A Suitability Analysis: Spatial Analyst, Raster Data, and DEMs

UC DAVIS EXTENSION

Using ArcMap in ArcGIS, we will determine the probable nesting locations of the rare marbled murrelet (*Brachyramphus marmoratus*) in the Navarro River watershed. The marbled murrelet is a secretive bird, but it is thought to make its nests in old growth forests on steep (> 20 degrees), west-facing slopes within 35 km of the ocean at or around the 150m elevation.

This type of analysis is a common one, called a *suitability analysis.* It is used to help us answer the question of what locations meet a set of conditions.

- **Summary of Procedures:** Create a new Document and assign Data Frame Properties (e.g., units=meters). Add nav_dem_10m layer. Generate *hillshade, slope and aspect* grids; load *coastdistance* and *old growth* grids.
- Query grids to determine probable nesting locations based on outlined habitat parameters.
- Display resulting habitat patches draped over the *DEM* with *hillshade* as a brightness theme and elevation contours overlaid.

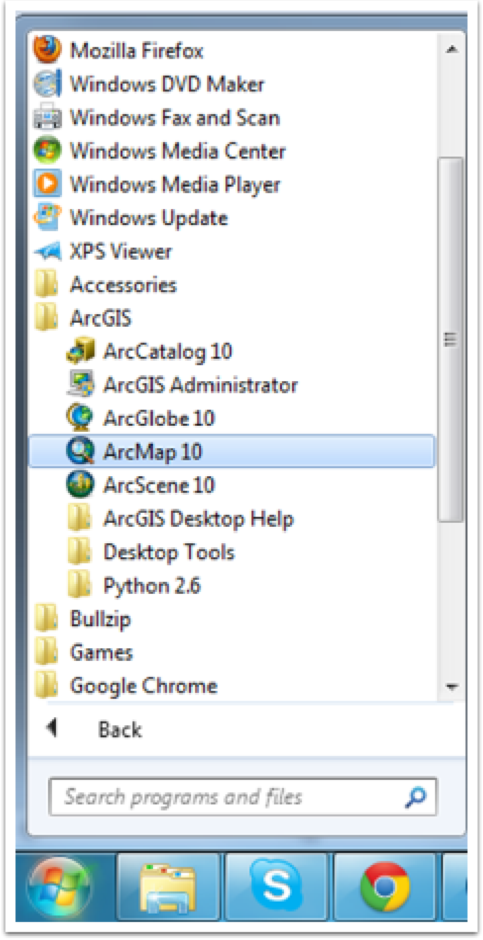
Review

1. We can set analysis options in environment settings
2. Suitability analyses are the process of determining what locations meet a set of criteria.
3. Symbology is the representation of data on a map

1. Start ArcMap

1. Go to the start menu
2. Click *All Programs*
3. Find and click on *ArcGIS*
4. Click on ArcMap

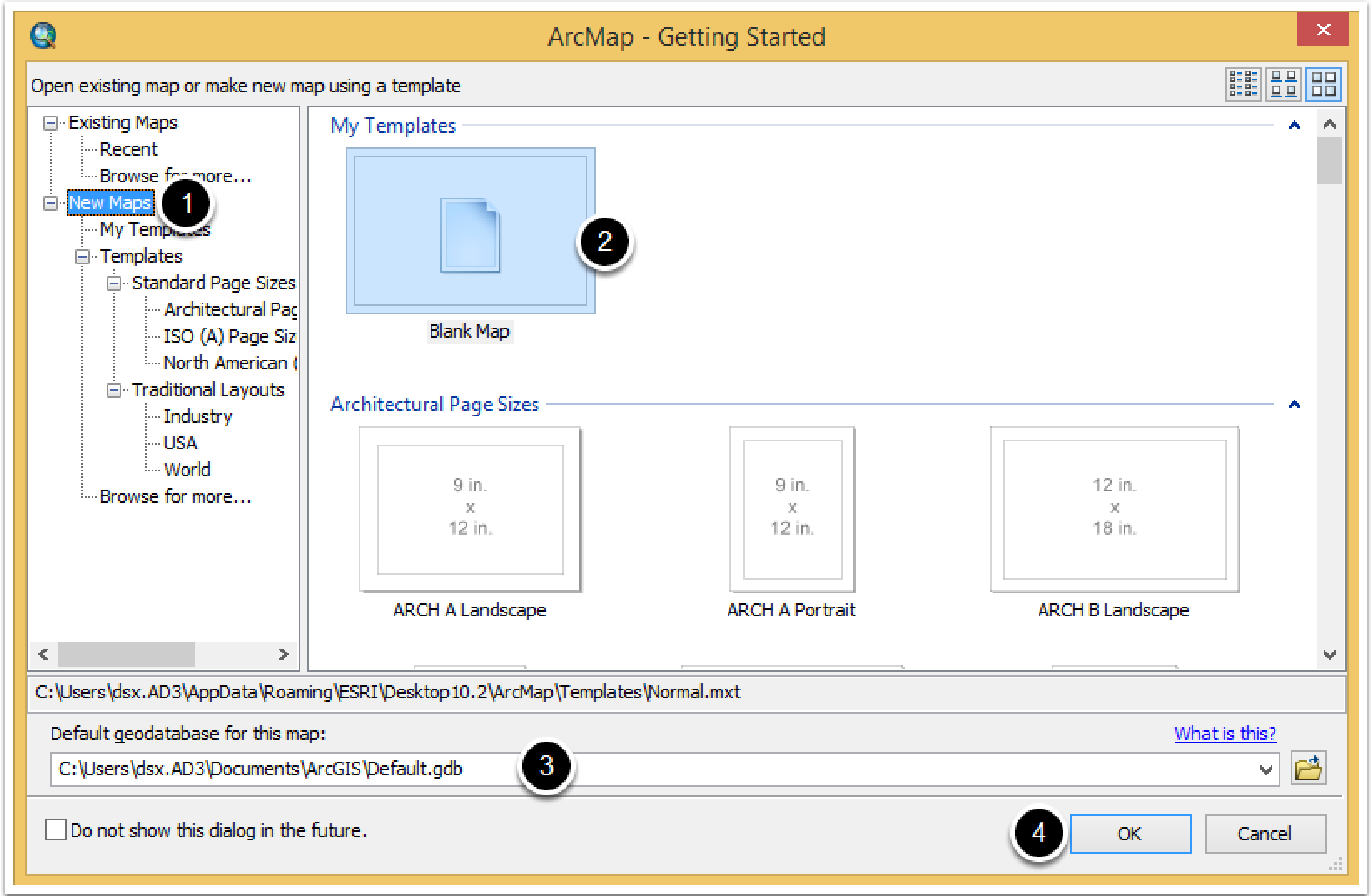
Hint: From the start menu, you can also just search for your programs by typing the name in the search box at the bottom


Mozilla Firefox
Windows DVD Maker
Windows Fax and Scan
Windows Media Center
Windows Media Player
Windows Update
XPS Viewer
Accessories
ArcGIS
ArcCatalog 10
ArcGIS Administrator
ArcGlobe 10
ArcMap 10
ArcScene 10
ArcGIS Desktop Help
Desktop Tools
Python 2.6
Bullzip
Games
Google Chrome
Back
Search programs and files

2. Create a new blank map

Create a new, blank map using the Getting Started box that will pop up automatically.

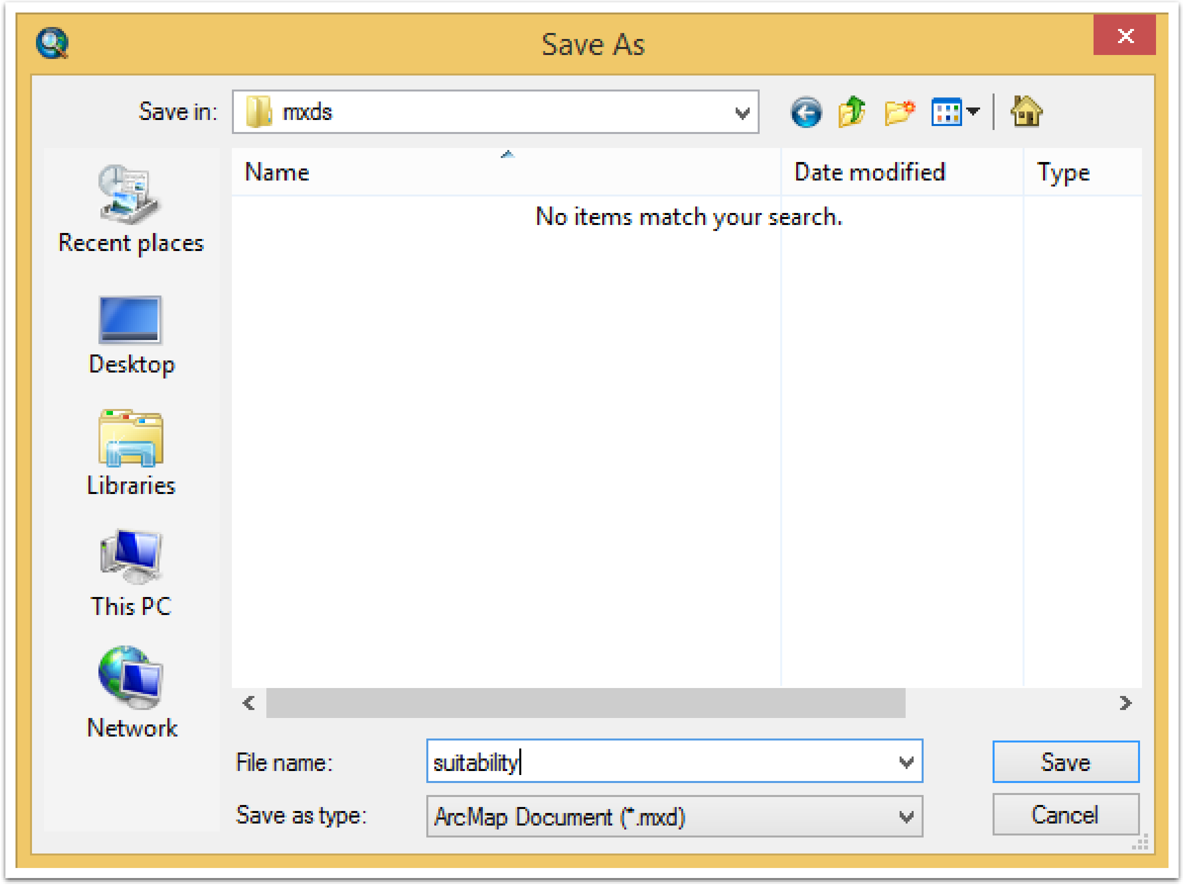
1. Select *New Maps* from the lefthand bar to see templates for new maps
2. Select *Blank Map* in the main window
3. Double check (or at least be aware of) your *default geodatabase*. No need to change it for now
4. Click *OK*



2.1 Save your map

First things first, let's save your empty map. Save it either by hitting *Ctrl+S* or going to the *File* menu and clicking on *Save*. You'll see a familiar box pop up.

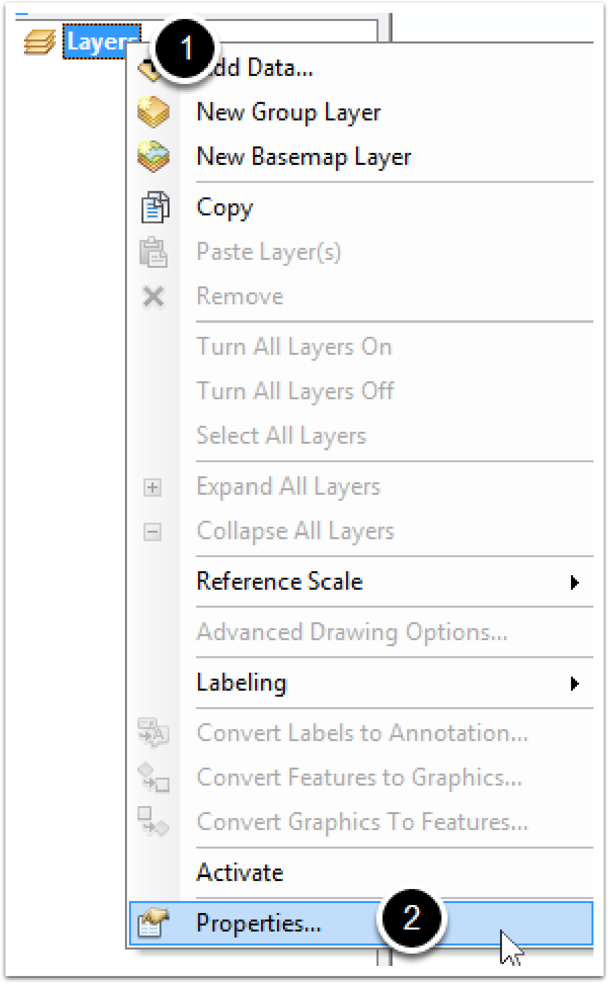
Navigate to the *mxds* folder inside your *Labs* folder and save this document as *suitability.mxd*



2.2 Set your data frame projection

I like to view California data in the NAD 1983 California Teale Albers projection - it's centered on California, so distortion is minimized. The problem, for this lab, is that we'll be using some rasters that came in other projections - and projecting rasters is difficult and should usually be avoided. So, instead of projecting the raster, let's just view it differently by setting the projection on our data frame.

