

NAME: [Surface Tools for Points, Lines and Polygons \(v. 1.6b\)](#)

Aka: surf_tools.avx

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AUTHOR: Jeff Jenness
Wildlife Biologist, GIS Analyst
Jenness Enterprises
3020 N. Schevene Blvd.
Flagstaff, AZ 86004 USA
jeffj@jennessent.com



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Please let me know if you cite this extension in a publication (jeffj@jennessent.com). I will update the citation list to include any publications that I am told about.

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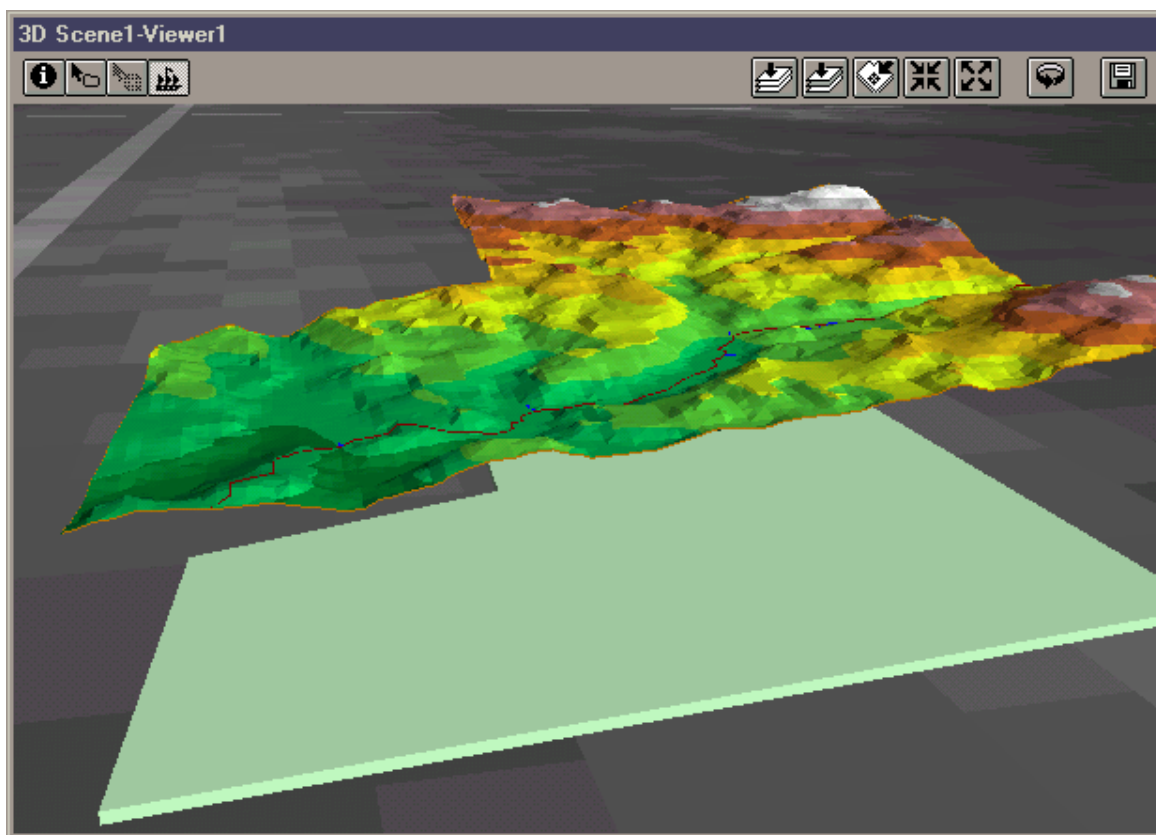
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Description:

This extension allows you to calculate various surface and topographic characteristics for points, lines or polygons in a theme:

- *Point Themes:* Calculate the X- and Y-Coordinates, the Slope, Aspect and Elevation, and the surface area, flat area and (Surface Area)/(Flat Area) ratios within a circular area surrounding each point. Also calculate the minimum, maximum, mean and standard deviation of elevation values, and identify the high and low points, in that circular area.
- *Line (or Polyline) Themes:* Calculate the surface length, the flat length, and the (Surface Length)/(Flat Length) ratio of each line, the minimum slope, maximum slope and average slope of that line, and the start, end, minimum, maximum and average elevation, elevation range and absolute/cumulative elevation change of that line. You can also create a profile chart of the elevation change of the line, and generate a point shapefile of the high and low points on that line.
- *Polygon Themes:* Calculate the surface area within polygons, the flat area and the (Surface Area)/(Flat Area) ratios within polygons. You can also calculate the surface area and the land volume within each polygon that lies above and below a specified elevation. Finally, you can calculate the highest elevation, the lowest elevation, and the elevation range, mean and standard deviation within each polygon, and you can generate a shapefile of the high and low points within that polygon.



GRID or TIN Elevation Theme: You can use either a GRID or TIN as your elevation theme. If you use a GRID, then this extension will create a TIN of the relevant area and calculate surface and topographic data from the new TIN.

Save TINs and Clip TINs: Because this extension uses TINs to calculate most surface and topographic data, it will either use an existing TIN or it will create a new TIN out of an existing elevation GRID. It then clips the TIN to the relevant area and gives you the option to both save these clipped TINs to your hard drive and display them on your screen. Therefore, even if you are not interested in the surface or topographic characteristics of

your features, you may still find this extension to be a useful tool for clipping TINs to polygon boundaries. CAUTION: A clipped TIN may not be exactly what you think it is. See [Clipping TINs](#) for an explanation of what happens when a TIN is clipped.

Multipart Polygons and Polygons with Holes: This extension works with both multipart polygons (a "single" polygon shape that actually contains multiple polygons), and polygons with holes. Your TINs and your surface/topographic calculations will reflect the correct polygon.


All or Only Selected Records: You can either use all the features (points, lines or polygons) in a theme for the analysis or you can restrict the calculations to a selected subset of features. If any of your features are selected, then only those selected features will be used in the analysis. If no features are selected, then all features in that theme will be used in the analysis.

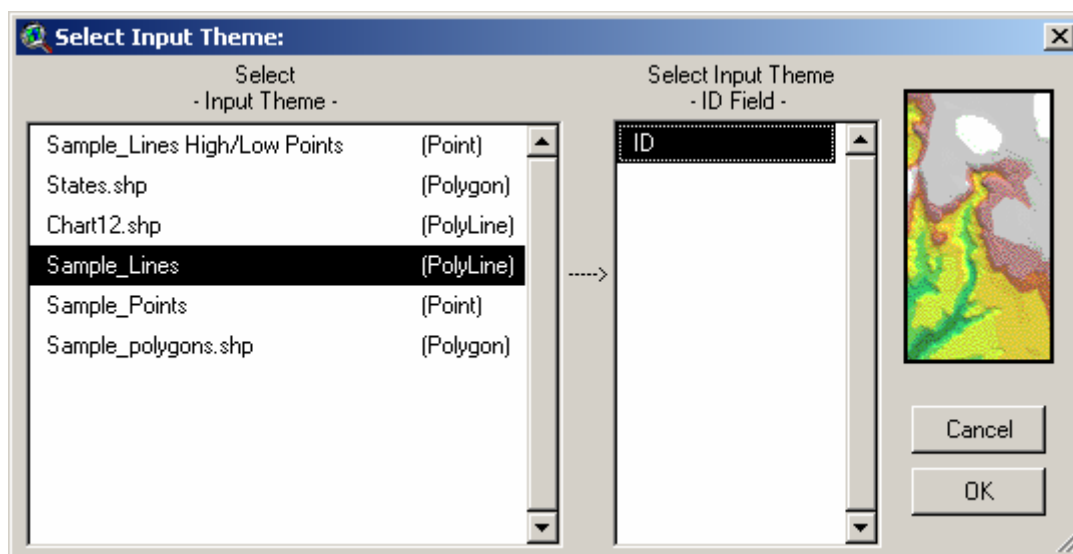
Output: Upon completion, you will have a RESULTS table containing any or all of the data mentioned above. Please see the links below to view explanations of data available for Point, Line or Polygon Input Themes. You also have the option to create a Point shapefile containing the high and low points near your points, along your lines or within your polygons. If you are working with a Line (or Polyline) theme, you have the option to create a profile chart of the lines.

Requires: This extension requires the Spatial Analyst and 3D Analyst extensions, as well as a feature theme and an elevation theme. The elevation theme can be either a GRID or a TIN, but it must completely encompass the features. This extension also requires that the file "avdlog.dll" be present in the ArcView/BIN32 directory (or \$AVBIN/avdlog.dll) and that the Dialog Designer extension be located in your ArcView/ext32 directory, which they usually are if you're running AV 3.1 or better. The Dialog Designer doesn't have to be loaded; it just has to be available. If you are running AV 3.0a, you can download the appropriate files for free from ESRI at:

<http://www.esri.com/software/arcview/extensions/dialog/index.html>

General Instructions:

- 1) Begin by placing the "surf_tools.avx" file into the ArcView extensions directory (../Av_gis30/Arcview/ext32/).
- 2) After starting ArcView, load the extension by clicking on **File --> Extensions...**, scrolling down through the list of available extensions, and then clicking on the checkbox next to the extension called "Surface Tools for Points, Lines and Polygons"
- 3) Decide which feature theme contains the features (points, lines or polygons) you're interested in, and if you want to run this extension on all those features or just a subset of them. If you want to just use a subset of the features, then select those features you're interested in. If any features are selected, then the extension will operate on only those selected features.
- 4) From your View toolbar, click on the  icon. This brings up the **Select Input Theme** dialog box:



The **Input Theme** list shows all of the Feature Themes available in the view and the shape types of those themes. Once you select your theme of interest, the **ID Field** list becomes active and shows a list of all the fields in that theme's Feature Attribute Table. You should select a field that contains a unique identifier for each feature. This identifier allows the RESULTS table to be joined with your theme's Feature Attribute Table, and without it you would have a hard time knowing which point, line or polygon was being described in the RESULTS data fields.

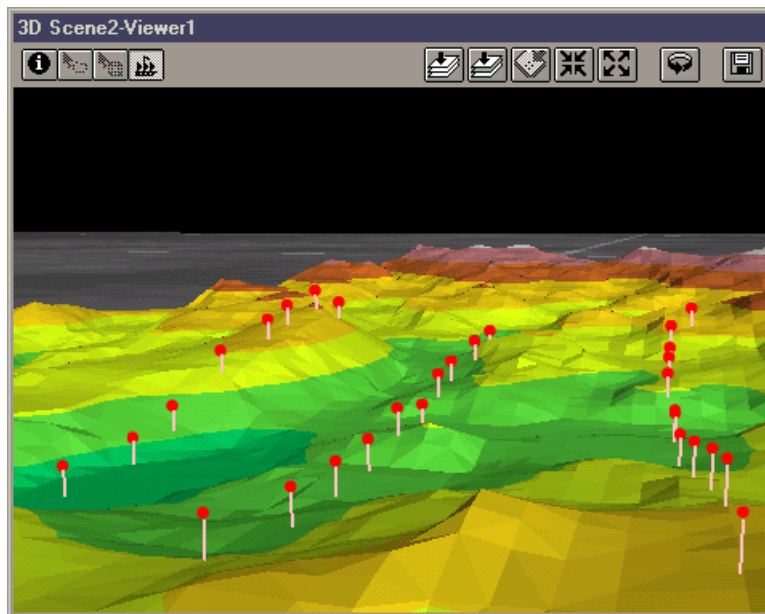
After you select your Input theme, the extension will query you for your Elevation Theme and the attributes you would like to calculate for your features. You will see one of three possible Dialog Boxes depending on the shape type of your Input Feature Theme:

Move on to "[Surface Tools for Points...](#)"

Move on to "[Surface Tools for Lines...](#)"

Move on to "[Surface Tools for Polygons...](#)"

Surface Tools for Points:



If your Input Theme is a Point theme, you will see the following dialog box prompting you for the proper elevation theme and the Point surface characteristics you wish to calculate:

Select Elevation Theme and Desired RESULTS data:

- Select Elevation Theme - GRID or TIN

Sample_tin
Sample_grid

Z-Factor: 1 Help

Buffer Factor: 10 Help

☐ Do you want to join your RESULTS table with your Point Attribute Table?

