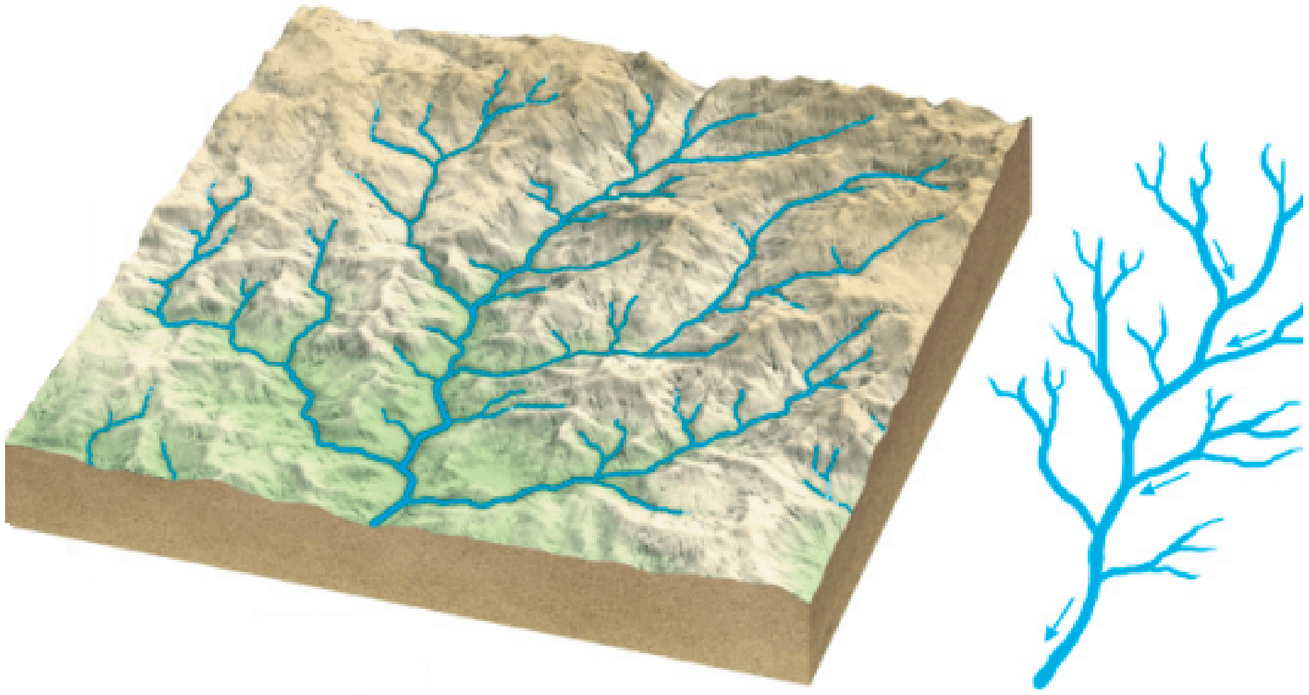
Understanding Drainage Systems

An introduction to the ArcPro
Hydrological Toolset

THE UNIVERSITY
OF BRITISH COLUMBIA
GIS CLUB

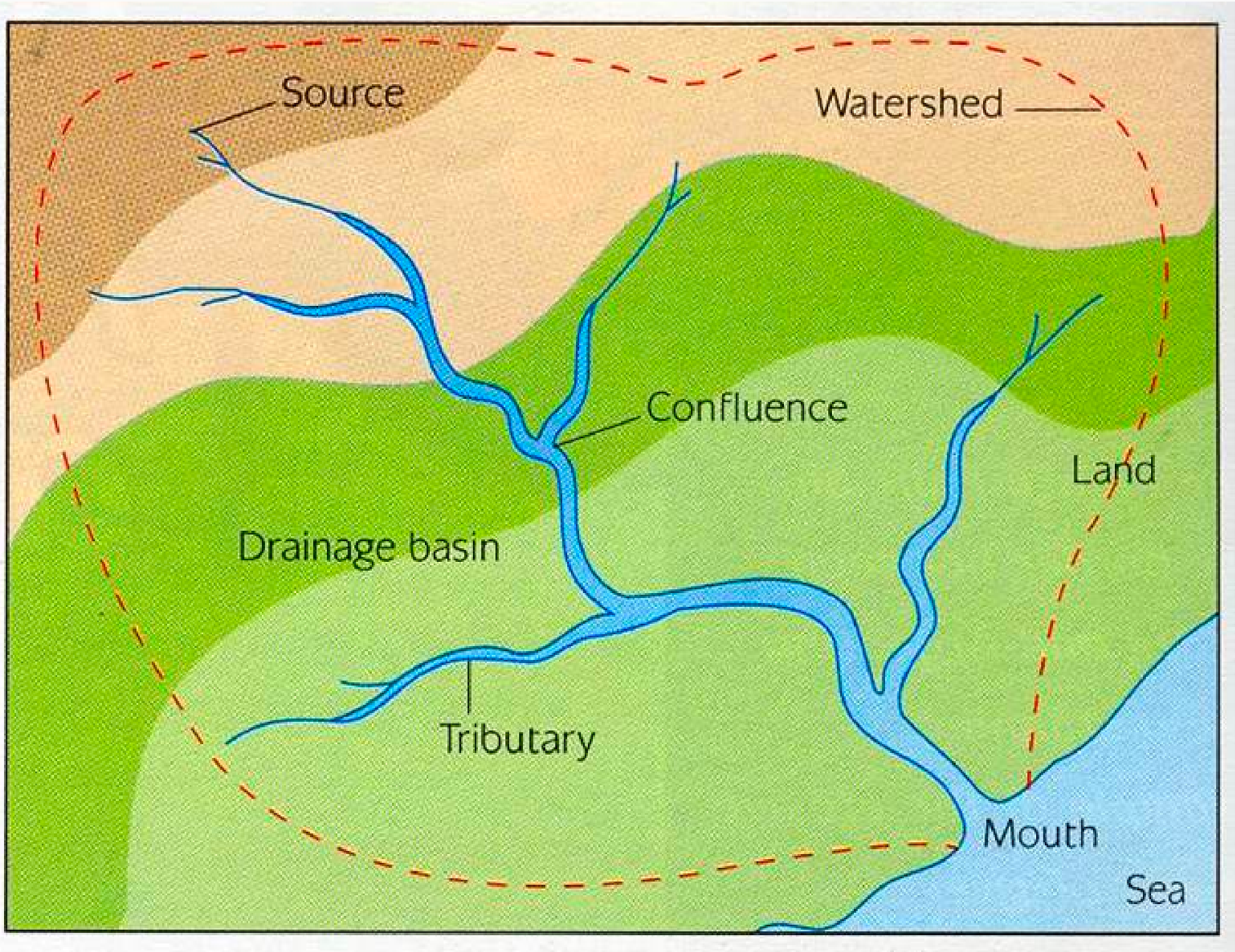
Drainage System:

The area upon which water falls and the network through which it travels to an outlet



Drainage Basin (Watershed):

An area that drains water and other substances to a common outlet.


Source
Watershed
Confluence
Land
Drainage basin
Tributary
Mouth
Sea

ArcGIS Hydrological Toolset

Used to model flow OVER a surface

Basin

Creates a raster delineating all drainage basins.

Fill

Fills sinks in a surface raster to remove small imperfections in the data.

Flow Accumulation

Creates a raster of accumulated flow into each cell. A weight factor can optionally be applied.

Flow Direction

Creates a raster of accumulated flow into each cell. A weight factor can optionally be applied.

Flow Distance

Computes, for each cell, the horizontal or vertical component of downslope distance, following the flow path(s), to cell(s) on a stream into which they flow.

Flow Length

Calculates the upstream or downstream distance, or weighted distance, along the flow path for each cell.

Sink

Creates a raster identifying all sinks or areas of internal drainage.

Snap Pour Point

Snaps pour points to the cell of highest flow accumulation within a specified distance.

Stream Link

Assigns unique values to sections of a raster linear network between intersections.

Stream Order

Assigns a numeric order to segments of a raster representing branches of a linear network.

Stream to Feature

Converts a raster representing a linear network to features representing the linear network.

Watershed

Determines the contributing area above a set of cells in a raster.

