Spatial Analysis Using ArcGIS 10.5

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GIS Facilities at the University of Maryland

McKeldin Library

ArcGIS 10.5 and QGIS (an open source GIS software package) are loaded on all public workstations in McKeldin Library, including those located in the McKeldin 6101 instruction laboratory. The laboratory is open to the public during library hours when not in use by a class or librarian. The laboratory schedule is posted on the window by the door and updated each week. Color printing and large format printing are also available in McKeldin Library.

The GIS laboratory is located on the fourth floor of McKeldin Library in room 41218 This laboratory is available for use by faculty, staff, and students using geospatial methods in their research at the discretion of GIS and Spatial Data Center Staff. ArcGIS 10.5 and QGIS are installed on all computers in this laboratory, as well as other geospatial, image processing, and statistical packages.

For a complete list of software packages available, please see our GIS Facilities link https://www.lib.umd.edu/gis/people-and-facilities

Other Facilities

There are other departmental (e.g., anthropology, architecture/urban planning, civil engineering, geographical sciences, and landscape architecture) 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 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 10.5, 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.

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.

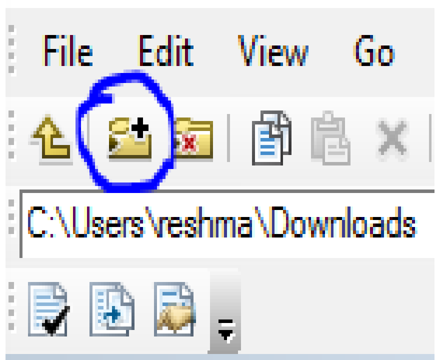
Exercise: Creating New Shapefiles (Two Ways)

Creating from scratch/by tracing

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

Let's first download the data we'll need for the exercises. Go to https://www.lib.umd.edu/gis/workshops and click on Data under Spatial Analysis workshop details. Make sure the data is downloaded to the Downloads folder. Go ahead and unzip the data by right clicking on the folder and clicking on extract. Now you should have the data required in the Downloads folder.

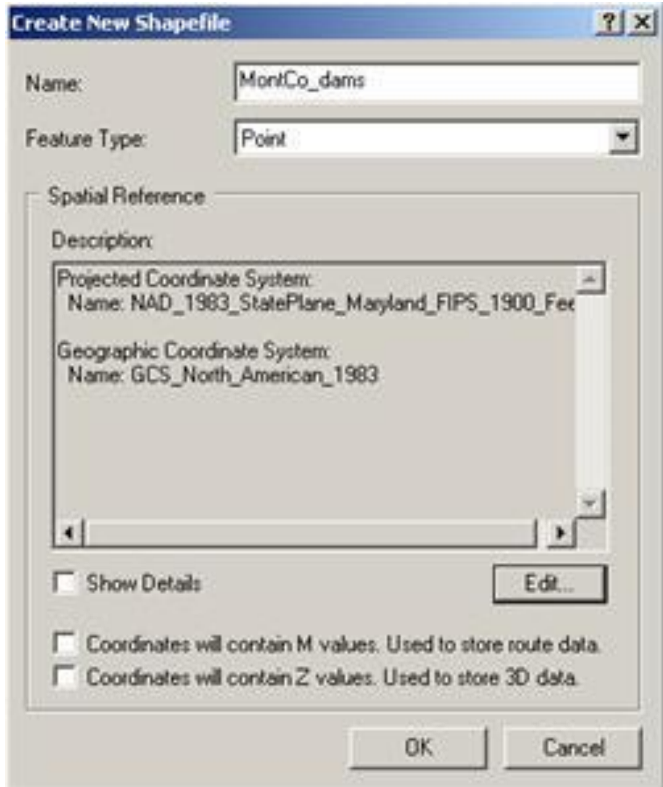
1. **Open ArcCatalog.**
2. **First we must highlight the folder in which we wish to create the shapefile in the catalog tree. Navigate to C:\USERS\"YourDirectoryID"\DOWNLOADS\Data. Highlight the Data folder. Click on the Connect to Folder icon and**



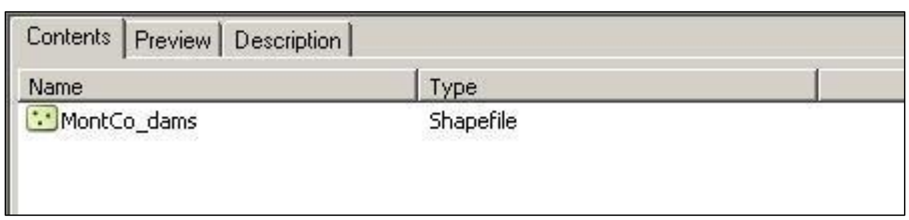
3. **Once the appropriate folder is selected we can create a new shapefile. Go to the Menu Bar (or right click on the highlighted folder) and select File > New > Shapefile. The 'Create New Shapefile' dialog box will appear.**
4. **First we must give our new shapefile a name. Type "MontCo_dams" in the 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. **Open the Projected Coordinate Systems folder by double clicking.**
8. **Open the State Plane folder by double clicking.**
9. **Open the NAD 1983 (US Feet) folder by double clicking.**
10. **Select the NAD 1983 State Plane Maryland FIPS 1900 (US Feet) file and click 'OK'.**
11. **Once you have returned to the Spatial Reference Properties dialog box click 'OK'.**

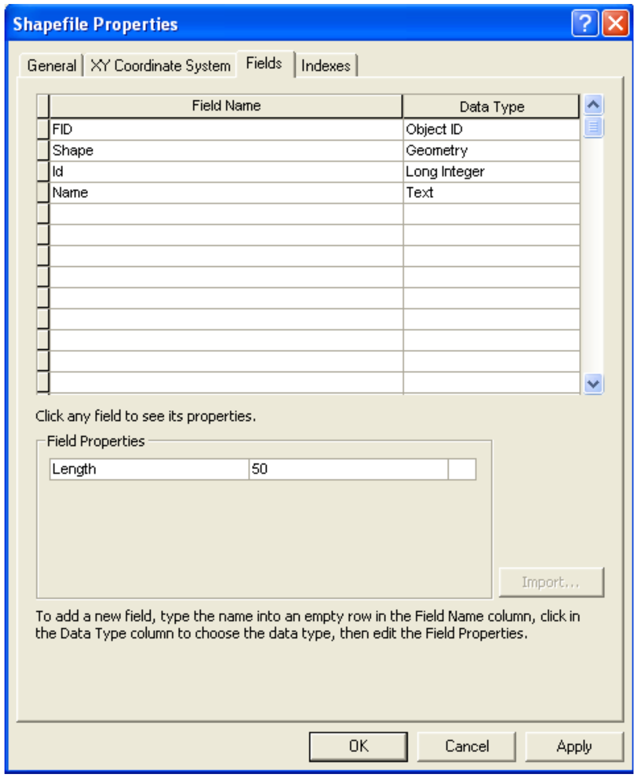


12. **Once you have returned to the Create New Shapefile dialog box click 'OK'.**



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 below 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'**.

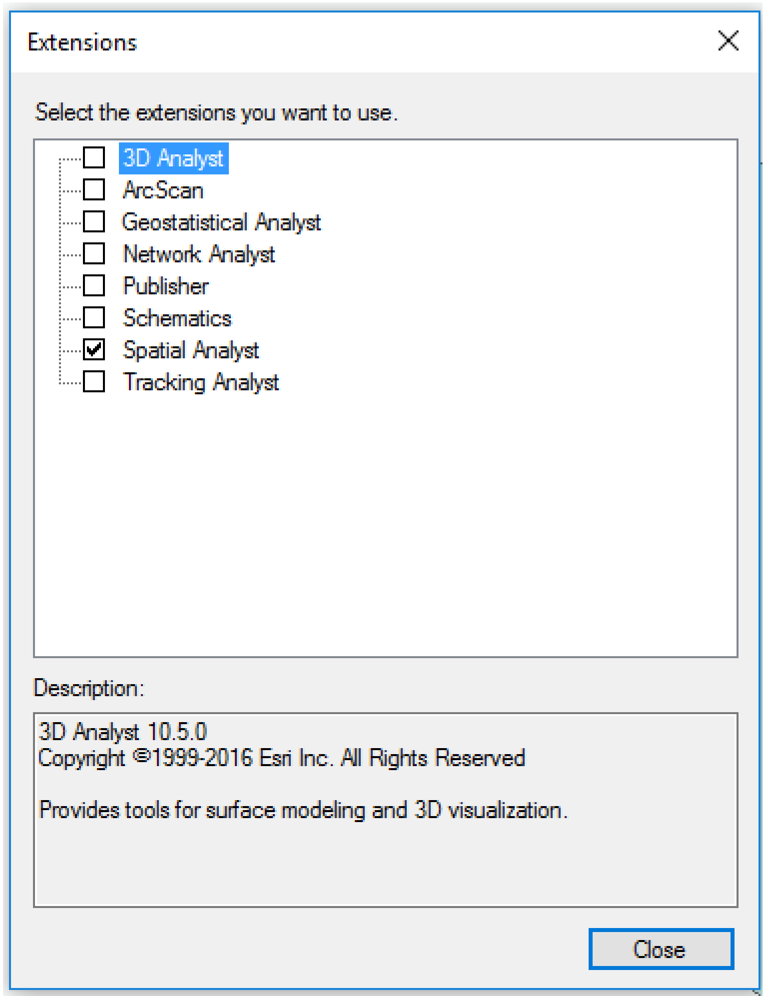


We are now going to add our new shapefile to ArcMap. When we add the new shapefile it will appear in the table of contents but nothing will appear on the screen. This is because we have not yet created any points for our shapefile.

