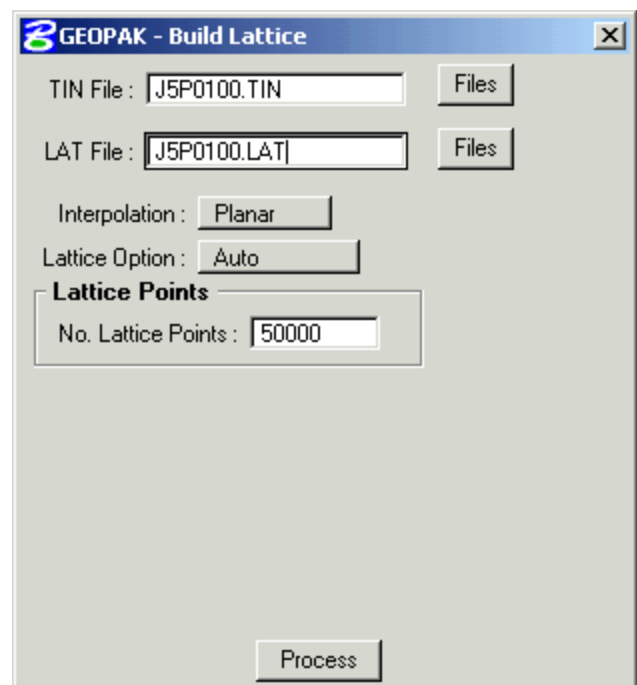
**None** no external triangles are dissolved.

**Sliver** long, thin triangles are dissolved.

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

### 6.2 Build Lattice

**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.



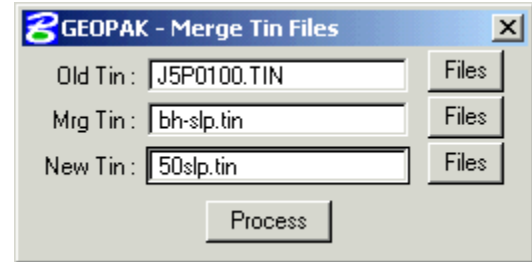
### 6.3 Merge Tin Files

**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.

**Old Tin:** Original TIN file to be supplemented with new information.

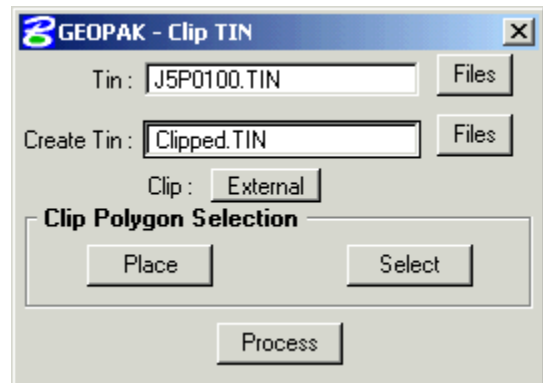
**Mrg Tin:** Tin file containing the supplemental information.

**New Tin:** Name of the new file containing the merged information.



### 6.4 Clip TIN

**Build > Clip** creates a new model (.TIN) from a clipped portion of an existing model. The area to be clipped (removed) is defined as internal or external to a user defined clip polygon. For example, a void is created if the internal option is chosen. The user may either place a polygon to define the clip boundary or select a polygon already plotted in the MicroStation drawing.



### 6.5 Build Pad

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

**Ground TIN:** Tin file containing original ground.

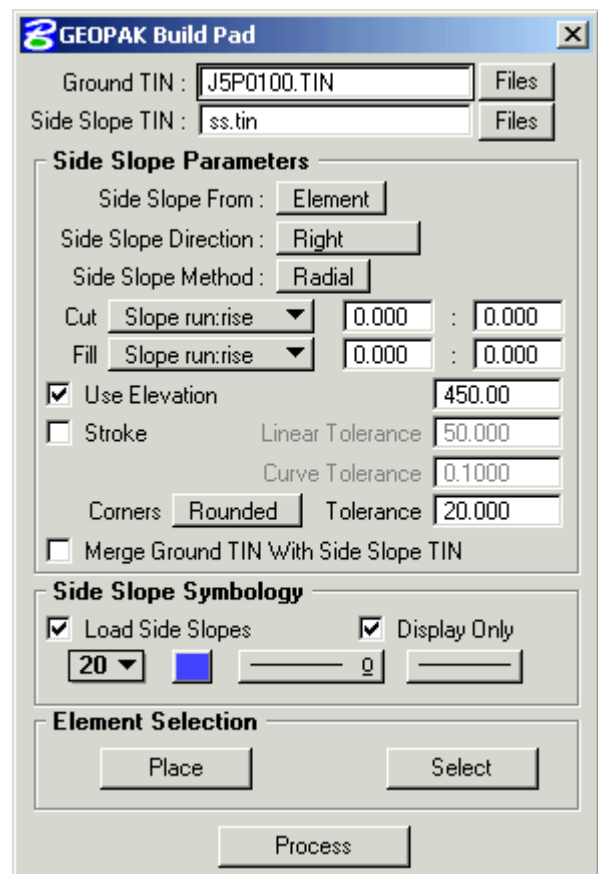
**Side Slope TIN:** Tin file containing the new side slopes created during this process.

**Side Slope From:** **Element**—an open line string.

**Pad**—a closed shape or polygon.

**Side Slope Direction:** Determines the direction of the slope. For **Element** the options are Right, Left, and Right/Left. For **Pad** the options are External, Internal, and External & Internal.

