

Liberty Hill Natural Area

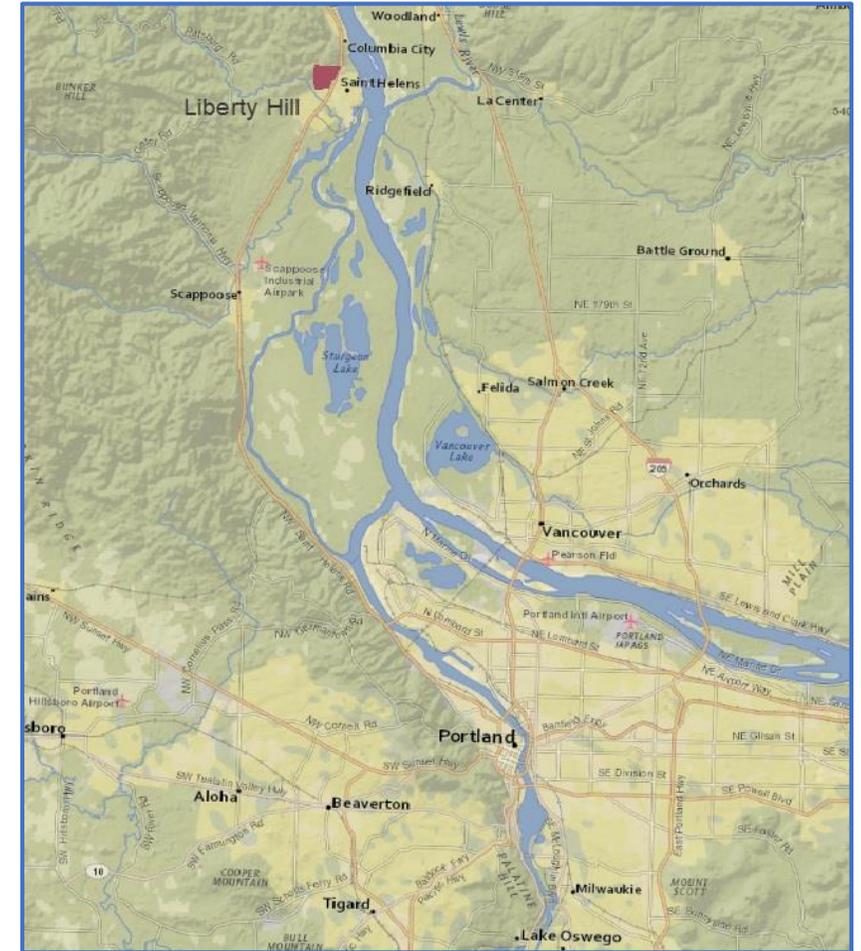
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Independent GIS Analyst: Volunteer

Acknowledgements

Gregg Bertrand and Paul Cedefelt at Portland District US Army Corps of Engineers (GIS, CADD, and Mapping Section) provided access to high resolution LiDAR point cloud data files in the AOC and Gregg also supplied guidance on a procedure to convert the text files into a triangulated irregular network (TIN) and ultimately into a grid digital terrain model (DTM) dataset.

Geology and Location

Liberty Hill is about 20-miles north-by-northwest of Portland, Oregon near the northern urban growth boundary of St. Helens, Oregon and is part of the Puget-Willamette Lowland. This lowland lies between the Coast Range and the Cascade Range. The oldest rocks exposed are middle Miocene lava flows partly of the Columbia River Basalt Group. Bedrock units formed a terrain of low relief prior to inundation by voluminous lava flows of the Columbia River Basalt Group. These lavas erupted from fissures in eastern Washington and Oregon, traversed the Cascade Range by way of broad structural lowlands, and spread out to cover large areas in and around the Coast Range.





Focal Plant Communities

Project Objectives

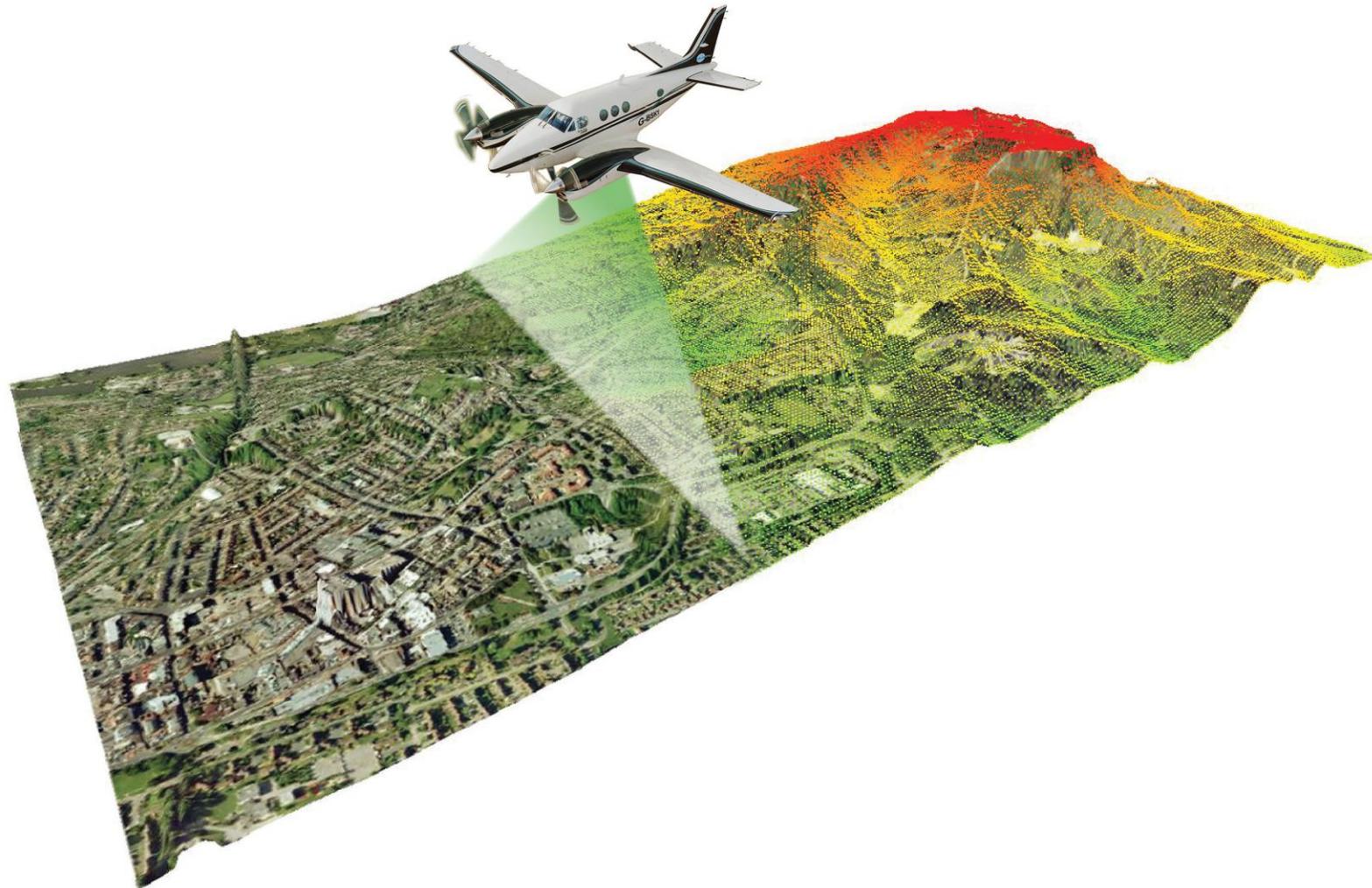
Answer two questions:

- Can high resolution LiDAR help inform surface water flow models on Liberty Hill and thereby assist in evaluating potential direct, indirect, and cumulative impacts of nearby and expanding mining activities on surface water access to focal wetlands and plant communities?
- Can high resolution LiDAR help inform surface water flow models on Liberty Hill and thereby assist in determining Federal Clean Water Act jurisdiction over mosaic in situ wetland plant communities?

Light Detection and Ranging (LiDAR)

- *Light Detection and Ranging*, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.
- A LIDAR instrument principally consists of a laser, a scanner, and a specialized GPS receiver. Airplanes and helicopters are the most commonly used platforms for acquiring LIDAR data over broad areas. Two types of LIDAR are topographic and bathymetric. Topographic LIDAR typically uses a near-infrared laser to map the land, while bathymetric lidar uses water-penetrating green light to also measure seafloor and riverbed elevations.

Light Detection and Ranging (LiDAR)



LiDAR Sources Considered

- US Geological Survey:
<https://earthexplorer.usgs.gov/>
- OpenTopography:
<http://opentopo.sdsc.edu/datasets>
- US Interagency Elevation Inventory:
<https://coast.noaa.gov/inventory/>
- NOAA DigitalCoast:
<https://coast.noaa.gov/digitalcoast/data/>
- Washington Department of Natural Resources:
<https://www.dnr.wa.gov/lidar>
- Puget Sound Lidar Consortium:
<http://pugetsoundlidar.ess.washington.edu/>
- Oregon Department of Geology and Mineral Industries:
<https://www.oregongeology.org/lidar/index.htm>

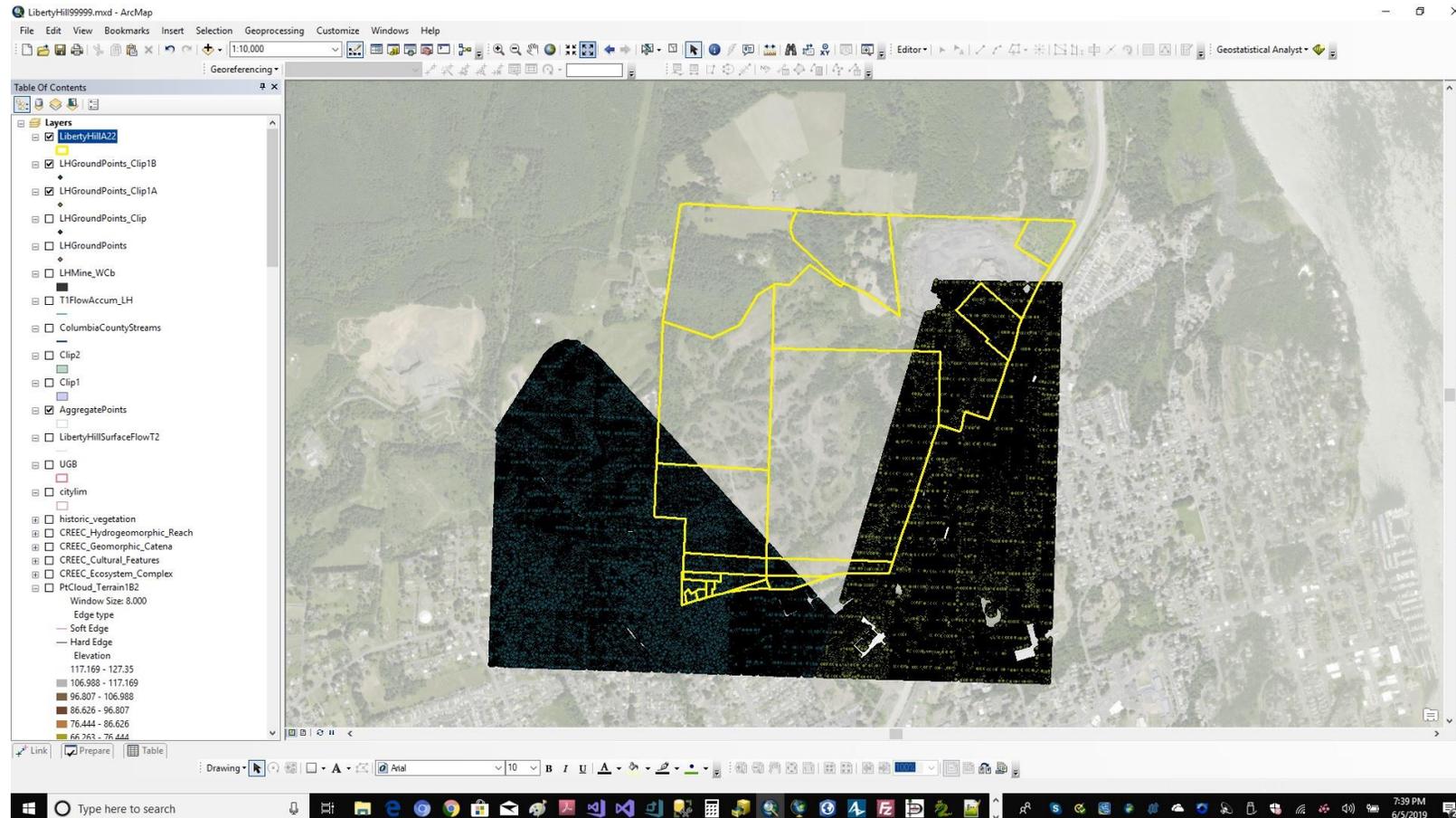
Disparate LiDAR Coordinate Systems, Cell Sizes, Unit Measures

- NAD_1983_2011_Oregon_Statewide_Lambert_Ft_Intl, Cell size: 1,1 International Feet
- NAD_1983_UTM_Zone_10N, Cell size: 4.78, 4.78 Meters, NAVD 1988
- NAD_1983_UTM_Zone_10N, Cell size: 5.58, 5.58 Meters, NAVD 1988

