January 2011

Manual for working with ArcGIS 10

WORKING WITH

ARCVIEW 10
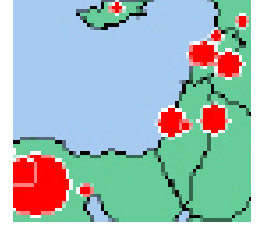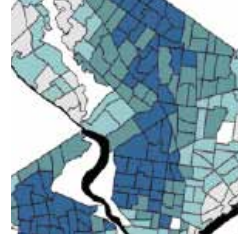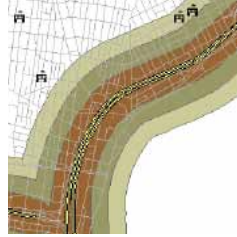
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INTRODUCTION TO THIS MANUAL

This manual is intended for undergraduate and graduate students learning to use ArcGIS 10 in a classroom setting. It is meant to be a complement, rather than substitute, for ArcGIS software manuals, Esri training products, or the ArcGIS help options. It reflects the order and emphasis of topics that I have found most helpful while teaching introductory GIS classes in urban studies, social work, and city planning. I expect that it will be particularly helpful to people new to GIS who may be intimidated by conventional software manuals. It may also be helpful as a resource to those who have completed a course in ArcGIS but don't always remember how to perform particular tasks. This manual does not try to be comprehensive, focusing instead on the basic tools and functions that users new to GIS should know how to use. Those who master these basic functions should have the skills to learn about additional tools, using the ArcGIS help menus, or just exploring additional menu options, toolbards, and buttons.

Each section in the manual introduces a general group of functions in ArcGIS, providing step by step instructions for using a set of tools with screen captures and a video showing those steps through screen captures.

One of the most difficult parts of learning how to use GIS is matching what you know you want to do in layman's or conceptual terms to the specific tool and technical language of ArcGIS. The table of contents provides an overview of the tools and functions covered, but you may find it just as helpful to use Adobe Acrobat's "find" function. The other challenge is trouble-shooting. ArcGIS products include an enormous range of functionality which allows it to meet the needs of a wide range of users. But this wide range also results in what can be an overwhelming and sometimes temperamental product. Figuring out why things don't work is key to getting ArcGIS to do what you want it to do and minimizing your frustration. The section on trouble-shooting at the end of this manual is intended to help identify common problems and solutions.

This manual is intended to be shared. You do not need my permission to share this with a friend or even post it on a course website. Because I am continually updating it, I always appreciate feedback, whether you found a typo or spelling mistake or want to suggest a better way of explaining particular concepts and techniques. The best way to succeed with GIS is to make learning how to use it a collective process, so please join me in making GIS work for us.

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Graphic Design by Caitlin Bowler, MCP '08

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1| Introduction to ArcGIS

ArcGIS is a collection of software products created by Environmental Systems Research Institute (Esri)--the Microsoft of GIS software--that includes desktop, server, mobile, hosted, and online GIS products. This introduction provides an overview of all of the products, but this manual focuses on the desktop applications, only.

Map made by Shimrit Keddem

Desktop GIS Products

The desktop GIS products allow users to integrate and edit data, create new map layers, and author maps. ArcGIS desktop includes a series of scaleable products. They are all based on the same architecture, but the more expensive products have more functionality. A matrix describing what functionality is available for each product can be found at http://www.esri.com/library/brochures/pdfs/arcgis10-functionality-matrix.pdf.

With the jump from ArcGIS 3.2 to ArcGIS 8, Esri brought ArcGIS into its ArcGIS system so that it uses the same structure as its more sophisticated GIS products. ArcGIS 3.x has similar functionality to ArcGIS 8, 9 and 10, but the products work in very different ways. That means that if you learned GIS using ArcGIS 3.x, you will probably need to do some work to be able to use ArcGIS 10. ArcGIS 10 adds some functionality to ArcGIS 9, but those two versions work in a very similar way, so if you learned how to use ArcGIS 8 or ArcGIS 9, you should have no trouble switching to ArcGIS 10.

ArcView

ArcView is the desktop version of ArcGIS meant for a general (non-professional) audience. It is the most popular desktop GIS software program, but it is not the only one. Even though it is the "baby" desktop GIS product within the Esri family of products, it is still over-kill for most basic GIS projects. Some people will call this "ArcGIS" rather than "ArcView." They are one in the same; ArcView is part of the ArcGIS collection, so it is a more specific way to describe the software.

ArcEditor

ArcEditor includes all the functionality of ArcGIS, adding the ability to edit features in a multiuser geodatabase so that multiuser editing and versioning are possible. ArcEditor also adds the ability to edit topologically integrated features in a geodatabase. The student version of ArcGIS that Esri provides is usually ArcEditor rather than ArcView.

ArcInfo

ArcInfo is Esri's professional GIS software. It includes all of the functionality in ArcGIS and ArcEditor, adding some advanced geoprocessing and data conversion capabilities. If you make a living as a GIS specialist, you'll want access to ArcInfo.

ArcReader

ArcReader is a free product for viewing maps. You can explore and query map layers, but you cannot change symbology or create new data like you can in ArcGIS. ArcReader is a good way to share the maps you created in ArcGIS with people who don't have access to the software.

EXTENSIONS FOR ArcGIS DESKTOP

While the basic ArcGIS desktop products include an enormous amount of functionality, extensions can also be purchased (some are free) that extend this functionality. Many of these are specific to particular industries or data formats. The following are some of the more frequently used extensions.

Spatial Analyst

Allows for modeling and analysis with raster (cell-based) data. This includes creating density surfaces and conducting map algebra.

3D Analyst

Includes ArcGlobe. Allows users to view visualize and analyze spatial data in 3D. This includes extruding polygons (such as parcels and building footprints) and draping surfaces (such as orthophotos) on elevation models. You can also create video animations that simulate flying through your study area.

Geostatistical Analyst

This sophisticated tool allows users to analyze raster (cell-based) and point data using advanced statistical methods. Methods include Kriging and inverse distance-weighting.

Network Analyst

Allows for network-based analysis such as routing, determining closest facility, and service areas. Unlike simple representations of street networks that can be manipulated without this extension, networks can store information about traffic flow, one-way streets, and travel time.

Tracking Analyst

Makes it possible to animate point data representing events at discrete times and places. You can view events happening across time and space using the "playback" feature.

Business Analyst

Designed to support business decisions through a series of advanced tools and extensive collection of industry data.

CommunityViz

Designed for visualizing and analyzing land-use decisions. This product is distributed by Placeways rather than Esri.
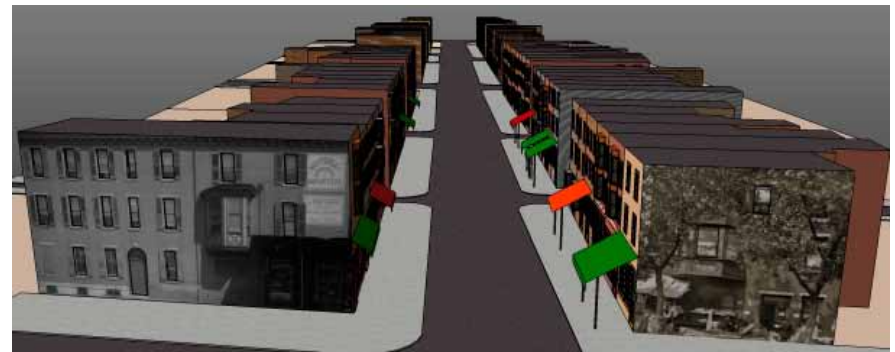
Model made by Shimrit Keddem

Scripts for ArcGIS Desktop

Extensions are simply bundles of scripts that are added together to ArcGIS. Individual scripts can also be added without purchasing whole extensions. These are generally written in Visual Basic, Python, or Avenue (the old programming language for ESRI) by users or ESRI staff members. A large collection are available for free at http://arcscripts.esri.com/.

Introduction to ArcMap

ArcMap is where you create maps and access most of the ArcGIS functionality. You can add and edit data, query and symbolize map layers, and create map layouts for printing.

Starting ArcMap

You can launch ArcMap in more than one way. The most common way is to click on the start menu and go to "All Programs," then the ArcGIS folder, then ArcMap 10. If you don't see ArcGIS in the list of programs, don't worry, it might still be intstalled on your computer. Look in c:\\Program Files for a ArcGIS folder. Open the ArcGIS folder, then the Desktop 10.0 folder, then the Bin folder inside that. Double-click on the ArcMap.exe file to start ArcMap. If it's not there then ArcGIS is **not** installed on your computer.

If you want to create a desktop icon for ArcMap (so you don't have to go through all of that again), right click on the ArcMap.exe file and choose "create shortcut." Then copy and paste the shortcut to your desktop.

When ArcMap opens, it will ask if you want to open an blank map, use a template, or browse for an existing map document. When you are first creating a map, you will probably start with a blank map so click "OK." If the default is to add an existing project, click on "My Templates" and then "Blank Map."
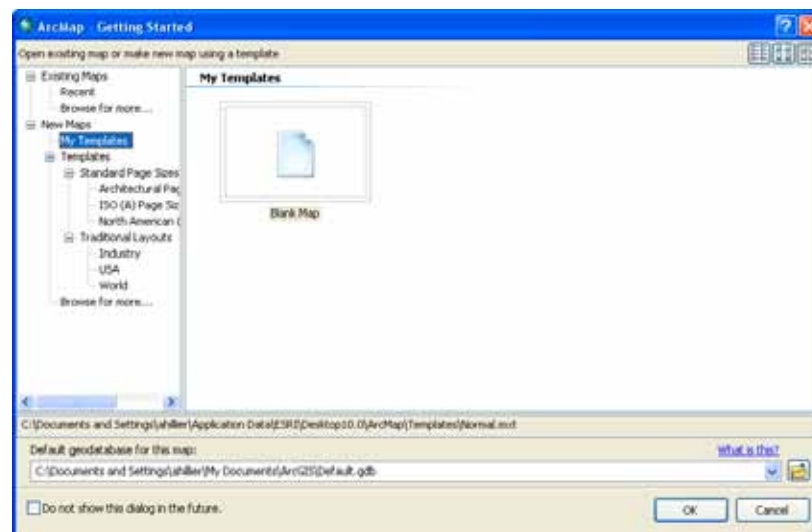
Adding Data

Unless you open an ArcView .mxd file that someone else created, you will need to add data to get started. From the file menu, go to "Add data" or click on the "Add data" button (yellow square with large black + sign) on the Standard toolbar. Navigate to the folder where you have your map layers. With ArcGIS 10, you can use the "Add Data" button to access to other options: Add Basemap and Add Data From ArcGIS Online. From the "Add Basemep" option, you can import Bing and Google aerial images, street and topo maps, and others. Through ArcGIS Online, you can import data many additional layers that include data (such as zip codes with 2010 population estimates). The "Add Data" option allows you to navigate to a folder and add your own map layers.
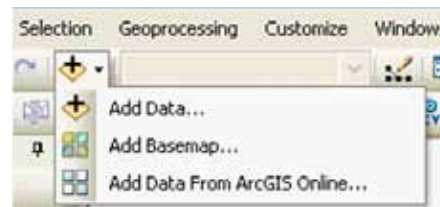
CATALOG WINDOW

ArcCatalog is a system for managing and organizing map files. One big difference with ArcGIS 10 is that a version of it (called "Catalog Window") is integrated into ArcMap. You can still open ArcCatalog without opening ArcMap but it is much easier to use from inside ArcMap. To launch ArcCatalog within ArcMap, click on the Catalog Window. ArcCatalog will open on the far right.
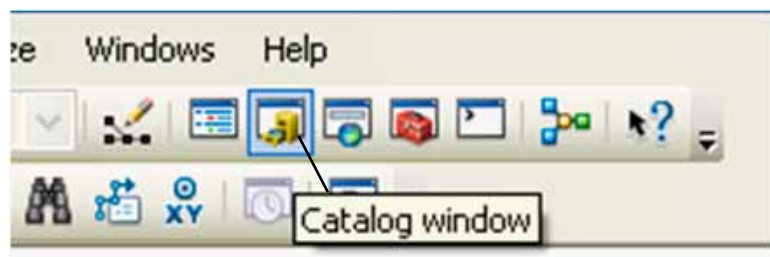
You can add map layers from ArcCatalog, but you can also view and add toolboxes, create geocoding services, edit and view metadata among other important "housekeeping" tasks. The tree within the Catalog Window will include a number of folders that are commonly used with ArcGIS. In order to add your own map layers, you will need to "Connect to Folder" to show ArcMap where those other important folders reside. To create a connection to a new folder, click on the "Connect To Folder" icon at the top of the Catalog Window or right
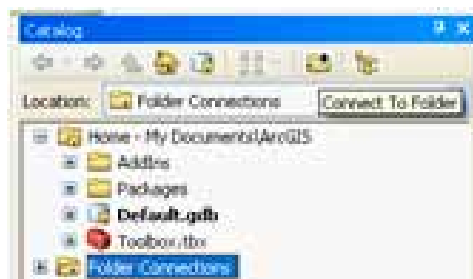

click on the folder named "Folder Connection" and choose "Connect Folder." Navigate until you find the folder with your data and click "OK." Your folder should now be listed under "Catalog" next to a icon. One note of caution: You do not need to do this repeatedly. Once you have established a connection to your folder, you will not need to do it again unless you change computers. If you create a new connection to the folder each time you use ArcGIS, your path options will become unmanageable. If you have one directory where you store all your GIS files, consider connecting to that rather than each individual folder inside.
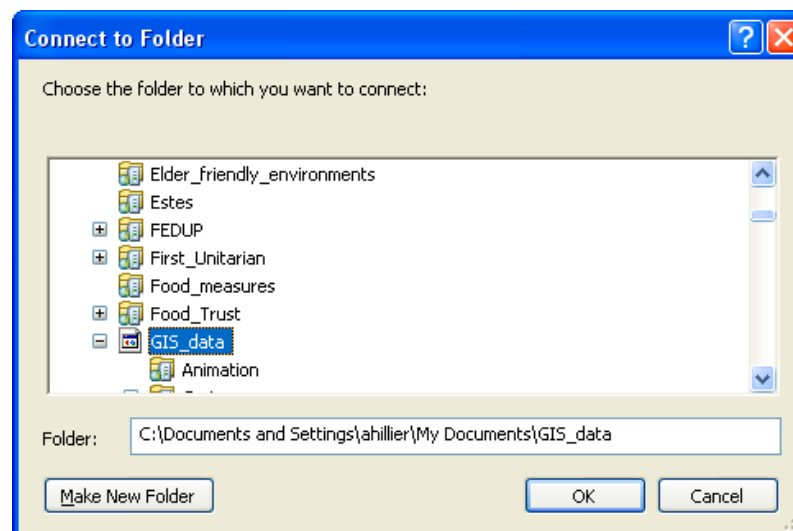

When you view map layers within ArcCatalog, you see them the way ArcGIS sees them. Some of the types of files used in ArcGIS, including shapefiles, coverages, and grids, are made up of multiple files that only together create a map layer. If you viewed them outside of ArcCatalog (in My Computer, for example), you would see all of the files listed with extensions such as .dbf, .shp,

.shx. Within ArcCatalog, you will see only a single file. This is especially helpful when you are moving or copying data.

View from Catalog Window
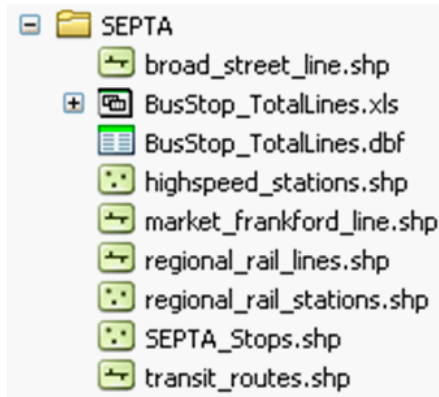
View from My Computer
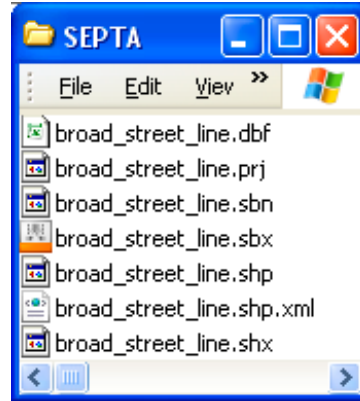
You can add data to ArcMap by dragging and dropping files from ArcWindow. The icons used to represent the data indicate the type of data. A light green icon with lines (broad_street_line.shp) indicates a line shapefile; a light green icon with three dots (highspeed_stations.shp) indicates a point shapefile; a light green icon with a square cut into three pieces is a polygon shapefile. An icon with a white square and two columns of lines (BusStop_TotalLines.dbf) is a table.

You can view and edit the metadata for any of your files. Right click on a file and go to "item description." In most cases, the metadata will probably be empty. If you get into the habit of filling in at least a basic description about what the data are, who created them and when, you will make it much easier to keep track of and share your files. Click on the "Edit" button to add or change the metadata.
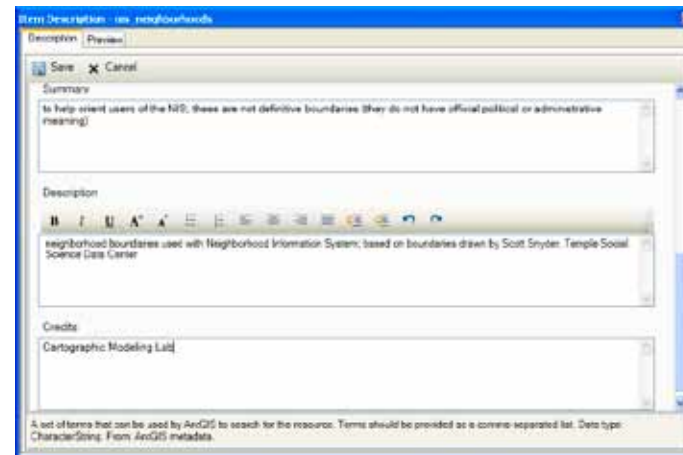
Other ArcCatalog Functions

ArcCatalog also has extensive search capabilities, making it possible to locate files based on name, location on your computer, geographic location, and date. You can create new shapefiles in ArcCatalog. This will be described in the section "Creating New Shapefiles."

Customizing the Interface

ArcMap is made up of many different windows and (dock-able) toolbars that you can resize and move around, so don't be surprised if ArcMap looks slightly different each time you open it.

The window on the left that lists your map layers is the Table of Contents; the window on the right that shows your map is the map display. You can close the table of contents by clicking on the "X." To bring your table of contents back, go to the Window menu, then Table of Contents. By clicking on the tack symbol next to the "X" you can hide the Table of Contents; to bring it back, click on the word "table of contents" which will be running vertically on the far left. Resize it by holding your cursor over the right edge until it changes to a two-headed arrow, then left-click and drag the edge to resize this window.

The map layers you add will draw in the order in which they appear in the Table of Contents--so the layer at the top will draw on top and the layer at the bottom will draw on the bottom. You can change the order by left clicking on the layer you wish to move and dragging it to a new position. The icons at the top of the Table of Contents allow for different views on your data--by source (so you can see where each file exists on your compute), by visibility (layers turned on will be listed first), and by selection (indicating whether any features are selected). You can only change the order of your layers from the first option, "List by Drawing Order" which is the default when you open ArcMap.

You can move a toolbar by double-clicking on it to the left of the buttons (where there is a sort of handle at the edge). You can "dock" it by moving it over any of the gray areas on the screen. To add or remove a toolbar, go to the Customize menu, then "Toolbars" or double-click on an empty gray part of the screen. Anything with a check mark next to it will be displayed.

You can add new buttons to existing toolbars from the "customize" option. Click on the "commands" button to see your options. One especially helpful button allows you to zoom continuously. Scroll down to the category on the left called "pan/zoom," then left click on the "Continuous Pan and Zoom" button on the right and drag it to your tools toolbar (the toolbar with the outline of a hand and an image of a globe in the middle) and release (see image on previous page). You can also add new buttons and tools by importing scripts. That process is explained in a later section called "Working with scripts."
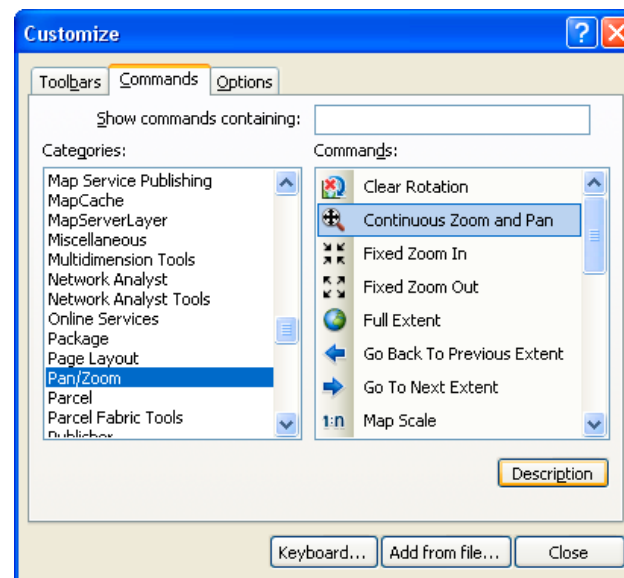
Navigating a Map

There are several tools available for zooming in and out of your map.

The **continuous zoom tool** gives you the greatest amount of control, but you have to add this by customizing your toolbar (see "Customizing the Interface" above). Click on the continuous zoom tool, then left click on your map, hold down the mouse button, and move your mouse away from you to zoom in and toward you to zoom out. If you right click and hold down, this becomes a tool for panning (moving map around without changing the extent).

Using the **non-continuous zoom tools**, you can click on your map to zoom in or out at a fixed amount or to draw a box around the area that you want to see in more or less detail. The new map will be drawn so that the area you drew the box around is in the middle of the map display.

The **fixed zoom in/fixed zoom out** tools give you the least control but also may keep you from zooming in or out too much and losing your map. Each time you click, you will zoom in or out a fixed amount.

The **pan tool** works like the continuous zoom tool when you right click on it. Think of the pan tool as a sticky hand you set down on a piece of paper. You use it to move your map up, down, left or right without changing the extent (the degree to which you are zoomed in or out).

You can also pan by using the scroll bars on the right and bottom of your map. However, these are not the best way to navigate since they are really designed for scrolling in word document or image.

The **full extent button** will zoom in or out so that all of your active (checked) map layers can be viewed. This is very helpful when you zoom in or out too much and can't see your map layers. You can also zoom in to a single layer by right clicking on the layer in the table of contents and choosing "zoom to layer."

The **previous extent button** allow you to return to the extent you had before zooming in or out. The next extent button allows you to jump forward an extent (after you have used the previous extent button). This is a sort of "undo" button in regard to navigation.

Identifying Attributes of Features

The points, lines, and polygons that make up vector map layers are all map features that have attributes stored in a table. This is part of what makes GIS unique, that it can connect attributes of a location to that location. You can access this information in several different ways. Using the identify ("i") tool, click on a map feature in the map display. An "identify results" box will display all of the information known about that feature. Notice the layers dropdown menu. The default in ArcMap is to display information only about the top-most layer. You can change this using the dropdown menu at the top of the identify pop-up box.
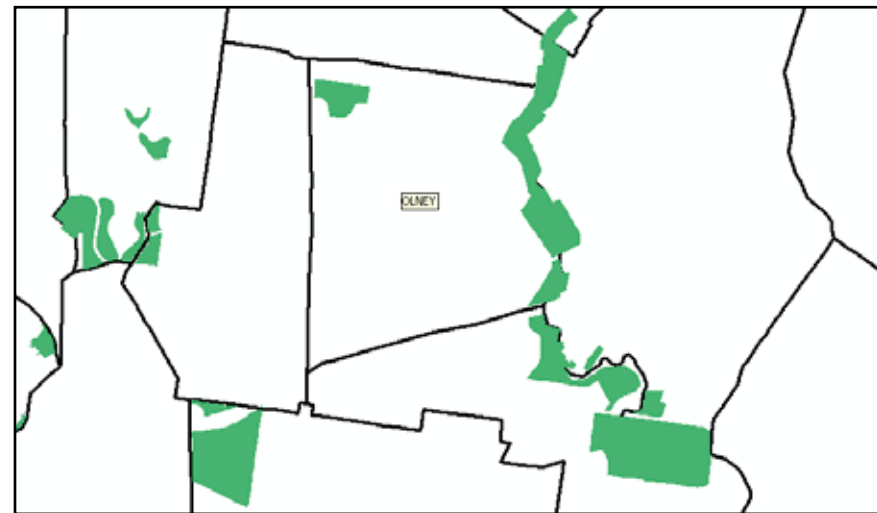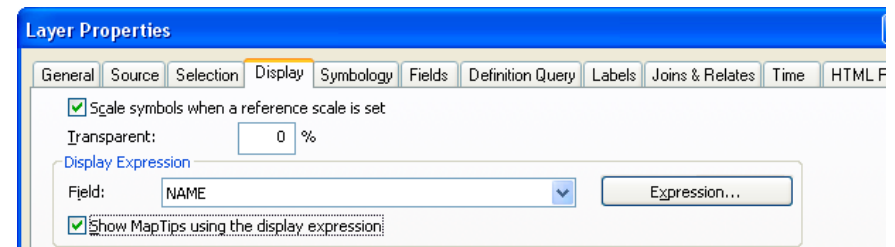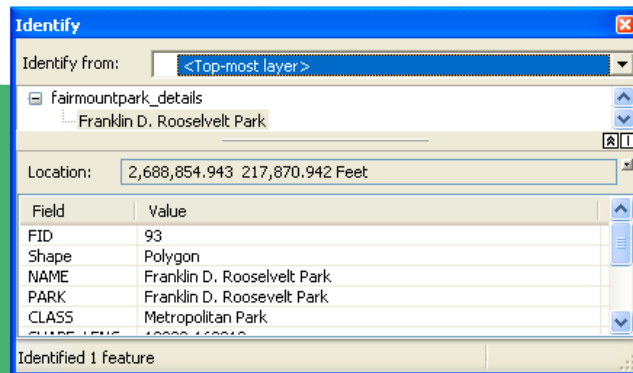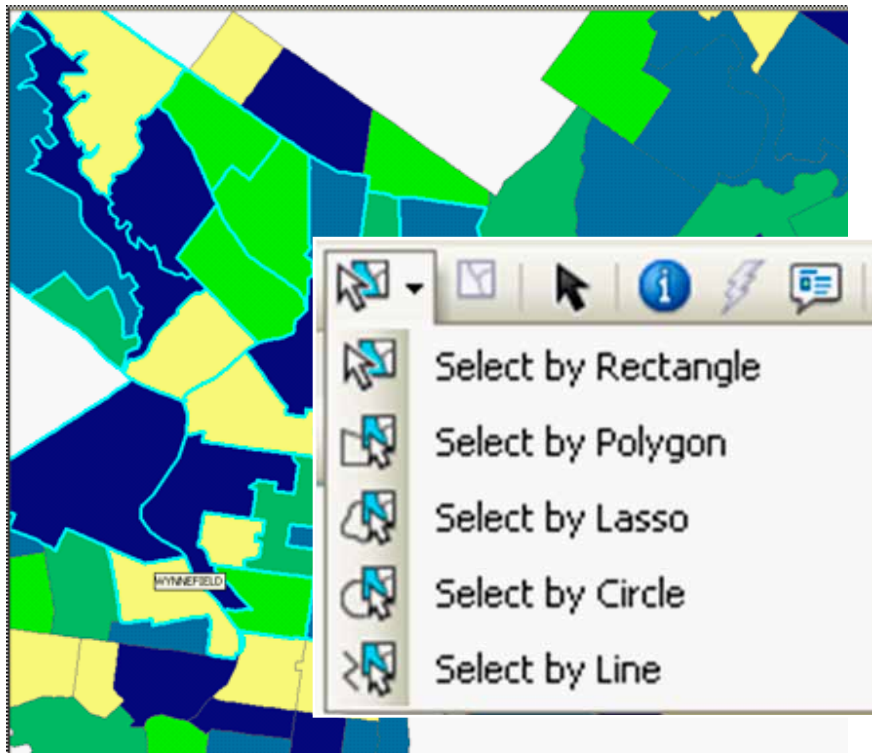

Showing Map Tips

Map tips are small text boxes that appear when you hold the cursor over a map feature. You can only see one attribute at a time (unlike the identify tool, which allows you to see all the attributes know for that map feature), but using map tips is much simpler and allows you to get a quick idea of the attributes. To turn on map tips, double click on your shapefile name in the table of contents and, from the Layer Properties, make the Display tab active. Put a check mark in the "Show Map Tips using the display expression" box. To change the "display expression," use the dropdown menu just above.

Selecting Features

You can also use the select features tool to identify attributes, either by clicking on a particular map feature or by drawing a rectangle, polygon, cirle, line or using the lasso selection tool. The selected features should become highlighted with a blue outline. Right click on the map layer that contains the feature(s) that you wish to investigate and go to "open attribute table." This table includes all the attributes of all the features in that layer. In order to view just the selected feature(s), click on the "Show Selected Features" button at the bottom of the table. Notice that there will be an indication of how many records out of the total have been selected.


You can also highlight a feature on the map by clicking on a row in the table (you need to click in the gray area on the far left). This way, you can find a specific place (such as Cyprus) on your map. You can change the selection color from "options..." in the Selection menu. It is also possible to use different selection colors for each layer. Double click on a map layer, or right click and go to "properties." Choose the selection tab and then select the last radio button, "Show selected features with this color." This will only change the selection color for this map layer.

To unselect records (and get rid of the blue highlight), you can do one of several things:

1. Open the attribute table (right click on the name in the Table of Contents and go to "Open Attribute Table") and then click on the "Clear Selected Features" button at the top;

2. With the attribute table open, click on the "Table Options" button on the top left and go to "Clear Selection" ;

3. From the Selection menu in ArcMap, choose "Clear Selected Features;

4. From the Table of Contents, click on the "List by Selection" button to see which map layer has selected features, then right click on the one with selected features and go to "Clear Selected Features."

Changing Map Symbols

ArcMap has many options for changing the way your data are displayed. Some of the simplest options involve the choice of color, fill pattern, and shape (for point data). To make changes, click on the map symbol in the table of contents. The symbol selector window that opens will look different depending upon the type of layer: point, line, or polygon. For points, you can choose a different marker from the default (which is a circle with a black outline). When you choose a new marker, the default size jumps from 4 point (quite small) to 18 point (quite large). You can find many more symbols by clicking on "Style References..." button (for example, there is a transportation, crime analysis and civic symbol pallette). You can change the color, size, and angle using the options on the right of the window. The "reset" button will undo any changes you have made to the symbol since opening the symbol selector window.
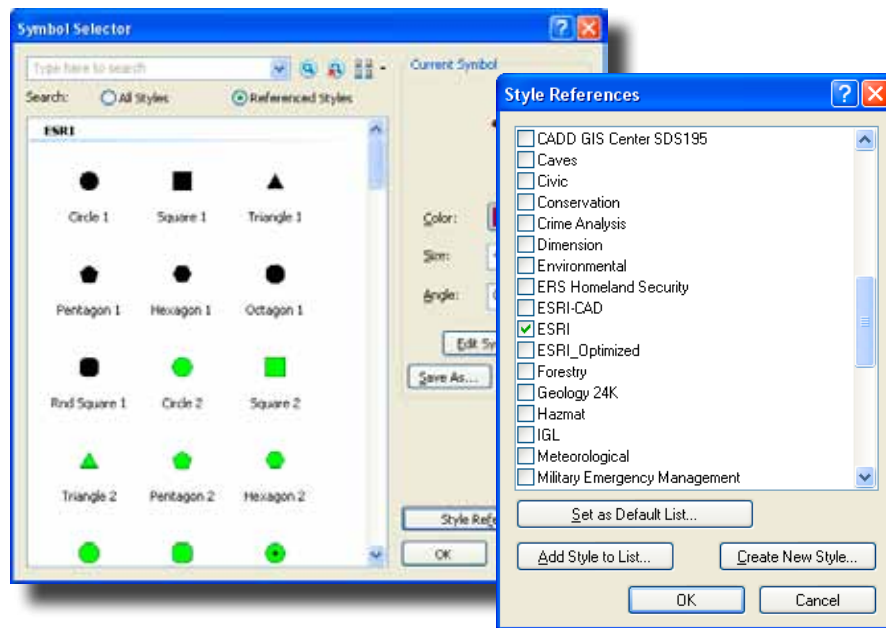
For lines, you can choose from a variety of patterns, thicknesses, and colors. There are industry standards for things like highways, expressways, and railroads.
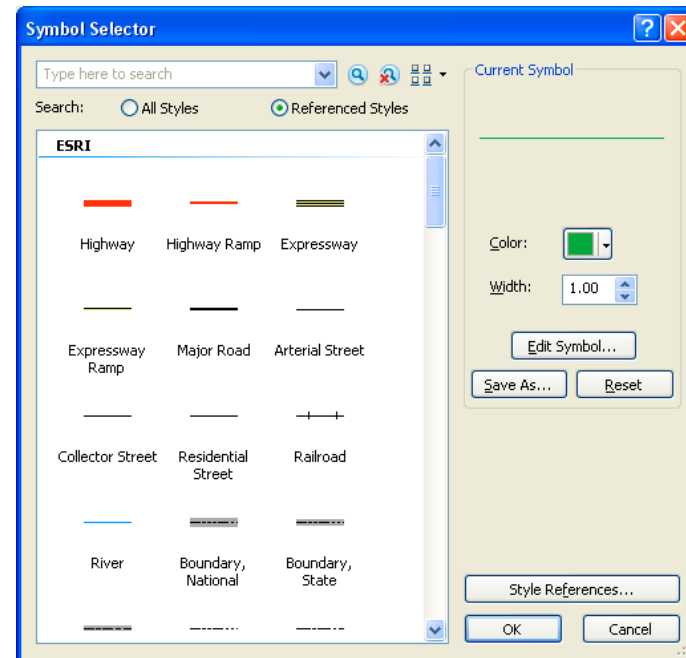
For polygons, you have choices about the fill pattern, fill color, and outline color. The properties button will give you additional options (and often too many options) but may be helpful in fine-tuning the crosshatch and ordered stipple patterns.

You can also symbolize your layers based on different values for each map feature. For example, you might use different size points to represent different cities around the world according to their population or use differ color markers to represent different types of hospitals. These are considered "thematic" maps and they will be discussed in the sections on displaying points, lines, and polygons.

Managing & Saving Data

Many of the frustrations of new GIS users relate to saving files. ArcGIS works differently from most software, so if you do not take care in naming and saving your files, you will not be able to find or open your work.

Saving ArcMap Documents (.mxd)

An ArcMap document is made up of all the map layers you have added and all of the functions you have applied to them. It is best to only save an ArcMap document when you have spent a significant amount of time.

When you open ArcMap, you are prompted to specify whether you wish to open an existing map document or create a new one. Most of the time when you are learning to use ArcView, you can create a new ArcMap document. If you will need to return to your work once you start symbolizing your map layers and designing a layout for printing, you will probably want to save an ArcMap document. You do this by going to the File menu and choosing save. This file will save all of the work you have done, including the list of data you have added and the changes you have made to layer properties, symbology, and the layout.

