Hyper-Resolution Hydrography for the CBW: More than just A LOT more blue lines

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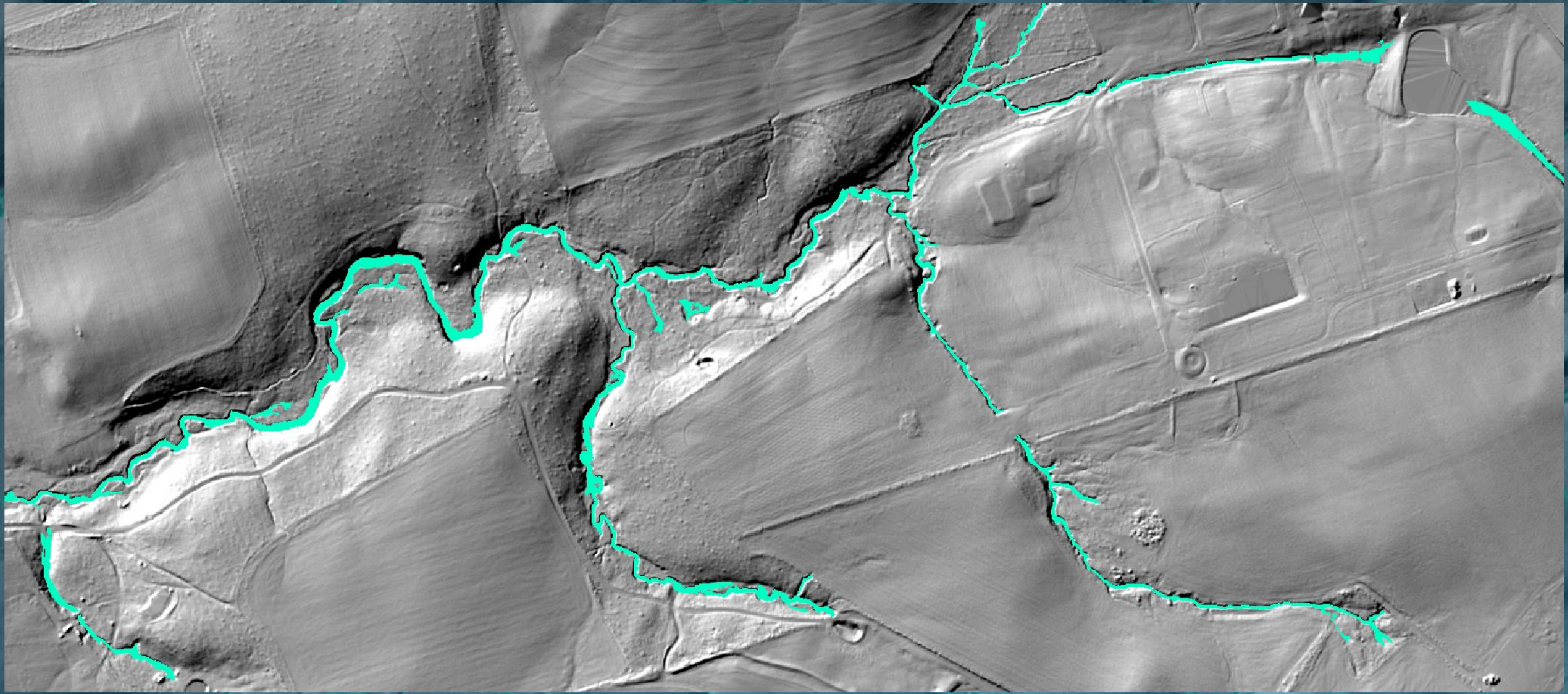
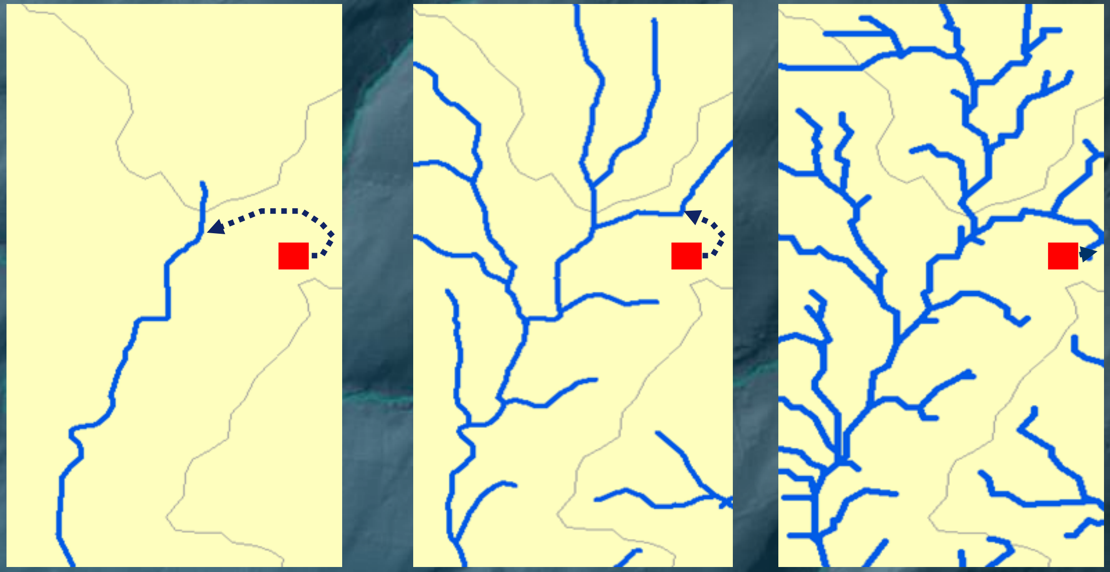


Need for Detailed Stream Maps

- Maps record *current status* and *future change*

- Quantify stream miles, hydraulic geometry
  - Discharge accrual
  - Modeling water, pollutant transport
  - Characterizing aquatic habitat

- Channel-Hillslope Processes
  - Hydrology, Water Quality, Buffers



1 National Hydrography Dataset (CRSE)1:100,000 2 Digital Line Graph (MED)1:24,000 3 High-resolution derived streams (FINE) >1:24,000

- Locating and Identifying Restoration Opportunities

Important to have *objective*, *uniform* product over broad landscapes and administrative units

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Need for new mapping approaches

