Salmon are a highly endangered species in California's rivers and streams. In this analysis, we will explore how activities in the surrounding regions, such as harvesting of trees for wood, may or may not affect the salmon in the streams below by looking at the locations of salmon nests, called *redds,* in relation to where timber (wood) harvesting is occurring.

This exercise builds on the previous exercise, and you'll use the streamlines and rasters you generated in the previous exercise.

Objective: Explore the cumulative effect of timber harvests on alteration of spawning redds using subwatersheds as units of analysis.

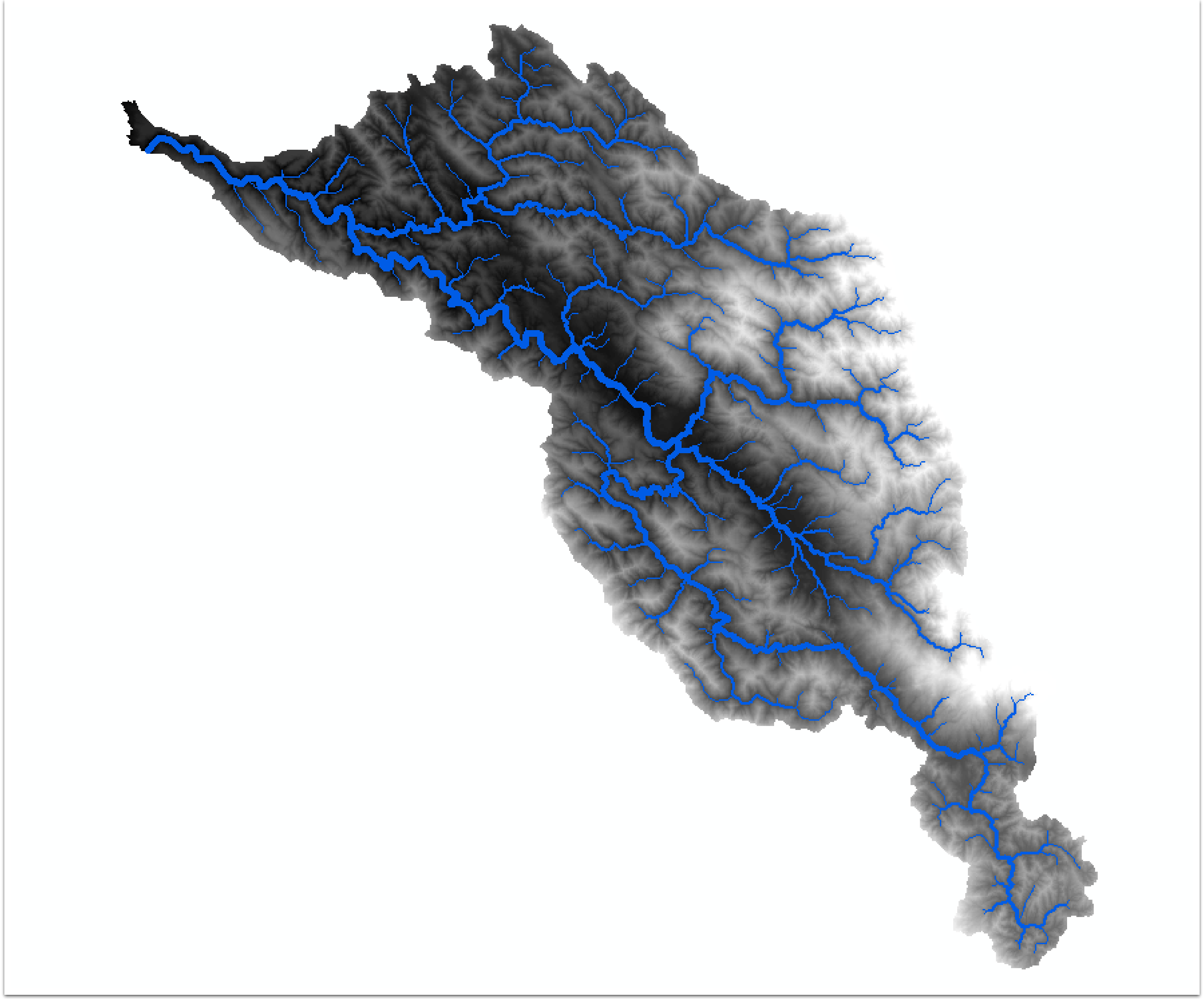
Steps we'll take:

- Evaluate number of spawning redds per subwatershed created for the Navarro Stream Network
- Evaluate the percentage of watershed harvested of the selected subwatersheds
- Incorporate field data from the California Department of Forestry
- Graph the relationship for timber harvsets as it relates to salmon spawning activity (redd locations)

1. Our starting point

Remember from the first week of the course that we generated streamlines based on the DEM. Remember also that the streamlines had intermediate raster products, one of which numbered the stream segments from 1 to 445 based upon where they converged, so each unique stream segment had its own ID. We'll build on those data products here.

If you completed the first exercise and saved your map document, then open that up now and continue on from there. If you didn't, then open the map package that came with this tutorial to access the data. You will need the geodatabase from the first tutorial regardless.

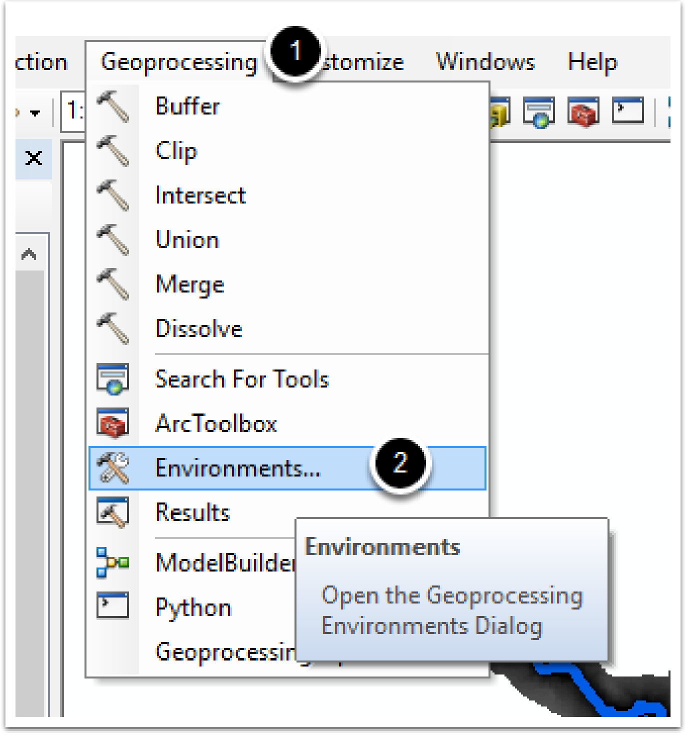


2. Set your environment variables for this analysis

To start out, let's set up our analysis environment. We'll do a number of steps here, so it'll be important get our environment settings right. In this case, we want these environment settings to be consistent across all the tools we run, so we'll set them within the map document rather than on each tool we run.

Recall that environment settings enable us to control or constrain the analysis. They are similar to tool parameters, but since they are commonly defined for many tools, they are set at a different level so that smart defaults can be set for many tools at once.

To set the analysis environment, go to the G*eoprocessing* menu (1) and click *Environments* (2)

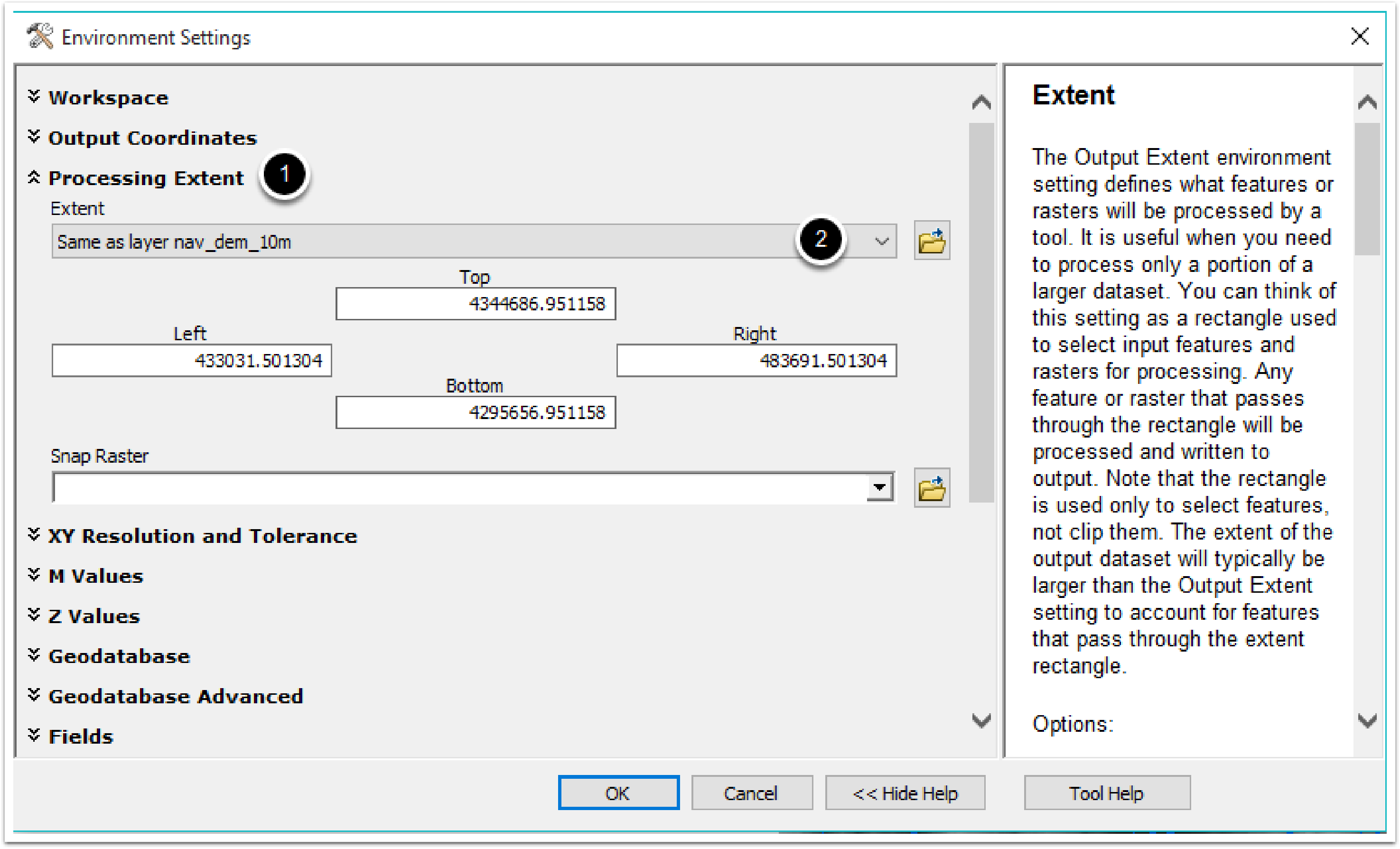


2.1 Processing Extent

First, we'll set the processing extent. By default, ArcGIS sets the processing extent to be the union of the inputs. If we think of the extent as a bounding box (a rectangle) that is the smallest that will fit the data in a raster or feature class while still maintaining north->south alignment, then the processing extent defines the area within which ArcGIS will analyze data. If you define the processing extent to be a smaller area than your inputs, then ArcGIS will only process the data in that area and disregard other data. If it's larger than your inputs, it will add null values around the edges (for rasters).

To use the union of inputs by default means that ArcGIS runs a union operation on the extents (if you don't remember what *union* does, take a look at the Union geoprocessing tool and its help, not the datasets, then fits a bounding box to that unioned extent and uses this as the extent. In this case, we'll set a different extent, which in many cases might be the same as, or larger than the default extent, since most of our data is derived from this layer.

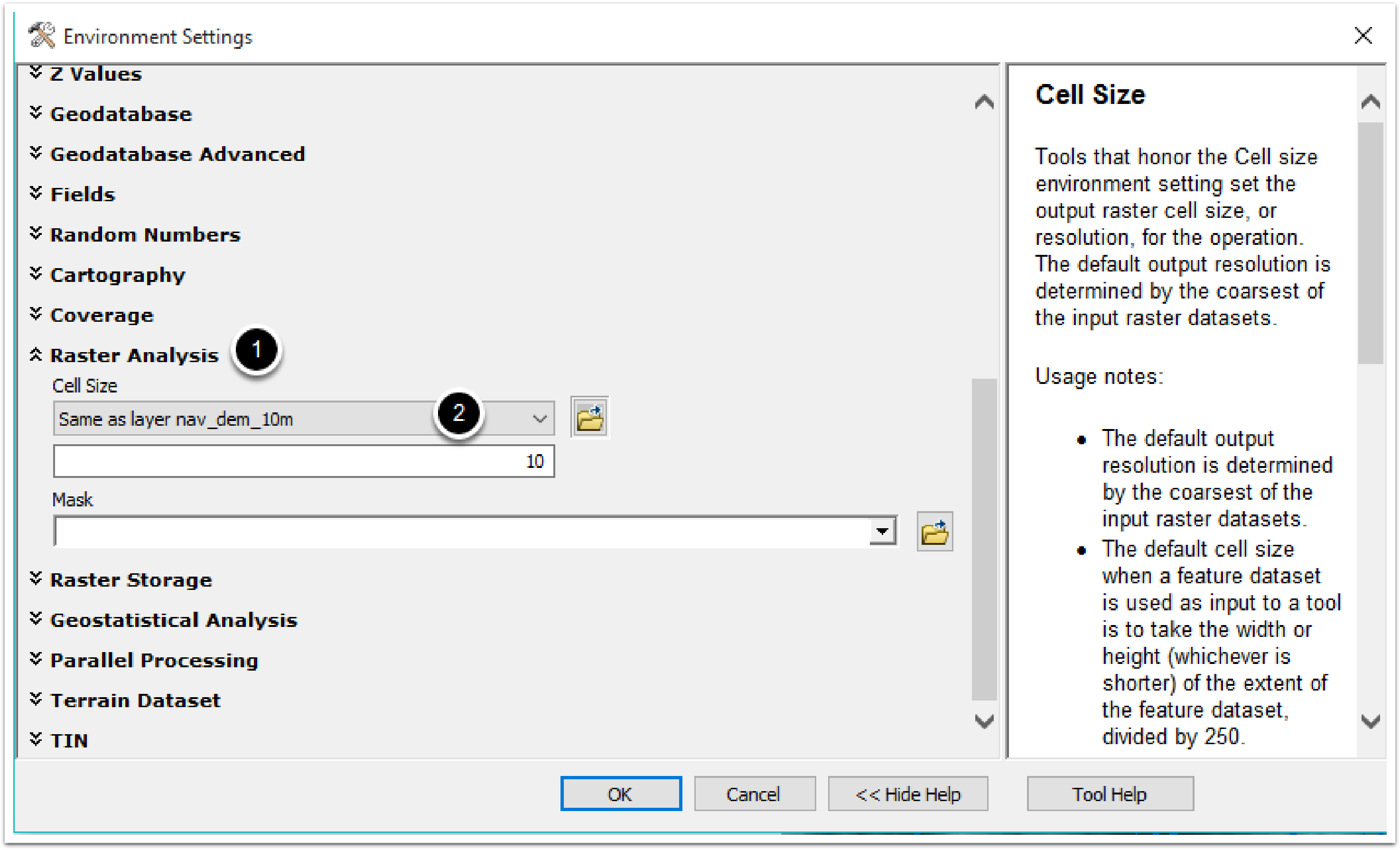
1. Expand the *Processing Extent* section.
2. In the dropdown for *Extent,* select *Same as layer nav_dem_10m* - notice that the coordinates in the boxes below update. This is ArcGIS pulling the bounding coordinates from the layer and storing them as the extent.



2.2 Cell Size

Now, let's set the cell size for the raster analysis. Again, since our current data is derived from nav_dem_10m, this may not be necessary, since it will be 10m by default, but if we add new data later that's not at 10 meter resolution, this will force a resampling of the data to 10 meters, rather than ArcGIS selecting the maximum cell size of all rasters involved and resampling other rasters up to that.

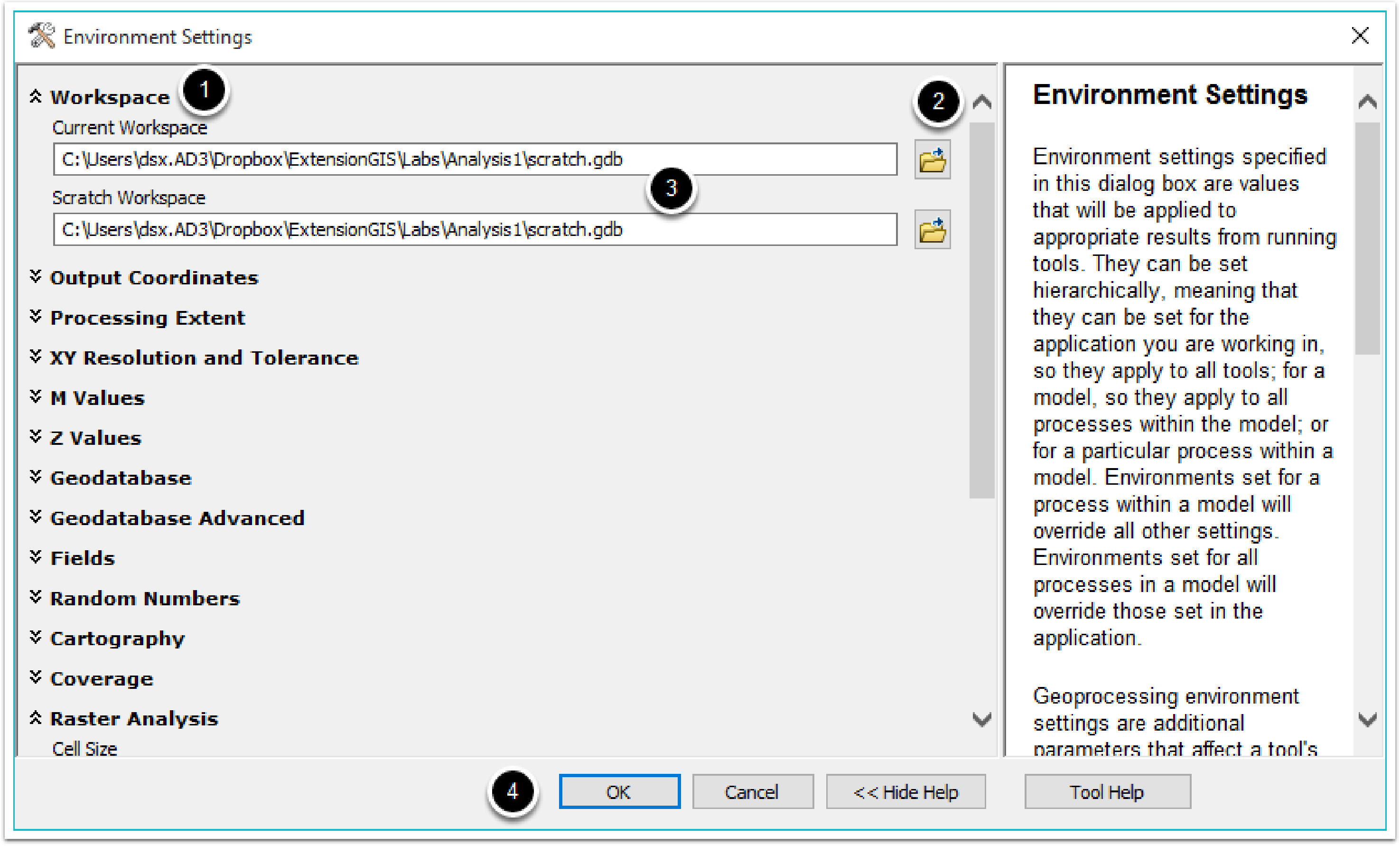
1. Expand the *Raster Analysis* section
2. Choose *Same as layer nav_dem_10m* as the Cell Size. Note that, again, ArcGIS pulls the value from the layer and updates the box below.



2.3 Set your workspace

Finally, we'll set the workspace. This sets the default places that ArcGIS puts calculations and where it offers to save your datasets to when running geoprocessing tools.

1. Expand the *Workspace* section.
2. If you don't already have a scratch geodatabase for this project, click the browse button (the folder with the arrow) and create one to use.
3. Set that geodatabase as the value for both *Current Workspace* and *Scratch Workspace*
4. Click OK to save your environment settings, then make sure to save your map document when you're finished so that if you exit and begin your analysis again, these settings will be picked up.



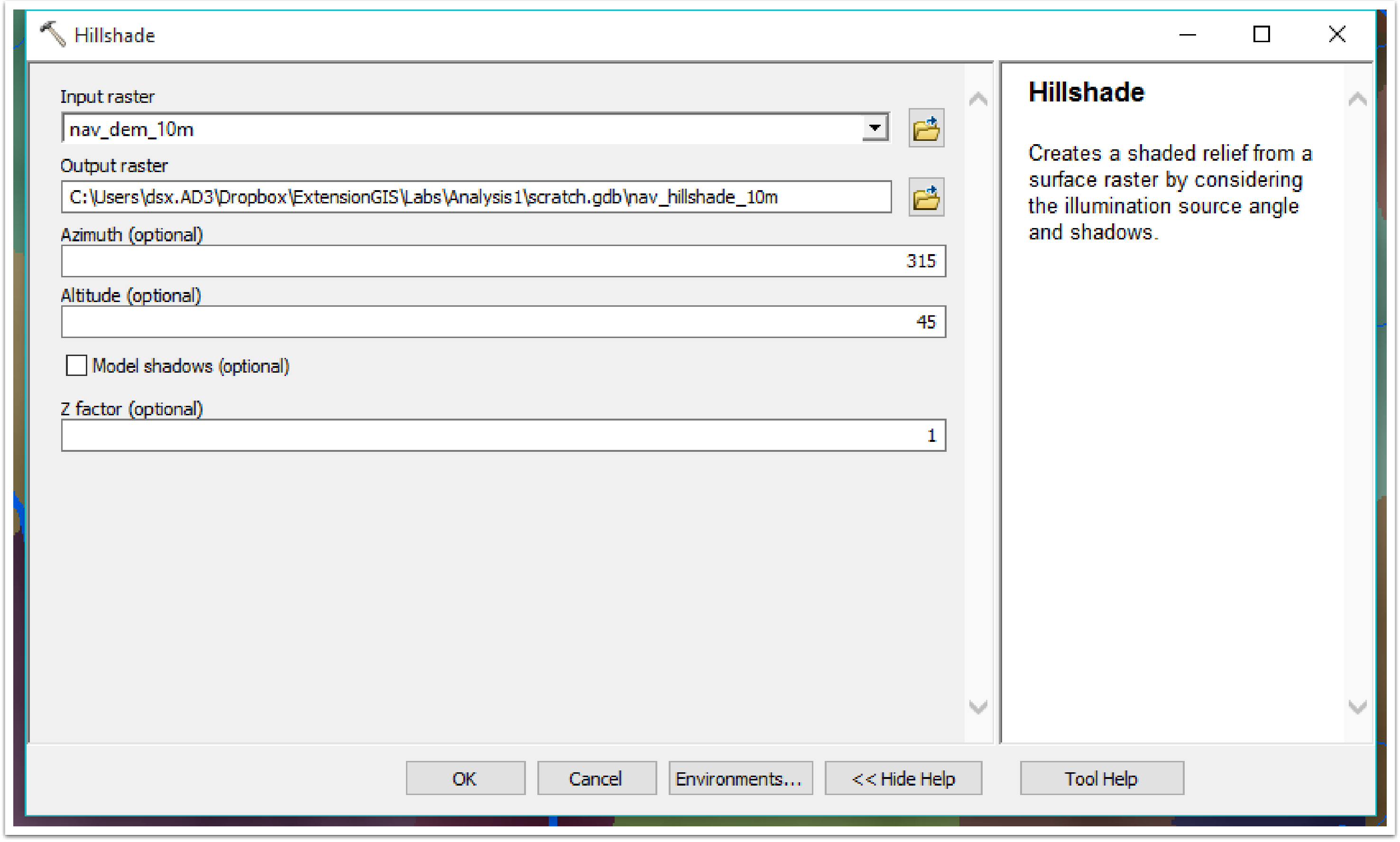
3. Make a hillshade

Now, let's make our data a little nicer to view and understand. We'll do this by creating a hillshade and overlaying our DEM on top of it.

To start, find the hillshade tool (search if you don't know where it is) and open it. Since a hillshade is derived from terrain/elevation data, think about what data should be provided as the input.

1. Select *nav_dem_10m* as your Input raster
2. ArcGIS should put the output in your scratch geodatabase by default since we set the environment variable. Give it the name *nav_hillshade_10m*

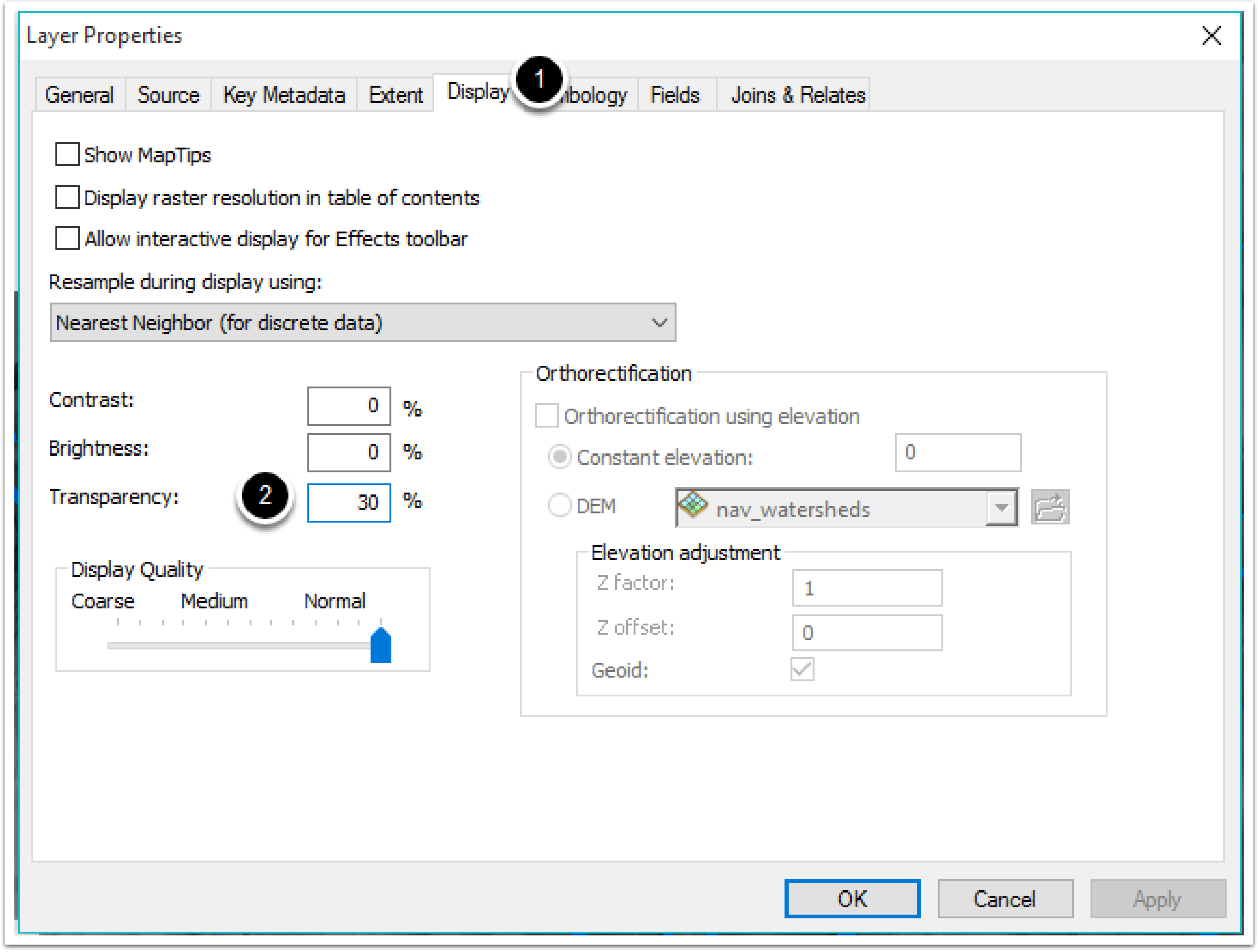
Leave the rest of the variables that control sun angle and shadows as their defaults and run the tool.



3.1 Change DEM to semi-transparent

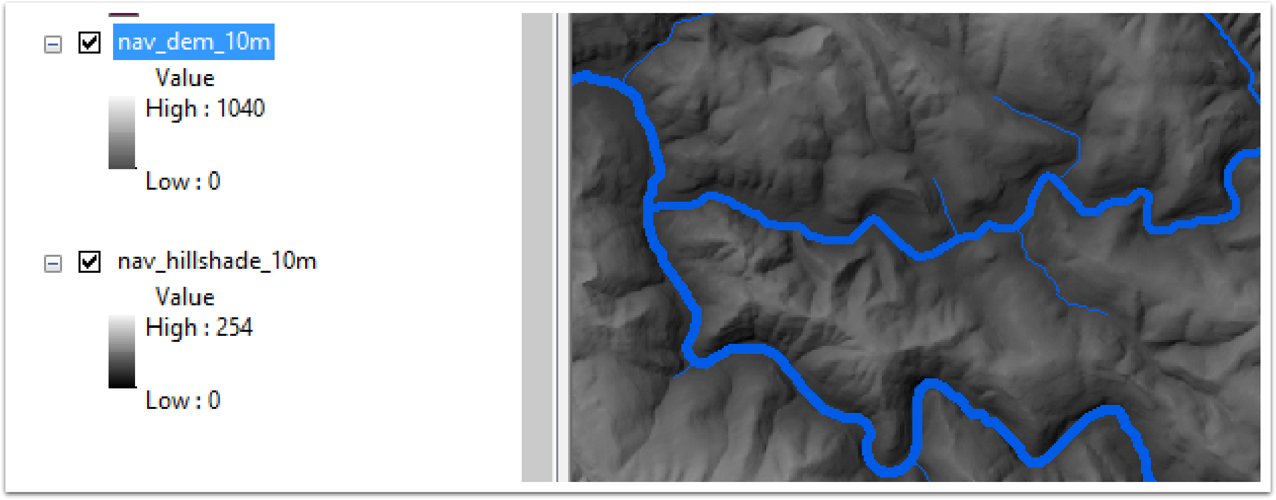
Once you have your hillshade in your map document, let's make it a little easier to see both the hillshade structure and the elvation in a single glance. To do so, we'll overlay the DEM on top of the hillshade with some transparency so we can see both.

Open up the layer properties for the ***DEM***. Go to the *Display* tab (1) and set the layer transparency to 30% (2). Click OK to close out the dialog.



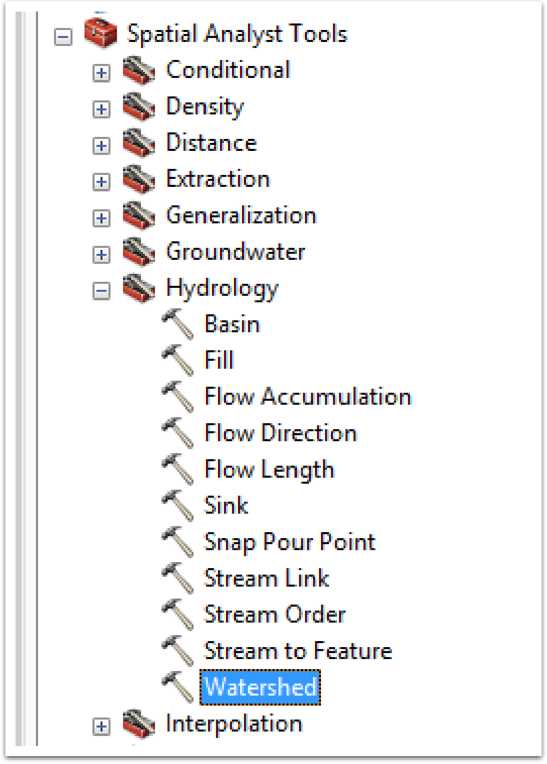
3.2 Viewing the Hillshade

Now, arrange the layers in the map document so that the semi-transparent DEM is layered on top of the hillshade. It should look something like the below picture when it's done.



4. Creating our analysis units

The first thing we want to do is create our unit of analysis for this project. We'll create a set of watershed values and polygons to work with our data, based on the stream network we built in the first lab. To create these, we'll use the *Watershed* tool in the Spatial Analyst toolbox. Open that now.



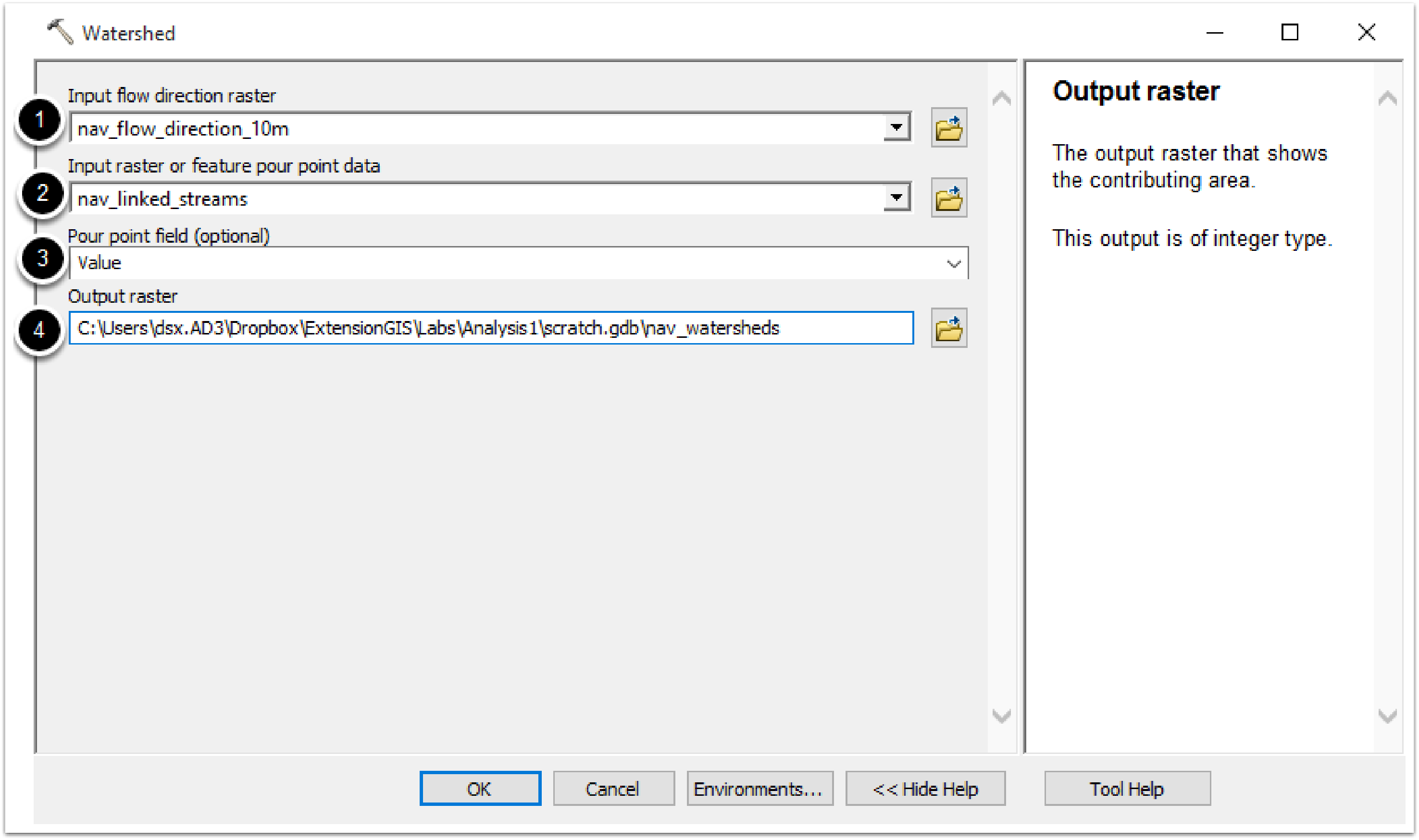
4.1 The Watershed Tool

The watershed tool will take a set of locations or streams and determine the area that flows into it, providing back a raster where cells with the same value are all in the same watershed. We get to decide how large each watershed is by providing the input features or raster. Any locations in the raster that share the same value will be considered the same feature, so the watershed tool will determine which cells flow into there, and give all cells that do the same value in the output. For this analysis, we'll provide the *nav_linked_streams* layer that we made previously where each segment of stream has its own value, which will give us a watershed for each stream segment.

1. For the *Input flow direction raster* choose *nav_flow_direction_10m*
2. For the *Input raster or feature pour point data*, choose *nav_linked_streams*

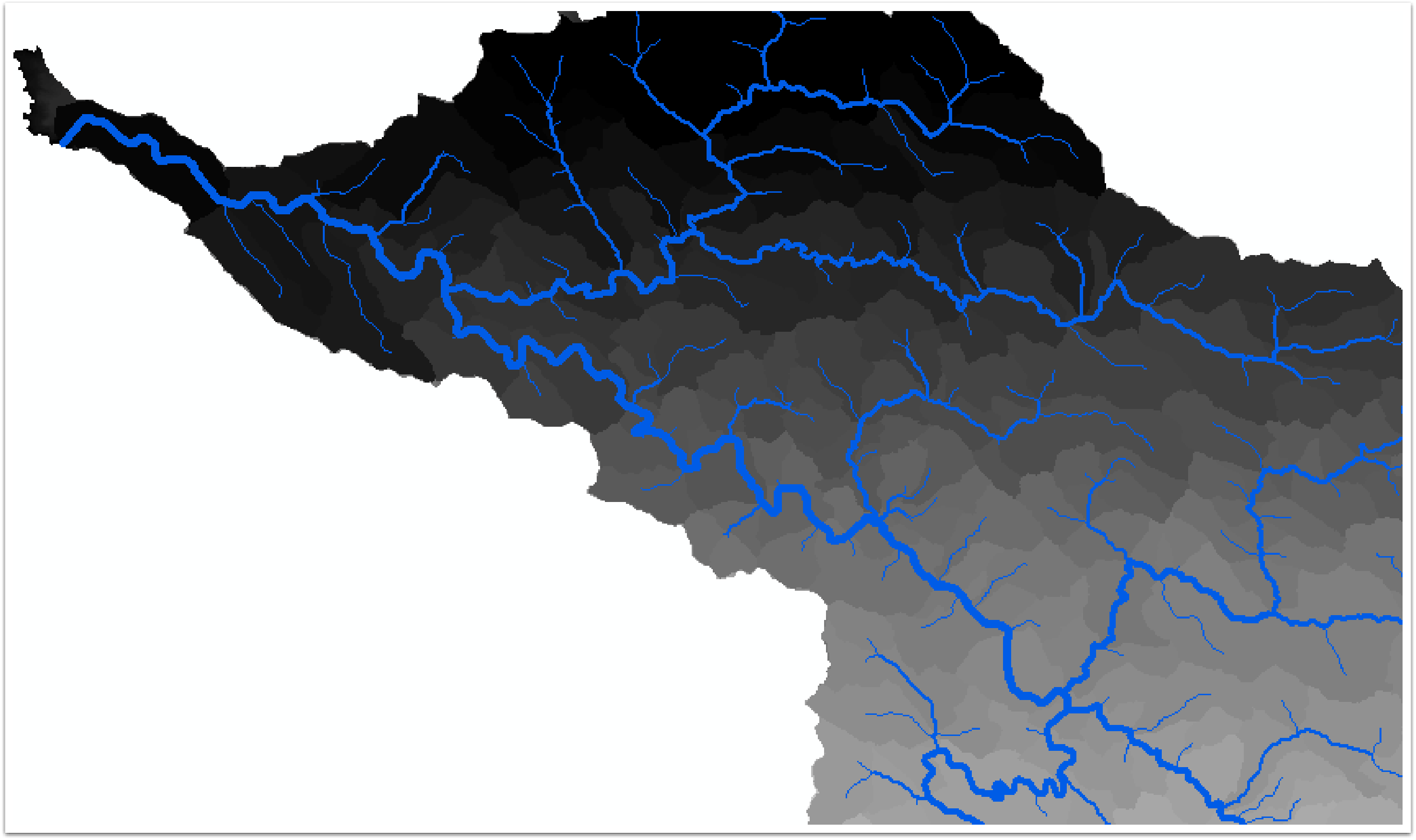
3. Choose *Value* as the *Pour point field,* which tells the tool to use the raster values, rather than an attribute to determine the points to join on.
4. Put the output raster in your scratch geodatabase, and name it *nav_watersheds*

Run the tool.



4.2 Watersheds

You'll see a pattern of what looks like polygons, but which are still raster cells - the coloration indicating that large areas share the same value, as we expected from running the tool.



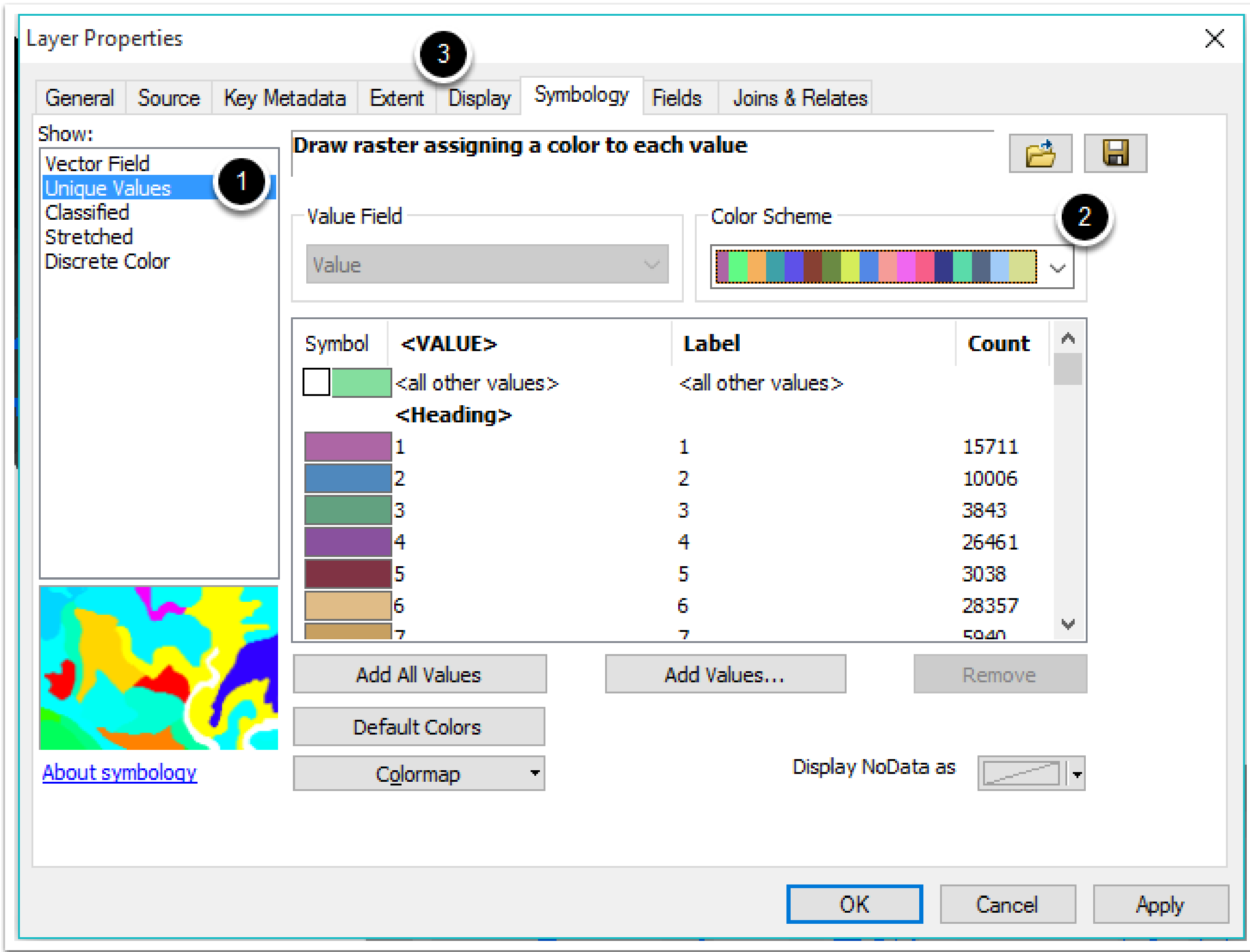
UC DAVIS EXTENSION

4.3 Change the symbology

Now, let's symbolize them so we can see everything better.

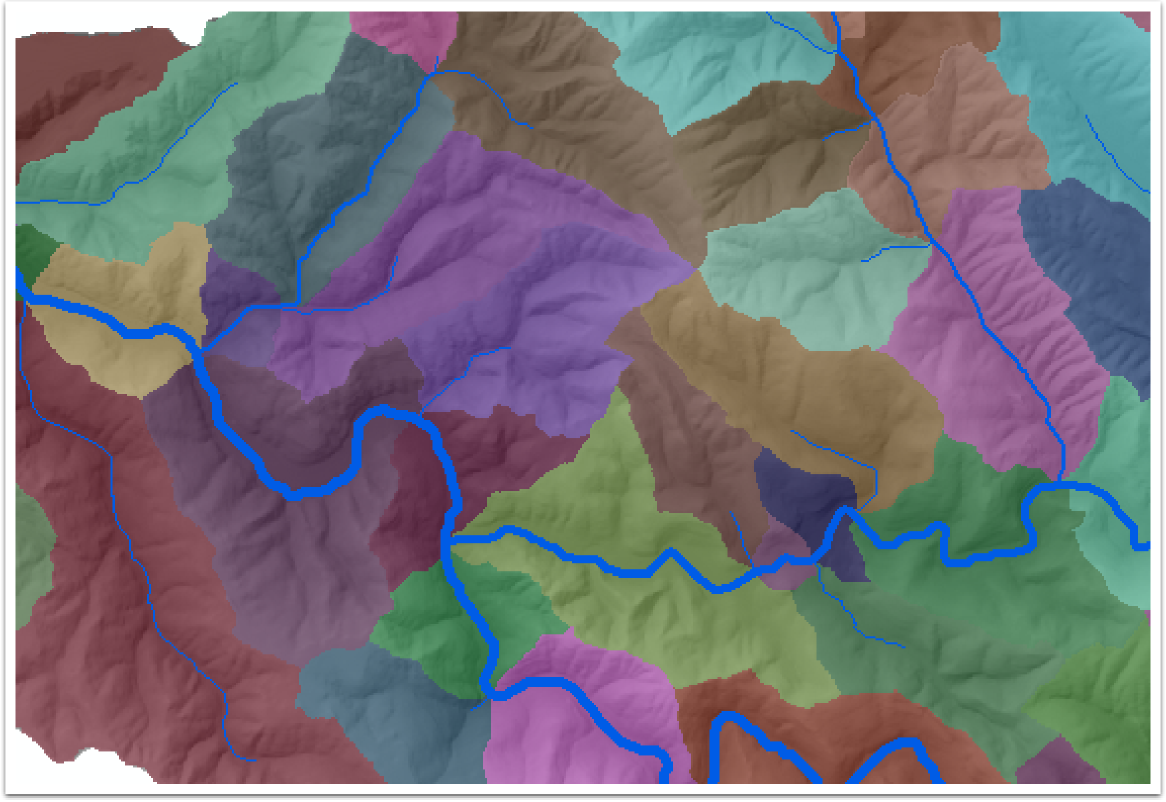
1. Open the symbology dialog and switch to a unique values render so that we can assign a random set of colors that better distinguishes each watershed than a grayscale strech can.
2. Choose a Color Scheme that has unique colors (rather than a ramp), so that the watersheds have different colors assigned to each one.
3. Go to the Display tab and change the layer to be 50% transparent so that it overlays on top of the DEM and hillshade.

Click OK to close out of the dialog.



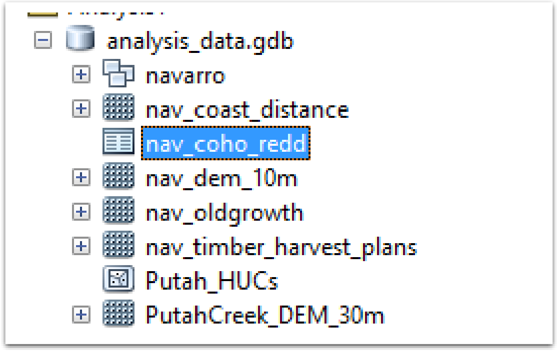
4.4 The Watersheds Layer

Now we can see each individual generated watershed on top of our DEM with the stream layer. Do the watersheds look sensible? Where does each one start and end on the stream network?



5. Adding the salmon nest data

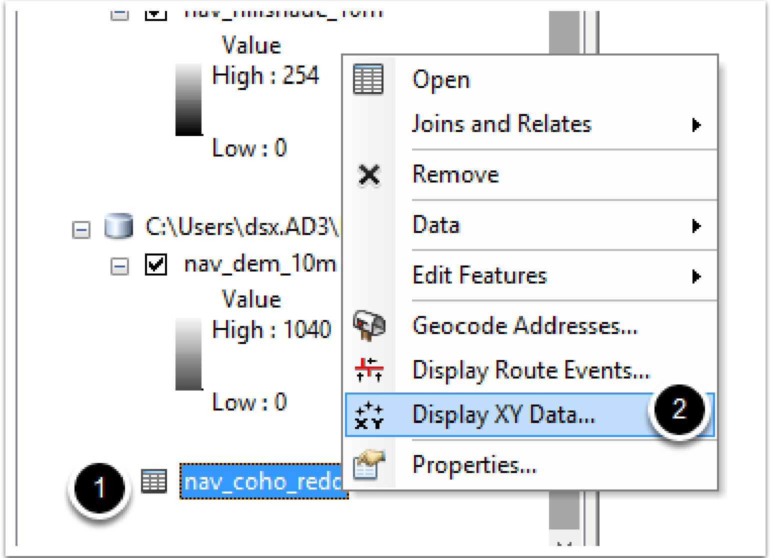
Now that we ahve watershed data, we'll start working with the salmon redds (nests). Add the table *nav_coho_redd* to your map document. This table contains the GPS-derived locations of the redds, as well as some other information. We'll use this data to create a spatial layer of the redds to compare with the watersheds.



5.1 Create the spatial layer

Remember how to turn a table with coordinates into a point feature class? Look at the attribute table for a moment and determine what field or fields we'd use to create a feature class from. If you can remember, try turning it into a point layer yourself! Otherwise, keep following along:

1. Right click on *nav_coho_redd*
2. Choose *Display XY Data* to bring up a dialog



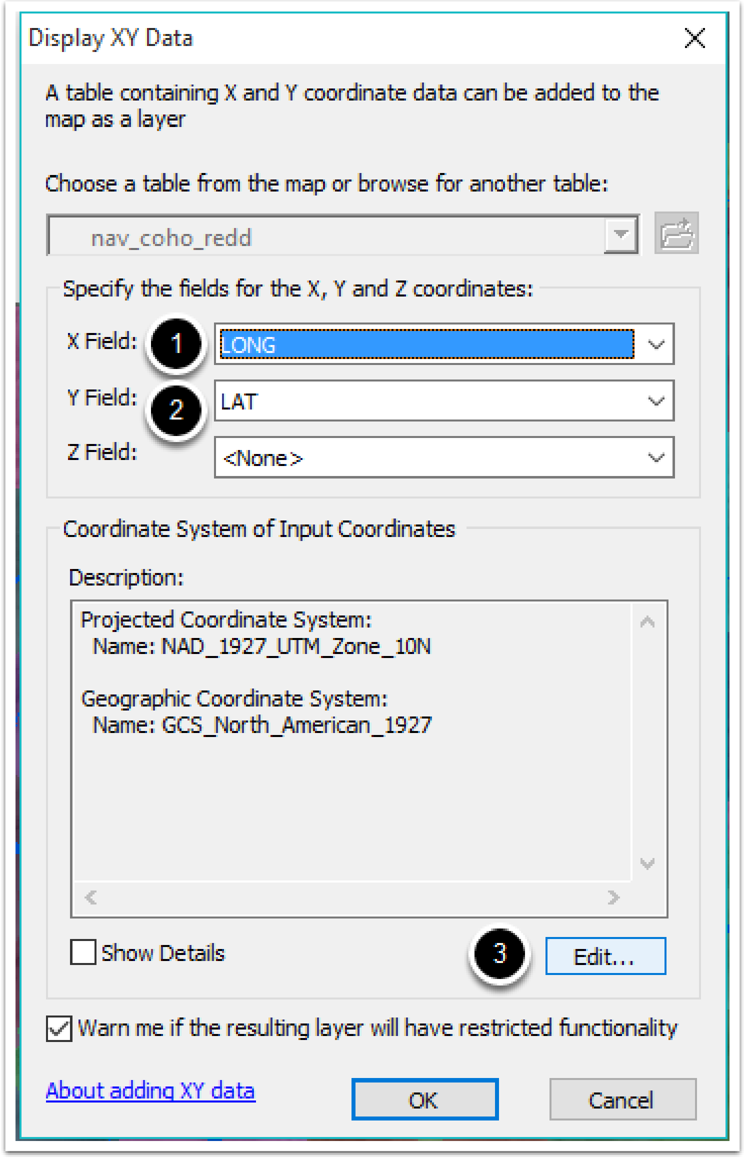
5.2 Display XY Data

This dialog may be familiar for many of you, but let's go through it again. Using this dialog, we define the spatial parameters necessary to turn table records into a feature class. As we've discussed spatial data, we need 1) a coordinate system (spatial reference) and 2) coordinates for our records. And, in fact, that's what we define in this dialog! We tell it which field defines the X value for each record, which field defines the Y value, and the spatial reference for those coordinate values!

So, to start, let's set up the coordinates:

1. For the X field, choose *LONG* (why not *LAT?)*
2. For the Y field, choose *LAT* (why not *LONG?)*
3. In the *Coordinate System of Input Coordinates* section, click the *Edit* box to define the coordinate system used by the LAT and LONG fields.

Sidenote: While it works, LONG is a poor choice for a field name. Think about why, and ask a question of your peers in the discussion if you can't figure out the answer.

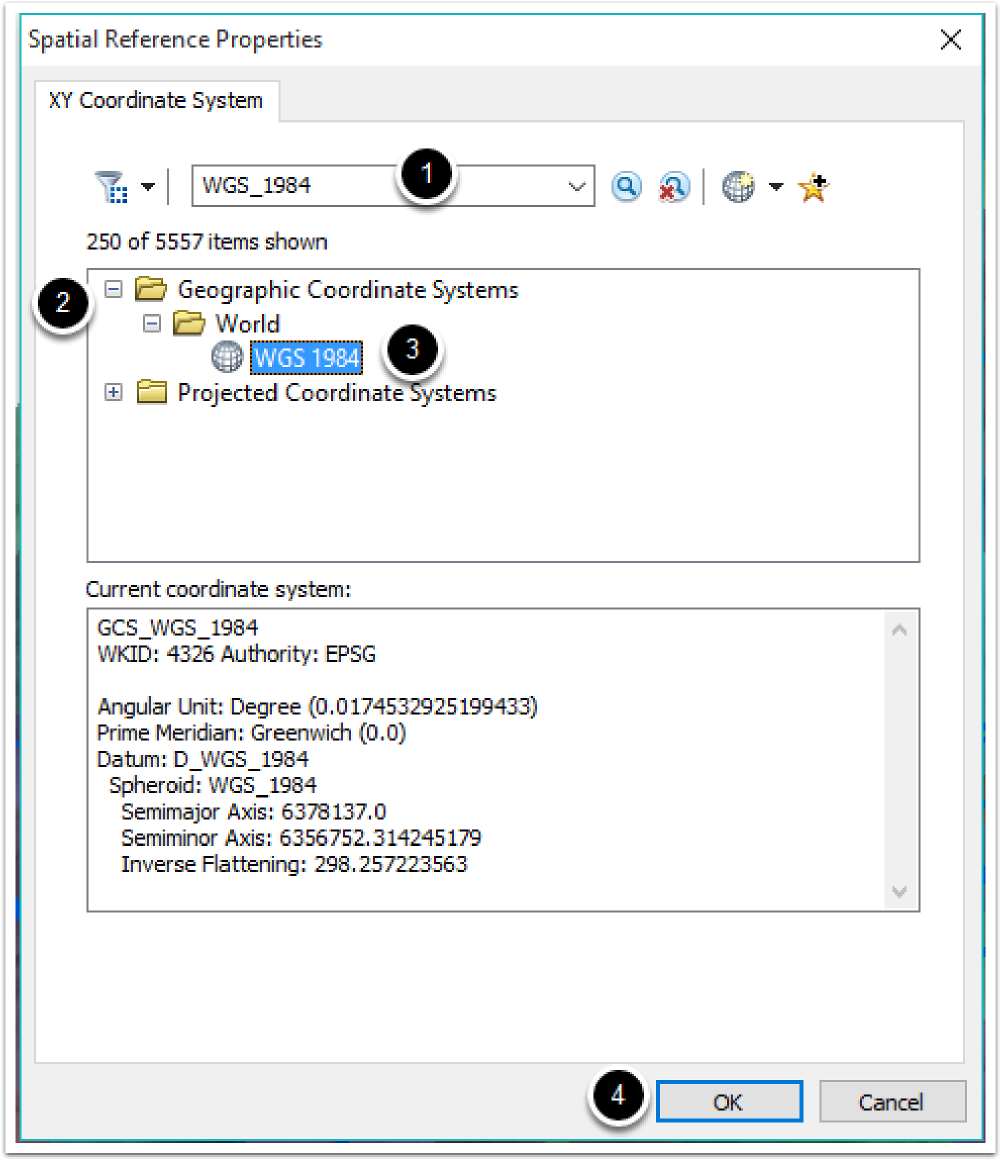


5.3 Find the coordinate system

Now, let's find the correct coordinate sytem. If you didn't know what to put here, you'd need to ask whoever provided you the data. In practice, data derived from a GPS is **almost always** in the WGS 1984 spatial reference. That's what we'll be using today.

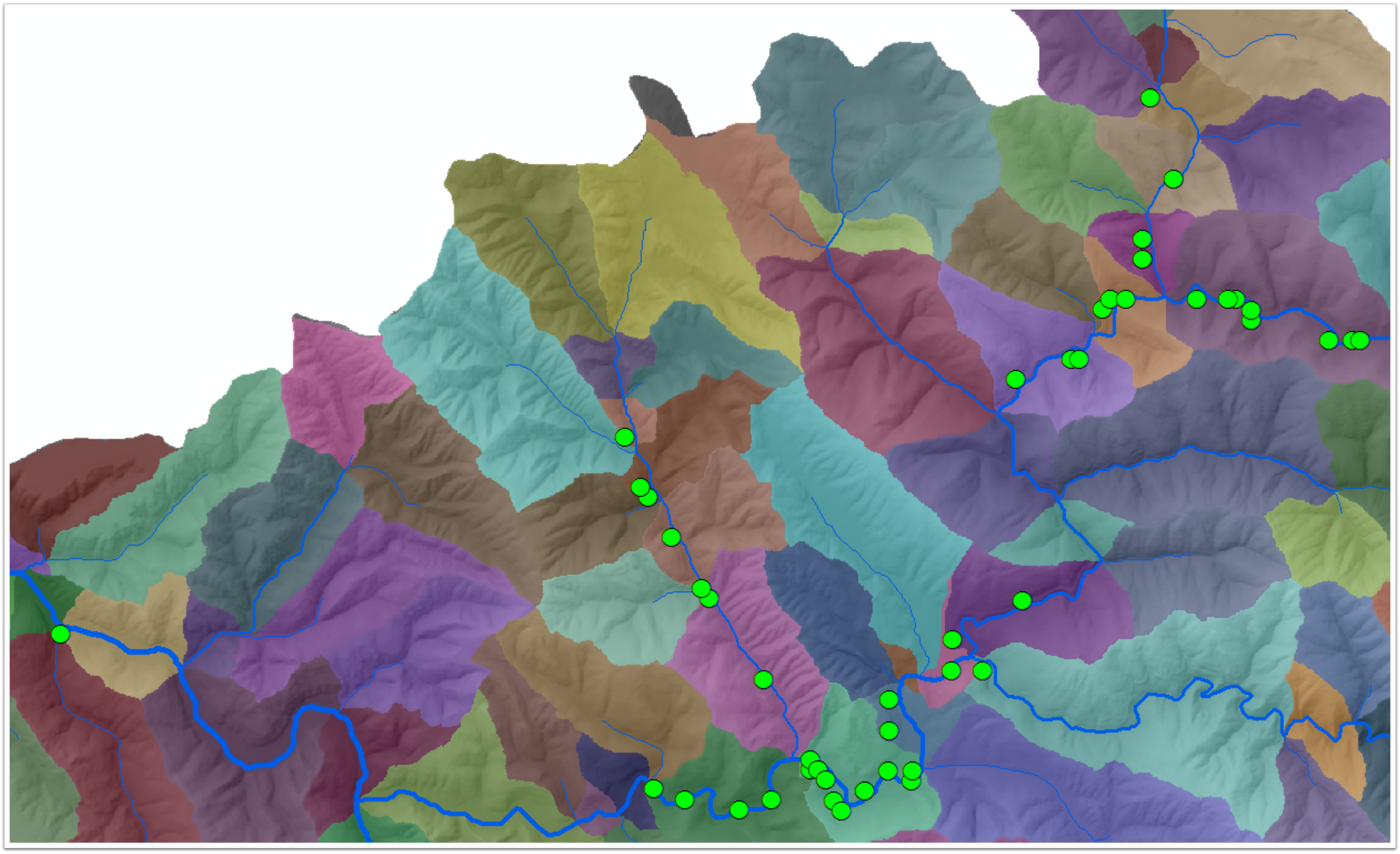
1. Type *WGS_1984* in the search box (note the underscore)
2. There will be 250 coordinate systems found, but one **one** will be in the *Geographic Coordinate Systems* section. Since our data is based on the raw geographic coordinate system WGS 1984 and not on a projected coordinate system built on top of WGS 1984, this is the one we want. Expand the *Geographic Coordinate Systems* section, then the *World* section

3. Choose *WGS 1984*
4. Click *OK* to save your choice, then *OK* on the *Display XY Data* dialog to run the process.



5.4 Viewing the Redds

Points will show up on the map - symbolize them in a way that makes them bright and easy to see. Look around and take note - are the points on the streamlines? Should they be?

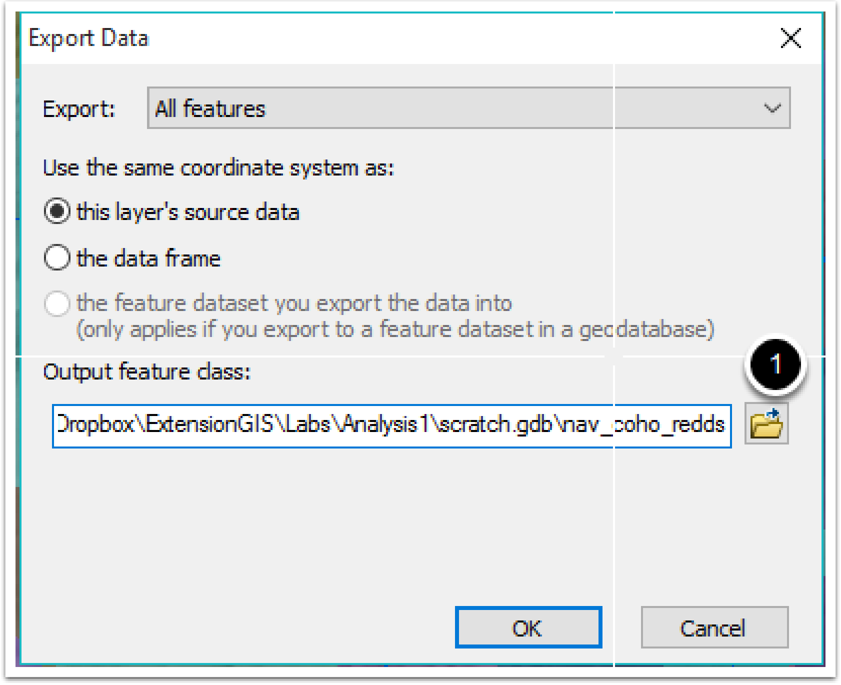


5.5 Saving your layer

Now we need to make this new layer permanent. It is currently an *event* layer that exists in this map document, but not a permanent dataset on disk. Export the data to your scratch geodatabase as *nav_coho_redds* (1)

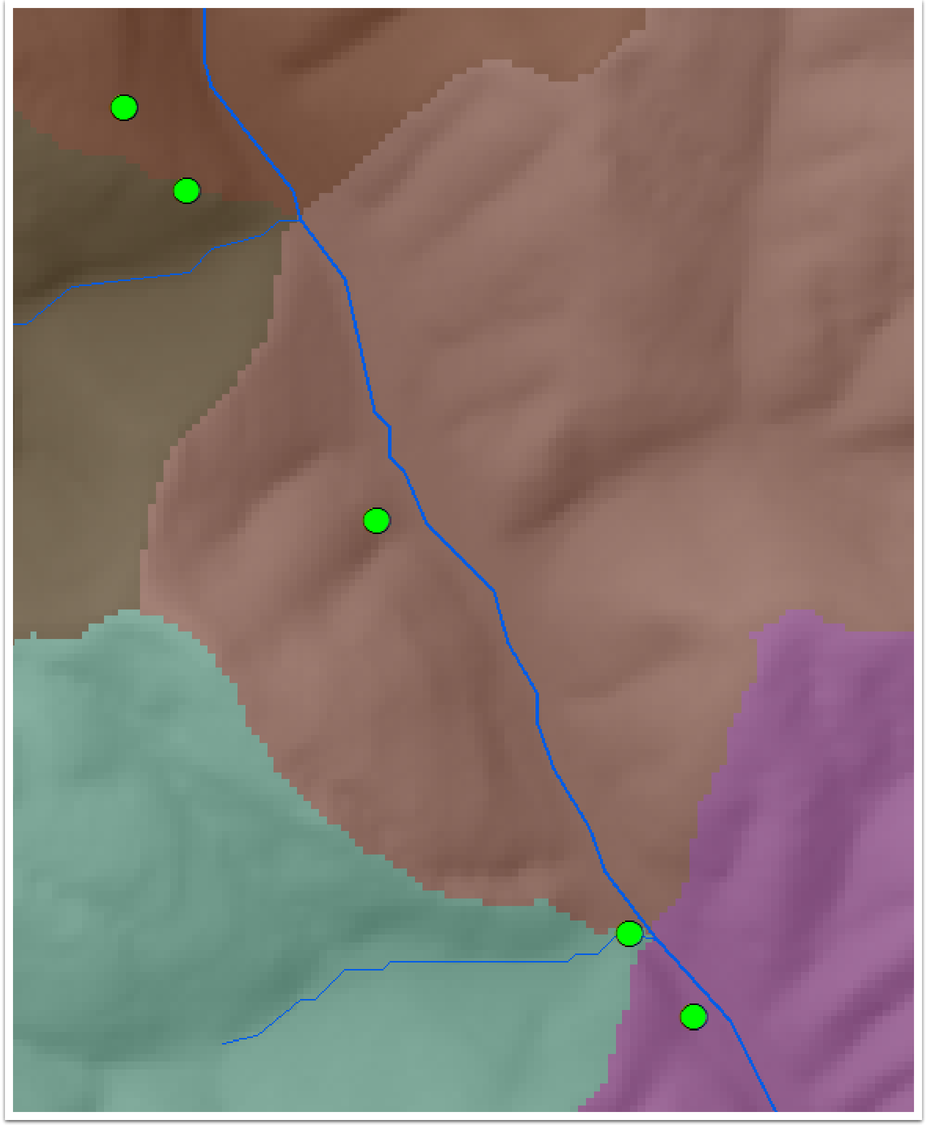
When prompted, add the new layer to your document, and change symbology to something bright and visible as well - feel free to copy the symbology over from the previous temporary layer.

When done, you can remove the temporary layer from map document.



6. Snapping Points

If you zoom in on some of the redds, you'll notice that the data don't often align perfectly to a stream even though they should have been captured at the streams. Some minor changes could be explained by rivers not being as thin as the features we have, but these points are too far from the centerline to be explained by that. This is a common problem with GPS-derived data, where the data may not align with other data you have. To correct the issue, we'll need to *snap* (move) the points to the streamlines.

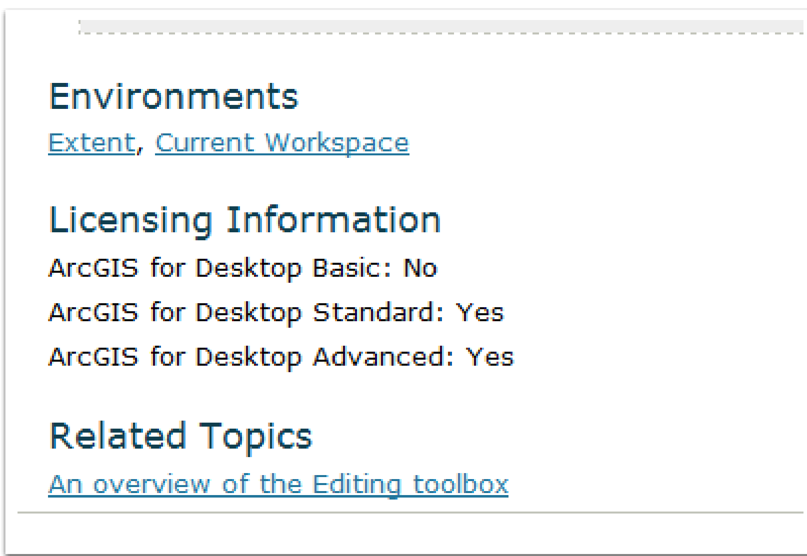


6.1 A note about license levels in ArcGIS

In this step, we're going to use a tool that isn't available in all license levels of ArcGIS - ArcGIS has three levels of licensing, each with different costs and features. We're going to use the *Snap* tool which isn't available in the ArcGIS for Desktop Basic license level. Other tools may only be available in the Advanced license level. If you are using the license from the course, you have an Advanced license, but if you didn't obtain that license or are using an employer's license, you may not be able to use the tool.

This exercise splits a bit here - Step 7 is for those of you with Standard or Advanced licenses, and step 6 is for those without.

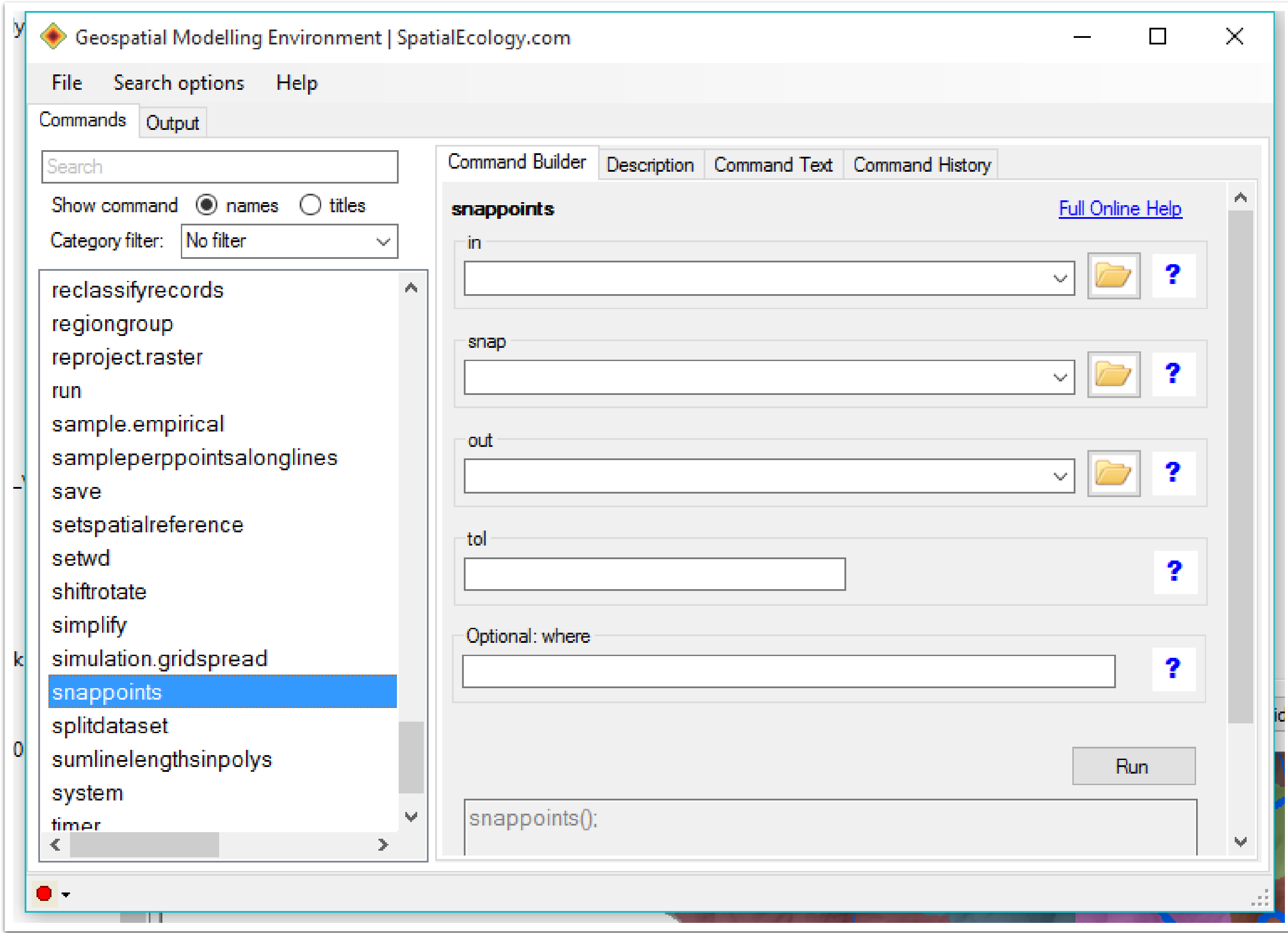
- If your license came from these courses, or if you know you have a Standard or Advanced license, skip to step 7.
- If you don't know what license level you have, try skipping to step 7, and if you get a licensing error, come back to this step and continue on.
- If you get a licensing error, or you know you have a Basic license, continue through step 6, and when you get to step 7, skip it and continue at step 8.



6.2 Geospatial Modeling Environment

Regardless of license level, Geospatial Modeling Environment (GME) is a useful supplemental tool for ArcGIS, but it's especially useful for those without the higher level ArcGIS licenses as it replicates and improves on some of the tools in ArcGIS that aren't available in the Basic license.

Instead of using the *Snap* tool in ArcGIS, we'll use the *snappoints* tool in GME. You'll need to download GME from http://www.spatialecology.com/gme/ first. Pay attention to the installation requirements, as you'll need to make sure to get the right version for your ArcGIS installation, and you'll need to install a supported version of the R programming language for these tools to work. Note that GME is not yet (as of this writing) available for ArcGIS 10.4 - it usually lags ArcGIS by approximately 1 version, so don't stay completely up to date on ArcGIS if you start to rely on GME.

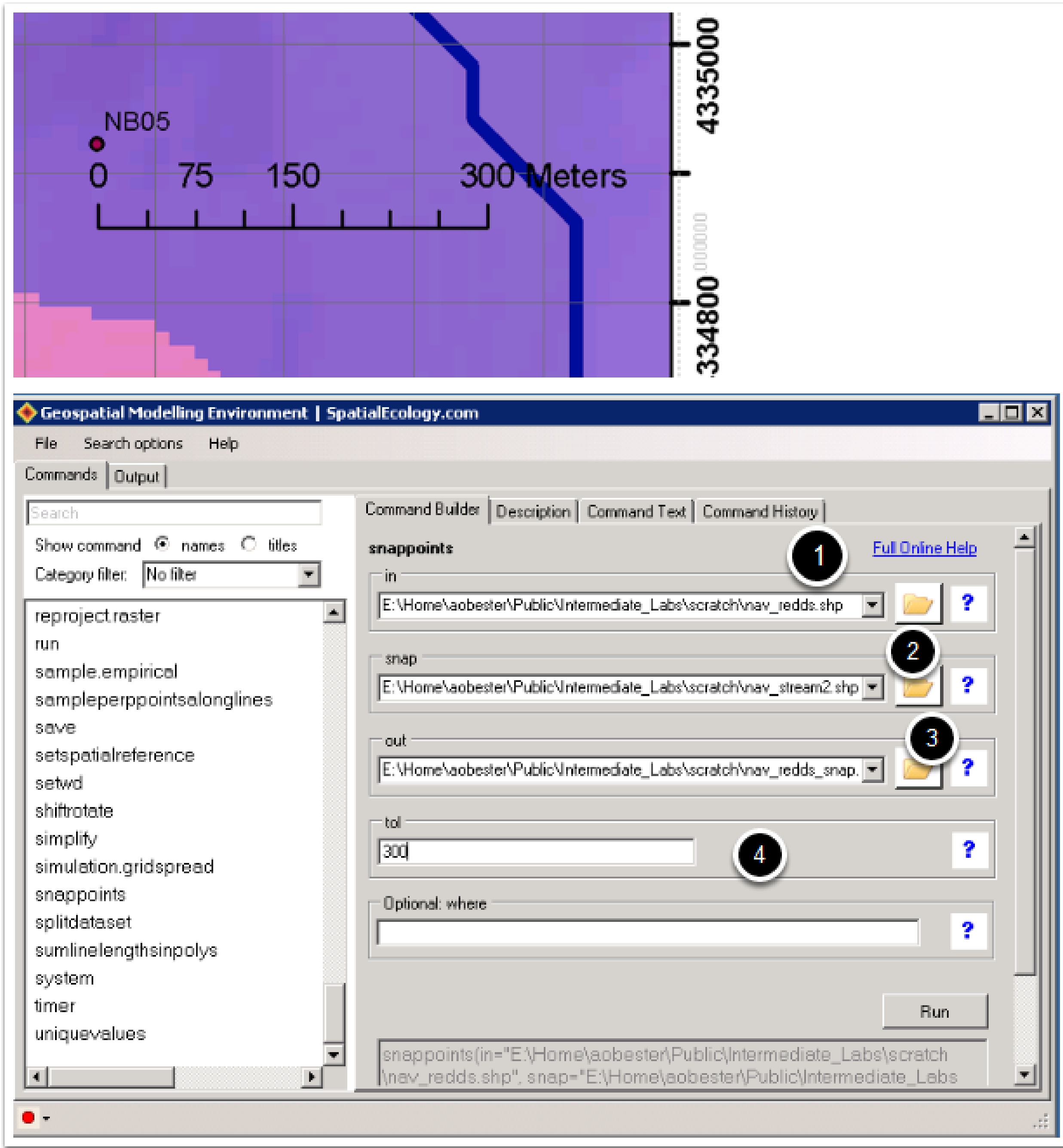


6.3 Snap Redds to Hydro Network

Use Geospatial Modeling Environment command builder for the command snappoints. See screenshot below. Before using GME, export your redds shapefile as *nav_redds.shp* and your streams as *nav_streams.shp* in a folder you can easily find. GME can technically work with file geodatabases, but in my experience it does so with more trouble - shapefiles come out cleaner.

