

Spatial Analysis Using ArcGIS Pro 2.3



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GIS Facilities at the University of Maryland

McKeldin Library

ArcGIS Pro 2.3, ArcGIS 10., 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 4118 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, ArcGIS Pro 2.3 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 Pro 2.3, 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.*

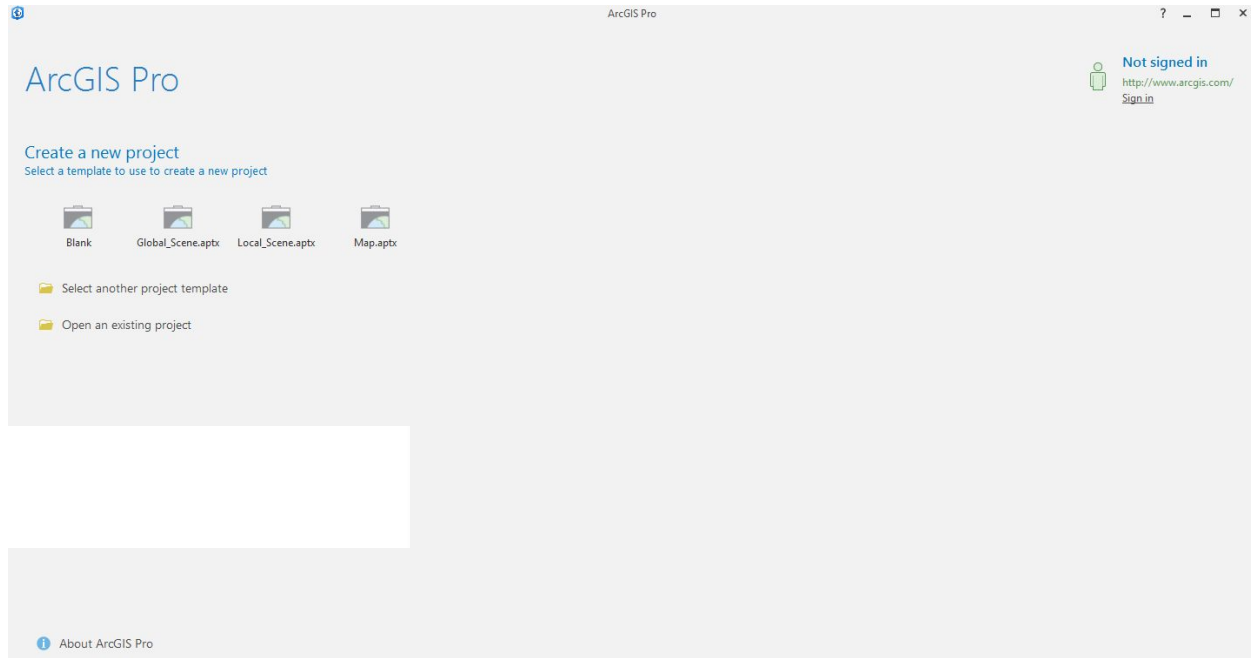
ArcToolbox allows us to perform these operations through sets of toolboxes. We will be using the Analysis and Data Management toolboxes. Within these main toolboxes, operations are grouped by the way that the derived data set is created.

Beginning with a Blank Project



1. Search for ArcGIS Pro in your Windows explorer:

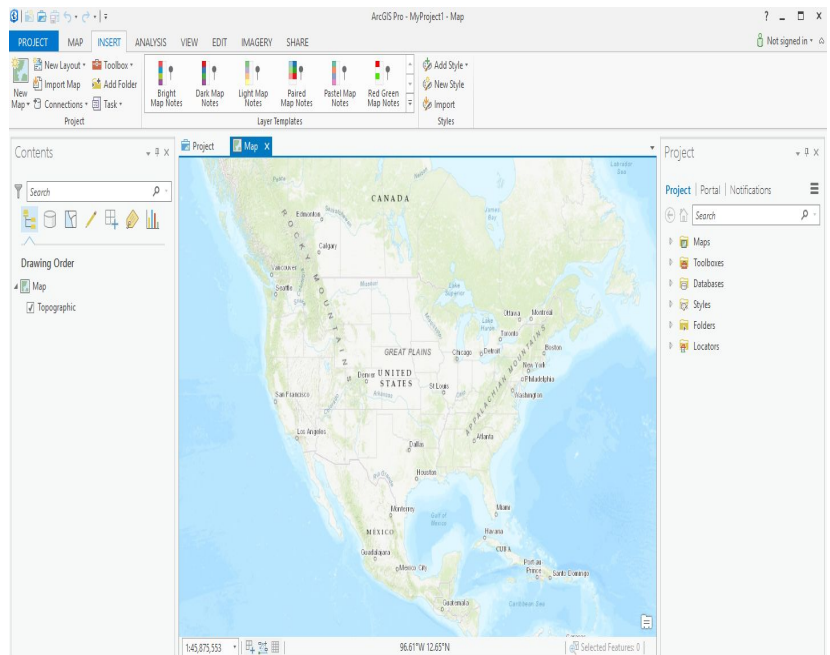
Upon opening ArcMap you may see the following startup window:



This is a new feature with ArcGIS Pro software that allows you to create projects. Each project contains its own geodatabase where you files will be stored. Since we're just beginning, we are going to create a new project. Click on **Map.aprx** to begin. Give your project an name and click **Okay**.

