UC DAVIS EXTENSION

1. Overview and Context

Remember from a previous course in the specialization when we developed streamlines for the navarro river watershed. There are many steps in developing a robust hydrography, which carries inherent properties from a digital elevation model (e.g., upstream area, stream order, etc.), and the process can be time consuming to get right. Now, we'd like to do the same process for another watershed, and in having a repeat need to run this process, let's now create it as a model tool in ArcGIS so that it can be automatically run based on the DEM any time we need it in the future.

Building *re-useable models* for geoprocessing tasks can be a time saver and allows for modification and sensitivity testing (running the tool with different parameters). We will build a generalized stream vectorization model in Model Builder and parameterize it with three different thresholds for minimum drainage area (1 ha, 1 km^2, 10 km^2).

What are the steps to vectorization of streams from a DEM?

1. Set the Environment (cell size, extent, workspace)
2. Run in order, Flow Direction > Flow Accumulation > Stream Threshold > Stream Link > Stream Line.
3. What are the inputs and outputs?
4. Think about attribution (e.g., drainage area, stream order) and potential confounding problems (i.e., sinks). How would these factor into your model?

1.1 Do your usual startup settings

To begin with

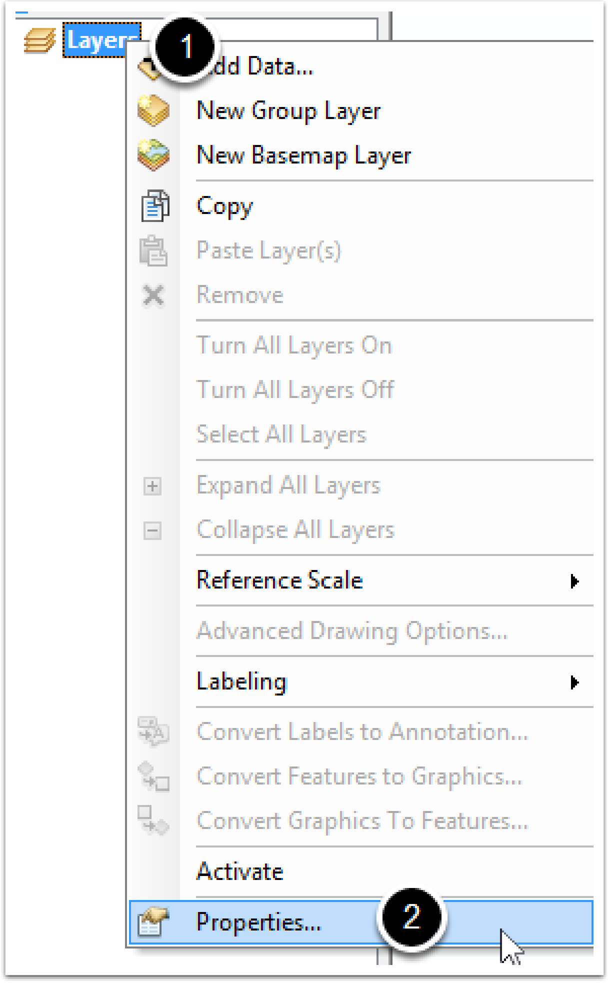
1. Start up ArcMap
2. Create a new blank map document
3. Set the paths to relative in the document properties (remember how?)
4. Save the document to a reasonable location

1.2 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 distortionis 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.

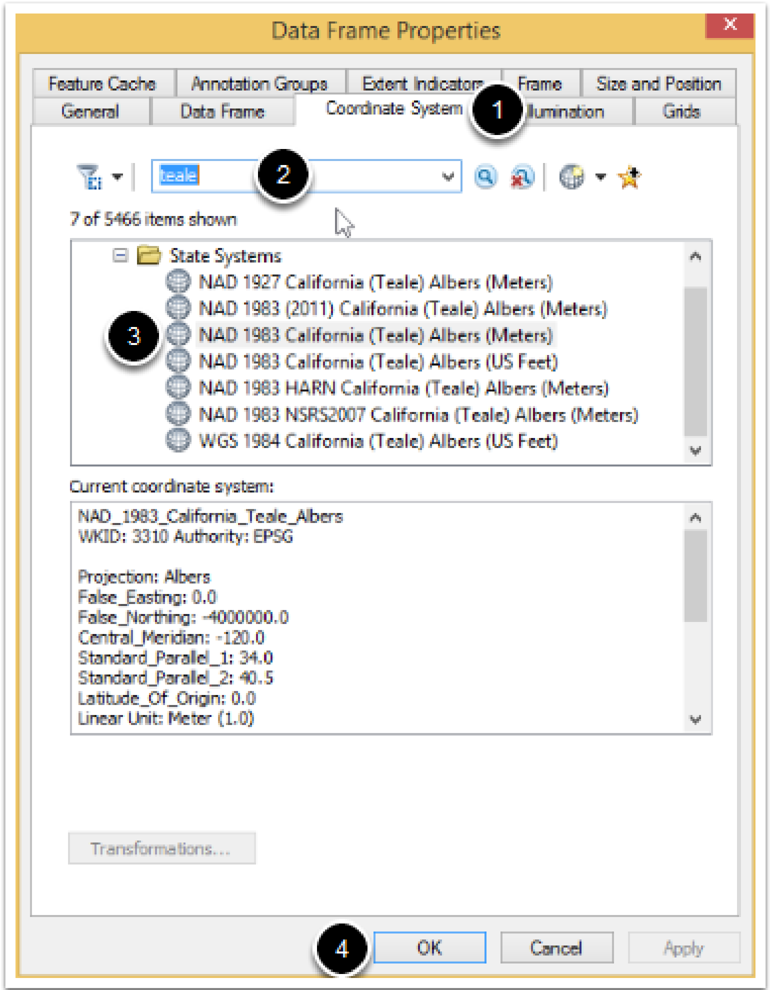
1. To get started, right click on your Layers root element

2. Then click properties



1.3 Continuing our document setup

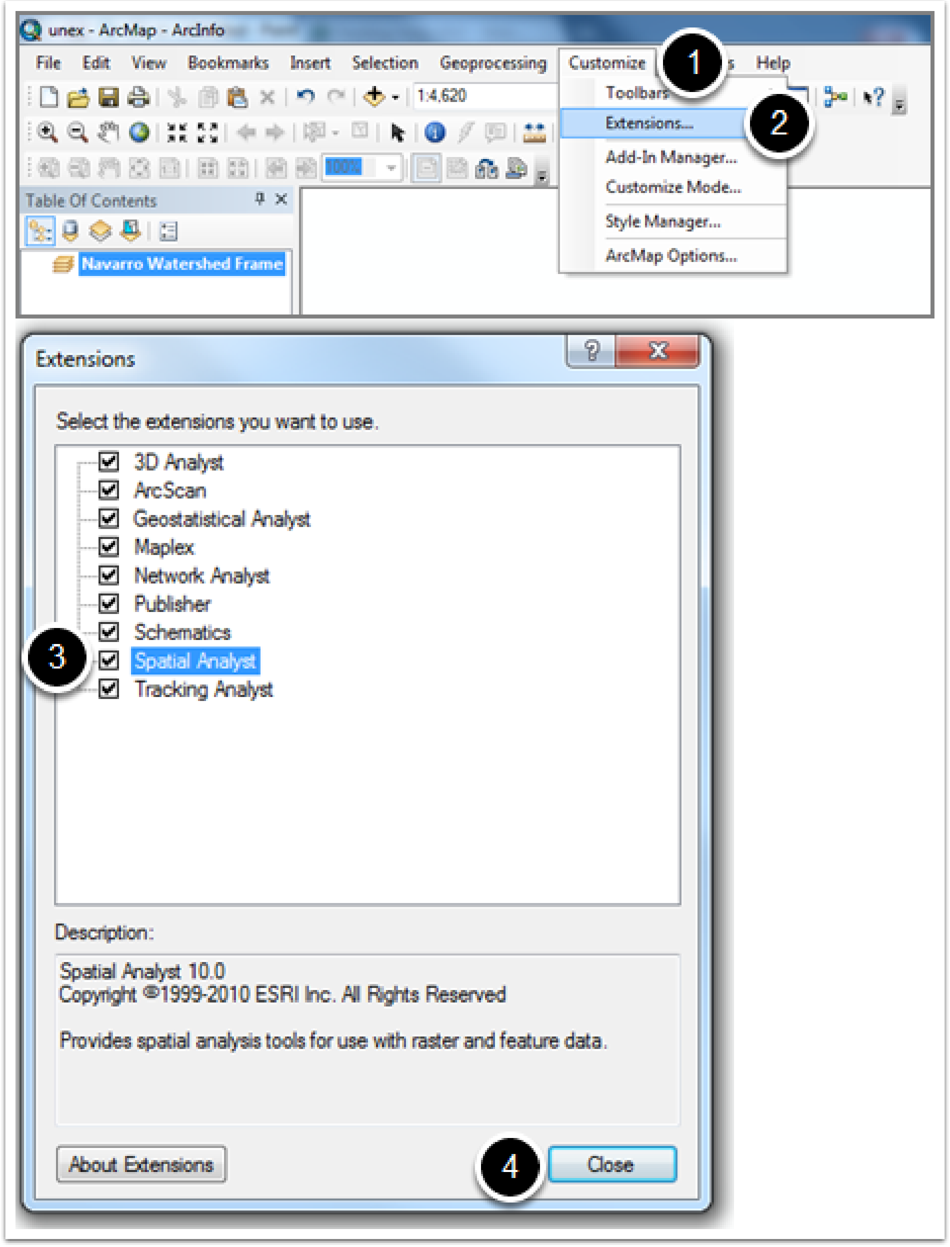
1. In the dialog that pops up, go to the Coordinate System tab
2. In the search box, type "Teale"
3. 7 coordinate systems will come up - select NAD 1983 California (Teale) Albers (Meters)
4. Click OK
5. Save your document again



1.4 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 generation 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:

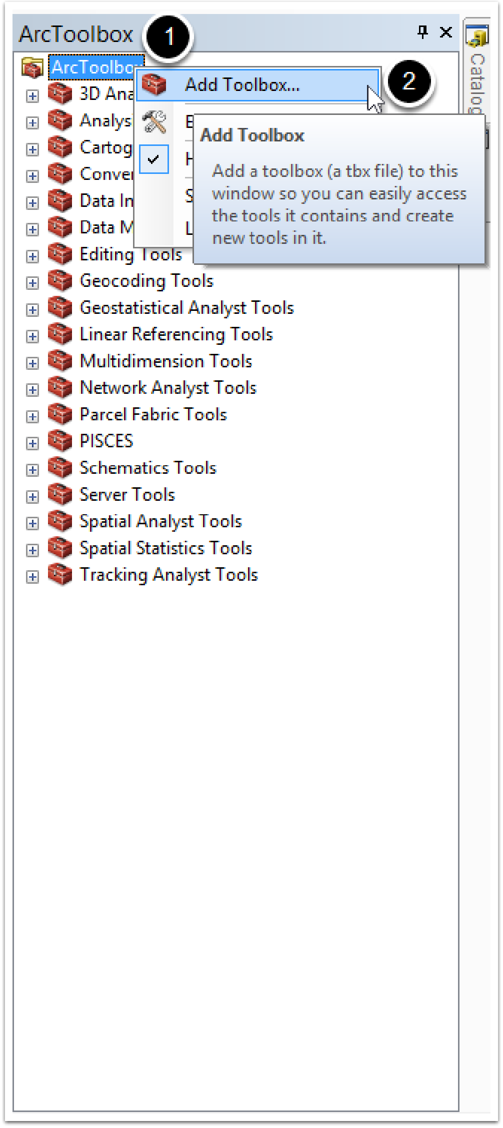
1. Select the *Customize* menu
2. Click Extensions…
3. Check the Spatial Analyst box
4. Select Close.



2. Create and add a toolbox

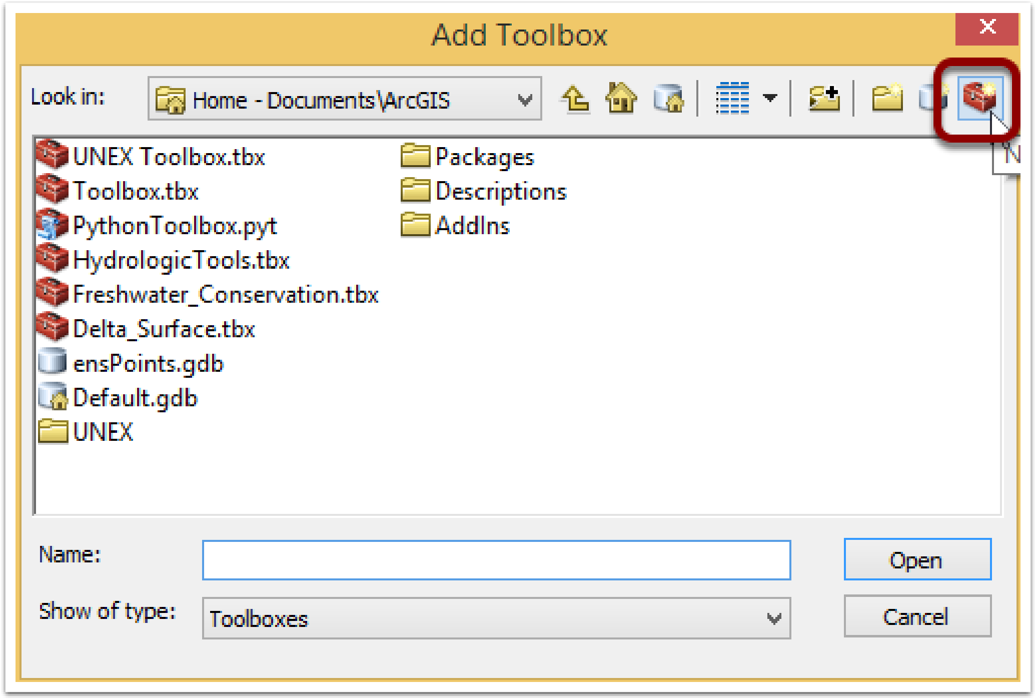
We need to create our own toolbox (just like the ones you see in ArcToolbox) in order to make our own tools and models. Conceptually, a model is an ArcGIS tool that you have the ability to create (very handy!).