Cancel OK

Data for RESULTS Table

Data on Surface Characteristics of each point -----

☐ X-Coordinate ☐ Y-Coordinate
☒ Elevation (from TIN) ☐ Elevation (from GRID)
☒ Slope (from TIN) ☐ Slope (from GRID)
☒ Aspect (from TIN) ☐ Aspect (from GRID)

Data on a Circular Area surrounding each point -----

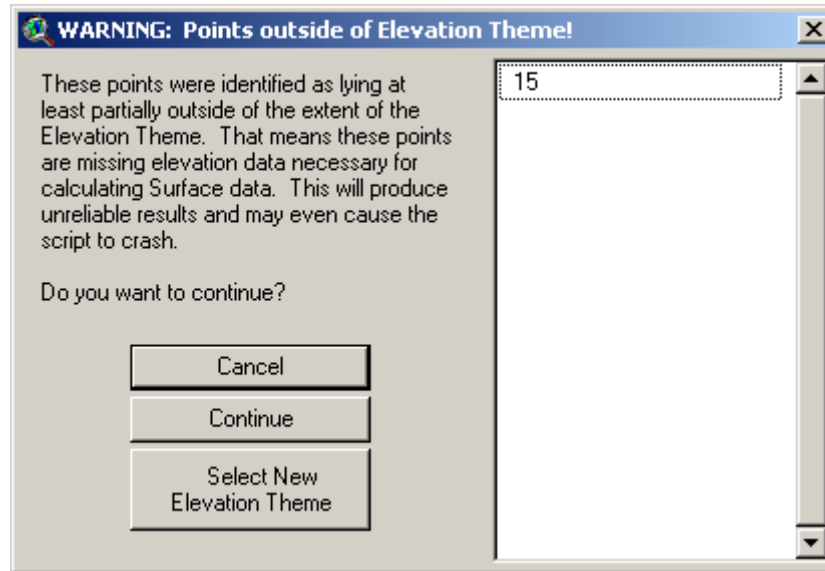
Circle Area = 1256.64 square map units
Circle Radius = 20 map units

☒ Surface Area of Circles ☒ Elevation Range in Circle
☒ Flat Area of Circles ☒ Highest Elevation in Circle
☒ Surface Area Ratio (Surface Area)/(Flat Area) ☒ Lowest Elevation in Circle
☒ Mean Elevation in Circle ☒ Elevation Standard Deviation in Circle

☒ Create Polygon Shapefile of Circular Areas ☒ Create Point Shapefile of High and Low Points

Your **Elevation Theme** can be either a GRID or a TIN. If you use a GRID, this extension will create a TIN surface from the GRID before calculating your point surface data. You will be prompted to enter a Z-Factor and a Buffer Factor for the extension to use when creating the TIN. Please see [Z-Factors and Buffer Factors](#) for an explanation of these parameters.

The Elevation Theme list contains all the TINs or GRIDs contained in your view. Pick the one you want to use to generate surface data from. You need to be careful to select one that actually covers all of your points, or else you will end up trying to calculate surface characteristics without any data. This will definitely give you questionable results and will probably cause the extension to crash. The extension checks to make sure that your points are all contained in the elevation theme extent and prompts you with the following dialog box if it finds problems:



If you see this warning, the author strongly recommends that you either pick another elevation theme or else go back to your point theme and select only those points that lie within the elevation theme. Remember that if any points are selected, then this extension will only operate on those selected points.

IMPORTANT: One user has reported errors when points lay exactly on the eastern boundary of the elevation theme, leading to the message "Text cannot be converted to a number: -1.#IND". The author has not been able to pin this problem down yet, but the user has found that shifting the point very slightly to the west solves the problem.

Output Data: You may include any or all of the 14 surface/topographic characteristics of the points in your RESULTS table. Some characteristics apply only to the exact point while other characteristics apply to a circular area surrounding the point. You also have the option to create a Point shapefile of the high and low points within that circular area, and you can automatically join your RESULTS table with your Point feature attribute table. Your RESULTS table will have any or all of the following fields:

Data on Surface Characteristics of each point: If your Elevation theme is a GRID, you have the option to calculate Slope, Aspect and Elevation based on either (or both) of the derived TIN surface or the original GRID theme. The author has found that Slope and Aspect can be surprisingly different when using GRIDs vs. TINs.

- **ID:** This contains ID values for each point taken from the ID Field you specified when you selected the Polyline Input Theme. The name of this field will also be the same as the ID Field you specified.
- **X-Coordinate:** The X-Coordinate of that point.
- **Y-Coordinate:** The Y-Coordinate of that point.
- **Elevation (TIN):** The Elevation of that point based on the TIN surface.
- **Slope (TIN):** The Slope of that point, in degrees, based on the TIN surface.
- **Aspect (TIN):** The Aspect of that point based on the TIN surface.
- **Elevation (GRID):** The Elevation of that point based on the GRID surface.

- **Slope (GRID):** The Slope of that point, in degrees, based on the GRID surface.
- **Aspect (GRID):** The Aspect of that point based on the GRID surface.

Data on a Circular Area Surrounding Each Point: You have the option to calculate surface features on a circular area surrounding each point. Enter either the Area or the Radius of the circle you wish to examine. As you enter a value in one text box, the other text box will automatically fill in with the appropriate value.

- **Surface Area:** The true surface area for the circle surrounding each point.
- **Flat Area:** The flat (or planimetric) area for the circle surrounding each point. This value is equivalent to the "Area" value found in many Polygon Feature Attribute Tables. **IMPORTANT:** This value should be the same for all points because the area of a circle with a constant radius will always be the same. **IF SOME AREAS ARE LESS THAN OTHERS,** then this means that those circles extended past the boundary of the TIN surface, and therefore this extension was not able to use the entire circular area to calculate these indices. In such cases, these indices may not be accurate.
- **Surface Area Ratio:** This value is equal to (Surface Area)/(Flat Area) ratio, and provides an index of the topographic roughness of the circle.
- **Mean Elevation in Circle:** Calculated as the weighted mean of triangle elevation values for all the TIN triangles inside the circle, with each triangle weighted by the surface area:

$$\text{Mean Elevation} = \frac{\sum_{i=1}^n f_i y_i}{\sum_{i=1}^n f_i}$$

where:

n = number of triangles in TIN

y_i = elevation of centerpoint of TIN triangle

f_i = area of TIN triangle

- **Elevation Range:** The range of elevation between the lowest and the highest point in that circle.
- **High Point in Circle:** The elevation of the highest point in that circle.
- **Low Point in Circle:** The elevation of the lowest point in that circle.
- **Elevation Standard Deviation in Circle:** Calculated using the formula for the standard deviation of grouped data, where the triangle area represents the frequency of each group. I treated this as a population standard deviation rather than a sample standard deviation (i.e. I divided by n instead of by $n-1$):

$$\sigma = \sqrt{\frac{\sum_{i=1}^q f_i (y_i - \bar{y})^2}{n}}$$

$$= \sqrt{\frac{\sum_{i=1}^q f_i y_i^2 - \frac{\left(\sum_{i=1}^q f_i y_i\right)^2}{n}}{n}}$$

where:

q = number of triangles in TIN

n = total surface area of triangles in TIN

y_i = elevation of centerpoint of each TIN triangle

f_i = surface area of each TIN triangle

Point Shapefile of High and Low Points: If you are interested in the actual X- and Y-Coordinates of the High and Low points in the circle surrounding each point, this option will create a Point Shapefile of those high and low points and add it to your view. The Feature Attribute Table for this shapefile will contain the following fields:

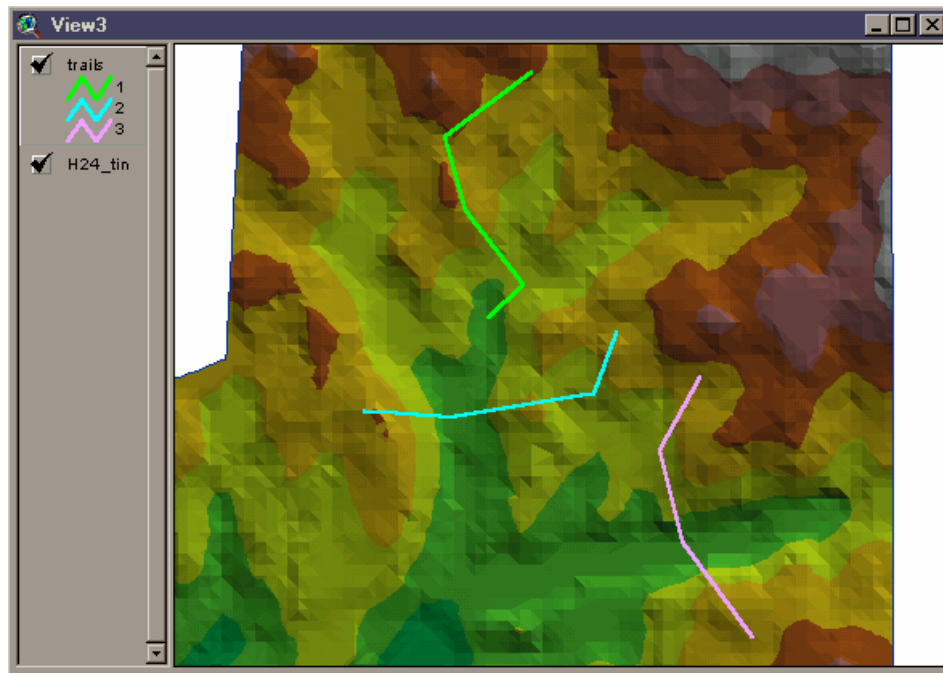
- **ID:** This field tells you which original point produced the circle that contains this particular high or low point, and contains ID values for each point taken from the ID Field you specified when you selected the Point Input Theme. The name of this field will also be the same as the ID Field you specified.
- **point_id:** This field assigns a unique numeric ID value to each high or low point.
- **high_low:** This field contains either the word "high" or "low", depending on whether that point is a high or low point on the line.
- **Elevation:** The elevation of that high or low point.
- **X-Coordinate:** The X-Coordinate of that high or low point.
- **Y-Coordinate:** The Y-Coordinate of that high or low point.

Polygon Shapefile of Circular Areas: If you have chosen to calculate data on the circular areas surrounding each point, you have the option to save these circular polygons into a new polygon shapefile. This might be useful if you wish to calculate other indices on these same circular areas using other ArcView extensions. The feature attribute table for this shapefile will contain the following fields:

- **ID:** This field tells you which original point produced the circle that contains this particular high or low point, and contains ID values for each point taken from the ID Field you specified when you selected the Point Input Theme. The name of this field will also be the same as the ID Field you specified.
- **area:** The area of the circular polygon, in square map units.
- **radius:** The radius of the circular polygon, in map units.
- **center_x:** The X-coordinate of the center of the circle, identical to the X-coordinate of the point that produced the circle.
- **center_y:** The Y-coordinate of the center of the circle, identical to the Y-coordinate of the point that produced the circle.

Move on to [Saving Data...](#)

Surface Tools for Lines (or Polylines):



If your Input Theme is a Line (technically a Polyline) theme, you will see the following dialog box prompting you for the proper elevation theme and the line surface characteristics you wish to calculate:

Your **Elevation Theme** can be either a GRID or a TIN. If you use a GRID, this extension will create a TIN surface from the GRID before calculating line surface data. You will be prompted to enter a Z-Factor and a Buffer Factor for the extension to use when creating the TIN. Please see [Z-Factors and Buffer Factors](#) for an explanation of these parameters.

If your input theme is a **PolylineZ**, you will also have the option to skip the elevation themes and run all your calculations on the internal Z-values of the actual shapes. PolylineZ shapes are three-dimensional and have all the information necessary to calculate all the indices in the dialog box above. You may still use an elevation theme if you have a PolylineZ, in which case this extension will convert the polylineZ to a normal polyline, then intersect that polyline with your elevation theme. CAUTION: In this case, you may get very short segments with extremely low slope values. This is most likely to be a problem if you're interested in the minimum slope of a line, because you may get nearly-overlapping

Select Elevation Theme and Desired RESULTS data:

Select
- Elevation Theme -
GRID or TIN

Nwgrd1
Q_TIN
Sample_grid_2
Sample_grid

Z-Factor: Help

Buffer Factor: Help

Line Length Options

☒ Surface Length of Lines
☒ Flat Length of Lines
☒ Surface Length Ratio
(Surface Len.)/(Flat Len.)

