WATERSHEDS

Getting Started

Modeling Watershed Geomorphology

with

TNTmips®

Before Getting Started

The movement of water over land surfaces is an important environmental factor that is governed primarily by terrain shape. The Watershed process in TNTmips® analyzes an elevation model and defines drainage networks and the boundaries between different drainage areas (watersheds) along with related attributes. The exercises in this booklet lead you through the main procedures involved in watershed modeling with the Watershed process.

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 the sample file WATRSHED in the TERRAIN data collection.

More Documentation This booklet is intended only as an introduction to watershed modeling. Consult the TNTmips reference manual, which contains more than 35 pages on the watershed process, 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.

The Watershed process is not available in TNTview or TNTatlas. 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 Modeling Watersheds

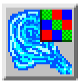
The Watershed process addresses the influence of terrain on surface water hydrology by modeling the movement of water over the land surface. The input data for the process is a DEM (Digital Elevation Model), a regular grid of elevation values stored as a raster object.

The Watershed process computes the local directions of flow and the gradual accumulation of water moving downslope across the landscape. From these intermediate results the process then computes the stream network and the boundaries between *watersheds*, the areas drained by particular stream systems. Watersheds can be further subdivided into *basins* associated with particular branches of the stream network. The flow path network, watershed boundaries, and basins are created as separate temporary vector objects. You can adjust several processing parameters to vary the level of detail in these objects before saving the final results. Varied attribute information is also created and saved with the flow paths and watersheds. The information created by these area-wide computations can be used as input for further analysis of water resource issues, flood and erosion hazard, and movement of pollutants.

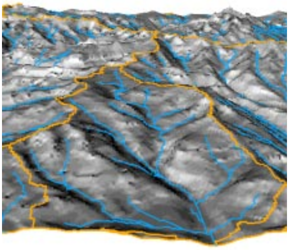
An interactive tool is also provided to generate flow paths and basins for particular point locations in the elevation model. This tool is useful for analyzing the impacts of point-source pollutants within a watershed.

A sequential processing option is available for filling depressions in the elevation model prior to determining the flow routing. This procedure may be useful in assessing the influence of any natural depressions in the landscape.

Additional terrain analysis processes in TNTmips are introduced in a companion booklet, *Getting Started: Analyzing Terrain and Surfaces*.



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



A 3D perspective view of a relief-shaded DEM with watershed boundaries (orange) and flow lines (blue) produced by the Watershed process.

An introduction to computing flow paths and watersheds is provided on pages 4-6, followed by a discussion of the effects of adjusting flow path and basin parameters on pages 7-8. Computed stream orders are explained on page 9. Page 10 shows how to generate flow paths and basins from seed points. The adjusted elevation raster and other products are explained on pages 11-12. Pages 13-14 discuss the use of null values and masks. Sequential processing is covered on pages 15-19.

Begin Watershed Analysis

STEPS

☑ press [Input Object...] in the Watershed Analysis window

☑ use the Select Object dialog to select DEM_W1 from the WATERSHD Project File in the TERRAIN data collection

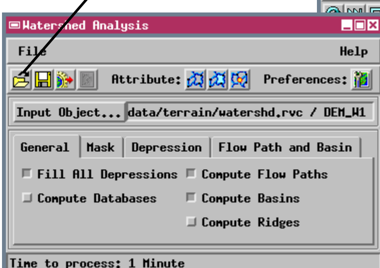
☑ check that the Fill All Depressions toggle button on the General panel is turned on

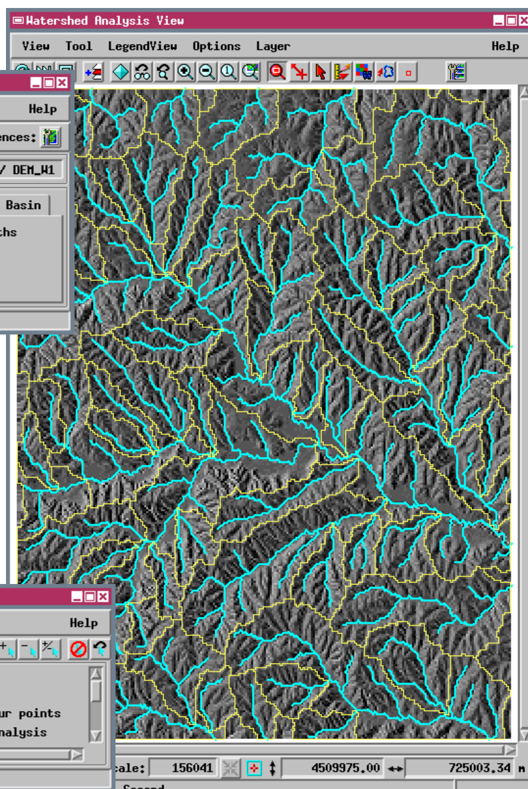
☑ press the Run icon button 

Starting the Watershed process opens the Watershed Analysis, Watershed Analysis View, and Layer Controls windows. The View window automatically displays the DEM you select for analysis and, after processing, selected results of the process.

The quickest way to fully delineate watersheds and flow paths in a DEM is to use the Fill All Depressions option, which is turned on by default. (We will explore the impact of this choice on processing in later exercises.) The Watershed process creates a series of temporary vector and raster objects that present different aspects of the results. To save any or all of these objects, press the Save As icon button on the Watershed Analysis window.

You can also use the Open icon button to select the DEM.

