CHAPTER **1**

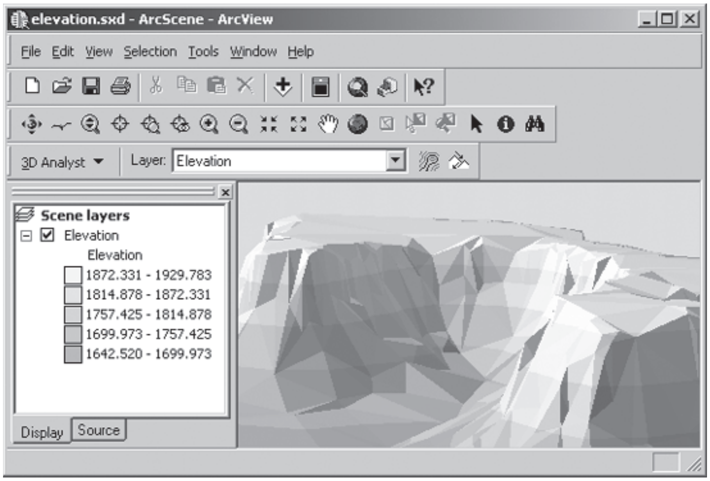
Introduction to 3D Data: Modeling with ArcGIS 3D Analyst and Google Earth

Introduction to 3D Data is a self-study tutorial workbook that teaches you how to create data and maps with ESRI's 3D Analyst software, and to integrate them with Google Earth.

The datasets for all of the exercises in the book are provided online at www.wiley.com/college/kennedy. You must already have ArcGIS 3D Analyst installed to use this tutorial, as the book does not come with any trial software. Most of the 3D Analyst exercises can be done with versions 9.1 or 9.2 of ArcView, ArcEditor, or ArcInfo; some exercises require 9.3. Google Earth is free.

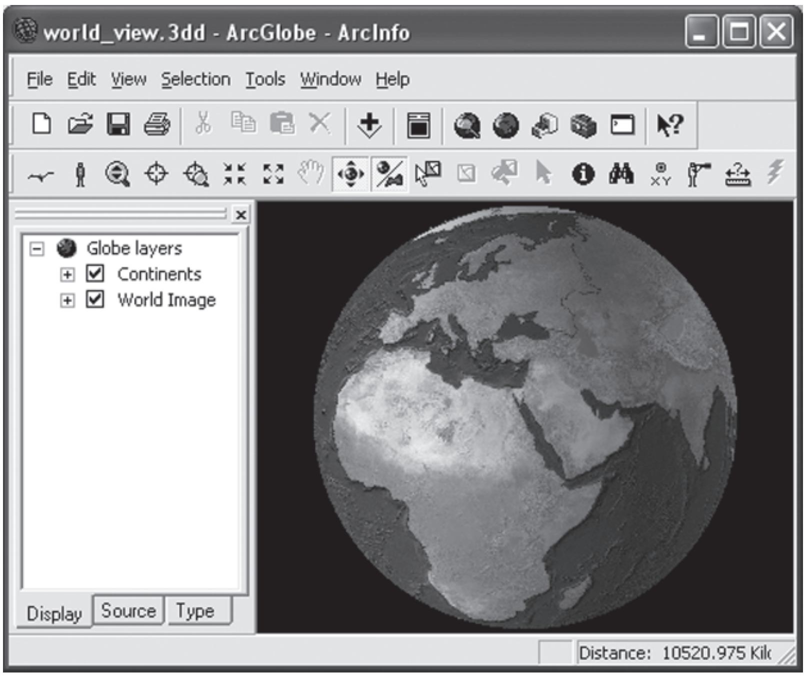
This book is designed for people who are already familiar with ESRI products, particularly ArcMap and ArcCatalog, but who would like to understand the ins and outs of the three-dimensional modeling environment. While you can do the exercises in any order, you should work through early chapters first, since instructions in later chapters are somewhat abbreviated.

3D Analyst is designed primarily to create surface elevation data and display it in three dimensions. It provides additional analysis functions such as viewshed, surface area, and volume calculation. Its original interface, ArcScene, presents data in three-dimensional space.



ArcScene models data in three-dimensional space

In version 9.0 ESRI added ArcGlobe to the package, which allows you to view large datasets in a global format.

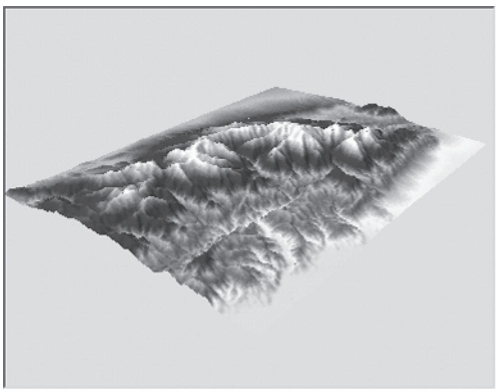


ArcGlobe models data on the earth

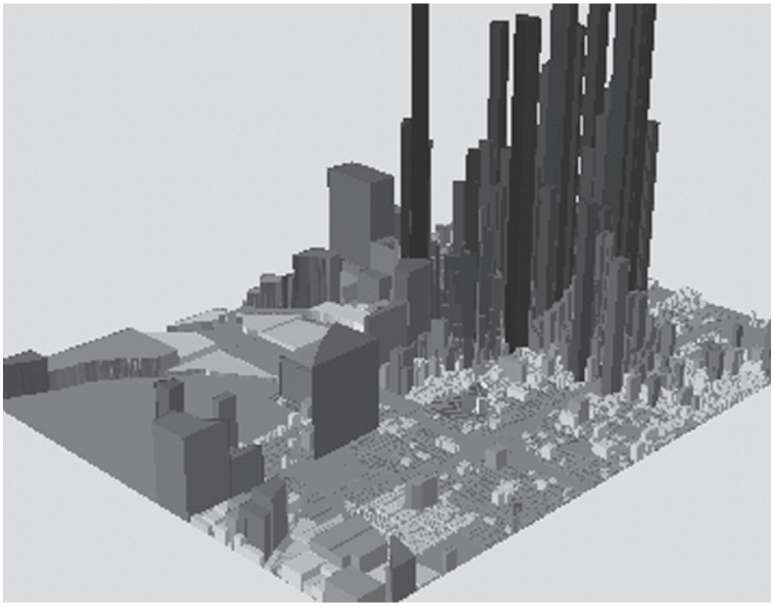
Increasingly, however, GIS users and the general public expect to be able to view maps interactively, on the web, for free. This is thanks largely to Google Earth, which has revolutionized the way we view spatial information. ArcGIS 3D Analyst has the power to create and analyze geographic data, but Google Earth has the speed and intuitive interface that makes it a staple for displaying maps and sharing spatial information.

