Creating and Assessing DEMs from Points and Raster data

UC DAVIS EXTENSION

Decreasing cost and increased availability of low-cost elevation acquisition have brought DEM/DTM generation back into use. While high-resolution national DEM data are now available, some applications have need or use for higher resolution or higher reliability data collected on-site.

In this lab, you will take a set of points collected by on-site equipment and generate a DEM from it. From that DEM, you will generate streamlines and verify and correct those streamlines. You will then merge your DEM into a more coarse regional DEM and assess the accuracy of your overall DEM.

1. Getting Familiar with the Study Area

In reality, unless you're an expert in terrain generation, you're unlikely to need to generate terrain for a study area unless you're *really* familiar with it. You would have been on the ground, you'd have a sense for how the area looks, and you'd probably know when something in your study area is a little off. We're going to be working on creating a DEM for an area in the Navarro River watershed, so you should know where that is, and explore it in Google Earth a bit first, or in ArcMap with a basemap (but I'd recommend Google Earth so you can explore in 3D).

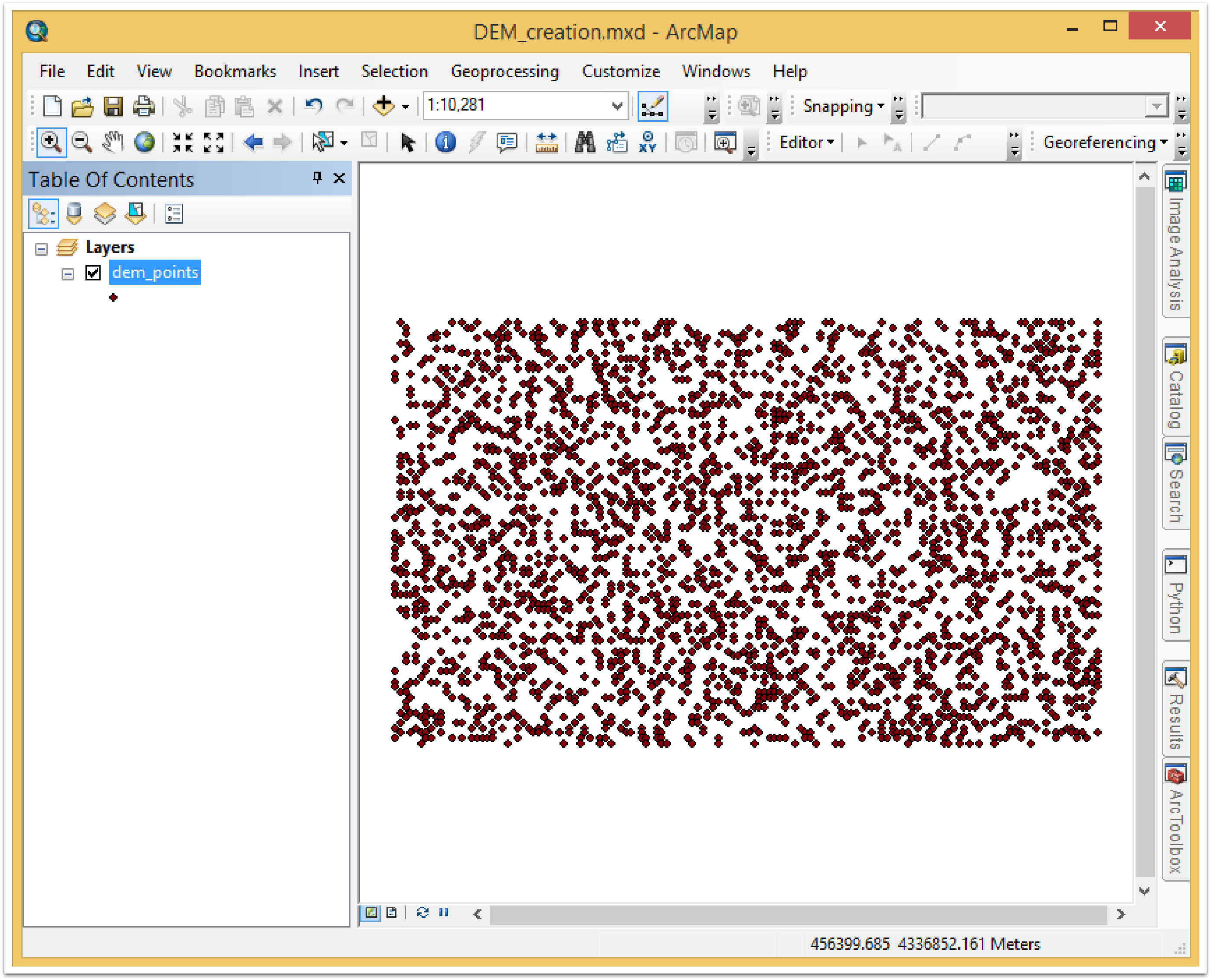
The image below is a screenshot of the area we're building the DEM of from within Google Earth. In case it prints out as a gray/black mess, the coordinates that this location are *39 degrees 10' 36.31" N, 123 degrees 29' 58.96" W* so you can navigate to it. Once you feel like you have a sense for what the area looks like and what the terrain appears to be like, go on to the next step.


Image USDA Farm Service Agency
Google e

2. Getting Started

To begin, open ArcMap. Add *dem_points* from *advanced.gdb* to your map document. These points are a subset of field elevation data from the area. I'd recommend setting your map document's default geodatabase to a new geodatabase in your data folder (something named *scratch.gdb* or something) for easy access to those results - that's not required and up to you though.

Before moving on, take a quick look at the attribute table of the *dem_points* dataset to familiarize yourself with it.

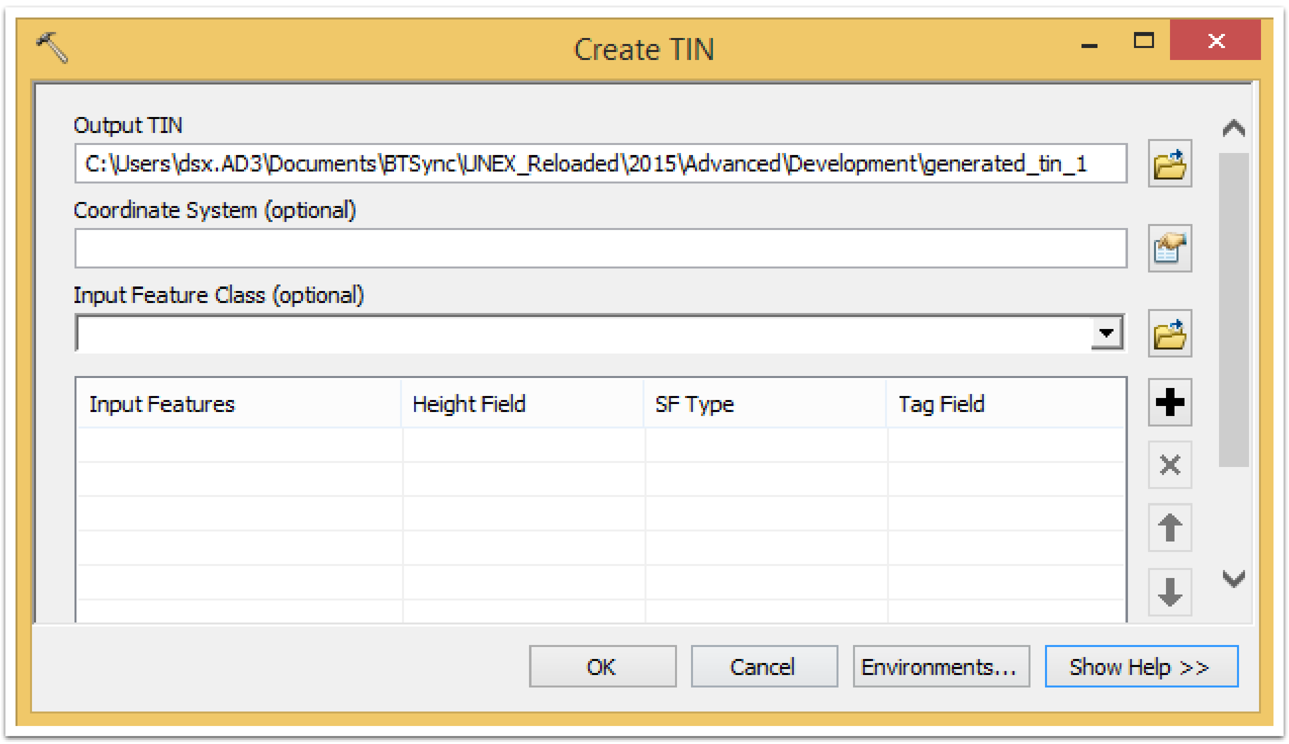


3. Making the initial DEM

To start with, we're going to make these points into a *Triangular Irregular Network* or *TIN*. This method of DEM generation is nice because it's simple to understand and doesn't try to do anything to fancy (which can get you into trouble when incorrectly applied). The TIN is a vector-like format that takes each point and connects it to its neighboring points to make a set of triangles. Each point location has Z values specifying elevations, and the triangle faces and edges provide the elevations for the locations between the points. It can then be converted into a more familiar raster format.