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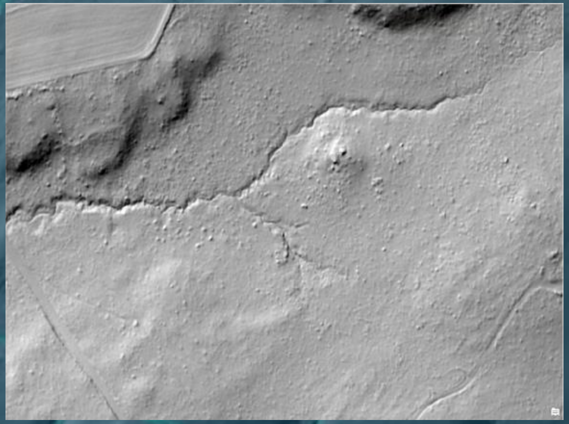
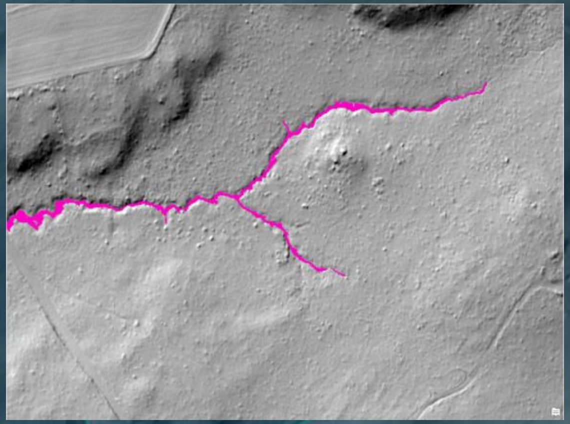
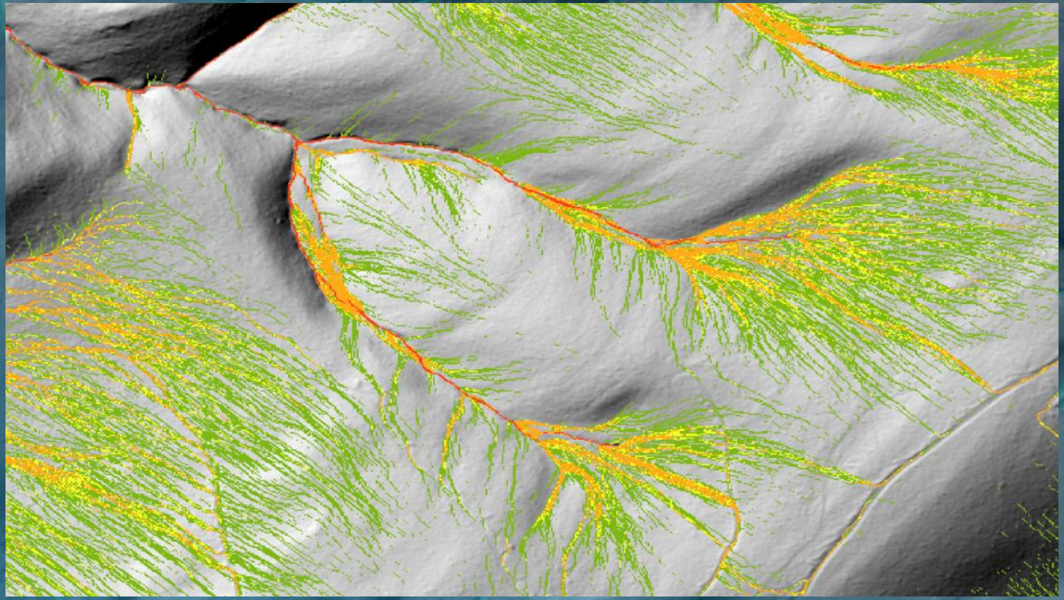
- High-Res Digital Elevation Data
  - Unprecedented detail, temporal frequency
  - Unmapped channels visible
  - Discontinuities, artifacts, infrastructure





- Existing tools rely on old technology
  - Developed for low resolution terrain models
  - Do not integrate available information
  - No methods move beyond 1D mapping



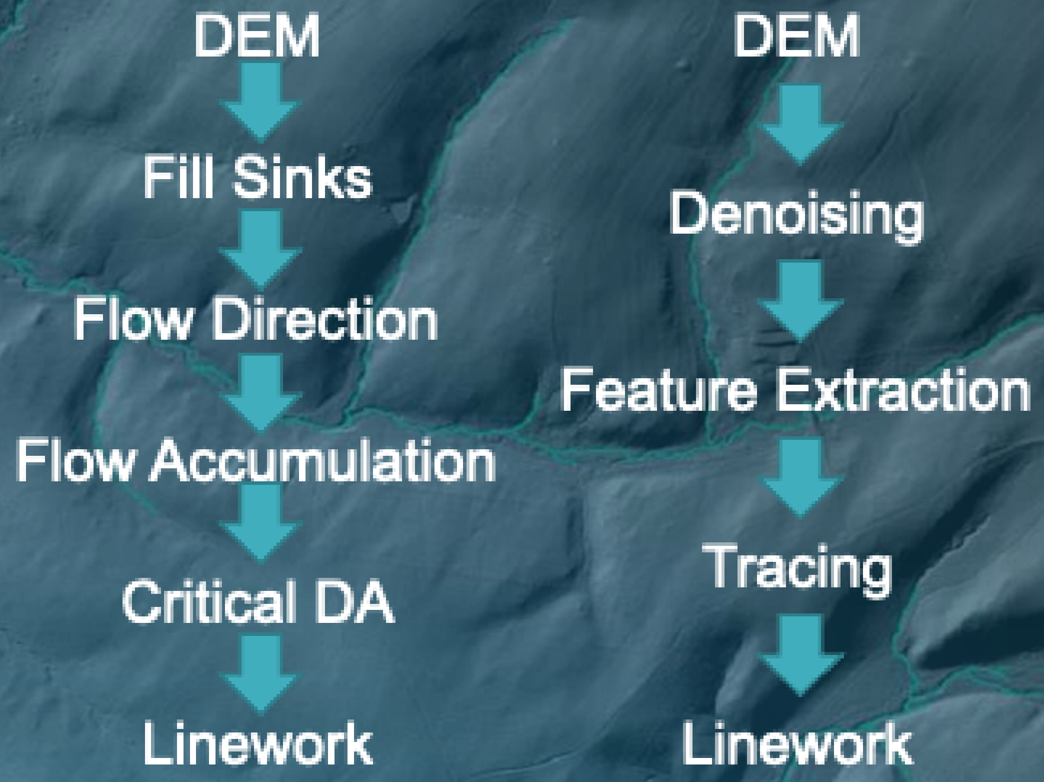
- Difficult to Automate
  - Regional thresholds often necessary
  - Manual corrections a challenge
  - Costs balloon over broad extents
  - Limited utility over time