With 3D Analyst, you can create TIN (Triangulated Irregular Network) and raster surface models from any vector elevation data such as contour lines, GPS points, or survey points. In ArcScene and ArcGlobe, you can drape images and vector features over surfaces, fly through your GIS data in 3D perspective, and make movies of your flights. You can extrude 2D points, lines, and polygons into lines, walls, and solids, and you can create multipatch “true 3D” features. You can calculate slope, aspect, hillshade, volume, and surface area; create contour lines, and determine visibility from any point on a surface. You can also determine lines of sight, create profile graphs of a surface, and digitize 3D features and graphics.

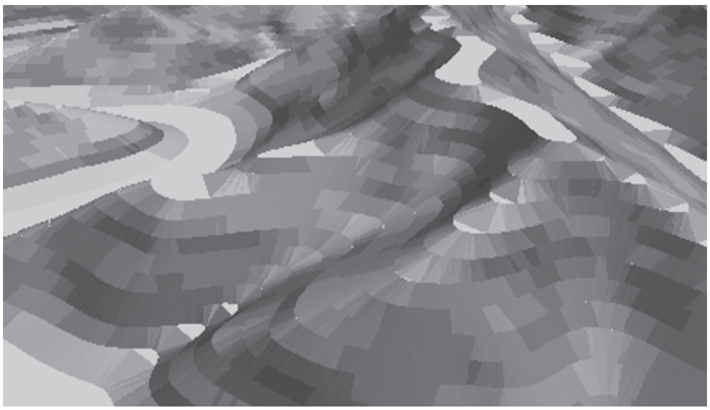
An elevation raster in ArcMap



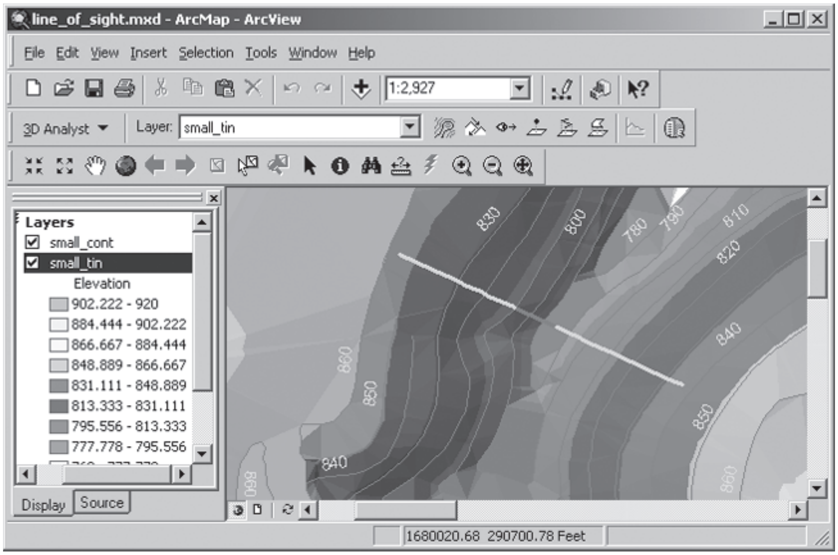
The same elevation raster in ArcScene



Parcels colored and extruded by land value



A TIN created from contour lines with faces symbolized by slope

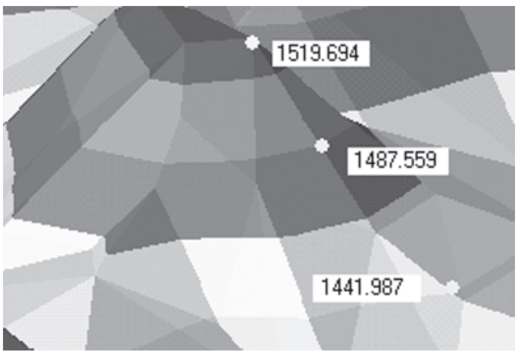


A line of sight drawn in ArcMap

3D Data Overview

X, Y, and Z Values

All geographical data contains horizontal x,y coordinate values. To work in three dimensions, you need data that contains z values as well. For each x,y location stored in a 3D dataset, a z value is stored that represents an attribute other than that location's horizontal position. In a terrain model, the z value represents elevation, or height about sea level.



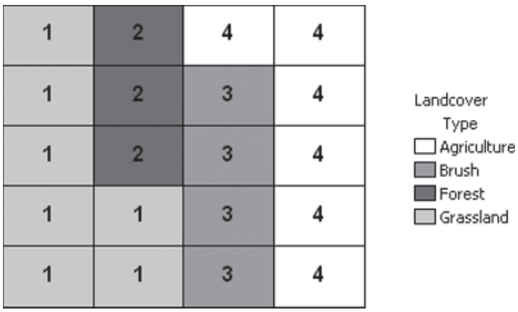
Three locations on the surface of a TIN, each labeled with their elevation (z) values in feet

3D Analyst works primarily with raster, TIN, and 3D vector feature data. Rasters and TINs are used to model surfaces, not just of terrain but of any phenomenon that varies continuously across an area, such as precipitation, chemical concentration, pollution dispersion, noise levels, population distribution, or soil pH.

Rasters

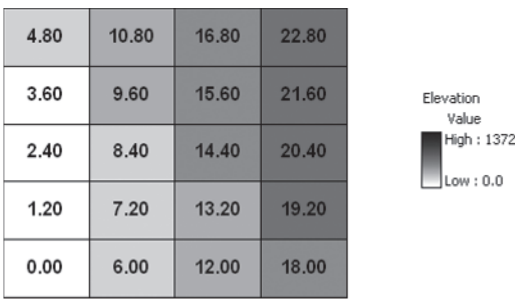
A raster represents a surface as a rectangular grid of evenly spaced square cells. Each cell is the same size and has a unique row and column address. A cell can represent a square kilometer, a square meter, or a square centimeter. The smaller the cells, the more detailed the raster, and the larger the file space taken up by the grid.