1. Open ArcToolbox, then right click on the root element
2. Select Add Toolbox



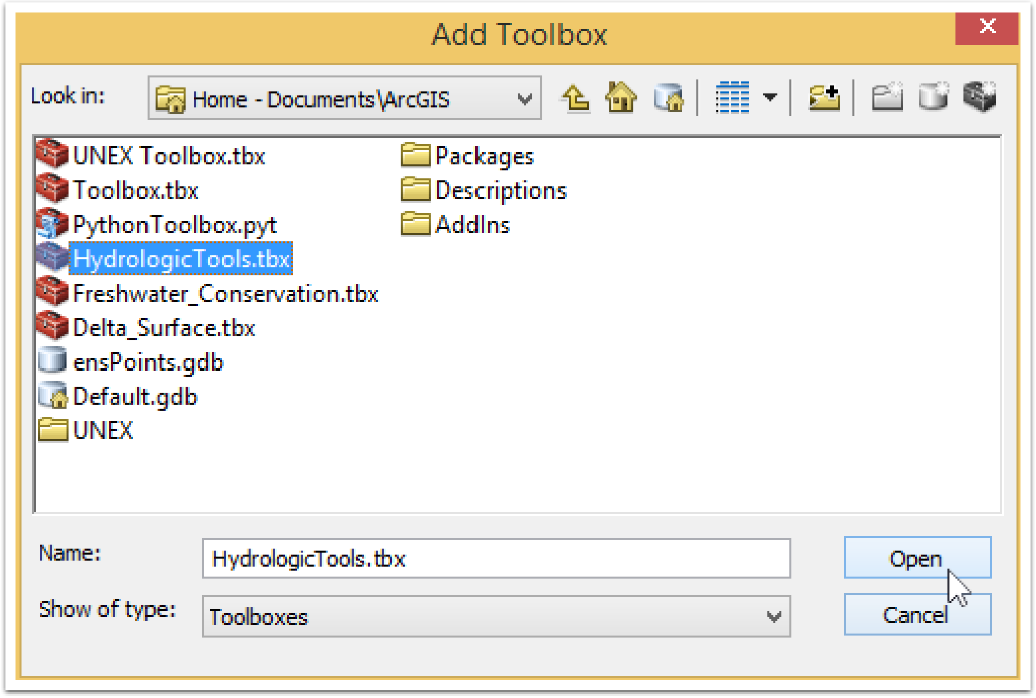
2.1 Create a New Toolbox

Navigate to your project folder for this lab. Select the create new toolbox icon in the top right, and name the new toolbox "Hydrologic Tools".



2.2 Add the toolbox

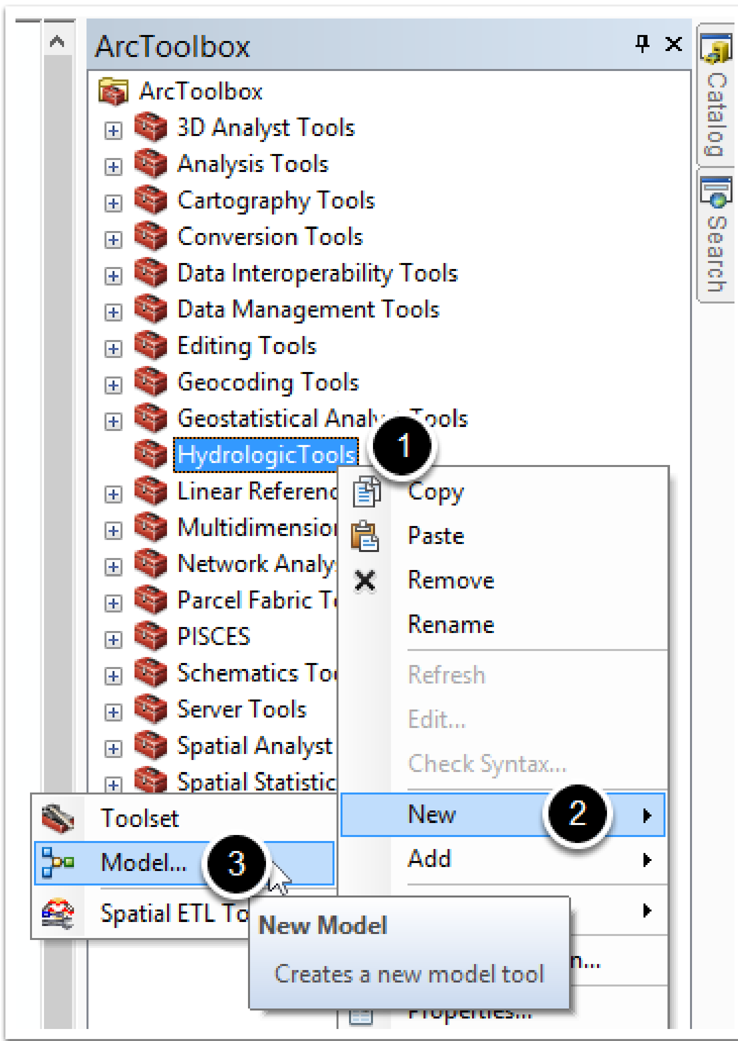
Select the toolbox (single click, not double) then click the *Open* button in the bottom right.



3. Create your model

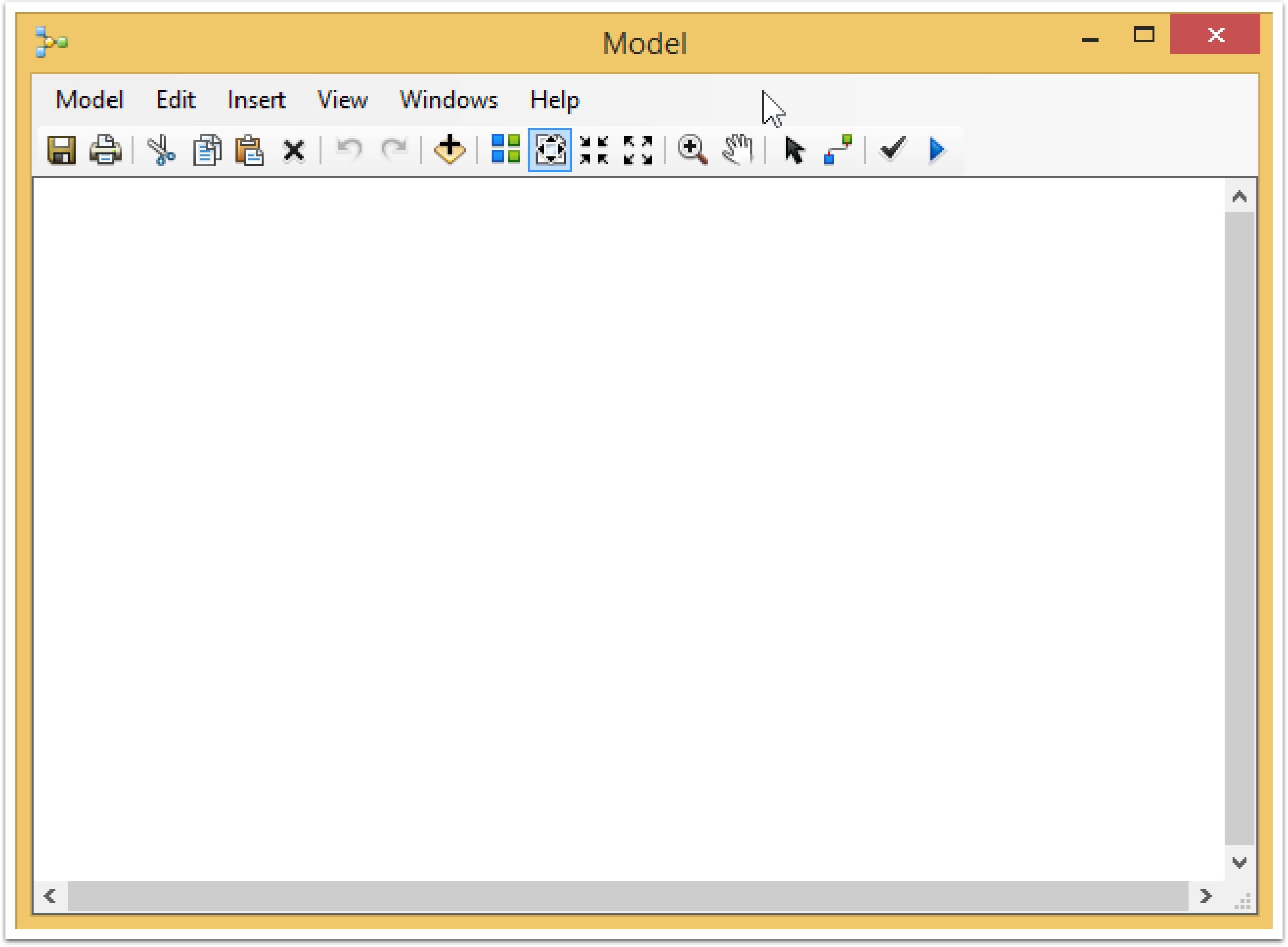
We need to now create an empty model to access ModelBuilder and to lay out our workflow. To do that, we'll create a new model in our toolbox.

1. Right click on your Hydrologic Tools toolbox
2. Go to new
3. Click *Model*



3.1 The ModelBuilder Window

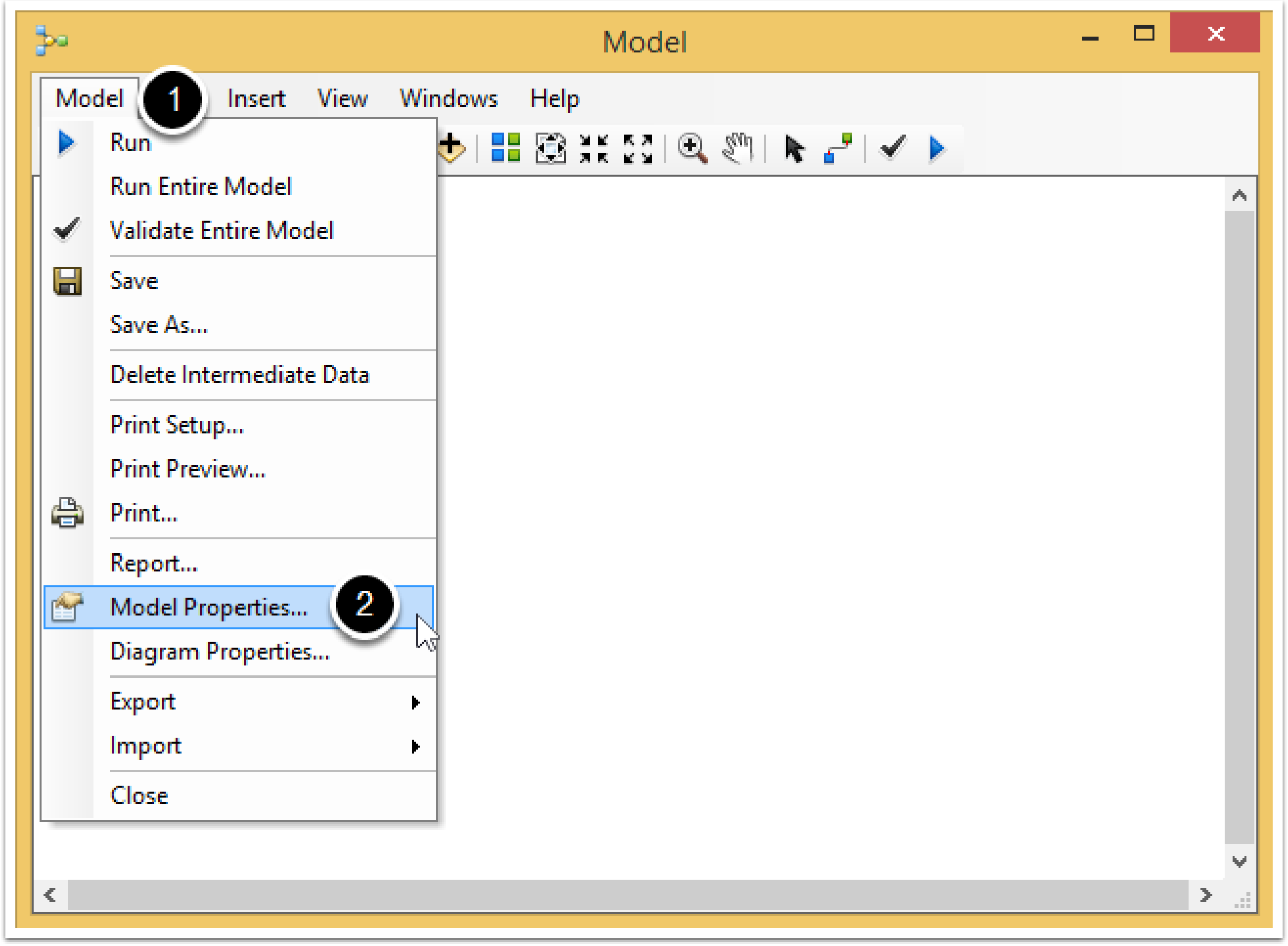
The ModelBuilder window will pop up automatically when you create a new model. It will be likely be unfamiliar and contain some new icons. We'll introduce most of them as we need them, but take a moment to look around, hover your mouse over icons to see what they do, and look through the menus to see what options you have.