UBC FLOW ACCUMULATION

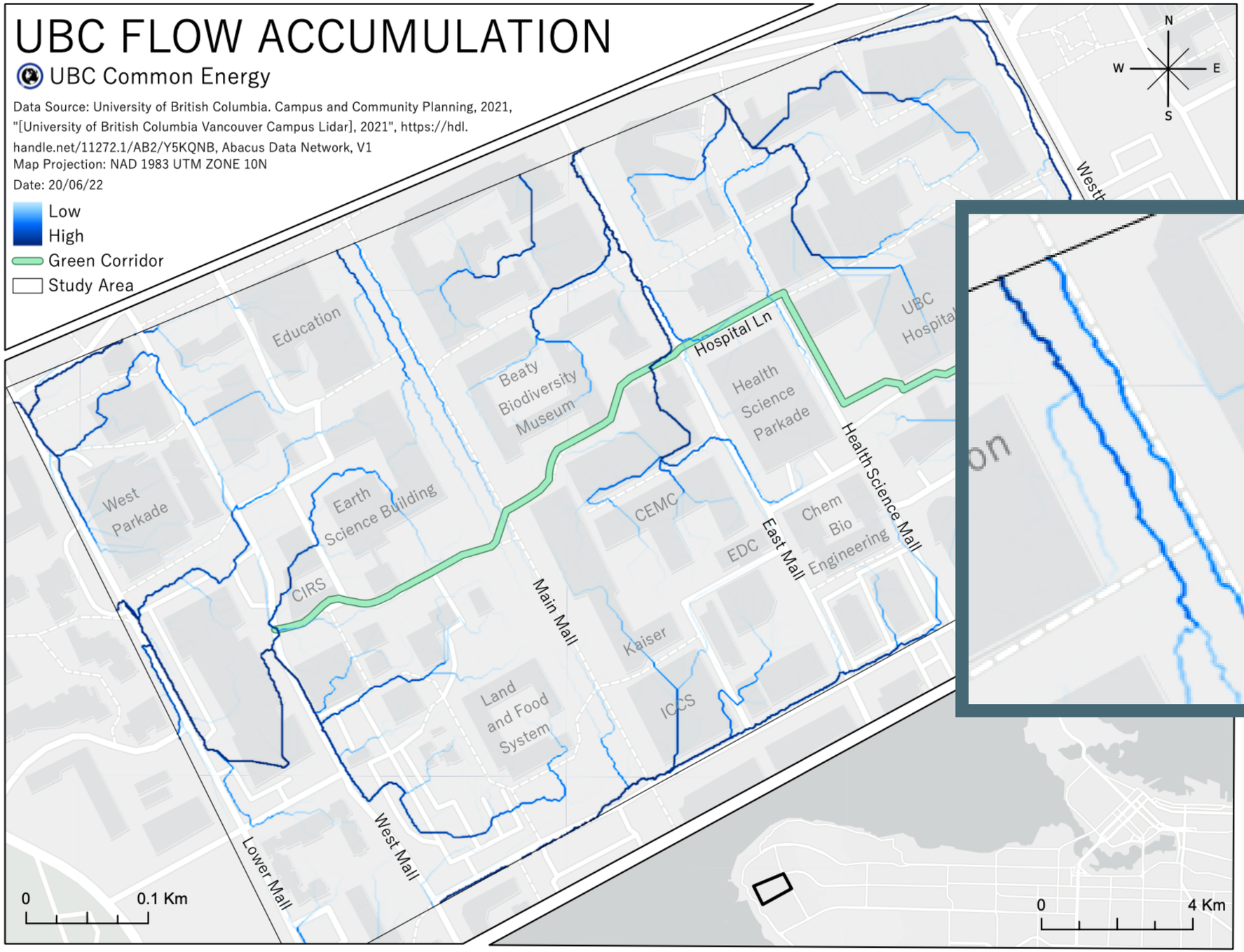
UBC Common Energy

Data Source: University of British Columbia. Campus and Community Planning, 2021, "[University of British Columbia Vancouver Campus Lidar], 2021", https://hdl.handle.net/11272.1/AB2/Y5KQNB, Abacus Data Network, V1

Map Projection: NAD 1983 UTM ZONE 10N

Date: 20/06/22

Low
High
Green Corridor
Study Area



HOW TO:

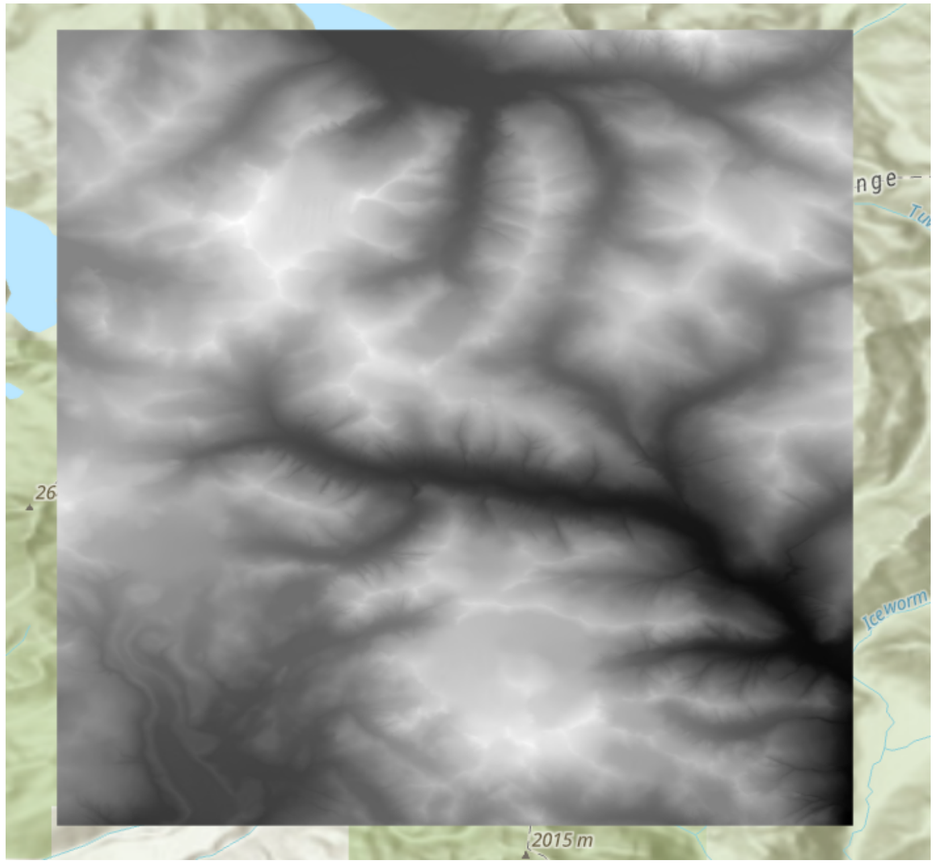
Create a Watershed Model Using the Hydrological Toolset

STEP 1:

Download DEM for desired area.

https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=d06b37979b0c4709b7fcf2a1ed458e03

092g15_w.dem

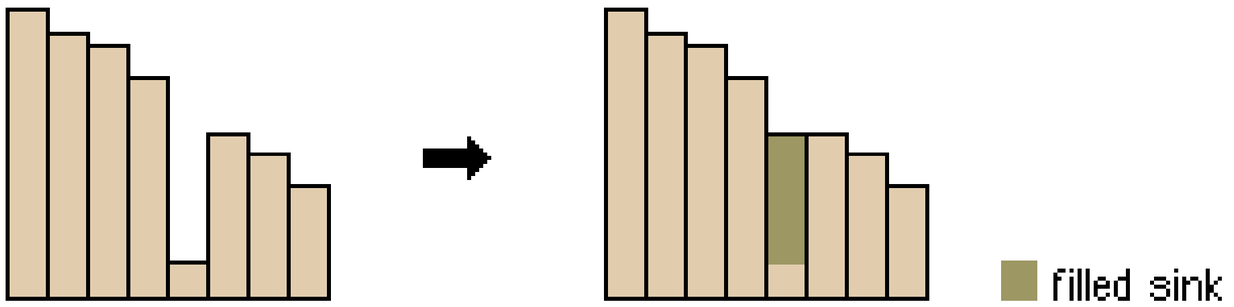


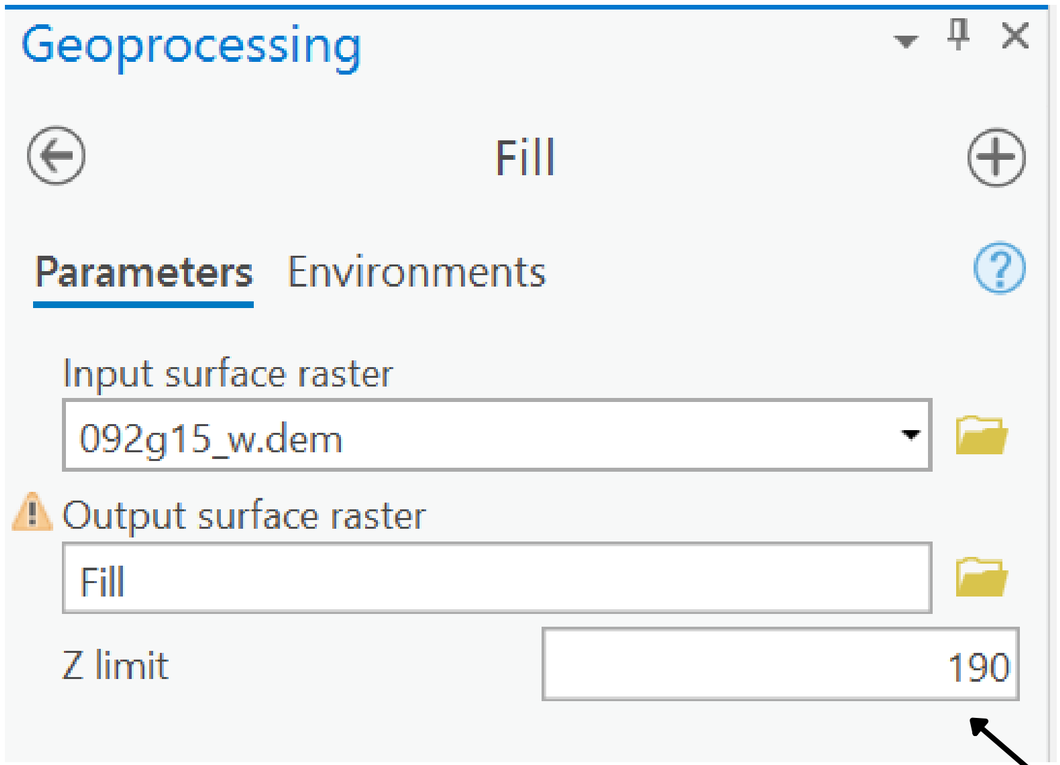
STEP 2:

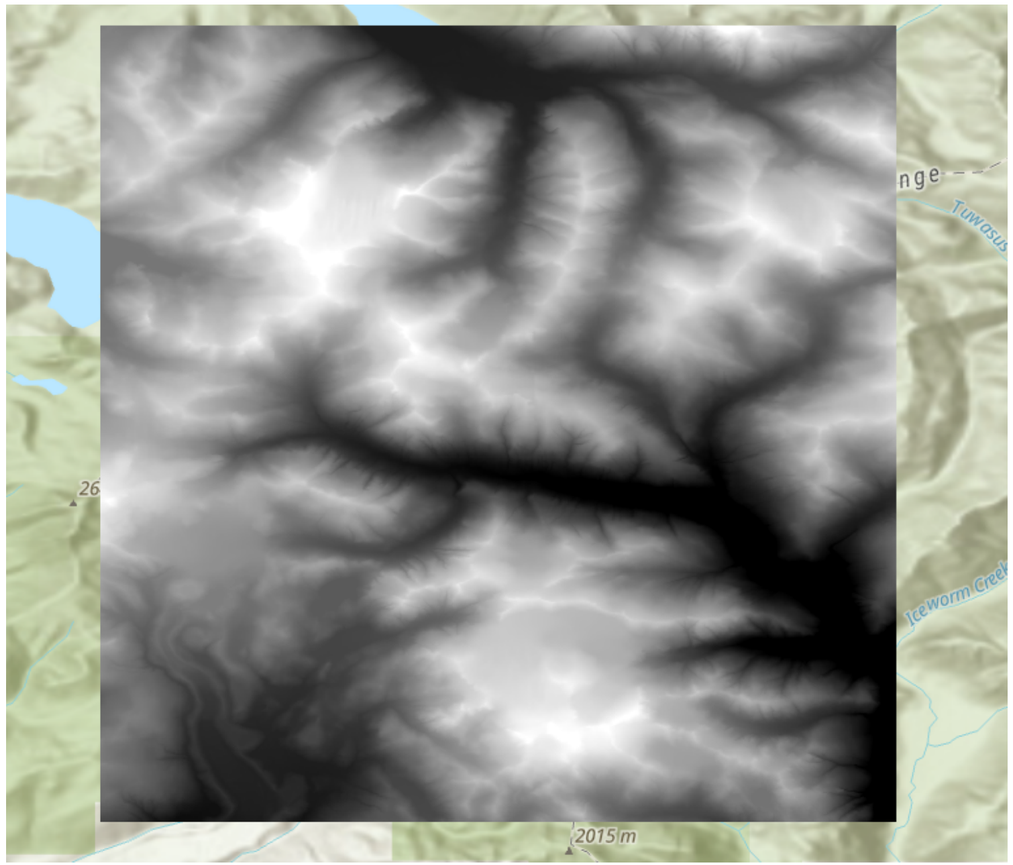
Fill Sink Tool

Sinks (and peaks) are often errors due to the resolution of the data or rounding of elevations to the nearest integer value.
Sinks should be filled to ensure proper delineation of basins and streams. If the sinks are not filled, a derived drainage network may be discontinuous.

This step is extremely important when working with datasets close ocean and lake outlets.







Z-Limit set to lowest elevation in DEM*

Finding sink depth

It is useful to know the depth of a sink or group of sinks. This information can be used to determine an appropriate z limit for the Fill tool, to understand the type of errors present in the data, and to determine if the sinks are legitimate morphological features. The following steps outline the general process to find sink depth:

1. Create a raster of sinks with values that identify their depth by running the Sink tool to locate sinks in the raster.

2. Use the Watershed tool to create a raster of the contributing area for each sink using the flow direction from the elevation raster and the output from the Sink tool as input for pour points.

3. With Map Algebra in Python, use the Zonal Statistics tool with the Minimum option to create a raster of the minimum elevation in the watershed of each sink:

   ```
   sink_min = ZonalStatistics(sink_areas, "Value", elev_ras, "Minimum")
   ```

   The **sink_areas** input is the output from the Watershed tool.

4. Create a raster containing the lowest elevation along the boundary of each watershed with the Zonal Fill tool (this corresponds to the elevation at which flow would leave the basin after filling to the rim):

   ```
   sink_max = ZonalFill(sink_areas, elev_ras)
   ```

5. Use the Minus tool to subtract the minimum value from the maximum value to find the depth again:

   ```
   sink_depth = Minus(sink_max, sink_min)
   ```

The above sequence can also be completed using the Sink, Watershed, Zonal Statistics, Zonal Fill, and Minus geoprocessing tools.

STEP 3:

Flow Direction

Creates a raster of flow direction from each cell to its downslope neighbor, or neighbors, using the D8, Multiple Flow Direction (MFD), or D-Infinity (DINF) method.

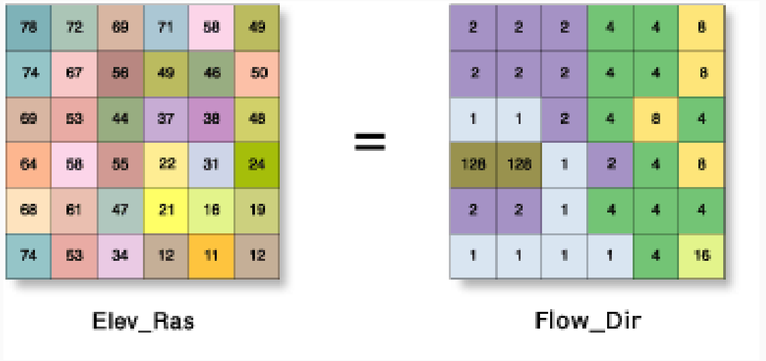
D8 Method: The direction water is flowing in a particular cell (8 directions) N, NE, E etc.; the 8 cardinal directions water can flow.

Flow Direction

Input: Surface Raster

Force all edge cells to flow outward (Optional)
Specifies whether edge cells will always flow outward or follow normal flow rules.

- Unchecked—If the maximum drop on the inside of an edge cell is greater than zero, the flow direction will be determined as usual; otherwise, the flow direction will be toward the edge. Cells that should flow from the edge of the surface raster inward will do so. This is the default.
- Checked—All cells at the edge of the surface raster will flow outward from the surface raster.



Flow direction type
(Optional)
Specifies the type of flow method that will be used when computing flow directions.

- D8—Flow direction will be determined by the D8 method. This method assigns flow direction to the steepest downslope neighbor. This is the default.
- MFD—Flow direction will be based on the MFD flow method. Flow direction will be partitioned across downslope neighbors according to an adaptive partition exponent.
- DINF—Flow direction will be based on the DINF flow method. This method assigns flow direction to the steepest slope of a triangular facet.

Output Raster: shows the flow direction from each cell to its downslope neighbors or neighbors using the D8, MFD, or DINF method. This output is of integer type.