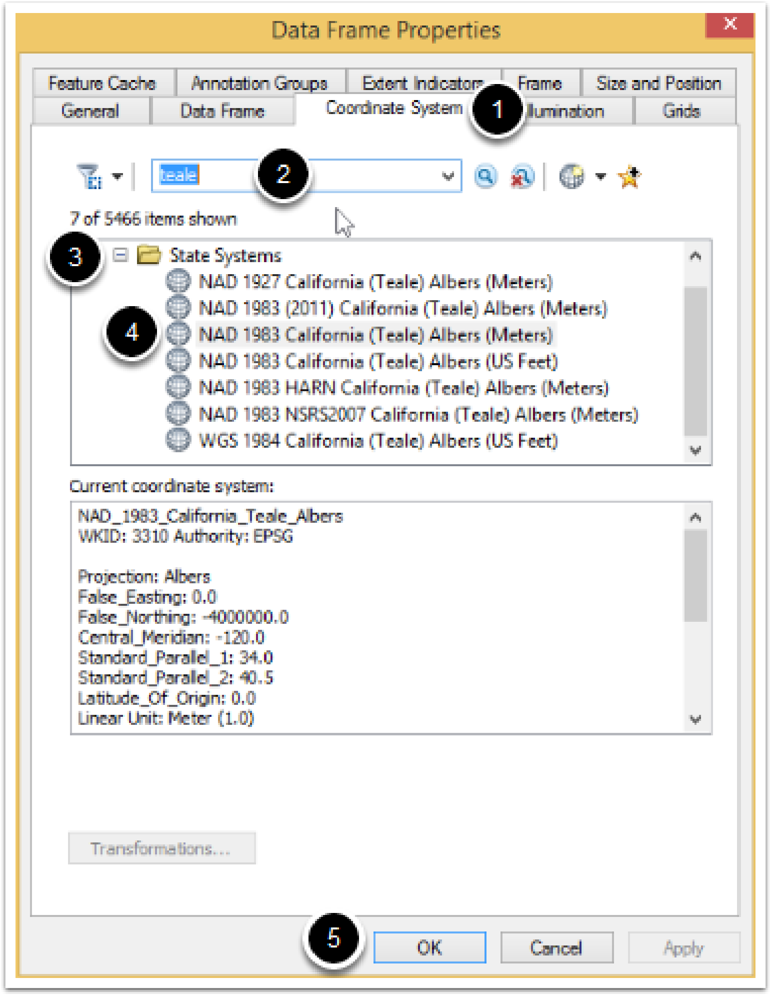
1. To get started, right click on your Layers root element
2. Then click properties



2.3 Continuing our document setup

1. In the dialog that pops up, go to the Coordinate System tab
2. In the search box, type "Teale", then hit the "Enter" key or click the Search button
3. Expand the plus sign boxes to see the coordinate systems

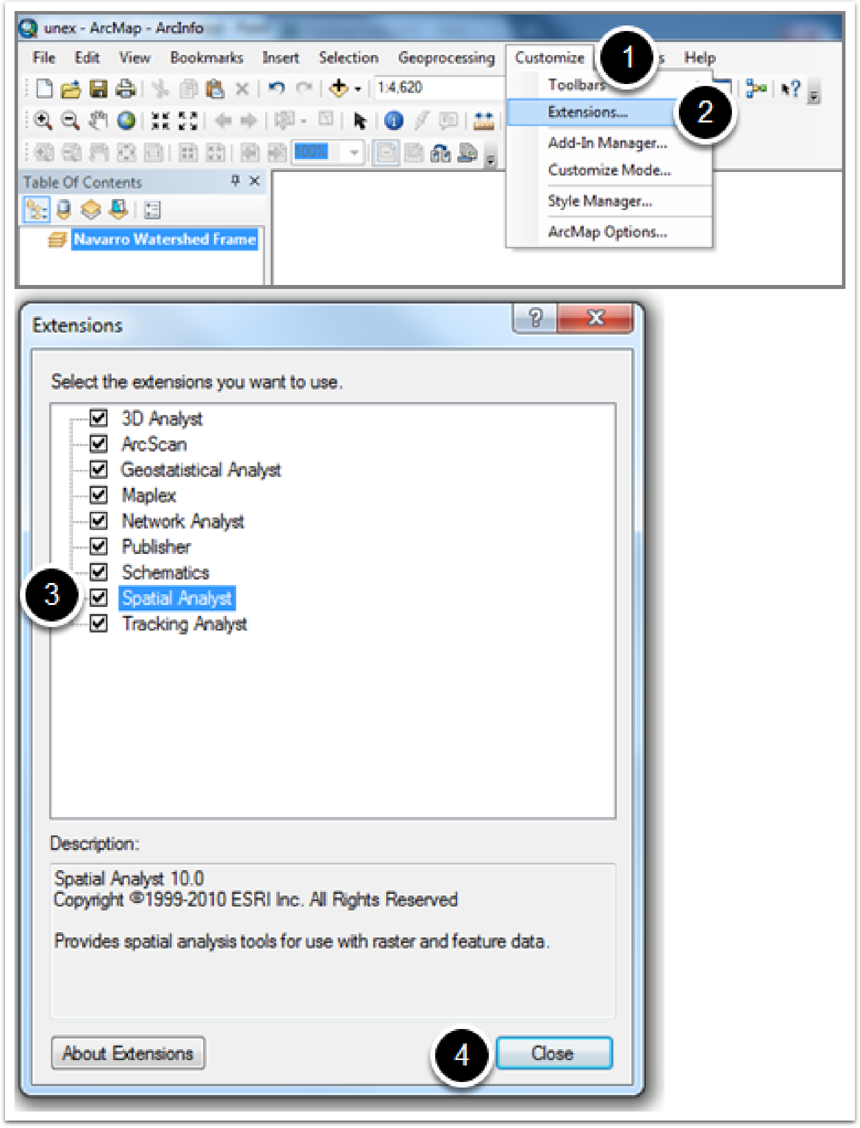
4. 7 coordinate systems will come up - select NAD 1983 California (Teale) Albers (Meters)
5. Click OK
6. Save your document again



3. Add the Spatial Analyst extension

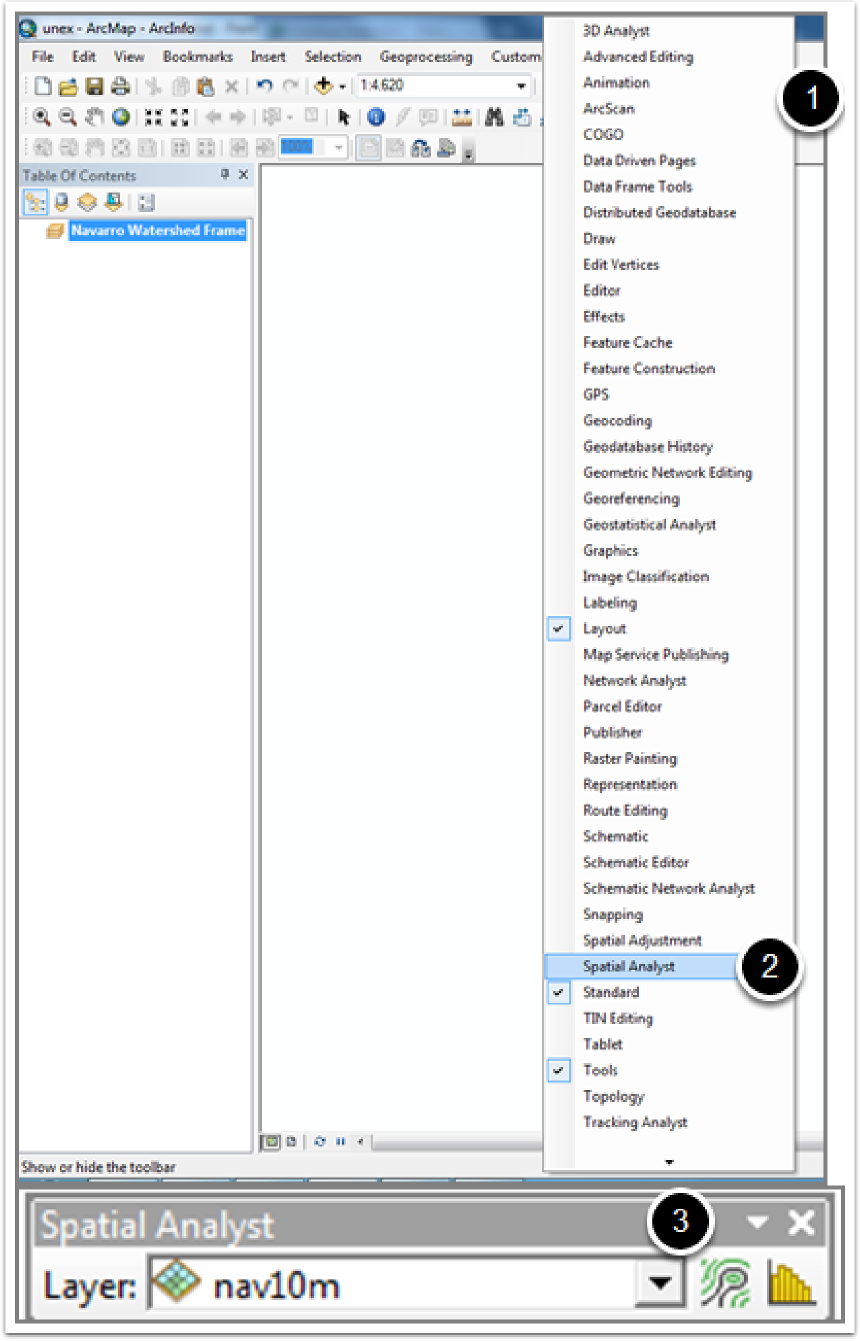
Let's start by making sure Spatial Analyst is enabled. Spatial Analyst is a very powerful ArcGIS tool for raster processing, making it essential for working with DEMs. It has a built in hydrology toolset that forms the basis for stream generatiojn from a DEM. It is not enabled by default though, so we'll need to go through a few steps to enable it. Add the Spatial Analyst Extension by:

1. Select the *Customize* menu
2. Click Extensions…
3. Check the Spatial Analyst box
4. Select Close.



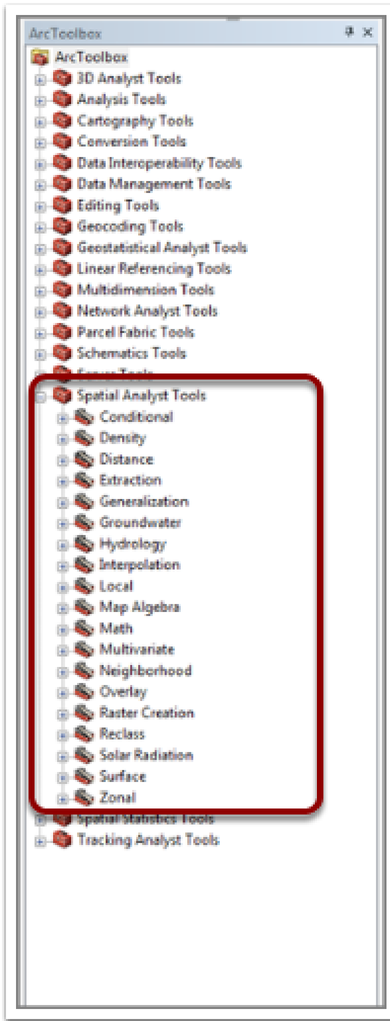
3.1 Add the Spatial Analyst Toolbar

1. Right click in a blank space on the toolbar a the top
2. Select the *Spatial Analyst* option in the menu that pops up
3. You'll see the Spatial Analyst toolbar floating nearby



3.2 View all of the Spatial Analyst tools

You can see all of the Spatial Analyst tools in the toolbox.



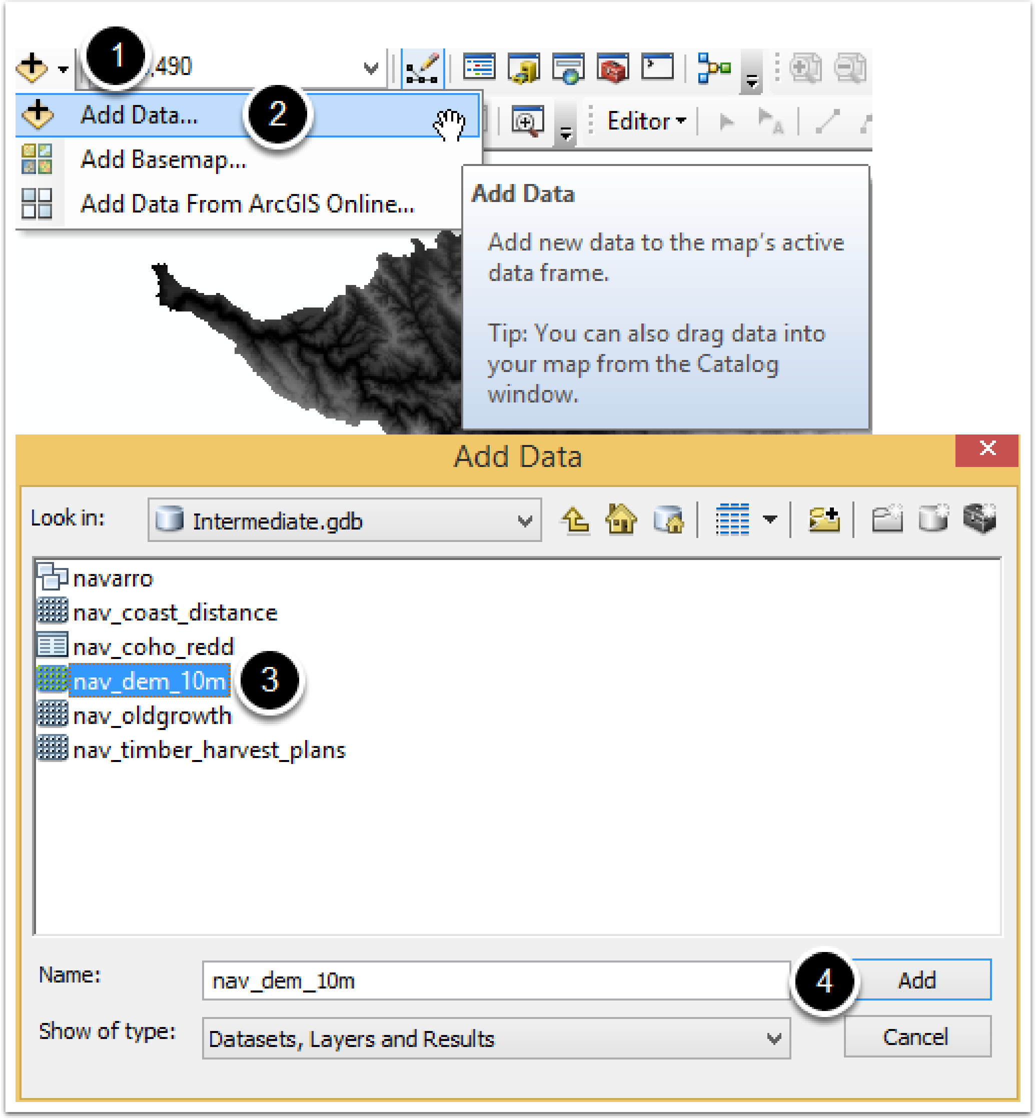
4. Add your navarro DEM

Add the Navarro River DEM from your data folder. It's located inside at *data/Intermediate.gdb/ nav_dem_10m.* If it's been a while since you've worked in ArcGIS, see the screenshots below for where to click

1. Click the *Add Data* button
2. Choose *Add Data* from the dropdown
3. Find our DEM, located in the class folder at *data/Intermediate.gdb/nav_dem_10m*

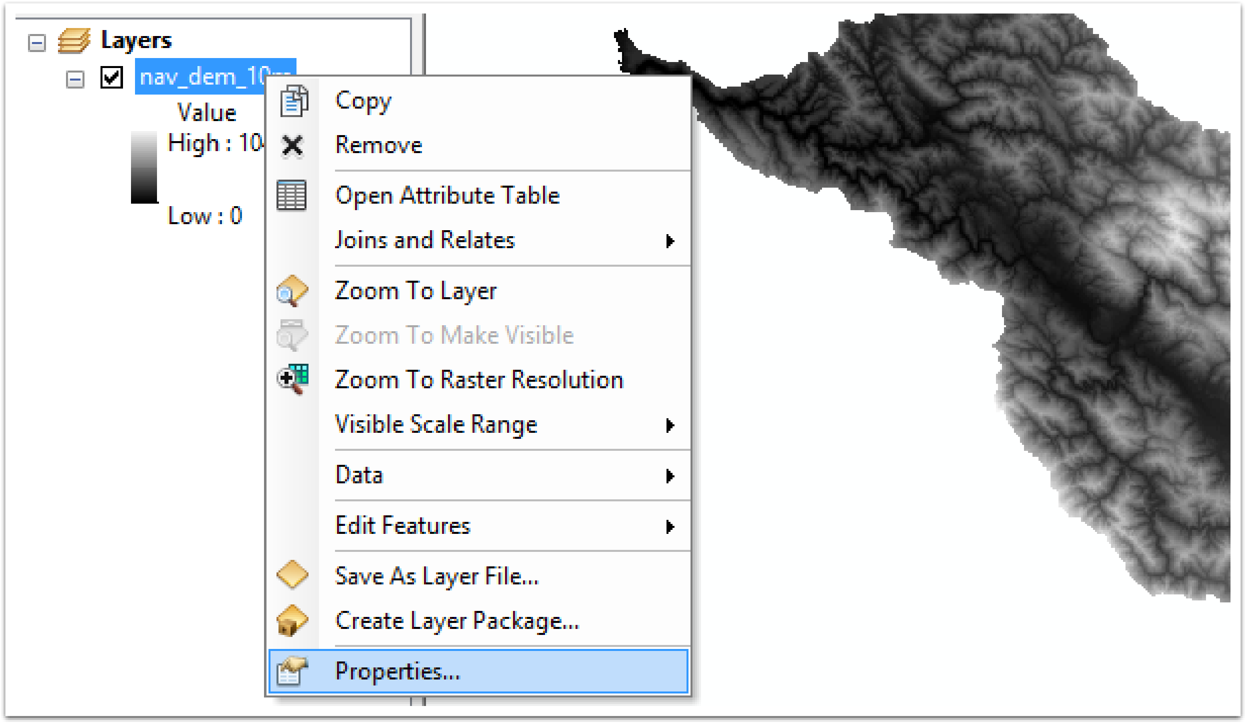
4. Click *Add*

When adding data, note the icon differences – can you tell the difference between the data types?