First, enable the 3D Analyst extension (same way you enable other extensions - from the *Customize->Extensions* menu option). Then, in ArcToolbox find the *Create TIN* tool either by searching, or by navigating to *3D Analyst Tools>Data Management>TIN>Create TIN*.

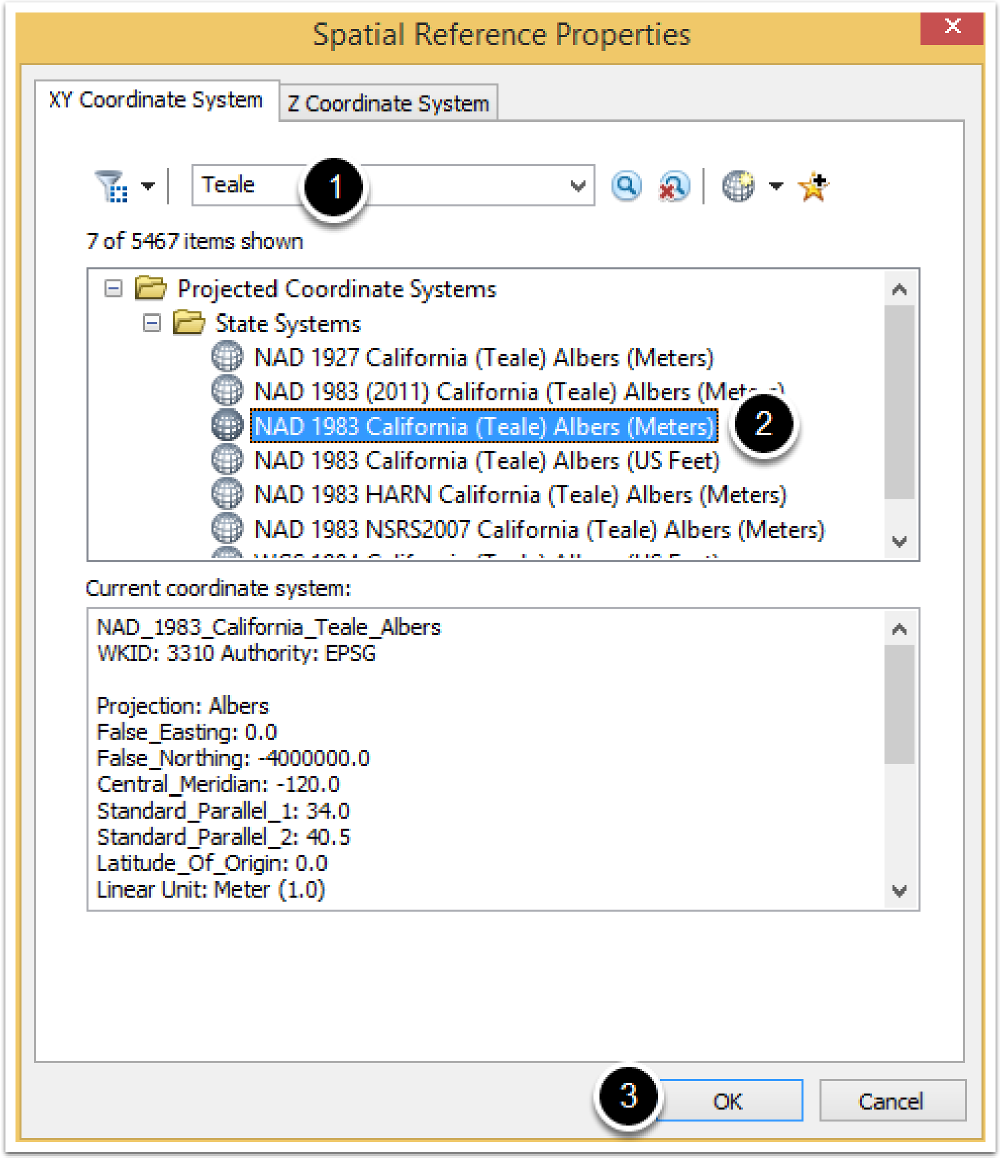
First, note that in this tool, you set the outputs before the inputs - just an oddity to pay attention to. Leave the output in your default geodatabase location, but it will use the folder, not the geodatabase, due to the needs of the TIN format. Name your output TIN *generated_tin_1*.



3.1 Set the coordinate system

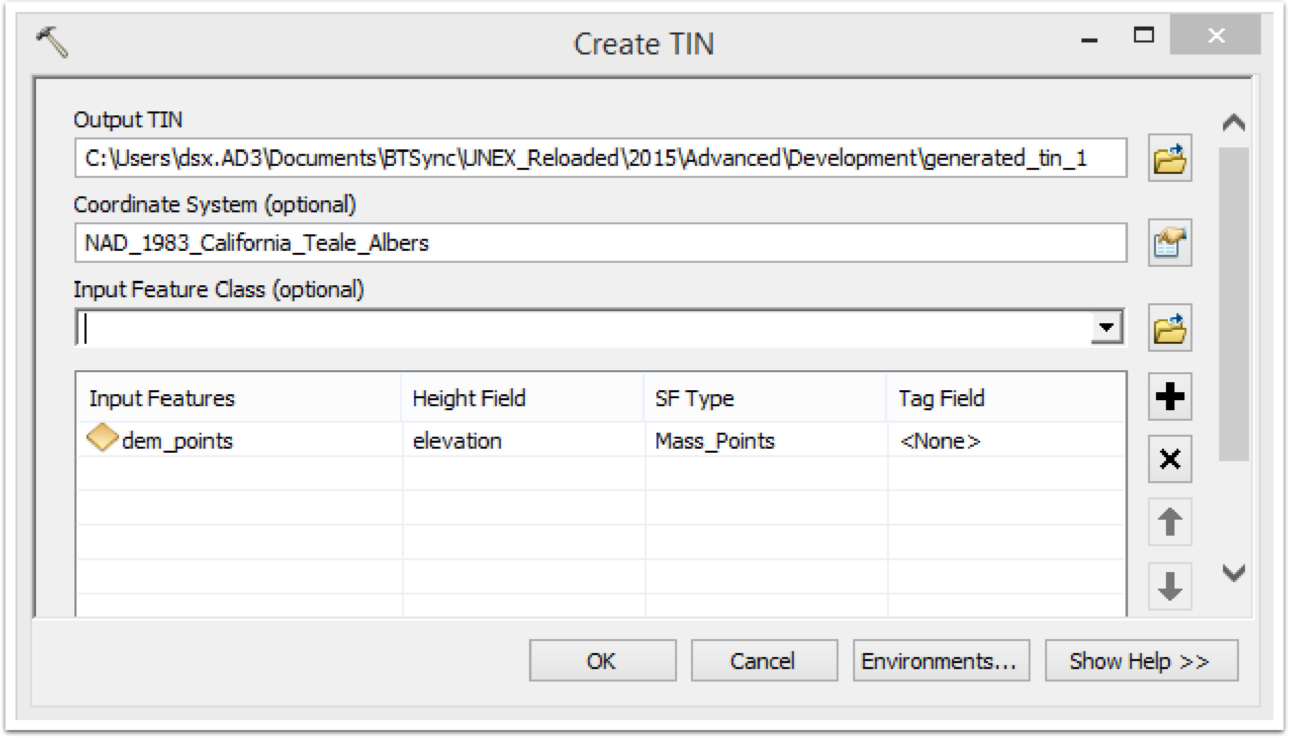
Set the output coordinate system to *NAD 1983 California (Teale) Albers (Meters).* To do so, click the button next to the *Coordinate System* box, then:

1. Type *Teale* in the search box
2. Click on the appropriate projection in the results
3. Click OK



3.2 Set your input features

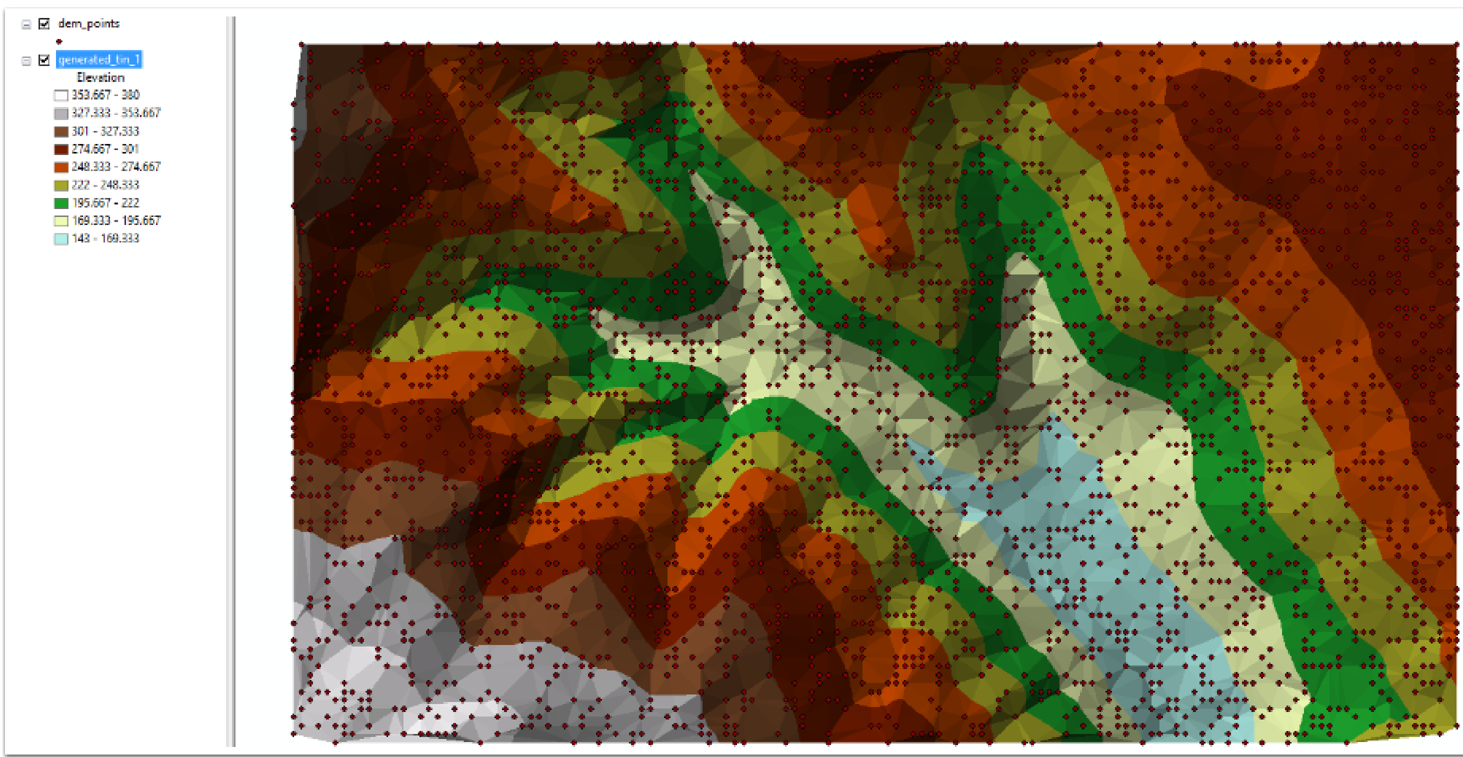
Select dem_points from the *Input Feature Class* dropdown and it will appear in the box below. Make sure that, under *Height Field* it is using *elevation* - this is the field that the *TIN* will use to determine your elevation values. Then, click OK.



3.3 The TIN view

Once processing is complete, you'll see a TIN dataset under your points, shaded into color bands by default. What's going on with the different shades of each color though? The TIN is rendered with a 3D tinting effect that will allow you to see the triangles and intuitively perceive depth in the TIN - if you've used other 3D animation software, it's similar in its rendering. Remember, the TIN is a truly 3D data structure (where the raster DEM is a 2D data structure construed as a 3D one). Zoom and pan around and take a look at how the triangles are connected and their various sizes. Will this affect your DEM accuracy? How are these sizes determined? Browse around the layer properties to see how it differs from other datasets.

If we were using more irregularly shaped field data, we would now need to run the *Delineate TIN Data Area* tool to constrin the TIN to the areas we want it to occur in - but since we're using a rectangular group of points, our TIN looks pretty good already.

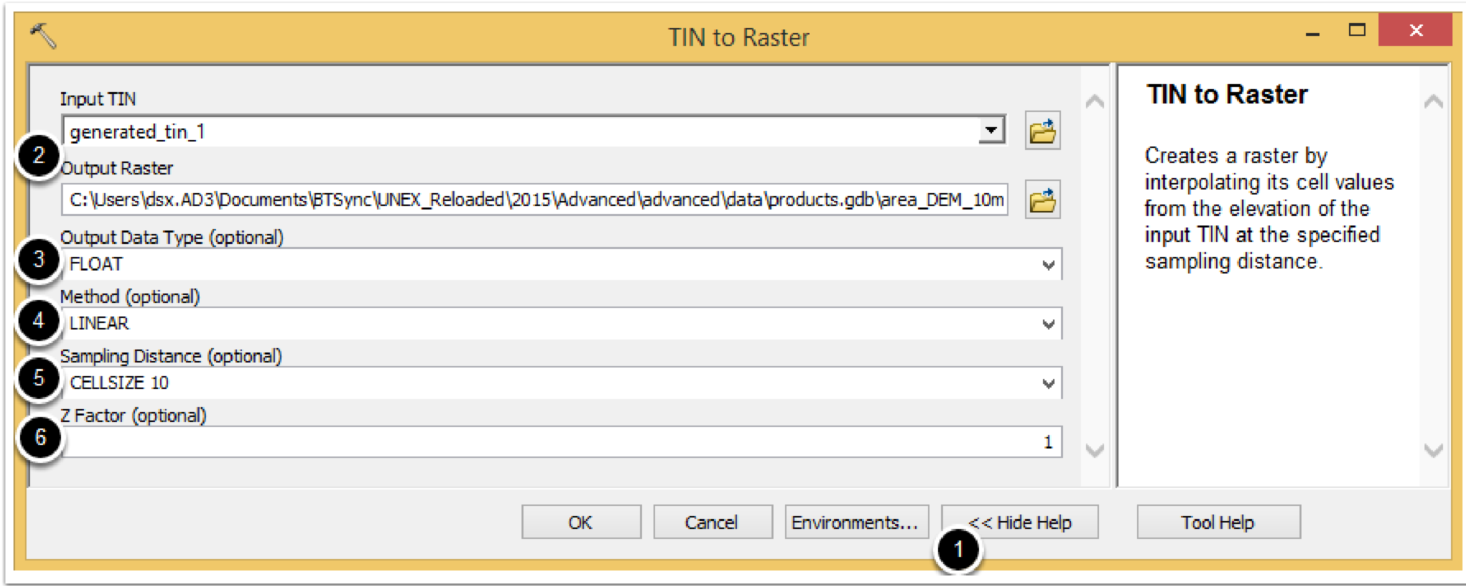


3.4 Back to raster

OK, the terrain looks decent to me, compared with what we'd expect for our study area. Now that we have this beautiful 3D terrain model, it's time to take it...back to raster format. Why? Because raster is used *everywhere* and TINs are pretty specific. Fortunately, there's a tool for this. Maybe you can guess that it's called *TIN to Raster* - search for it, or find it under *3D Analyst Tools>Conversion>From TIN>TIN to Raster* and run it.

1. Make sure that you're showing the tool's help sidebar (bottom right button if you aren't) and take the time to read through the overview, but also what the main parameters do.
2. Use your TIN for the input TIN, and save your Output Raster in your products geodatabase (*products.gdb*) - I named mine *area_DEM_10m*.
3. Most DEMs are integer data (why might that be?), but leave yours as FLOAT for now in order to better capture the surface variability.
4. Look at the help for the *Method* parameter, but leave it at its default setting of *Linear*.
5. For *Sampling Distance,* look through the help parameters, then change the value to say *CELLSIZE 10* (what does that mean in this case?)
6. Again, look at the help for Z Factor to understand what it means, and leave it at its default value of 1.

Click OK



4. Assess your DEM

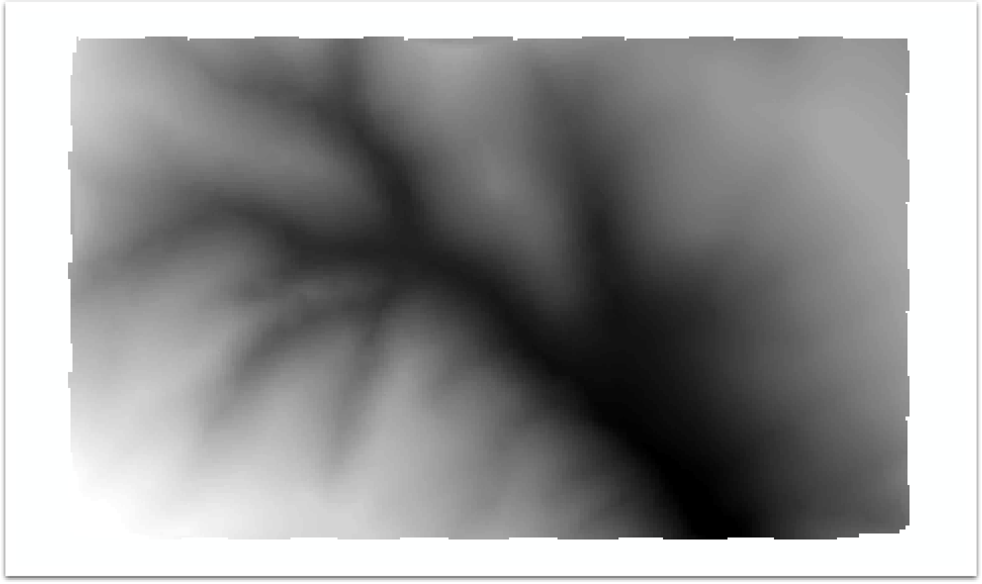
When the process finishes, you might need to turn off layers above it to see it. Then assess your DEM - does it look like what you'd expect based on your knowledge of the area and what your TIN looked like? Is it smoother or coarser than your TIN? In what ways?