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

Before we start, let's make sure the Spatial Analyst extension that we need for these exercises is turned on.

Go to Customize tab that you see at the top and click on extensions and check the box next to Spatial Analyst.



1. **Choose 'A new empty map' and click 'OK'.**
2. **Select the add data button** 
3. **Navigate to C:\USERS\"YourDirectoryID"\DOWNLOADS\Data 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:\USERS\"YourDirectoryID"\DOWNLOADS\Data 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).

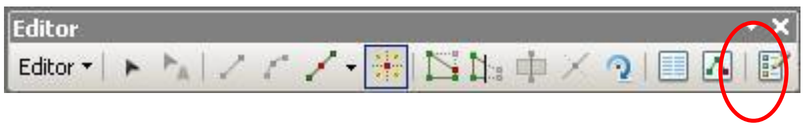
We are going to create the points for our new point file by using a point file that was downloaded from the National Map Seamless Server.

1. **Use the 'Add Data' icon, navigate to C:\USERS\"YourDirectoryID"\DOWNLOADS\Data and add 'md_dam_points.shp'.**

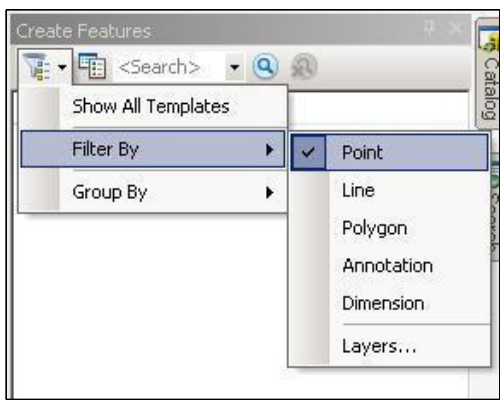
You can see that this is a file containing points for dams in and around Montgomery County. We will trace points for only those dams that are within our county boundary. To do this we must use the Editor toolbar. If the Editor toolbar is not currently displayed, **go to the menu bar and select Customize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

From the Editor toolbar **select Editor > Start Editing**. The computer will ask you which folder you wish to edit from. **Select 'md_dam_points.shp' and press Continue.**

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

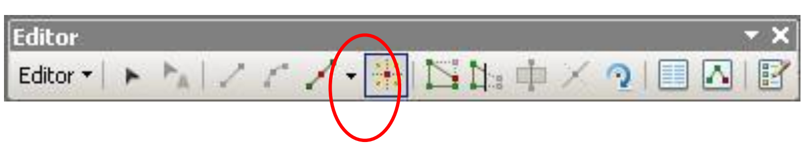


A "Create Features" window will open on the right side of the screen. We will be creating points, so you may need to click the drop-down and choose Filter By > Point as shown below.



Click on the 'MontCo_Dams' file name in the Create Features box to select the file for editing.

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.)

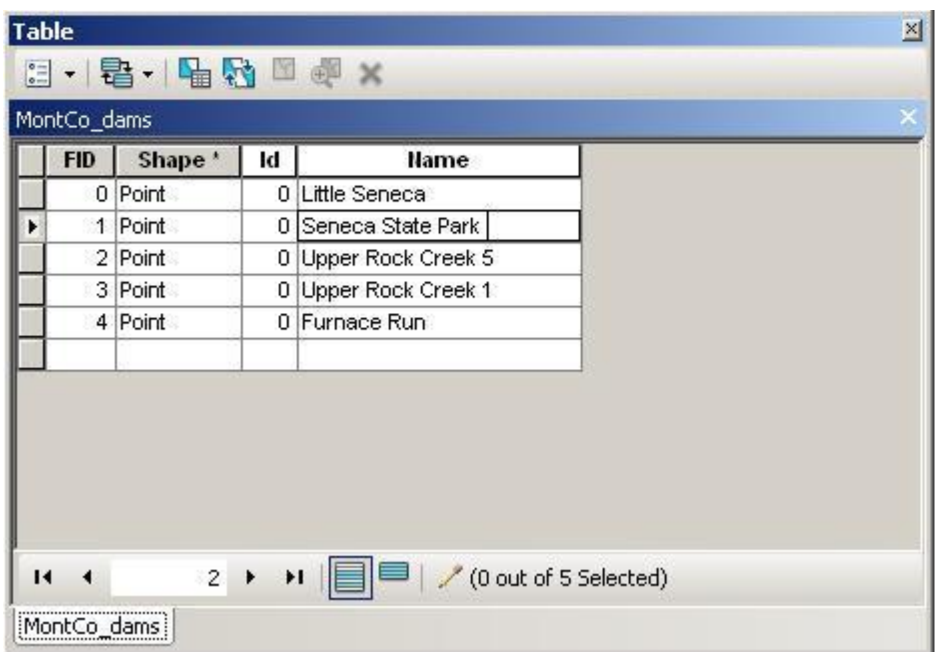


We are going to use the mouse to draw a point over top of each dam that is within Montgomery County. You will see that the tool automatically zooms and centers the points you want to trace when you hover over them. To place a new point on the map, left click once with the mouse. Each time you click on 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. **Select MontCo_Dams in your Layers list so it is highlighted in blue. Right click and open the attribute table.**
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.** (In reality, each point corresponds to a specific dam, but for the purpose of this exercise we are not worried about labeling each dam correctly).
6. When you have finished **go to the editor toolbar and select Editor > Save Edits, then select Editor > Stop Editing.**



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:\USERS\”YourDirectoryID”\DOWNLOADS\Data 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 “Sub regions” 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. **Open the Projected Coordinate Systems folder by double clicking.**
3. **Open the State Plane folder by double clicking.**
4. **Open the NAD 1983 (US Feet) folder by double clicking.**
5. **Select the NAD 1983 State Plane Maryland FIPS 1900 (US Feet) file and click ‘OK’.**
6. 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 below 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.**

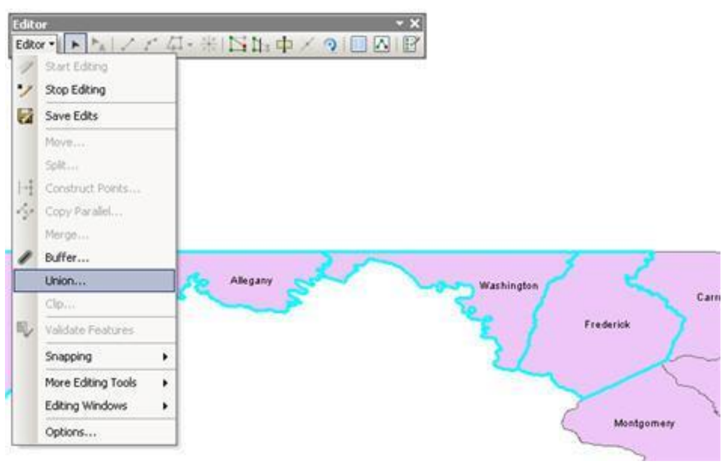
13. Under Field Properties we may choose the number of characters to be allowed in this field. For our purposes we will **keep the default of 50.**
14. **Click OK**.
15. **Close ArcCatalog**.

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:\USERS\"YourDirectoryID"\DOWNLOADS\Data**. **Next we must add the new Subregions shapefile we just created which is located in the same directory.**

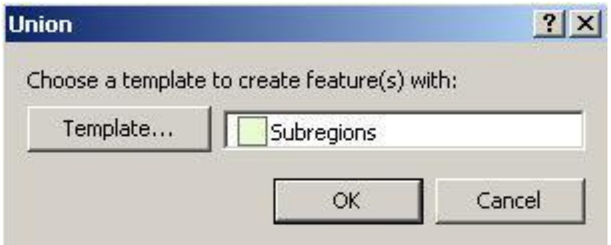
We will break the State into four regions: Western Maryland, Southern Maryland, the Eastern Shore, and the Baltimore-Washington Metropolitan Area. To add labels to the counties in Maryland, **right click on 'mdcounties' and scroll down to 'Label Features'**.