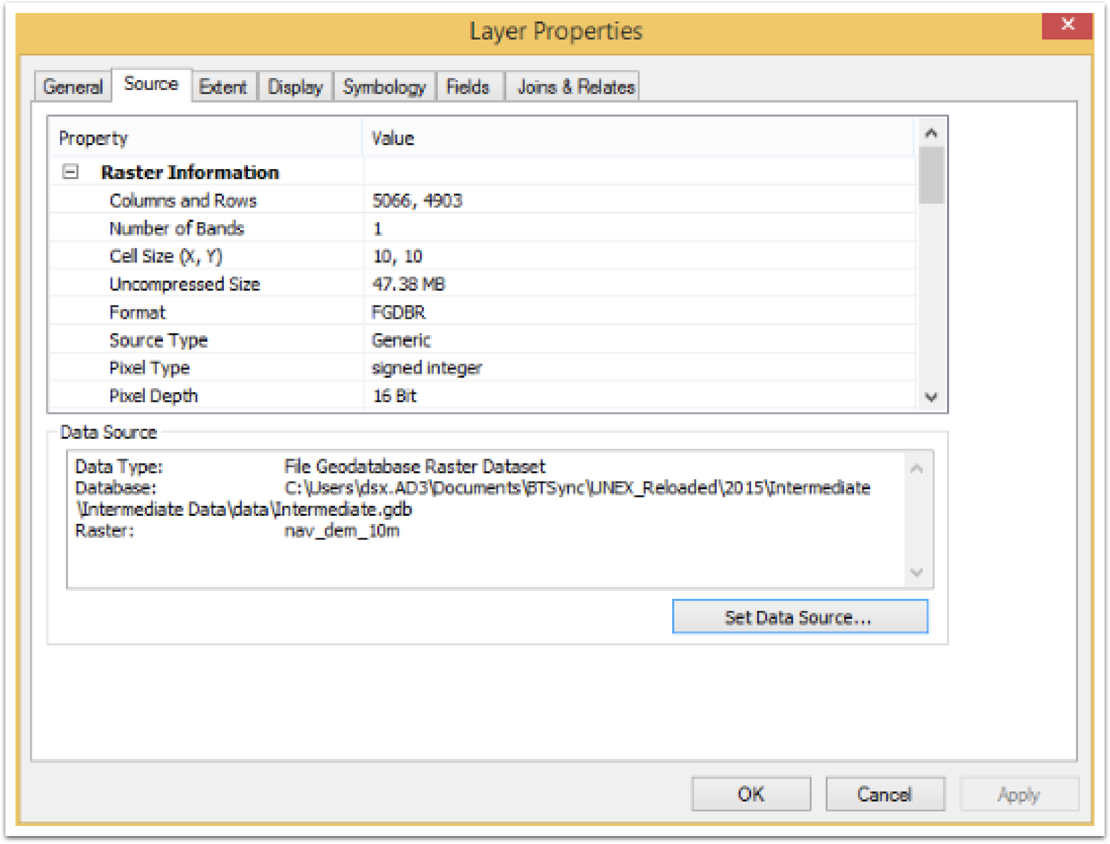
4.1 Change your DEM Legend

1. Right click on the DEM layer
2. Select *Properties*



4.2 Explore a bit

Take a look at the information available to you on the *Source* tab - number of rows and columns, bands, the cell size. What else? Scroll through the properties box and take a look at the full palette.

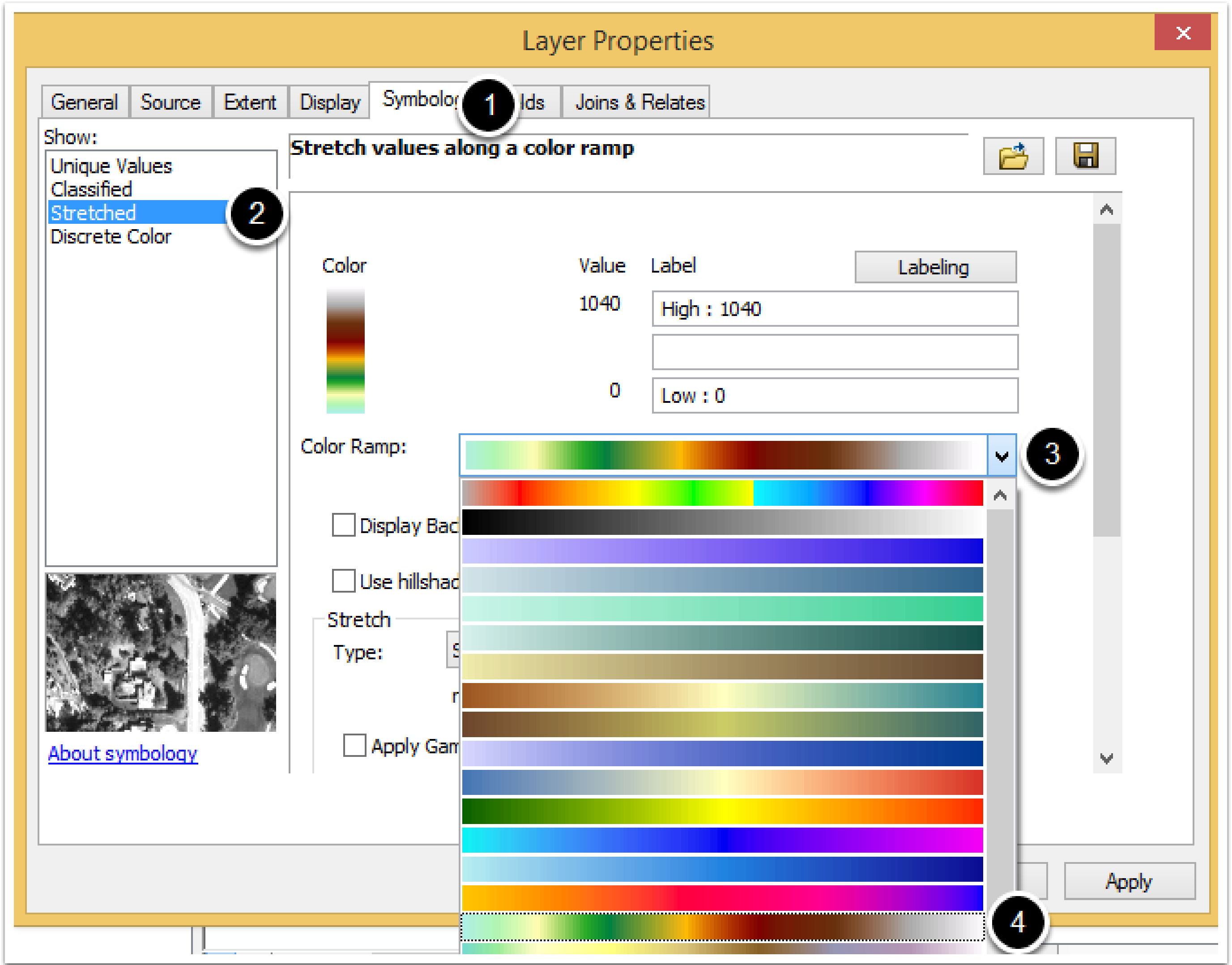


4.3 Set the elevation color ramp

As a reminder on how to set symbology:

1. Click to the symbology tab
2. Make sure to select the *Stretched* renderer on the lefthand side
3. Select the color ramp dropdown
4. Select the Elevation #1 ramp (see screenshot). Hint: If you right click on the color ramps and uncheck “Graphic View” you get a text description of potential uses, including seeing one labeled as "Elevation #1" - this isn't pictured below though.

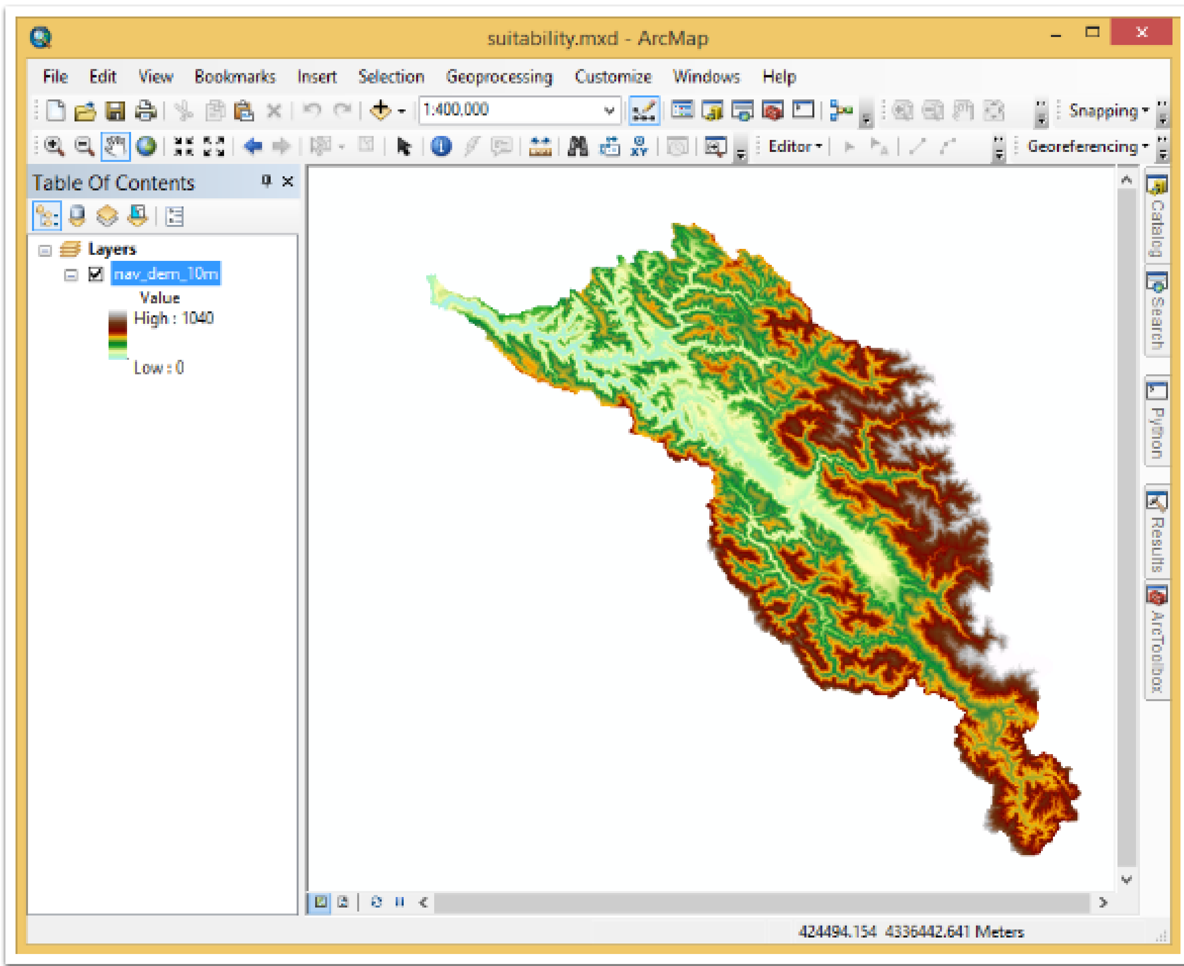
Click OK out of the dialog.


Layer Properties
General
Source
Extent
Display
Symbolog
lds
Joins & Relates
Show:
Unique Values
Classified
Stretched
Discrete Color
Stretch values along a color ramp
Color
Value
Label
Labeling
1040
High : 1040
0
Low : 0
Color Ramp:
Display Bac
Use hillshad
Stretch
Type:
Apply Gam
About symbology
Apply
1
2
3
4

4.4 Explore the watershed

First, what's happening with the colors - are they matching to reality (in a color for color sense and in an elevation sense)?

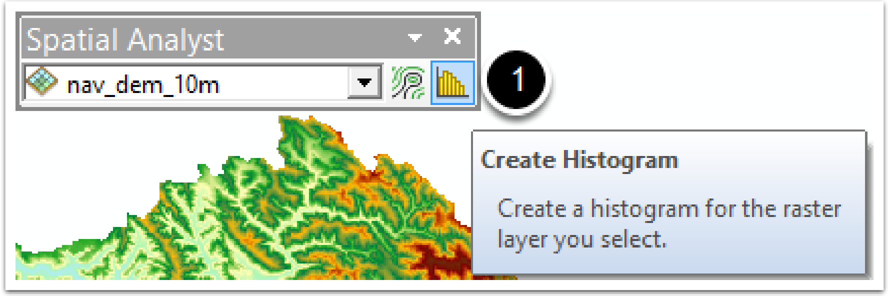
1. There is an alternate way of getting to the Data Layer Properties Form. What is it?
2. There is an alternate way of changing the Data Layer Legend ramp colors. Can you find it?
3. What about a quick rename of the Data Layer?
4. How do you turn all of the layers 'off' (so they aren't visible anymore) ?



5. Create a histogram of your elevations

ArcMap will generate a histogram of our elevations using Spatial Analyst.

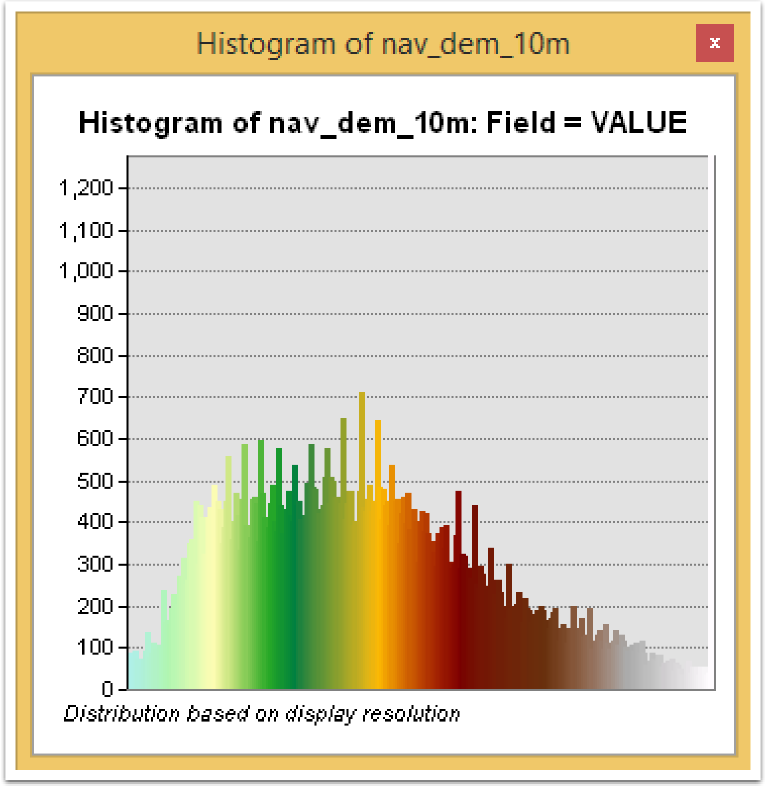
1. Click the histogram button on the Spatial Analyst toolbar after making sure that your navarro DEM is selected.



