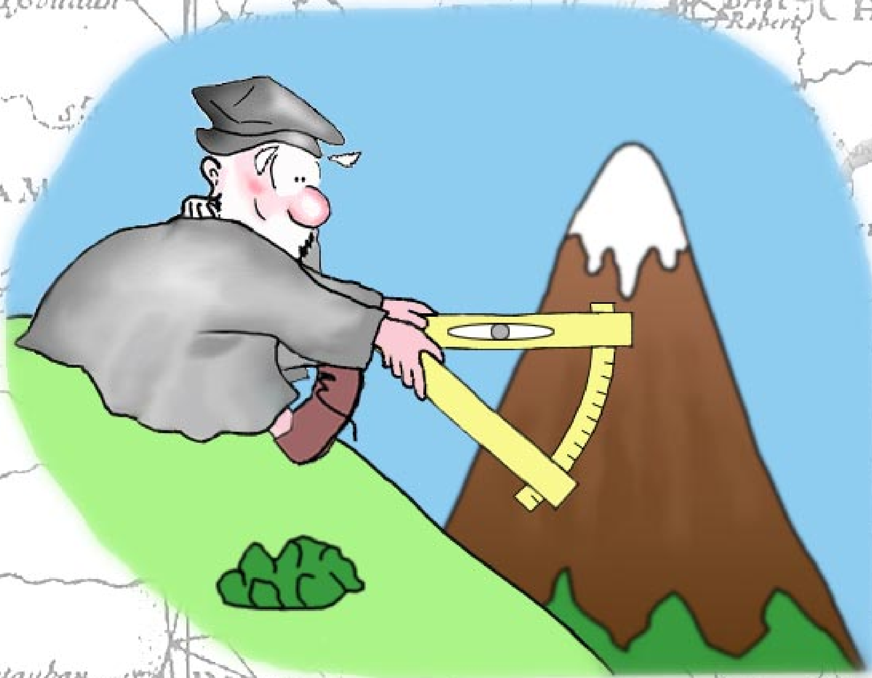
TERRAIN ANALYSIS

Getting Started

Analyzing Terrain and Surfaces



with

TNTmips®

Before Getting Started

The shape of the land surface is an important aspect of any area's physical environment. Topography profoundly influences many physical and biological processes and provides the backdrop for human activities such as construction, transportation, communication, resource management, and recreation. Because of the varied ways in which natural or manmade systems interact with landscapes, computer analysis and modeling of terrain requires a number of specialized software tools. This booklet introduces a series of TNTmips® processes that allow you to analyze elevation rasters and to model various types of interaction with terrain.

Prerequisite Skills This booklet assumes that you have completed the exercises in *Getting Started: Displaying Geospatial Data* and *Getting Started: Navigating*. Those exercises introduce essential skills and basic techniques that are not covered again here. Please consult those booklets and the TNTmips reference manual for any review you need.

Sample Data The exercises presented in this booklet use sample data that is distributed with the TNT products. If you do not have access to a TNT products CD, you can download the data from MicroImages' web site. In particular, this booklet uses sample files in the TERRAIN data collection. Be sure the sample data has been installed on your hard drive so changes can be saved as you use these objects in the following exercises.

More Documentation This booklet is intended only as an introduction to terrain and surface analysis. Consult the TNTmips reference manual, which contains more than 15 pages on terrain analysis processes, for more information.

TNTmips and TNTlite® TNTmips comes in two versions: the professional version and the free TNTlite version. This booklet refers to both versions as "TNTmips." If you did not purchase the professional version (which requires a hardware key), TNTmips operates in TNTlite mode, which limits the size of your objects and does not allow export.

All the exercises can be completed in TNTlite using the sample geodata provided.

Randall B. Smith, Ph.D., 16 August 2001

It may be difficult to identify the important points in some illustrations without a color copy of this booklet. You can print or read this booklet in color from MicroImages' Web site. The Web site is also your source for the newest Getting Started booklets on other topics. You can download an installation guide, sample data, and the latest version of TNTlite.

http://www.microimages.com

Welcome to Analyzing Terrain

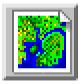
TNTmips provides a number of tools for visualizing and analyzing Digital Elevation Models (DEMs). Appropriate contrast enhancement and use of color palettes can significantly aid in visualization of DEMs in a 2D display. A DEM can also be displayed with relief shading, which helps you visualize the surface by portraying it as if it were illuminated from a particular compass direction and elevation angle, both of which you can adjust interactively. These tools are also applicable to other rasters that represent 3D mathematical surfaces, such as gridded gravity or crop yield values.

The Slope, Aspect, and Shading process computes general terrain characteristics from a DEM. Slope and Aspect refer to the magnitude and direction, respectively, of maximum downward slope. Slope and aspect rasters can be used as components in more complex environmental models, such as predicting soil erosion or landslide hazards. The shading raster provides a fixed alternative to displaying the DEM with interactive relief shading.

The Viewshed process performs line-of-sight analysis of a DEM to define a viewshed, the portion of the terrain that is visible from a given viewpoint on or above the ground. Viewshed analysis can be used to find optimal sites for communication facilities such as television or cell phone transmitters or for military observation posts or fire towers. It can also be used to assess the visual impact of activities such as mining and logging.

