Image from NASA:
https://commons.wikimedia.org/wiki/File:Earth_Western_Hemisphere_transparent_background.png#filelinks

GIScience

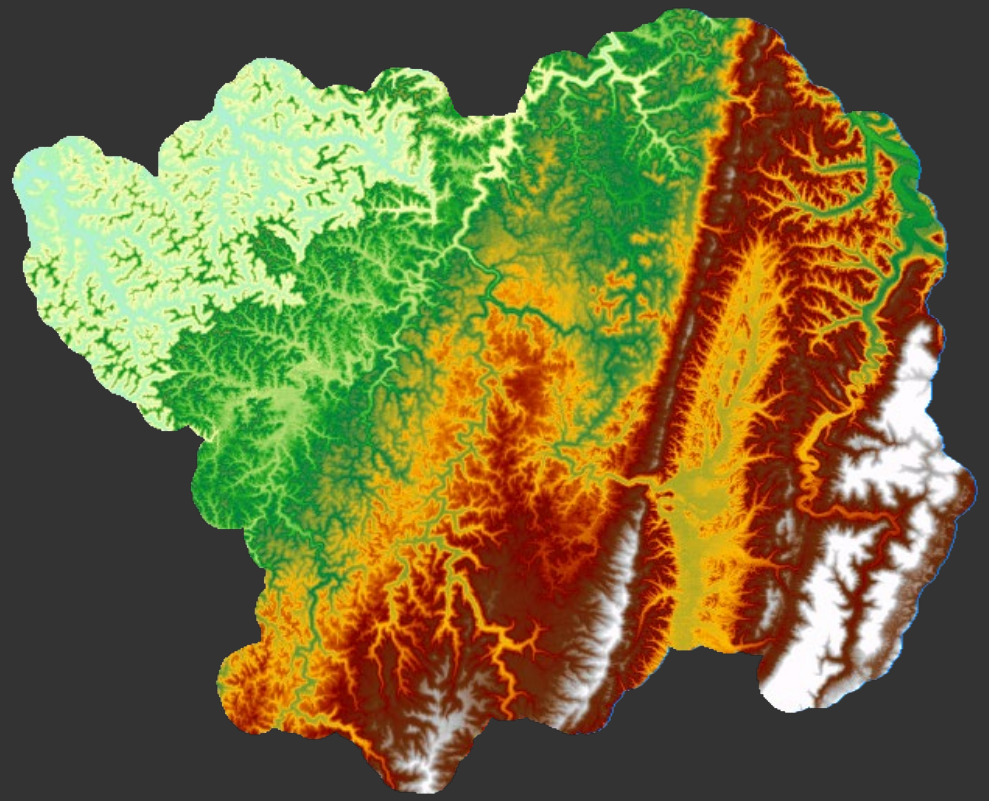
Surface Hydrologic Analysis

WV VIEW

AmericaView℠
Empowering Earth Observation Education
AmericaView.org - Est. 2003

Modeling Surface Water Flow

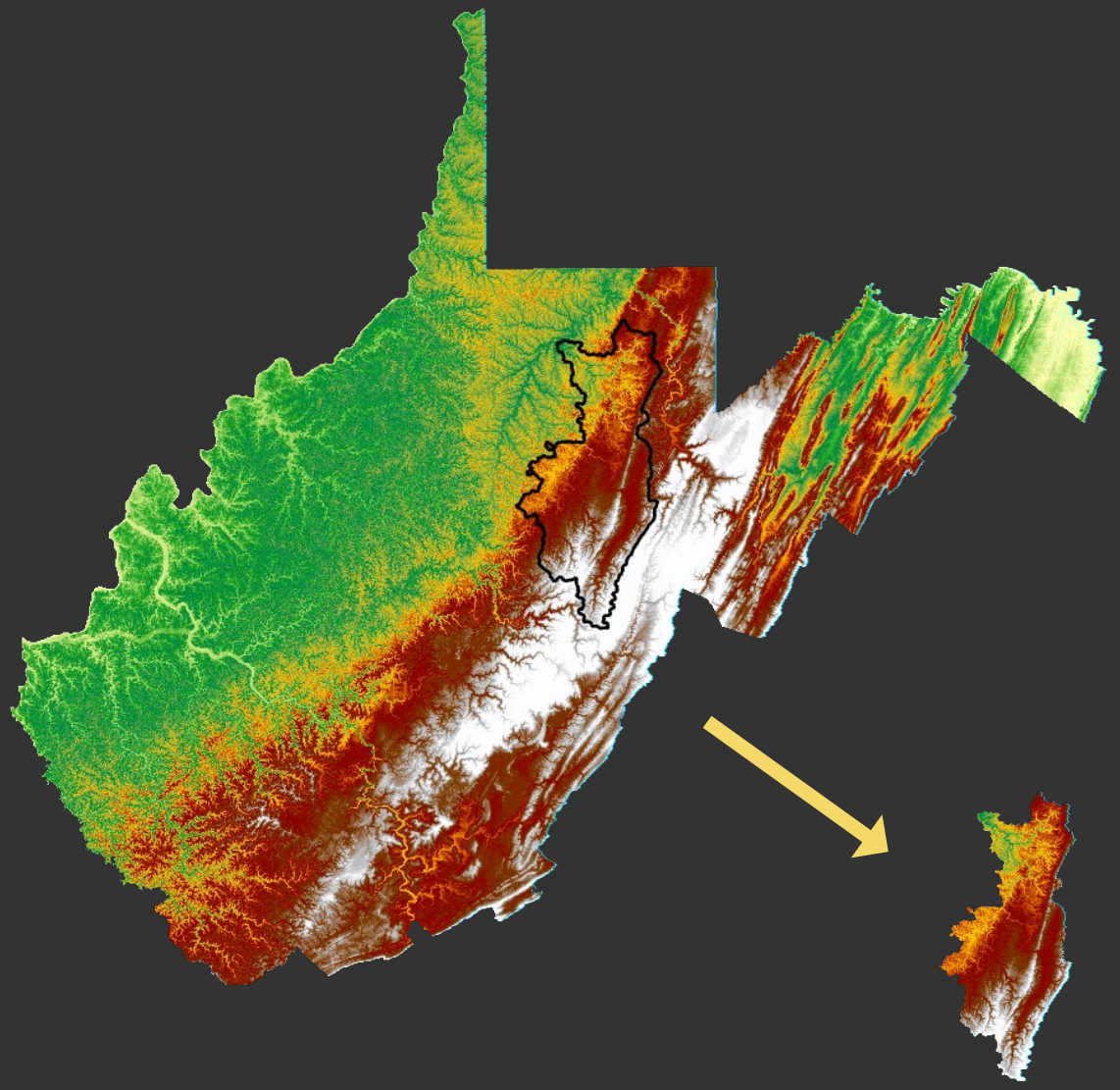
- Modeling surface flow starts with a DEM



Preparation

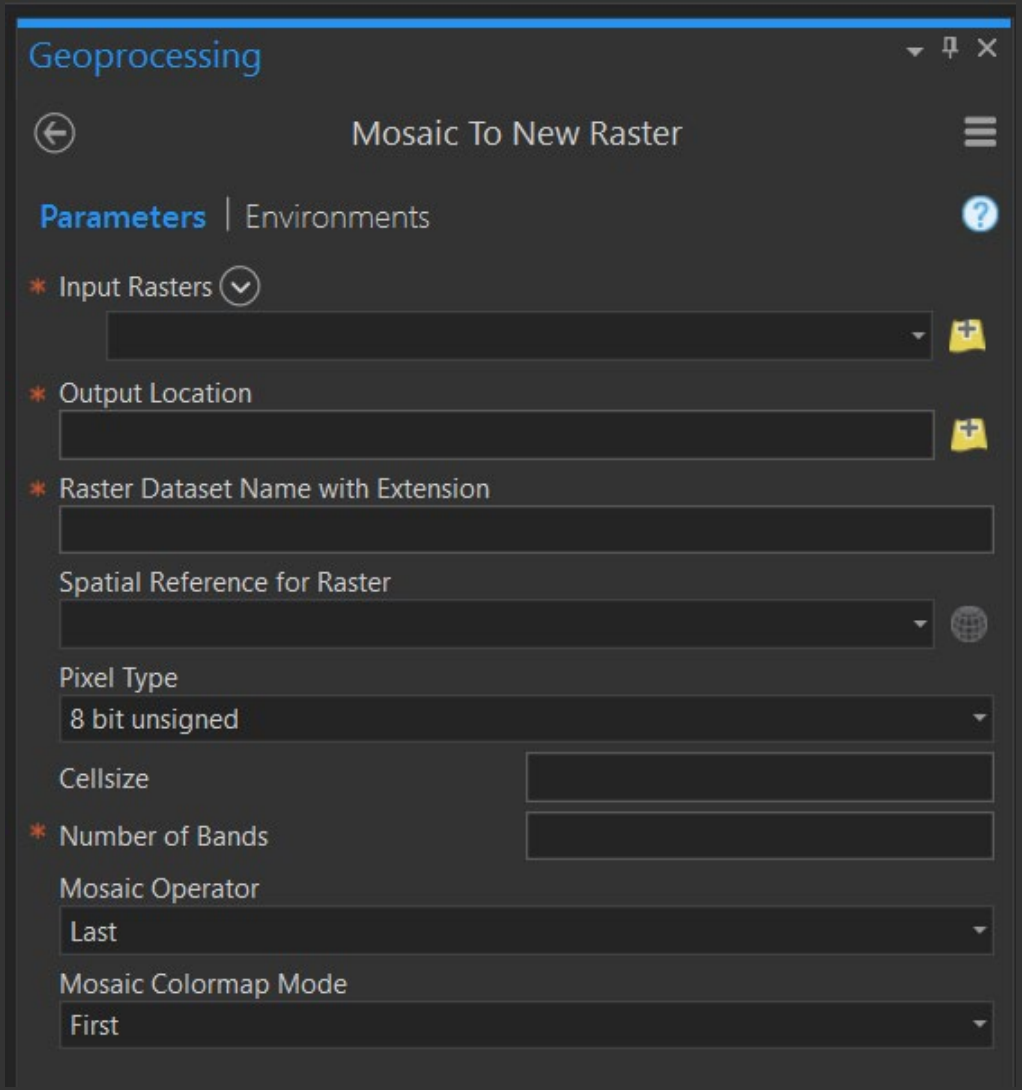
Extraction Methods

- Extract by Circle = extract cells that fall into a circle that is defined by a center coordinate and radius
- Extract by Mask = extract cells that fall within a raster or polygon mask
- Extract by Point = extract cells at point locations
- Extract by Polygon = extract cells that fall within the extent of a polygon as defined by its vertices
- Extract by Rectangle = extract cells that fall within a rectangular extent

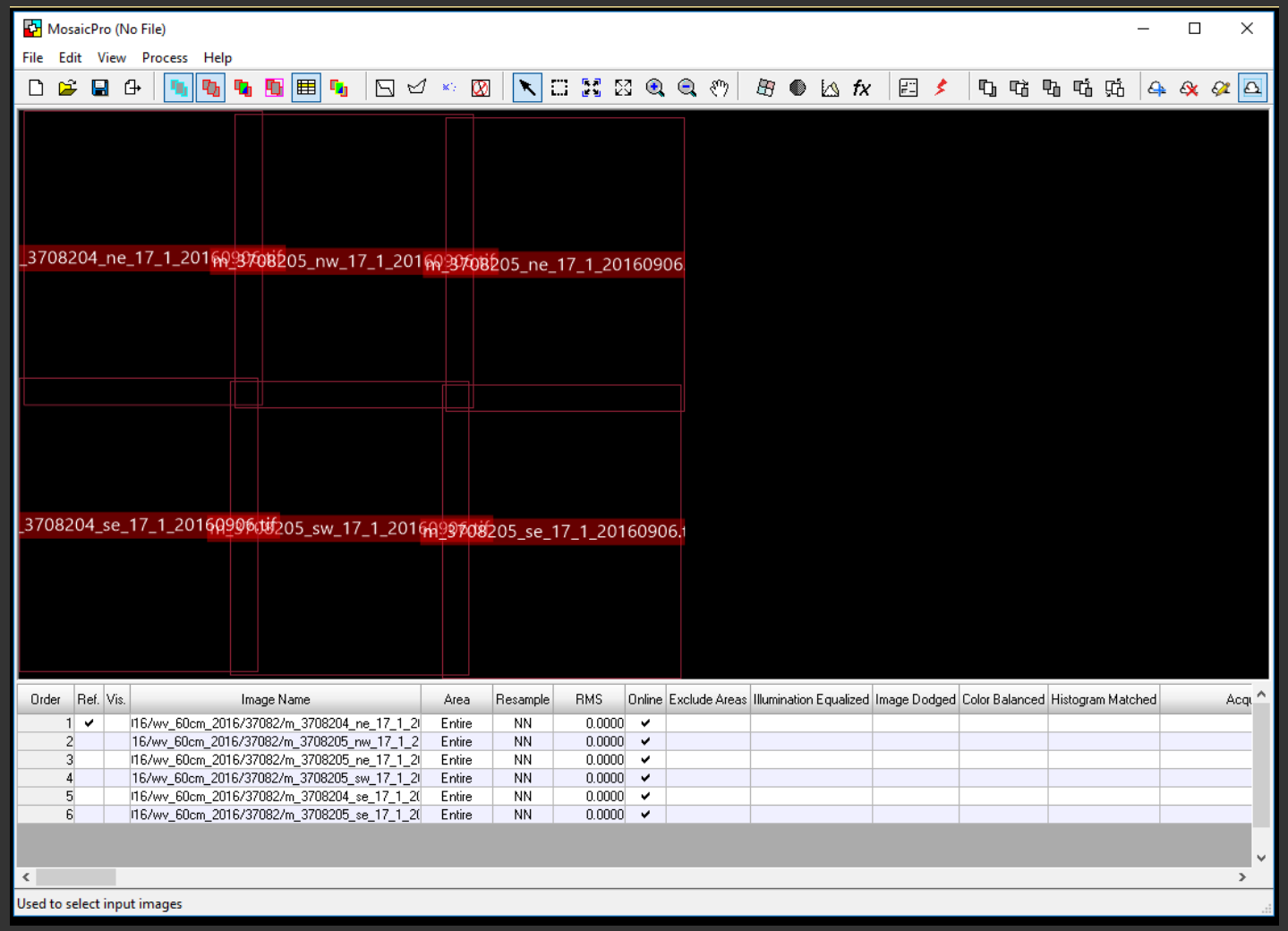


Mosaic to New Raster

- Combine single band or multiband raster grids into a single raster
- Can be used for all types or raster grids, including images
- Must specify file extension, pixel type, cell size, and number of bands

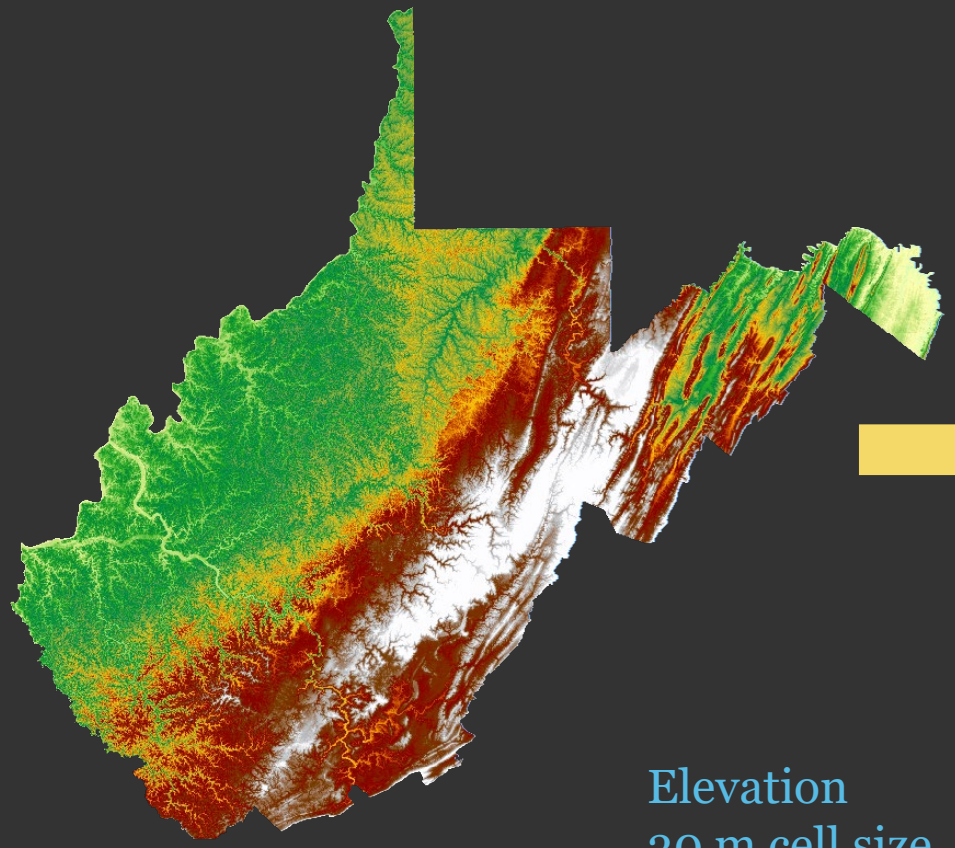


Mosaic Outside of ArcGIS

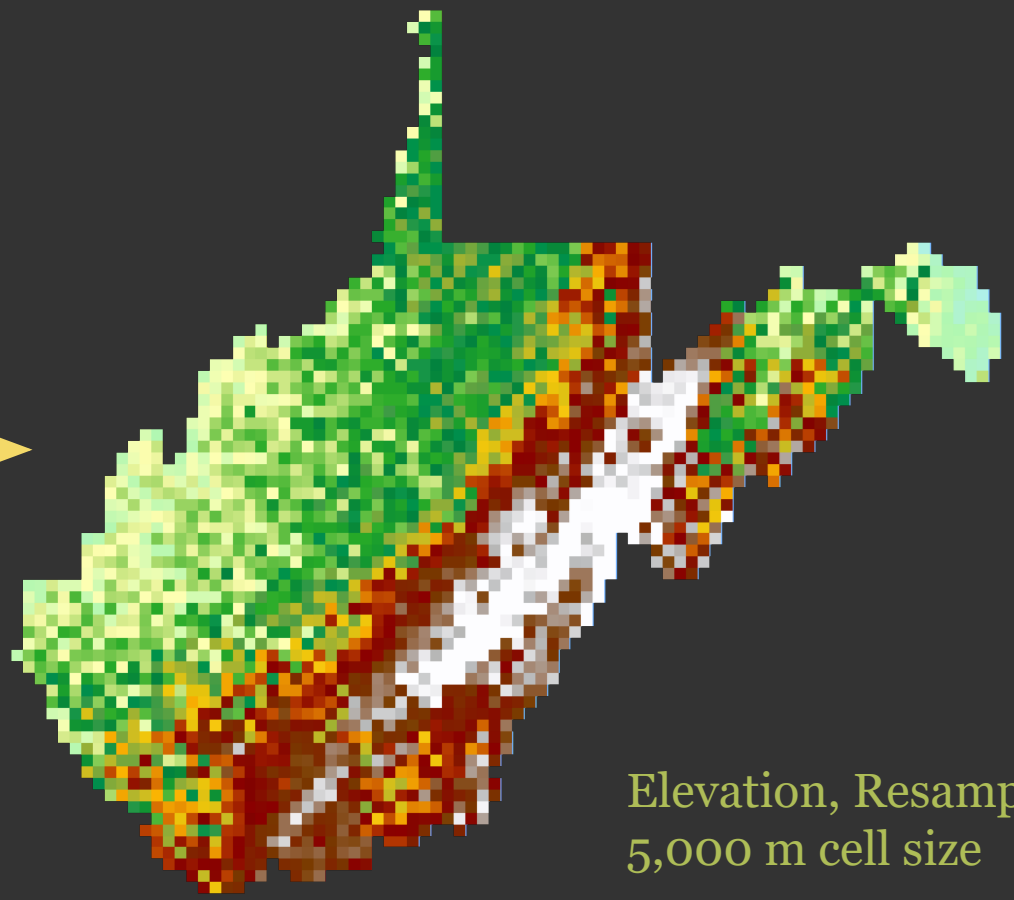


Resampling

- Change the cell size



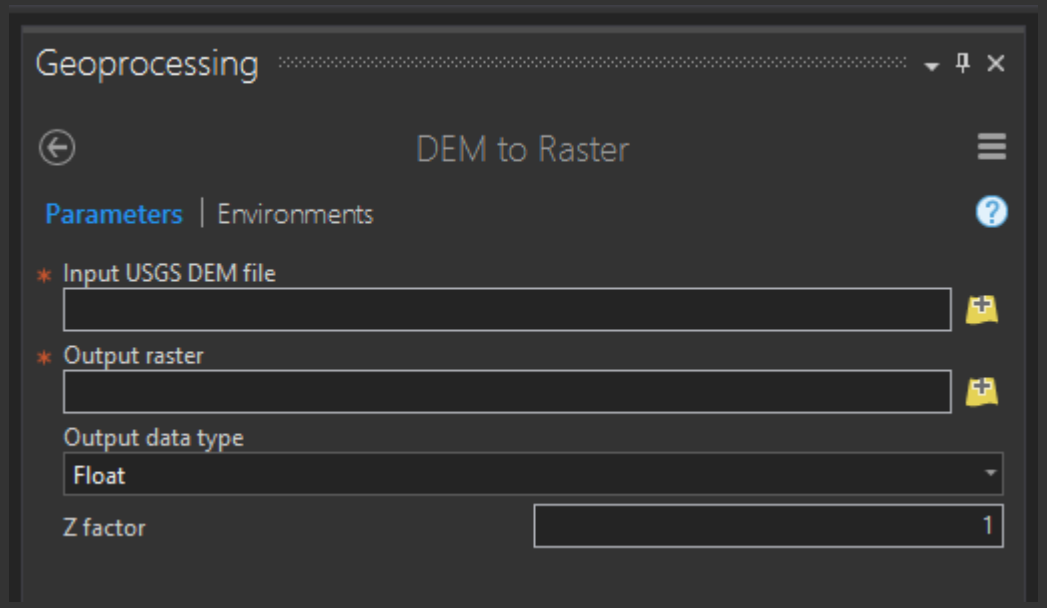
Elevation
30 m cell size



Elevation, Resampled
5,000 m cell size

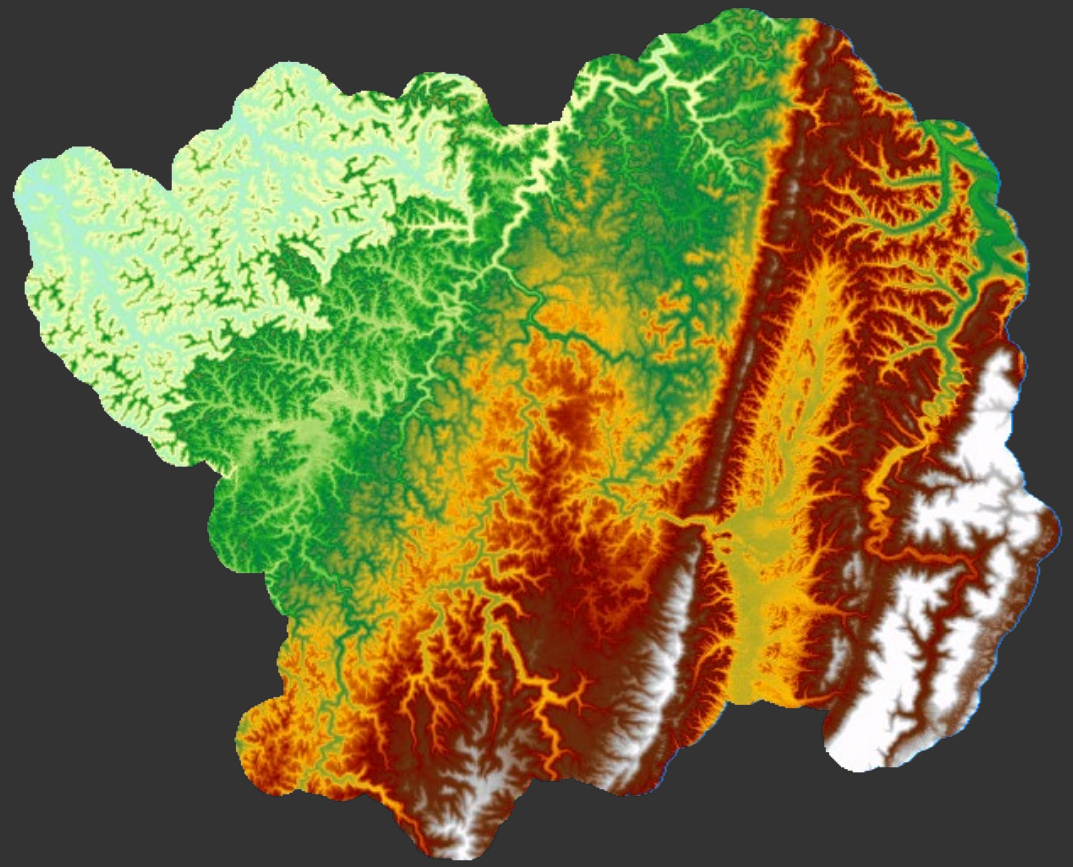
DEM to Raster

- Converts a DEM in United States Geologic Survey (USGS) format to a raster dataset



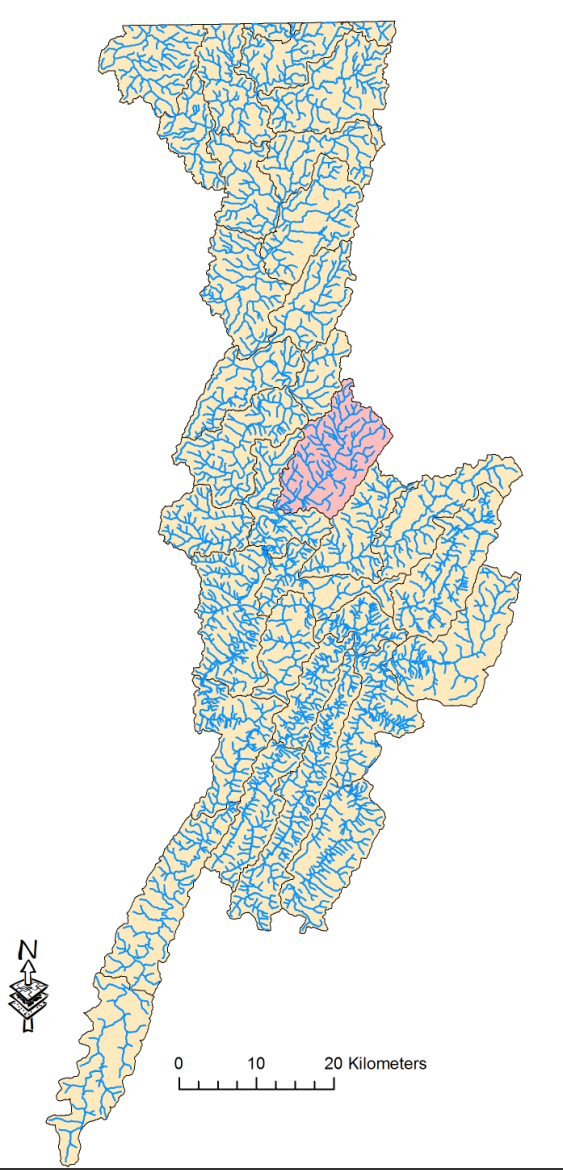
Things to know about your data

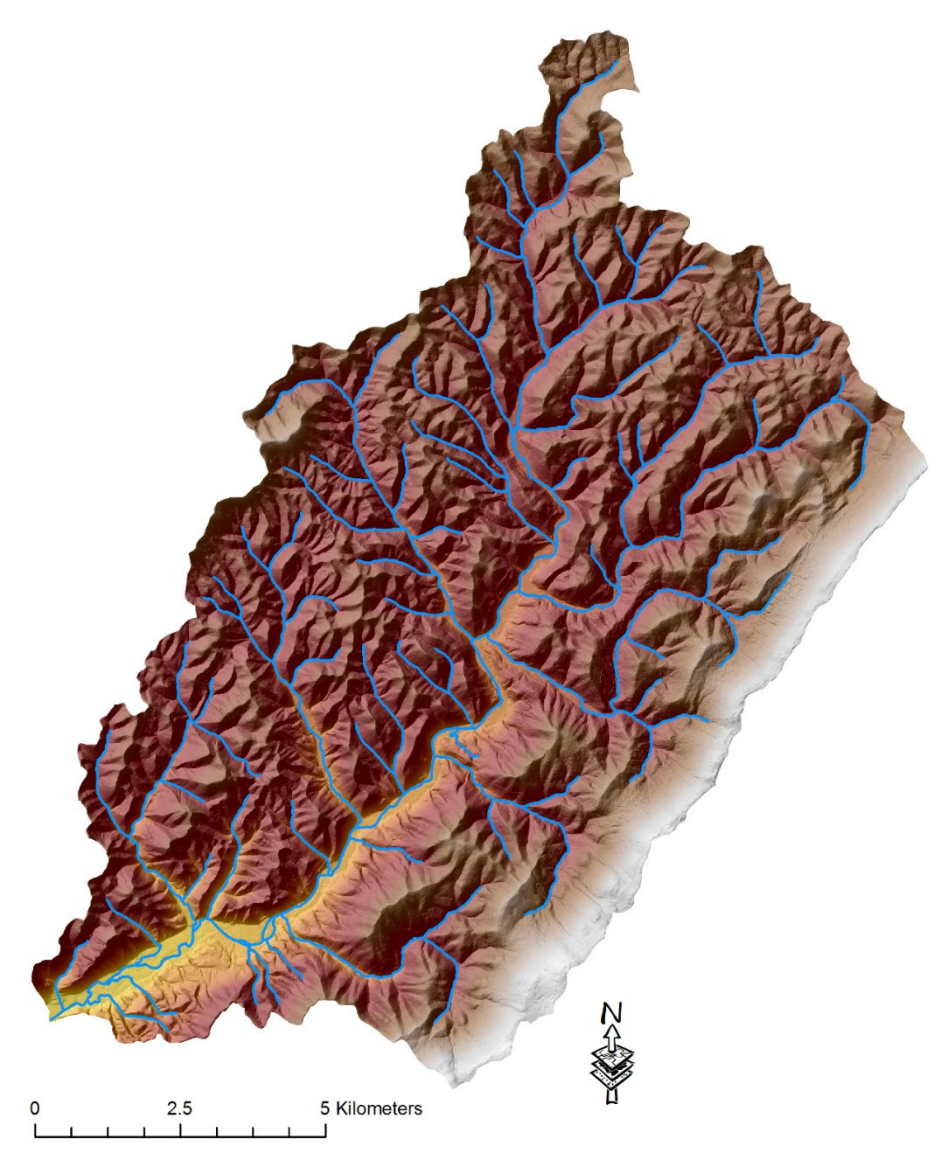
1. Source
2. Collection date(s)
3. Feet or meters?
4. Vertical datum
5. Horizontal datum
6. Accuracy/precision