Think for a moment about what factors in the TIN creation process and the raster conversion affect your output raster. Let's tweak one of those, the *Samping Distance* on the *TIN to Raster* tool, repeatedly to see how it changes our output. (**Tip**: To keep rerunning a process quickly, you can open up the *Results* pane (under the *Geoprocessing* menu) and double click on your last tool run in the session to bring up a prefilled tool window - tweak the parameters (including the *Output Raster*) in order to get your desired results)

Run *TIN to Raster* 3 more times, setting the following parameters

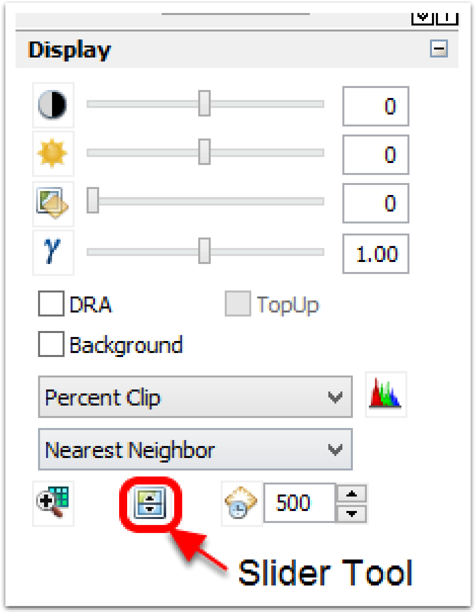
1. **Sampling Distance:** *CELLSIZE 30* **Output Raster:** *area_DEM_30m*
2. **Sampling Distance:** CELLSIZE 5 **Output Raster:** *area_DEM_5m*
3. **Sampling Distance:** OBSERVATION 250 **Output Raster:** *area_DEM_obs250*

Feel free to run any other values you'd like to explore as well.



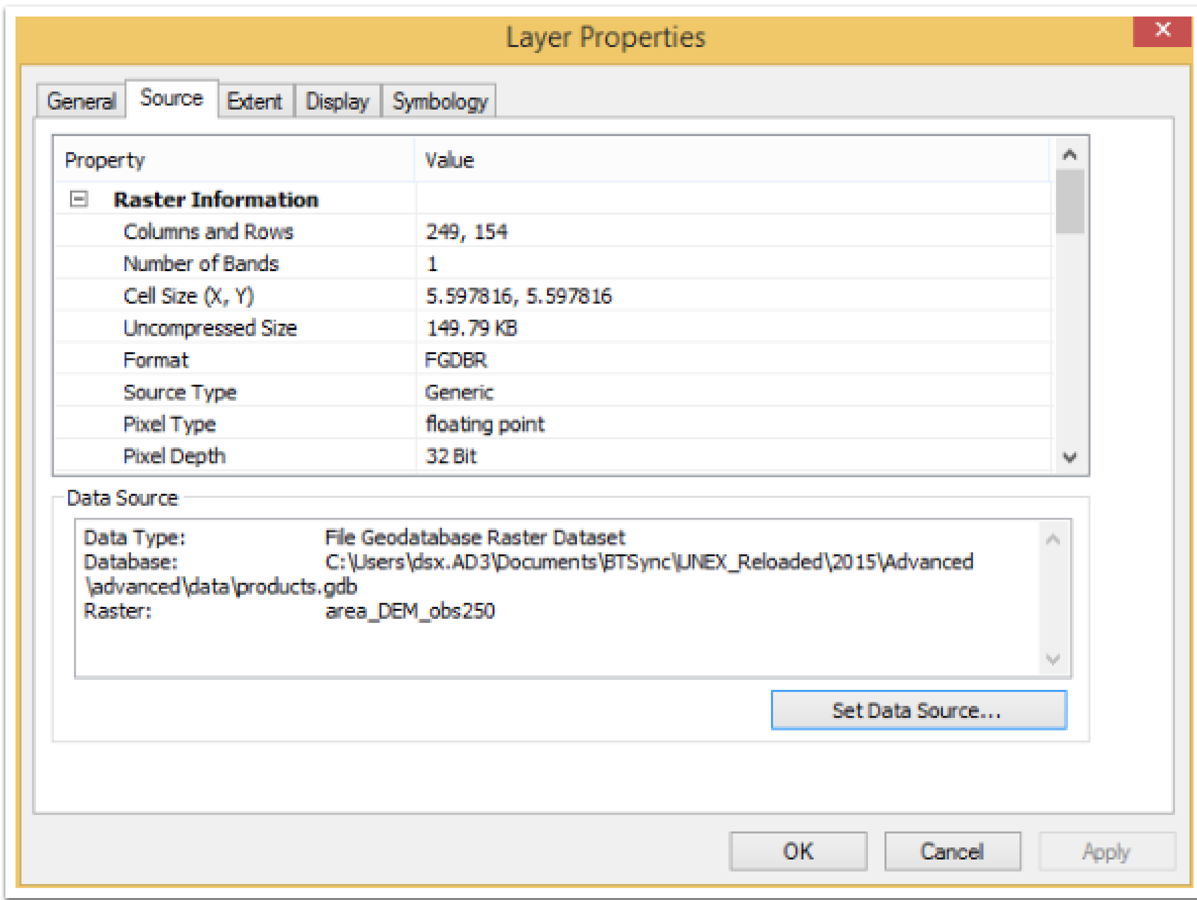
4.1 Comparing the DEMs visually

Use the *Image Analysis* sidebar (from the *Windows* menu) to compare your different DEMs. Turn on the layers for two that you'd want to compare (try the 30m and the 5m first, for an obvious change), and use the *Slider* tool (see image below) to drag across the images and compare them.



4.2 Comparing the Cellsize methods

Now, use the slider on the *area_DEM_obs250* and the *area_DEM_5m* layers. Do they look visually different to you? Check the cellsize of *area_DEM_obs250* in the layer's properties to see what the tool determined it to be. Would you expect this? If you need a reminder of how it determined that cellsize, look at the tool help pane again for what it does when you set *OBSERVATIONS 250*.

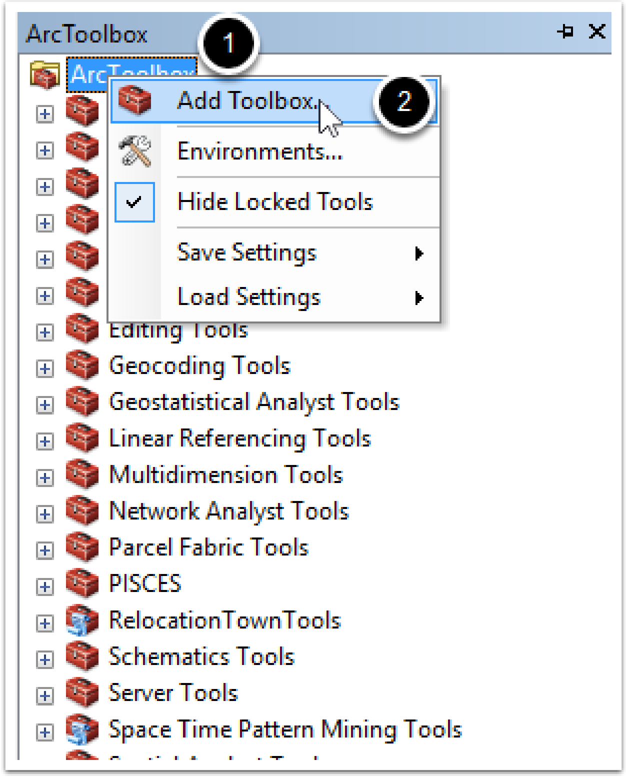


4.3 Add the streamlines toolbox

To further assess the DEMs, we'll need a new tool in ArcToolbox. We'll explore more about what it does in a moment, but for now, know that you can build custom geoprocessing tools of your own - you'll learn how to do this in the next course in the specialization, but for now, we'll use one of these custom tools.