Since the grid is uniform, its horizontal (x,y) coordinates don't need to be stored in each cell. Instead they are calculated from the x,y location of the lower-left cell in the grid. Each cell does, however, hold its own z value that represents a quantity or a category of phenomena such as elevation, crop yield, or reflected light.



Cells in a landuse grid. All cells with the same value are symbolized by the same color

While landuse could also be represented by discrete vector polygons, vector data cannot represent values that change gradually, or continuously, over an area.

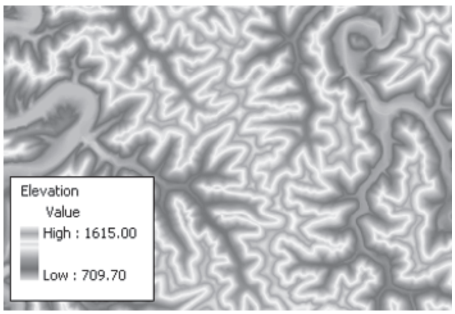


Cell in a continuous grid, symbolized by value range

Raster data is often divided into two categories: image and thematic. In an image, the surface phenomenon is the reflection or emission of light, or some other band in the electromagnetic spectrum, and can be measured by camera or satellite.

An aerial photograph. Cells in this raster represent light reflected from the earth's surface

When a phenomenon such as light is measured by a camera or a satellite, each cell's value represents the light and color at that point on the surface. A thematic raster, however, represents a category or quantity of a phenomenon such as elevation, pollution, population, rainfall, or noise. Since readings cannot be taken at every location, samples are taken instead, and a surface model is made. The model approximates the surface by interpolating the values between the sample points.

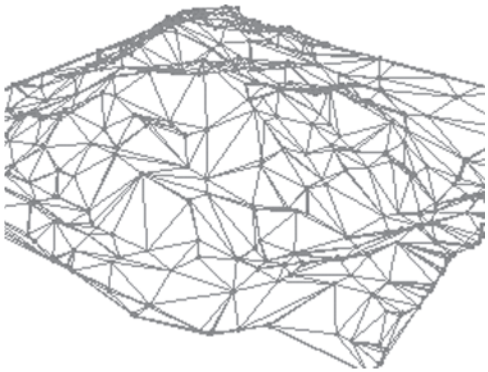


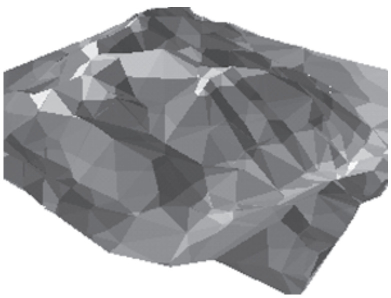
A thematic raster of elevation values. A few of the cells represent samples actually taken, but most of the values have been interpolated

3D Analyst uses the z value stored in each cell to display the raster in 3D. Elevation values are commonly shown, but any numeric cell value can be illustrated in three dimensions. Even though images and many thematic rasters don't contain elevation values, you can still display them in 3D by draping them over a 3D surface model with the same geographic extent.

TINs

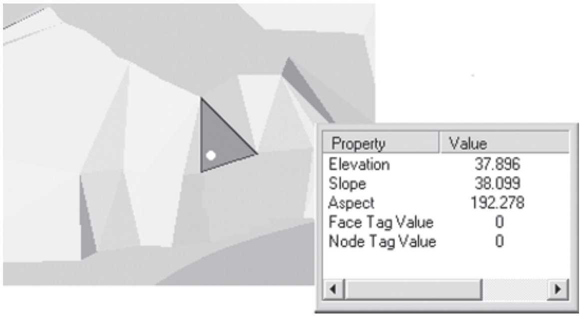
A Triangulated Irregular Network (TIN) represents a surface as a set of irregularly located points, joined by lines to form a network of contiguous, non-overlapping triangles that vary in size and proportion. Each triangle node stores an x, y, and z value.





The structure of a TIN. Top: only the TIN edges and nodes are shown. Bottom: the TIN's triangles (faces) are colored to represent elevation

Like rasters, the values in a TIN are interpolated from sample points. The sample points form the triangle nodes, and the interpolation (or triangulation, as it's generally called) consists of connecting the nodes by lines. Once the TIN is built, the elevation of any location on a TIN surface can be estimated using the x, y, and z values of the bounding triangle's vertices. The slope and aspect for each triangle face is also calculated.



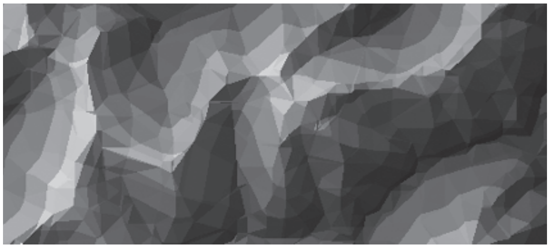
When you identify any point on the face of a TIN, the node x, y, z values are used to interpolate the elevation at that point. The node values are also used to calculate the slope and aspect of each triangle face

Because the nodes can be placed irregularly over the surface, TINs can show greater detail where a surface is highly varied or where you want more accuracy. A TIN is only as good as the initial sample points taken; mountainous areas need many more samples per square unit than flat areas do in order to create an accurate terrain model.

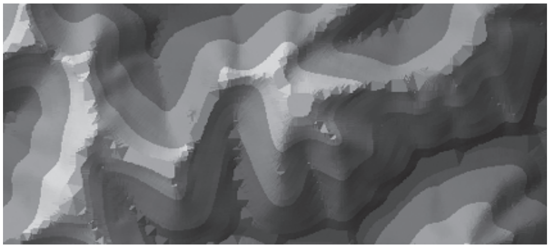
TIN models are less widely available than raster surface models; they take longer to build and require much more disk space. They are typically used for precise modeling of small areas.

Terrain Datasets

A terrain dataset represents a surface in the same way that a TIN does, but uses a different storage system. Elevation measurements collected by LiDAR or SONAR are typically used to create a terrain because they can result in millions of mass points. This enables the creation of a very accurate surface, but also makes for a large file size. Terrain datasets get around this by separating the TIN representations into multiple levels of resolution, called pyramids, for faster drawing of large datasets. At smaller scales, a coarser TIN representation is drawn; at larger scales, more detailed features are shown.