3.2 Modify your model's properties

We should start by modifying the properties of our new model so we understand what it is in the future, and so others can too, if we send the model to them. To do that,

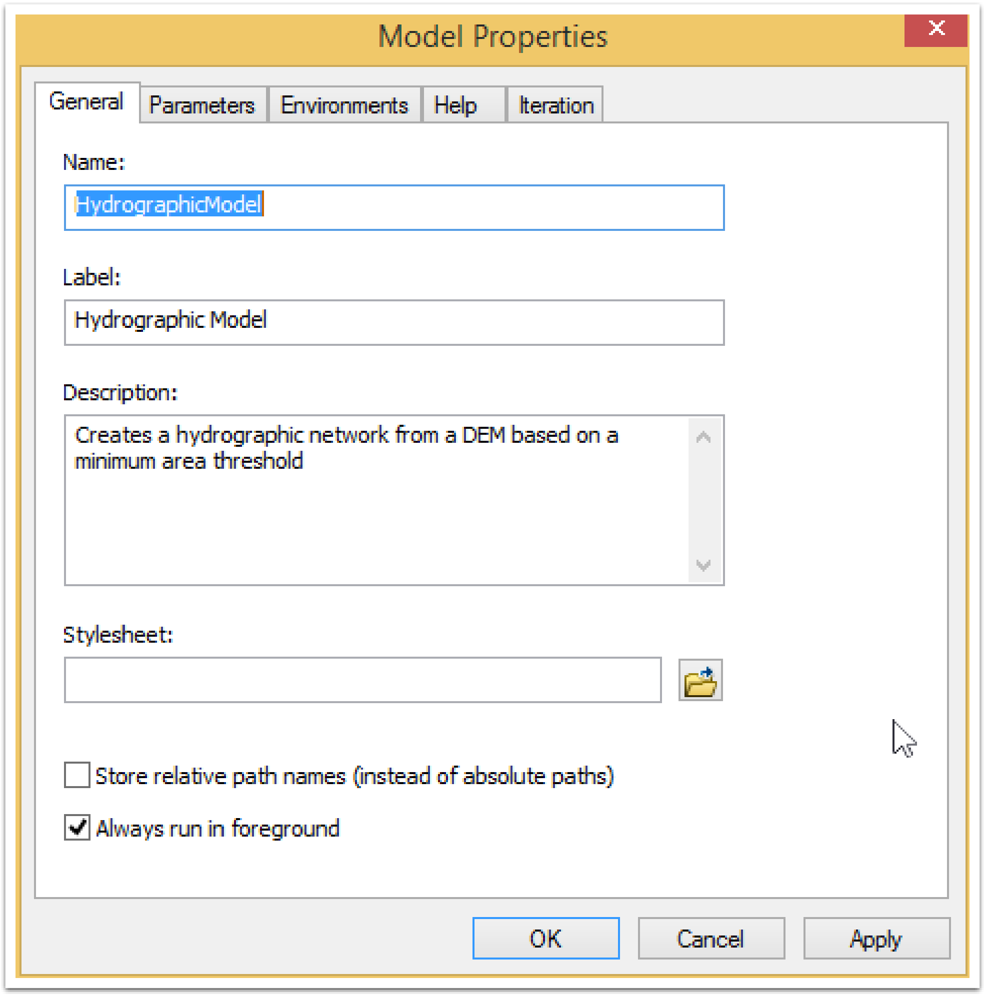
1. Click the *Model* menu
2. then click on *Model properties*



3.3 The model properties dialog box

The model properties dialog box will pop up. On the default page, we can set a name (no spaces) and a human readable label, along with a description. Do that now - a name like "HydrographicModel" is recommended, with a label like "Hydrographic Model" - feel free to give it names that suit you though. Note the ability to store relative path names and to always run in the foreground, but don't change them yet.

Also, look through the other tabs to get familiar with what's available in this properties box. Then click OK to go back to your blank model.



4. Modelbuilder Basics

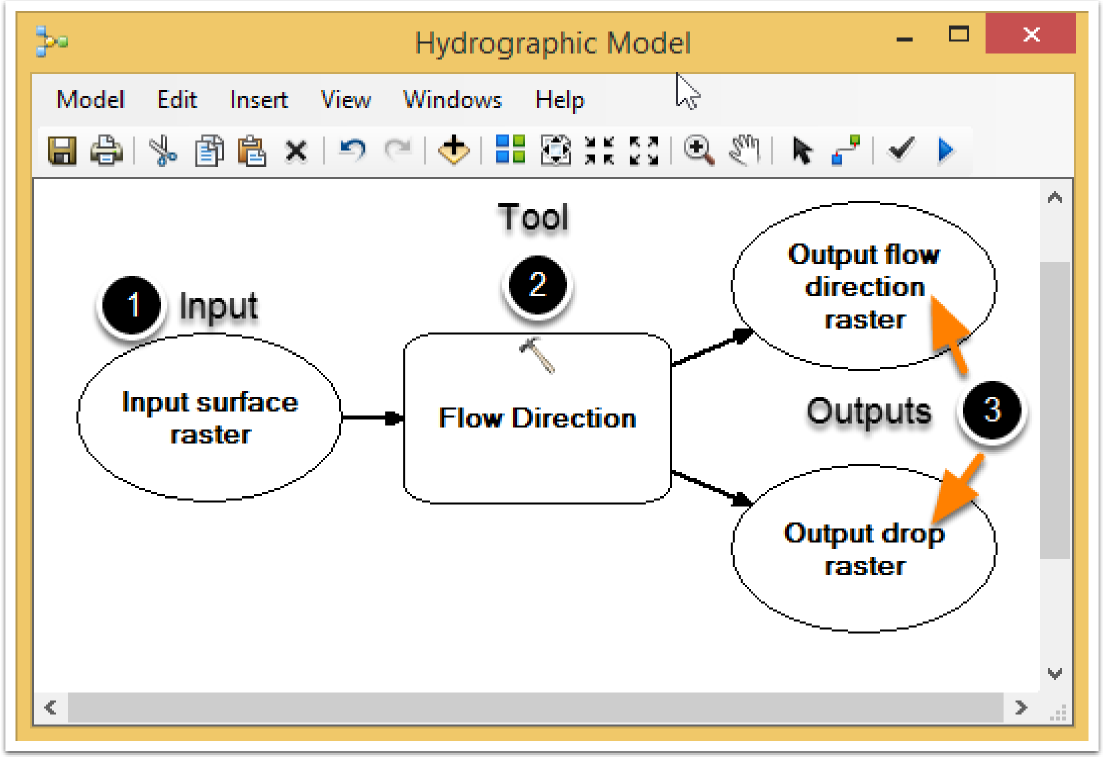
You don't need to match this screen yet - conceptual demo

Modelbuilder tools are composed of a sequence of other tools chained together - similarly to what you would do when you run geoprocessing tools in order, but giving you a reproducable and externally validate-able (I know, not a word) tool.

You can think of each element on the canvas as being one of the following:

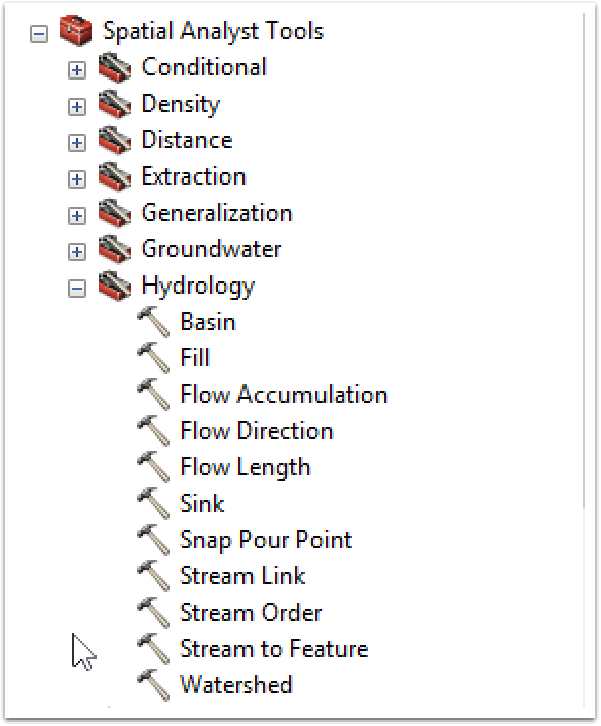
1. An input

2. A tool
3. An output (but these are often just inputs to the next item in the chain!)



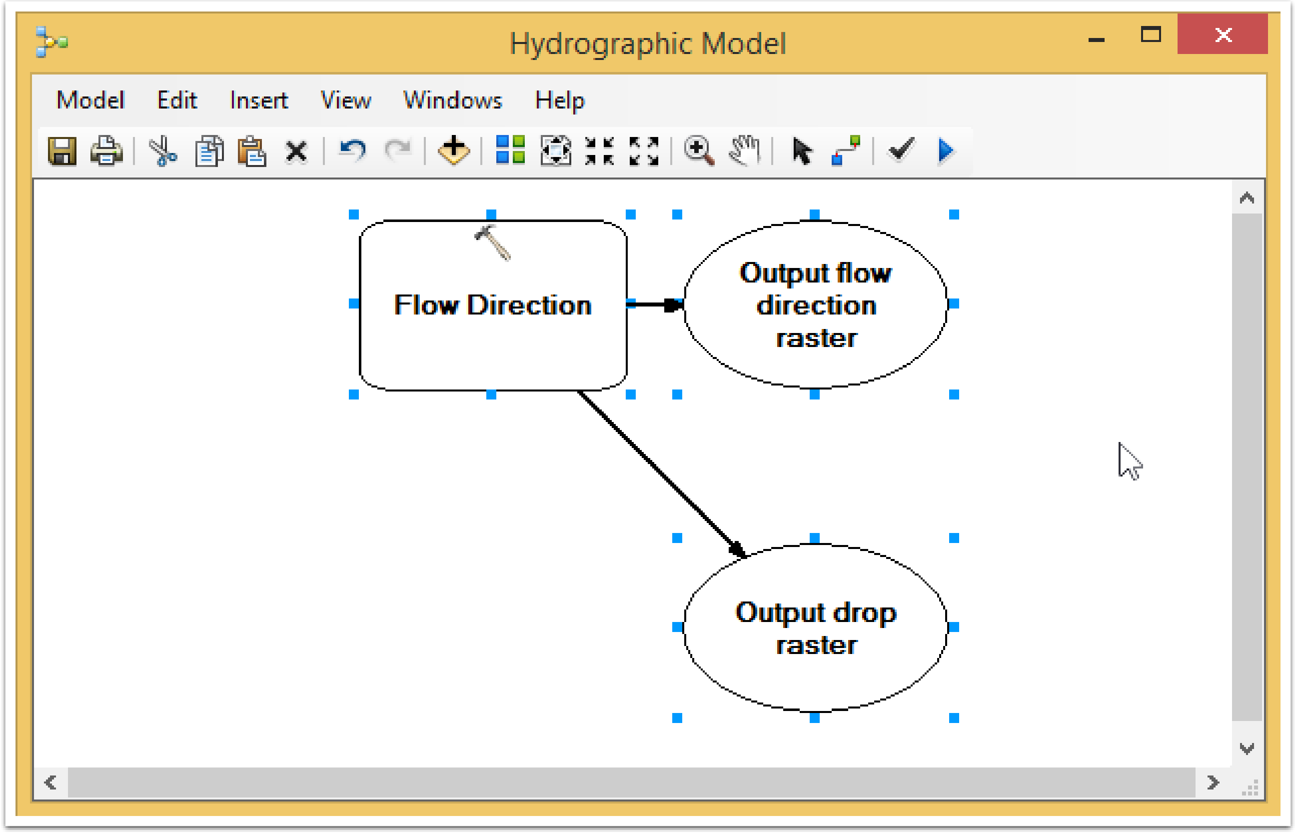
4.1 The spatial analyst toolbox

The spatial analyst toolbox will be our friend for this model, but is useful in general for all kinds of raster processing. When you have time, explore the *Conditional* and *Zonal* toolboxes as each is broadly useful. For this exercise, we'll be focusing on tools in the *Hydrology* toolset. Expand the toolset and talke a look at the list of tools.



4.2 Adding items to your model's canvas

While you can click the traditional *Add Data* icon near the center of the toolbar to bring in tools, the fastest way is to drag and drop. Click on the Flow Direction tool in ArcToolbox, hold your mouse down and drag it into the ModelBuilder window - then release your mouse. You'll end up with something similar to the below screenshot.

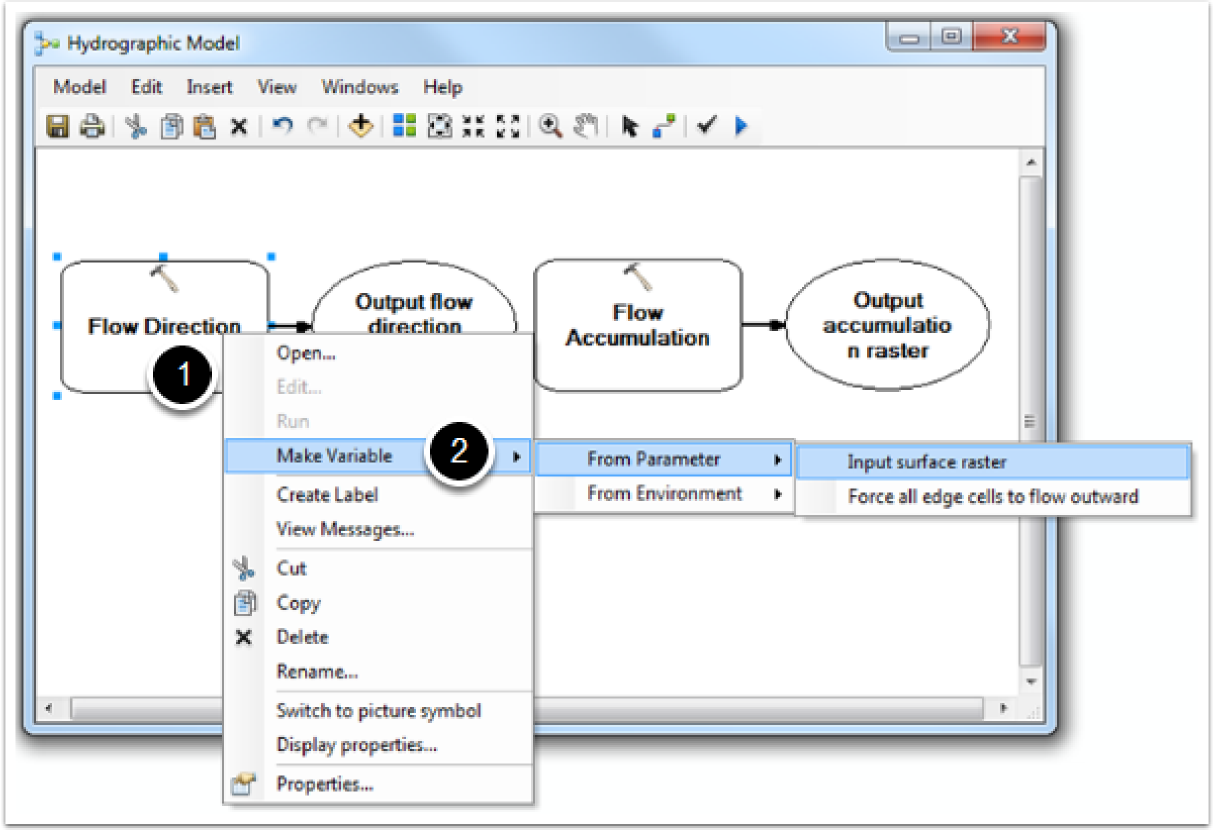


4.3 Making your tool configurable

Right now, we have a technically near complete tool - though all it would do is run Flow Direction - but we're still missing *Flow Direction's* **input.** So let's add that. We could either specify it permanently, or make it configurable by users of our tool at the time it's run. Generally speaking, configurability is good, so we'll opt for the latter option.