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. **Select the Sub regions shapefile** – this will cause the software to choose the correct source data for that shapefile to edit.
6. **Go to the Editor Toolbar once again and select Editor > Union.**

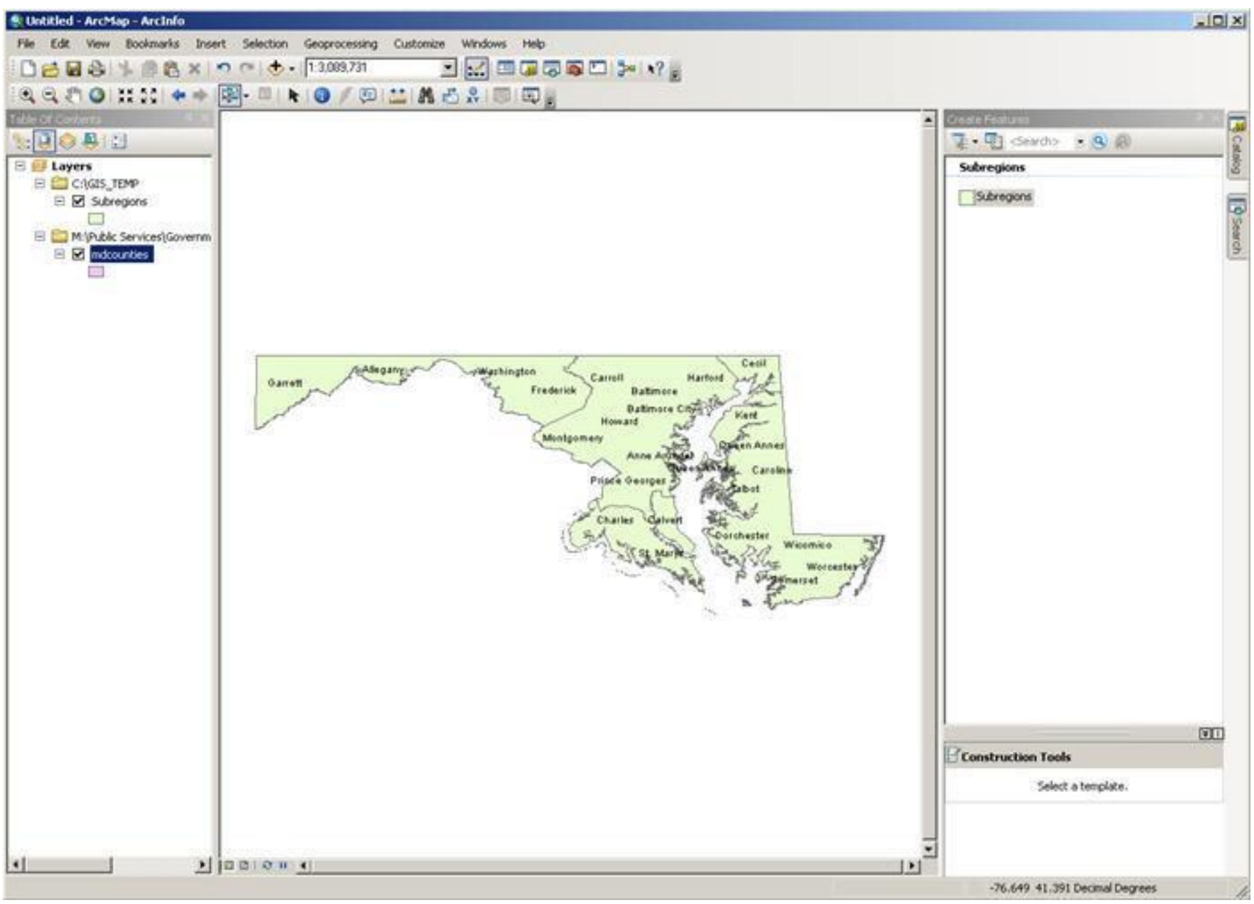


If prompted to choose a template, click OK.



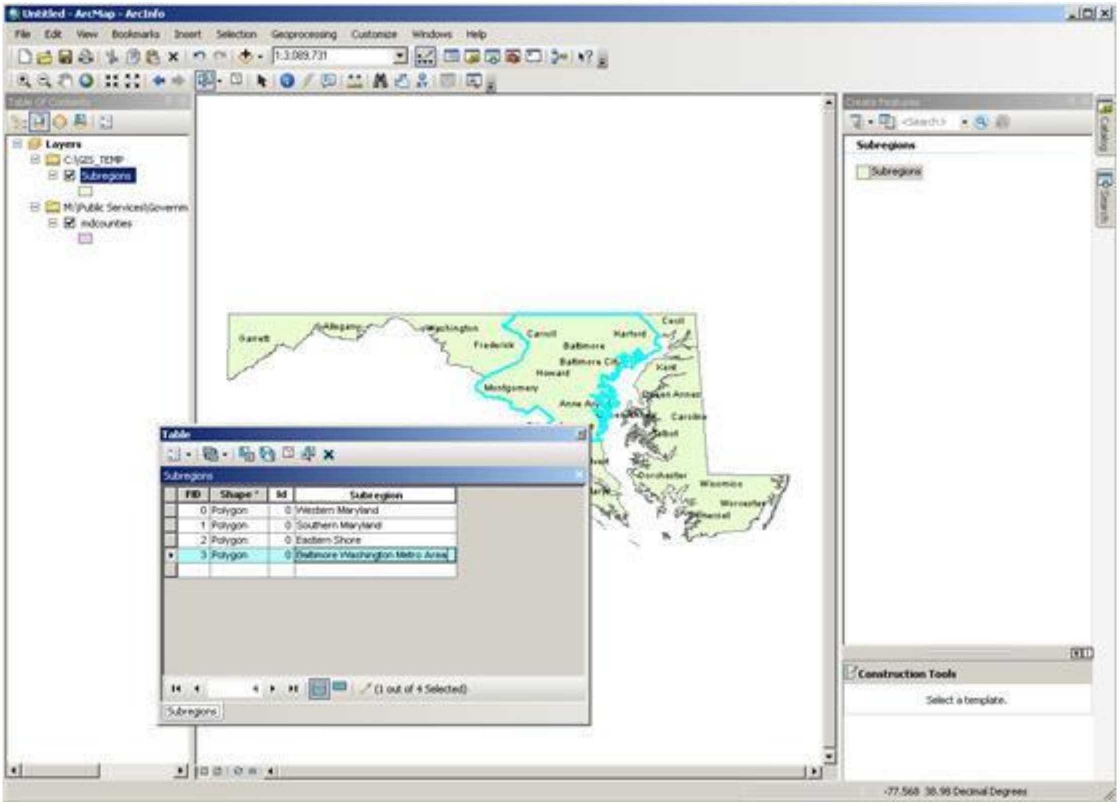
7. **Click the 'Clear Selected Features' icon**  **.**

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. Mary's), the Eastern Shore (Cecil, Kent, Queen Anne's, Talbot, Caroline, Dorchester, Wicomico, Somerset, and Worchester) 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' and save the map.**

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.

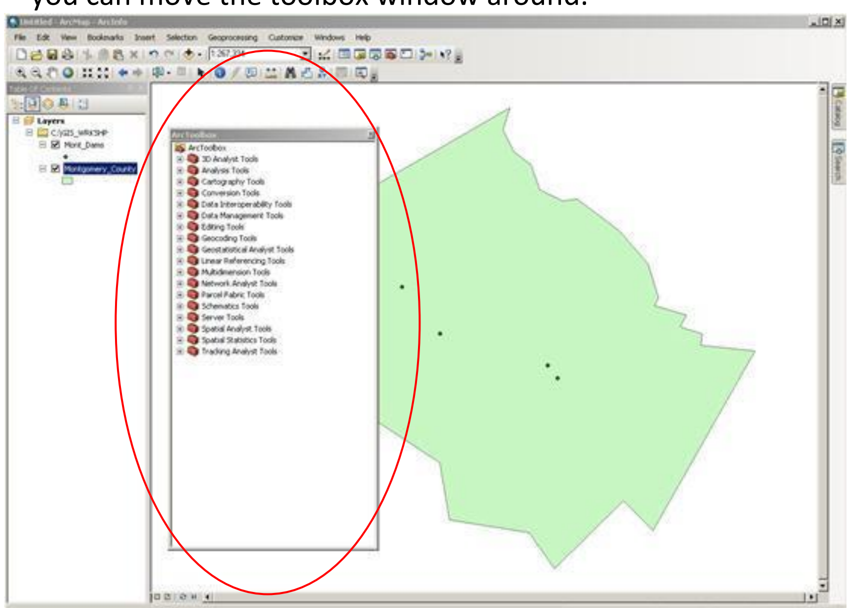
If you do not already have the file available in the table of contents, do the following:

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

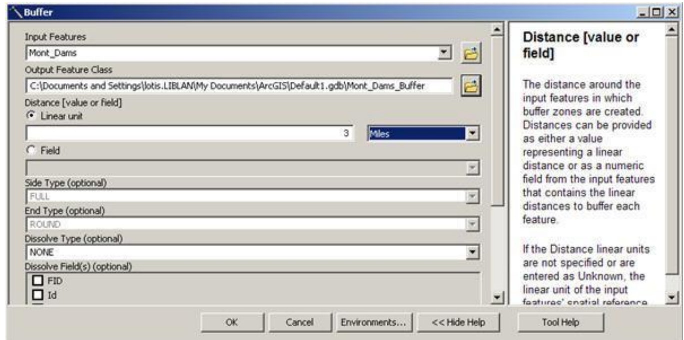
Let's pretend that we are working for Montgomery County and are looking into disaster planning. We'd like to know who will be affected if one or all of the dams break and how we can get emergency response teams to the area. We have been told by experts that we should be looking into a 3 mile radius of 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.