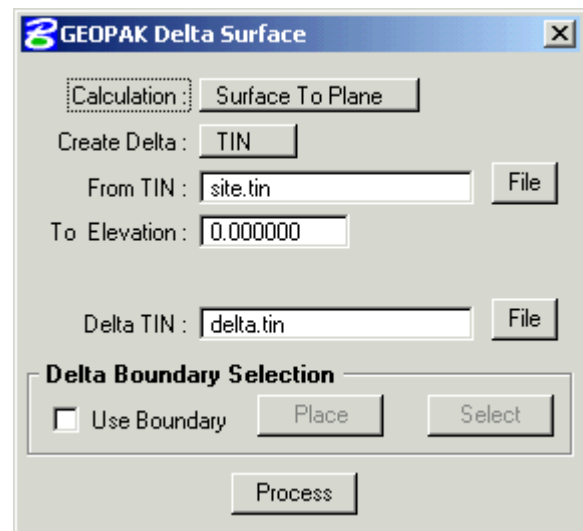
**Side Slope Method:** **Radial**—Sends out radials at the user-defined slope.



	<b>Planer</b> —Sends out radials but adjusts the slopes of the radials onto a plane at the user-defined slope. This option produces a different result from Radial only if the elements or pad are not level.
<b>Cut:</b>	Slope applied to cut sections in terms of run:rise, rise:run, percent, or unit/unit.
<b>Fill:</b>	Slope applied to fill sections using the same options as above.
<b>Use Elevation:</b>	If toggled on, the pad is located at the user-defined elevation; otherwise, the elevation is taken from the pad.
<b>Stroke:</b>	Lets the user apply linear and curve tolerances using the stroking tolerances described above under <b>4 Settings</b> .
<b>Corners:</b>	Options are <b>Rounded</b> or <b>Straight</b> . The tolerance, applied at the toe of the slope, provides for additional radials at convex corners
<b>Merge Ground TIN With Side Slope TIN:</b>	If activated, the Side Slope TIN is merged into the Ground TIN, which becomes the new Side Slope TIN. This enables new boundaries to be added, taking into account any previous boundaries that have been processed.
<b>Load Side Slopes:</b>	Draws side slopes into the MicroStation file if activated.
<b>Display Only:</b>	Available only if Load Side Slopes is activated. If Display Only is checked, the elements are only temporary and disappear when the screen is refreshed. Otherwise, the elements are permanent.
<b>Place:</b>	Lets the user place the pad boundary.
<b>Select:</b>	Lets the user select an existing boundary.
<b>Process:</b>	Begins the process.

## 6.6 Delta Surface

**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.



## 7 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 breaks.

**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.

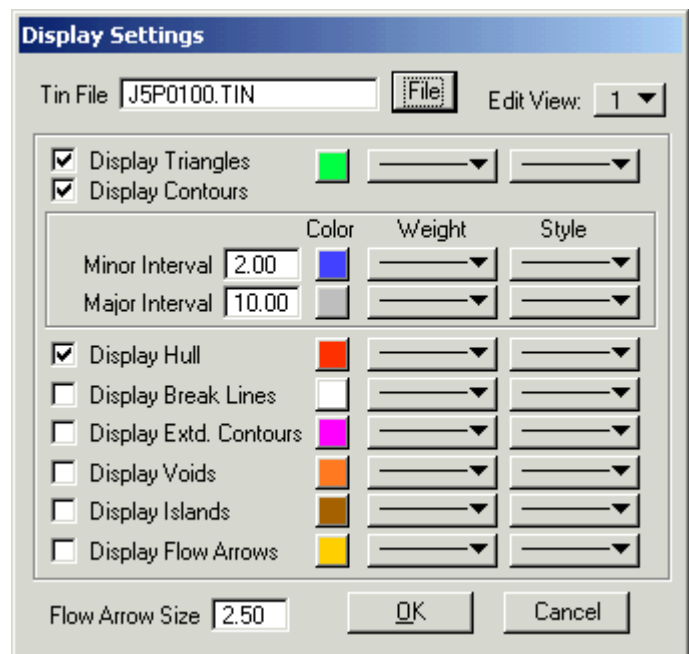
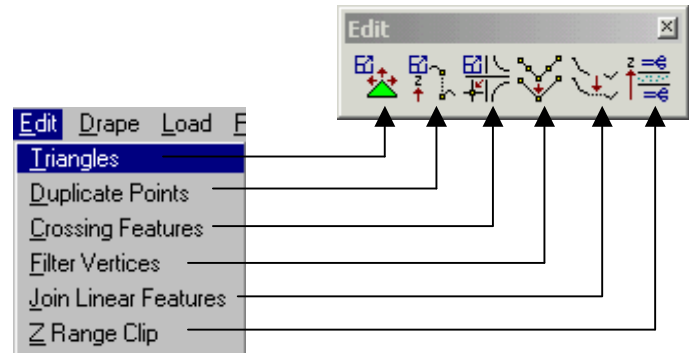
**Z Range Clip** – Deletes information from the survey data file (.dat) based on given elevation information.

As indicated in the above descriptions, only the **Edit > Triangles** option allows the user to work with the TIN model; therefore, it is the only tool that will be presented in depth. The other tools work with the data input files prior to creating the TIN.

### 7.1 Display Settings

This dialog automatically opens when selecting **Edit > Triangles**. It allows the user to choose the Tin File and Edit View as well as control what is displayed during the ending session. Any graphics displayed, as part of the edit process, will disappear once the session is ended and the screen is refreshed.