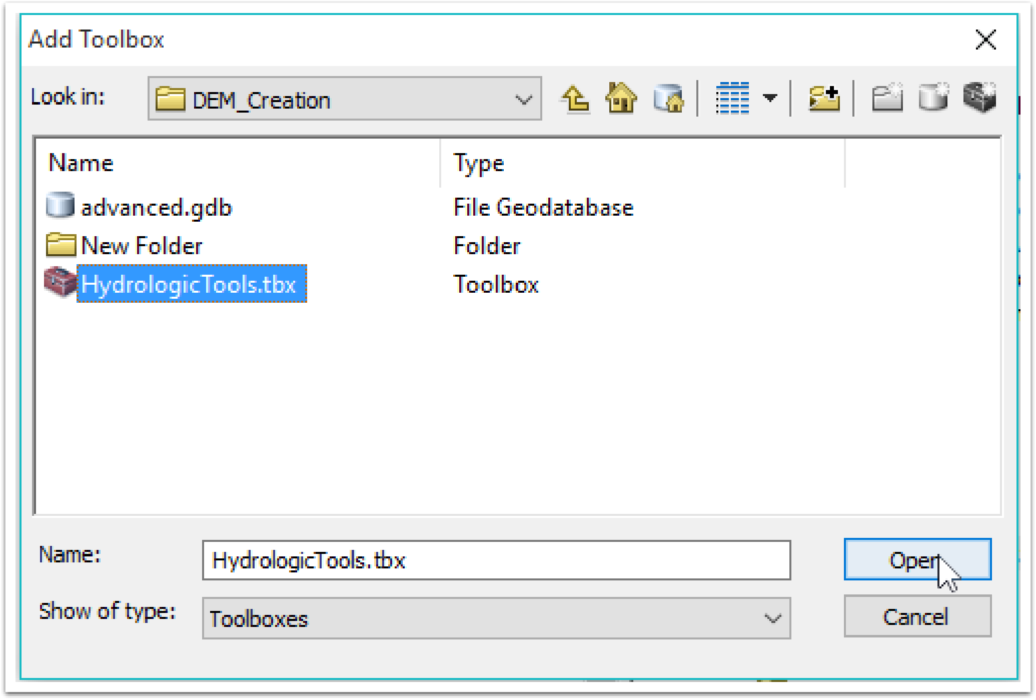
To add the toolbox,

1. Right click on the root element of *ArcToolbox*
2. Click *Add Toolbox*



4.4 Find and add the toolbox

Navigate to the folder that has your geodatabase for this tutorial and find *HydrologicTools.tbx* - click on it, but don't double click on it - click once on it, then click *Open* to add it to your ArcToolbox.



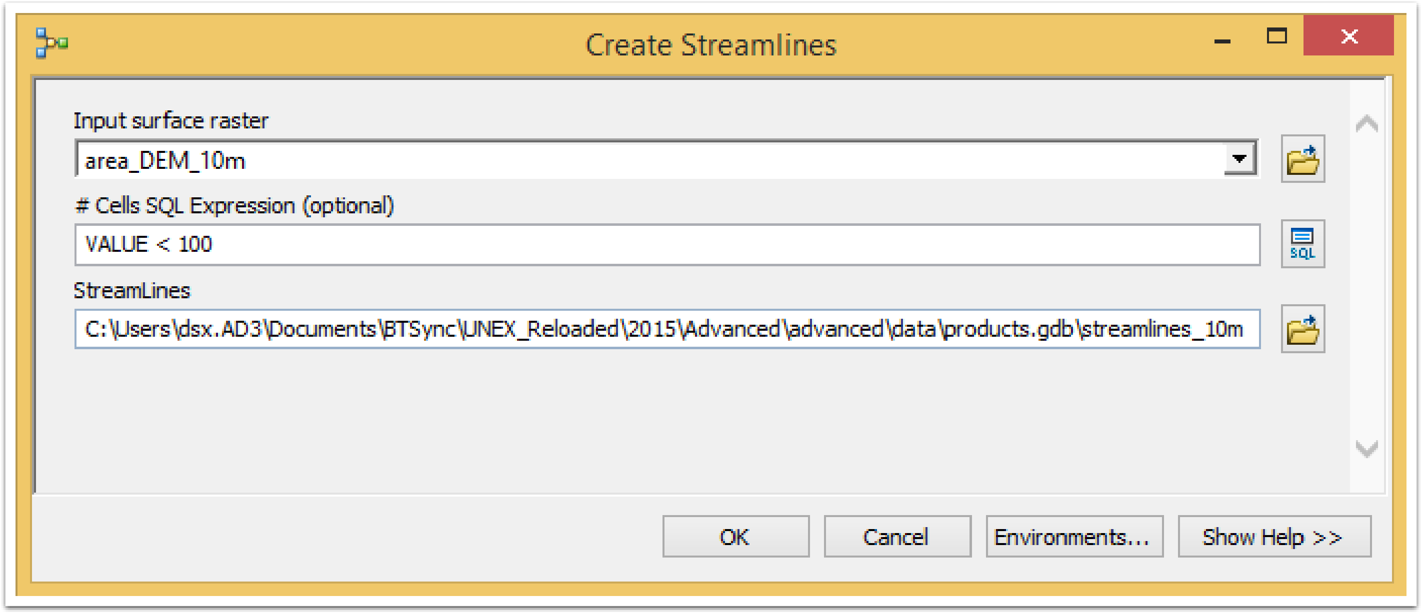
4.5 Figuring out which cellsize to use

One measure of DEM information content is how many sinks - ie, localized low points that capture all water flowing in, without an outlet - the surface has. Generally speaking, these sinks are rare on the landscape, so a DEM that has fewer sinks is likely better capturing the surface's true information. For now, we'll limit our assesment to just the 5 meter and 10 meter DEMs you generated, and we'll do a visual assessment.

Once you have HydrologicTools.tbx in ArcToolbox, the toolbox will show up in your ArcToolbox tree. Locate it in the tree by name, then expand the toolbox and you'll see it contains just a single tool, named *Create Streamlines*. Double click the tool to run it.

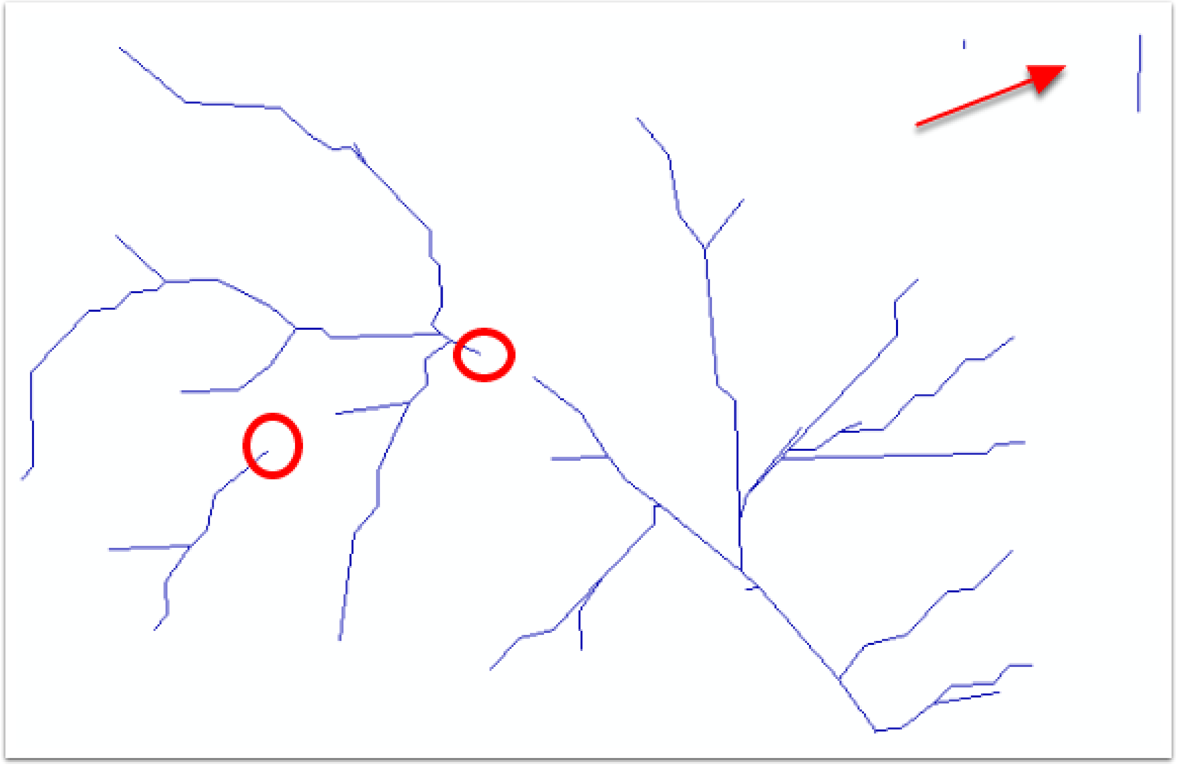
This tool runs all the processing necessary to create streamlines from a digital elevation model. It takes a parameter (named *# Cells SQL Expression*) that is a raster calculator expression to determine how many upstream cells, as a proxy for upstream area, are necessary before an area is considered a stream. The default is 100 cells, so it is written as VALUE < 100.

The first time through, we'll run it with the 10m DEM surface and with the default value for *# Cells SQL Expression*. Save your output in your *products.gdb* geodatabase as *streamlines_10m*. Run the tool.