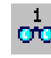
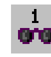




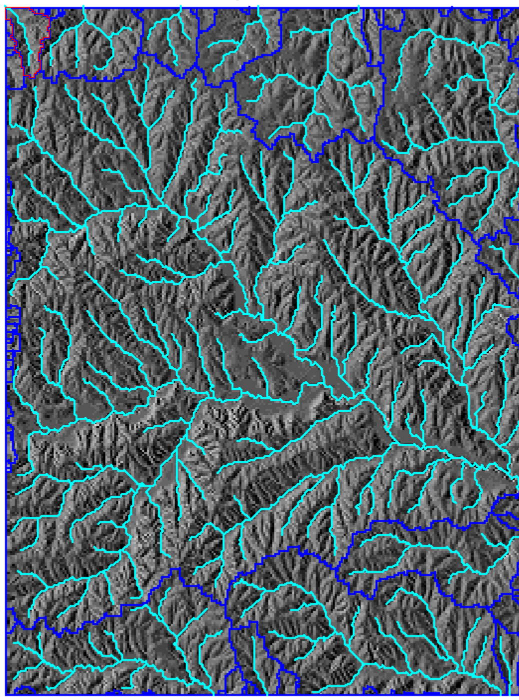
Each temporary vector object created by the Watershed process is displayed with a pre-assigned color. You can change the color or line width by clicking the Vector icon button for a layer to open the Vector Layer Controls window.

Flow Paths and Watersheds

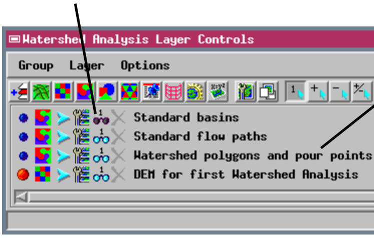
After you run the Watershed process using the Fill All Depressions option, two vector objects depicting standard basins (named STDBASIN) and standard flow paths (STDFLOWPATH) are displayed over the input DEM in the View window. Other output vector and raster objects are listed in the Layer Controls window but are initially hidden. We will return to the standard basins object later, but for the moment we will hide it and instead show the vector object representing watershed polygons (WATERSHED).

STEPS
- ☑ in the Layer Controls window, click on the Hide/Show icon button for the STANDARD BASINS vector object to hide it 
- ☑ repeat for the WATERSHED POLYGONS object to show it 

The lines in the flow paths vector (shown in cyan color) represent the computed network of actual and potential stream channels that drain each watershed. The boundaries of the watersheds are shown as blue polygons in the watershed vector object. The watershed boundaries follow topographic divides between different drainage systems.



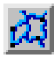
Use the Hide / Show icon buttons to control which of the available layers are currently displayed. The glasses icon is cyan for a displayed layer and gray for a hidden layer.

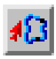


Each object's description is used by default for its layer name in the Layer Controls window. If you wish, you can select Default Layer Name from the window's Options menu to change the layer names to either Object Name or File Name / Object Name. This change does not take effect until you exit and restart the process.

Watershed Properties

STEPS

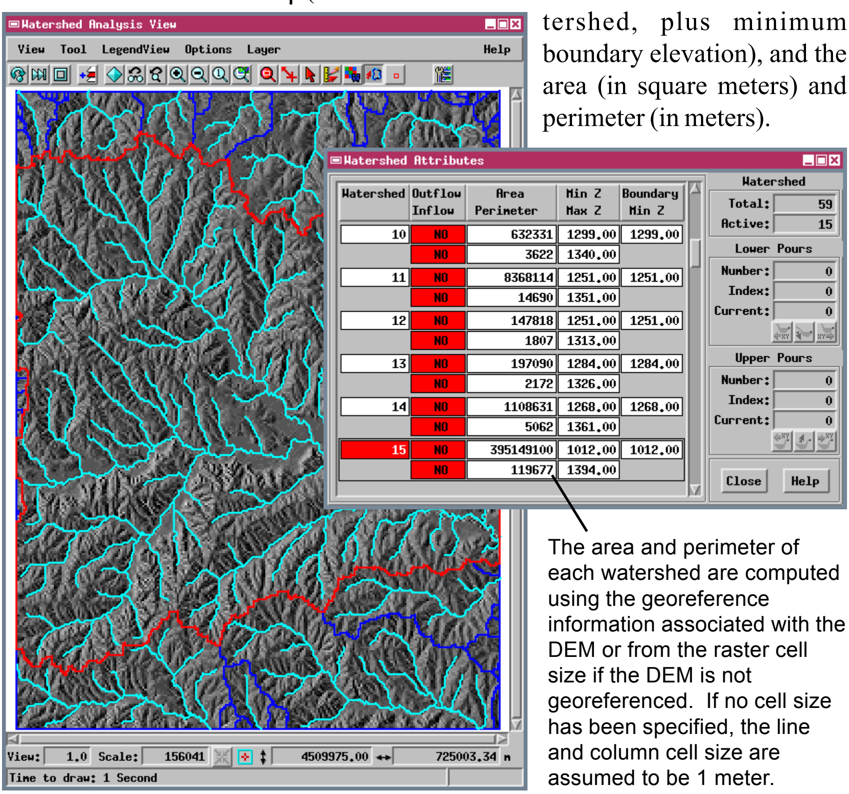
☑ press the Watershed Attributes icon button in the Attributes toolbar on the Watershed Analysis window 

☑ press the Select Watershed icon button at the top of the View window 

☑ left-click with the mouse inside the large central watershed polygon

The Watershed Attributes window presents a scrolling list of the basic properties of the watersheds that were found by the process. When all depressions are filled, each watershed drains to the edge of the raster object (or to the boundary between valid and null raster values, which can be used to represent a coastline). Each watershed in this case has neither inflow from an upstream watershed nor outflow to a downstream watershed, as indicated by the Outflow / Inflow column in the window. Watersheds that drain beyond the edge of the raster in the same direction may in fact join downstream and form parts of larger regional watersheds.

The watershed attributes include elevation values (minimum and maximum elevations within the watershed, plus minimum boundary elevation), and the area (in square meters) and perimeter (in meters).



The area and perimeter of each watershed are computed using the georeference information associated with the DEM or from the raster cell size if the DEM is not georeferenced. If no cell size has been specified, the line and column cell size are assumed to be 1 meter.