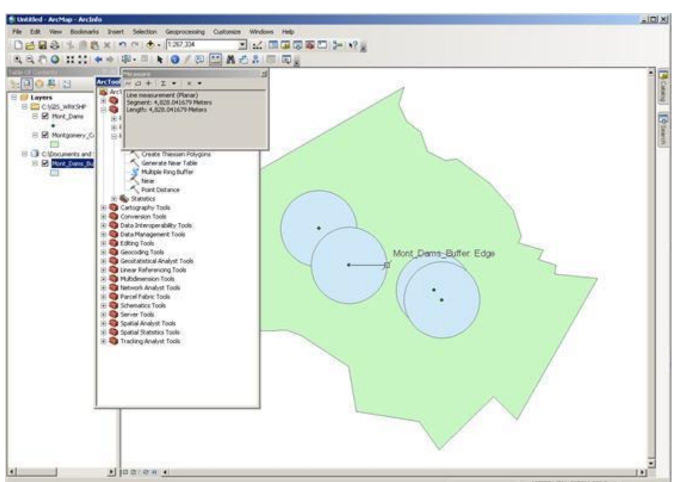
2. **Single click on the plus sign next to Analysis Tools.**
3. **Single click on the plus sign next to Proximity.**
4. **Double click on Buffer.**



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 Data folder in DOWNLOADS** in the box for 'Output Feature Class' and name the new file 'Mont_Dams_Buffer'. If you are unable to navigate to the Data 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.**

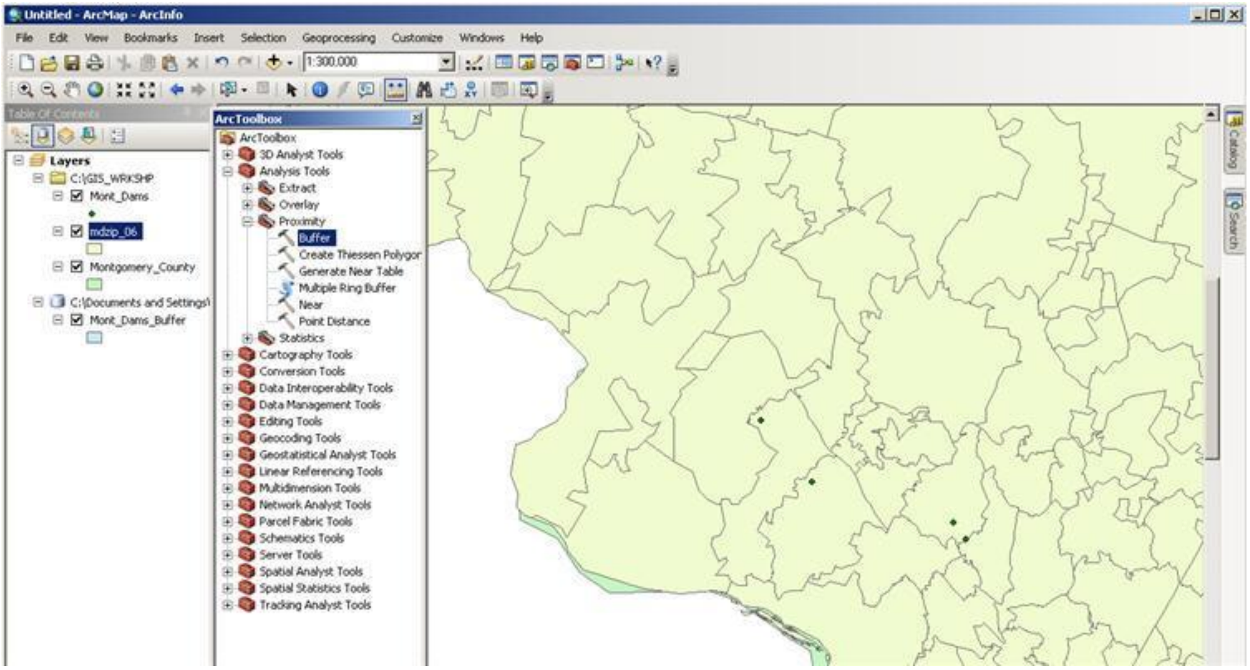
The table shows each dam and the buffer distance of 3 miles displayed in feet (15,840 Feet = 3 miles).

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.

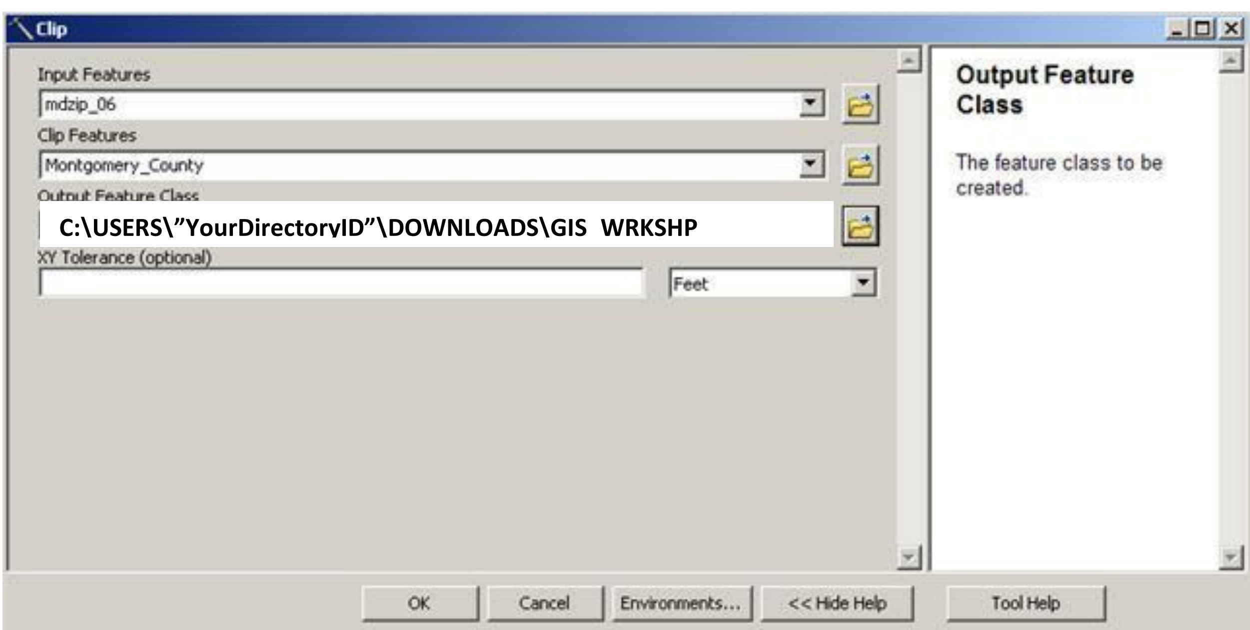
Usually associated with the “within” condition, the clip function works like a cookie cutter. In our case we will be using the state zip code file as the input layer (the cookie dough) and cutting it with Montgomery County (the cookie cutter). We’ll end up with the shape of Montgomery County and the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

1. **Click on the add data icon.** 
2. **Navigate to C:\USERS\”YourDirectoryID”\DOWNLOADS\Data.**
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.)