Data for RESULTS Table

SLOPE DATA:	Degrees	Percent
Average Slope:	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Maximum Slope:	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Minimum Slope:	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/> Indicate Up vs. Down		

ELEVATION DATA:

☒ Beginning Elevation
☒ Ending Elevation
☐ Highest Elevation
☒ Lowest Elevation
☐ Elevation Range
☐ Average Elevation of Line
☐ Absolute Change in Elevation
☒ Cumulative Elevation Change
☒ Cumulative Elevation Decrease
☒ Cumulative Elevation Increase
☐ Save High and Low Points

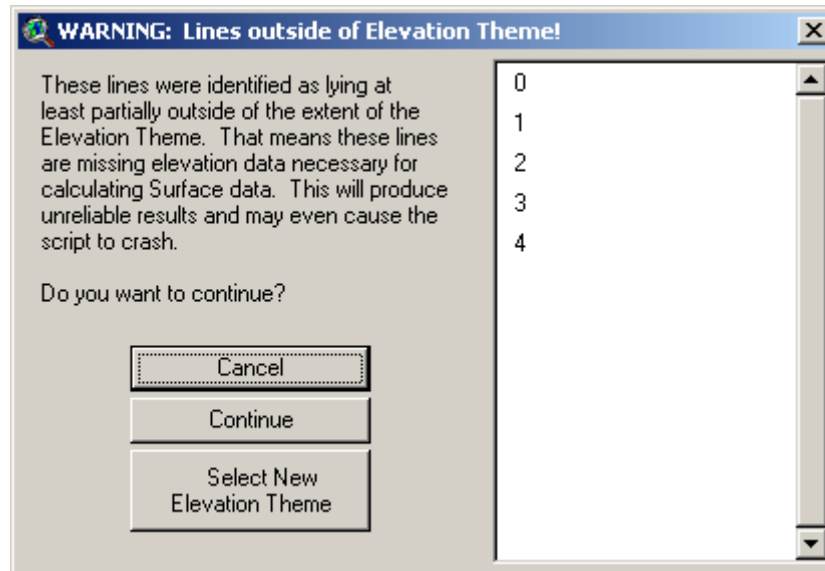
☒ Do you want to create a Line Elevation Profile Chart?

☐ Do you want to join the RESULTS table with your Polyline Feature Attribute Table?

Cancel OK

vertices that have a 0-slope.

The Elevation Theme list contains all the TINs or GRIDs contained in your view. Pick the one you want to use to generate surface data from. You need to be careful to select one that actually covers all the area covered by your lines, or else you will end up trying to calculate surface characteristics without any data. This will definitely give you questionable results and will probably cause the extension to crash. The extension checks to make sure that your lines are all contained in the elevation theme extent and prompts you with the following dialog box if it finds problems:



If you see this warning, the author strongly recommends that you either pick another elevation theme or else go back to your line theme and select only those lines that lie within the elevation theme. Remember that if any lines are selected, then this extension will only operate on those selected lines.

Output Data: You may include any or all of the 11 surface/topographic characteristics of the lines in your RESULTS table. You also have the option to create a Point shapefile of the high and low points along each line and a profile chart illustrating the elevational changes along the length of the line, and you can automatically join your RESULTS table with your Polyline feature attribute table. Your RESULTS table will have any or all of the following fields:

- **ID:** This contains ID values for each line taken from the ID Field you specified when you selected the Polyline Input Theme. The name of this field will also be the same as the ID Field you specified.
- **Surface Length:** The length of the line as it follows the TIN surface. The line is intersected with the TIN surface such that it gains a new vertex with an elevation value every time it crosses a TIN triangle edge.
- **Flat Length:** The length of the line as if it were on a perfectly flat surface. This "Flat Length" is the length referred to in the "Length" field in most polyline Feature Attribute Tables.
- **Length Ratio:** The (Surface Length)/(Flat Length) ratio. Because the surface length will always be \geq to the flat length, this ratio will always be ≥ 1 . This value gives some sense of the general steepness of the line.
- **Avg. Slope (deg):** A measure of average slope of the line, in degrees. This value is derived by measuring the slope and surface length of each segment of the line after it has been intersected with the TIN surface, and applying the following formula to calculate the average line slope.

$$\text{Average Slope} = \frac{\sum_{i=1}^n (SL)}{\sum_{i=1}^n L}$$

where:

n = Number of segments in polyline

S = Segment Slope (in Degrees)

L = Segment Surface Length

- **Min. Slope (deg):** The minimum slope found on that line.
- **Max. Slope (deg):** The maximum slope found on that line.
- **Avg. Slope (%):** The average slope found on that line, calculated by converting the average slope from *degrees* to *%-slope*.
- **Min. Slope (%):** The average slope found on that line, calculated by converting the minimum slope from *degrees* to *%-slope*.
- **Max. Slope (%):** The maximum slope found on that line, calculated by converting the maximum slope from *degrees* to *%-slope*.
- **Start Elevation:** The elevation of the starting point on that line.
- **End Elevation:** The elevation of the ending point on that line.
- **Up or Down:** The predominant vertical direction of the line. 1 = uphill, 0 = flat, -1 = downhill.
- **Low Point Elevation:** The lowest elevation found on that line.
- **High Point Elevation:** The highest elevation found on that line.
- **Average Elevation:** A measure of average elevation of the line. This value is derived by measuring the average elevation and surface length of each segment of the line after it has been intersected with the TIN surface, and applying the following formula to calculate the average line elevation.

$$\text{Average Elevation} = \frac{\sum_{i=1}^n (EL)}{\sum_{i=1}^n L}$$

where:

n = Number of segments in polyline

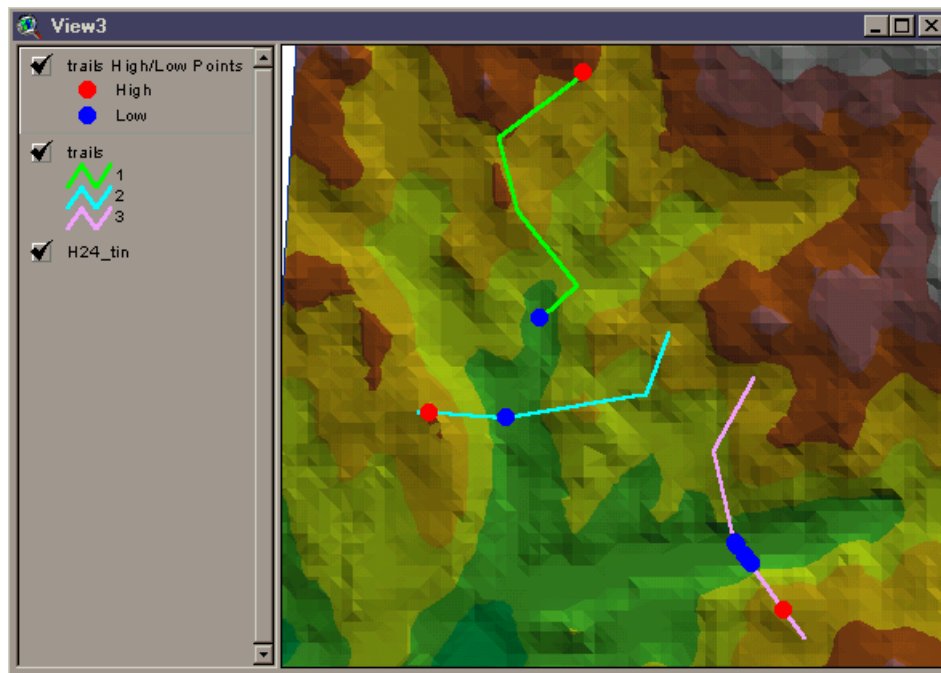
E = Segment Midpoint Elevation

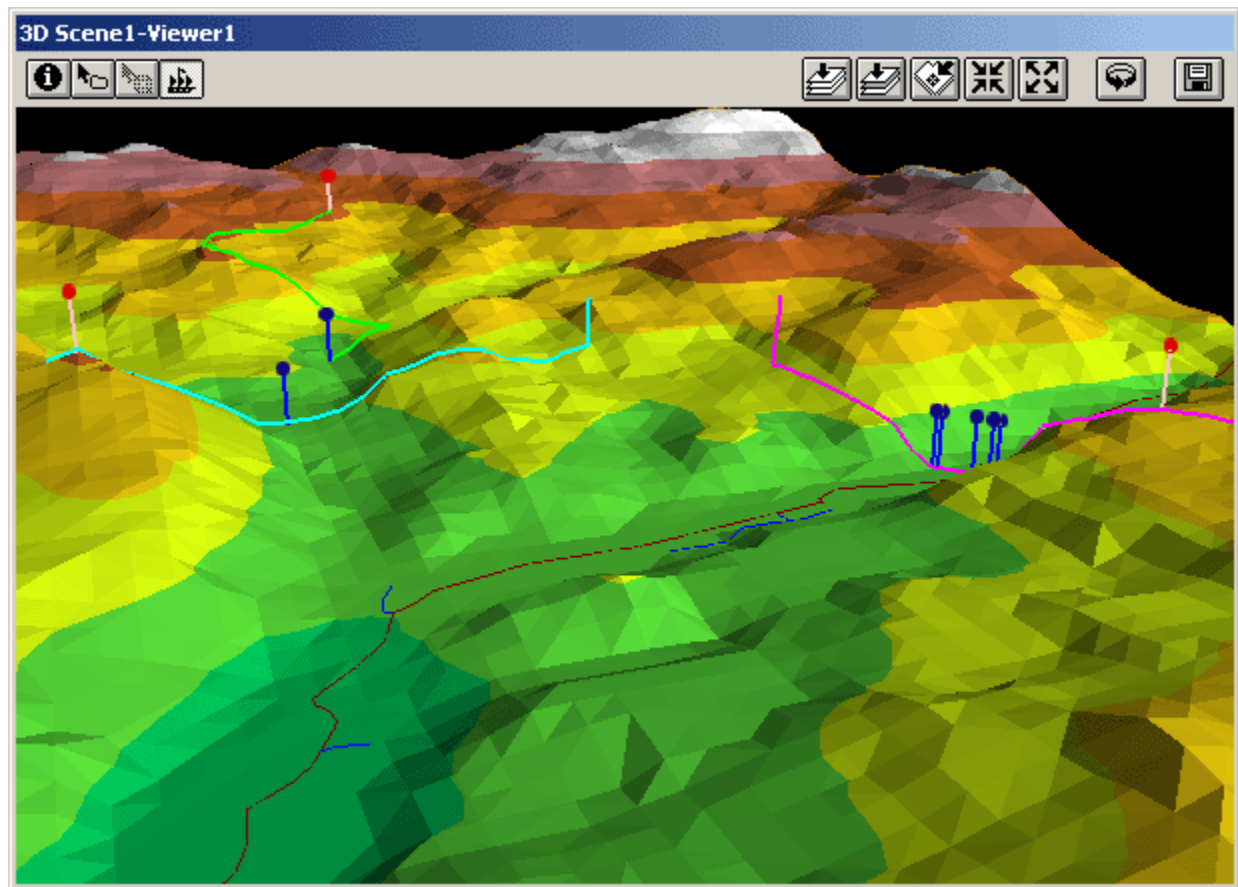
L = Segment Surface Length

- **Elevation Range:** Equal to (Maximum Elevation) - (Minimum Elevation).
- **Absolute Elevation Change:** Equal to the absolute value of (Starting Elevation) – (Ending Elevation).
- **Cumulative Elevation Change:** The total vertical distance the line covers. For example, if a line rose 100 meters, then dropped 50 meters, then rose 100 meters and then dropped 50 meters again, the Cumulative Elevation Change would be 300 meters. This value will always be \geq the Elevation Range.
- **Cumulative Elevation Increase:** The sum of all the elevation increases along the line, going from the beginning to the end of the line. For example, if a line rose 100 meters, then dropped 50 meters, then rose 100 meters and then dropped 50 meters again, the Cumulative Elevation Increase would be 200 meters.
- **Cumulative Elevation Decrease:** The sum of all the elevation decreases along the line, going from the beginning to the end of the line. For example, if a line rose 100 meters, then dropped 50 meters, then rose 100 meters and then dropped 50 meters again, the Cumulative Elevation Decrease would be -100 meters.

