

Spatial Analysis Using ArcGIS 10



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GIS Facilities at the University of Maryland

McKeldin Library

There are two GIS workstations located in the Government Documents GIS & Computer Lab on the fourth floor of McKeldin Library. They are available on a walk-in basis when the Library is open. In addition, there are available datasets for other parts of the world including suburban Maryland; Washington, DC; the Washington Metropolitan Area; Europe; etc. Color printing is available in McKeldin Library.

The instruction labs on the sixth floor of McKeldin Library (6101, 6103, and 6107) are restricted access during the earlier part of the semester, but open to the public during the later part of the semester. ArcGIS software is installed on all computers in these labs, and can be used when they are open. Please see the following website for more information on the instruction labs: <http://www.lib.umd.edu/UES/labs.html>

Other Facilities

There are other departmental (e.g., anthropology, architecture/urban planning, civil engineering, landscape architecture, and geography) GIS laboratories on campus that are restricted to faculty, staff, and students in each of those disciplines. Additionally, the Office of Information Technology's software licensing program (<http://www.oit.umd.edu/slic>) offers ArcGIS and ArcInfo for various platforms at special/reduced rates for faculty and staff at the University of Maryland.

Introduction

A GIS (Geographic Information System) is a powerful tool used for computerized mapping and spatial analysis. A GIS provides functionality to capture, store, query, analyze, display and output geographic information.

For this seminar we will be using ArcGIS Desktop 10, the newest version of a popular GIS software produced by ESRI. This course is meant to teach some fundamental GIS operations using ArcGIS. It is not meant to be a comprehensive course in GIS or ArcGIS. However, we hope this seminar will get you started using GIS and excited about learning more.

Components of ArcGIS Desktop 10

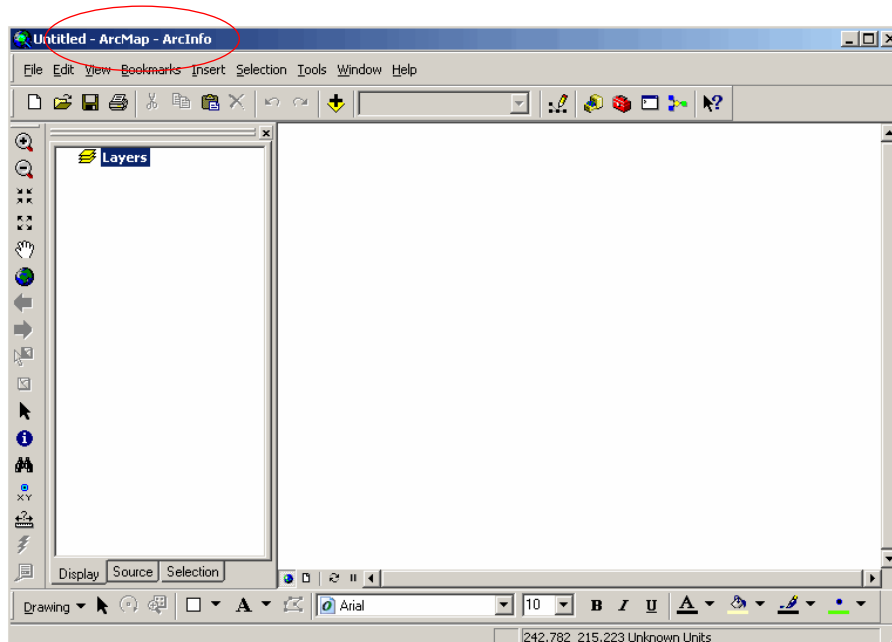
ArcMap, ArcCatalog, (and ArcToolbox)

ArcGIS Desktop is comprised of a set of integrated applications, which are accessible from the start menu of your computer: ArcMap and ArcCatalog. ArcMap is the main mapping application which allows you to create maps, query attributes, analyze spatial relationships, and lay out final projects. ArcCatalog organizes spatial data contained on your computer and various other locations and allows for you to search, preview, and add data to ArcMap as well as manage metadata and set up address locator services (geocoding). ArcToolbox is the third application of ArcGIS Desktop. Although it is not accessible from the start menu, it is easily accessed and used within ArcMap and ArcCatalog. ArcToolbox contains tools for geoprocessing, data conversion, coordinate systems, projections, and more. This workbook will focus on Arc Map and ArcCatalog.

Software Products (Licensing Levels)

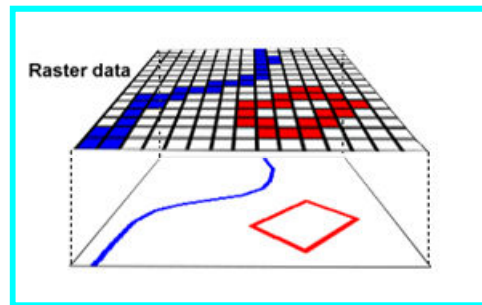
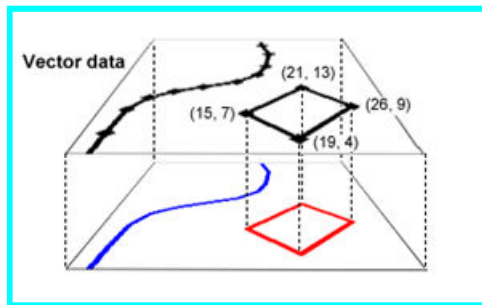
ArcMap is made up of 3 software product levels: ArcView, ArcEditor, and ArcInfo. These products share a common architecture but provide increasing levels of functionality. ArcView provides the base mapping and analysis tools. ArcEditor provides all ArcView capability including additional processing and advanced editing. ArcInfo provides all ArcEditor capability plus advanced analysis and processing. While these levels are crucial to consider when purchasing software, it is also important to be aware of the limitations of the level you are using.

Look at the menu bar at the top of the window in either ArcMap or ArcCatalog to see which level you have.

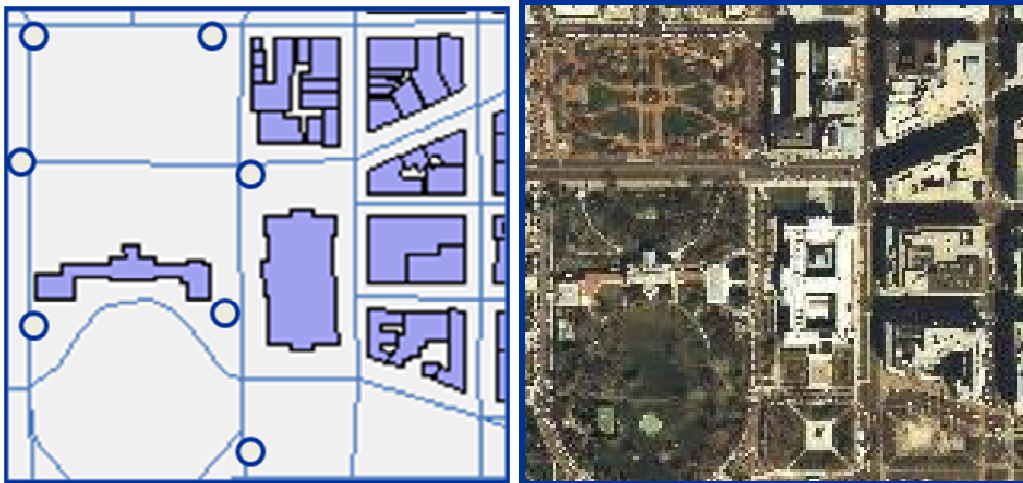


Data Types

- **Vector** - uses geometric objects – points, lines and polygons – to represent real features on the earth's surface such as light poles, roads and buildings. Ideal for discrete themes with definite boundaries.
- **Grid (Raster)** - is composed of a continuous grid cells that represents a portion of the earth's surface. Ideal for continuous themes where there is lots of change.



Graphic Source: Crown, Inc. (<http://www.ordsvy.gov.uk/gis-files/stage1/>)



Extensions to ArcGIS

ArcGIS has additional, optional software modules that add specialized tools and functionality to ArcGIS Desktop. ArcGIS Network Analyst, ArcGIS StreetMap, and ArcGIS Business Analyst are examples of ArcGIS extensions. Source: The GIS Dictionary at ESRI.com.

For example:

- 3D Analyst
- Geostatistical Analyst
- Spatial Analyst (provides spatial modeling and analysis features. It allows the creation, querying, mapping, and analysis of cell-based raster data and integrated vector-raster analysis)
- Survey Analyst
- Tracking Analyst

Geoprocessing through ArcToolbox

According to ESRI, **geoprocessing** refers to the tools and processes used to generate derived data sets. What is derived data? The **derived data** is a new file that results from taking a data layer and processing it.

There are many ways to conduct geoprocessing. In fact, there are over 200 within ArcGIS Desktop. This tutorial will NOT show you how to use all of them, but we will look at five of the most common geoprocessing operations: buffer, clip, dissolve, intersect, and spatial join. *See the table at end of the Five Common ArcToolbox Tools for details.*

ArcToolbox allows us to perform these operations through sets of toolboxes. We will be using the Analysis and Data Management toolboxes. Within these main toolboxes, operations are grouped by the way that the derived data set is created.

Exercise: Creating New Shapefiles (Two Ways)

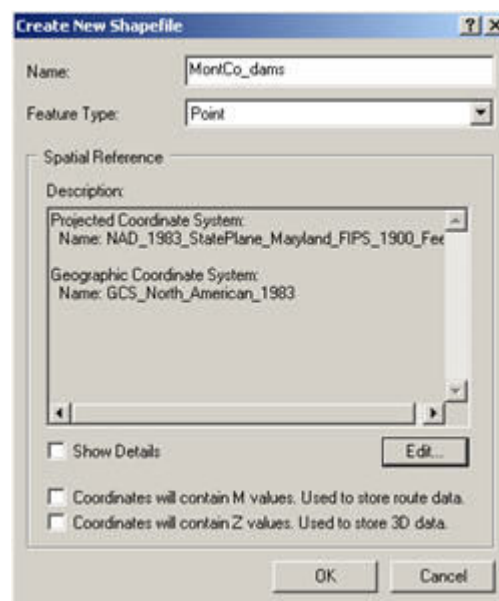
Creating from scratch/by tracing

We will be creating our shapefile within ArcCatalog and then adding it to ArcMap.

1. **Open ArcCatalog.**
2. **First we must highlight the folder in which we wish to create the shapefile in the catalog tree. Navigate to C:\Documents and Settings\arcgis\Desktop\GIS_TEMP. Highlight the GIS_TEMP folder.**
3. **Once the appropriate folder is selected we can create a new shapefile. Go to the Menu Bar (or right click on the highlighted folder) and select File > New > Shapefile. The 'Create New Shapefile' dialog box will appear.**
4. **First we must give our new shapefile a name. Type "MontCo_dams" in the Name box.**
5. **Next we must tell the computer whether we are creating a point file, a polyline file, or a polygon file. Choose point file in the 'Feature Type' dropdown box.**

We also have the option to tell the computer the coordinate system we wish the data to be displayed in.