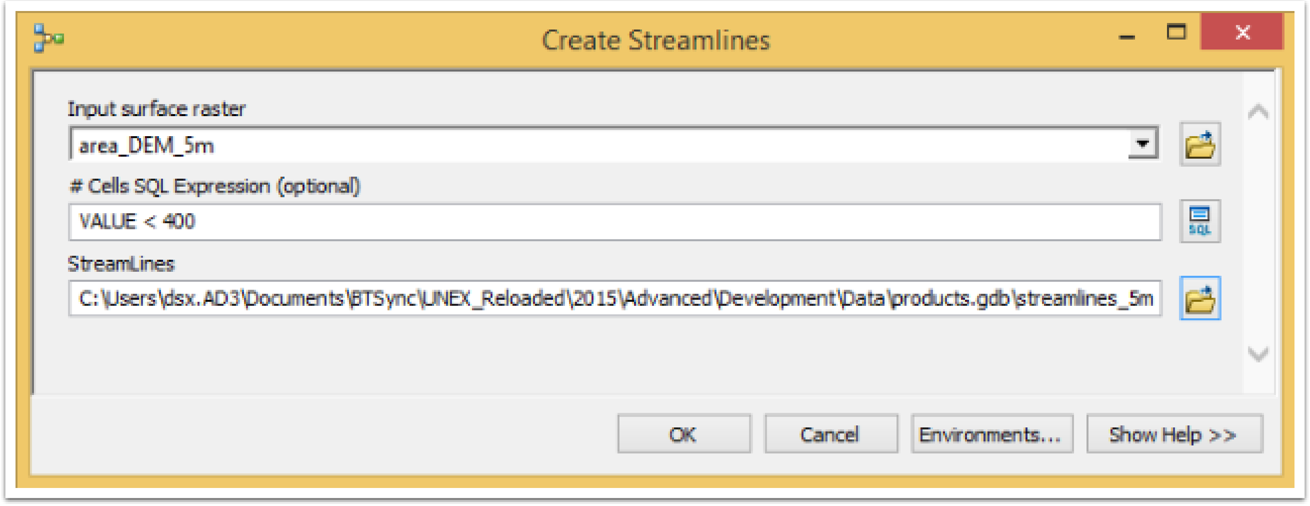
4.6 Everything but the sink(s)

Taking a look at the output that is returned by the tool, I see two primary sinks - the places where streamlines abrupty end. These are circled below. There's another location that could be a sink, but is probably water flowing the other direction out of our study area. At the circled locations, our streamlines disappear as the water gets trapped in our DEM. So, streamlines generated from our 10 meter DEM have 2 sinks.



4.7 Assessing the 5m DEM

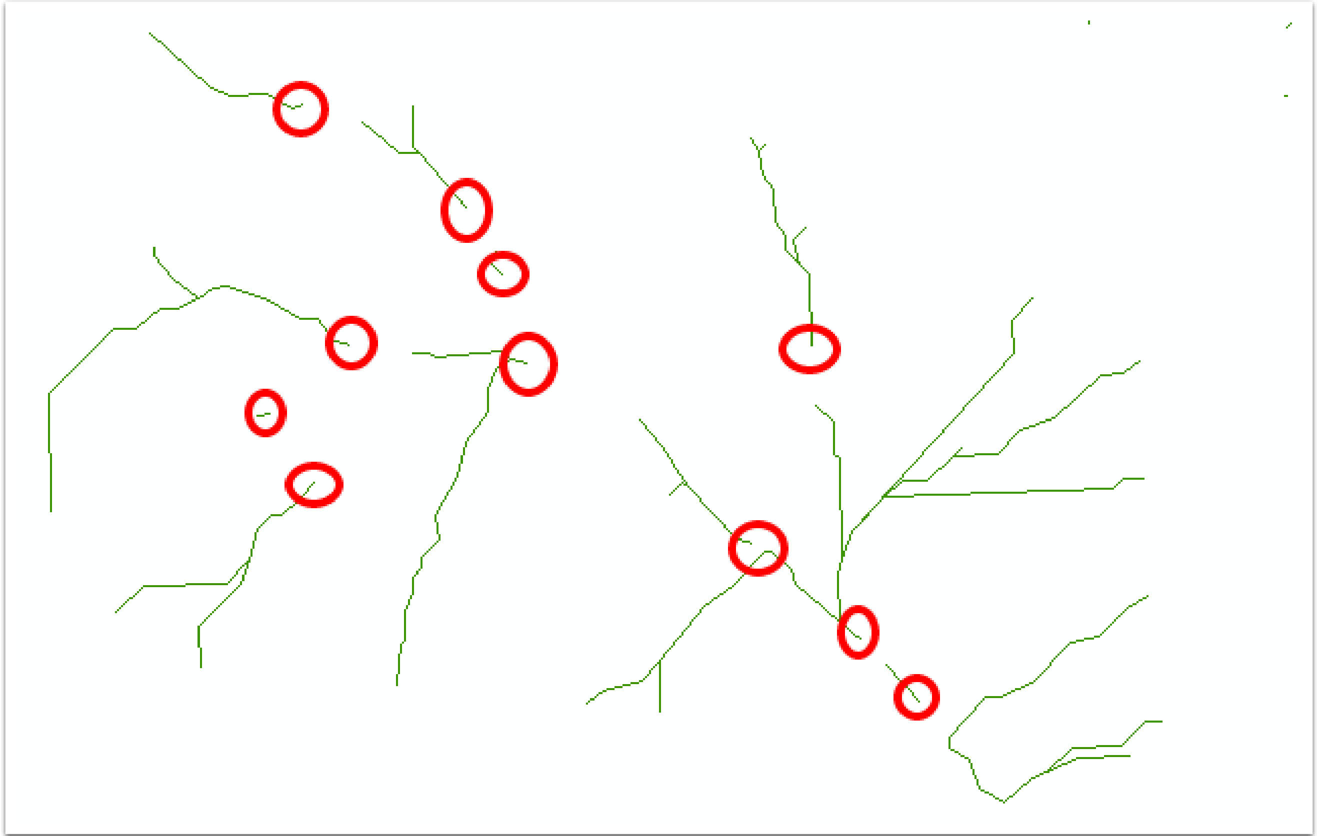
Now, run the same tool again, but on the 5m DEM. This time, think for a moment about the *# Cell SQL Expression* parameter. It identifies the number of cells upstream that are required before something is considered a streamline - if we wanted 100 cells for the 10m DEM, how many would we want to get approximately equivalent streamlines from a 5m DEM? 400! So, set the *# Cells SQL Expression* parameter to *VALUE < 400*.



4.8 Counting up your sinks

Let's count the number of sinks in the 5m DEM now. They are all circled below. By my count, we have 11 sinks - almost 6 times as many as the 10 meter DEM for this small area! **For a quick analysis of DEM information content, this suggests that we should probably choose the 10m DEM and streamlines instead of the 5m.**

For now, remove all other DEM surfaces, except your 10m version, from your map document.

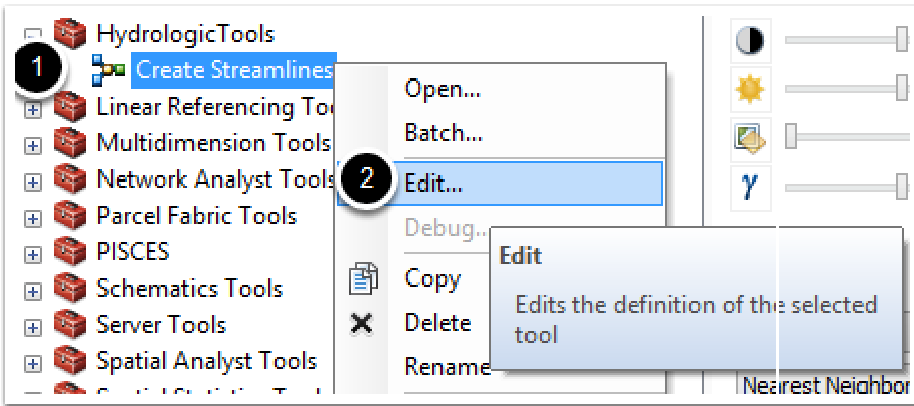


5. Optional: Creating streamlines without sinks

You're done, for now, with your DEM and analysis of sinks. If you want to continue on, you can follow the remaining steps, but only if you *already* know how to use ModelBuilder in ArcGIS. If you don't know what it is, you probably don't know how. So, come back to this after finishing the fourth course in the specialization and try it then!

At some level, sinks in DEMs are inevitable unless the DEM has undergone *hydrologic reconditioning* such as the DEMs from NHDPlus. Let's modify our *Create Streamlines* model to do this as part of its workflow so that we get more correct streamlines out of the process.