The .mxd file does NOT save all of the data you included in your map. Instead, it includes information about the location of those files on your computer (or network, or Internet) and the formatting changes you made. This means that you cannot move the data files you've included in a map document or just put your .mxd file on a thumb drive to open on a different computer without running into problems. It also means that map documents can be difficult to transfer from one computer to another. If you do move one of the files used in your map document, that layer will be shown with a ! next to it and will not draw when you open your map document. If you click on the grayed out check

mark beside the layer name, ArcMap will bring up a dialog asking where you moved the file. Navigating to the file in its new location and clicking "add" will solve the problem.
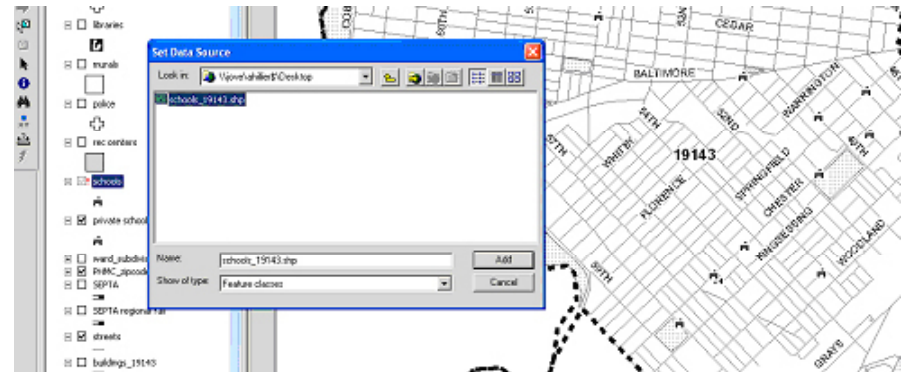

Saving Relative Paths

Relative paths can help you avoid the red exclamation points some of the time. If you have all of the files belonging to a map document in a single folder, you can move it to a new location and still open it with relative paths. From the File menu, go to "Map Document." and check the box next to "Pathnames" that says "Save relative pathnames to data sources."
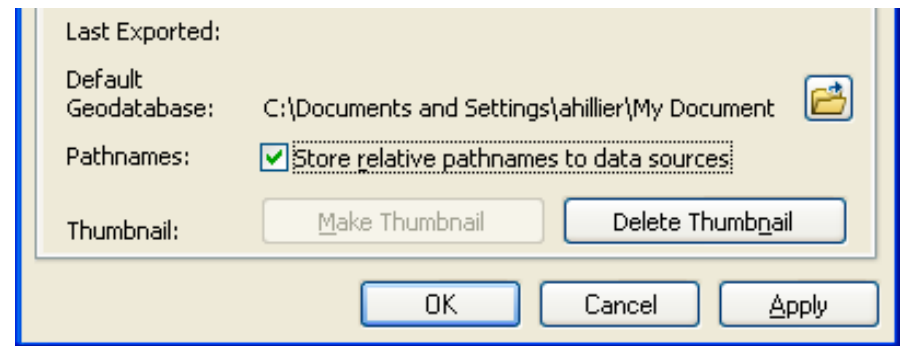
Creating Map Packages

ArcGIS 10 includes an option to package up your .mxd file with all the data used to create the map document on the model of Adobe products. This is especially useful for moving your files for a specific project from one computer (or location on a computer) to another or sharing the files with someone else. From the File menu, go to "Create a Map Package." You must save the map document (.mdx) file first, then the map package.You will also need to give the map document a description (title, summary and other information are optional) and indicate where you want to save the map package. Once you have identified the location where the package should be saved, click the "Validate" button to make sure all of the associated files can be found. Then click "Share" to create the map package. Map packages have the extension .mpk.
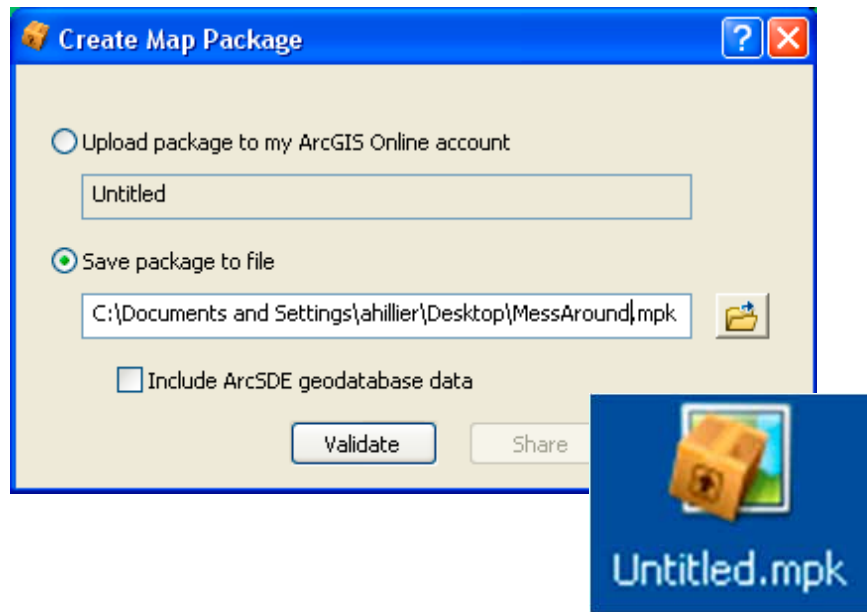
Saving Map Layers

In addition to saving the entire workspace with a map document, you can save an individual map layer (.lyr). This file will store all the formatting changes you have made to the layer. This is particularly helpful if you want to use the same layer, with the same symbology, in another map document. As with the .mxd file, the .lyr file only includes information about the formatting and the path to the original data (generally a shapefile). Moving your original data, or moving the .lyr file to another computer, will create problems.

Naming Files

Naming your files in a clear and consistent manner will make working with ArcMap much easier. You need to develop your own naming convention that makes sense to you. You may create multiple versions of the same shapefile that are only slightly different, so your naming convention should reflect those differences (in year, projection, attributes, geographic level, etc.). For example:

> Phila_tracts_2000_UTM.shp
> Phila_tracts_1990_UTM.shp
> Phila_bgroups_2000_stateplane.shp
> NYC_tracts_1990_UTM.shp
> NYC_tracts_1990_StatePlane.shp
> PA_tracts_2000_StatePlane.shp

ArcGIS can work with file names that are more than 8 characters, but really long names can be difficult to work with. ArcGIS can also work with files that have spaces in their name (such as Phila tracts.shp), but this can create problems (especially with attribute names) so it is best to avoid by using underscores (_).

Saving and Storing Files

The most important thing in storing files for ArcMap is to think through a system BEFORE you start, so you can avoid moving files and disabling your map documents and layers. Consider creating a new directory for each new mapping project. Keep all map documents, map layers, and tables in that directory. Even though it will require more storage space, you may want to keep separate copies of the same map layer, such as a streets layer, in each project folder where you will be using it. As you work with ArcGIS, you will also be creating new tables and shapefiles. Whenever ArcGIS is creating a new file, you will be given an opportunity to give it a name and specify a location with a dialogue box like this:
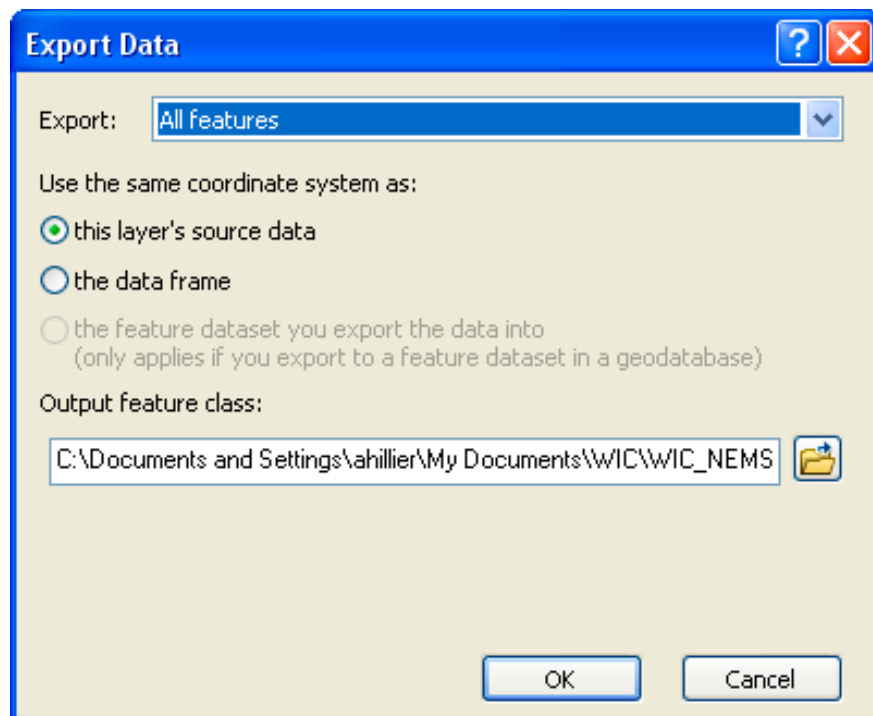
Click on the folder icon to show ArcView exactly where you want the new file and then give the file a new name. Otherwise you will end up with files called "Export_Output.shp" and other unhelpful things like that. No one can help you if you don't know where your files are or what you called them (trust me, this is about the worst problem you can have with ArcGIS).

As you create new versions of old layers, delete the old layers to keep your files neat. And remember, it's best to delete files from the Catalog Window.

DATA FORMATS

ArcGIS can work with many different types of data, only some of which are described in this section. ArcGIS 10 can work with more different data formats than previous versions of ArcGIS.

Tabular data

Tabular data includes things like comma delimited or fixed width text files, Excel worksheets, ACCESS files, and dbase files. This is where you store attribute data, which includes any information you have about a location. For example, you might know the types of programs offered at a recreation center or the total population of a zip code. In order to be mapped, tabular data generally
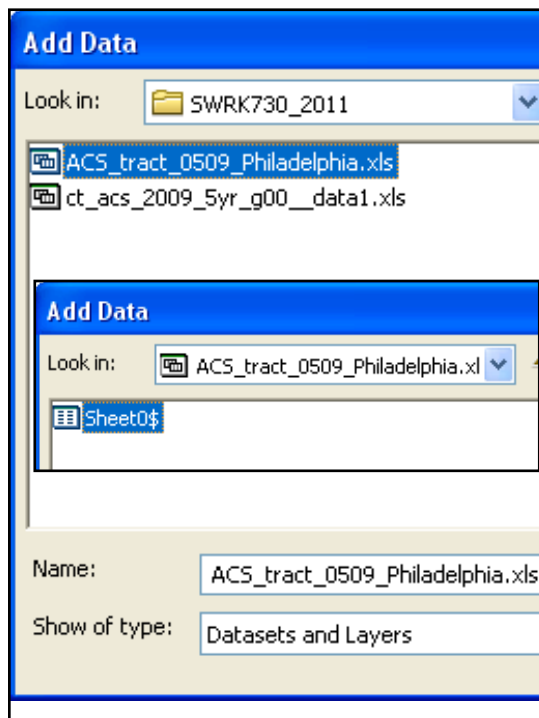

needs to be linked to spatial/ geographic data. Unlike some earlier versions (8 and earlier), ArcGIS 10 can work with Excel files. When you add an Excell file to ArcMap, you must specify which worksheet you wish to add, so try to remember to name your worksheets in Excel (no spaces in the name). When you add data, double-click on the name of the .xls file to see the names of the worsheets. Highlight a worksheet and click "add."

Adding XY Data

Some tabular data include XY coordinates. For example, data might be collected using a GPS device or a data vendor might sell the names and addresses of supermarkets and include XY coordinates for mapping. Converting lists of addresses to points on a map usually involves a process called geocoding and is explained later in this manual. You do not need to geocode if your table already includes XY coordinates. From the File menu, go to "Add Data" and
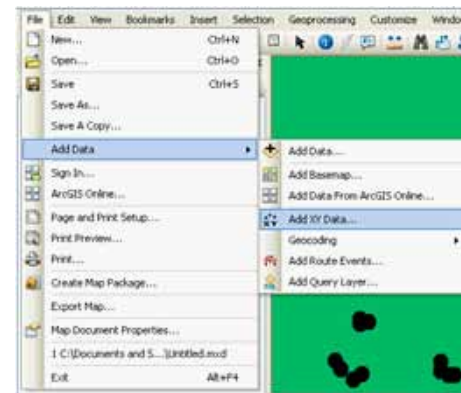
"Add XY Data." From the "Display XY Data window," choose the field that contains the X (longitude) and Y (latitude) coordinates. If you know the projection used to collect or create the data, click on the Edit button and set the projection (projections will be described later so don't worry if this doesn't make sense at this point).
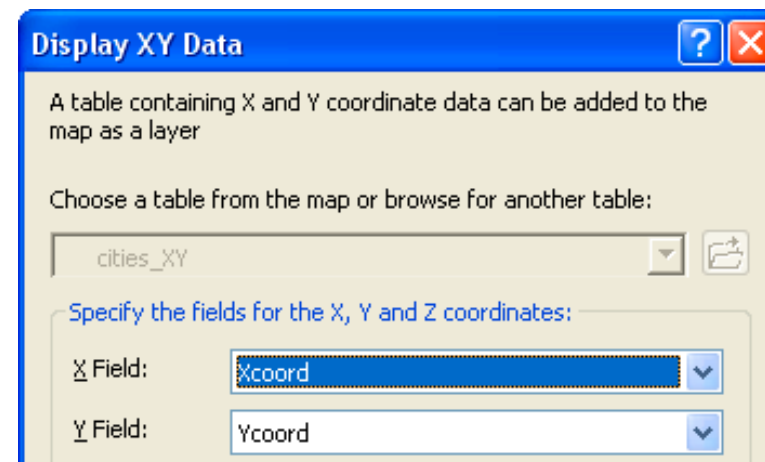
Geographic data

The tabular data you use in ArcGIS can be used in other programs like Excel, SPSS, SAS, and STATA, but the geographic data you use can only be used in GIS programs. Geographic data store information about location so that they can be represented as map layers. Geographic data can be categorized as vector or raster. This manual deals primarily with vector data.

Shapefiles

Shapefiles are the most common format for vector data in ArcGIS. Vector data use points, lines, and polygons to represent map features. Vector GIS is excellent for representing discrete objects, such as parcels, streets, and administrative boundaries. Vector GIS is not as good for representing things that vary continuously over space, such as temperature and elevation.

Esri created the shapefile format in order to represent vector GIS data in a simpler format than their coverage format used in ArcInfo. As with other formats of geographic data, shapefiles link information about the location and shape of the map features to their attributes. Other GIS programs will allow you to use shapefiles, but geographic files from other GIS programs must be converted to shapefiles before ArcGIS can read them. Shapefiles are made up of three or more files that need to be stored in the same directory in order for ArcGIS to recognize them as shapefiles. When you look at your shapefiles through ArcMap or ArcCatalog, you will only see one file, but if you look at them directly on your hard drive or thumb drive, you will see multiple files with the following extensions:

> **.shp** - the file that stores the feature geometry (point, line, or polygon)
> **.shx** - the file that stores the index of the feature geometry

.dbf - the dBASE file that stores the attribute information of features. When ashapefile is added as a theme to a view, this file is displayed as a feature table.

.sbn and **.sbx** - the files that store the spatial index of the features. These two files may not exist until you perform theme on theme selection, spatial join, or create an index on a theme's shape field.

.pjr – the file that stores information about the projection. This will only exist for shapefiles with defined projections.

The shapefile stores information about the shape of the map features, describing them in the "shape" field of the attribute table as point, line, or polygon. It also stores information about the real world location of each vertex that makes up the map features. Using this information, ArcView can calculate area and perimeter for polygon features.

Topology

On of the biggest complaints about the shapefile format is that it does not contain information about topology. Topologic formats (like coverages used in ArcInfo) contain detailed information about the relationships among features in the same map layer. This allows for a variety of operations to ensure the integrity of lines and polygons and to carefully edit and create new geographic features. In creating the shapefile format, ESRI intentionally created something that is simpler than existing topologic formats for desktop (rather than professional) GIS users.
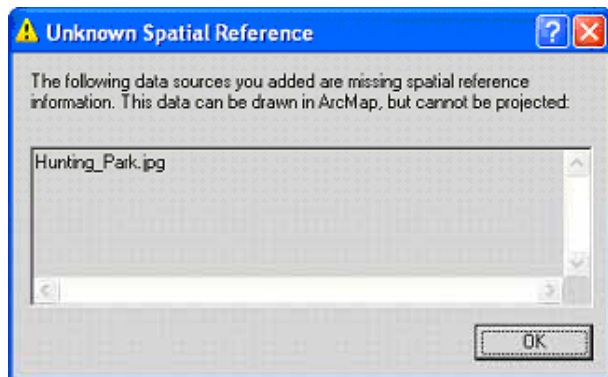
Images

ArcGIS allows you to import and export many different types of images. The images you import may be scanned paper maps, aerial photos, or other pictures or photos that you "hot link" to your map features. ArcMap can import a wide

range of file types. You can also export finished maps in ArcMap in a number of formats: EMP, BMP, EPS, TIFF, PDF, JPEG, CGM, JPEG, PCX, and PNG. Images are like tables in that they may contain information about a particular location, but they do not store location information so they cannot be mapped. When you add a large image to ArcMap, you will often be prompted to decide whether you wish to "build pyramids." Generally you want to say "yes" because this will make it easier to work with the image in ArcMap.
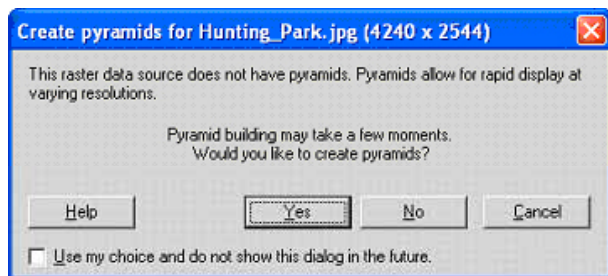

You will also receive a message that ArcMap is unable to draw the image as a map layer because it is missing information about location. So why would you add an image to ArcMap in the first place? Because images like aerial photographs and scanned historical maps can be transformed into map layers through a process called georectifying.

Raster map layers

Raster data use grids made up of regular cells, or pixels, to represent spatially continuous data. They look like regular images, but each pixel is assigned real world coordinates and an attribute value (such as precipitation level or eleva-

tion), so the data can be mapped. The user defines the cell size, allowing for very fine or course raster surfaces. Even when the cell size is very small, you can see the individual square cells when you zoom in.
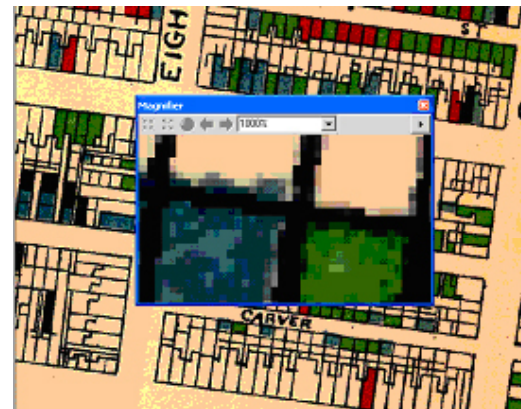
You can view raster layers in ArcMap without any additional extensions, but you need the Spatial Analyst extension to analyze or create new raster layers. When raster layers have the same size cells, their values can be added, subtracted, multiplied, divided and queried using map algebra (a system developed by Dana Tomlin). You can add raster data to ArcMap just as you do vector data, using the "add data." Be sure to highlight the layer you want, then click "add" (if you double click, you will see the individual bands that make up your raster lay). ArcMap saves raster layers in its GRID format. ArcCatalog recognizes GRIDs and other image formats (including BMP, JPEG, TIFF) as raster layers.

Geodatabases

ESRI has moved toward a new geographic data model called a geodatabase that used Microsoft ACCESS files to store multiple tables, shapefiles, and raster images. Geodatabases are more complicated than shapefiles and a license for ArcEditor (not just ArcView) is required to edit geodatabases. Shapefiles are generally sufficient for individual projects, but geodatabases are more appropriate for work environments where multiple people are accessing information or when advanced editing is required.

2 | SPATIAL DATA

GEORECTIFYING IMAGES

Georefectifying allows you to convert a paper map into a GIS map layer. Essentially, the process assigns X and Y coordinates to points on your digital map image, shifting, rotating, and scaling your map so that you can view it as a map layer along with your shapefiles. The simplest form of this, using onscreen tools, is explained below. This is especially value for incorporating historical maps to GIS.

Create a raster image

Scan your paper map. The higher resolution, the better. ArcMap can handle pretty big files, and it can work with lots of file types (.jpg, .tif, .bmp). If you have a choice, go with .tif and 300 dpi or better.

Add reference layers (shapefiles)

Before you add your scanned image, add a shapefile that covers the same geographic area. This might be a street centerline file, city boundaries, or something similar. Be sure that you can identify a few places on your scanned maps on this shapefile (such as a landmark or street intersection). Otherwise, you will not be able to use on-screen georectifying.

Add map image

Add your image to ArcMap just as you would a shapefile or table, using the button or from the file menu, choose "add layer." Depending upon the size of your image, a dialogue box will ask you if you'd like to add pyramids. Click "OK." Don't worry if you get a warning message that your image lacks projection information. At this point, your scanned map is just an image, so it shouldn't contain any spatial information. The name of your image should now appear in the table of contents, but you will not see your image drawn with your shapefile

because it is in "pixel space" since there is no coordinate information. To see your image, right click on the name and choose "zoom to layer."
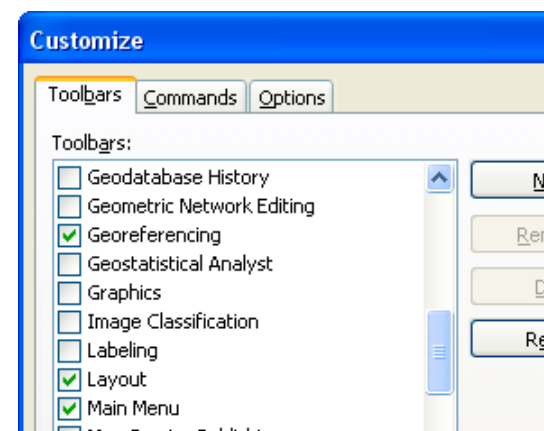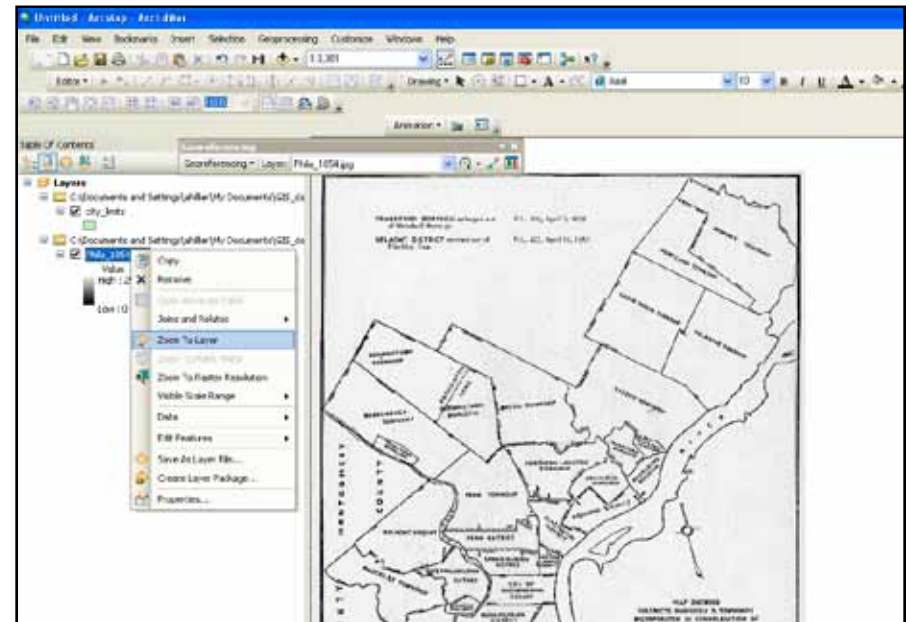

In order to start georectifying, you'll need to switch back so that you can see your shapefile, rather than your image. Right click on the shapefile and choose "zoom to layer." From the view menu, choose toolbars, then Georeferencing.

From the georeferencing menu, choose "fit to display." Now your reference layer(s) should draw on top of your map image in the view map window. If your scanned map is upside down, use the "Flip or Rotate" tools.
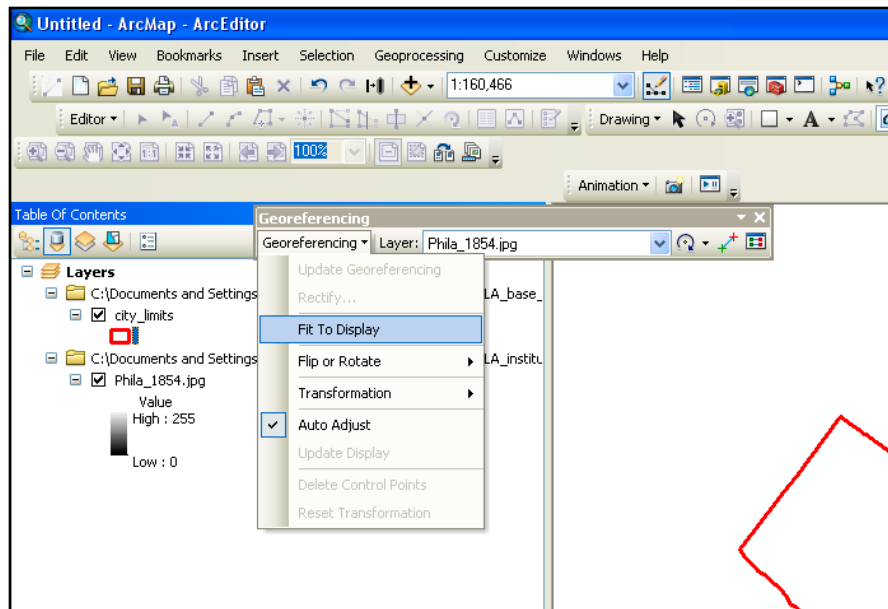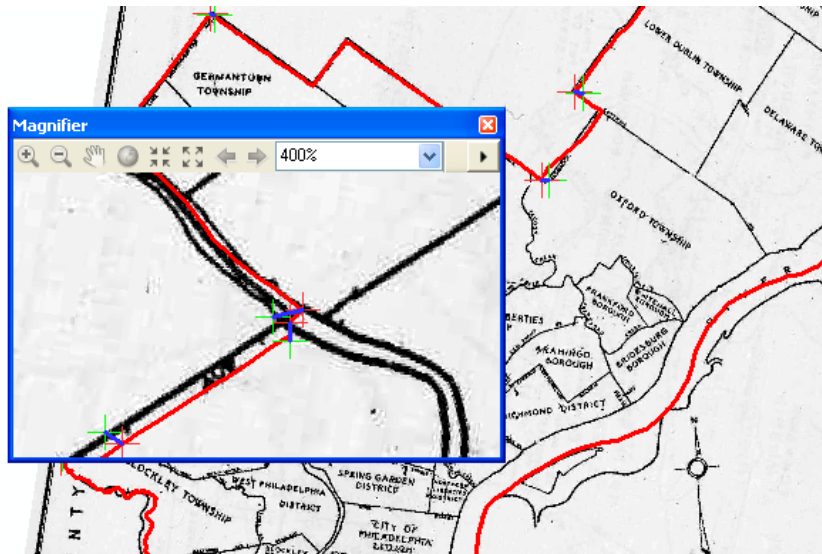

Add control points

Click the "add control points" button. Create your first control point on your image by clicking once on your scanned map, then click on the shapefile in the corresponding spot. Your image should shift closer to your shapefile. If it gets further away, you probably reversed the order. Be sure to click on your scanned map first, then the shapefile. You may find it helpful to use the magnifier window (from the window menu, choose "magnifier") so that you can see your map details without zooming in. Continue to add control points. After doing this a few times, your image should be more or less lined up with your shapefile. Continue to add control points as long as doing so improves the alignment.
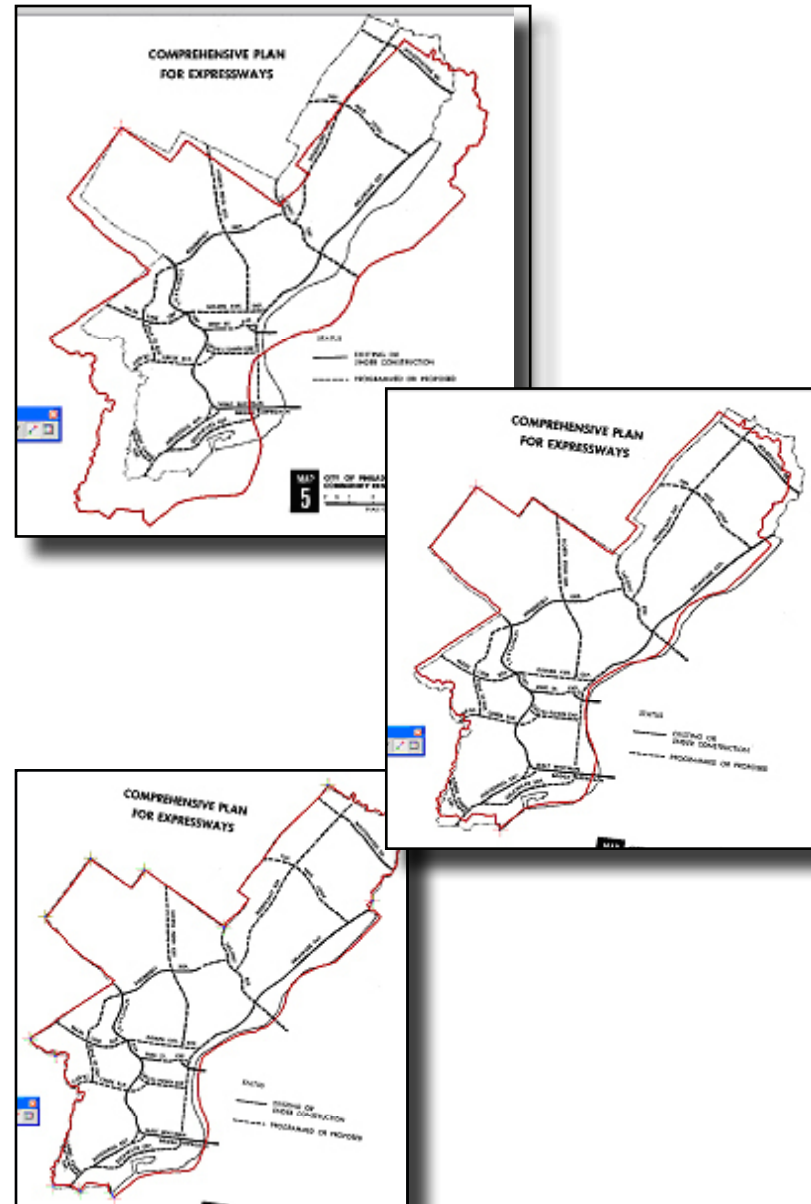
In most situations, your map image will not line up perfectly with the shapefile and you should not expect it to. The original map you scanned may have been created using a different projection system or included distortions and the map may have been further distorted or damaged over time. If the image gets further and further away from the shapefile, however, try starting over. From the georeferencing menu on the georeferencing toolbar, go to "delete control points" and "reset transformation," then choose "fit to display" again. You can also delete a single control point using the "view links" button. The control points are listed in the order that you created them, so the most recent control point will be listed last. To delete one, hightlight it and click the delete (X) button.

You may find it easier to line up the scanned map and reference shapefile using the magnifier tool. From the Windows menu, choose "Magnifier." Move the Magnifier window over your maps in areas where you are having trouble lining them up. You can add control points from inside the Magnifer window.

Transformations

If you have six or more control points, you can perform a second order; if you have twelve or more control points, you can perform a third order transformation. But be sure to look at how these transformations distort your map. You may be better off with the first-order transformation.
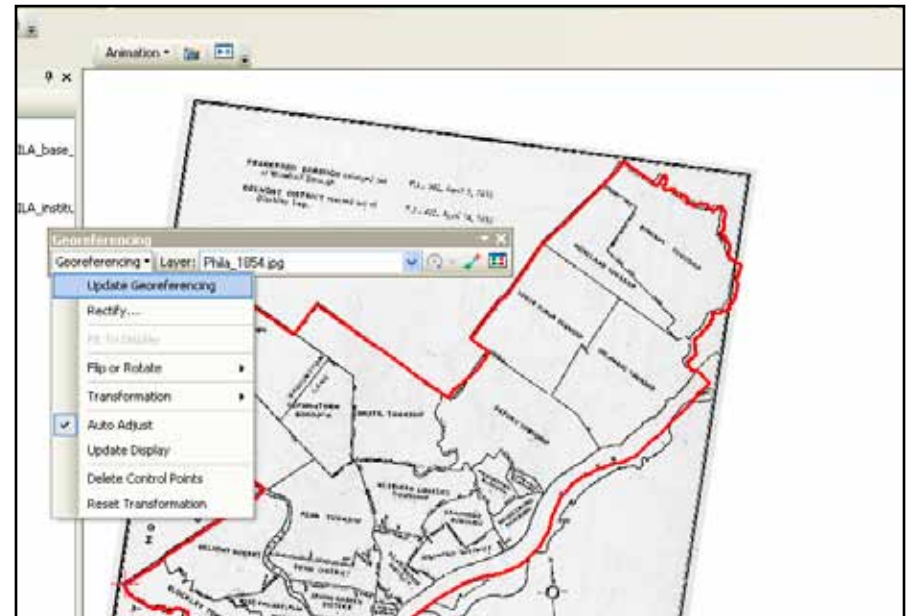
Saving the Georeferenced Image

In order to permanently save the transformation, choose "Update Georeferencing." This will add the spatial information directly to your scanned map (meaning you will loose the original version). If you choose "rectify" from the georeferencing menu, ArcMap will create a new image with the spatial data. Note that the new rectified map may be very large and may look slightly different (darker, poorer resolution).
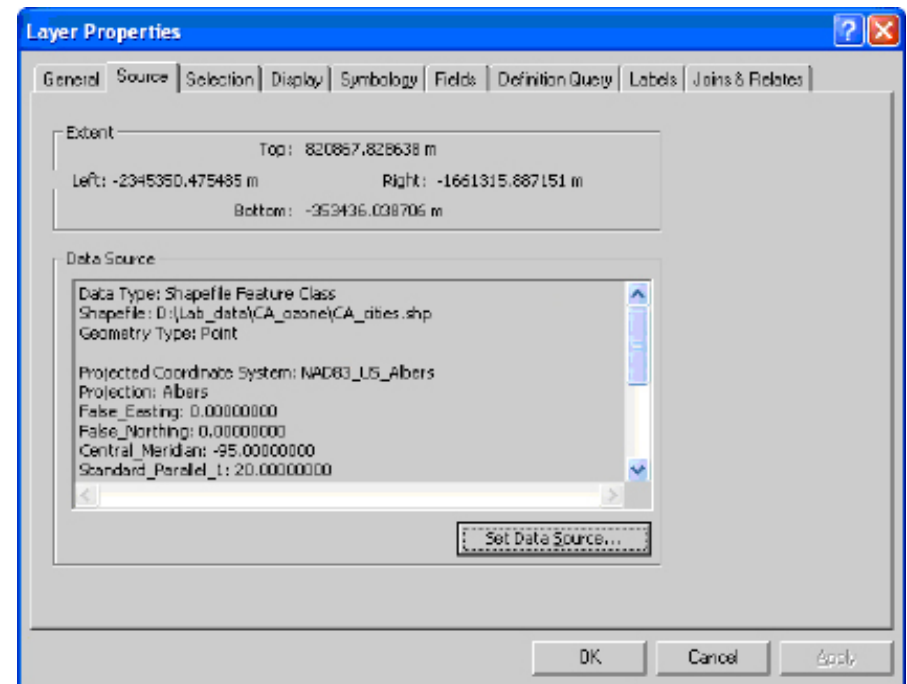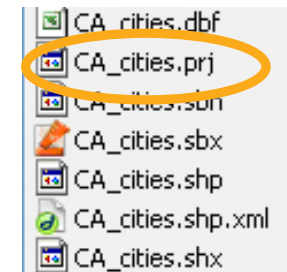
WORKING WITH PROJECTIONS

Projections are probably the trickiest part of working with spatial data. The stakes are high because if data are not projected properly, you might not even get your map layers to draw together. Don't be afraid to ask someone for help or to start over (download the original data again). Hopefully there is some consulation in knowing that most people have a hard time with this stuff.

Projections manage the distortion that is inevitable when a spherical (okay, ellipsoid) earth is viewed as a flat map. All projection systems distort geography in some way—either by distorting area, shape, distance, direction, or scale. There are dozens of different projection systems in use because different systems work best in different parts of the world and, even within the same parts of the world, GIS users have different priorities and needs. When you are looking at a relatively small area, such as a single city, there is relatively little distortion because the curve of the earth is slight. But knowing and setting projections properly is also important for getting your may layers to draw together, distance units to make sense, and some of ArcView's tools to work. So in the end, it's practical to take care in projecting your data.
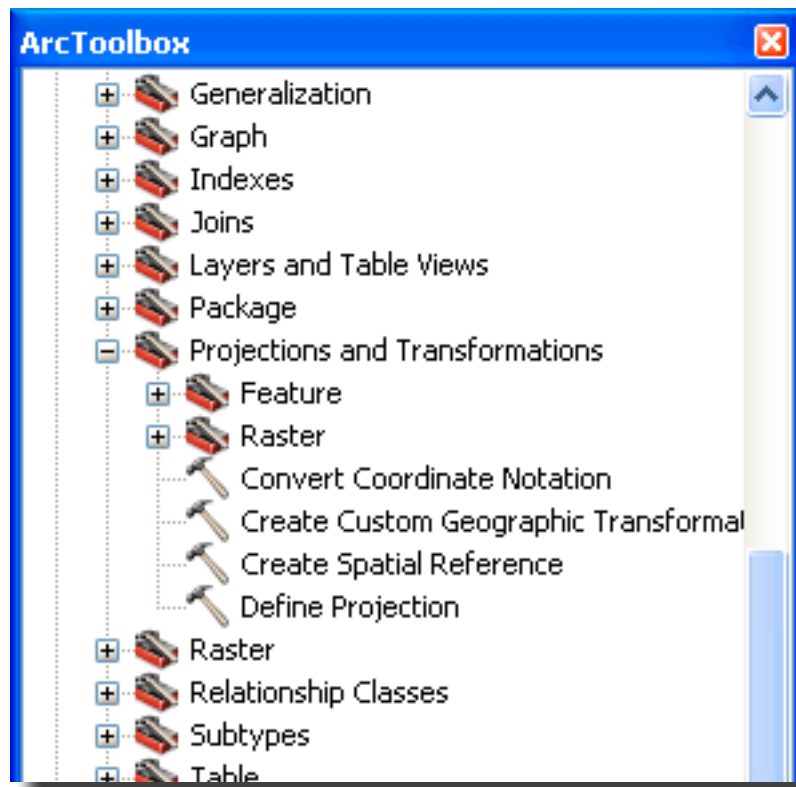
Recognizing the Coordinate System

Map layers can be drawn according to a geographic coordinate system (unprojected) or projected coordinate system. Geographic coordinate systems indicate location using longitude and latitude based on a sphere (or spheroid) while projected coordinate systems use X and Y based on a plane. As long as computer screens and printed maps are flat, projected coordinate systems will be more appropriate for working with GIS data. You may not always know the coordi-nate system being used, particularly if you inherit data or download it from the Internet. If you are lucky, the map layer will include a .proj file which contains information about the coordinate system, or the metadata will provide some explanation. You can look at the information in the .prj file—the detailed spatial reference information—by clicking on the "general" tab of the layer properties from ArcMap. Alternatively, you can click on the "fields" tab of the layer properties from ArcCatalog, click inside the "shape" field and click on the "..." button to the right of "Spatial Reference." You can

Working with "Unprojected" Layers

In most cases, you will want to convert unprojected map layers—those with a geographic coordinate system—to projected map layers. Any of the files you download from the US Census website or Esri TIGER files site will be in this "unprojected" format. There are two steps involved in this process. First, you must create a .proj file by "defining" the map layer as unprojected; then you can "project" the map layer using the projection of your choice. You can access the tools for doing this by clicking on the ArcToolbox icon inside ArcMap. Click on "data management tools" and then "projections and transformations."