Watersheds

Watersheds





Surface Hydrologic Modeling

The Process

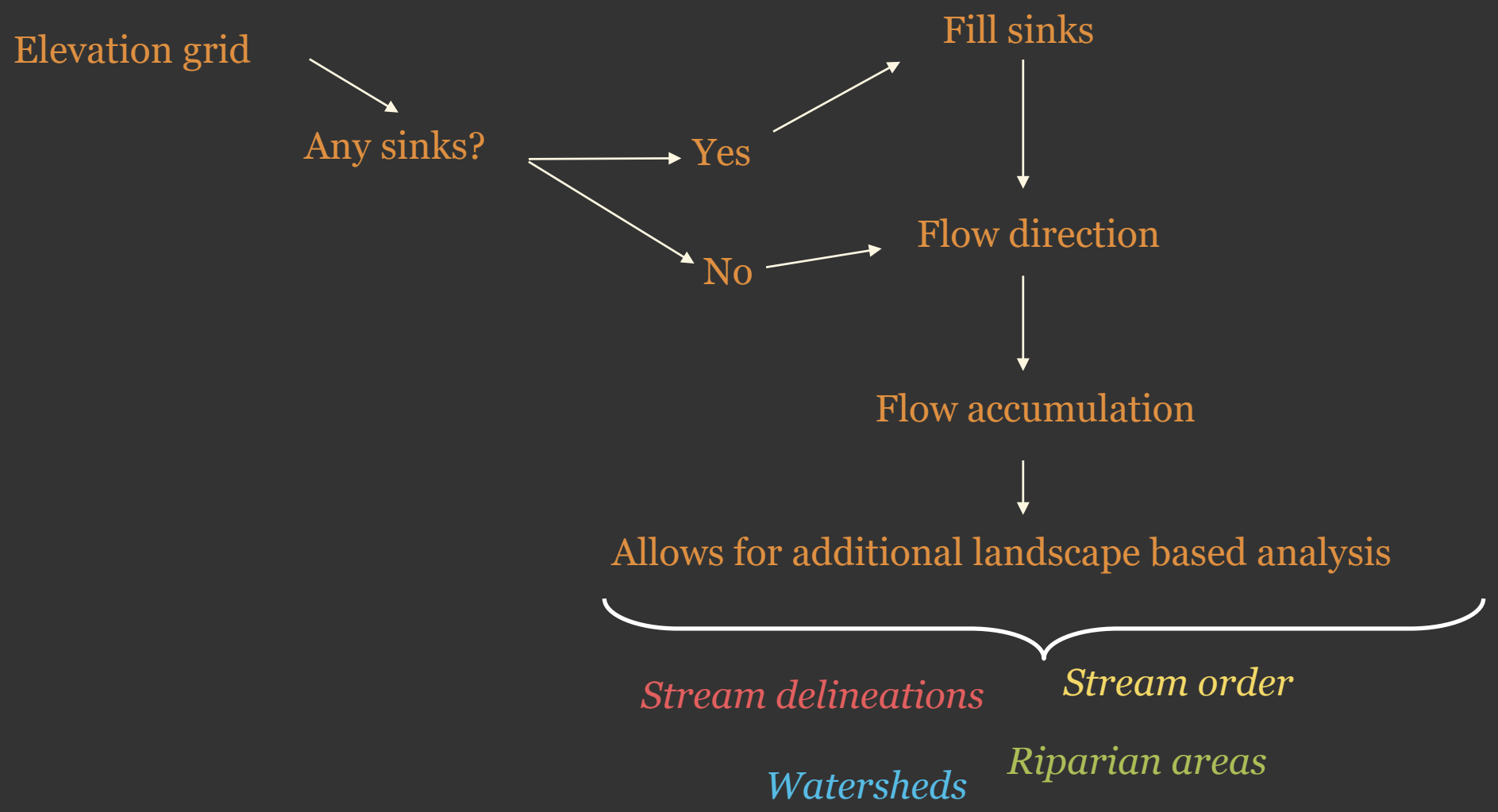
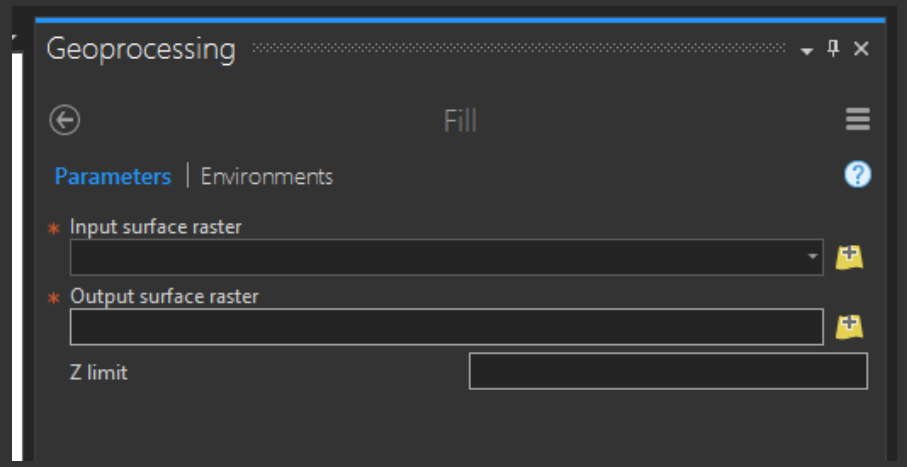


Diagram by Mike Strager

Fill Sinks

- Depressions in the DEM where water gets trapped
- A sink prohibits calculating future flow direction grid values.
- A sink occurs when all neighboring cells are higher than the processing cell.
- Sometimes they are natural features!
- Input= DEM

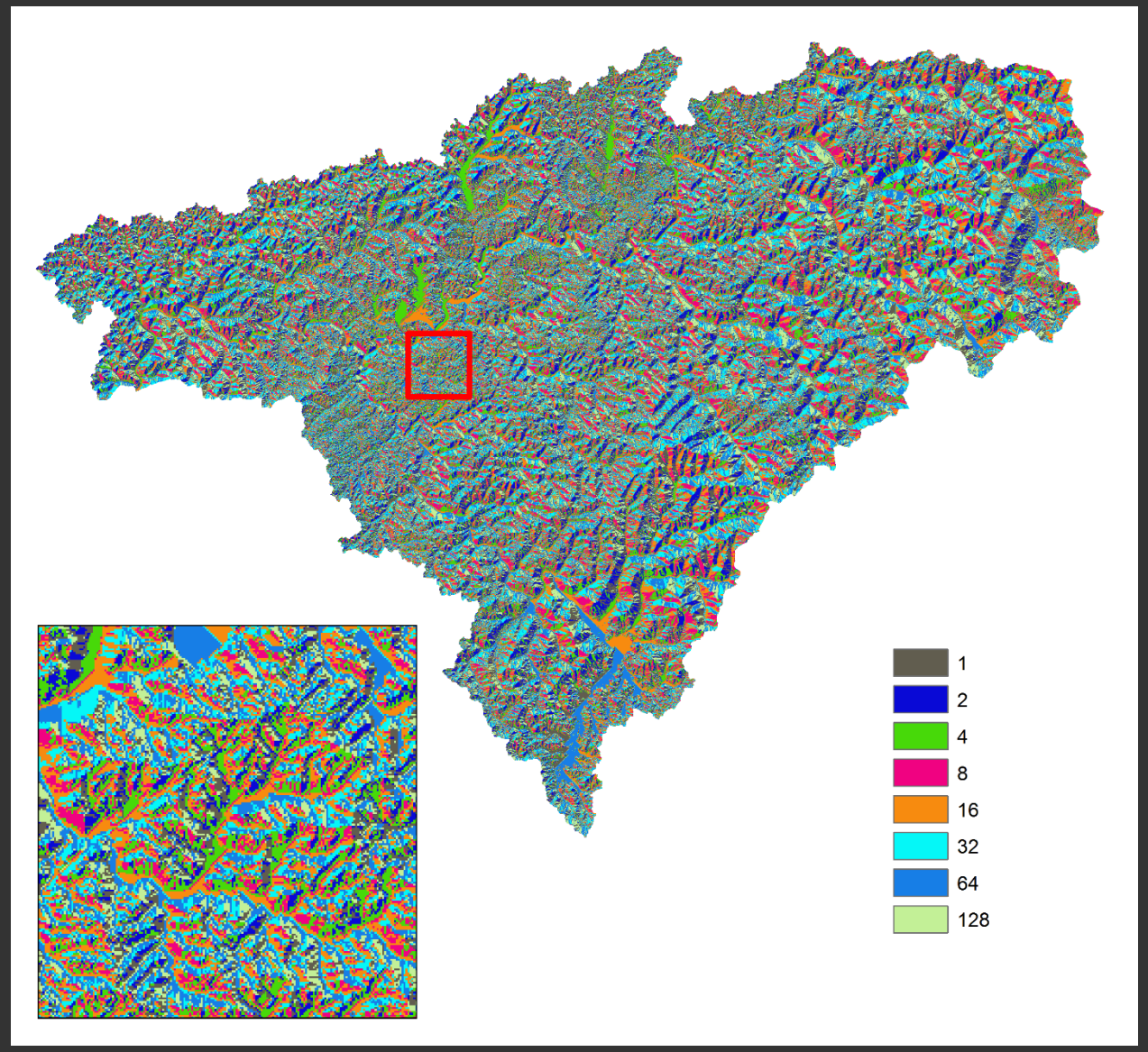
112	111	110
113	108	110
112	112	112



Flow Direction

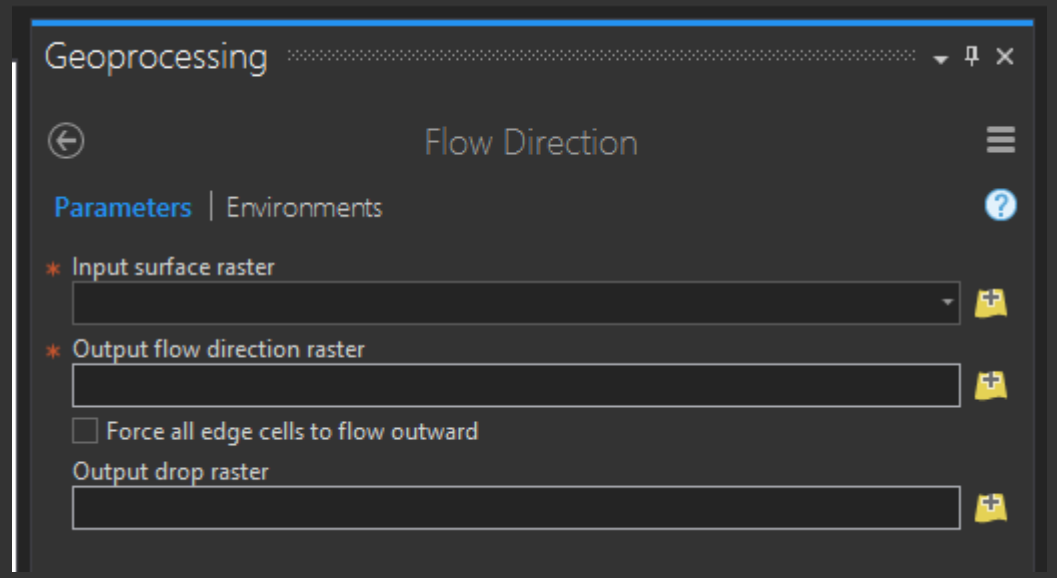
- Created from an elevation surface
- Direction values are assigned
- Flow direction grids are used in many hydro GIS functions
- Input = Filled DEM