ArcGIS Pro stores each project in the C:\Documents\ArcGIS\Projects folder. If you do not specify a location when saving your work, this is the location to which it will be saved.

Now you will be in a new, blank map document in ArcGIS Pro.



Exercise: Creating New Shapefiles

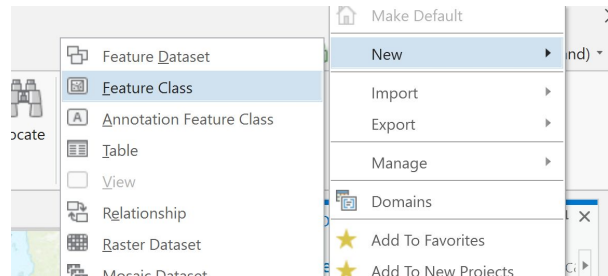
Creating from scratch/by tracing

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.

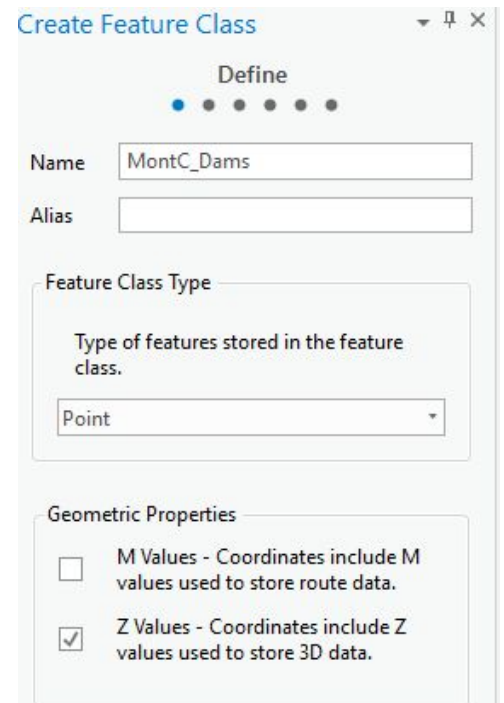
1. On the Catalog tab on the right side of your screen, click the arrow next to the Databases element to expand this option. Notice

that a .gdb has been created to store all the data for this project. Expanding this option would allow us to see all of the data related to this project, but since we have yet to add anything it is currently empty.



2. Right click on your Spatial Analysis.gdb, and click new → Feature Class



3. The 'Create Feature Class' dialog box will appear.
4. First we must give our new shapefile a name. Type "MontCo_dams" in the Feature Class 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 'Geometry Type' dropdown box.
6. Click Next 2 times



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

7. Open the Projected Coordinate Systems folder by clicking the small arrow.
8. Open the State Plane folder.
9. Open the NAD 1983 (US Feet) folder.
10. Select the NAD 1983 State Plane Maryland FIPS 1900 (US Feet) file and click 'Finish'.

The MontCo_Dams file now appears in the Catalog of our map. We can now create the column headings for our attribute table. Right click on the file and select **add to current map**.

1. **Right click on the MontCo_Dams feature class (now in the contents pane on the right) and click the option for “Attribute Table”.** A blank table will appear.
2. **Select the Add option at the top of the table.**  The fields titled 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 Length, we may choose the number of characters to be allowed in this field. For our purposes we will keep the default of 255.
6. **Click the Save button located in the Fields tab.** 
7. **Now close both the attribute table, as well as the Fields table.**

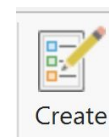
We are now going to add the Montgomery County file titled “county.shp”. **Click on the ‘Add Data’ icon and navigate to C:\USERS\“YourDirectoryID”\DOWNLOADS\Data to find this file.** If you do not see the file, it may be that your scale is too large—either zoom in or make your scale larger (try 1:400,000).



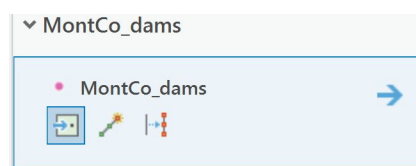
We are going to create the points for our new point file by using a point file that was downloaded from the National Map Seamless Server.

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 tab. Once there, click the ‘Create’ button.