Defining projections

Defining a projection registers the current coordinate system of your map layer. It involves reporting to ArcView the nature of the data that you have, not changing that data. To "define" the coordinate system for your unprojected map layer, click on the "Define Projection" wizard. First you will be asked to choose a data layer. If you added the relevant map layer to ArcMap, you will be able to find it in the dropdown menu. Otherwise you will need to click on the folder icon to locate your map layer. Then you can choose the coordinate system using the button. Click the "select" button on the Spatial Reference Properties. In most cases, you can choose "Geographic Coordinate Systems," "North America," and "NAD 1983 Datum," then click "okay." You should not notice a difference in how the map layer is drawn as a result of defining the coordinate system. But as a result of defining it, there is now a .proj file associated with your map layer and you can look at the detailed spatial reference information. Before you define a layer as unprojected, ArcView will refer to it as "assumed geographic."

Projecting shapefiles

Projecting a shapefile changes the projection system. You can only do this if you have defined (registered) the existing projection. You can project map layers that are unprojected (geographic coordinate system) or change the projection on layers that already have a projected coordinate system. In order to project the map layer, click on the "Project" wizard. If you are projecting a shapefile, use the "Project" wizard listed under "Features." If you are projecting a raster image, use the "project" wizard listed under "raster."

As with the "define" wizard, you will be asked to specify the map layer. Next, because you will be changing the original layer, you are asked to name the new layer that will be created. By default, ArcView will add "_Project" to the original name. You may wish to give your layer a different name. Click on the button to the right of "Output Coordinate System" to choose your projection. Click on the "select" button on the Spatial Reference Properties, then choose "Projected Coordinate Systems." Now you need to choose your projection. For relatively small areas like Philadelphia, the differences in projection systems (the distortion in shape, area, distance, direction, and scale) are minimal. You are best off choosing whatever projection system is most commonly used. In Philadelphia, that is State Plane 1983 (feet) Pennsylvania South. For the Philadelphia MSA, consider UTM zone 18N. After making your selection, click "okay." ArcView will indicate that there is a "Datum conflict between map and output." In order to map your newly projected layer, create a new ArcMap document and add the new (projected) layer. You should notice a change in the coordinates that show in the bottom right of the map.
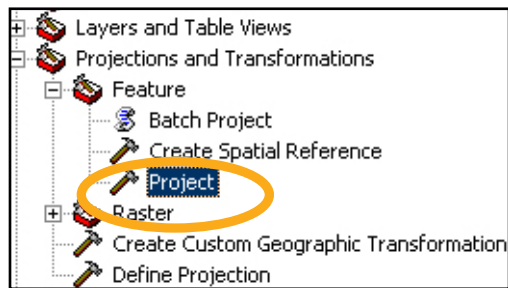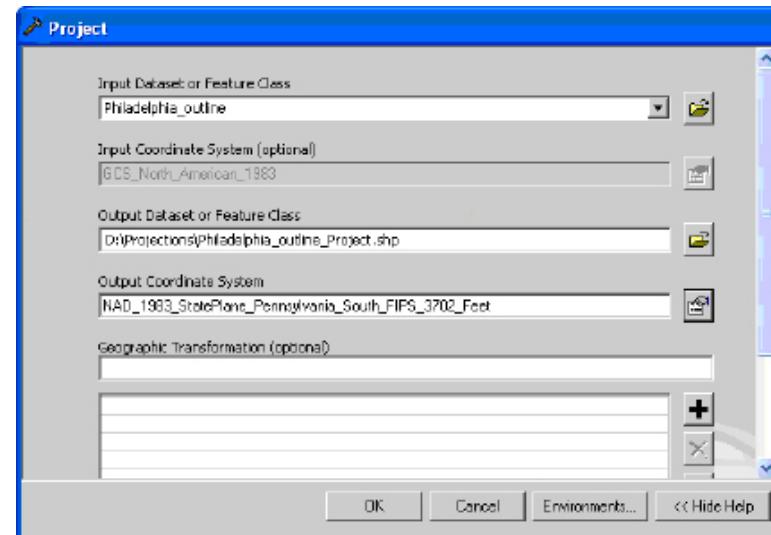
Working with Projected Map Layers

Sometimes the map layers you acquire will already be projected but won't carry a .proj file so you won't know the projection. The best thing to do in this situation is to look at the original source for information about the projection system, either on a website, in metadata that came with the file, or by calling the person who created the data. If these approaches all fail to reveal the projection, map the data in order to guess the projection. You may recognize the projection by the units showing in the gray bar below the map. If they are not in longitude and latitude, they are probably projected. As you work with a particular projection system, you will come to recognize the map units and range of coordinate values. For example, State Plane coordinates for Philadelphia are generally in feet and look like 2691607.78, 246268.98. UTM coordinates will be in meters and look like 486850.72, 4430095.19.

3 | MAKING MAPS

SYMBOLIZING POINTS

The real strength of a GIS is in allowing you to use different symbols to represent different values, linking your attribute data to your spatial data. ArcMap offers a wide range of colors and symbols for representing your point data. Keep in mind that just because there are near infinite combinations that the simplest symbols (such as block dots) may be the most effective.

Single Symbol

The default in ArcMap is to represent all points with the same size, shape, and color symbol. This is how ArcMap will display your point shapefiles when they are first added to a map document or when you create them through geocoding or adding XY data. Open the layer properties (double click on the shapefile name or right click and go to "Properties,") and click on the "Symbology" tab. In the box on the left side, "single symbol" will be highlighted. You can change the size, shape, or color of the symbol by clicking on it, but as long as "Single symbol" is selected, all of your points will appear the same.

Changing the symbol

ArcView has numerous palettes of symbols used in various industries, such as conservation and policing. These specialized symbols are effective when used carefully with an audience that will recognize them as industry standards. The symbols included in the default palette may not be ideal for your map. For example, the symbol for a school bears little resemblance to a large urban school. To view additional pallete, click on the "style references" button. The "civic" palette contains a number of choices for schools. In most cases, however, you are better off sticking with the default symbols. You don't need the symbol of a needle to represent drug crimes. Resist the temptation to make your dots
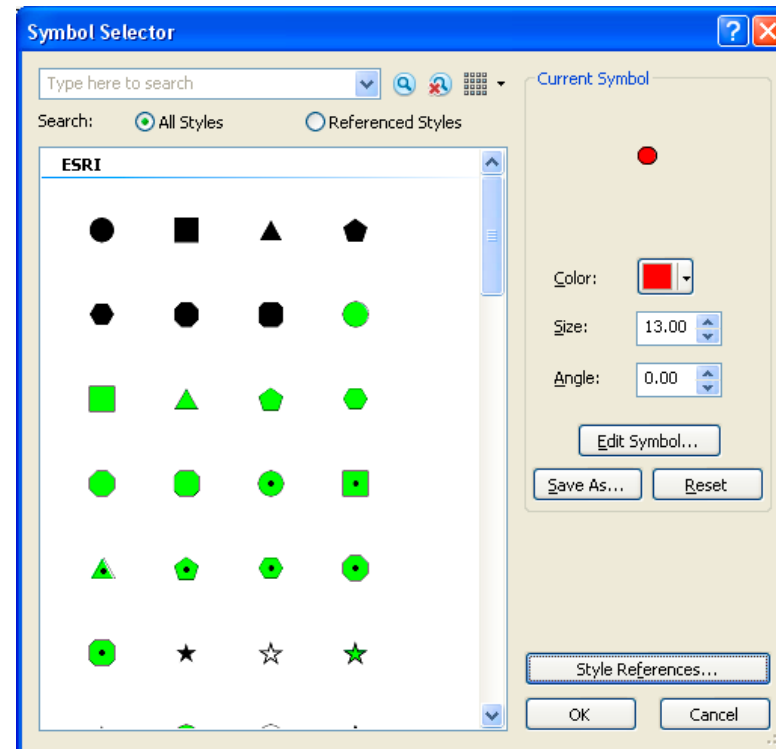

look like the real thing (such as a dead body for a homicide) These are, after all, symbols and you will be able to describe the symbol in the legend.
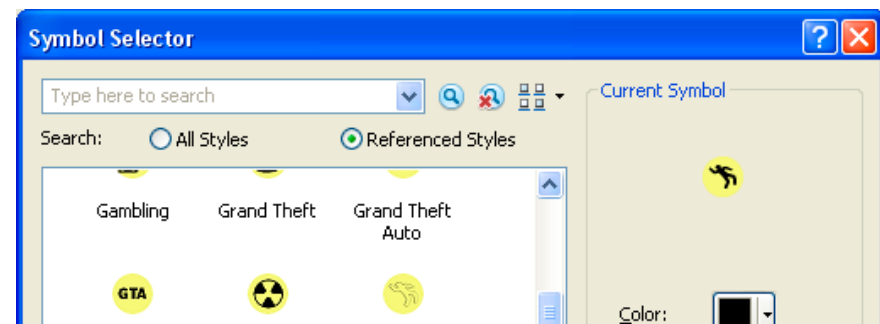
Categories

Categorical variables classify data into unique categories so that each observation (event, person, building, etc.) fits in only one category. For example, a hospital might be managed by a non-profit, church, federal government, state government, or for-profit entity. The unique values option listed under "categories" in the symbology tab allows you to use a different symbol for each of the points in a shapefile based on a categorical variable. This can work well for small files (10 or fewer points) but can quickly be overwhelming for larger files. Choose the field with the values you wish to use to represent your points, then click the "Add All Values" button in order to bring up all the categories. If you want to show only a few categories (for example, bus stops for a subset of routes), click the "Add Values" button, highlight the values you want, and clik "OK."
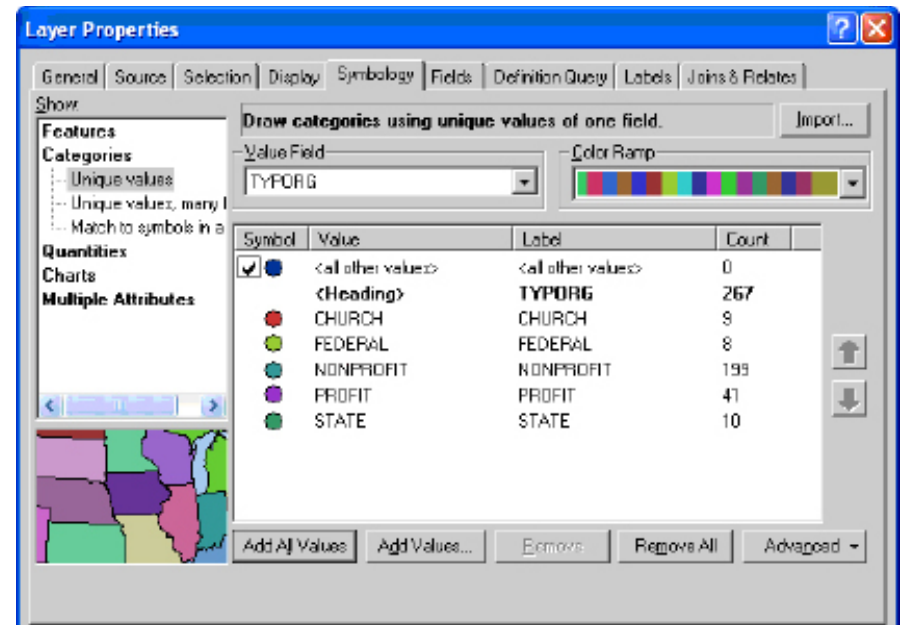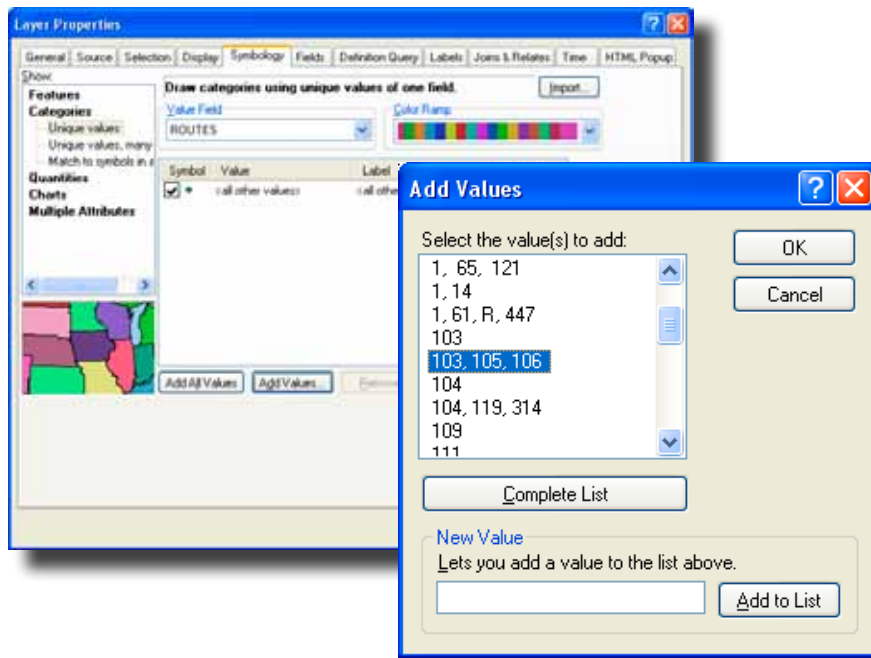
ArcMap will list a symbol for "<all other values>" that you can remove by taking away the check mark. You can change the individual symbols by clicking on them. You can make changes to all of the symbols, or selected symbols (hold down the shift key to select two or more) by right clicking. To remove a value, right click on it and choose "Remove Value(s)." Use the black arrows on the far right to move values up and down (the order here will be the order your values appear in the legend on your map).

Choose colors that communicate that these are separate categories. Don't use a graduated color ramp with light to dark shades of the same color. This implies that one category is more or less than another when, in reality, they are just different. In addition to different colors, you can use different sizes and symbols... but don't go too crazy.

Quantities

Categorical variables correspond to categories and are generally represented using text variables (or numbers used as codes for individual categories). Quantities, such as the population of a city or air emissions, are continuous and must be presented with numbers. Graduated symbols and proportional symbols are the best choices to show different quantitative values for points. Graduated symbols allow you to have different size symbols to represent different attribute values. With the symbology tab active, click on "Quantities" and then "Graduated symbols." From the "Values:" dropdown menu, select the field with the values you wish to use. Use the "classes" dropdown menu to change the number of categories. There are many ways to break up value ranges into categories. To change the classification system, click on the "Classify" button and use the
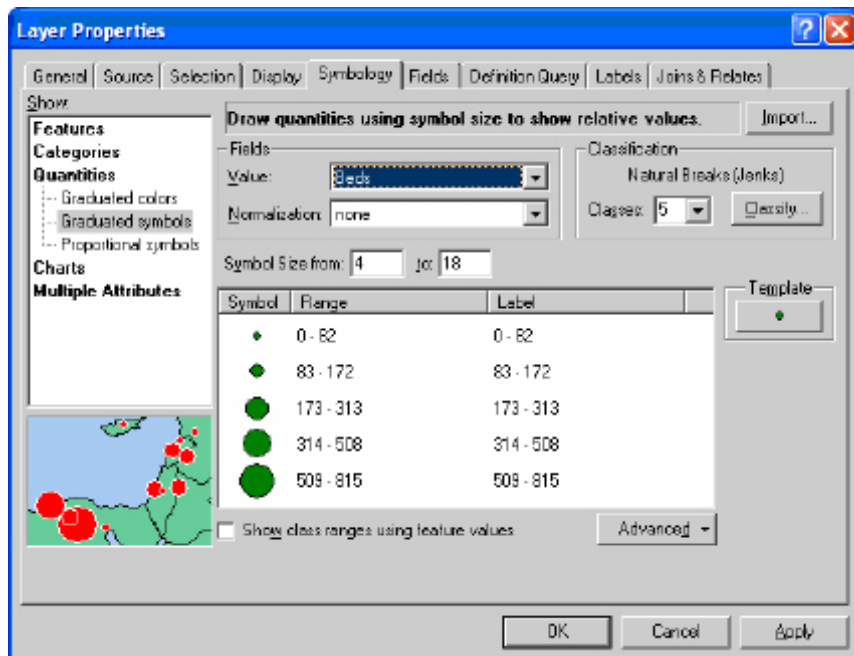
Method dropdown menu to choose a different classification system. There is no one "right" classification system. Your choice should be based on the distribution of your values and the goals of your map. In the end, you want to make sure that you have a map that shows variability, so you don't want a classification system that groups everything together.

● **Natural Breaks (Jenks):** This is the default in ArcGIS. It uses a formal (Jenks Optimization) to minimize the variance within classes and maximize the variance between classes. It usually works well, but be sure to round off the values manually.
● **Equal Interval:** This sounds like a good idea because it breaks your data into classes of equal size. The problem is, most data are not distributed evenly so this usually makes maps with lots of observations (map features) in only one or two classes.
● **Quantile:** This divides the observations (map features) into even groups of 4 (quartile) or 5 (quintile). By definition, it does a good job of showing variability.
● **Standard Deviation:** This shows how far values are from the mean. It works well when you want to show how extreme high and low values are, but you'll probably want to modify the legend to show actual values and not standard deviations which don't make sense to most audiences.

You can also adjust the cutoff points by moving the blue vertical lines in the histogram below that show the frequency of values. Alternatively, you can change values manually on the previous screen by clicking on them (you will only be able to change the ending value).

Proportional symbols are similar to graduated symbols, but the size of the symbol reflects the relative size of the quantity. For example, a hospital that has 100 beds would be represented with a symbol that is twice as large as a hospital with 50 beds. Proportional symbols are preferable except in situations where the symbols become too large and obscure other points.

Symbolizing Polygons (Area Data)

The options for symbolizing polygons (such as census tracts) are basically the same as the options for symbolizing points, but the attribute data that you have for polygons will often be different so you will utilize the same options in different ways.

Graduated Color

You can use different colors—or different shades of the same color—to represent different continuous variables (such as household income or median age) to create choropleth maps. From "Layer Properties," click on the symbology tab. On the left side of the screen, click on "Quantities" and "Graduated Color." Choose the field with the values you wish to use. Use the "Classes" dropdown menu and the options in "Classify" to change the number of categories or method for breaking values into categories.
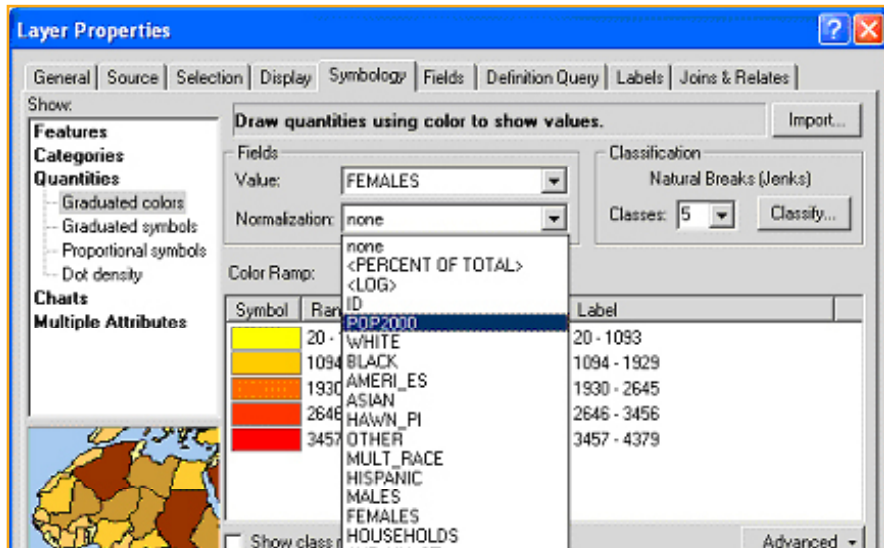
Choropleth maps are generally better at representing rates (such as percent registered voters) rather than counts (such as total voters). You can transform count data into rate data using the "Normalization" dropdown menu in the "graduate color" option. In order to use this appropriately, you will need to select the variable from your attribute table that serves as an appropriate denominator. For example, in order to show the percent of households receiving public assistance, normalize the total number of households receiving public assistance by the total number of households. Do not use the "<PERCENT OF TOTAL>" option to create a rate (this will use a denominator based on the total number of map features, not a true denominator for your variable).

Graduated color works best when you use the same shade of a single color, with lighter shades representing lower values and darker shades representing higher values, or intuitive color schemes such as yellow to orange to red or yellow to green to blue. But keep in mind that it may be impossible to distinguish between more than four or five shades of the same color, depending upon the quality of your printer.

Color ramps like these show an intuitive ramp from low (light) to high (dark). Use these to represent continuous values.
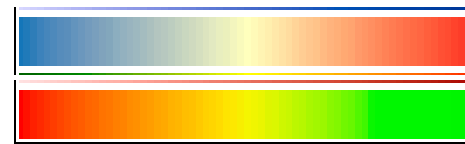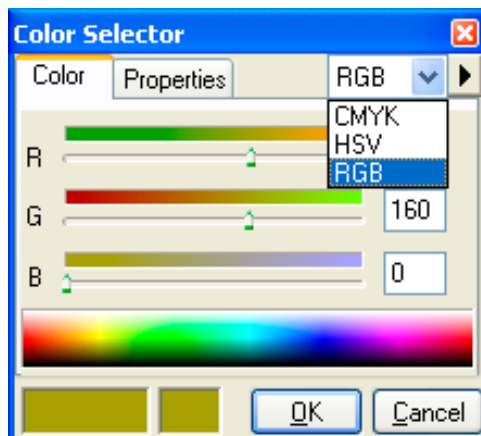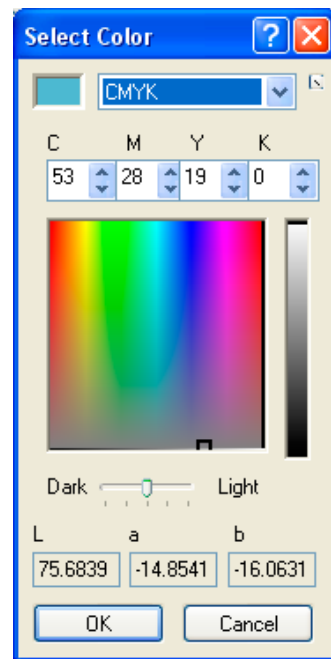
Diverging color ramps like these work well when you need to show above and below a mean (std).

Color ramps like these don't have an intuitive high or low.

You can fine tune your colors by going to "more colors" when choosing a color from the symbol selector. Here you can play with the hue(H), saturation(S), and value(V).


Customizing a color ramp

You can create your own color ramp if you are not happy with any of the default choices. To do so, go to the "Customize" menu and choose "Style Manager." Expand the folder on the top left and click on the "Color Ramps" folder Right click in the empty space on the right, choose "new," and select Algorithmic Color Ramp. Select a color for Color 1 (the beginning of the color ramp), then a second color for Color 2. Give your new color ramp a name and close the Type the name of the new color in the Contents window. Your new color ramps should appear at the top of the dropdown list of color ramps in the Symbology tab.
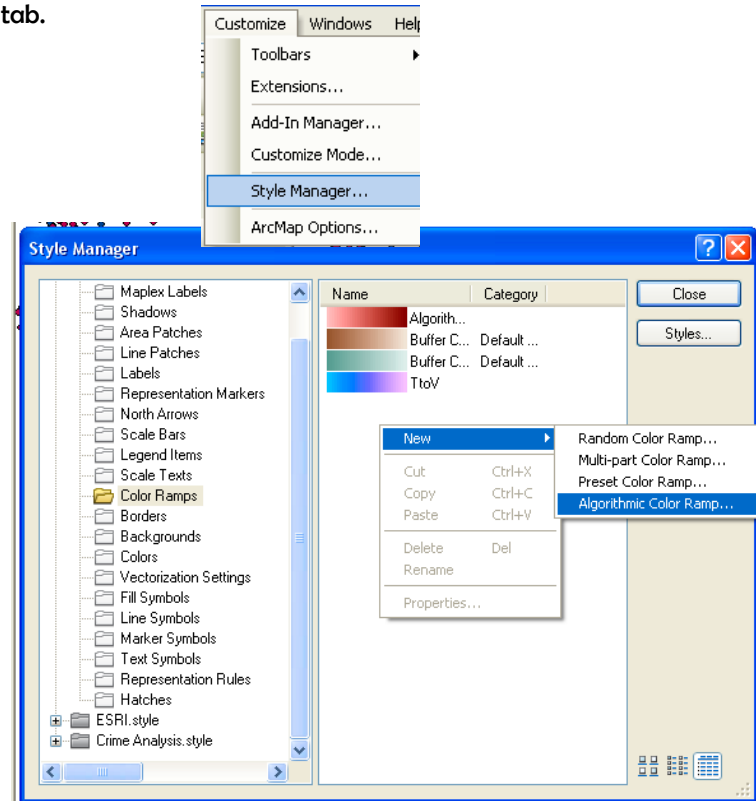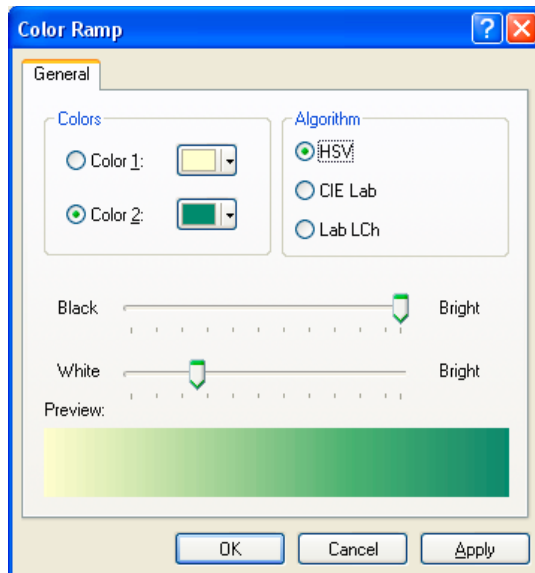
The new color ramp I created (above) will show at the top of my list of color ramps in the "Symbology" tab (below).

You can find a more detailed explanation of algorithmic, random, multi-part, and preset color ramps that can be created in ArcGIS in the help section.
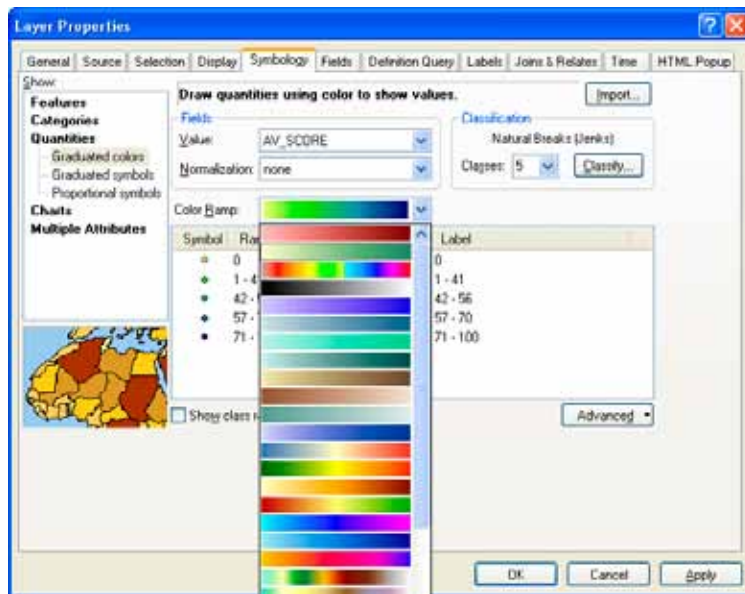
Fill Patterns

You can use different patterns in addition to, or instead of, using different colors to represent different values. Patterns are particularly helpful when you are restricted to printing maps in black and white. Choose "Graduated Colors" from the Symbology tab and select the field with the values you want to display. Set the number of classes and the method of classification, so that you are happy with the value ranges. Then click on the symbols and change the fill using the symbol selector. Click on the Properties button to fine-tune the fill pattern. This may involve changing the background from white to "No color" so you can draw a layer symbolized with a fill pattern on top of a layer with solid colors in order to see the relationship between two different attributes.
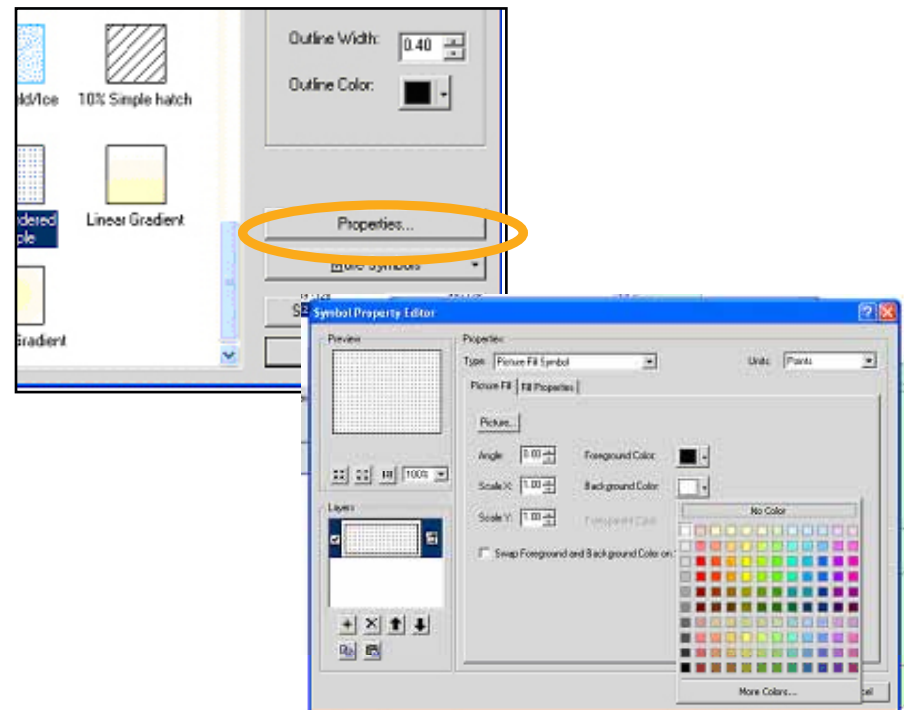
Dot Density

Dot density maps use randomly placed dots within polygons to represent different values for aggregate data. They provide an alternative to choropleth maps for count data. If you use this option, be sure to remember—and carefully communicate on your map—that the points do not represent precise locations, as they do in a point layer. Failing to do so may generate confusion and concern about data confidentiality. One major limitation of this type of map is that the dots may be distributed across parts of the polygon that don't make sense. For example, if you use dot density to show the number of foreign-born in a map of counties, the dots might appear in non-residential areas. You can avoid this problem by selecting a "mask" (such as parks and industrial areas) where dots should not be placed.

To create a dot density map, open the Layer Properties and make the Symbology tab active. Click on "Quantities" and "dot density." From "Field Selection," choose the field you wish to use as the basis for the map. Counts (such as the total number of households on public assistance) are appropriate for dot density maps, but averages, medians, and rates are not. Choose your dot size, or keep the default (which is advisable, at least to start). The "Min," "Mean," and "Max" boxes will give you a preview of how your map will look. The "Dot Value" indicates how many units each dot represents. Change this as needed to create dot densities that have enough dots to show variation but not so many that they are all on top of each other. You can change the color of the dot by clicking on it under "Symbol" in the top right part of the screen. Checking "maintain density" will ensure that the dot density looks the same as you zoom in and out (by making the dots bigger and smaller).
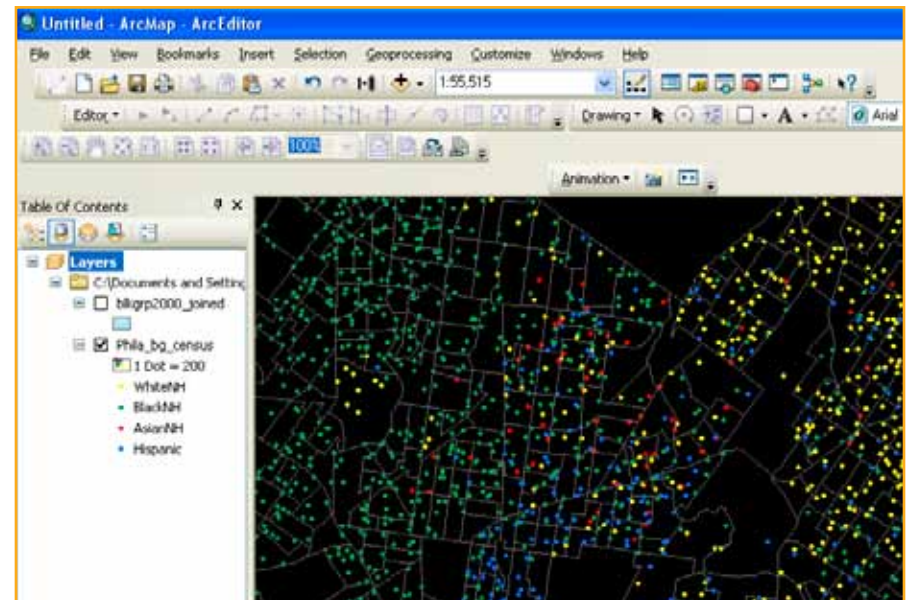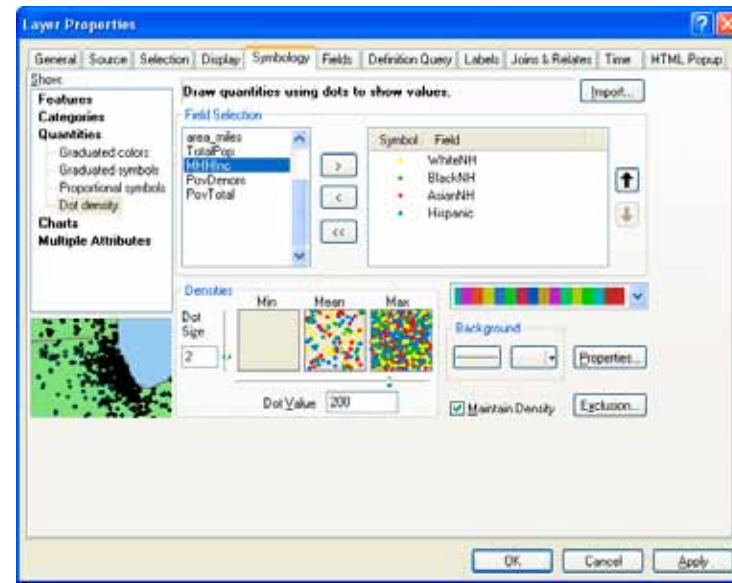
Pie Charts

Charts are good for showing multiple values and the relationship between values on different variables. Pie charts are especially good for showing proportions. For example, individual pie pieces can be used to show the breakdown in race for the population in a census tract. For the pies to work, you must be able to put every person into a racial group, or you must use an "other" category. Pies contain a lot of information, so it can be difficult to display them clearly. To create pie charts, click on "Charts" and "Pie" from the Symbology tab. Holding down the shift key, select the fields that you want to include. Make sure that together, they add up to 100 percent (you may need to create and calculate a new "other" field in your attribute table before using charts). Click on the "Background" button to change the color or fill ("Hollow" or white backgrounds might be best, so that you don't have too many colors in your map). If you check "Prevent Chart Overlap," ArcView will use "leader lines" to indicate where the pie charts belong if there is no room to display them within the map feature. Click on the Properties button to make adjustments to the look of the pie (3D, rotation, height).