5.1 Evaluate your histogram

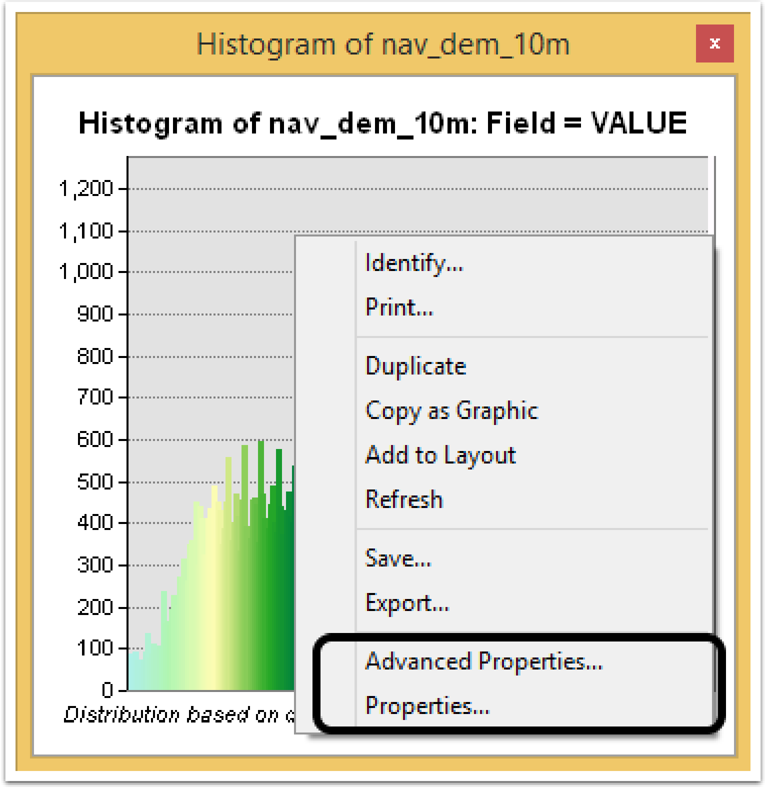
Again, does your histogram match what you expect to see based on the layer's display in the map viewer? What is it telling you? Note the large number of values (hard to see) in a single bar on the far right of the graph!

Where would the mean value and standard deviations fall? Is this DEM normally distributed? Will this affect your analyses?



5.2 Look around at the options

If you right click on the graphic, the dropdown menu offers *Properties* and *Advanced Properties*. Open up each of those in turn and see what they have to offer and what changes and options you can make on your graphic - can you find where you can change the scale of the graphic and the maximum values?

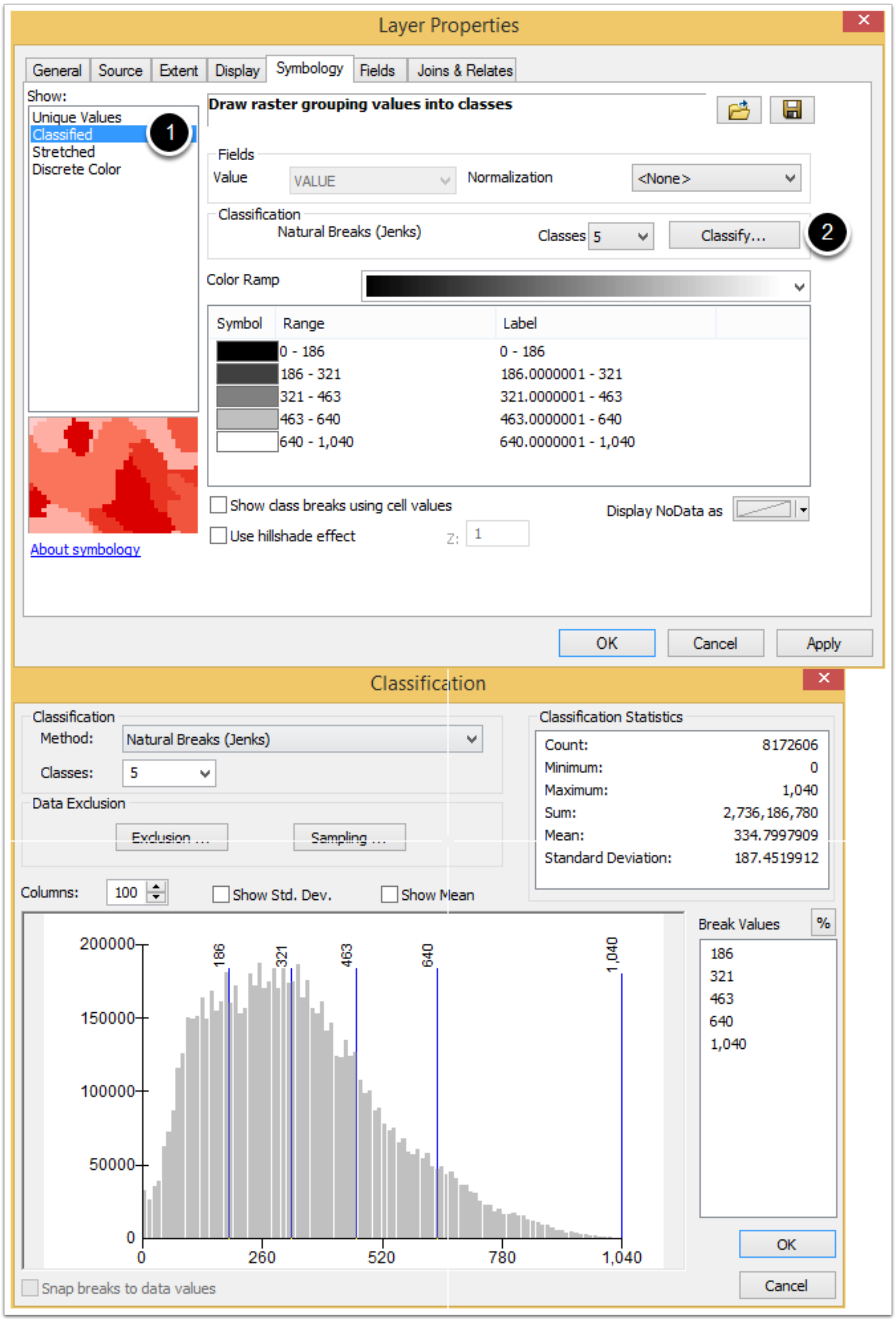


5.3 Other ways to view a histogram

You can also see a histogram with other properties by looking at the symbology when using the *Classified* renderer. Open up the symbology palette

1. Select the *Classified* renderer on the left,
2. then click the *Classify* button

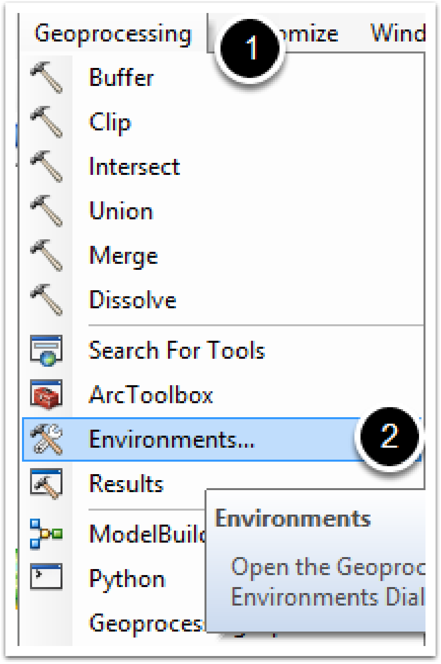
ArcGIS will show you what it's using to determine the elevation classes - and you can change those options from this palette there too. Take a look around and try playing with the settings here a bit, thinking about potential other uses for these options. When you are done, cancel out of these boxes, leaving the classification alone.



6. Analysis Setup

To begin our analysis, we'll need to set up our *Geoprocessing Environments* (recall what those are). Environment Variables (or simply "Environments" as they are often called) help us maintain consistency and formats in the analysis and output and provide us with data management options. We can set them in two places, in a specific geoprocessing tool, or for an entire ArcMap document, where they will be used for all geoprocessing tools that they apply to - we will do that now.

1. Click the *Geoprocessing* menu
2. Select *Environments*

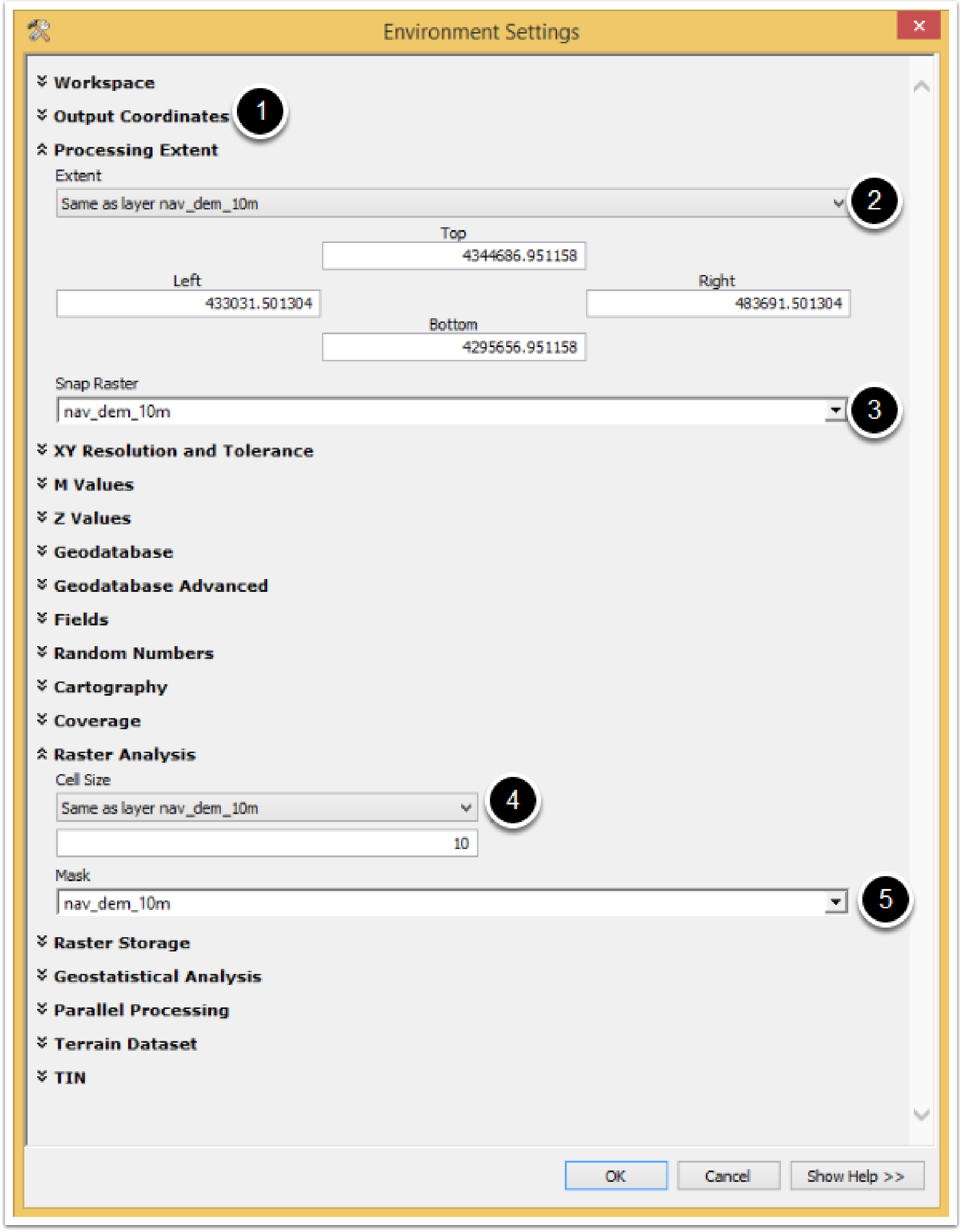


6.1

1. The *Environment Settings* window will pop up, we're going to set Output coordinates to be the same as nav_dem_10m (not shown in picture, but marked by icon 1)
2. Set the *Extent* to be *Same as layer nav_dem_10m*
3. Set the snap raster to *nav_dem_10m* (what do you think this does?)
4. Set the cell size to be *Same as layer nav_dem_10m*
5. and finally, set the *Mask* to *nav_dem_10m* (what does this do?)

What other environment settings might you set? Look around at what's available to get a sense for them for when you need them. Note also that ArcGIS help specifies for each tool the environment settings that affect them.

Finally, note that when you set the values for the environment settings, some of them may appear to not stay set. That usually means it has read in the information from the layer, and set the values for the extent below (as in the Extent setting).

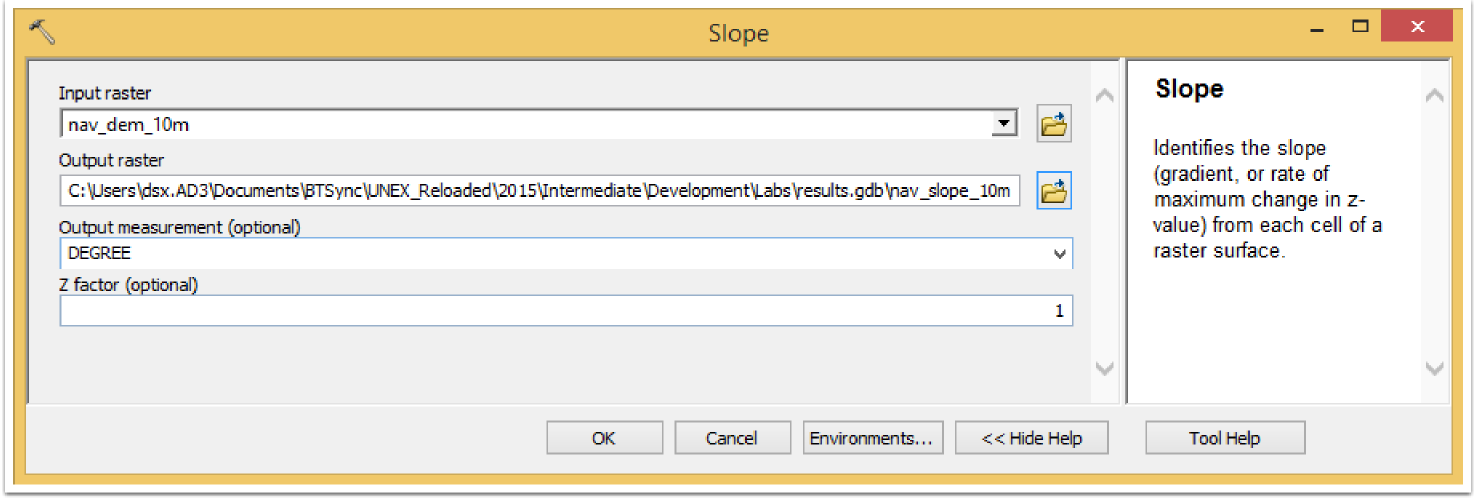


7. Create a slope grid

Recall that the marbled murrelet creates its nests on steep terrain (> 20 degrees) - so we'll need to incorporate that into our analysis. To begin this process, we'll make a slope raster from our output raster. Conceptually, if you know the elevations of each location, you can determine the slope to neighboring locations - that's what this geoprocessing tool does.