In a lower-resolution pyramid of a terrain dataset, fewer triangles are calculated during display. This pyramid level would normally be drawn at a smaller scale in ArcMap

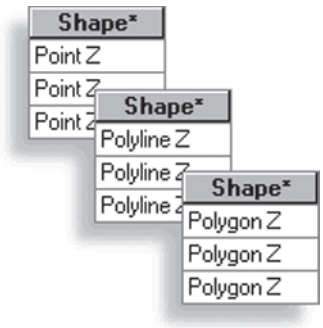


In the finest resolution pyramid, all triangulations are represented in the terrain dataset. This pyramid level would normally be drawn at a large scale in ArcMap

3D Features

3D vector features, like their 2D counterparts, represent objects or clearly bordered areas such as buildings, land parcels, roads, power poles, and wells. Often, the z values in 3D features are used to represent an attribute other than height. For example, you might create a scene that shows city points extruded into 3D columns based on their population.

Like TINs, 3D features store z values along with x, y coordinates as part of their geometry. A point has one z value; lines and polygons have one z value for each vertex in the shape. You can identify 3D feature classes by looking at the Shape field in their attribute tables.



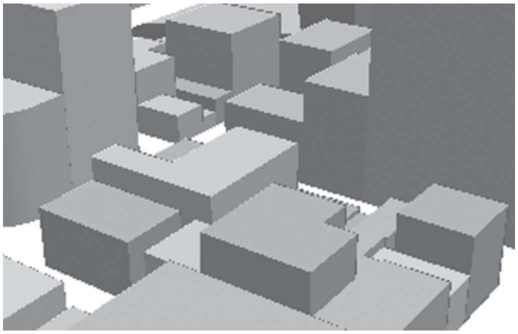
A 3D feature class shows a Z value in its Shape field

2.5-Dimensional and 3-Dimensional Data

Generally, when we talk about 3D data, we mean 2.5 D data. Rasters, TINs, and terrains are surfaces that store exactly one z value for each x, y value pair. Also, when we turn points, lines, or polygons into solids, we're really just extruding 2D coordinates by a set of specified values.

True 3D geometric structures are represented in 3D Analyst by multipatch features. Multipatches are made of planar 3D rings and triangles stitched together to model objects like spheres, trees, rooftops, or buildings with overhanging features.

Software programs like Sketchup (Google's free 3D modeling software), 3ds Max, OpenFlight, and VRML 2.0 can create models that 3D Analyst can import into a geodatabase and use as symbols. They can also be used as graphics in ArcScene or ArcGlobe, without committing them into a geodatabase.



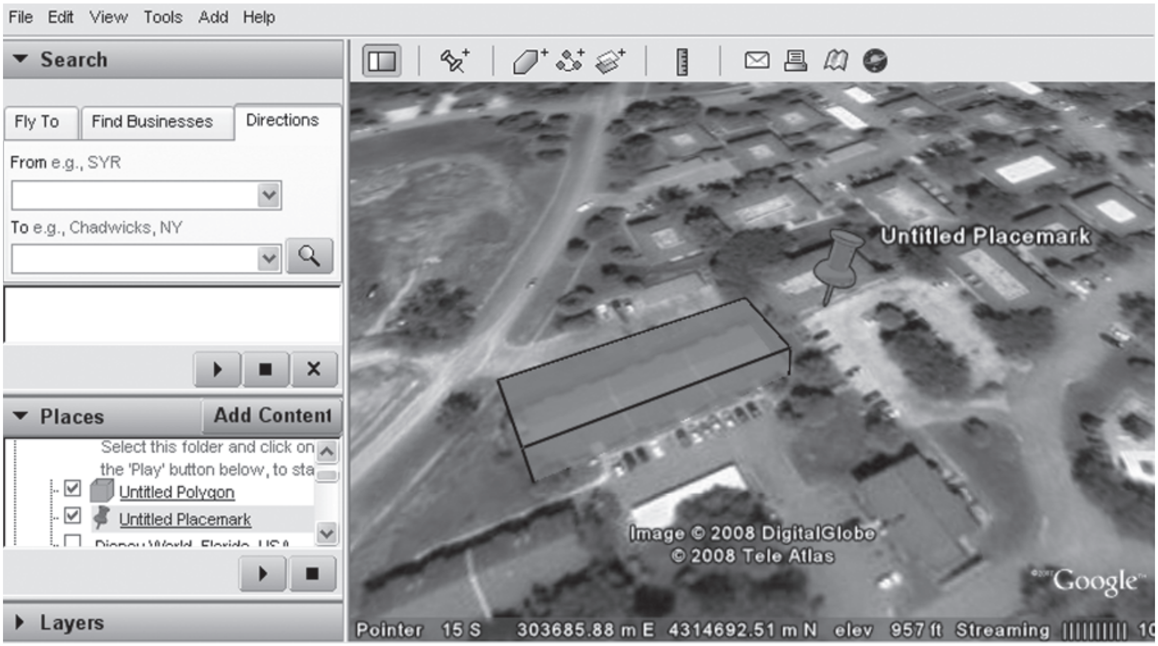
3D features extruded from 2D polygons. Each x,y vertex has one companion z value

Multipatch (true 3D) features can handle multiple z values per x,y vertex, permitting realistic representations of features that include overhangs or textures

KML

KML is Google Earth's file format for displaying 3D data. You may be used to seeing the most common form of KML document in Google Earth and Google Maps: the Placemark. This is similar to a point feature class in ArcGIS in that it represents a geographically referenced point on the earth. It differs completely, of course, in the file structure and instructions used for rendering. KML is a tag-based structure similar to HTML and XML that can be created or altered in any text editor. Generally, though, you will create 3D features directly in Google Earth, or import files created in Sketchup into Google Earth.

Besides Placemarks, KML allows you to create or place polygons, lines, and raster image overlays in Google Earth.



A Placemark and a Polygon created in Google Earth. The KML code for the Placemark object is shown below:

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			</Icon>
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		</Point>
	</Placemark>
</Document>
</kml>
```


Now that you've had an introduction to 3D data structures, you're ready to learn how to use 3D Analyst.

Load the Tutorial Data

The next two exercises will teach you how to work with 3D data in ArcCatalog. Before you can do any exercises, however, you need to load the 3D Analyst tutorial data and add the ArcScene, ArcGlobe, ArcCatalog, and ArcMap program icons to your desktop.

Visit the support website for the book to download the tutorial data at www.wiley.com/college/kennedy. Click on the cover for *Introduction to 3D Data: Modeling with ArcGIS 3D Analyst and Google Earth*. On the next page click the link for the Student Companion Site on the right side of the page and follow the links for the 3DDATA.zip archive. Download the zip file to your desktop and extract the archive to the drive of your choice using a program such as WinZip or 7-Zip (freely available at www.7-zip.org). If you have the disk space, I recommend that you copy it directly under your C: drive, so that the full pathname reads "C:\3DDATA."

Once the contents of the 3DDATA.zip archive are copied to your hard drive, you can delete the zip file as you won't need it again.

Add the Program Icons to Your Desktop

Note: ArcGIS 3D Analyst must be installed before you can create shortcuts to it on your desktop. If you have not installed the software, please see the ArcGIS 3D Analyst installation guide.

1. On the taskbar of your desktop, click the Start menu. Move your cursor to Programs, then ArcGIS, and right-click on ArcScene.
2. Choose Send to . . . , and then click Desktop (Create Shortcut). A shortcut to ArcScene is added to your desktop. (This procedure is for Windows XP; if you're running Windows 2000, NT, or Vista, it may be a little different.)
3. Use the same procedure to add the ArcGlobe icon to your desktop. If you don't already have desktop icons for ArcCatalog and ArcMap, you should add them as well.

Exercise 1-1

Preview Data in ArcCatalog

With 3D Analyst loaded in ArcCatalog, you can preview both 2D and 3D data in three dimensions. In this exercise, you'll examine a TIN of Coletown, KY, and a 3D shapefile of contour lines.

Step 1. Start ArcCatalog

Double-click the ArcCatalog icon on your desktop. If you didn't make an ArcCatalog desktop icon, either see the instructions immediately above, or click the Start menu, point to Programs, point to ArcGIS, and click ArcCatalog.

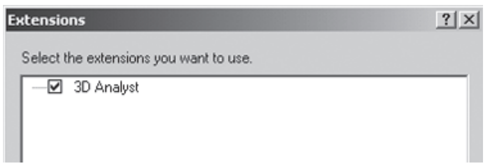
From the Tools menu, choose Options.

Click the General tab. At the bottom of the dialog, uncheck the box next to "Hide file extensions."

Click OK.

Step 2. Load the 3D Analyst Extension

From the Tools menu, choose Extensions. In the dialog, check the box next to 3D Analyst. Click Close.



Step 3. Load the 3D View Toolbar in ArcCatalog

From the View menu, click Toolbars and check the box next to 3D View Tools and Globe View Tools.

These tools let you view and navigate your data in 3D and in Globe view, query 3D features, and create perspective-view thumbnails.

Other than the Launch ArcScene button, 

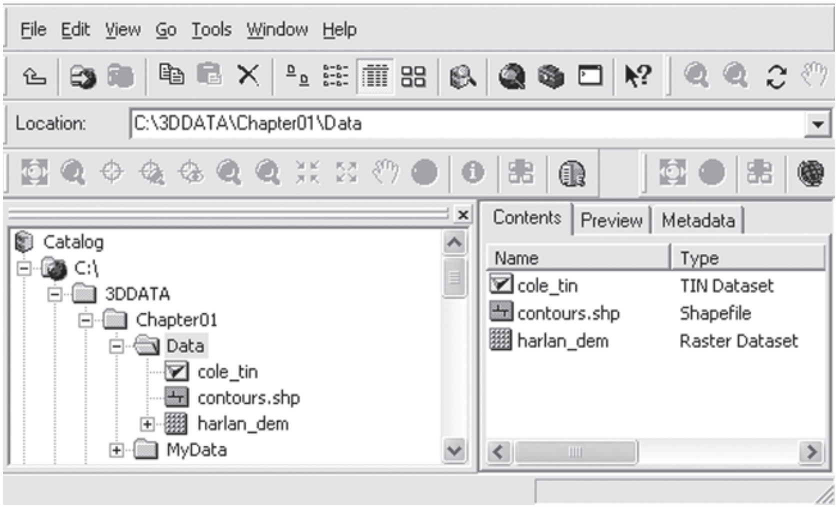
the Launch ArcGlobe button, 

and the Create Thumbnail buttons, 

these tools are also found on the Tools toolbars in ArcScene and ArcGlobe, respectively.

Step 4. Look at ArcCatalog's Contents

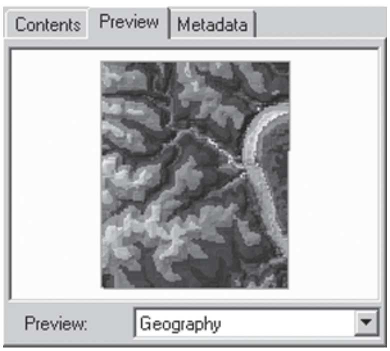
In the Catalog tree on the left, navigate to the 3DDATA\Chapter01\Data folder. Click the plus sign next to the Data folder to open it.