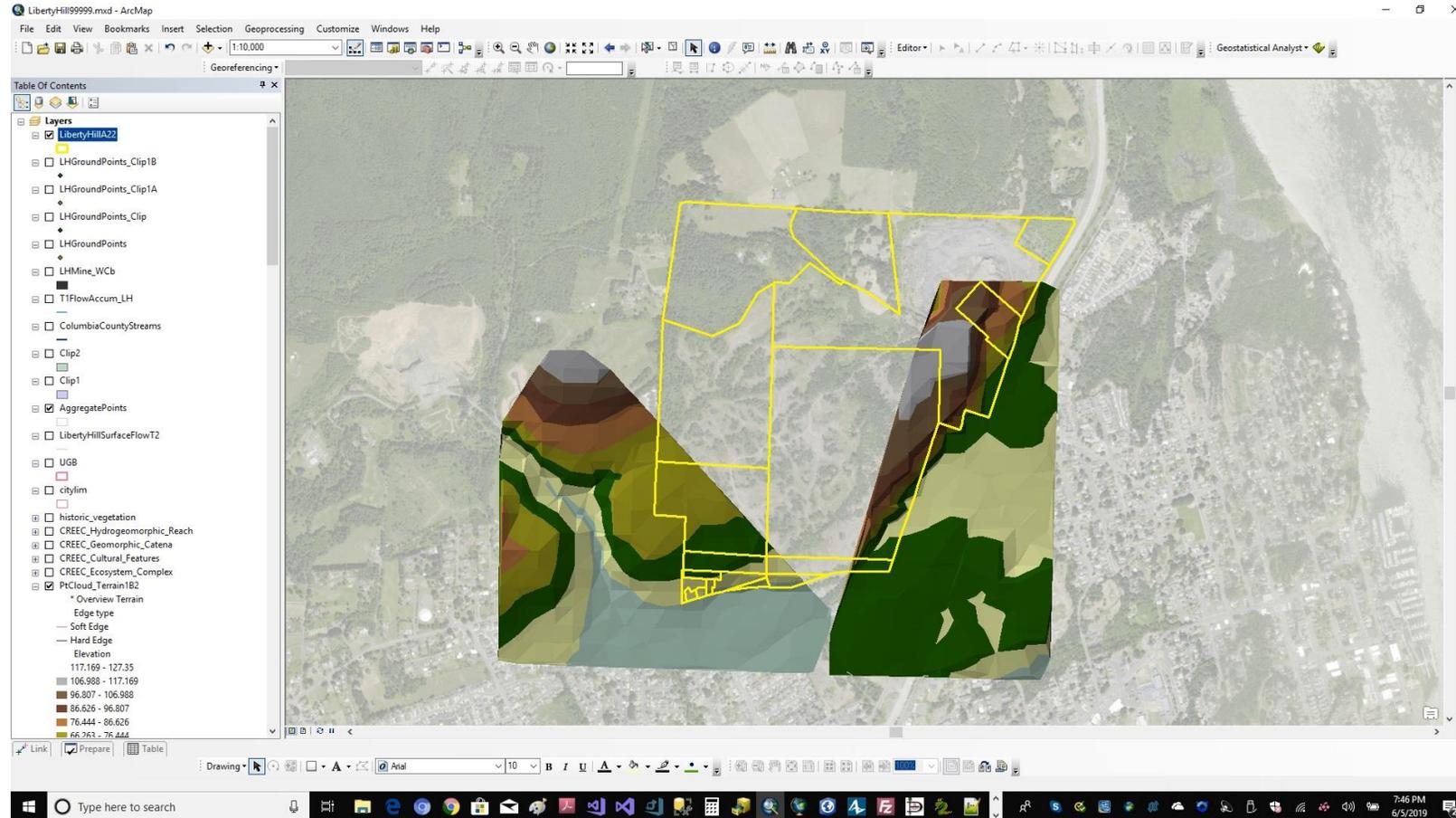
Steps Used to Create Grid DTM from Point Cloud Data

- Create File Geodatabase and Terrain Feature Dataset to Contain Terrain Surface (set horizontal coordinate system to match LiDAR – NAD 1983 - UTM Zone 10);
- Set Vertical Coordinate System to match LiDAR - NAVD 88;
- Add Terrain Pyramid Levels;
- Make Sure Point Cloud Feature Class (Points Cloud Text File) has been Imported into the Geodatabase Feature Dataset and then Add it To Inform Terrain Tool;
- Build Triangulated Irregular Network (TIN) Terrain; and
- Convert TIN Terrain to Raster.

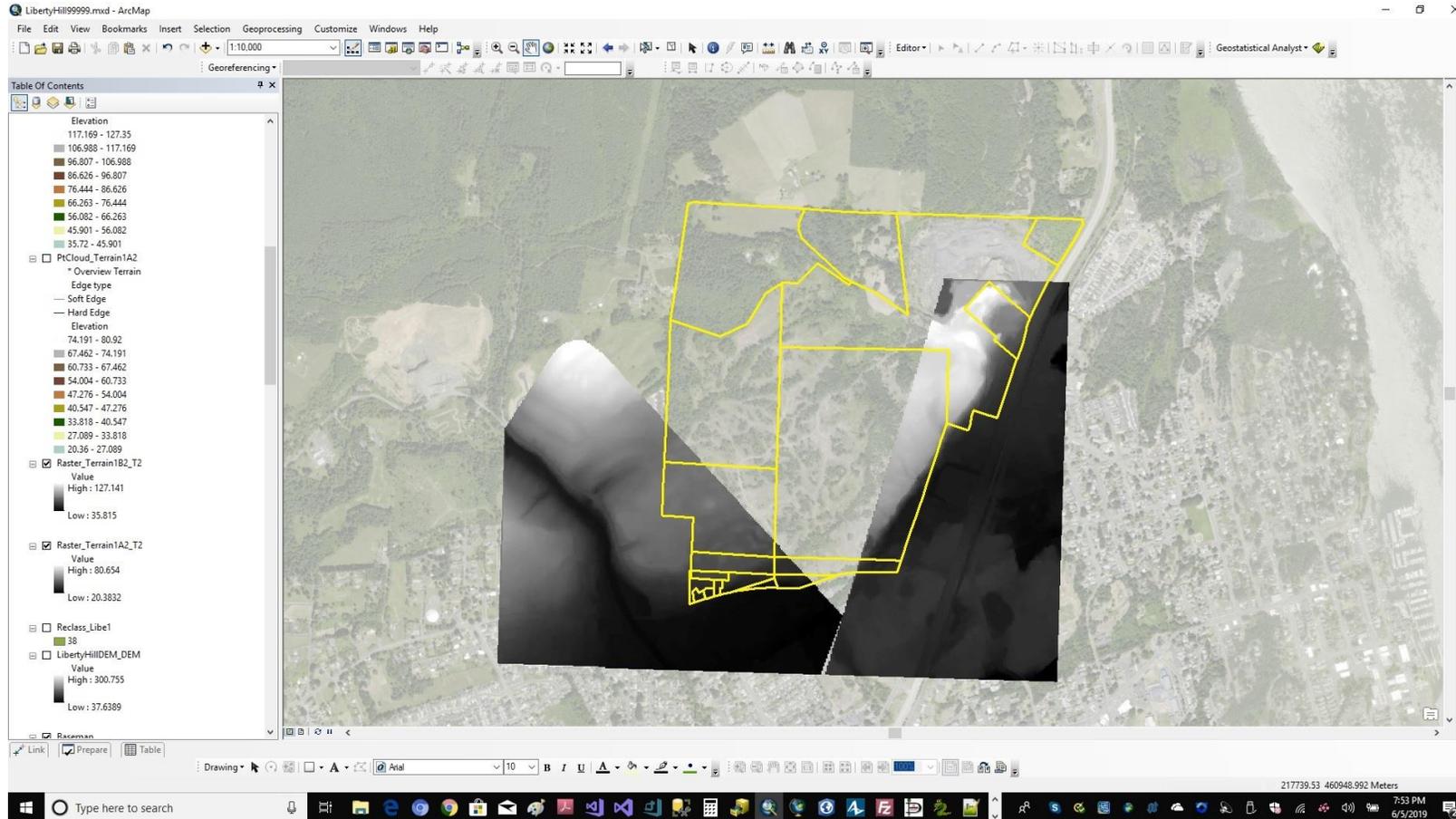
LiDAR Informed Point Clouds Available for AOC