Point Shapefile of High and Low Points: If you are interested in the actual X- and Y-Coordinates of the High and Low points on each line, this option will create a Point Shapefile of those high and low points and add it to your view. The Feature Attribute Table for this shapefile will contain the following fields:

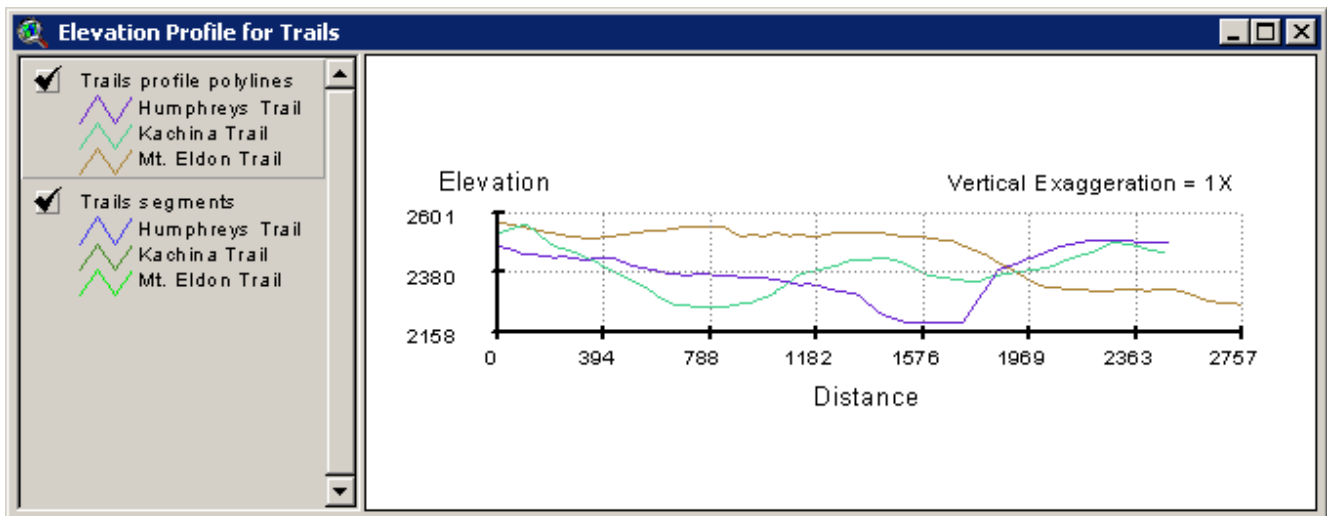
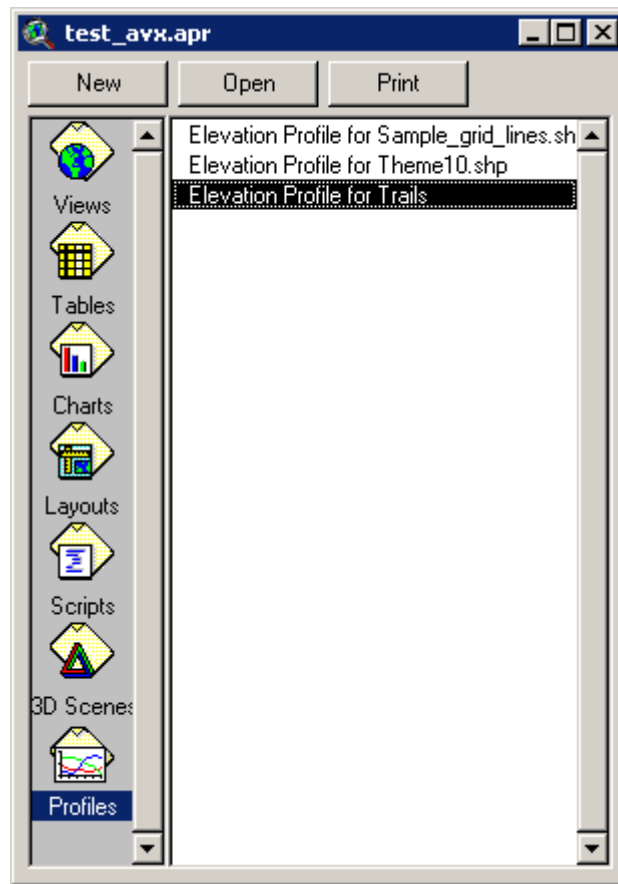
- **ID:** This field tells you which original line contains this particular high or low point, and contains ID values for each line taken from the ID Field you specified when you selected the Polyline Input Theme. The name of this field will also be the same as the ID Field you specified.
- **point_id:** This field assigns a unique numeric ID value to each point.
- **high_low:** This field contains either the word "high" or "low", depending on whether that point is a high or low point on the line.
- **Elevation:** The elevation of that high or low point.
- **X-Coordinate:** The X-Coordinate of that high or low point.
- **Y-Coordinate:** The Y-Coordinate of that high or low point.





Create a Profile Chart of Each Line:

This extension attempts to produce a presentable chart illustrating the elevational changes over the length of the line. The chart will appear in a new class of documents called "Profiles" which should appear at the bottom of your project window:



Profile Chart Components:

Your original polyline theme is represented by two profile themes in this chart. The top one is called "[Your Polyline Theme Name] profile polylines" and contains a single line for each of your original polylines. The feature attribute table for this theme contains the following fields:


- **ID:** This field tells you which original line is represented by this profile line, and contains ID values for each line taken from the ID Field you specified when you selected the Polyline Input Theme. The name of this field will also be the same as the ID Field you specified. If you wish, you can join your RESULTS table to this Feature Attribute Table using this field.

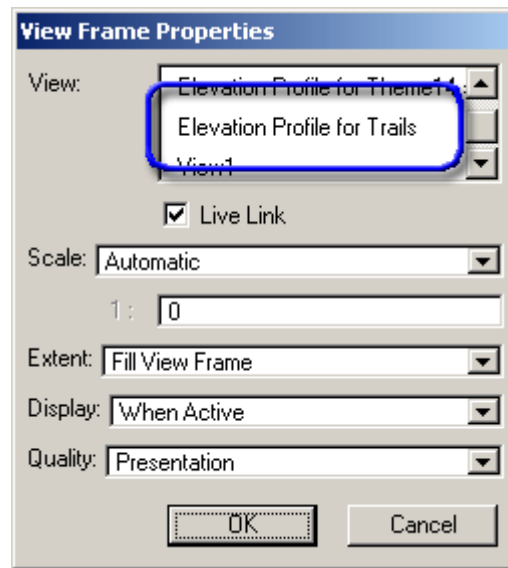
- **Section:** Some polylines are actually multiple lines that may or may not be joined together. This chart will show each section of a multi-part polyline as a separate line, and this "Section" field assigns a unique ascending number to each section of that polyline.
- **Surface Length:** The length of the line as it follows the TIN surface. The line is intersected with the TIN surface such that it gains a new vertex with an elevation value every time it crosses a TIN triangle edge.
- **Flat Length:** The length of the line as if it were on a perfectly flat surface. This "Flat Length" is the length referred to in the "Length" field in most polyline Feature Attribute Tables.
- **Beginning Elevation:** The elevation of the starting point of your polyline.
- **Ending Elevation:** The elevation of the ending point of your polyline.

The second theme representing your polylines is called "[Your Polyline Theme Name] segments," and contains a separate line for each straight-line segment of your original polylines. You can use these segments to find information about portions of your polylines. The feature attribute table for this theme contains the following fields:

- **ID:** This field tells you which original line produced this line segment, and contains ID values for each original line taken from the ID Field you specified when you selected the Polyline Input Theme. The name of this field will also be the same as the ID Field you specified.
- **Section:** Some polylines are actually multiple lines that may or may not be joined together. Each section of a multi-part polyline has a separate Section ID number, and this "Section" field tells you which section of your original line produced this line segment.
- **Segment:** Each original line will have multiple segments represented in this table, and this "Segment" field uniquely identifies each segment within that original line.
- **Slope:** The slope, in degrees, of this line segment.
- **Surface Length:** The true 3-dimensional length of this line segment.
- **Surface Distance Range:** This tells you the measure of the starting and ending points of the line segment, using the surface length of the line, and is written in text format (i.e. "132.445 to 144.556").
- **Flat Length:** The length of the line segment assuming no elevational changes, and is equivalent to the "Length" field found in many Polyline Feature Attribute Tables.
- **Flat Distance Range:** This tells you the measure of the starting and ending points of the line segment, using the flat length of the line, and is written in text format (i.e. "132.445 to 144.556").
- **Beginning Elevation:** The elevation of the starting point of the line segment.
- **Ending Elevation:** The elevation of the ending point of the line segment.

Adding Profile Chart to Layouts:

The Profile chart itself is based on the View document type and can be added to layouts in the same manner that Views are added to layouts; simply click the  button in the layout, draw your box to hold the chart, and then look for the profile chart in the list of views:



Click 'OK' and the chart will be added to your layout in a View frame, and will behave in all the same ways that other View frames do.

Profile Chart GUI Tools:







Because the profile chart is based on the View document type, it has many of the same zooming and editing tools available to it that Views do. There are also several special tools that allow you to modify and customize the chart in a variety of ways:




Profile Tools

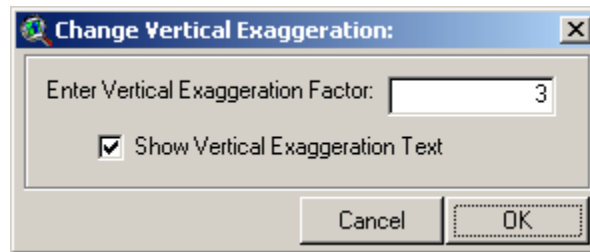
Many of these buttons and tools should be familiar from the View interface and these controls operate identically to the View controls. There are several tools for adding text and graphics to the Profile that are also copied from the View tools but they are presented here as separate tools rather than in a drop-down menu of tools.


Profile-Specific Tools:

-  Change the Vertical Exaggeration of the profile chart.
-  Change X-Axis attributes of the profile chart.
-  Change Y-Axis attributes of the profile chart.
-  Change text properties of profile labels.
-  Refresh and redraw the profile chart.
-  Get profile characteristics by clicking on the chart.


Changing the Vertical Exaggeration:

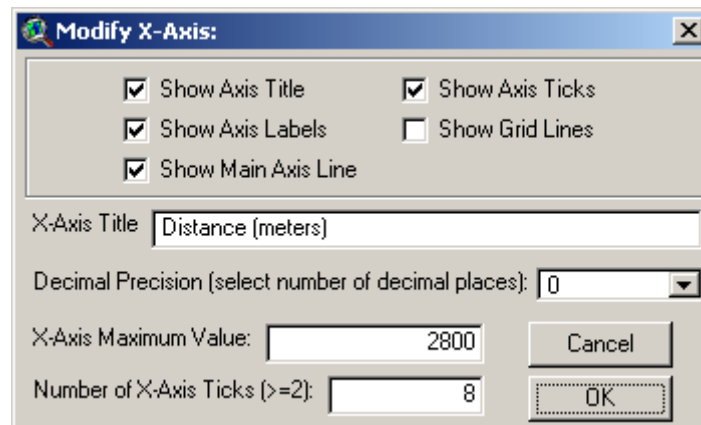
If you wish your chart to be either stretched or squashed vertically, you can change the vertical exaggeration. The chart opens with a default vertical exaggeration of 1, which shows the true relative elevation change over the length of the line. This may not be graphically useful for some purposes, however, so you can easily change the exaggeration factor by clicking the  button and setting a new value:




Use the  button to change the font and size of your Vertical Exaggeration text.


