Watershed Delineating System

What is a watershed?

A watershed is an area of land that drains or “sheds” water into a specific waterbody. Watersheds drain rainfall and snowmelt into streams and rivers. These smaller bodies of water flow into larger ones, including lakes, bays, and oceans which are often called outlets. Watersheds can vary in size. A watershed for a tiny mountain creek might be as small as a few square meters. Some watersheds are enormous and usually encompass many smaller ones.

Reference: https://www.nationalgeographic.org/encyclopedia/watershed

This guide will show you the steps involved in delineating a watershed region by running a series of tools which have been implemented from WhiteboxTools.

What is Whitebox Tools?

WhiteboxTools is an advanced open-source geospatial data analysis platform developed at the University of Guelph’s Geomorphometry and Hydrogeomatics Research Group (GHRG). Dr. John Lindsay and Anthony Francioni are the co-founders of Whitebox Geospatial Inc.

Reference: https://www.whiteboxgeo.com/

What is a Raster?

In its simplest form, a raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.

Reference:

https://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/what-is-raster-data.htm

You can get the raster data sets from https://earthexplorer.usgs.gov/ or https://www.eorc.jaxa.jp/ALOS/en/index_e.htm or from other similar website that provides it.

Note: Above mentioned both websites will require you to sign up in order to download raster data sets.

Before we begin, add the raster to map view. Click on 'Add raster layer' from Layer menu and then select the raster file to load.

Steps to delineate a watershed:

Step 1) Fill Depressions

From Tool Box, double click on 'Fill Depressions' from Hydrological Analysis section. This tool is used to fill all of the depressions in a digital elevation model (DEM) and to remove the flat areas. This is a common pre-processing step required by many flow-path analysis tools to ensure continuous flow from each grid cell to an outlet located along the grid edge. The tool algorithm operates by first identifying single-cell pits, that is, interior grid cells with no lower neighbouring cells. Each pit cell is then visited from highest to lowest and a priority region-growing operation is initiated. The area of monotonically increasing elevation, starting from the pit cell and growing based on flood order, is identified. Once a cell, that has not been previously visited and possessing a lower elevation than its discovering neighbour cell, is identified the discovering neighbour is labelled as an outlet (spill point) and the outlet elevation is noted. The algorithm then back-fills the labelled region, raising the elevation in the output DEM to that of the outlet. Once this process is completed for each pit cell (noting that nested pit cells are often solved by prior pits) the flat regions of filled pits are optionally treated with an applied small slope gradient away from outlets (note, more than one outlet cell may exist for each depression). The user may optionally specify the size of the elevation increment used to solve flats, although **it is best to not specify this optional value and to let the algorithm determine the most suitable value itself**. The flat-fixing method applies a small gradient away from outlets using another priority region-growing operation (i.e. based on a priority queue operation), where priorities are set by the elevations in the input DEM. This in effect ensures a gradient away from outlet cells but also following the natural pre-conditioned topography internal to depression areas.

Reference:
https://whiteboxgeo.com/manual/wbt_book/available_tools/hydrological_analysis.html#FillDepressions

Step 2) D8 Pointer

From Tool Box, double click on 'D8 Pointer' from Hydrological Analysis section. This tool is used to generate a flow pointer grid using the simple D8 (O'Callaghan and Mark, 1984) algorithm. The user must specify the name of a digital elevation model (DEM) that has been hydrologically corrected to remove all spurious depressions and flat areas. The local drainage direction raster output by this tool serves as a necessary input for several other spatial hydrology and stream network analysis tools in the toolset. Some tools will calculate this flow pointer raster directly from the input DEM.

By default, D8 flow pointers use the following clockwise, base-2 numeric index convention:

.	.	.
64	128	1
32	0	2
16	8	4

Notice that grid cells that have no lower neighbours are assigned a flow direction of zero. In a DEM that has been pre-processed to remove all depressions and flat areas, this condition will only occur along the edges of the grid. Grid cells possessing the NoData value in the input DEM are assigned the NoData value in the output image.

Reference:

https://whiteboxgeo.com/manual/wbt_book/available_tools/hydrological_analysis.html#D8Pointer

Step 3) D8 Flow Accumulation

From Tool Box, double click on ‘D8 Flow Accumulation’ from Hydrological Analysis section. This tool is used to generate a flow accumulation grid (i.e. catchment area) using the D8 (O'Callaghan and Mark, 1984) algorithm. This algorithm is an example of single-flow-direction (SFD) method because the flow entering each grid cell is routed to only one downslope neighbour, i.e. flow divergence is not permitted. The user must specify the input digital elevation model (DEM) or flow pointer file. If an input DEM is used, it must have been hydrologically corrected to remove all spurious depressions and flat areas.

In addition to the input DEM/pointer, the user must specify the output type. The output flow-accumulation can be 1) cells (i.e. the number of inflowing grid cells), catchment area (i.e. the upslope area), or specific contributing area (i.e. the catchment area divided by the flow width. The default value is cells. The user must also specify whether the output flow-accumulation grid should be log-transformed, i.e. the output, if this option is selected, will be the natural-logarithm of the accumulated flow value. This is a transformation that is often performed to better visualize the contributing area distribution. Because contributing areas tend to be very high along valley bottoms and relatively low on hillslopes, when a flow-accumulation image is displayed, the distribution of values on hillslopes tends to be 'washed out' because the palette is stretched out to represent the highest values. Log-transformation provides a means of compensating for this phenomenon. Importantly, however, log-transformed flow-accumulation grids must not be used to estimate other secondary terrain indices, such as the wetness index, or relative stream power index.