The Cut and Fill Analysis process compares two elevation rasters of the same area and identifies locations where their elevation values differ. These areas are traced to form polygons in an output vector object. The volume of material added or subtracted is calculated for each polygon and stored in an attached database table.

STEPS
- ☑ choose Display / Spatial Data from the TNTmips main menu
- ☑ open a New 2D Group



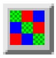
A companion booklet, *Getting Started: Modeling Watershed Geomorphology*, introduces the Watershed process, which computes stream networks, watersheds, and related properties from a DEM.

You can also view DEMs and other rasters in3D in the TNTmips Display process. See the booklet *Getting Started: 3D Perspective Visualization* for further information.

Techniques for creating consistent and effective 2D displays of DEMs are introduced on pages 4-7. Pages 8-9 cover the Slope, Aspect, Shading process. The Viewshed process is discussed on pages 10-14, followed by an introduction to the Cut and Fill process on page 15.

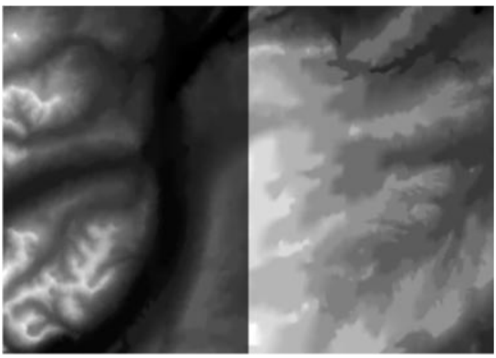
Set Consistent Contrast and Colors I

STEPS



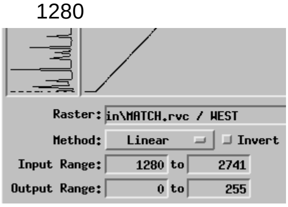
- ☑ press the Add Raster icon button in the Group Controls window and choose Quick-Add Single
- ☑ navigate to the MATCH Project File in the LITEDATA / TERRAIN data collection and select rasters EAST and WEST

When you work with a set of adjacent DEM or other surface rasters, each raster will have a different range of values, but the same numerical value has the same meaning in each. To convey that meaning consistently when the rasters are displayed, a given range of surface values should be displayed with the same range of gray tones (or colors) in each raster. Achieving that consistency requires that you adjust the contrast enhancement for each raster.



The problem is illustrated by the two DEMs used in this exercise. Elevations in raster EAST range from 1280 to 1707 meters and in raster WEST from 1340 to 2741 meters. The default linear contrast table that has been saved with each raster stretches the full range of gray tones from each raster's minimum to it's maximum value. As a result, the same gray tones correspond to different elevation ranges in each raster and the DEMs do not appear to match along their common boundary.

- ☑ press the Tools icon button in the WEST layer icon row and select Enhance Contrast from the dropdown menu
- ☑ in the Raster Contrast Enhancement window, change the value in the left (minimum) Input Range box from 1340 to 1280



- ☑ choose Save from the Enhancement window's File menu, then choose Close

To properly adjust the contrast, you should first examine the histograms of all the rasters in the set to determine the overall minimum and maximum values. For rasters EAST and WEST the overall range is from 1280 to 2741. You can then open the Raster Contrast Enhancement window for each raster and set the Input Range values to match the overall range of the raster set rather than the raster's own particular range. (Alternatively, use the Project File Maintenance process to copy the first adjusted contrast subobject to all subsequent rasters.) Gray tones are then spread over this larger overall range for each raster, producing consistent gray tones for the corresponding elevation ranges in each (see illustration on the following page).

This exercise continues on the following page.

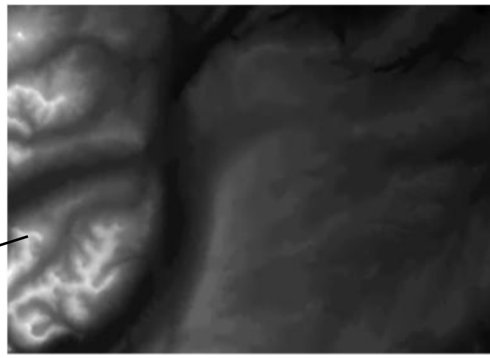
Set Consistent Contrast and Colors II

Color is usually more effective than gray tones in bringing out detail in a displayed DEM or surface raster. Once you have set up a consistent contrast table for each raster, you can use the Color Palette Editor to select a standard color palette or to design your own. (A linear contrast enhancement is recommended if you are going to use a color palette.) The palette should be saved as a subobject for each raster in the set. The same color is then assigned to the corresponding elevation range in each displayed raster.

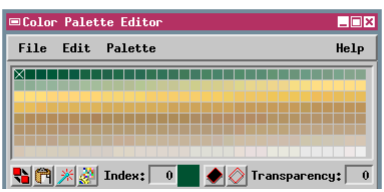
STEPS

☑ repeat the last three steps for the EAST layer, but change the right (maximum) Input Range value from 1707 to 2741

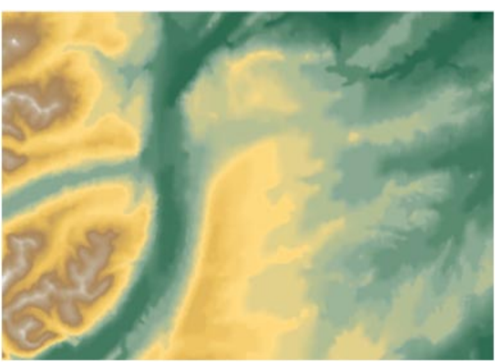
☑ redraw the View window



Rasters WEST and EAST displayed with gray tones in each raster spread linearly over the overall elevation range. Gray tones now match at the boundary.



The EarthTones color palette, one of many Standard Color Palettes available in TNTmips.



EarthTones palette applied to rasters EAST and WEST.

☑ press the Tools icon button in the WEST layer icon row and select Edit Colors from the dropdown menu

☑ click on the Palette menu in the Color Palette Editor window and select the Earth Tones palette

☑ if the Earth Tones palette is not shown on the initial menu, choose More Palettes and select it from the scrolling list in the Standard Color Palettes window and click [OK]

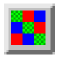
☑ choose Save As from the Color Palette Editor's File menu and save the palette as a subobject of raster WEST

☑ repeat the last step and save the palette as a subobject of raster EAST

When you have completed this exerise, remove both raster layers from the display group but keep the group open.

Display DEM with Relief Shading

STEPS

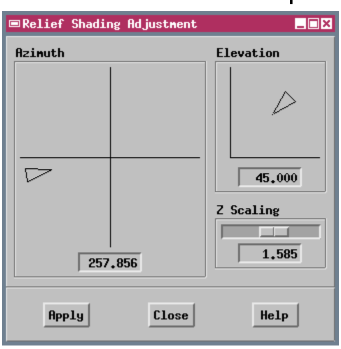


☑ press the Add Raster icon button in the Group Controls window and choose Quick-Add Single

☑ select raster CLKDEM from the SHADE Project File

☑ press the Tools icon button in the layer icon row and select Relief Shading from the dropdown menu

☑ vary the Azimuth setting in the Relief Shading Adjustment window, click [Apply] and note the effect on the DEM

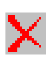


☑ vary the Elevation setting and note the effect

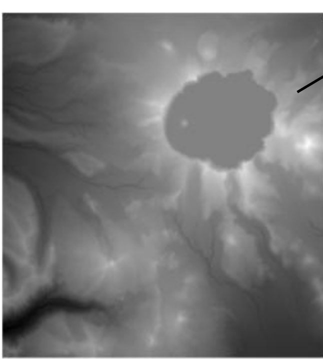
☑ vary the Z Scaling setting and note the effect

The Relief Shading tool shows how the surface would appear if illuminated by an infinitely distant light source (assuming that the surface represents a uniform material). The Relief Shading Adjustment window allows you to vary the azimuth (compass direction) and elevation angle of the light source and the Z-scaling (vertical exaggeration). The azimuth can vary from 0 to 360 degrees clockwise from north. Surface features perpendicular to the illumination direction are accentuated by shadowing, while those trending parallel to it are less visible. Decreasing the elevation angle generally darkens the shaded image and increases the contrast between shadowed and illuminated areas. To produce a brighter image that preserves shadow contrast, increase both the elevation angle and the z-scaling.

NOTE: you can change the display parameters for a raster so that it is automatically displayed with relief shading each time you add it to a group. To do so, open the Raster Layer Controls window and turn on the Relief Shading toggle button. The last-used (or default) shading settings will be used. Any changes in the shading settings that you make subsequently for the raster using the Relief Shading Adjustment window are not automatically saved. To force a save of the new settings, turn the Relief Shading toggle button off and then back on.

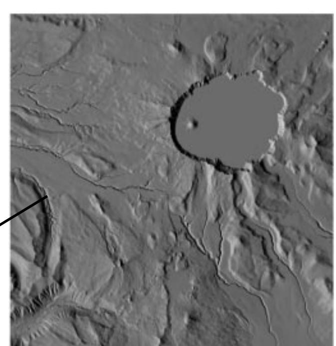


Remove the CLKDEM *layer from the display group when you have completed this exercise.*



DEM of Crater Lake area, Oregon in grayscale.

Crater Lake DEM displayed with relief shading settings shown in the illustration above.

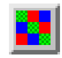
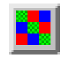


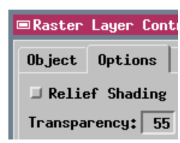
Create a Color Shaded Relief Display

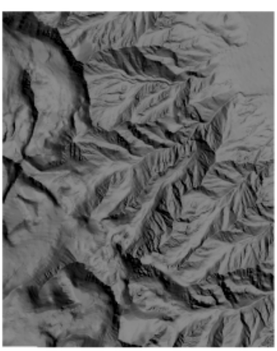
You can combine the effects of color-mapped elevation and relief shading to create color shaded relief displays. If you expect to use such a display repeatedly, it is best to work with two copies of the DEM, which can be set up to use different display parameters. Set up one copy of the DEM to display with relief shading, and the other to display with a color palette. Then display both DEMs in the same display group, with the color-mapped version on top partially transparent. The resulting view combines the textural information from the shaded layer with the color-coded elevation information from the overlying layer.