Click on the Size button if you want to have different size pie charts depending upon the total (such as total population). If you choose to "Vary size using a field," you may need to exclude records with a zero value. To do this, click on the Exclusion button and, using the appropriate field name, create an expression such as "[TotalPop] = 0." You may need to play with the minimum size on the previous screen to make the maximum size pie chart a reasonable size.
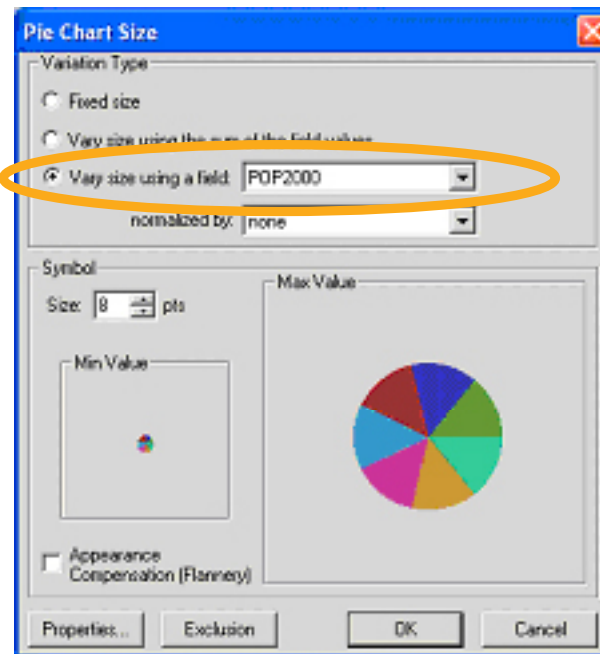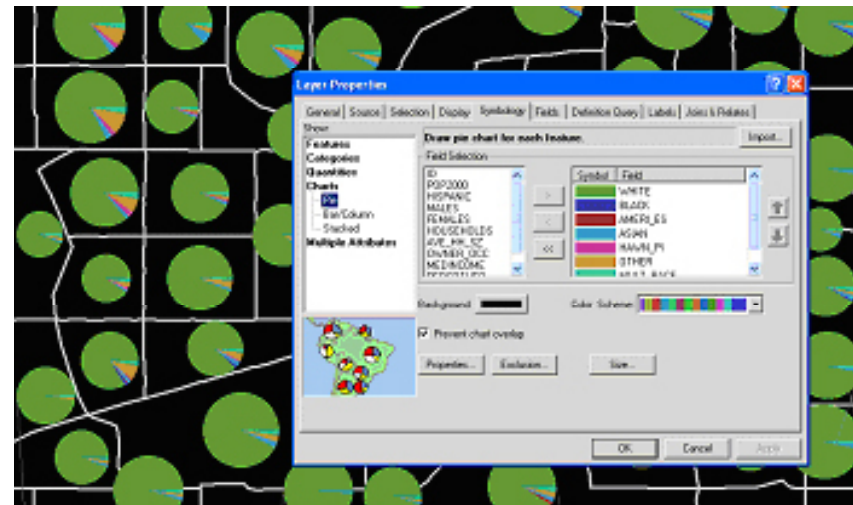
Bar/Column Charts

Bar charts can be used to compare values on two or more variables that do not represent proportions (they don't have to be subsets that add to 100 percent). For example, the map on the right compares the total population by block group to the total number of households. To switch from column (vertical) to bar (horizontal) charts, go to Properties on the Symbology tab of Layer Properties and switch the radio button under "Orientation."

Stacked Charts

Stacked charts can be used to compare values on two or more variables (such as race) that are subsets of a larger variable (such as total population) when you don't know, or don't want to display, all of the subsets. You have many of the same options for formatting (size, color) that you have with the other types of charts.
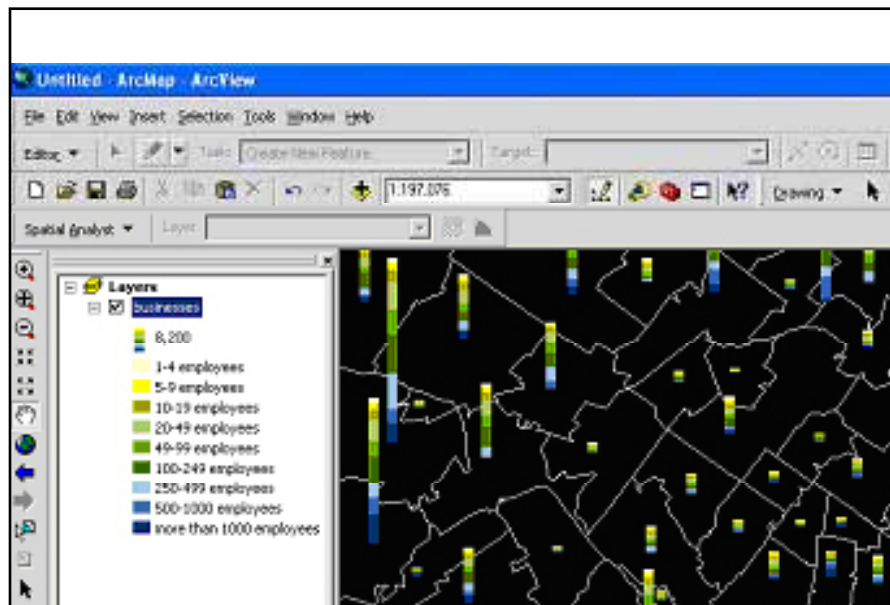
LABELING FEATURES

Labeling features can be frustrating and tedious, but labeling features well is important to making your maps readable and communicating their meaning, so it's worth the effort to learn.

Using Text Boxes to Label Features

You can place text on a map in order to label map features. The text tools require that you type the feature name yourself while the label tools take advantage of feature names stored in the attribute table. The text tool can work well if you only have a few map features to label.
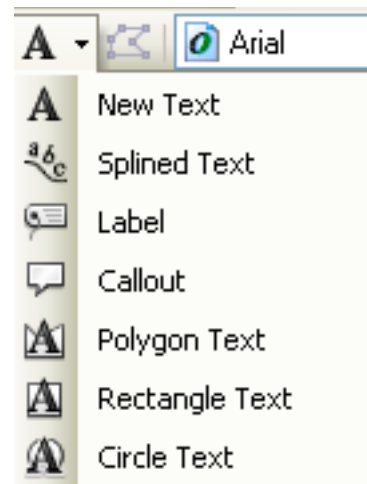
Click on the large letter "A" on the drawing toolbar. This will bring up seven different text and label options. Click on the "A." Click on your map where you want your text to appear and type your label in the text box. Hit the enter key, or click your cursor outside the text box to complete. You can move the text around using the "Select Elements" tool. Double clicking on the text will bring up the Properties, where you can change the size and font (using the "Change Symbol" button).

The **callout text tool** works similarly, except that it allows you to place your text away from the map feature while still indicating what is being labeled. Click on the tool and then click on your map feature. Before letting go, you can move

From the "text properties" dialogue box, choose "change symbol," then "properties," then the "advanced text" tab, then the "properties" button below "text background". From here, you can choose between two different style callouts. Click on the "symbol" button to change the background color.
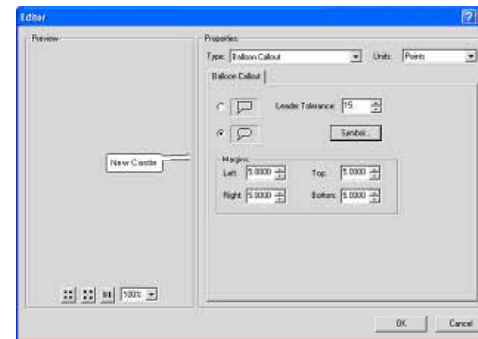

A third option is the **spline text tool**. This allows you to write text along a curved line. This works well for labeling rivers and curvy roads. Click on the spline tool, then click on the starting point for your label. Continue to click along the curve (you don't need to make many clicks) and double click to finish. Then type your label in the text box. You will probably need to try this several times to get a label with which you are happy (just click on the label with the "Select Elements" tool and hit the "delete" key to delete a label).

the cursor to where you would like the label to be. Type your label. Using the "Select Items" tool, you can move the text box so that it is closer or further from the map feature. The yellow background with black text may not be what you want (actually, it probably won't be what you want).

Manually Placing Labels

Using the label tools in ArcMap, rather than the text tools, allows you to use the values in a layer's attribute table for your labels (in other words, you don't have to type the label out as you do with the text tools). By manually placing labels, you also avoid having your labels act as a group (which happens with auto labeling), so it's easier to move or edit a single label.

Before you can use the label tools in ArcMap, you need to indicate which field in the attribute table of your map layer you want to use as the basis for labels. From Layer Properties, click on the "Labels" tab. Leave the "label features in this layer" box empty (clicking this creates auto labels). Choose the appropriate field from the Label Field dropdown menu. Click on symbol to change the size, style, or font for your labels. (Guessing what size to make your labels is difficult and you will probably need to make small adjustments after seeing what
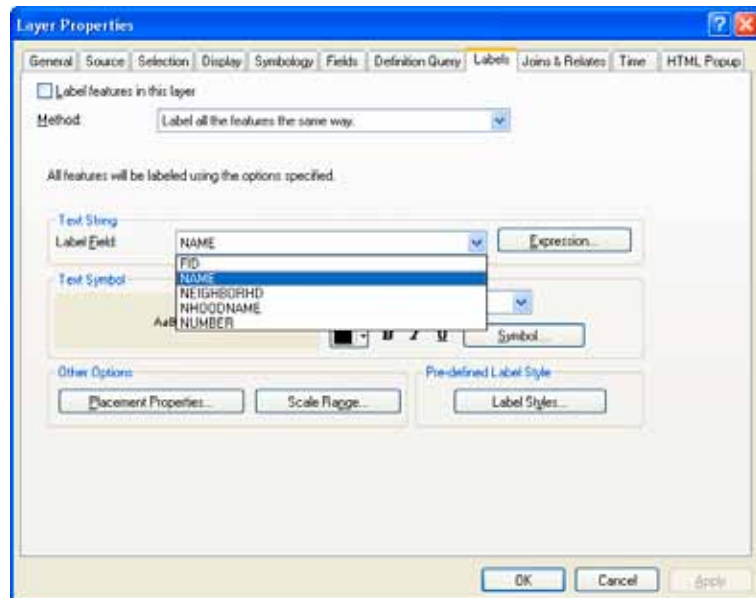
works). Using the "Placement Properties" button, you can instruct ArcView what to do about duplicate labels. The "Scale Range" allows you to instruct ArcView when to draw or not draw labels, depending on the extent. In order to do this, you need to know the exact scales you'll be using (so you probably just want to leave this alone). The "Label Styles" button gives you access to some fancier label options. The highway labels are particularly helpful. Now you can use the label tool to manually label your map features.
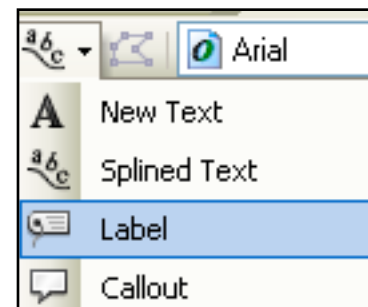
Close the "Layer Properties" dialog box. Click on the button marked "A" on the drawing toolbar and choose the "Label" tool. The "Labeling Options" window will open. Decide if you want ArcView to decide the best label position or if you want to determine that yourself. The "Choose a style" radio button gives you access to those fancier labels again. You can move these labels (using the "Select Elements" tool which is the black arrow) and change their size and style (double click to bring up Properties). You can delete a label by clicking on it and pressing the "Delete key" on the keyboard. To delete all labels, from the Edit menu choose "Select all elements" and click the "Delete" key.
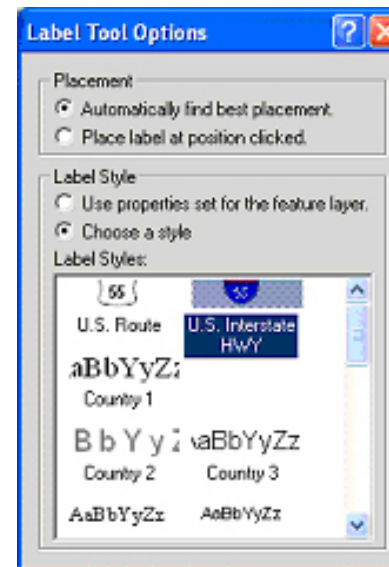
Auto Labeling

You may find it easier to automatically label all of your features. This saves time if you are happy with the way the labels look, but it offers you much less control over the label placement. When you automatically label features, the labels are "dynamic" so changes you make to one (moving it, changing the style) are made to all. To label your map features automatically, go to Layer Properties, click on the Label tab, and put a check mark in the "Label Features in this layer" box. You can also label automatically by right clicking a map layer and going to "Label Features." To delete your labels, you'll need to return to the Label Properties box and remove the check mark from "Label Features in this layer" box or right click and go to "Label Features." You can select "In the map" as a place to store the annotation.

Converting Labels to Annotation

One solution to the problem that auto labeling presents with groups of labels is
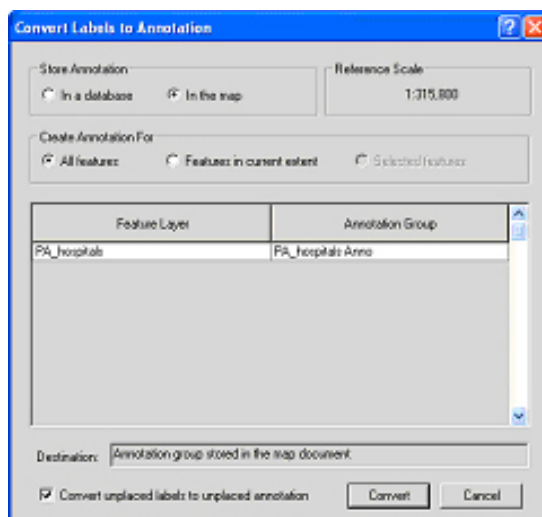
to convert them to annotation. This allows them to function as individual text boxes so you can change the style for a single label. To do this, right click on your map layer after labeling it and go to "Convert Labels to Annotation."

Using a Halo with Labels

Sometimes labels are difficult to see on top of a map that includes many different shades and colors. By creating a halo around the label, it will stand out. To create a halo, double-click on the label text to bring up the "Properties" dialog box, then click "change symbol," "properties," and select the "mask" tab. Choose the "halo" radio button. You can select a halo color other than white and adjust the thickness (1.5 point may be enough).
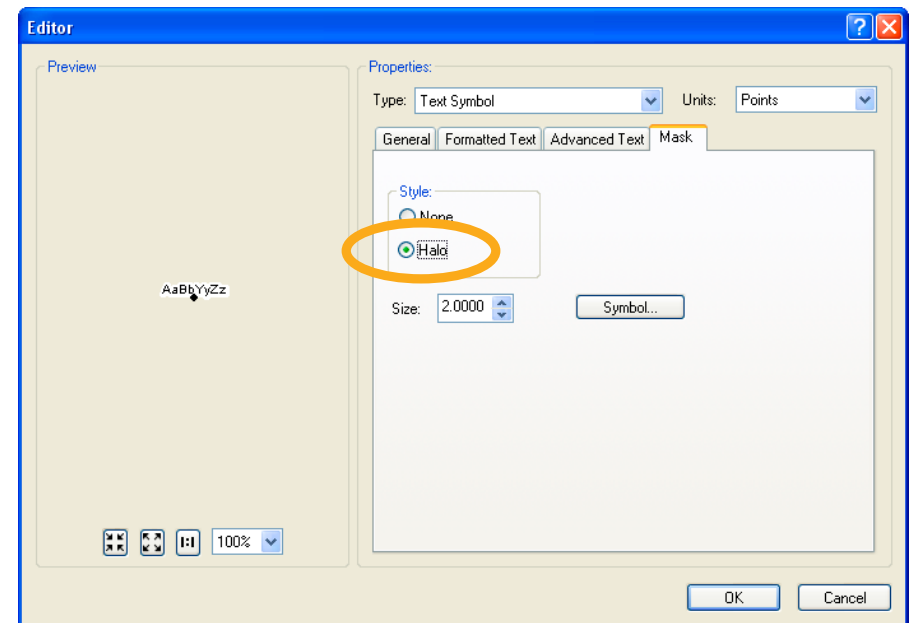
Designing Map Layouts

Displaying data so that you can analyze spatial patterns on a computer screen is one thing; printing out a map for other people to look at is quite another. ArcMap thinks of these as distinct functions and makes available a series of tools for designing map layouts that you don't need until you are ready to print.

Layout View

When you open ArcMap, you are in "Data View" and use the Tools toolbar to navigate your map. When you switch to the Layout View, you have access to a different range of tools and use the Layout toolbar to navigate. To switch to "Layout View," click on the icon at the bottom of your map display that looks like a piece of paper (next to the globe icon) or, from the View menu, go to Layout View.
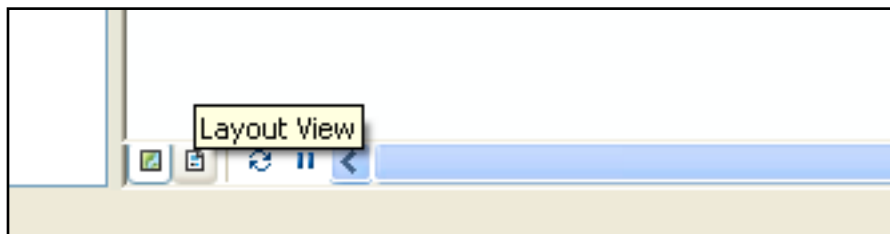
 In Layout View, you get a much better idea of how your map will look when it's printed. ArcMap will automatically place a border ("neat line") around your map. You can remove this by right clicking on the border (so the line is turquoise and perforated) and going to "Properties." Click on the "Frame" tab. From here you can choose a different style or color frame (to get rid of it altogether, choose "no color" from the color selector). You can also change the background color and add a shadow (to add a shadow, you'll need to change the X and Y offset to something other than 0).
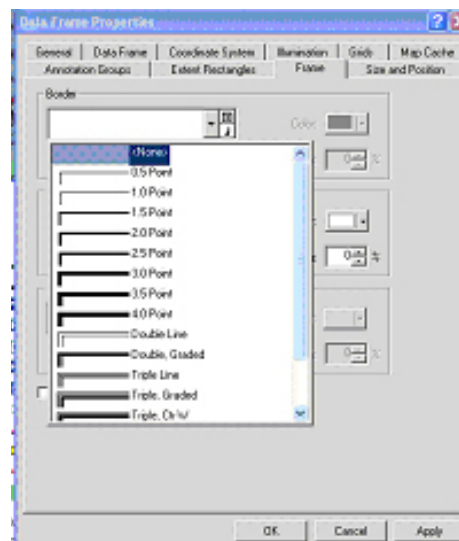

To make your map larger or smaller on the page, you can use the zoom tools on the Tools toolbar or on the Layout toolbar. The Layout toolbar also includes a pan tool that you can use to move your whole layout. To move just your map (and not the whole page), use the pan tool in the Tools toolbar. The fixed zoom tools in the Layout toolbar work like the ones on the Tools toolbar. The "Zoom to whole page" button is especially useful.

One of the biggest differences in Layout View is that many more options in the "Insert" menu become active. These options allow you to add elements—including a title, legend, north arrow, scale bar, and image—to your layout. Each of these will be separate objects in your layout that can be moved and resized through their Properties. You won't see any of them if you switch back to Data View since they are meant to clarify printed maps, not help you interpret your map on screen (in fact, the layout view is probably more confusing to look at from the screen because it adds so many elements and usually shrinks your map). You can add text in the Layout View, but you are better off trying to label features from the Data View, using the label or text tools.

Working with Grids and Rulers

You can bring up a number of options aimed at helping you to place the objects within your layout by right clicking in your layout outside of the neat lines. From "Options," you can specify ruler units and turn on and off rulers and grids when the "Layout Options" tab is highlighted. Choosing to "snap" to the grid or rulers will help you to line up objects, but it will also limit your ability to make fine-level adjustments.
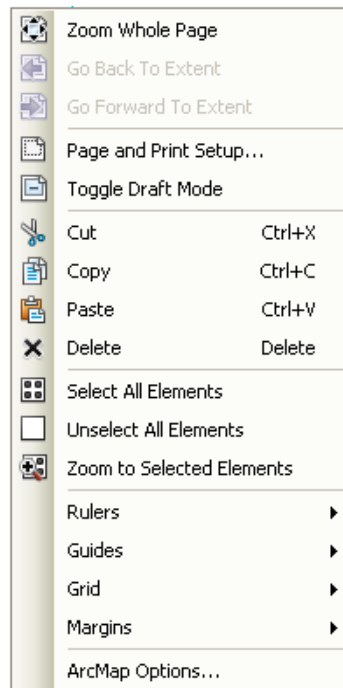
Adding a Title

To add a title, from the Insert menu go to "Title." Type your title in the text box and hit the enter key or click the cursor outside the text box. Double click on the title to bring up the Properties where you can make changes to the text and formatting.

Adding a Legend

Unless your labels are able to fully explain your map features, you will want a legend on your layout. ArcMap gives you great flexibility in formatting your legend, and all the choices can be overwhelming. To add a legend, from the Insert menu go to "Legend." Your first choice is what map layers you want included. ArcView will guess that you want to include all active layers. This may not be the case if you have layers such as a county boundary, rivers, or other obvious features that don't need to be included in the legend. To remove a layer from the legend, click on its name on the right side of this first screen and click

on the "<" button. The order your layers are listed under "Legend Items" will correspond to the order in which they appear in your legend. To change the order, click on the name and hit the up or down arrows (don't worry; this won't affect the order in which they are drawn).

If you want more than one column in your legend, make the adjustment here. To see what your legend will look like (before working your way through the rest of the screens), click the "Preview" button. If you are satisfied with it, you can click the Finish button and skip the other steps. Otherwise, click the "Preview" button again and click "Next." On the second screen of the Legend
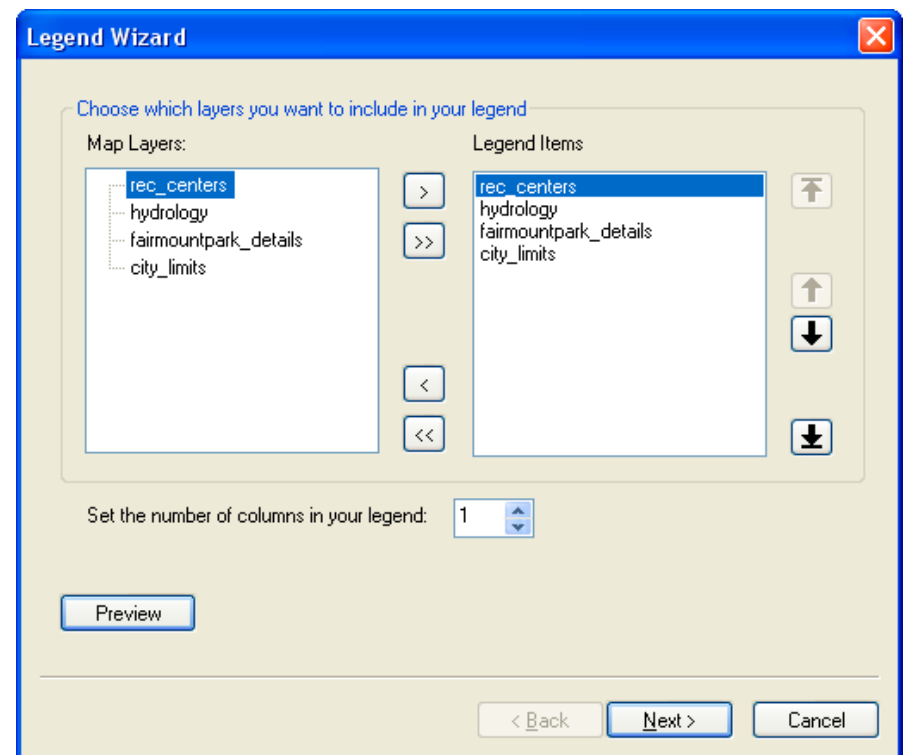
Wizard, you can give your legend a title or leave the word "Legend" as the title (or just leave it blank). The third screen allows you to create a frame and shadow around your legend (not necessary, but depending upon your layout it may be helpful, particularly if you gave your layout a background color). On the fourth screen, you can change the symbols and symbol size used to represent lines and polygons in your layout. On the final screen, you can make adjustments to the spacing between items in your legend. Click "Finish." To make changes after you have created your legend, double click on it to bring up Properties.

Cleaning up your map legend

Chances are that you'll need to clean up your legend at this point. Some of your map layer names may have underscores or other cryptic notations. The legend will use the same names that appear in the table of contents. You can change the label names in the table of contents without changing the name of the shapefiles on your computer. From the table of contents, click once on the map layer name, then click again (but not quickly). The label name should become
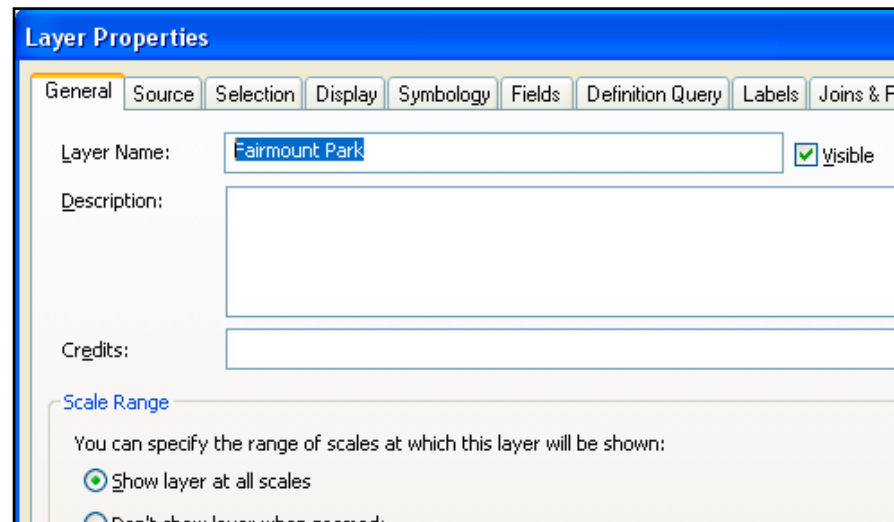
highlighted, allowing you to make changes. You can also change the map label names from the "Layer Properties" dialog box, from the "General" tab.

You may also need to translate some of the values that appear in your legend. For example, you may choose to symbolize a parcel shapefile with two different colors for the codes "1000" and "9999" which represent streets and sidewalks, respectively. From the "Symbology" tab, type in "street" and "sidewalk" under the Labels. Be careful not to change the numbers listed under "Value" because this will change your map.
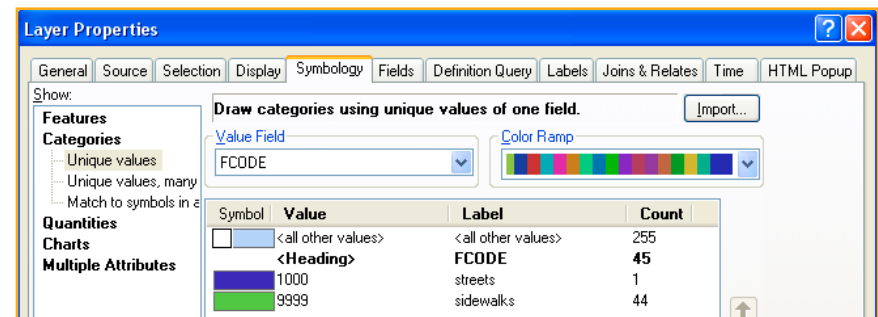
For maps symbolized using graduate colors, you may also want to make adjustments using the "Label" section. For income, be sure to add $ and commas. For percentages, click on the word "Label" in the "Symbology" tab, choose "format labels" and select "percentage." If your number looks like a decimal (0.15 for 15%), choose the second radio button and click on "Numeric option." Here you can change the number of decimals (in most cases, choose 0 or 1).

Adding a North Arrow

You may decide that a north arrow is not necessary (unless you choose to rotate your map so that north is no longer towards the top of the page; in that case, it is definitely necessary). If you do wish to add a north arrow, from the Insert menu go to "North Arrow." Choose a style from the "North Arrow Selector" (prefer-ably something simple, and small). You can move it around on your layout by clicking on it. Double click to change the size or style. Consider a small north arrow and one that is discreet.

No   N *Yes*

Adding a Scale Bar

To add a scale bar, you must identify the appropriate units for your map. You can set these from the Data View or Layout View. From Layout View, right click in the layout (anywhere inside the neat lines), go to Properties, and make the General tab active. From the map units dropdown menu, choose the units used for the original map projection (see "Working with Projections").
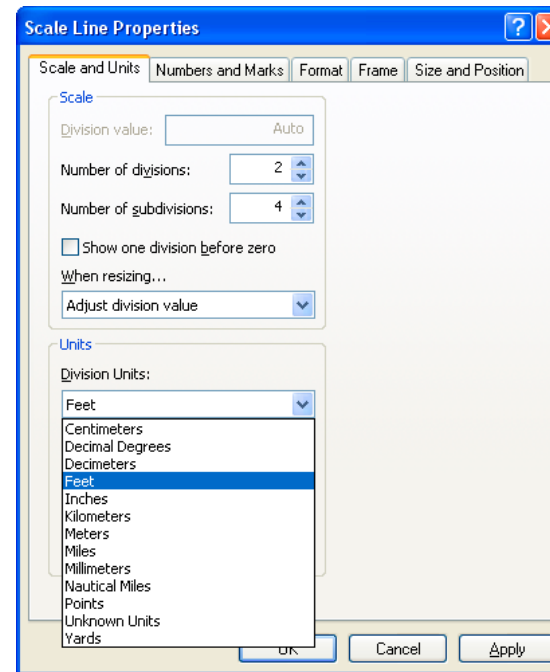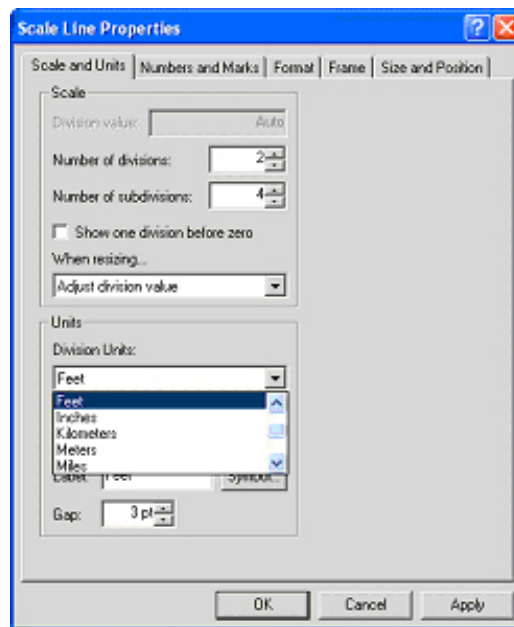
Once this is set, you can choose any display units you want. To add your scale bar, from the Insert menu, go to "Scale bar." Click on a style and hit "OK." Your scale bar should appear on your map. You can move or resize it by clicking on it. Double click to bring up the Properties, where you can change the number of divisions and as well as the font size (by clicking the Symbol button or from the format tab). You can also change the division units, from feet to miles or km, here. If your units read "unknown units," you will need to define your map projection before proceeding.

1 centimeter = 2,916 meters

Adding Scale Text

You may wish to include a text description of the map scale, particularly if this is important to your audience and you deliberately chose a scale (as opposed to maximizing the size of your map based on the size of your page). To add scale text, from the Insert menu go to "Scale Text." Double click on the scale text in your layout to bring up the Properties, where you can make changes to the format and units.

Rotating a Map

You can rotate your map to better fit the page or to make it easier to read (just because you can do this doesn't mean it's a good idea). If you do this, make sure that you have a north arrow on your map. As you rotate your map, your north arrow will adjust to indicate which direction is north. From the View menu, go to Toolbars (or just right click on a gray part of the GUI) and Data Frame Tools. Click on the "Rotate Data Frame" button, then click and hold down on your map, moving your map to change the rotation. To restore the original orientation, click on the "Clear Rotation" button.
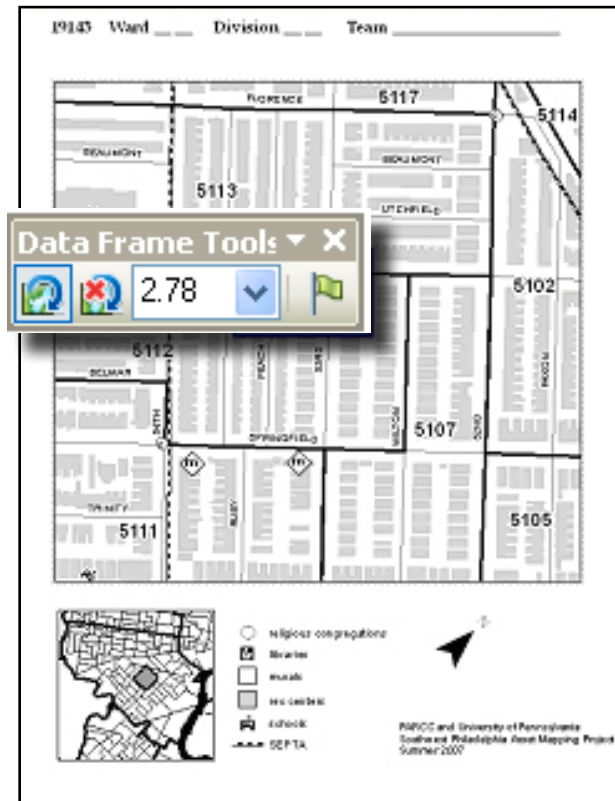
MULTIPLE-MAP LAYOUTS

You may need to create a printed map that includes more than one map, either because you can't fit everything (such as Alaska and Hawaii) on your main map, you want to show a series of small multiples (same map with different variables), or because you want to zoom into a small area for your main map and indicate on a smaller overview map what area the larger map covers.
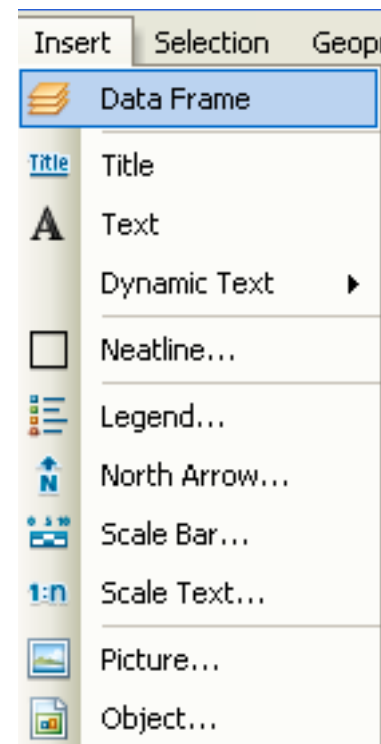
Adding Group Layers

Most of the time you will only need one data frame in a map document. Working with data frames can make your map document complicated and prone to crash. But if you need to include more than one map in your layout (including the same map at a different extent), you'll need two or more data frames. When you open ArcMap, you'll just have one data frame (called "Layer") and every map layer you add to your map document becomes part of this frame. To create a second data frame, from the Insert Menu go to "Add Group Layer."