6. **Select the edit button.** The Spatial Reference Properties dialog box will open.
7. **Choose the Select button** to choose a predefined coordinate system.
8. **Open the Projected Coordinate Systems folder by double clicking.**
9. **Open the State Plane folder by double clicking.**
10. **Open the NAD 1983 (US Feet) folder by double clicking.**
11. **Select the NAD 1983 StatePlane Maryland FIPS 1900 (US Feet) file and click 'Add'.**
12. **Once you have returned to the Spatial Reference Properties dialog box click 'OK'.**

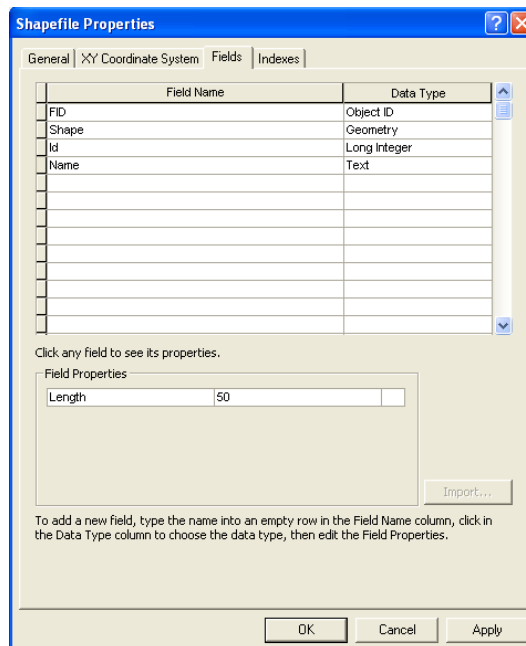


13. Once you have returned to the Create New Shapefile dialog box click 'OK'.




The MontCo_Dams file now appears in the Contents Tab of the Catalog Display. We can now create the column headings for our attribute table.


1. **Double click on the MontCo_Dams** file in the contents tab of the catalog display. The Shapefile Properties dialog box opens.
2. **Select the Fields tab.** The fields titled FID, Shape, and id are automatically added to each shapefile. We are going to add a field.
3. **Select the box in the Field Name column under Id.** You can now type directly into the box. We are going to call this field "Name." When creating new fields, keep in mind that ArcGIS will reject titles that have too many characters and titles with spaces.
4. **In the Data Type column, select Text from the drop-down box.**
5. Under Field Properties we may choose the number of characters to be allowed in this field. For our purposes we will keep the default of 50.
6. **Click 'OK'.**



We are now going to add our new shapefile to ArcMap. When we add the new shapefile it will appear in the table of contents but nothing will appear on the screen. This is because we have not yet created any points for our shapefile.

Open ArcMap from ArcCatalog by clicking on the Launch ArcMap icon . Minimize ArcCatalog. Once ArcMap opens:

1. Choose 'A new empty map' and click 'OK'.
2. Select the add data button .
3. Navigate to C:\Documents and Settings\Arcgis\Desktop\GIS_TEMP and select the MontCo_Dams file we just created.
4. Click 'Add'.

We are also going to add the Montgomery County file titled "county.shp". Click on the 'Add Data' icon  and navigate to C:\ESRI\GIS_WRKSHP to find this file. If you do not see the file, it may be that your scale is too large—either zoom in or make your scale larger (try 1:400,000).

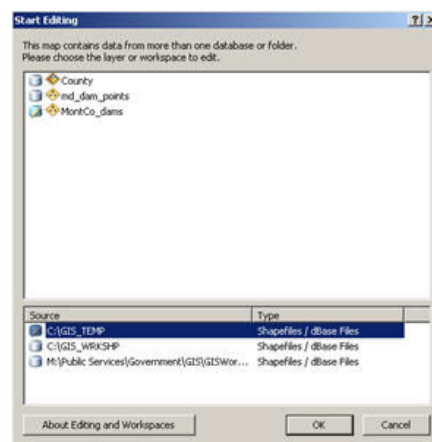
We are going to create the points for our new point file by using a point file that was downloaded from the National Map Seamless Server.

1. Use the 'Add Data' icon, navigate to C:\ESRI\GIS_WRKSHP, and add 'MD_dam_points.shp'.

You can see that this is a file containing points for dams in and around Montgomery County. We will trace points for only those dams that are within our county boundary. To do this we must use the Editor toolbar. If the Editor toolbar is not currently displayed, go to the menu bar and select **Customize > Toolbars > Editor**.



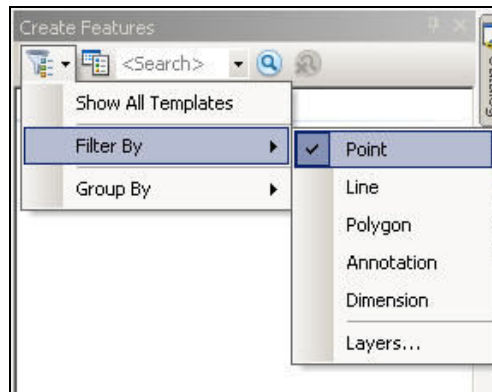
From the Editor toolbar select **Editor > Start Editing**. The computer will ask you which folder you wish to edit from. Select the folder that contains the Mont_dams file we created, which is C:\Documents and Settings\Arcgis\Desktop\GIS_TEMP. Click OK.



On the Editor Toolbar we want to select the task **Create New Feature** by clicking on this icon:



A “Create Features” window will open on the right side of the screen. We will be creating points, so you may need to click the drop-down and choose Filter By > Point as shown below.



Now the point icon on your Editor toolbar should be active. Click on the point icon. (You’ll notice that your cursor changes to an arrow with a point.)



We are going to use the mouse to draw a point over top of each dam that is within Montgomery County. You will see that the tool automatically zooms and centers the points you want to trace when you hover over them. To place a new point on the map, left click once with the mouse. Each time you click on the map it will create a new point.

When you have finished placing all of your points on the map, go back to the Editor Toolbar and **select Editor > Save Edits**. After you have saved your edits **select Editor > Stop Editing**.

Turn off all layers except MontCo_dams and you will see that the shapefile you created now contains the points you traced. **Right click on MontCo_Dams and scroll down to Open Attribute Table**. The new points also show in your attribute table. From here we will input the names of the dams in the attribute table.

1. If your editor toolbar is not currently active, **go to the menu bar and select Customize > Toolbars > Editor**. The editor toolbar should now appear.
2. Using the editor toolbar **select the ‘Editor’ button and scroll down to ‘Start Editing’**.

3. The computer will ask you which folder you wish to edit from. Again, **select the folder that contains the MontCo_Dams file, which is C:\Documents and Settings\Arcgis\Desktop\GIS_TEMP. Click 'OK'.**
4. **Place your cursor in the Name column of the attribute table and type the first dam name which is "Little Seneca."** You can widen the column by placing your cursor at the top of the column, holding the left mouse button and dragging it right.
5. **Place the cursor in the name column in each row to name that dam. Name the remaining dams: Seneca State Park; Upper Rock Creek 5; Upper Rock Creek 1; and Furnace Run.**
6. When you have finished **go to the editor toolbar and select Editor > Save Edits, then select Editor > Stop Editing.**

FID	Shape *	Id	Name
0	Point	0	Little Seneca
1	Point	0	Seneca State Park
2	Point	0	Upper Rock Creek 5
3	Point	0	Upper Rock Creek 1
4	Point	0	Furnace Run


7. **Close the attribute table.**

That's it! You've created a point shapefile. You could do the same by tracing from an aerial photograph, an old scanned map, etc.

Creating by modifying an existing file

You can create points, polylines, and polygons in ArcCatalog by using the same steps described above. But what if creating an entirely new shapefile is not conducive to what we are trying to accomplish? Let's say we want to create a shapefile that breaks the state of Maryland into various regions. It would be very time consuming to trace the entire State of Maryland, and it would also be very inaccurate. Instead we can use our file of Maryland counties to create a new shapefile of regions.

Let's begin by creating a new shapefile in ArcCatalog like we just did for our point file.

1. **Open ArcCatalog** .
2. First we must highlight the folder in which we wish to create the shapefile in the catalog tree. **Navigate to C:\Documents and Settings\Arcgis\Desktop\GIS_TEMP in the catalog tree.**
3. Once the appropriate folder is selected we can create a new shape file. **Go to the Menu Bar (or right click on the highlighted folder) and select File > New > Shapefile.** The Create New Shapefile dialog box will appear.
4. First we must give our new shapefile a name. **Type "Subregions" in the Name box.**
5. Next we must tell the computer whether we are creating a point file, a polyline file, or a polygon file. **Choose polygon file.**


We also have the option to tell the computer the coordinate system we wish the data to be displayed in. We will use the same system as before—Maryland State Plane.

1. **Select the edit button.** The Spatial Reference Properties dialog box will open.
2. **Choose the Select button** to choose a predefined coordinate system.
3. **Open the Projected Coordinate Systems folder by double clicking.**
4. **Open the State Plane folder by double clicking.**
5. **Open the NAD 1983 (US Feet) folder by double clicking.**
6. **Select the NAD 1983 StatePlane Maryland FIPS 1900 (US Feet) file and click 'Add'.**
7. Once you have returned to the Spatial Reference Properties dialog box **click 'OK'.**
8. Once you have returned to the Create New Shapefile dialog box **click 'OK'.**

The Subregions file now appears in the Contents Tab of the Catalog Display. We can now create the column headings for our attribute table.


9. **Double click on the Subregions file in the catalog tree.** The Shapefile Properties dialog box opens.
10. **Select the Fields tab.** The fields titled FID, Shape, and id are automatically added to each shapefile. We are going to add a field.