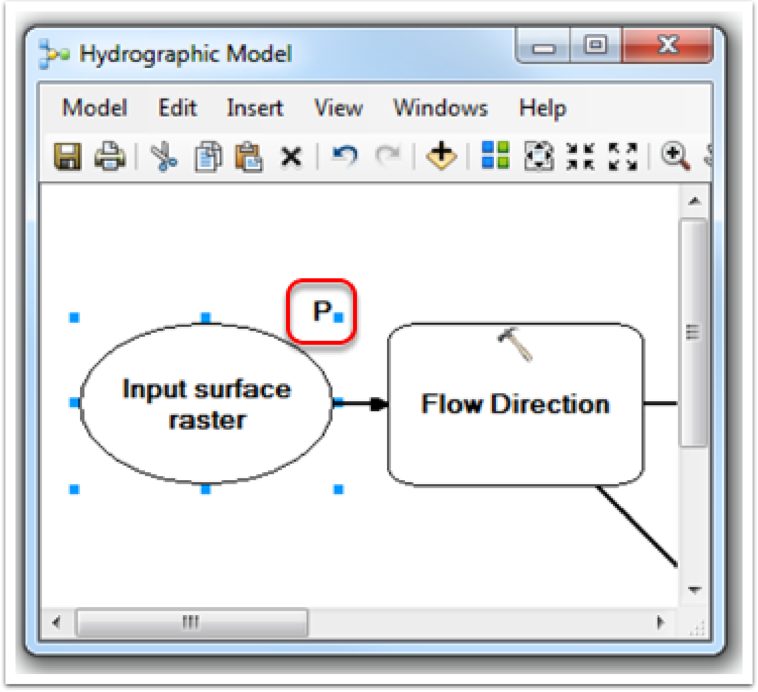
1. Right-mouse click on the Flow Direction tool on the canvas, and
2. select *Make Variable* > *From Parameter* > *Input Surface Raster* to create an input object (our DEM).

When we select *Make Variable* > *From Parameter,* note that we see a listing of all of the inputs to that tool, and can choose to make them *variables* (ie, things that change between or within runs) in our tool. If you want to verify this, run the *Flow Direction* tool from ArcToolbox and you'll see the same two options.



4.4 Making your variables into model parameters

Turning the *Input Surface Raster* into a variable is only half of what we need to do to make it a configurable option. We need to make it a *model parameter* - ModelBuilder terminology for an input argument or option. When you make it a model parameter, it will appear like your other inputs in a geoprocessing tool box. To do this, right click on it and select *Model Parameter* from the dropdown. When you are done, you will see the letter P in the upper corner of the item.

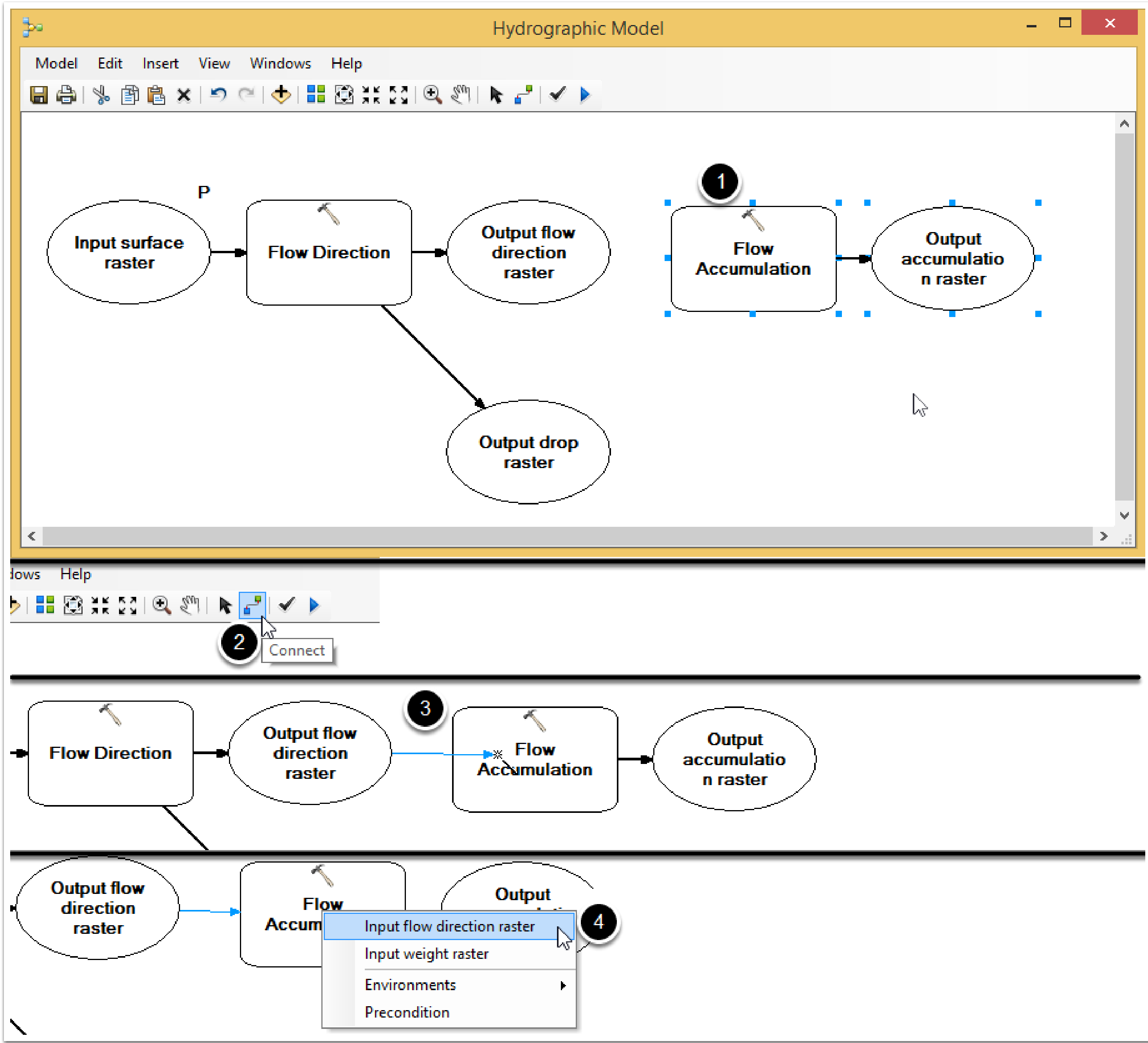


4.5 Connecting multiple processes together

Now, let's make ModelBuilder do something valuable by connecting together two processes. To do this, we'll add the next process in the chain, and feed the output of the *Flow Direction* tool into *Flow Accumulation* as one of its required inputs. To get started:

1. Drag the *Flow Accumulation* tool from the Hydrology toolset onto your canvas, just as you did with the *Flow Direction* tool.
2. Select the *Connect* tool from the toolbar (see screenshot)
3. Click on *Output flow direction raster* and then move your mouse to the *Flow Accumulation* process and click again.

4. Select *Input Flow Direction Raster* from the menu that appears - this tells it that the data we're providing will be the input for that tool parameter.

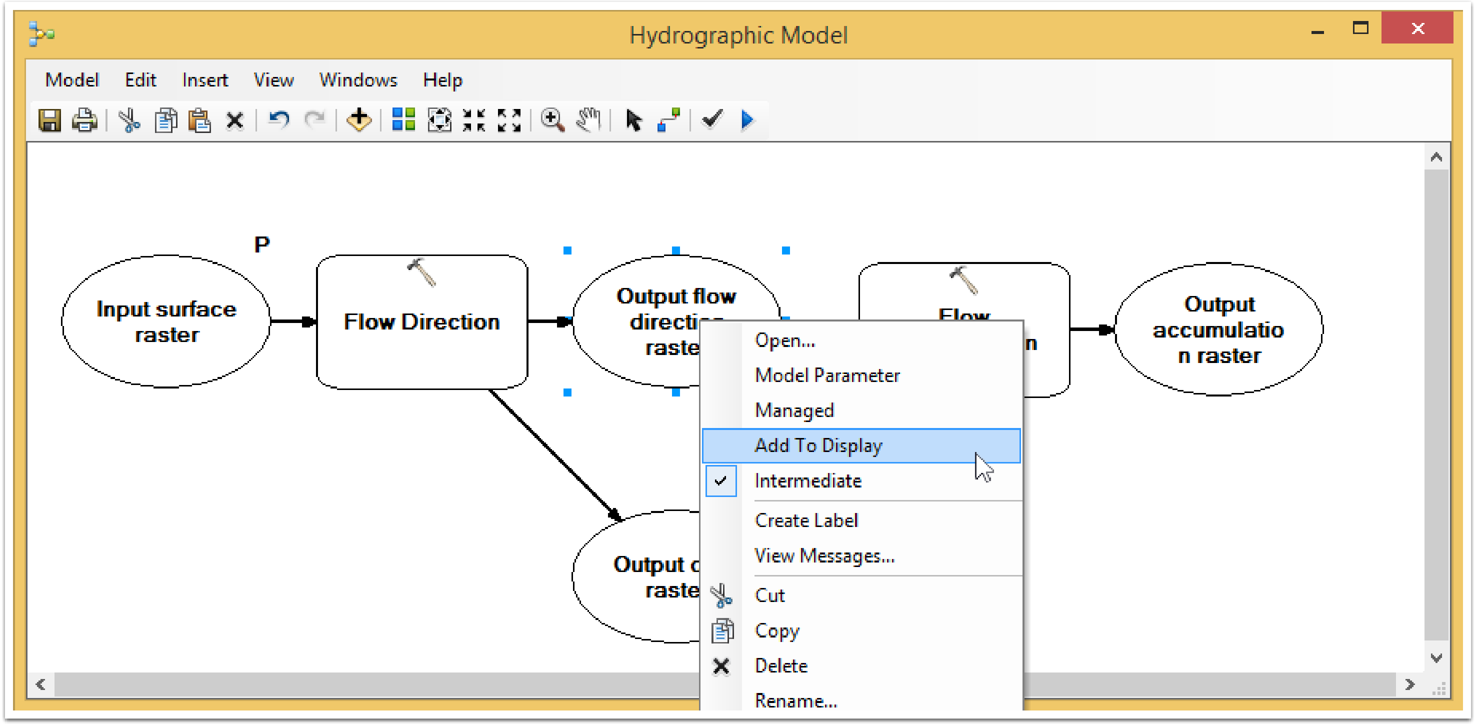


4.6 Making your results viewable

We'll need some way to view our results. By default, ArcGIS will place any outputs into your default geodatabase for the map document. If you don't know where that is, or don't want to go find it afterward, we can make it automatically add important results to our Table of Contents, just like other geoprocessing tools.

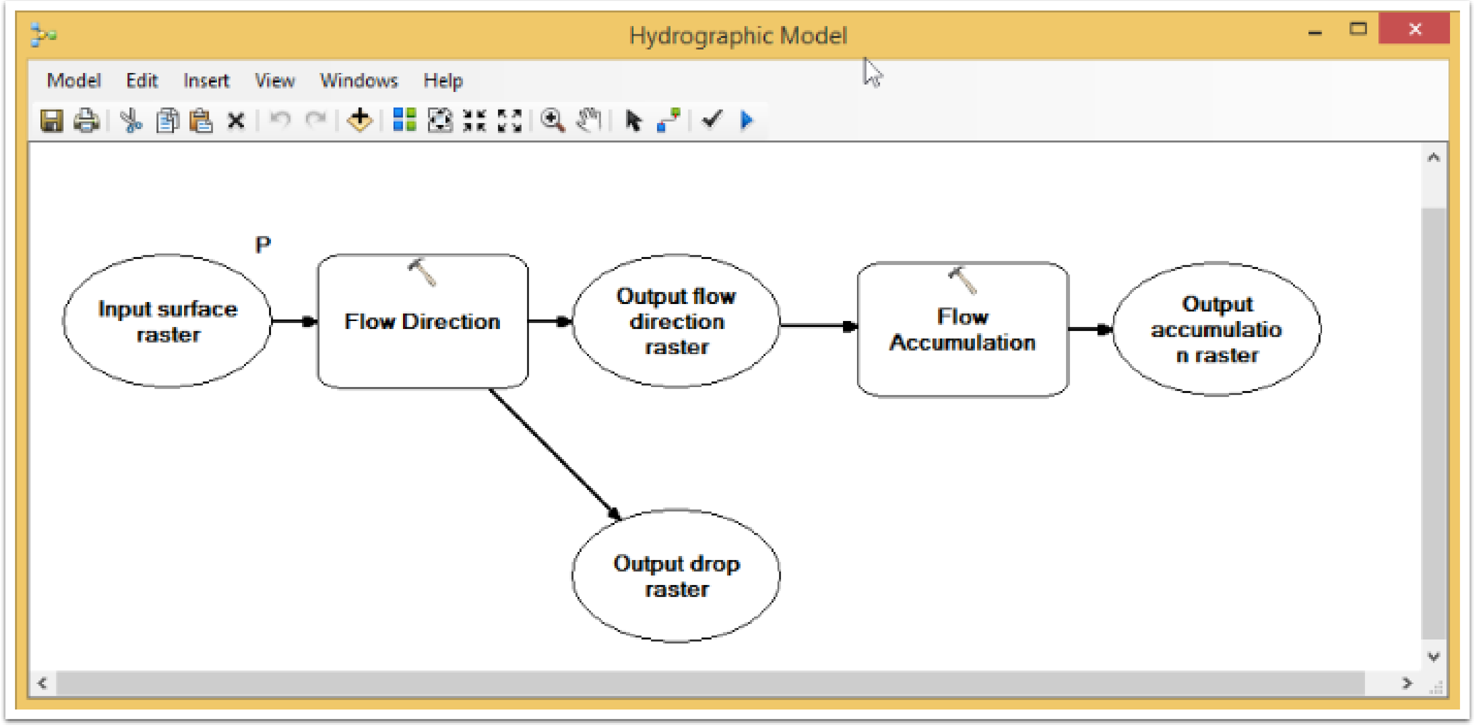
1. Right click on *Output flow direction raster*
2. Select *Add to Display*
3. Do the same for *Output accumulation raster*

You won't see any text icons like the P that appears for making something a model parameter, but if you right click on the outputs again, you'll see that *Add to Display* is checked.