The Create Features window will pop up and will ask you which layer you wish to edit. **Select ‘MontCo_dams’ and make sure the first option underneath (create a new point feature) is selected.**



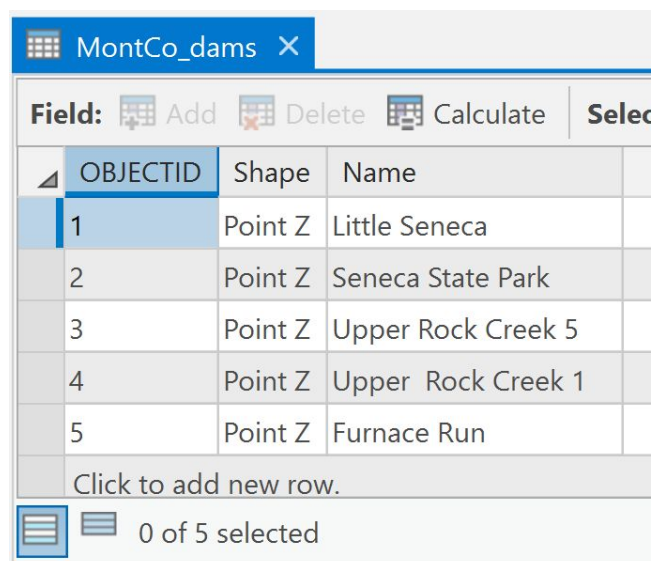
Now the point icon on your Editor toolbar should be active. (You'll notice that your cursor changes to an arrow with a point.)

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. You should end with 5 points total.

When you have finished placing all of your points on the map, go back to the Edit tab and **click Save** again. When prompted, choose to save all edits.

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. **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.
2. **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).
3. When you have finished **click Save.**



Field:	Add	Delete	Calculate	Select
OBJECTID	Shape	Name		
1	Point Z	Little Seneca		
2	Point Z	Seneca State Park		
3	Point Z	Upper Rock Creek 5		
4	Point Z	Upper Rock Creek 1		
5	Point Z	Furnace Run		
Click to add new row.				
0 of 5 selected				

4. **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.

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.

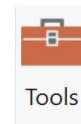
If you do not already have the file available in the table of contents, do the following:

1. **Delete the layers currently in your map. Then 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. **On the Analysis tab, click once on the “Tools” button.**

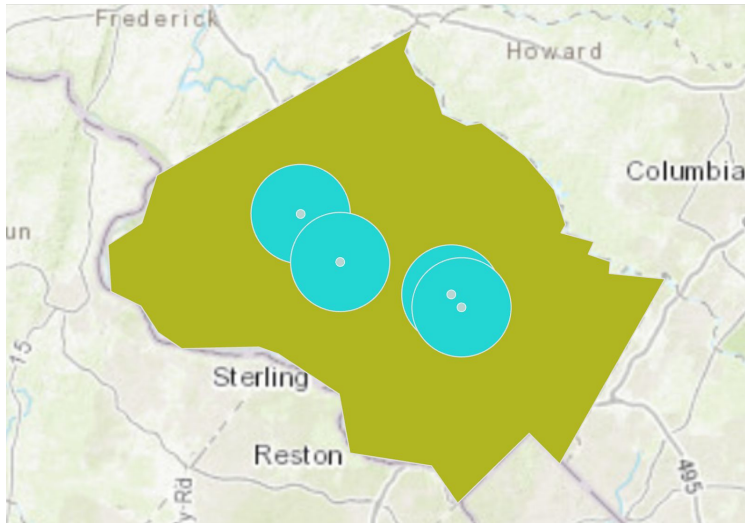


2. **Search for the Buffer (Analysis Tools). Double click this tool.**

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 add data 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 ‘Run’.** 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.

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.**

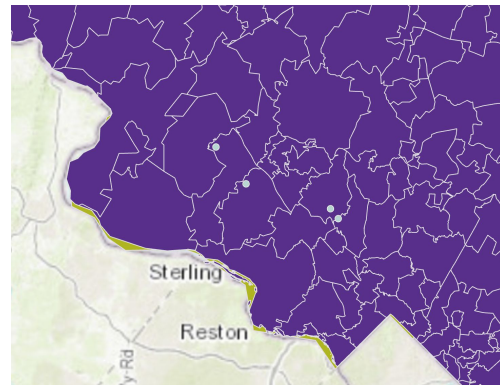
OBJECTID	Shape	Id	Name	BUFF_DIST	ORIG_FID	Shape_Length	Shape_Area
1	Polygon	0	Rock Creek Dam	15840	0	99525.655266	788243189.704539
2	Polygon	0	Bristow Dam	15840	1	99525.655266	788243189.704539
3	Polygon	0	Washington Hills Dam	15840	2	99525.655266	788243189.704539
4	Polygon	0	Clark Dam	15840	3	99525.655266	788243189.704545

Click to add new row.

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.