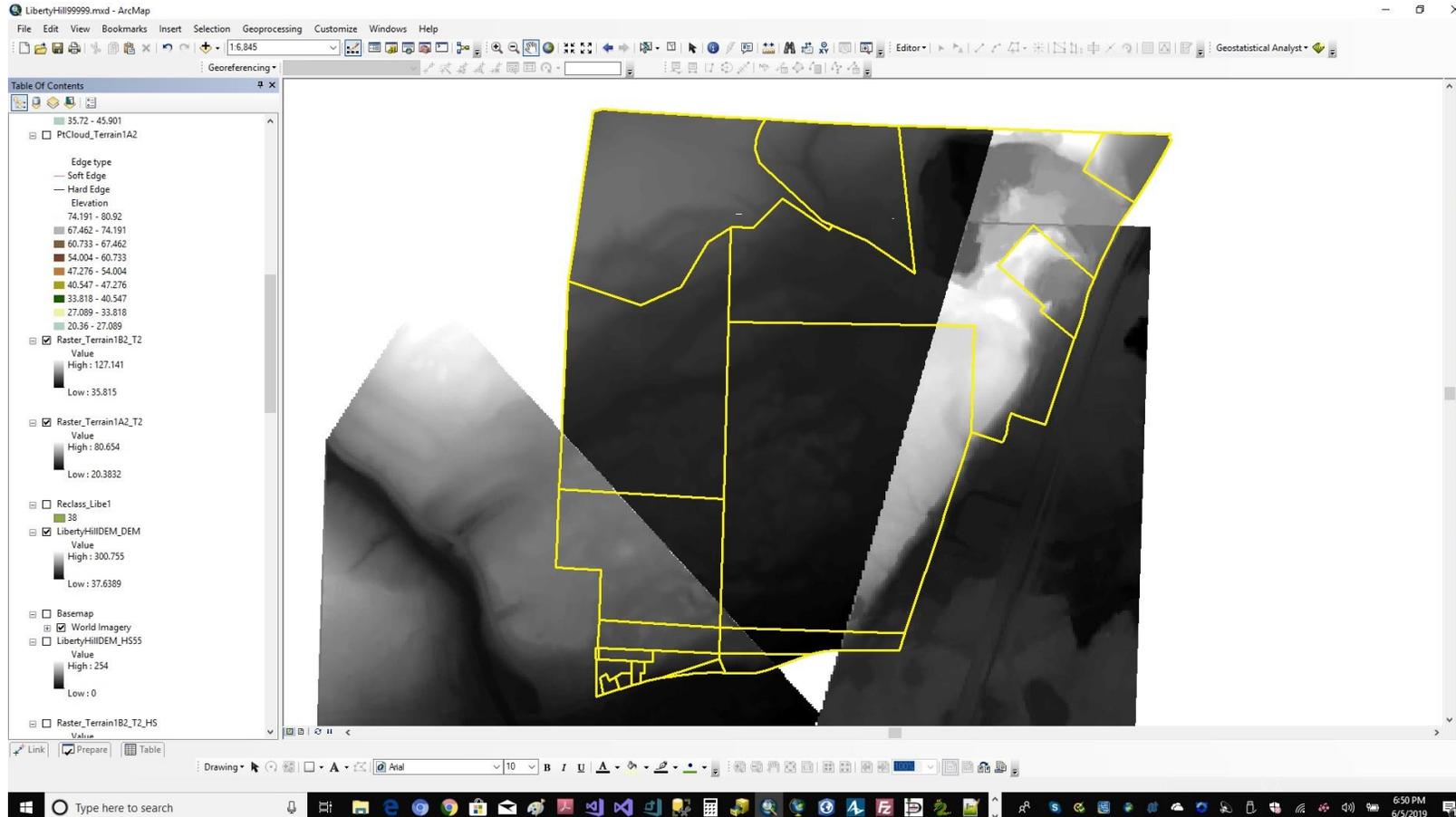
Point Clouds Converted to TINs for AOC



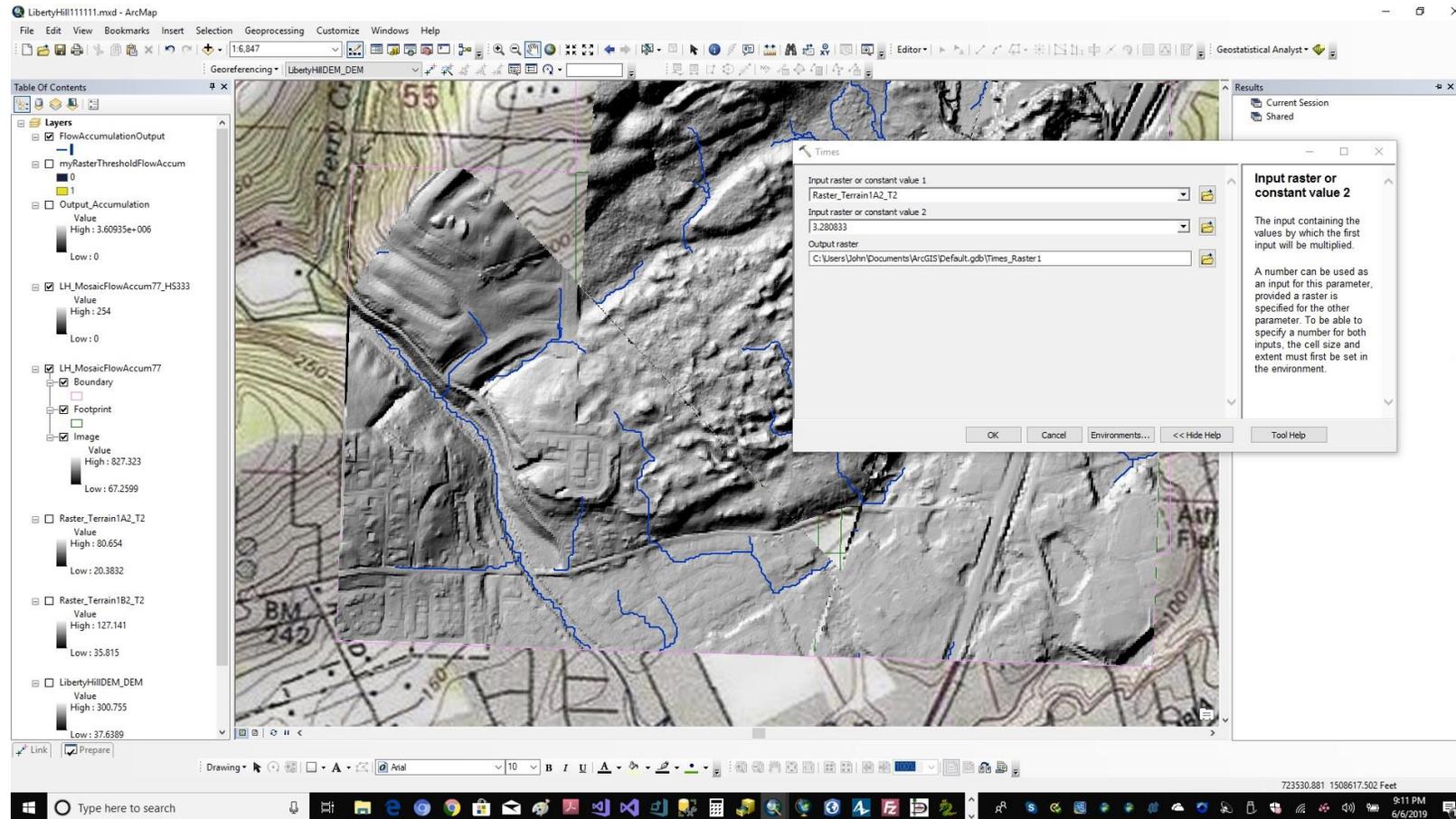
TINS Converted to DTMs for AOC



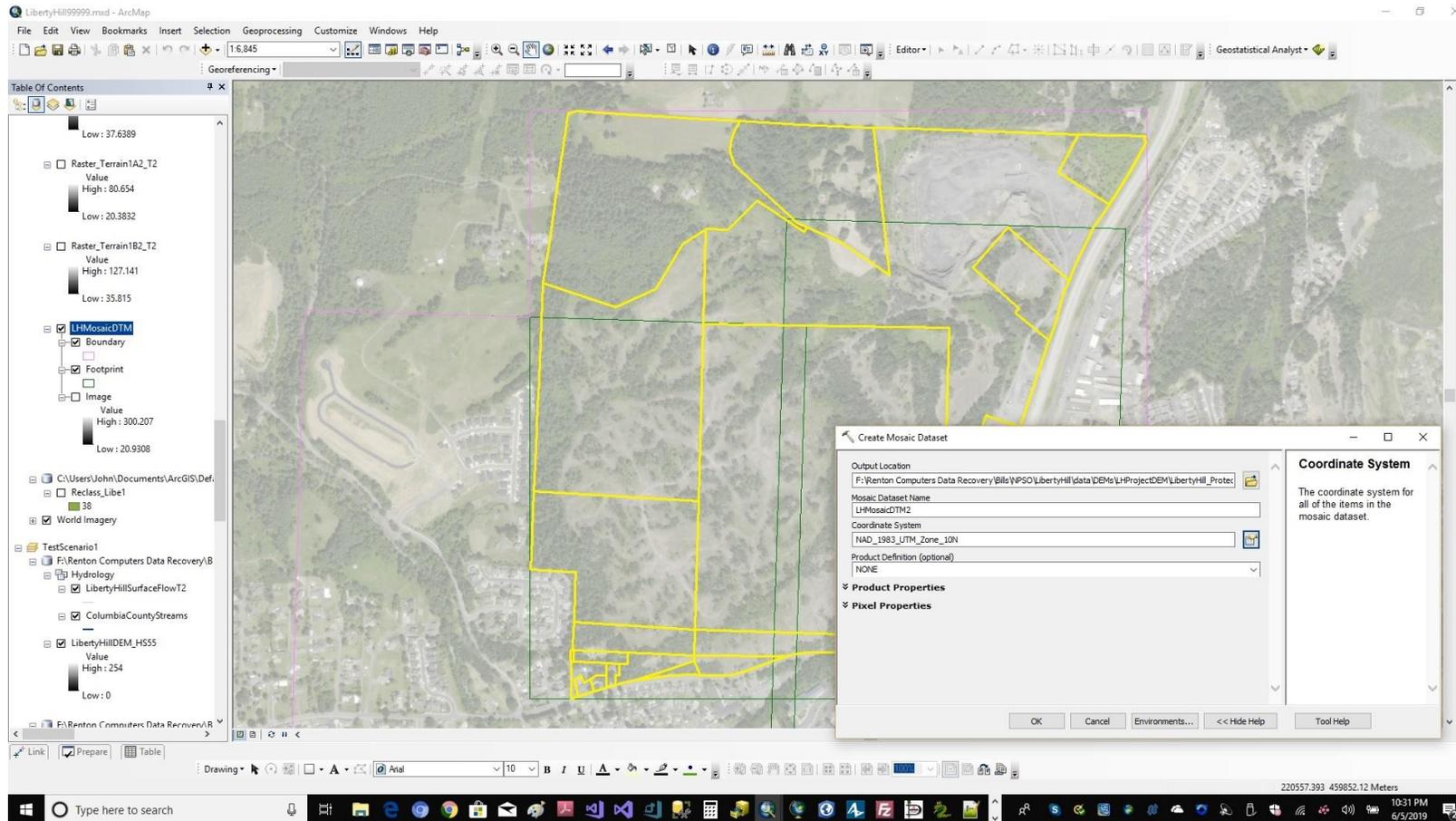
Different DTMs Cover AOC



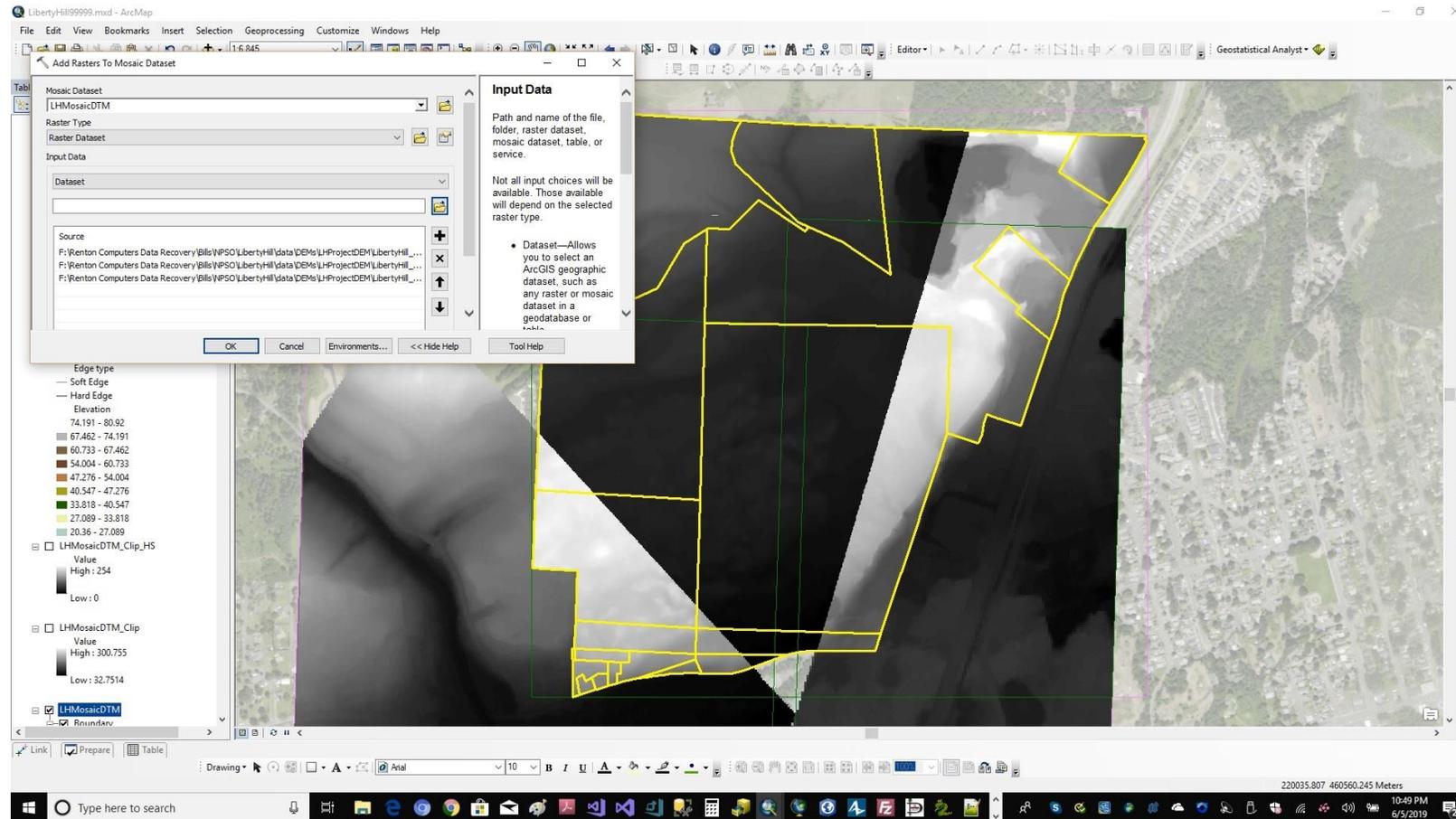
Convert DTMs to Common Units of Measure (e.g., meters to feet)