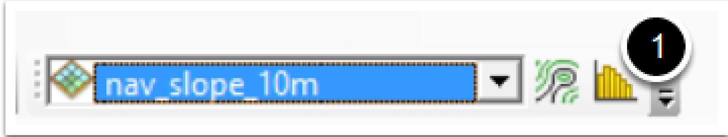
Locate the Slope tool either by using the Search panel, or by finding it under *Spatial Analyst Tools > Surface > Slope.* We'll use our DEM as our input raster - save the output raster somewhere reasonable that you can find it later. For the Output measurement, what option should we select? Check the problem statement to determine what to use.

Once the slope raster is generated, Change the Legend Value Classification to *Standard Deviation* type on the symbology palette. Then, examine the slope of the Navarro DEM. Does it seem representative of a coastal watershed?



7.1 Assessing the slope

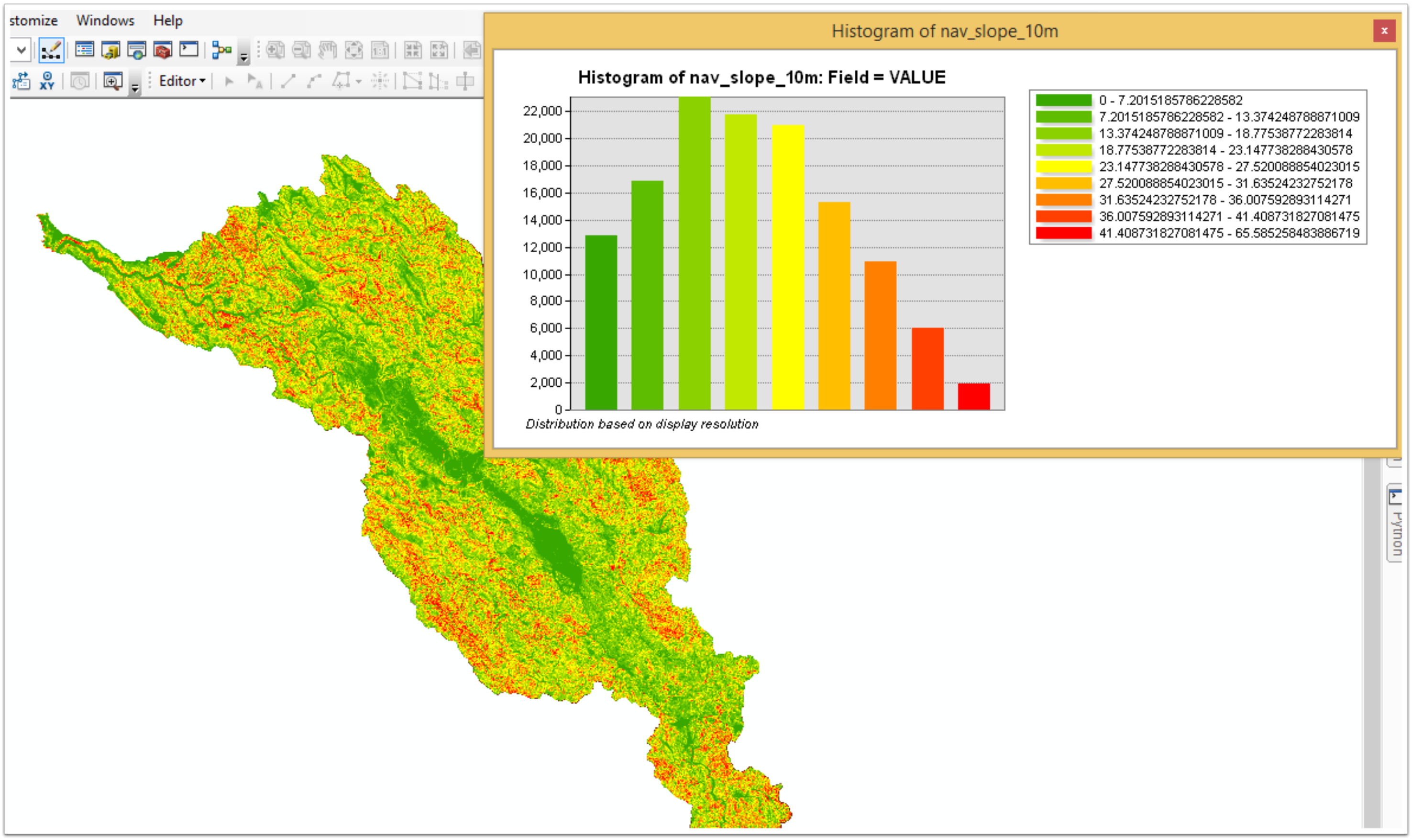
What is the distribution of Degree Slope in the Watershed? Select your slope layer on the *Spatial Analyst* toolbar and click the *Histogram* button (1).



7.2

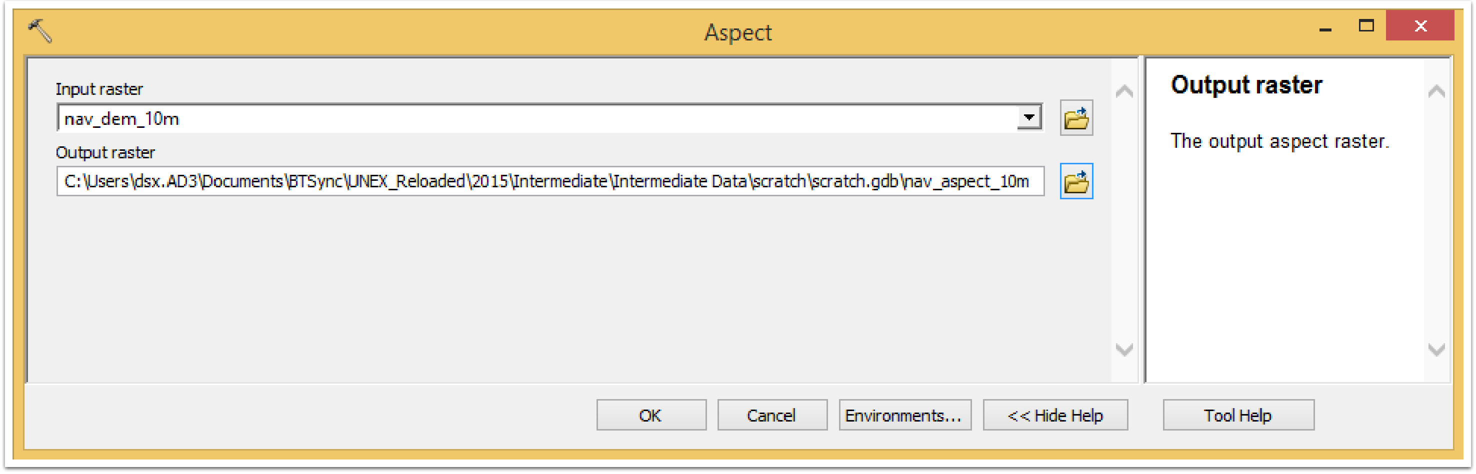
- What does the histogram tell you about the watershed?
- Can you achieve a similar histogram by using the Layer Properties form?
- Which is more informative?

Note: You may have a different number of columns/classes in the histogram



8. Generate an Aspect Grid of the Navarro DEM

Generate a raster grid representing aspect (remember what aspect is?) by selecting the Aspect tool from the Spatial Analyst toolbox (*Spatial Analyst > Surface > Aspect).* What do you think the input raster should be? See the screenshot below for a hint.

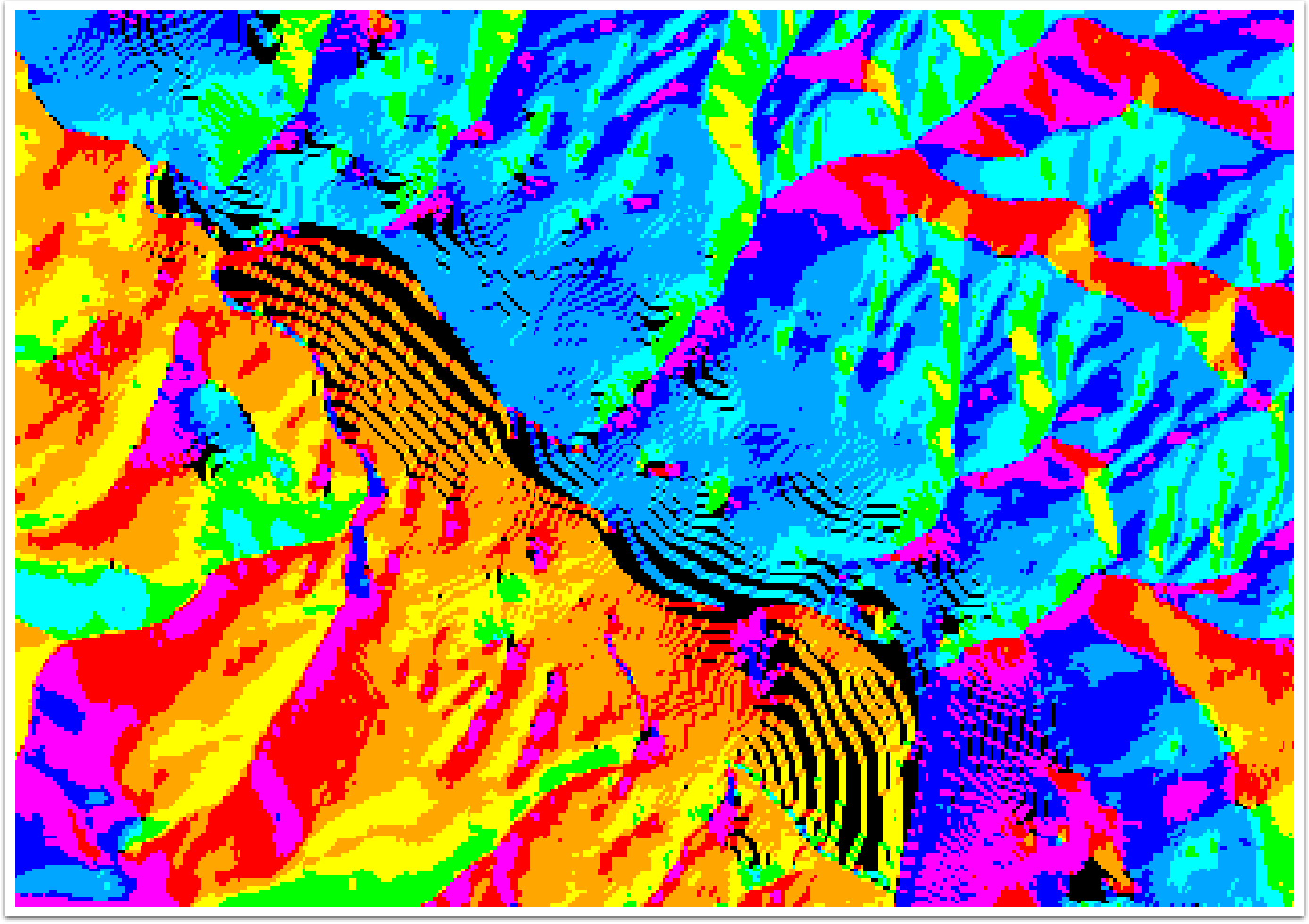


8.1 Examine the aspect output

Once it's generated, Examine the Legend associated with Aspect of Navarro DEM. What are the values depicting?

What value is used for flat areas? Is there anything peculiar about the output? Make flat areas black and examine the output up close.

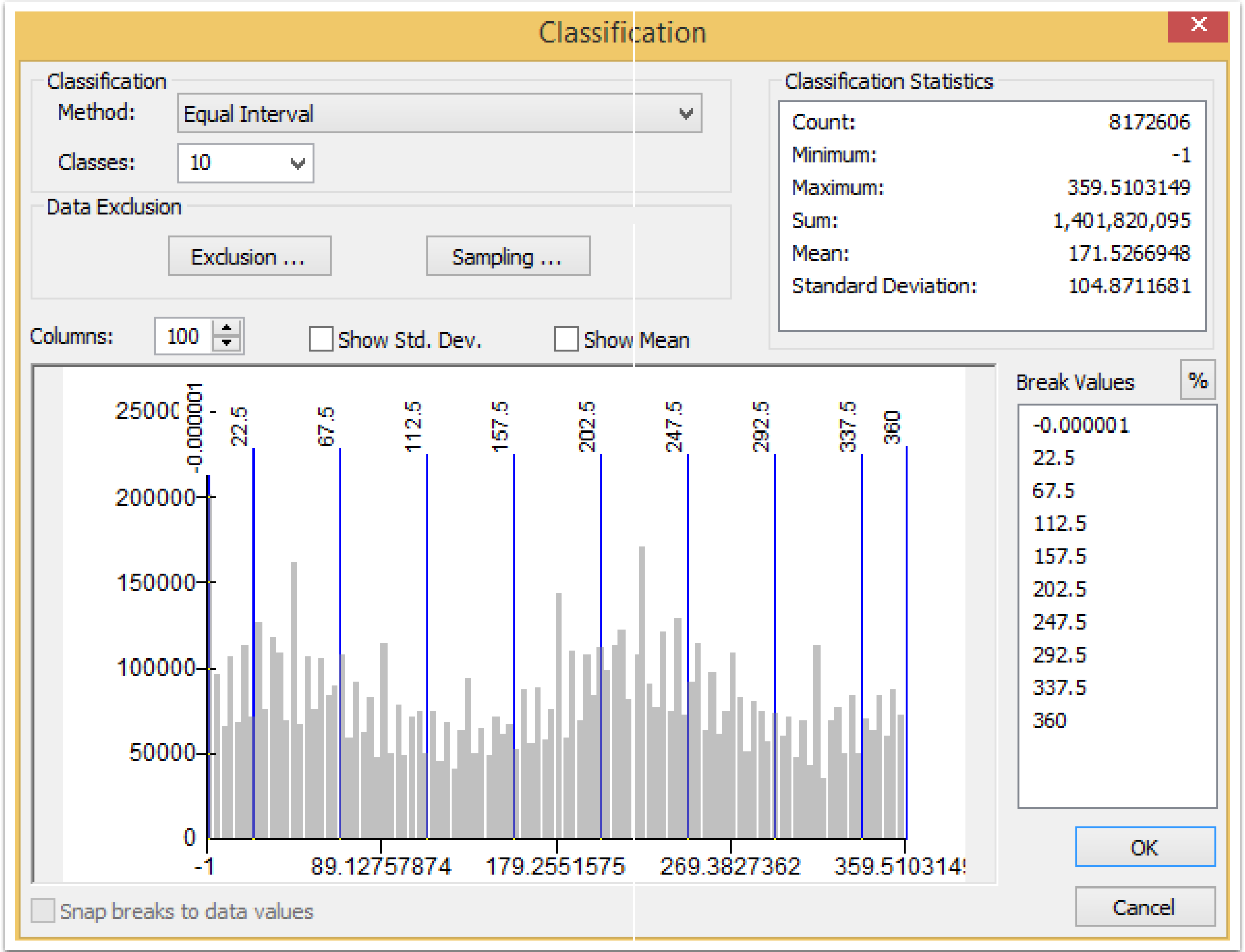
Does the Slope grid show similar terracing? The DEM?