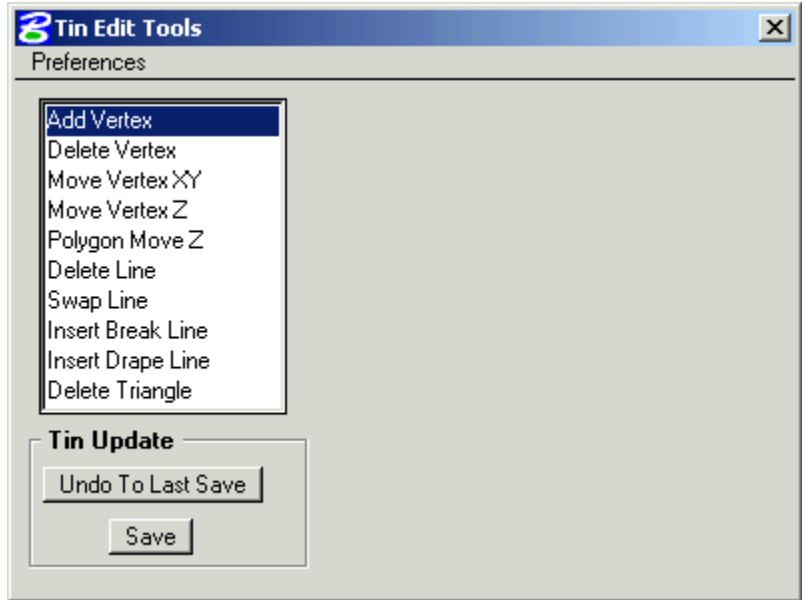
After the changes are made to the settings, clicking the OK button will save them and cause the TIN to be displayed as set. The display settings can be changed during the edit session by selecting **Preferences > Display** from the **Tin Edit Tools** dialog.



### 7.2 Tin Update

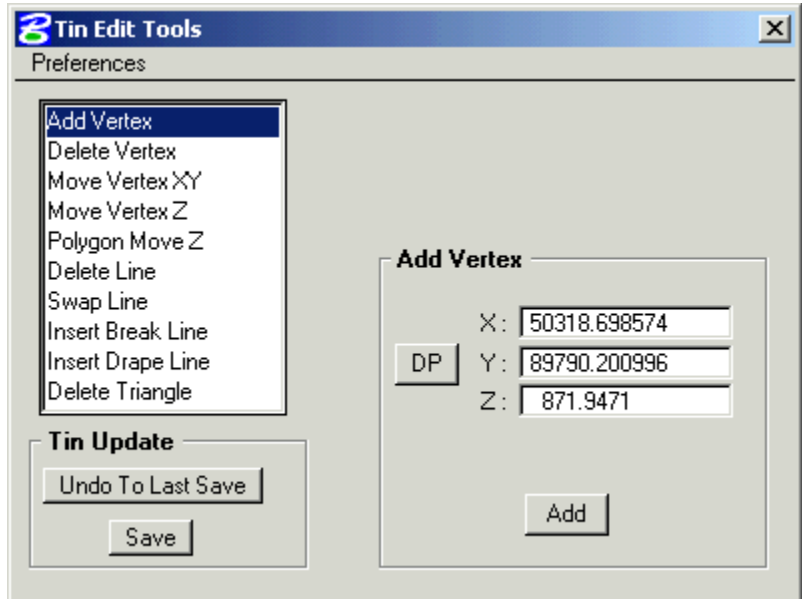
When the Tin Edit Tools is first started, it looks like the dialog shown to the right. The blank area of the dialog changes depending upon the tool selected.

The **Tin Update** section of the dialog has two options. Initially, any changes are only temporary. The user can either reject all of the changes since the last save by clicking on the **Undo to Last Save** button or make the changes permanent by selecting **Save**.



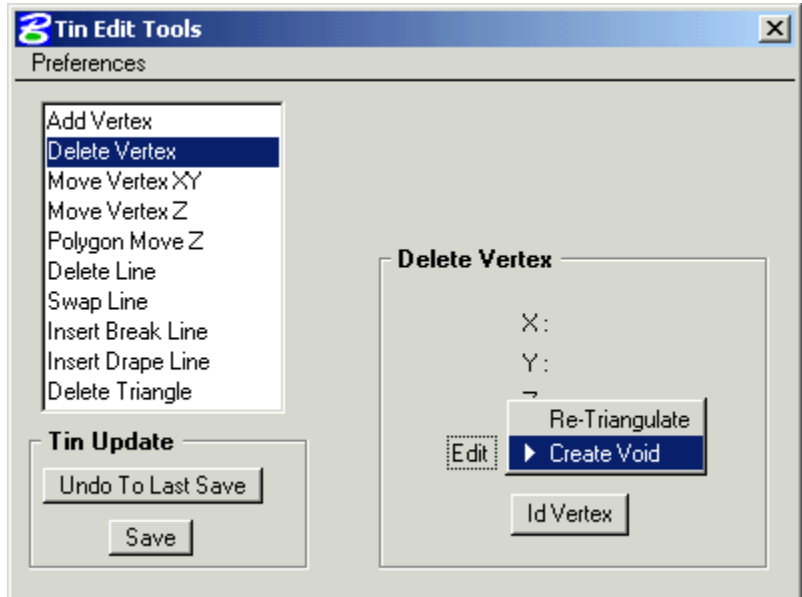
### 7.3 Add Vertex

A vertex can be added by providing the **X**, **Y**, and **Z** values in their respected fields. This information can be read from the TIN being edited by selecting the **DP** button and moving the cursor on the displayed TIN. The **X** and **Y** values are determined from the position of the cursor, while the **Z** value corresponds to elevation of the existing triangle at that location. Once the data point is accepted, the fields can be edited to reflect the desired values. The vertex is inserted into the TIN by selecting the **Add** button.



### 7.4 Delete Vertex

Two **Edit** options are available. **Re-Triangulate** creates new triangles from the remaining vertices. **Create Void** deletes the vertex and all associated triangles to create a void. Selecting **Id Vertex**, then data pointing and accepting on the desired vertex or vertices completes the process.