Geoprocessing

Flow Direction

Parameters Environments

Input surface raster

Fill

Output flow direction raster

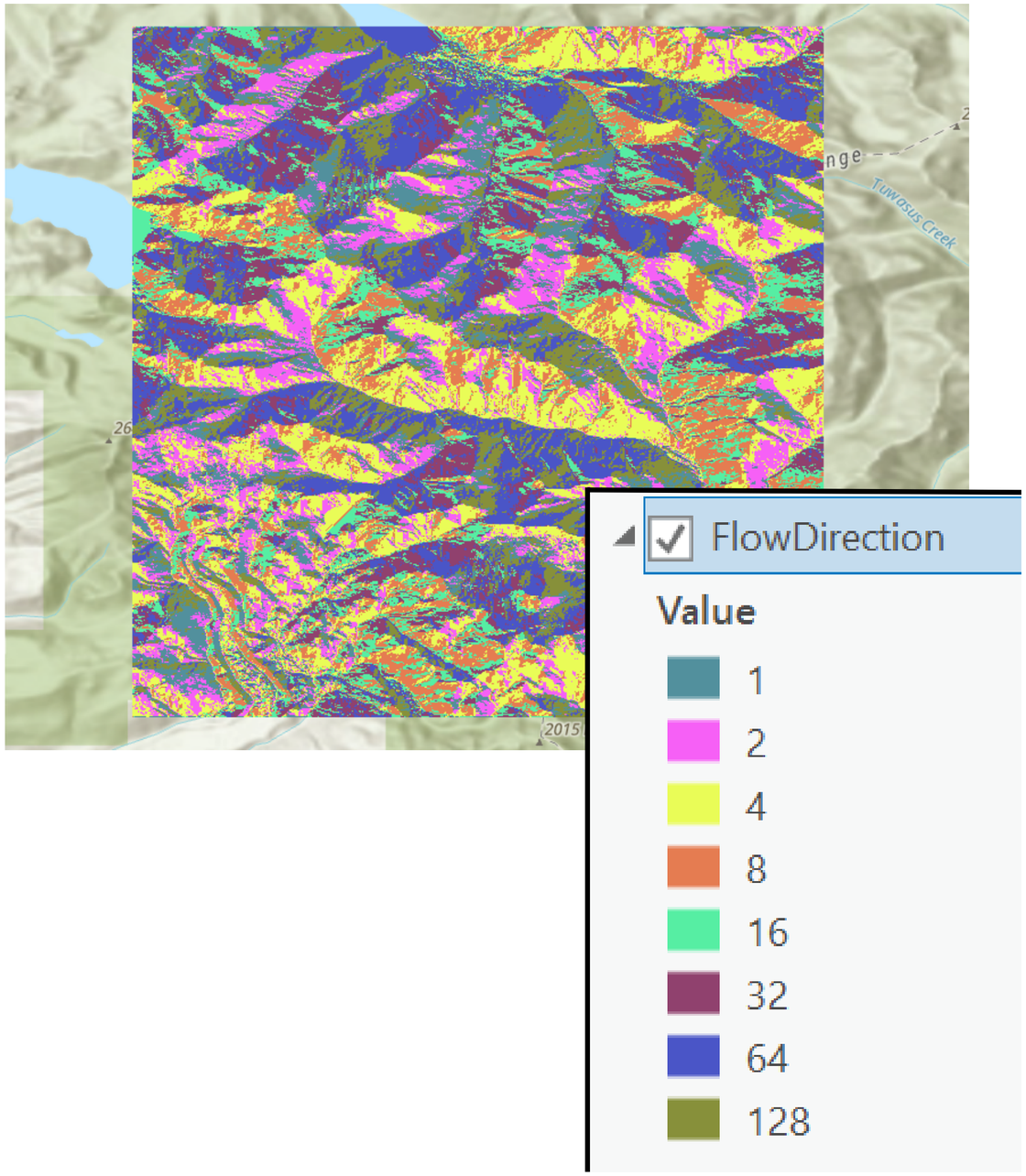
FlowDirection

Force all edge cells to flow outward

Output drop raster

Flow direction type

D8



STEP 4:

Flow Accumulation Tool

The Flow Accumulation tool calculates the accumulated flow to each cell, as determined by the accumulated weight of all cells that flow into each downslope cell.

The amount of cells that flow into each-other.

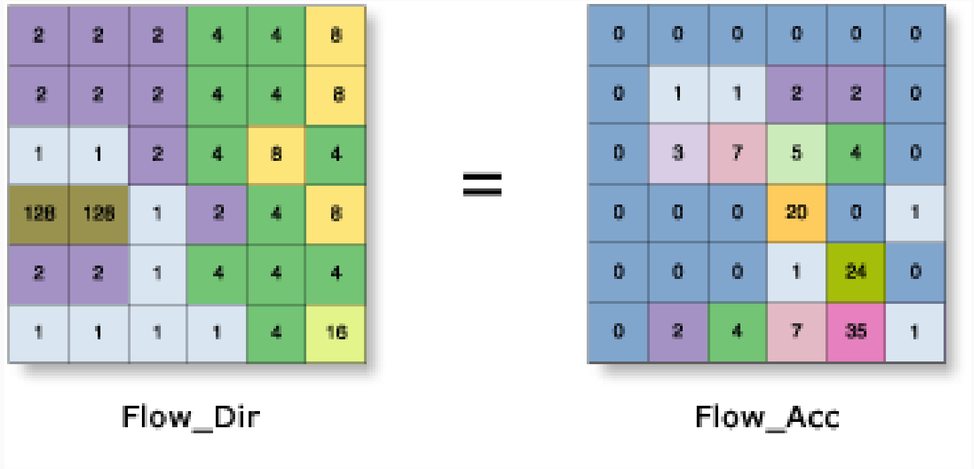
Flow Accumulaiton

he input raster that shows the direction of flow out of each cell.
The flow direction raster can be created using the Flow Direction tool.
The flow direction raster can be created using the D8, Multiple Flow Direction (MFD), or D-Infinity method. Use the Input flow direction type parameter to specify the method used when the flow direction raster was created.

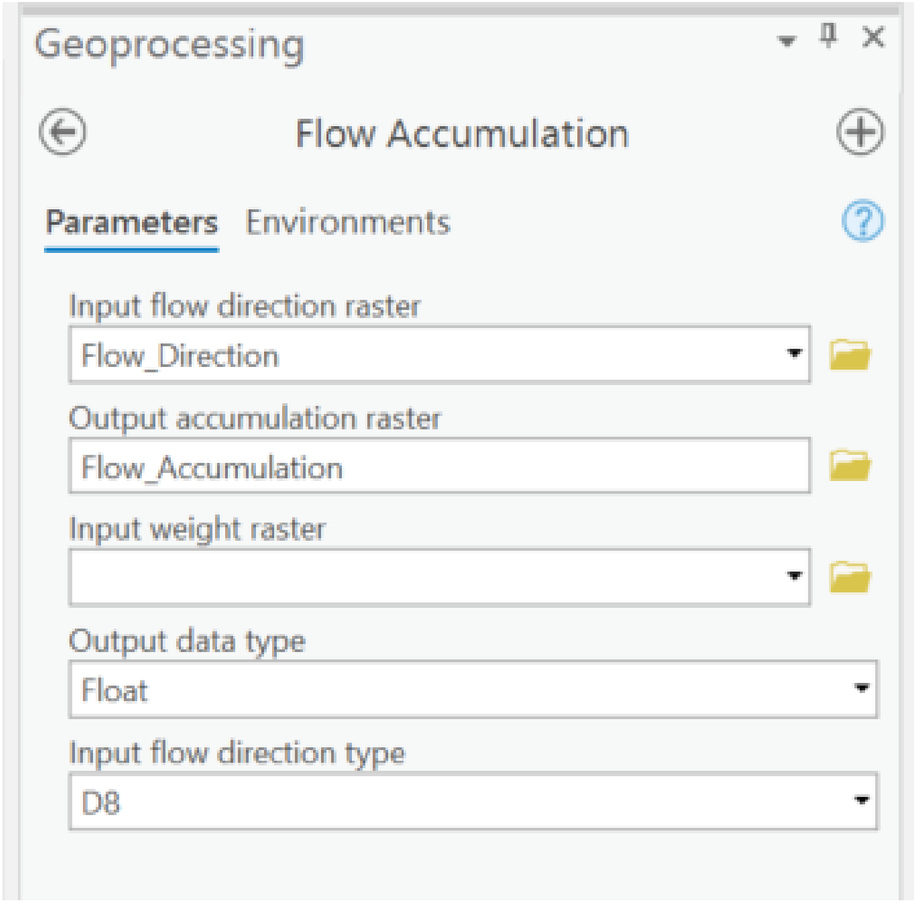
FAn optional input raster for applying a weight to each cell.
If no weight raster is specified, a default weight of 1 will be applied to each cell. For each cell in the output raster, the result will be the number of cells that flow into it.

Specifies the input flow direction raster type.

- D8—The input flow direction raster is of type D8. This is the default.
- MFD—The input flow direction raster is of type Multi Flow Direction (MFD).
- DINF—The input flow direction raster is of type D-Infinity (DINF).



The output raster that shows the accumulated flow to each cell.

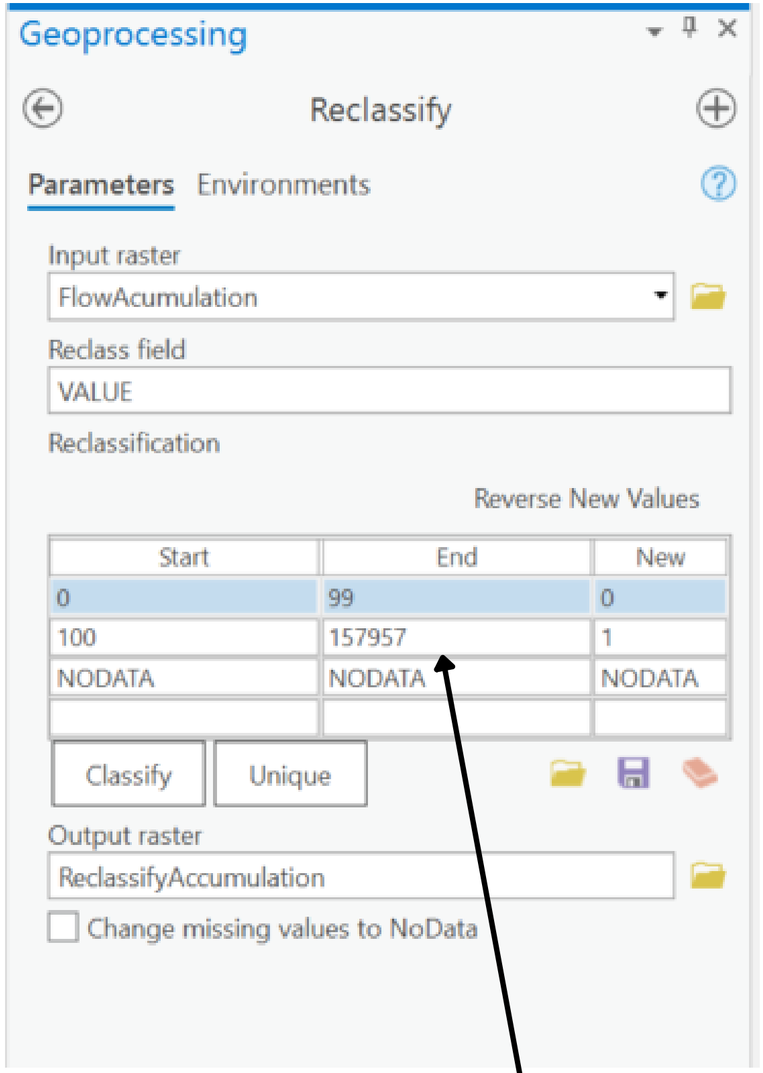

Geoprocessing
Flow Accumulation
Parameters
Environments
Input flow direction raster
Flow_Direction
Output accumulation raster
Flow_Accumulation
Input weight raster
Output data type
Float
Input flow direction type
D8