1. **in:** nav_redds.shp (find it using the browse button)

2. **snap:** nav_streams2.shp (find it using the browse button)
3. **out:** nav_redds_snap.shp (find the output folder using the browse button, or copy and paste it from the box above, then add your filename to the end of the path)
4. Use 300m as the search tolerance value (if you want to know why, examine the data in ArcGIS to see how far the data rare from the streams), but this means that redds can move up to 300m. Click Run to run the tool and see the output results of the command.



6.4 Snap Results

Back in ArcMap, add your *nav_redds_snap.shp* to your map document to compare to your *nav_redds.shp.* Symbolize it so you can easily see the differences between the two layers. Convert nav_redds_snap.shp back into your scratch geodatabase as a feature class, and use it in place of nav_coho_redds in future steps.

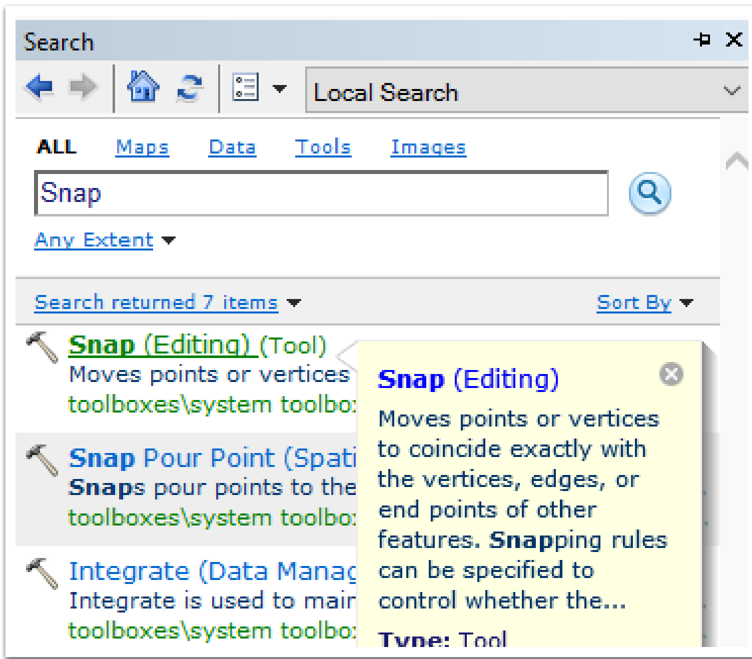
- Was a 300m snap search distance enough to capture all of the redds and snap them to streamlines?
- What is the count of records between the two data sets (check the attribute table)? Are they the same? What might this indicate?
- What about the new field in *nav_redds_snap* called SnapDst? What was the maximum distance snapped from redd points to the hydrographic network?

When done, skip to step 8!

DESC_	POSITION	LAT	LONG	WSHED	NUM	GPSID	SNAPDST
BARTON GULCH--RAY GULCH	N 39.173 W 123.676	39.173	-123.676	1	1	NR01	28.290129
N. FORK CONF.--.75 mi. UPSTREAM	N 39.170 W 123.558	39.17	-123.558	2	1	SB01	90.283041
HGWY 128--DUTCH HENRY CREEK	N 39.167 W123.570	39.167	-123.57	3	1	NB01	112.166298
HGWY 128--DUTCH HENRY CREEK	N 39.170 W 123.562	39.17	-123.562	4	1	NB02	24.486699
HGWY 128--DUTCH HENRY CREEK	N 39.173 W 123.562	39.173	-123.562	5	1	NB03	146.750967
HGWY 128--DUTCH HENRY CREEK	N 39.177 W 123.553	39.177	-123.553	6	1	NB04	70.686139
DUTCH HENRY--REDWOOD CREEK	N 39.199 W 123.554	39.199	-123.554	7	1	LNF01	89.807066
DUTCH HENRY--REDWOOD CREEK	N 39.201 W 123.547	39.201	-123.547	8	1	LNF02	91.001681
DUTCH HENRY--REDWOOD CREEK	N 39.201 W 123.546	39.201	-123.546	9	1	LNF03	97.020416
DUTCH HENRY--REDWOOD CREEK	N 39.206 W 123.543	39.206	-123.543	10	1	LNF04	129.397784
DUTCH HENRY--REDWOOD CREEK	N 39.207 W 123.542	39.207	-123.542	11	1	LNF05	74.511627
DUTCH HENRY--REDWOOD CREEK	N 39.207 W 123.540	39.207	-123.54	12	1	LNF06	53.387566
DUTCH HENRY--REDWOOD CREEK	N 39.207 W 123.531	39.207	-123.531	13	1	LNF07	101.67571
DUTCH HENRY--REDWOOD CREEK	N 39.207 W 123.526	39.207	-123.526	14	1	LNF08	28.76481
DUTCH HENRY--REDWOOD CREEK	N 39.205 W 123.524	39.205	-123.524	15	1	LNF09	89.207749
DUTCH HENRY--REDWOOD CREEK	N 39.206 W 123.524	39.206	-123.524	16	1	LNF10	40.187801
DUTCH HENRY--REDWOOD CREEK	N 39.203 W 123.514	39.203	-123.514	17	1	LNF11	58.464392
DUTCH HENRY--REDWOOD CREEK	N 39.207 W 123.527	39.207	-123.527	18	1	LNF12	11.8643
DUTCH HENRY--REDWOOD CREEK	N 39.203 W 123.511	39.203	-123.511	19	1	LNF13	3.350091
DUTCH HENRY--REDWOOD CREEK	N 39.203 W 123.510	39.203	-123.51	20	1	LNF14	12.46501
CONF. W/ NORTH BRANCH--UNK. TRIB.	N39.211 W123.538	39.211	-123.538	21	1	JS01	125.693788
CONF. W/ NORTH BRANCH--UNK. TRIB.	N39.211 W123.538	39.211	-123.538	22	1	JS02	125.693788
CONF. W/ NORTH BRANCH--UNK. TRIB.	N39.213 W123.538	39.213	-123.538	23	1	JS03	94.374428
CONF. W/ NORTH BRANCH--UNK. TRIB.	N39.219 W123.534	39.219	-123.534	24	1	JS04	7.062065
CONF. W/ NORTH BRANCH--UNK. TRIB.	N39.219 W123.534	39.219	-123.534	25	1	JS05	7.062065
CONF. W/ NORTH BRANCH--UNK. TRIB.	N39.227 W123.537	39.227	-123.537	26	1	JS06	130.339995
HGWY 128--FLYNN CREEK RD X-ING	N39.169 W123.586	39.169	-123.586	27	1	FC01	25.199581

7. Use the Snap tool to move the points

For those of you who have the license from this specialization, or who otherwise have an ArcGIS Standard or Advanced license, find and open the *Snap* tool.



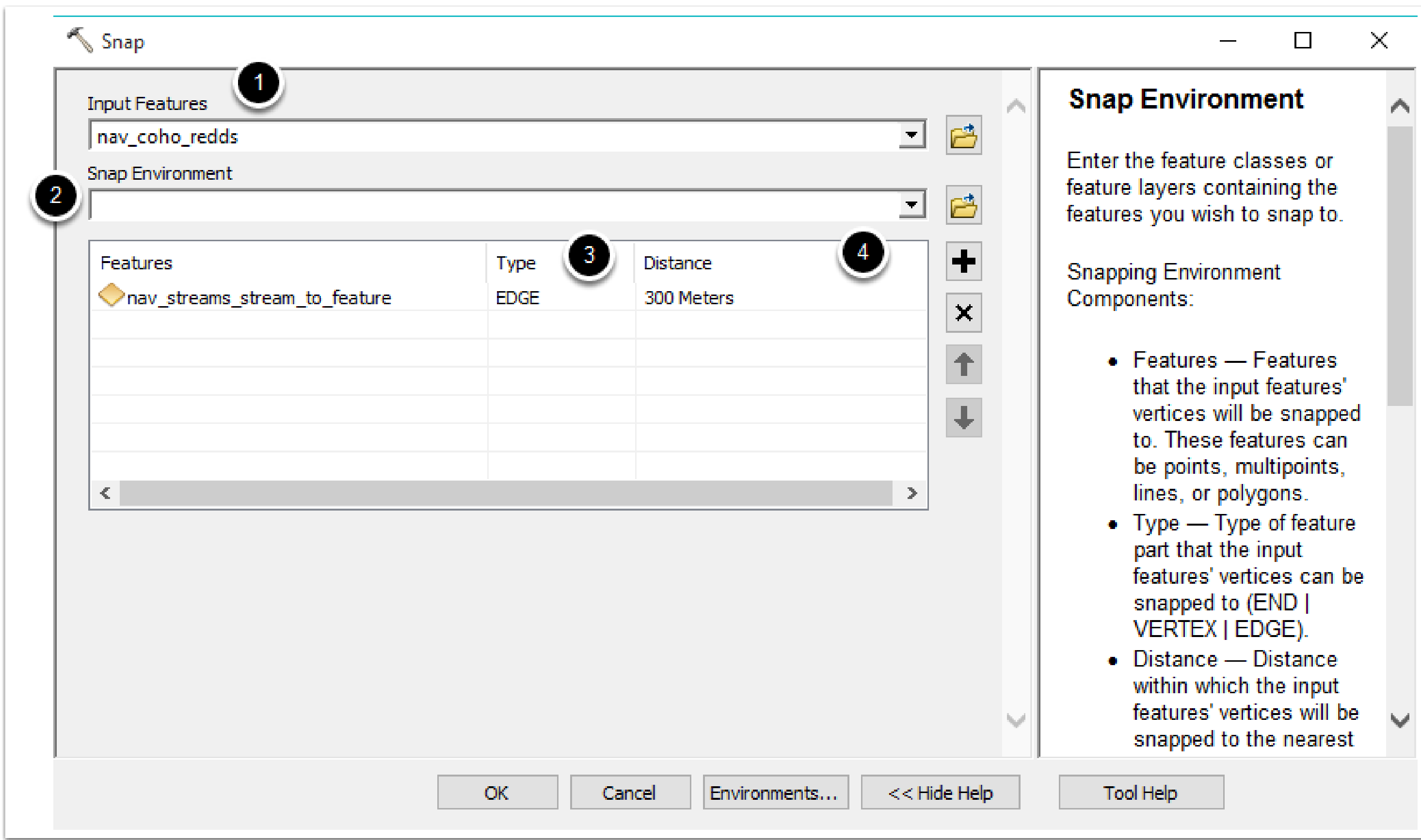
7.1 Snapping Points

The *Snap* tool lets us create a *Snap Environment* - similar to when editing features in ArcMap. You can add many feature classes to the snap environment, and specify what parts of the features should be snapped to, and the maximum snapping distance for each features to be snapped to each feature class. In this case, our snap environment will be a single feature class - the *nav_streams_stream_to_feature* layer.

We have two things to consider when using this tool - first is that it operates on the data in place - that is, our points will be moved within the dataset we provide - a copy won't be output with the changes, so we don't get to compare the before/after impacts of the tool unless we copy the layer before we run the snap - we won't do that this time, but it's something to keep in mind. The second thing to keep in mind is that it snaps to the closest item in the snap environment, which might not always be the most correct. If you look again at the image in step 6, the second point from the top will end up moving to the stream just below it, but given the consistent offset to the left of the main stream of all the points, it seems like maybe it should actually move to the right to the main stream. So, we introduce some error in correcting our other errors - something to be aware of!

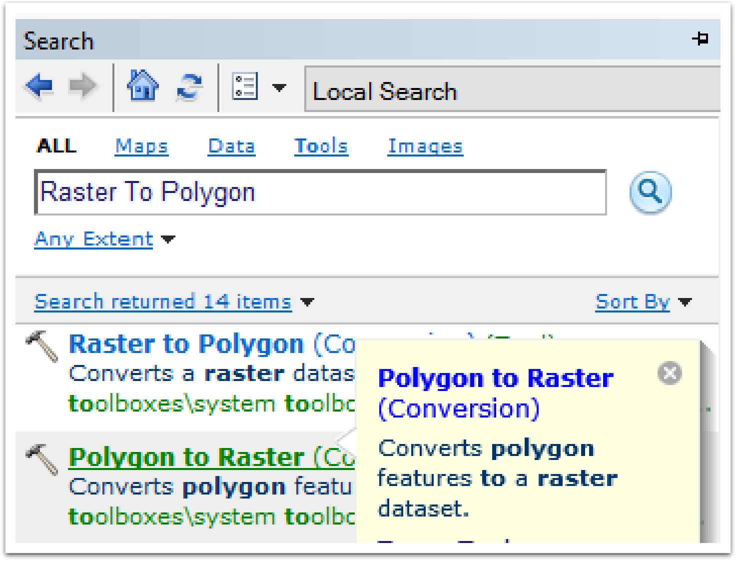
1. For *Input Features* use *nav_coho_redds,* since we want to move those points to the streamlines.
2. In the *Snap Environment* dropdown, select *nav_streams_stream_to_feature.*
3. For *Type,* in the row for *nav_streams_stream_to_feature,* select *edge* from the dropdown. This tells ArcGIS to only snap the points to the closest river line. Take a look at the other options and consider what happens if you choose the other one of them instead.
4. For the *Distance* parameter, type in *300 meters*. 300 meters was chosen by examining the dataset for how far the points are from the rivers. Feel free to use the measure tool yourself and look to see if you can find any point further from the river lines.

Run the tool.



8. Tabulating the redds in the watersheds

Now that we have the points in the correct location (as much as possible), we need to attach that data to the watersheds - but before we do, we need to make the watersheds into polygons so that we can attach meaningful attributes at all. To do so, we'll use the *Raster to Polygon* tool. Search for and open it up now.



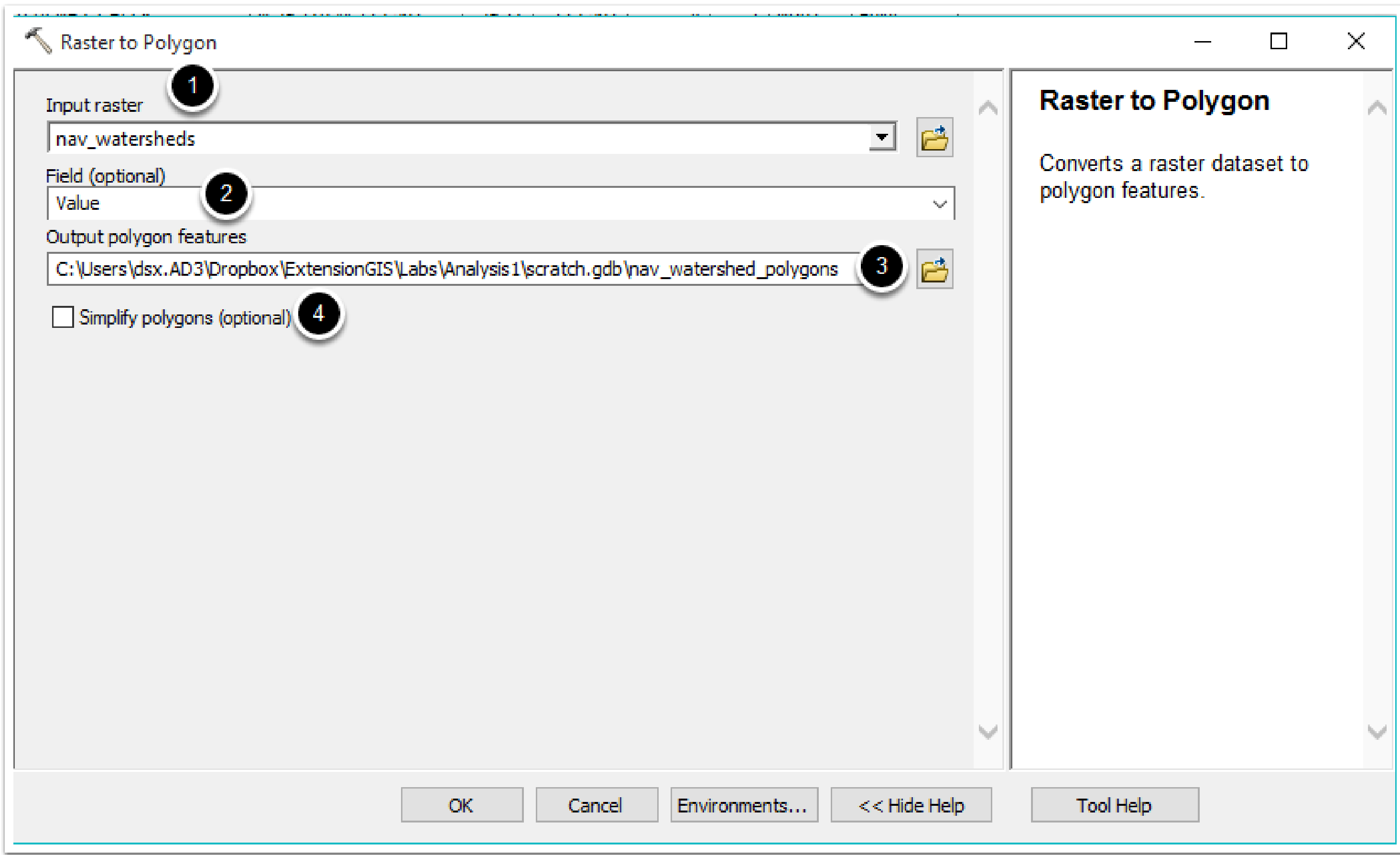
8.1 Converting a raster to polygons

The Raster to Polygon tool takes contiguous areas in a raster with the same value and turns them into a polygon, repeating across the entire raster. Since our watersheds layer is in this format, with each watershed being a contiguous unit of the same value, we can easily convert them to polygons. As a sidenote, the *Reclassify* and *Region Group* tools can help turn other rasters into this kind of format too.q

1. Provide the raster *nav_watersheds* as the *Input raster*
2. For field, use *Value,* which pulls the cell's values as a field
3. Name the output *nav_watershed_polygons*
4. Don't choose to simplify the polygons (think for a moment about the impact of that).

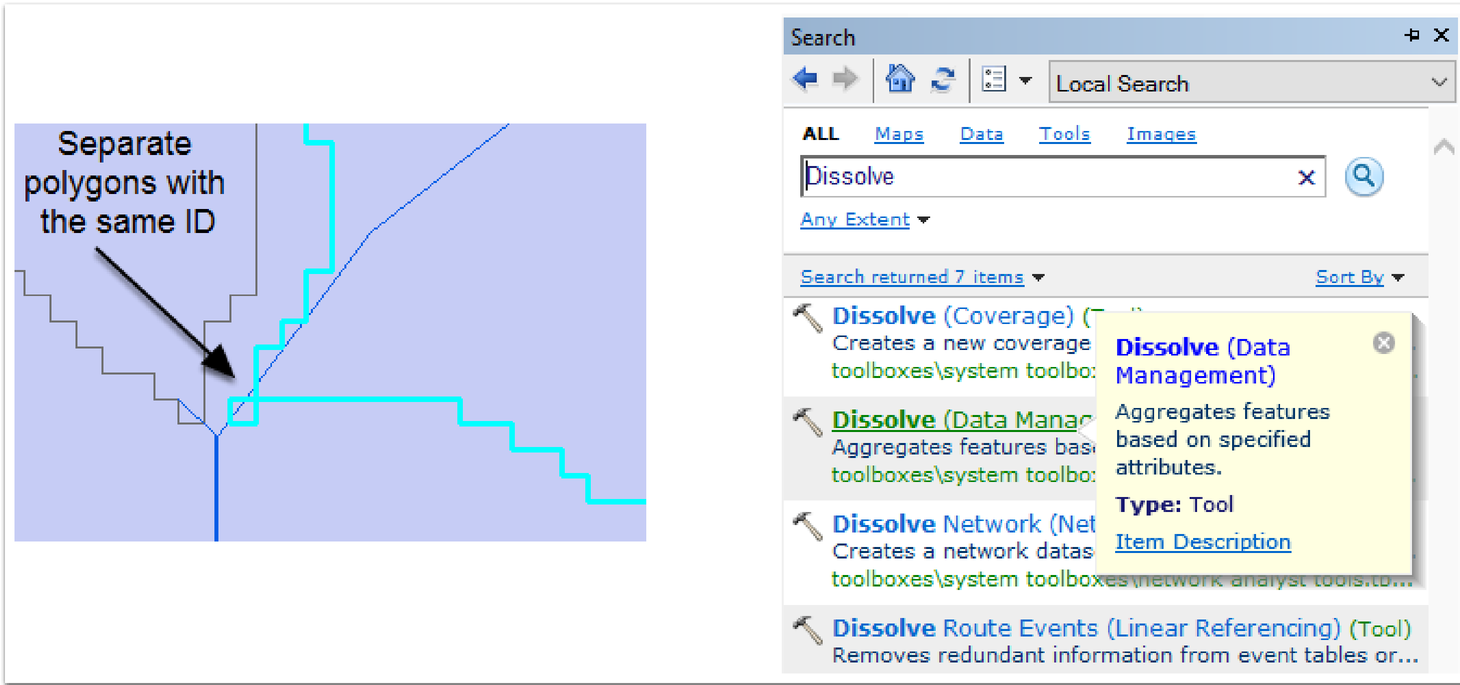
Run the tool, then take a look at the output - is it what you'd expect? What attributes does it have?

Then, take a look at how many records there are - if each contiguous value area became a polygon, why do we have more attributes than we had values in the raster (445 in *nav_watersheds*)



8.2 Dissolving

The key word for the raster to polygon conversion was *contiguous*. While cells can flow into each other across diagonals, they don't have to be adjacent otherwise (above, below, right, or left of), so when converting to polygon, these locations become separate polygons that need to be dissolved together. Can you find a location where this occurred (hint, look for a duplicate value for attribute *grid_code*, the converted raster's value, in the attribute table, and look around the edges of the duplicated polygons.



8.3 Dissolving the polygons

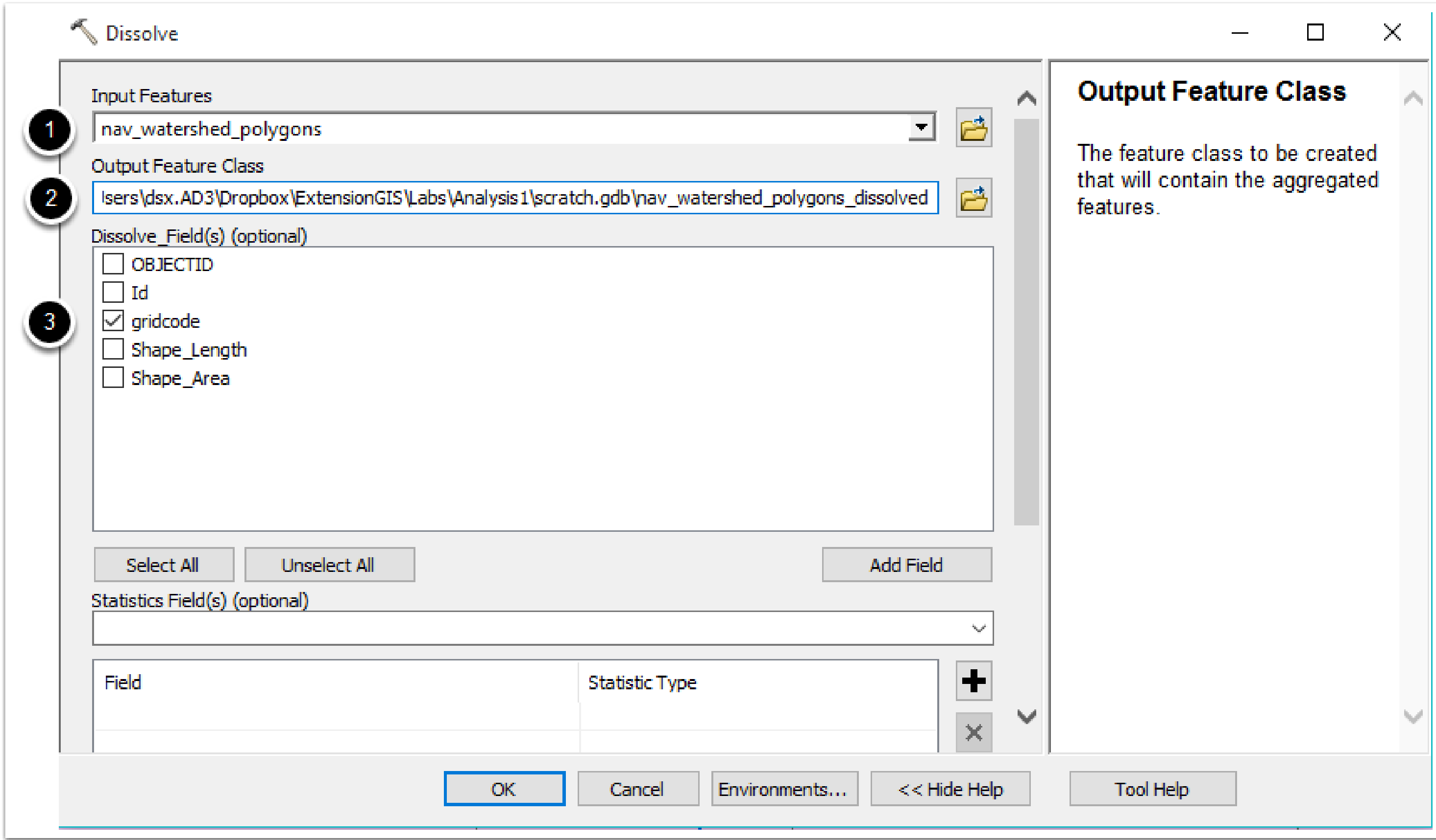
We'll solve this issue of multiple polygons per watershed with the *Dissolve* tool. Remember that dissolving takes features and removes touching boundaries between them. We can either have it remove all boundaries, or only boundaries between features that share a common value in a field. We'll do that this time.