32	64	128
16		1
8	4	2



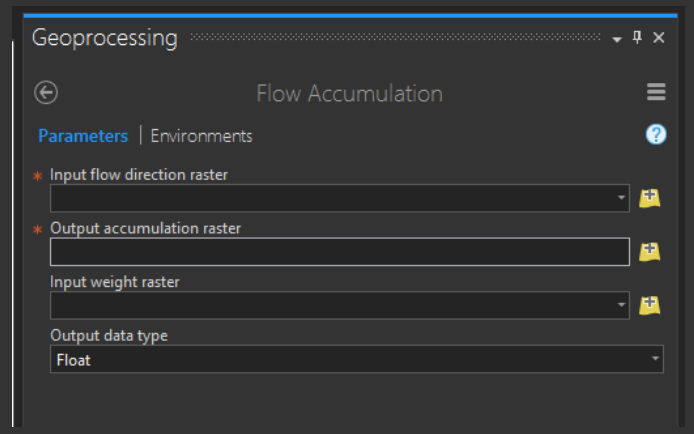
Flow Direction

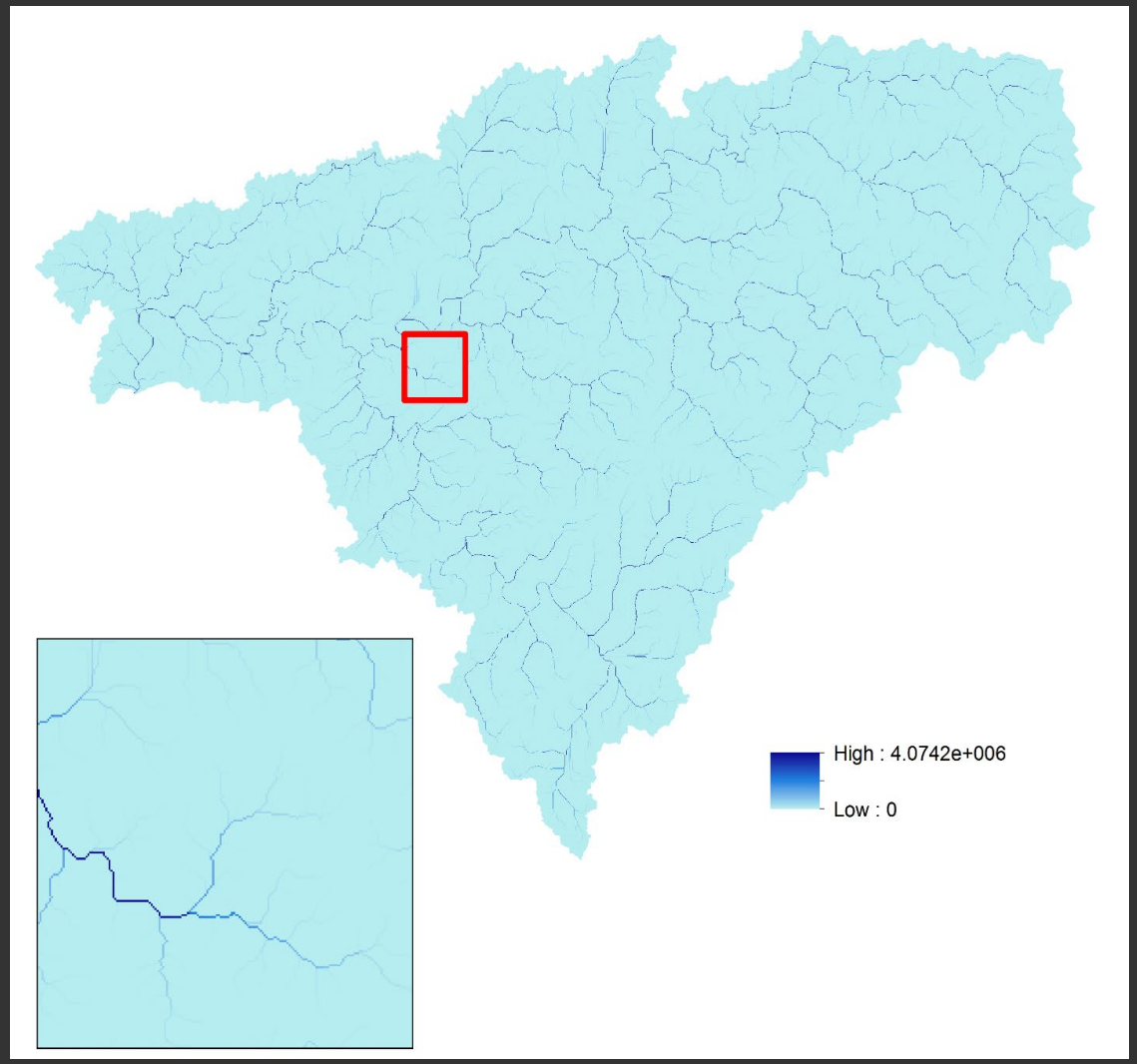
- Created from an elevation surface
- Direction values are assigned
- Flow direction grids are used in many hydro GIS functions
- Input = Filled DEM
- Can force edge cells to flow outward



Flow Accumulation

- Accumulated flow = number of cells flowing into each cell in the output grid. Current processing cell is not considered in this accumulation.
- Output cells with a high flow accumulation are areas of concentrated flow and may be used to identify stream channels.
- Output cells with a flow accumulation of zero are local topographic highs and may be used to identify ridges
- Input = Flow direction grid





Calculations from a flow accumulation grid

Estimating Drainage Area

Flow Accumulation Value X Cell Area X Required Conversion Factors

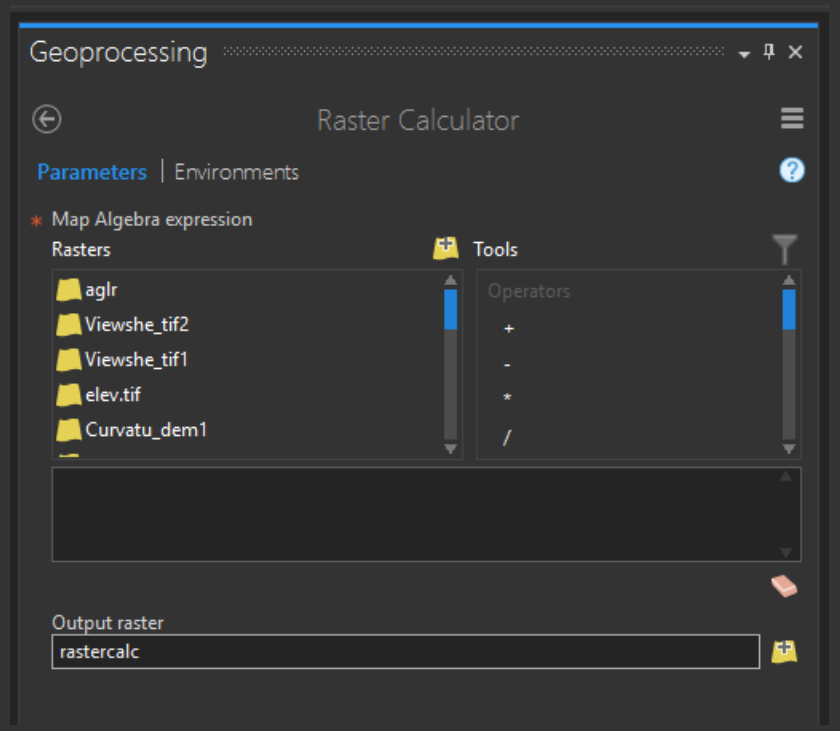
Estimating Discharge

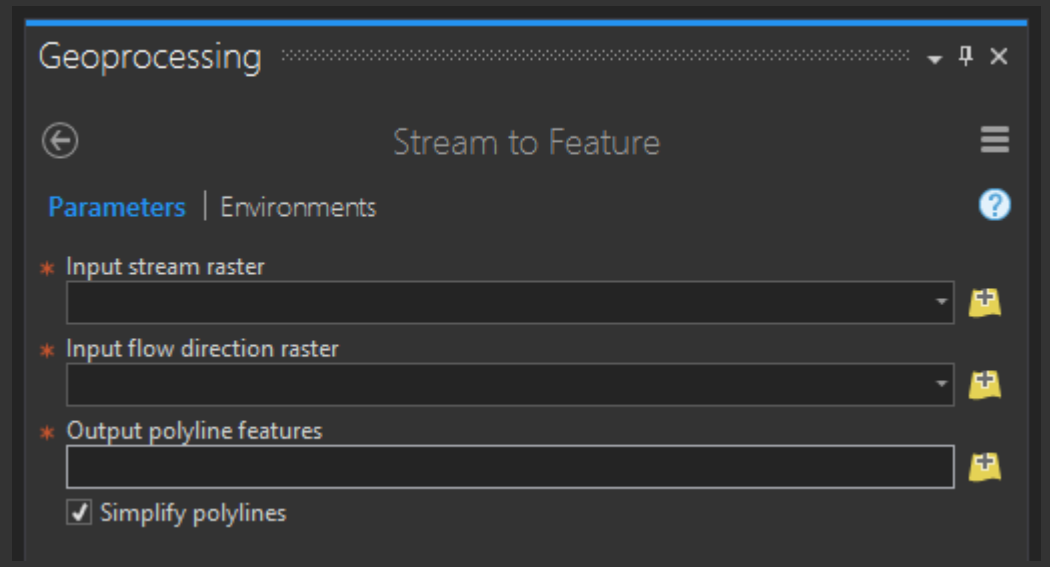
Discharge = Volume of Water / Unit Time (ft^3/s, cm^3/s, etc.)

$$\frac{Flow\ Accumulation\ 1}{Discharge\ 1} = \frac{Flow\ Accumulation\ 2}{Discharge\ 2}$$

Defining Streams

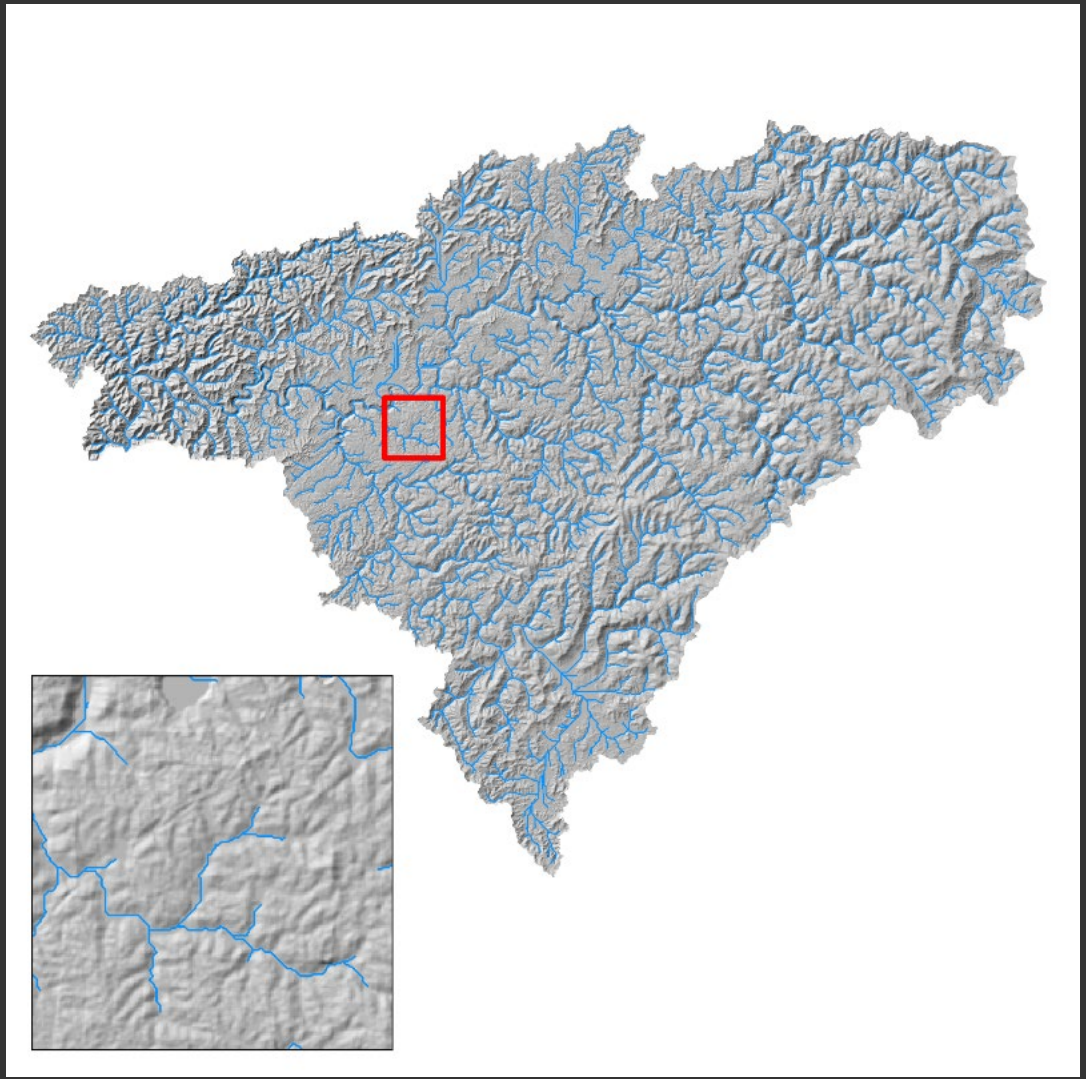
- How much flow accumulation is required to create a stream?