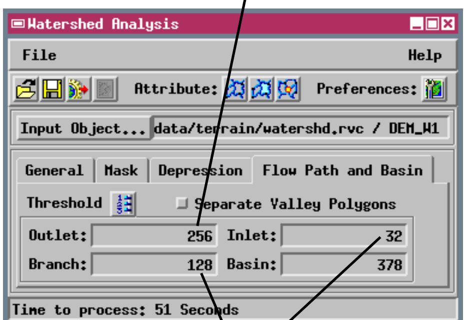
Flow Path Parameters

STEPS
- ☑ close the Watershed Attributes window
- ☑ click on the Flow Path and Basin tab to expose its panel

If you closely examine the watershed and flow path vector objects, you will see that flow paths do not extend all the way upstream to the watershed boundaries. Also, no flow paths are shown for some smaller watersheds around the edges of the DEM. The parameter values shown on the Flow Path and Basin panel are default thresholds that were used by the process to compute the current flow path and basin vectors. You can modify these parameter values and recompute new flow path and basin vector objects that show greater or lesser detail.

In order to generate flow paths, the Watershed process computes the number of upstream cells that contribute flow to each cell in the DEM. These flow accumulation values are used in part to trace flow paths upstream, beginning with the highest accumulation values where streams reach the boundaries of the area. The Outlet parameter sets the flow accumulation threshold for initiating a flow path at the edge of the raster. Only boundary cells with flow accumulation values greater than the Outlet threshold are used to initiate a flow path.

Increase the value of the Outlet parameter if you don't want to create flow paths for smaller watersheds around the periphery of the DEM that currently show them.

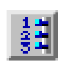


Decrease the values of the Inlet and Branch parameters if you want to extend flow paths closer to the upper watershed boundaries and increase the number of tributary flow paths shown.

The Inlet parameter determines how far upstream each flow path is traced toward its headwaters. A flow path terminates when the flow accumulation value for the next upstream cell falls below the Inlet parameter value.

The Branch parameter controls the upstream splitting of flow paths at potential junctions between tributaries or branches. A branch flow path is created when the flow accumulation value at the mouth of the tributary is greater than the Branch parameter value.

To restore the default values for the Flow Path and Basin parameters, click the Set to Defaults icon button.



Recompute Flow Paths and Basins

STEPS

☑ use the Show / Hide icons in the Layer Controls window to hide the WATERSHED vector layer and unhide the BASINS layer

☑ change the value of the Inlet parameter to 16

☑ change the value of the Branch parameter to 64

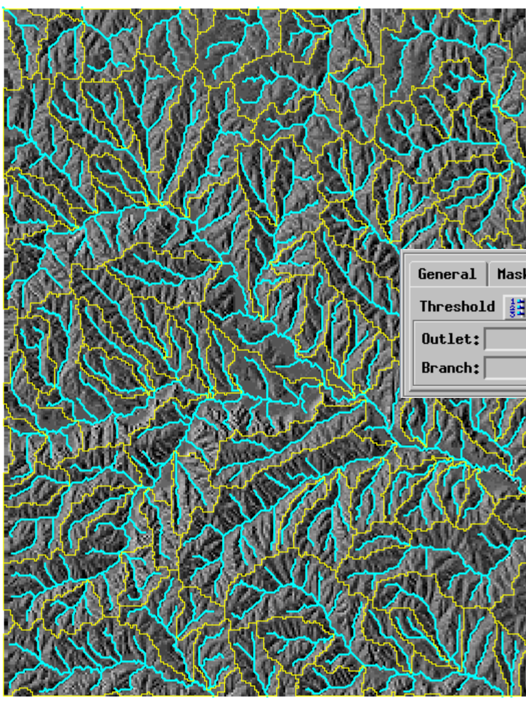
☑ change the value of the Basin parameter to 256

☑ press the Run icon button

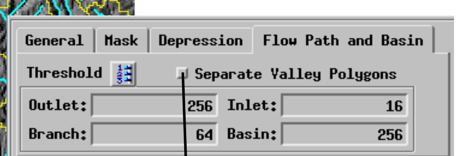
☑ if you don't want to save the previous process results, click [No] in the Verify window, otherwise click [Yes] and name the output objects

The polygons in the standard basins vector object (shown in yellow in the illustration on page 4) show subdivisions within larger watersheds. Each basin (subwatershed) is the area drained by a network of branches of the main stream. The lowest elevation in each basin is the junction between its stream network and a larger stream.

The Basin parameter sets an area threshold for generating basin polygons within each watershed. A basin polygon is created for each branch system that drains an area (expressed as a number of cells) greater than or equal to the value set for the Basin parameter. Because flow accumulation is expressed as the number of cells contributing flow, the area of a basin is equivalent to the flow accumulation value of the cell at the mouth of its tributary system.



The changes you make to the flow path and basin parameters in this exercise create a denser, more detailed flow path network with more numerous and longer branches, and more numerous and smaller basins.



If you turn on the Separate Valley Polygons toggle before recomputing flow paths and basins, large elongate basins associated with master streams are partitioned into separate polygons at branch intersections. The minimum size of these polygons is also set by the Basin parameter value.

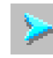
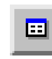
Stream Order

Since stream segments in each watershed join downstream to form larger streams, the relative importance of each segment can be expressed as a numerical rank or *order* within the stream network. The Watershed process computes stream order for each line element in the standard flow path vector object using four different ordering systems that are described and illustrated below. The resulting values are stored in the STREAM_ORDER table.

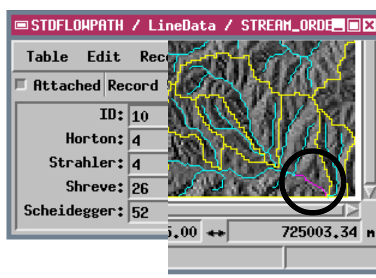
Strahler: The smallest headwater segments are assigned order 1. Order increases downstream by 1 whenever two streams of equal order join. For example, two streams of order 2 join to form a third-order stream. But the order number does not increase when a higher-order stream is joined by a lower-order stream.