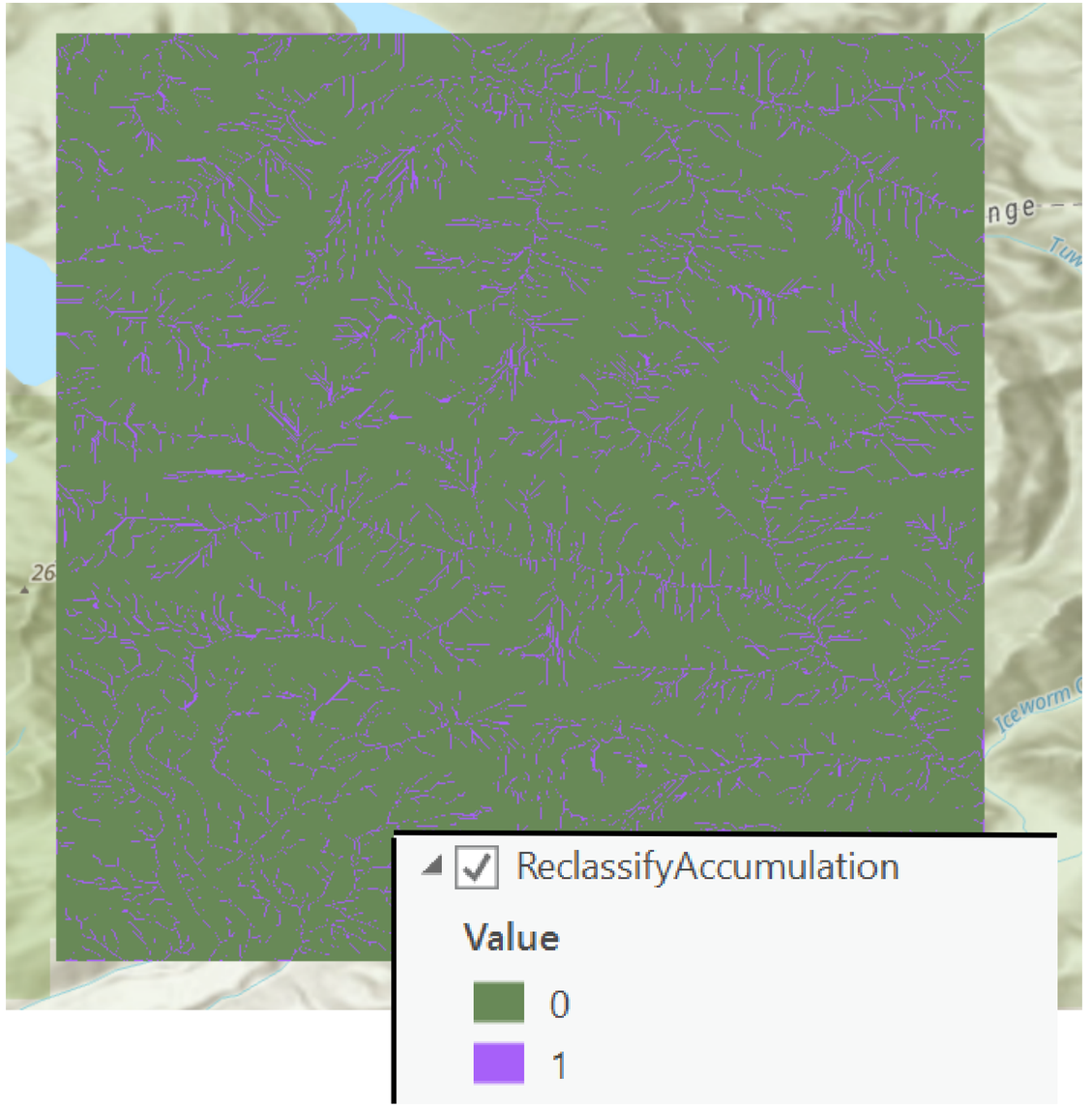

2015 m

Step 5:

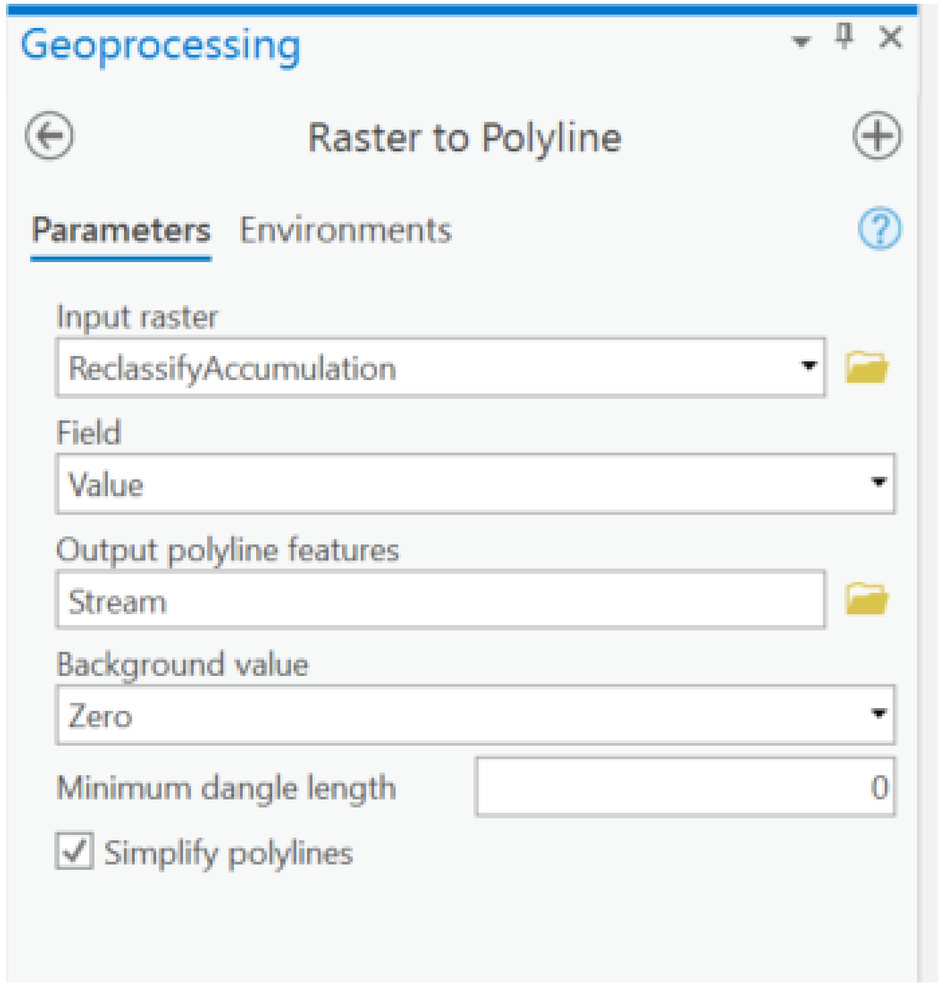
Reclassify Cells to the desired stream level. In this example we are creating a 100-count stream.

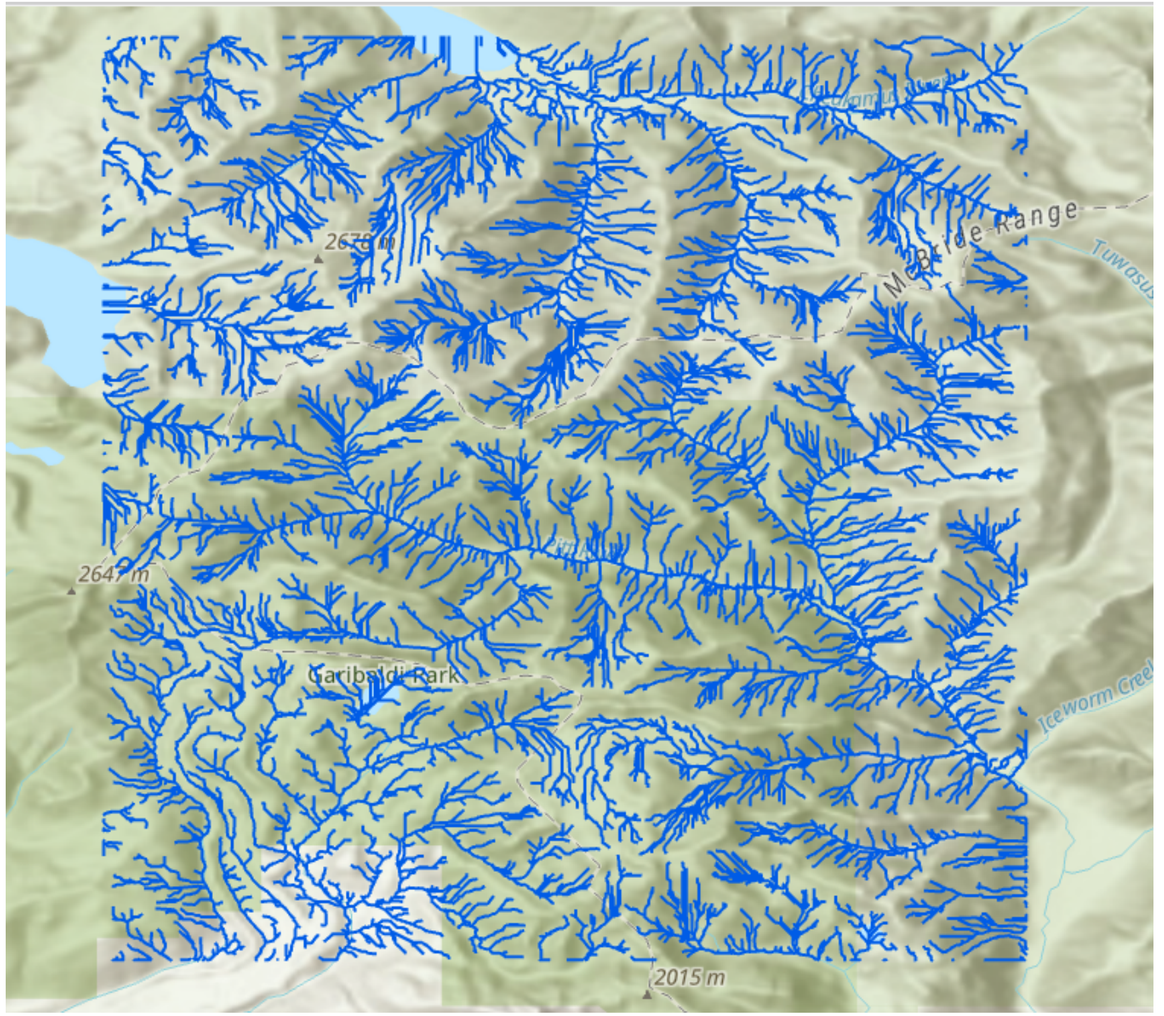
Convert outcome **Raster to Polyline**.





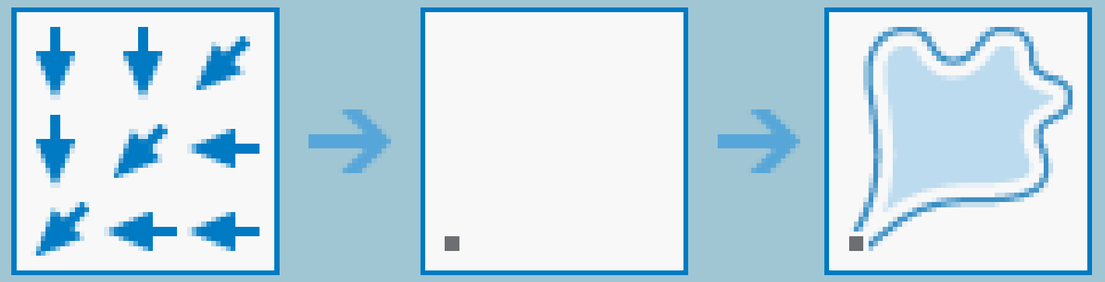
Reclassify values such that those with a value from 0-99 will represent "0" and those greater than 100 will represent "1". Use the maximum value from the Flow Accumulation Raster.

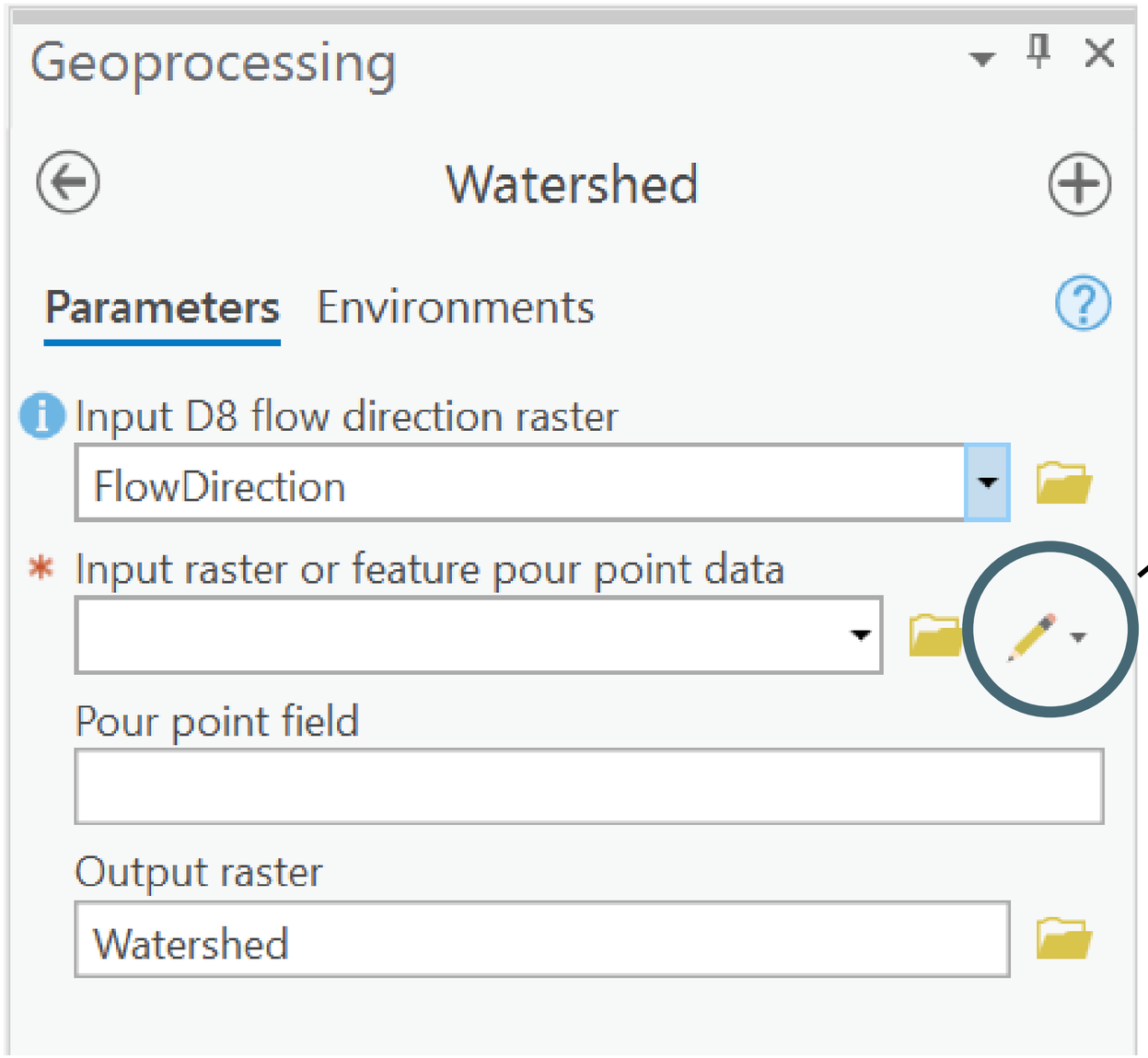

Geoprocessing
Raster to Polyline
Parameters
Environments
Input raster
ReclassifyAccumulation
Field
Value
Output polyline features
Stream
Background value
Zero
Minimum dangle length
0
Simplify polylines


2647 m
Garibaldi Park
2015 m

STEP 6:

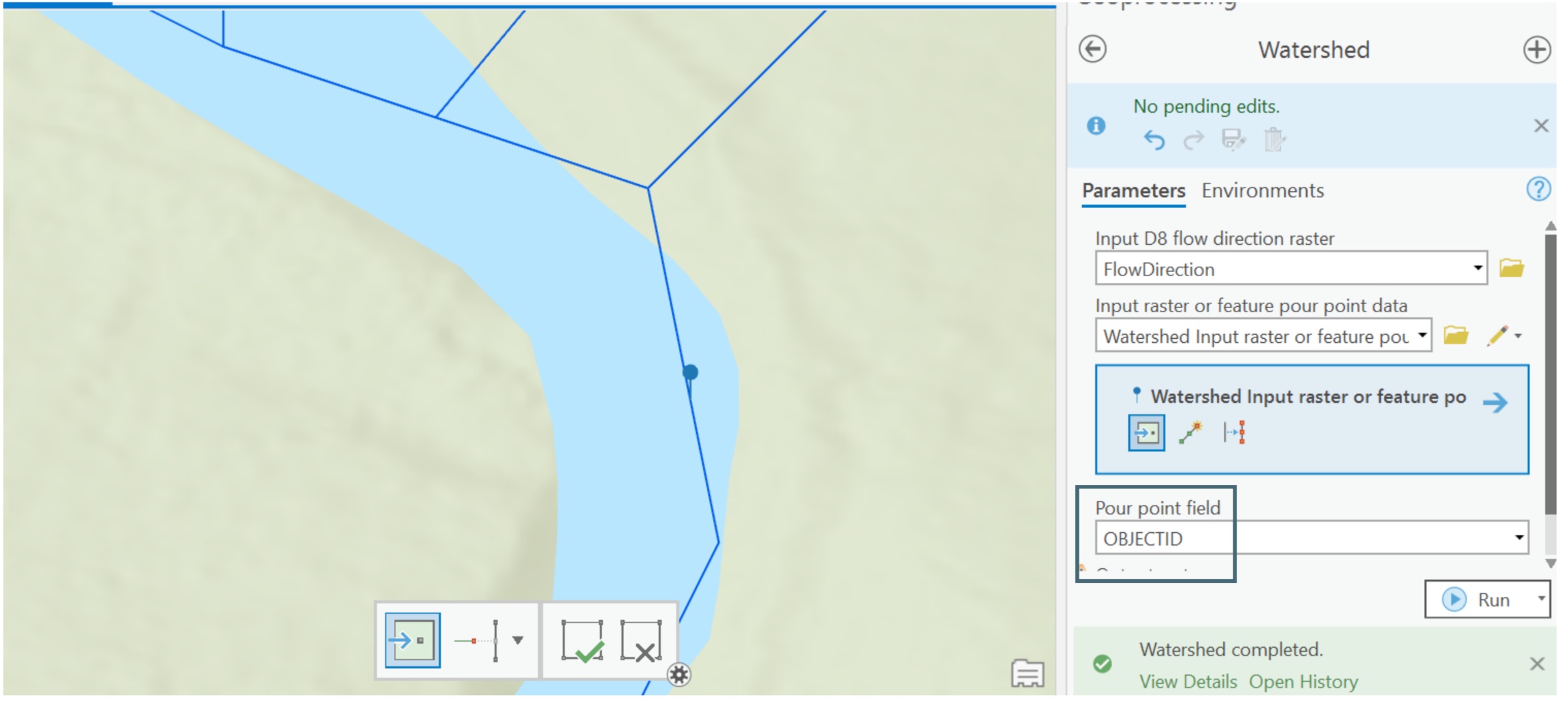
Run Watershed Tool





Determine your **Pour Point**.

This is the watershed outlet.

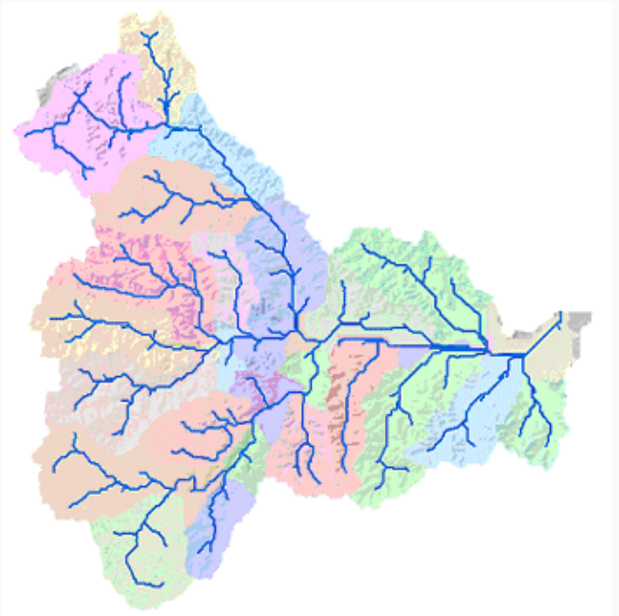

Watershed
No pending edits.
Parameters
Environments
Input D8 flow direction raster
FlowDirection
Input raster or feature pour point data
Watershed Input raster or feature pou
Watershed Input raster or feature po
Pour point field
OBJECTID
Run
Watershed completed.
View Details
Open History

Watershed (Spatial Analyst)

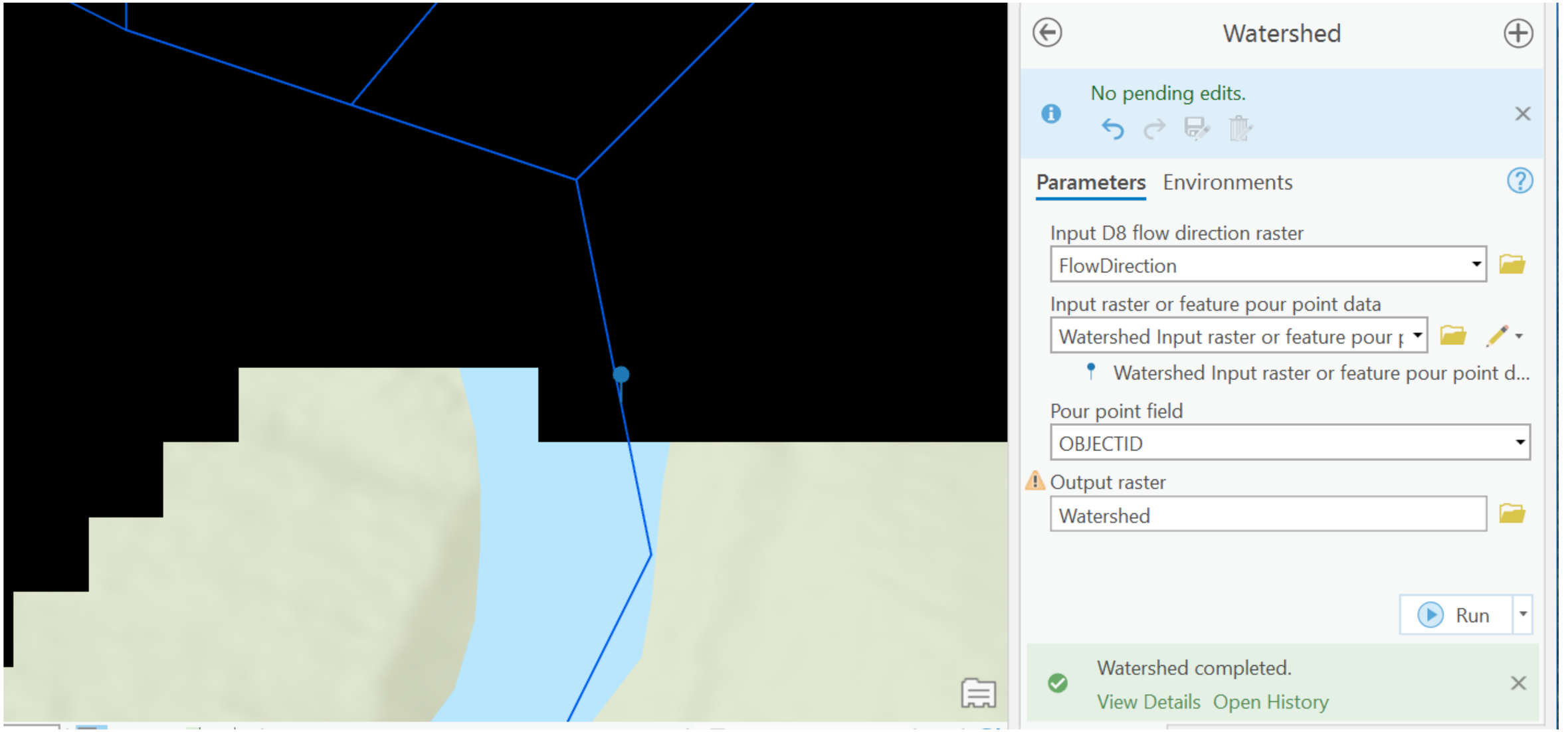
Input D8 flow direction raster
The input raster that shows the direction of flow out of each cell.
The flow direction raster can be created using the Flow Direction tool, run using the default flow direction type D8.

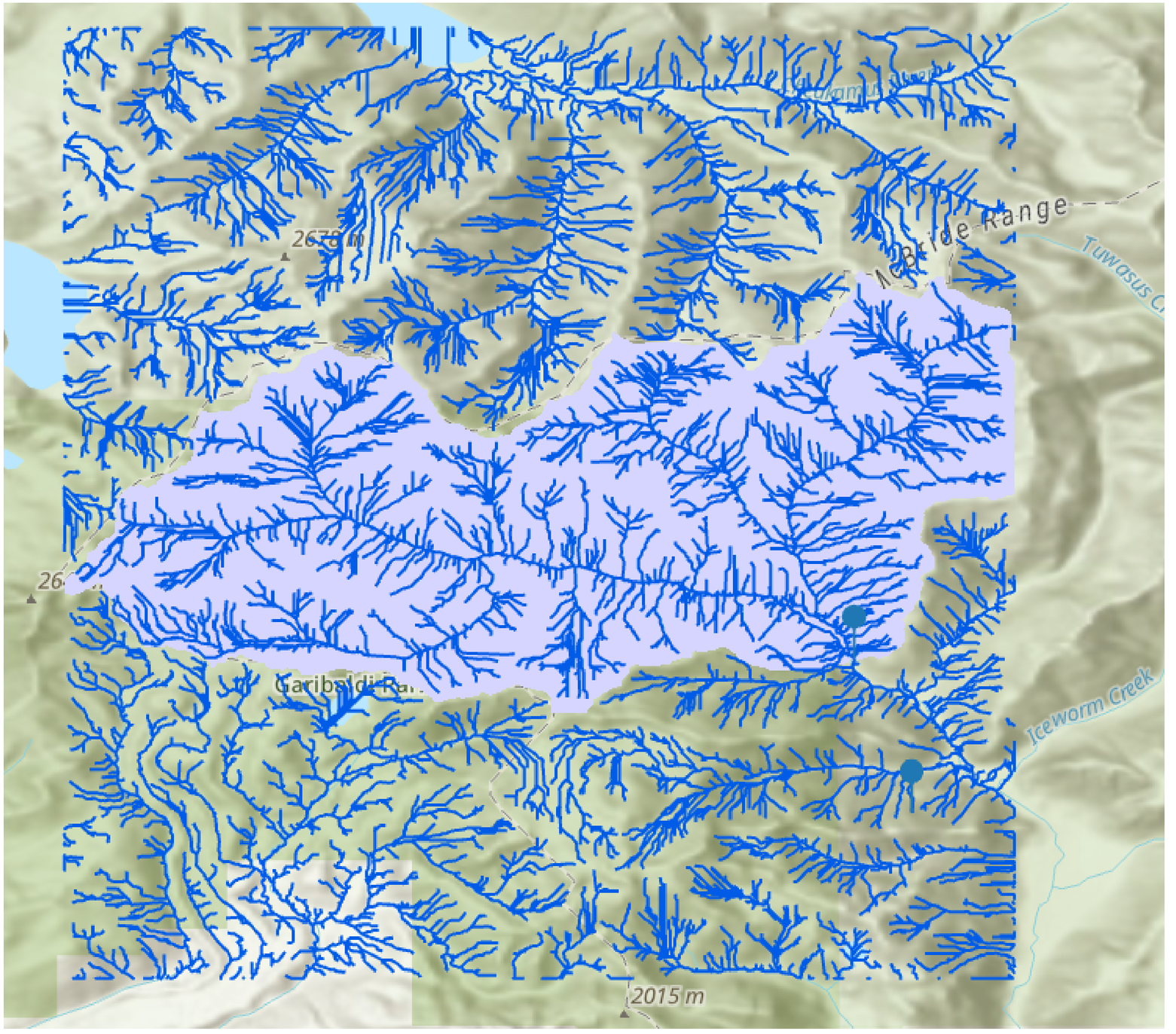
The input pour point locations.
For a raster, this represents cells above which the contributing area, or catchment, will be determined. All cells that are not NoData will be used as source cells.
For a point feature dataset, this represents locations above which the contributing area, or catchment, will be determined.