The converted raster values became a field called *gridcode* on the polygons, and we'll use that as our dissolve field. Any polygons with the same value in the gridcode field will become one polygon - since our boundaries aren't shared, we'll create *multipart* polygons, where multiple polygons become one feature for a record.

1. Provide the *nav_watershed_polygons* layer as your input features.
2. Name the output features *nav_watershed_polygons_dissolved*

3. Check the box next to *gridcode* to have the tool use that as the Dissolve Field

Run the tool



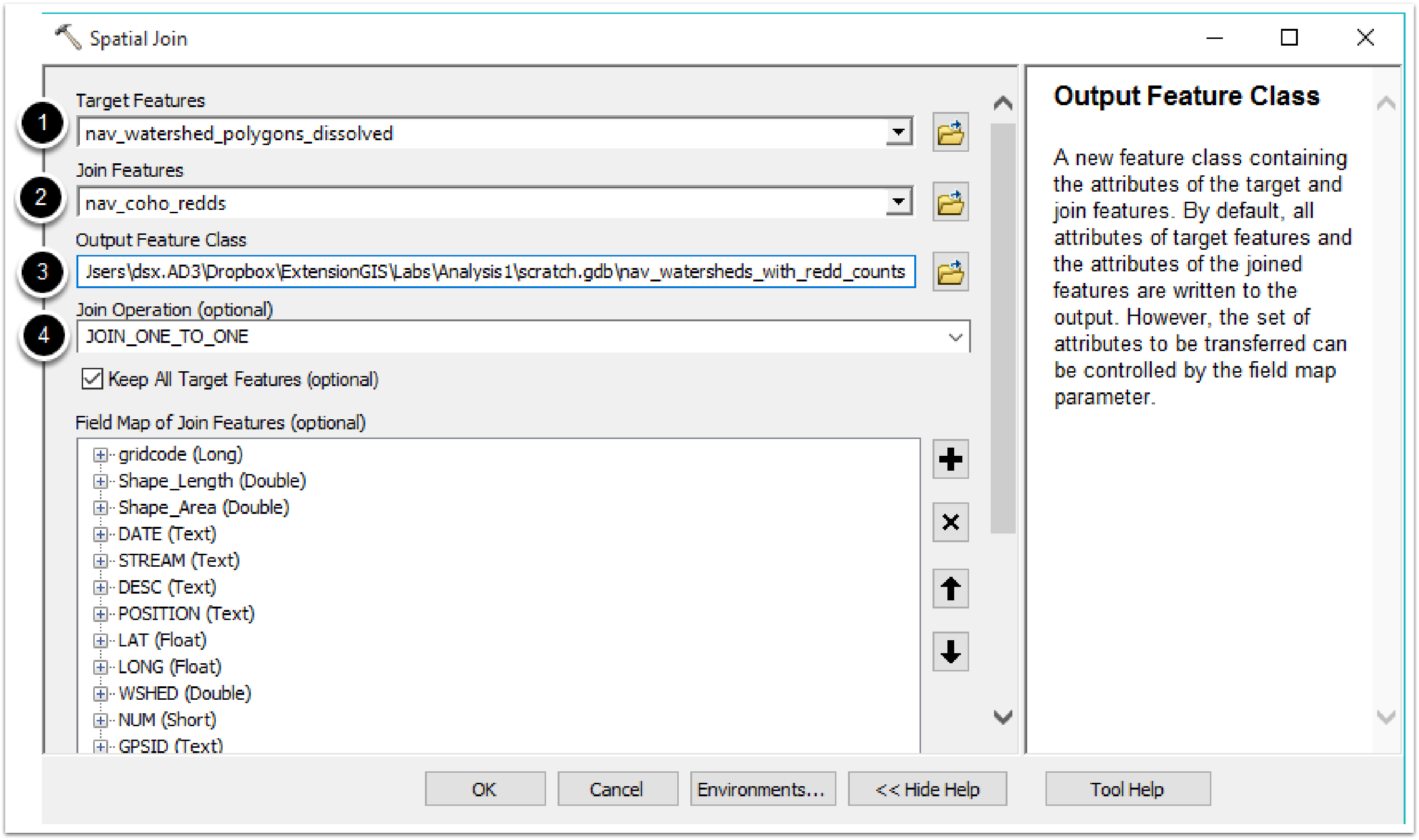
9. Attaching the data together

OK, we've dealt with our current data management needs, since we now have our redd features created and snapped, and our watershed polygons created. We still haven't loaded the timber harvest plan data, but if we ultimately plan to attach it to the watersheds, we can continue with the data we're already using by attaching a count of the number of redds to each watershed.

The first tool that should come to mind when thinking of attaching information based on location is... Spatial Join! Other tools for different data types would be Zonal Statistics as Table, Extract Multivalues to Points, etc. But for now, we need the excellent powers of the Spatial Join tool (I love this tool). One nifty trick about it is that if you use the JOIN_ONE_TO_ONE mode of the tool, it will give you a field called JOIN_COUNT indicating the number of features joined. In this case, we're not really concerned with the attributes, but just with the number of redds in each watershed, so that's perfect. Let's run it now. Find it and open it up.

1. Think about which features are your *join features* and which features are your *target features*. Join features contain the attributes to attach and target features become the output features, with their own attributes, plus the attributes of the join features. Use *nav_watershed_polygons_dissolved* as the target features.
2. Use *nav_coho_redds* as the join features
3. Name the output *nav_watersheds_with_redd_counts*
4. Use *JOIN_ONE_TO_ONE* as your *Join Operation* because we want to get the JOIN_COUNT field and only a single record for each watershed should remain.

Leave everything else as its default, and run the tool

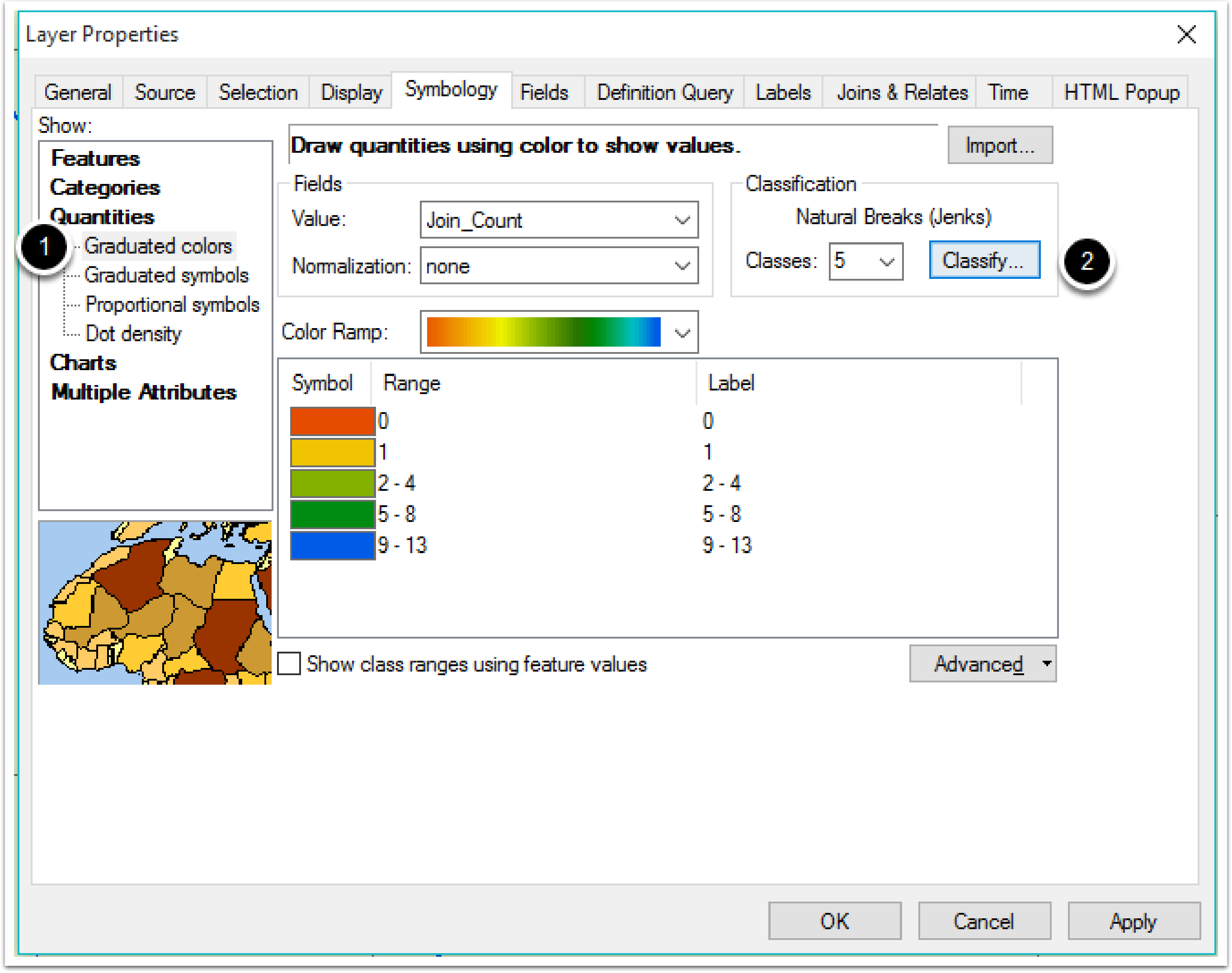


9.1 Symbolize the Redd Counts

Once it finishes, let's symbolize the data. By default, most of the data will have a value of zero. Most watersheds don't have any of these redds located in them. Let's exclude those from our color ramp to make the symbology clearer and so we can more easily overlay the data on top of the DEM/hillshade.

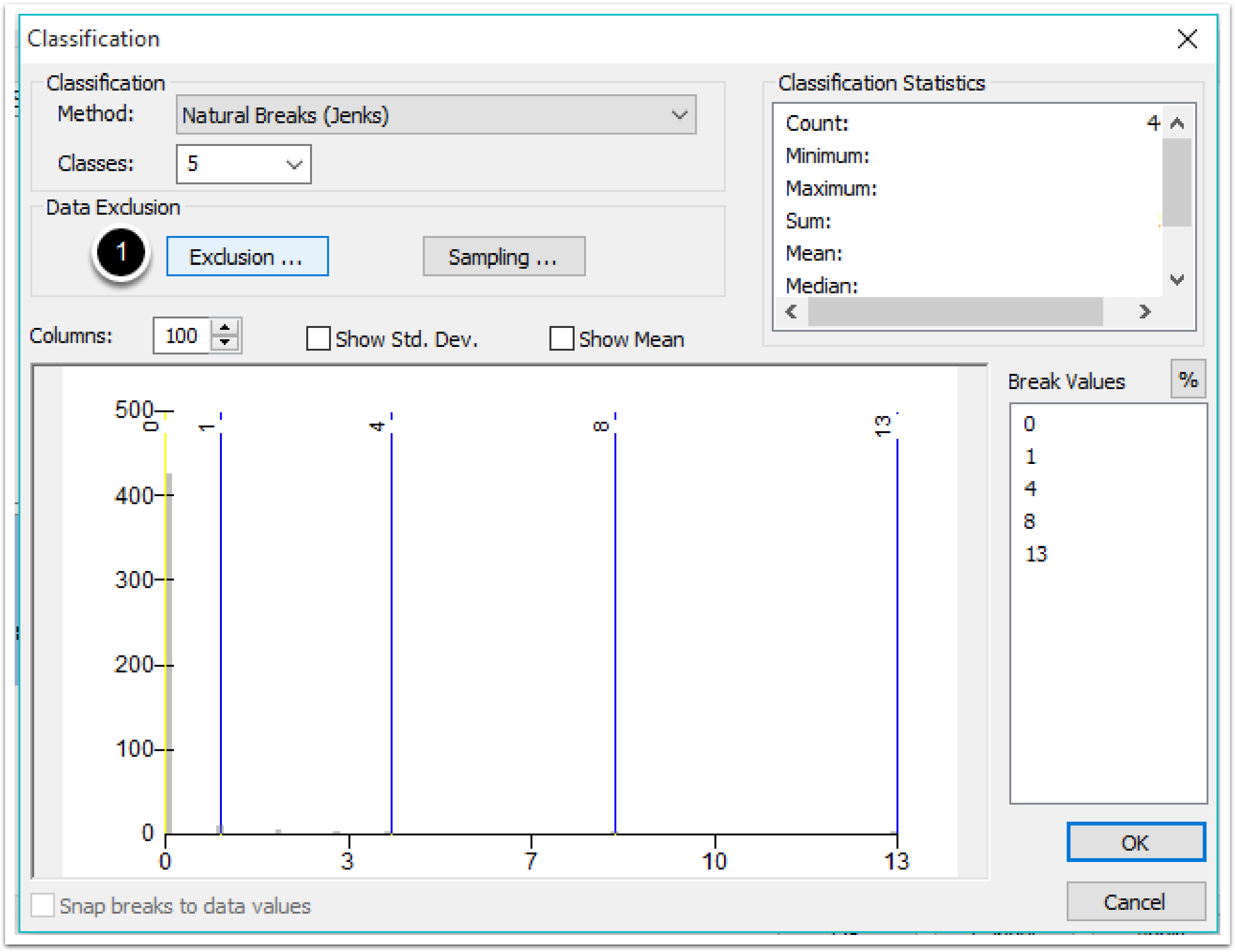
1. On the *nav_watersheds_with_redd_counts* layer, go to symbology and switch to *Graduated Colors* in the *Quantities* section.

2. Click *Classify* to change our symbol classification options.



9.2 Excluding Data

1. In the *Classification* dialog that comes up, click the *Exclusion* button.

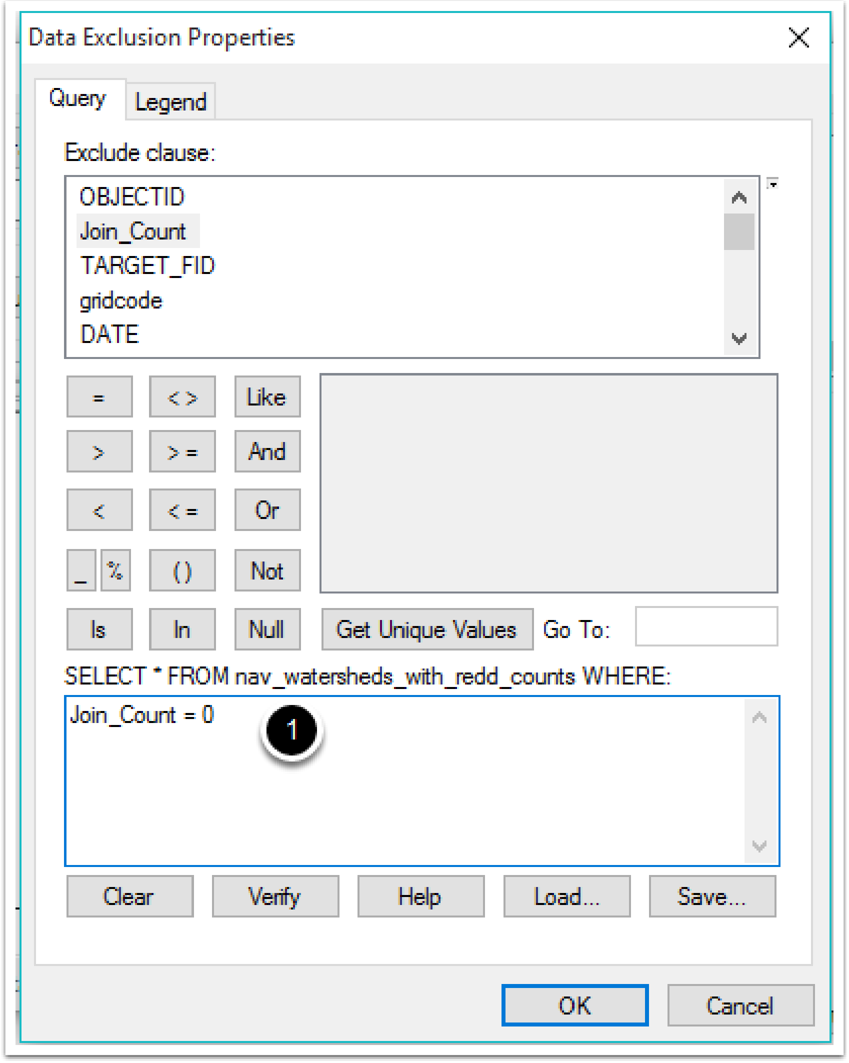


9.3 Writing the Query

Now, we need to write an attribute query - ArcGIS will exclude records that this query selects from being symbolized. We want to exclude any records where there aren't any redds, so in the query box (1), write

```
Join_Count = 0
```

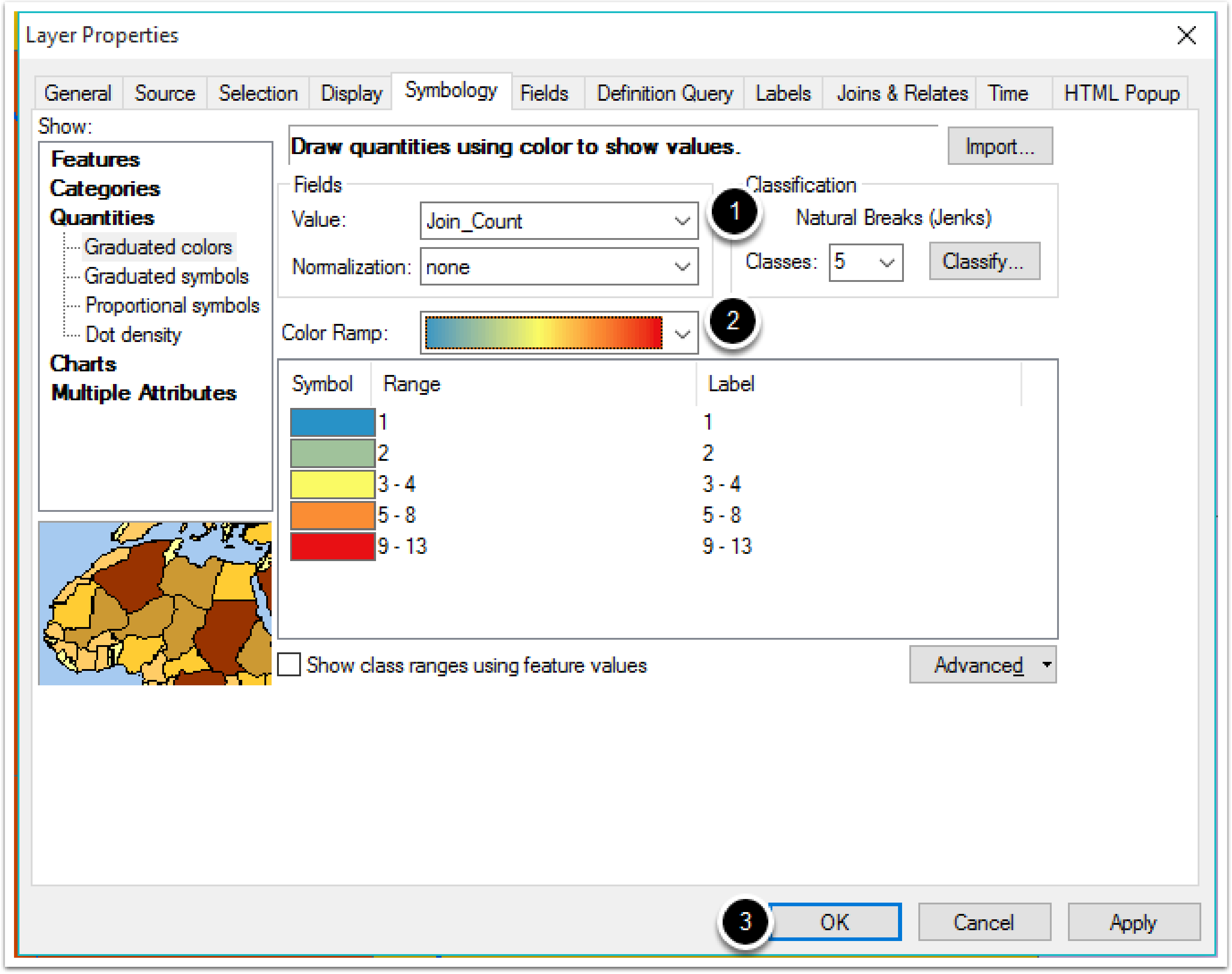
Join count is the new field that was added for us by the spatial join operation, indicating the number of redds that were joined to the watersheds. So, excluding records where join_count = 0 excludes records without any redds! Click OK to close this box, and the OK to close the Classification dialog.



9.4 Finishing the Exclusion

The query may not automatically update. If it doesn't, then change the *Value* option in the field box, and then change it back. It should update so that records with 0 redds aren't included.