### 7.5 Move Vertex XY

This option lets the user move a vertex using the following process:

- 1) Select **Id Vertex**,
- 2) **Data point** on the desired vertex and accept,
- 3) **Move the cursor** to the new location, and
- 4) **Data point** to accept.

Only the X and Y of the values are changed. The Z value remains the same.

### 7.6 Move Vertex Z

This tool does just the opposite of the previous one. The X and Y values remain the same, while the Z value is changed to the supplied **Elevation**. The process is:

- 1) Select **Id Vertex**,
- 2) **Data point** on the vertex to fill in the X, Y, & Z,
- 3) **Enter** the new **elevation**, and,
- 4) **Data point** to accept.

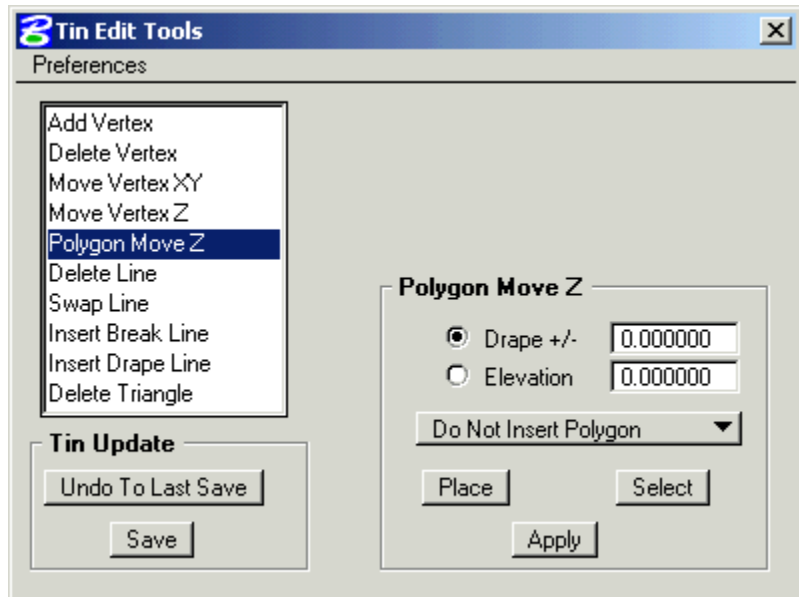
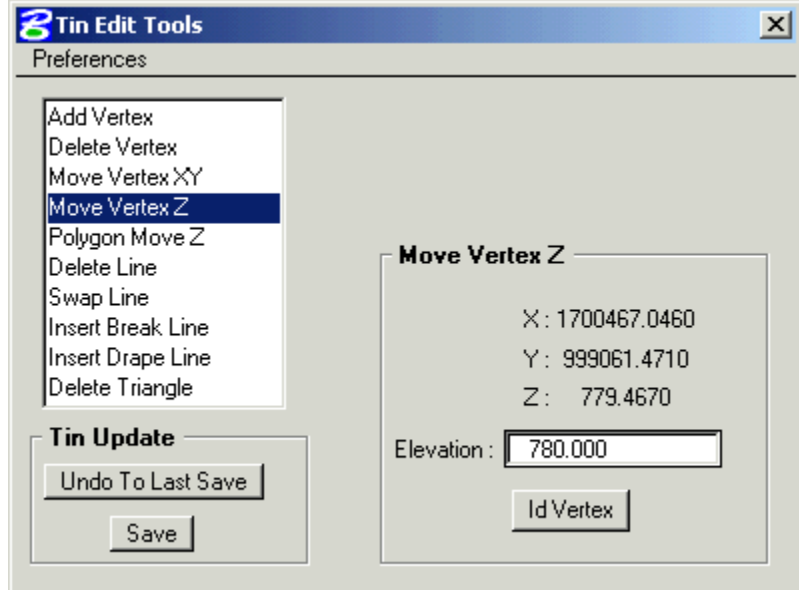
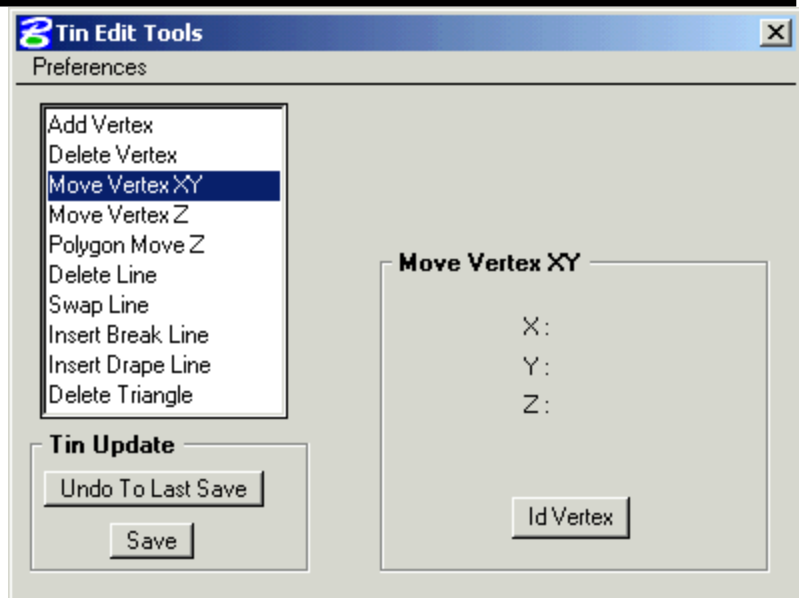
### 7.7 Polygon Move Z

All vertices within the specified polygon are raised or lowered and the model is re-triangulated.

Specifying a **Drape** moves all of the vertices a fixed amount while toggling on **Elevation** moves all of the vertices to the same value.