HOG ROCK NATURE TRAIL



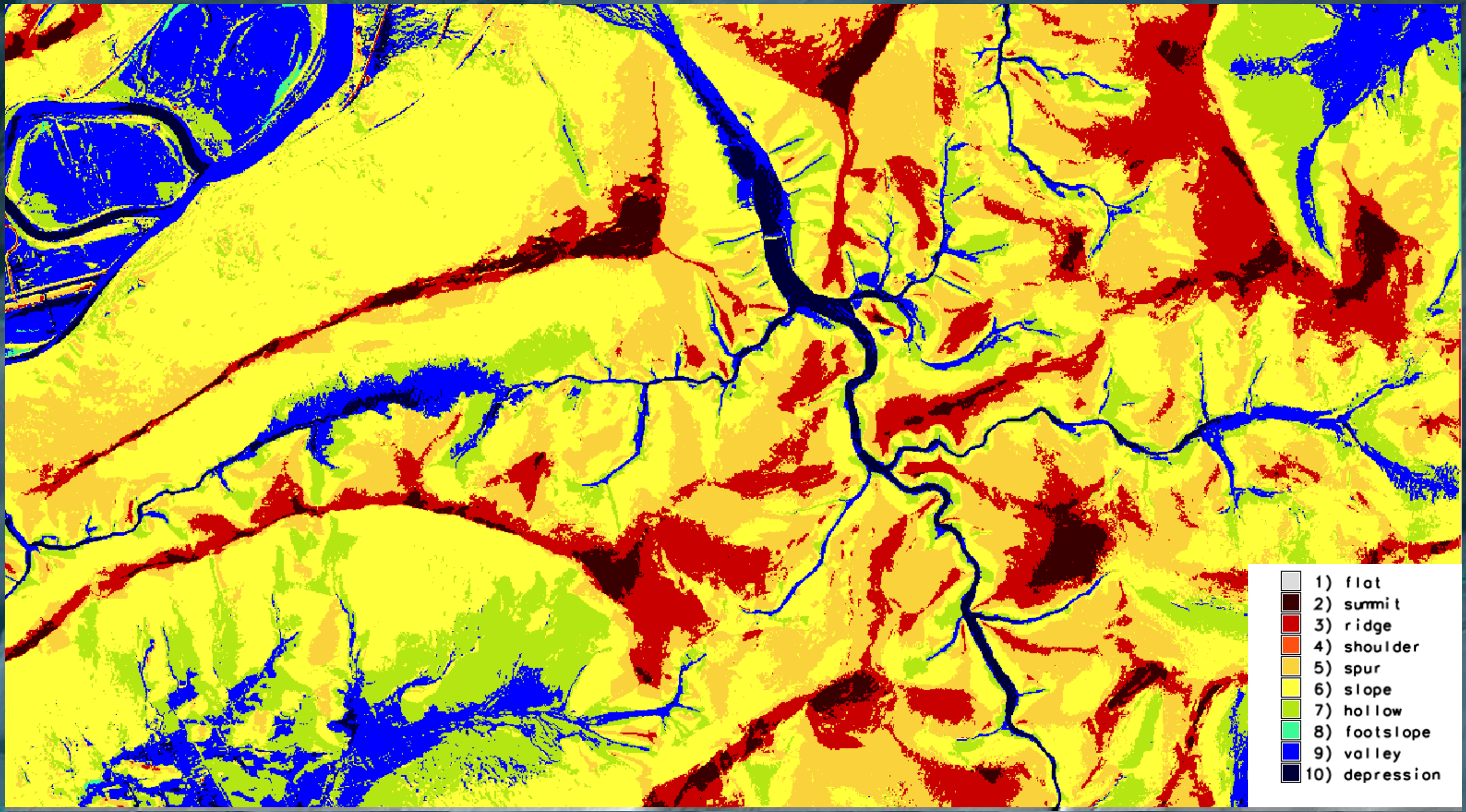
Evolution of Delineation Approaches

- Conventional Approaches: Band (1986), Tarboton & Baker (2008):
  - Developed for coarse DEMs
  - Canned functions
  - Anomalies: pits, infrastructure
  - Absence of fluvial features
  - Commission/Omission
- Novel Approaches for LiDAR: Passalacqua et al. (2010)
  - Denoising recognizes nature of data
  - Feature extraction seeks channel-like phenomena
  - Alternatives to steepest descent
  - Best suited for natural terrain



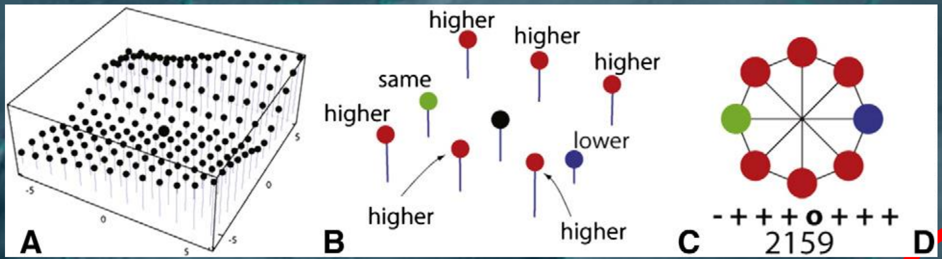
Feature Extraction: Geomorphons

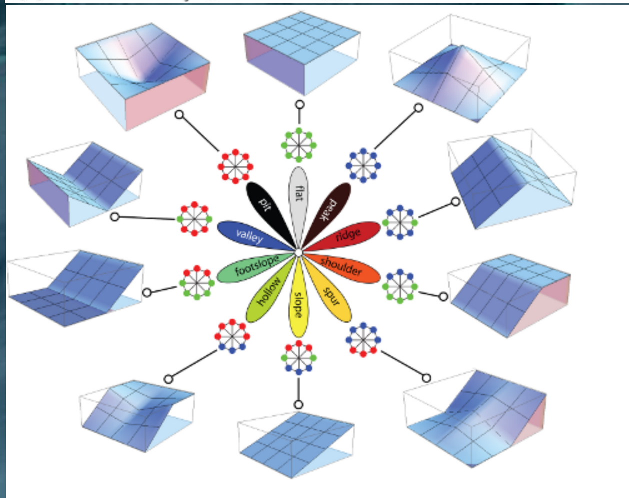
- Note broad floodplain (1)
- Tributary valleys and channels (2)
- Associated ridges and slopes (3)
- Headwaters (4)



Computer Vision: Geomorphons

- Landform classification algorithm by Jasiewicz & Stepinski (2013)
- Evaluates 8 directional position and relative elevation bounding line-of-sight to determine landform
- **Classifies pattern rather than degree**
- Delineates contiguous *features* rather than pixels
- Adjustable parameters, host of encoded information