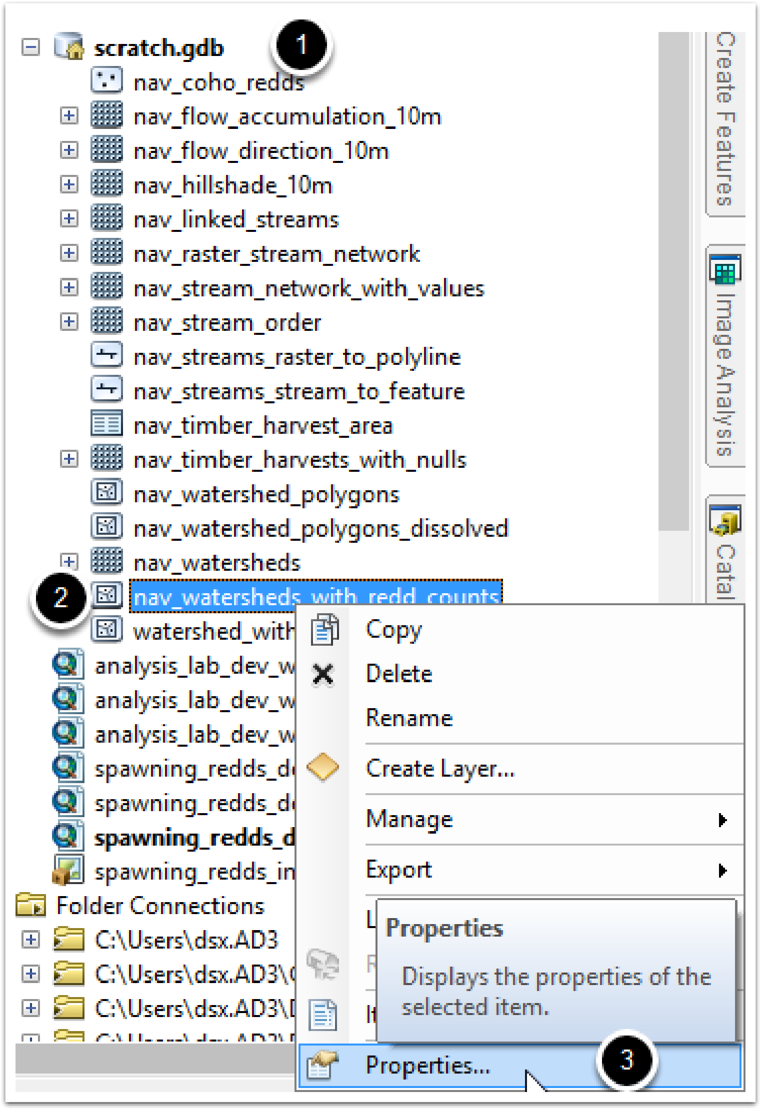
1. Change the *Value* option to the *Join_Count* field.
2. Pick an appropriate color ramp for displaying the data
3. Click OK to save your changes



9.5 Rename Join_Count

Since it seems like we'll want to make more use of the Join_Count field, let's rename it to something that is more intuitive, like simply *Redds.*

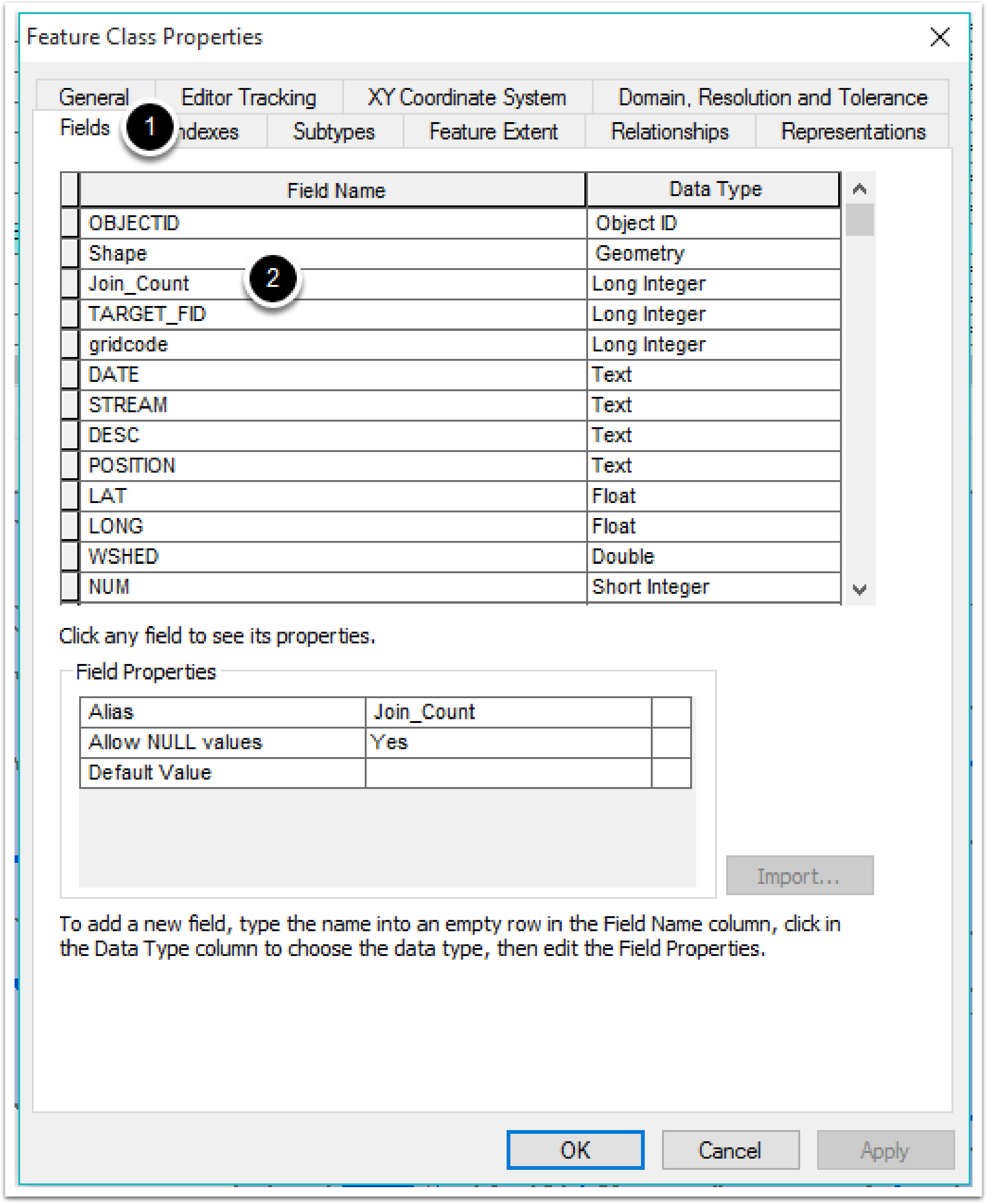
1. To do so, find the layer *nav_watersheds_with_redd_counts* in the Catalog window. It should be in your scratch database.
2. Right click on it
3. Click on *Properties*



9.6 Find the field

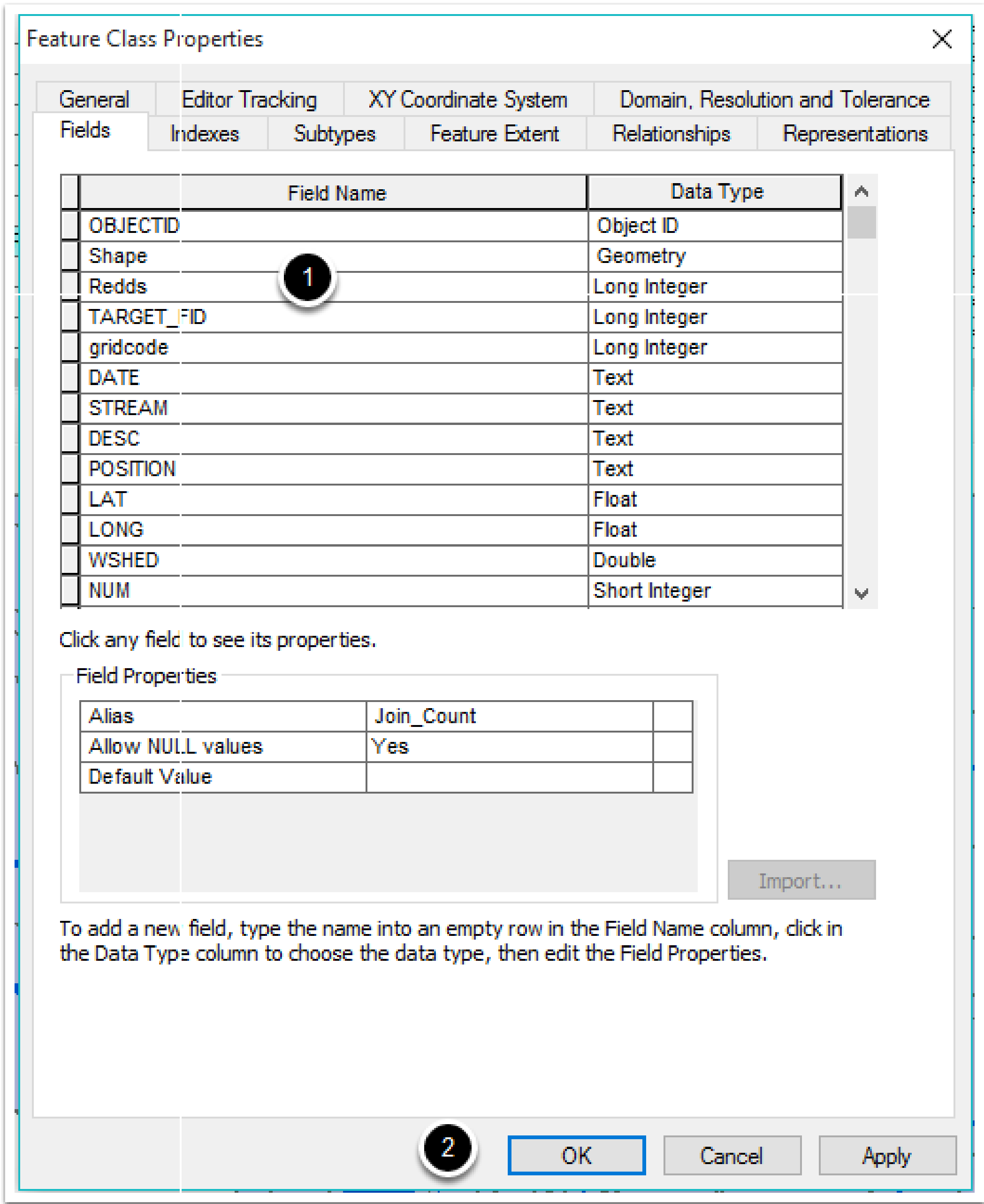
Now, let's find the field.

1. Go to the *Fields* tab
2. Find the field named *Join_Count* and click into it to select the text.



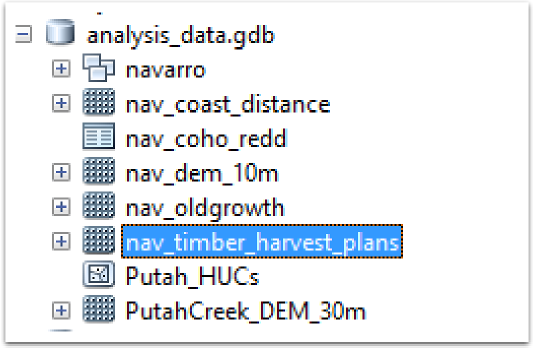
9.7 Change the name

With the text selected, change the name *Join_Count* to *Redds* (1), then click OK to change the name (2) - it will update in your map document as well.



10. Adding the Timber Harvest Data

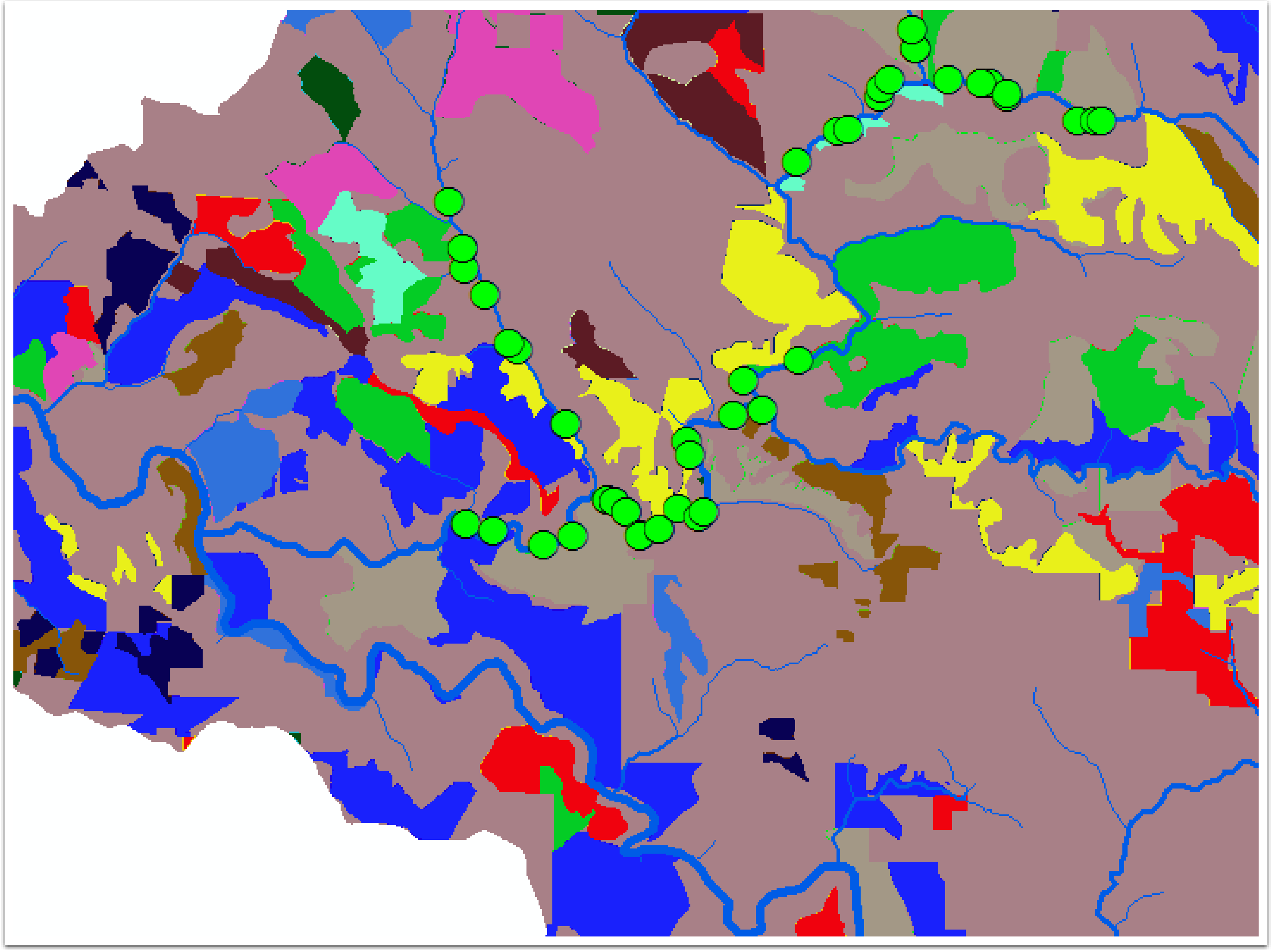
Now we have the redds attached to the watersheds. Let's load up the timber harvest plan data. Add the layer *nav_timber_harvest_plans* to your map document. (Sidenote: Have you saved your map recently?)



10.1 Patchwork raster

The layer will be a little like a patchwork quilt. With different colors and shapes everywhere. What do they represent? Look in the table of contents at the values.

Each different value/color represents a year. All cells that have that year's value were harvested in that year. We'll use this information to attach information about what years were havested back to the watersheds.



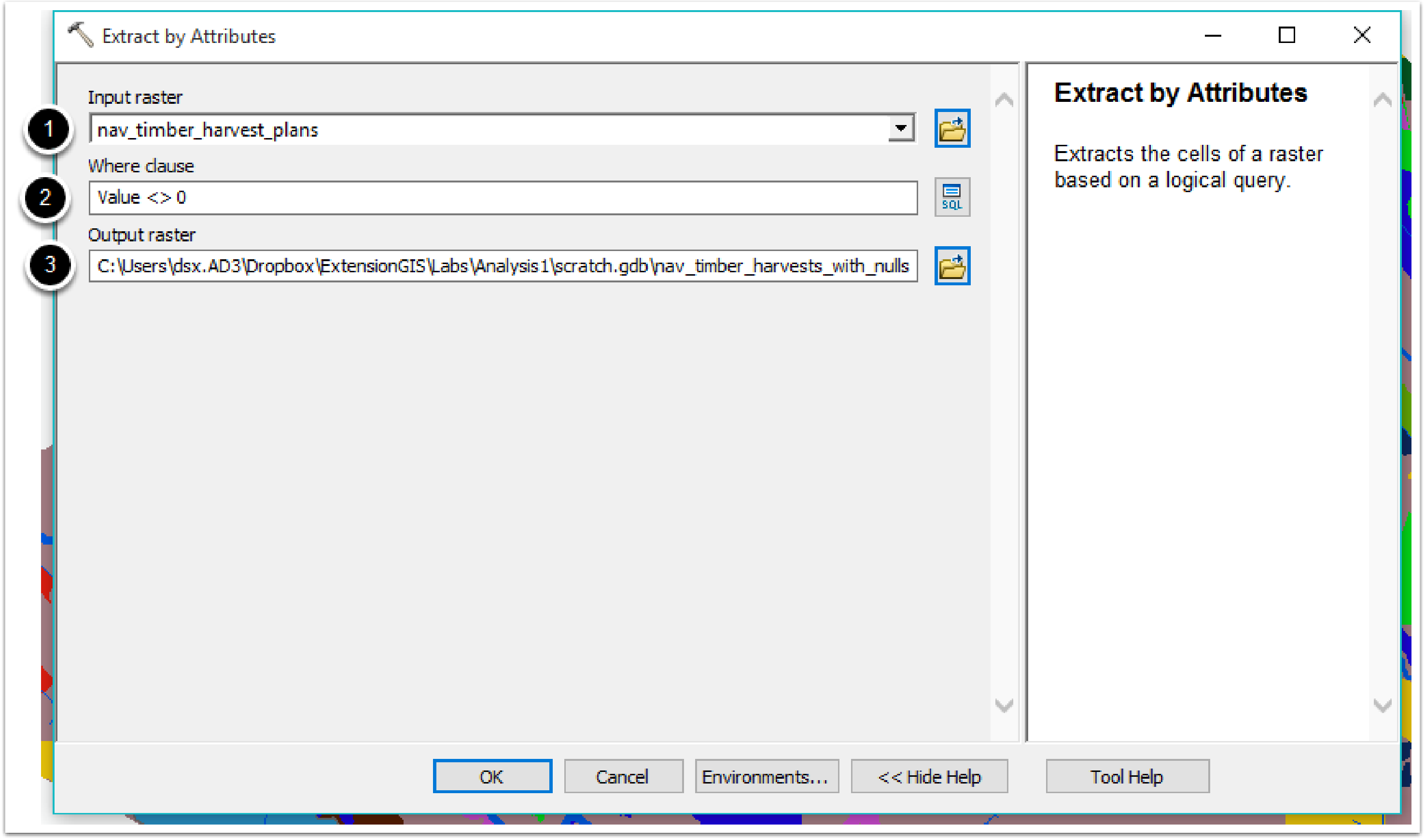
10.2 Extract Only the areas that have Timber Harvest Plans

We're going to want to attach this data to the watersheds as well (start thinking how we might accomplish this!). But, to start with, let's remove the background value of 0 so that places without timber harvests don't get attached. For this, we'll use the *Extract By Attributes* tool in the Spatial Analyst toolbox to make a new raster from all the cells that match a query. Find that tool and open it.

Out input raster is the timber harvest raster since that's what we want to extract values from. Put *nav_timber_harvest_plans* as the input (1). For the *Where clause* we want to extract all values that aren't zero (the background value), so our query (2) will be `Value <> 0`

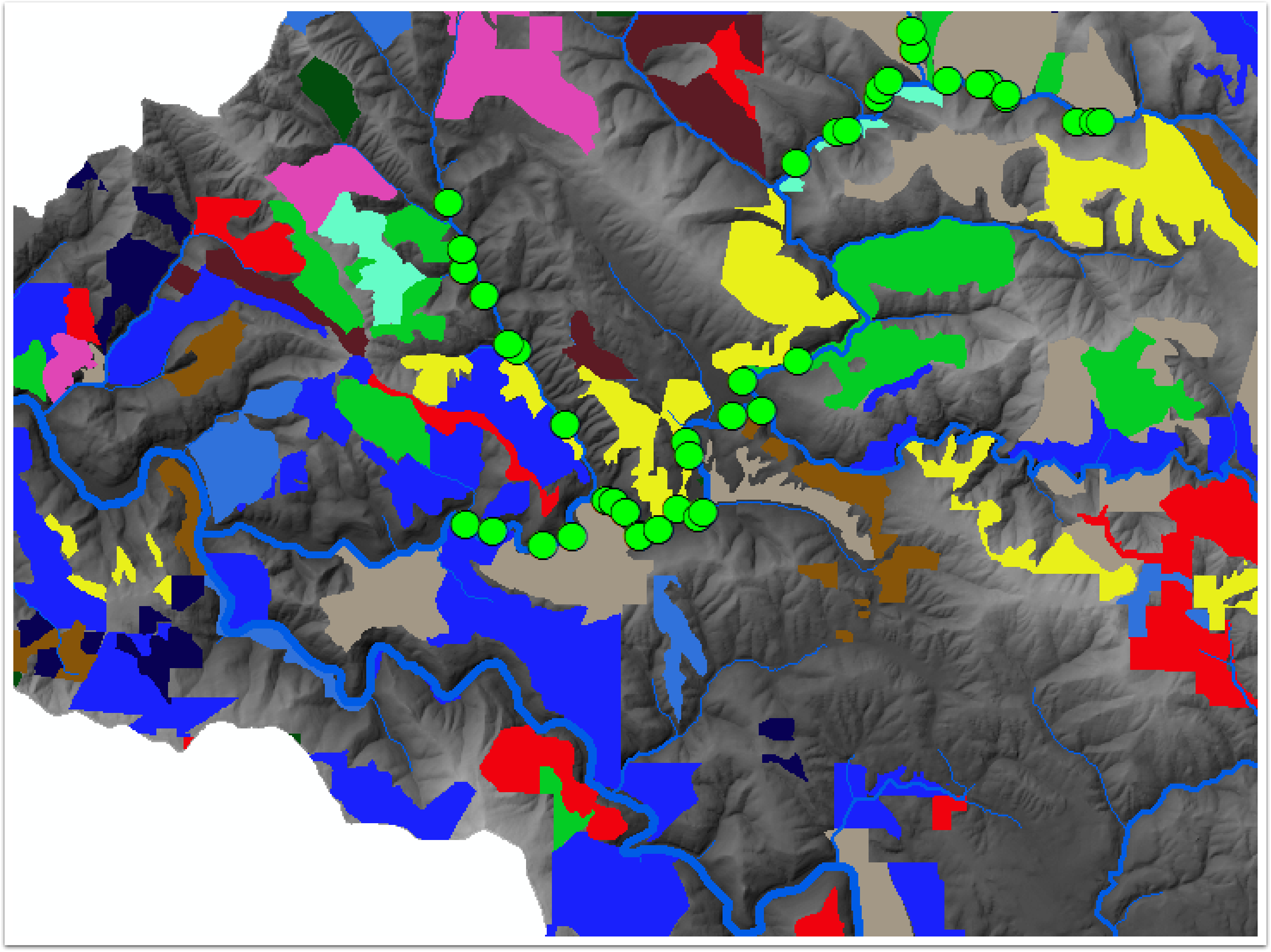
The <> symbol in there is an old way of saying "is not equal to" - so you can read that query as "The cell value is not equal to zero" and the overall action of the tool as "Extract all of the cells of nav_timber_harvest_plans where the cell value is not equal to zero (and use null values otherwise), and place the output in nav_timber_harvests_with_nulls". Put in *nav_timber_harvests_with_nulls* as the output raster and run the tool.

Bonus: What other tool could we have used to accomplish this same task?



10.3 Output

The output is what we'd expect - the cells that match with a year are shown in the new dataset, but the rest of the cells are null, so we can see what's below it in the table of contents.



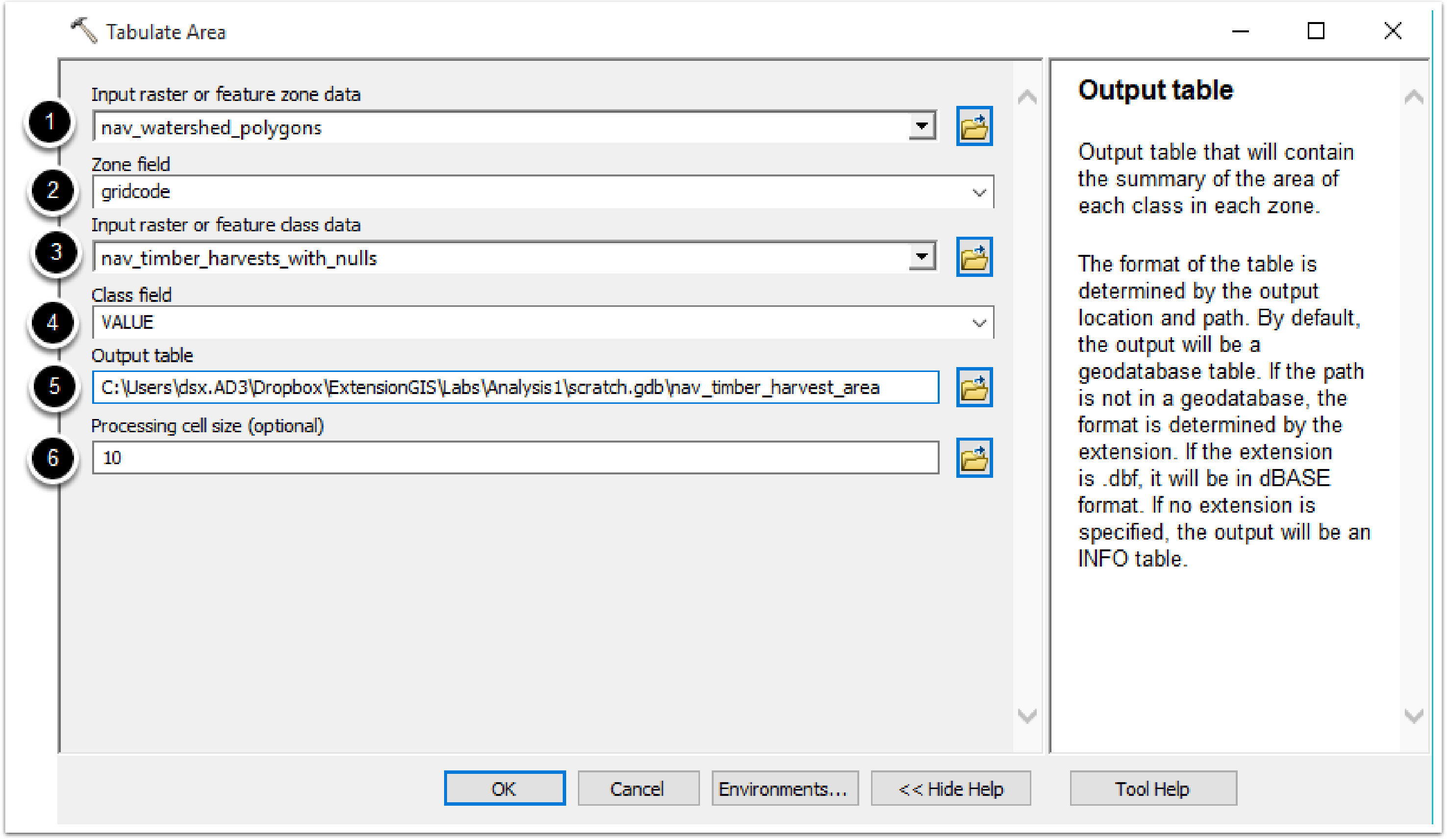
11. Attaching the timber harvests to the watersheds

Now that we have the timber harvest plans isolated, let's attach them to the watersheds for analysis. I hope the term "spatial join" has already popped into your head - but that's not what we'll use this time since it involves a raster. Instead, we'll use *Tabulate Area,* a more specialized tool that will attach the values of the raster as a field on our watersheds, and then put the area of the raster that was that value as the value of the field for each watershed.

Find the Tabulate Area tool now, and open it up.

1. Our zone data to extract the data to is *nav_watershed_polygons*. Since Tabulate Area outputs a table rather than modifying in place, we can use either watershed polygon layer we have here.
2. For the zone field, once again use *gridcode* so that we get values we can use to join the table back to the watersheds
3. Use *nav_timber_harvests_with_nulls* as the Input raster class data- that's the raster Tabulate Area will extract data from
4. Tabulate Area uses groupings, or *classes* (think like classifications, not education), to determine what fields to put in the ouput table. We want these classes to be the years, so the raster's cell value has the classes. Use *VALUE* as the *Class field.*
5. Name the output table *nav_timber_harvest_area* and save it in your scratch geodatabase
6. Set the processing cell size to 10 to match the watershed DEMs (and remember that we set environment settings that can affect this tool!)

Run the tool.