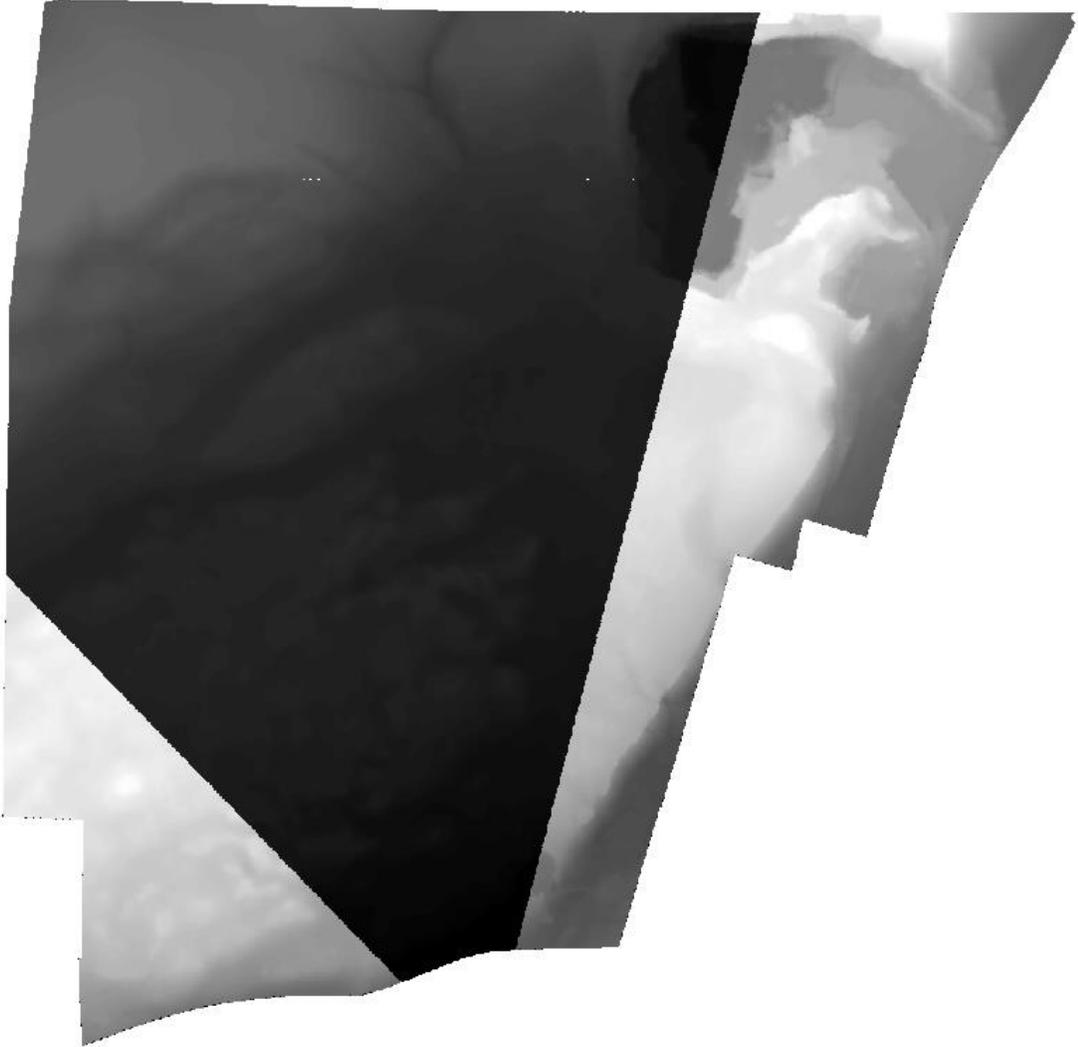
Create Empty Mosaic



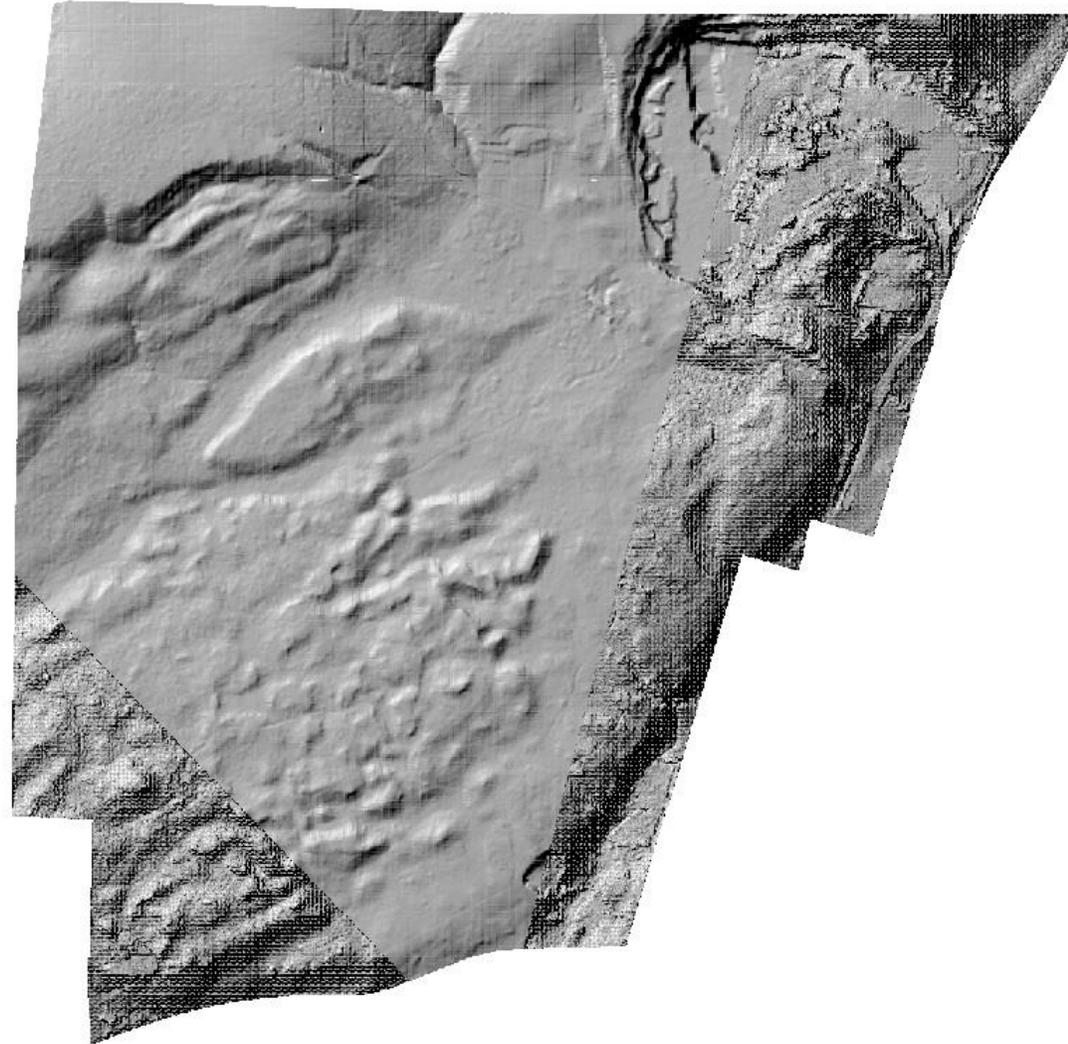
Populate Mosaic with Available DTMs



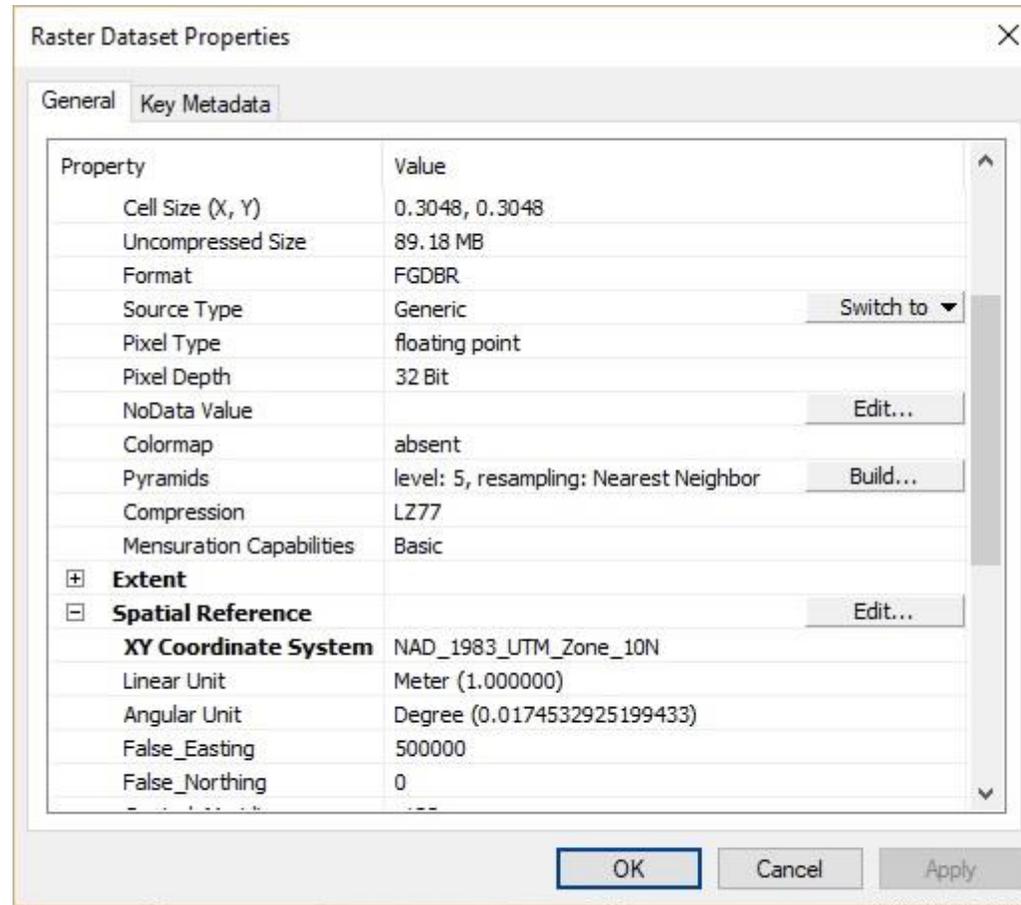
Clip to Liberty Hill AOC = LiDAR Informed Digital Terrain Model



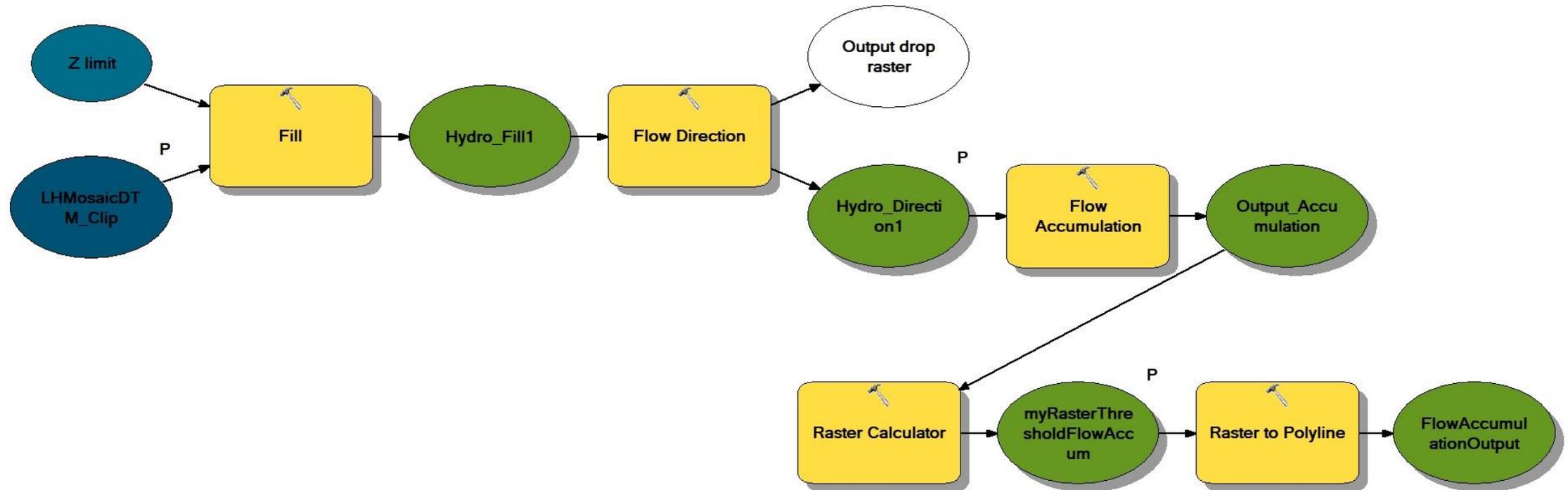
Liberty Hill LiDAR Informed Digital Terrain Model (Hillshade)



Liberty Hill Digital Terrain Model Statistics



Flow Accumulation Model



Fill Tool

Summary

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

Usage

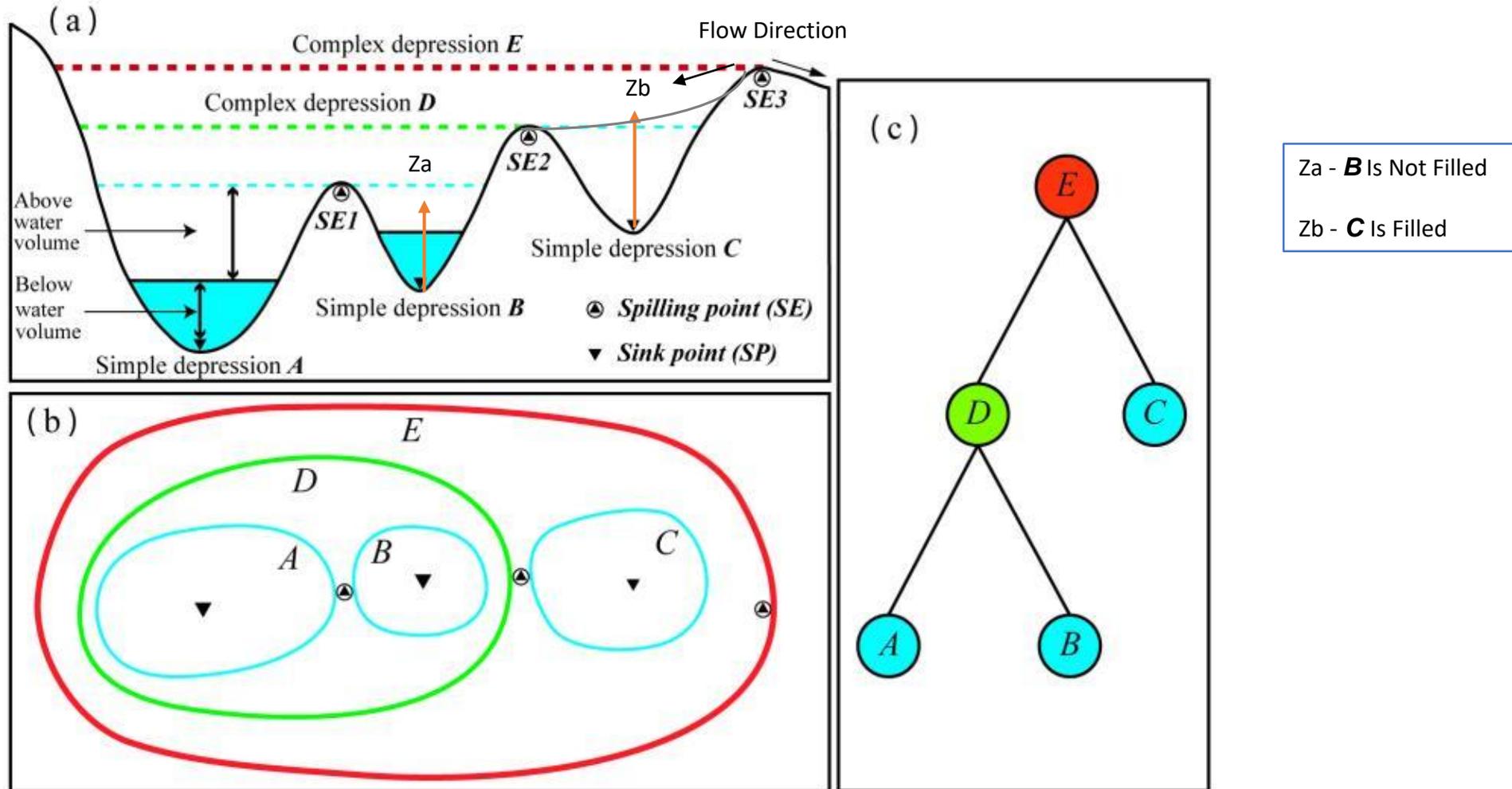
A sink is a cell with an undefined drainage direction; no cells surrounding it are lower. The pour point is the boundary cell with the lowest elevation for the contributing area of a sink. If the sink were filled with water, this is the point where water would pour out.