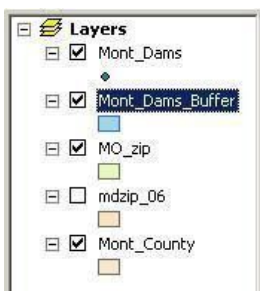
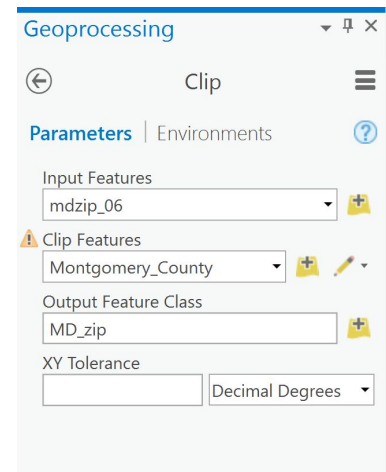


Usually associated with the "within" condition, the clip function works like a cookie cutter. In our case we will be using the state zip code file as the input layer (the cookie dough) and cutting it with Montgomery County (the cookie cutter). We'll end up with the shape of Montgomery County and the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

A layer for the zip codes in Maryland from 2006 will be added. **Re-open the Geoprocessing pane if it is not already open. Search for Clip.**

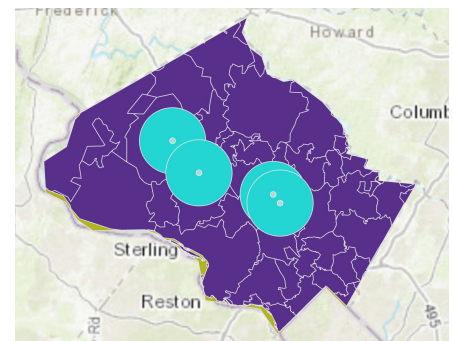
1. Click on the drop down box under 'Input Features' and choose 'mdzip_06'.
2. Under 'Clip Features' choose 'Montgomery_County' in the drop down box.
3. Navigate to (using the add data)
C:\USERS\YourDirectoryID\DOWNLOADS\Data as the location for the 'Output Feature Class'.
4. Name the file 'MD_zip'.
5. Click save then 'Run'.



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 (and above MD_zip).

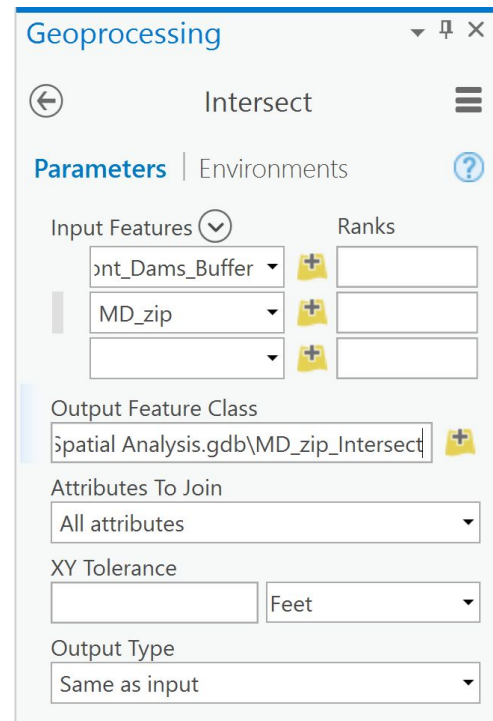
You should see the zip codes for Montgomery County as well as the dams and buffers around the dams.



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.

1. From the Geoprocessing menu: **Search for and Double click on 'Intersect'**. The Intersect window will open.
2. **From the Input Features drop down box, choose Mont_Dams_Buffer.** (It will appear in the box list area, not the drop- down.)
1. **Repeat this process and choose the MD_zip file.**
2. **Save the output file to the Data folder in DOWNLOADS and call the file MD_zip_Intersect.** Click 'SAVE'.
3. **Click 'Run'.**



Turn off all layers EXCEPT:

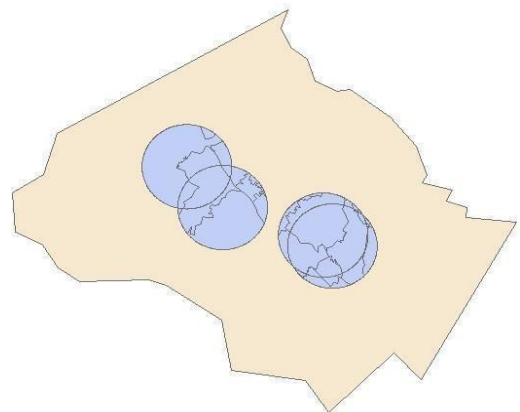
- the newly created **MD_zip_Intersect** file and
- **Montgomery_County**

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.



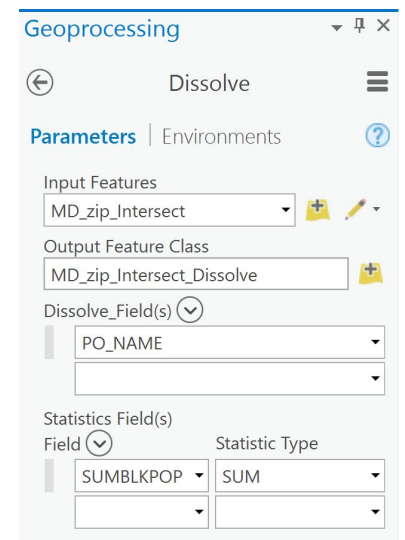
4. Dissolve

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.