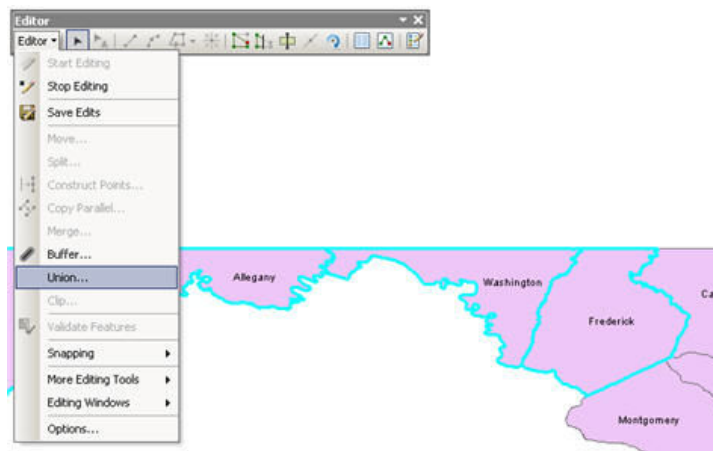
11. **Select the box in the Field Name column under Id.** You can now type directly into the box. We are going to call this field “Subregion.” When creating new fields, keep in mind that ArcGIS will reject titles that have too many characters and titles with spaces.
12. **In the Data Type column, select Text from the drop-down box.**
13. Under Field Properties we may choose the number of characters to be allowed in this field. For our purposes we will **keep the default of 50.**
14. **Click OK.**
15. **Close ArcCatalog.**

Now that we have created our new shapefile, let's go into ArcMap and start with a new, empty map. We are going to re-add our new files. Do not save changes. We must first **add the 'mdcounties' shapefile to our map** . This file can be found in C:\ESRI\GIS_WRKSH. **Next we must add the new Subregions shapefile we just created which is located in C:\Documents and Settings\Arcgis\Desktop\GIS_TEMP.**

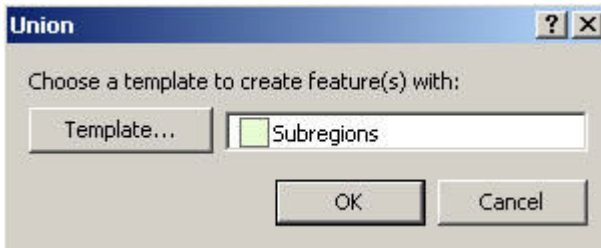
We will break the State into four regions: Western Maryland, Southern Maryland, the Eastern Shore, and the Baltimore-Washington Metropolitan Area. To add labels to the counties in Maryland, **right click on 'mdcounties' and scroll down to 'Label Features'.**

We will use the mouse to select our first region, Western Maryland. To do this:

1. **Click on the 'Select Features' icon** .
2. **Hold down the shift button on your keyboard and left click on Garrett, Allegany, Washington, and Frederick.**
3. If the editor toolbar is not visible, **go to the menu bar and select 'Customize > Toolbars > Editor'.**
4. Once your Editor toolbar is visible, **select Editor > Start Editing.**
5. **The computer will ask you which folder you wish to edit within. Click on the Subregions shapefile** – this will cause the software to choose the correct source data for that shapefile to edit. Click OK to close the dialog box.
6. **Go to the Editor Toolbar once again and select Editor > Union.**

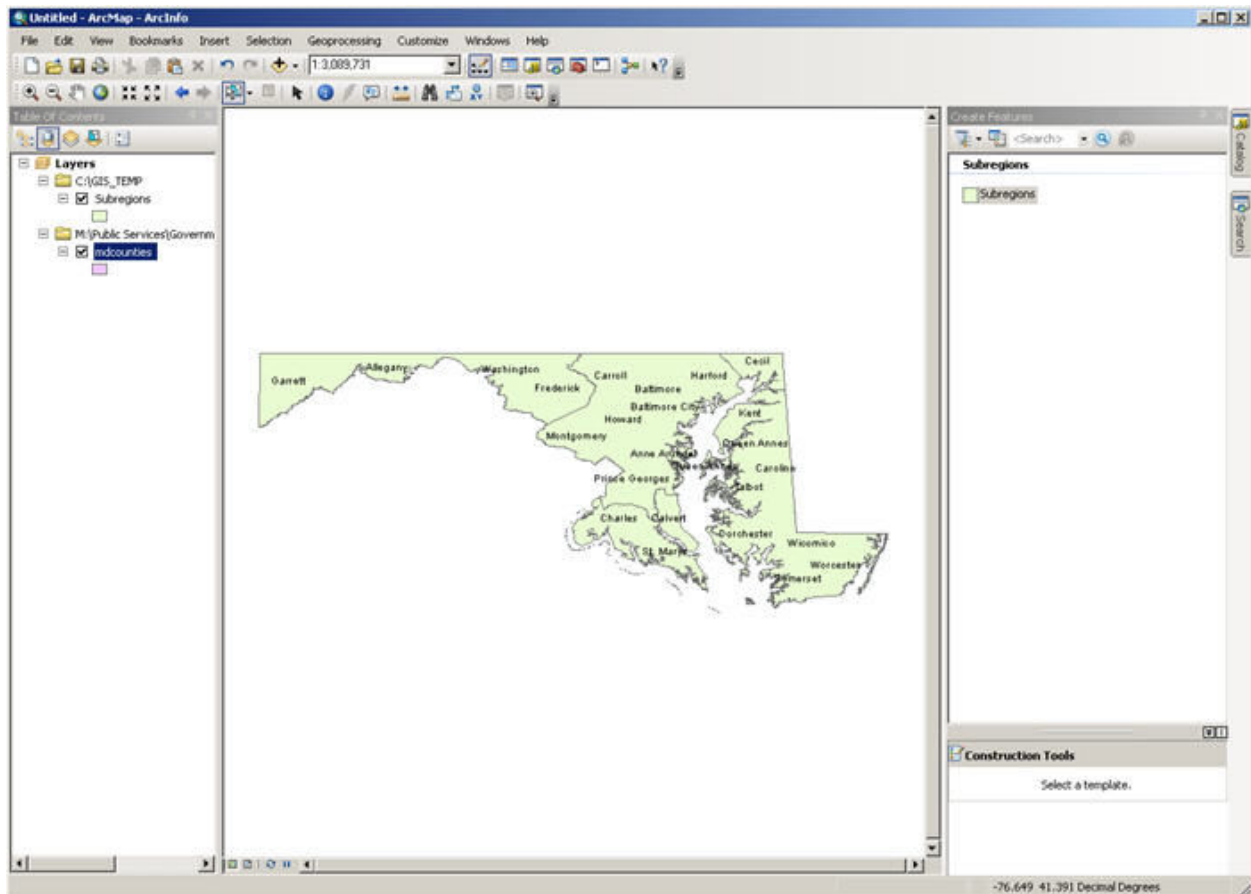


If prompted to choose a template, click OK.



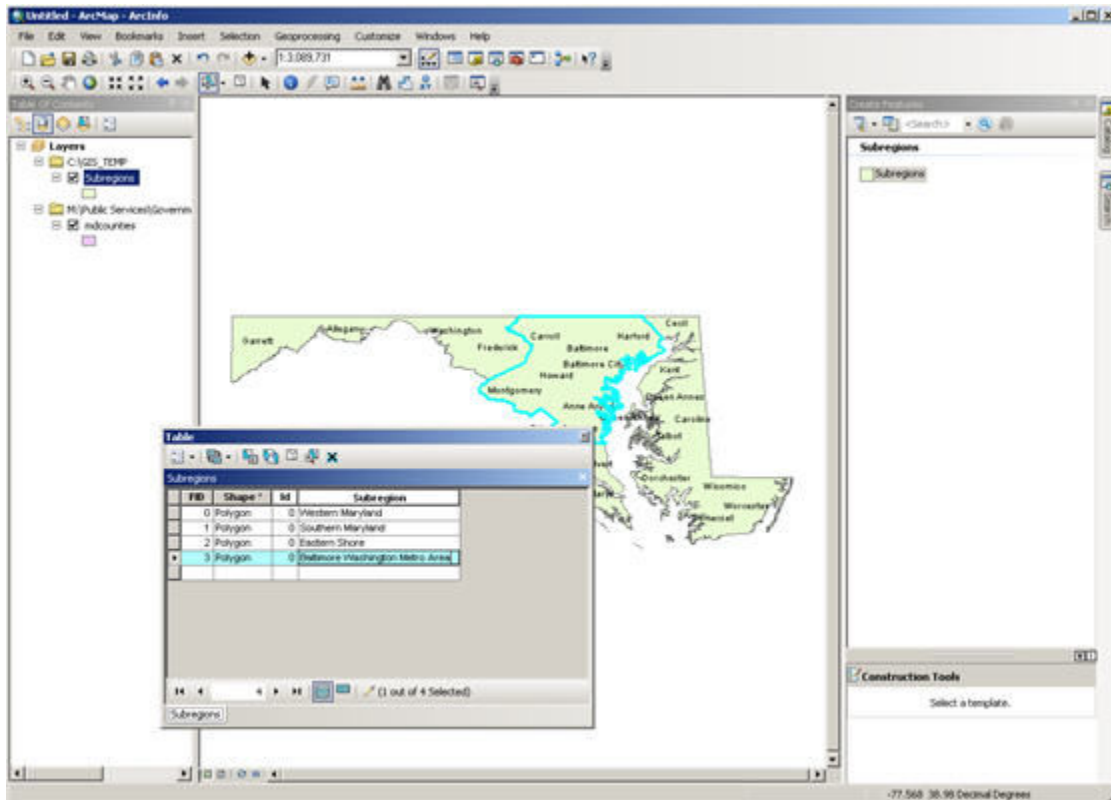
7. Click the 'Clear Selected Features' icon  .

All of the counties we selected are now visible as one single region within the Subregions shapefile. We will now go through the same steps to create the regions of Southern Maryland (Calvert, Charles, and St. Marys), the Eastern Shore (Cecil, Kent, Queen Anne's, Talbot, Caroline, Dorchester, Wicomico, Somerset, and Worcester) and the Baltimore-Washington Metropolitan Region (Carroll, Howard, Baltimore County, Baltimore City, Harford, Anne Arundel, Montgomery and Prince George's). Click 'Clear Selected Features' when you are finished.



After we have created our four new polygons, we can go into the attribute table and fill in the name for each region.

1. **Right click on Subregions and scroll down to 'Open Attribute Table'.**
2. We are still editing Subregions so we can type directly into the attribute table. **Label the four polygons we just created in the column titled 'Subregion'.**



3. **Close the attribute table.**
4. **Save your edits (Editor > Save Edits) and stop editing (Editor > Stop Editing).**

We will also want to change the color of each region to make them distinctive.


1. **Right click on 'Subregions' and scroll down to properties.**
2. **Select the Symbology tab in the Layer Properties dialog box.**
3. **In the Show Box select Categories > Unique Values.**
4. **In the Value Field dropdown box select 'Subregion'.**
5. **Click 'Add All Values'.** Choose red for Balto/Wash Metro Area, orange for Eastern Shore, yellow for Southern Maryland, and green for Western Maryland (or whatever colors you like).
6. When finished **click 'OK'.**

Exercise: Five Common ArcToolbox Tools

1. Buffer

Our first geoprocessing task will be creating a new area around an already existing layer. This is called a **Buffer**. Buffers can be created around any of the vector file types—points, lines, and/or polygons. We will be using the point file of dams in Montgomery County named Mont_dams.