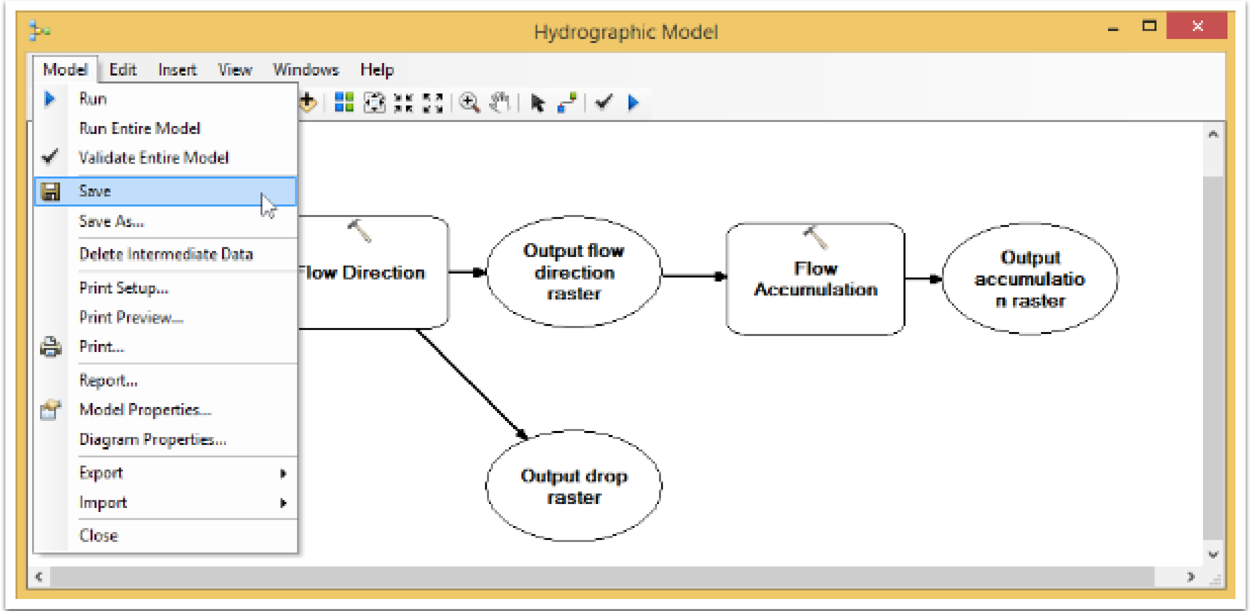
4.7 Celebrate!

Now, time to celebrate - you've just made your first model - and in some ways, your first program. After all, isn't a model just ArcGIS processes chained together using a bit of logic for future automation? That's a program in my book. Your model should now look something like the below picture.



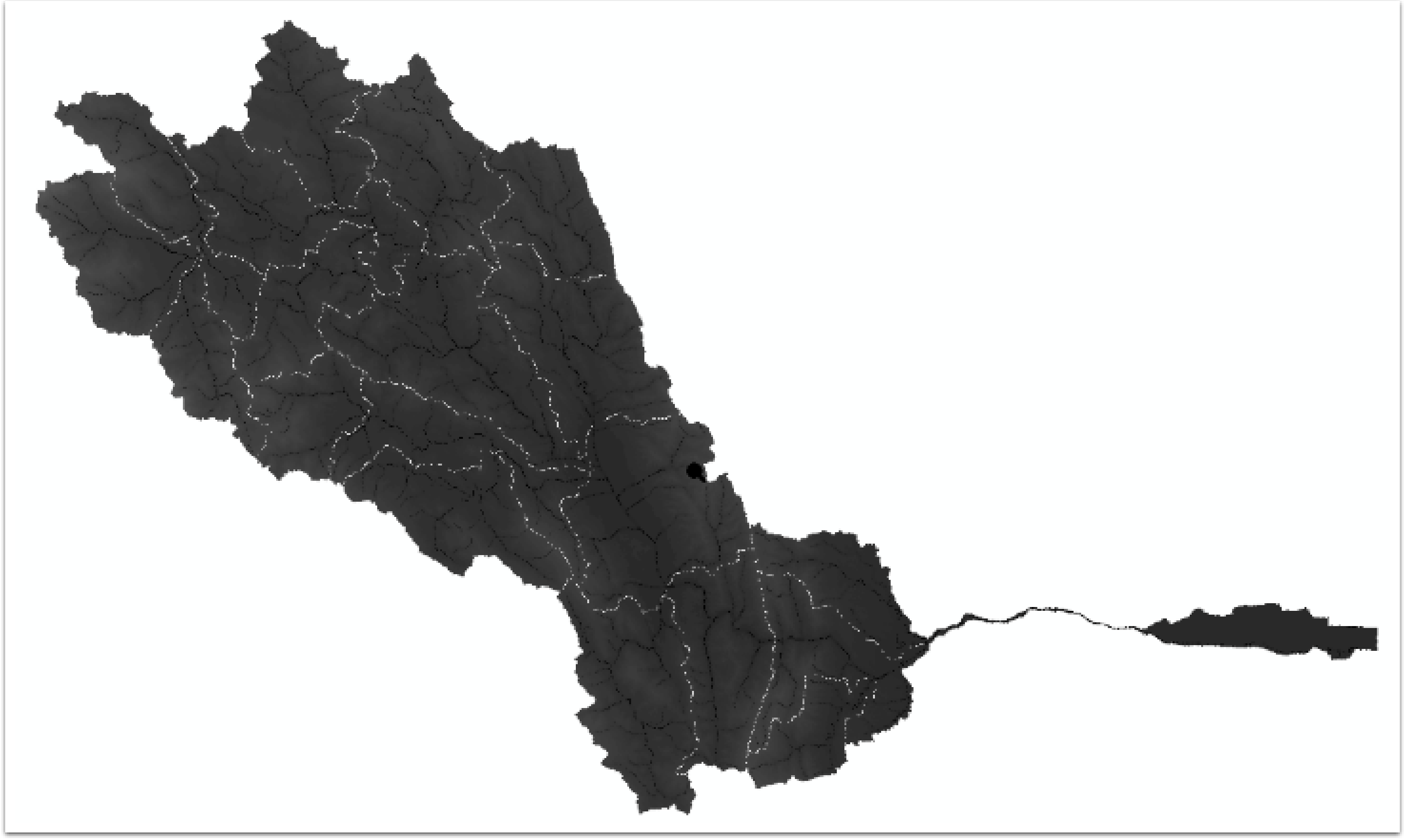
5. Testing your model

Now is a great time to save your model (it's in the usual place, but feel free to see the screenshot below). Close your model for now by clicking the red X in the top right corner. In your toolbox, you should now see your model *Hydrographic Model* available as a geoprocessing tool. It's possible it will still be called *Model* but if you right click on your toolbox and select *Refresh*, it should show the new, correct name.



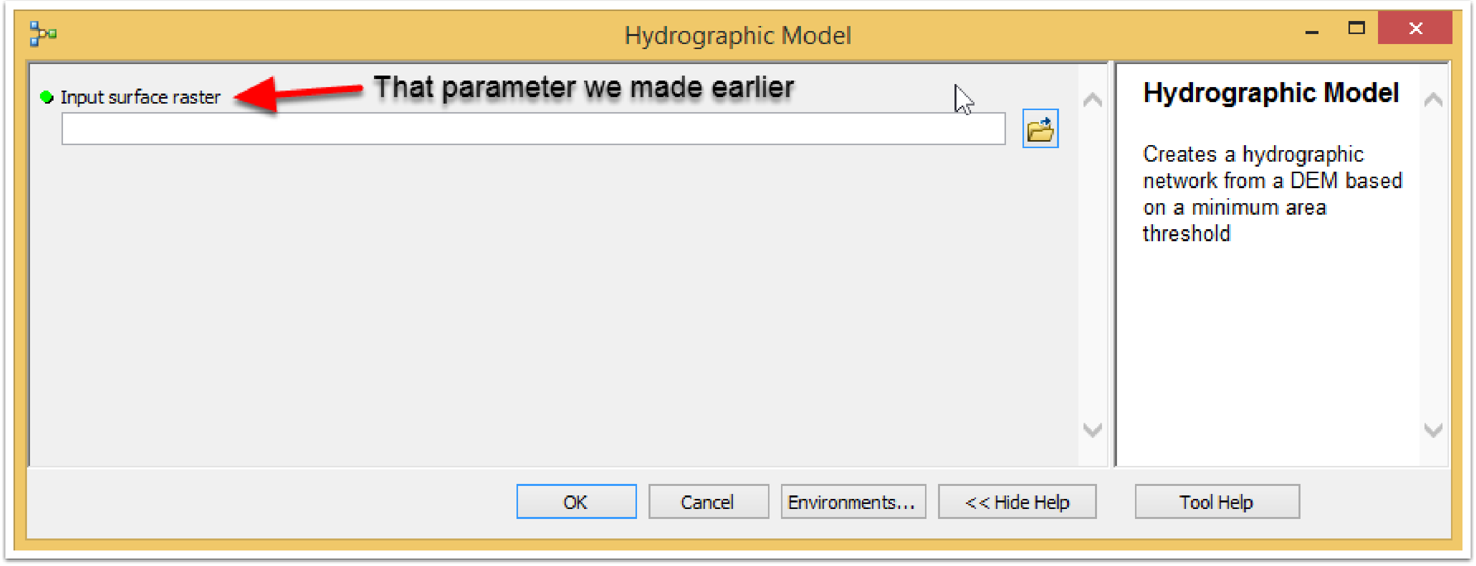
5.1 Add the Putah Creek DEM

Putah Creek (sort of) flows through Davis, so let's use it for our modeling. Click the *Add Data* button. Navigate to the *ModelBuilderData.gdb* geodatabase and add PutahCreek_DEM_30m to your map. It should look something like the below DEM. What are those lines running through the DEM (the dark and the light ones)? Why would a DEM have such distinct lines? *Hint: This is a special type of DEM called a HydroDEM.*



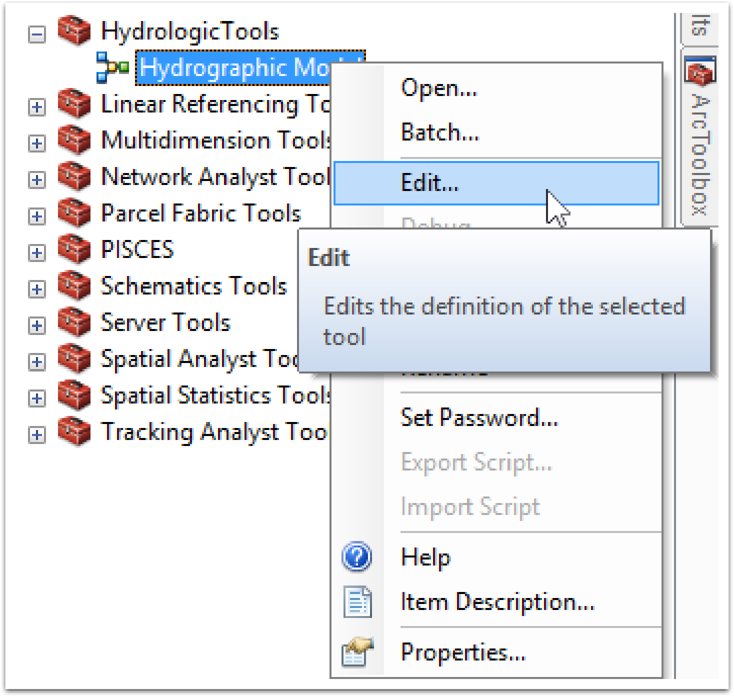
5.2 Viewing your model as a geoprocessing tool

Your model can be treated exactly like a geoprocessing tool now. We're not quite ready to run it yet, but go ahead and double click on it in its toolbox to see what it looks like. It should look like a geoprocessing tool. Note the input parameter we made - it showed up!



5.3 Editing an existing tool

So, we want to continue working on our tool. Double clicking on it *runs* our tool, so we'll need another way in. Right click on it, and select *Edit...* Maybe you guess this already though.



5.4 Validating your model

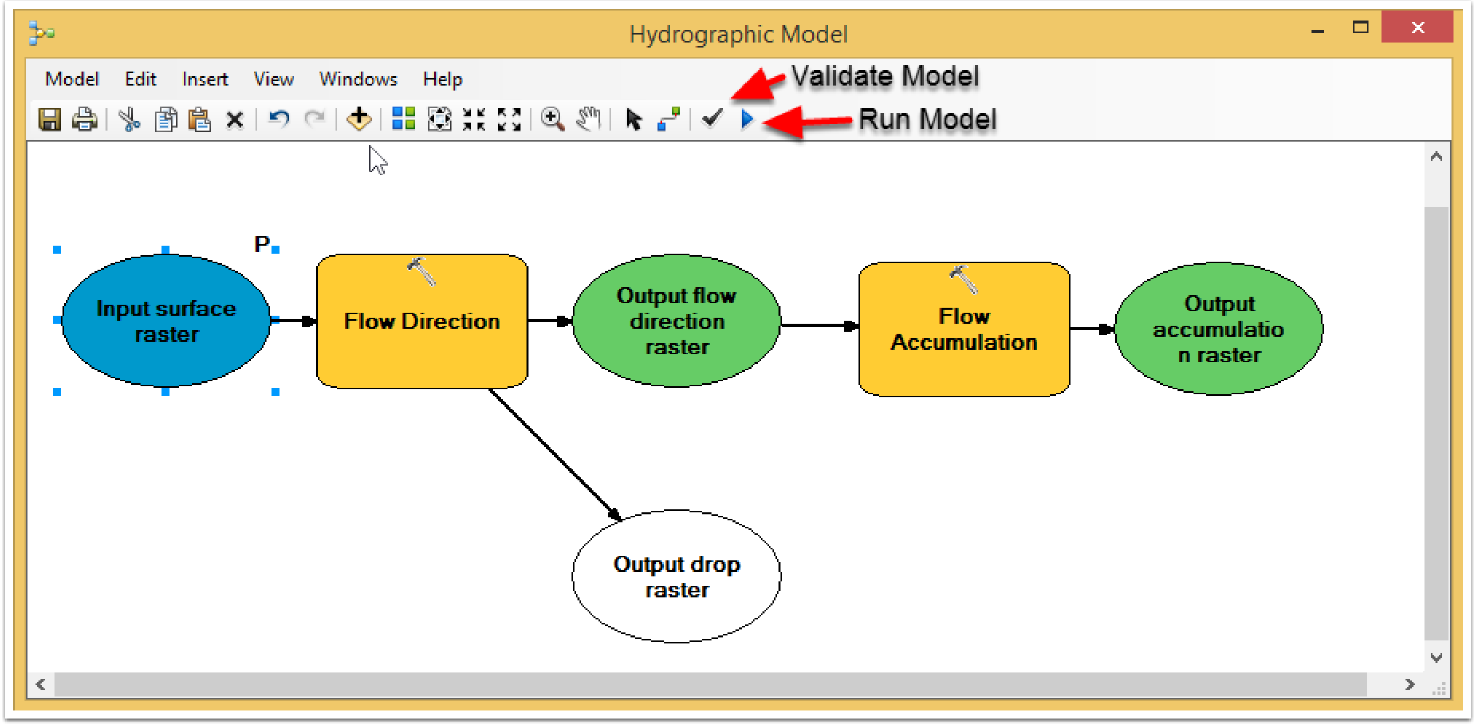
Before we continue, we want to test to make sure this part of the model performs. We call this iterative development - break your problem into chunks, and then test each chunk before making your model more complex. But we need to associate the Putah Creek DEM with our model in order to test it.