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1	FL	FL	FS	FS	FS	VL	VL	VL	_
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3	SH	SH	SL	SL	SL	HL	_	_	_
4	SH	SH	SP	SL	SL	_	_	_	_
5	RI	RI	SP	SP	_	_	_	_	_
6	RI	RI	RI	_	_	_	_	_	_
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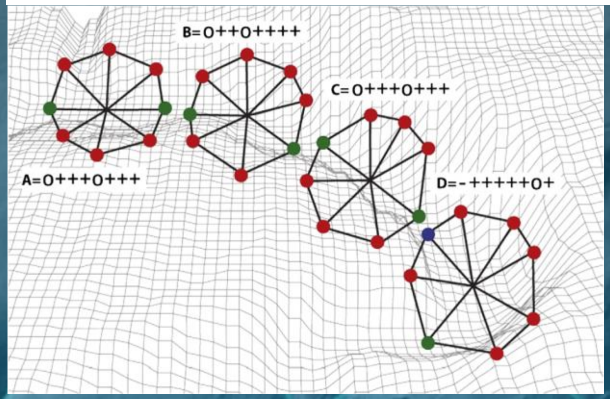
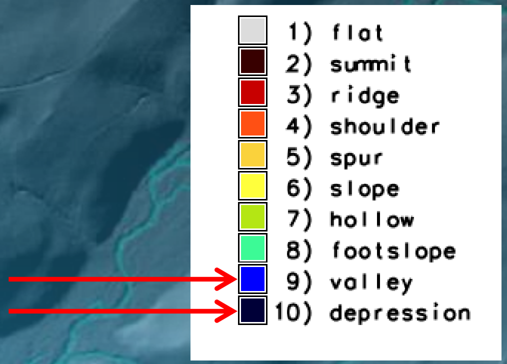
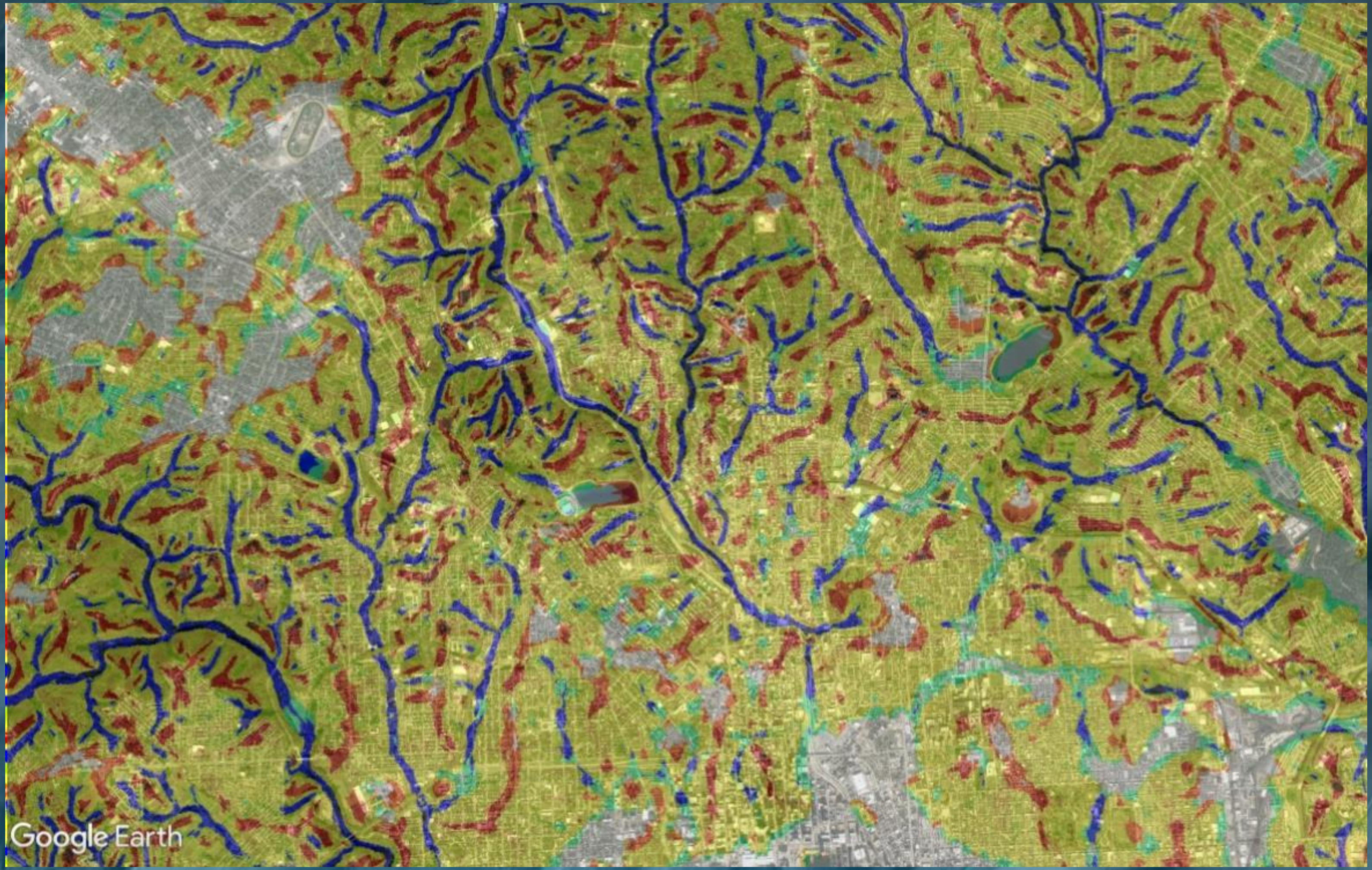