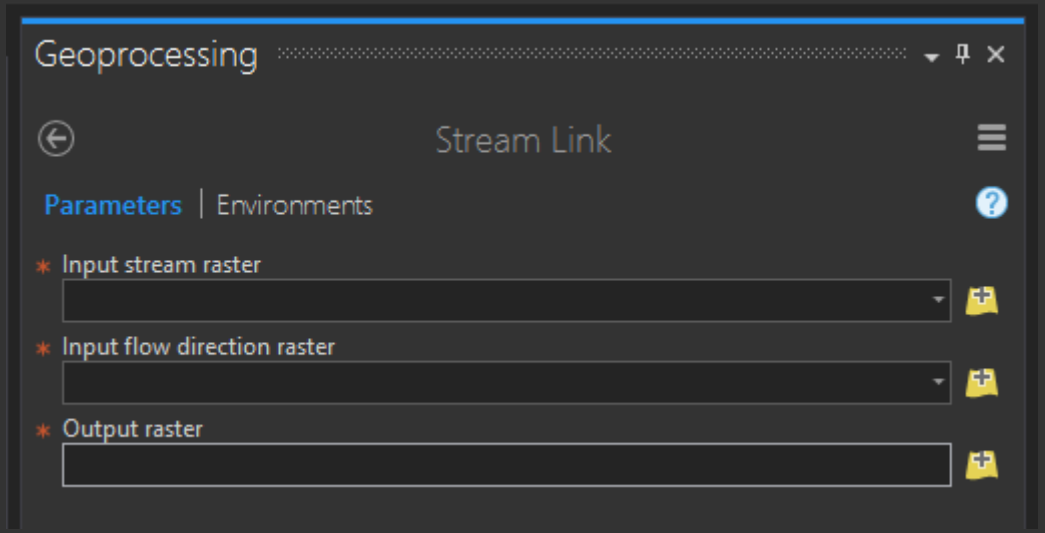
Input = Flow accumulation grid

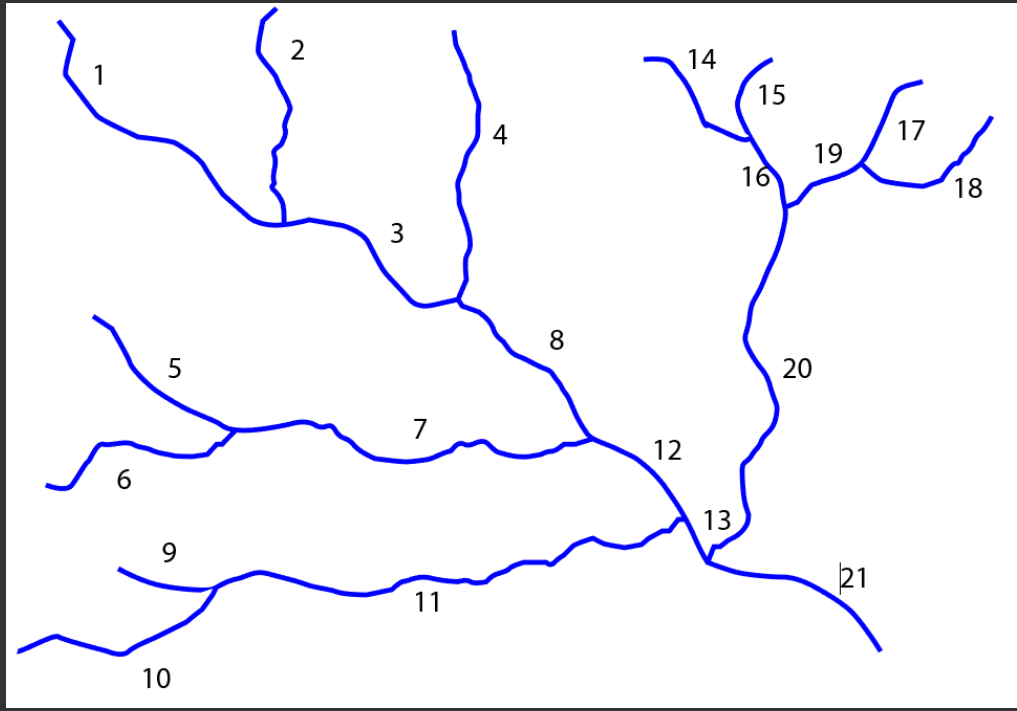
Synthetic Stream Network



Stream Link

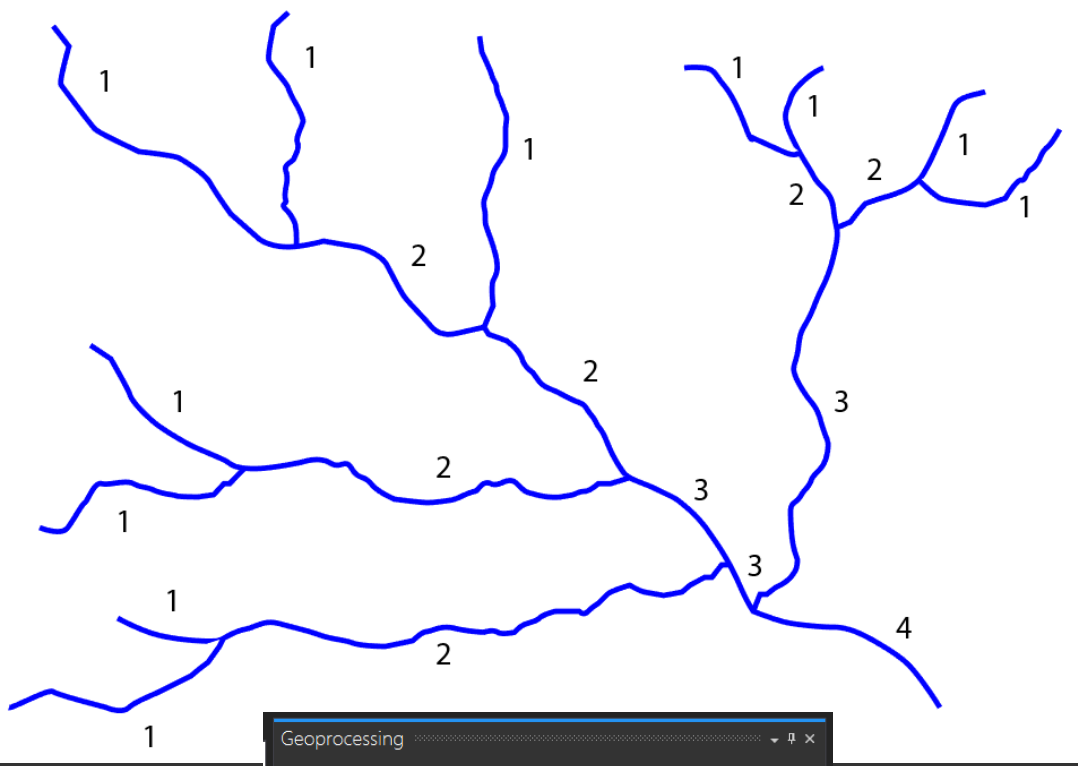
- Assigns unique values to sections of a raster linear network between intersections