Horton: This system begins with the same ordering scheme as the Strahler system, but the main stream maintains the same order number all the way upstream to a single headwater source. The order of major tributaries is treated in the same way. At each junction where two segments of equal Strahler order meet, the longest or most direct upstream segment is renumbered to the higher order of the main stream or branch.

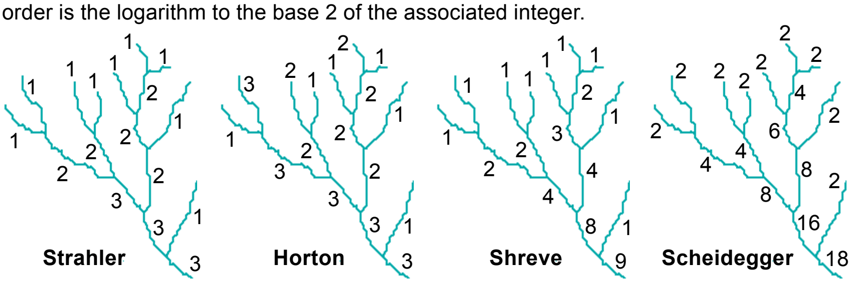
STEPS

- ☑ in the Layer Controls window, click the Details icon button for the STANDARD FLOW PATHS layer 
- ☑ click the Show Tables icon button for lines 
- ☑ click the View Table icon button for the table STREAM_ORDER 
- ☑ in the STREAM_ORDER table window, select Single Record View from the Table menu
- ☑ press the Select icon button in the View window and select a segment of the stream that drains toward the lower right corner of the DEM as shown in the illustration 

Shreve: The order or "magnitude" of a stream segment formed at a junction is the sum of the magnitudes of the two tributaries. For example, the confluence of a magnitude 1 and magnitude 3 stream forms a magnitude 4 stream. The magnitude of any stream segment equals the number of its magnitude 1 sources, which means that the Shreve magnitude is more simply related to predicted flood flow than other ordering systems.



Scheidegger: This system defines for each segment an "associated integer" (shown in the STREAM_ORDER table) that is twice the Shreve magnitude. The Scheidegger stream order is the logarithm to the base 2 of the associated integer.

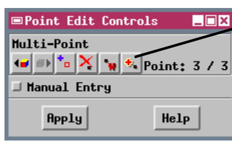


Basins and Flow Paths from Seed Points

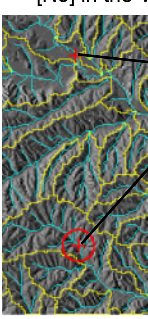
STEPS
- ☑ choose Close from the Table menu in the STREAM_ORDER table window
- ☑ click the icon button for the Seed Points tool at the top of the View window 
- ☑ left-click in the bottom of the major valley near the center of the area; a cross-in-circle cursor appears and the Add New Point button becomes active in the Point Edit Controls window
- ☑ reposition the cursor if necessary to place it on the existing flow line, then click the Add New Point button to add the point
- ☑ left-click on a flow path in one of the smaller valleys
- ☑ click the Add New Point button to add the point
- ☑ press the Apply button on the Point Edit Controls window, then [No] in the Verify window

In some instances you may want to know the extent of the watershed upstream from a designated point. For example, the point might represent a stream sample locality where a chemical anomaly was detected and the upstream watershed represents the region containing the potential source. On the other hand, if a point source of pollution has been identified, you would want to predict the downstream flowpath along which the pollutant would be dispersed.

The Seed Points tool allows you to place one or more seed points that can be used to compute a downstream flow path, upstream basin, or both for each point. These options are controlled by the corresponding toggle buttons on the General panel in the Watershed Analysis window.



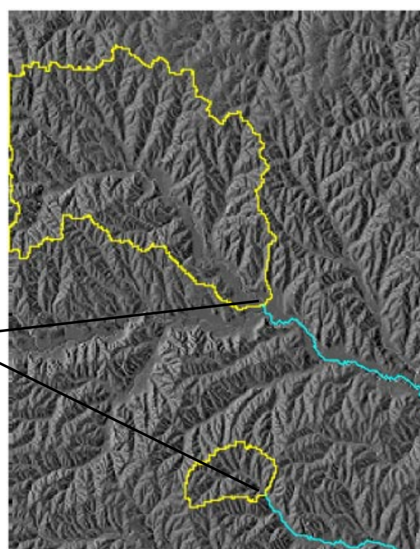
If you select the Quick-Add option, each left-click adds a seed point. Although this option is faster, you don't have the opportunity to reposition the prospective point before adding.



Marked seed point.

Cursor marking prospective seed point location.

Computed basins and flow paths for two seed points.



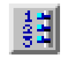
- ☑ when you are ready to return to computing flow paths and basins for the entire DEM, simply select another tool (such as the Zoom Box) from the View window toolbar 

Adjusted Elevation

Depressions are areas in a DEM that are completely surrounded by higher elevation values. Subsidence, movement along geologic faults, and the advance and retreat of glaciers can create sizeable natural depressions, and activities such as mining and quarrying create smaller man-made depressions. But natural depressions are rare in common landscapes that are shaped primarily by stream flow, and consequently most depressions in a DEM do not represent real landscape features. They are data errors, or result from the averaging involved in assigning elevation values to cells of finite area. These spurious depressions interfere with the correct routing of flow paths during the watershed analysis, especially in areas of low relief.

The Watershed process solves this problem by first locating and “filling” the depressions. It increases the values of cells inside each depression to the elevation of the lowest bounding cell (the pour point or outlet), simulating the natural filling of depressions with water to form ponds and lakes. When you run the Watershed process with the Fill All Depressions option turned on, a depressionless version of the DEM (ELEVATION, with object description “Adjusted elevation”) is created. This depressionless DEM is used to compute the flow paths, basins, and watersheds.