The 3DDATA\Chapter01\Data folder contains one TIN, one raster, and one shapefile feature class. Notice the icons that ArcCatalog uses to represent TIN and raster data types.

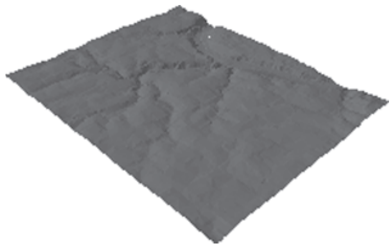
Step 5. Preview the TIN Dataset

Click cole_tin in the Catalog tree, then click the Preview tab above the display. The TIN is displayed in two dimensions (also called the orthographic or planimetric view). The faces of the TIN are colored by elevation value.



Click the arrow next to the Preview menu below the display, and select 3D View.

The TIN is displayed in three dimensions (perspective view). By default, the angle is from the southwest, and the TIN is no longer symbolized by elevation values but by a single color for all faces. This was introduced in version 9.0 as an attempt to speed up drawing time.



Step 6. Use the Navigate, Zoom, and Pan Tools

The three tools that you will use most to examine your 3D data are Navigate, 

Zoom In/Out, 

and Pan. 

The Navigate tool lets you rotate your data in any direction around the center of the display. Click the Navigate tool.

Place your cursor over the center of the TIN in the display, hold down the left mouse button, and move the mouse in any direction. You can inspect the TIN from any angle (except from underneath; for that you need to be in ArcScene).

To reset the view, click the Full Extent button. 

Click the Zoom In/Out tool. Place your cursor at the top center of the TIN in the display. As in ArcMap, holding down the left mouse button while dragging the mouse up and down zooms the display in and out.

Click Full Extent again.

Not surprisingly, the Pan tool moves your data horizontally, vertically, or diagonally across the display. Click the Pan tool. Place your cursor over the center of the display, hold down the left mouse button and drag the cursor in any direction. When you're finished, click Full Extent.

Step 7. Pan and Zoom with the Navigate Tool

In addition to rotating your data in the display, the Navigate tool also lets you pan and zoom without changing tools.

Click the Navigate tool again. 

Place the cursor over the center of the display. Hold down the center mouse wheel and drag the cursor in any direction. When you're comfortable panning with the Navigate tool, click Full Extent.

With the Navigate tool still selected, hold down the right mouse button. Drag it down in the display to zoom in, up to zoom out. You can also scroll with the mouse wheel to achieve the same effect. When you're comfortable zooming with the Navigate tool, click Full Extent.

Step 8. Experiment with the Other Navigation Tools

The Narrow and Expand Field of View buttons and the Zoom In and Zoom Out buttons work the same way in ArcScene as they do in ArcMap.

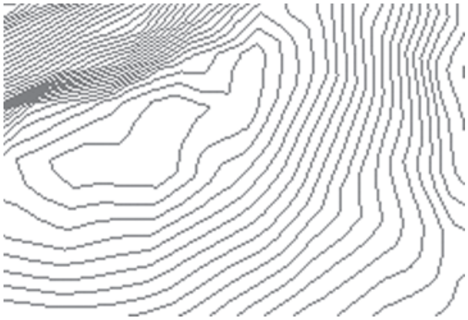
Feel free to experiment with them. When you're finished, set the display back to Full Extent.

Step 9. Preview 3D Vector Features

In the 3DDATA\Chapter01\Data folder in the Catalog tree, click contours.shp. Make sure the Preview tab above the display is selected. Click the Navigate tool, and set the Preview menu below the display to 3D View.

(If you only see "contours," not "contours.shp" in the Data folder, click the Tools menu in ArcCatalog and choose Options. On the General tab, uncheck the box at the bottom that says "Hide File Extensions.")

Put your cursor over the contour lines in the Preview display, hold down the left mouse button and rotate the contours in different directions. Hold down the right mouse button to zoom in, then navigate some more.



Notice that the contour data rotates more quickly and smoothly than the TIN data. That's because the contour shapefile takes up much less disk space.