Pour point field
(Optional)
The field used to assign values to the pour point locations.
If the pour point dataset is a raster, use Value.
If the pour point dataset is a feature, use a numeric field. If the field contains floating-point values, they will be truncated into integers.



Output raster
The output raster that shows the contributing area.
This output is of integer type.

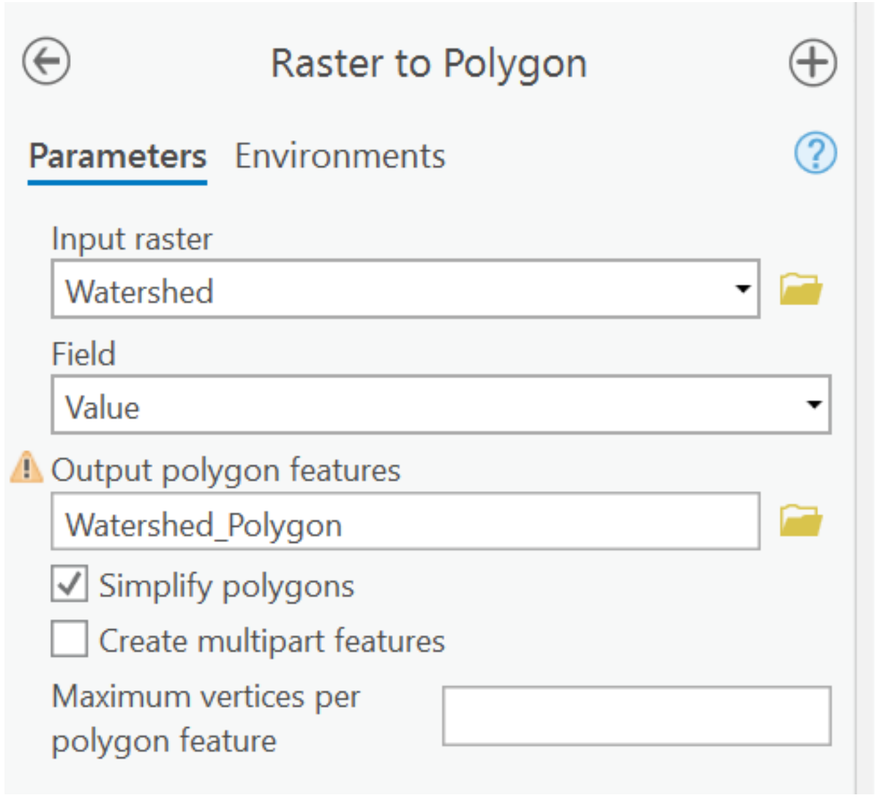

Watershed
No pending edits.
Parameters
Environments
Input D8 flow direction raster
FlowDirection
Input raster or feature pour point data
Watershed Input raster or feature pour p
Watershed Input raster or feature pour point d...
Pour point field
OBJECTID
Output raster
Watershed
Run
Watershed completed.
View Details
Open History

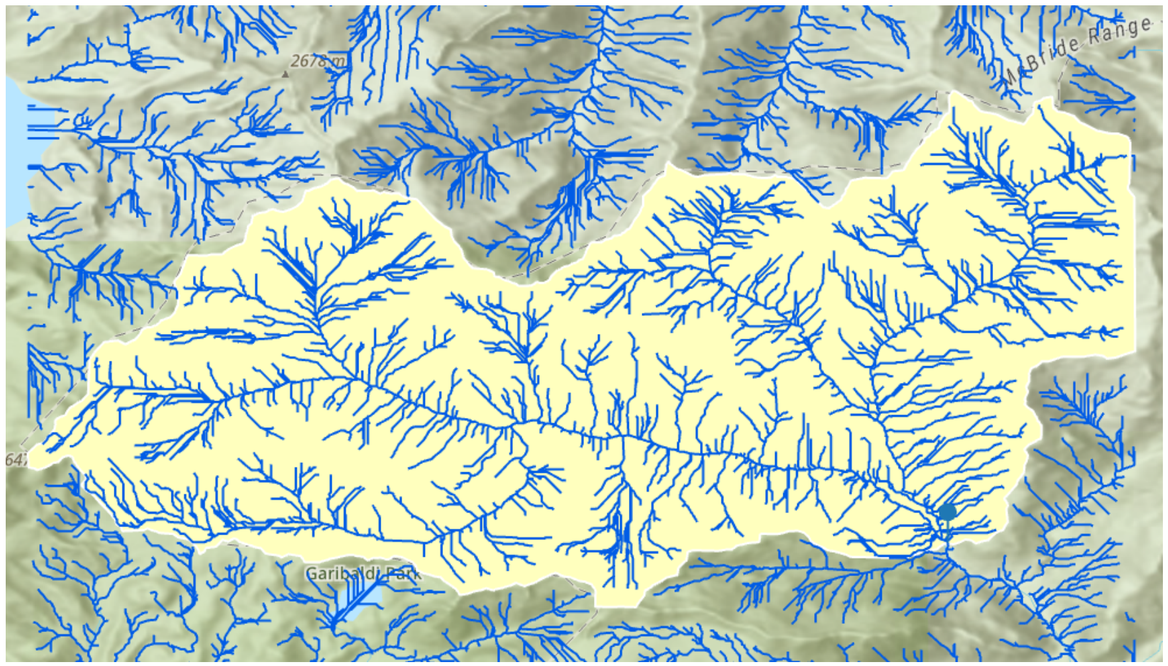

Ice Ridge Range
Tuwasus C
2676 m
26
Garibaldi Ra
Iceworm Creek
2015 m

STEP 7 (optional):

Run the **Raster to Polygon** tool to create polygon features from the watershed raster.

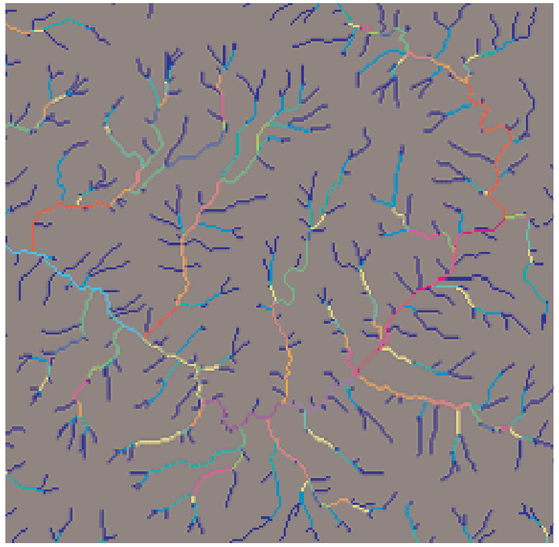
Turn your watershed into a polygon!

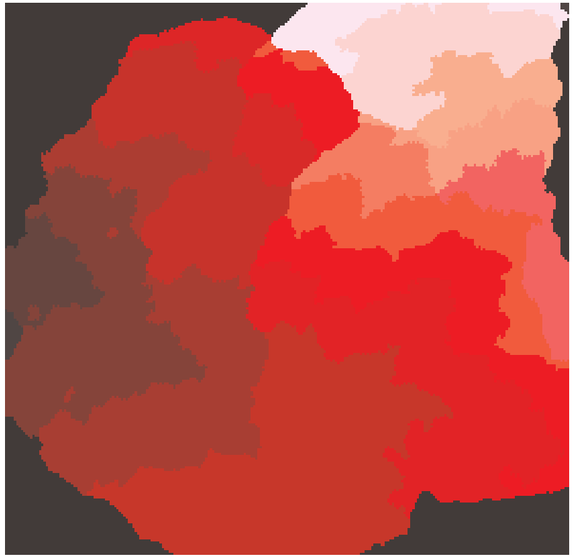




More things you can do!

Determine Stream Order





Determine flow length (time it takes water to travel through the watershed)

https://support.esri.com/en-us/knowledge-base/how-to-create-a-watershed-model-using-the-hydrology-too-000023169

https://www.youtube.com/watch?v=aY_j130uaFo

https://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/creating-a-depressionless-dem.htm

https://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/how-watershed-works.htm

https://ftp.maps.canada.ca/pub/nrcan_rncan/vector/index/index_pdf/NTS-SNRC_Index%205_British_Columbia_300dpi.pdf