STEPS

☑ on the Flow Path and Basin panel, press the Set to Default icon button 

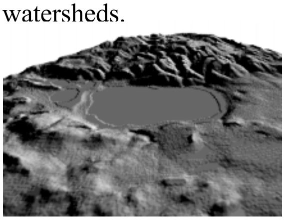
☑ on the General panel, turn on the Compute Ridges toggle button

☑ click the Run icon button, then [No] in the Verify window 

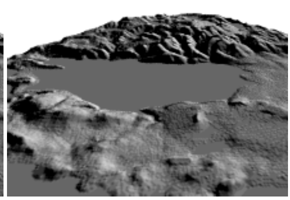
☑ use the Hide / Show icon buttons in the Layer Controls window to hide the STANDARD FLOW PATHS, STANDARD BASINS, and input DEM layers

☑ use the same controls to show the ADJUSTED ELEVATION raster (which will display without relief shading)

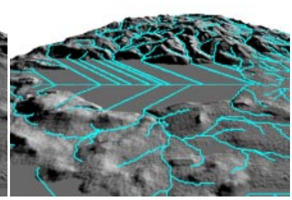
DEM_W1 includes no large natural depressions like the one illustrated below. It does have many small spurious depressions, but you would need to look very closely to see any noticeable differences between it and the depressionless DEM.



Perspective view of a relief-shaded DEM with a large natural depression partially filled by water to form a pond (uniform gray surface in center). The water level is lower than the lowest natural outlet (pour point).



Perspective view of the corresponding area of the depressionless DEM. Elevations in the depression have been raised to the level of the lowest pour point, simulating complete filling with water.

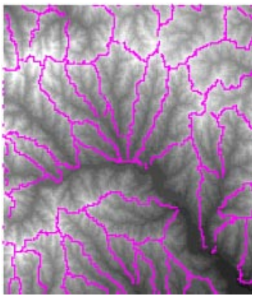


Computed flow paths overlaid on the depressionless DEM. Flow paths are routed across the flat areas created by filling depressions, linking inlet streams and outlet streams.

Other Watershed Products

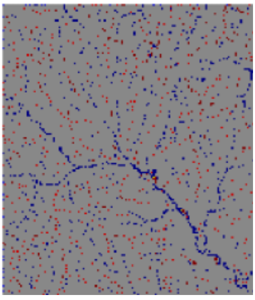
STEPS
☑ use the Layer Controls to show the STANDARD RIDGES object
☑ hide the STANDARD RIDGES and ADJUSTED ELEVATION layers, then show the other layers discussed below

The Watershed process also produces one other vector object and several raster objects. Some of these products show particular aspects of the terrain and may be useful for specialized analysis, but others are primarily intermediate objects used to produce the objects discussed previously. More detailed information about these objects can be found in the TNTmips Reference Manual.



Lines in the Standard ridges vector object (displayed here over the depressionless DEM) follow the topographic divides that separate different watersheds and basins. Portions of the basin boundaries that cross uniform slopes or flat areas are not included as ridge line segments.

Brighter tones in the Flow accumulation raster indicate higher flow accumulation values and trace out the branching pattern of potential flow paths. This intermediate object is used to generate the flow path vector object and the watershed and basin boundaries.



The Flat areas and extrema points raster indicates the location and type of locally-significant elevation values in the original DEM. To assess its signficance, each elevation is compared to that of its 8 nearest neighbors. The majority of cells are not significant and are shown in gray. Cells that have isolated (single) local maximum or minimum values are shown in bright red and bright blue, respectively. Cells that are part of contiguous groups forming local maxima or minima are shown in dark red and dark blue. Flat areas are in yellow.

Two other temporary raster objects are created in the Watershed process. Values in the Flow directions raster (shown to the right) encode the local direction of flow relative to the surrounding 8 cells. The direction value increases clockwise from top right to top. This raster is used along with the Flow accumulation raster to produce the final flow path and basin vector objects. The Watershed raster (not shown) contains a unique cell value for each watershed.

Use Null Values to Limit Processing

The Watershed process traces watersheds, flow paths, and basins to the edge of the DEM raster or to the boundary between valid elevation values and *null values*. A null value is a specifically-designated numerical value that is usually used to represent "blank" or "no data" cells in a raster object. For example, a DEM that has been resampled to a map projection may be rotated so that valid elevation values do not fill the full rectangular extents of the raster object, leaving "blank" areas at the edges and corners that are represented by a null value. These null areas are automatically excluded from processing in the Watershed process, and they are displayed transparently in the View window.

In a DEM of a coastal area the ocean is normally represented by cells with a value of 0, which of course is the elevation value that represents mean sea level. But since real drainage systems terminate at the coastline, there is no reason to include the ocean areas in the analysis. As shown by the DEM in this exercise, by setting the null value for the DEM to 0 you can automatically exclude the ocean areas from processing. (DEMs are usually signed 16-bit rasters with a default null value of -32768).

STEPS

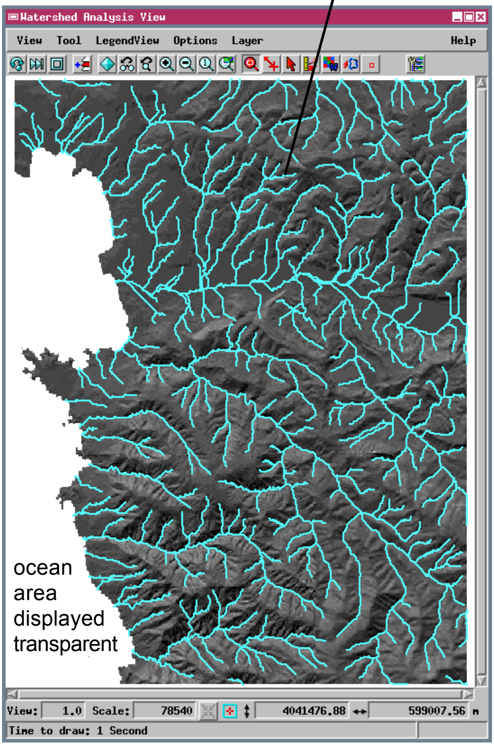
☑ press [Input Object...] in the Watershed Analysis window, then [No] in the Verify window

☑ use the Select Object dialog to select DEM_W2 from the WATERSHD Project File

☑ turn off the Compute Ridges toggle button on the General panel

☑ press the Run icon button 

Standard Flow Paths for DEM_W2 (Standard Basins layer has been hidden).