8.2

Examine the distribution of the ASPECT raster data (choose either method - spatial analyst or the layer symbology properties. Symbology properties are shown below):

- What pattern do you notice?
- Can you take a mean value of ASPECT?
- Is there a way to handle these data in a linear fashion?

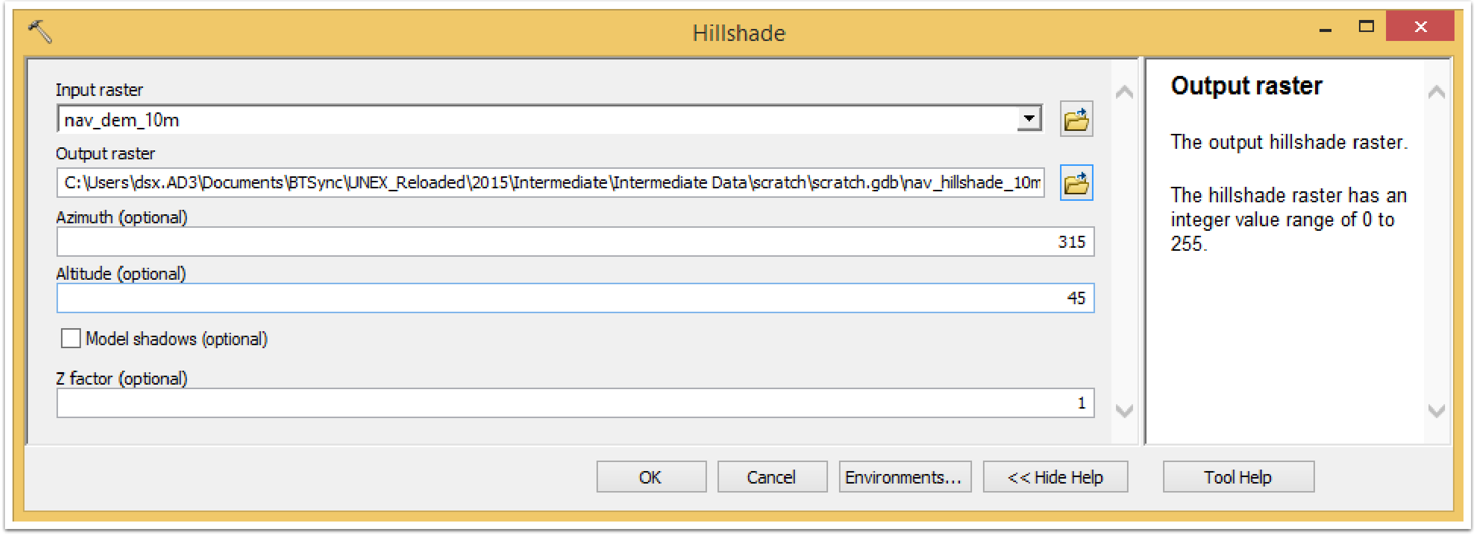


9. Generate a Hillshade Grid of the Navarro DEM

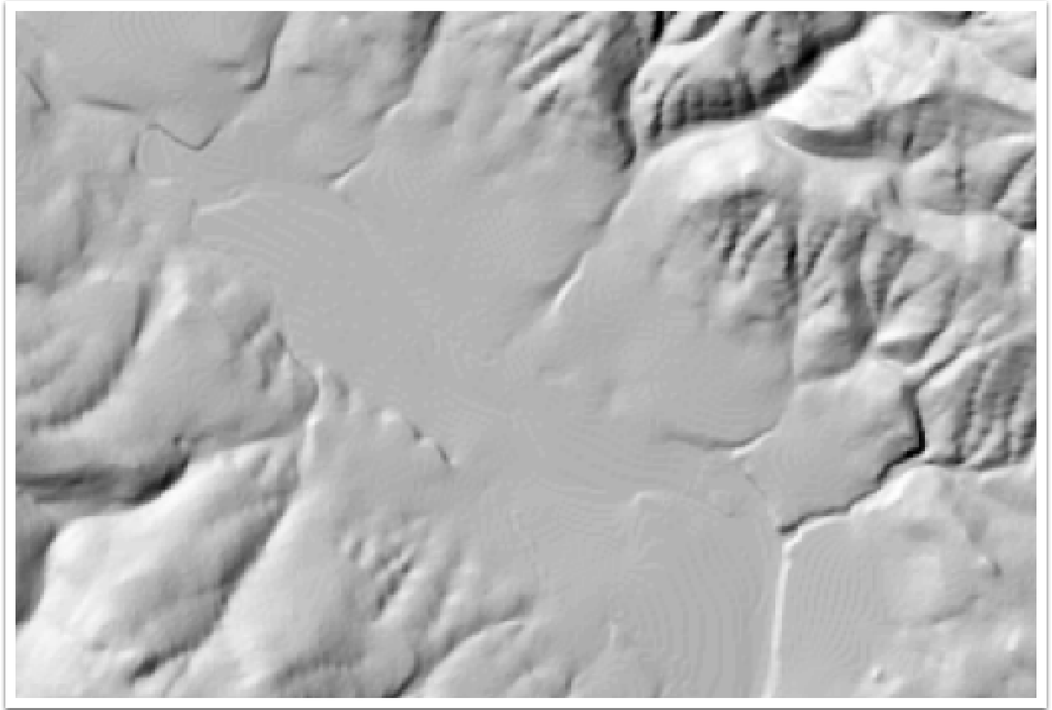
Generate a grid representing HILLSHADE by selecting the Hillshade tool in the Spatial Analyst toolbox

Use the built in Geoprocessing Tool Help to determine what the Azimuth and Altitude input parameters are used for and why you might want to change them.

Accept the default parameters of Azimuth = 315 and Altitude = 45 and select OK.

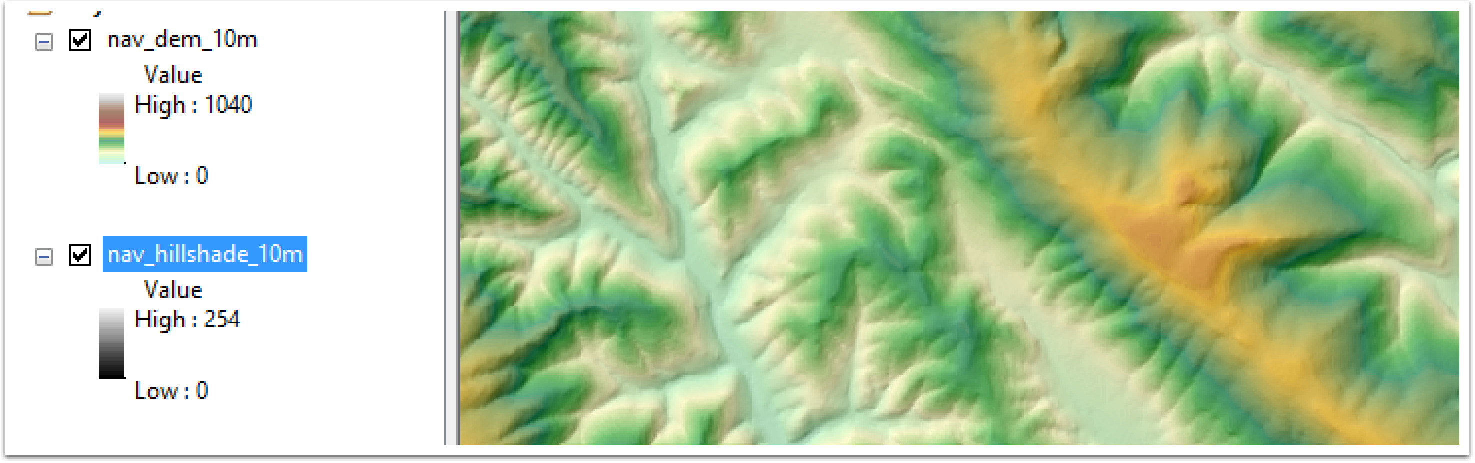


9.1



9.2 A better hillshade

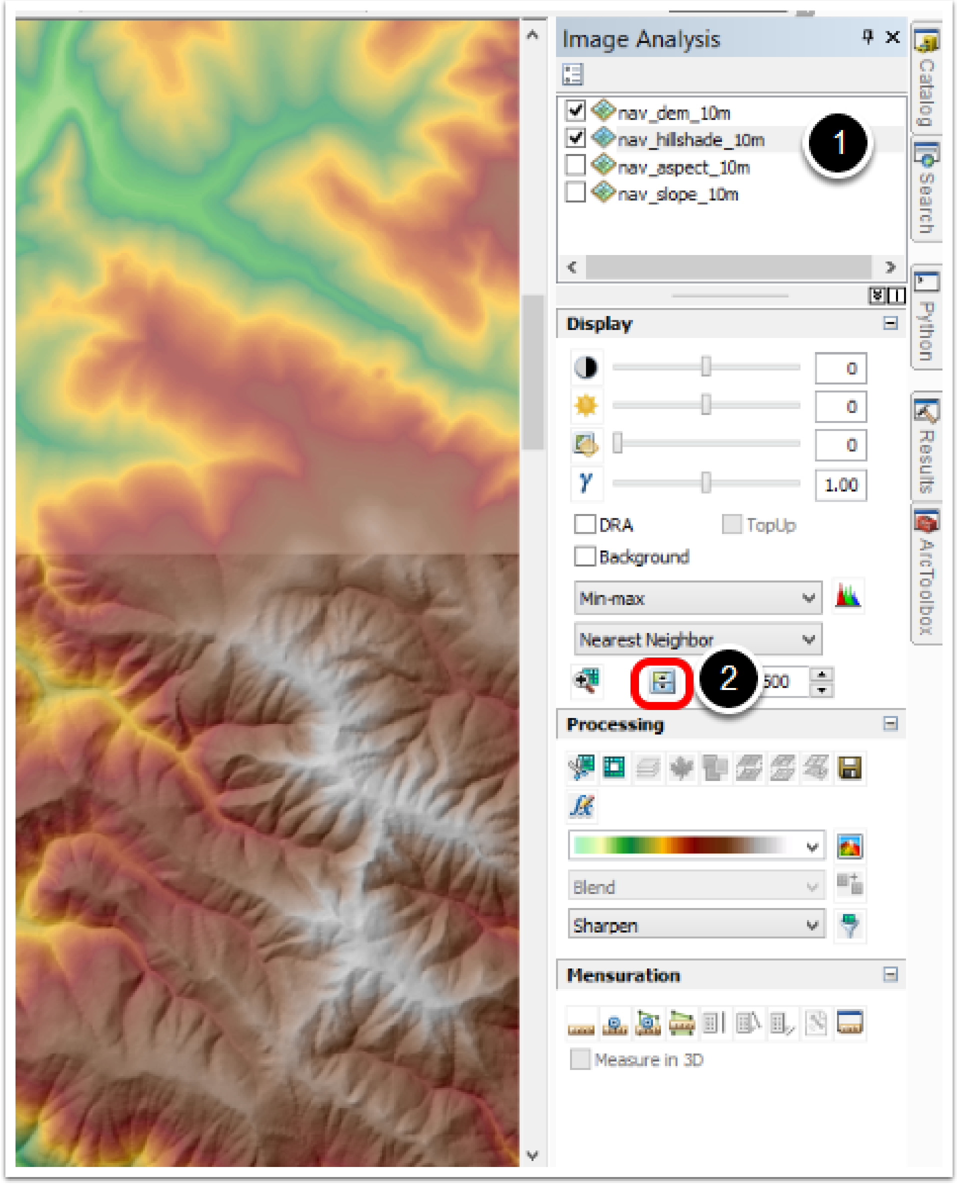
The default hillshade is ok, but let's visualize it a little better in a quick way. Set the transparency of nav_dem_10m to 40% (in layer *Properties->Display)* and move it above the nav_hillshade_10m raster grid. Notice the draping effect? This is 2/3 of a "Swiss Hillshade," which combines a hillshade layer, a DEM, and an "aerial perspective" layer to create a more natural hillshade.



9.3 The Image Analysis Window

Let's just take a quick look at how this new version of the hillshade compares to the plain ArcMap version. To do this, we'll bring up the *Image Analysis* window (under the *Windows* menu in ArcMap). Let's use the *Swipe Layer* tool to compare the images. Then:

1. Highlight *nav_hillshade_10m* in the pane that appears
2. Click the *Swipe Layer* button (in red box in image)
3. Click into your map view and, while holding the mouse button down, move the mouse up and down to explore the difference between the pure DEM and the DEM/Hillshade combination

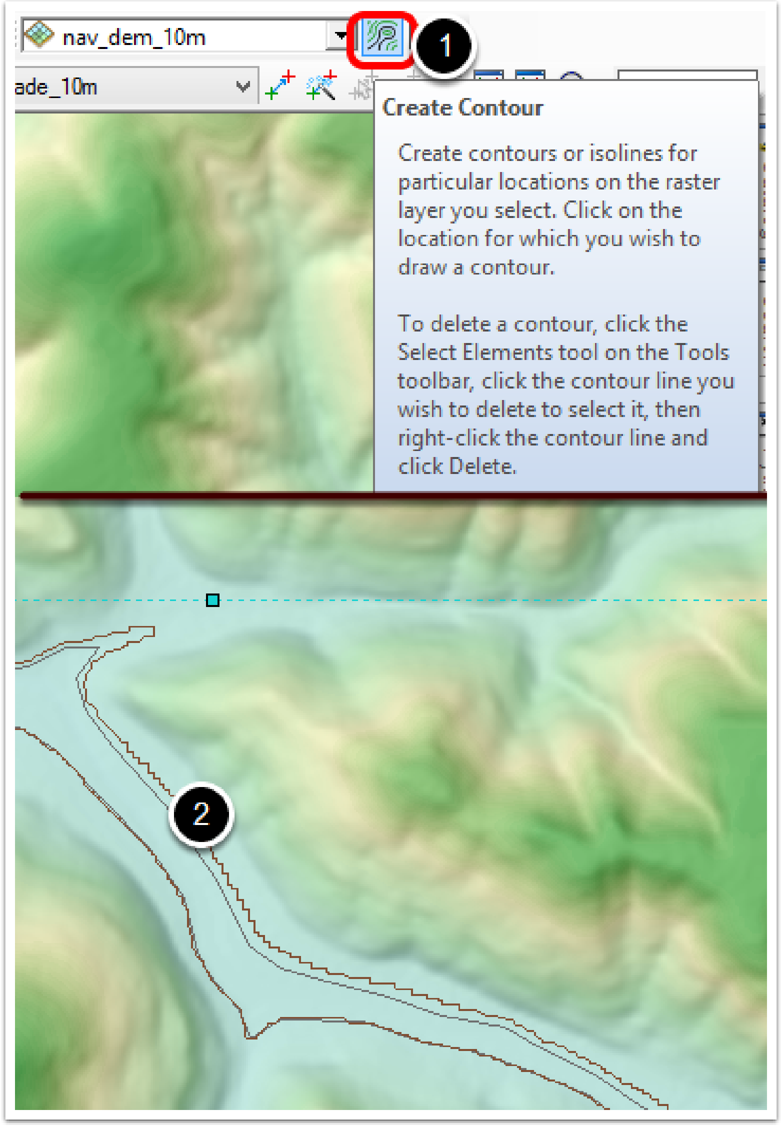


10. Creating Contours from a DEM

Add the *nav_estuary* feature class to your map document (located in the *data* folder inside of *Intermediate.gdb*).

