

Exercise 2: Surface Analysis



Introduction

After the intensity of the previous exercise, it's time for a little fun. This exercise proceeds without the usual opening scenario used to set the stage of the exercise. Instead you are going to make maps purely for display purposes. These maps will show the study area's surface contour, slope, and aspect. Finally, you will perform a Cut/Fill analysis to discover surface changes of the same area from two different time periods.

Objectives

Upon completion of this exercise, you will be familiar with:

- i. The properties of the Digital Elevation Model
- ii. Creating a Contour Map
- iii. Creating a Slope Map
- iv. Creating an Aspect Map

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Part 1: Prepare the analysis environment

REMINDER: When using Spatial Analyst, it's important to set the analysis environment first.

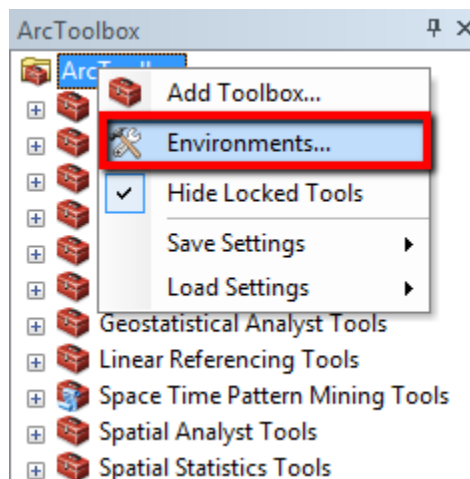
Environment settings are part of the map document and are not carried from one map document to another. In the previous exercise, we set the analysis environment from Geoprocessing | Environments. This time we will set the analysis environment settings from ArcToolbox.

A. Open the Slope_Aspect map document.

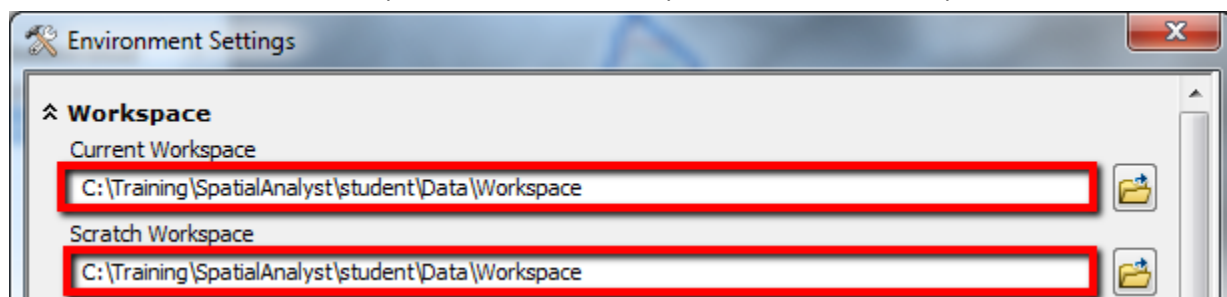
1. Start **ArcMap**, if needed.
2. Browse to and open ...\\Data\\Slope_Aspect.mxd.

B. Set the geoprocessing environment.

1. Open ArcToolbox. 
2. Right click **ArcToolbox** and select **Environments**.

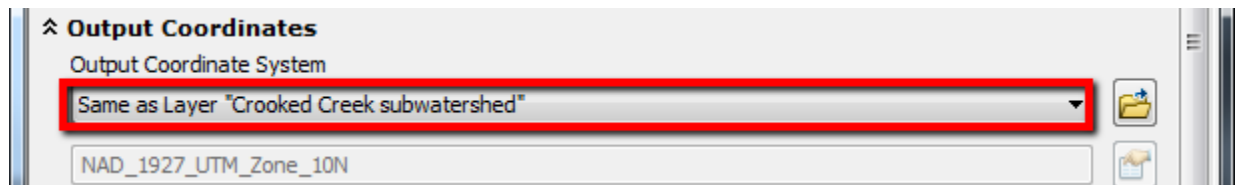


3. Click on **Workspace**.
4. Set the Current workspace and Scratch workspace to: ...\\Data\\Workspace.



5. Click on Output Coordinates.

6. From the *Output Coordinate System* drop down list choose ‘Same as Layer “Crooked Creek subwatershed”’.

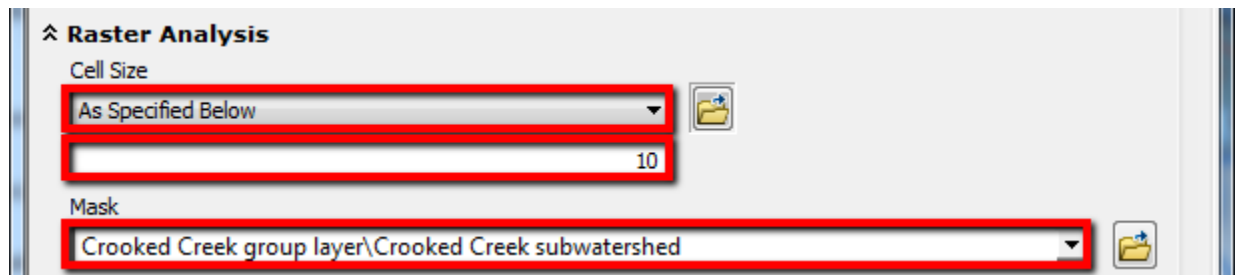


IMPORTANT: With raster analysis, all input and output rasters should use the same coordinate system. Do not use the “Output Coordinate System” parameter to re-project the output raster.

7. In the Environment Settings window, collapse the Workspace and Output Coordinates.
8. Scroll down and expand on **Raster Analysis**.

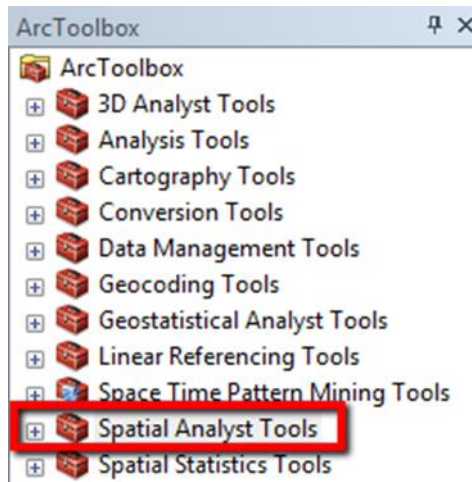
Because our analyses for this exercise involves raster datasets, we need to set the output cell size and analysis mask used to limit the analysis extent.

9. From the **Cell Size** drop-down list, choose “As Specified Below,” and enter **10**. The units are map units (meters).
10. For the **Mask**, click on the drop-down arrow and select **Crooked Creek subwatershed**.



11. Click **OK** to close the Environment Setting box.
12. Close/collapse and open toolboxes, if needed.

Spatial Analyst Tools are near the bottom of the ArcToolbox window. The tools in the Spatial Analyst toolbox will only work if the Spatial Analyst extension has been activated. The extension should still be active from the previous exercise. If not, go to the Customize menu | Extensions, and activate it now.



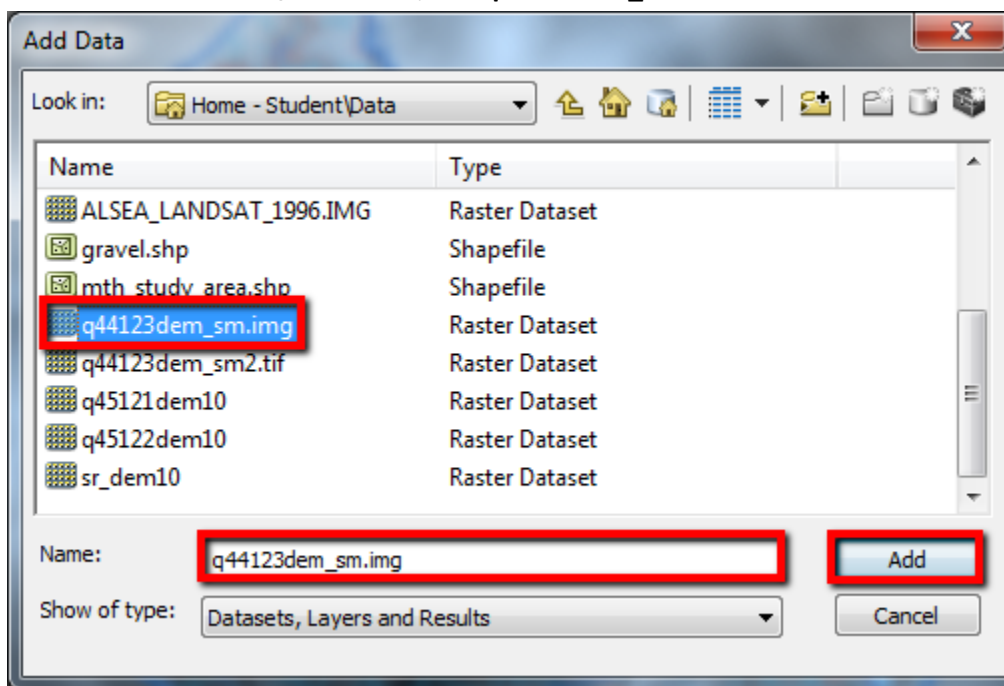
13. **Save** the map document.

Part 2: Examine the Properties of a DEM

A requirement of creating contours, slopes, or aspect maps is elevation data. We will use a DEM (Digital Elevation Model). Each cell in a DEM represents surface elevations.

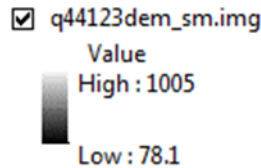
A. Load a DEM.

1. From the ...\\Data folder, add **q44123dem_sm**.



2. If prompted to create pyramids, click **No**.

The raster layer represents a Digital Elevation Model (DEM). DEMs are produced from USGS topo maps (either 7.5', 15', or 1 $\frac{1}{4}$ quadrangles). Each cell in a DEM represents a sample point of surface elevation. The lighter the shade of gray used to color a cell, the higher the elevation value. The units are in meters. Check with your GIS Coordinator on how to add local district DEMs to your GIS project.



B. Examine properties of the DEM.

1. Open the **Properties** of the **q44123dem_sm** layer.
2. Change the layer name to **DEM10**. (Hint: General tab)

General Source Key Metadata Extent Display Symbology

Layer Name: ☒ Visible

3. Activate the **Source** tab then answer the following questions:

General **Source** Key Metadata Extent Display Symbology

Property	Value
<input checked="" type="checkbox"/> Raster Information	
Columns and Rows	1998, 1401
Number of Bands	1
Cell Size (X, Y)	10, 10
Uncompressed Size	10.68 MB
Format	IMAGINE Image
Source Type	Generic
Pixel Type	floating point
Pixel Depth	32 Bit

What is the X,Y cellsize? _____ meters.

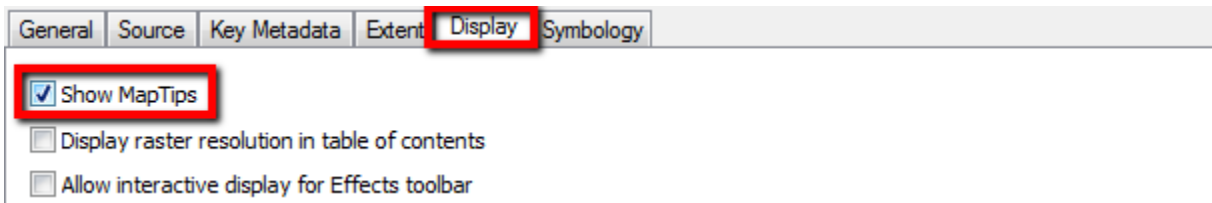
What is the Pixel type? _____.

The floating point pixel type allows for the storage of real (decimal) numbers for each pixel.

To nearest tenth of a meter, what is the layer's minimum elevation? _____ meters. Hint: Find the layer's statistics.

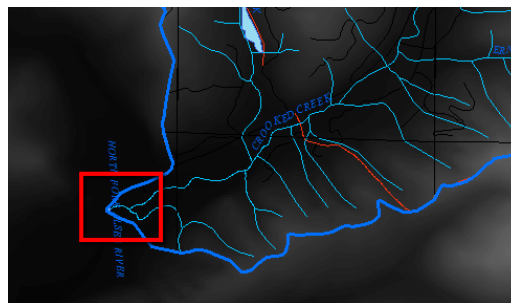
What is the layer's maximum elevation? _____ meters.

4. Activate the **Display** tab.
5. Put a checkmark for **Show Map Tips**.



NOTE: The Show Map Tips option uses the primary display field for the tip message. The primary display field for a raster dataset using a "floating point" pixel type defaults to the Value field. You can change a raster's primary display field only when it is possible to open the layer's Value Attribute Table (VAT).

6. Click **OK**.



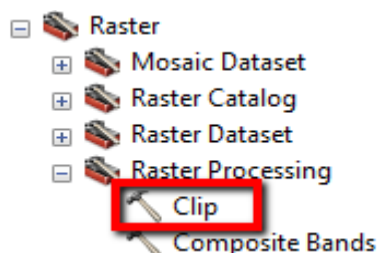
What is the elevation at the pour point (exit point) of the subwatershed? _____ meters.

Hint: the subwatershed's pour point is located in the southwest corner.

You have probably noticed that the DEM is larger than the study area. To reduce the processing time in creating the contour-slope-aspect maps, it would help to reduce the size of the DEM to the extent of the study area. Let's find the ArcToolbox function that clips raster datasets.

C. Clip raster datasets to your area of interest.

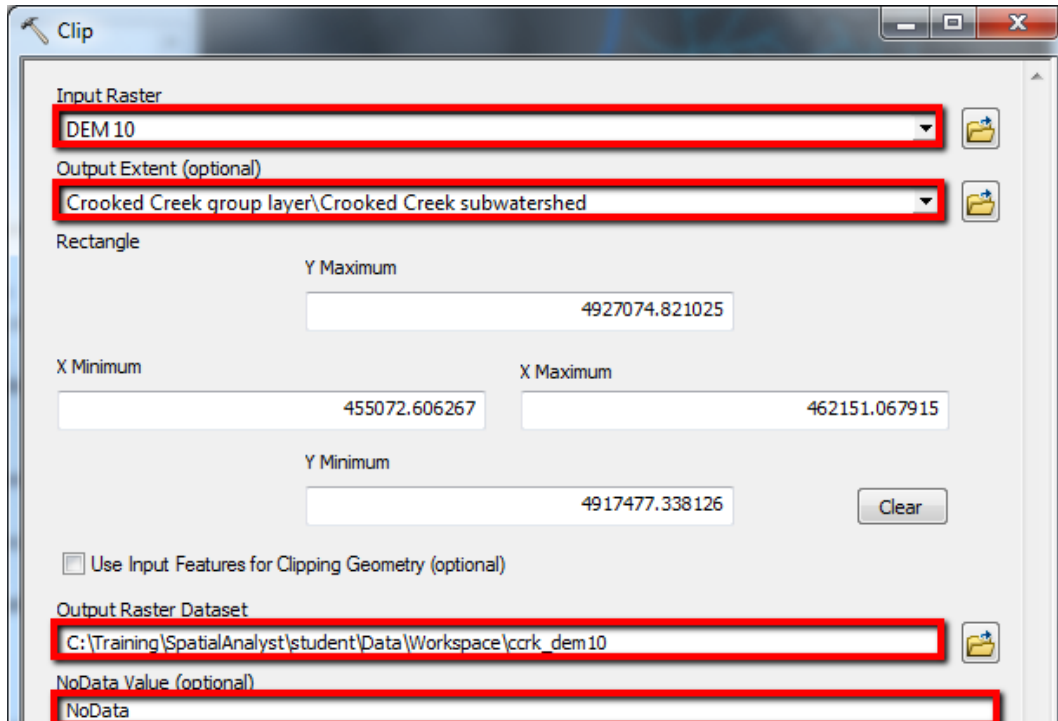
1. In ArcToolbox find and double click the **Clip** tool. (**Data Management Tools | Raster | Raster Processing | Clip**). (NOTE: There are other Clip tools, but this is the only one that works with raster datasets.)