The z-limit specifies the maximum difference allowed between the depth of a sink and the pour point and determines which sinks will be filled and which will remain untouched. The z-limit is not the maximum depth to which a sink will be filled.

Consider a sink area where the pour point is 210 feet in elevation, and the deepest point within the sink is 204 feet (a difference of 6 feet). If the z-limit is set to 8, this particular sink will be filled. However, if the z-limit is set to 4, this sink will not be filled since the depth of this sink exceeds this difference and would be considered a valid sink.

All sinks that are less than the z-limit, and lower than their lowest adjacent neighbor, will be filled to the height of their pour points.

The Z-Limit in Flow Accumulation Model



Flow Direction

Summary

Creates a raster of flow direction from each cell to its steepest downslope neighbor.

Usage

Flow Direction tool is an integer raster whose values range from 1 to 255.

If the direction of steepest drop was to the left of the current processing cell, its flow direction would be coded as 16. If a cell is lower than its eight neighbors, that cell is given the value of its lowest neighbor, and flow is defined toward this cell. If a cell has the same change in z-value in multiple directions and is not part of a sink, the flow direction is assigned with a lookup table defining the most likely direction. See Greenlee (1987). The output drop raster is calculated as the difference in z-value divided by the path length between the cell centers, expressed in percentages.

Flow Direction (Spatial Analyst)

78	72	68	71	58	49
74	67	58	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	18	19
74	53	34	12	11	12

Elev_Ras

=

2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

Flow_Dir

Flow_Dir = FlowDirection(Elev_Ras)

Calculating the Direction of Flow

The direction of flow is determined by the direction of steepest descent, or maximum drop, from each cell. This is calculated as follows:

$$\mathbf{maximum_drop = change_in_z\text{-}value / distance * 100}$$

The distance is calculated between cell centers. Therefore, if the cell size is 1, the distance between two orthogonal cells is 1, and the distance between two diagonal cells is 1.414 (the square root of 2). If the maximum descent to several cells is the same, the neighborhood is enlarged until the steepest descent is found.

When a direction of steepest descent is found, the output cell is coded with the value representing that direction.

Flow Accumulation

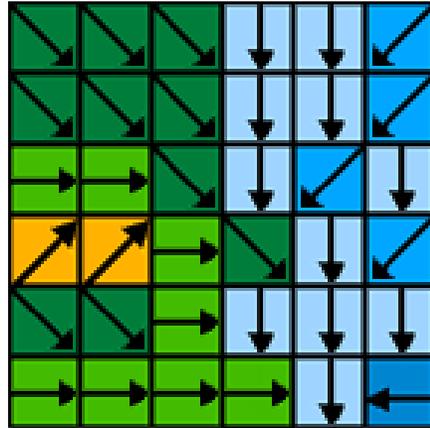
Summary

Creates a raster of accumulated flow into each cell.

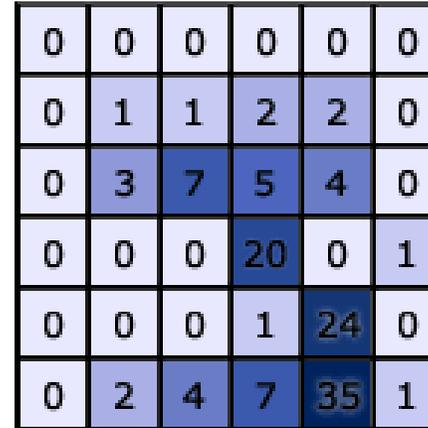
Usage

The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell.

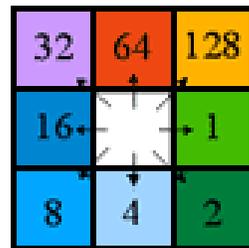
Flow Accumulation



Flow direction



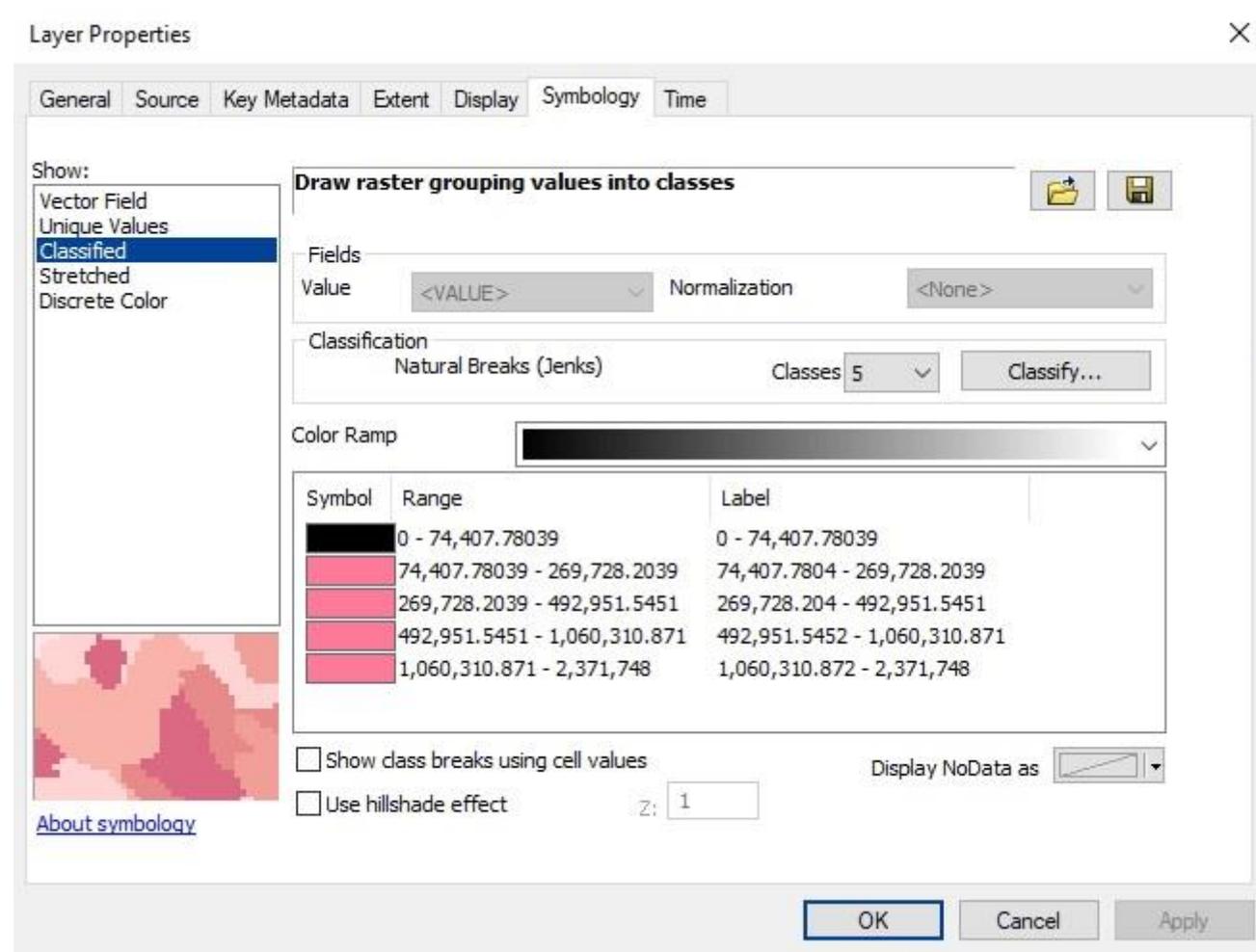
Flow accumulation



Direction coding

$$\mathbf{Flow_Acc} = \mathbf{FlowAccumulation(Flow_Dir)}$$

Raster Calculator Threshold



Raster Calculator

Summary

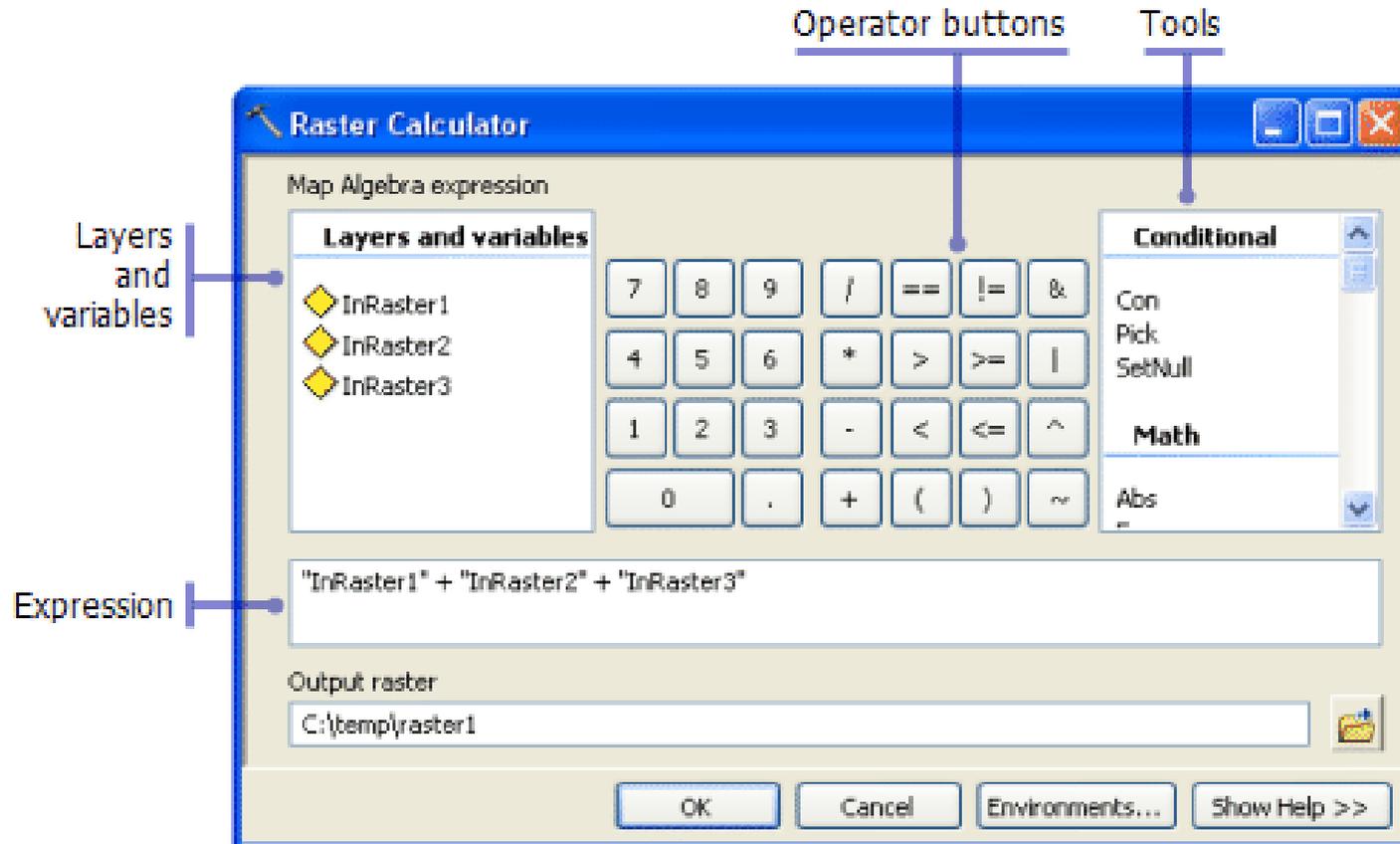
Builds and executes a single Map Algebra expression using Python syntax in a calculator-like interface.