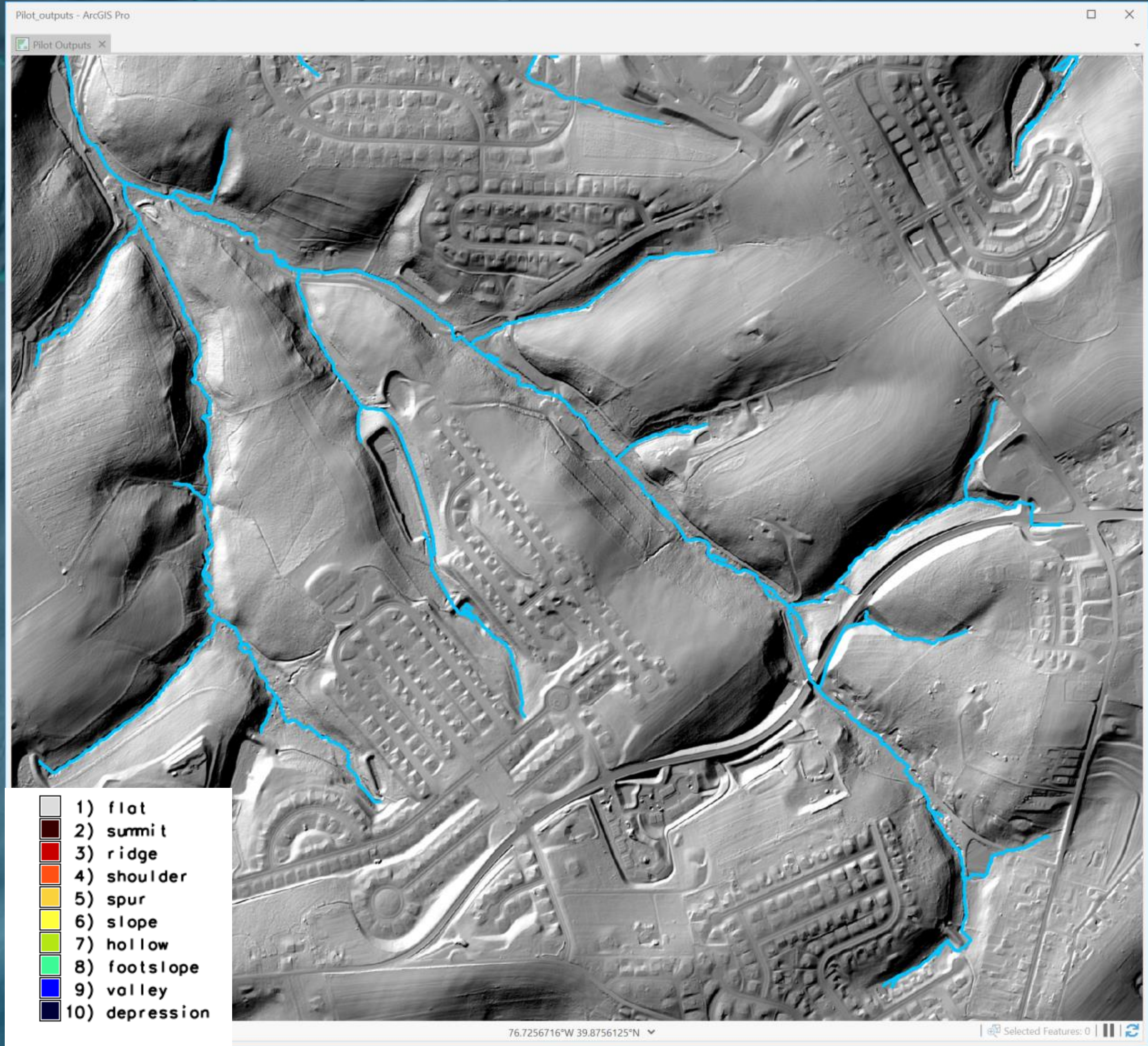
Example: Geomorphons

- Detection of forms can be constrained to focus on specific features (e.g., valleys)
- Note continuity of blue valley forms
- Helpful in narrowing the search for channel like features, even in their absence



Methodology: modular, parallelized

1. Lidar elevation
2. Valley-scale features
3. Channel-scale features
4. Identify valley network
5. Extract features using valley network
6. Classify channel skeleton
7. Develop attributes
8. Connect channel network



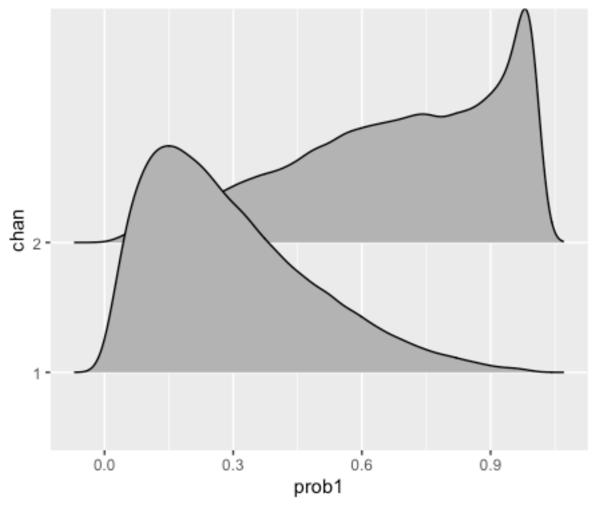
Channel classification

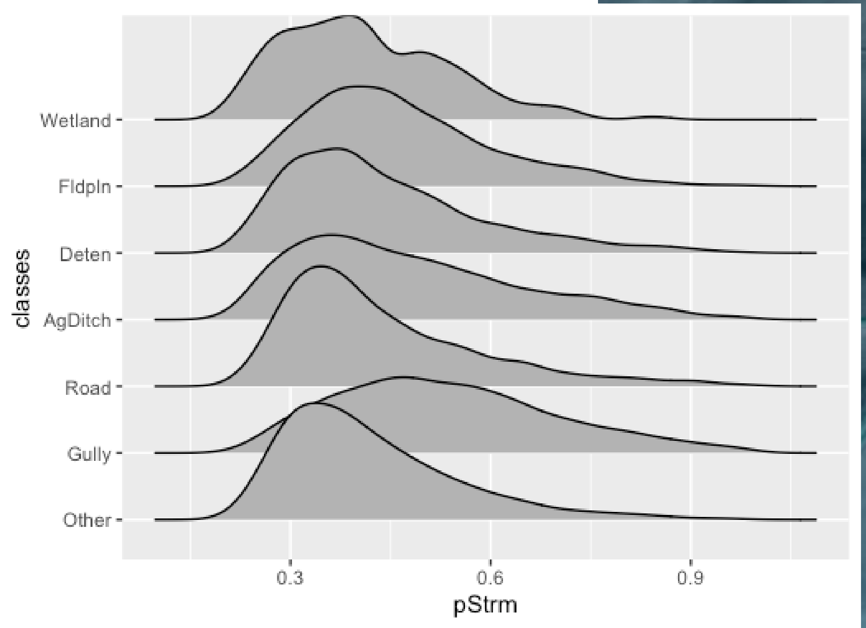
- Random forest model classifies channel-like features based on terrain characteristics, shape, land cover

- Outputs probability of feature being a stream vs something else

- Select features are used to produce “blue line” maps. Non-stream features are retained, can be used for other flow-related analyses