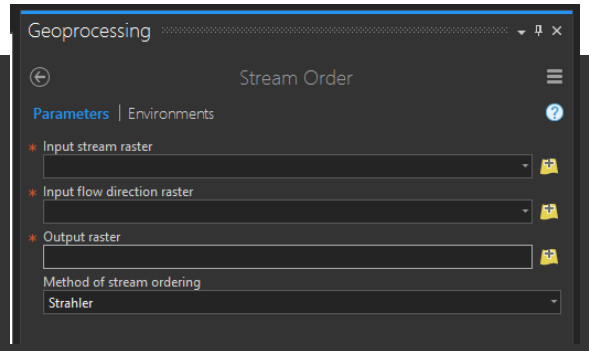


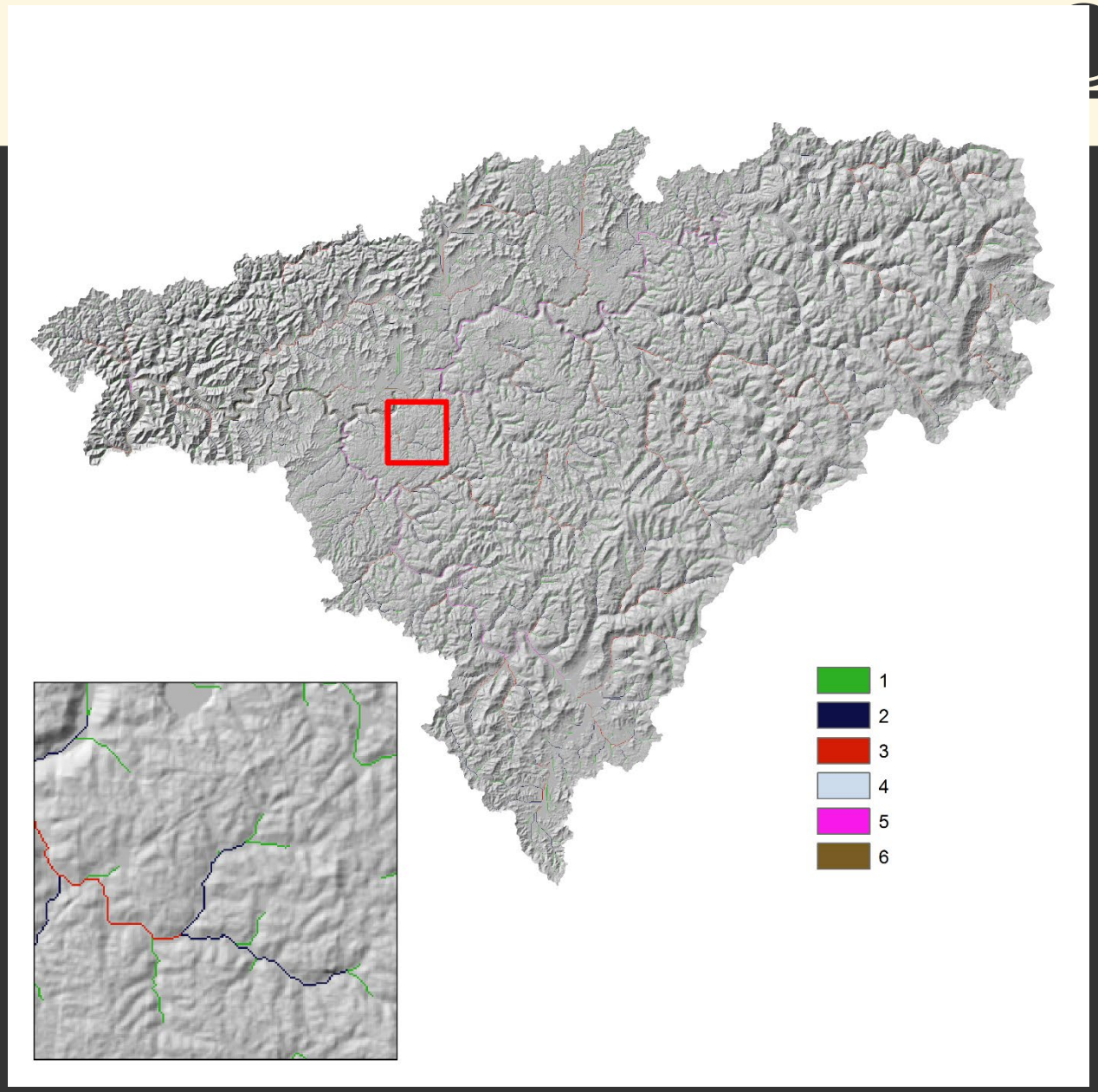


Input = Stream raster and flow direction grid

Stream Order

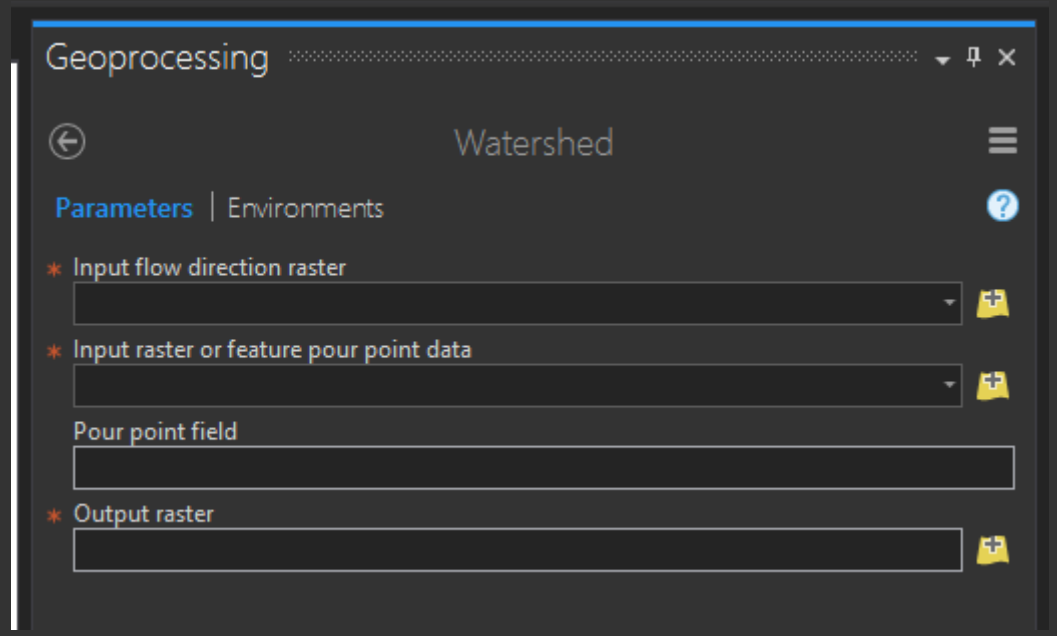


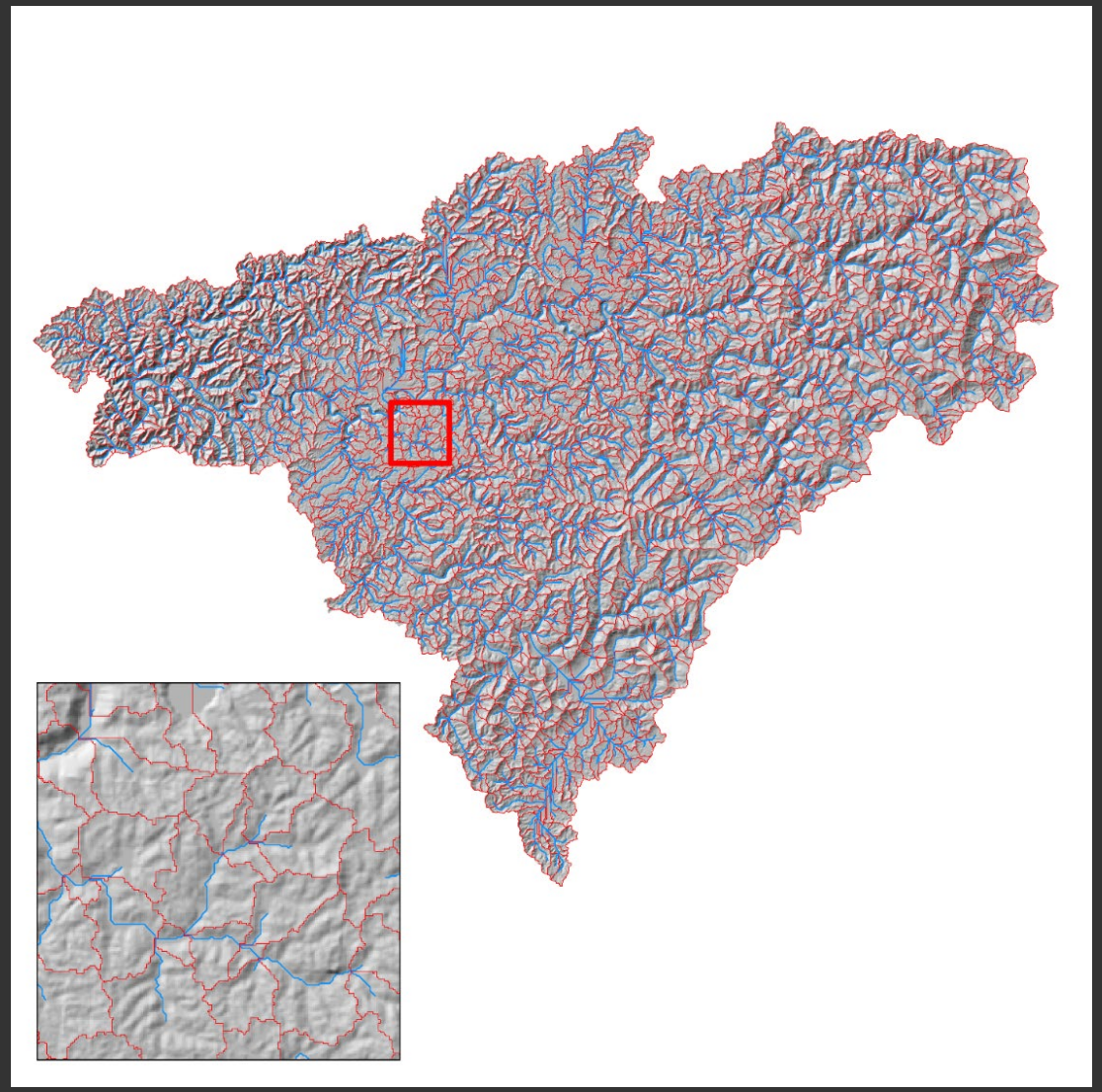




Input: Stream raster and flow direction grid

Create your own Watersheds

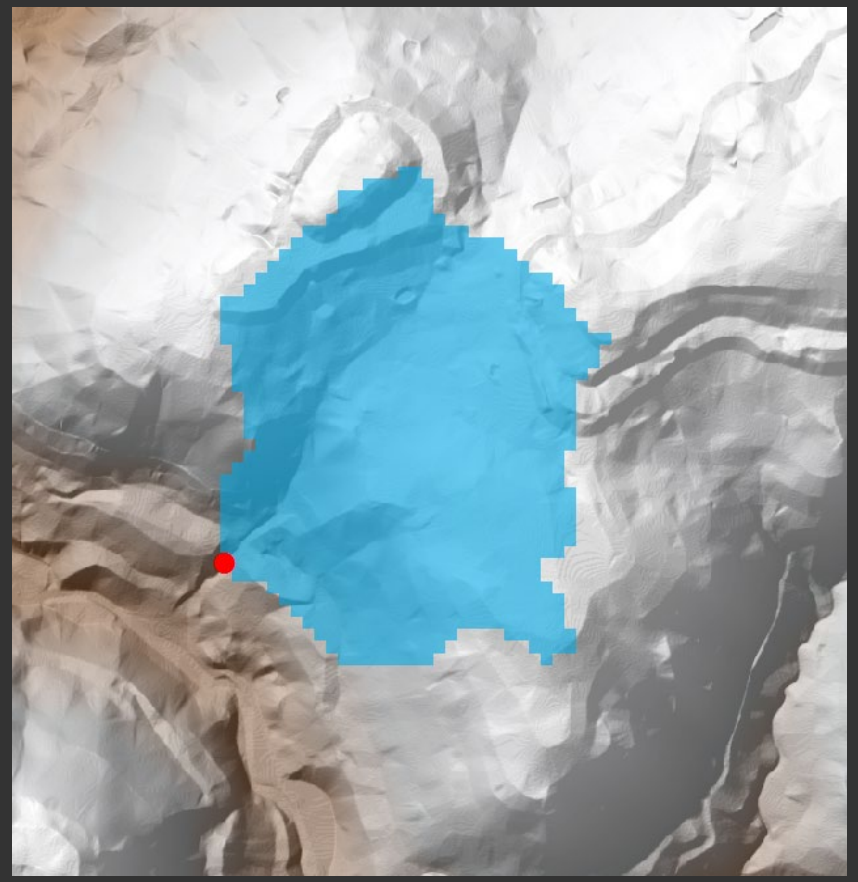




Input = Flow direction raster and pour points (can use stream link grid)

Catchment Areas for Pour Points

- Can define catchment areas for point locations
- Often you will need to snap the point to the largest flow accumulation cell within a search radius



Input = Flow direction raster and pour points (can use stream link grid)