1. Double click on *input surface raster*
2. You'll see that familiar parameter window. When we click on an input in ModelBuilder, we get the opportunity to define that input as a constant for this model.
3. From the dropdown box for the parameter, select your Putah Creek DEM (*PutahCreek_DEM_30m*)
4. Click OK

You'll see your screen update to add colors! Whoa! What do they mean?

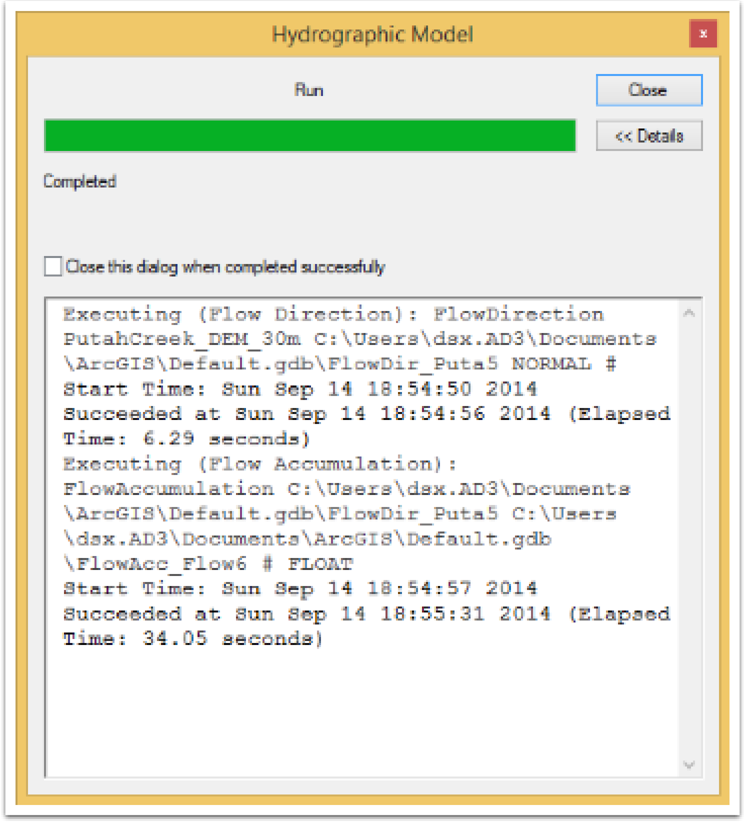
In ModelBuilder, a black and white model is your cue that your model isn't yet ready to run - though this can be deceptive - if you're leaving something as an undefined parameter for later - like you would to create a reusable tool, it'll stay black and white. Since we just defined that value though, everything that now has enough information to run will fill in with colors. Inputs will turn blue, processes/tools will turn golden yellow, and outputs will turn green. If they don't change colors, try clicking the checkmark on the toolbar (*Validate Entire Model*) to see if it's ready to run.

Save your model, then click the *Run* button (blue triangle next to *Validate Model*)



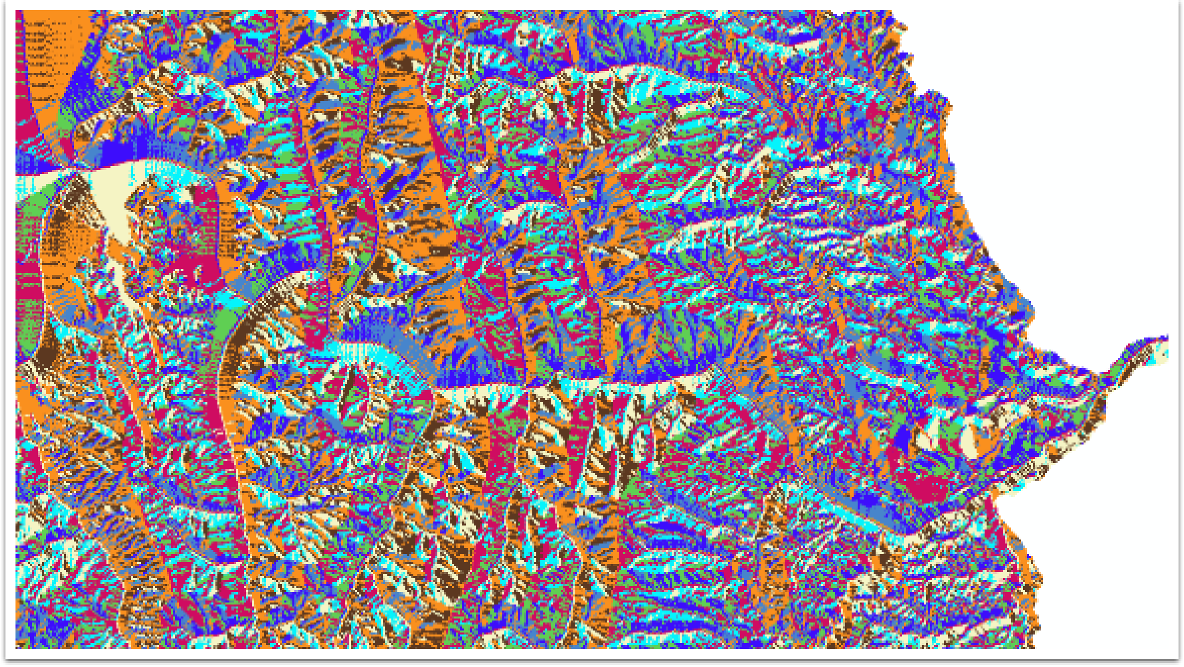
5.5 The running model

Just a quick note - running the model will give you the standard geoprocessing tool dialog, but you'll see it run a number of tools in a row, because that's really what we're doing, right?



5.6 Examine and explore your results

Explore your output for a moment - what does it mean? What is a flow direction raster? What is a flow accumulation raster? Why do they look this way (I think that flow direction rasters in ArcGIS tend to look like Andy Warhol hillshades)?

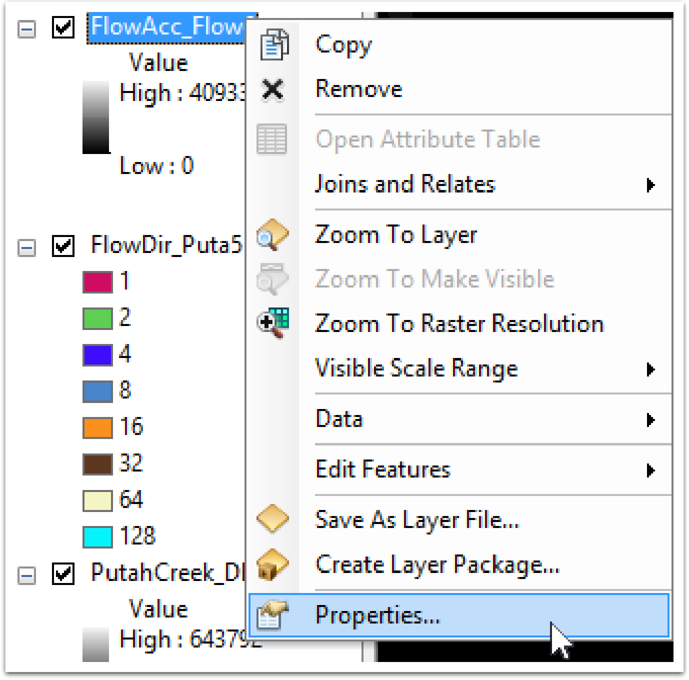


5.7 Exploring flow accumulation rasters

A quick note on exploring flow accumulation rasters. It's pretty hard, in large part because of the massive difference between the minimum and maximum values. The low values are incredibly common, while the high values are incredibly rare (think about this for a second - why is this?). So the default symbology - a black to white color ramp - isn't very useful here. Almost everything is black - this makes understanding a flow accumulation raster somewhat hard. So, let's tweak our symbology a bit.

5.8 Bring up the symbology dialog

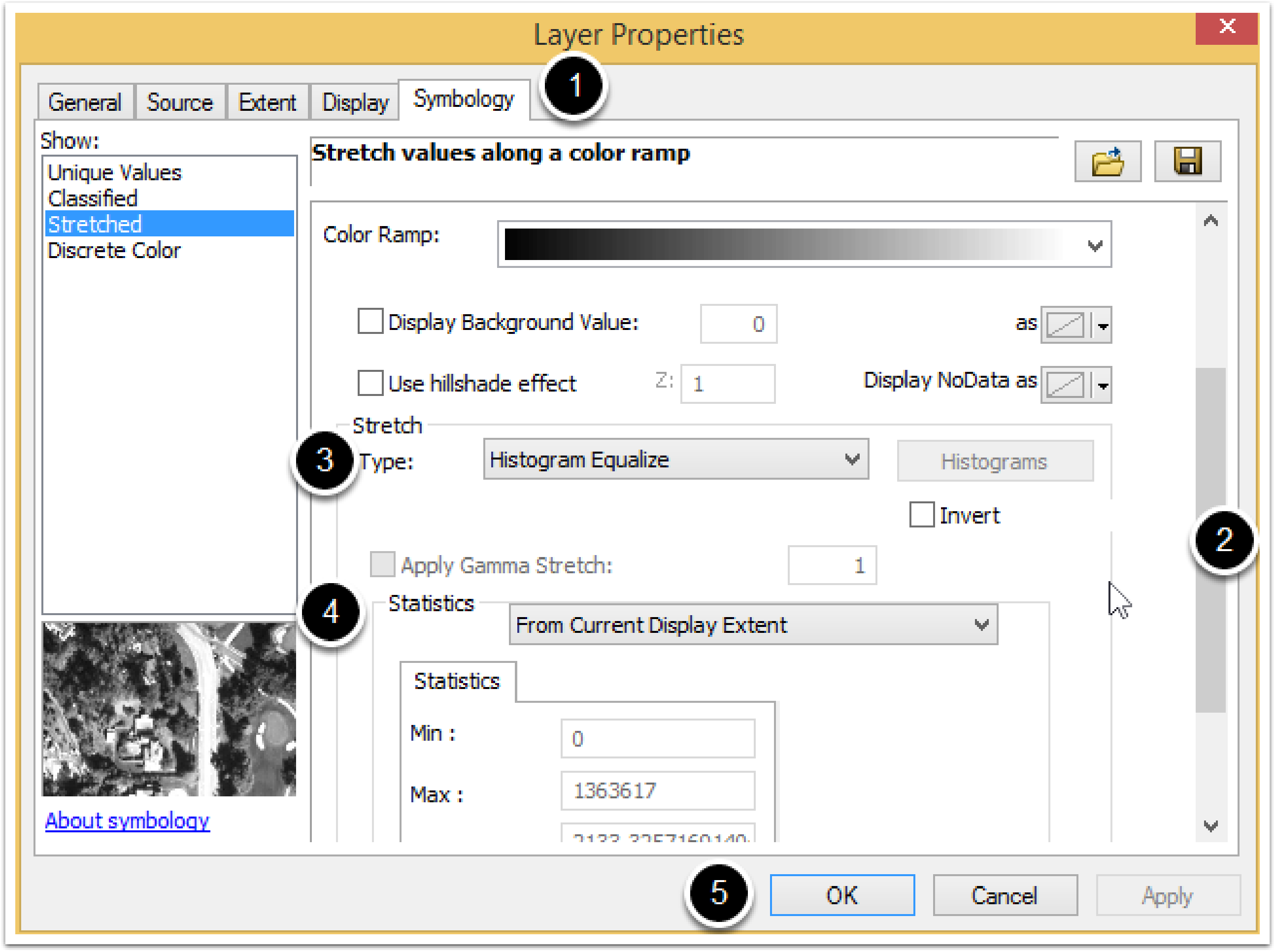
You're familiar with this by now. Right click on the flow accumulation layer, and go to properties



5.9 Changing the raster stretch and bounds

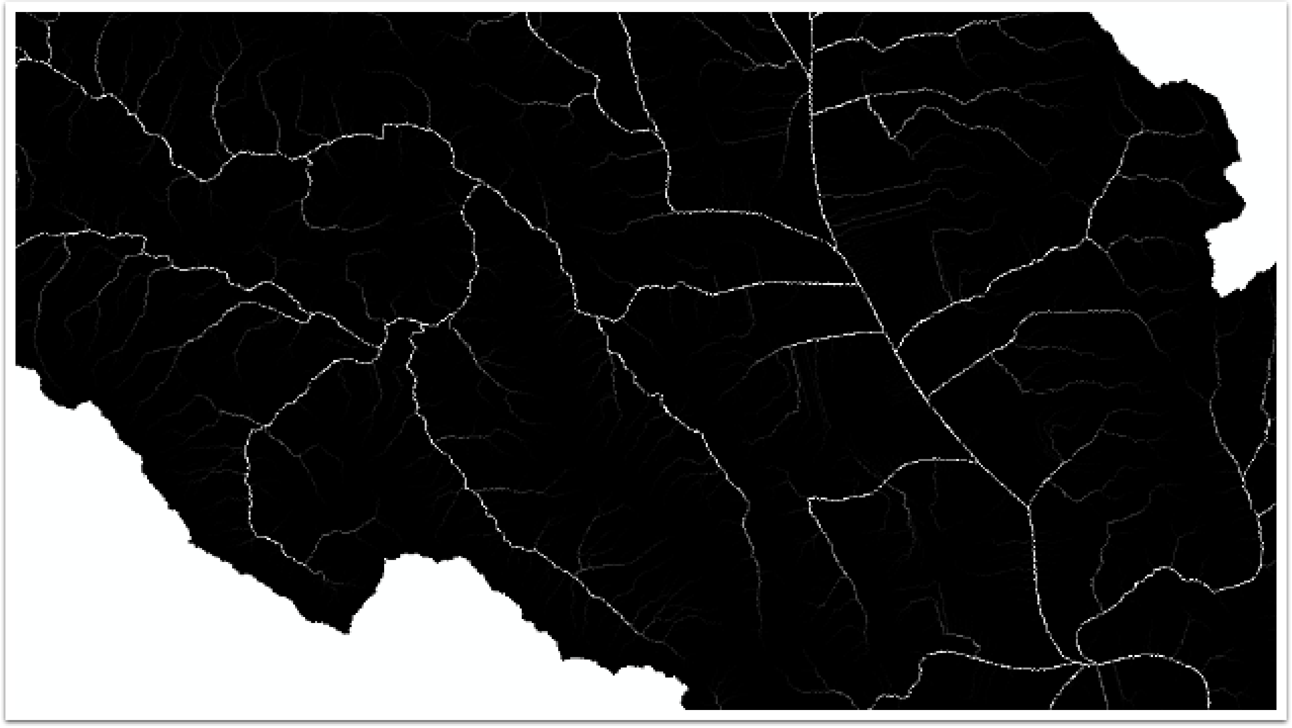
Let's make the flow accumulation raster stretch based upon distributing the values bebtter amongst the available colors, and also set the bounds based upon what you're viewing at each moment (your current display extent).