Four options are available for controlling the move. They are:

- 1) **Do Not Insert Polygon**, which moves the points inside the polygon without using the polygon for any other purpose;



- 2) **Insert Polygon**, which uses the polygon as a break line to define the legs of new triangles with the elevations of the legs being determined by the elevation of the break line;
- 3) **Insert Polygon Delete Points**, which removes all points from inside of the polygon and new triangles are drawn based on the elevation of the polygon; and
- 4) **Insert Polygon Create Void**, which uses the polygon as a break line and creates a void inside of the polygon.

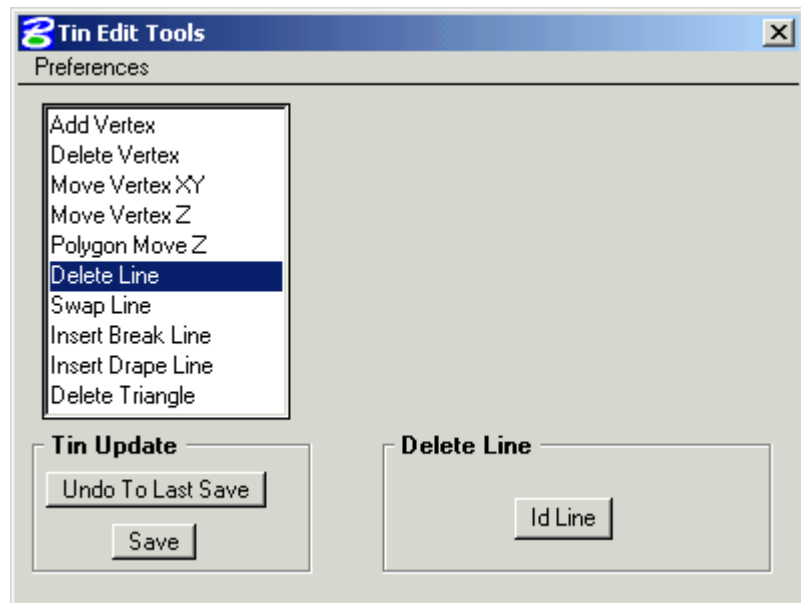
After choosing the move option, the user can either **Place** a polygon or **Select** a polygon already plotted in the drawing. Once the polygon is defined, pressing **Apply** starts the process.

### 7.8 Delete Line

A void is created from all of the triangles that share the deleted line. To do this, select **Id Line** and data point on the line to be deleted.

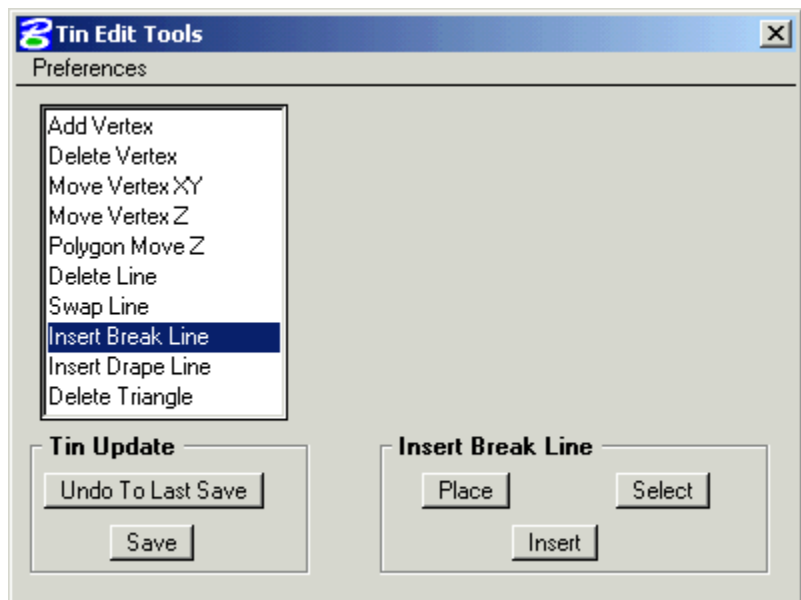
### 7.9 Swap Line

Since the Swap Line dialog is almost identical to the Delete Line dialog and functions in the same way, it is not shown. To use it, select **Id Line** and data point on the line you want to swap. If possible the line between the triangles will be rotated and drawn between the other two possible vertices.



### 7.10 Insert Break Line

The Insert Break Line tool uses the coordinates from the break line to re-triangulate the TIN. As seen in the dialog to the right, two options are available. If an existing line is used, click on **Select** and data point on the line in the drawing. Elevations will be obtained from the line. If a new line is to be placed, click on **Place** to open the **Define Break Line** dialog box shown on the next page.

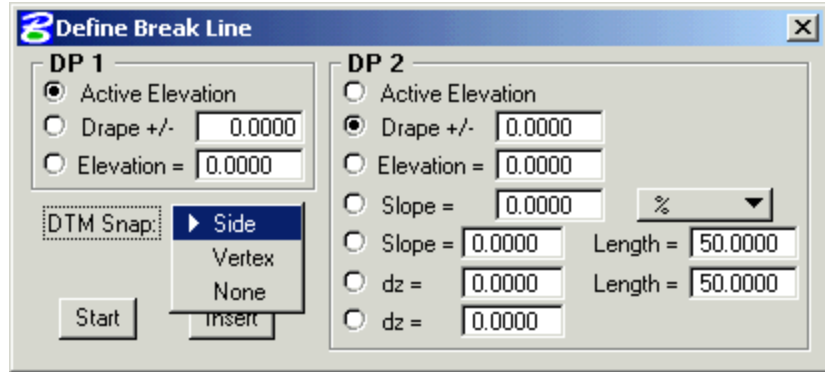


The **Define Break Line** dialog to the right controls the placement of the break line. The **DP1** section controls the elevation for the start of the line. The following options are available:

**Active Elevation:** The DP1 elevation is obtained from the TIN model.

**Drape +/-:** The DP1 elevation is set from the TIN model plus or minus the entered drape value.

**Elevation =:** The DP1 elevation is set to the elevation value entered into the provided field.



Three DTM Snap modes are available. They are **Side**, which snaps to a triangle side; **Vertex**, which snaps to a triangle vertex; and **None**, which inserts the point at the location of the cursor.