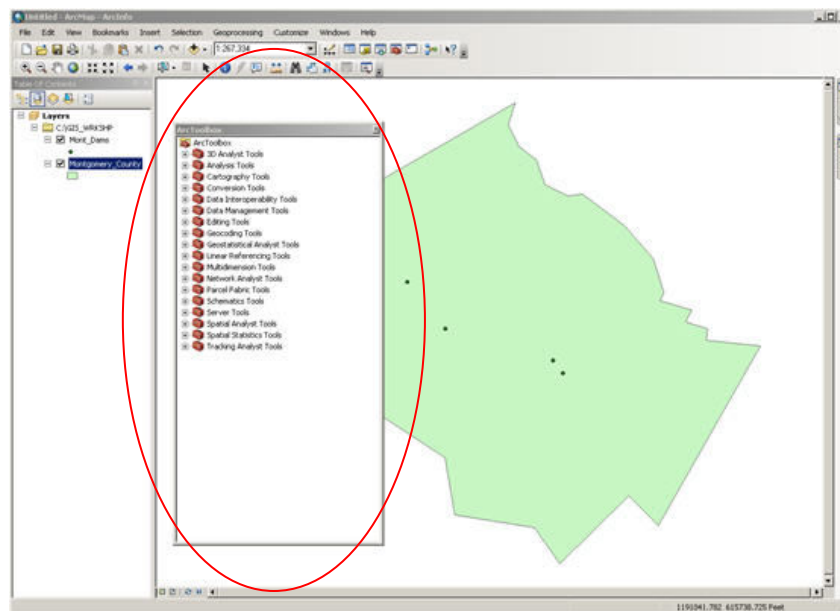
If you do not already have the file available in the table of contents, do the following:

1. **Open ArcMap and a new blank map. Click on  Add Data.**
2. **Navigate to C:\ESRI\GIS_WRKSHp\ and select the Mont_dams shapefile. Click Add.**
3. **Also add Montgomery_County.shp for background.**

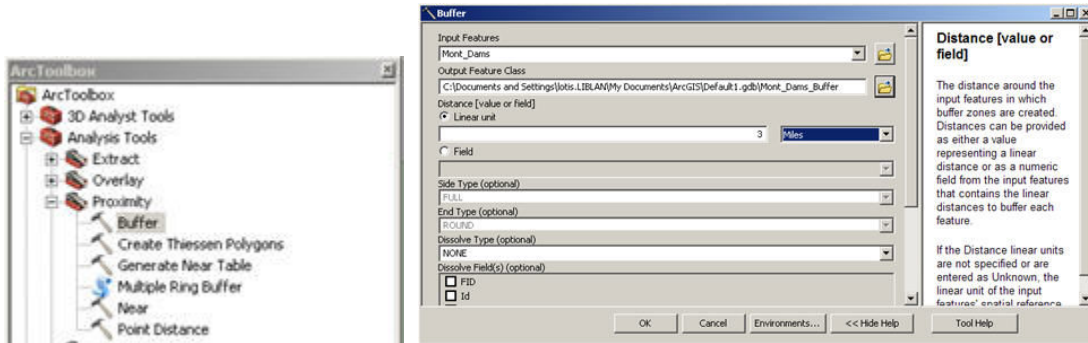
Let's pretend that we are working for Montgomery County and are looking into disaster planning. We'd like to know who will be affected if one or all of the dams break and how we can get emergency response teams to the area. We have been told by experts that we should be looking into a 3 mile radius of the dams (remember, this is pretend). This is a great situation to create a **buffer**. Buffers are new areas of a certain distance that can be created around points, lines, or polygons. We will make a 3 mile buffer around the dams to see the areas that will be affected if the dams break.

We will use ArcToolbox to create our buffers.


1. **Click once on the Toolbox icon.  Notice that ArcToolbox is now open **within** ArcMap – you can move the toolbox window around.**



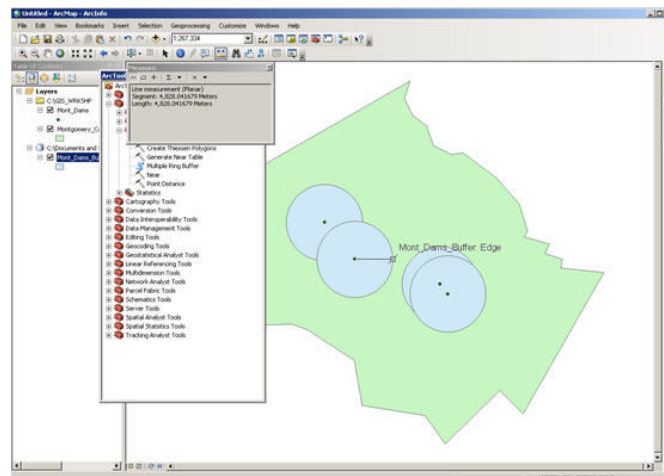
2. **Single click on the plus sign next to Analysis Tools.**
3. **Single click on the plus sign next to Proximity.**
4. **Double click on Buffer.**



The buffer window will open.

1. In the 'Input Features' box at the top **choose Mont_Dams from the drop down box.**
2. Using the browse icon  **navigate to the GIS_TEMP folder on the Desktop in the box for 'Output Feature Class' and name the new file 'Mont_Dams_Buffer'.** If you are unable to navigate to the GIS_TEMP folder, you can save the new buffer shapefile to the default geodatabase that is automatically populated.
3. Under Distance, **type in 3** for linear unit.
4. **Choose 'Miles'.**
5. **Click 'OK'.** You will see a little progress window at the bottom of the screen, and when the process is complete a temporary window with a check mark will pop up.
6. **Using the 'measure' tool, measure a radius.**

The new shapefile, Mont_Dams_Buffer, now appears in the table of contents and in the map display.



Let's look at the attribute table of the buffer file. In the table of contents, **right click on Mont_Dams_Buffer > Open Attribute Table.**


OBJECTID	Shape	ID	Name	BUFF_DIST	Shape_Length	Shape_Area
1	Polygon	0	Rock Creek Dam	15040	99525.655229	788243189.130553
2	Polygon	0	Brookline Dam	15040	99525.655275	788243189.362274
3	Polygon	0	Washington Hills Dam	15040	99525.655121	788243203.254898
4	Polygon	0	Clark Dam	15040	99525.655569	788243194.512795

The table shows each dam and the buffer distance of 3 miles displayed in feet (15,840 Feet = 3 miles).

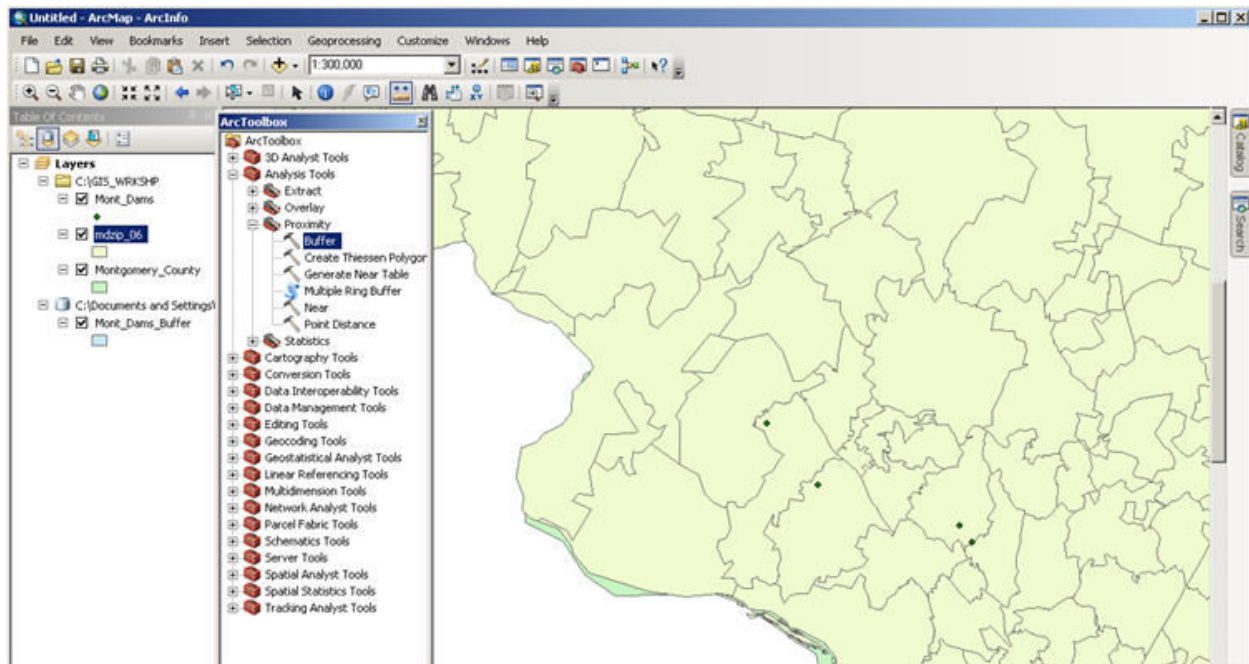
2. Clip Operation

Now that we have a 3 mile buffer of the areas that will be affected by a break in the dams, let's look at **who** will be affected. We will use zip codes as a way to identify areas. The only zip code file that we could find is for the entire state of Maryland. We'd like it to be for only Montgomery County. This is a perfect opportunity to use the **clip** function.

Usually associated with the "within" condition, the clip function works like a cookie cutter. In our case we will be using the state zip code file as the input layer (the cookie dough) and cutting it with Montgomery County (the cookie cutter). We'll end up with the shape of Montgomery County and the attributes of the zip codes.

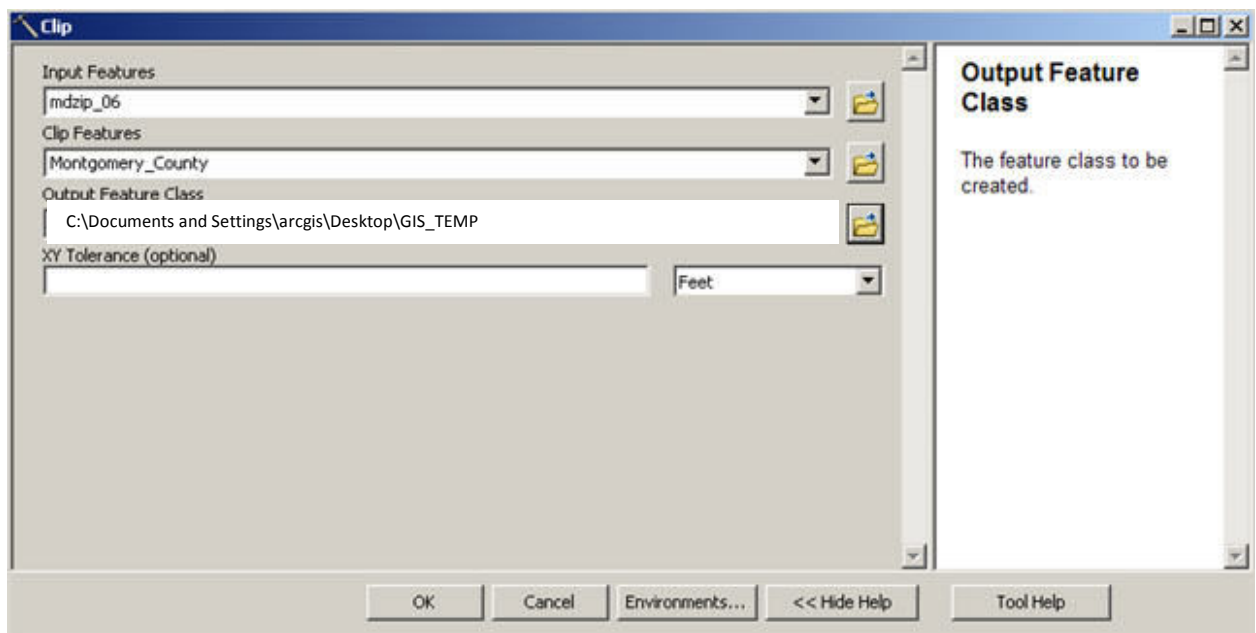
1. Click on the add data icon. 
2. Navigate to C:\ESRI\GIS_WRKSHP\.
3. Double click on mdzip_06.