11.1 Look at the results

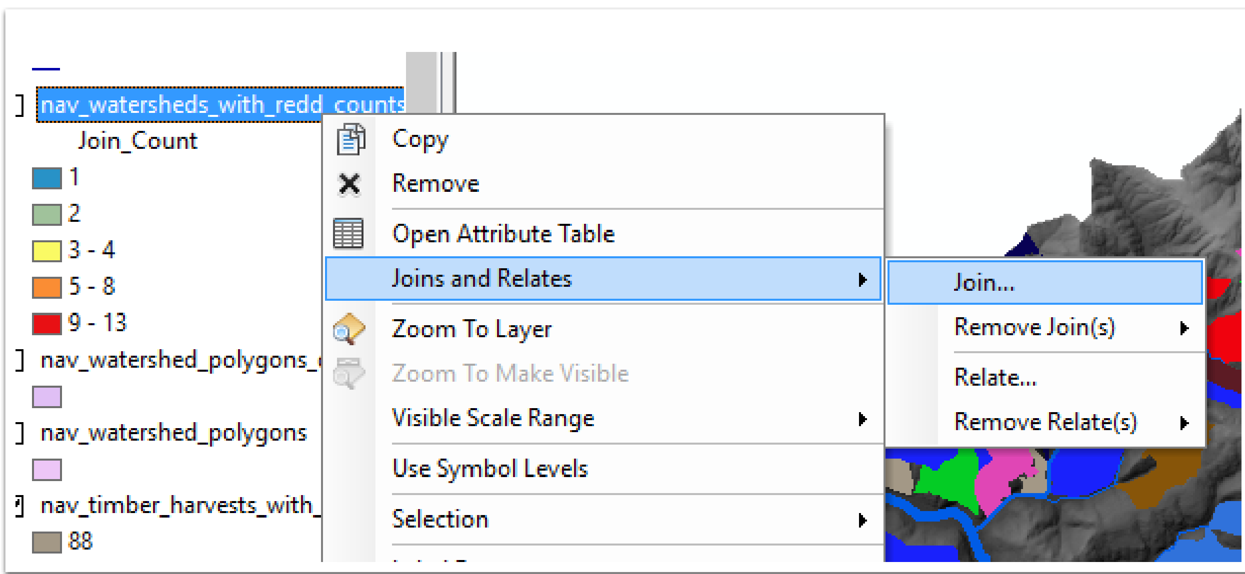
Open the output table and examine it a bit. What fields are there and what do they contain? What did tabulate area do? Do the values make sense (why are there so many zeros?)

nav_timber_harvest_area

OBJECTID *	GRIDCODE *	VALUE_88	VALUE_89	VALUE_90	VALUE_91	VALUE_92	VALUE_93	VALUE_94	VALUE_95	VALUE_96	VALUE_97	VALUE_98	VALUE_99
1	1	0	346300	0	0	0	94600	818500	0	0	0	0	0
2	2	0	694300	0	0	0	0	14900	0	0	0	0	0
3	3	0	0	0	0	0	0	7400	0	0	0	0	0
4	4	0	139400	740700	0	0	0	0	0	0	133900	33400	0
5	6	0	158500	1113600	0	0	0	89700	0	0	0	0	0
6	7	0	0	166000	0	0	0	0	0	0	0	0	0
7	8	0	0	0	0	0	0	419900	0	394100	0	1000	0
8	9	1795600	48000	4800	145200	143100	692100	0	0	0	0	0	0
9	10	2700	153400	133400	2700	0	0	0	0	932200	0	0	0
10	11	126100	1300	402500	264200	0	0	0	0	0	0	6300	0
11	12	0	439800	49100	0	0	0	299200	0	787900	60600	8800	0
12	13	524300	0	58700	0	0	0	0	0	6000	0	655200	0
13	14	443200	0	0	157000	0	0	0	0	0	0	0	0

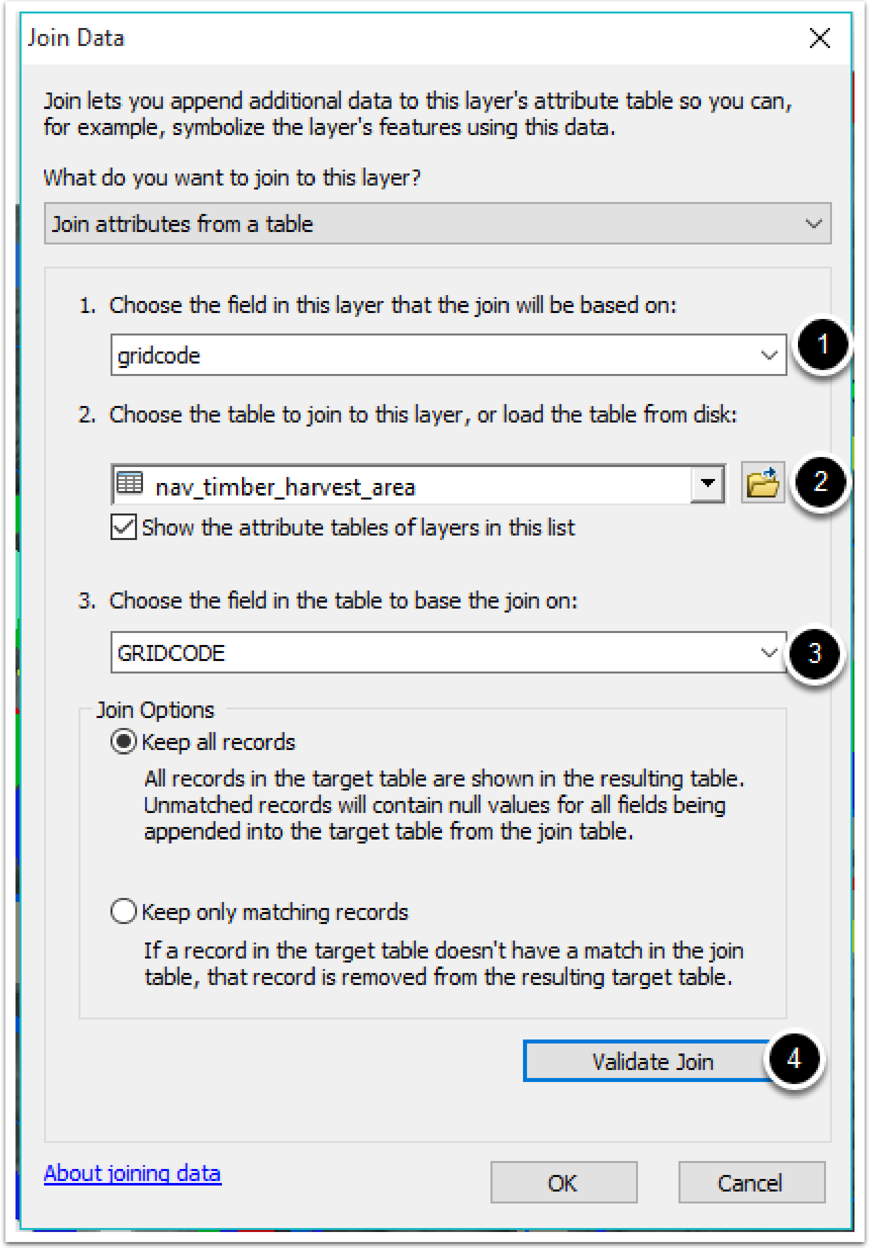
11.2 Join the data

Now, we'll run a join to attach that table back to *nav_watersheds_with_redd_counts.* Initate the join from *nav_watersheds_with_redd_counts*.



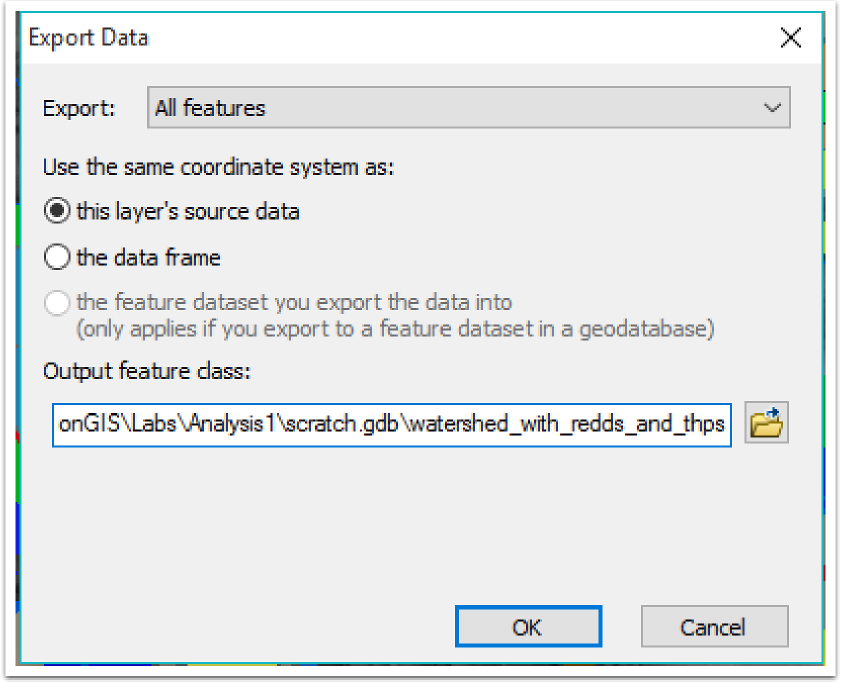
11.3 Setting up the Join

A familiar dialog will come up. Remember that in this case, we want to join this data to our new tabulate area results based on the field *gridcode* (1,3) in each one - Tabulate Area attached it to each record for us. Set up the join to table *nav_timber_harvest_area* that Tabulate Area just generated (3), then validate it (4), and click OK to finish.



11.4 Export Features

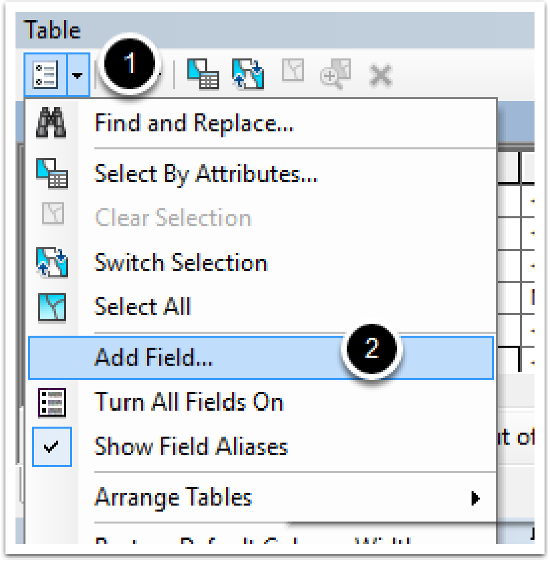
Now, export the nav_watersheds_with_redd_counts as a new feature class named *watershed_with_redds_and_thps* in your scratch geodatabase. This makes a new layer that hasa all of the data permanently attached to it. Add it to your map when prompted



12. Starting the analysis!

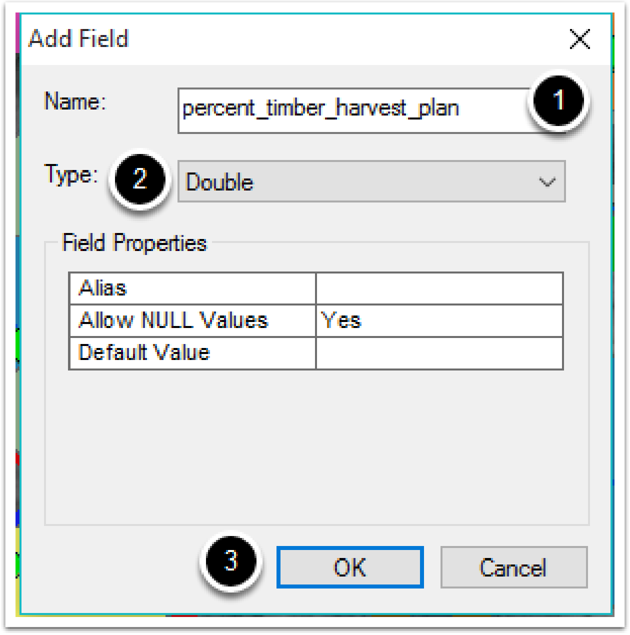
OK! Now we're really digging into the question. We've done the heavy lifting and gotten our data all attached to a common unit of aggregation - the watersheds in this case. We can begin the analysis now! What we're going to assess is the relationship between the number of redds and the percentage of the watershed that was part of a timber harvest plan in any year during the span of years our timber harvest data covers. To do so, we'll need to add a new field and calculate a value for it that represents the percentage of the watershed that was under timber harvest.

To start, open the attribute table for *watershed_with_redds_and_thps* (not shown) and go to the table menu (1) and click *Add Field* (2).



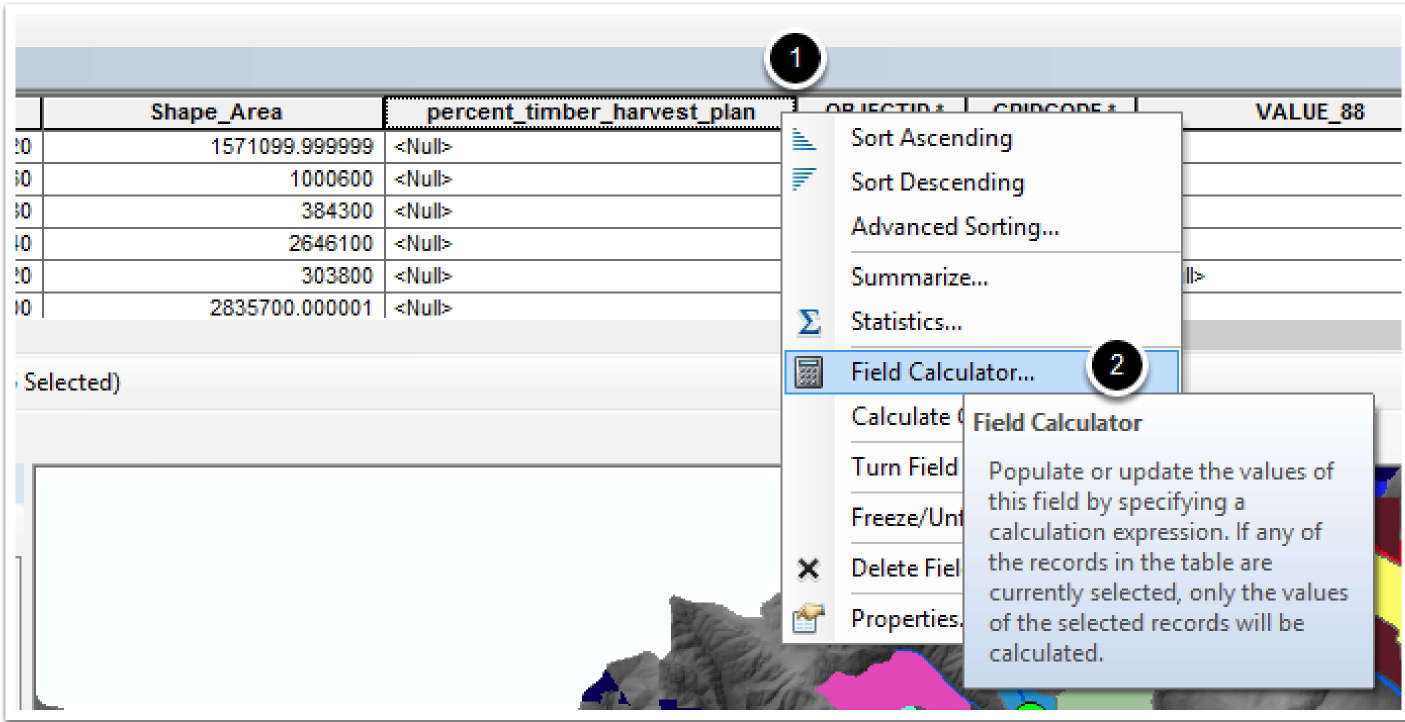
12.1 New field dialog

In the new field dialog, name the field *percent_timber_harvest_plan* (1). What should the data type be? It's going to hold a decimal number (a percentage of the area that was timber harvested), so it should be a format that can hold decimals. You could use a *Float* but we'll use a *Double* instead (2). Click OK to add the field (3).



12.2 Calculating the Field Value

Once we have the field added, let's calculate it. Right click on the field you just added (*percent_timber_harvest_plan*) (1) and go to *Field Calculator* (2)



12.3 Creating the Expression

Again, our goal with the field calculator is to find the percentage of the area of each watershed that has been part of a timber harvest. What expression gets us there? Let's break the problem down.

First, we can think of percentage area under timber harvest as:

```
(total area under timber harvest / total watershed area) * 100
```

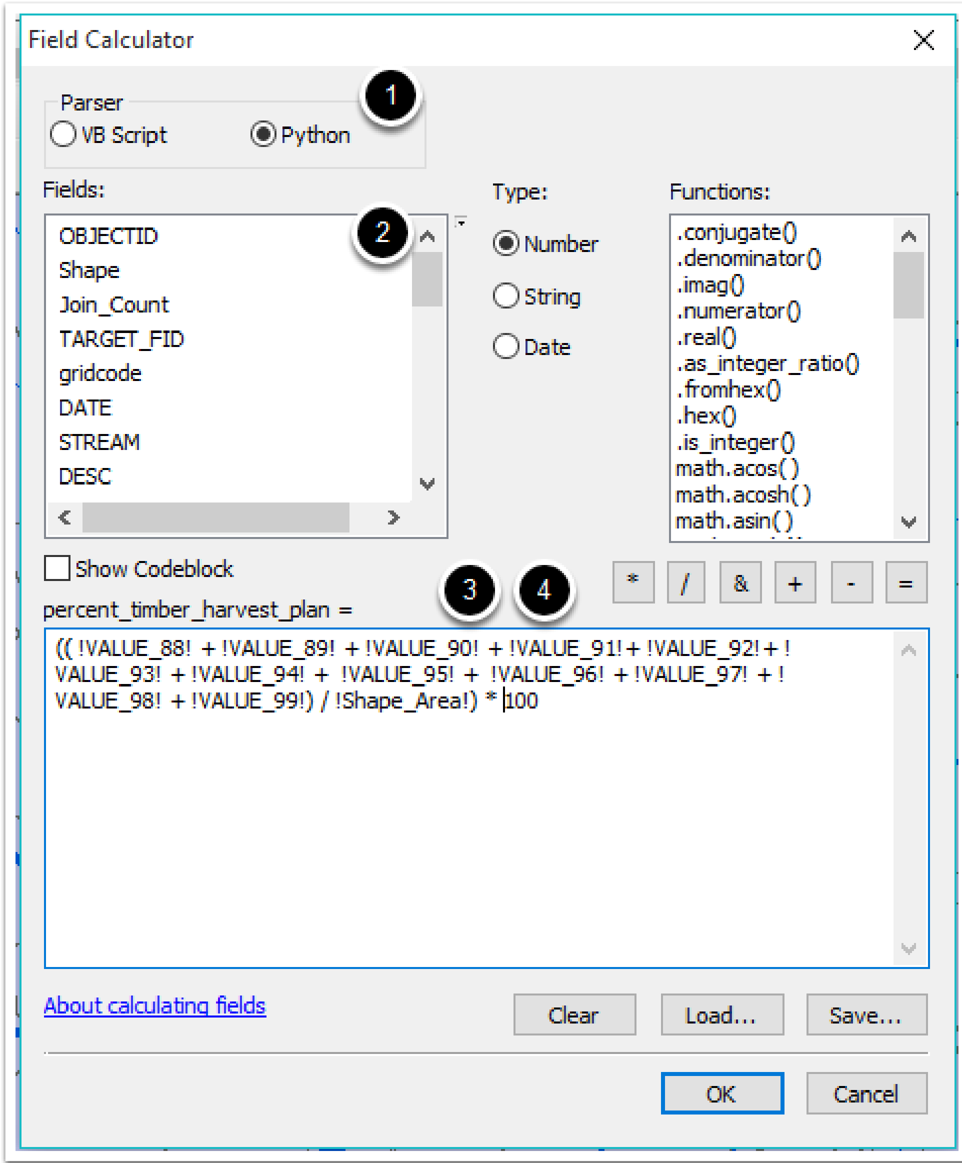
We fortunately already have a field that gives us the denominator (total watershed area) - When using a file geodatabase, the Shape_Area field is always updated with the current area of the feature (in square units of the coordinate system of the feature class). So that part is ready, but what about the numerator (total area under timber harvest)? We don't have that yet. But we do have a way to get it. Take a look at the table - we have fields from our tabulate area calculation that give areas for timber harvest in the watershed by year. To get the total area under timber harvest, we just need to add all of those up. Our modified expression (still in pseudocode - not ready to type into the calculator, but just a way to think about the expression) would look like:

```
((sum of yearly timber harvest area fields) / Shape_Area field) * 100
```

Now, we could write out the expression manually, but that would take a long time for you to type in, and getting the syntax right would be hard. Instead, we'll use the tools in the query builder.

1. In the field calculator dialog, switch the *Parser* to *Python.*
2. In the *Fields* box, scroll down until you see the fields from running Tabulate Area (named things like *VALUE_88, VALUE_89*, etc.). Double click the first one (VALUE_88) to add it to the bottom box, then manually type a plus sign in the box, then double click the next field (VALUE_89), then add a plus sign after it, and continue through this process, adding all the fields with plus signs until you've added VALUE_99 (but don't add a plus sign after it - look at the image below if you need a reference. This is our numerator, since it creates the sum of yearly timber harvest area fields, so we now need to surround it in parentheses so that they all get summed up before being divided. Again, see the screenshot below for reference.
3. After adding the parentheses, add the division sign (forward slash /) to the bottom box by typing it in, then find the *Shape_Area* field in the *Fields* box and double click it to add it to the box. Now we have our numerator divided by our denominator.
4. To be extra careful, now surround everything in parentheses. We do this so that when we multiply it by 100 to turn the fraction into a percentage, we make sure to multiple everything by 100, instead of just the Shape_Area. There will now be two parentheses at the front of the expression, one before the division operator, and one at the end
5. Finally, add `* 100` to the end to multiply the result by 100 and create the percentage.

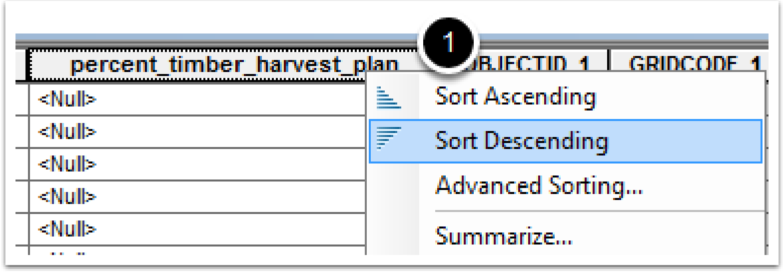
When done, verify it against the expression in the screenshot, and then click OK to run it and calculate the field


Field Calculator
Parser
VB Script
Python
1
Fields:
OBJECTID
Shape
Join_Count
TARGET_FID
gridcode
DATE
STREAM
DESC
2
Type:
Number
String
Date
Functions:
.conjugate()
.denominator()
.imag()
.numerator()
.real()
.as_integer_ratio()
.fromhex()
.hex()
.is_integer()
math.acos( )
math.acosh( )
math.asin( )
Show Codeblock
3
4
* / & + - =
percent_timber_harvest_plan =
((!VALUE_88! + !VALUE_89! + !VALUE_90! + !VALUE_91! + !VALUE_92! + !VALUE_93! + !VALUE_94! + !VALUE_95! + !VALUE_96! + !VALUE_97! + !VALUE_98! + !VALUE_99!) / !Shape_Area!) * 100
About calculating fields
Clear
Load...
Save...
OK
Cancel

12.4 Look at the values

Now that we have the values calculated, let's examine them. There will still be some 0 values since not every watershed has timber harvests.

Right click on the field header and select *Sort Ascending* to sort the records so that the largest percentages are at the top.



12.5 Examine the results

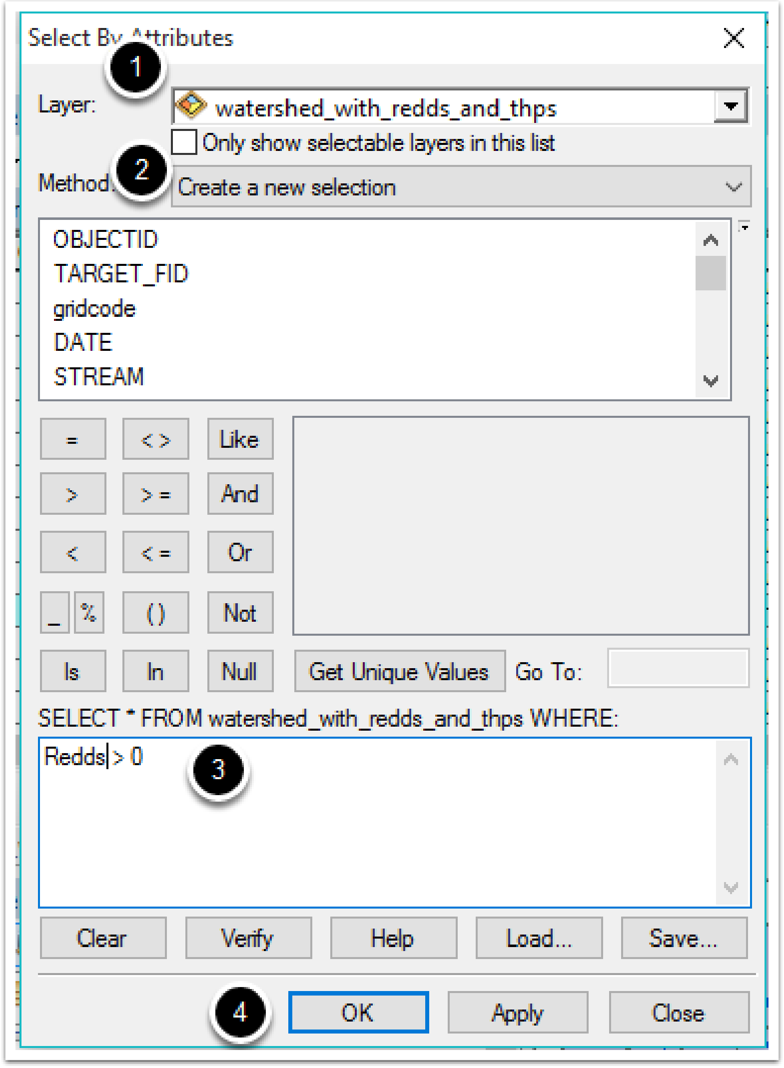
Do these numbers look good? If you select the record that's above 99% timber harvests, does it look on the map like that's correct? Is most of that watershed covered with timber harvests? Do some spot checking to confirm, but in all likelihood, it will look fine.