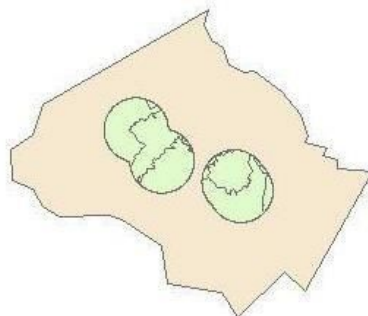
1. Go back to the Geoprocessing Pane.
2. Search for and double click on 'Dissolve.'

The Dissolve window will open.

3. In the drop down box for 'Input Features' select MD_zip_Intersect.
4. For 'Output Feature Class', use the add data button and navigate to Data in DOWNLOADS. Save the file as "MD_zip_Intersect_Dissolve."
5. Select "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.
6. Under the box for 'Statistics Field(s) use the drop down box to select SUMBLKPOP.
7. 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.
8. Click "Run"



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.



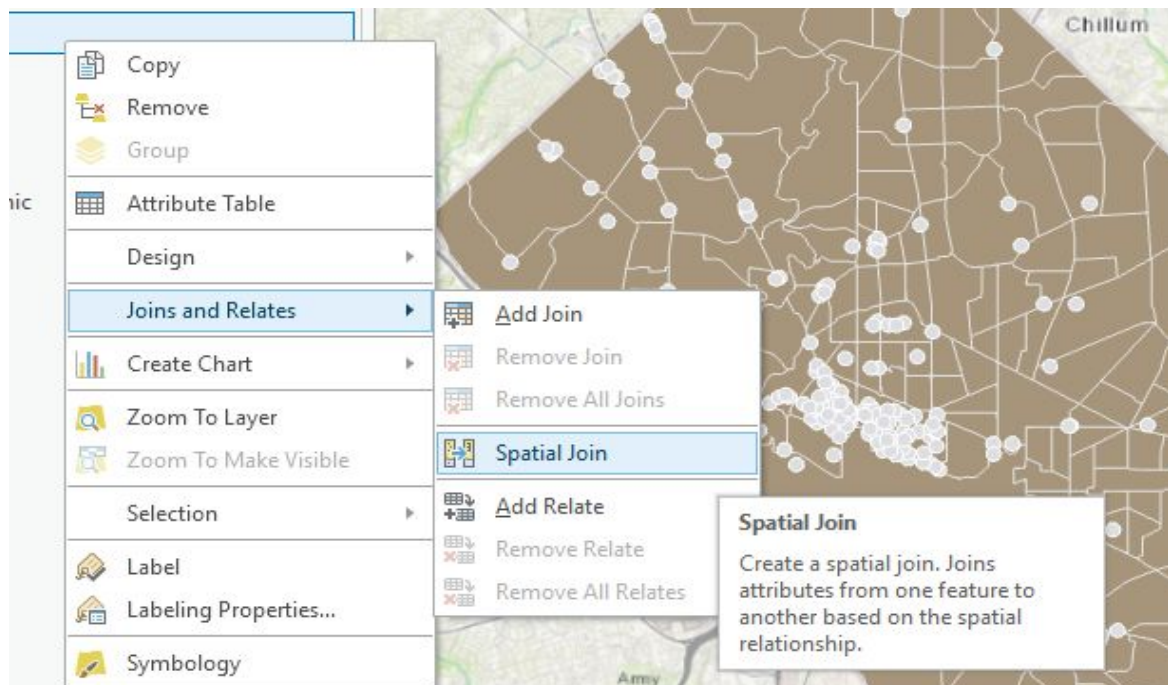
5. Spatial Join

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 ArcGIS Pro by Clicking the 'INSERT' tab and selecting 'New Map'. You will now have a second map tab titles Map1. You can rename this map by double clicking on the map layer in your contents pane and changing the name in the General tab. Now you can 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 by right clicking the layer → Joins and Relates --> Spatial Join. You can also search for the tool in the Geoprocessing window.



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. In the Output Feature Class box, name the file SpatialJoin.
4. Choose JOIN_ONE_TO_MANY. (There may be many banks located within one census tract polygon.)
5. 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.
6. Keep the remaining default values listed for the remaining boxes as well.
7. Click 'OK'. Wait for the spatial join to run.

A new feature class 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.