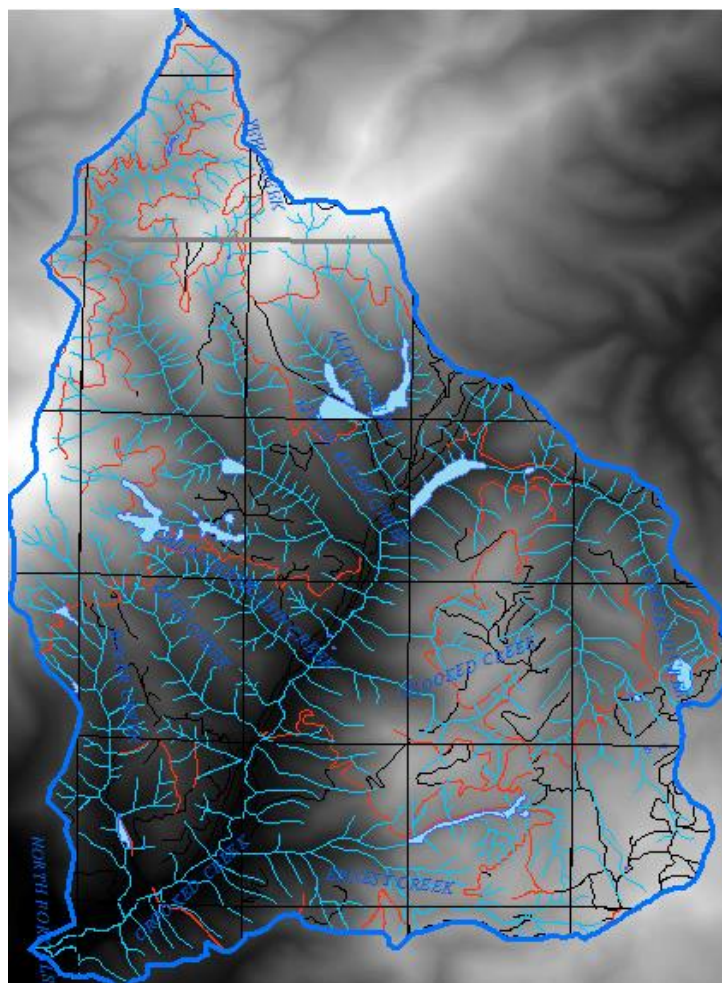
2. In the Clip tool dialog, set the following parameters:

- Input Raster: **DEM10**

- Output Extent: **Crooked Creek subwatershed**
- Output Raster Dataset: **cckr_dem10**
- NoData Value (optional): **NoData**



3. Click **OK**. After the process completes, a new (clipped) raster dataset is added to the Table of Contents.
4. Remove **DEM10** from the Table of Contents. (Right-click DEM10 | Remove)
5. Move the **cckr_dem10** layer to the bottom of the Table of Contents.
6. Click the **Zoom to Full Extent** button.



Was the evaluation successful? The extent of the new raster layer should not exceed the rectangular bounds of the subwatershed. An interesting question you should ask at this point is whether or not the new raster layer is permanent or temporary? What do you think?

7. Open the raster's layer Properties, activate the **Source** tab, and check the value for Status.

Is the new raster layer permanent or temporary? _____

8. Activate the **Symbology** tab.

By default, a Stretched symbology scheme is applied with a grayscale color ramp—a typical color ramp scheme for DEMs.

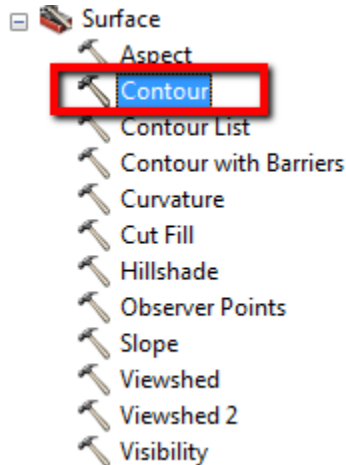
9. Without any changes, **close** the **Layer Properties** window. You are now ready to make a contour map.

Part 3: Create a contour map

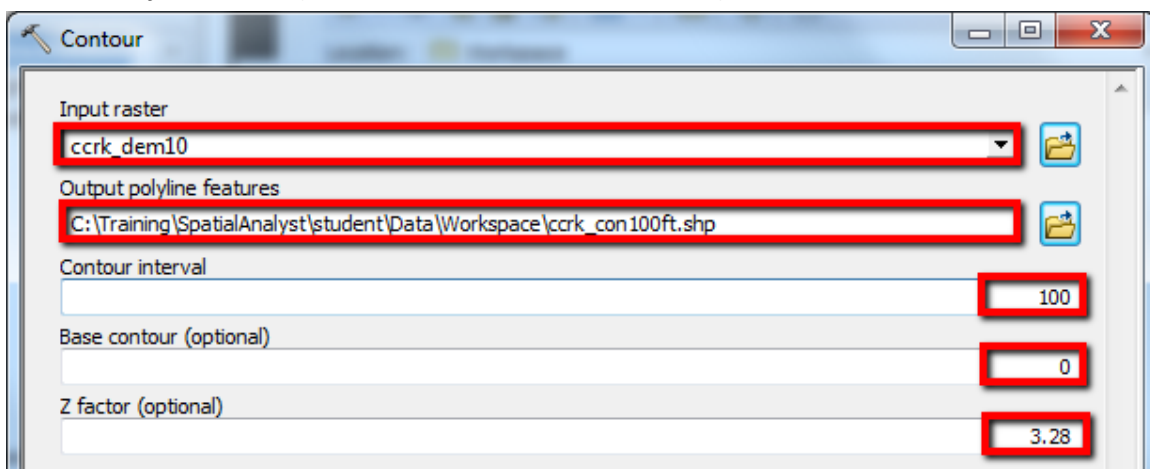
Contours are equal lines of elevation. A requirement of creating contours, slopes or aspect maps is elevation data. We will use a DEM (Digital Elevation Model). Each cell in a DEM represents surface elevations.

A. Create 100 foot contours from ccrk_dem10.

1. From ArcToolbox, expand Spatial Analyst Tools.
2. Expand the **Surface** tool set and launch (double-click) the **Contour** tool.

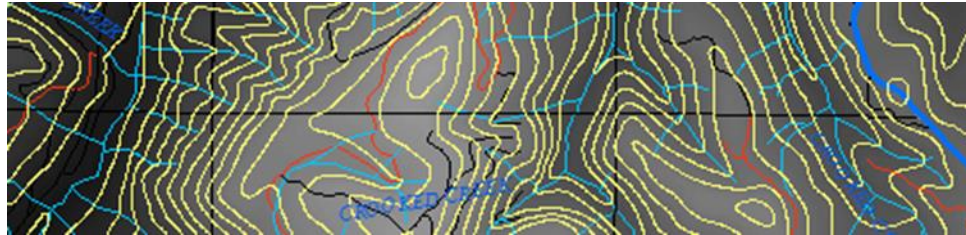


3. Set the following parameters in the Contour window:
 - *Input raster:* **ccrk_dem10**
 - *Output polyline features:* ...\\Data\\Workspace \\ccrk_con100ft
 - *Contour interval:* **100** (Note: The smaller the contour interval, the longer the processing time.)
 - *Base Contour:* **0**
 - *Z factor:* **3.28** (This value converts meters to feet.)



4. Click **OK**.
5. After the process is complete, a new layer is added to the Table of Contents.

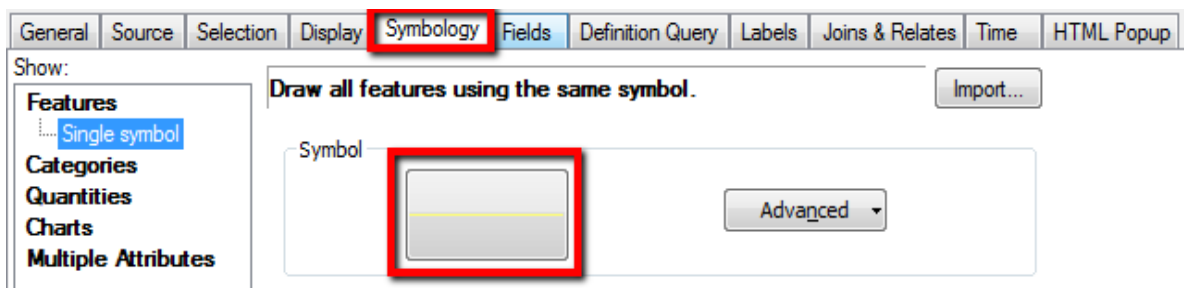
Contour lines are drawn to the extent of the Crooked Creek subwatershed. At this scale, the contour lines nearly cover up the map. The contours are best viewed at a large scale. If you want, zoom in on some contour lines. When done, return to the full extent.



