Data Analysis of high-resolution LiDAR DEMs using fill, flow direction, flow accumulation, and watershed boundaries tools

GIS in Environmental Science and Management
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Introduction

In this exercise we will begin with LiDAR DEM data and manipulate it through various Spatial Analysis tools in ArcMap 10 to define a watershed boundary within a specified field area. This portion of a project analysis will utilize a variety of tools from the Spatial Analysis Toolbox functions including; Fill, Flow Accumulation, Flow Direction, Snap Pour Point, Watershed, Raster Calculator, and Reclass.

To summarize this procedure, we will first apply the Fill tool to remove any pits and imperfections in the DEM layer, then we will apply the Flow Direction tool to determine cardinal and subcardinal flow directions from each cell within the range of the DEM layer, then we will apply the Flow Accumulation tool to sum the flow directions to the lowest points indicating stream channels and drainage networks, and finally we reclassify and use the Snap Pour Point tool in order to apply the Watershed tool which will define the boundaries of water flow from cells in the DEM layer into the streams identified by flow accumulation.

Background

The data analysis of a LiDAR DEM through Fill, Flow Direction, and Flow Accumulation tools will produce a watershed boundary layer summing the drainage network of an area of interest. This type of analysis is of interest when performing studies which look at the water flow patterns where drainage outlets are located. Variations of this analysis range from urban setting where an outlet point may be at the location of a storm grate, or in a natural setting where the outlet point may be located where a stream meets a river.

Goals

The goal of this specific portion of an analysis is primarily to identify watershed boundaries in a specified field area. However this type of analysis may be applied to a variety of studies. For example, defining the watershed boundaries in an urban setting allows us trace chemicals such as nitrate and phosphorus which have been deposited from leaves on roads and sidewalks and have been incorporated into runoff, potentially causing poor water quality.

Data Required

- LiDAR DEM of appropriate field area
- A weighted raster data layer (optional)
- Shapefile containing watershed outlet points - storm grates (optional)

Outputs

Sequentially through this procedure, the following outputs will be created: a Fill layer, a subtracted raster calculation layer, a flow direction layer, a flow accumulation layer, an outlet point shapefile, a snap pour point layer, and a watershed boundary layer.
Procedure

We will use the Hydrology function from Spatial Analysis in ArcToolbox to access and apply the fill, flow direction, flow accumulation, and watershed tools. To access these tools select the ArcToolbox at the top of the page (small square icon, with small red box inside).

Select ArcToolbox → Spatial Analysis Tools → Hydrology. Displayed below hydrology, will be the primary tools used for this analysis.

The fill tool is used to “fill” in pits and sinks in the surface raster of the LiDAR layer to remove any imperfections. A pit, or a sink, is a cell in the data with an undefined drainage direction, in which none of the neighboring are lower. These imperfections may be actual physical depression in the area of interest or a result of errors in the DEM data. Regardless, if the fill function is not applied before applying the subsequent functions the pits may become problematic when identifying downhill flow directions.

To apply the fill tool select; ArcToolbox → Spatial Analysis Tools → Hydrology → Fill.
In the fill window, for input specify your LiDAR DEM layer, name the output something like “fill_area2”, and leave the Z limit box blank. See example below. Select OK and allow the fill function to run. A fill_area2 layer should be added to your table of contents.

Your map should look something like this.

We will now use the Raster Calculator to subtract the LiDAR DEM layer from the fill_area2. To do this, go to Arctoolbox → Spatial Analysis Tools → Map Algebra → Raster Calculator.
In the text box at the bottom of the Raster Calculator window, via selection (not by typing) subtract the LiDAR DEM from fill_area2. Name your output something like rastercalc_area2. Select OK. A rastercalc_area2 layer should be added to your data layer.

Your map should look something like this:

The flow direction tool is used create a raster layer which calculates the flow direction from one cell to its steepest downslope neighboring cell. The raster layer created through this function will contain a directional coding in which each cell will be assigned a number identifying the primary flow direction. There are 8 possible number codes corresponding to cardinal and subcardinal directions that may be assigned to each cell; 1=due east, 2=southeast, 4=due south, 8=southwest, 16=due west, 32=northwest, 64=due north, and 128=northeast. The flow direction tool will allow us to identify the flow patterns of the water in the study area.
To apply flow direction select Arctoolbox → Spatial Analysis Tools → Hydrology → Flow Direction. Select fill_area2 as your input source, and name your output something like flowdirection_area2. Check the box indicating “Force all edge cells to flow outward (optional)”. You may leave the output drop raster empty. Select OK. A flowdirection_area2 layer should be added to your data layer.

Your map should look something like this, with values ranging from 1 to 128:

Next we will use the Flow Accumulation tool. The function of the Flow Accumulation tool is to create a raster set that accumulates the flow directions of each cell in your data set. This function is determined by accumulating the weight of each of the cells throughout the layer which
flow into the same downslope cell. The flow accumulation tool allows for the identification of streams or drainage paths through the specified area. The output of this step produces a layer displaying the number of cells accumulating into a single specified cell. To apply the Flow Accumulation tool select Arctoolbox → Spatial Analysis Tools → Hydrology → Flow Accumulation.

![Flow Accumulation tool](image)

Choose flowdirection_area2 as the input, and name the output something like flowacc_area2. At this point you may select an appropriate input weight raster, however in this example we will leave it blank. Choose float as your output data type, and select OK. A flowacc_area2 layer should be added to your data set.

Your map should look something like this:
As a final step we will define the watershed boundaries of the specified area. First, we must reclassify the flow accumulation layer into two classes in order to separate the streams from the remainder of the data. To do so, go to ArcToolbox → Spatial Analysis Tools → Reclass → Reclassify. Select your flowaccumulation_area2 as your input source, and value as your reclassify field. Assign “NoData” values to the old values that are less than 50,000 and “1” to old values that are greater than 50,000. Name your output raster something like streams_area2. A new raster layer should be added to your data frame.
We now need to create a new point shapefile from the raster layer and name it something like output_area2. To create the shapefile go to Arctoolbox, select a folder, right click, select new→ shapefile. Be sure to specify the correct coordinate system, in this case NAD_1983_CORS96_UTM_Zone_15N.

Once we have converted this data into a shapefile, we may then identify the watershed output point. Start editor and digitize a point near the outlet of the largest watershed. When performing this analysis in an urban setting, you may use storm grates as the outlet points. Be sure to save edits and stop editing once your point is digitized.

To define the watershed, we will first start by selecting Arctoolbox → Spatial Analysis Tools → Hydrology → Snap Pour Point. Indicate the recently created shapefile of outlet point - output_area2 as your input, select Id as the Pour point field, flowaccumulation_area2 as the input accumulation raster, a snap distance of 3 and name the output raster something like area2_pour_point.
Now, to define the watershed boundaries select **Arctoolbox → Spatial Analysis Tools → Hydrology → Watershed**. Use flowdirection_area2 as your input flow direction raster, area2_pour_point as the input raster, value or blank as the pour point field, and an appropriate output raster name such as area2_watershed. Select OK. Your map should now look something like this, defining the watershed boundaries: