## Project 2: Watershed Functions

Save and close your project, above, if you haven't done so already. Then, open a new project, and add the *driftless* DEM.

We'll be using ArcToolbox for this new project, but **be forewarned** – these tools are buggy. You are best bet is to start early, follow the instructions carefully, save often, and if it doesn't work, close ArcMap and restart from the beginning (meaning create a new project, and repeat the steps). If this doesn't work, please contact one of the instructors for help – no sense in banging your head against a wall. (see *Video: Watershed*).

Open **ArcToolbox→Spatial Analyst Tools – Hydrology**. This should display the tools shown at the right:
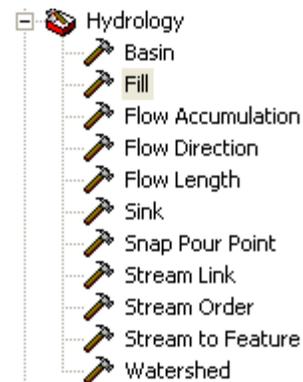
We'll be applying them in the following order:
(The order is important.)

Fill
Flow Direction
Flow Accumulation
Snap Pour Point (on a point feature we'll create)
Watershed

We use the fill command to fill and pits in the DEM. As described in chapter 11 of GIS Fundamentals, pits are local depressions along which a stream would be expected to flow. These depressions may be real, or they may be due to errors in the data. However, a DEM is a representation of a waterless terrain surface, (the flow algorithms used here are programmed on this basis). So, local pits or flat areas may "trap" our routefinding when we are trying to identify downhill directions. The simplest of watershed processing routines begins by simply filling the pits. More sophisticated ones may fill the pits, and "burn in" a stream line, along which the DEM is lowered after filling to maintain a downstream flow.

Apply the **Fill** tool from the **Hydrology** toolbox. Specify the driftless DEM as input, and something like *filled_dem* for the output name. Don't bother with the Z limit, here and in the subsequent tasks, and click on OK to run the tool.

After a minute, the filled data set should be automatically added to your view. Subtract (via the Raster Calculator) the *driftless* DEM from your *filled_dem*, and display the calculation. Change the color display and Display Background Value as dark blue.   Notice the location and range of the fills; it should look something like shown on the right.
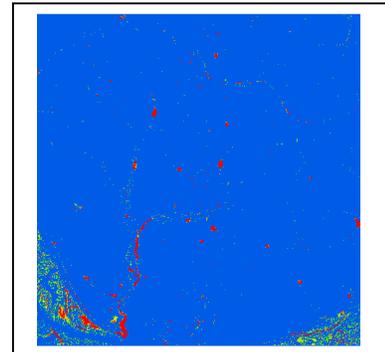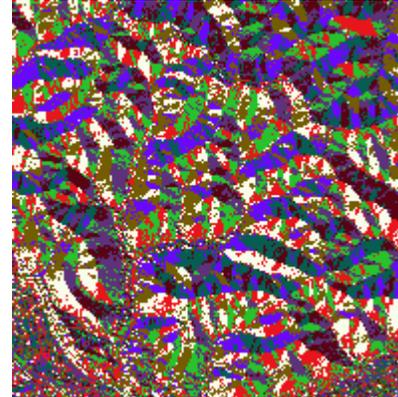
Now, apply the **Flow Direction** tool, using the filled DEM as your input, and specifying a flow direction output data layer; name the output *f_direction*. Check the box "flow all edge cells to flow outward".
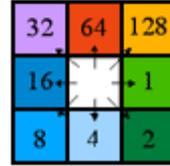
As noted in the textbook, this flow direction layer will contain a direction coding, with a set of numbers that define the cardinal and sub-cardinal direction, something like the figure to the right. The number 1 in a cell means water flows due east, 128 indicates northeast, 64 water flows north, and so on. This is a discreet categorization, all the water flows from a cell to an adjacent cell in only one of 8 directions. This method is known as the D8 flow direction, to distinguish it from methods that can send a portion of the water from a cell to multiple neighboring cells.

Your output from the flow direction tool should look something like the figure to the right, and the symbols should show 8 values from 1 to 128, corresponding to flow direction.

Now apply the **Flow Accumulation** tool from ArcToolbox. This finds the highest points, and accumulates the area (or number of cells) downhill, according to the flow direction.

Specify the input as *f_direction*, name the flow accumulation raster as *f_accum*, ignore the weight raster, and specify an output data type of Float.

This should generate a display similar to the graphic at right. If you look closely, you will see some narrow, perhaps intermittent white lines in a dark background.

Notice the maximum and minimum value for the data layer, they will be something like $1.63 * 10^6$ and 0.
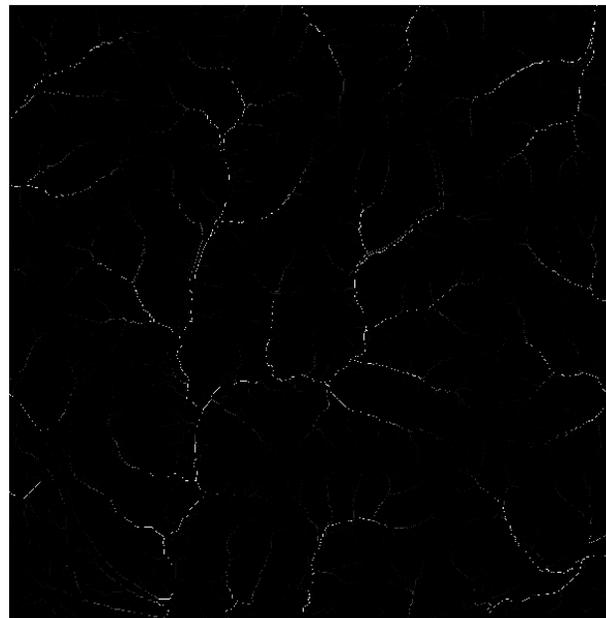
These numbers are the cells that drain to any given cell. For example, a cell with a value of 12,847 receives water

from that many cells. Since these cells are 3 m by 3 m, each cell counts for 9 square meters, and there are about 111,000 cells per square kilometer.
We may use this flow accumulation grid to approximate where streams will be found on the surface, and to determine outlet points for watersheds.

In any given small region and geology, there is usually a rough correspondence between drainage area, here measured with flow accumulation, and stream initiation. For example, once a drainage area of 0.45 square kilometers is reached, a stream may form. This would be 0.45 km2 * 1,000,000 m^2/km^2 / 9 m^2/cell, or about 50,000 cells. So if we symbolize the flow accumulation layer so all cells above 50,000 are blue, and all equal or below are no color, we will get an approximate idea of where the streams will be found (this threshold is made for this exercise, but is probably not too far off).

You may apply the symbolization by reclassifying the flow accumulation layer into two classes, and setting the lower threshold to 50,000, the upper threshold to the maximum value, as described in previous labs. (Hint: Spatial Analyst Tools→Reclass→Reclassify, Classify use NoData for the under 50,000 values and 1 for above 50,000, name the output, *d_streams*)

We must apply a couple of more steps to define our watersheds. First you must create an empty point shapefile using ArcCatalog, name the file *outlet.shp*, and specifying a coordinate system equal to that used for the *driftless* DEM.

Then we must digitize a watershed outlet point. Add the new empty *outlet* shapefile, make it the active editing target, and display the DEM with the recolored flow accumulation grid over it.
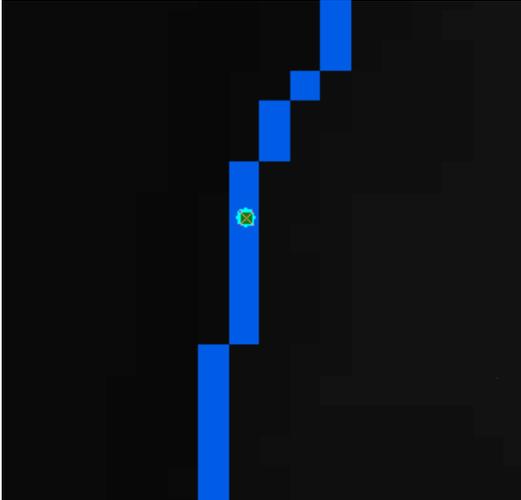
Zoom into the southwest quadrant, so that your view looks similar to that at right. Digitize a point near the location shown below, along the stream near the outlet to the largest watershed in the DEM.
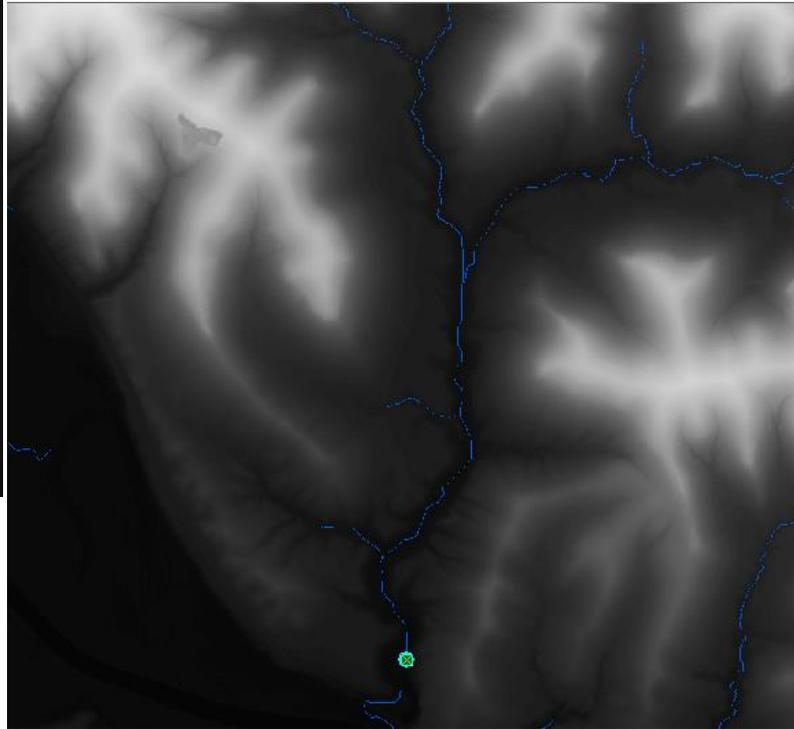
Remember, the figure at the right is zoomed to about ¼ of the DEM extent. You'll want to zoom in much closer to digitize the point, so you can place it near the center of one of the stream cells.

A zoom something like that shown here is more appropriate: Start Editing, add your point, then save your edits and stop editing.

Now apply the **Hydrology→Snap Pour Point** tool.

- Specify *Outlet* as your input raster or feature pour point dataset,

- any pour point field, (Id is fine)

- the flow accumulation raster you created earlier, *f_accum*

- a new output raster to contain your raster pour point, name it *r_pour_pt*

- an appropriate snap distance, something like 3 to 9 (about 1 to 3 cells).

This should create a raster with a single cell for a value, near your digitized outlet.

Now, run the **Hydrology→Watershed** tool, specifying your flow direction raster (*f_direction*), your just created raster pour point layer (*r_pour_pt*), leaving the pour point field as "Value", and specifying an appropriately-named output watershed, like *watershed*.

This should create a watershed layer something like that to the right. Changed the color, and made the raster 50% transparent.

Now convert the d_streams from a raster to a shapefile. This will display the streams more clearly.

Use
A**rcToolbox→Conversions→From Raster→Raster to Polyline**

Name the output something like *Derived_Streams.*
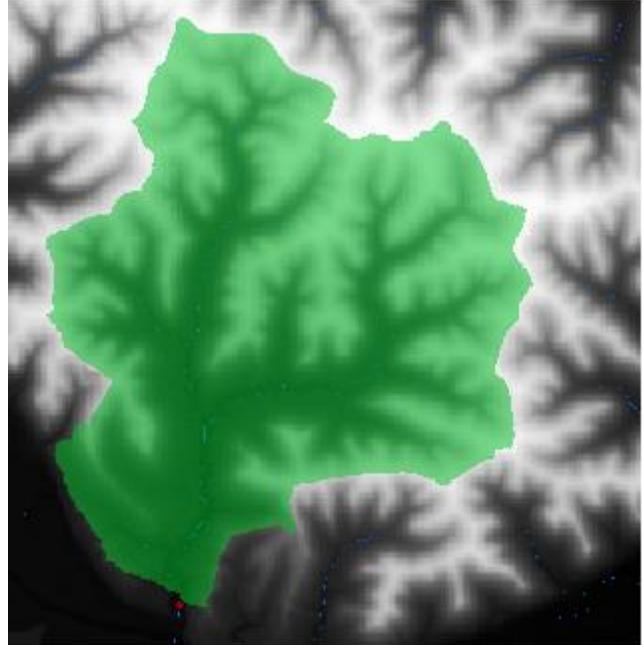
Select Background value as NODATA and Simplify polylines.