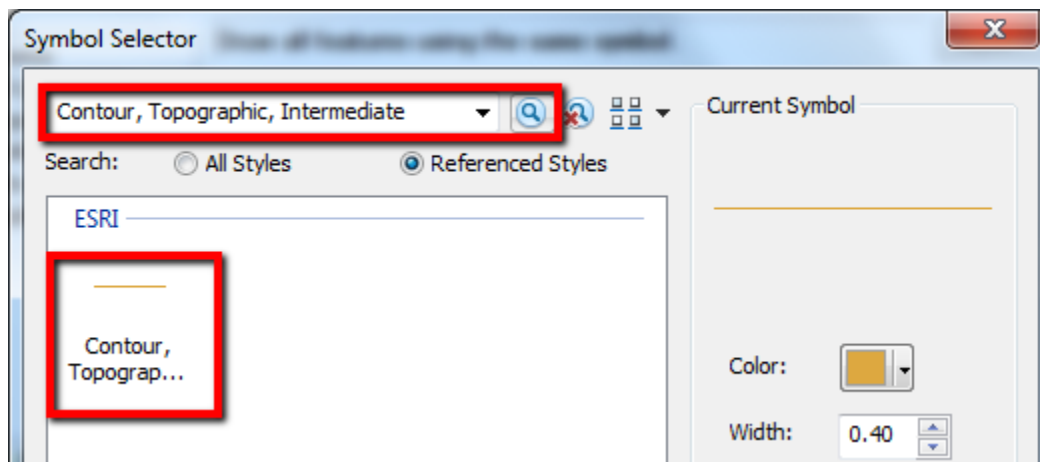
To avoid confusion with the lines drawn for the Roads layer, let's change the color of the contour lines. We will use ArcMap's predefined symbol for Contours.

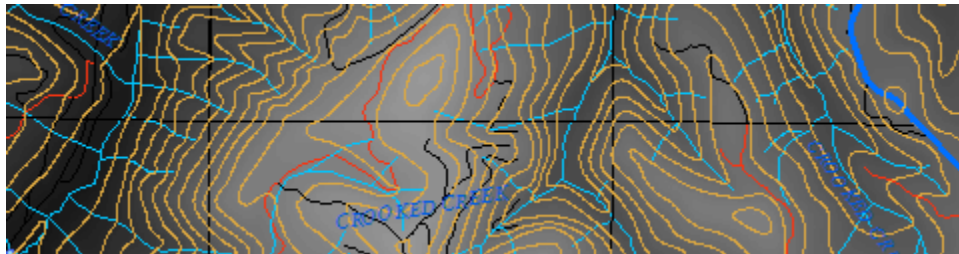
B. Apply a new symbology to the contour layer.

1. Open the layer Properties of ccrk_con100ft.
2. Under the **Symbology** tab, click the **Symbol** button.



3. Search for and apply the symbology called: **"Contour, Topographic, Intermediate."**
4. Click **OK** to accept the parameters. The symbology for the contour layer reflects the chosen parameters.





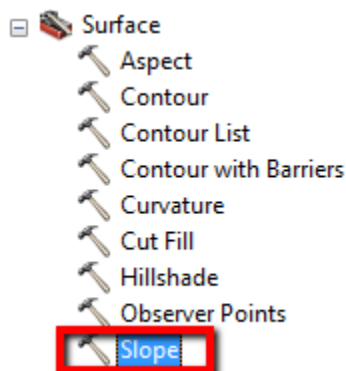
5. Turn off the **ccrk_con100ft** layer and save the map.

Part 4: Create a slope map

A slope map can be used to illustrate how gentle or steep the surface is changing with regards to elevation. For a DEM, the Slope tool measures the rate of elevation change. The output of the Slope function is a new raster dataset. You have the option to set the output units to degrees or percent rise (a.k.a., percent slope). (FYI: $45^\circ = 100\%$ slope).

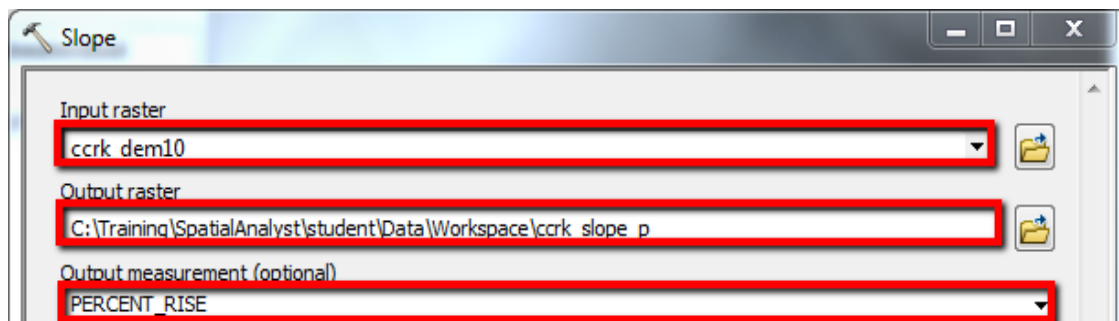
A. Launch the Slope tool.

1. From ArcToolbox's **Spatial Analyst | Surface** tools, launch the **Slope** tool.



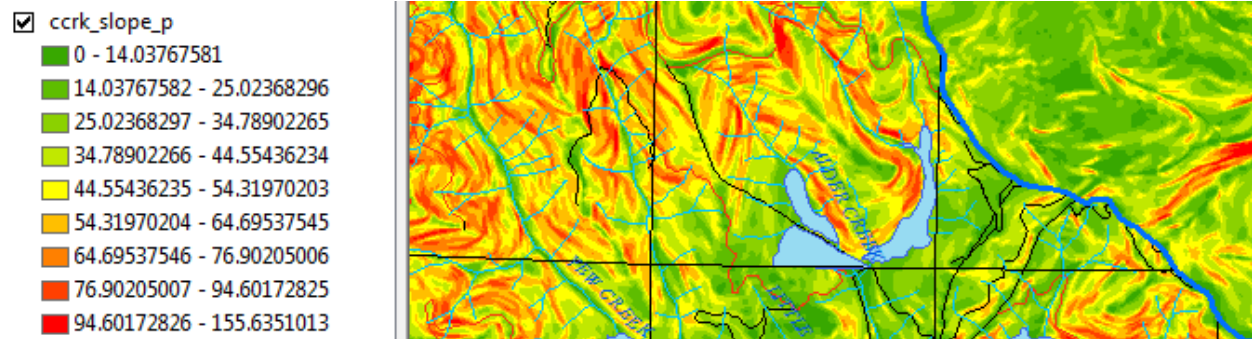
2. Set the following parameters:

- **Input raster:** **ccrk_dem10**
- **Output raster:** **...\\Data\\Workspace\\ccrk_slope_p**. (*p is for percent*)
- **Output measurement:** **PERCENT_RISE**
- **Z factor = 1**



FYI: Since slope degrees or slope percent are reported, a Z factor conversion between meters and feet is unnecessary and could even mess up your results.

3. Click **OK**. When the process is complete a new raster layer is added to the TOC.



4. If the output layer doesn't shade as above automatically, open the Layer Properties window and click the Symbology tab.
 - i. Under Show: click Classified (select Yes, to compute a histogram)
 - ii. Change the Classes to 9
 - iii. Right click the Color Ramp and uncheck Graphic View
 - iv. In the Color Ramp dropdown, choose Slope

Layer Properties

General Source Key Metadata Extent Display Symbology

Show:

- Vector Field
- Unique Values
- Classified
- Stretched
- Discrete Color

Draw raster grouping values into classes

Fields

Value: <VALUE> Normalization: <None>

Classification

Natural Breaks (Jenks) Classes: 9

Classify...