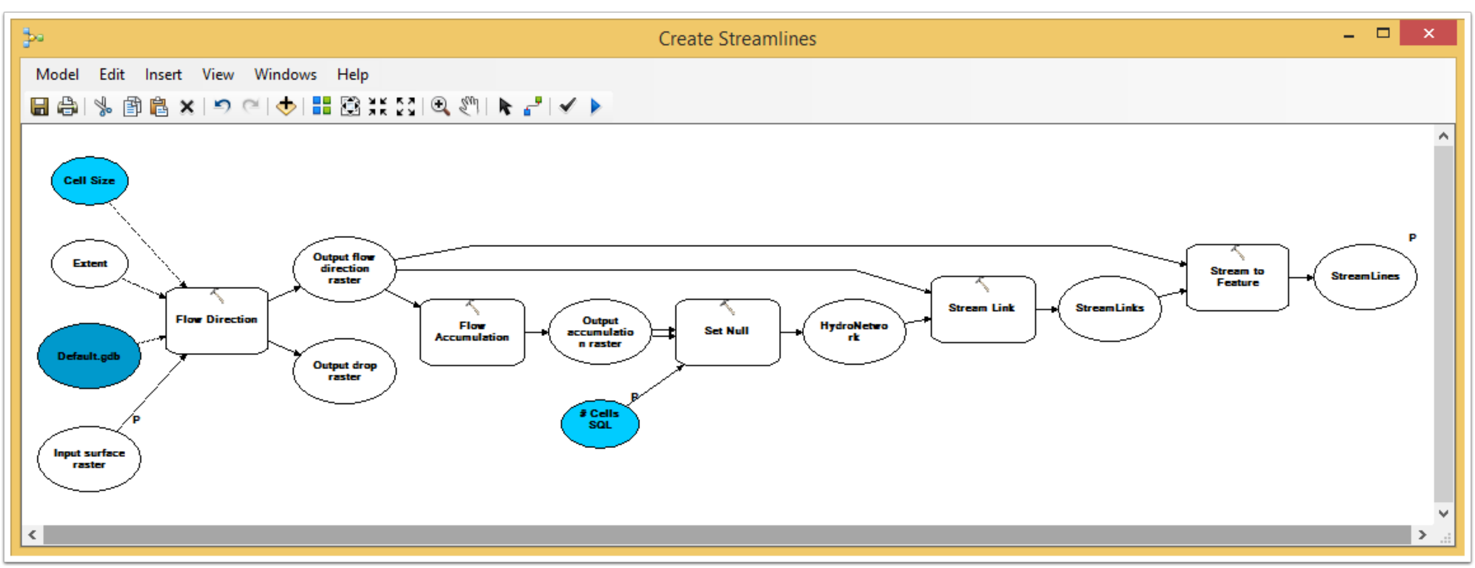
To get started, right click on *Create Streamlines* in the toolbox and then click on *Edit.*



5.1 Understanding the model

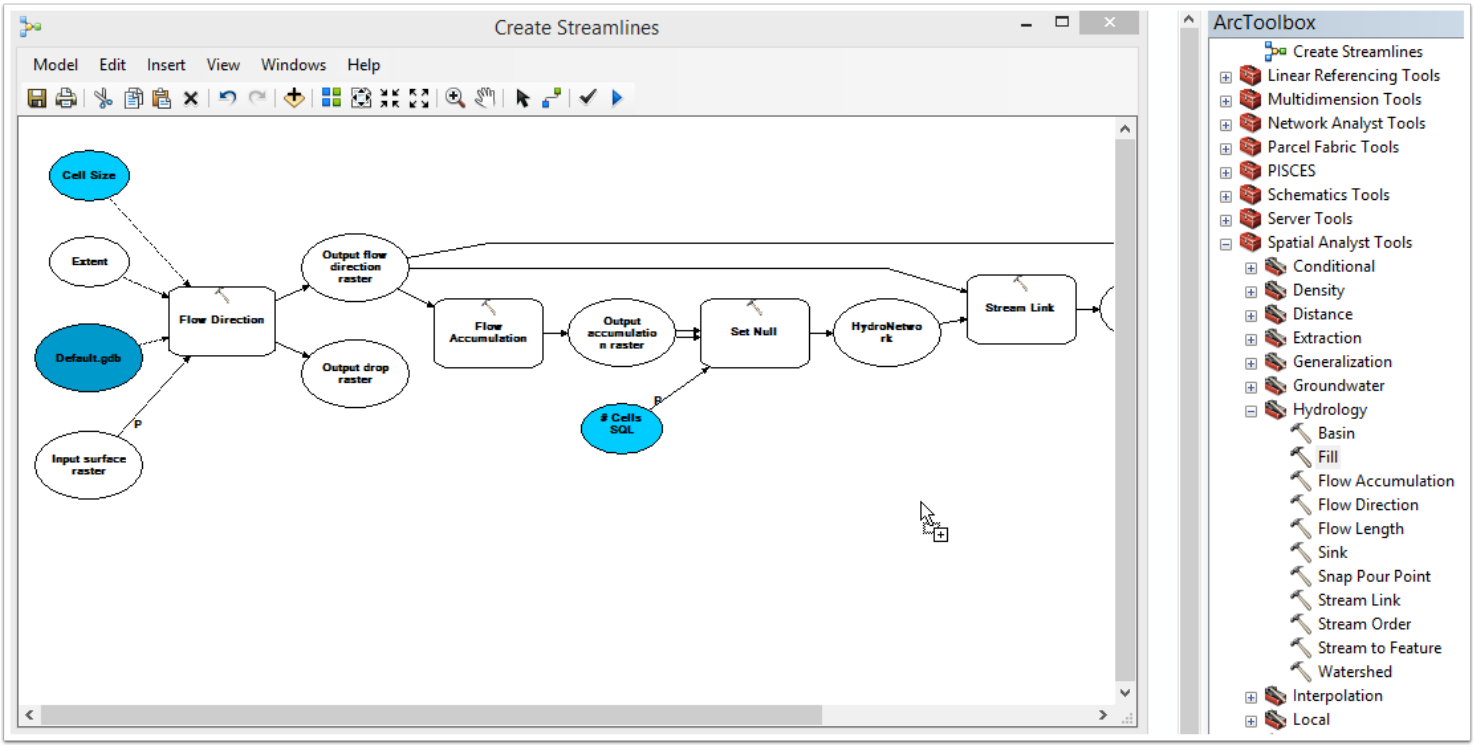
If you didn't build a similar model to this (in the Intermediate class), take a moment to look it over and understand it - what processing workflow does this model go through?

Once you understand the model, consider where the weak point is in it for dealing with sinks? At what point do we need to make a correction in order to recondition the DEM?



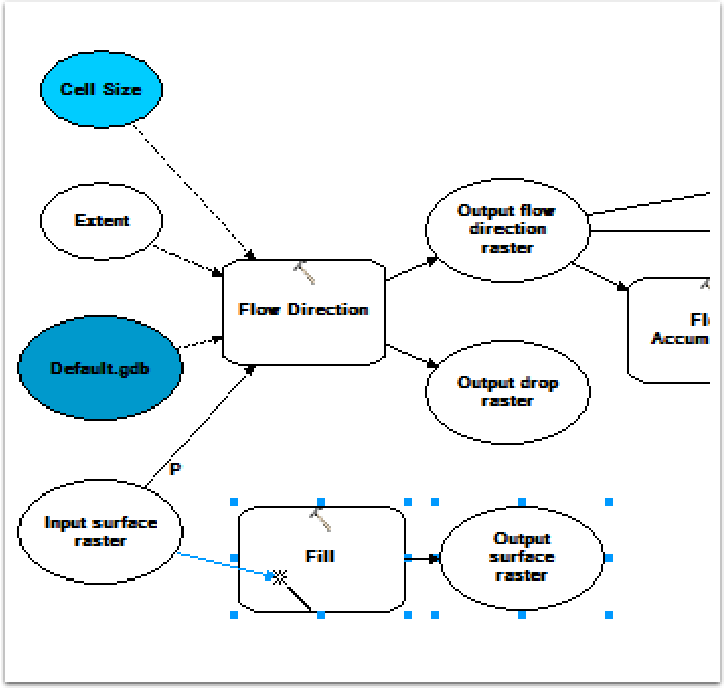
5.2 Adding the Fill tool

To remove our sinks, we need to use the *Fill* tool, which will find the local low points in the surface, and raise them up until they flow again. Drag the *Fill* tool onto your model's canvas (it can be found in *Spatial Analyst Tools>Hydrology>Fill).*



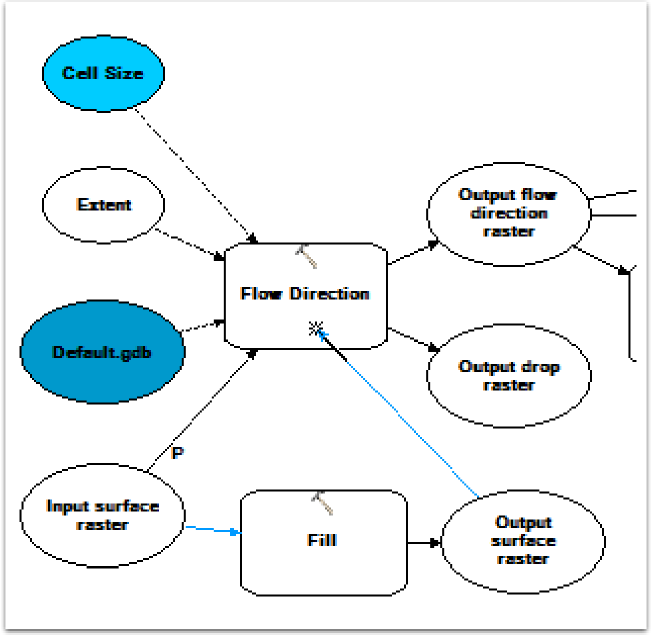
5.3 Rerouting the model's flow

Now, we need to reroute the model's flow (to reroute the DEM's flow? Kind of poetic GIS, isn't it?). Instead of plugging our DEM directly into the *Flow Direction* tool, we'll connect it directly to the *Fill* tool instead. Select the connector tool on the ModelBuilder toolbar and connect *Input surface raster* to the *Fill* tool. When you click down on *Fill* it will prompt you for what the input variable **is**. Think for a moment: what does this data mean to that tool? In this case, it's the *input surface raster* so select that from the menu that comes up.