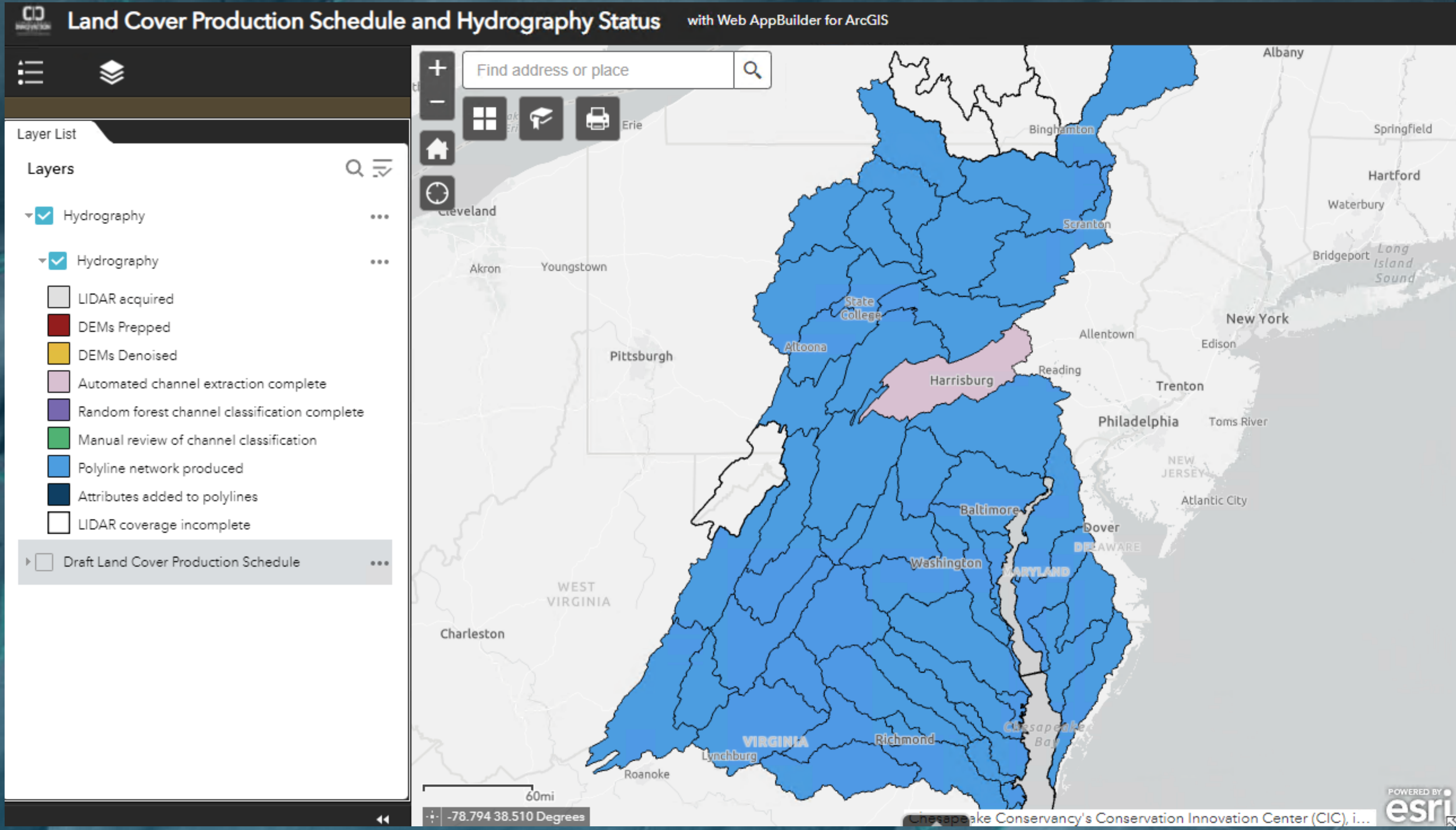
- Wetlands, Floodplain features, Detention feature, Ag ditch, Roadside ditch, Gully, Other (crevice, slide, anthropogenic feature)





Fully Automated Data products

- Scripts parallelized within each of 53 HUC8s
  - Processes all HUC10/12
- Inputs
  - Lidar DEM
  - High-resolution Land Cover
- Denoising
  - Usually takes 1-8 hours
  - Only needs to be done once
- Channel extraction
  - Usu. 2-6 hours per HUC8
  - Repeatable, updatable
  - ~20 d for CBW



Fully Automated Data products

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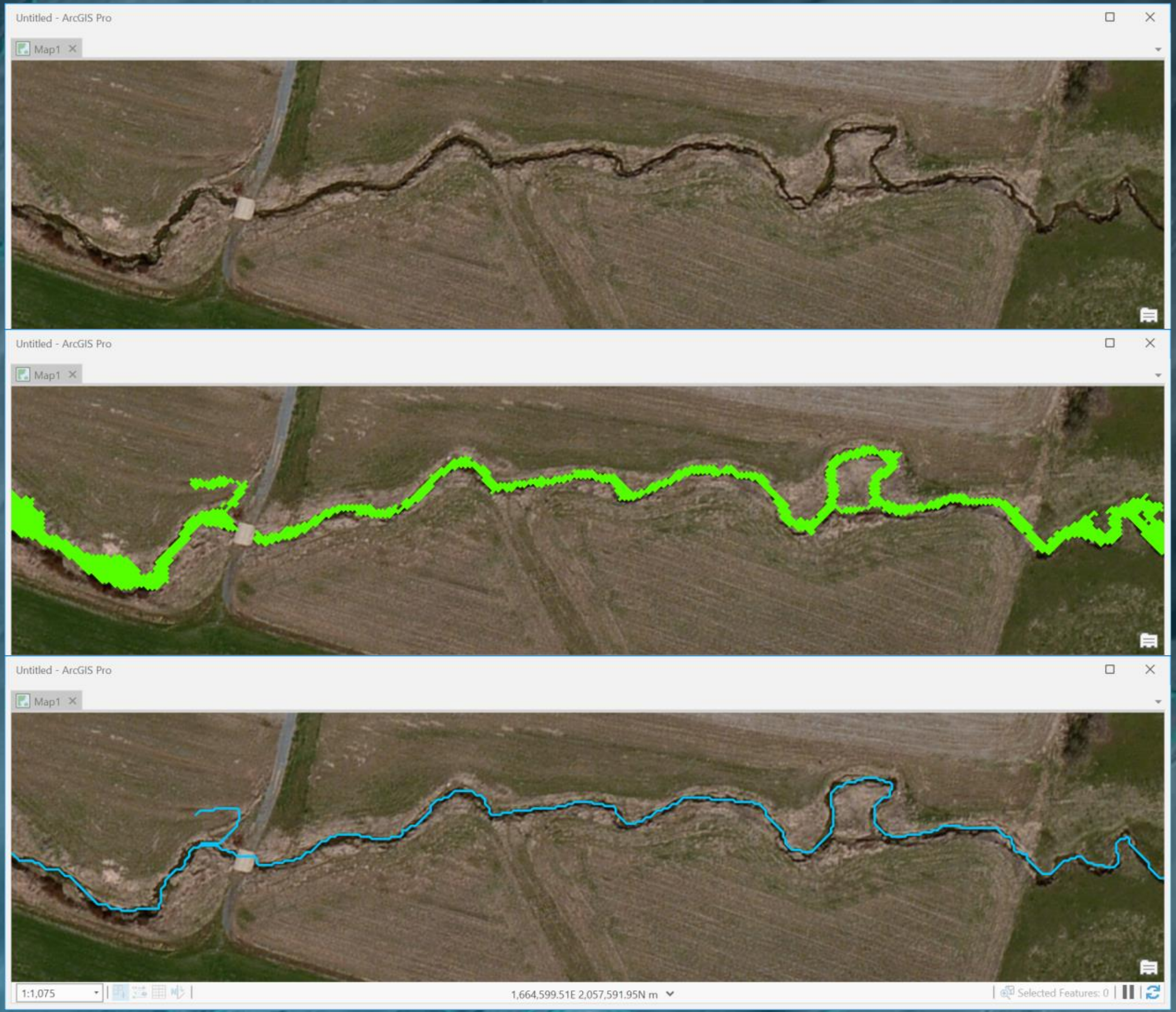
- Raster channel skeleton
  - 2-D representation of channels
  - Includes discontinuities (e.g. karst, road crossings)
  - Meshes well with high-res LU/LC
  - *Spatially-explicit* layers of channel width and bank height
- Polyline stream network
  - 1-D linear representation of channels
  - Connects the channel skeleton
  - Line segments associated with features, also **culverts, open water, connectors**
  - Reach-scale attributes