Step 10. Compare the File Sizes of the Datasets

Click on the Metadata tab above the display. Enlarge the window so you can see all three tabs: Description, Spatial, and Attributes.

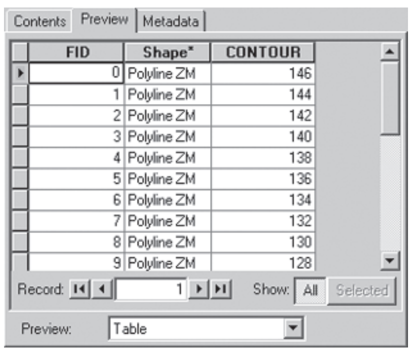
Click on Description. Scroll down to "Data storage and access information," and click on it. Scroll down some more, and click on "Accessing the data." Note that the file size of contours.shp is 0.070 MB.

In the Catalog tree to the left of the Preview display, click on cole_tin. Make sure that the Metadata tab and the Description heading are selected. Scroll down again to "Data storage and access information," click on it, and scroll further to "Accessing the data."

The file size of cole_tin is 0.429 MB, six times larger than contours.shp. (Depending on a few factors having to do with metadata and thumbnail graphics, your file sizes may vary somewhat.)

Step 11. Preview the 3D Shapefile Attribute Table

As you read earlier, one way to tell if a feature class contains 3D features is to look at its attribute table. You can do this in ArcScene, ArcGlobe, ArcMap, or ArcCatalog. In the Catalog tree, click on contours.shp again. Click on the Preview tab above the display, and set the Preview menu below the display to Table.



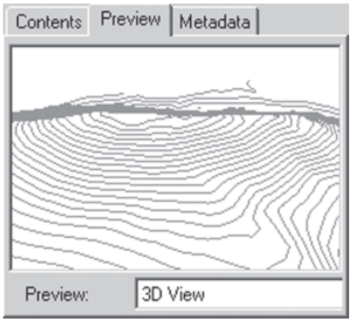
FID	Shape*	CONTOUR
0	Polyline ZM	146
1	Polyline ZM	144
2	Polyline ZM	142
3	Polyline ZM	140
4	Polyline ZM	138
5	Polyline ZM	136
6	Polyline ZM	134
7	Polyline ZM	132
8	Polyline ZM	130
9	Polyline ZM	128

Look at the Shape field in the table. The xpression *Polyline ZM* indicates that this is a 3D polyline feature. A 2D polyline feature would have a Shape field value of *Polyline.*

Step 12. Query 3D Shapefile Attributes

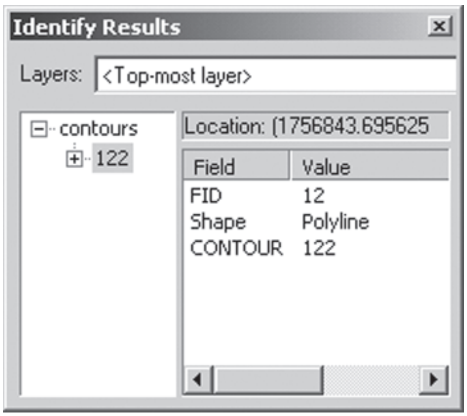
You can also select individual 3D features and look at the attributes in ArcCatalog. In the Preview menu below the display, select 3D View. Notice that all of the 3D tools become active again.

Click the Navigate tool. Put your cursor over the display, hold down the right mouse button, and drag it downward to zoom in on the contour lines.



Click the Identify tool. 

Click on one of the contour lines. ArcCatalog highlights it and the Identify Results box appears, listing the contour line's ID number, its z-value (height), and the x,y location at the point clicked.



Click on a few more contour lines, and note their elevations. When you're finished, close ArcCatalog.

In this exercise, you loaded the 3D Analyst extension in ArcCatalog, previewed a TIN and a 3D shapefile, learned to use the 3D navigation tools, looked at 3D feature class attributes, and examined metadata. In the next exercise, you'll preview a raster dataset in ArcCatalog and create a layer from it.

Exercise 1-2

Create a Layer File in ArcCatalog

In this exercise you'll preview a Digital Elevation Model of Harlan, KY, create a layer file, symbolize it, and make a 3D thumbnail.

Step 1. Start ArcCatalog

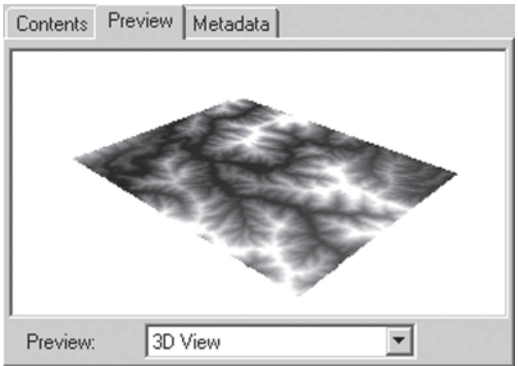
Double-click the ArcCatalog icon on your desktop. If you didn't make an ArcCatalog icon, click the Start menu, choose Programs, then ArcGIS, then ArcCatalog.

Step 2. Preview the Raster Dataset

Navigate to the contents of your 3DDATA\Chapter01\Data folder, and click on harlan_dem.

Click the Preview tab above the display.

Change the Preview menu from Geography to Globe View, and then to 3D View. Notice that even though the DEM is shown in 3D perspective, it still looks flat.



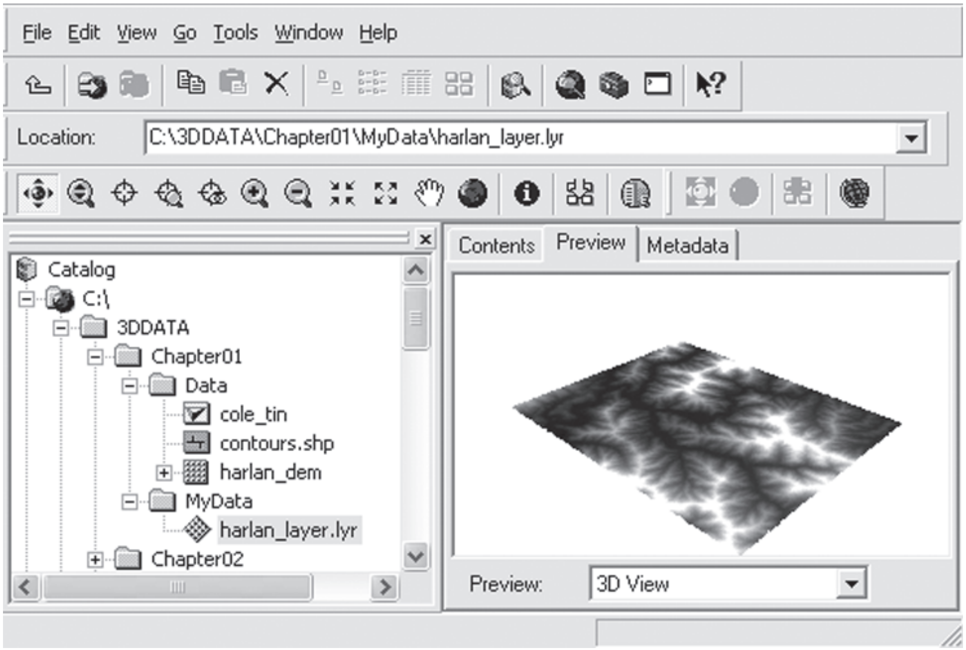