Changing the X-Axis Attributes:


This option allows you to set the X-Axis title, the number of divisions, the maximum distance value, the decimal precision of the distance values, and whether you want to turn off any of the graphics. Click the  button to open the "Modify X-Axis Window":



Use the  button to change the font and size of your X-Axis text.

Changing the Y-Axis Attributes:

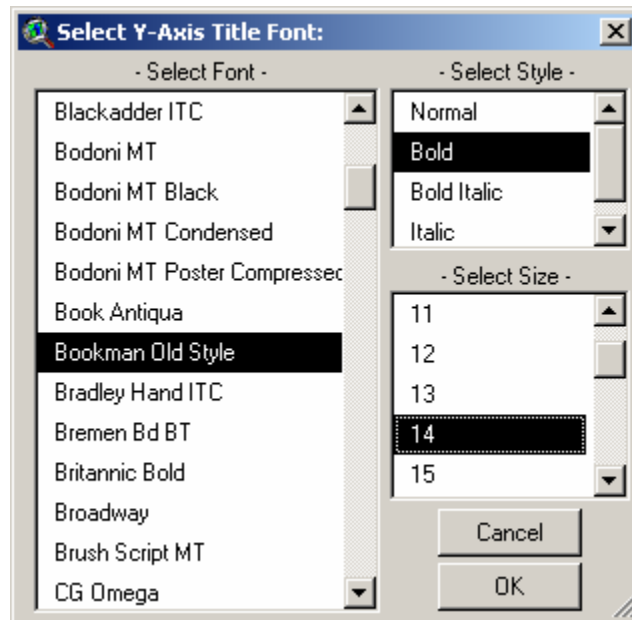
This option allows you to set the Y-Axis title, the number of divisions, the minimum and maximum elevation value, the decimal precision of the elevation values, and whether you want to turn off any of the graphics. Click the  button to open the "Modify Y-Axis Window":

Use the  button to change the font and size of your Y-Axis text.

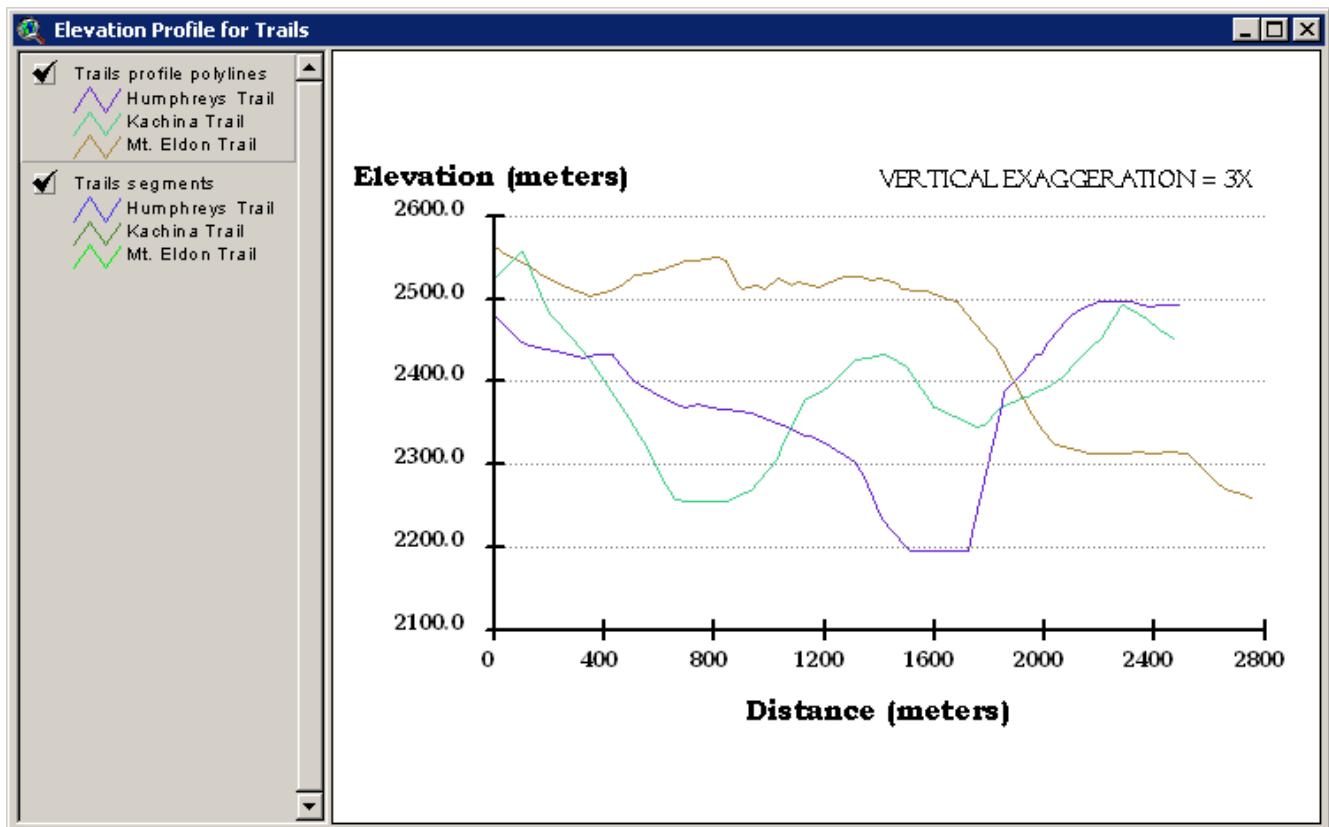
Changing Text Attributes:

This option allows you to change the font and size for the 5 general Profile text classes, and also specify whether or not you want them to be shown in the profile.


To change the font or font size of any of the text classes, simply click on the appropriate button and set your preference for that class:





After you have set all your fonts, click the 'OK' button to apply the changes. Based on all the preferences specified in the examples above, the modified profile chart would look like the following:

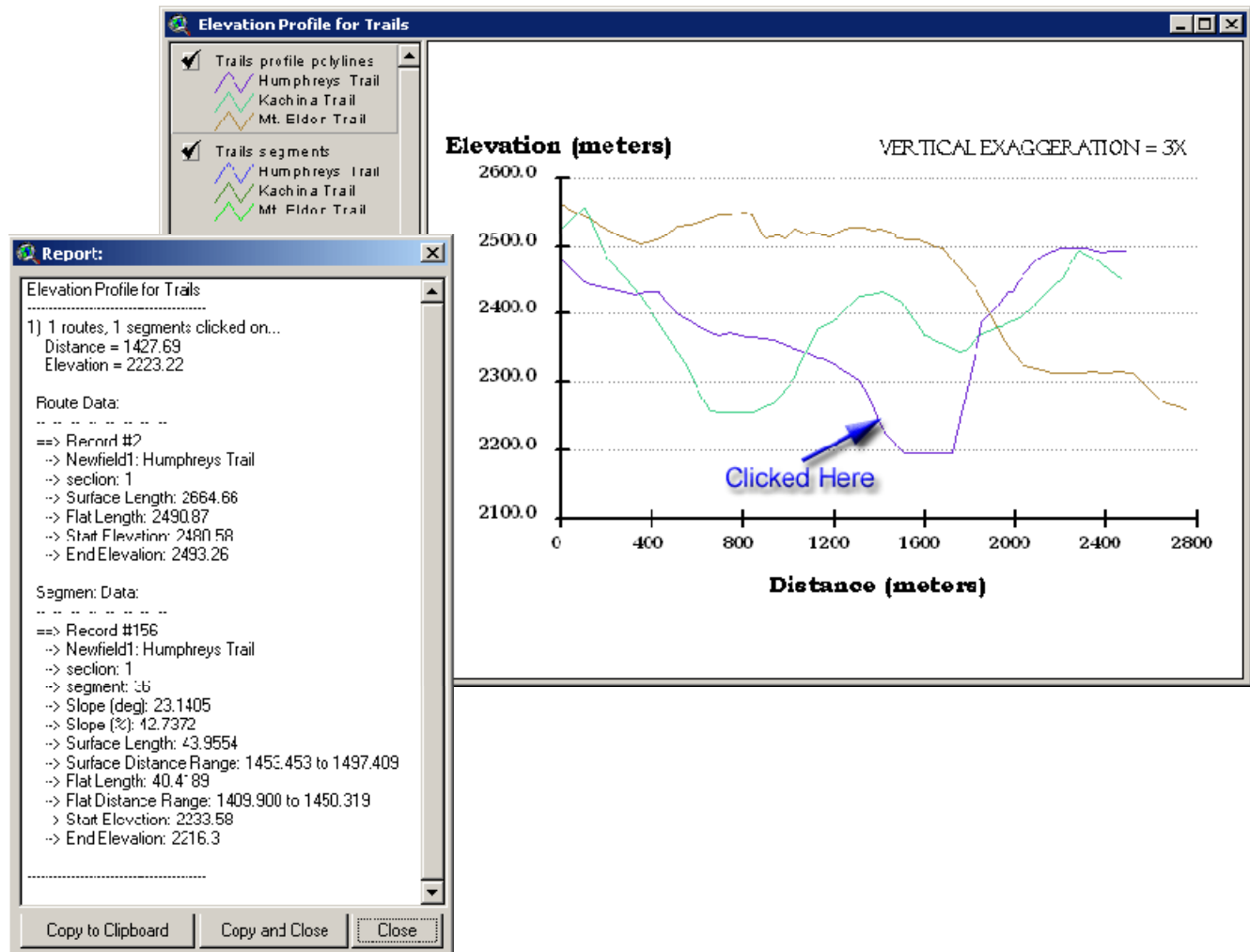



Refreshing your Profile Chart:

If you make any general changes to the extent of the chart, such as changing the window size, zooming or panning, you can regenerate the chart by clicking the  button. This refits the chart into the current window and resets all the text so the font sizes are appropriate.

Querying the Chart:

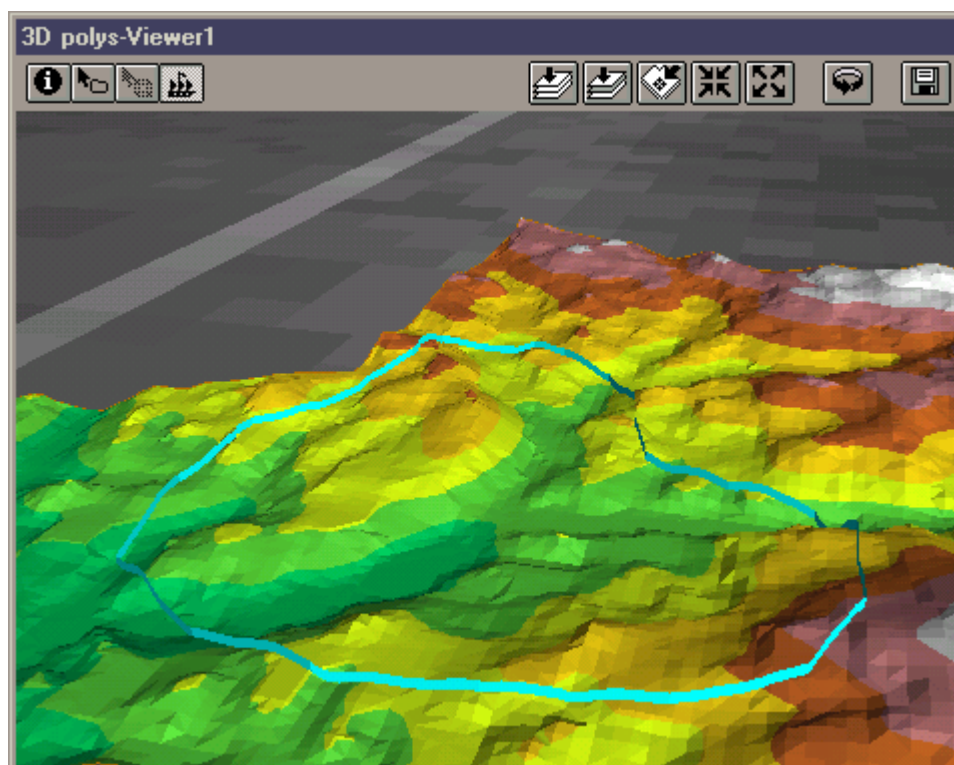
As with a theme in a view, you can identify feature attributes for that theme by clicking on the  tool and then clicking on the lines you are interested in. You may select different portions of the lines and calculate average slopes or (Surface Length)/(Flat Length) ratios. The Profile window also includes the  tool which provides slightly more profile-specific attribute data:



Keep in mind that 3D Analyst also offers a profile chart: If you convert your Line shapefile to a 3D shapefile (From View, see Menu Item "Theme", then "Convert to 3D Shapefile..."), then open a Layout, you will be able to use the  tool to generate a profile chart within a Layout. This option offers a few graphical functions but no analytical options.