Drainage Density

- Three HUCs from App Mtn, Pied, and Outer CP
- Area km^2
- DD km / km^{-2}
- Hyper-resolution more than doubles the drainage density
- Rank order does not remain the same

HU 8	Area	NHD	HypRes	Ratio
Raystown	2492	1.46	3.29	2.25
Gunpowder/ Patapsco	3671	1.3	3.35	2.57
Choptank	2844	1.56	3.32	2.12

Advantages:

- Direct Detection:
  - initiation not based on thresholds
  - inherently flexible across different geographies
- Precise Alignment, Dimensions:
  - Location, width aligned with imagery/land cover
- Connecting Features not only Terrain:
  - no need for hydro-enforced drainage
  - Method expects discontinuities, connects using upstream-downstream position

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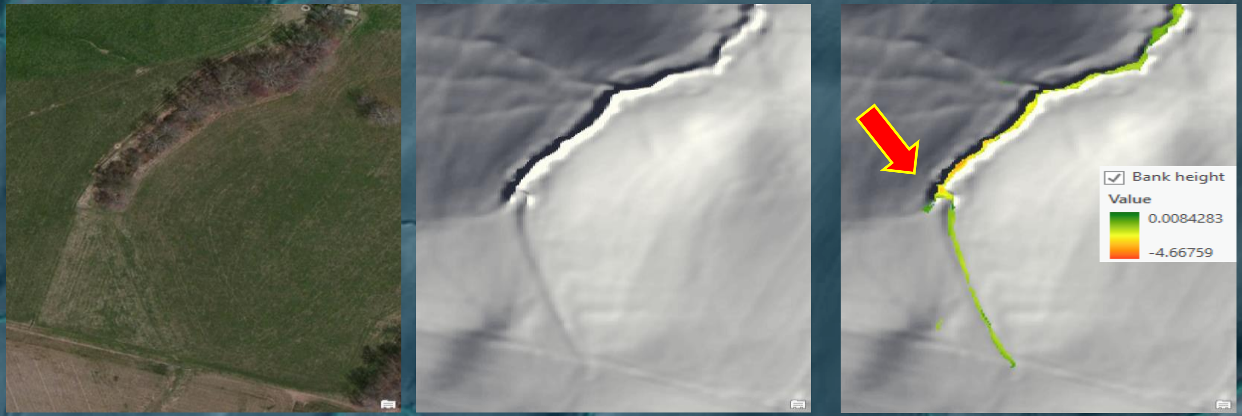
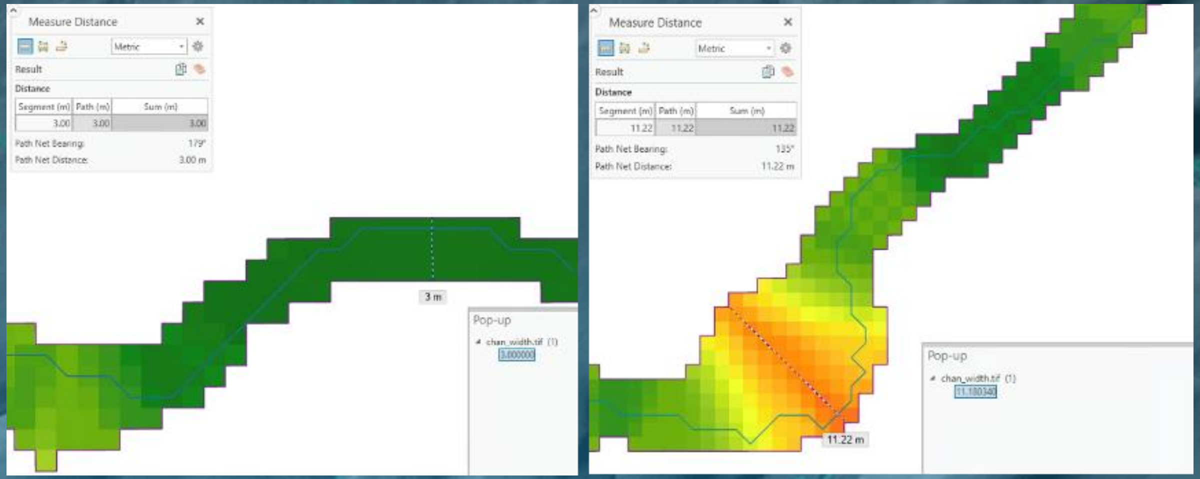
Feature Attribution