The DP2 section controls the elevation of the second and subsequent data points. The options are:

**Active Elevation:** The DP2 elevation is obtained from the TIN model at the location of the data point.

**Drape +/-:** The DP2 elevation is set from the TIN model at the data point plus or minus the entered drape value.

**Elevation =:** The DP2 elevation is set to the elevation value entered into the provided field.

**Slope = (1<sup>st</sup> option):** Applies the specified slope along the break line and assigns the elevation to DP2 based on the elevation at the previous data point the change in slope. The slope can be positive or negative in terms of a percent or unit / unit by using the pull down box to the right of the slope value. In this option the distance from the previous DP and this one is variable.

**Slope = (2<sup>nd</sup> option):** Applies the slope along a line of the specified length. The distance between the DP points is fixed at the value entered.

**Dx = (1<sup>st</sup> option):** Applies a change in elevation of the specified amount at the specified distance from the previous data point.

**Dx = (2<sup>nd</sup> option):** Applies a change in elevation of the specified amount. The distance between the DPs controls the distance between the two points.

Press **Start** to begin the process and data point on the screen to indicate the location of DP1. Add additional legs to the break line by adjusting the values in the DP2 part of the dialog and data pointing as needed. Once the break line is complete, press **Insert** to re-triangulate based on the break line.

## 7.11 Insert Drape Line

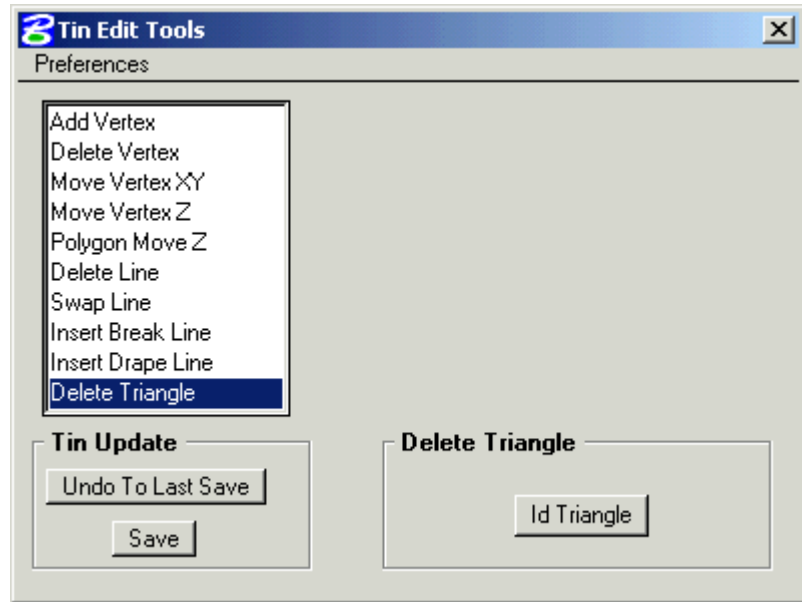
An inserted drape line causes legs of triangles to be drawn at the location of the drape line. All elevations are obtained from the TIN model. The only effect upon the model is that additional triangles are added without a change in the elevation or slope of any point.

### 7.12 Delete Triangle

As the name implies, this tool deletes a single triangle. The steps are:

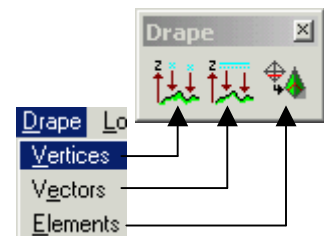
- 1) Select the **Id Triangle** button,
- 2) Data point **inside** the triangle to be deleted, and
- 3) Accept the data point.

If a contour line does not run through a single triangle being deleted, which is surrounded by other triangles, it may not appear that anything is happening because the legs of the other triangles are still visible.



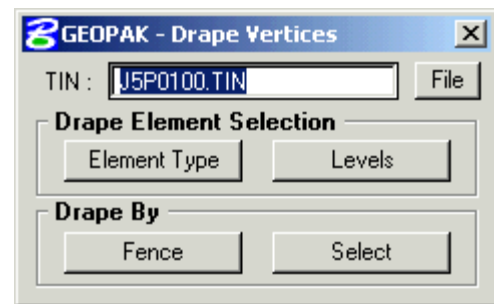
## 8 Drape

The drape tools shown to the right adjust the elevations of MicroStation elements to those obtained from a triangulated model. Three drape options are provided: Vertices, Vectors, and Elements



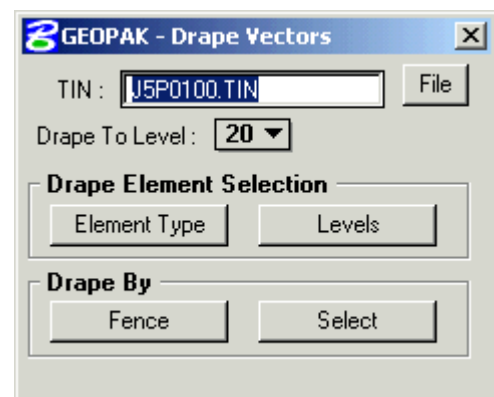
### 8.1 Drape Vertices

The vertices of MicroStation element are draped onto the TIN model. As a result the Z value of the element vertices are assigned by the TIN model to coincide with the model. Candidate elements for drape selection are based on **Element Type** and **Levels**. Once these are set, the **Select** button can be used to identify the actual elements to be draped. The **Fence** method drapes all elements that meet both the fence and the element selection search criteria. The fence must be placed prior to pressing **Fence**.