To add new data to a particular data frame, right click on its name and go to "Add Data" or highlight its name and use the Add Data button (or, from the Insert menu, go to "Add Data"). If you want to move a layer to a different data frame once it is in ArcMap, right click on it and go

to "Copy." Then right click on the name of the data frame where you want to move it and go to "Paste Layer." The layers in only one data frame can be displayed in the map view at a given time. It does not matter which one is listed first in the table of contents; it matters which one is active. To display the layers in a data frame, right click on its name and go to "Activate." When you switch to the layout view, you will see that there are two map images, one for each data frame. You will likely need to resize and move these to fit together.
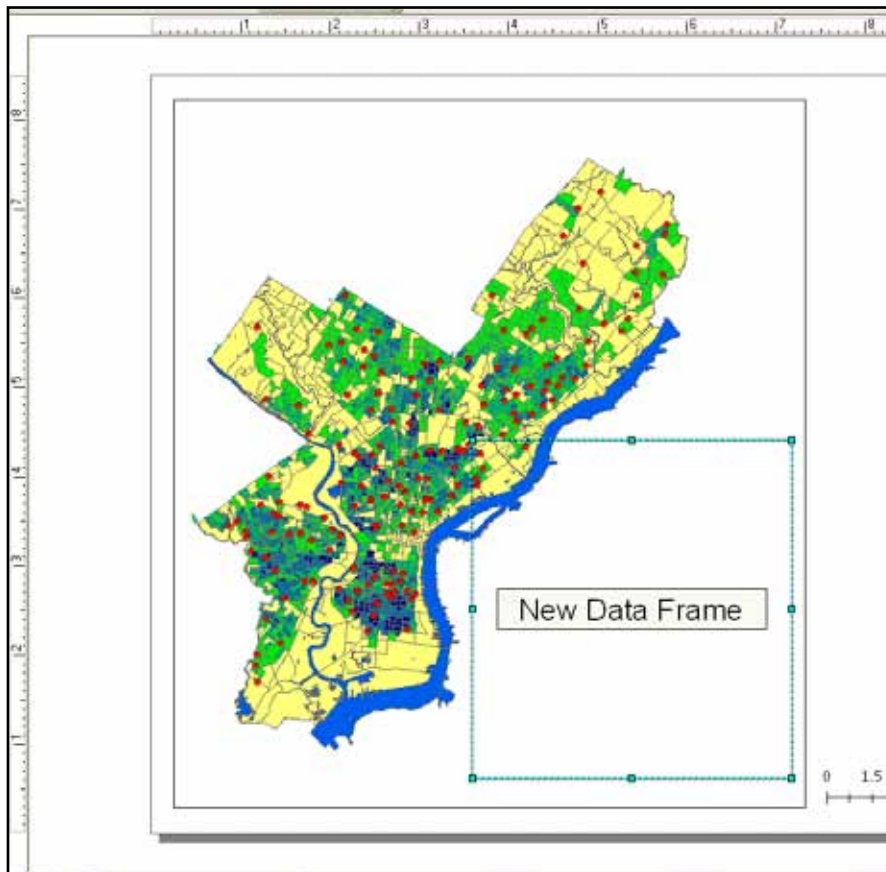
Creating Inset Maps

If you want to have an overview map that shows on a larger map the outline of the area your detailed map includes, you'll need to create an extent rectangle. To do this, follow the instructions above to create two map layers: a detail layer and an overview layer.
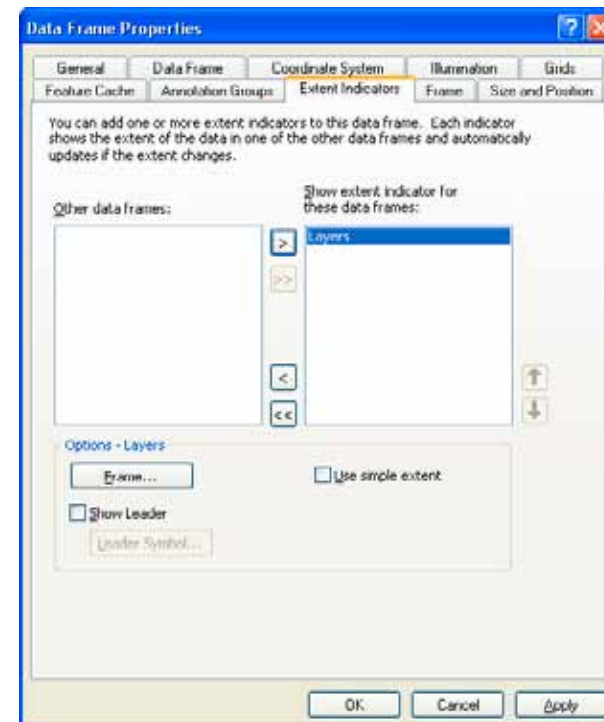
Zoom in on your detail layer in the map view and resize it in the layout view so that it looks the way you want. Then right click on the overview layer in your table of contents. From "Properties" click on the "Extent Rectangle" tab. Move your detail layer from the left to the right side. Click on the "Frame" button to make changes to the outline of your box.

EXPORTING MAPS

If you just need paper copies of your maps, you will probably have the best results printing them from ArcView. But if you need to insert maps into Power Point or word processing files, will need to export your maps.

Exporting Process

You can export a map from ArcMap when you are in Data View or Layout View. However, if you want your exported map to include titles, legends, scale bars, north arrows, and anything else you added to the layout, you'll want to export from Layout View. From the File menu, go to "Export Map." There are many options for export formats in the "Save as type" drop downmenu.

.PDF: The .pdf format allows you to open the map directly (without inserting it into PowerPoint or MS Word) as long as you have Acrobat Reader. This is probably the best option if you need to send someone a map or post a map on the Internet.

.JPG: The .jpg format will compromise the quality of your image, so be sure to click on the "options' button when you export and increase the resolution to at least 200 dpi (300 dpi will be as good as you need for most things). The .jpg format is good because it stores your map in a fairly small file.

.TIF and .EPS: The .tif and .eps formats work well if you are going to open your maps in a graphics software package, but they result in larger files.

Screen Capture: If all else fails, you can take a screen capture (push the print screen button or alt + print screen buttons, then choose "paste") and crop the image, but this will not result in a presentation-quality map.

Inserting Maps into Power Point

Save your map as an .jpg. With Power Point open, go to the Insert menu, "Picture," and "from file," then Navigate to you map image and click "Insert." You may notice that there is a lot of white space around your map. Eliminate this using the crop tool. You must have the map image active (click on it so that you see small squares at the corners). Click on the crop tool and crop the image by clicking on one of the small boxes and dragging the cursor (if you do this without having the crop tool active, you will shrink the whole image).

You are probably better off creating map titles in Power Point rather than ArcView. Also, if you are making a map specifically for Power Point, consider making the legend larger than usual (14 points or more) so that your audience can read it.
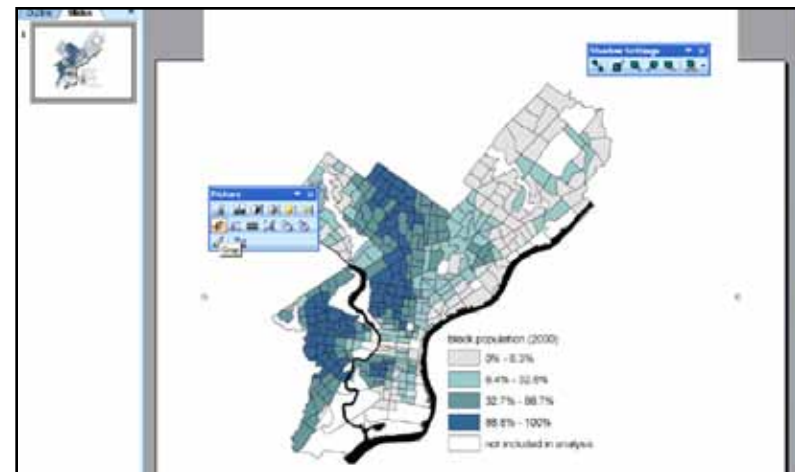
Inserting Maps into Microsoft Word

Follow the same procedures for inserting a map into Microsoft Word. You may have less flexibility in moving the map around than in PowerPoint, but you should be able to crop and resize it.

4 | MODIFYING ATTRIBUTES

WORKING WITH TABLES

Attribute Tables for Shapefiles

Every shapefile has an attribute table associated with it. You can open the table by right clicking on the shapefile name and going to "open attribute table." The table will have as many rows, or records, as it does map features. The total number of records will be shown at the bottom of your table. There can be any number of columns (fields). Two columns are standard: FID, the feature ID, and Shape, which can be point, polyline, or polygon. The rest of the fields will vary. In most cases, there will also be a column that identifies each map feature with a unique name, such as a census tract number or neighborhood name. There may be additional fields identifying attributes of the map feature (type of crime at a particular address, number of people living in a census tract).
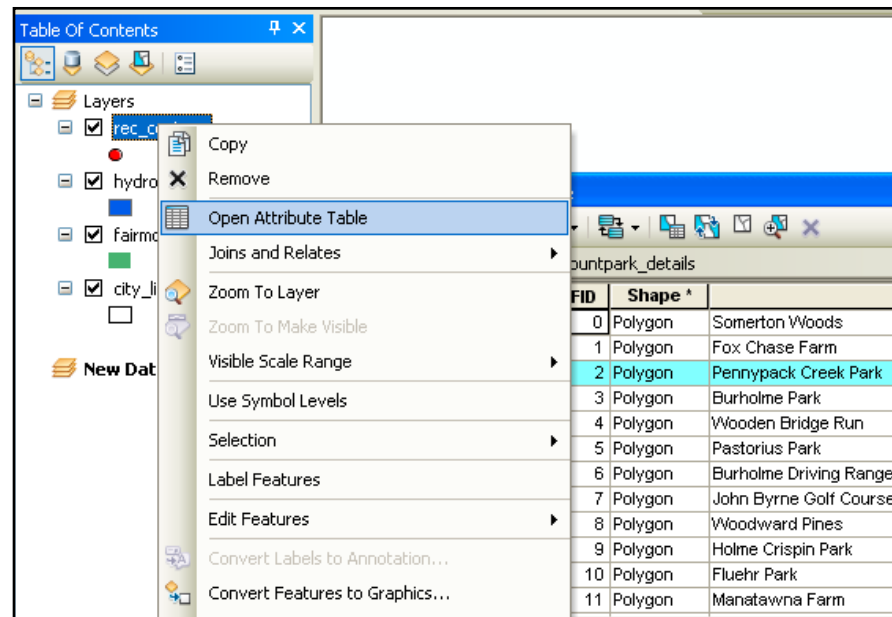
Other Attribute Tables

Often you will have attribute data in a table separate from your shapefile. For example, you may have a census tract shapefile with no attribute information and a table with all of the 2000 census tract data. ArcMap can read Excel (.xls), dBase (.dbf), comma-delimited (.txt or .csv) and tab-delimited (.tab) text tables but will only allow editing for .dbf tables (you can convert .txt tables to .dbf in EXCEL, SPSS, ACCESS, or in ArcMap). You can add attribute tables to ArcMap just as you do shapefiles, using the "add data" button, from the file menu, "Add Data." or from Catalog Window. You must have the Table of Contents set for "List by Sources" in order to see tables listed. Open these attribute tables the same way: right click on the name and go to "Open."
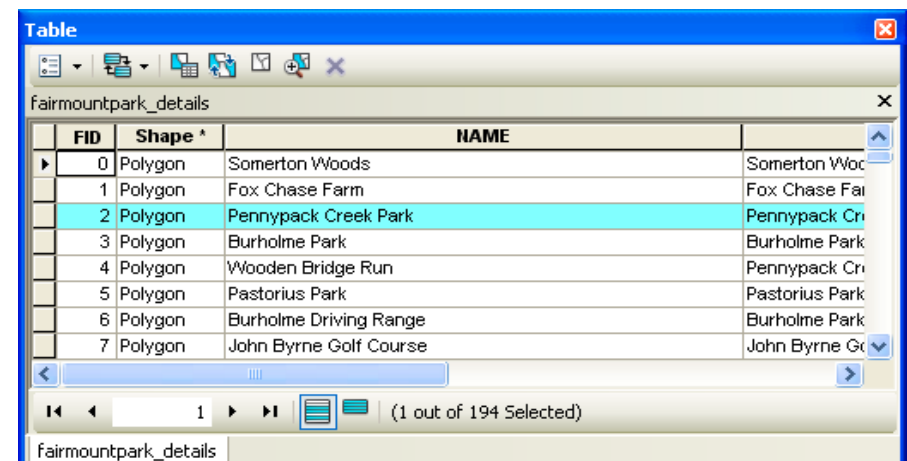
You can work with tables—sort values, freeze columns, generate summary statistics, select records, and export tables—without worrying about messing up your original data the way you can in Excel if you are not careful. You cannot change any of the data in your table unless you go to "start editing" from the editor toolbar... except to add or delete fields.
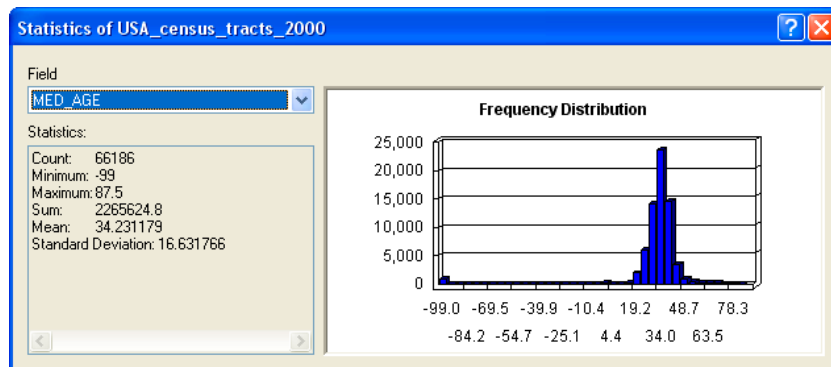
Sorting Records

You can sort values in an attribute table by right clicking on the field name and going to "sort ascending" or "sort descending."

Summary Statistics

You can bring up summary statistics for any numeric field (numeric fields will be justified right) by right clicking on the field name and choosing "Statistics." You can obtain summary statistics on additional fields from the drop down menu.

Selecting Records

You can select a subset of your records to look at more closely in a number of different ways. You can highlight an individual record (row) by clicking in the gray area at the far left side of the table. To highlight multiple records, hold the control key down. At the bottom of the table, ArcMap will indicate how many of the total records are highlighted. Click on the "Selected" button to view only the selected records. You can switch the selection, so that all of the highlighted records become un-highlighted and all un-highlighted records become highlighted. From the options menu, choose "Switch Selection." You can also select all records or clear selection from the options menu.

Freezing Columns

Freeze a column (meaning that it will remain in view even as you scroll) by right clicking on the field name and going to "Freeze/Unfreeze Column."

Exporting Tables

You may need to export your table from ArcMap, because you have made changes, need to convert a .txt table to .dbf, or for any other reason. With your table open, go to the options menu and "Export." If you have some records highlighted, you can choose to export just the selected records or all of the records.
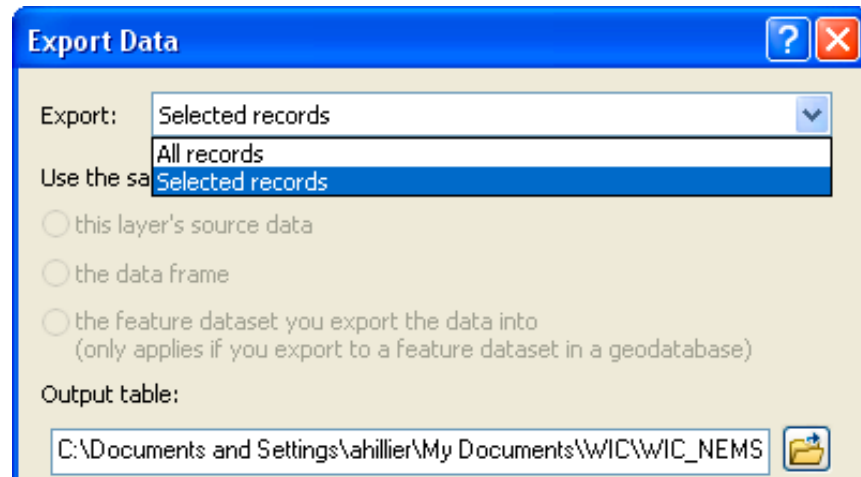
Delete Field

You can delete a field by right clicking on its name and going to "Delete Field." ArcMap will give you a warning that the deletion is permanent and not reversible. Do this with caution. Changes will be permanent not just within your map document, but in your original file on your hard drive, as well.
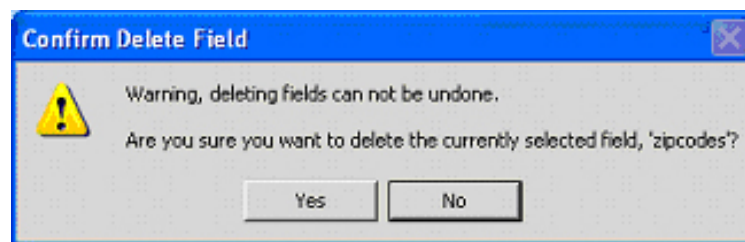
CALCULATING VALUES IN TABLES

You may find it easier to edit your attribute tables outside of ArcView, but ArcView has fairly sophisticated tools for calculating values. In ArcView, you can edit values in an existing field or create a new field and calculate new values. Keep in mind that you cannot change the format (text, integer, long integer) of an existing column, so if you need to transform the format of a column, you will need to create a new field.

Creating a New Field

To create a new field, open your table in ArcMap (you can also add fields from ArcCatalog). This can be a free-standing table or one that is associated with a map layer, but only .dbf tables can be edited. Click on the Table Options menu (top left corner of the attribute table) and go to "Add Field." If this option is grayed out, you do not have permission to edit the table. Most likely, this is because your table is in .xls format. If this is the case, export the table (an option within that same menu) and save it as a .dbf. Add the .dbf version back in and try again.

From "Add Field," give your field a name. Do not use ?,&,$,#,@,*,!,~ or spaces and keep your field name to 10 or fewer characters. From the dropdown menu, choose the type of field. Different field types allow different types of values:

Short integer: numeric, no decimal place, up to 19 characters

**Long integer**: numeric, no decimal place, up to 19 characters

Float: numeric, with decimal places, (default 1 before decimal and 11 after)

Double: numeric, with decimal place (default 7 before decimal and 11 after)

Calculating Values Outside an Edit Session

To calculate the value of your new field (or an old field), right click on its name and go to "Calculate Values." ArcMap will ask you if you are sure that you want to calculate values outside an edit session, warning that you will not be able to undo your results. Say "yes."

ArcMap will bring up the Field Calculator. If your value is a constant, you can simply type the value in the box at the bottom. More likely, your new value will be based on values in other fields, so you will need to use the calculator. You can create an expression by double clicking on the field names. For example, to calculate the percent of the population 65 and up, click on the field name with the total 65 and up, click on the "/" button, and click on the field name with the total population. If any of the records in your table are highlighted, ArcMap will only perform calculations on the highlighted records. You can also calculate values from ArcToolbox (under "Data Management Tools", then "Calculate Field").
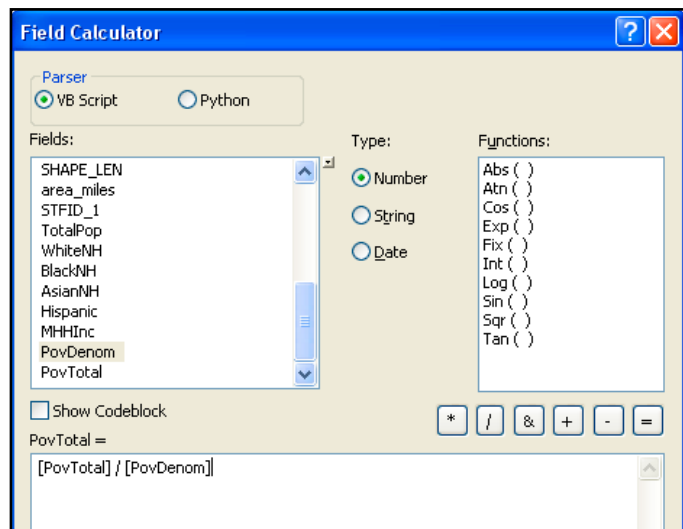
Calculating Values on Selected Records

You can get an error while calculating values for many different reasons. ArcMap will not allow you to divide by zero, so if the denominator (total population in example above) is zero for any of your records, ArcMap will not calculate any of the values.

To get around this problem, you need to select only the records where the denominator is something other than zero. Start by selecting the records with a zero in the denominator (because there are fewer of these). Do this by right clicking the field with your denominator and sorting ascending. Hold down the control key and highlight all the records with a zero. From the options menu, choose "Switch Selection" so that all of the records with non-zero values are highlighted. Now you should be able to proceed with calculating values.

Calculating Values Inside an Edit Session

When you need to calculate a new variable, the best approach is to calculate a value outside an edit session, just described. But when you need to change the value on just one or two values, you may want to try editing inside an edit session. Go the Edit toolbar and, from the edit menu, choose "start editing." You can only edit the contents of one directory at a time in an edit session, so you need to identify the directory that contains the table you wish to edit. Open your table and double-click on the value in your table you wish to edit. When you are finished, go to "stop editing" in the edit toolbar and say "yes" to saving edits.

CALCULATING AREA, PERIMETER & LENGTH

Calculating Area

Usually there will be a field called "area" in a shapefile when you receive it that indicates the area of each polygon map feature. If your shapefile is missing this field or if you have edited the shape and size of the map features, you will need to calculate area, yourself. Area can be especially helpful when you are trying to normalize values and create densities (calculating persons per square mile, for example).

Create a new field called "area" and format it as a double. Right click on your new field and go to "Calculate Geometry." From the "Property" menu, choose "Area." Note the projection and map units. You can change the units as long as the projection is defined (known).
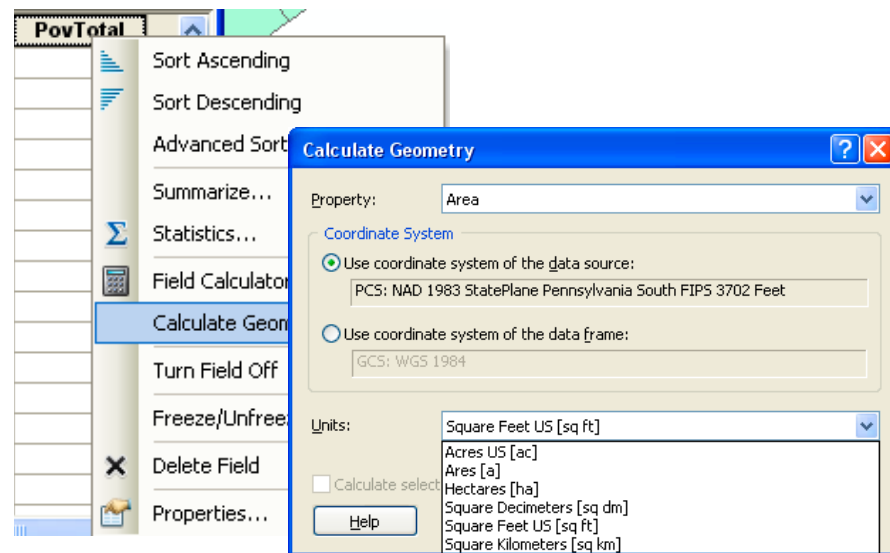
You can also calculate area using ArcToolbox. "Calculate Area" can be found in the Spatial Statistics Tools section, under "Utilities." Choose the polygon layer for which you want to calculate area, then determine a name and location for the new shapefile you will create. The new layer will be added automatically to the table of contents when ArcView is done calculating the area. The units will be what is used by the projection system for that map layer.

CREATING XY COORDINATES

Adding XY Coordinates to a Point Layer

Just as you may need to convert a table with XY data into a map layer, you may need to add XY coordinates to an existing layer containing points. The easiest way to do this is by using "Add XY Coordinates" in ArcToolbox (under "Data Management Tools" go to "Features" to fine "Add XY Coordinates"). Simply choose the point layer you want to assign XY coordinates and click "OK." The coordinates will be in whatever units are defined by your projection (often feet or meters). You can also do this using the "calculate geometry" option.

Joining Tables

You can link map features to their attributes in GIS but only when your attributes are in the same file as your geographic data. Often you will have attributes stored in a separate table that you will need to join to a shapefile in order to symbolize your map with the data. You might think of a shapefile as a series of containers that can hold attribute data. Often you will obtain shapefiles that have no attribute data—in effect, empty containers.

Identifying a key

In order to join an attribute table to a shapefile, you will need to identify a field that is common to your attribute table and the attribute table associated with your shapefile. This field is known as a key, or unique identifier, because it uniquely identifies each record in your table and shapefile on which ArcView can join, or match, your data. The values must be formatted in an identical way. If they are not, you must edit one of the fields or create a new field and recalculate the values so that they match perfectly.

Tables with census data may contain multiple fields that uniquely identify each record that may have names such as "TRT2000," "STFID," and "TRACTID." The field name doesn't have to be the same in the attribute table and the shapefile in order to join them; they just have to be formatted in the same way. While you may perform joins on census data most frequently, you can join attributes to shapefiles for other data: zipcodes, councilmanic districts, counties. You can join on a name (such as neighborhood name, or the name of an institution), although keep in mind that differences in spelling and spacing will keep records from joining. To make sure that both columns are formatted the same way, look and see how they are justified. Left justified columns are formatted as text; right justified columns are formatted as numbers.

Joining a table

To join attribute data to a shapefile, you must add the shapefile to ArcMap. Right click on its name in the table of contents, go to "Joins and Relates," and then "Join...". Choose "Join attributes from a table" in the first dropdown menu. In the second dropdown menu, identify the key you'll use in your shapefile. Next, choose the table you wish to join (this does not need to be added to ArcMap). Finally, identify the key in this table. Click on "validate join" to have ArcGIS check to see if the two fields are a match. If you receive a message that one of the fields is not indexed, chose "yes" to have it indexed. Individual records might not match because of problems with the key or because there are different numbers of records in each of your files. When you open your shapefile, there should be new fields that contain the data from your attribute table. The join holding the data together is not permanent, so if you add the shapefile to another map document, you will not have the appended data. To make the join permanent, right click on the shapefile name, go to "Data," and choose "Export Data..." This works like a "save as," so it creates a new shapefile.
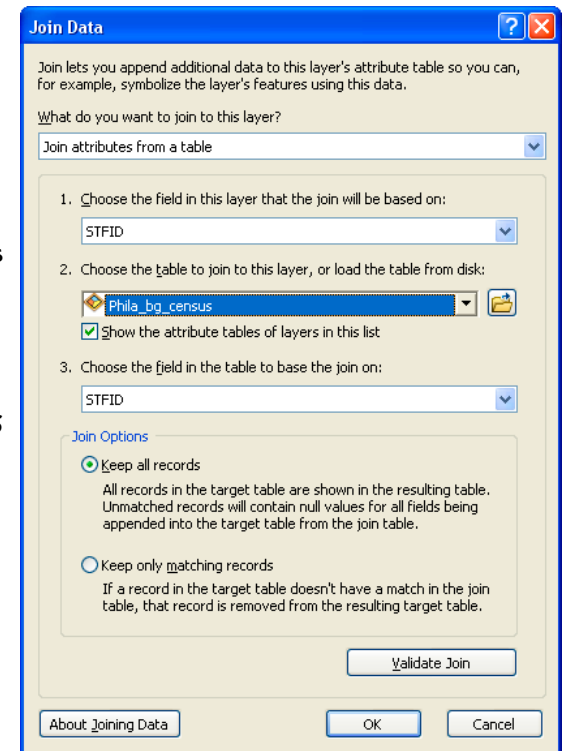
5 | CREATING & AGGREGATING POINTS

GEOCODING

Geocoding refers to the process of transforming street addresses into map features. In order to geocode, you need to have a table with addresses and an address locator based on a street centerline file that matches the geographic extent of your addresses. Through the geocoding process, ArcGIS will create a new point shapefile by matching each street name and number in your table to a place along a line segment in your streets shapefile that represents a certain range of house numbers. The image here shows how each section of a street centerline file has a known street name (ST_NAME) and address range (L_F_ADD and R_F_ADD). ArcView uses this information to locate the addresses in your table (called Foodsite_addresses here).
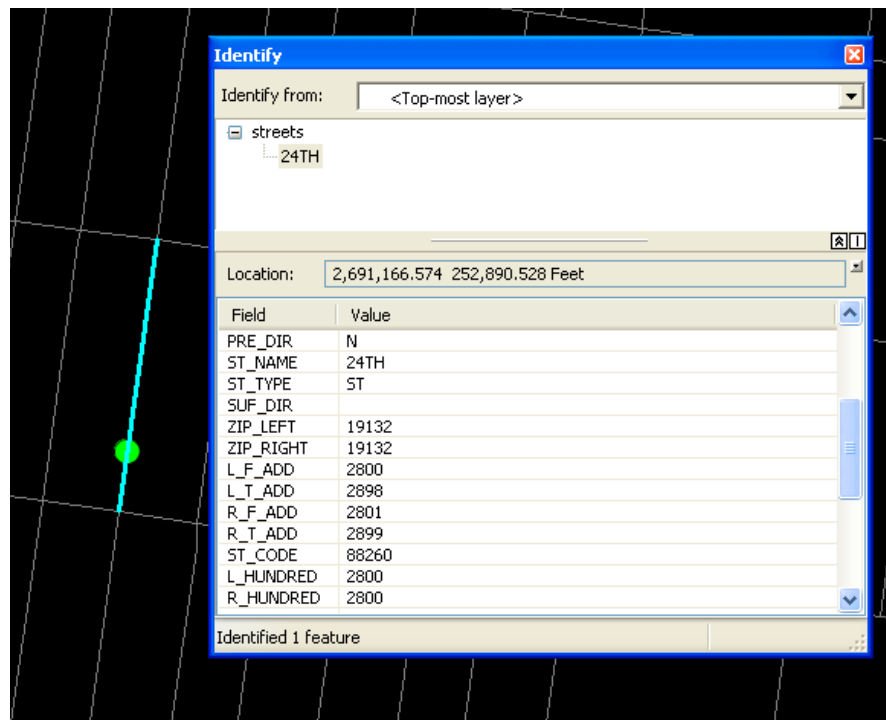
Preparing Tabular Data

In order to geocode, you need a table (.dbf, .xls, or comma-delimited .txt) that has a field with street addresses. If the parts of the street address—house number, street direction, street name, and designation/ type—are in separate fields, you will need to collapse these into a single field. You need separate fields for zip code, city, and state. Intersections can be used (Lehigh Avenue & N Broad Street) but house ranges (123-127 N Broad Street) and PO boxes will not, so make sure you change these to addresses with a single house number before you try to geocode.

## Finding or Creating a Geocoding Service

ArcGIS 10 comes with an address locator for the entire country. With earlier versions of ArcGIS, you had to purchase Esri's StreetMap extension in order to match addresses for the whole country or create individual address locators for one county at a time using your own street centerline file.

Geocoding Addresses

Add your table of addresses. Right click on the file name and go to "geocoding."
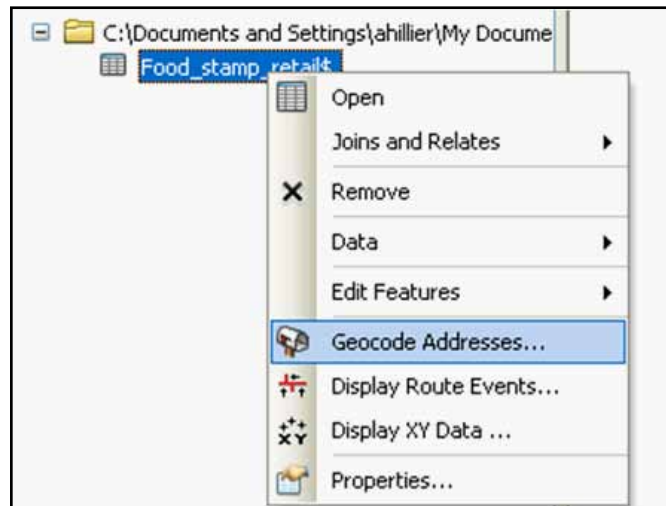
Next, you'll need to pick an existing geocoding service. The US Geocoding Service is fine for all US street addresses. Note: you will have to be connected to the Internet during the geocoding process to use this address locator.
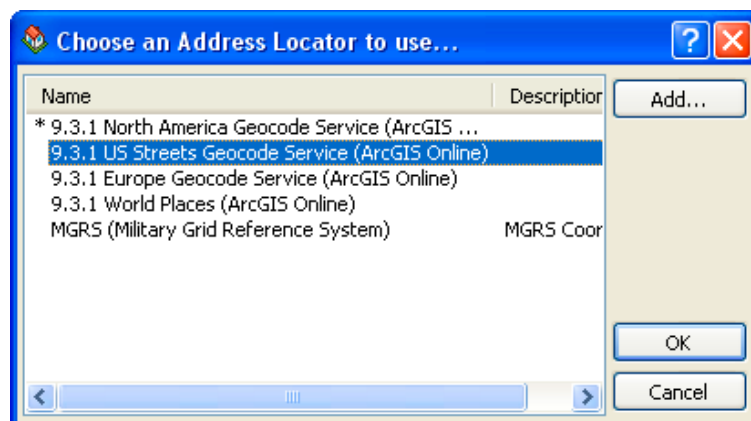
On the dialog box that pops up, first use the dropdown menu at the top to identify the table with your addresses. Then indicate the variable names for the street/intersection, city, state, and zip code. Since the geocoding process creates a new shapefile, be sure to click on the folder beneath "Output shapefile or feature class" and give your shapefile a name and proper location.
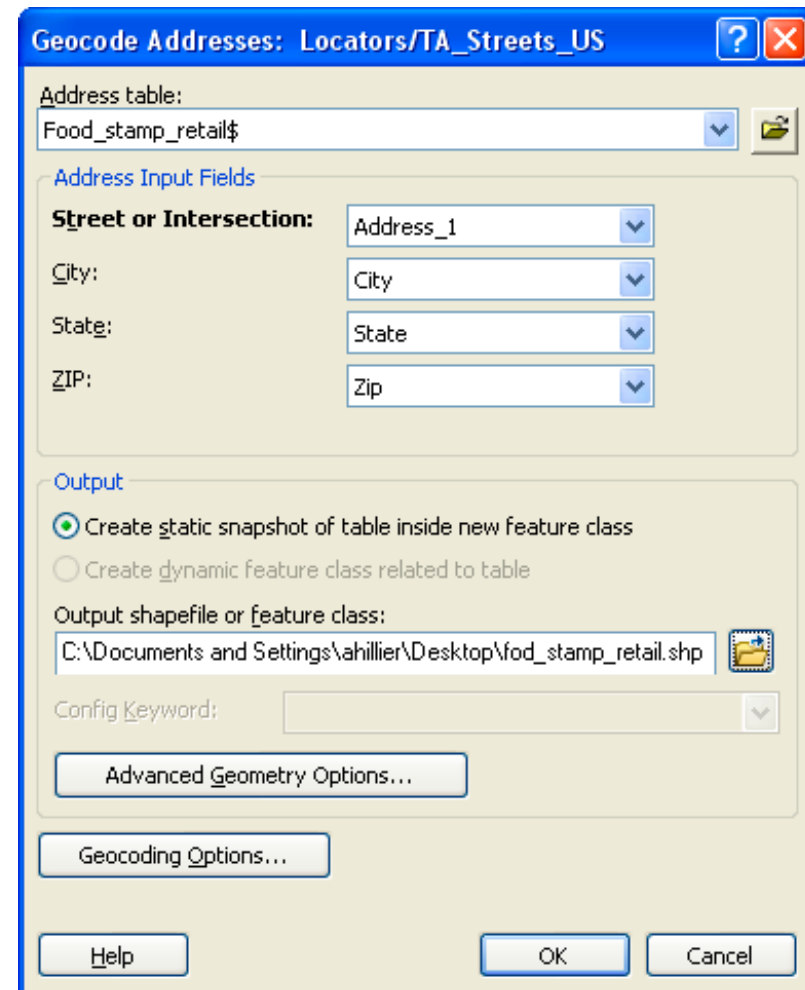
The "Geocoding Options" allow you to indicate the level of sensitivity for the matching process. Essentially, ArcView needs to match the house numbers and street names in your tabular data with information in the streets shapefile. If the spelling of the street name is slightly different or an appropriate range of house numbers cannot be located, ArcView will assign the match a less than perfect score (100 is a perfect match). ArcView can geocode based on street intersections in addition to specific house numbers. In the "Intersections" section you can identify symbols (or "AND") used in your tabular data to indicate intersections. The "Side Offset" option allows you to place points slightly away from the middle of the street centerline file. While ArcView will know what side of the street your address falls on, your points will appear to fall directly on the centerline unless you specify an offset. 15-20 feet is adequate. Under "Output Fields," if you check "X and Y coordinates," ArcView will add X and Y fields to the point shapefile with your addresses. be listed under "Address Locators" in the Catalog. Once you have
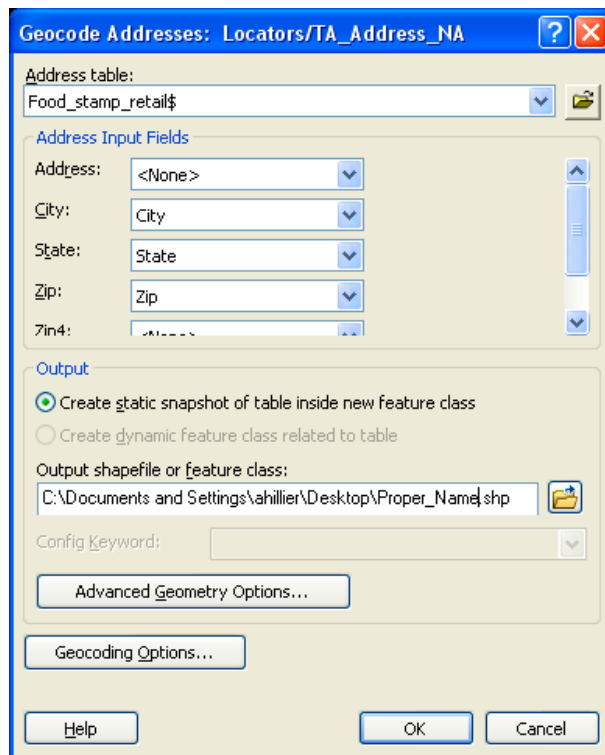
created an address locator, you don't need to do it again (unless you go to a new computer).