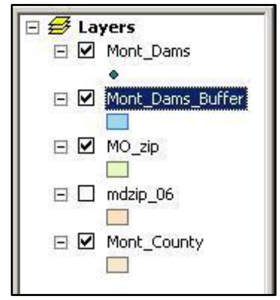
A layer for the zip codes in Maryland from 2006 will be added. **Re-open the ArcToolbox window if it is not already open. Under Analysis Tools > Extract, double click on Clip. Or from the menu bar, click on Geoprocessing > Clip.**

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.**



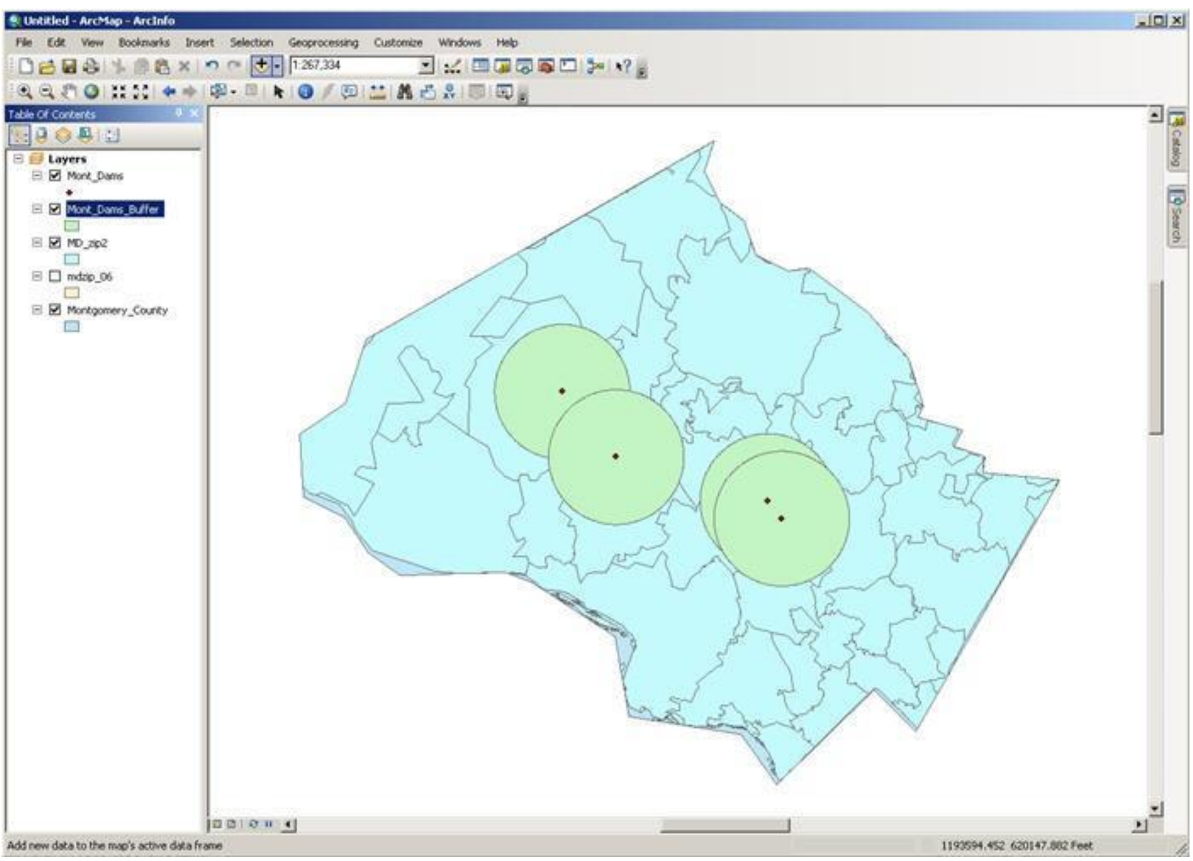
3. **Navigate to (using the browse icon ) C:\USERS\"YourDirectoryID"\DOWNLOADS\Data as the location for the 'Output Feature Class'.**
4. **Name the file 'MD_zip'.**
5. **Click save then 'OK'.**

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



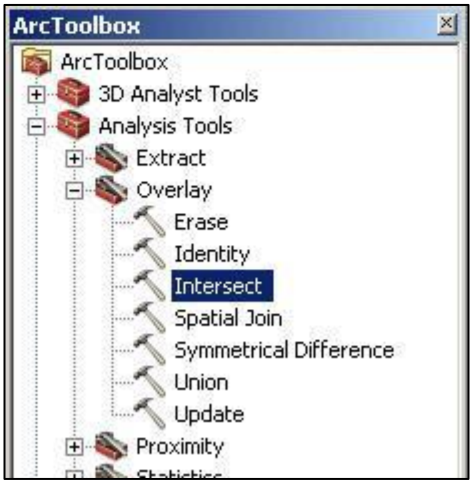
1. **Turn off md_zip06.**
2. **Click on and hold the left mouse button and drag Mont_Dams_Buffer under Mont_Dams.** (If necessary, click on the "List By Drawing Order" icon  – then you will be able to move layers.)

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.

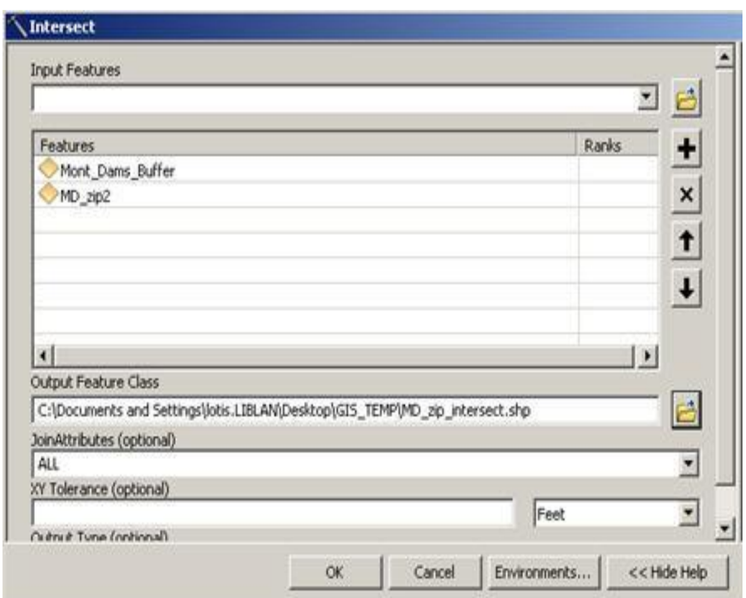


From the ArcToolbox menu:

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'.**

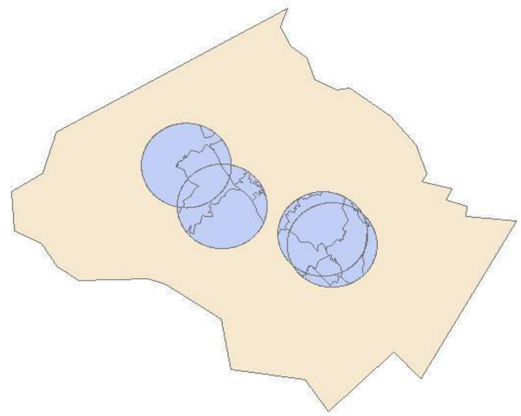
The Intersect window will open.

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 Data folder in DOWNLOADS and call the file MD_zip_Intersect. Click 'SAVE'.**
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

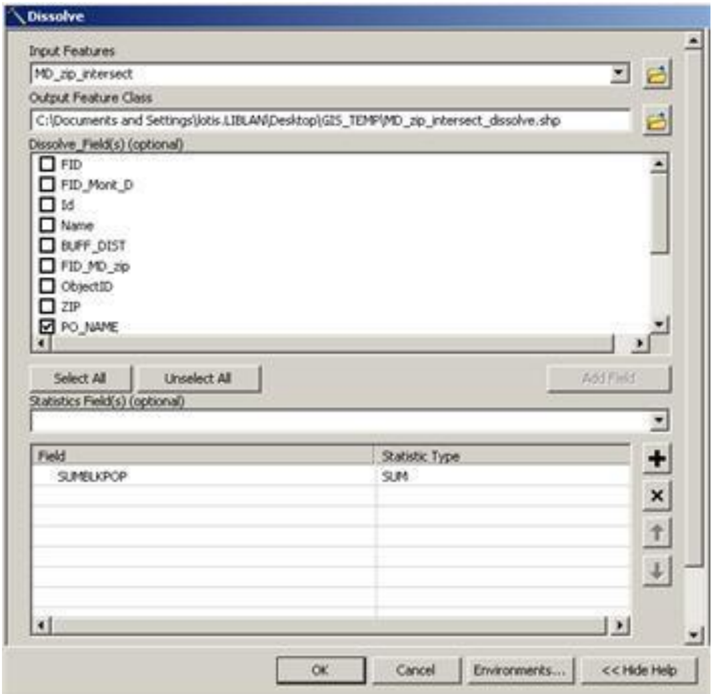
Still pretending to be Montgomery County, we have decided that it would be nice to have a map and table of the post offices in charge of each zip code. We'd like to quickly contact the post offices so they can send out emergency information to the residents in the affected areas. As the larger areas 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.'**

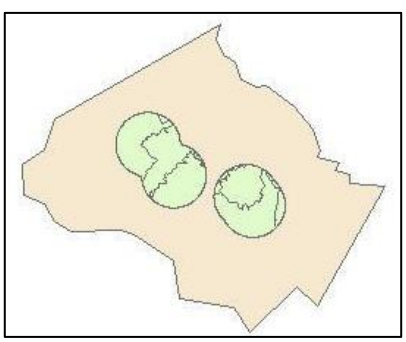
The Dissolve window will open.