As you saw in Exercise 1, TINs and 3D vector features display their height values in ArcCatalog when you select 3D View. Rasters, however, are drawn as though they lie on a flat surface. In order to see the heights of an elevation raster in ArcCatalog, you have to create a layer file (.lyr) from the raster and specify its 3D drawing properties.

Step 3. Create a Layer File from the Raster

In the Catalog tree, right-click harlan_dem and choose Create Layer. Name it harlan_layer, and save it in your 3DDATA\Chapter01\MyData folder (not the Data folder).

Again in the Catalog tree, open the MyData folder and click once on harlan_layer.lyr to highlight it.

Select the Preview tab above the display, and choose 3D View from the Preview menu.

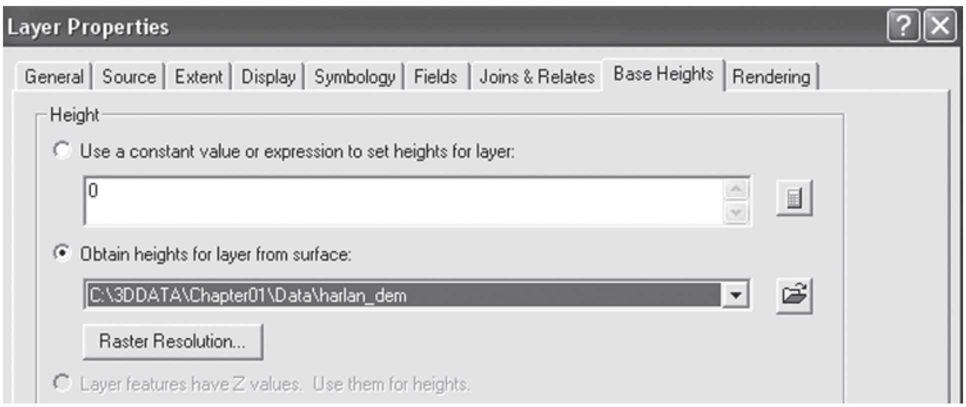


Harlan_layer .lyr is not a copy of harlan_dem; in fact, it's not a raster dataset at all. As with the .lyr files for other data types that you may have used previously with ArcCatalog, it's a much smaller file that contains a copy of the display instructions for harlan_dem. You can't change the 3D viewing properties of the original harlan_dem in ArcCatalog, but you can change the 3D viewing properties of harlan_layer.

Step 4. Set Base Heights for Harlan_layer

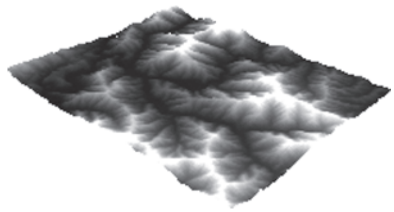
In the Catalog tree, right-click harlan_layer and click Properties.

In Layer Properties, click the Base Heights tab. Choose "Obtain heights for layer from surface," and make sure that the surface used is harlan_dem from the Chapter 1 Data folder.



This setting uses the elevation values stored in harlan_dem to define the base heights of harlan_layer. You'll learn more about base heights in the Chapter 2.

Click OK to close the Layer Properties dialog, and look at harlan_layer in 3D View.



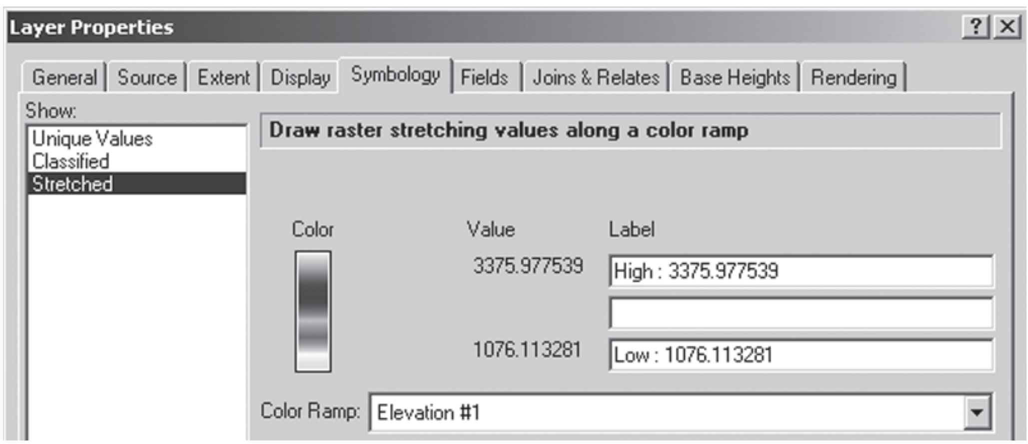
Harlan_layer draws in 3D, but you'll change the color scheme to better reveal its elevation levels.

Step 5. Change the Layer's Color Scheme

Right-click harlan_layer in the Catalog tree again, and click Properties.

In Layer Properties, click the Symbology tab. In the Color Ramp dropdown list, right-click on the color ramp itself (not on the dropdown arrow). Click Graphic View to uncheck it. This replaces the color ramp with its name.

Click the Color Ramp dropdown arrow and scroll down until you see Elevation #1. Click to select it.



Click OK to close the Layer Properties dialog.

Preview harlan_layer again in 3D.

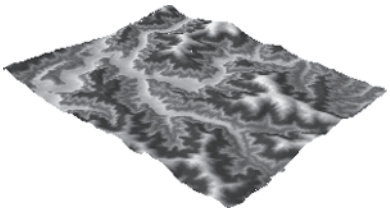
The elevation levels of this piece Harlan County are much more apparent now, but you can improve the perspective further by adding shading to the surface.

Step 6. Add Shading to the Layer

Open Layer Properties again for harlan_layer.

Click the Rendering tab. In the Effects frame, check "Shade areal features relative to the scene's light position."

Click OK.



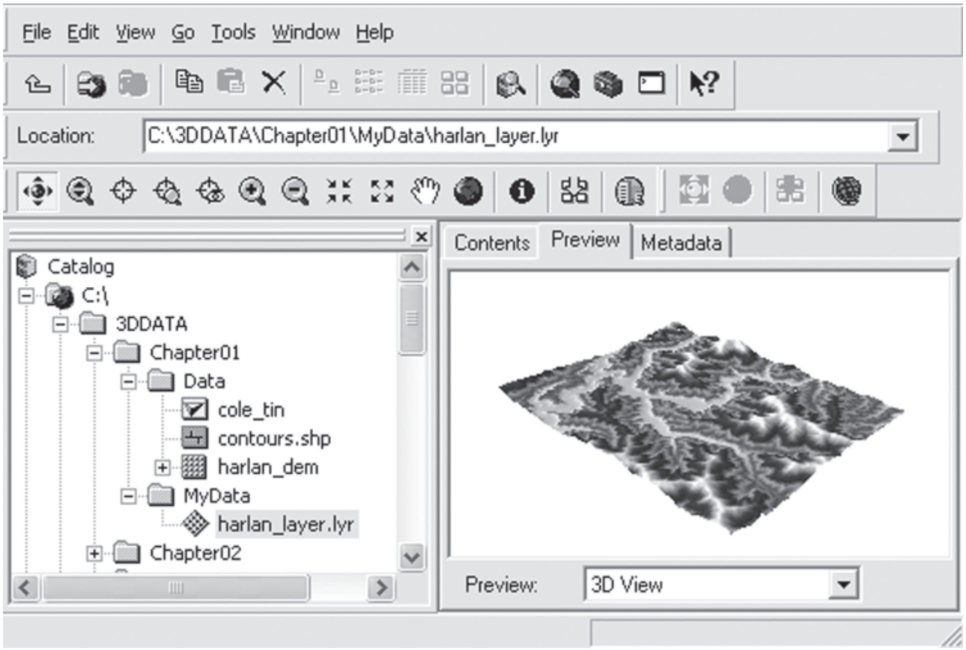
Because you illuminated the surface from a realistic sun angle, the elevation of the landscape stands out in greater relief. You'll learn more about illumination in Chapter 2.

Step 7. Create a 3D Thumbnail

In the Catalog tree, click once on harlan_layer.lyr, and select the Contents tab above the display.

ArcCatalog shows the name, file type, and file size of harlan_layer. You'll create a 3D thumbnail to go along with the information.

Click on the Preview tab above the display, and select 3D View from the Preview menu. The 3D tools are activated.



Click the Create Thumbnail button on the 3D toolbar. 

Click the Contents tab again. The new harlan_layer 3D thumbnail is added to the file description.

Close ArcCatalog.

In this chapter, you learned how to use the 3D Analyst navigation tools and how to preview, create, and symbolize 3D data in ArcCatalog. Chapter 2 will introduce you to the ArcScene interface.