Move on to [Saving Data...](#)

Surface Tools for Polygons:



If your Input Theme is a Polygon theme, you will see the following dialog box prompting you for the proper elevation theme and the Polygon surface characteristics you wish to calculate:

Select Elevation Theme and Desired RESULTS data:

Select
- Elevation Theme -
GRID or TIN

Sample_tin
Sample_grid

Z-Factor:

Buffer Factor:

Data for RESULTS Table

----- AREA and VOLUME DATA -----

☒ Surface Area of Polygon: ☒ Surface Area Ratio
(Surface Area)/(Flat Area)

☒ Flat Area of Polygons

☐ Surface Area above (Elevation in Z-Coordinate units)

☐ Surface Area below (Elevation in Z-Coordinate units)

☐ Volume above (Elevation in Z-Coordinate units)

☐ Volume below (Elevation in Z-Coordinate units)

----- ELEVATION DATA -----

☒ Highest Elevation ☒ Elevation Range

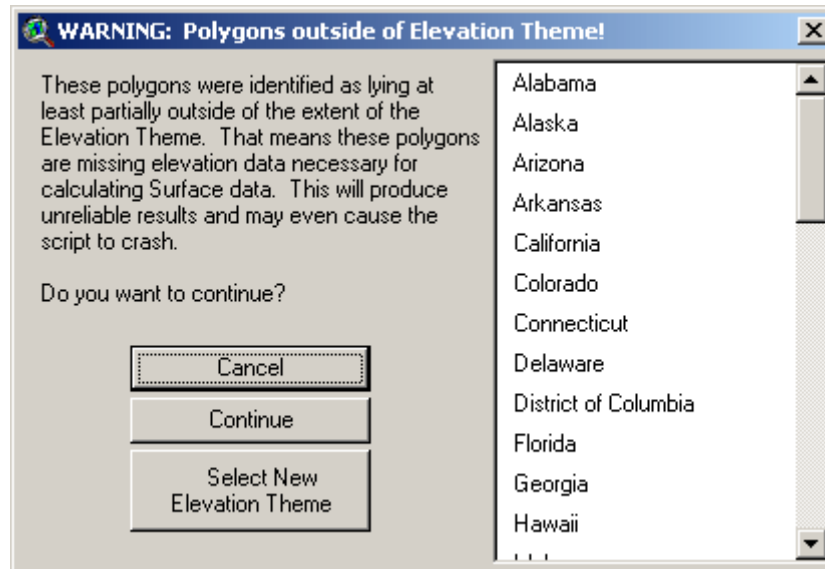
☒ Lowest Elevation ☒ Elevation Standard Deviation

☒ Mean Elevation ☒ Create Shapefile of High and Low Points

☐ Do you want to join the RESULTS table with the Polygon Attribute Table?

Your Elevation Theme can be either a GRID or a TIN. If you use a GRID, this extension will create a TIN surface from the GRID before calculating your polygon surface data. You will be prompted to enter a Z-Factor and a Buffer Factor for the extension to use when creating the TIN. Please see [Z-Factors and Buffer Factors](#) for an explanation of these parameters.

The Elevation Theme list contains all the TINs or GRIDs contained in your view. Pick the one you want to use to generate surface data from. You need to be careful to select one that actually covers all of your polygons, or else you will end up trying to calculate surface characteristics without any data. This will definitely give you questionable results and will probably cause the extension to crash. The extension checks to make sure that your polygons are all contained in the elevation theme extent and prompts you with the following dialog box if it finds problems:



Output Data: You may include any or all of the 10 surface/topographic characteristics of the polygons in your RESULTS table. You also have the option to create a Point shapefile of the high and low points within your polygons and you can automatically join your RESULTS table with your Polygon feature attribute table. Your RESULTS table will have any or all of the following fields:

- **ID:** This contains ID values for each polygon taken from the ID Field you specified when you selected the Polygon Input Theme. The name of this field will also be the same as the ID Field you specified.
- **Surface Area:** The surface area, in square map units, within that polygon.
- **Flat Area:** The flat (or planimetric) area, in square map units, within that polygon. This is what the surface area would be if the polygon were perfectly flat, and is equivalent to the polygon "area" value in most polygon feature attribute tables.
- **Surface Area Ratio:** This value is equal to (Surface Area)/(Flat Area) ratio, and provides an index of the topographic roughness of the polygon. This value will always be ≥ 1 because the surface area will always be \geq flat area.
- **Surface Area Above _____:** The surface area above a horizontal plane located at a specified elevation.
- **Surface Area Below _____:** The surface area below a horizontal plane located at a specified elevation.
- **Volume Above _____:** The surface volume above a horizontal plane located at a specified elevation.
- **Volume Below _____:** The surface volume below a horizontal plane located at a specified elevation.
- **Highest Elevation:** The elevation of the highest point in that polygon.

- **Lowest Elevation:** The elevation of the lowest point in that polygon.
- **Mean Elevation:** Calculated as the weighted mean of triangle elevation values for all the TIN triangles inside the polygon, with each triangle weighted by the surface area:

$$\text{Mean Elevation} = \frac{\sum_{i=1}^n f_i y_i}{\sum_{i=1}^n f_i}$$

where:

n = number of triangles in TIN

y_i = elevation of centerpoint of TIN triangle

f_i = area of TIN triangle

- **Elevation Range:** The range of elevation between the lowest and the highest point in that circle.
- **Elevation Standard Deviation:** Calculated using the formula for the standard deviation of grouped data, where triangle area represents the frequency of each group. I treated this as a population standard deviation rather than a sample standard deviation (i.e. I divided by n instead of by $n-1$):

$$\sigma = \sqrt{\frac{\sum_{i=1}^q f_i (y_i - \bar{y})^2}{n}}$$

$$= \sqrt{\frac{\sum_{i=1}^q f_i y_i^2 - \frac{\left(\sum_{i=1}^q f_i y_i\right)^2}{n}}{n}}$$

where:

q = number of triangles in TIN

n = total surface area of triangles in TIN

y_i = elevation of centerpoint of each TIN triangle

f_i = surface area of each TIN triangle

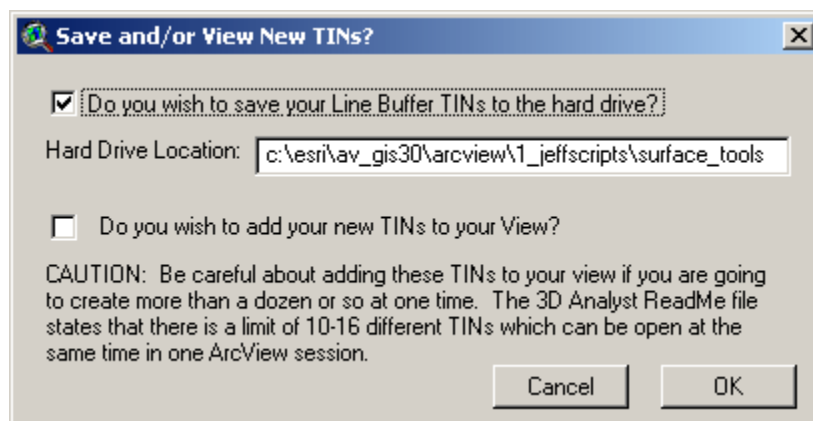
Point Shapefile of High and Low Points: If you are interested in the actual X- and Y-Coordinates of the High and Low points in your polygons, this option will create a Point Shapefile of those high and low points and add it to your view. The Feature Attribute Table for this shapefile will contain the following fields:

- **ID:** This field tells you which polygon contains this particular high or low point, and contains ID values for each polygon taken from the ID Field you specified when you selected the Polygon Input Theme. The name of this field will also be the same as the ID Field you specified.
- **point_id:** This field assigns a unique numeric ID value to each high or low point.
- **high_low:** This field contains either the word "high" or "low", depending on whether that point is a high or low point on the line.
- **Elevation:** The elevation of that high or low point.
- **X-Coordinate:** The X-Coordinate of that high or low point.
- **Y-Coordinate:** The Y-Coordinate of that high or low point.

Move on to [Saving Data...](#)

Saving Data to Disk:

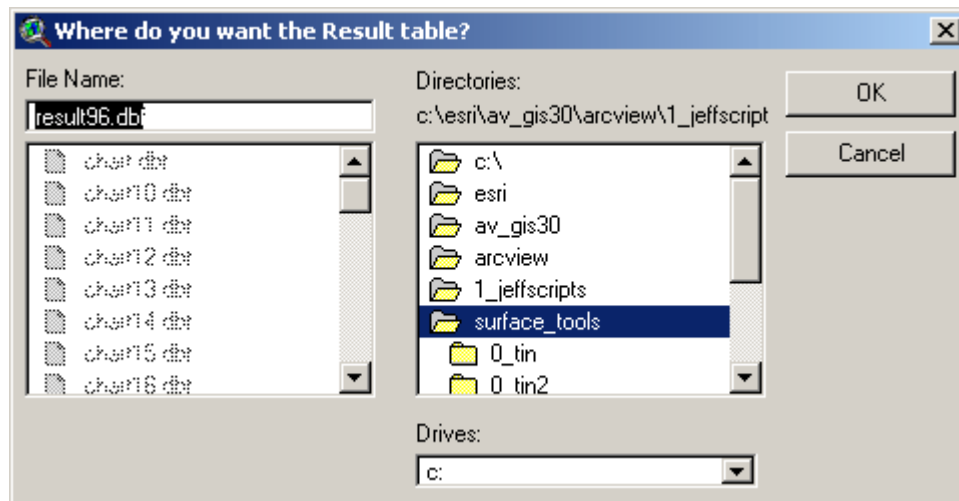
Select Location to save TINs, and decide whether to put TINs into active View: If your elevation theme is a GRID, then this extension must generate a TIN surface to calculate surface and topographic characteristics of your features. If your elevation theme is a TIN and you are calculating surface data for polygons or circles around points, then this extension will create clipped TINs within the polygon boundaries (see [Clipping TINs](#) for a description of a clipped TIN). In either case you have the option to save the new TINs and add them to your view.



As this extension calculates TINs and surface area data for each polygon, it has to save the TIN to the hard drive at least temporarily. By default it will save it to your Current Working Directory, but you can change this by typing in a new path name. If you uncheck this option, the TIN will still be saved to the Current Working Directory but it will then be deleted as soon as the surface characteristics have been calculated. This allows you to save hard drive space if you really don't want or need the TINs.

You also have the option to add your TINs to your View. If you want to do this, you must save the TINs to your hard drive. I've included a warning here that you might want to be careful about adding the TINs to your view if you're creating more than a dozen or so at once. The author has had his ArcView session crash before when he's run scripts that add lots of TINs to his view. The 3D Analyst ReadMe file states that "There is a limit of 10-16 different TINs which can be open at the same time in one ArcView session. The number varies depending on whether the TIN directory contains TMSK, TNVAL, and TTVAL files. Do not try to open more than 10 different TINs in the same project. You can have more than 10-16 TIN object variables if some of them reference the same TIN source that's stored on disk."

Specify Hard Drive Location to save the RESULTS table: Regardless of whether you choose to join your RESULTS table with your polygon Feature Attribute Table, you will still be prompted to specify a location on the hard drive to save your RESULTS table. This is a standard ArcView Dialog Box and should be familiar to most users. This table is a permanent table and will not be deleted when ArcView is shut down.



You may also see similar dialog boxes prompting you for a location to save your "High and Low Points" shapefile, if you have checked this option.

Updates:

This extension replaces the extension called "Surface Areas and Ratios." This extension duplicates all functions in "Surface Areas and Ratios" and adds many new functions.