Usage

The Raster Calculator tool allows you to create and execute a map algebra expression that will output a raster:

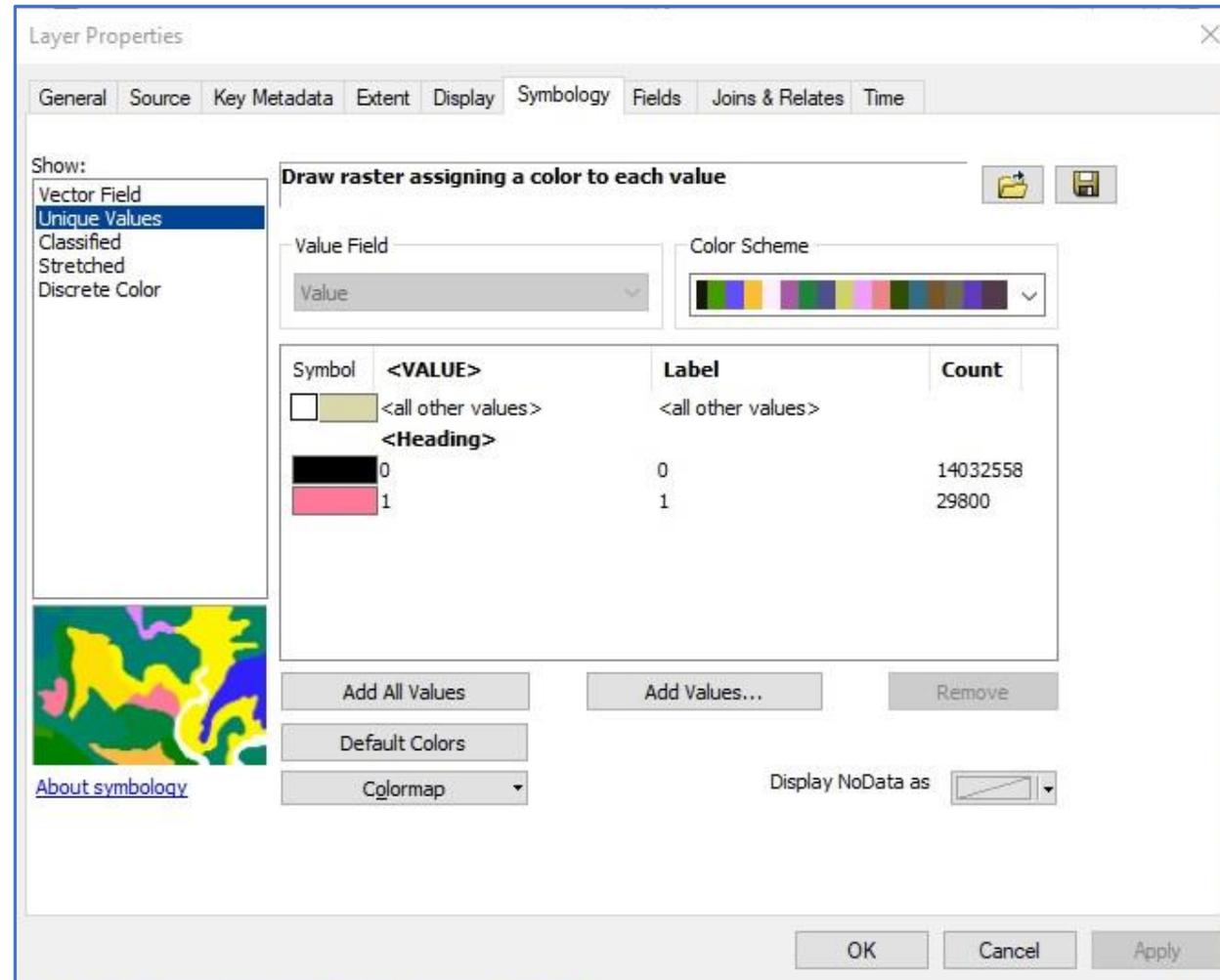
```
myRasterThresholdFlowAccum = Raster("Output_Accumulation") > 74407.8039
```

Raster Calculator

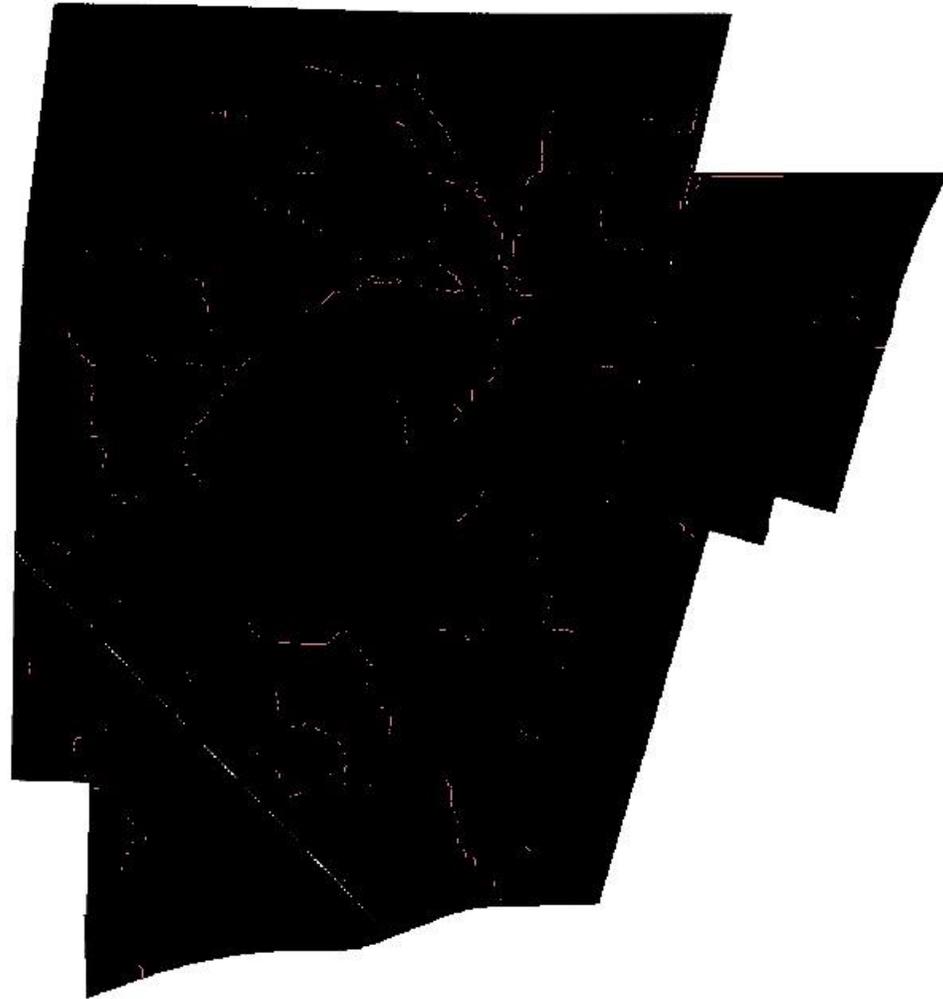


myRasterThresholdFlowAccum = Raster("Output_Accumulation") > 74407.78039

Raster Calculator Output



Flow Accumulation Model Output



Raster to Polyline

Summary

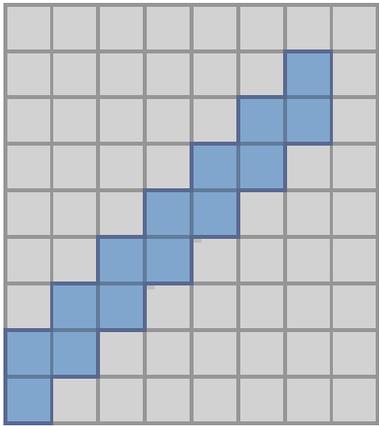
Converts a raster dataset to polyline features.

Usage

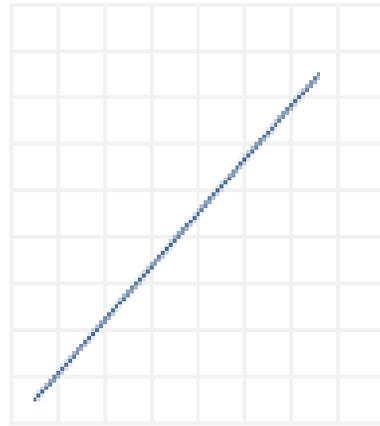
The input raster can have any valid cell size greater than 0, and may be any valid integer raster dataset.

The Field parameter allows you to choose which attribute field of the input raster dataset will become an attribute in the output feature class. If a field is not specified, the cell values of the input raster (the VALUE field) will become a column with the heading Grid_code in the attribute table of the output feature class.