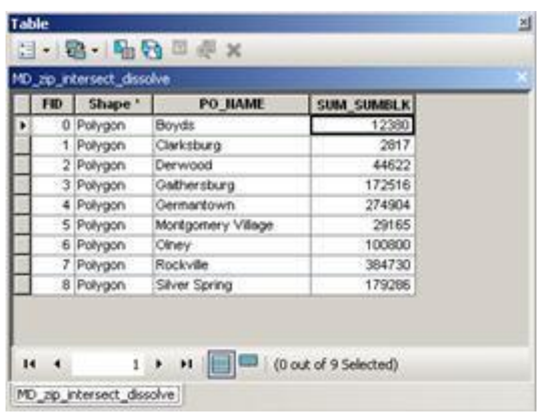
5. **In the drop down box for 'Input Features' select MD_zip_Intersect.**
6. **For 'Output Feature Class', use the browse button and navigate to Data in DOWNLOADS. Save the file as "MD_zip_Intersect_Dissolve."**
7. **Check the box next to "PO_Name" in the 'Dissolve_Field(s) box.** This allows us to dissolve 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	Boyds	12380
1	Polygon	Clarksburg	2817
2	Polygon	Derwood	44622
3	Polygon	Gaithersburg	172516
4	Polygon	Germantown	274904
5	Polygon	Montgomery Village	29165
6	Polygon	Olney	100800
7	Polygon	Rockville	384730
8	Polygon	Silver Spring	179286

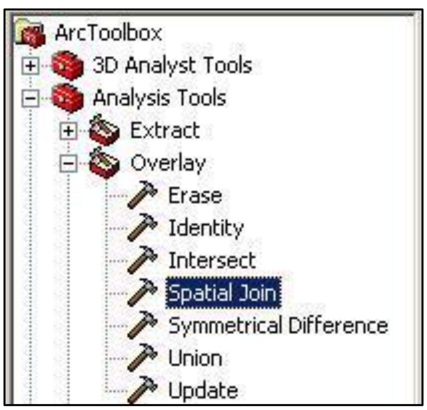
5. Spatial Join

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 TractPly and BankPt shapefiles. Open a new map in ArcMap and add these two files (navigate to C:\USERS\"YourDirectoryID"\DOWNLOADS\Data).

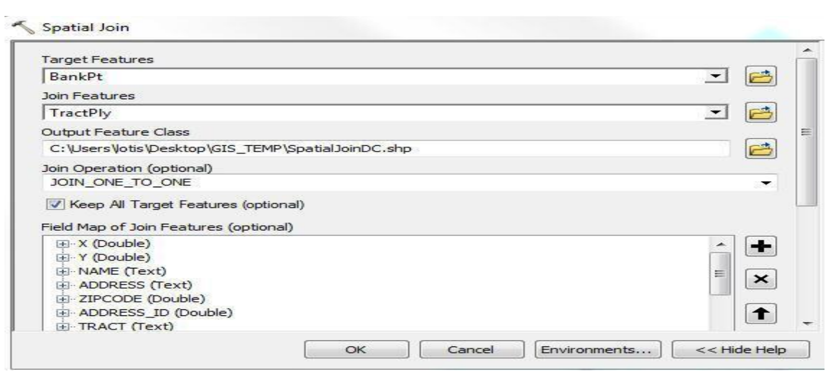
A spatial join can be useful, as in this example, for determining which points fall within polygons.

You can perform a spatial join either through ArcToolbox or by right clicking on a layer, choosing Properties > Join and in the Join Data box, "Join data from another layer based on spatial location". Using ArcToolbox will give you a little more control over the details and the ability to exclude fields from the new attribute table if you wish, so we will use that method.



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.'**

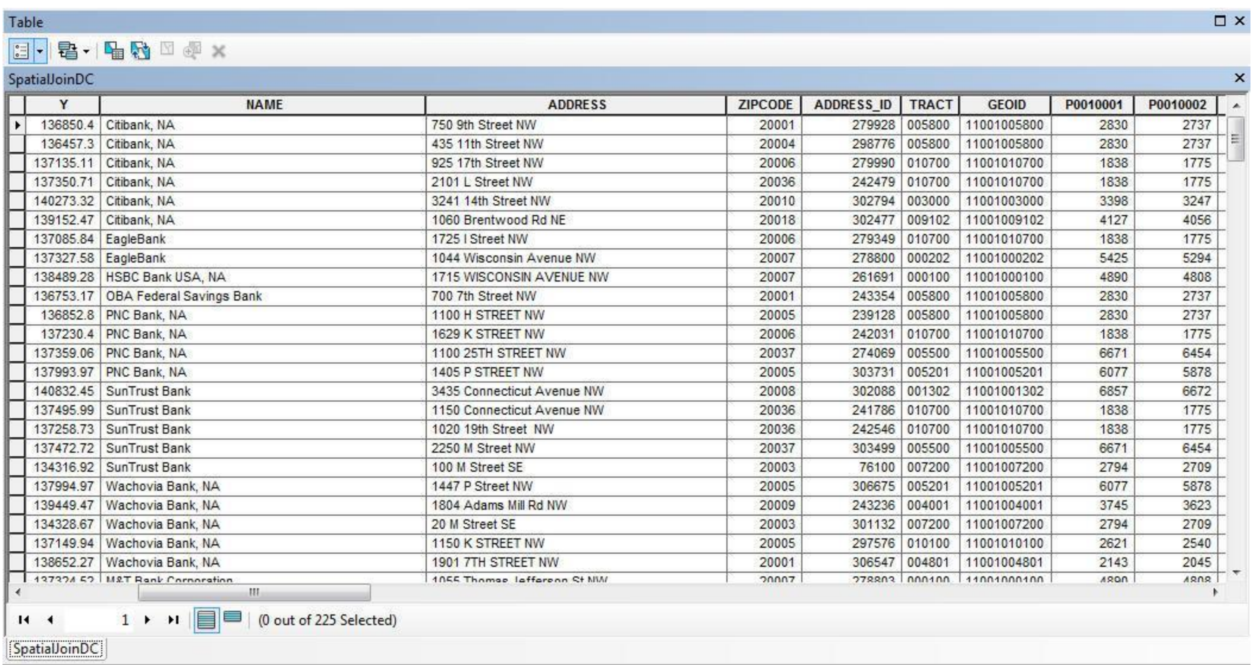


In the 'Spatial Join' box,

1. **Select “BankPt” in the drop down box under Target Features.**
2. **Choose “TractPly” in the ‘Join Features’ drop down box.**
3. **Navigate to the Data folder in DOWNLOADS in the ‘Output Feature Class’ box using the browse icon.**
4. **Name the file spatialjoin.**
5. **Choose JOIN_ONE_TO_MANY.** (There may be many banks located within one census tract polygon.)
6. The “Field Map of Join Features” is where you can specify if you would like to remove certain fields from the joined attribute table – this can be helpful if you have extraneous fields. For example, all we really want out of the attribute table of the census tracts layer is the field containing the census tract number (TRACT), so we could remove all the fields after GEOID for clarity if we wanted to.
7. **Keep the remaining default values listed for the remaining boxes as well.**
8. **Click ‘OK’.** Wait for the spatial join to run.

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

Let’s check the attribute table. Scroll through and see how this spatial join added the attributes for TractPly to the end of the BankPt file.