(You will get a warning about a datum conflict, and you will see that the layers do not quite match up.)




A layer for the zipcodes in Maryland from 2006 will be added. **Re-open the ArcToolbox window if it is not already open. Under Analysis Tools > Extract, double click on Clip. Or from the menu bar, click on Geoprocessing > Clip.**

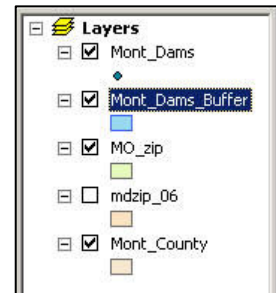
1. **Click on the drop down box under 'Input Features' and choose 'mdzip_06'.**
2. **Under 'Clip Features' choose 'Montgomery_County' in the drop down box.**



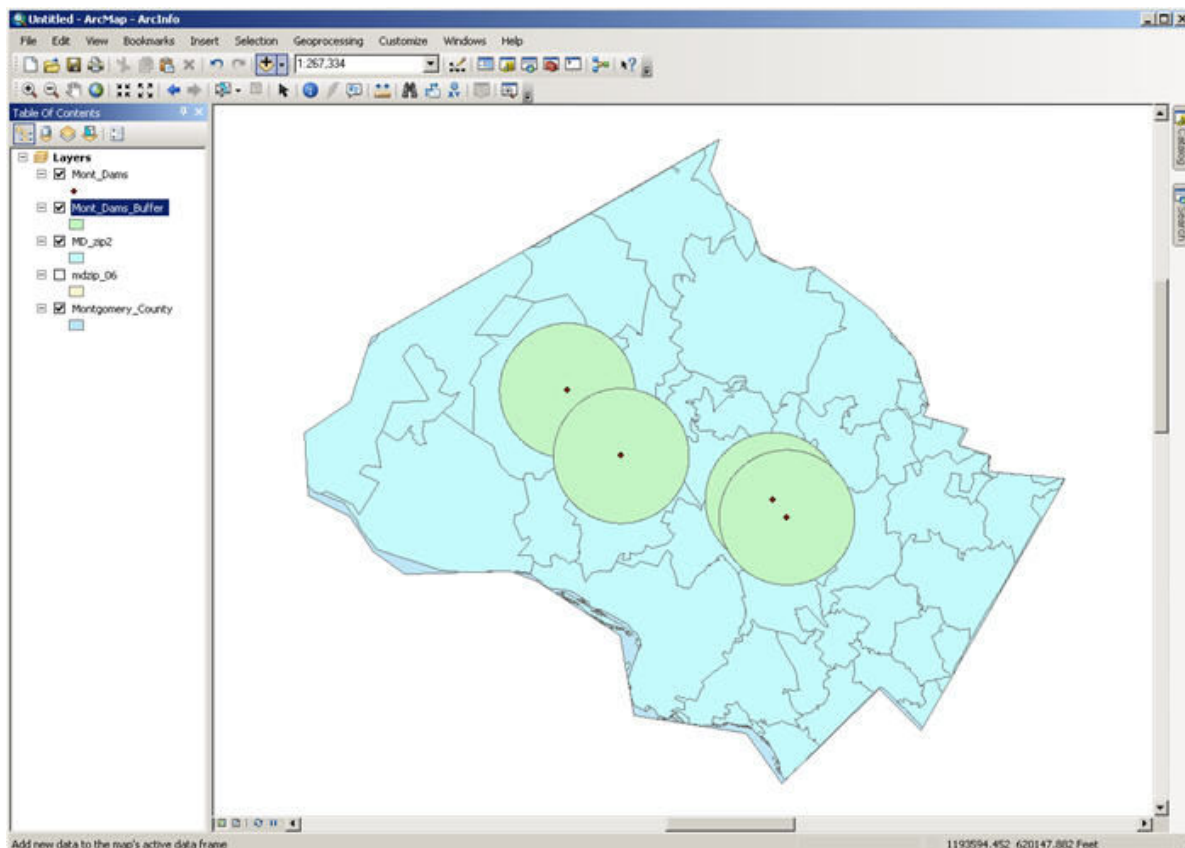
3. Navigate to (using the browse icon ) or type in the Desktop GIS temp folder path as the location for the 'Output Feature Class'.
4. Name the file 'MD_zip'.
5. Click 'OK'.

Let's reorganize our layers so that we can see everything.

1. Turn off md_zip06.
2. Click on and hold the left mouse button and drag **Mont_Dams_Buffer** under **Mont_Dams**. (If necessary, click on the "List By Drawing Order" icon  – then you will be able to move layers.)

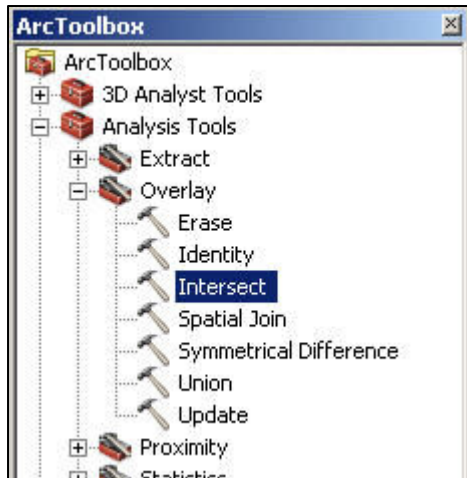


You should see the zip codes for Montgomery County as well as the dams and buffers around the dams.



3. Intersect

Now that we have the zip codes in Montgomery County, we can use that with the buffer of the dams that we created. We can visually see where the overlap between the two files is, but we can take a closer look by using the **intersection** operation.

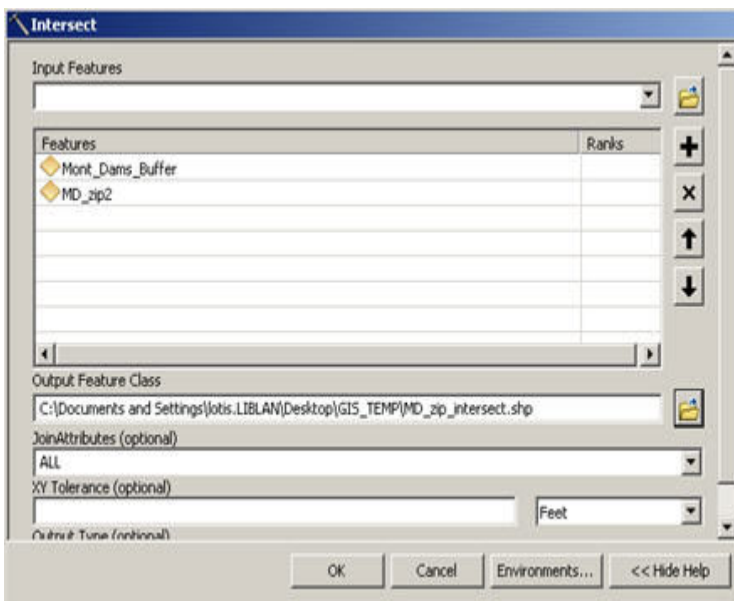


From the ArcToolbox menu:

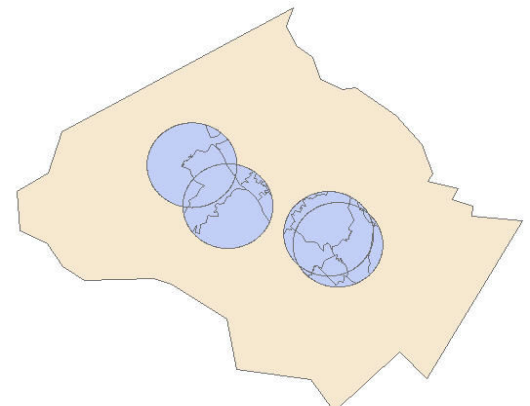
1. Single click on the plus sign to the left of 'Analysis Tools'.
2. Single click on the plus sign to the left of 'Overlay'.
3. Double click on 'Intersect'.

The Intersect window will open.

1. From the Input Features drop down box, choose **Mont_Dams_Buffer**. (It will appear in the box list area, not the drop-down.)
2. Repeat this process and choose the **MD_zip** file.
3. Save the output file to the **GIS_TEMP** folder on the desktop and call the file **MD_zip_Intersect**.
4. Click 'OK'.



Turn off all layers EXCEPT:



- the newly created **MD_zip_Intersect** file and
- **Montgomery_County**

In the map display we can visually see the zip code areas in the 3 mile buffer.

Right click on MD_zip_Intersect and open the attribute table.

The attribute table has attribute information of **both** the zip codes and the dams that are in a 3 mile buffer of the dams. The shape of the file is of the shared areas.


Close the attribute table.

4. Dissolve

Still pretending to be Montgomery County, we have decided that it would be nice to have a map and table of the post offices in charge of each zip code. We'd like to quickly contact the post offices so they can send out emergency information to the residents in the affected areas. As the larger areas have multiple zip codes that belong to one post office, we'd like to combine the areas both visually and in the attribute table. The dissolve operation is ideal for this. As the dissolve operation allows you the option of adding statistical fields, we use the layer we just created (MD_zip_intersect) and add a column with the sum of population for zip codes that are combined.

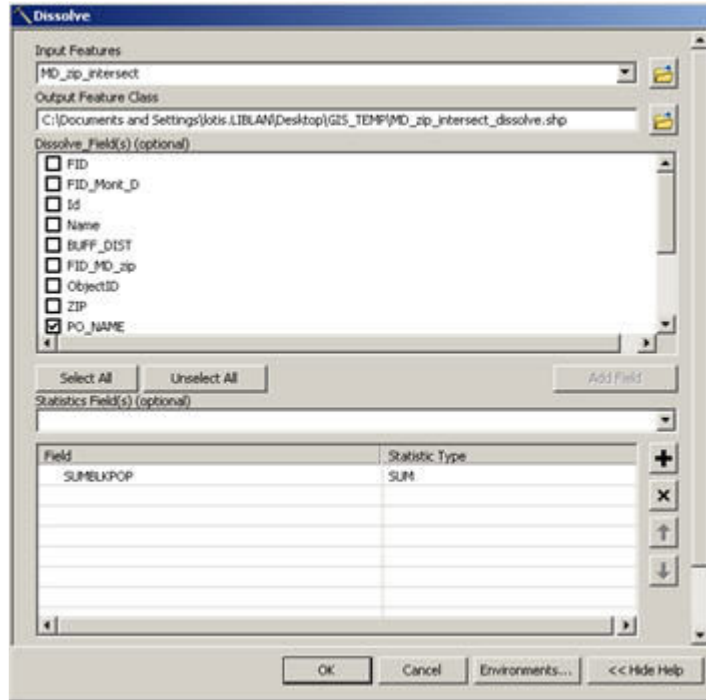
- 1. Go back to ArcToolbox.**
- 2. Click once on the plus sign to the left of 'Data Management Tools.'**
- 3. Click once on the plus sign to the left of 'Generalization.'**
- 4. Double click on 'Dissolve.'**

The Dissolve window will open.