You can set a value as null for a raster object using the Project File Maintenance process (Support / Maintenance / Project File). Select the desired object and click the Edit icon button to open the Edit Object Information window. Turn on the Has Null Value toggle button and enter the desired value in the text field next to the toggle.

Mask Parts of the DEM

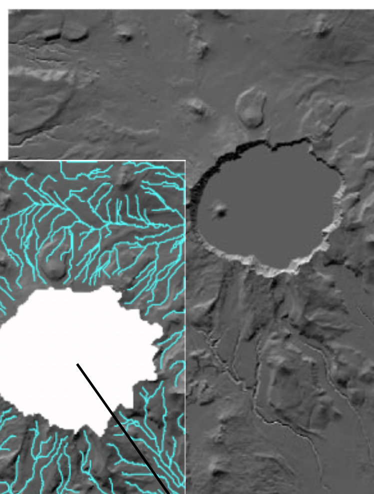
STEPS

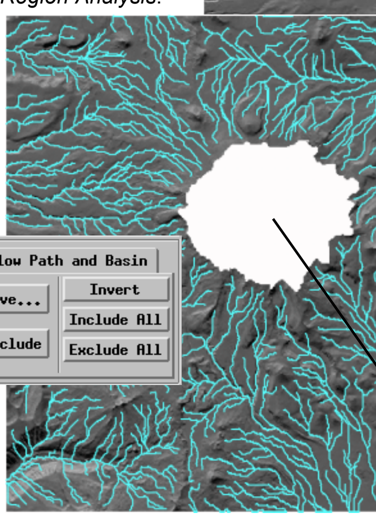
- ☑ press [Input Object...] in the Watershed Analysis window, then [No] in the Verify window
- ☑ use the Select Object dialog to select DEM_W3 from the WATERSHD Project File
- ☑ on the Mask panel, click [Exclude]
- ☑ in the Select Object window, select the BASINREGION region object from the WATERSHED Project File
- ☑ if the View window does not redraw automatically to show the masked area transparent, press the Redraw icon button 
- ☑ press the Run icon button 

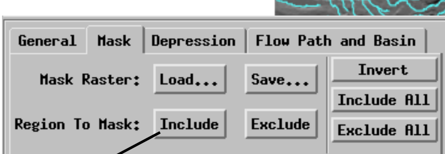
Another way to limit processing to parts of a DEM is to use the masking capability of the Watershed process. A mask is a binary raster that contains a value of 1 for each cell that will be processed and a value of 0 for cells that will be excluded. You can use a mask to exclude a particular area that spans a range of elevation values. In the Crater Lake (Oregon, USA) example used in this exercise, we might be interested in drainage patterns in the area surrounding the crater and want to exclude the lake surface and inner crater walls.

You can load a mask raster that you have prepared outside the Watershed process by pressing the Load button on the Mask panel. The option used instead in this exercise is to use a temporary internal mask raster created from one or more region objects. A region object can modify the internal mask to designate the area to include in processing or an area to exclude from processing.

You can generate region objects within the Watershed process using a variety of standard methods; for more information, see the booklet *Getting Started: Interactive Region Analysis*. You must save any newly-created region to a Project File before you can select it using the Include or Exclude buttons.







Press [Include] to select a region that outlines an area that you want to include in the processing.

The region used in this exercise was created by using the Basin region generation method.

Process Depressions Sequentially

When you run the Watershed process with the Fill All Depressions option turned off, the process takes a sequential approach to filling depressions and finding watersheds. In the initial run the process fills all single-cell depressions in the original DEM surface to create an Adjusted Elevation raster. If you press the Run button again, the process attempts to fill all remaining depressions. In many cases, however, small depressions may be nested inside larger ones. As these small depressions are filled they merge into a residual larger depression. These complex relationships may not be resolved in a single processing pass, so it may take several runs to fill all depressions. Only when all depressions are filled does the process compute and display flow paths and basins.

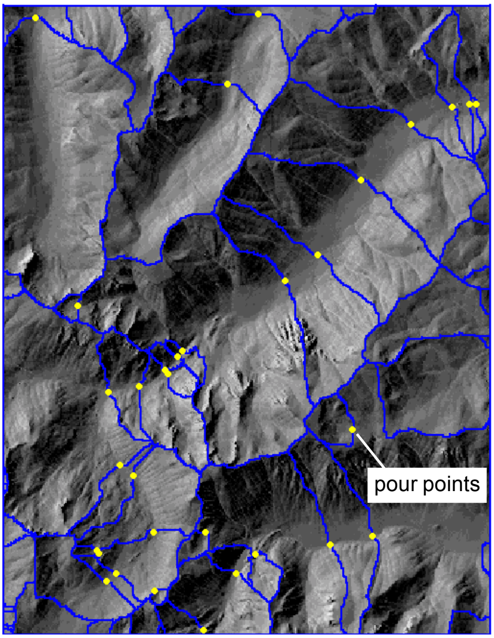
If all depressions are not filled at the end of a run, a set of watershed polygons are displayed automatically in the View window. Some of these watersheds drain to the edges of the raster (or to a null boundary), while others drain into a remaining depression in the adjusted DEM. Yellow point symbols in the watershed vector object indicate the locations of *pour points* along the boundaries of watersheds containing a depression. A pour point is the point through which water would spill over into the downstream watershed if the depression were completely filled.

By running the Watershed process sequentially, you can investigate the characteristics of watersheds and depressions at each stage and identify depressions that are natural features of the landscape rather than DEM artifacts.