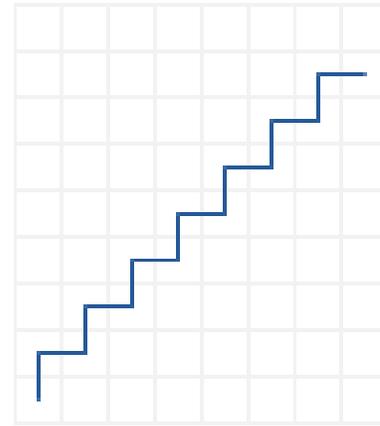
Raster to Polyline



Input raster



Simplified output



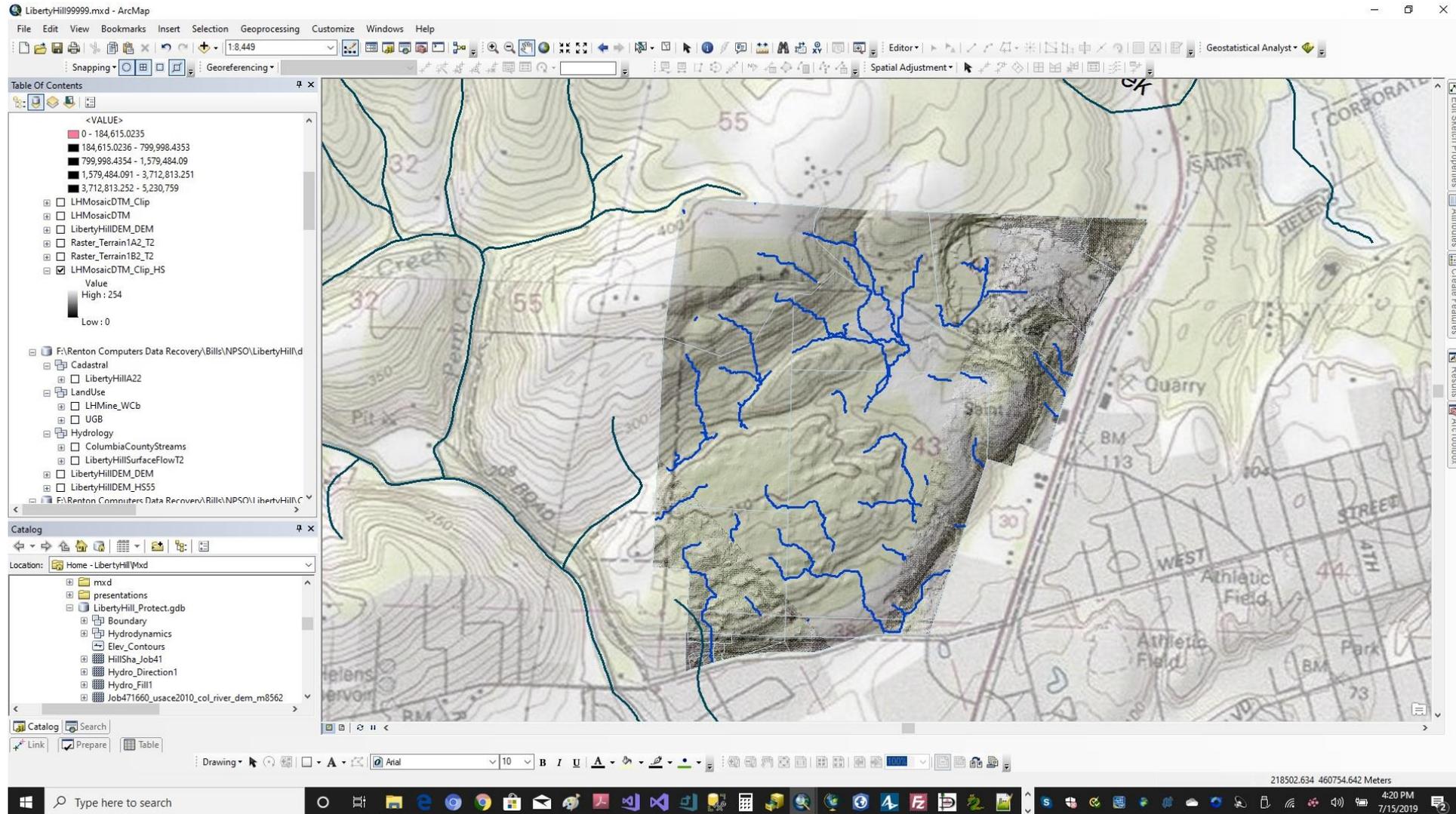
Non-simplified output

Legend

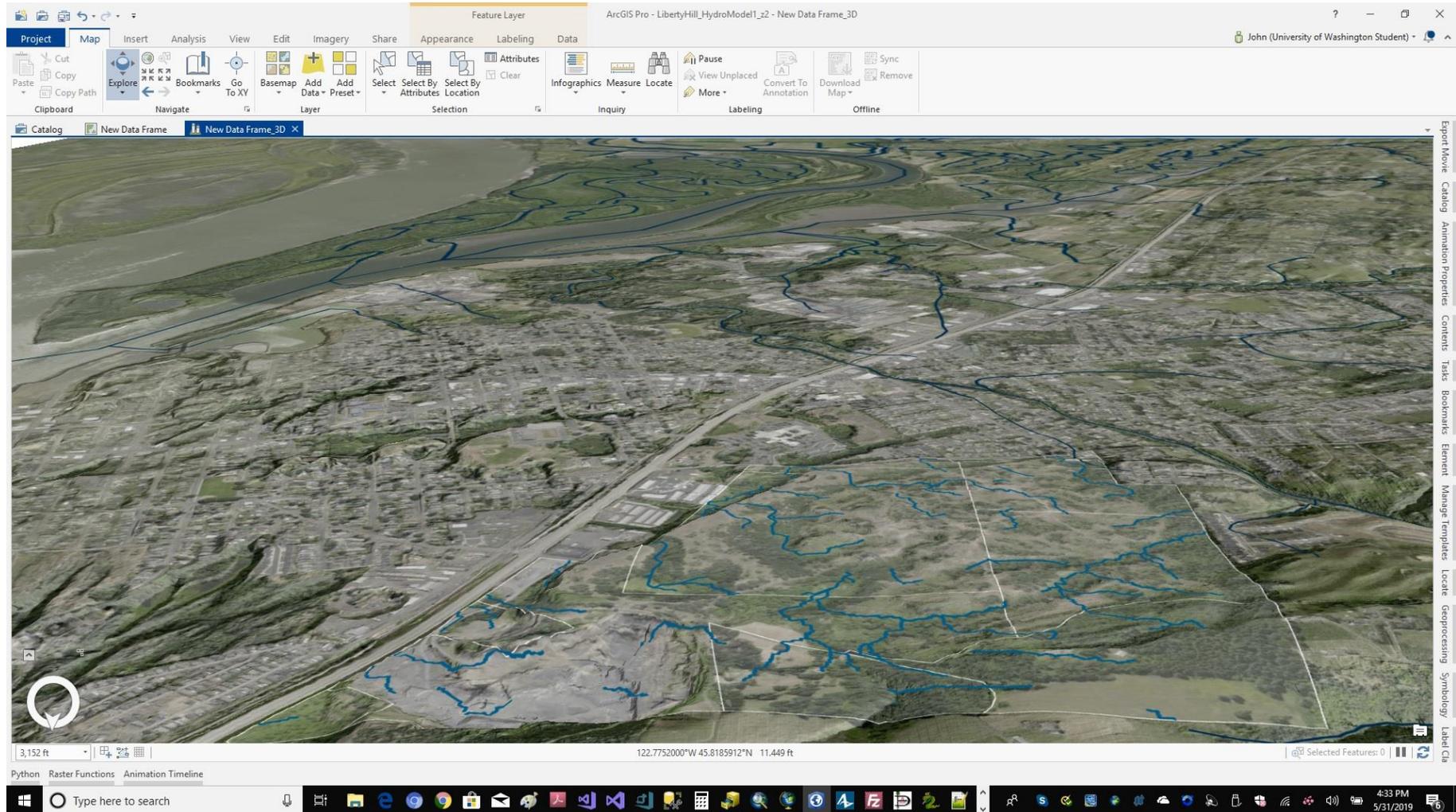
■ 1

■ NoData

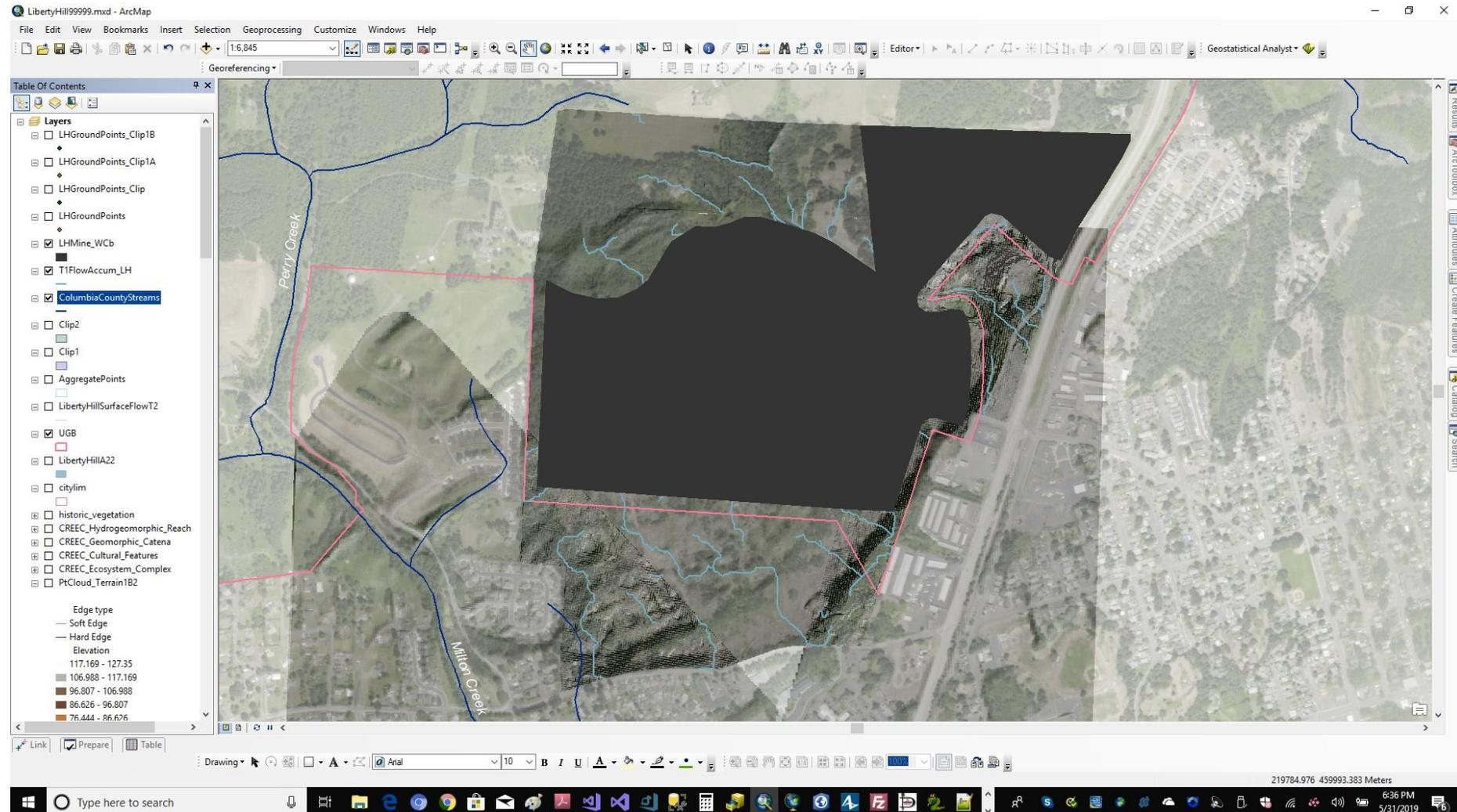
Liberty Hill Flow Accumulation Model (Z Limit: 2)



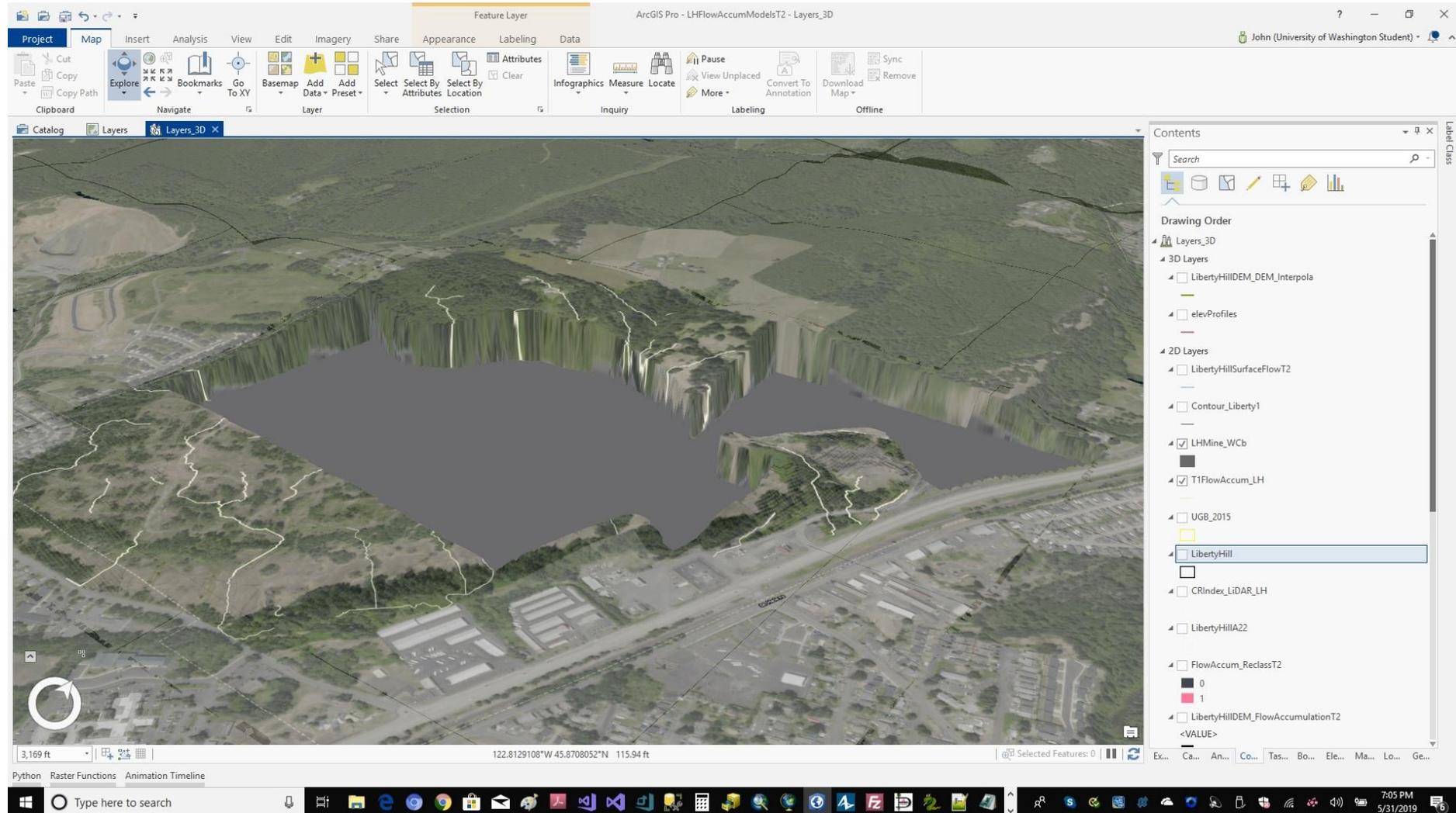
Liberty Hill Flow Accumulation Model (Z Limit: 2)