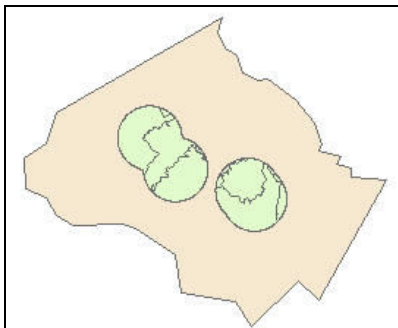
- 5. In the drop down box for 'Input Features' select MD_zip_Intersect.**
- 6. For 'Output Feature Class', use the browse button  and navigate to the desktop. Call the file "MD_zip_Intersect_Dissolve."**
- 7. Check the box next to "PO_Name" in the 'Dissolve_Field(s) box.** This allows us to dissolve the lines that connect zip codes that are shared by the same post office name.
- 8. Under the box for 'Statistics Field(s) use the drop down box to select SUMBLKPOP.**

9. In the box to the right, 'Statistics Type,' choose "SUM." We are going to add a field to our new attribute table with population. As some areas will be combined, we'd like to see the combined population totals for those areas.

10. Click "OK."



In the map display you can see that there are now 2 areas instead of 3. Open the attribute table by **right clicking on MD_zip_Intersect_Dissolve**. You can see that all 43 zip codes are handled by 9 post offices. In addition, we have the combined population for those areas in a new column.



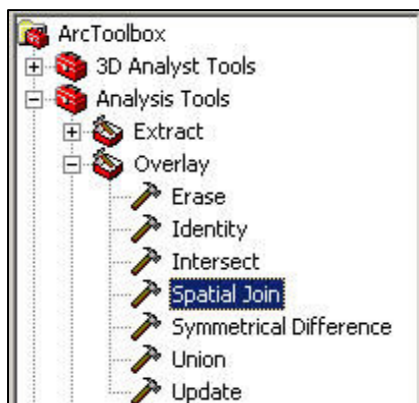
FID	Shape *	PO_NAME	SUM	SUMBLK
0	Polygon	Boyd's		12380
1	Polygon	Clarksburg		2617
2	Polygon	Derwood		44622
3	Polygon	Gatherburg		172516
4	Polygon	Germantown		274904
5	Polygon	Montgomery Village		29165
6	Polygon	Olney		100800
7	Polygon	Rockville		384730
8	Polygon	Silver Spring		179286

5. Spatial Join

Let's investigate another option in the toolbox. In a **spatial join**, fields from one layer's attribute table are appended to another layer's attribute table based on the relative locations of the features in the two layers. Let's take a look at how it works.

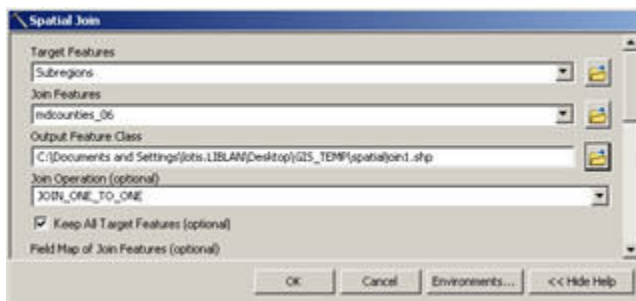
We will be using the Subregions and mdcounties_06 shapefiles. Open a new map in ArcMap and add these two files (navigate to C:\ESRI\GIS_WRKSHP\).

We will first combine attributes of these two files based on subregional areas. Because we are basing it on Subregion, the shape of the file will be Subregion as well.




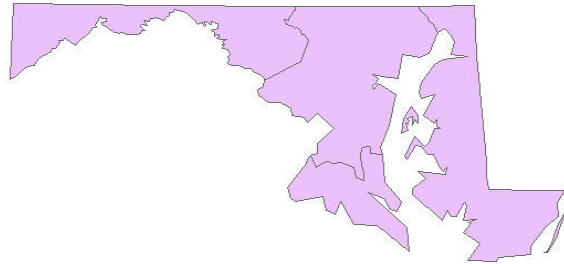
From ArcToolbox,

1. **Left-click on the plus sign to the left of 'Analysis Tools.'**
2. **Left-click on the plus sign to the left of 'Overlay'**
3. **Double click on 'Spatial Join.'**



In the 'Spatial Join' box,

1. **Select "Subregions" in the drop down box under Target Features.**
2. **Choose "mdcounties_06.shp" in the 'Join Features' drop down box.**
3. **Navigate to the GIS_TEMP folder on the desktop in the 'Output Feature Class' box using the browse  icon.**
4. **Name the file spatialjoin1.**
5. **Click 'OK'.**
6. **Look at the 'Join Operation' options. See how we can join one to one or one to many. Keep one to one.**
7. **Keep the remaining default values listed for the remaining boxes as well.**
8. **Click 'OK'.**
9. **A box showing the programming for the task will appear. When it is finished running, close the programming box.**



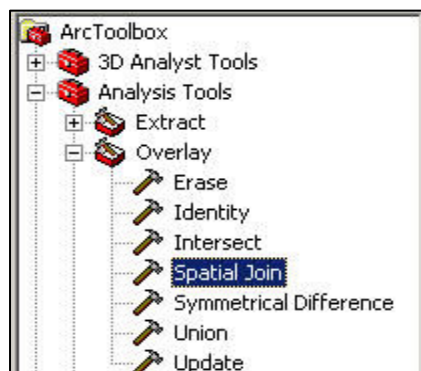
A new shapefile, spatialjoin1, will be added to the map and table of contents. As you can see, the shape is of the subregions.

Let's check the attribute table. Scroll through and see how this spatial join added the attributes for mdcounties_06 to the end of the Subregion file.

TARGET_FID	Id	Subregion	ObjectID	NAME	STATE_NAME	STATE_FIPS	CITY_FIPS	FIPS	POP2000	POP2000
0	0	Western Maryland	1071	Washington	Maryland	24	043	24043	131923	14
1	0	Balto/Wash Metro Area	1073	Cecil	Maryland	24	015	24015	85951	€
2	0	Southern Maryland	1197	Anne Arundel	Maryland	24	003	24003	489656	51
3	0	Eastern Shore	1073	Cecil	Maryland	24	015	24015	85951	€

Looking at the attribute table we can see how this spatial join is far from ideal. It only lists one county per Subregion. It also has Cecil County listed for both the Balto/Wash Metro Area and the Eastern shore. It looks like we need to take another step in order to have the shape of the Subregions with the counties included in those areas.


First, let's try to complete a spatial join combining attributes of these two files based on mdcounties. Remember that because we are basing it on mdcounties, the shape of the file will be in the shape of the counties.



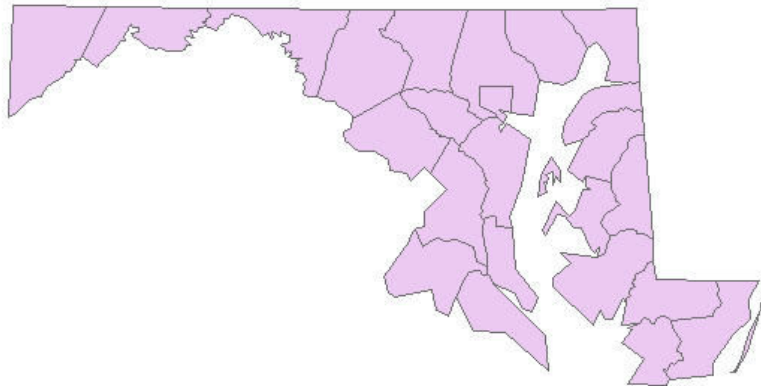
From ArcToolbox,

- 10. Left-click on the plus sign to the left of 'Analysis Tools.'**
- 11. Left-click on the plus sign to the left of 'Overlay'**
- 12. Double click on 'Spatial Join.'**

In the 'Spatial Join' box,

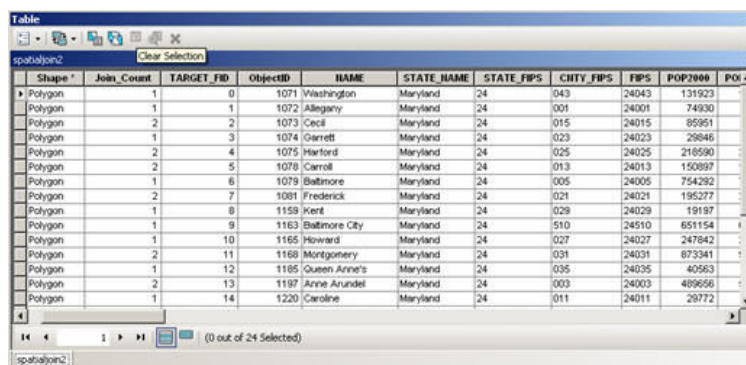
13. Select "mdcounties_06" in the drop down box under Target Features.
14. Choose "Subregions" in the 'Join Features' drop down box.
15. Navigate to the GIS_TEMP folder on the desktop in the 'Output Feature Class' box using the browse  icon.
16. Name the file spatialjoin2.
17. Keep the defaults for the remaining boxes.
18. Click 'OK.'
19. A box showing the programming for the task will appear. When it is finished running, close the programming box.

A new shapefile, spatialjoin2, will be added to the map and table of contents. As you can see the shape is of the counties.



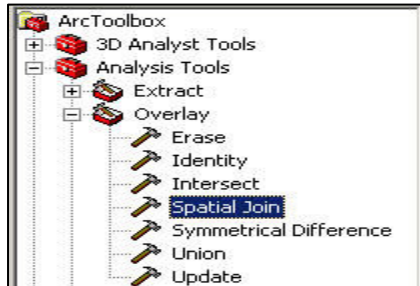
Let's check this attribute table. **Right click on spatialjoin2 and open the attribute table.** Scroll through and see how this spatial join added the attributes for Subregions to the end of the mdcounties file.

This spatial join was able to combine all of information about the counties and add the information about which Subregion they are a part of. It took the shape of the mdcounties file.



Shape*	Join_Count	TARGET_FID	ObjectID	NAME	STATE_NAME	STATE_FIPS	CITY_FIPS	FIPS	POP2000	POI
Polygon	1	0	1071	Washington	Maryland	24	043	24043	131923	
Polygon	1	1	1072	Allegany	Maryland	24	001	24001	74930	
Polygon	2	2	1073	Cecil	Maryland	24	015	24015	89961	
Polygon	1	3	1074	Garrett	Maryland	24	023	24023	29846	
Polygon	2	4	1075	Hartford	Maryland	24	025	24025	218590	
Polygon	2	5	1078	Carroll	Maryland	24	013	24013	150897	
Polygon	1	6	1079	Baltimore	Maryland	24	005	24005	754292	
Polygon	2	7	1081	Frederick	Maryland	24	021	24021	195277	
Polygon	1	8	1159	Kent	Maryland	24	029	24029	19197	
Polygon	1	9	1163	Baltimore City	Maryland	24	510	24510	651154	
Polygon	1	10	1165	Howard	Maryland	24	027	24027	247842	
Polygon	2	11	1169	Montgomery	Maryland	24	031	24031	873341	
Polygon	1	12	1185	Queen Anne's	Maryland	24	035	24035	40563	
Polygon	2	13	1197	Anne Arundel	Maryland	24	003	24003	489656	
Polygon	1	14	1220	Caroline	Maryland	24	011	24011	29772	


So, what if you want all of this information but not in the shape of counties? Why don't we try a spatial join again targeting Subregions with our newly created spatialjoin2 file.