The "Advanced geometric options" allows you to make a choice about projection ("spatial reference"). The default is to use the same projection (Geographic Coordinate System: GCS_WGS_1984) as the US Geocoding Service. If you do that, your projection will be defied (as geographic, meaning it hasn't been projected) but you will need to project it. Alternatively, you can add a shapefile to ArcGIS with the desired projection and then use the geometric options to choose "use map's spatial reference" or you identify the projection system you want to use.

Click "OK" to to start the automatic geocoding process. After a few seconds (longer if you have thousands of records), ArcView will give you a report showing how many matches were made. You can either click "close" to look at the addresses that did map or "Rematch" to review the unmatched records.
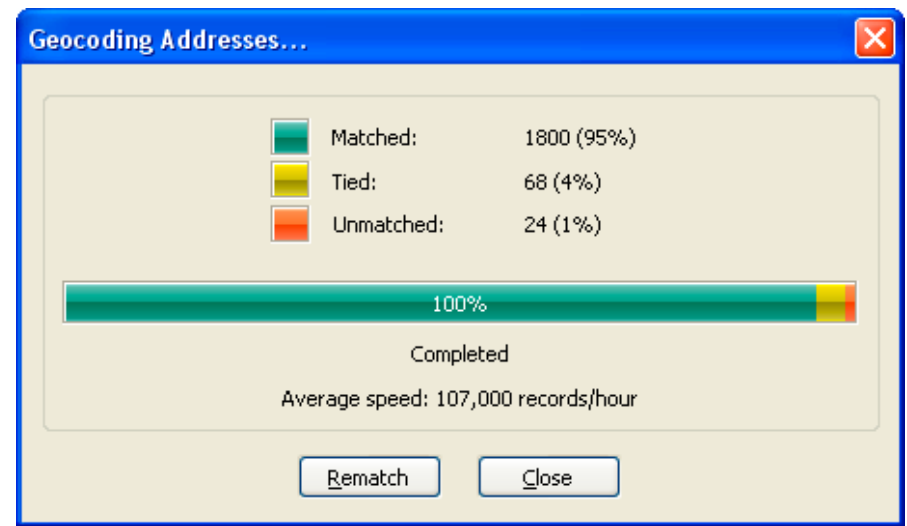
If you click "Done," you can open the attribute table for the shapefile created through the geocoding process, you will see that several fields have been added to your original address table. The "Status" field indicates whether the record was matched (M) or left unmatched (U). The "Score" field indicates how closely the record matched the street centerline file. The "Side" field indicates on which side of the street the address was matched. The "Arc_Street" field is the address used in the match. This will be the same as the original address unless you edited it during the "Interactive Review."

If you click "Rematch," you will be able to review the detailed results from the geocoding process, including which addresses were matched, tied (more than one location on the street centerline file matched the address), or left unmatched because there were no candidate locations with an acceptable score. It is best to review both the unmatched and the tied addresses. From the "Show results" dropdown, chooose "Unmatched Addresses" to get started.
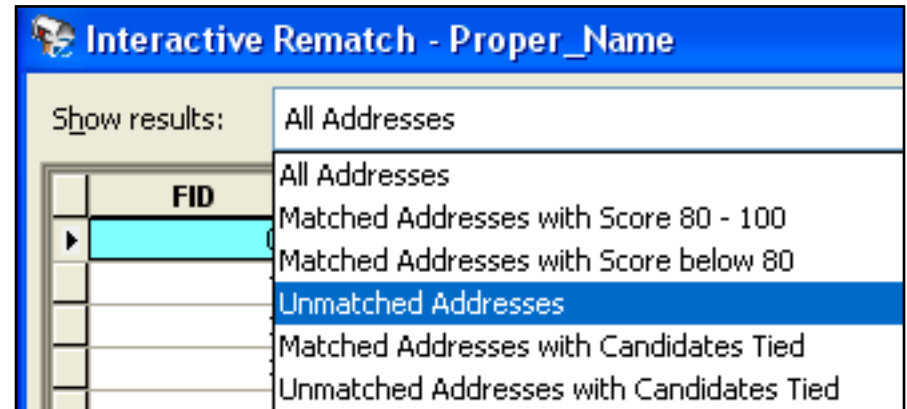

Highlight a record. To make changes (such as correct a spelling mistake or to change the house number), click in the "Street or Intersection" box. Once you have made a change, click the "Enter" button on your keyboard. Candidate addresses should appear on the right. Highlight the best one and click the "Match" button.
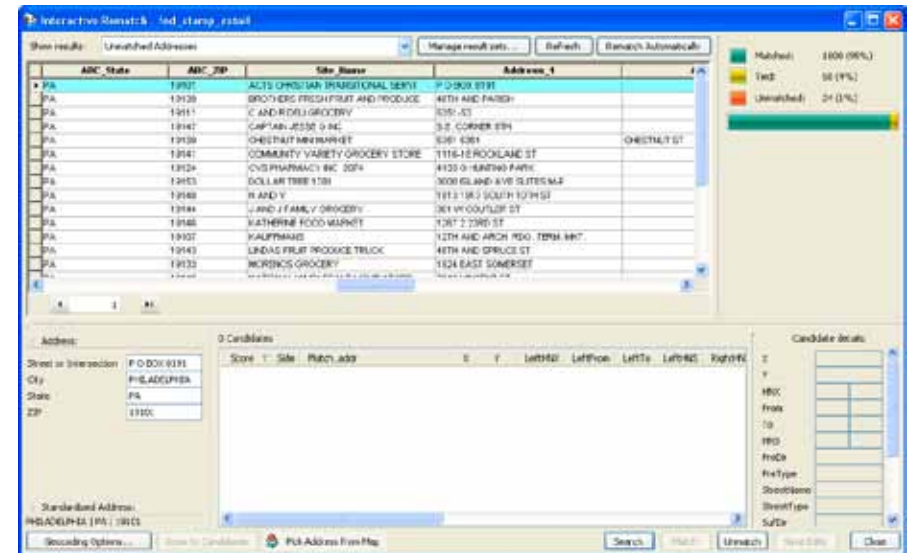
Reviewing and Rematching Addresses

You can resume the "Interactive Review" even after you've clicked "done" and stopped geocoding using the Geocoding Toolbar. The "Review/Rematch Address" button is on the far right side (mailbox with arrows). You can also geocode a single address using the toolbar or start geocoding addresses in a table (an alternative to right-clicking on the table name and going to "Geocode Addresses."
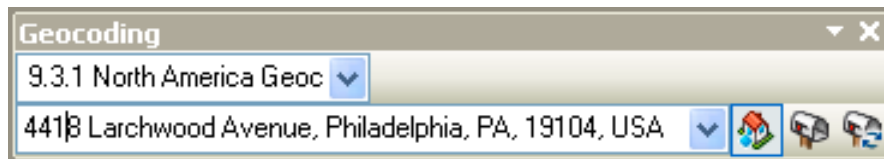
Determining an acceptable match rate

Aim for a match rate of at least 90 or 95 percent. Be sure to write down the match rate so that you can report it later. Often you will receive a list of addresses that contains some PO Box numbers or missing data that will prevent you from matching all your records. Other times your addresses will look fine but simply won't match the street centerline file. The most important thing to determine is if the error (the unmatched records) is random or systematic. If you have done all that you can to gather complete and accurate addresses, random error is acceptable and probably unavoidable. Systematic error is not. Be sure to check for patterns in your unmatched records (either by interactively reviewing unmatched records or, after finishing geocoding, open the attribute table and sort by "status" to review all the "U," unmatched records). In Philadelphia, look for problems with Roosevelt Boulevard and numbered streets (particularly 2nd – 9th Street). There is no guarantee that the matched records will be mapped in the right place. Do a spot check with the "Identify" tool to make sure that records mapped somewhere that makes sense to you.

SPATIAL JOINS

Tabular joins use a common unique identifier to attach an attribute table to a shapefile. Spatial joins use common geography to append fields from one layer, or information about a layer, to another layer. This allows you to assign the characteristics of an area—such as a census tract or city council district—to individual houses, individuals, or events as well as to aggregate points by areas.

Assigning Area Characteristics to Points

Using a spatial join, you can determine into what area/polygon a point falls. For example, you might need to determine in what council district each public school falls in.

You must have a point theme and a polygon theme in ArcMap in order to do this. Right click on the point theme, go to "Joins and Relates...," and choose "Join." In the first
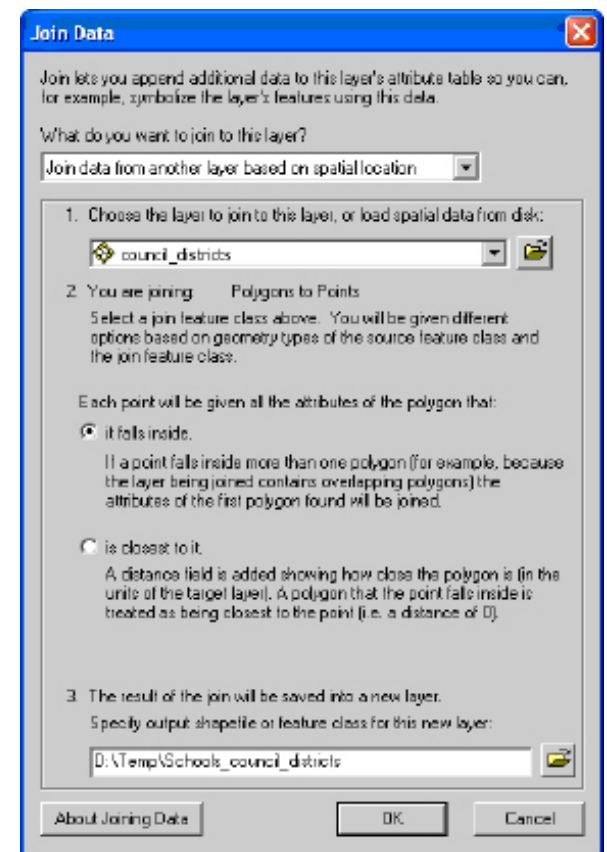
dropdown menu, indicate that you want to join data to that layer based on spatial location. In the next dropdown menu, choose your polygon layer. Next, choose the first radio button so that each point is given all the attributes of the polygon it falls inside. If you have points outside your polygon (for example, if you have a census tract map of Philadelphia with points representing addresses in the city and just outside it), choose the second radio button. Specify the name and location of the new point shapefile that will be created and click "OK." The resulting point shapefile will have as many new columns as your polygon shapefile. This may include only the polygon identifier (such as the census tract

council district. You must have a point theme and a polygon theme in ArcMap in order to do this. Right click on the polygon theme, 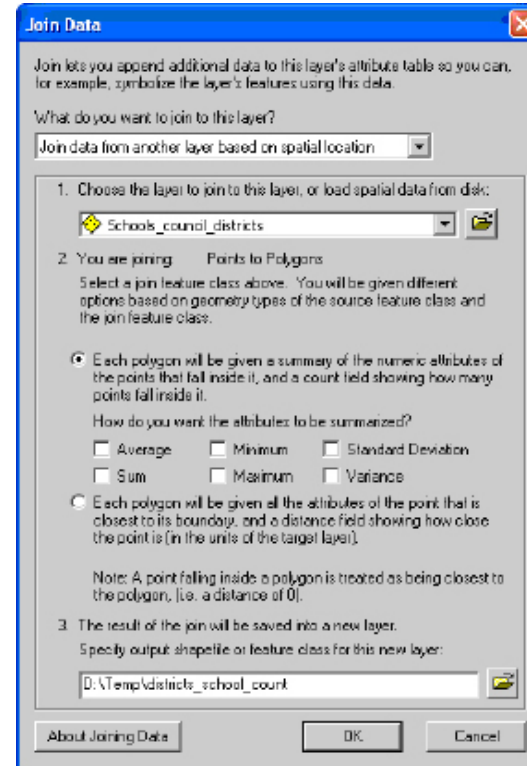go to "Joins and Relates...," and choose "Join." In the first dropdown menu, indicate that you want to join data to that layer based on spatial location. In the next dropdown menu, choose your point layer. Next, the radio button should be set for the second from the top option, "Each polygon will be given a summary of the numeric attributes of the points that fall inside it, and a count field showing how many points fall inside it." If your points do not all fall within your polygons (for example, you have a map of city council districts and points representing addresses in the city and just outside it), choose the second radio button, instead. You can then decide if you want to summarize the attributes of your points by their areas in the boxes below (for example, if your schools attribute table included a column with the total number of children enrolled, you could summarize that data so that you know how many children are enrolled in schools in each council district. Choose "Sum" in a situation like this). Finally, specify the name and location of the new area shapefile that will be created. Click "OK."

Aggregating Points by Polygons

Using a spatial join, you can also determine how many points fall in each polygon. For example, you might want to know how many schools fall in each

If you did not check any of the boxes to summarize the attributes of the points, your new shapefile will have only one new field called "count." This will indicate how many points fall into each polygon. You will probably want to change the name to something that you will remember (by creating a new field called "SchoolCount," for example, and calculating it as equal to "Count"). Now you can use this count value as the basis of a thematic map.

Depending upon the type of file you start with (right click on), the spatial join dialog box will give you different options. If you use a spatial join between two point shapefiles, you can calculate the distance between the points in one file to the closest point in the other file. For example, if you have a shapefile for public schools and for libraries, you can determine which public library is closest to each school and how far that school is. Add both point shapefiles to ArcMap. Right click on the shapefile to which you want to join information (so in this example, the public schools), choose "Joins and Relates" and then "Joins..."

From the first dropdown menu, choose "join data from another layer based on spatial location." Then choose the library shapefile as the basis for the spatial join. Notice that ArcView will recognize that ou are joining Points to Points.

The first radio button allows you to summarize the attribute for the points closest to each point in your first shapefile and gives you a count of how many points from the second shapefile are closest to each point in the first shapefile. The second radio button (more helpful for our example) allows you to identify the point in the second shapefile (library) that is closest to each point in the first shapefile (schools) as well as a distance field indicating how far apart they are. Notice in the table below that the Andoraa library is the closest library to the Shawmont School 4328 feet away).

From the first dropdown menu, choose "join data from another layer based on spatial location." Then choose the library shapefile as the basis for the spatial join. Notice that ArcView will recognize that you are joining Points to Points.

6 | Querying & Measuring

Querying by Attribute

With GIS, you can identify a subset of map features based on their attributes or their location. You may use queries as an intermediary step, as part of getting to know your data, to create new values, or to answer your research questions.

Select by Attribute

To start a query, from the Selection menu go to "Select by Attributes." Your first choice is what layer in your map you wish to query (attribute queries are limited to a single layer). In the Method drop down menu, you need to decide whether you are building on a previous query or starting fresh.
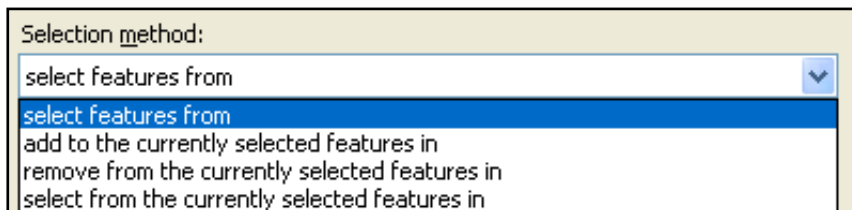
From here, the query dialog is similar to the Field Calculator. Build an expression using the field names and functions, connecting statements with "AND" or "OR" as necessary. If you want help working through these steps, click on the Query Wizard button. Click "Verify" to make sure ArcMap likes your expression. You can import (Load) and save expressions (using the buttons OR using Ctrl + C and Ctrl + V with a word processing file). Note that if the values you input are text, rather than numbers, you need to put single quotes around them (for example, 'BROAD'). When you click "Apply," the map features that satisfy your query will be highlighted with a bright blue outline.

To review the selected records, right click on the map layer and go to "Open Attribute Table." Click on the Select button at the bottom to view only the selected records. You can calculate values on an existing or new field for only the selected records. You can also look at summary statistics for only the selected records by right clicking on a column name and going to "Statistics." By looking at the statistics for the length field on the selected southbound one-way streets, we can see that there are 3,462,432 feet (655.7 miles) of southbound one-way streets in Philadelphia.

To see all of the selected records, from the Selection menu, go to "Zoom to Selected Records." You can create a new shapefile that only includes your selected map features by right clicking on its name in the Table of Contents, going to "Data" and "Export Data." Choose the radio button regarding coordinate systems (you'll probably want the default). Make sure you have "Selected Records" chosen in the Export drop down menu. To un-select all records, from the Selection menu choose "Clear Selected Features." You can perform an additional query (adding, removing, or selecting from this selected group) or close the query dialog.
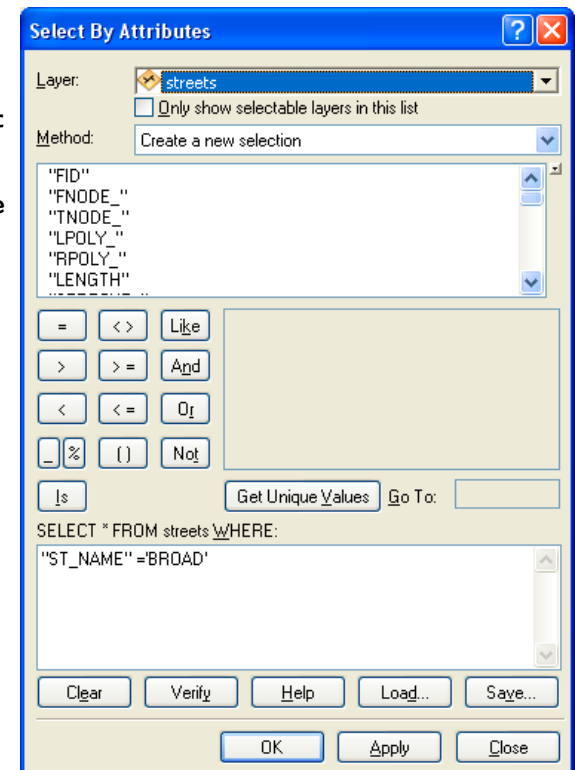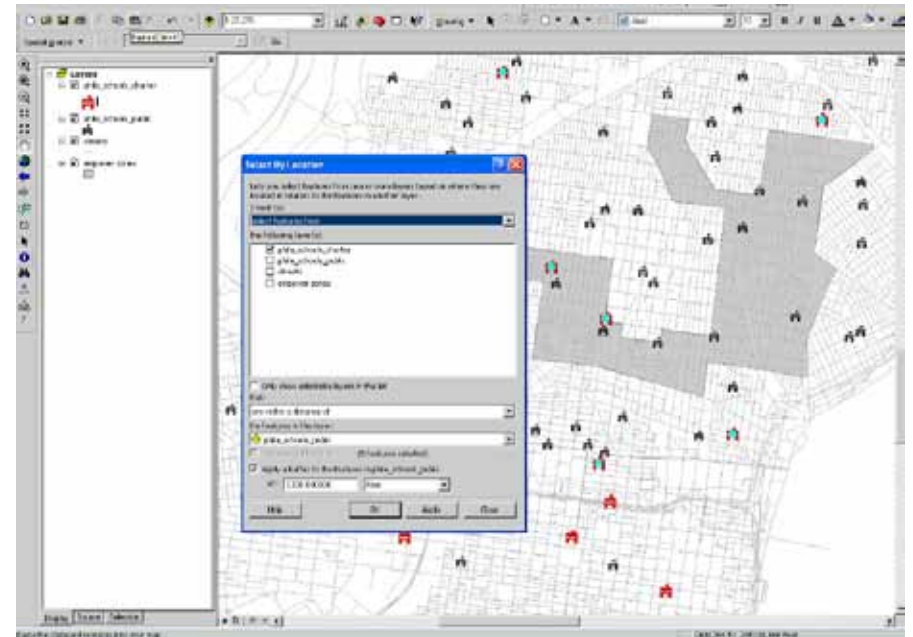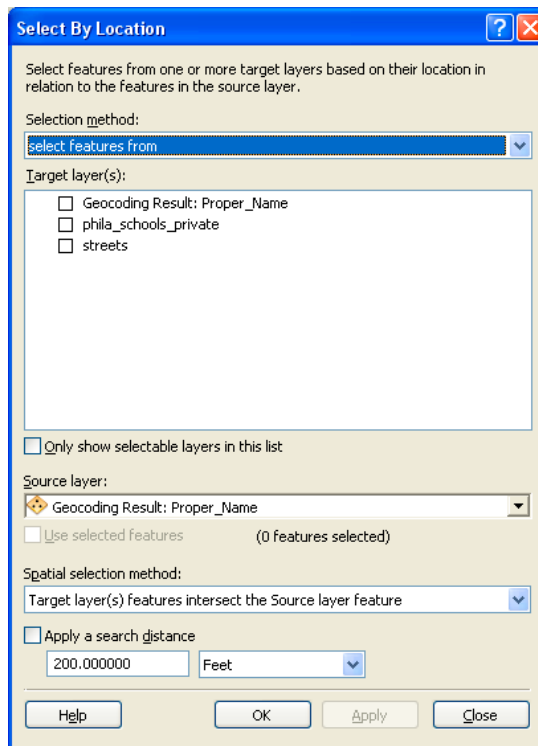
QUERYING BY LOCATION

The ability to query based on the location of map features is something unique to GIS, and combining attribute and location queries really takes advantage of GIS functionality.

Select by Location

To select features in a map layer based on their location, from the Selection menu go to "Select by Location." Your first choice is the selection method. Are you starting from scratch or querying a subset of map features already selected? In the next box, put a check mark next to the map layer(s) whose features you wish to select. The drop down menu then provides various relationships between the features in that layer and the "source" layer, identified in the next drop down menu.

For distance-based queries, you will be able to select your units as long as the map units have been specified in the Data Frame properties. This query shows which charter schools are within ¼ mile (1320 feet) of public schools.

Combining Attribute and Location Queries

The "Select by Attribute" and "Select by Location" dialogs do not allow you to mix the type of query. But by performing one type of query first and then conducting a subsequent query on the selected records, you can perform attribute and location queries on the same map layer. For example, you may be interested in which schools are located within 500 feet of class 1 (highways) streets. Using the "Select by Attribute" dialog, identify all the code 1 streets first, then select the schools "within a distance" of 500 feet of the selected streets. Under "Selection Method," be sure to choose "select from the currently selected features in" when you perform the second (location) query; otherwise you will loose the results form your attribute query. There is no limit to how many queries you can combine.

Using Query Results

The turquoise highlight feature is meant to help you visualize relationships, but it is not meant for final maps. Once you have identified a subset of records, create a new variable and symbolize it properly using the symbology tab. For example, if you want to create a map showing the schools that are located within 500 feet of highways, complete the query and then use the query results to create a dummy variable indicating which schools meet the query definition. Do this by opening the attribute table for the schools. Create a new variable called "Class1500" (for 500 feet within class 1 street) that is formatted as an integer. Right click on the new column, then go to "Field Calculator." Set Class1500 = 1. Only the highlighted records will be assigned this value. Assign the other records = 0 by going to "switch selection" from the "option" button on the bottom of the table.
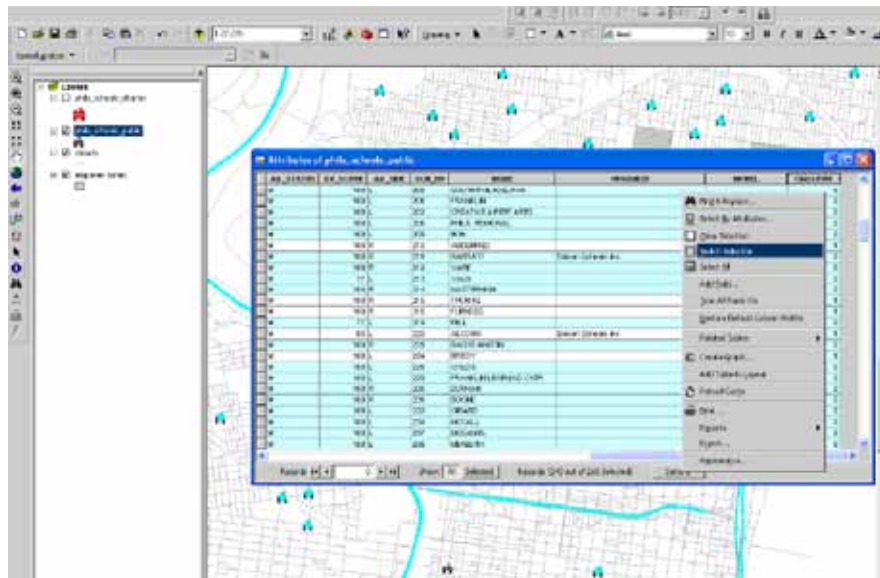
MEASURING DISTANCES

Using the Measure Tool

The measure tool (on the Tools toolbar; it looks like a ruler) allows you to draw a line, or a series of connected lines, to roughly measure the Euclidean (as the crow flies) distance between points.
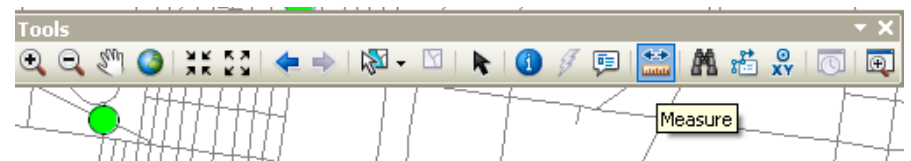
Click on it and then click on your map at the starting point. Move your cursor to your end point, or next point, repeating until you are done. Double click to finish. The measure tool will use the map units particular to that map layers projection or the display units you specified in the Data Frame Properties. You can change this from the Data Frame Properties (right click on the name of the Data Frame, go to Properties, and the General tab) or in the Measure pop-up box.

The black triangle pointing down includes various distance units to choose from.

You can also calculate Area using the tool shaped like a polygon. Simply draw a polygon and double click to finish.

Measuring with Attribute Data

If you need more accurate measures of distance than you can get using the measure tool, you can use the values in the perimeter (polygons) and length (line) fields of the shapefile attribute tables. Select the features of interest, then right click on the perimeter or length field and go to "Summary." The "sum" field will indicate the total distance. For example, if you need to know the total length of Broad and Market Streets, go to "Select by Attributes" and select all line segments in the street centerline file called "BROAD" or "MARKET." Then open the attribute table associated with the street centerline file, right click on the "length" column heading, and go to "Summary." The "sum" should indicate how long Broad and Market Streets are.

BUFFERS

Buffers allow you to visualize zones around map features. If you are interested in seeing which schools fall within 500 feet of class 1 (highways), you can create a 500 foot buffer around class 1 streets. For analysis purposes, queries by location may be more helpful because they will allow you to actually select the schools within 500 feet of class 1 roads. But you may want to create buffers, as well, so that you can visualize this relationship.

The easiest way to create buffers is using the Buffer Wizard. You'll need to add this to one of your toolbars (from the View menu, go to Toolbards, then Customize, then click on the "Commands" tab, then click on the "Tools" Category. Click on "Buffer Wizard" and drag it to one of your toolbars. Click on the new tool to launch the wizard. Select the map layer you wish to buffer using the first dropdown menu. You can choose to buffer all features or just the currently selected features in a map layer. Click "Next." Determine the distance for your buffer (adjust the distance units at the bottom). If you want to have more than one buffer, choose "As multiple buffer rings." Click "Next."
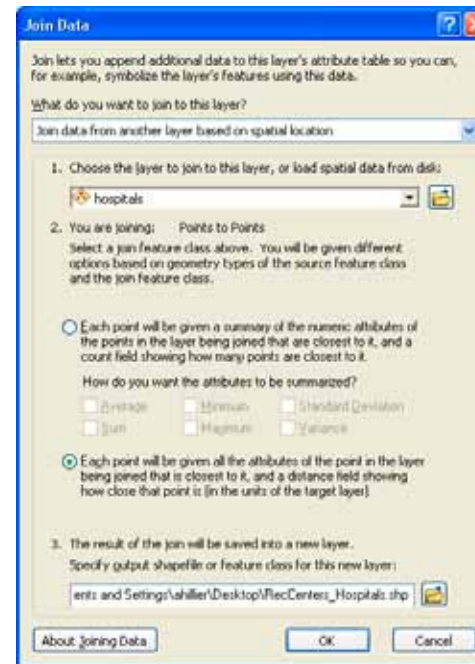
On the final screen of the Buffer Wizard, choose whether you want to dissolve the boundaries between buffers--since in many cases, your buffers will overlap. In the next section, you will choose "only outside polygon(s)" in most cases. Your final choice is whether to make your buffers graphics, which are temporary, or as a new shapefile, which is permanent. If you are just playing around to figure out what size your buffer should be, use graphics. If you plan to use the buffers for any analysis, be sure to save it as a shapefile. If you choose to make a shapefile, click on the folder icon, indicate where the shapefile should be stored, and give it a name. Then click "Finish."
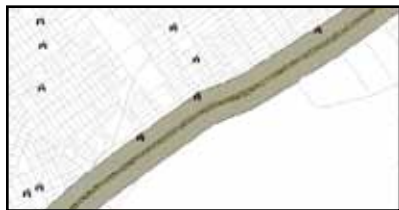
Calculating Distances with Spatial Joins

The spatial join tool allows you to determine the relationship between two shapefiles. This is helpful if you need to determine in what polygon (such as neighborhood) a point (such as a school) falls. But you can also use it to calculate the distance between the closest features in two different shapefiles. For example, you might want to know the distance between each of your clients' home and the closest health clinic or supermarket.

Add both shapefiles to ArcMap. Right click on the shapefile to which you want to calculate the distance, then go to "Joins and Relates" and then "Joins." Choose the spatial join option, then indicate the second shapefile, and choose the second radio button which will calculate a distance field indicating how far features are from your first shapefile to the closest feature in this second shapefile. Indicate the location and name of the new shapefile and click "OK." Your new shapefile will look like the original shapefile but will have a new field in the attribute table indicating distance to the closest feature in the second shapefile.

AV_ADD	AV_STATUS	AV_SCORE	AV_SIDE	Distance
OLD YORK & TABOR ROAD	M	70		8121.851624
OLD YORK & TABOR ROAD	M	70		3457.545113

Calculating Network Distances

The measuring tool, buffers, and spatial join tools all calculate Euclidean, or straight line ("as the crow flies") distance. This can be useful to get a general idea of how far apart geographic features are, but Euclidean distance does little to show how people move from one place to another. ArcGIS's Network Analyst allows you to calculate distance along a network--such as a street network.

Creating a Network Database

Most street centerline files can be used with Network Analyst, but you must go through a series of steps to convert it into a network dataset. First, make sure that the Network Analyst Extension is turned on. From the Customize menu in
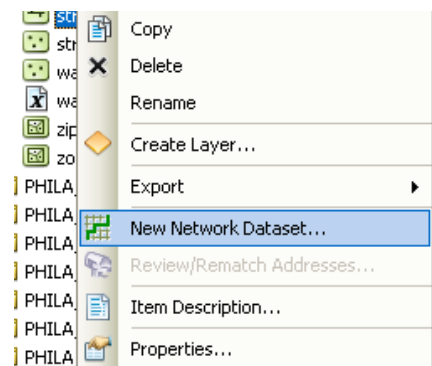
ArcCatalog, go to "Extensions" and put a check mark next to "Network Analyst." If it is grayed out, you do not have access to this Exension (meaning your license doesn't include it or you neglected to choose to load extensions when you first installed ArcGIS). Open ArcCatalog and navigate to the folder with your street centerline file. Right click on the file name and go to "New Network Dataset...". Give your street network a name; it must end with "_ND." Click "Next" and say "Yes" to modeling turns. Click "Next," "Next," and "Next" again.
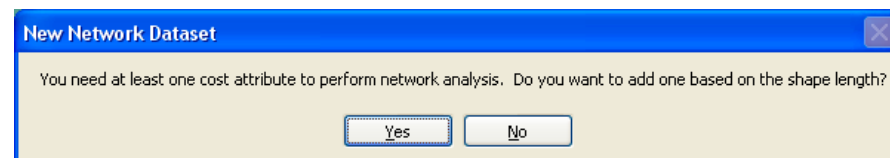

On the screen "Specify attributes for network dataset," click "Next." A dialog box will pop up indicating that you need at least one "cost attribute." The default is to base the "cost" on the length of the street segments. Ideally, you would have additional information such as how long it takes to travel along certain streets, or how much it costs (tolls, fares, etc.) Say "OK" then "Next" (yes, you want to be able to generate driving directions), and then "Finish." ArcGIS will then need to build the network which could take a minute.

Using a Network Database

In order to use your network, you'll need to add it to ArcMap. First, make sure the Network Analyst Extension is turned on in ArcMap. From the Customize menu, go to "Extensions" and put a check mark next to "Network Analyst." Then add your network database into ArcMap--the same way you add a shapefile. Be sure to add the network file, not the junctions. The network file will have a special icon and the extension ".nd."
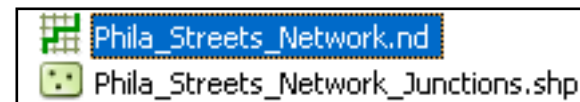

ArcGIS will ask if you want to add all the related features. You can say "No" to avoid having lots of extra data on the map (if you say "Yes," you'll see all the junctions which are shown as points at every intersection). The network file will look just like a street centerline file when it's mapped. Next, turn on the Network Analyst toolbar (from the Customize menu, go to "Toolbars" and select "Network Analyst." The toolbar includes a menu on the far left. Click on the
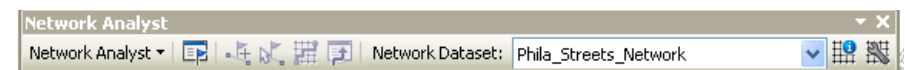
button beside that, "Hide/Show Network Analyst Window." A new window will appear beside the Table of Contents.

Network Distance to Closest Facility

You can calculate the distance between the features in one shapefile to the closest features in another shapefile--just like you can with the Spatial Join tool except that with Network Analyst, you can calculate the distance along a street network in order to approximate travel by foot or vehicel. From the dropdown menu on the Network Analyst toolbar, choose "New closest facility." A number of new items will appear in the Table of Contents. In the Network Analyst
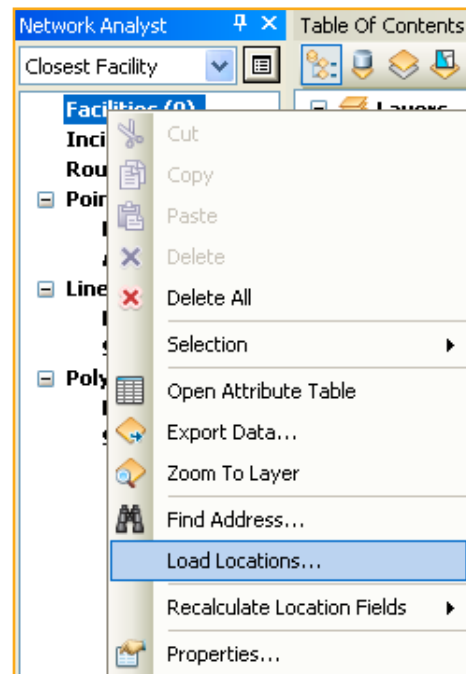
window, right click on "Facilities" and go to "Load Locations." Choose the shapefile that you are calculating distances to (such as clinic, school, hospital, etc) and click "OK." Another way to think of "facilities" is "destinations." Give ArcMap a minute to load. Right click on "Incidents" and choose the second shapefile (the "origins"), then click "OK." Give ArcMap time to load. You should see the total number of facilities and incidents listed in the Network Analyst window in parentheses. If you discover that you made a mistake, the best thing is to start over (go to the Network Analyst menu in the toolbar, choose

"New closest facility," then load the facilities and incidents again). Click the "solve" button (two to the right from the dropdown menu on the Network Analyst toolbar). Right click on "Routes" in the Network Analyst window and go to "open attribute table."
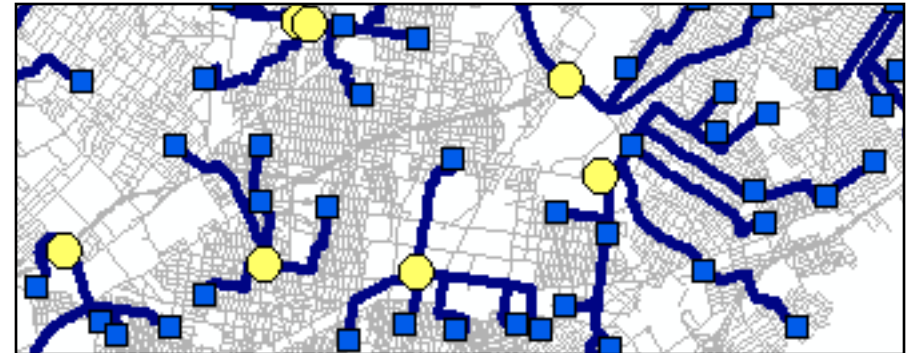

Service Areas (Network buffers)

You can create network buffers which will calculate an area of a specified distance along a network from features in a specified shapefile. Rather than the circles you get when buffering points with the Buffer Wizard, you will get diamonds (if your streets network is a perfect grid) or some odd-shaped polygons. From the dropdown menu on the Network Analyst toolbar, choose "New Service Area." Right click on "facilities" in the Network Analyst window and go to "Load locations." Choose the shapefile you wish to buffer from the dropdown menu and click "OK." Click on the "Service Area Properties" button in the upper right corner of the Network Analyst window.