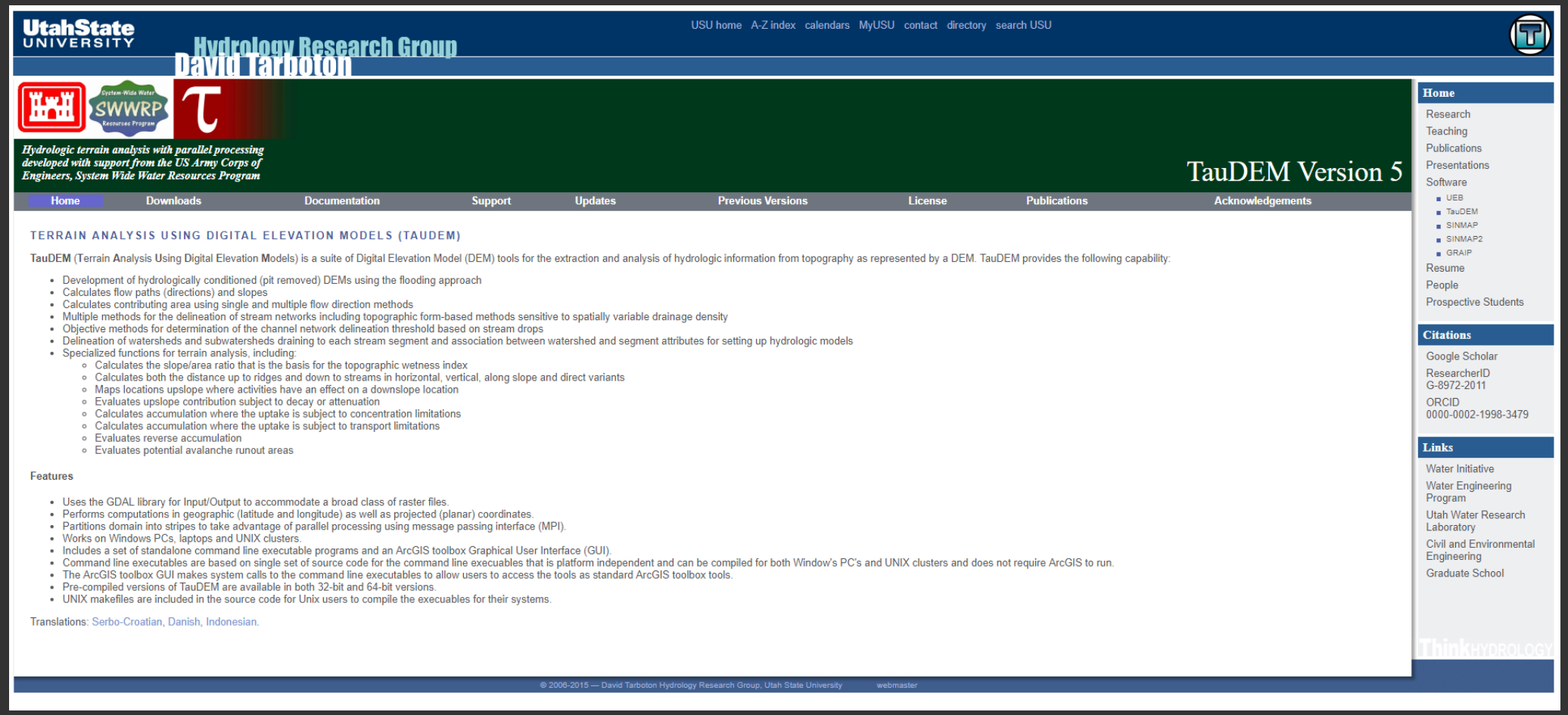
D8 vs. D-Infinity

Issues with D8 Method

1. Produce flow in parallel lines along principal directions (Moore, 1996)
2. Cannot represent adequate divergent flow over convex slopes and ridges (Freeman 1991)
3. Does not do well in highly variable topography with floodplains and wetlands (Liang and Mackay 2000)

- More robust methods, such as D-Infinity, are available

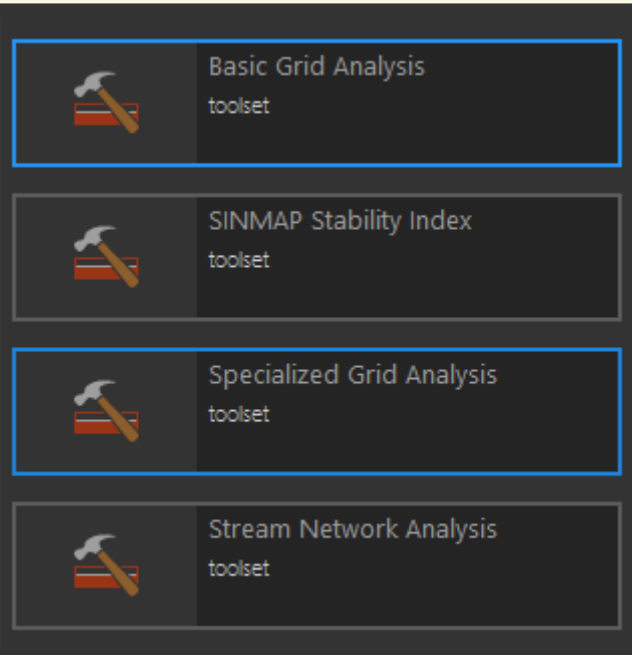
Another Option: TauDEM



http://hydrology.usu.edu/taudem/taudem5/index.html

Another Option: TauDEM

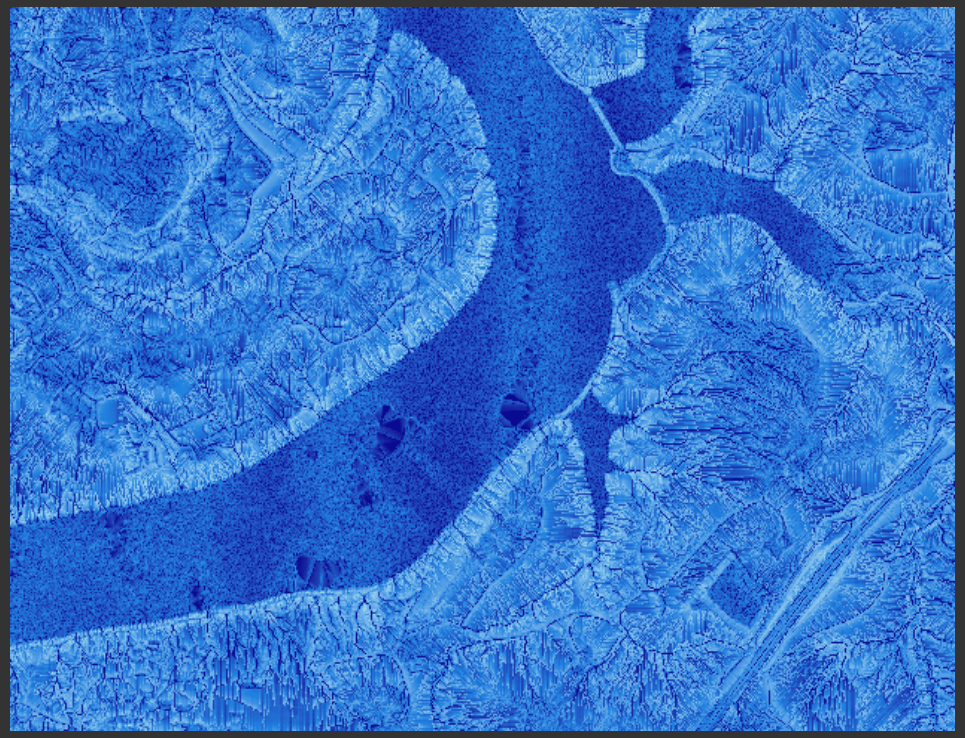
- TauDEM Tools 10 2
  - Basic Grid Analysis
    - D-Infinity Contributing Area
    - D-Infinity Flow Directions
    - D8 Contributing Area
    - D8 Flow Directions
    - Grid Network
    - Pit Remove
  - SINMAP Stability Index
    - Create Parameter Region Grid
    - Stability Index
  - Specialized Grid Analysis
    - D-Infinity Avalanche Runout
    - D-Infinity Concentration Limited Acccumulation
    - D-Infinity Decaying Accumulation
    - D-Infinity Distance Down
    - D-Infinity Distance Up
    - D-Infinity Reverse Accumulation
    - D-Infinity Transport Limited Accumulation
    - D-Infinity Upslope Dependence
    - D8 Distance To Streams
    - Slope Average Down
    - Slope Over Area Ratio
    - Topographic Wetness Index
  - Stream Network Analysis
    - ConnectDown
    - D8 Extreme Upslope Value
    - GageWatershed
    - Length Area Stream Source
    - Move Outlets To Streams
    - Peuker Douglas
    - Peuker Douglas Stream Definition
    - Slope Area Combination
    - Slope Area Stream Definition
    - Stream Definition By Threshold
    - Stream Definition With Drop Analysis
    - Stream Drop Analysis
    - Stream Reach And Watershed
    - Watershed Grid To Shapefile



Compound Topographic Moisture Index (CTMI)

- Measure of steady state wetness as estimated from terrain characteristics

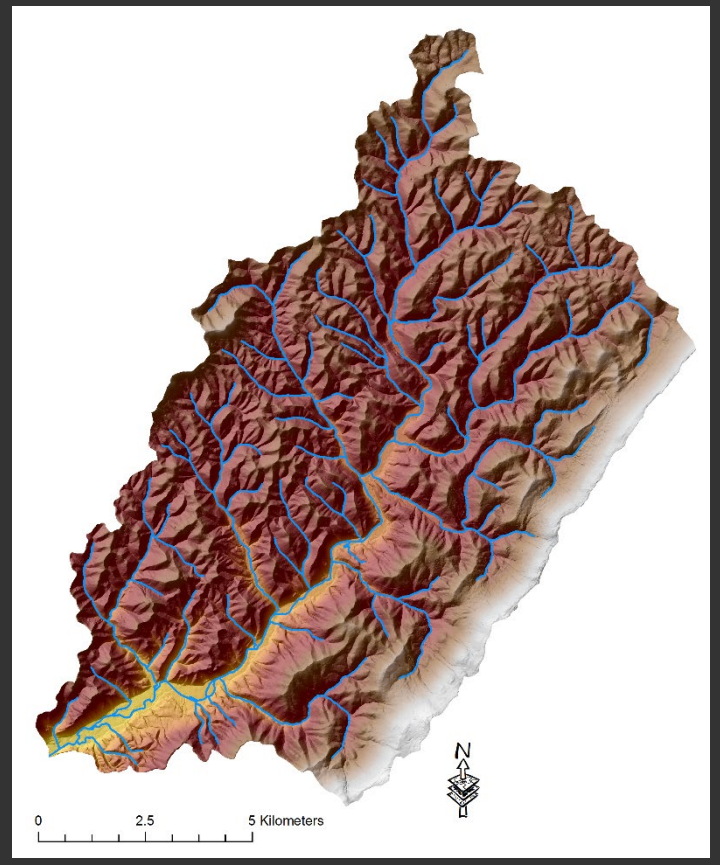
$$\ln\left(\frac{\text{(Upstream contibuting area)}}{\tan(\text{Slope})}\right)$$



Moore, I.D., P.E. Gessler, G.Z. Nielsen, and G.A. Petersen, 1993. *Terrain attributes: estimation methods and scale effects, Modeling Change in Environmental Systems* (A J. Jakeman, M.B. Beck, and M. McAleer, editors), Wiley, London, United Kingdom, pp. 189-214.

Gessler, P.E., I.D. Moore, N.J. McKenzie, and P.J. Ryan, 1995. Soil-landscape modelling and spatial prediction of soil attributes, *International Journal of Geographic Information Systems*, 9(4): 421-432.

Some Issues with Modeling Surface Water Flow



A watershed is complicated

Lots of things impact surface runoff:

- Topography
- Geology
- Soils
- Antecedent soil moisture conditions
- Characteristics of the watershed
- Hydrologic modifications
- Watershed size, shape, orientation, etc.

This is the end of this lecture module.

Please return to the West Virginia View Webpage for additional content.