You can vary the brightness and contrast of the merged view by adjusting the relief shading settings for the lower DEM; a relatively bright shaded image produces brighter colors. Vary the transparency setting of the color-mapped DEM to control the relative contribution of the color and shaded versions. Increasing the transparency will subdue the colors and place more emphasis on the terrain shading.

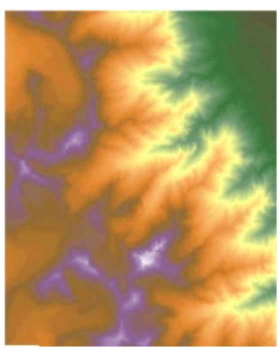
STEPS

- ☑ Quick-Add raster object MWDEM1 from the SHADE Project File 
- ☑ note the relief-shaded view of the DEM
- ☑ Quick-Add raster object MWDEM2 from the SHADE Project File 
- ☑ note the color-mapped view of the DEM
- ☑ press the Tools icon button in the WWDEM2 layer icon row and select Controls from the dropdown menu 
- ☑ on the Options panel of the Raster Layer Controls window, change the value in the Transparency field to 55, then press [OK]

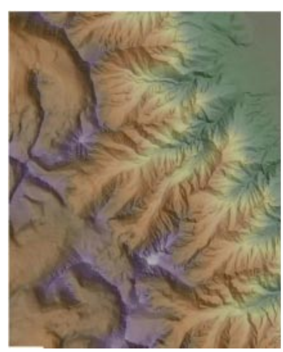




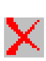
Relief-shaded view of MWDEM1.



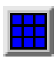
Color-mapped view of WMDEM2.



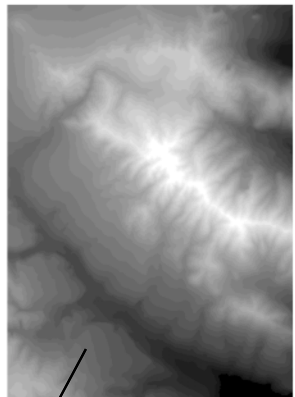
Color shaded relief view of the two versions of the DEM.

 *Remove both layers from the display group when you have completed this exercise.*

Compute Slope, Aspect, and Shading

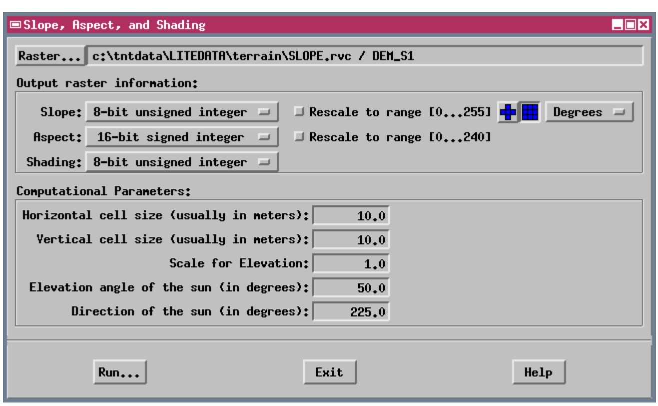
STEPS
- ☑ choose Process / Raster / Elevation / Slope, Aspect, and Shading from the main menu
- ☑ click [Raster...]
- ☑ navigate to the SLOPE Project File and select object DEM_S1
- ☑ in the Output Raster Information panel of the Slope, Aspect, and Shading window, turn off the Rescale to Range [0...255] toggle button for the Slope raster
- ☑ press the Square icon button to set the shape of the neighborhood used to determine the slope 
- ☑ turn off the Rescale to Range [0...240] toggle button for the Aspect raster
- ☑ change the value in the Direction of Sun text field to 225.00
- ☑ press [Run...]
- ☑ use the standard Select Objects dialog window to name a new Project File and accept the default names for the output Slope, Aspect, and Shading raster objects

The Slope, Aspect, and Shading process creates a separate raster object for each of these characteristics of the terrain. All of the output values are computed for each cell in the input DEM from the elevations of the neighboring cells. The Cross and Square icon buttons determine which neighboring cells are used in the calculations. If you use the default Cross option, only four neighboring cells (above, below, left, and right) are used. If you choose the Square option, all eight bordering cell values are used. If you don't need to compute all three characteristics, then only name the desired output objects.



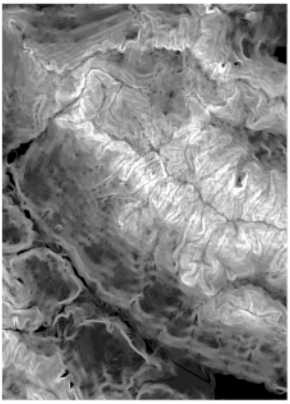
A grayscale representation of DEM_S1 with normalized contrast enhancement. To accomodate the range of possible Earth surface elevations (in either meters or feet) without scaling, most DEM rasters use a signed 16-bit data range (-32,768 to +32,767). Elevations in all of the DEMs used in this booklet are in meters.

Press [Exit] on the Slope, Aspect, and Shading window when you have completed this exercise.