Click on the "Analysis Settings" tab and specify the distance for your buffers. You can also indicate if you want the network to consider one-way streets (for driving) or no (for walking). Click "OK," then click on the "Solve" button on the Network Analyst toolbar.
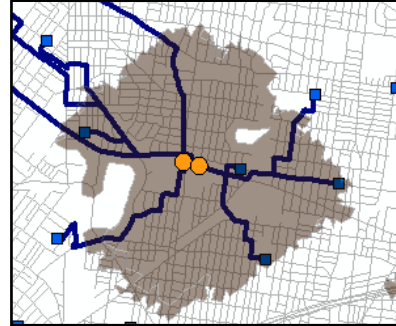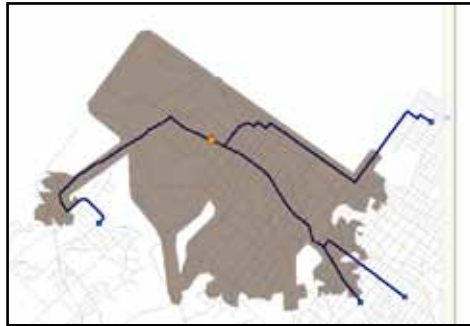
Notice how different the shapes of the service area are based on the street network. Also, look at what happens on the edges of your network. This is a verion of the broader class of problems called "boundary effects." Street boundaries do not actually stop at the edge of a city the way data files do.

Network Routes

You can determine the short-ened network route from two or more points--just the way you do with online applications like GoogleMaps or MapQuest. Add in the points along the route. From the Network Analyst toolbar dropdown menu, choose, "New Route." In the Network Analyst window, right click on "Stops" and go to "Load locations." Choose the point shapefile with your loca-tions and click "OK." Then click the

"solve" button on the Network Analyst toolbar. Notice that the default route is

to travel to the locations in the order in which they are listed in your shapefile. This might be necessary (for example, if the stops are listed in the order in which you make them during the day such as coffee shop, work, lunch, car wash, food store, home), but in other cases, you may want to maximize your efficiency (imagine you are running errands or making home visits). Click on the "Route properties" button (on the Network Analyst window) and go to the "Analysis Settings" tab . Check "Reorder Stops to Find Optimal Route" and decide if you need to preserve the First or Last stops. Click "OK" and then click the "Solve" button again.
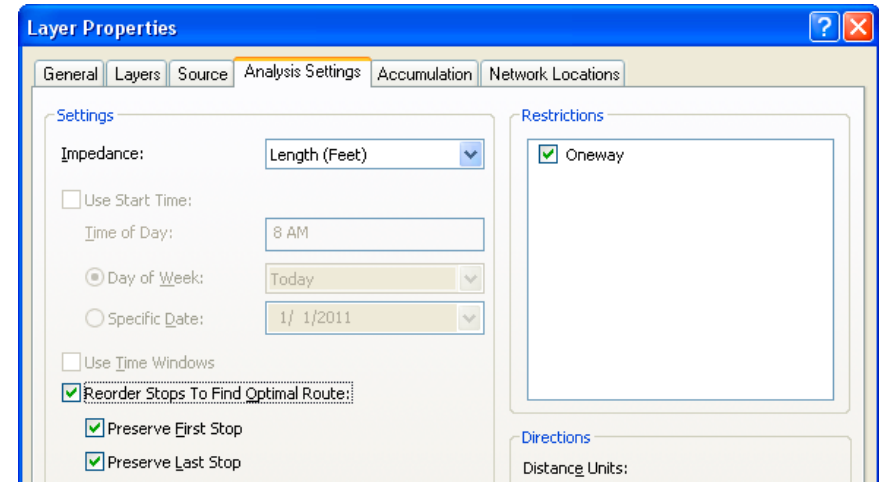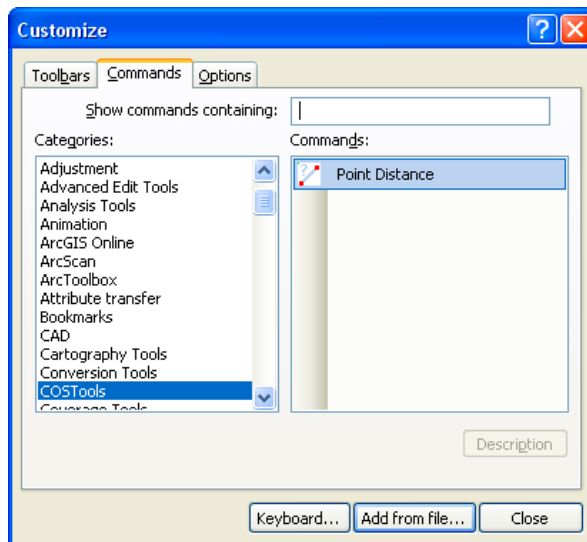

In order to generate driving directions for your route, click on the "Directions Window" button next to the "Solve" button. Notice how similar they look to what you get from one of the mapping websites (they use the same technology).
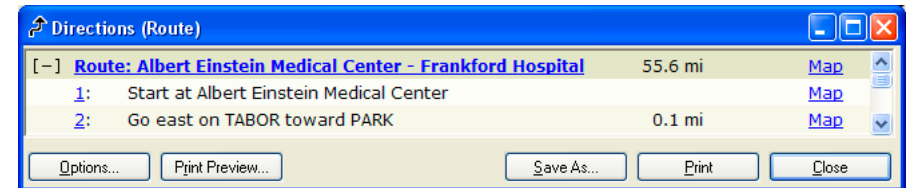
Distance between Matched Pairs

When you calculate the distance between two sets of points using the Spatial Join or Network Analyst, you can only calculate the distance between the closest facilities. If you want to calculate the distance between points in one file to matched points in another, you need to use a script. Imagine, for example, that you have patient addresses and their health care provider. You can download cripts to extend ArcGIS functionality from the Esri website or you can create them, yourself.
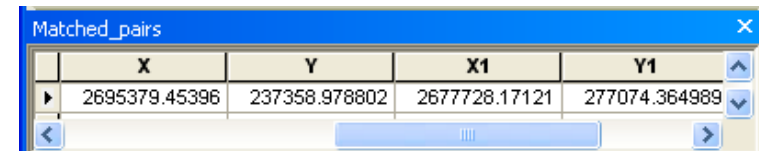
The Point Distance script (http://arcscripts.esri.com/details.asp?dbid=13523) allows you to calculate the distance between matched points. After downloading it from the website, you need to add it to ArcMap. From the Customize menu in ArcMap, go to "Toolbars" and "Customize." Click on the "Commands" tab and click on the "Add from File" button. Search for the script (it will have the extension .dll) and then click "Open." A new category, "COSTools," will appear under "Categories" and a "Point Distance" tool will appear under "Commands." Drag and drop the Point Distance tool to one of your toolbars.
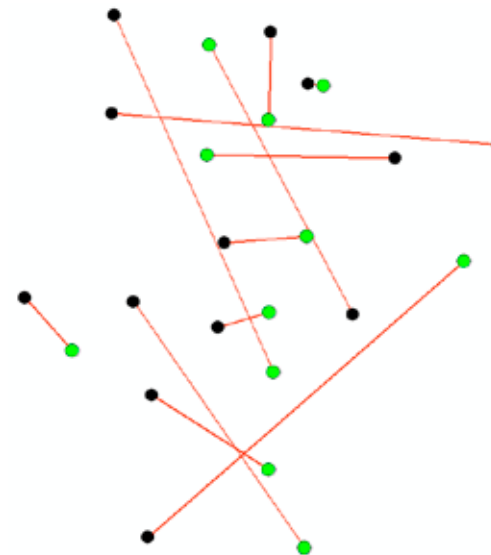
In order to work with the Point Distance tool, you will need to add a table or shapefile that has fields corresponding to the X and Y coordinates for both points.

You can create a file like this using the "Calculate Geometry" feature, to calculate the X and Y coordinates of a point. You'll need to join the tables from the two separate (matched) shapefiles using some sort of common unique identifier.

Click on the Point Distance tool to open the dialog. Choose "Matched_pairs.shp" from the dropdown. You will generate a new line shapefile connected the matched points; give this new file a name under "Output Line Shapefile." Select the X and Y values for the first set of points for the "From" fields and the second set of X and Y values for the "To" fields. Then click "Process." Say "yes" to adding the new shapefile to ArcMap. Right click on the new shapefile and go to "Open Attribute Table." The distances will appear in the variables "Distances_2D" (these will be in feet because of the projection settings for the shapefiles). The new line shapefile will connect the location of the first point to its matched pair.
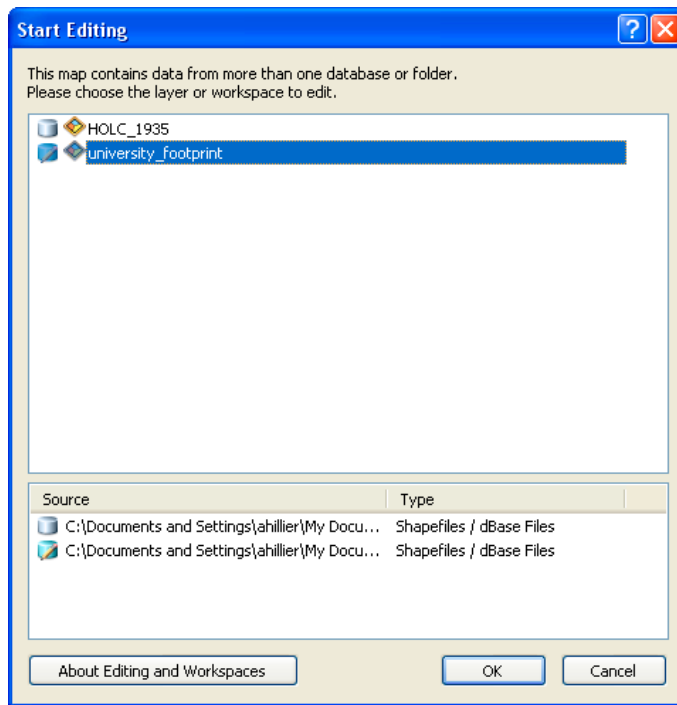
7 | CREATING NEW GEOGRAPHIC FILES

EDITING SHAPEFILES

Editing shapefiles is tricky—and a bit dangerous—territory. If possible, use the geoprocessing tools such as clip, union, intersect, and dissolve to make changes to your shapefiles rather than using the editing tools described below. The directions provided here are very minimal. If you need to do much editing of shapefiles, you should seek out additional resources (such as the Esri Virtual Campus course on digitizing).
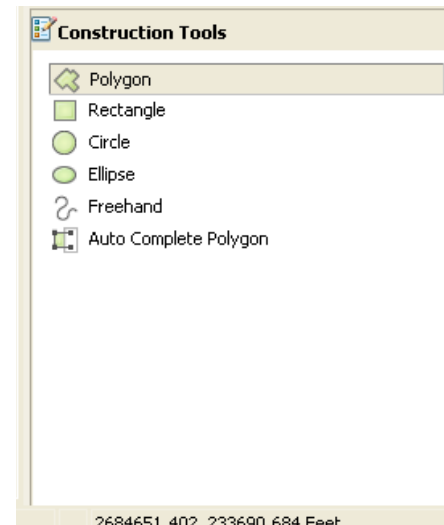
Deleting and Modifying Features

In order to make changes to a shapefile, you must start an edit session. From the Editor toolbar, choose "start editing." If you have multiple shapefiles in your map document that are from different sub-directories on your computer, you will need to specify which directory will be part of the edit session (you can only edit the files in a single folder at one time).

A new window will appear on the far right

side of your screen, next to the Catalog Window if you have that open. To save edits, from the Editor menu on the Editor toolbar, choose "Stop Editing" and say "yes" to saving edits. Notice that you do not have a "save as" option. You may want to make a backup of your original data before editing. Click on the name of your shapefile in the top section so that options appear under "Construction Tools." You can use any of these to add features to your shapefile. You can "snap" a new feature to an existing feature to avoid small "sliver" polygons between two map features. The snapping options are available in the Edit menu.

You can also edit existing features by clicking on the edit tool (looks like the head of a black arrow) and double-clicking on a feature. Notice that green squares appear at ever vertex of your feature. You can add or delete features using the "Edit Vertices" toolbar that appeared when you double-clicked on the map feature. You can also split a polygon in half. To do this, highlight the feature you wish to split (this involves a single click, not a double-click; you want to see the blue highlight but not all the vertices). Click on the "Cut Polygons Tool." Draw a line across the polygon and double click to complete the spit.
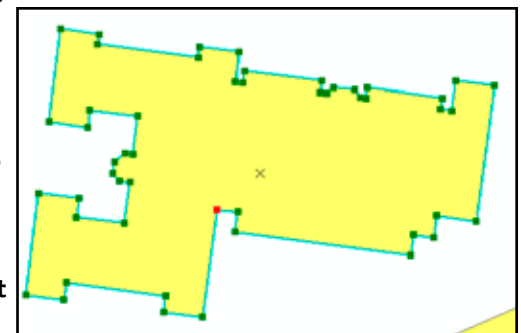
Merging Features

In order to dissolve the boundaries between two or more polygon features, you must start an edit session. Using the edit tool and the shift key, click on the features you wish to merge (they should become highlighted). You can also select map features based on their attributes by opening the attribute table and selecting the corresponding records. From the Editor menu on the Editor toolbar, select "Merge." By merging the two features, you are also merging the attributes. ArcGIS will ask you to choose the feature with with other features should be merged; the attributes from this feature will be maintained. To save edits, from the Editor menu on the Editor toolbar, choose "Stop Editing" and say "yes" to saving edits.
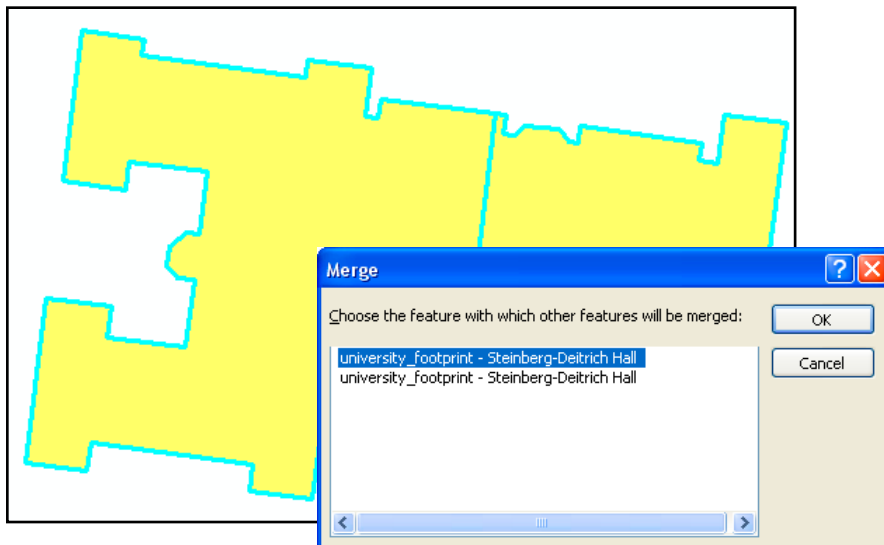

Updating Area, Length, and Perimeter

Keep in mind also that editing shapefiles can change attribute values that you may need to update. Follow the directions in the section of this guide entitled "Calculating Area."

Geoprocessing

There are a number of different functions you can perform on map layers, either based on location or attribute value, that result in new map layers. In ArcGIS 10, these are once again called "geoprocessing" functions. You must define the projection for map layers before using any of these functions. If you have selected a subset of features within a map layer, the functions will only be performed on the selected features.

Dissolve

The dissolve operation allows you to collapse the boundaries between polygons if they share the same value on a particular attribute. For example, you could create a neighborhood map layer by assigning each census tract to a neighborhood and then dissolving the boundaries. From the Geoprocessing menu, go to "Dissolve" to bring up the Dissolve wizard. On the first screen, identify the map layer whose features you wish to dissolve under "input features." If the layer is already added to ArcMap, you can use the dropdown menu. Otherwise you will need to click on the folder icon to locate the may layer. ArcMap will give the new shapefile that will be created a default name (adding "_Dissolve" to the input layer name). If you want to rename this or change the location, click on the folder to the right of "input feature class." Next, choose the "Dissolve Field"--the column from that layer's attribute table that contains the information you wish to use for the dissolve. This must be an attribute for which multiple map features (polygons)
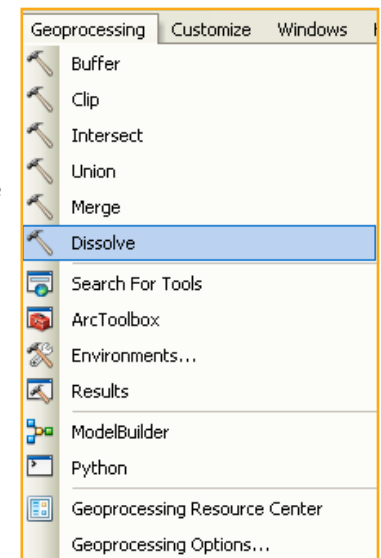
have the exact same value (numbers or text). ArcGIS will create a new shape-file that combines all of the map features (census tracts) into a single polygon (neighborhood). You can aggregate data for the original geographic units to the new (dissolved) geographic units using the optional "Statistics Field."
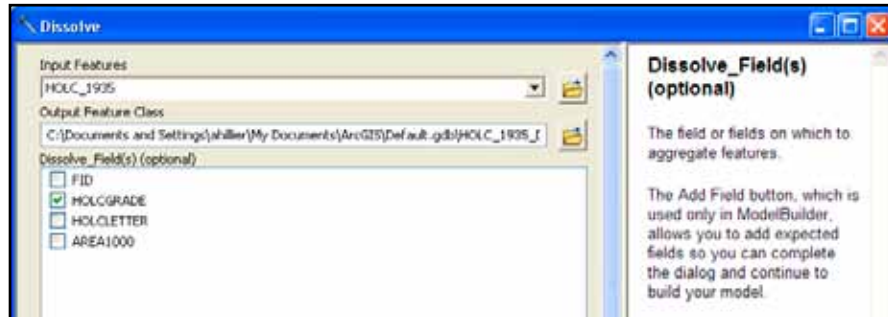

Merge

Appending allows you to incorporate two or more non-overlapping layers into a single map layer without changing their map features. You can append point, line, and polygon layers. Appending can save you time when it comes to symbolizing features and lead to more consistent symbology. For example, you can merge census tract files from several counties so that when you display the percent of homeowners, you don't have to repeat the process of classifying your data for each county.

From ArcToolbox, you can find "Append" under "Data Management Tools" and "General." Under "input features," list all the map layers you wish to merge. You can use the dropdown menu if you have added the map layers to ArcMap, but you will need to add them one at a time (if you add them directly from your computer, not from ArcMap, you can highlight multiple shapefiles and add

them all at once). A new layer will be created containing all of the features of all of the shapefiles. Specify the location and name for this new shapefile and click "OK." After a few seconds, you will see "Merge... Merge...Merge" appear at the bottom right of your screen. When ArcGIS has completed this process, the new shapefile will appear at the top of the top of the Table of Contents.
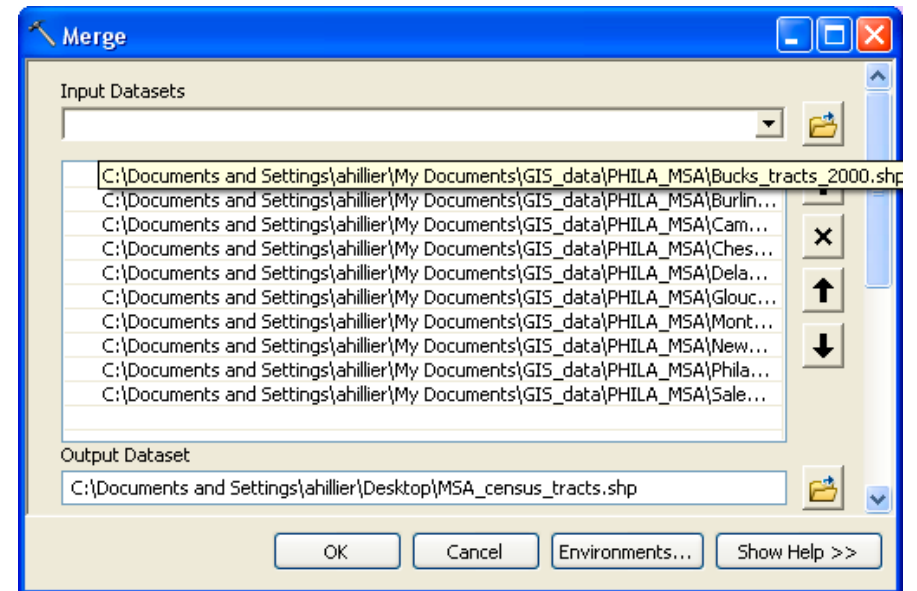
Clip

Clipping allows you to turn one shapefile into a cookie-cutter in order to cut out part of a larger shapefile. For example, you might need to create a map layer of streets for the area within a single police district but your street centerline file covers the entire city. Using a street file that is clipped by the police district boundaries will allow you to work with a smaller and more manageable file that looks neater. From the Geoprocessing menu, go to "Clip." On the next screen, you need to identify an input feature (the layer to be clipped) and the clip features (cookie cutter). The default name for the new shapefile will be the input feature name plus "_Clip." If you want to change this or the location of the new file, click on the folder to the right. You can leave "Cluster Tolerance' at 0. Changing it will allow slightly mismatched map layers to be considered "coincident."
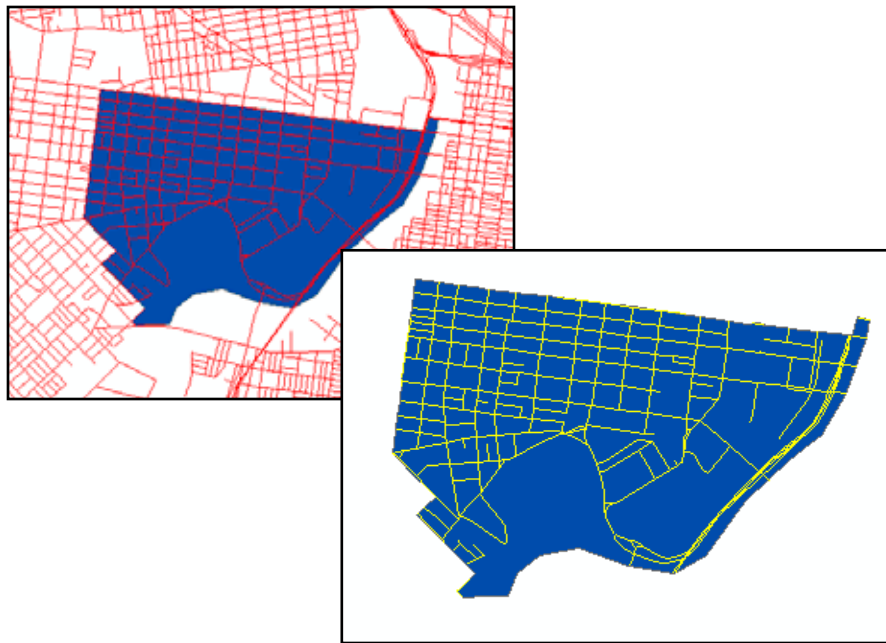
Intersect

Intersect allows you to fuse two overlapping layers together to create a new shapefile that includes the attributes of both layers for the area in which the layers overlap. In effect, this combines the union (described below) and clip operations. You can intersect two polygon layers or a line and polygon layer. From the Geoprocessing menu, select "Intersect." On the next screen, select the input features. The default name for the new shapefile will be the first input feature name plus "_Intersect." If you want to change this or the location of the new file, click on the folder to the right. If you intersect a line and polygon layers, the resulting shapefile will contain "polylines" that act like lines. If you intersect polygon layers, the resulting shapefile will contain polygons. Length, perimeter, and area values will be inaccurate after you perform an intersection, so if you need these, be sure to recalculate them.


Union

Union is similar to intersection in that it fuses the boundaries of two layers together, but rather than clipping the resulting shapefile to include only the area covered by both, it creates a new shapefile that covers the combined extent of the layers. From the Geoprocessing menu, choose "Union." On the next screen, select the input features. The default name for the new shapefile will be the first input feature name plus "_Union." If you want to change this or the location of the new file, click on the folder to the right.

8 | DIGITIZING

Most of the time you will use shapefiles that someone else created. Using existing shapefiles saves time and generally results in more accurate map layers. But if you need a line or polygon file that doesn't exist—such as a boundary for your study area—you will need to create it yourself. Digitizing is the process of drawing or tracing map features to create a new geographic file. Before on-screen digitizing was available, this process involved tracing a paper map on a digitizing tablet and then assigning real world coordinates to certain parts (like georectifying). But ArcView has on-screen digitizing tools that allow you to create new shapefiles without additional hardware or software.
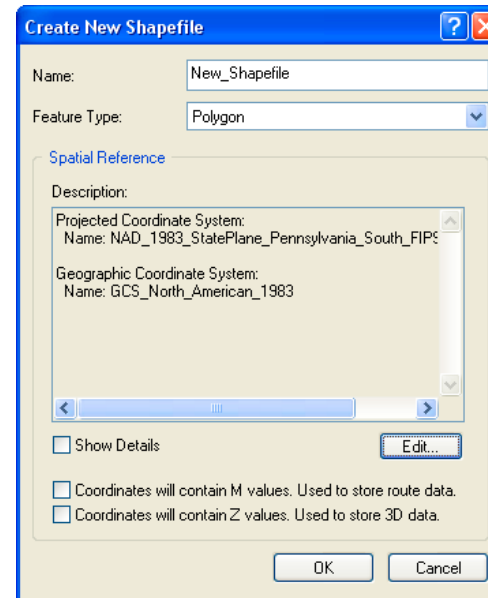
Creating New Shapefiles

You'll need to create a new empty shapefile to get started. You can make a copy of an existing shape-file, delete all of its features (start editing, highlight all the features, and click the "Delete" key on your keyboard) and then create new features. Alternatively, you can create a brand new shapefile. To create a new shapefile, right click in a folder within the Catalog Window and go to "New" and "Shapefile." Decide what kind of shapefile you need (point, line, polygon), give it a name, and set the projection if you know what you'll be using.
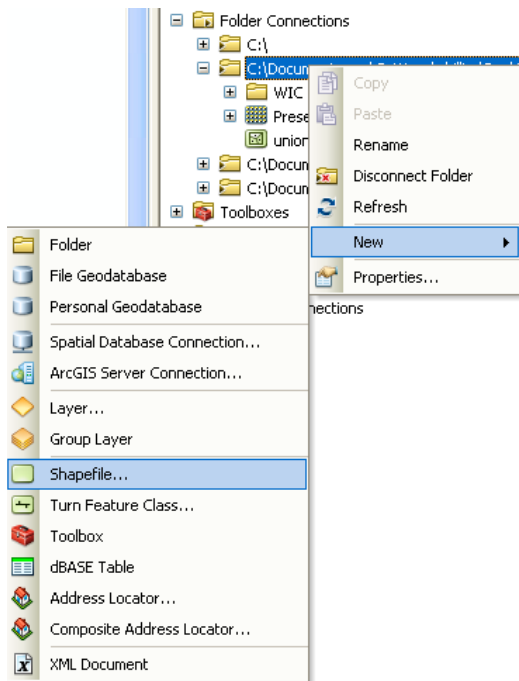
Next, open ArcMap and add your new shapefile, along with other map layers that may help you draw your new features. Start an edit session: from the Editor menu in the Editor toolbar, choose "Start Edit Session," and indicate which directory contains the shapefile (shell) you just created. Click on your new shapefile name in the "Create Features" window that should appear on the far right, next to the Catalog Window, to bring up the construction tools. Create one or more features (remember, the snap options in the Editor menu will allow you to make much neater shapefiles) and then go to "Stop Editing" and say "Yes" to saving changes. Open the attribute table for your new shapefile. Notice that there are FID and Shape fields but nothing else. You can add attributes manually, by creating new fields and filling in the values or by joining an existing at-tribute table to the new shapefile.
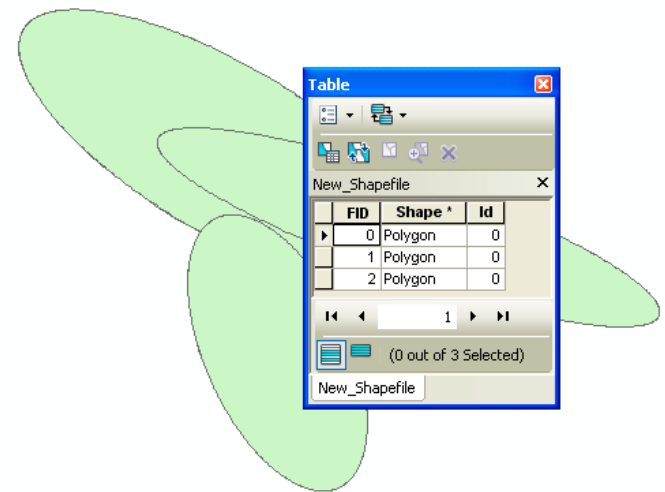
Digitizing using the Merge Tool

The tools in ArcMap for dissolving boundaries between features provide another approach to digitizing. This may give you less control over the shape of new map features, but it provides an easier way of creating new shapefiles that line up with existing shapefiles. In order to create shapefiles using the dissolve tools, you need to have a shapefile that can serve as building blocks for your new file. For example, you may want to create a map of health districts. If the districts are based on census tracts, you can use a shapefile of census tracts to build your new district file. A census block file may prove the most helpful since its boundaries correspond to streets. It is a good idea to make a copy of the shapefile you will use so you don't mess up the original.
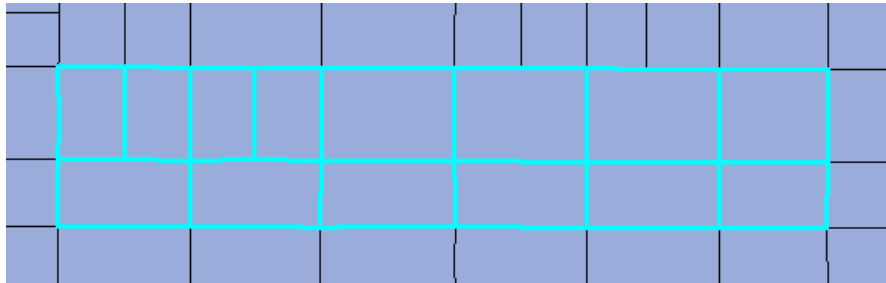

Using the "Select Features" tool, highlight the blocks that make up the new area for which you are creating a shapefile. You can select multiple features by holding down the shift key. You can also draw a box around the area containing the individual features (this is faster). To dissolve the boundaries between the blocks, from the Editor menu go to "Start Editing," then choose "Merge." Stop editing and save edits to finish. If your new shapefile only needs to include this single map feature, you can right click on the new feature you just created, go to "Data" and "Export Data." Be sure that the Export drop down menu indicates that only selected features will be included. Alternatively, you may need to repeat the process of dissolving boundaries to create all of the map features.

Creating a Mask

Masks are shapefiles that allow you to cover up areas that you don't want to show without clipping them. Clipping data only works with shapefiles, not with grids/raster data, so masks are especially useful when you are working with raster data. To do this, add a shapefile of the area you want to be able to see—for example, a neighborhood or city—and an empty polygon shapefile. Start editing the new shapefile and create a rectangle around your other shapefile, large enough to cover up any area you don't want to see. Stop editing and save changes. Use the "Union" tool in the Geoprocessing menu to fuse these two shapefiles together. Then start editing the resulting fused shapefile. Highlight the inside of the new shapefile (the area you want to be able to see), open the attribute table and click the "delete" key. Save your changes.
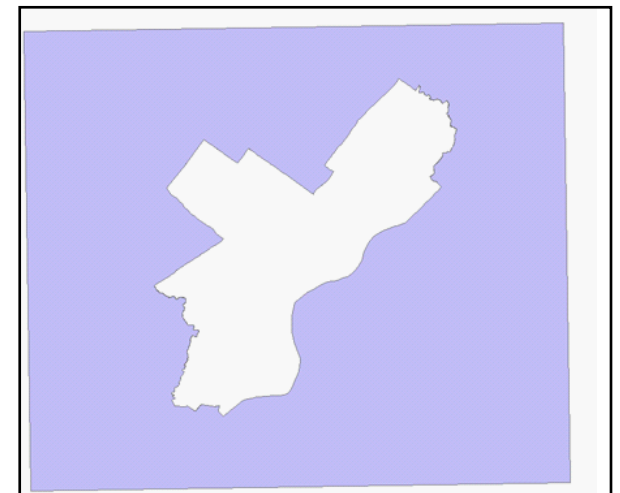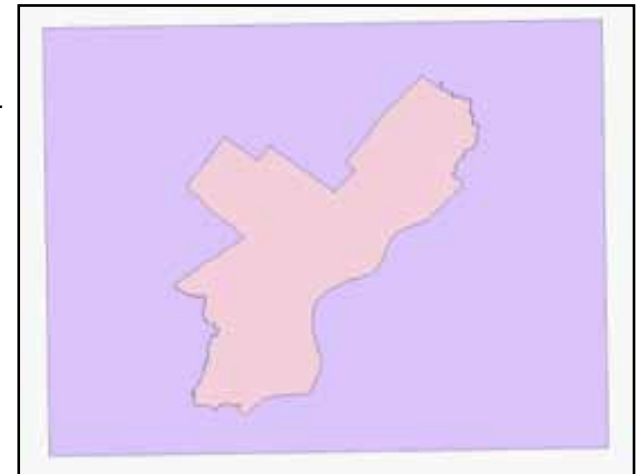
9 | CREATING DENSITY MAPS

Working with grids/raster data involves a whole different set of concepts and tools--well beyond the scope of this introductory manual. Raster data have a number of advantages over vector data, the most important of which is that it shows continuous change over space without the awkward dependence upon administrative units (like zip codes and census tracts) that have little meaning for our lives. Density maps provide simple yet visually powerful alternatives to the more common maps showing points or data aggregated by areas.

Spatial Analyst

Spatial Analyst is an extension for ArcGIS that allows you to work with raster data. From the Customize menu in ArcMap, go to "Extensions" and put a check mark next to "Spatial Analyst." If it is grayed out, you do not have a license for this product. Next, add the Spatial Analyst toolbar (Customize menu, "Toolbars," then "Spatial Analyst"). In earlier versions of ArcGIS, the Spatial Analyst toolbar included a number of tools. In ArcGIS 10, those tools are only accessible from
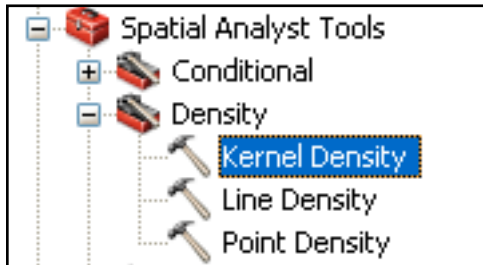
ArcToolbox. Open the ArcToolbox Window (using the button at the top of ArcMap that looks like a red toolbox). Expand the "Spatial Analyst Tools" section and then expand the "Density" section.