Potential Direct Impacts



Potential Direct Impacts

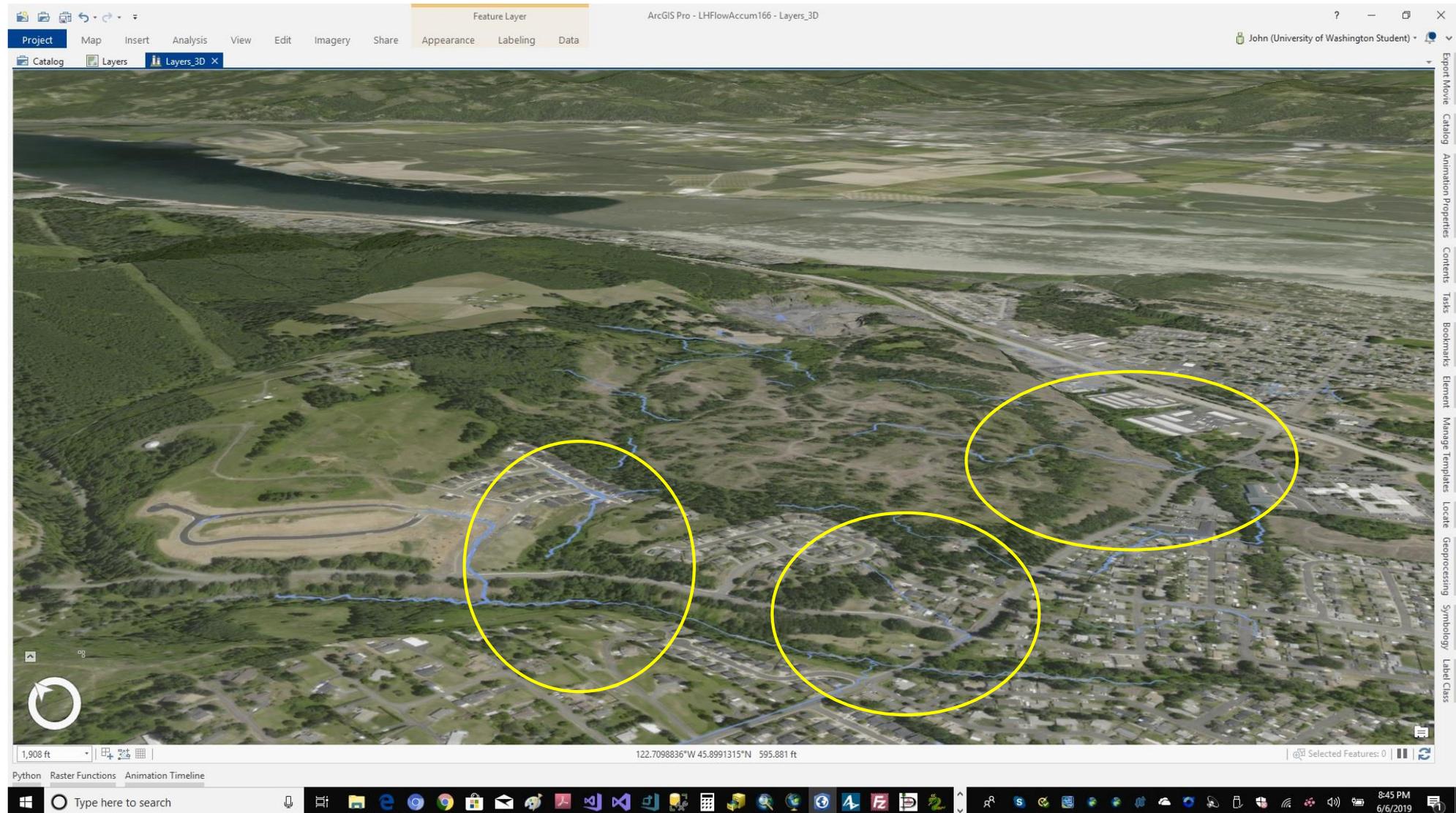


Federal Clean Water Act WOTUS Jurisdiction

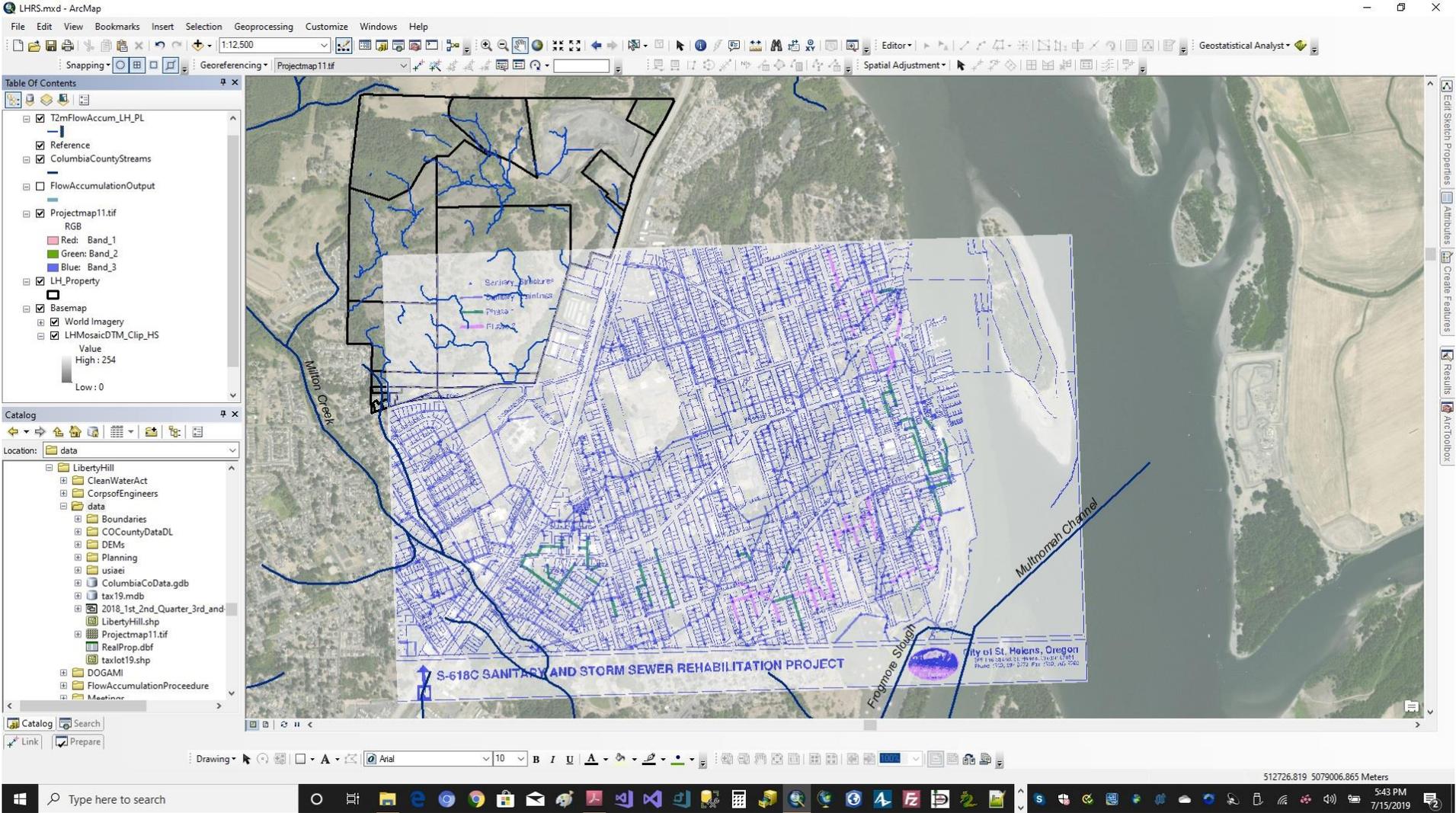
The Federal Clean Water Act regulates discharges into Waters of the US (WOTUS) as defined by the following:

- Traditional navigable waters (TNWs) - would be large rivers and lakes, tidal waters, and the territorial seas—such as the Atlantic Ocean, the Mississippi River, the Great Lakes, and tidally influenced waterbodies, including wetlands, along coastlines—used in interstate or foreign commerce.
- Tributaries - would be rivers and streams that flow to traditional navigable waters—such as Rock Creek, which feeds to the Potomac River in Washington, D.C.
- These naturally occurring surface water channels ***must flow more often than just when it rains—that is, tributaries as proposed must be perennial or intermittent***. Ephemeral features would not be tributaries under the proposal.
- Tributaries - can connect to traditional navigable waters directly, through other “waters of the United States,” or through other non-jurisdictional surface waters so long as those waters convey perennial or intermittent flow downstream.
- Adjacent wetlands - that physically touch other jurisdictional waters would be considered jurisdictional.

Are These Criteria Met Here?



Flow Accumulations Modeled, Existing Area Drainages, and Georeferenced Underground Stormwater Conveyance System



Problems With Model Applications

- The accuracy of the DTM surfaces used in the models are called into question because:
 - The LiDAR coverage of AOC required acquisitions of various data sources with different resolutions and accuracy standards; and
 - Point Cloud data provided by the Corps were not just last return points (e.g., not bare earth).
- Z – Limit determinations were more or less ad-hoc estimates. Work is needed to make better informed Z – Limit decisions that insure the models do not treat actual terrain vertical depressions as errors;
- The models are designed to find the most likely pathways for linear flow and do not directly account for sheet flow, which is likely the most prevalent type of flow in the AOC;
- The models are designed to only model surface flow and do not account for potential surface to groundwater recharge and discharges in the AOC.

Conclusions and Recommendations

Question 1:

Can high resolution LiDAR help inform surface water flow models on Liberty Hill and thereby assist in evaluating potential direct, indirect, and cumulative impacts of nearby and expanding mining activities on surface water access to focal wetlands and plant communities?

Answer 1:

These model runs demonstrate LiDAR informed DTMs can assist in modeling terrain surface flows but the questions about impact determinations require more information about the spatial extents of the focal resources of concern and the range of spatial extents of future mining footprints as well as hydrology modeling better suited to also document spread-out sheet flow and subsurface groundwater flow.

The likely jurisdictional sequence is:

One or more Liberty Hill drainages,
Milton Creek,
Scappoose Bay,
Multnomah Channel, and
Columbia River

Question 2:

Can high resolution LiDAR help inform surface water flow models on Liberty Hill and thereby assist in determining Federal Clean Water Act jurisdiction over mosaic in situ wetland plant communities?

Answer 2:

These model runs demonstrate LiDAR informed DTMs can assist in modeling terrain surface flows but the questions about Federal Clean Water Act jurisdiction are apparently mostly hinging on whether or not the wetland plant communities in the AOC are adjacent to and abutting either perennial or intermittent streams. The test of intermittent vs ephemeral is "cannot flow exclusively in response to a rainfall event." The determination of whether the surface water flows at Liberty Hill AOC meet the jurisdictional criteria of intermittent streams will likely require more complex hydrologic modeling than provided here and / or have to be made by a field staff person from the US Army Corps of Engineers. But as a side note, this interpretation of the law appears to me to ignore the concept of a "significant nexus" and thereby can possibly be challenged if evidence can be accumulated that demonstrates the role these essential headwaters play in the physical, chemical, and biological integrity of downslope receiving WOTUS.

Model Python Script

- `-*- coding: utf-8 -*-`
- `# -----`
- `# FlowAccumModel2.py`
- `# Created on: 2019-06-05 23:47:22.00000`
- `# (generated by ArcGIS/ModelBuilder)`
- `# Usage: FlowAccumModel2 <Hydro_Direction1> <myRasterThresholdFlowAccum> <LHMosaicDTM_Clip>`
- `# Description:`
- `# -----`

- `# Import arcpy module`
- `import arcpy`

- `# Script arguments`
- `Hydro_Direction1 = arcpy.GetParameterAsText(0)`
- `if Hydro_Direction1 == '#':`
 - `Hydro_Direction1 = "F:\\Renton Computers Data Recovery\\Bills\\NPSO\\LibertyHill\\data\\DEMs\\LHProjectDEM\\LibertyHill_Protect.gdb\\Hydro_Direction1" # provide a default value if unspecified`

Model Python Script

- `myRasterThresholdFlowAccum = arcpy.GetParameterAsText(1)`
- `if myRasterThresholdFlowAccum == '#' or not myRasterThresholdFlowAccum:`
- `myRasterThresholdFlowAccum = "F:\\Renton Computers Data Recovery\\Bills\\NPSO\\LibertyHill\\data\\DEMs\\LHProjectDEM\\LibertyHill_Protect.gdb\\myRasterThresholdFlowAccum" # provide a default value if unspecified`

- `LHMosaicDTM_Clip = arcpy.GetParameterAsText(2)`
- `if LHMosaicDTM_Clip == '#' or not LHMosaicDTM_Clip:`
- `LHMosaicDTM_Clip = "LHMosaicDTM_Clip" # provide a default value if unspecified`

- `# Local variables:`
- `Z_limit = "2"`
- `Hydro_Fill1 = "F:\\Renton Computers Data Recovery\\Bills\\NPSO\\LibertyHill\\data\\DEMs\\LHProjectDEM\\LibertyHill_Protect.gdb\\Hydro_Fill1"`
- `Output_drop_raster = ""`
- `Output_Accumulation = "F:\\Renton Computers Data Recovery\\Bills\\NPSO\\LibertyHill\\data\\DEMs\\LHProjectDEM\\LibertyHill_Protect.gdb\\Output_Accumulation"`

Model Python Script

- `FlowAccumulationOutput = "F:\\Renton Computers Data Recovery\\Bills\\NPSO\\LibertyHill\\data\\DEMs\\LHProjectDEM\\LibertyHill_Protect.gdb\\Hydrodynamics\\FlowAccumulationOutput"`
- `# Process: Fill`
- `arcpy.gp.Fill_sa(LHMosaicDTM_Clip, Hydro_Fill1, Z_limit)`
- `# Process: Flow Direction`
- `arcpy.gp.FlowDirection_sa(Hydro_Fill1, Hydro_Direction1, "NORMAL", Output_drop_raster)`
- `# Process: Flow Accumulation`
- `arcpy.gp.FlowAccumulation_sa(Hydro_Direction1, Output_Accumulation, "", "FLOAT")`
- `# Process: Raster Calculator`
- `arcpy.gp.RasterCalculator_sa("myRasterThresholdFlowAccum = Raster(\"%Output_Accumulation%\") > 1084972.769", myRasterThresholdFlowAccum)`
- `# Process: Raster to Polyline`
- `arcpy.RasterToPolyline_conversion(myRasterThresholdFlowAccum, FlowAccumulationOutput, "ZERO", "0", "SIMPLIFY", "Value")`

References

- US Army Corps of Engineers 2013. *Columbia River LiDAR Project*, Portland District, Contracts: W9127N-10-D-0002 / 0001 and W9127N-09-D-0009 / 0006, Portland, Oregon.
- <https://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/create-terrain.htm>
- <https://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/how-terrain-pyramid-level-definition-works.htm>
- <https://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/add-feature-class-to-terrain.htm>
- <http://desktop.arcgis.com/en/arcmap/10.3/tools/3d-analyst-toolbox/build-terrain.htm>
- <http://desktop.arcgis.com/en/arcmap/10.3/tools/3d-analyst-toolbox/terrain-to-raster.htm>

References (continued)

- <https://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-fill-works.htm>
- <https://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/flow-direction.htm>
- <https://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/flow-accumulation.htm>
- <http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/raster-calculator.htm>
- <http://desktop.arcgis.com/en/arcmap/10.3/tools/conversion-toolbox/raster-to-polyline.htm>
- Plant Community Photographs - larissalibertyhill@gmail.com

Questions?