Color Ramp

Sym...	Range	Label
	0 - 14.03767581	0 - 14.03767581
	14.03767581 - 25.02368296	14.03767582 - 25.02368296
	25.02368296 - 34.78902265	25.02368297 - 34.78902265
	34.78902265 - 44.55436234	34.78902266 - 44.55436234
	44.55436234 - 54.31970203	44.55436235 - 54.31970203
	54.31970203 - 64.69537545	54.31970204 - 64.69537545
	64.69537545 - 76.90205006	64.69537546 - 76.90205006

☐ Show class breaks using cell values

☐ Use hillshade effect

Display NoData as

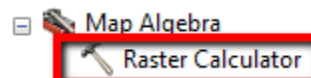
z: 1

About symbology

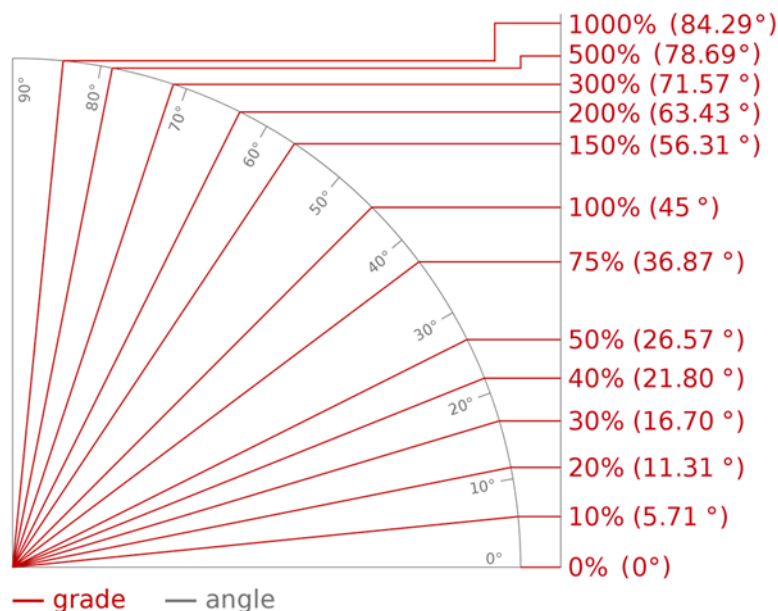
For this exercise, let's apply our slope map as a tool for conducting a soil erosion study. We will assume those slopes exceeding 44% (~22°) are areas requiring a soil erosion assessment. Finding slopes greater than 44% requires a tool from the Map Algebra toolset.

B. Use the Raster Calculator to find slopes that are greater than 44%.

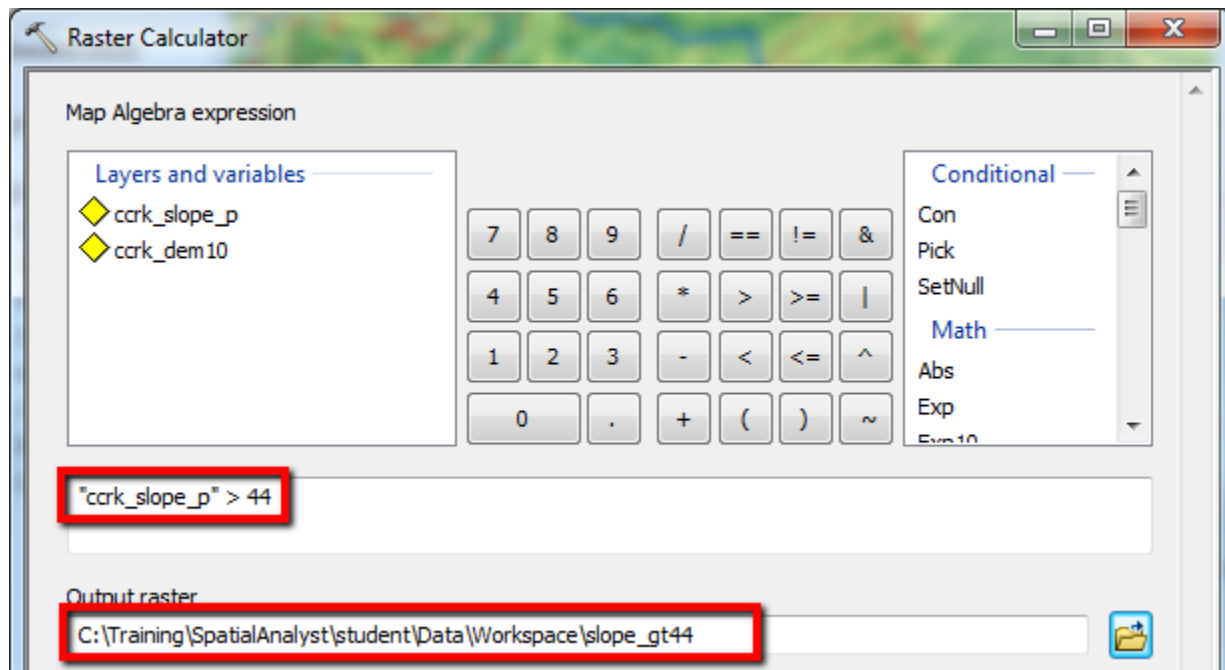
1. From *ArcToolbox*, locate **Spatial Analysts' Map Algebra** toolset and launch the **Raster Calculator**.



The Raster calculator window opens. In the expression window, you must build a mathematical equation used to evaluate the input raster. In this example, we need to evaluate the `ccrk_slope_p` raster for slope values greater than 44%.



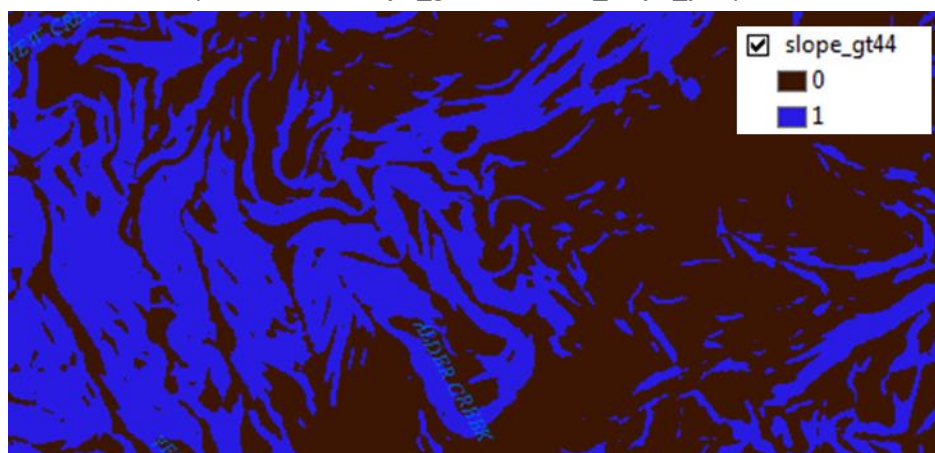
2. Enter the following expression: `"ccrk_slope_p" > 44`
3. Name the *output raster* to: `slope_gt44`.



4. Click **OK**.

After the evaluation is complete, the output raster dataset (which is permanent) is added to the data frame. Areas with a cell value of 1 (true) have slopes exceeding 44%. These are the areas that require a soil erosion assessment.

5. Turn off and collapse both the **slope_gt44** and **ccrk_slope_p** layers.



Part 5: Create an aspect map

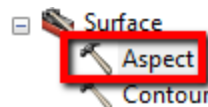
An aspect map identifies the down-slope direction of a surface. The values for the aspect layer are given in compass degrees (e.g., 0 = North, 90 = East, 180 = South, 270 = West). In addition,

standard colors are used to represent the compass degree (e.g., 0 = Red, 90 = Yellow, 180 = Cyan, 270 = Purple).

A common use of an aspect map is in vegetation classification and harvest planning. In the Northern Hemisphere, south facing slopes receive relatively more sunlight than other slopes, which in turn increases crop yields. For example, to obtain a maximum yield, vineyards prefer to plant their grape vines on south-facing slopes.

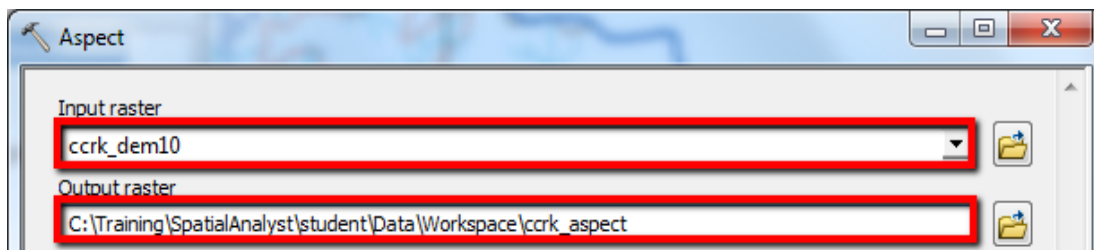
A. Launch the Aspect tool.

1. From the **Surface** toolset, launch the **Aspect** tool.



2. Set the following parameters in the *Aspect* window:

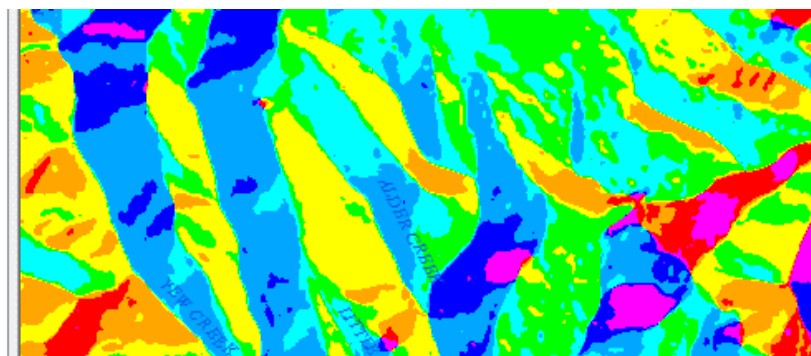
- *Input raster:* **cckr_dem10**
- *Output raster:* **...\\Data\\Workspace\\cckr_aspect**



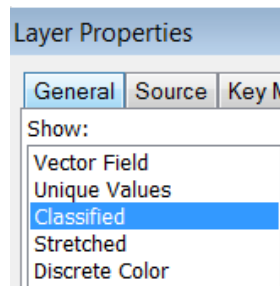
3. Click **OK**.

When the process is complete a new raster layer is added to the TOC. You can see that Crooked Creek more or less subdivides the subwatershed. The southern half of the subwatershed has a dominance of northwest facing slopes, while the northern half of the subwatershed is dominated by south and southwest facing slopes.

- ☒ cckr_aspect
 - Flat (-1)
 - North (0-22.5)
 - Northeast (22.5-67.5)
 - East (67.5-112.5)
 - Southeast (112.5-157.5)
 - South (157.5-202.5)
 - Southwest (202.5-247.5)
 - West (247.5-292.5)
 - Northwest (292.5-337.5)
 - North (337.5-360)



4. If the output layer doesn't shade as above automatically, open the Layer Properties window and click the **Symbology** tab.
 - i. Under **Show:** click **Classified**

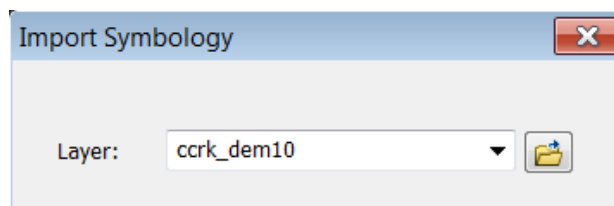


ii. Click Browse button.

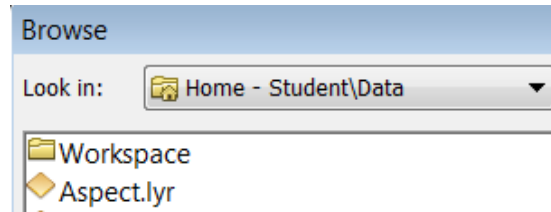
Draw raster grouping values into classes



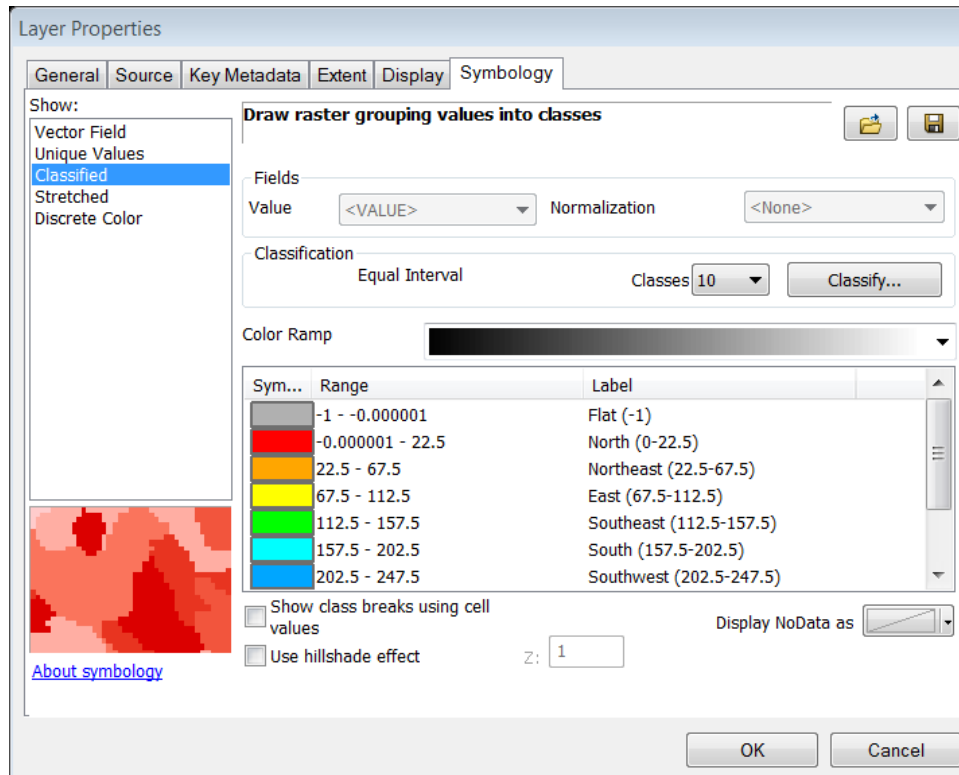
iii. Select the Browse button again to look for the Aspect symbology layer file.



iv. Select Aspect.lyr



v. Click OK to see the Symbology and labels.



- vi. Click OK to close the Layer Properties window.
5. Turn off and collapse the **crrk_aspect** layer.
6. **Save** the map.

Part 6: Cut/Fill Analysis

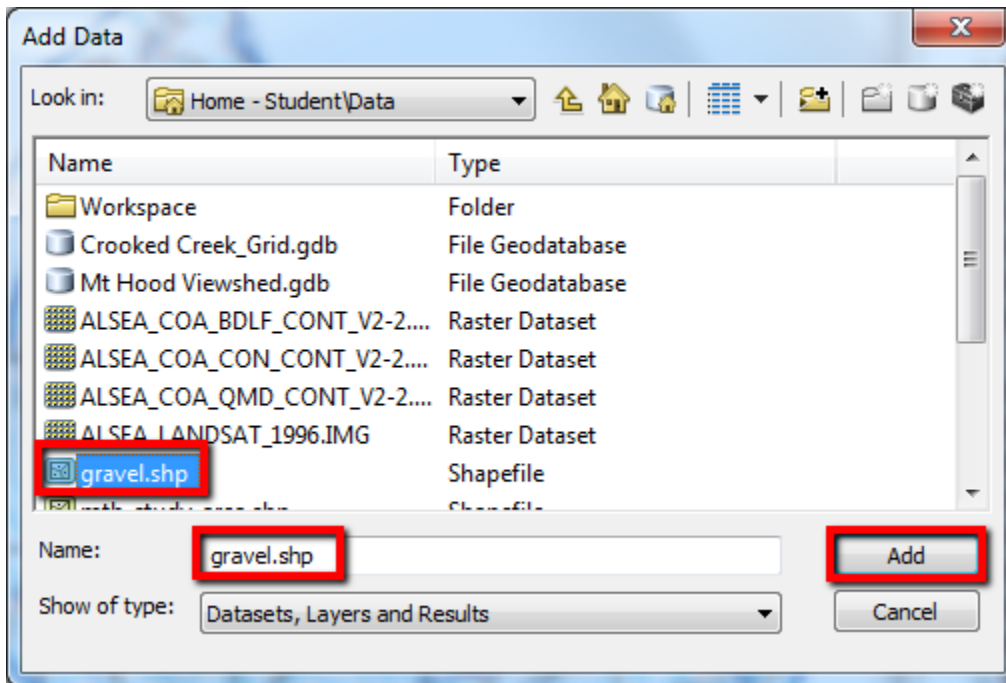
Besides Contour, Slope, and Aspect, there are other “Surface” tools in ArcToolbox. In the next exercise, you will try both the Hillshade and Viewshed tools. So, as a challenge, let’s give the Cut/Fill function a whirl. By taking two surface rasters (e.g., DEMs) that cover the same area but from two different time periods, the Cut/Fill function produces a raster displaying regions of surface material addition, removal, or no change over the time period.

Suppose a contractor has been given the task of removing rock from a gravel pit. The gravel will be used for road construction. After the road construction is complete, the remaining gravel will be dumped near a location along Crooked Creek.

Your challenge is to use the Cut/Fill tool to report the net gain and/or loss of surface material remaining. Keep in mind that this is only an example designed to demonstrate the functionality of the tool. In a real-world scenario, far more sophisticated analysis would be required. In order to determine the net gain/loss, you need a second raster that represents a surface change over a period of time.

A. Convert the gravel layer to a raster.

1. From the **Data** folder, add the dataset called **gravel.shp**.



2. Turn off the Crooked Creek group layer.

The shapefile represents a polygon feature class showing the location of the gravel pit (the larger polygon in the NW) and the location of the tailings dumped near Crooked Creek (the smaller polygon towards the east).

3. Zoom in and use the Identify tool to answer the following questions:

What is the depth of the gravel pit? _____ meters.

What is the depth of the tailings? _____ meters.

You might be inclined to think that there is more gravel in the tailings than was removed from the pit. However, the surface area of the gravel pit is twice the size of the area of the tailings. Therefore, the volume of gravel removed is greater than the volume of gravel dumped.

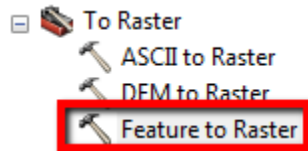
4. **Close** the *Identify* result window.
5. If you zoomed in earlier, zoom back to the full extent.

By converting the gravel layer to a raster dataset, and adding the raster to the DEM layer, we can use the depth values in the gravel layer as an indicator of surface elevation change.

The gravel layer is composed of three polygons. There is a gravel pit, a tailings site, and then the rest of the Crooked Creek subwatershed with a zero depth. When using arithmetic operators (+, -, *, /, etc.) between two or more raster datasets, the calculation requires a value for each cell, even if the value is zero. In other words, cells with NO DATA are ignored in the

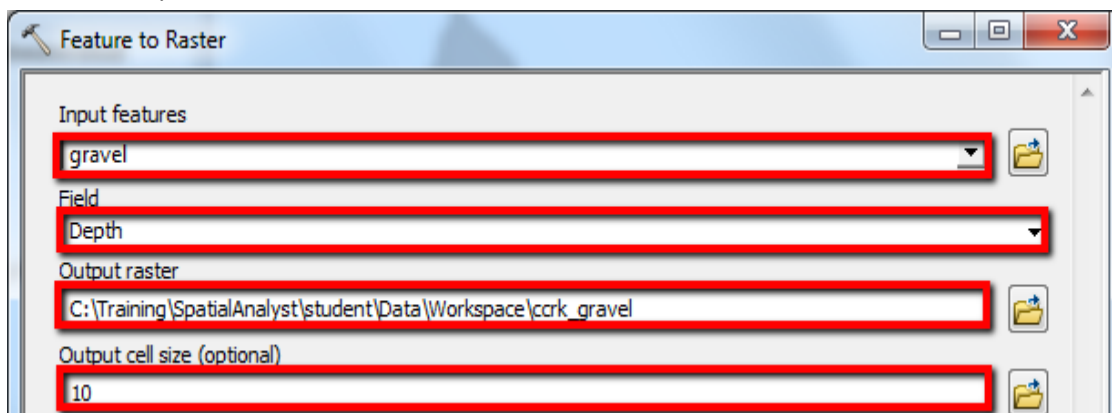
calculation. So, before evaluating a calculation between rasters, you'll want to be sure the cells pertaining to the study area contain a numeric value (as opposed to NO DATA). This has taken care of this for you.

6. In ArcToolbox open the *Feature to Raster* tool (**Conversion Tools | To Raster | Feature to Raster**).

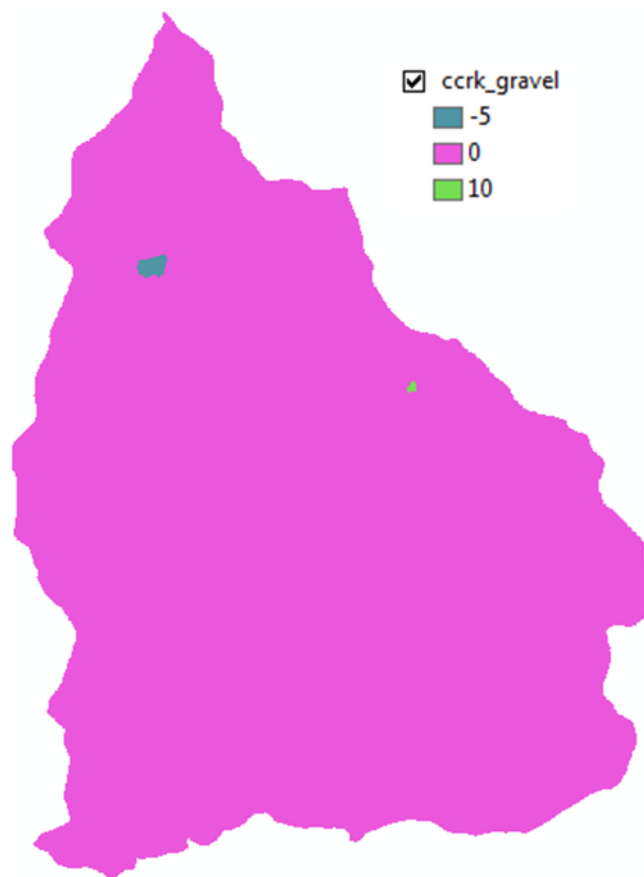


7. Allow the following parameters:

- Input features: **gravel**
- Field: **Depth**
- Output raster: **ccrk_gravel**
- Output cell size: **10**



8. Ensure the parameters match those displayed and click **OK**.

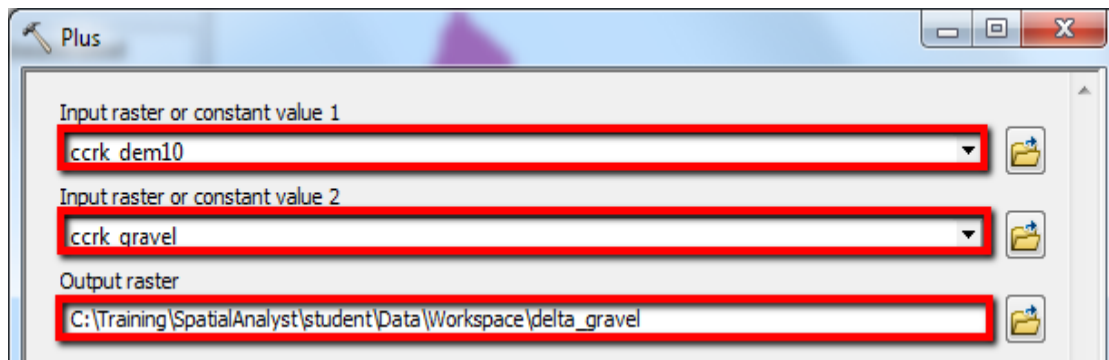


9. *Turn off* the gravel layer.

Next, we need to create a raster layer that represents the sum of the DEM raster with the GRAVEL raster. Under the Spatial Analyst Tools toolbox | Math toolset, there is a tool called **Plus** that Adds (sums) the values of two rasters together on a cell-by-cell basis.

B. Use the Plus tool to combine DEM & gravel data.

1. Open Spatial Analyst | Math | Plus.
2. Set the following parameters:
 - i. Input raster1: **ccrk_dem10**
 - ii. Input raster2: **ccrk_gravel**
 - iii. Output raster: **delta_gravel**

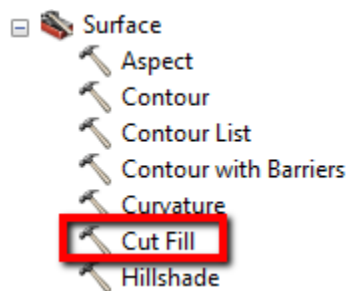


3. Click **OK**.
4. Turn off the *ccrk_gravel* layer.

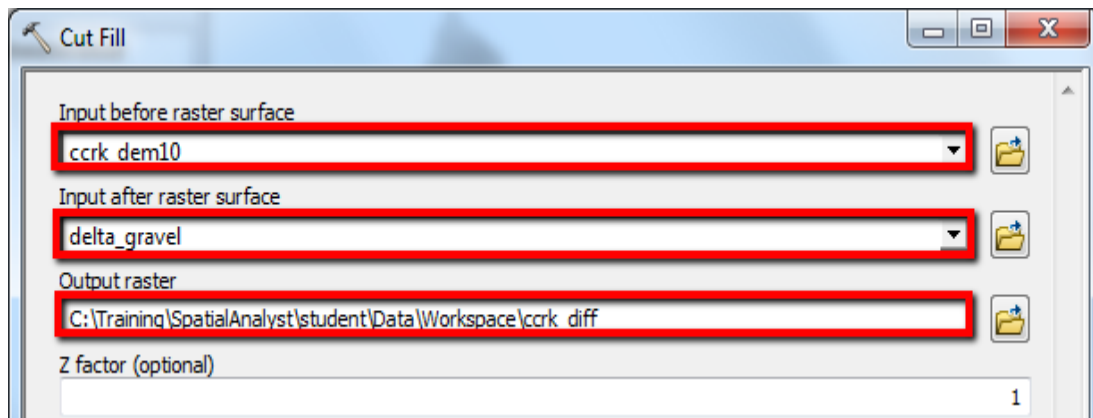
The new calculation depicts surface relief that now accounts for the change in elevation caused by the added depths of the gravel pit and of the tailings. The new *delta_gravel* DEM will be used as the second raster in the Cut/Fill function.

C. Use the Cut/Fill tool to determine surface elevation changes.

1. From Spatial Analyst | Surface, open the Cut/Fill tool.



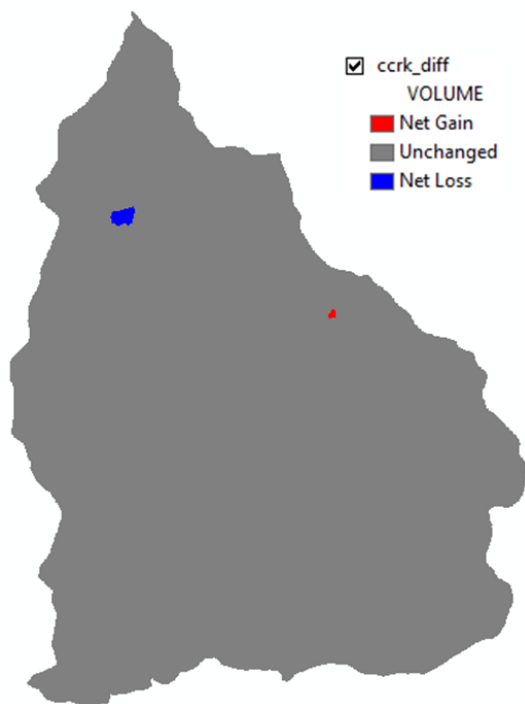
2. Set the following parameters in the *Cut/Fill* window:
 - Input before raster surface: **ccrk_dem10**
 - Input after raster surface: **delta_gravel**
 - Output raster: **...\data\Workspace\ccrk_diff**
 - Z factor: **1**



3. Click **OK**.

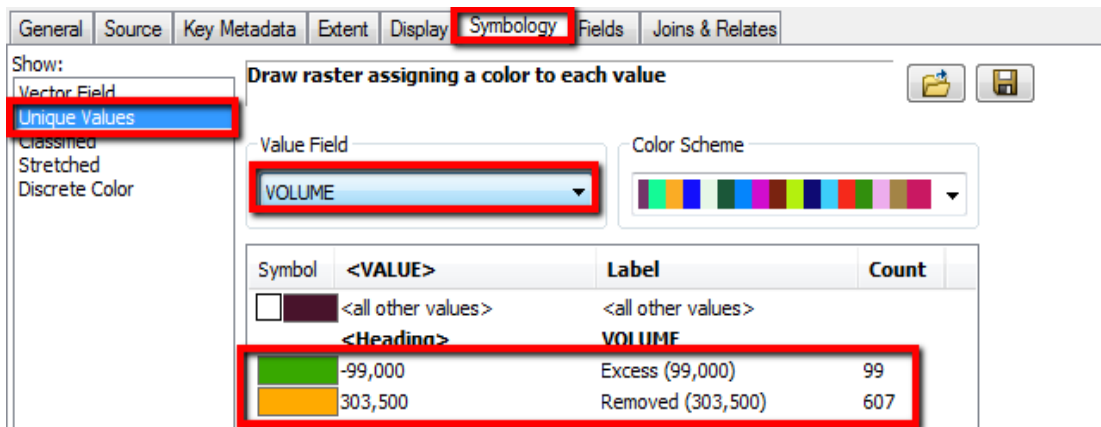
After the analysis completes, a new layer called `ccrk_diff` is added to the data frame. The new raster represents the subtraction of the "Before" surface from the "After" surface.

Take a look at the results. Displayed are three colors depicting the gains and losses of surface material. Red is a net material gain, blue is a net loss, and gray is no change in volume. Let's change the `ccrk_diff` layer's symbology to report actual volumes (in cubic meters) of materials gained and lost.



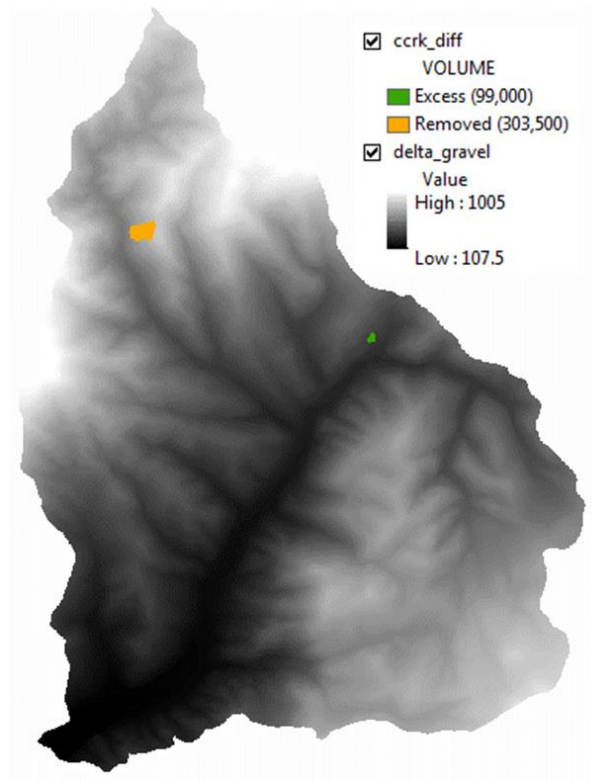
D. Re-symbolize the `ccrk_diff` layer.

1. Open the **Properties** for the **ccrk_diff** layer.
2. Activate the **Symbology** tab and apply the following changes:
 - *Show*: Unique Values
 - *Value Field*: Volume
 - Remove the zero value
 - Modify *<Heading>* to read Volume (cubic meters).
 - For the *-99,000* value, use Green, and update the label to Excess (99,000)
 - For the *303,500* value, use Orange, and update the label to Removed (303,500).



NOTE: Negative volume indicates areas that have been filled; positive volume indicates areas that have been cut.

3. Click **OK**.



How much gravel was used in the road construction? ____ m³.

Hint: You might want to use the Calculator (Start | Program | Accessories).

FYI: To convert the cubic meters to cubic feet, multiply the volume by 35.3. To convert cubic feet to cubic yards, divide the cubic feet volume by 27.

4. Turn off all layers, **except ccrk_diff** and then turn on the **Crooked Creek group layer**.

The Cut/Fill Thickness to Volume procedure is adaptable to many environmental science applications (e.g., mining).

5. Save the map document and exit ArcMap.

Congratulations! You have completed Exercise 2!