- The 1.1 update adds functionality for PointZ, PolylineZ and PolygonZ feature types, and fixes a file-naming error that occurred intermittently when the user chose not to save TINs to the hard drive.
- The 1.2 update corrects a logical error made when calculating average slopes, adds the ability to calculate slopes in both "%-Slope" and "Degrees", and adds the ability to save circles around points as a separate polygon shapefile.
- The 1.3a update corrects an error calculating planimetric area when the reference surface dips below 0.
- The 1.4 update (December 13, 2003) fixes a bug that occasionally triggered an error with the message "SurfaceTools.SurfaceRatio: Unrecognized object: TIN at 37137".
- The 1.4 revision also adds several tools to the Line Profile window to make it more useful and interesting, allowing the user to customize many aspects of the chart including the vertical exaggeration factor. The revision also adds options to the Polyline window to calculate the beginning and ending elevations of lines, plus whether the line goes predominately up or down.
- The 1.4a revision (January 13, 2004) corrects a bug with the "Buffer Factor Help" button, in which it would return the error message "Error in SurfaceTools.BufferHelp2 at 214 -- A(n) Nil object does not recognize request Open" if accessed from the Polyline or Polygon windows.
- The 1.5 revision (May 11, 2004) adds the options to calculate the elevation mean and standard deviation within polygons and circular areas around points, and the absolute elevation change for polylines. Also made some internal changes to speed up the calculation time when identifying high/low points, and to clean up some of the temporary files that previously were left on the hard drive.
- The 1.6 revision (February 13, 2005) adds the options to calculate cumulative increases and decreases along polylines, as well as rewrites certain functions to stop it from crashing on ArcView 3.1.
- The 1.6a revision (May 5, 2006) adds functions to check scripts for errors, and slightly modifies some of the dialogs.
- The 1.6b revision (February 11, 2008) fixes a bug in which multiple coincident extreme points were generated (i.e. several Lowest Points, all at the same location). Now only one point feature will be generated for each unique location.

Updates to this extension, plus an on-line version of this manual, are available at:

http://www.jennessent.com/arcview/surface_tools.htm

Enjoy! Please contact the author if you have problems or find bugs.

Jeff Jenness
Jenness Enterprises
3020 N. Schevene Blvd.
Flagstaff, AZ 86004
USA

jeffj@jennessent.com
<http://www.jennessent.com>
(928) 607-4638

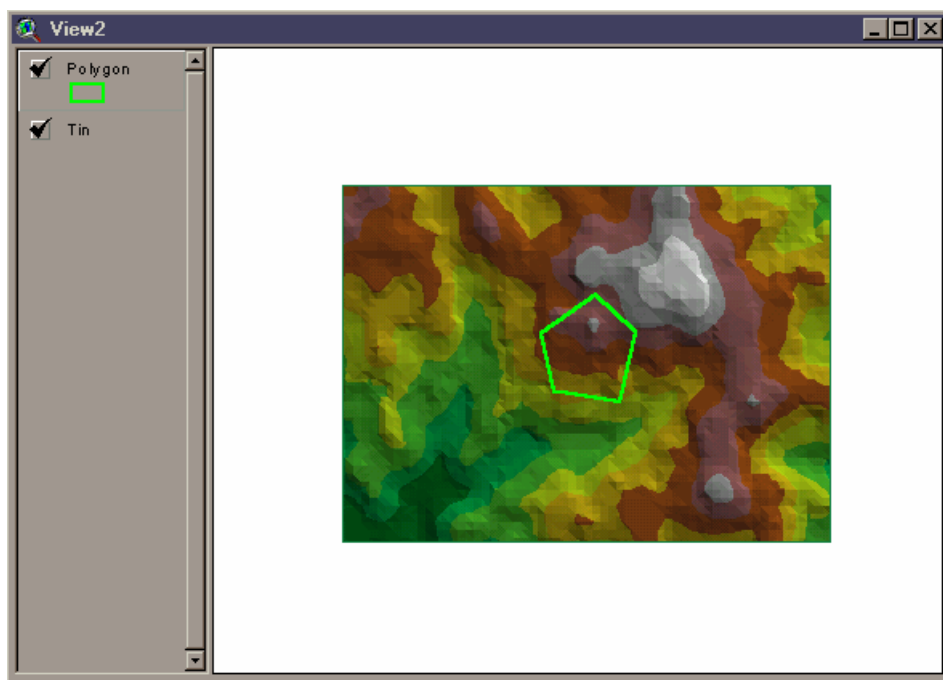
Please visit *Jenness Enterprises* [ArcView Extensions](http://www.jennessent.com/arcview/extensions) site for more ArcView Extensions and other software by the author. We also offer customized ArcView-based [GIS consultation](http://www.jennessent.com/gis_consultation) services to help you meet your specific data analysis and application development needs.



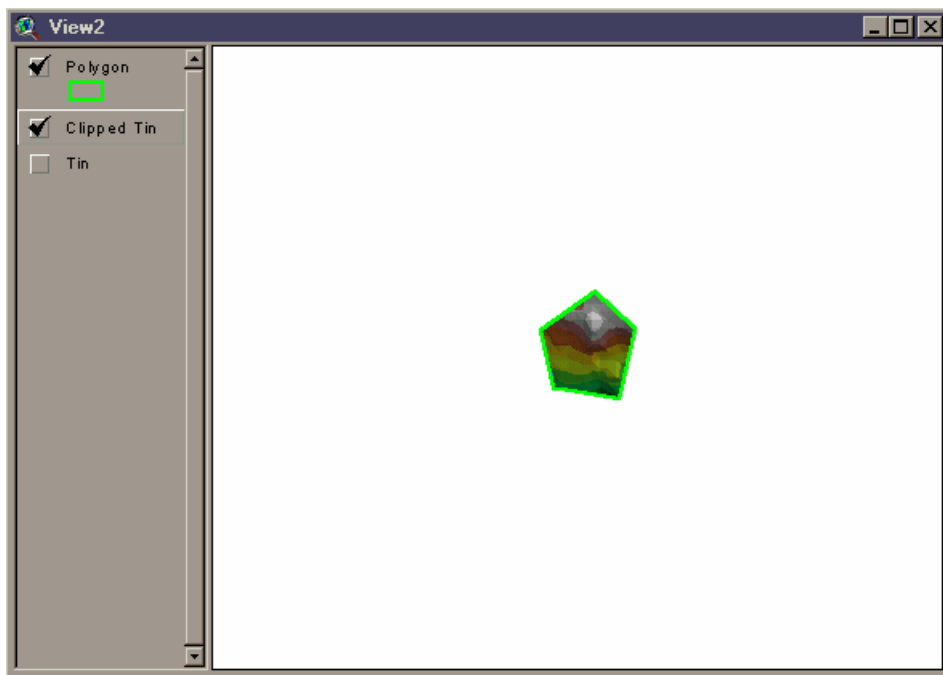
Appendix A: Clipping TINs:

ArcView 3D Analyst offers an option to add "Clip" boundaries to existing TINs that allows you to restrict most calculations to only that portion of the TIN that lies within the Clip boundary. Visually, the TIN actually does appear to be "Clipped", in the way that most ArcView users are familiar with clipping polygon and polyline shapes:

TIN Prior to Clipping:

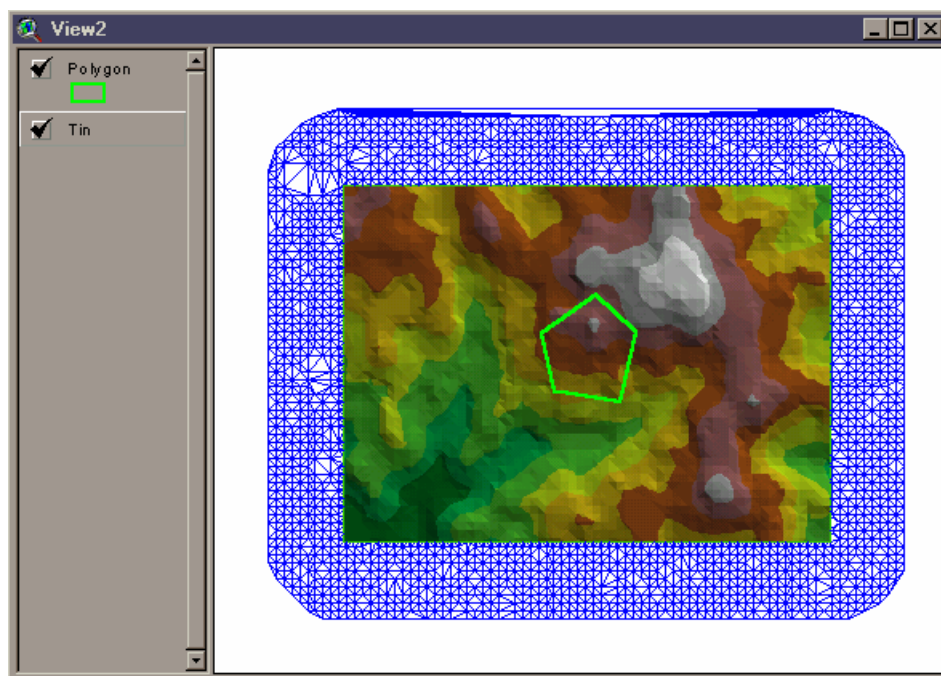


TIN After Clipping:

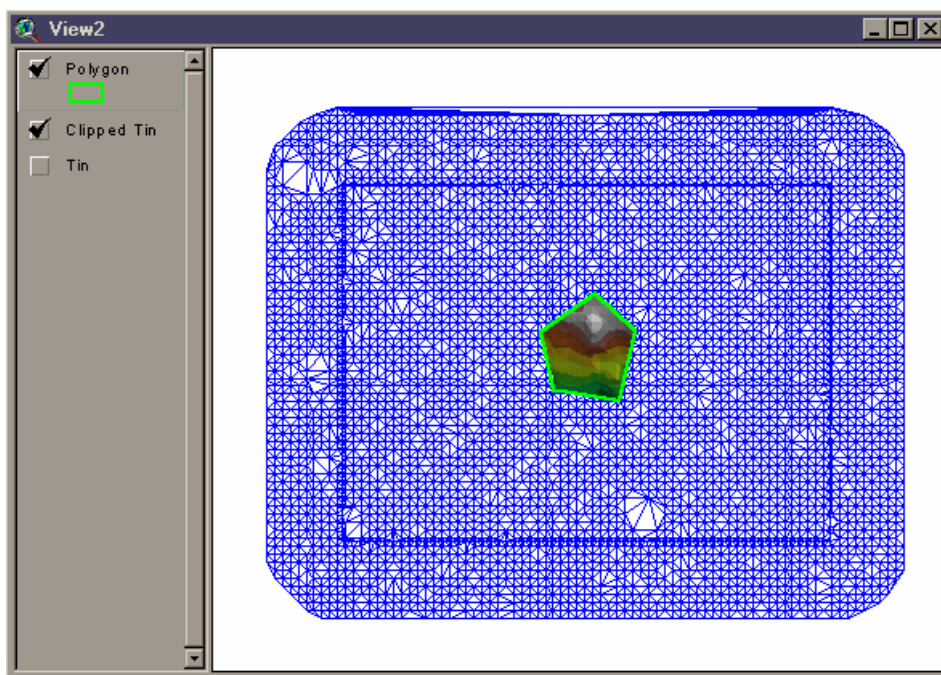


However, the TIN itself is still just as large as it was before. What ArcView has done is to add a "Clip Boundary" inside the TIN that marks off a "Zone of Interpolation". 3D Analyst functions such as Surface Area, Volume, etc. are hereafter only applied to that portion of the TIN that lies within this Zone of Interpolation. If you change the display properties of the TIN to show you all the lines, including those that occur outside the Zone of Interpolation, you will see that the TIN still covers the entire area it did before:


TIN Prior to Clipping, with "Outside" lines visible:



TIN After Clipping, with "Outside" lines visible:



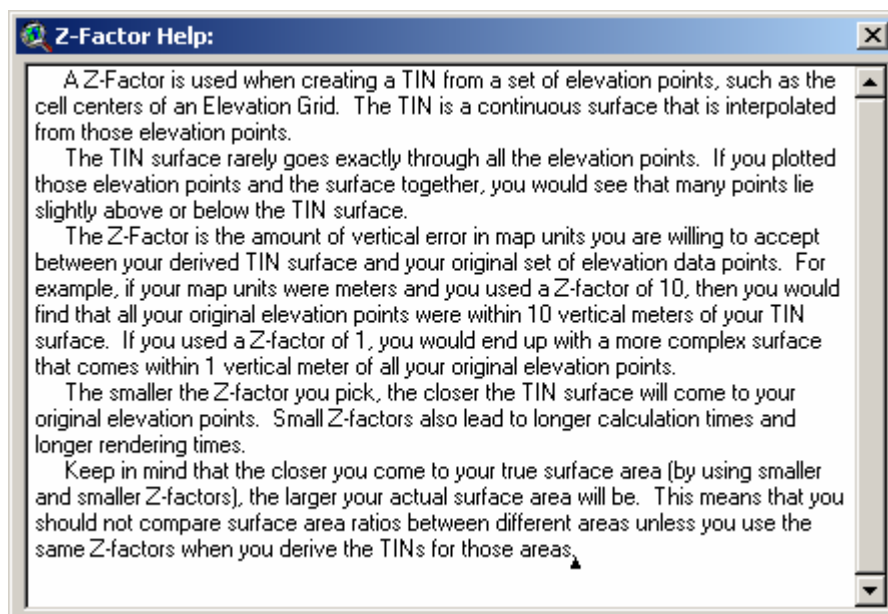
The "Surface Tools for Points, Lines and Polygons" extension allows you to clip TINs to polygon boundaries and save your clipped TINs to your hard drive. However, because the entire TIN is retained, you should be aware that your "clipped" TINs will take just as much hard drive space and will take just as long to draw as your original TIN. This is why it may seem to take a unusually long time to draw a "small" TIN like the clipped tin above.



Appendix B: Z-Factors and Buffer Factors:

There are two parameters to consider when calculating TINs; the **Z-Factor** and the **Buffer Factor**. These two factors affect how this extension creates a TIN from a GRID, so they only apply if your elevation theme is a GRID. If your elevation theme is a TIN, these two options become inactive and can't be edited.

Both the **Z-Factor** and the **Buffer Factor** come with *Help* buttons to give you some clue as to what they do. Click the *Help* buttons to open the following help screens:



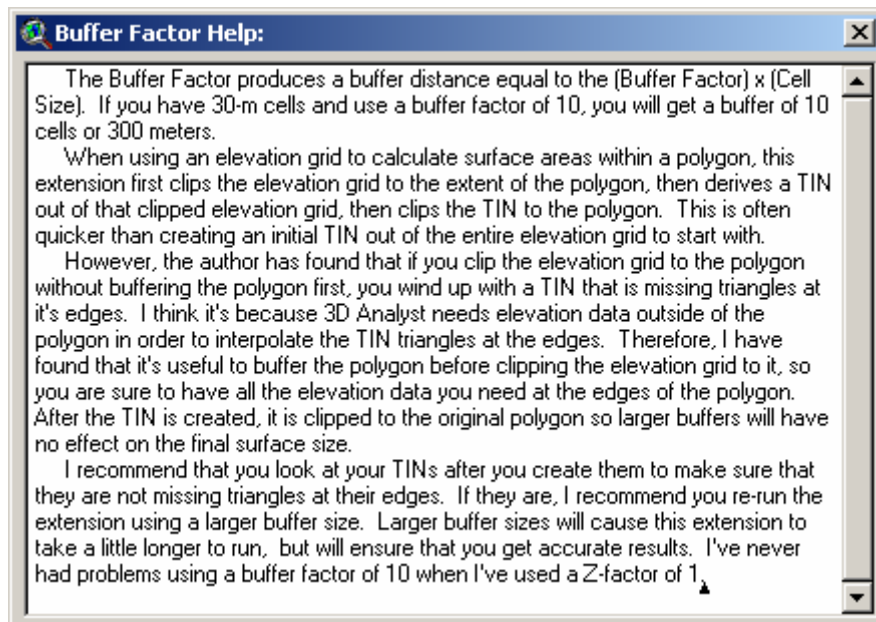
Z-Factor Help: A Z-Factor is used when creating a TIN from a set of elevation points, such as the cell centers of an Elevation Grid. The TIN is a continuous surface that is interpolated from those elevation points.

The TIN surface rarely goes exactly through all the elevation points. If you plotted those elevation points and the surface together, you would see that many points lie slightly above or below the TIN surface.

The Z-Factor is the amount of vertical error in map units you are willing to accept between your derived TIN surface and your original set of elevation data points. For example, if your map units were meters and you used a Z-factor of 10, then you would find that all your original elevation points were within 10 vertical meters of your TIN surface. If you used a Z-factor of 1, you would end up with a more complex surface that comes within 1 vertical meter of all your original elevation points.

The smaller the Z-factor you pick, the closer the TIN surface will come to your original elevation points. Small Z-factors also lead to longer calculation times and longer rendering times.

Keep in mind that the closer you come to your true surface area (by using smaller and smaller Z-factors), the larger your actual surface area will be. This means that you should not compare surface area ratios between different areas unless you use the same Z-factors when you derive the TINs for those areas.



Buffer Factor Help: The Buffer Factor produces a buffer distance equal to the (Buffer Factor) x (Cell Size). If you have 30-m cells and use a buffer factor of 10, you will get a buffer of 10 cells or 300 meters.

When using an elevation grid to calculate surface areas within a polygon, this extension first clips the elevation grid to the extent of the polygon, then derives a TIN out of that clipped elevation grid, then clips the TIN to the polygon. This is often quicker than creating an initial TIN out of the entire elevation grid to start with.

However, the author has found that if you clip the elevation grid to the polygon without buffering the polygon first, you wind up with a TIN that is missing triangles at its edges. I think it's because 3D Analyst needs elevation data outside of the polygon in order to interpolate the TIN triangles at the edges. Therefore, I have found that it's useful to buffer the polygon before clipping the elevation grid to it, so you are sure to have all the elevation data you need at the edges of the polygon. After the TIN is created, it is clipped to the original polygon so larger buffers will have no effect on the final surface size.

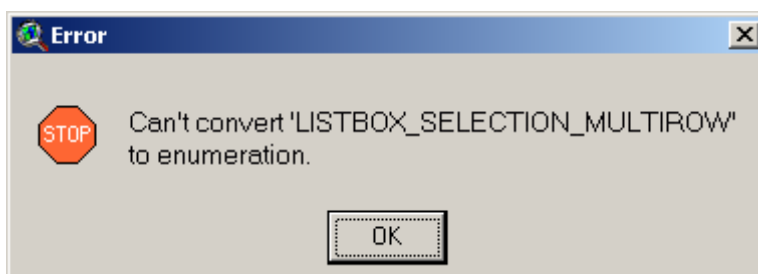
I recommend that you look at your TINs after you create them to make sure that they are not missing triangles at their edges. If they are, I recommend you re-run the extension using a larger buffer size. Larger buffer sizes will cause this extension to take a little longer to run, but will ensure that you get accurate results. I've never had problems using a buffer factor of 10 when I've used a Z-factor of 1.

Appendix C: Troubleshooting:

If you encounter some strange crash, please click the menu item "Check 'Surface Tools' Scripts" in either the View or Project Help menu. With any luck, that function will generate a report with enough information for the author to find and fix the problem.

Otherwise, the problem may be found and explained below:

Problem: Extension Fails to Load, with the following error message:

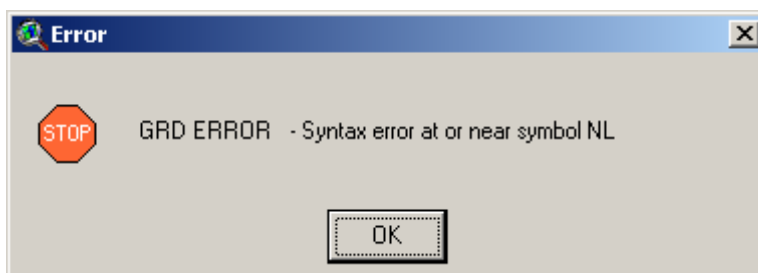


Solution: This problem is caused by an outdated version of the Dialog Designer. For some reason, some versions of ArcView 3 were shipped with an older version of Dialog Designer which didn't support this "LISTBOX_SELECTION_MULTIROW" option (which basically means that a listbox on a dialog is set so that you can select multiple items from the list).

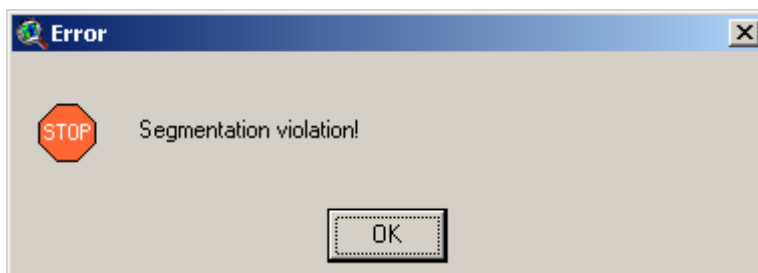
ESRI has a newer version of the Dialog Designer available on their website for free download. Please link to:

<http://support.esri.com/index.cfm?fa=downloads.patchesServicePacks.viewPatch&PID=25&MetalD=483>

Problem: Extension crashes in mid-operation, producing an obscure message stating that there is a syntax error at or near symbol NL:



This is sometimes followed by the infamous Segmentation Violation message:



Sometimes ArcView crashes completely and vanishes without showing these messages; while other times it vanishes after showing these messages.

Solution: There is no simple solution to this problem. It is due to a bug in Spatial Analyst and 3D Analyst which causes ArcView to crash after approximately 32,500 grid operations or if ArcView tries to hold > 50 grids in memory at one time. You can force the error to occur by writing a short script that checks the cell value at a particular point, then loops over 32,500 iterations. You can also trigger it by running the Zonal Statistics function on a point theme containing over 32,500 points. You would probably trigger this error if you tried to classify

grids using > 50 classification values because it creates a separate grid for each classification and then merges them for the final output.

I am unaware of a simple way to work around this problem. If possible, use smaller point data sets or try to use fewer grids in your analysis. Alternatively, I hear that ArcGIS 9 was expected to fix this problem.

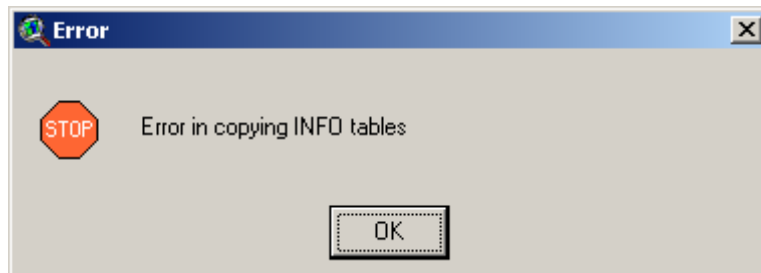
Problem: Unable to find grid in a directory, even though you know it is there.

Solution: This is probably due to a space or invalid character in the pathname. For some reason, Spatial Analyst doesn't recognize a grid if it lies in a folder with a space or period in it. For example, if you store your grids in the standard default Windows directory "My Documents," you will probably not see the grid listed in the "Add Theme" dialog at all. The "Add Theme" dialog will show you all the shapefiles and images, but no grids. The only solution is to move your grid to a different file location where it does not lie in a path with invalid characters.

Problem: You load your grids but you are unable to do any calculations on them. They don't act like grids.

Solution: You may have loaded them as images. Grids can be loaded as either images or grids, and you can't do any of the grid functions on them if you have loaded them as images. Try adding them to your view again, but make sure that you have "Grid Data Source" selected instead of "Image Data Source".

Problem: Extension crashes in mid-calculation, with the message:



Solution: This error may be caused by either a corrupt INFO directory or if your working directory pathname is too long. I am unaware of the exact pathname size that triggers the error, but I think it is around 80 characters. If you have over 80 characters in your pathname and you see this error, then you can probably avoid it by changing your work directory to someplace closer to the root.