1. Go to the *Symbology* tab
2. Scroll down so you see the *Stretch* box
3. Change the *Type* to Histogram Equalize - this will distribute the values amongst the colors better
4. Change *Statistics* to *From Current Display Extent* - this option will set the bounds of color ramp based upon what you are viewing - when you zoom or pan, it will recalculate colors - handy!
5. Click OK



5.10 The flow accumulation raster

Does this look more familiar now? What do you think "flow accumulation" means?

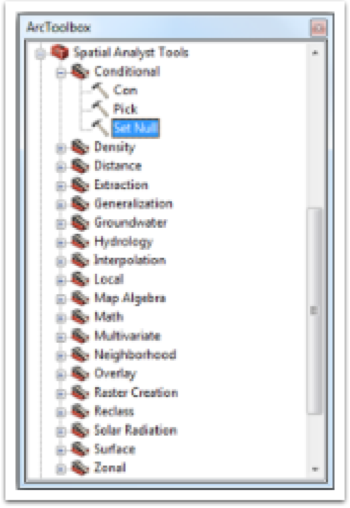


6. Fleshing out our model!

OK. We made sure that our model works, and learned a bit about the core elements of delineating streamlines - flow direction and flow accumulation. Now, let's finish our model for creating vector hydrography.

Bring your model back up if you closed it at any point by right clicking on it in ArcToolbox and going to *Edit.*

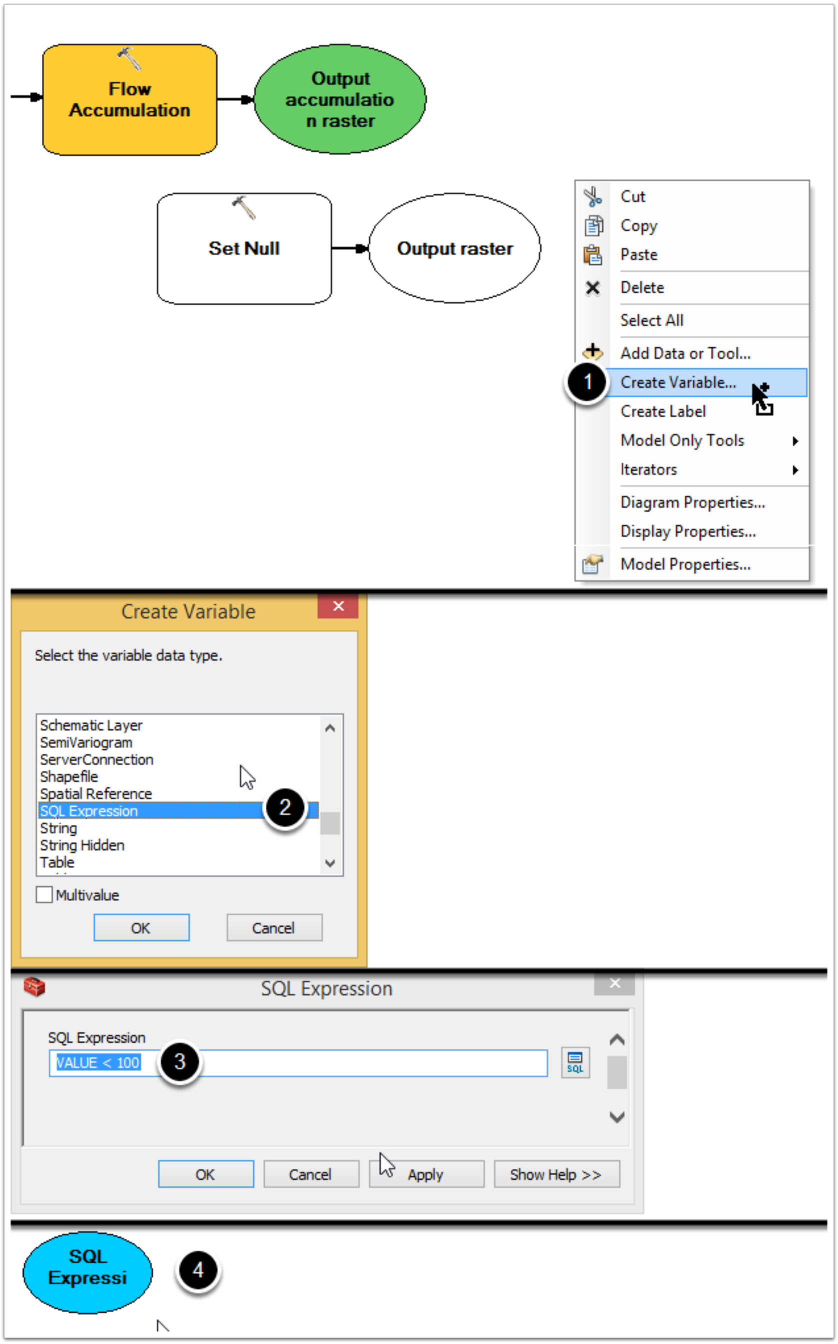
Start by dragging the *Set Null* tool to your canvas (located under *Spatial Analyst Tools > Conditional*). This tool helps us set cells in a raster to *null* values (values to ignore) based on a condition we specify.



6.1 Defining our null condition

Now we need to define our null value. Let's make it a variable so that we can easily overwrite it later.

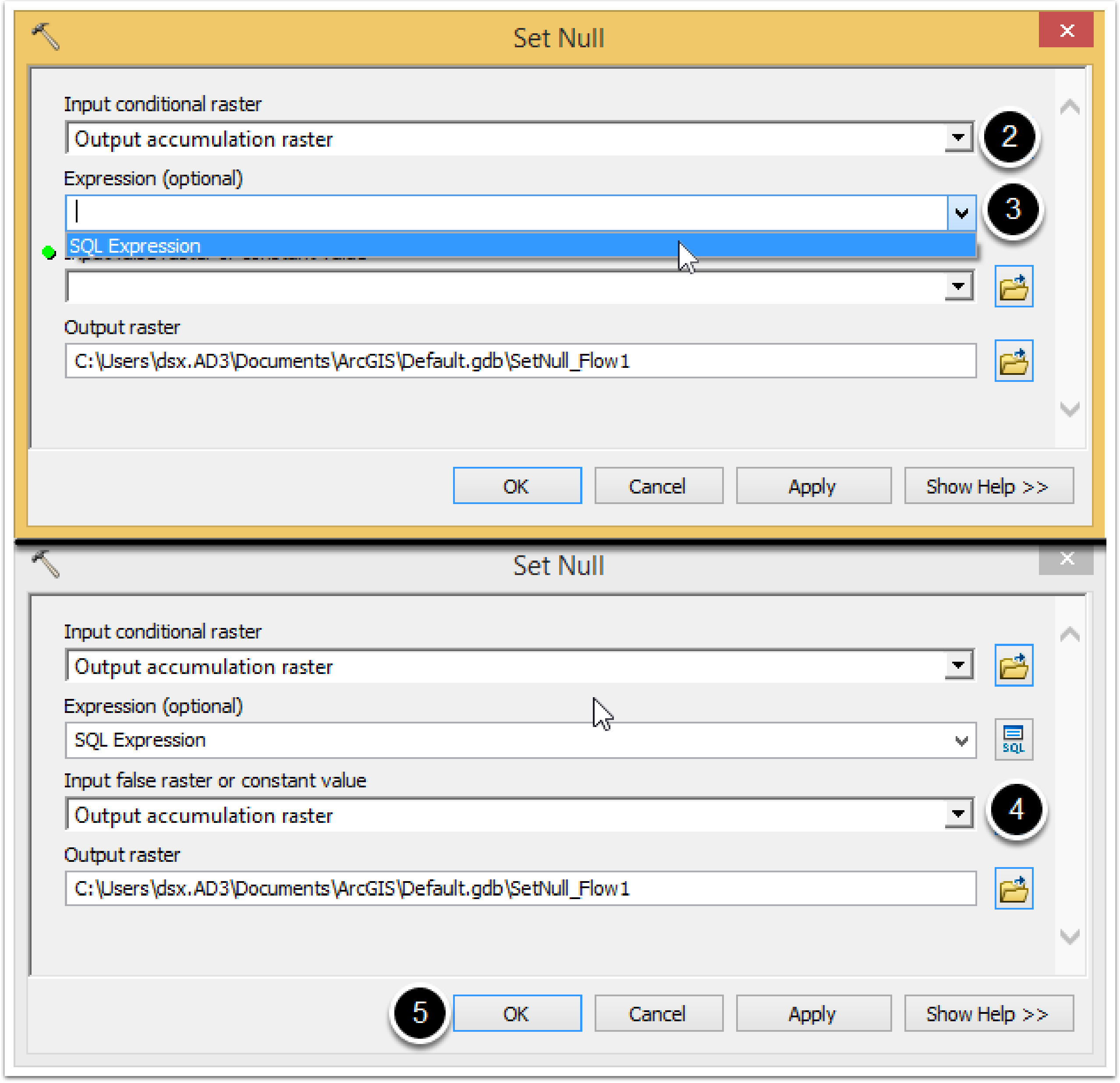
1. Right click in a blank space in your model and select Create Variable
2. Scroll down (or hit *S* on your keyboard to get close) and find *SQL Expression* in the box. Click on it, then click OK
3. Double click on your new variable *SQL Expression*. It will bring up a box to define a value. Put in *VALUE* < *100* and click OK
4. Note that once you define it, *SQL Expression* turns light blue in color to indicate that it's ready to use. Variables all turn light blue.



6.2 Setting low values to null

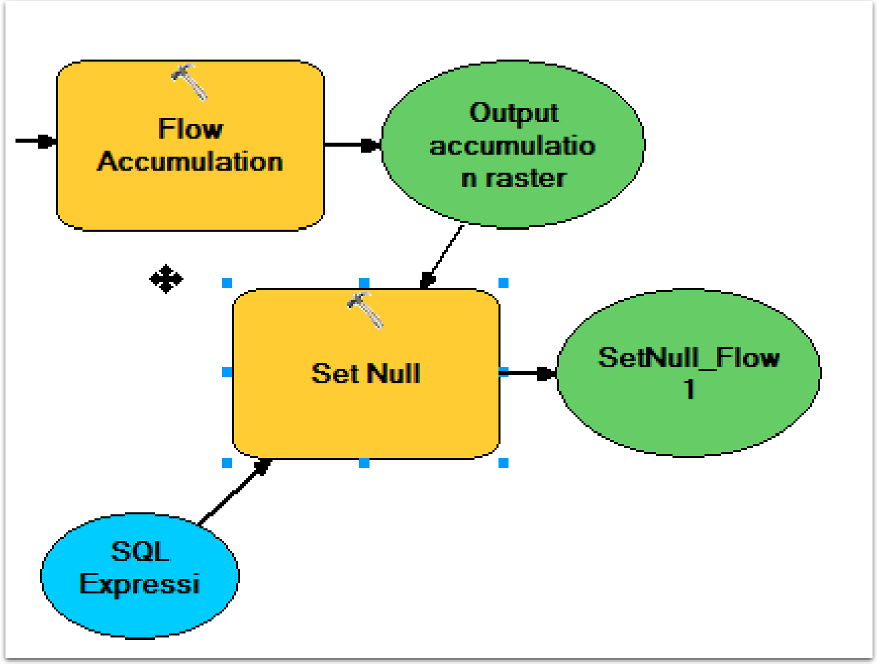
A quick note. I'm not caring much yet about how I organize my canvas because once we link everything together, we'll click a button and ModelBuilder will auto-organize our canvas for us. We'll do this later. For now,

1. Open the *Set Null* tool by double clicking on it on your canvas.
2. Set your *Output accumulation raster* as the *Input conditional raster*
3. Set *SQL Expression* as your *Expression* using the dropdown
4. Set *Output accumulation raster* as your *Input false raster or constant value* (why are we using this raster twice here?)
5. Click OK to save your settings.



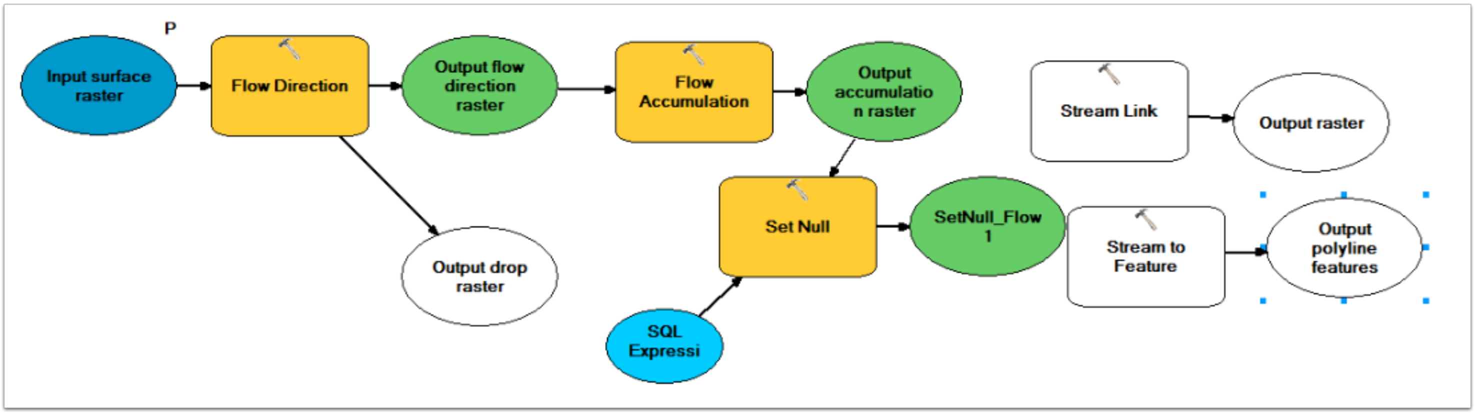
6.3 Autoconnecting parts

Note that now that you've defined things in the tool dialog, ModelBuilder automatically made the connections for you, when you selected another item in the same ModelBuilder canvas. It understands the relationships you're defining and these things propogate throughout the interface.