GPSID	percent_timber_harvest_plan	OBJECTID_1
<Null>	99.15832	79
<Null>	97.969634	11
<Null>	97.216608	118
<Null>	96.824848	67
<Null>	96.730865	232
<Null>	94.879298	115
<Null>	94.768675	17
<Null>	93.820586	167
<Null>	93.512741	222
<Null>	93.248063	102
JS01	93.068693	13
<Null>	92.324388	16
<Null>	88.590288	147
<Null>	87.592989	34

13. Examining the relationship

Great! We've now generated our last piece of data before we can examine the relationship between timber harvests and salmon redds. One last piece of data management to do! We only want to examine watersheds that have redds, since otherwise it will be mostly zeros. To do this, we'll make a new temporary layer using *Select By Attributes.* Open Select by Attributes now.

1. Set the layer to select as *watershed_with_redds_and_thps*
2. Confirm that *Method* is set to *Create a new selection*
3. In the query box, type `Redds > 0`, which will select all the watersheds that have more than 0 redds - great!
4. Click OK to run the query and get the selection.

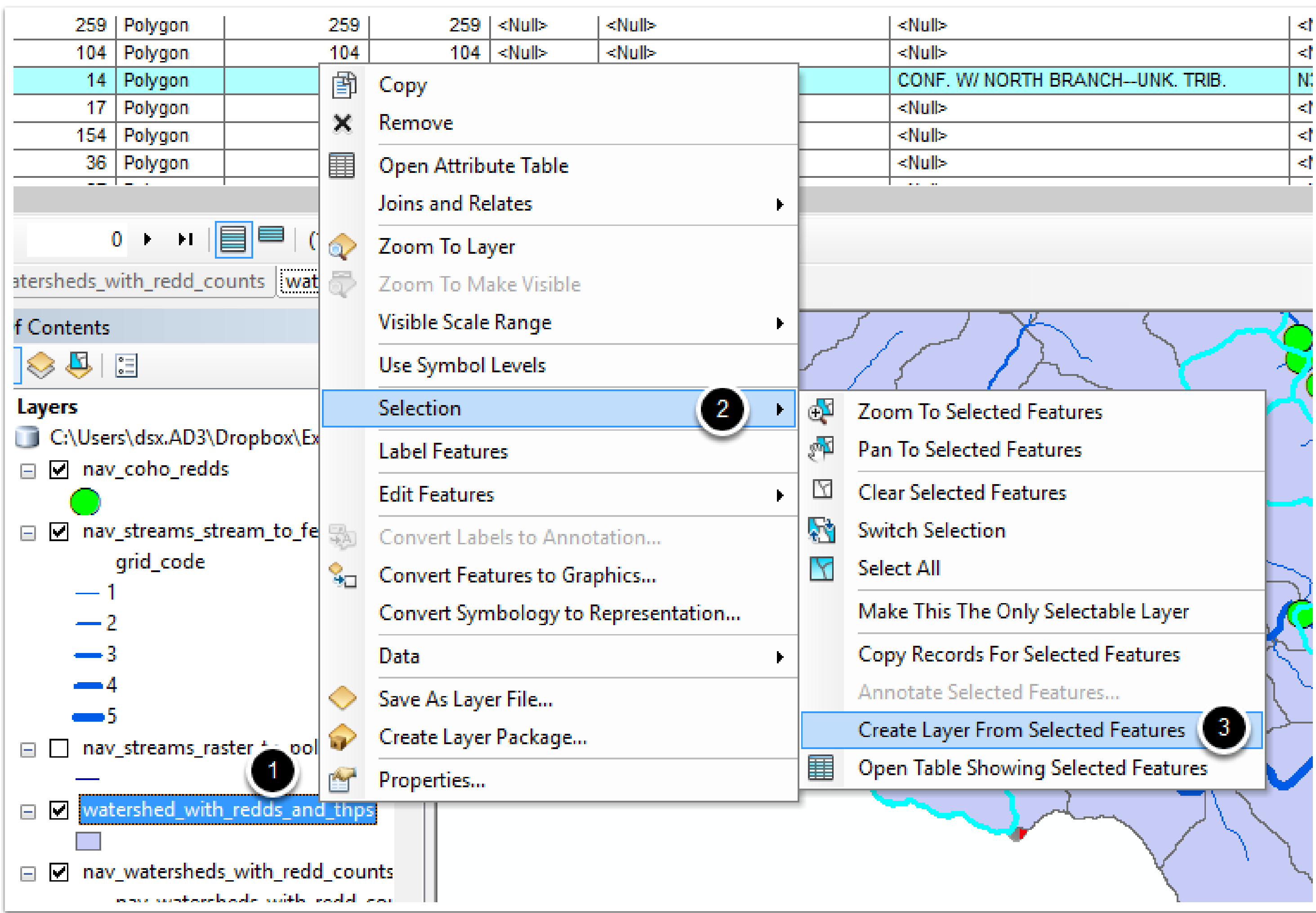


13.1 Make a new layer

Now, let's turn those selected features into a new layer we can examine.

1. Right click on the layer with the selection
2. Go to the *Selection* submenu
3. Click *Create Layer From Selected Features*

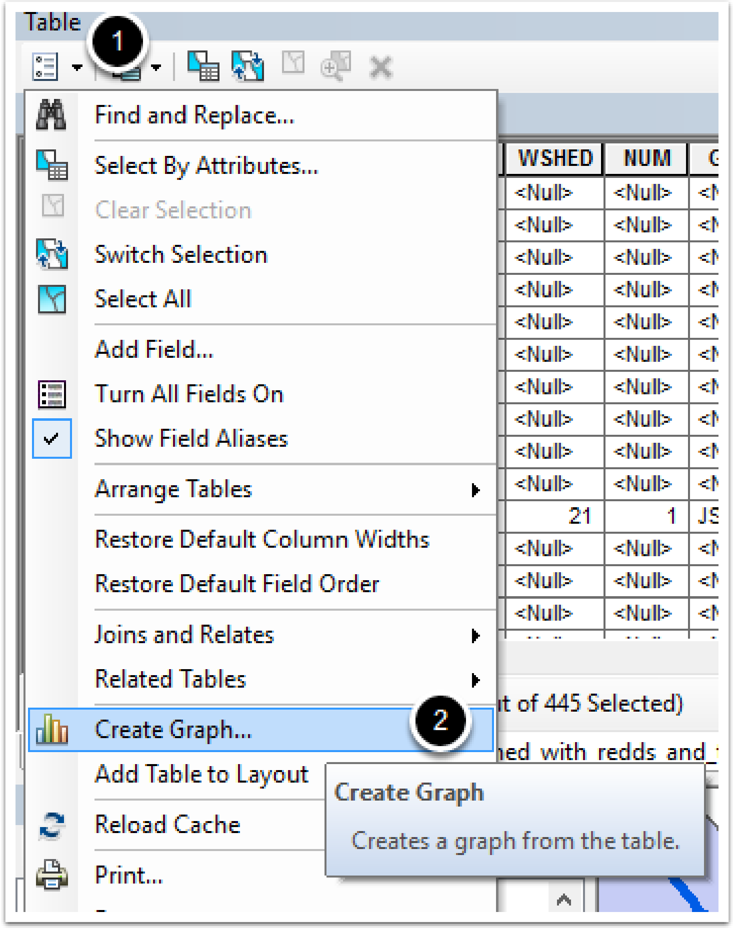
A new layer named *watershed_with_redds_and_thps selection* will be added to the map document



13.2 Finally, examining the relationship

Now, we can finally look at how these data relate - we'll do that with a graph of the number of redds vs the percentage of the watershed under timber harvest. Open the attribute table for the new layer created from the selection.

1. Open the table menu
2. Go to *Create Graph*



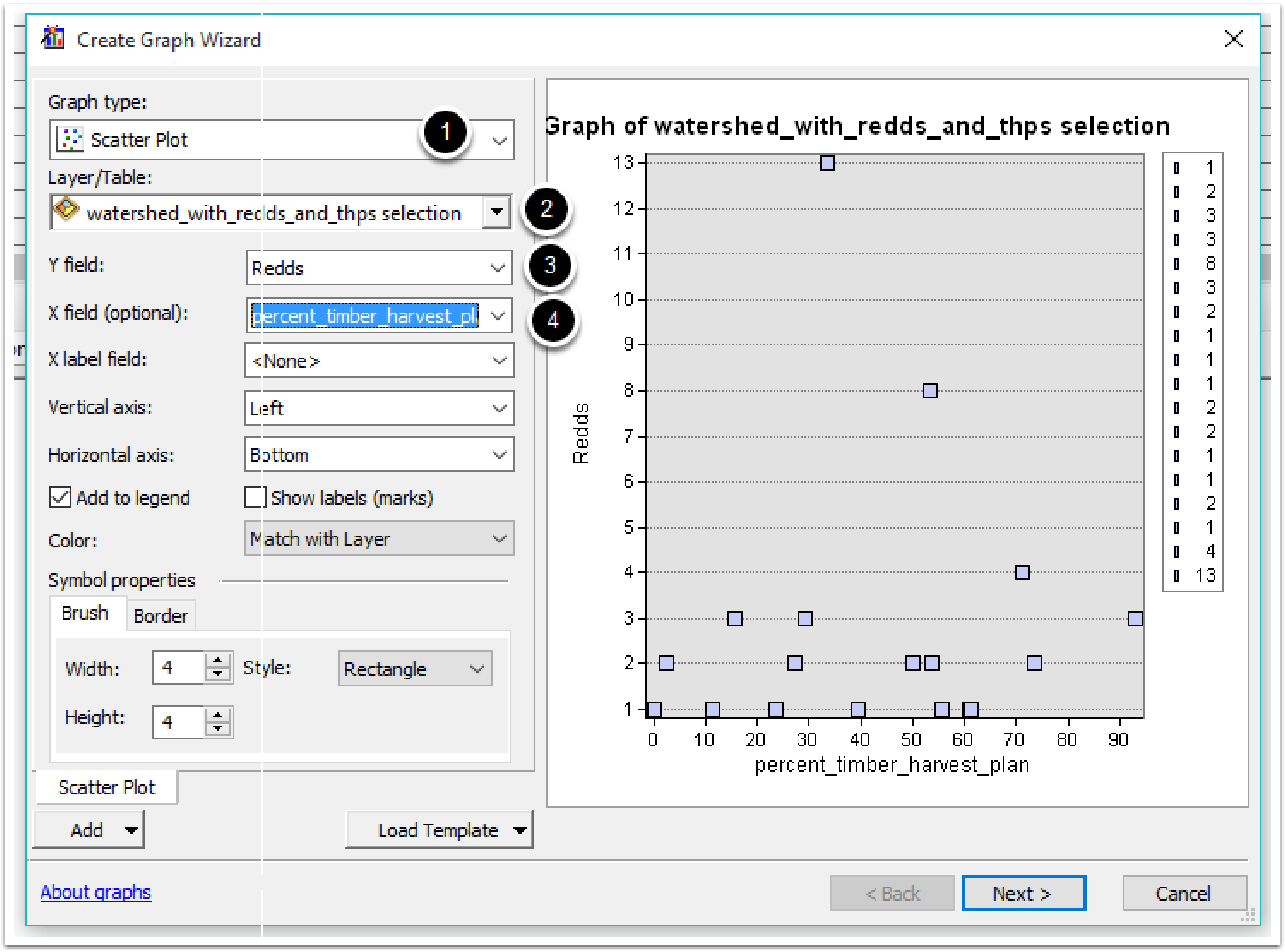
13.3 Creating the scatter plot

The *Create Graph Wizard* opens up. We'll look at these with a scatter plot that examines redds vs timber harvest area.

1. In the *Graph type* section, select *Scatter Plot*

2. In the *Layer/Table* section, we can choose any layer in our map document to make the graph based on - not just the layer we had open in the attribute table. Make sure that *watershed_with_redds_and_thps selection* is chosen here. Once you do, we'll have the ability to create graphs based on the attributes in this feature class
3. For the *Y field* choose *Redds*. Why this field? Well, you may remember that in graphs, your Y variable is usually the *dependent* variable - that is, we suspect that the value of Y is influenced by, or depends on, the value of X. So, since we suspect that the number of redds is influenced by the timber harvests - or that's what we're investigating, at least - then we set Redds to our Y value
4. For the *X field,* choose the field we calculated, named *percent_timber_harvest_plan*

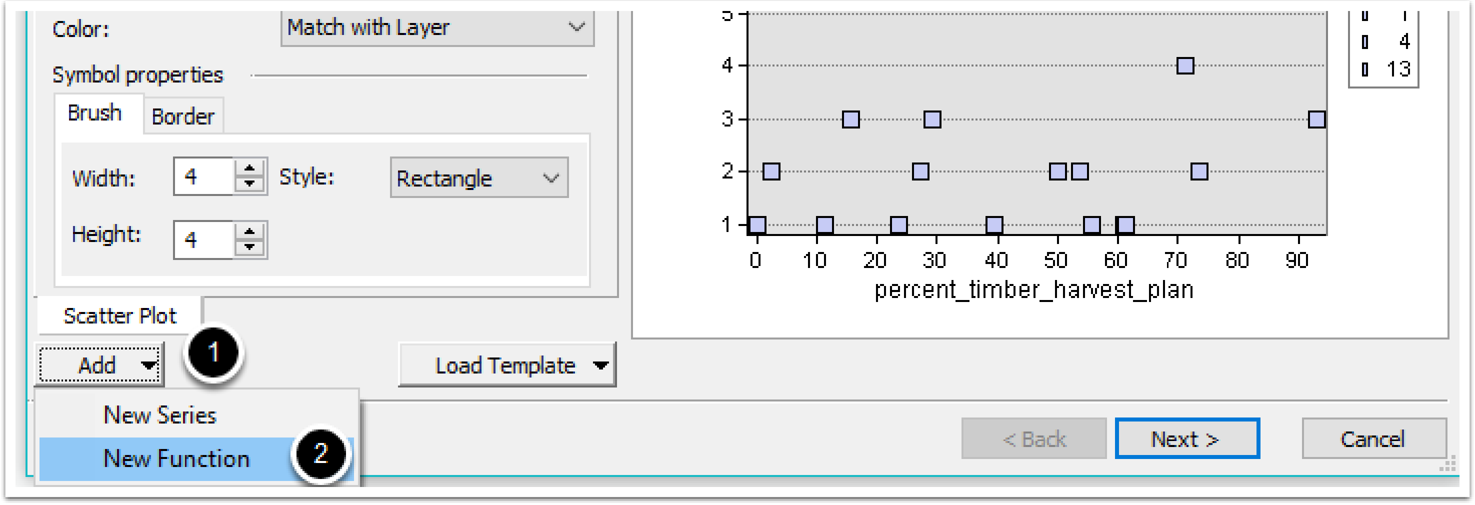
You should see the graph update, but it's a little hard to make out much of a relationship here right now!



13.4 Adding a function

Now that we've added the data to the graph, but it's hard to discern any relationship, let's add a function that can show us what might be going on.

1. Near the bottom, click the *Add* button so we cand add more data to our graph
2. Click *New Function.* This will let us add things like trendlines

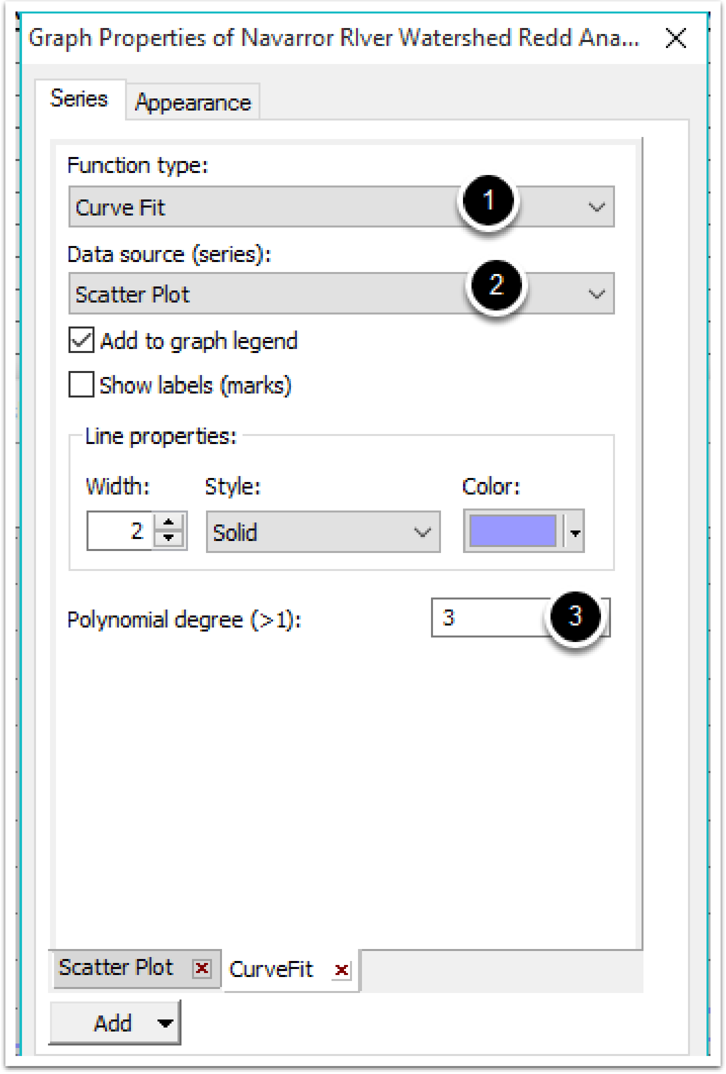


13.5 Changing the trendline

The side pane will change to show the new graph (note the tabs at the bottom for toggling between the differet *series* on the chart).

In this case, we want to see the trend of the data, but the data is probably too complicated to use a simple trendline, so we'll try a *Curve Fit.* Select Curve Fit from the *Function type* dropdown (1). Once you do, specify that the data source for the curve will be from the data named *Scatter Plot* that we just set up, using the *Data source (series)* dropdown (2). Your graph should update, but won't be complete yet. Further down, there is an option to select the *Polynomial degree* of the curve, which is a parameter that specifies how complex the curve can be while fitting the data (3). Try some different numbers here and see what happens with your graph, but when done, settle on the number 3.

Click *next* to continue to finalizing the graph (not pictured).



13.6 Interpreting the graph and finalizing the data.

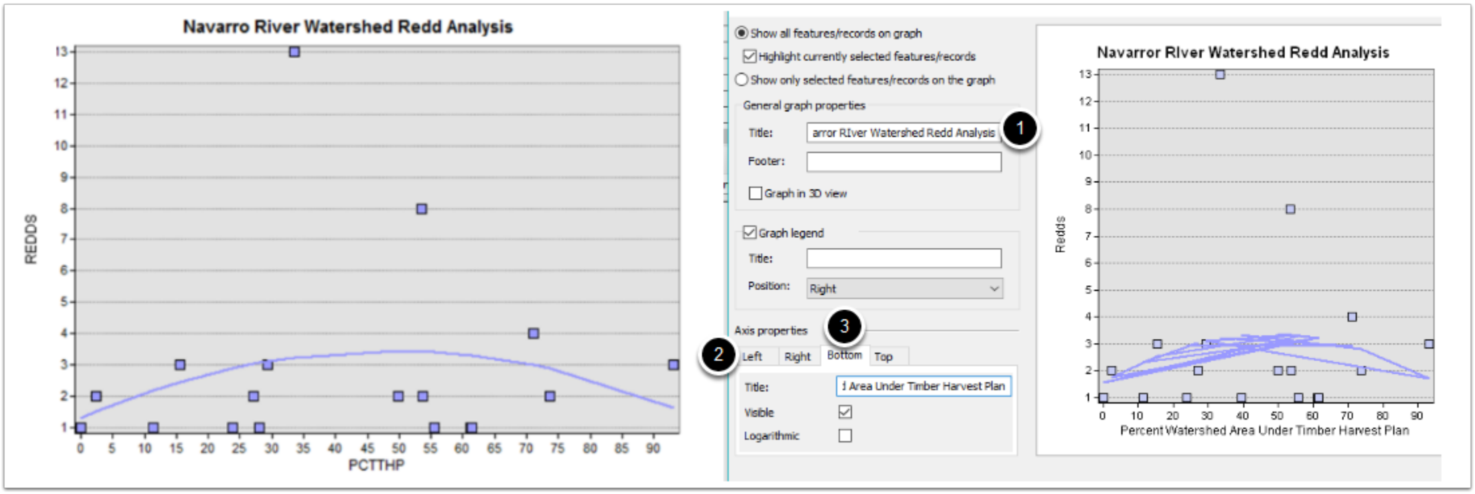
Which version of the graph below do you get? The grpah on the left is the correct version, and the graph on the right seems to be encountering an error in ArcGIS - not in what you're doing. If you get the graph on the right, see if you can debug the issue or work around it - maybe there's some oddity in what we're doing (though I haven't found it) - maybe you'll find the solution I haven't found. In previous versions of ArcGIS, the graph came out correctly as on the left. Interpret your graph as if it looks like the one on the left. Another potential workaround is to export the data table for analysis in Microsoft Excel (or other spreadsheet software).

This graph is the result of your analysis - the potential answer to our question of what impacts timber harvesting might have on salmon redds. What do you see in this graph - how should we interpret the data and results? Is there a trend here? Where there are more redds with moderate timber harvesting?

Think about this: What are potential sources of error in this graph? Think about the full process. Is there truly a trend, or do we just have some outliers influencing it? Are there mechanisms that could cause there to be more redds in areas that have a medium percentage are under timber harvest? If you're not an expert in these areas, you might not be able to answer these questions, but these are the types of questions you'll need to answer with your own data - are you seeing real trends, or artifacts of the data or processing?

Your analysis is now complete! To finalize the graph, do the following:

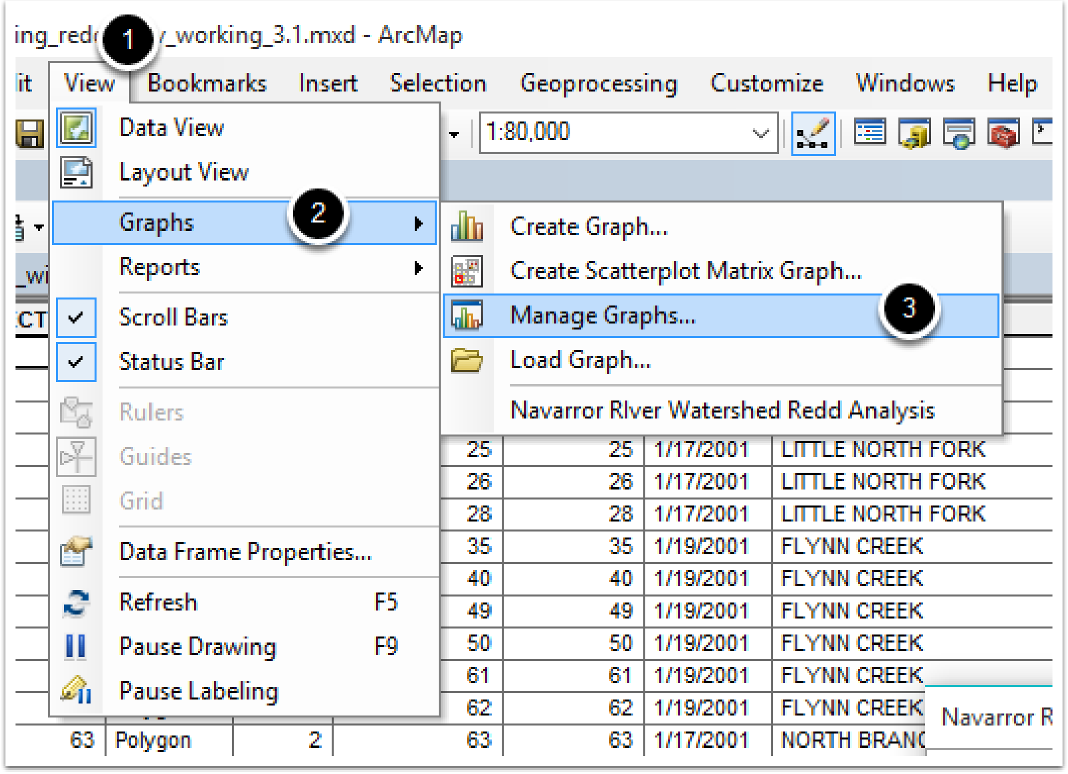
1. Give the graph the title *Navarro River Watershed Redd Analysis* in the *Title* field of the *General graph properties* section.
2. Title each axis appropriately - for the left axis, give it the name *Redds* on the *Left* tab in the *Axis Properties* section.
3. On the *Bottom* tab for the bottom axis, give the axis the title *Percent Watershed Area Under Timber Harvest Plan*
4. Click *Finish* to save your graph (not pictured).



14. Bonus: Finding your graphs again

After completing your graph, it pops up in a box in your map. If you happen to close that box, it can appear that the graph is missing or unretrievable. It's not! To see all of your graphs, you can:

1. Go to the *View* menu
2. Go to the *Graphs* submenu
3. Open *Manage Graphs*



14.1 The Graph Manager Sidebar

The *Graph Manager* sidebar will pop up, with an entry for all of the graphs in the current document. If you right click on a graph in the Graph Manager, you'll get options to edit and view the graph again.

On your own: See if you can figure out how to add the graph to a layout view (see course video on graphs for more), and how to export graphs as an image.