OBJECTID	Shape	Join_Count	TARGET_FID	JOIN_FID	X	Y	NAME	ADDRESS	ZIPCODE	ADDRESS_ID	count	TRACT	GEOID
1	Point	1	0	84	397881.2405	136850.4	Citibank, NA	750 9th Street NW	20001	279928	1	005800	11001005800
2	Point	1	1	84	397674.5105	136457.3	Citibank, NA	435 11th Street NW	20004	298776	1	005800	11001005800
3	Point	1	2	122	396689.8405	137135.11	Citibank, NA	925 17th Street NW	20006	279990	1	010700	11001010700
4	Point	1	3	122	395933.7105	137350.71	Citibank, NA	2101 L Street NW	20036	242479	1	010700	11001010700
5	Point	1	4	140	397213.1305	140273.32	Citibank, NA	3241 14th Street NW	20010	302794	1	003000	11001003000
6	Point	1	5	56	400543.6005	139152.47	Citibank, NA	1060 Brentwood Rd NE	20018	302477	1	009102	11001009102
7	Point	1	6	122	396499.6005	137085.84	EagleBank	1725 I Street NW	20006	279349	1	010700	11001010700
8	Point	1	7	20	394538.5805	137327.58	EagleBank	1044 Wisconsin Aven...	20007	278800	1	000202	11001000202
9	Point	1	8	18	394218.1995	138489.28	HSBC Bank USA, NA	1715 WISCONSIN AV...	20007	261691	1	000100	11001000100
10	Point	1	9	84	398075.2505	136753.17	OBA Federal Savings...	700 7th Street NW	20001	243354	1	005800	11001005800
11	Point	1	10	84	397624.8305	136852.8	PNC Bank, NA	1100 H STREET NW	20005	239128	1	005800	11001005800
12	Point	1	11	122	396712.9005	137230.4	PNC Bank, NA	1629 K STREET NW	20006	242031	1	010700	11001010700
13	Point	1	12	82	395360.5105	137359.06	PNC Bank, NA	1100 25TH STREET NW	20037	274069	1	005500	11001005500
14	Point	1	13	80	397200.8405	137993.97	PNC Bank, NA	1405 P STREET NW	20005	303731	1	005201	11001005201
15	Point	1	14	12	394964.9705	140832.45	SunTrust Bank	3435 Connecticut Av...	20008	302088	1	001302	11001001302

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

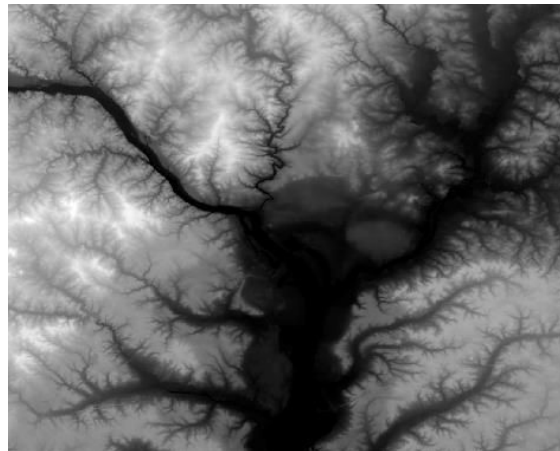
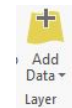
The analytical functions we have just performed in ArcGIS are based on a vector data structure of points, lines and polygons. As demonstrated, this data model is ideal for elements that have discrete boundaries like airports, highways and urban areas. But what if our data does not have discrete boundaries 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!

Create a new Map tab and rename it 'Raster'

Examine raster data

1. Add an elevation data to your map by clicking on the Add Data icon
2. Navigate to C:\USERS\“YourDirectoryID”\DOWNLOADS\Data \elev. 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.

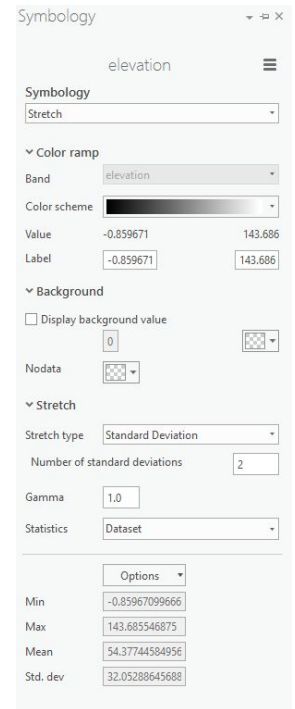
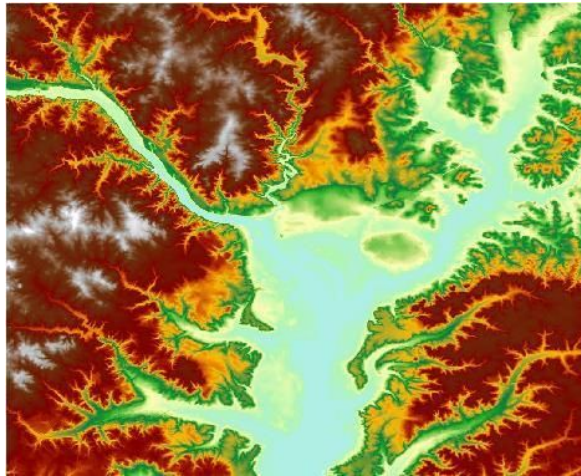


3. Right click on the elevation layer and go to 'Properties'.

- Look at the "Source" tab and expand the 'Raster Information' tab to find the size of the cells, the extent of the data, what spatial reference it is using.
- Close out of the Properties window.
- Right click on the layer again and select Symbology.
- If you click on color ramp, you can see the different color schemes that can be used to show change in elevation.
- Choose the same color ramp as below for this exercise.



- Close the Symbology pane.



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

- Open the Geoprocessing pane.
- Search for the following tool: **Project Raster**. Click on the tool to open it.
- Use pull-down menu for **Input Raster** to and browse to your elevation model.
- In the **Output Raster** Dataset blank file location enter the name you want for your new file. Remember ArcGIS Pro does not accept long names or spaces.
- For **Output Coordinate System**, Click the globe icon and choose: **Projected Coordinate System → State Plane --> NAD 1983 US Feet (2011) → Maryland State Plane FIPS1900 US Feet** and click ok.
- Finally, go to the blank labeled **Resampling Technique** and choose **Cubic Convolution**
- Click Run.

Resampling

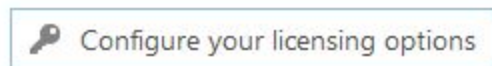
When a raster dataset is projected from a plain geographic coordinate system to a projected one, the size and shape of the cells is transformed. You can think of Resampling as creating a new grid of cells and assigning values to the new cells based on the values of the old cells. The default method (Nearest 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.

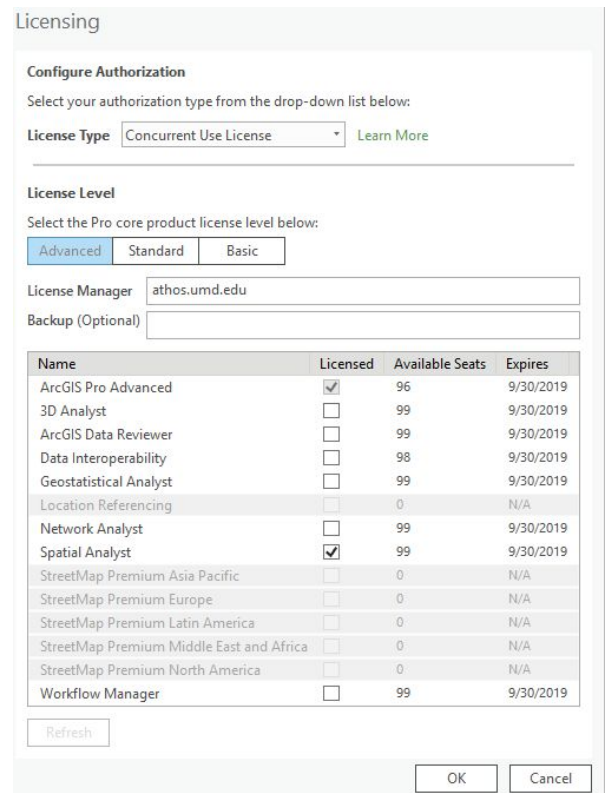
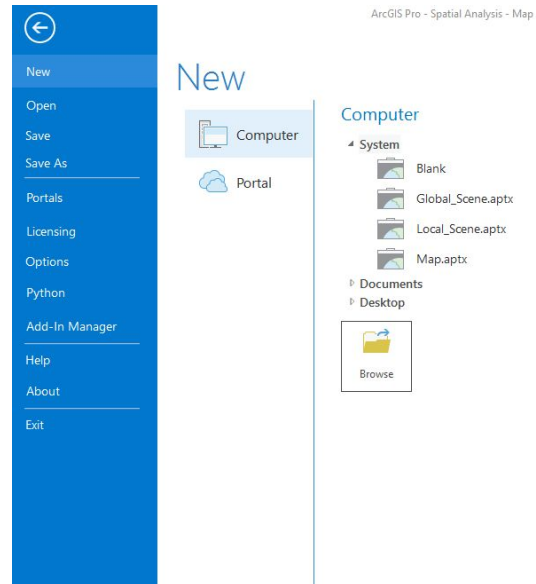
1. In your Geoprocessing pane, search for the 'Contour (Spatial Analysis)' tool.
2. If the tool is not yet licensed, Click the project tab. You will be brought to this screen. Now click the 'Licensing' tab.

3. Click to 'Configure your licensing options'.



4. In the licensing window, click box next to Spatial Analyst to enable it. Then click OK.

5. Now click the back arrow to return to your project.



Now, In the 'Contour' box,

1. Select "elevation" in the drop down box under 'Input raster'.
2. In the 'Output polyline feature' box, name the file **contour1**. Remember that in ArcGIS Pro, each project automatically has its own geodatabase where all files are stored. Therefore, we don't have to tell it where to put each file.
3. Put '10' (or your own choice) in the 'Contour interval'.
4. Keep the defaults for the remaining boxes.
5. Click 'Run'

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

6. Right click on your contour1 layer to open the attribute table.
7. 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)