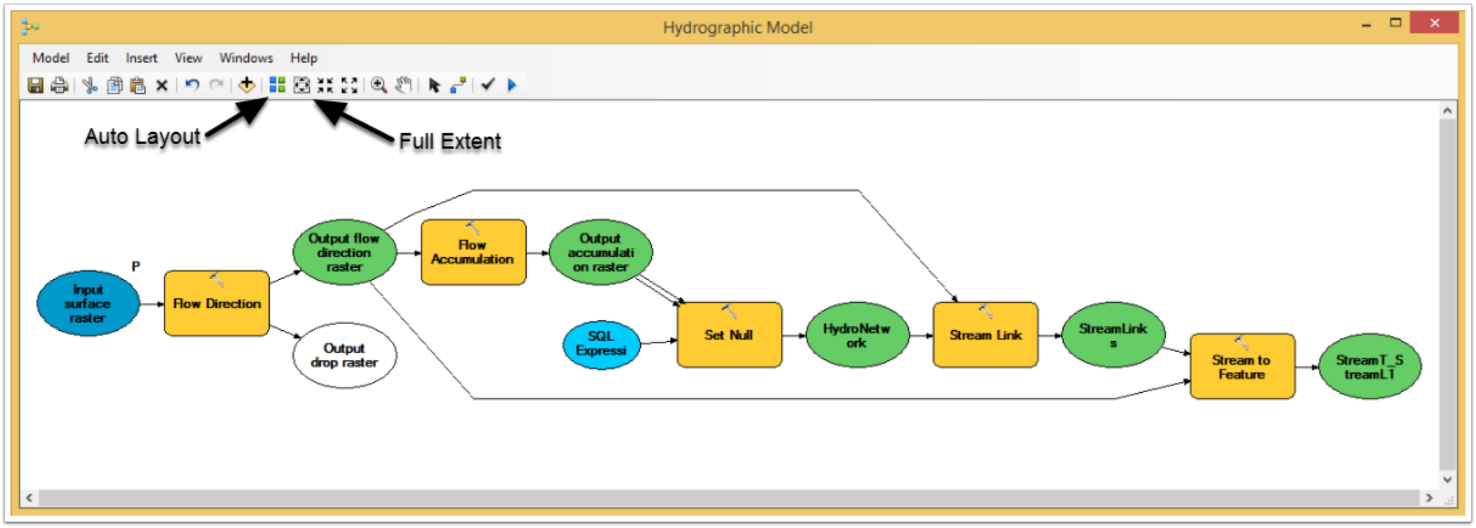
6.4 Adding our additional tools

1. Drag two tools from the *Spatial Analyst Hydrology Toolset* to your canvas: *Stream Link* and *Stream to Feature.*
2. Rename (by right clicking on the objects and selecting *Rename*) the *Set Null* output object from *SetNull_Flow...* (or similar) to *HydroNetwork* and the Stream Link output object from *Output raster* to *StreamLinks.*



6.5 Make the connections

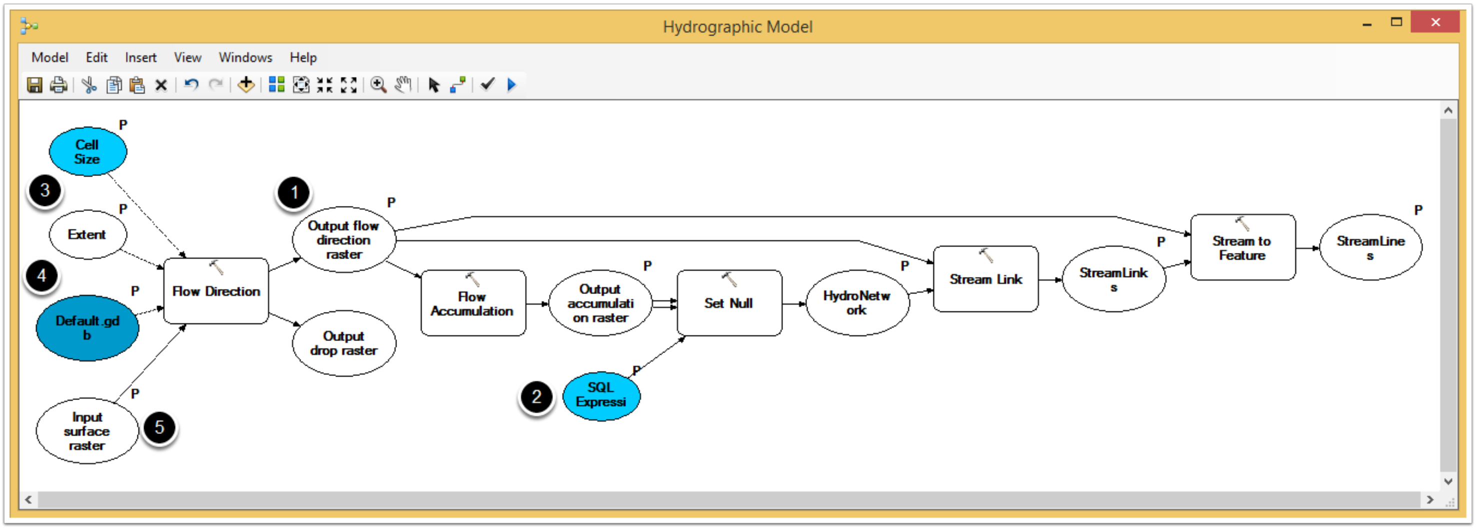
1. Set your *HydroNetwork* layer as the *Input Stream Raster* for *Stream Link* (whether you use the connector tool or the tool dialog is up to you)
2. Set your flow direction raster layer as the *Input Flow Direction Raster* for *Stream Link*
3. Do the same thing with your flow direction raster, but as the input for *Stream to Feature*
4. Set your output from *Stream Link* (named *StreamLinks*) as the other input to *Stream to Feature*.
5. For future viewing, rename the output of *Stream to Feature* to something like *StreamLines.*
6. Everything should light up in color. One last step for this main part: Click the *Auto Layout* button, then the *Full Extent* button to make viewing your model tolerable again.



6.6 Add your environments, set your parameters

1. Individually right click on each of the output rasters from the tools (flow direction, accumulation, hydro network, stream links, and stream to feature) and make each one a parameter so you can select where to save them.
2. Do the same for your *SQL Expression* so that you can change the value when you run it (but it will keep what we defined as the default.
3. Let's also add in our environment settings for our flow direction raster. We'll add *Current Workspace*, *Extent*, and *Cell Size* by right clicking on *Flow Direction* and selecting *Make Variable > From Environment* and selecting each one in turn. You'll need to find each one in the submenu, but exploring the environment settings available to you is a good thing to do.
4. Make each of those environments into model parameters, then click *Auto Layout* and *Full Extent* again to see your results

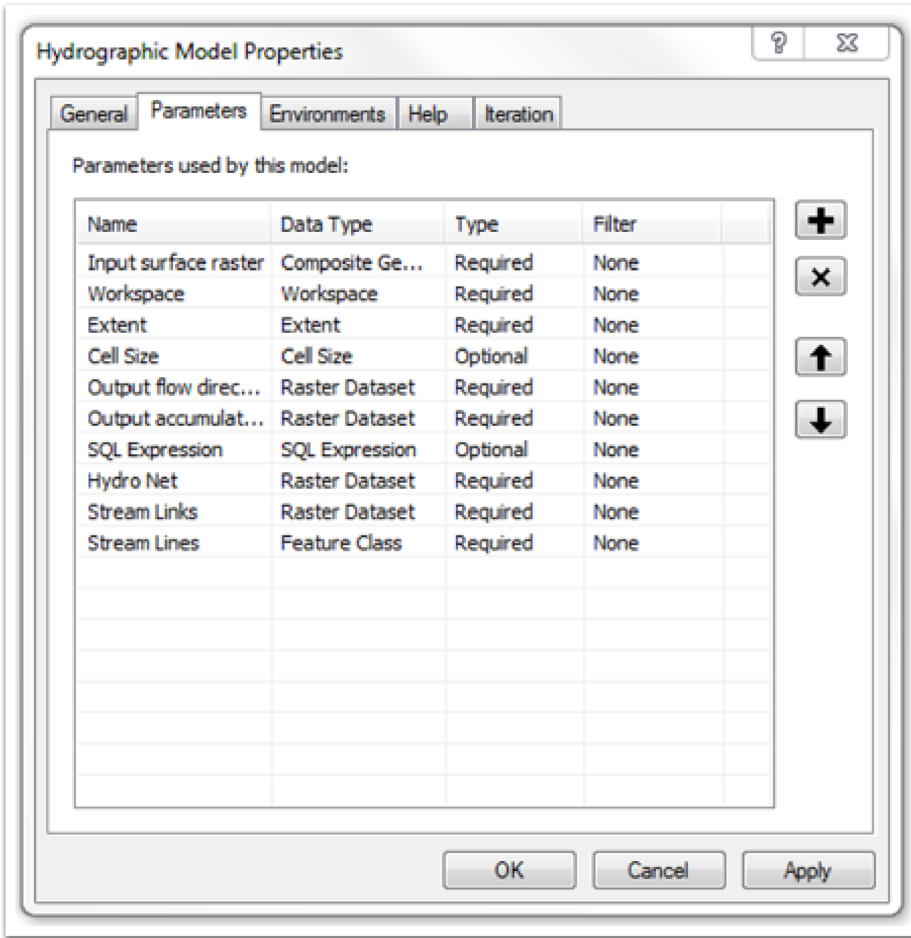
5. For final cleanup, double click on *Input Surface Raster* and remove the definition of *PutahCreek_DEM_30m* (select it, then delete) and click OK. The color will mostly disappear, but now our model is generic and flexible.



6.7 Reorder parameters

Open your model properties again (remember how?) and re-order the model parameters to depict a logical flow of model inputs and outputs. They may already look fine to you. Click OK.

Save and close your model.

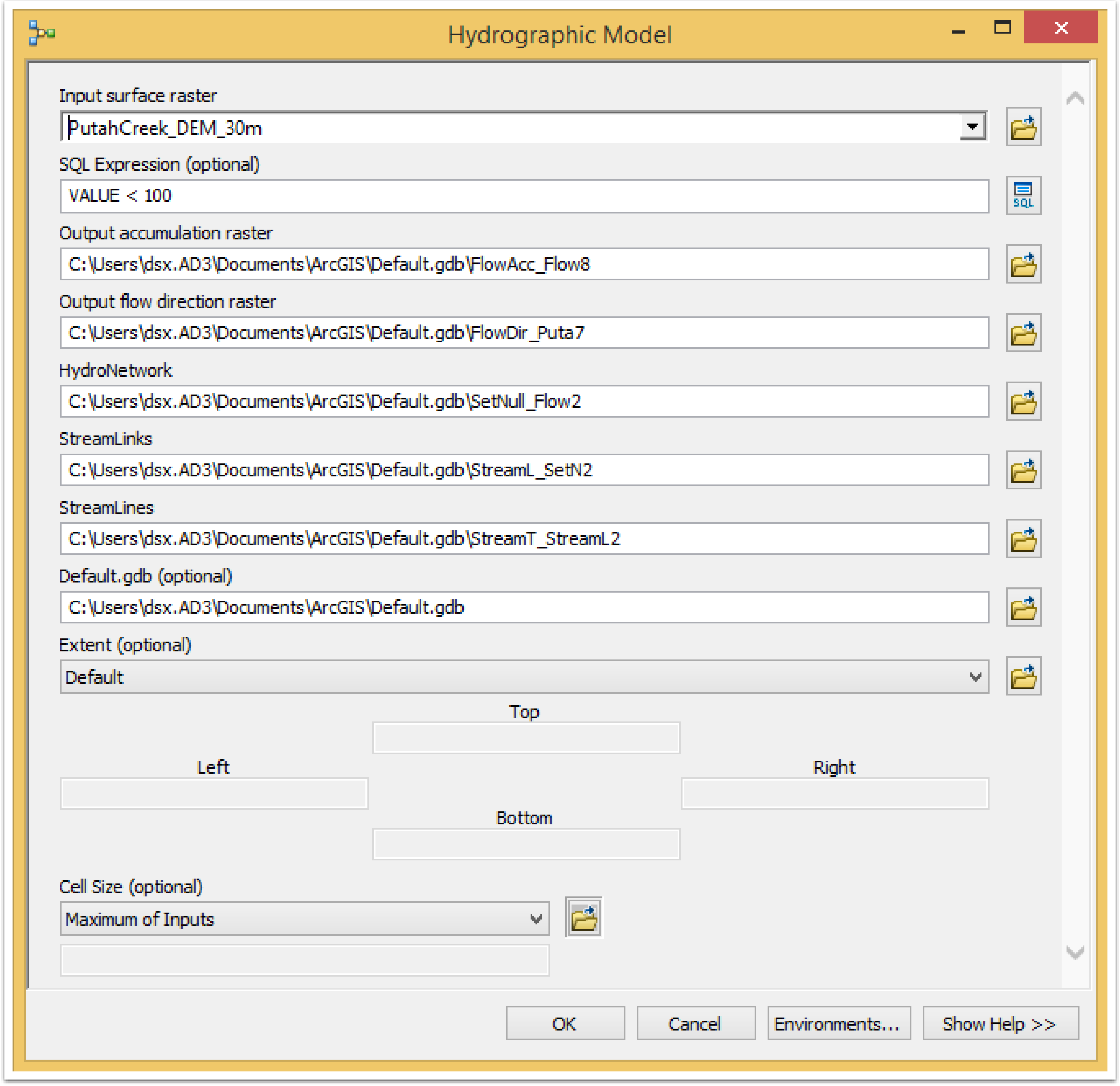


6.8 Run your model!

Double click your model in the toolbox to open the dialog. Look at all those parameters! Yikes! Fortunately, we'll only set one of them.

Set *Input surface raster* to *PutahCreek_DEM_30m* and the rest of the fields will fill in. Click OK to run the tool and wait while it finishes. Then, since we set each of the output raster to parameters and they have explicit paths, they'll show up in our Table of Contents. You'll have a number of layers to look at, but turn them all off temporarily, except the StreamLines layer (whatever it ends up being named. Mine was StreamT_StreamL2 when I accepted defaults. Yours may be different, but should be at the top of your Table of Contents).

Do these look like reasonable streamlines? Compare them to your Hydro DEM and your Flow Accumulation rasters. Do they seem to capture where you think streamlines should be?



7. One (two) more time!

Run the model two more times, setting your SQL Expression value to *VALUE < 10,000* and *VALUE < 100,000* - what do you think this will do to the final output? Examine the outputs from the three different runs for what is consistent and what is different. Think about how you might modify the model so that it wouldn't have to run flow direction and flow accumulation each time.

8. Extra Credit

Want an extra thought experiment and workflow to add to your model?

Bankfull Width for a nearby watershed, the Navarro River, is defined as **~2.5 * (Drainage Area in SqKm^$^{0.5}$).**

Create a similar hydro model that buffers the polylines by the bankfull width values for each stream segment to find the area for the stream that is commonly considered streambed.

Remember:

- A flow accumulation raster can be a proxy for upstream area
- There are quite a few ways to get the flow accumulation data attached to stream segments