5.4 Connect Fill's output to Flow Direction

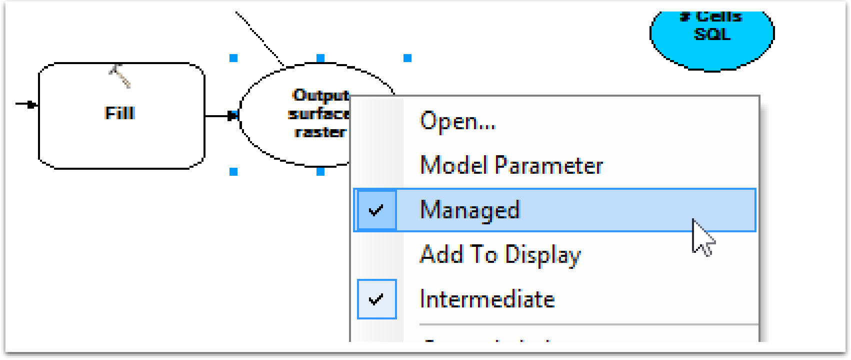
Now, connect the output of *Fill* tool (*output surface raster*) to Flow Direction in the same way - again, considering what this data means to the *Flow Direction* tool. Once again, it happens to be the *Input surface raster* so select that when prompted.



5.5 Save and close

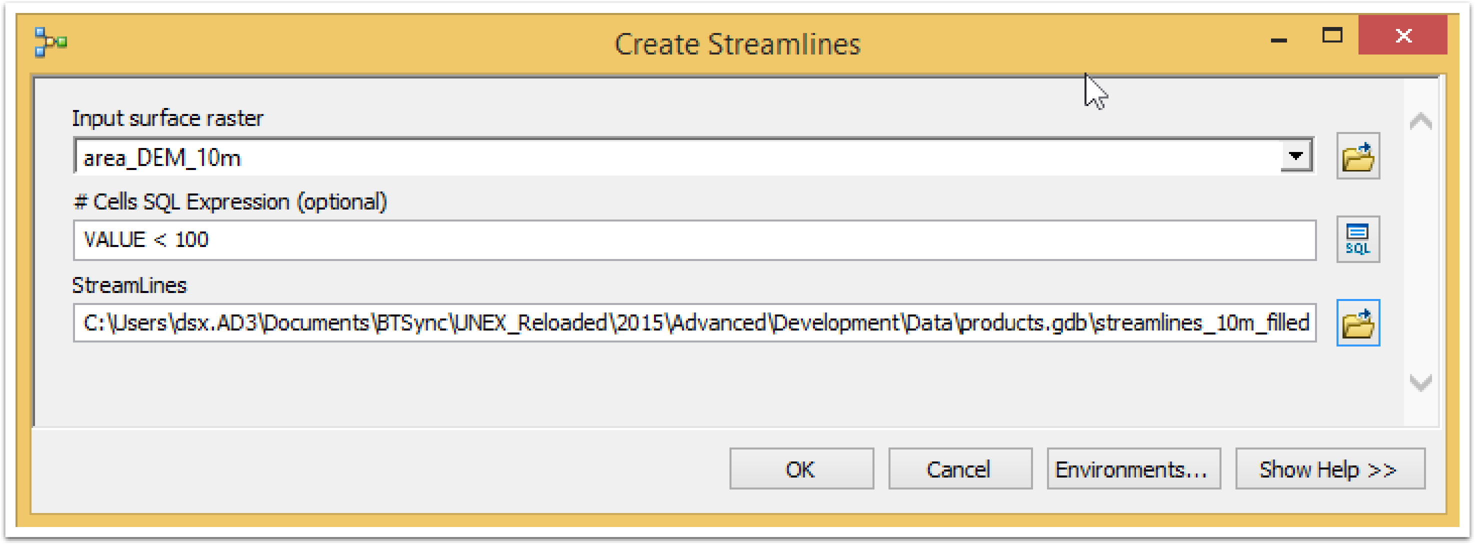
Once you've made the connection, right click on the *Output surface raster* from the *Fill* tool and select *Managed*. This tells ArcGIS that you don't want to specify where that data is stored because it isn't something you will need to inspect - you just need it as input to another tool.

When you're done with that step, save your model and close the model window.



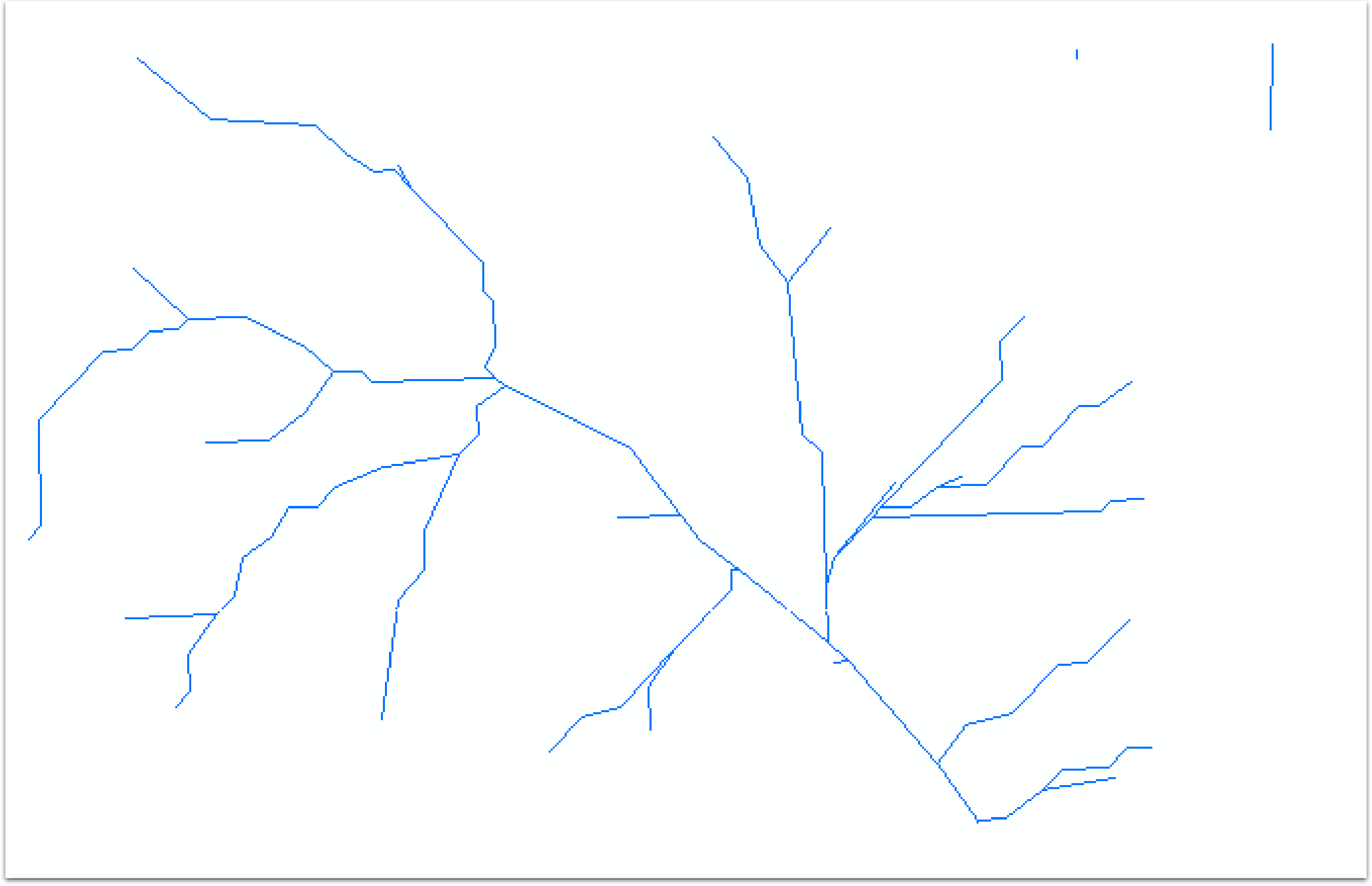
5.6 Run the modified tool

Now, double click on your Create Streamlines tool to run it. Select your 10m DEM as your *Input surface raster* and leave the SQL Expression as its default of *VALUE < 100*. For *StreamLines* save it into your products geodatabase again as *streamlines_10m_filled.* Click OK to run the tool.



5.7 Inspect your Streamlines

How do these streamlines look? You shouldn't see any more sinks or discontinuities in your streamlines (except that top right corner). If you see any, double check your model's workflow.



6. What's next and some extra credit

You have now created a DEM from field data, assessed the DEM for appropriate cell sizing, and used it to generate streamlines.

This exercise is incomplete though and just scratches the surface of DEM creation. You can try some of it for extra credit though.

If you have some time to try additional steps, a common need is to integrate precise local observations with an externally created regional DEM. Try loading the raster *nav_dem_10m* from your data geodatabase and figure out how to integrate your localized DEM with it. Hint: You'll need to specify snap raster and cellsize environment settings and it will likely involve using the Con tool and/or raster calculator.