STEPS

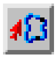
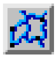
- ☑ press [Input Object...]
- ☑ click [No] in the Verify window if you don't want to save your previous results
- ☑ select DEM_W4 from the WATERSHD Project File
- ☑ turn off the Fill All Depressions toggle button on the General panel
- ☑ press the Run icon button

The DEM used in this series of exercises has a cell size of 30 meters and shows a mountainous terrain which has been modified greatly by glacial erosion. Natural depressions and lakes are common in glacially-eroded valleys such as these.

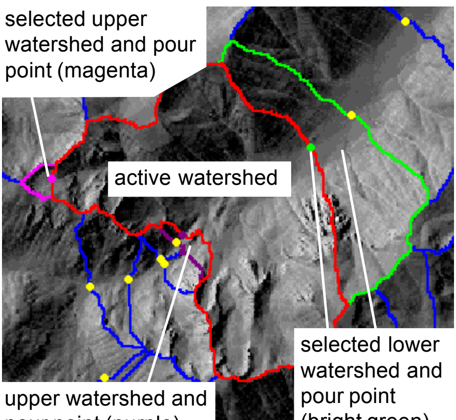


Watershed Relationships

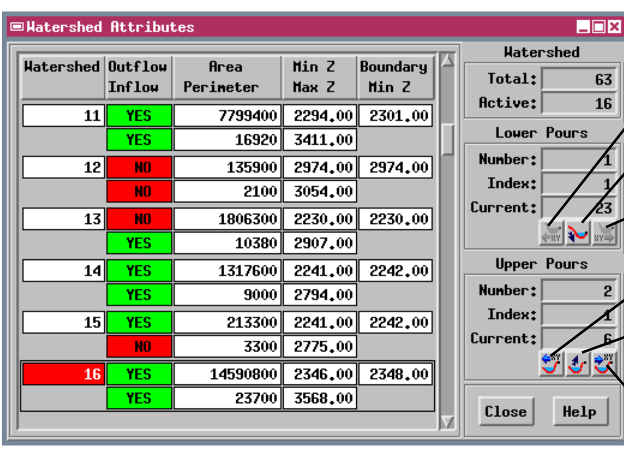
STEPS

- ☑ press the Select Watershed icon button at the top of the View window 
- ☑ left-click with the mouse inside the large watershed polygon at the center of the DEM
- ☑ click on the Watershed Attributes icon button on the Watershed Analysis window 

When depressions remain in the adjusted elevation raster, a single large watershed may be divided into a number of individual watershed polygons. A particular watershed polygon may have one or more upstream watersheds that would drain into it if their depressions were filled. The same watershed may also drain into a downstream watershed (or less commonly more than one) if its depression is filled. These relationships are displayed graphically when you use the Select Watershed tool to select a watershed polygon. The *active watershed* and its upper and lower neighbors are shown in different highlight colors. One neighboring upper watershed (if any) is automatically designated the *selected upper watershed* and shown in a different highlight color than the remaining *upper watersheds*; the same system is used for multiple lower watersheds.



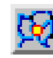
You can use the icon buttons on the Watershed Attributes window (illustrated below) to use these hydrologic relationships to change the active watershed selection.

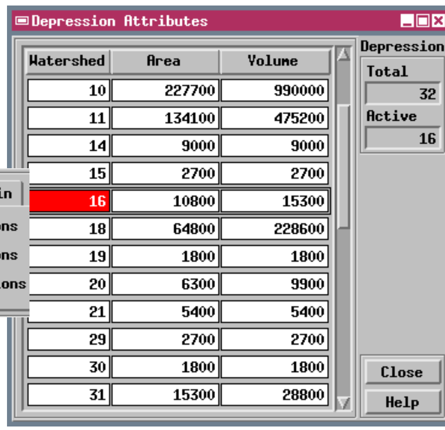


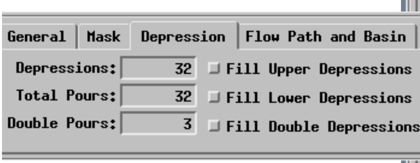
Watershed	Outflow / Inflow	Area / Perimeter	Min Z / Max Z	Boundary Min Z
11	YES	7799400	2294.00	2301.00
	YES	16920	3411.00	
12	NO	135900	2974.00	2974.00
	NO	2100	3054.00	
13	NO	1806300	2230.00	2230.00
	YES	10380	2907.00	
14	YES	1317600	2241.00	2242.00
	YES	9000	2794.00	
15	YES	213300	2241.00	2242.00
	NO	3300	2775.00	
16	YES	14590800	2346.00	2348.00
	YES	23700	3568.00	

Depression and Pour Point Attributes

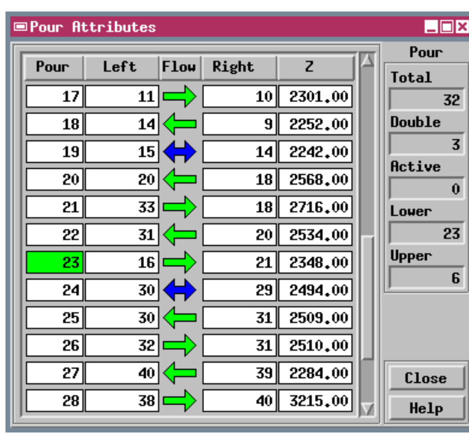
The Depression panel on the Watershed Analysis window shows the total number of depressions and pour points for the current stage of analysis. The area and volume of individual depressions is shown in the Depression Attributes window, where depressions are identified by the number of their watershed polygon. The active watershed is highlighted in the Depression Attributes and Watershed Attributes windows in the same color used in the View window. For example, the watershed selected in the previous exercise is number 16, and its included depression covers 10,800 square meters. The input DEM has a cell size of 30 meters, so the area of a single cell is 900 square meters. Dividing the depression area by the cell area shows that this depression covers 12 raster cells.