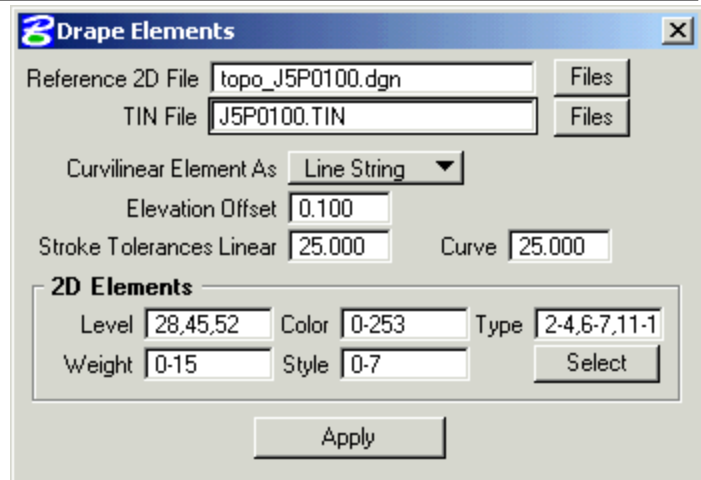
### 8.2 Drape Vectors

In addition to the MicroStation element vertices, the Drape Vectors tool also creates new vertices where the elements cross triangle legs. As a result, new line strings are created with each vertex reflecting either a vertex from the original linear element draped onto the model or an intersection between the element and a triangle leg. The tool, as shown to the right, works like the previous tool with the addition that the user specifies the level on which the new line string is drawn.



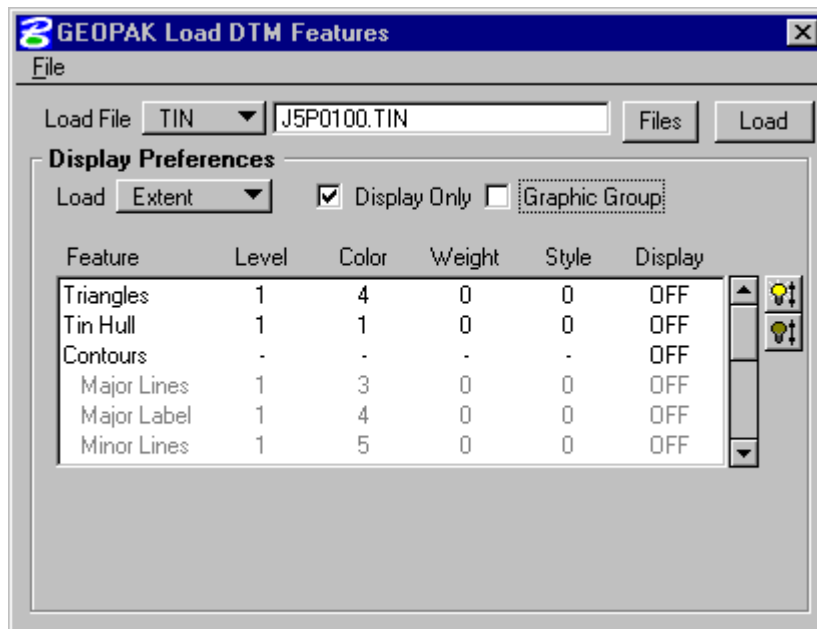
### 8.3 Drape Elements

References MicroStation 2D elements to draw into a 3D file maintaining their X and Y values, while modifying the Z value coincident with a TIN model plus and optional offset. The 2D linear element can be brought in as a **Line String**, **Curve String**, or **B-spline**, as specified by **Curvilinear Elements As**. The rest of the dialog provides areas to set the **Files** used, **Elevation Offset**, the **Stroking Tolerances**, and the **2D Elements** search criteria.



## 9 Load

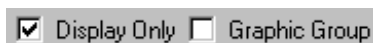
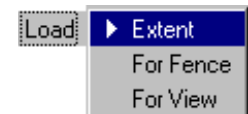
**Load** is the process by which we can visualize the DTM data, the TIN model, the lattice model, and the contours. By clicking on **Load >> DTM Feature**, or by clicking on the icon, the following dialog will appear.



The user can choose to load the DTM data (.dat), the TIN file (.TIN), or the lattice file (.lat).



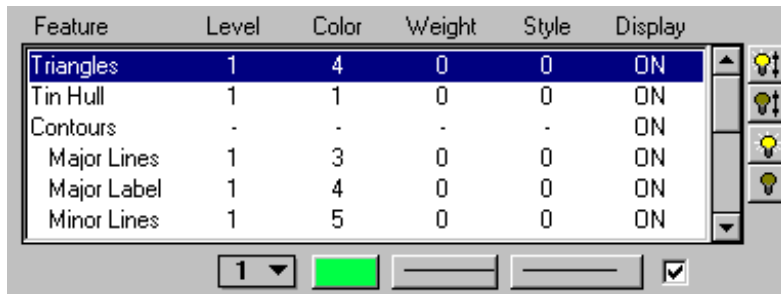
Each of these files can be loaded for the model extents, within a fence, or within a window.



Toggleing 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).