1. Zoom in on the Estuary. Make sure that on the *Spatial Analyst* toolbar, the *nav_dem_10m* is selected. Then, select the Contour Tool (it looks like a thumbprint) from the Spatial Analyst Toolbar.
2. Use the tool to draw a contour around the Estuary by clicking on the View Frame once at the edge of the Estuary Polygon. What happens when you do this? Zoom out a step or two. What do you think is going on? Do these contours behave like contours you're more familiar with?

This can be done for as many elements that the DEM attributes and structure can support, but it could be very laborious to do the entire watershed. Further, note that these are graphic elements and can be edited as such, they are **not** layers. This means that from a data standpoint, they're no longer meaningful, except to a human who can interpret them. To delete the contours, you can use your *Select Elements* tool (the normal pointer on the toolbar next to the *Identify* tool), then once they are highlighted (with the dashed line box around them), you can hit the delete key to delete the element.

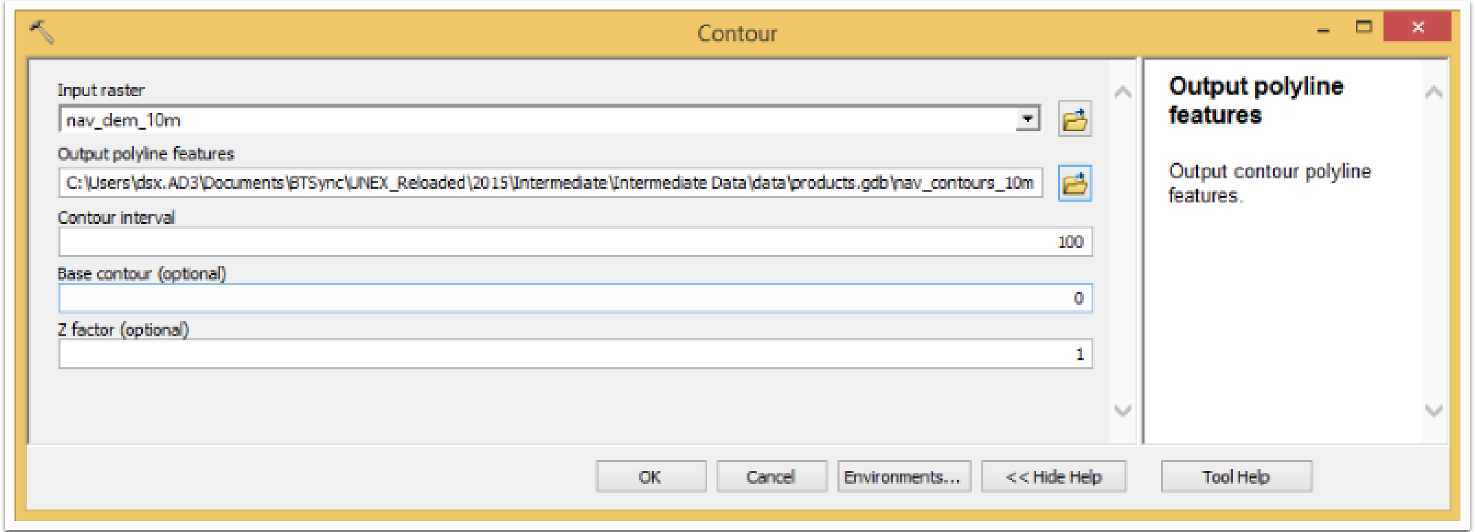

nav_dem_10m
ade_10m
1
Create Contour
Create contours or isolines for particular locations on the raster layer you select. Click on the location for which you wish to draw a contour.
To delete a contour, click the Select Elements tool on the Tools toolbar, click the contour line you wish to delete to select it, then right-click the contour line and click Delete.
2

10.1 Create contours for the whole watershed

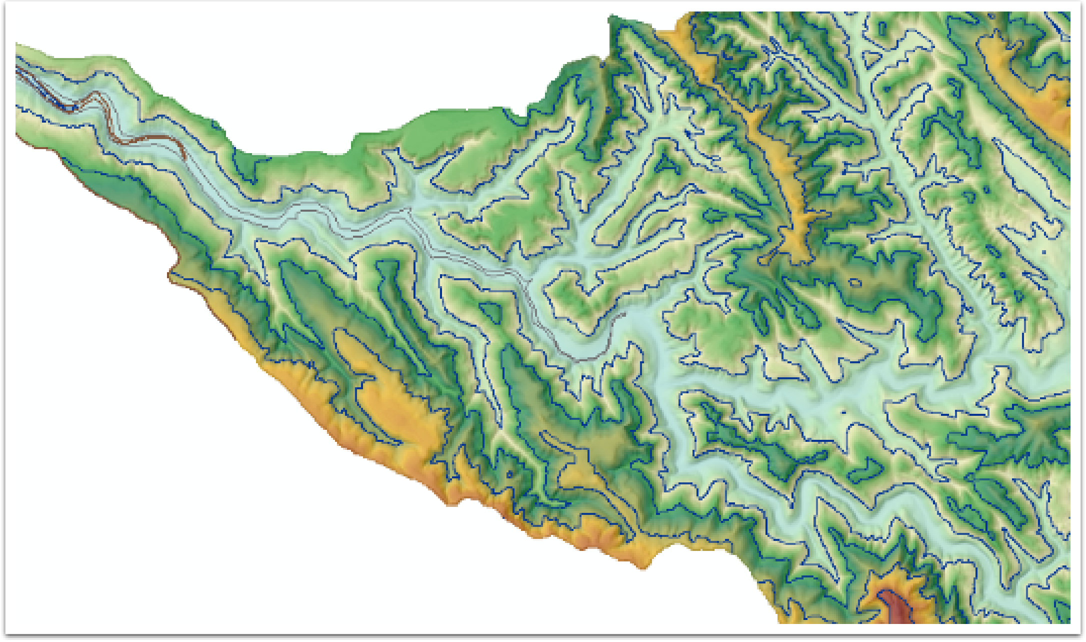
So, let's create contours "the right way" now - in a way that preserves the geography of the data and gives us a true feature class as its outut. Open the *Contour* tool (*Spatial Analyst Tools* > *Surface* > *Contour*). Think for a moment about what your input to this tool will be, just as a matter of practice.

Yup, it's your DEM - Put the output in a sensible location and set the C*ontour interval* to 100m (this parameter is really up to you, but if you want consistent results, set it to 100). Set the *Base contour* to 0 (we are operating at sea level after all).

When it's done, right click on your resulting contours layer in the table of contents and select *Zoom to Layer* to get an overview of the results.



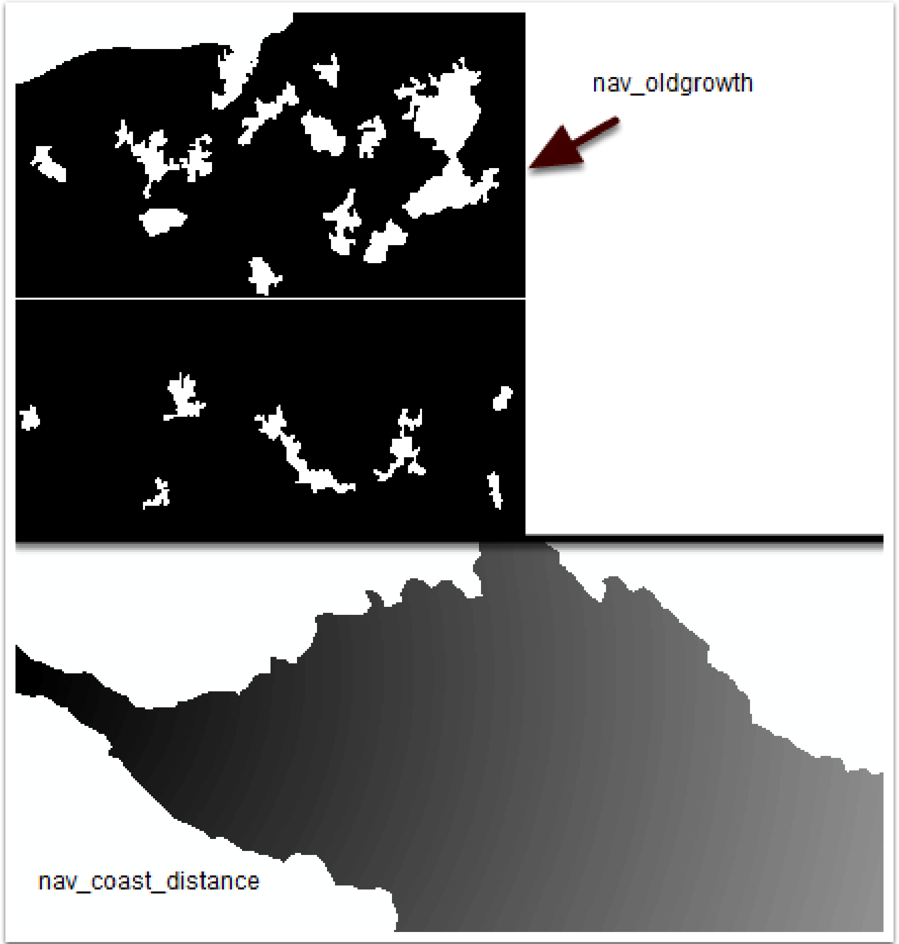
10.2 Contour Results



11. Putting the pieces together

We have most of the information we need at this point - our DEM, slope, and aspect grids - but we still need to know where the old growth forests are, and the distance from the coast. For these two items, we'll load them from our data geodatabase (data/Intermediate.gdb/*nav_oldgrowth* and data/Intermediate.gdb/*nav_coast_distance*).

Once we have loaded that data, we can begin processing our data for suitable habitat.



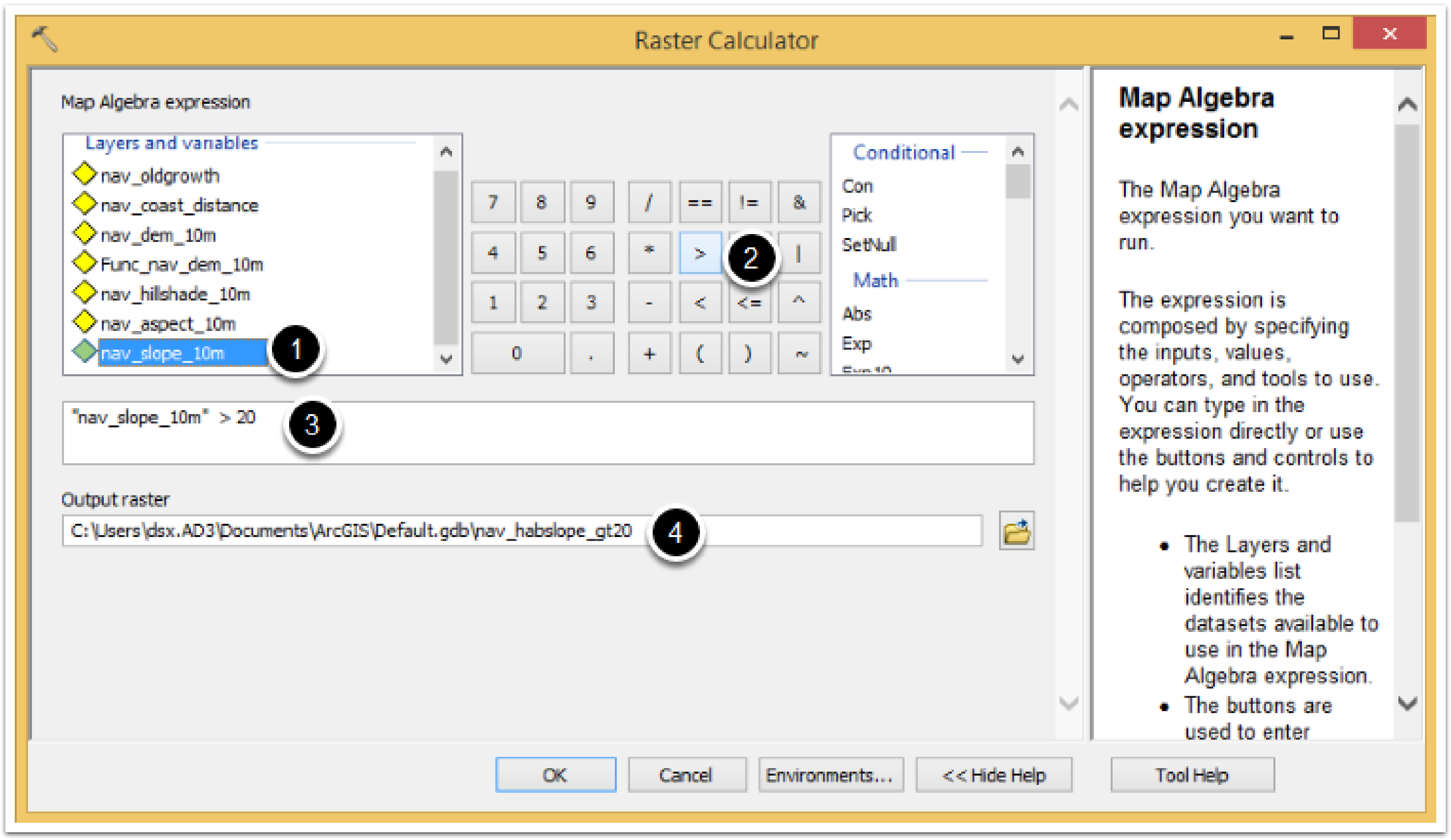
11.1 Finding ideal slope condition

Now, we need a way to pull the locations from our slope raster that meet our slope conditions of being greater than 20 degrees slope. Start by opening the *Raster Calculator* geoprocessing tool (find it via search, or under *Spatial Analyst Tools > Map Algebra > Raster Calculator*).

This tool works a lot like *Select by Attributes* on a vector dataset - we need to construct a query, against the raster's cell values (or multiple rasters' values), that identifies cells that we are interested in. It then creates an output layer with just those cells (and everything else is Null). Think for a moment about what your query might be.

In this case, if you're storing your rasters in a geodatabase, your query should be something like *"nav_slope_10m" > 20* - but let's construct it together.