STEPS
- ☑ click on the Depression tab on the Watershed Analysis window
- ☑ press the Depression Attributes icon button on the Watershed Analysis window 
- ☑ press the Pour Attributes icon button 
- ☑ scroll down in the Pour Attributes window to show pour point 23





Identification numbers of the upper and lower pour points for the active watershed are highlighted in the Pour Attributes window in the appropriate colors. The columns Left and Right list the numbers of the watersheds that lie on the respective sides of the vector line separating them (relative to the arbitrary direction of that line in the vector topology). The arrows indicate the direction of potential flow through the pour point. In this example, pour point 23 is the selected lower pour point for watershed 16, which drains to watershed 21.



Fill Depressions Selectively

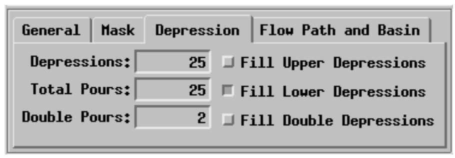
STEPS

☑ close the Pour Attributes, Depression Attributes, and Watershed Attributes windows by pressing their respective Close buttons

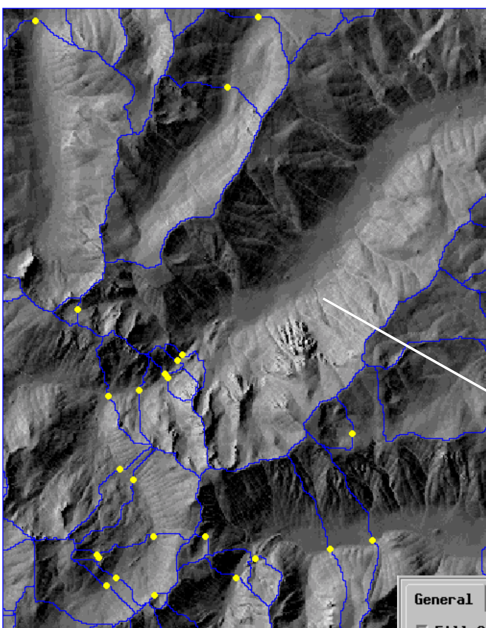
☑ on the Depression panel in the Watershed Analysis window, turn on the Fill Lower Depressions toggle button

☑ press the Run icon button, then [No] in the Verify window

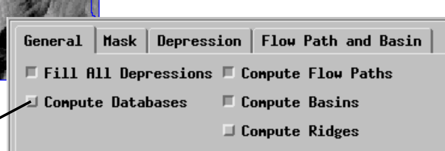
When you have selected a watershed polygon with the Select Watershed tool, you can run the watershed process again to fill only the depression in that watershed or those in watersheds hydrologically related to it as well. These options are controlled by toggle buttons on the Depression panel.



The Fill Upper Depressions option fills depressions in the selected watershed polygon and in all watersheds upstream from it. The Fill Lower Depressions option fills depressions in the selected watershed polygon and in all watersheds downstream from it. If neither of these toggle buttons is turned on, then only the depression in the selected polygon is filled. (If no watershed polygons are selected, all watershed polygons are processed).



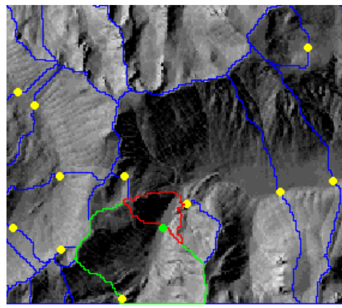
New watershed polygon created by filling depressions in the selected watershed polygon and in those downstream from it. Other watersheds were unaffected.



To save watershed, depression, and pour point data as attached database tables, turn on the Compute Databases toggle before running the watershed analysis.

Double Depressions and Pour Points

If two adjacent depressions share a pour point, and neither has another pour point that is lower in elevation than the shared one, then the two depressions form a *double depression*. The pour point that they share is termed a *double pour point*. If either of these depressions is filled, it will spill over through the double pour into the other member of the double depression. Only when both members are filled will flow continue to downstream watersheds.

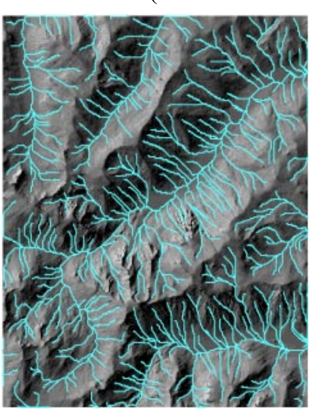


The watershed and depression selected in this exercise form part of a double depression. Pour point 24 is the double pour point linking the two members. Double pour points are indicated in the Pour Attributes window by a blue double-headed arrow.

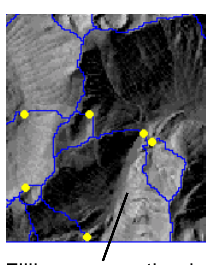
23	40	←	37	2862.00
24	54	↔	42	2515.00
25	43	→	36	3123.00

You can choose to fill only double depressions by turning on the Fill Double Depressions toggle button and then running the process. This options fills all double depression pairs within the DEM without regard to any set of watershed polygons you may have selected (unlike the other toggle buttons on the Depression panel).

STEPS
- ☑ select the small watershed polygon near the center bottom of the DEM, as shown in the illustration below
- ☑ click the Pour Attributes icon button 
- ☑ in the Pour Attributes window, scroll down to show pour point 24
- ☑ on the Depressions tabbed panel of the Watershed Analysis window, turn off the Fill Lower Depressions toggle and turn on the Fill Double Depressions toggle button
- ☑ press the Run icon button, then [No] in the Verify window 
- ☑ turn off the Fill Double Depressions toggle
- ☑ press the Run icon button, then [No] in the Verify window; this run should produce flow paths 



Final flow paths for the DEM.



Filling merges the double depressions. For the example above the merged watershed drains northeast through a pour point to the major valley.

WATERSHEDS

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