Kernel Density Maps

Add a point shapefile to ArcMap (one with at least 100 points; the more the better). Double-click on the Kernel Density option. This will calculates the magnitude of per unit area using a kernel function which will result in a smoothly tapered surface. Some people call these "heat" maps or "hot spot" maps. There are other methods for creating density maps, but the Kernel function creates an especially smooth map that weights close points more than points further away. From the first drop-down menu, select your point shapefile. The next drop-down, "Population field," is optional and should be used if there is an attribute by which you want to weight the points (for example, if you are mapping hospitals, you might choose "beds" as the population field). ArcMap will create a new raster layer so specify an appropriate location and name. The Output cell size refers to the size of the individual cells that will make up the grid. The smaller you make these, the finer (smoother) your density map will be, but small cells also create big files. ArcMap will offer a suggested search radius. This refers to how far away from each cell points will influence the density value. The smaller the radius, the coarser the density map.
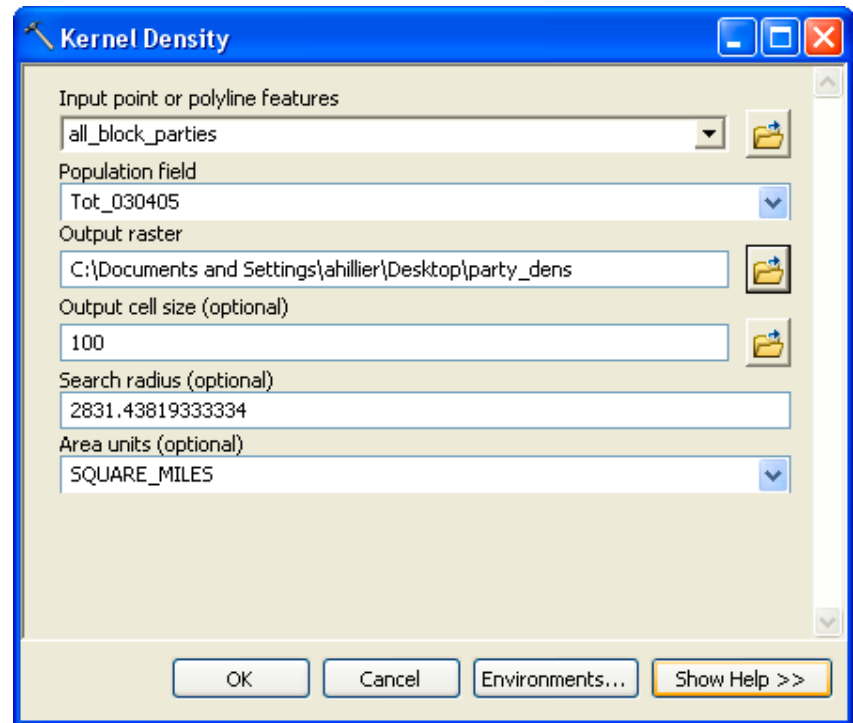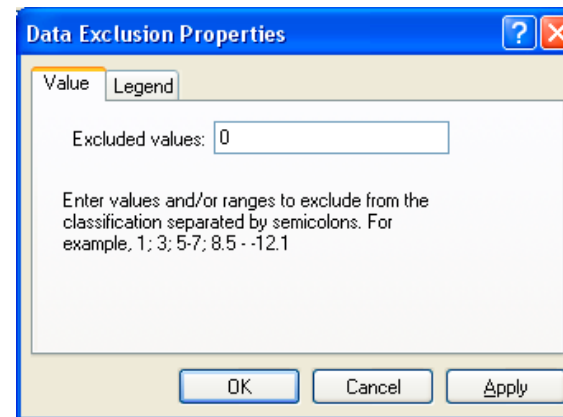
It will take a few seconds for ArcMap to generate the density map. You will see the words "Density... Density... Density" appear at the bottom right of your screen while it is still processing. Be patient because this is a lot of processing. In effect, ArcGIS is calculating the number of points within the search radius you specified for every cell across the area covered by your point shapefile and weighting the points based upon how close they are to the cell. A new raster layer will appear in your Table of Contents, under your point shapefile. Turn off your point shapefile so you can inspect the new layer.
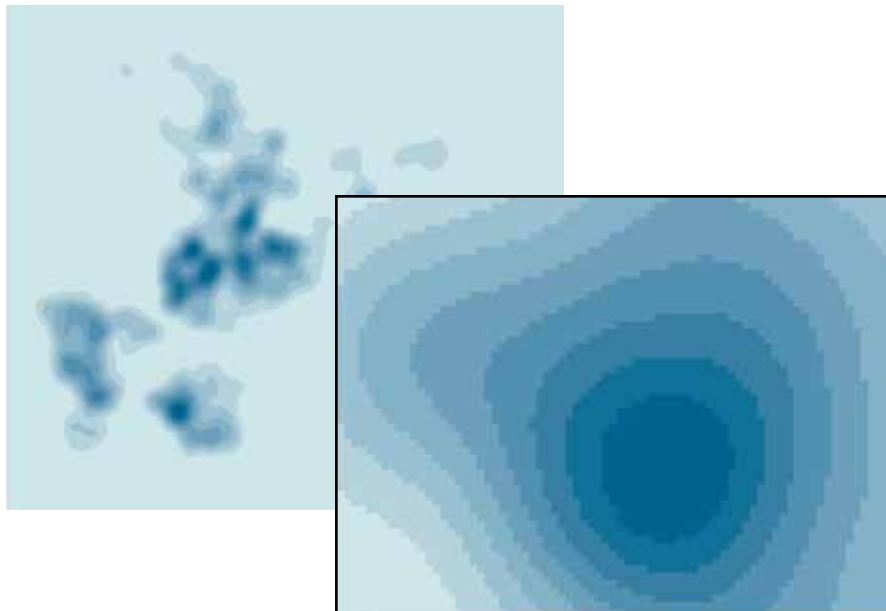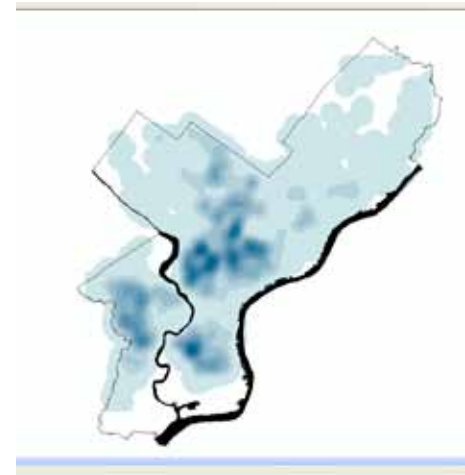

If you zoom in on the density map, you will be able to see the individual cells that make up the raster surface. Each of these cells will be the size you specified when you calculated the raster density. If your map looks too grainy, even when you are zoomed out, try a smaller cell size. Use the Identify ("i") tool to identify the attributes for an individual cell. Notice that there is just one attribute, the

"pixel value." This represents the density value of points based on that location. The number doesn't mean much by itself, but it is useful as a relative measure. Don't try to interpret the numbers too literally. You might consider changing the labels for your density map layer using the options in the "Symbology" tab of the Layer Properties. You can exclude cells from the color ramp where the density value is zero from the Symbology Tab. Click on the "Classify" button, then "Exclusion" and type "0" in for the Excluded value.

There are no hard and fast rules for determining the appropriate search radius, even though this choice will have a big impact on how smooth your data are. You may want to try severl different radii to make sure the pattern you are seeing is robust. Keep in mind that the distribution of your points may reflect an underlying distribution (such as population or housing stock) rather than some "significant" clustering.

10 | WORKING WITH 3D

3D Models of Vector Data

3D modeling happens in ArcScene rather than ArcMap. ArcScene is a separate application (.exe file) that you can launch from the Start Menu (Programs, ArcGIS, then ArcScene). Once open, it looks similar to ArcMap with a Table of Contents in the left, where the names of your map layers will appear, and a big space to the right where your map layers will draw. You add map layers into ArcScene just like ArcMap, with the "Add Data" button or from the File menu, "Add Data." Don't worry if your map layers look funny when you first add them. Vector polygons layers will draw as solid fill colors without any outlines. Points and lines will look more similar to the way they draw in ArcMap. It is possible to make points and lines 3D, but polygons work better.

Most of the buttons on the tools toolbar for navigating your map layers are the same in ArcScene as ArcMap, but a few are new.
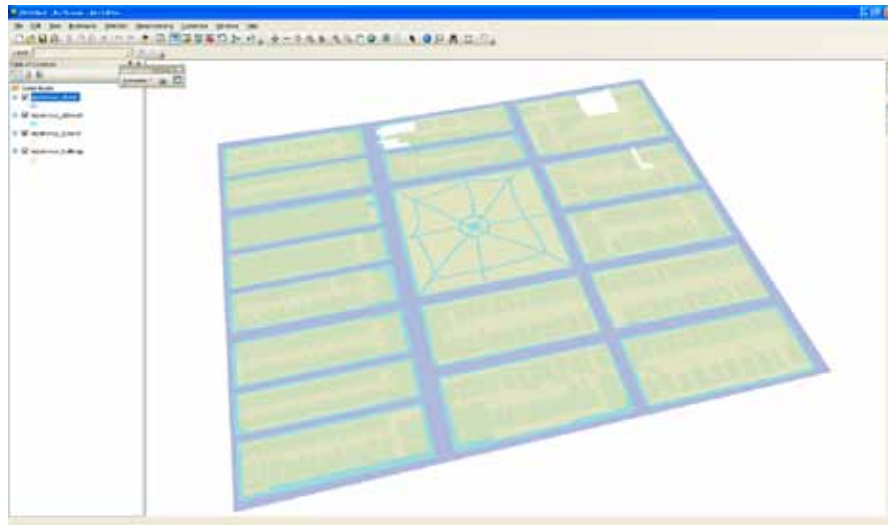

The navigate button ⊕ is the most useful. When you hold down the right mouse button, you ⊕ can spin and twist your map layers, looking above or below them and from any angle. If you click the left mouse button, you will be able to zoom in and out continuously. If you hold both buttons down, you can pan your map layers (move them around without zoom in or out or tilting them). The zoom in/out button allows you to zoom in and out continuously (like the continuous zoom tool in ArcMap). It is even easier in ArcScene to loose track of where you are than it is in ArcMap. Click on the full extent button 🌐 to bring your map layers back. The fly tool allows you to swoop in 🌐 and around your model (caution: this may cause motion sickness). Hit "Esc" to stop.
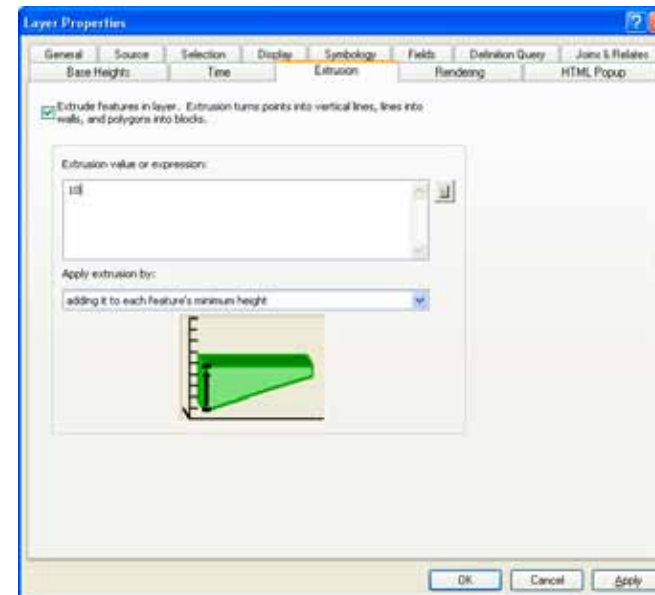

In order to make your polygons 3D, double click on the map layer. Most of the tabs under "Layer Properties" are the same as ArcMap, but some are new. Click on the "Extrusion" tab. Here you can enter a constant value under "Extrusion Value or Expression" in order to make the entire layer the same height. This makes sense in some situations, such as when extruding streets and sidewalks in an impervious surface layer.
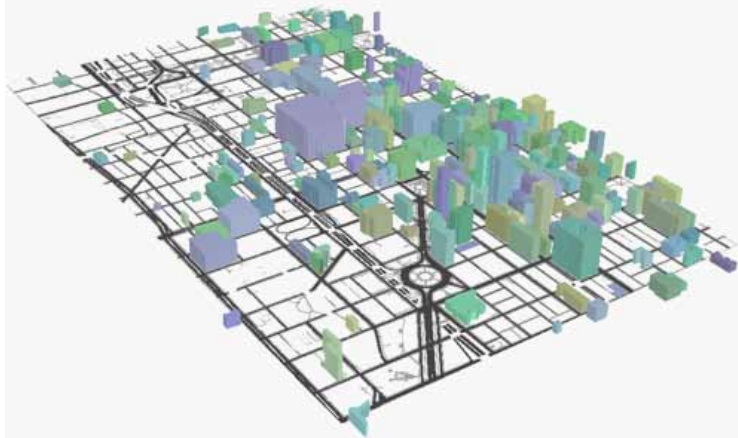
More often, you will want to extrude the polygons based on an attribute. For example, if you have a height variable, you can extrude the polygons to reflect this. Click on the little calculator to the right of the "Extrusion value or expression" box and use the "Expression Builder" to create a formula for the height of the building. You may need to adjust the formula later to make your relative heights work, but don't worry too much at this point. Click "OK" and then click "OK" again. Now your buildings should be different heights. You can use attributes other than height or elevation as the basis of the extrusion. For example, you can extrude neighborhoods based on the amount of crime.

In order to see the differences in the height more clearly, use the
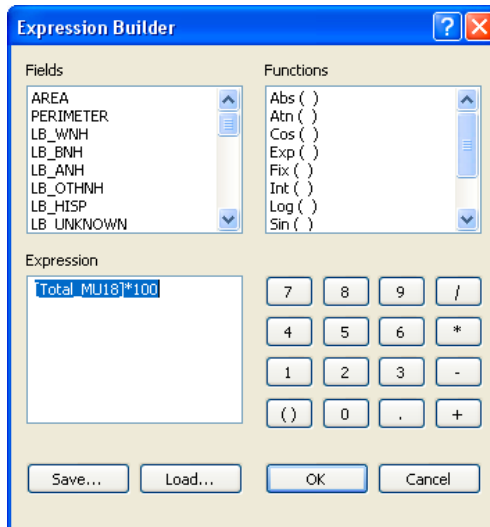
options under the Symbology tab (use this just the way you do in ArcMap) to make different heights different colors (graduated color map based on height variable). You can use different variables for the basis of your extrusion and symbology, especially when you are extruding based on height or elevation. For example, you can use the extrusion option to make buildings different heights and then use the symbology options to use different colors to show which properties are vacant.

Scene Properties

Instead of having "Data Frames," like in ArcMap, ArcScene has "scenes." You can change the properties of the scene--including the background color, vertical exaggeration, and illumination--from the Scene properties. Double-click on the word "Scene Properties" at the top of your table of contents or go to the View menu and "Scene Properties." From the General tab, you can change the background color (black looks pretty cool). You can also change the vertical exaggeration. This is especially helpful when your layers look too flat or way too tall after extrusion. Click on "calculate extent" for ArcScene's suggestion for how much you should exaggerate the vertical extent.

If you put a check mark in the "Enable Animated Rotation" box, you can make your 3D scene spin around continuously. Rotate your scene with the navigate
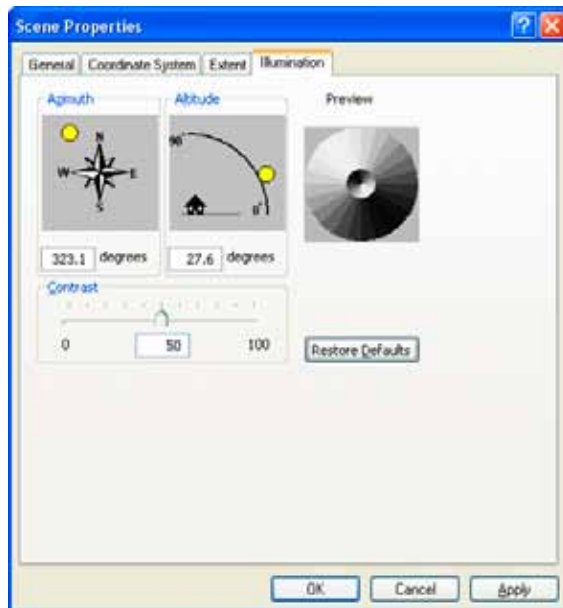
button, then let go of the mouse button while the scene is still moving. Imagine that your scene is sitting on top of a lazy susan and you are just giving it a push in the right direction. Hit "Esc" to stop the animation. From the Illumination tab, you can change the height and direction of the sun to adjust the lighting in your 3D scene.

3D Models for Raster Data

Raster data makes for great 3D models in ArcScene. Add your raster layer to ArcScene just as you do vector layers. If you are asked about building pyramids, say "yes." Don't worry if your map layer looks funny when you add it. From the "Layer Properties" click on the "Base Heights" tab. Click the radio button next to "obtain heights for layer from surface." This means that the values stored in your raster layer will be used as the basis for the layer's height. Then from the "Symbology" tab, switch to a classified map and symbolize your map using one of the color ramps. You may want to exclude all 0 raster values (click on classify, then exclusion and type in "0") and add extra classes so that the color ramp shows more gradual differences in value.
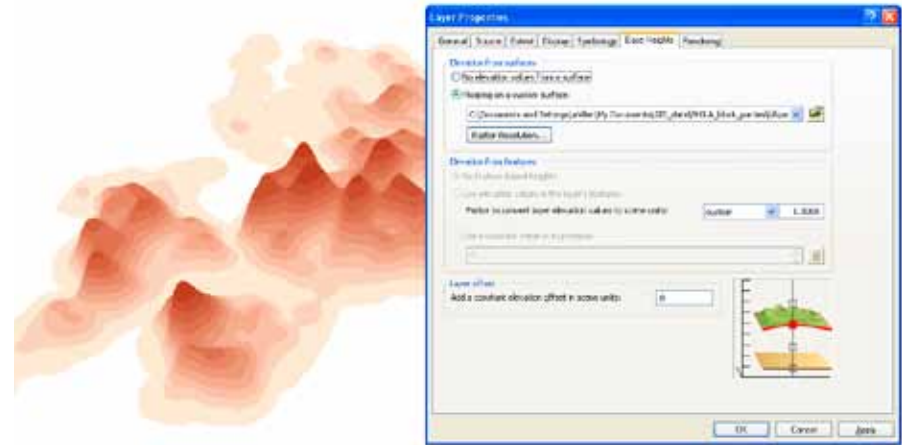
Animating 3D Scenes

To animate your 3D scene, you need the Animation Toolbar to be visible ("View" menu to toolbars, then "Animation"). The animation will be based on a series of snapshots of your 3D scene. Use the navigate tool to create the first perspective. Click on the camera button once (or use "Ctrl" + "A"). Use the navigate tool to choose your next perspective, then click on the camera. When you have created all your images, open the animation tools (using the button at the far right of animation toolbar). Click on the play button to view your animation. You can adjust the length (from options button) and speed (from Animation menu, Animation Manager) of your animation.

Saving 3D Scenes

You can save your 3D scene in the same way you save a map document in ArcMap. Instead of an .mxd file, you will create an .sxd file. Since these behave in the same way as .mxd files, you need to remember to keep the .sxd file with the shapefiles or raster layers upon which the 3D scene is built. To export an image from ArcScene as a 2D image, go to the "File menu" and "Export scene" and "2D." You can also save an animation as a video file.

11 | ANIMATING TIME SERIES DATA

ArcGIS has two tools for representing time series data--the Animation Toolbar and the Tracking Analyst. Both require that each record in your shapefile is "time-stamped" meaning that one of the attributes is a date. This could be in the format of seconds:minutes:hours such as the data generated by GPS devices or simply a year or decade associated with census data. Tracking Analyst works best with GPS data while the Animation Toolbar works well with area data that are part of a time series and point data that have start and end dates.
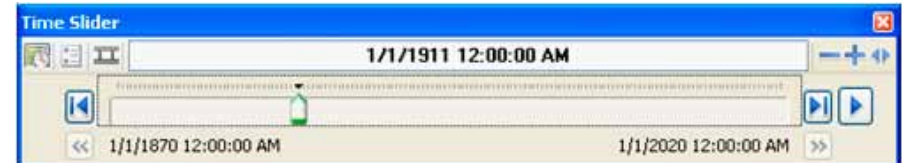
Animation Toolbar

Make the animation toolbar active (from the Customize menu, go toToolbars, then Animation). Add in the shapefile that you want to animate, for example, a point

shapefile with all the theaters in Philadelphia that operated between 1880 and 2009. From the Layer Properties, go to the "Time" tab and enable time on this layer. Choose the appropirate drop-down option under "Layer Time" indicating whether you have a start and end date or just single point in time. Indicate the fields with the start and end times and make sure the "Time Step Interval" is set. Click "OK." From the menu on the Animation Toolbar, go to "Create Time Animation." Use the "Animation Controls" to decide how long the animation should run. Then click the play button to watch the animation.
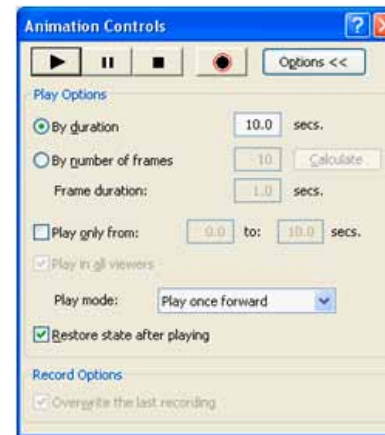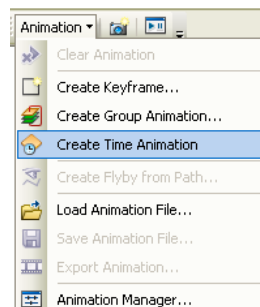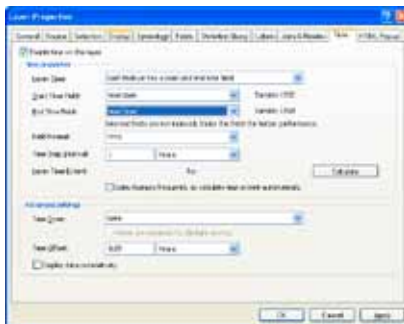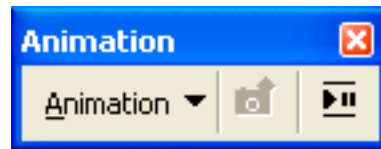
Under "Start Time," choose the variable that includes the opening date, then choose the format. If you have an End Time, fill in those fields the same way. Then click "Create." Click on the button the far right side of the Animation toolbar to access the animation controls. Press the "Play" button. Your points should begin appearing and disappearing. You can also view the change over time using the Time Slider. When temporal data are present, the time slider button on the Tools toolbar is activated. Click on it to open the Time Slider.


You can export the animation as a video from the Animation menu on the Animation toolbar. Note: these files can become large very quickly.

You can also animate areal (polygon) data such as US census data, although this involves some considerable reformatting to work. In order to animate, you need to have a separate row for each record (polygon, such as a census tract) for each time period. In order for this polygon shapefile to work with the Animation toolbar, you must create a new record (representing a state) for each time period. You can do this by merging multiple copies of the same shapefile together using the Merge toolbar. In the end, your table should list each of your

geographic areas (census tracts, states, etc) multiple times, each time with a different date and value for the variable of interest.


Before you can view the animation, you must symbolize your polygon shapefile. The map that appears will be for the first data point. Go to the layer properties and click on the "Time" tab. Put a check mark in the first box, to "Enable time on this layer." Identify the field with the date and specify the time interval. Click "OK." Next, add the Animation toolbar (Customize" menu, then "Toolbars"). From the Animation menu, choose "Create Time Layer Animation." You should receive a message that the Time Layer Animation has been created; click "OK." Click on the "Open Animation Tools" button on the Animation Toolbar, then click the Options button. Click on "Options" from the Animation controls to change the speed of the animation. You can also create a video. From the Animation menu, choose "Export Animation..."
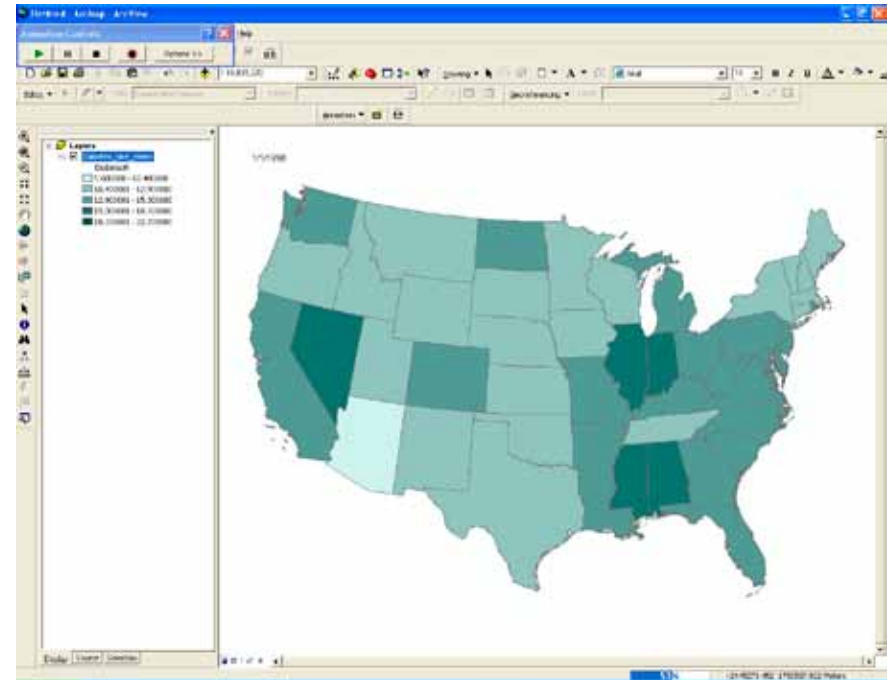
Tracking Analyst

Tracking Analyst is ideal for working with data collected with a GPS. Add your point shapefile. Be sure the Tracking Analyst Extension is turned on (from the Tools menu, go to "Extensions" and make sure there is a check mark next to Tracking Analyst). Make the Tracking Analyst toolbar visible (from the View menu, go to "Toolbards" and then "Tracking Analyst."
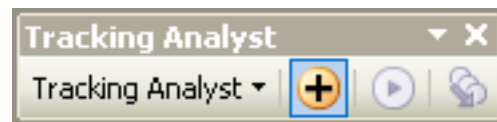

Click on the "Add Temporal Data" button on the Tracking Analyst toolbar (yellow dot with a + in the middle). If your shapefile includes the time attribute, you can select the first radio button. Next, click on the browse button to locate your shapefile. From the next drop-down window, choose the variable that includes your time field. Click "Next." Specify the format of your time data and click "Next," then click "Finish" (you don't need to specify a query. A new "Events" theme will appear in your Table of Contents.
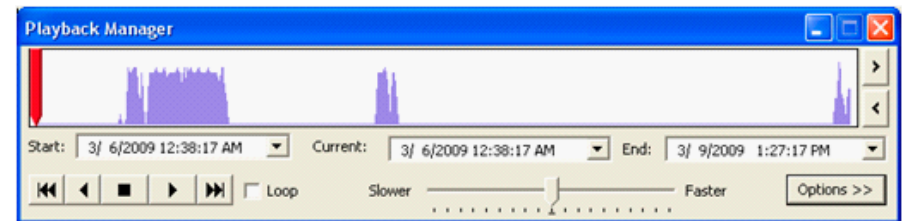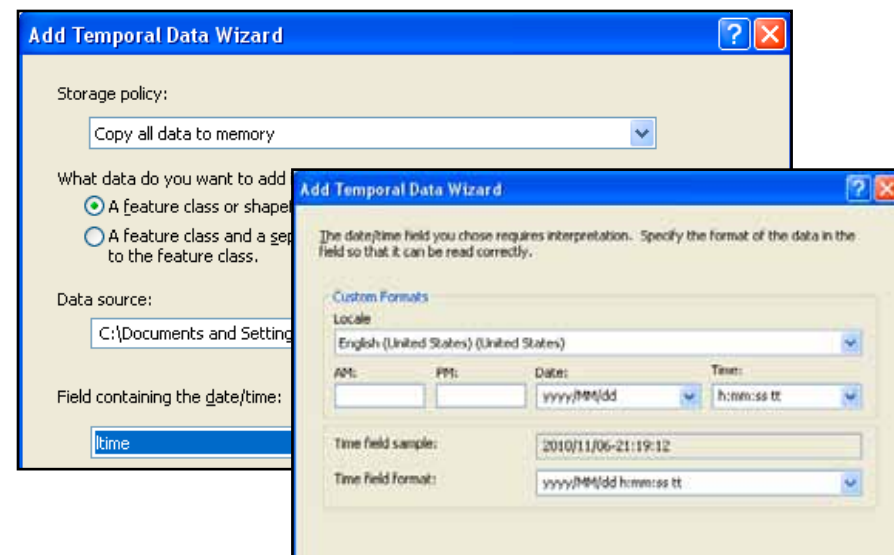
Click on the white "Playback Manger" button. You can manually move through your animation by dragging the red bar across your data points. Click on "Options" to adjust the playback rate (1 second per hour, for example) and then fine-tune the playback rate with the Slower-Faster bar. Push "Play."
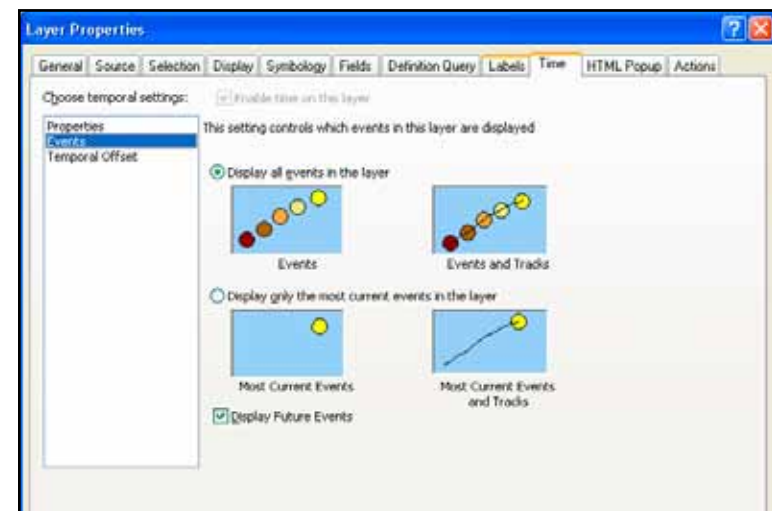
You can change some of the symbology to make it easier to see the movement of the points. Double-click on your "Events" theme. From the "Time" tab, consider your two options for displaying the events. The second option works well if you have the original point shapefile (not the event theme). Be sure to make the dots small (2pt) and black and make the event symbol bold (such as a big red circle).
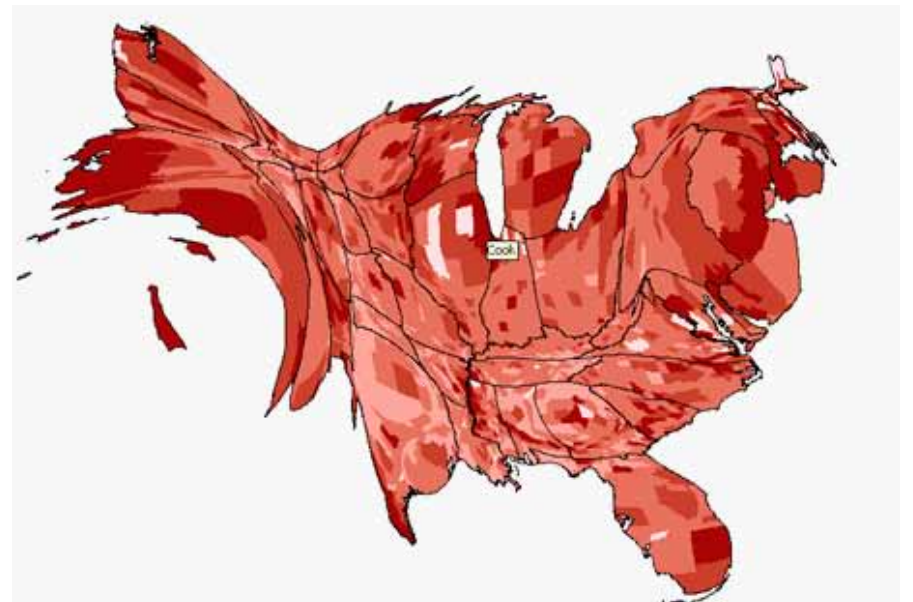
12 | CARTOGRAMS

Cartograms are the quintessential "un-GIS" map in that they deliberately distort area in order to better represent some attribute value. The best cartograms are hand-drawn, but in recent years, automated computer routines for reshaping maps have become better and better. The Cartogram script written by Tom Gross for ArcGIS based on the methodology developed by Mark Newman and Michael Gastner at the University of Michigan works quite well and is available for free download at http://arcscripts.esri.com/details.asp?dbid=15638. The file you download will be an .exe and will add a "Read Me" file and ArcMap document demo to your Start menu, under "Programs."

Cartograms work with areal (polygon) data. This Cartogram script requires that your data be in the form of a geodatabase, which take the form of Access databases and can incorporate multiple shapefiles. You can create a personal geodatabase in ArcCatalog. To add the cartogram script, launch ArcToolbox (click on the red toolbox at the top of the screen). Right click in an empty area and go to "add toolbox." From the cartogram folder, add the cartogram toolbox. You should see it listed in your ArcToolbox favorites. If you have trouble, it is probably because you do not have permission to add new programs to your computer.
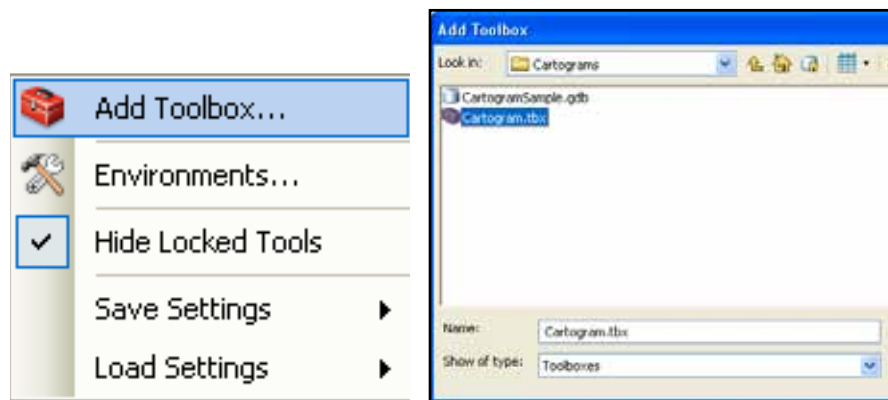
Add the shapefile in that will be the basis of your cartogram. The cartogram tool will only work with non-zero and positive attribute values, so be sure to recode the variable(s) of interest as necessary. From ArcToolbox, double click "Create a cartogram." In the first dropdown menu, choose your map layer. In the second, choose the attribute that will be the basis for the cartogram (counts work better than rates). In the third dropdown, click on the folder on the right, navigate to your geodatabase. Give your cartogram a name and click "Save." Leave the remaining dropdown menus blank or leave the default values if they appear. Put a check mark in "Copy the Original Polygon Features table to the Output Cartogram Features." Click OK.

Symbolize your resulting cartogram by double-clicking on the new shapefile and going to the symbology tab. Graduated colors will likely be the best choice.

13 | Troubleshooting

I can't save my files...
Are you saving to a write-able drive (you can't save to a cd)? If so, change the location where you are trying to save the file. Have you run out of room on your drive? Try deleting some old files (if you are deleting map layers, be sure to use ArcCatalog).

My scale bar isn't right...
Are the units "unknown"? You need to define the projection for one or more of your map layers. Do the units show up but not make sense? For example, does it show that Center City Philadelphia is 30 miles wide? Your projection was probably defined incorrectly. Start over with your original map layer and work through the projection steps again.

My map looks skewed...
Did you export the map in import it into MS Word, PowerPoint or other file? You may have skewed it here, while resizing. Export the map again. Resize only from the corners, not the sides (resizing from the sides squishes the map). Are your data projected? Check the coordinates in the bottom right of your map in the map view. If you see longitude/latitude coordinates, that's the problem. Be sure to define, then project the data.

I can't join my attribute table...
Are you starting with the shapefile? Be sure to right click on the shapefile you are joining your data to, then choose "join." Have you identified an identical join field in both tables? Open both tables. Sort them both ascending to descending to make sure they are the same. Count the number of digits. Make sure both are formatted as string (left justified) or number (right justified).

I can't open the attribute table after the join...
Right click on the shapefile to which you were trying to join the attribute table, go to "Data" and "Export Data" to save the file under new name, then add it back in. Are there spaces in names of any of your variables? Make the changes outside ArcMap (in Excel, for example) or in ArcMap, by creating a new column with a new variable name, then set it equal to the old variable, then delete the column with the space in the name.

I can't add/open my table to ArcView...
Is it open anywhere else (like in Excel)? If so, close and re-try. Are there spaces in the names of any of your variables? If so, correct this in Excel, re-save, and try again.

I can't see my table in the table of contents...
Click on the "List by Source" button on the top left corner of the Table of Contents.

I can't move my layers up or down in the Table of Contents
Click on the "List by Drawing Order" button on the top left corner of the Table of Contents, then retry.

I made a change, but I don't see it on the screen...
Refresh the graphics (arrows in a circle next to map view and layout view buttons).

I get an error message when I calculate values...
Are you dividing by zero? Sort the column with your denominator to look for zeros. Highlight every row with a zero, switch the selection so that all non-zero rows as highlighted, then try your calculation again.

I just get 0 and 1 when I'm trying to calculate a percent...
You probably formatted your column as a short integer rather than double. Delete the column (right click on column name, delete) and create a new one.

Still stuck?
Close ArcView, re-start and try again. Try a new computer somewhere else (different lab). Ask for help. Don't worry, pretty much everyone does at some point (or at least they should).