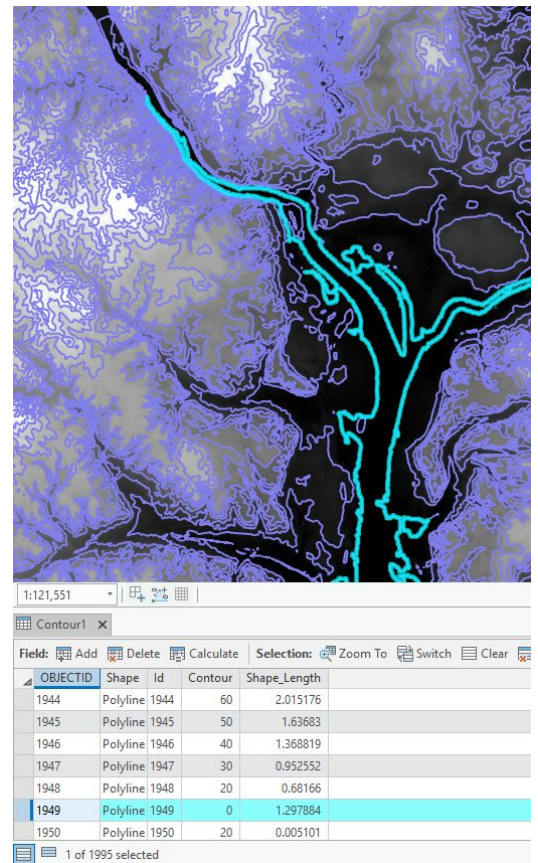
Examining slope tells you how steep the terrain is—this kind of output can then be analyzed and used for a variety of determinations such as likelihood of flooding, best places to locate buildings, etc. What the software is doing in this case is calculating the maximum rate of change between each raster 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. Search for the 'Slope.' geoprocessing tool.

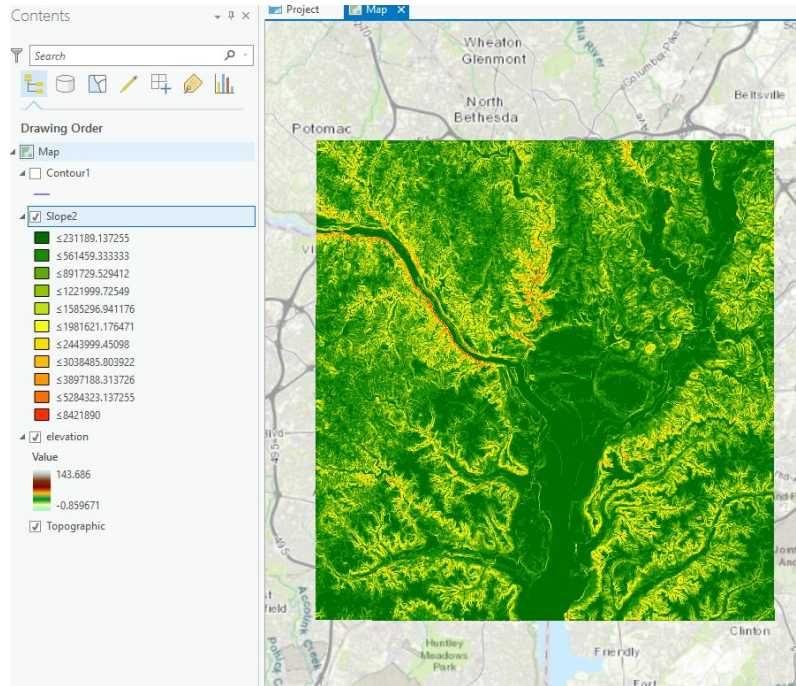
In the 'Slope box',

1. Select "elevation" in the drop down box under 'Input raster'.
2. Name the Output Raster **slope1**.



3. Put "PERCENT_RISE" in the drop down box under 'Output measurements'.
4. Keep the defaults for the remaining boxes.
5. Click 'Run.'

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. To see this better, open the Symbology pane, and change the Method to 'Natural Breaks (Jenks)' and the Color scheme to Green to Red.



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

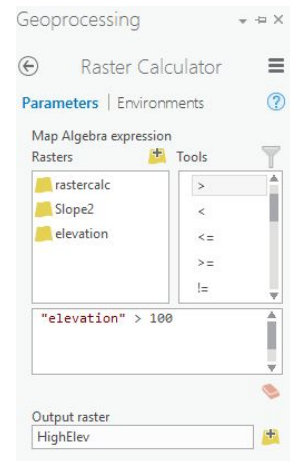
The formula used in map algebra can be a simple mathematical operation like addition, multiplication, division or subtraction (**arithmetic operators**), as in the first example. Map algebra can also use **Boolean operators** (And, Or, Xor, Not) as in the second example, or it can use a more complex 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. Search for and Double click on 'Raster Calculator' in the Geoprocessing pane.
2. Use the buttons to get the following expression into the box (or directly type): "elevation" > 100
3. Give the output raster a name (such as HighElev).
4. Click OK. If you do not see the map, zoom out.

Your result will look like this (colors may vary):



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 downside 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

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>