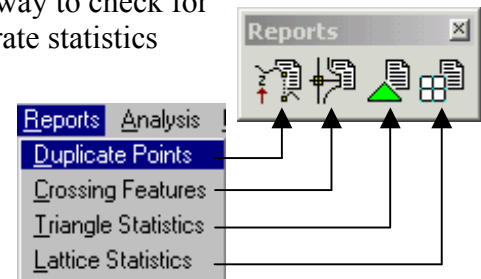
- Will turn on all items.
- Will turn off all items.
- Will turn on only the selected item.
- Will turn off only the selected item.

## 10 Reports

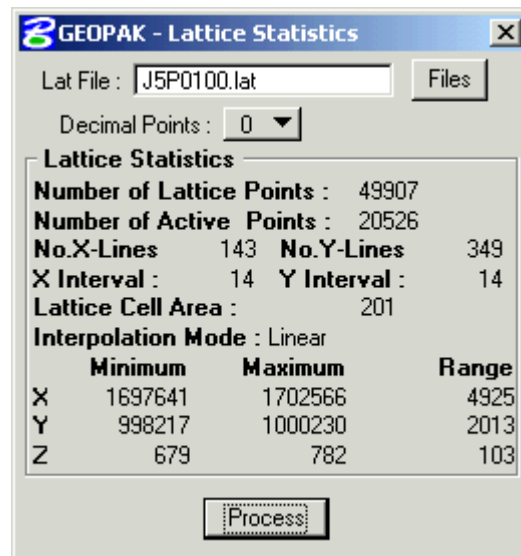
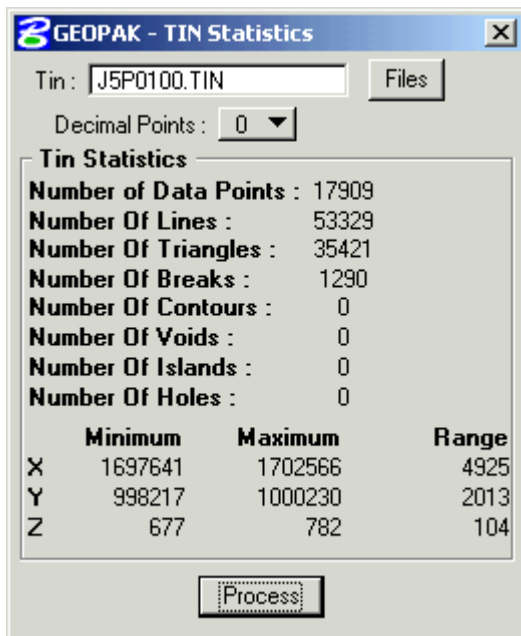
The options under the **Reports** pull down and icons include a way to check for duplicate points or crossing breaklines, and the ability to generate statistics associated with a **.TIN** or **.lat** file.

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

**Crossing Features** – reports intersecting break lines 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. An example of each is shown below.



## 11 Analysis

The **Analysis** tools allow the user to view the digital terrain model through many different methods such as a profile, themes, and drainage.

**Height** – Show the user the x, y, and z coordinates and the slope of a given data point. The contour at that elevation, the triangle the point lies within, and the direction of flow can be displayed.

**Profile** – Will display the profile of the digital terrain model between two points.

**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.

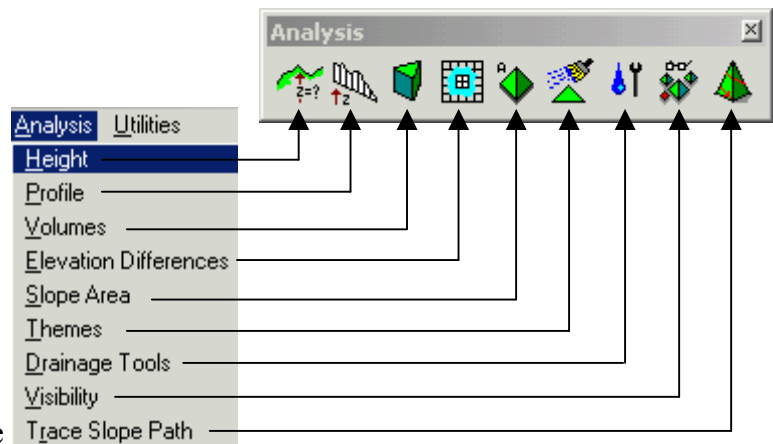
**Slope Area** – Displays the slope area of a TIN model, or a portion of a TIN model.

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

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

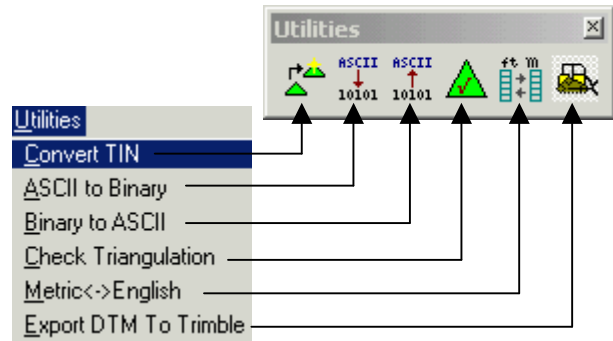
**Visibility** – Displays lines of sight (which triangles can and cannot be seen), or what is visible between two specified points.

**Trace Slope Path** – Displays the path traced along a model based on a given slope. Two options are provided. The **Follow Slope** method moves along the surface of the model at the specified slope along a zigzag path. The **Direct Slope** method only uses the model elevation at the end points of a straight line and finds possible solutions.



## 12 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 DTM to Trimble DTX or TTM.



**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 Lattice to Trimble** – generates an ASCII file from a lattice or TIN for use in Trimble field equipment. A **Triangle Tin** file is exported to a **Trimble TTM** file and a **Lattice** file to a **Trimble DTX** file.

For more information on these items, see the GEOPAK *Terrain & Subsurface Modeling* manual or the online help.