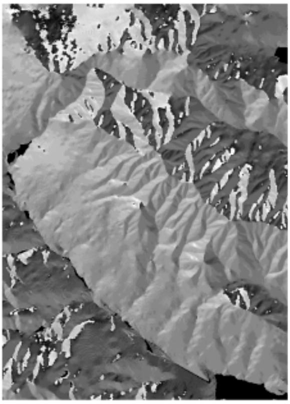
Slope, Aspect, and Shading Results

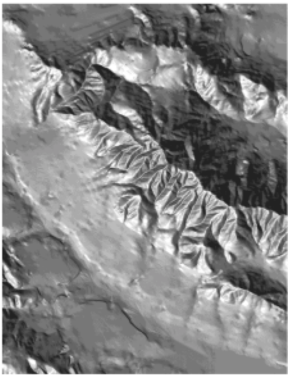
Use the open display group to view the input raster (previous page) and the output rasters shown below.



Slope Slope can be expressed as either an angle measured from the horizontal in degrees (0 to 90) or as percent slope [100 x tangent(slope); a slope angle of 45 degrees is equal to a 100 percent slope]. Choose Degrees or Percents from the option menu to make this selection. When Degrees is selected, the Rescale to range [0...255] option is turned on by default to spread the output values across the entire 8-bit data range and increase detail. If you would rather preserve the original numeric slope angle values, turn this toggle button off. (All output rasters on this page are shown with auto-normalized contrast enhancement.)

Aspect Aspect values increase clockwise from north, so that northeast-facing slopes are darkest and northwest-facing slopes are brightest (the DEM is assumed to be oriented with north at the top). In order to fit the output values in the default 8-bit data range, the Rescale to range [0...240] toggle button is also turned on by default. Using this choice, 0 = north, 60 = east, 120 = south, and so on. If you turn the rescale option off, the output data type automatically changes to 16-bit signed, and aspect values are expressed by azimuth angle (0 to 360 degrees clockwise from north). Flat areas are indicated by values of -1.





Shading The slope and aspect values are used to calculate a static relief-shaded view of the surface. You can edit the relevant Computation Parameter text fields (Scale for Elevation, Elevation angle, and Direction) to vary the shading effect. The Shading process uses a different algorithm than the interactive Relief Shading procedure in Spatial Data Display, so similar parameter settings will produce different results in the two processes. The appearance of the Shading raster will also vary depending on the contrast enhancement method you use in displaying it.

Viewshed Analysis

STEPS

☑ choose Process / Raster / Elevation / Viewshed from the main menu

☑ in the Select Object window, navigate to the VIEWSHED Project File and select object DEM_V1

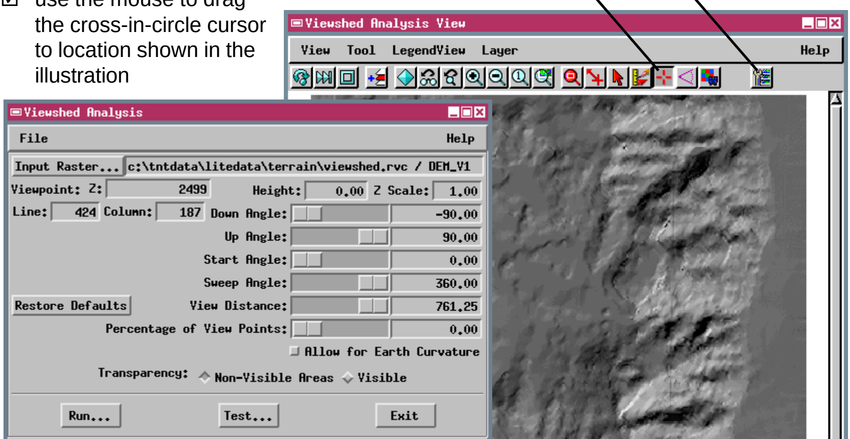
Starting the Viewshed process opens the Viewshed Analysis, Viewshed Analysis View, Layer Controls, and Point Edit Controls windows. The Viewshed Analysis window displays the input raster and allows you to select the viewpoint location for your viewshed analysis.

The Viewshed Analysis window opens with the Select Viewpoint tool active. Keep this tool active for the following steps:

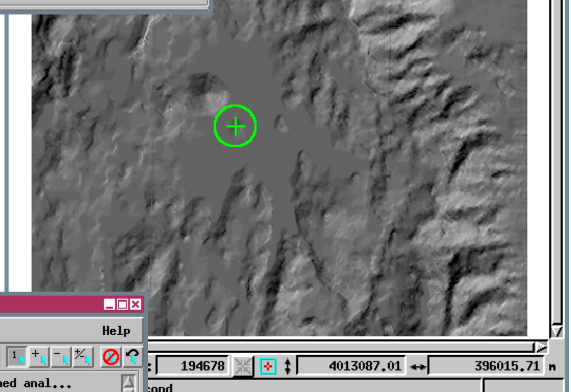
If the Layer Controls window does not open automatically when you start the Viewshed Process, you can open it by pressing the Layer Controls icon button.