Y	NAME	ADDRESS	ZIPCODE	ADDRESS_ID	TRACT	GEOID	P0010001	P0010002
136850.4	Citibank, NA	750 9th Street NW	20001	279928	005800	11001005800	2830	2737
136457.3	Citibank, NA	435 11th Street NW	20004	298776	005800	11001005800	2830	2737
137135.11	Citibank, NA	925 17th Street NW	20006	279990	010700	11001010700	1838	1775
137350.71	Citibank, NA	2101 L Street NW	20036	242479	010700	11001010700	1838	1775
140273.32	Citibank, NA	3241 14th Street NW	20010	302794	003000	11001003000	3398	3247
139152.47	Citibank, NA	1060 Brentwood Rd NE	20018	302477	009102	11001009102	4127	4056
137085.84	EagleBank	1725 I Street NW	20006	279349	010700	11001010700	1838	1775
137327.58	EagleBank	1044 Wisconsin Avenue NW	20007	278800	000202	11001000202	5425	5294
138489.28	HSBC Bank USA, NA	1715 WISCONSIN AVENUE NW	20007	261691	000100	11001000100	4890	4808
136753.17	OBA Federal Savings Bank	700 7th Street NW	20001	243354	005800	11001005800	2830	2737
136852.8	PNC Bank, NA	1100 H STREET NW	20005	239128	005800	11001005800	2830	2737
137230.4	PNC Bank, NA	1629 K STREET NW	20006	242031	010700	11001010700	1838	1775
137359.06	PNC Bank, NA	1100 25TH STREET NW	20037	274069	005500	11001005500	6671	6454
137993.97	PNC Bank, NA	1405 P STREET NW	20005	303731	005201	11001005201	6077	5878
140832.45	SunTrust Bank	3435 Connecticut Avenue NW	20008	302088	001302	11001001302	6857	6672
137495.99	SunTrust Bank	1150 Connecticut Avenue NW	20036	241786	010700	11001010700	1838	1775
137258.73	SunTrust Bank	1020 19th Street NW	20036	242546	010700	11001010700	1838	1775
137472.72	SunTrust Bank	2250 M Street NW	20037	303499	005500	11001005500	6671	6454
134316.92	SunTrust Bank	100 M Street SE	20003	76100	007200	11001007200	2794	2709
137994.97	Wachovia Bank, NA	1447 P Street NW	20005	306675	005201	11001005201	6077	5878
139449.47	Wachovia Bank, NA	1804 Adams Mill Rd NW	20009	243236	004001	11001004001	3745	3623
134328.67	Wachovia Bank, NA	20 M Street SE	20003	301132	007200	11001007200	2794	2709
137149.94	Wachovia Bank, NA	1150 K STREET NW	20005	297576	010100	11001010100	2621	2540
138652.27	Wachovia Bank, NA	1901 7TH STREET NW	20001	306547	004801	11001004801	2143	2045
137324.52	M&T Bank Corporation	1055 Thomas Jefferson St NW	20007	278803	000100	11001000100	4890	4808

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!

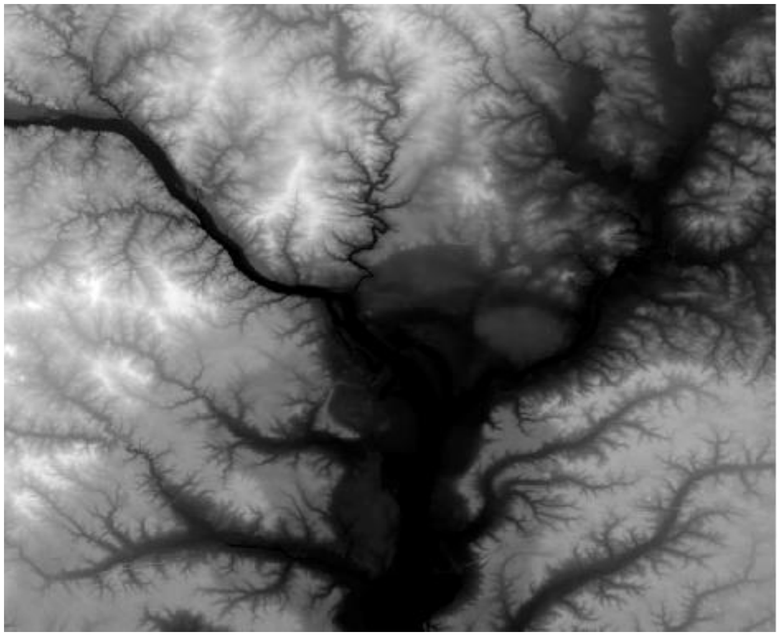
The Spatial Analyst Extension and Toolbar

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

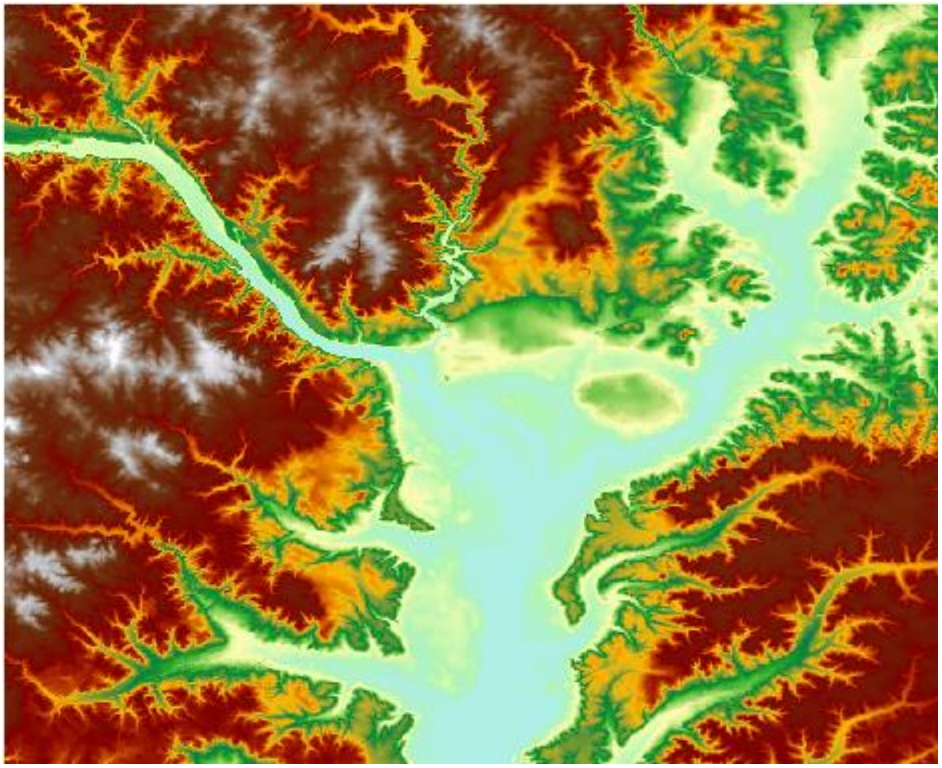
1. **Open ArcMap and create a new blank map.**
2. **Click on 'Customize' > Extensions.**
3. **Turn on 'Spatial analyst' by checking the box next to it.**

Examine raster data

1. **Add an elevation data to ArcMap by clicking on the Add Data icon** 
2. **Navigate to C:\USERS\"YourDirectoryID"\DOWNLOADS\Data \elevation. You should see the following image. The greater the elevation the lighter the areas looks and the lower elevation, darker the areas looks. However, we can use color ramps (color schemes) other than black to white to highlight the same information. You may have to take into account whether your audience may have color blindness. But for now let's practice changing the color ramp.**



3. **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.
    b. Look at the "Symbology" tab to see some color ramp options for display.
    c. If you click on color ramp, you can see the different color schemes that can be used to show change in elevation.
    d. These color ramps also have names. To see their names right click on "Color ramp" and uncheck "Graphic view". Let's pick "Elevation #1" for this exercise.
    e. Look at the "Extent" tab to see the coordinates of the image's extent.
    f. Click apply



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.

The coordinate system used for the elevation raster uses Decimal Degrees for latitude and longitude (X and Y) and meters for the elevations (Z). Most of the analysis we want to do using elevation datasets – such as creating a hill shade raster or creating contour intervals requires us to transform the coordinate system of the raster so that X, Y and Z are all in the same units. Choose the projected coordinate system that is appropriate for the area of geographic coverage.

Project Elevation Model

- Click the toolbox icon on the ArcMap toolbar to bring up the Geoprocessing Toolbox
- Open the following chain of expandable toolsets: **Data Management Tools> Projections and Transformations > Raster > Project Raster**
- Use pull-down menu for **Input Raster** to and browse to your elevation model.
- In the **Output Raster** Dataset blank file location enter the Data folder in DOWNLOADS and name the file. Remember ArcMAP does not accept long names or spaces.