Grid cells possessing the **NoData** value in the input DEM/pointer raster are assigned the **NoData** value in the output flow-accumulation image.

Reference:

https://whiteboxgeo.com/manual/wbt_book/available_tools/hydrological_analysis.html#D8FlowAccumulation

Step 4) Extract Streams

From Tool Box, double click on ‘Extract Streams’ from Stream Network Analysis section. This tool is used to extract, or map, the likely stream cells from an input flow-accumulation image. The algorithm applies a threshold to the input flow accumulation image such that streams are considered to be all grid cells with accumulation values greater than the specified threshold. As such, this threshold represents the minimum area (area is used here as a surrogate for discharge) required to initiate and maintain a channel. Smaller threshold values result in more extensive stream networks and vice versa. Unfortunately, there is very little guidance regarding an appropriate method for determining the channel initiation area threshold. As such, it is frequently determined either by examining map or imagery data or by experimentation until a suitable or desirable channel network is identified. Notice that the threshold value will be unique for each landscape and dataset (including source and grid resolution), further complicating its a *priori* determination. There is also evidence that in some landscape the threshold is a combined upslope area-slope function. Generally, a lower threshold is appropriate in humid climates and a higher threshold is appropriate in areas underlain by more resistant bedrock. Climate and bedrock resistance are two factors related to drainage density, i.e. the extent to which a landscape is dissected by drainage channels.

The background value of the output raster will be the NoData value unless the ‘Use zero for background value’ is checked.

Reference:

https://whiteboxgeo.com/manual/wbt_book/available_tools/stream_network_analysis.html#ExtractStreams

Step 5) Raster Streams To Vector

From Tool Box, double click on ‘Raster Streams To Vector’ from Stream Network Analysis section. This tool converts a raster stream file into a vector file. The user must specify: 1) Input raster streams file, 2) Input raster D8 pointer file, and 3) Output vector file. Streams in the Input raster streams file are denoted by cells containing any positive, non-zero integer. A field in the vector database file, called STRM_VAL, will correspond to this positive integer value. The database file will also have a field for the length of each link in the stream network. The Input raster D8 pointer file must be calculated from a DEM with all topographic depressions and flat areas removed and must be calculated using the D8 flow pointer algorithm. The output vector will contain PolyLine features.

Reference:

https://whiteboxgeo.com/manual/wbt_book/available_tools/stream_network_analysis.html#rasterstreamstovector

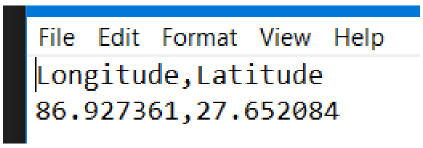
Note: When creating a vector file, make sure to give .shp extension to file name.

Click on ‘Add vector layer’ from Layer menu and select the vector streams file with .shp extension to load it onto the map. Adding a vector layer might take some time (5 – 10s) depending upon the number of features of the vector file.

Step 6) Create an outlet point for watershed

Left click on the map to get the coordinates of that location. Make a CSV file which contains the coordinates of the point. Make sure the CSV file has UTF – 8 (Comma delimited) encoding type.

E.g.:


File Edit Format View Help

```
Longitude,Latitude
86.927361,27.652084
```

Step 7) CSV Points To Vector

Once the CSV file with coordinates of the point is created, From Tool Box, double click on ‘CSV Points To Vector’ from Data Tools section. This tool can be used to import a series of points contained within a comma-separated values (*.csv) file into a vector shapefile of a POINT ShapeType. The input file must be an ASCII text file with a .csv extensions. The tool will automatically detect the field data type; for numeric fields, it will also determine the appropriate length and precision. The user must specify the x-coordinate and y-coordinate fields. All fields are imported as attributes in the output vector file. The tool assumes that the first line of the file is a header line from which field names are retrieved.

Reference:

https://www.whiteboxgeo.com/manual/wbt_book/available_tools/data_tools.html#CsvPointsToVector

Step 8) Add an outlet point on map.

Click on 'Add vector layer' from Layer menu and select the vector point file with .shp extension to load it onto the map.

Step 9) Watershed

From Tool Box, double click on 'Watershed' from Hydrological Analysis section. This tool will perform a watershedding operation based on a group of input vector pour points, i.e. outlets or points-of-interest. Watershedding is a procedure that identifies all of the cell's upslope of a cell of interest (pour point) that are connected to the pour point by a flow-path. The user must specify the D8-derived flow pointer (flow direction) raster, a vector pour point file (Created in step 7; .shp extension), and the output raster. Watersheds will be assigned the input pour point FID value.

Reference:

https://whiteboxgeo.com/manual/wbt_book/available_tools/hydrological_analysis.html#Watershed

Step 10) Raster to Vector Polygons

From Tool Box, select 'Raster To Vector Polygons' from Data Tools section. This tool converts a raster data set to a vector of the POLYGON geometry type. The user must specify the raster file and the output vector. All grid cells containing non-zero, non-NoData values will be considered part of a polygon feature. The vector's attribute table will contain a field called 'VALUE' that will contain the cell value for each polygon feature, in addition to the standard feature ID (FID) attribute.

Reference:

https://whiteboxgeo.com/manual/wbt_book/available_tools/data_tools.html#RasterToVectorPolygons

Click on ‘Add vector layer’ from Layer menu and select the vector polygon file with .shp extension to load it onto the map.

You can use the ‘Vector renderer’ from ‘Renderer Box’ to apply different colours and sizes to vector layer which are loaded on the map.