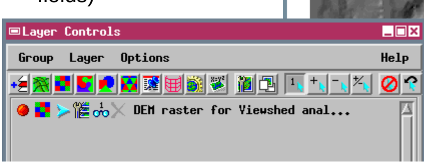
Select Viewpoint

☑ use the mouse to drag the cross-in-circle cursor to location shown in the illustration



☑ use the arrow keys on your keyboard to move the viewpoint until the Line field in the Viewshed Analysis window reads 424 and the Column field reads 187 (or enter these values directly into the fields)





This exercise continues on the next page.

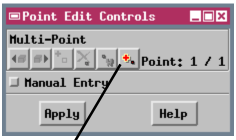
Run a Viewshed Test

The results of a Viewshed analysis are encoded as a binary raster in which cells with a value of 1 are visible from the selected viewpoint. The Test option allows you to preview the results by computing a temporary viewshed raster that is displayed in the Viewshed Analysis window. The initial display of the temporary viewshed raster shows cells in the viewshed (visible) in white and the remaining cells (non-visible areas) transparent so that the input raster shows through. You can reverse this relationship if you desire by using the Transparency toggle buttons on the Viewshed Analysis window.

To identify cells that are visible from your selected viewpoint, the viewshed process analyzes the 3D lines connecting the viewpoint and each cell. If a sightline remains above the ground surface between the viewpoint and cell, the cell is visible. The extent of a computed viewshed can be very sensitive to small differences in elevation around the viewpoint.

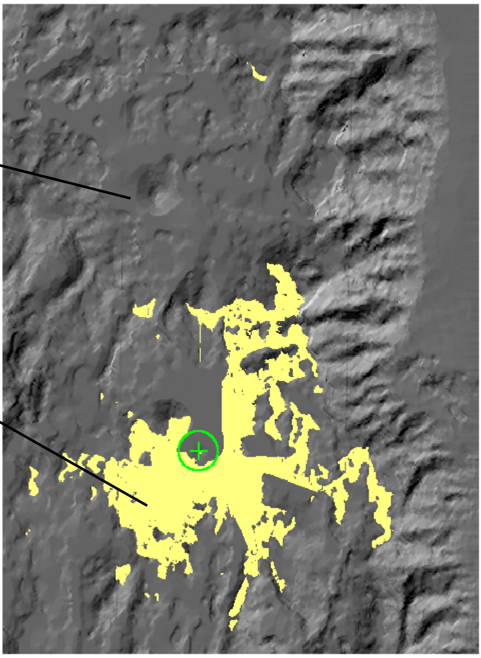
STEPS

☑ click the Test button at the bottom of the Viewshed Analysis window



You can compute a joint viewshed for multiple viewpoints. If you turn on the Quick-Add icon button in the Point Edit Controls window, each left mouse-click places an additional viewpoint. You can then test or run the process in the normal manner.

The input DEM has been set to display with shaded relief using the controls accessed from the Relief Shading option on the Tools icon button menu. Once set, these and other display parameters are stored with the DEM and used automatically by the Viewshed process.



The computed viewshed is shown in yellow in this illustration for clarity. You can create this effect by selecting Edit Colors from the Tools icon button menu for the temporary viewshed raster and changing the color for index value 1. (See the booklet *Getting Started: Getting Good Color* for more information on editing color palettes).

Vary the Viewpoint Height

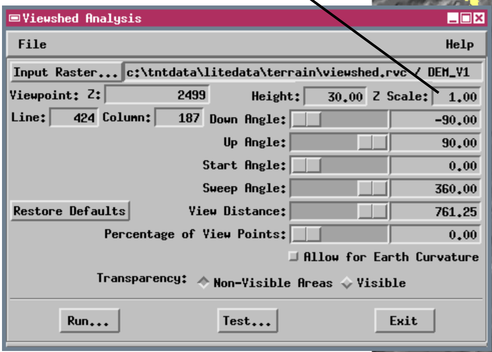
STEPS

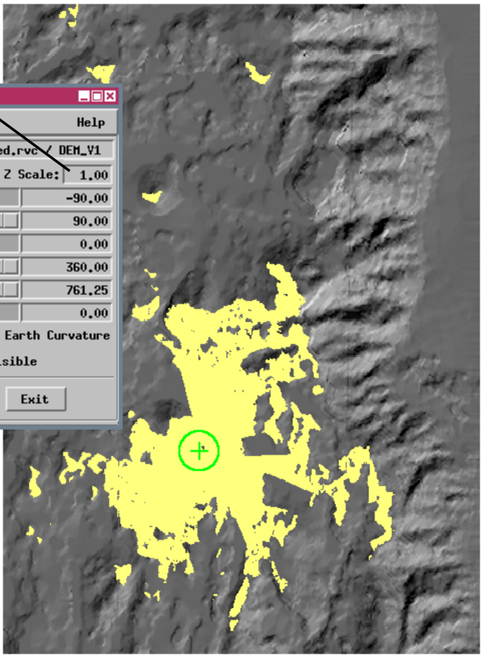
- ☑ type 30 in the Height text box in the Viewshed Analysis window and press [Enter] or [Tab]
- ☑ press [Test]

The Z Scale parameter applies only to the value entered for the Height. The entered Height value is divided by the Z Scale value (default value = 1.00) to determine the actual viewpoint height above the surface. The Z Scale parameter enables you to correctly use a height value in units different from the elevations in the DEM. For example, to use a height of 100 ft with a metric DEM, enter a Height value of 100 and a Z Scale value of 3.281 (the number of feet in a meter).