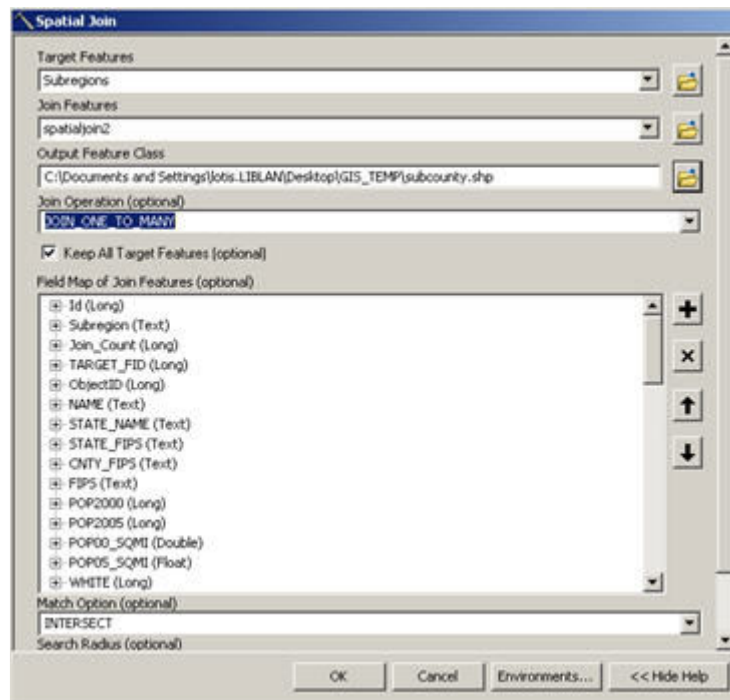


From ArcToolbox,

20. Left-click on the plus sign to the left of 'Analysis Tools.'
21. Left-click on the plus sign to the left of 'Overlay'
22. Double click on 'Spatial Join.'

In the 'Spatial Join' box,

23. Select "Subregions" in the drop down box under Target Features.
24. Choose "spatialjoin2" in the 'Join Features' drop down box.
25. Navigate to the GIS_TEMP folder on the desktop in the 'Output Feature Class' box using the browse  icon.
26. Name the file subcounty.
27. Under the 'Join Operation' box, chose **JOIN_ONE_TO_MANY.**
28. Keep the remaining default values listed for the remaining boxes as well.
29. Click 'OK.'



The new layer will be added. It has the shape of the Subregion file. Let's look at the attribute table. **Right-click on the subcounty layer in the table of contents and open attribute table.** As you can see, this new file has the shape of the Subregions and also includes attributes of all of the counties.



Join_Count	TARGET_FID	JOIN_FID	Id	Subregion	Join_Cou_1	TARGET_F_1	ObjectID	NAME	ST#
1	0	0	0	Western Maryland	1	0	1071	Washington	Mary
1	1	1	0	Western Maryland	1	0	1072	Allegany	Mary
1	3	3	0	Western Maryland	1	0	1074	Garrett	Mary
2	5	5	0	Western Maryland	1	0	1078	Carroll	Mary
2	7	7	0	Western Maryland	1	0	1081	Frederick	Mary
2	11	11	0	Western Maryland	1	0	1168	Montgomery	Mary
2	2	2	0	BaltoWash Metro Area	1	1	1073	Cecil	Mary
2	4	4	0	BaltoWash Metro Area	1	1	1075	Harford	Mary
2	5	5	0	BaltoWash Metro Area	1	1	1078	Carroll	Mary
1	6	6	0	BaltoWash Metro Area	1	1	1079	Baltimore	Mary
2	7	7	0	BaltoWash Metro Area	1	1	1081	Frederick	Mary
1	9	9	0	BaltoWash Metro Area	1	1	1163	Baltimore City	Mary
1	10	10	0	BaltoWash Metro Area	1	1	1165	Howard	Mary
2	11	11	0	BaltoWash Metro Area	1	1	1168	Montgomery	Mary
2	13	13	0	BaltoWash Metro Area	1	1	1197	Anne Arundel	Mary

This was possible from the option to complete a one to many join. The first time we attempted we used a one to one join, however it still would not have worked even if we had chosen the one to many option. Why? Well, at that time our file did not have any attributes in either file linking counties to subregions. It was only after we completed the spatial join based on county that the information was available in the attribute table.

Conclusion

ArcGIS Desktop has over 200 geoprocessing tools. In this tutorial, we've seen five of the most commonly used Geoprocessing tools:

1. **Buffer:** create a new area around an object.
2. **Clip:** create new files with the shape of one layer and the attributes of another.
3. **Intersect:** create a file with the shape of the shared areas and attributes of both layers.
4. **Dissolve:** remove the boundaries between adjacent areas that have the same values for attributes.
5. **Spatial Join:** add attributes of one file to another based on location.

Operation	Description	Attribute table changes?	New Shape is:	Attribute Table	Toolbox location
Buffer	Creates a new polygon at a buffered distance around a point, line or another polygon.	None	New polygon of distance	Attributes of layer buffered.	Analysis > Proximity > Buffer
Clip	Cuts out a piece of one theme using another theme as a "cookie cutter."	None	Overlay layer	Input layer	Analysis > Extract > Clip
Dissolve	Removes boundaries or nodes between adjacent polygons or lines that have the same values for a specified attribute.	Yes	Polygon layer of areas that share the specified value.	Only contains values that the dissolve affects. Lose all other attributes.	Data Management > Generalization > Dissolve
Intersect	Integrates two spatial data sets while preserving only those features falling within the spatial extent common to both themes (similar to Boolean AND).	Yes	Just the areas in common between the layers.	Combined attribute table of all layers used in operation.	Analysis > Overlay > Intersect
Spatial Join	Creates a table join in which fields from one layer's attribute table are appended to another layer's attribute table based on the relative locations of the features in the two layers.	Yes	Shape of target features layer (first one input)	Target layer attribute table with join features attributes at end.	Analysis > Overlay > Spatial Join
Union	Joins two layers together visually with the new attribute table consisting of shared/overlapping areas. NOT shown in this class.	Yes	Both layers used in operation	Attributes of shared areas	Analysis > Overlay > Union (Can also perform this via Editor Toolbar in ArcMap.)

Exercise: Spatial Analysis with Raster Data

Background

The analytical functions we have just performed in ArcGIS are based on a vector data structure of points, lines and polygons. As demonstrated, this data model is ideal for elements that have discrete boundaries like airports, highways and urban areas. But what if our data does not have discrete boundaries and is *continuous* over space (for example, elevation, slope, aspect or soil type)? The *raster* data model can be particularly beneficial in analyzing data that is continuous. As stated earlier, raster data is composed of a two-dimensional matrix of grid cells, with each cell assigned a numerical value.


In the following section, we will work through some analyses that may be performed on raster data. Bear in mind that with raster data, even more than with vector data, for a successful outcome it is essential to understand the parameters of the data you're working with and what you hope to achieve in your analysis. The exercises below are simply to introduce you to where the tools are located and to show you some of the mechanics—for true analysis, you will have to make the decisions!

The Spatial Analyst Extension and Toolbar

In order to use the raster model in ArcGIS we need to load the Spatial Analyst extension and activate the Spatial Analyst Toolbar.

1. **Open ArcMap and create a new blank map.**
2. **Click on 'Customize' > Extensions.**
3. **Turn on 'Spatial analyst'.**
4. **Go to Customize > Toolbars and make sure there is a check next to Spatial Analyst.**

Examine raster data

1. **Add an elevation data to ArcMap by clicking on the Add Data icon** 
2. **Navigate to C:\ESRI\GIS_WRKSHP\elevation**
3. **Use the 'identify' tool to get each cell's value**
4. **Right click on the elevation layer and go to 'Properties'.**
 - a. Look at the "Source" tab to find the size of the cells, the extent of the data, what spatial reference it is using, and other good information.
 - b. Look at the "Symbology" tab to see some color ramp options for display. Right click on "Color ramp" and uncheck "Graphic view" to see the names of the color ramps—pick "Elevation #1".
 - c. Look at the "Extent" tab to see the coordinates of the image's extent.

Surface Analysis

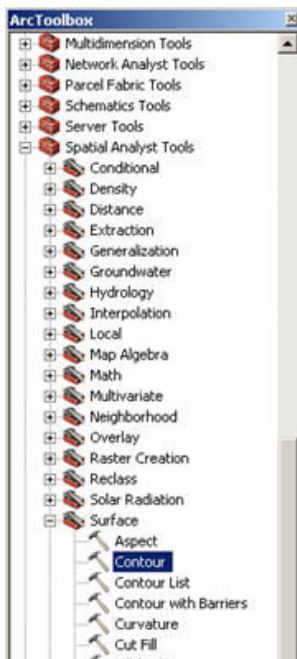
Surface analysis produces a new dataset—this can help you identify or derive patterns within the original dataset that may not have been evident. We will look at two examples: **contour** and **slope**. Contour will produce a vector output, while slope will produce a raster output. The raster output you get from spatial analysis on grid data can be either grid with unique values or Boolean.

Contour (Vector)

Why might you want to see contours? This is a very good way to look at the overall gradation of the land, and is familiar to the eye. Using contour as an example also illustrates how you can get a vector result from a raster original.

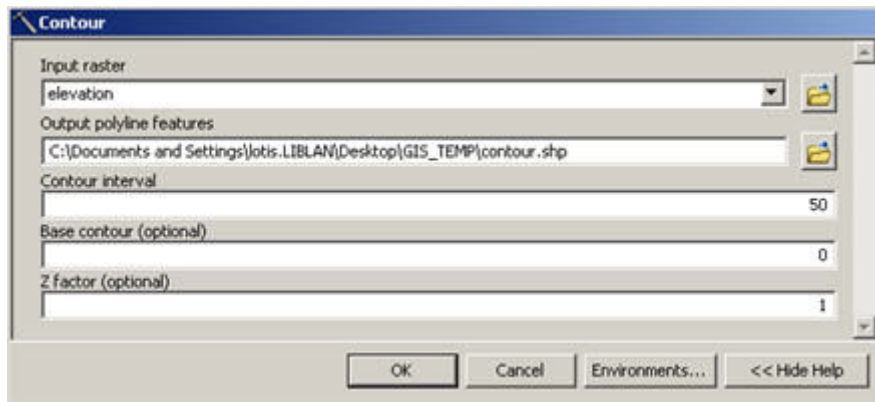
From ArcToolbox,

1. **Left-click on the plus sign to the left of ‘Spatial analyst.’**
2. **Left-click on the plus sign to the left of ‘surface’**
3. **Double click on ‘Contour.’**



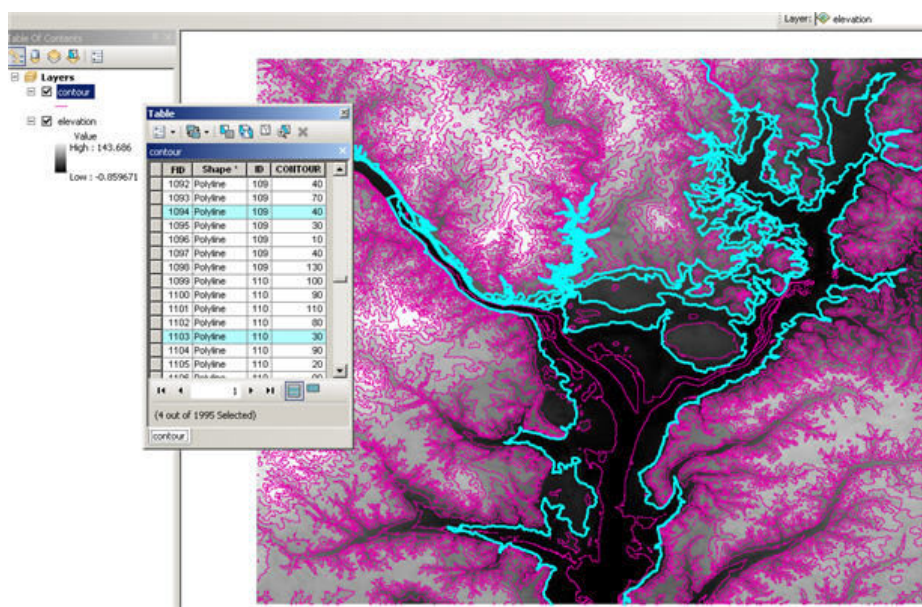
In the 'Contour' box,

1. Select "elevation" in the drop down box under 'Input raster'.
2. Navigate to the GIS_TEMP folder on the desktop in the 'Output polyline feature' box using the browse icon.
3. Name the file contour1.
4. Put '10' (or your own choice) in the 'Contour interval'.
5. Keep the defaults for the remaining boxes.
6. Click 'OK.'
7. A box showing the progress for the task will appear. When it is finished running, close the programming box.



Elevation raster data is converted into vector data—contour lines.

8. Right click on contour1.shp to open the attribute table.
9. Highlight a line and notice that the corresponding line on the map is highlighted.



Let's try another function from the surface menu.


Slope (Grid)

Examining slope tells you how steep the terrain is—this kind of output can then be analyzed and used for a variety of determinations such as likelihood of flooding, best places to locate buildings, etc. What the software is doing in this case is calculating the maximum rate of change between each raster cell and its neighbors. You can calculate your slope output either as percent slope or degree of slope. We will use percent in this example, and our output will be a raster.

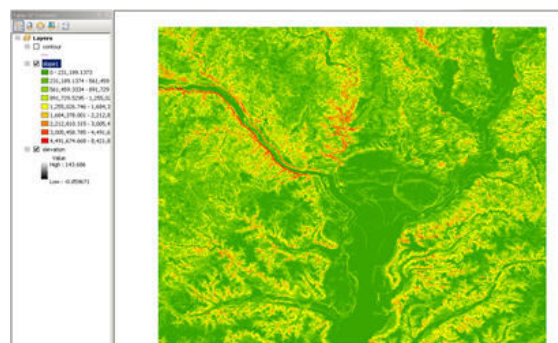
From ArcToolbox,

1. **Left-click on the plus sign to the left of 'Spatial analyst.'**
2. **Left-click on the plus sign to the left of 'Surface'**
3. **Double click on 'Slope.'**

In the 'Slope box',

1. **Select "elevation" in the drop down box under 'Input raster'.**
2. **Navigate to the GIS_TEMP folder on the desktop in the 'Output polyline feature' box using the browse  icon.**
3. **Name the file slope1.**
4. **Put "PERCENT_RISE" in the drop down box under 'Output measurements'.**
5. **Keep the defaults for the remaining boxes.**
6. **Click 'OK.'**
7. **A box showing the progress for the task will appear. When it is finished running, close the programming box.**

The resulting output is a slope map of the elevation data. The grid cells have been given new values based on the difference between their elevation value and that of their neighbors. In the example the dark areas are those with the steepest slopes.



Spatial Analysis Using Map Algebra: Boolean

Map algebra uses a predefined, mathematical formula applied to the corresponding cells of overlaid themes to create a new theme with the numerical result assigned to the cell. For example, if you add two themes, the value assigned to a cell will be the sum of the values of the cell in each old layer that corresponds to the location of the cell in the new layer.

3	2	1
0	0	1
2	1	4

5	0	3
1	2	0
4	1	4

8	2	4
1	2	1
6	2	8

Input 1

Input 2

Output

Calculation: add the values of corresponding cells.

Here's another visual example. We have two input rasters, each with cells that have values ranging from 0 to 5. We'd like to compare, and find only cells where the value is not zero in both of the inputs. This is what it would look like:

3	2	1
0	0	1
2	1	4

5	0	3
1	2	0
4	1	4

Input 1

Input 2

Calculation: find where values are nonzero in the cells of both inputs. (1=true; 0=false)

Output:

1	0	1
0	0	0
1	1	1

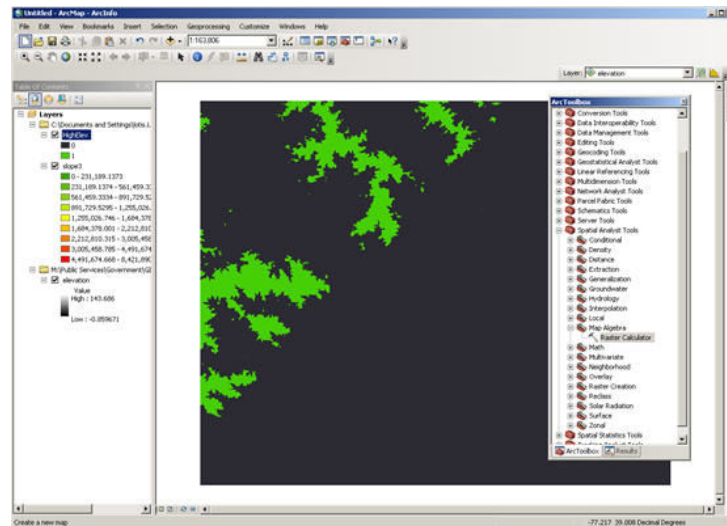
The formula used in map algebra can be a simple mathematical operation like addition, multiplication, division or subtraction (**arithmetic operators**), as in the first example. Map algebra can also use **Boolean operators** (And, Or, Xor, Not) as in the second example, or it can use a more complex operation involving logarithms, exponents, powers and trigonometric functions such as sine and cosine (**mathematical functions**).

This can be useful for detailed analysis. You can construct mathematical formulas using the values of your grid cells in each layer.

In ArcMap with ArcToolbox open,

1. Expand 'Spatial Analyst Tools' and 'Map Algebra'.
2. Double click on 'Raster Calculator'.
3. Use the buttons to get the following expression into the box (or directly type):
"elevation" > 100
4. Give the output raster a name (such as HighElev) and save it to the GIS_TEMP folder on the desktop.
5. Click OK.

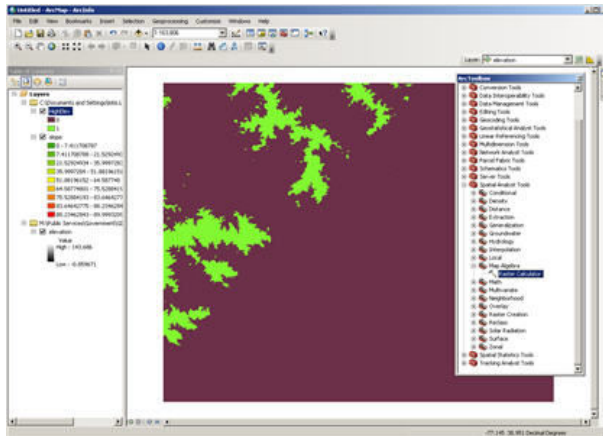
Your result will look like this:



What if we want to combine two rasters? For example, say we are growing a certain kind of crop that does best in areas with low elevation and slope. We can use map algebra to find areas where the elevation and slope are both high and then eliminate those areas from consideration when we do our planting.

1. Double click on the Raster Calculator tool.
2. Use the buttons to get the following expression into the box (or directly type):
("elevation">100) & ("slope1">75.0)
3. Give the output raster a name and save it to the GIS_TEMP folder on the desktop.
4. Click OK.

In the resulting raster, cells either have a value of 0 or 1. 0 indicates false and 1 indicates true. Therefore, the areas classed as 1 are the areas of high elevation and slope (the areas you want to avoid).



Conclusions

The examples provided here are very simple ones. We could have built a query that was far more complex. Other areas such as wetlands, parks, etc. could have been incorporated into the model and eliminated from consideration.

Grid analysis can be very complex. For example, you can use the themes of slopes, wetland areas, soils, forested areas, areas served by water/sewer utilities, proximity to transit, etc. to determine the best sites for building. The accuracy of the analysis depends on several things:

- **The accuracy and currentness of your data** – The old saying “garbage in, garbage out” holds true here. You want to have data that is current and accurate for the purpose of your analysis. Spatial Analyst allows vector data to be converted to grid data so any investment in vector data is not lost.
- **The resolution of your data** – The finer the resolution, the more detailed your analysis. You can set a resolution size so high that the grid data approaches vector data in appearance. The down side of very high resolution data is the amount of storage space that it uses. A resolution should be chosen appropriate to the scale for the data and the task at hand.
- **The values you assign to the cells and the appropriateness of your mathematical formula** – Spatial analysis is ultimately a judgement call of what is deemed “valuable” for some purpose, and your formula should be logical in its structure and sequence. The reasoning behind the value assignments and the formula used must be defensible.

We have worked through just two spatial overlay processes. There are many other potential uses. Overlay analysis could be used to determine the best sites for habitat protection areas or forest conservation areas. It can predict areas likely to erode based on soil types, slopes and landuse. It can delineate areas impacted by air traffic noise. The possibilities are almost endless. The power of GIS is the ability to perform this analysis quickly and efficiently.

Need to know more about raster data?

Recommended Virtual Campus Course: Working with Rasters in ArcGIS Desktop
(see next page for instructions on how to sign up)

More Training and Information

UM students, faculty and staff have access to free online courses provided by ESRI. These cover a wide range of GIS topics and skills. To sign up for a class, please contact gis@umd.edu with the name of the course you are interested in and your UMD e-mail address to obtain a registration code.

Course list: <http://training.esri.com/gateway/index.cfm?fa=aul.premiumCourses>

University of Maryland Libraries' GIS Data Repository: <http://libraries.umd.edu/gis/>

The data used in this workshop and some of the GIS data in the Libraries' collection are available for downloading from this site (because of licensing restrictions, for some data you will need to authenticate with your directory ID and password before downloading).

University of Maryland Libraries' Maps and GIS Website:

<http://www.lib.umd.edu/GOV/geospatial.html>

At this site, you can access guides to finding GIS data and maps, as well as the slides and workbooks from the Libraries' series of GIS workshops.