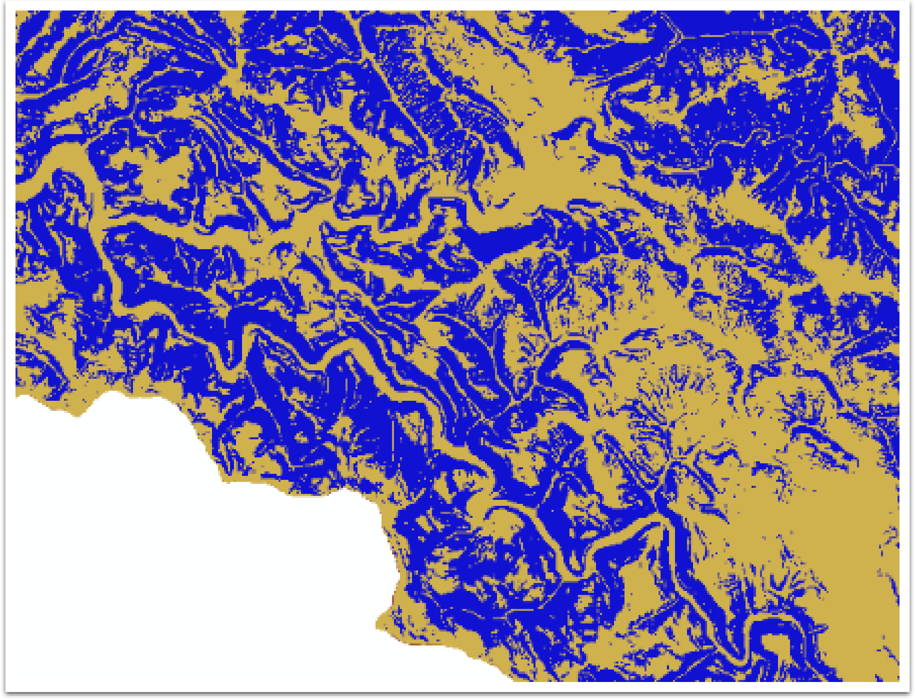
1. Double click on *nav_slope_10m* in the *Layers and variables* box to add it to the query box (directly below it). Double clicking it here takes care of any necessary quoting based upon the workspace the rasters are stored in (geodatabase, folder, etc).
2. Click the *greater than* symbol (>) in the set of buttons to add it to the query experession box.
3. Click into the query expression box and add *20* to the end of the expression so that it matches the image below. What is this expression saying now?
4. Save your output raster somewhere useful. I left mine in my default geodatabase since it's an intermediate product and named it *nav_habslope_gt20*



11.2 Slope selection results

You should see something similar to the below as a result (your colors may be different). Take a look at the legend entries for this raster - what do you think they mean? Why do the numbers come out as 0 and 1?

In computer science in general, 0 and 1 tend to represent "false" and "true" respectively, or "no" and "yes". If we think of the expression we put into raster calculator as a question "Is the slope greater than 20 degrees?" then the values in the raster are answering that question as "yes" (1) and "no" (0) for each location.



11.3 Additional selection of ideal locations

Let's now create the equivalent analysis grids for aspect, elevation, and coast distance. For each of these, we'll run raster calculator again - think about what your expressions will be.

(1) Aspect Expression: (“nav_aspect_10m" > 225) & ("nav_aspect_10m" < 315)

Output raster: nav_habaspect_225_315

Your expression will vary if you didn't store your rasters in a file geodatabase. To get the correct expression, you can double click the layer *nav_aspect_10m* in the layer list instead of typing it in. It will then surround it in the correct *delimiters* (quotes). Make sure to include the parenthesis in this case. What is that expression saying?

(2) Elevation Expression: ("nav_dem_10m" > 50) & ("nav_dem_10m" < 250)

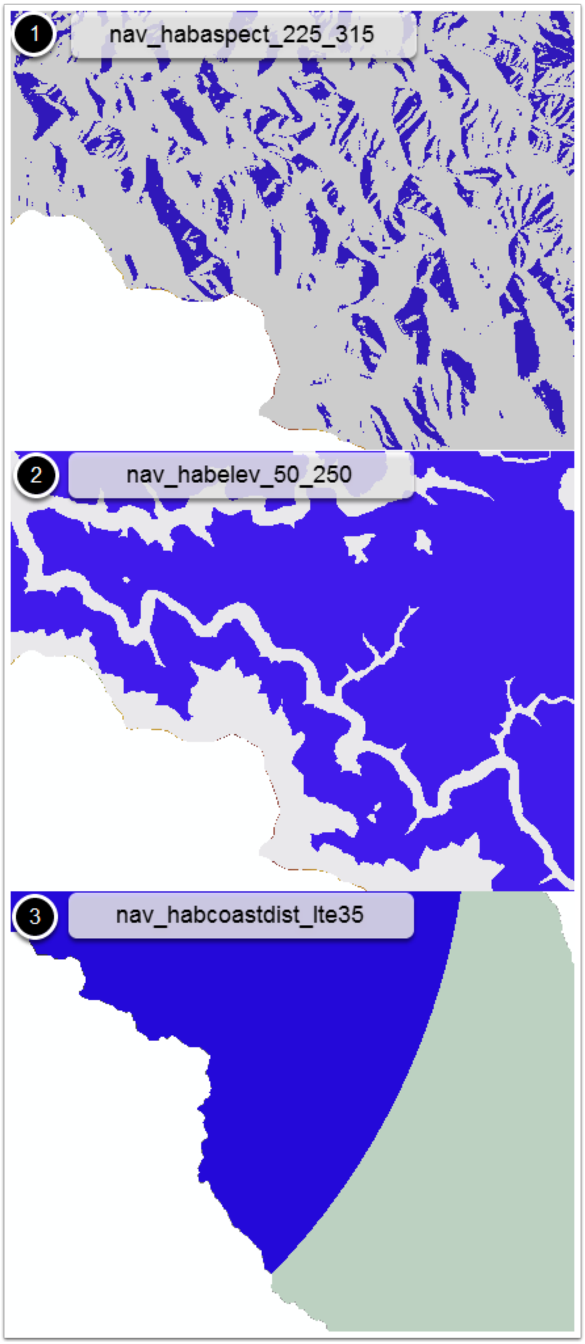
Output raster: nav_habelev_50_250

The same cautions as the aspect raster apply.

(3) Coast Distance Expression: "nav_coast_distance" <= 35

Output raster: nav_habcoastdist_lte35

Why is coastdist <= 35? Should it be <= 35,000 instead? Look at the legend for *nav_coast_distance* to understand what value to use better.Do we need to do anything with the Old Growth Raster?



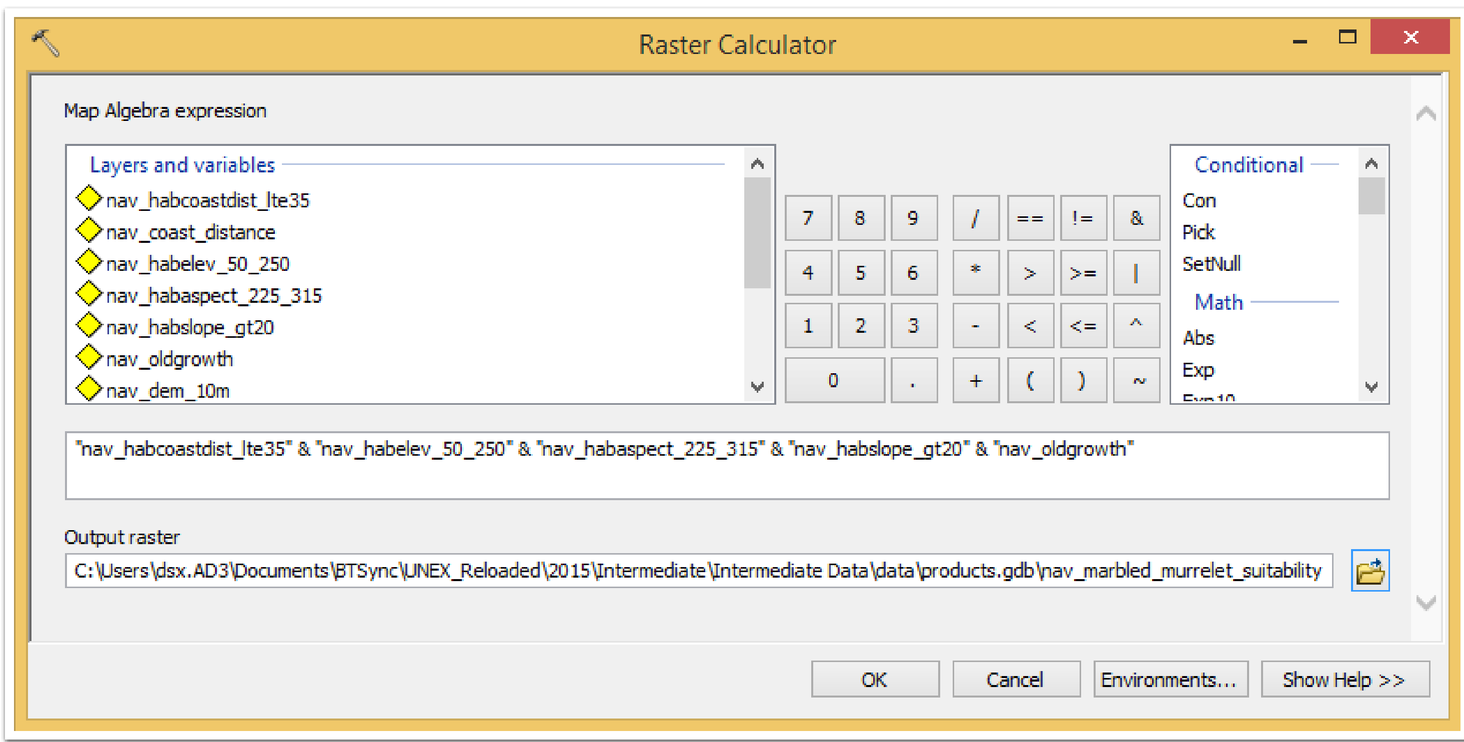
11.4 Combining our suitability rasters

Ok, now we have separate rasters for suitability, based on each parameter. We need to combine them into a single raster indicating overall suitability for the species. If each raster habitat suitability raster uses 0 for unsuitable and 1 for suitable, then what combination of these rasters gives us overall suitability?

We're looking for the locations where all of the rasters have a value of 1, correct? That's where each of suitability requirement is met. To get a resulting raster indicating those locations, we'll again use raster calculator. In previous expressions, we've used the *&* operator to chain requirements - saying multiple criteria must be met. We'll do the same here. Once again, it's a question, but it's written a little differently. Since 0 is always "false" and 1 is always "true" we can jut chain together the layer names. For example, putting *"nav_habcoastdist_lte35"* is equivalent to *"nav_habcoastdist_lte35" == 1* in this instance. Knowing that, what does our full expression look like?

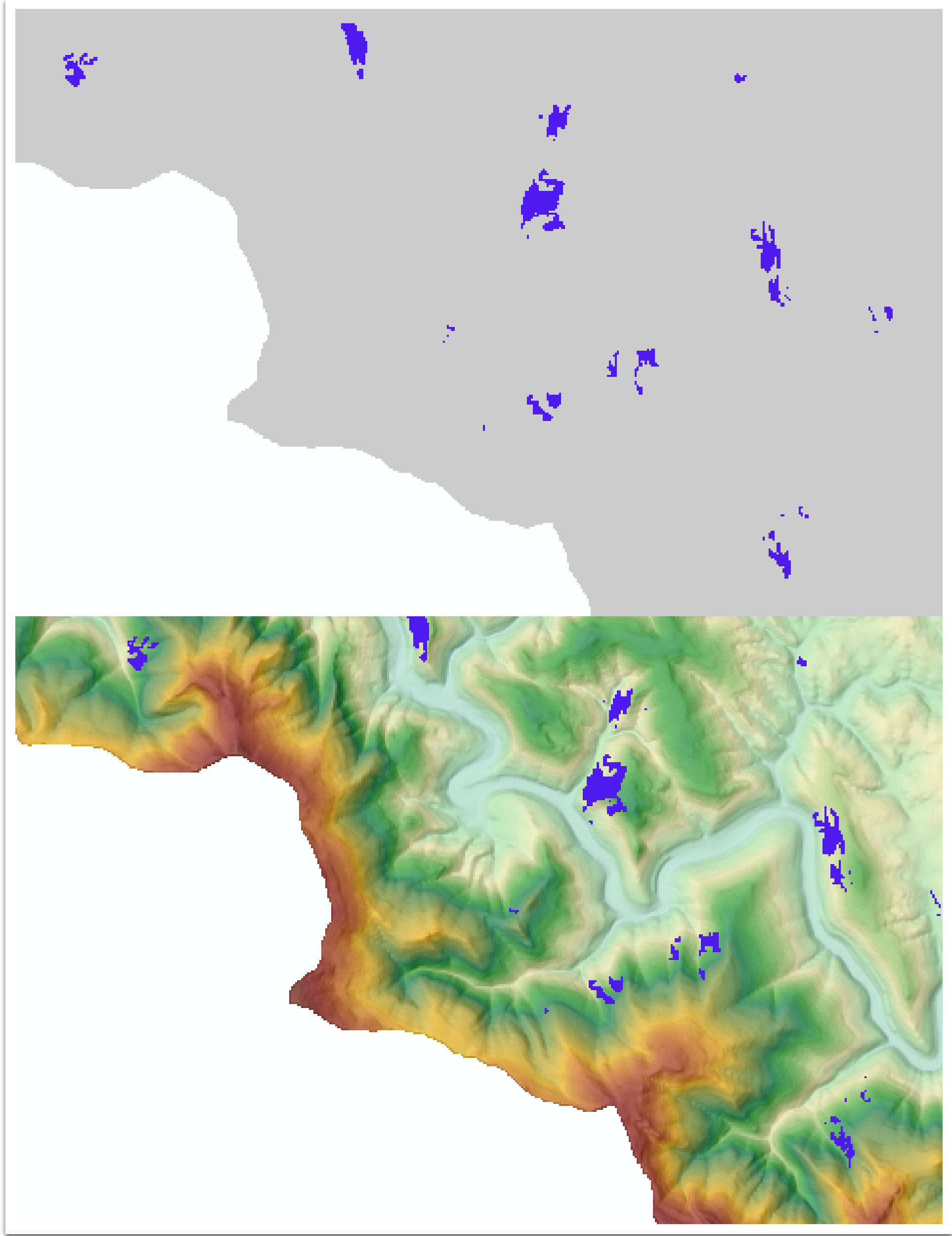
The expression you'll want to put in should be something akin to *"nav_habcoastdist_lte35" & "nav_habelev_50_250" & "nav_habaspect_225_315" & "nav_habslope_gt20" & "nav_oldgrowth"*

Again, double clicking the layer names from the box instead of typing them will get the quoting correct for you, but if you already know that you're using the correct quotes, go ahead and type it in. Read through that expression and make sure it makes sense to you. Save it in your Products geodatabase (*data\products.gdb*) as *nav_marbled_murrelet_suitability*



11.5 Viewing and Interpreting your Results

You'll get another raster as a result, effectively answering the question of "where is suitable habitat for the marbled murrelet" as the 0 and 1 value set we've seen before (top image, below). Set the symbology for the 0 values to transparent, and the 1 values to something like a blue, then show it with just your DEM/Hillshade combination below it (bottom image, below). Examine the locations. Does it seem like there are limitations to the analysis? What are they? Does the habitat show up where you'd expect it to?



12. Some additional thoughts

- Examine your output. How do they differ from the Old Growth patches?

- What about the quality of the patches, are there characteristics that might need further investigation?
- What other data layers would be helpful to address this problem statement?
- Why would one use a PERCENT SLOPE versus a DEGREE SLOPE algorithm on a DEM?
- What other habitat related information could be generated from your identified nesting patches?
- If this were a probability exercise, as opposed to presence/absence, which data might you use as a weighting term?
- Why use fixed vs. temporary file names for raster data?

13. Extra Credit - Patch Area

What is the area of each habitat patch? Hint: you will need to string together a series of commands to isolatte each patch and calculate its area.

Command Sequence (each from raster calculator):

Syntax: SetNull("nav_marbled_murrelet_suitability" ==0,1)

Output Raster: nav_mm_patch

2. Syntax: RegionGroup("nav_mm_patch")

Output Raster: nav_mm_zone

3. Syntax: ZonalGeometry ("nav_mm_zone", "VALUE", "AREA")

Output Raster: nav_mm_area

Does this raster command sequence make sense? What does the data in the final raster even mean? Look up each command in ArcGIS Help.

Can you think of another way to get this information?