The viewpoint in the previous exercise is on the surface at the top of a small hill rising about 60 meters above a flat area. Although this is the highest elevation on the hill, the very low slopes on the hilltop block most of the sightlines to the foreground north of the hill. You can model visibility from different heights by entering a value in the Height field in the Viewshed Analysis window. A Height value of 1 or 2 meters usually gives a better representation of the area seen by a person standing at the same location.

For many viewshed applications the desired viewpoint is at the top of a tower some distance above the ground. In this exercise the viewpoint is placed 30 meters above the ground. As expected, the size of the viewshed is greatly increased by elevating the viewpoint. By running a number of viewshed tests with different heights you can determine the minimum tower height required to produce a desired viewshed.





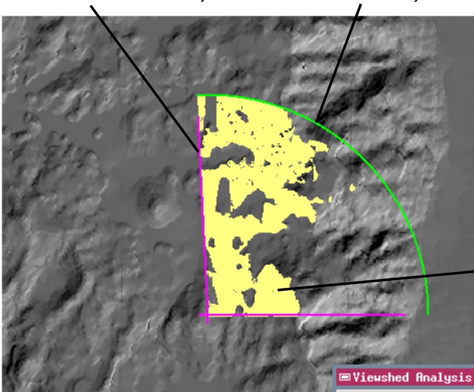
Viewshed for a viewpoint 30 meters above the ground surface.

Limit the Horizontal Field of View

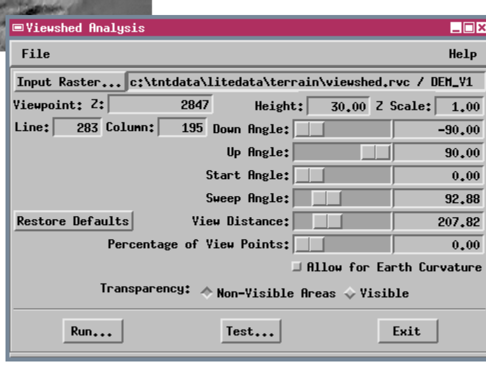
If you are interested only in the view in a particular direction, you can use the Field of View tool to place horizontal limits on the viewshed analysis. The parameters related to this tool can be set graphically in the View window or by using sliders in the Viewshed Analysis window. The two radial lines of the tool limit the horizontal angle of view, or Sweep Angle. The position of the lower radius line defines the Start Angle, which is measured counter-clockwise in degrees from the positive x coordinate axis. The position of the arc corresponds to a radial distance limit, or View Distance, which is measured in raster cell units.

Click and drag on the radius lines to change the Start Angle and Sweep Angle (using the right or left arrow cursor).

Click and drag on the arc to change the View Distance (using the hand cursor).

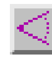


Click and drag within the wedge to reposition the viewpoint (using the four-point arrow cursor).



NOTE: You can set field of view limits using the sliders in the Viewshed Analysis window without turning on the Field of View tool, but in that case the Viewshed Analysis window will not show you the limits you have set. Conversely, merely switching from the Field of View tool back to the Viewpoint tool does not reset the field of view parameters to the default settings; any adjustments you may have made remain in effect.

STEPS

- ☑ click on the Remove icon button for the temporary viewshed raster in the Layer Controls window 
- ☑ click on the icon button for the Field of View tool in the Viewshed Analysis View window 
- ☑ drag the cross at the center of the circle graphic to the location shown in the illustration
- ☑ use the arrow keys to move the viewpoint until the Line field reads 283 and the Column field reads 195
- ☑ move the View Distance slider in the Viewshed Analysis window until the value is about 200
- ☑ keep the Start Angle slider at a value of 0
- ☑ move the Sweep Angle slider until the value is about 90
- ☑ press [Test]

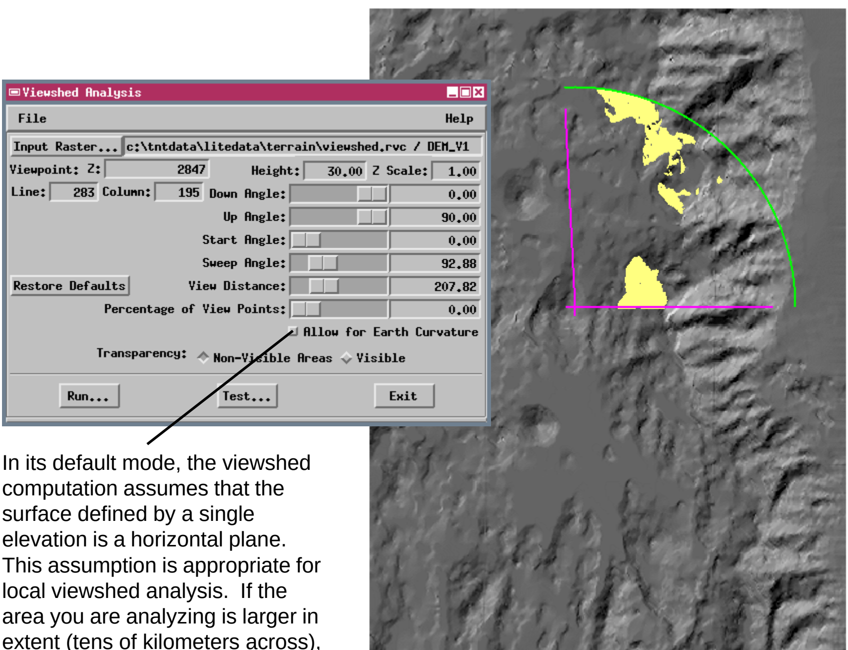
Limit the Vertical Field of View

STEPS

- ☑ move the Down Angle slider in the Viewshed Analysis window all the way to the right; the value will read 0.00
- ☑ press [Test] on the Viewshed Analysis window
- ☑ press [Run]
- ☑ use the standard Select Objects dialog to name a new Project File and an output raster object

You can also use the Viewshed Analysis window to limit the vertical field of view for the current viewpoint. For this purpose the vertical field of view is divided into two parts by a horizontal plane at the elevation of the viewpoint. To set a lower limit on the field of view for the computation, use the Down Angle slider to set the maximum downward angle (0 to 90 degrees below the horizontal). Set an upper limit by using the Up Angle slider (0 to 90 degrees above the horizontal plane).

When you are ready to create a permanent output raster with the results of the viewshed analysis, use the Run option on the File menu.



In its default mode, the viewshed computation assumes that the surface defined by a single elevation is a horizontal plane. This assumption is appropriate for local viewshed analysis. If the area you are analyzing is larger in extent (tens of kilometers across), you will achieve more accurate results by turning on the Allow for Earth Curvature toggle button.

- ☑ *close the Viewshed process by choosing File / Exit when you have completed this exercise*

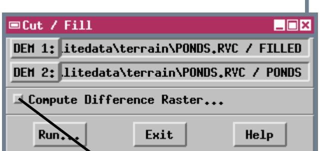
Cut and Fill Volumetric Analysis

In the Cut and Fill Analysis process you select two elevation models that have the same size, geographic extents, and cell size. Elevations in the model selected as DEM2 are subtracted from those in DEM1. Polygons outlining the areas of net elevation difference are displayed automatically in the View window at the conclusion of processing.

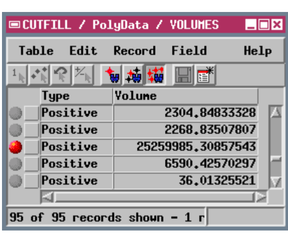
The Cut and Fill process can be used to assess changes in landscapes through time due to erosion and deposition or landsliding. In this exercise we instead compare the DEM of an area with natural depressions, many of which contain ponds, with its depressionless equivalent (FILLED) produced by the Watershed process. Polygons with positive volumes identify depressions that have additional water storage capacity.

STEPS

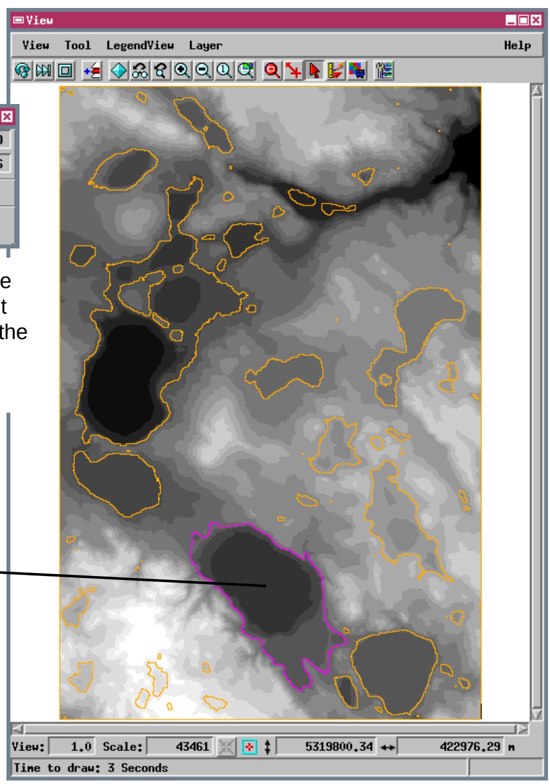
- ☑ select Process / Raster / Elevation / Cut and Fill Analysis from the TNTmips main menu
- ☑ press [DEM1] on the Cut / Fill window and select raster FILLED from the PONDS Project File
- ☑ press [DEM2] and select raster PONDS from the same file
- ☑ press [Run] and create an output Project File
- ☑ accept the default names for the output vector object and attached database table



Turn on the Compute Difference Raster toggle button if you want to save the raster that records the difference in elevation for each cell location in the input DEMs.



The VOLUMES table records the volume difference for each polygon, and whether the difference is positive or negative.



TERRAIN ANALYSIS

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MicroImages, Inc.
11th Floor - Sharp Tower
206 South 13th Street
Lincoln, Nebraska 68508-2010 USA

Voice: (402) 477-9554
FAX: (402) 477-9559
email: info@microimages.com
internet: www.microimages.com