- In the pull-down for the **Output Coordinate System** choose***: Projected Coordinate System, State Plane, NAD 83 US Feet, then Maryland State Plane FIPS1900 US Feet*** and click ok.
- Finally, go to the blank labeled **Resampling Technique** and choose **Cubic**
- Click ok

Resampling

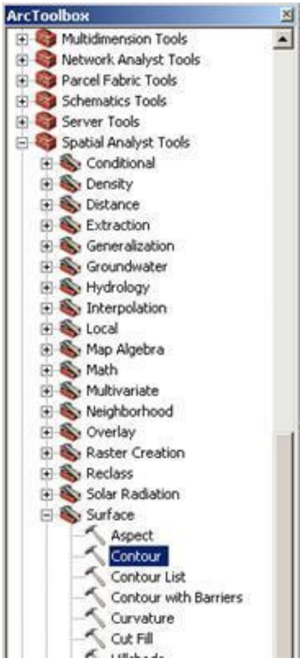
When a raster dataset is projected from a plain geographic coordinate system to a projected one, the size and shape off the cells is transformed. You can think of Resampling as creating a new grid of cells and assigning values to the new cells based on the values of the old cells. The default method (Nearest Neighbor Resampling) simply assigns a value to the new cell based on the value of the cell in the old raster that is nearest to the center of the new one. This is the right thing to do with rasters whose values represent categories. For rasters that represent a continuous surface the **Nearest Neighbor** method can create stair-stepped striations. For continuous value rasters, like elevation models, the **Cubic** resampling method is best. (Source: http://www.gsd.harvard.edu/gis/manual/dem/)

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.

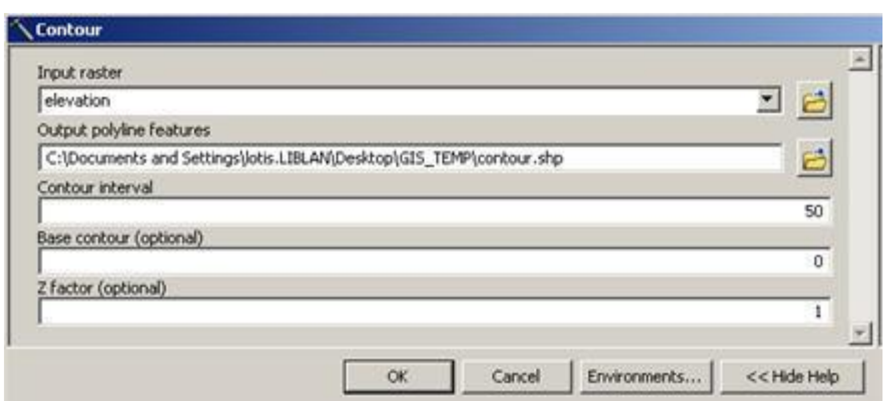
From ArcToolbox,

1. **Go to ArcTools and Left-click on the plus sign to the left of 'Spatial analyst tools.'**
2. **Left-click on the plus sign to the left of 'surface'**
3. **Double click on 'Contour.'**



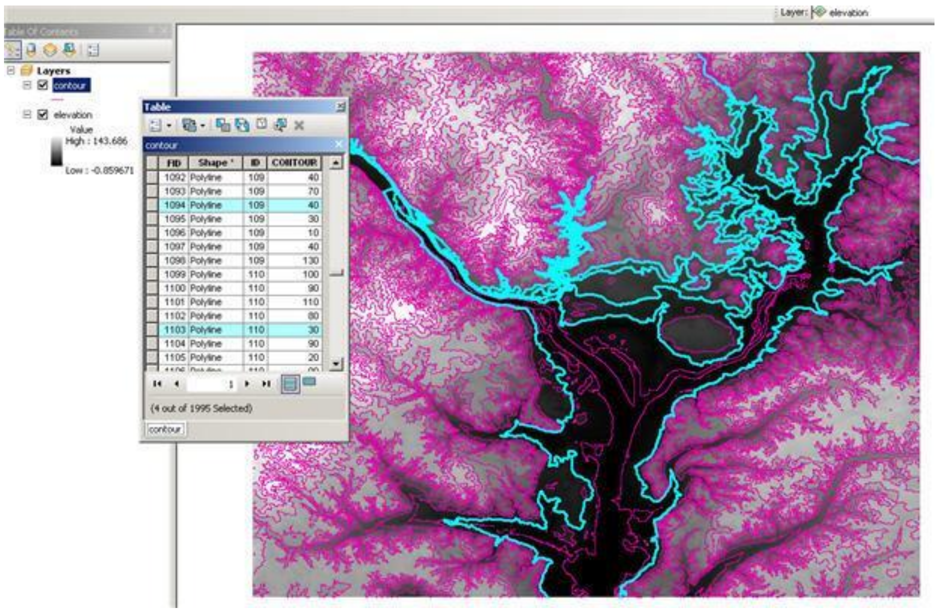
In the ‘Contour’ box,

1. **Select “elevation” in the drop down box under ‘Input raster’.**
2. **Navigate to the Data folder in DOWNLOADS 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,

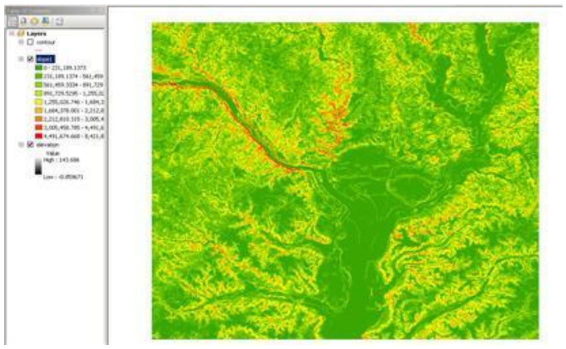
1. **Go to ArcTools and Left-click on the plus sign to the left of 'Spatial analyst tools.'**
2. **Left-click on the plus sign to the left of 'Surface'**
3. **Double click on 'Slope.'**

In the 'Slope box',

1. **Select "elevation" in the drop down box under 'Input raster'.**
2. **Navigate to the Data folder in DOWNLOADS in the 'Output raster' box using the browse icon.**
3. **Name the file slope1 and click save.**

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

8	2	4
1	2	1
6	2	8

5	0	3
1	2	0
4	1	4

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

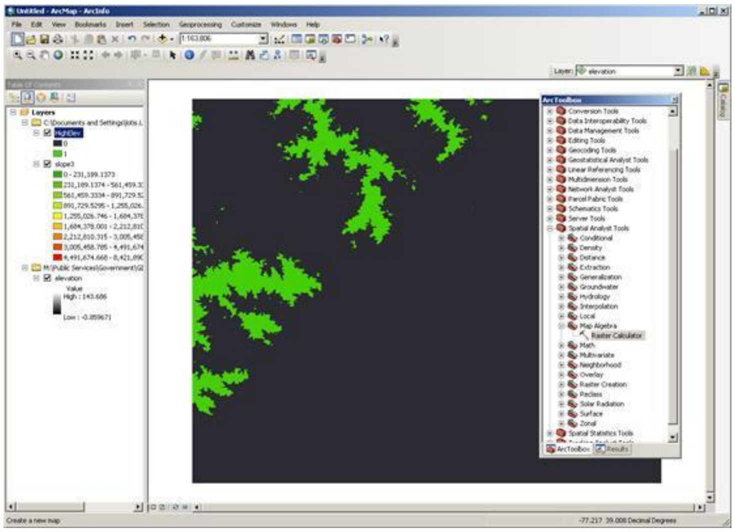
The formula used in map algebra can be a simple mathematical operation like addition, multiplication, division or subtraction (**arithmetic operators**), as in the first example. Map algebra can also use **Boolean operators** (And, Or, Xor, Not) as in the second example, or it can use a more complex 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 Data folder in DOWNLOADS.**
5. **Click OK. If you do not see the map, zoom out.**

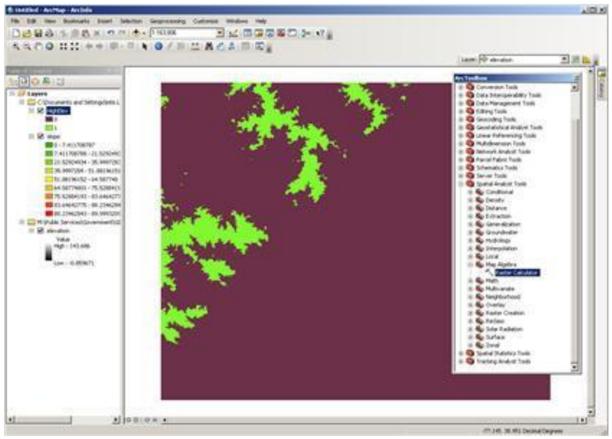
Your result will look like this:



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 Data folder in DOWNLOADS.**
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 utlimately 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 possibilties 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

University of Maryland at College Park students, faculty, and staff have access to free online courses provided by ESRI. These cover a wide range of GIS topics and skills. To gain access to online classes, please contact *kelleyo@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: https://www.esri.com/training/unlimited-esri-training/

University of Maryland Libraries' GIS and Spatial Data Services Center website:
http://lib.umd.edu/gis/

University of Maryland Libraries' GIS and Spatial Data Services Center workshop series:
https://www.lib.umd.edu/gis/workshops