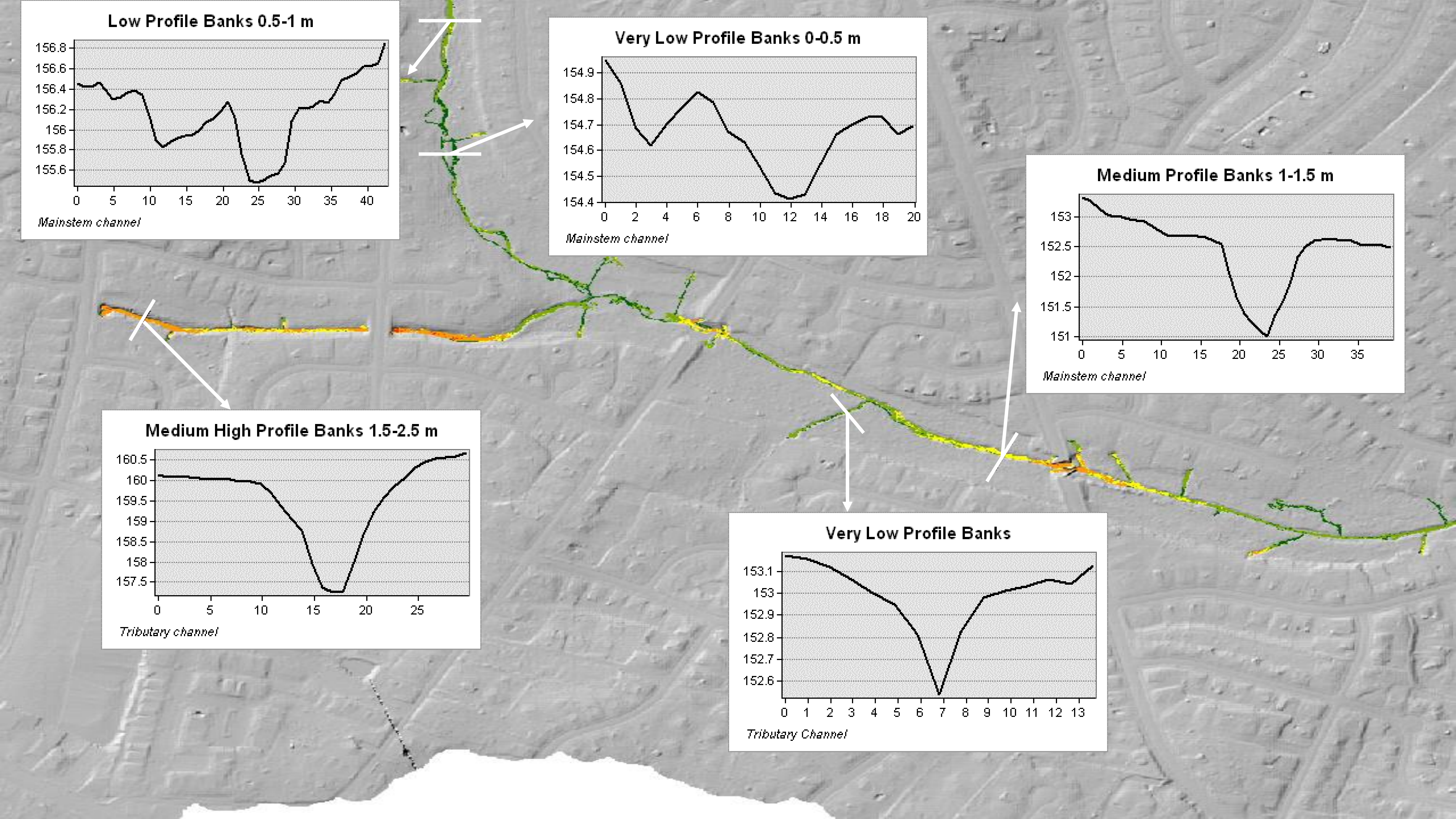
- Each pixel has its own Geomorphon attributes
  - Orientation, shape, extent
  - Can be used to assess consistency in terrain signal
- *Spatially-explicit* layers of channel width and bank height are produced automatically
- Each feature (group of contiguous pixels) can be analyzed independently
- Such information would be lost in reach-scale summary

Example #1: Bankheight identifies headcuts



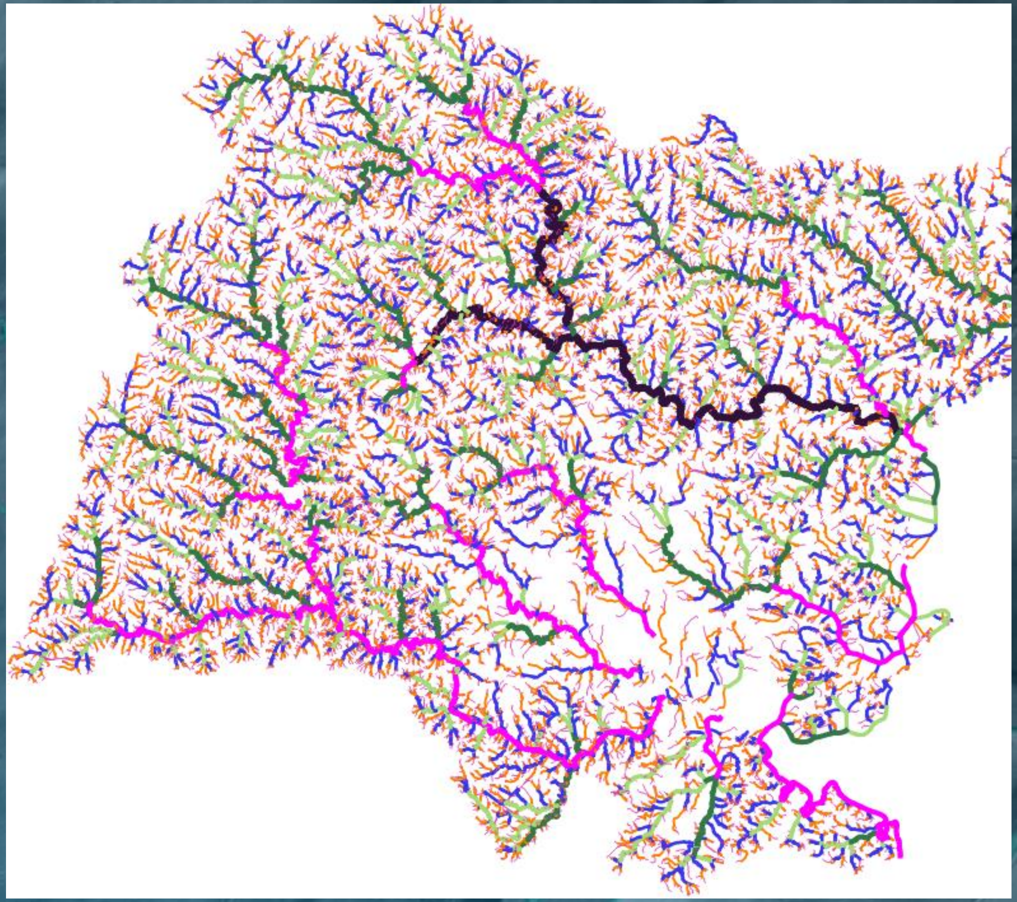
Example #2: Channel width track hydraulic shifts




Low Profile Banks 0.5-1 m
Mainstem channel
Very Low Profile Banks 0-0.5 m
Mainstem channel
Medium Profile Banks 1-1.5 m
Mainstem channel
Medium High Profile Banks 1.5-2.5 m
Tributary channel
Very Low Profile Banks
Tributary Channel

Linked Networks with Attributes

- Strahler stream order developed from the linear network of lines
- Also Shreve magnitude, D-link
- Each reach tracks and links across HUC boundaries:
  - length
  - elevation drop
  - width distributions
  - bank height distributions
  - Upstream/downstream distances
  - proportion of connectors between features



Piedmont Terrain

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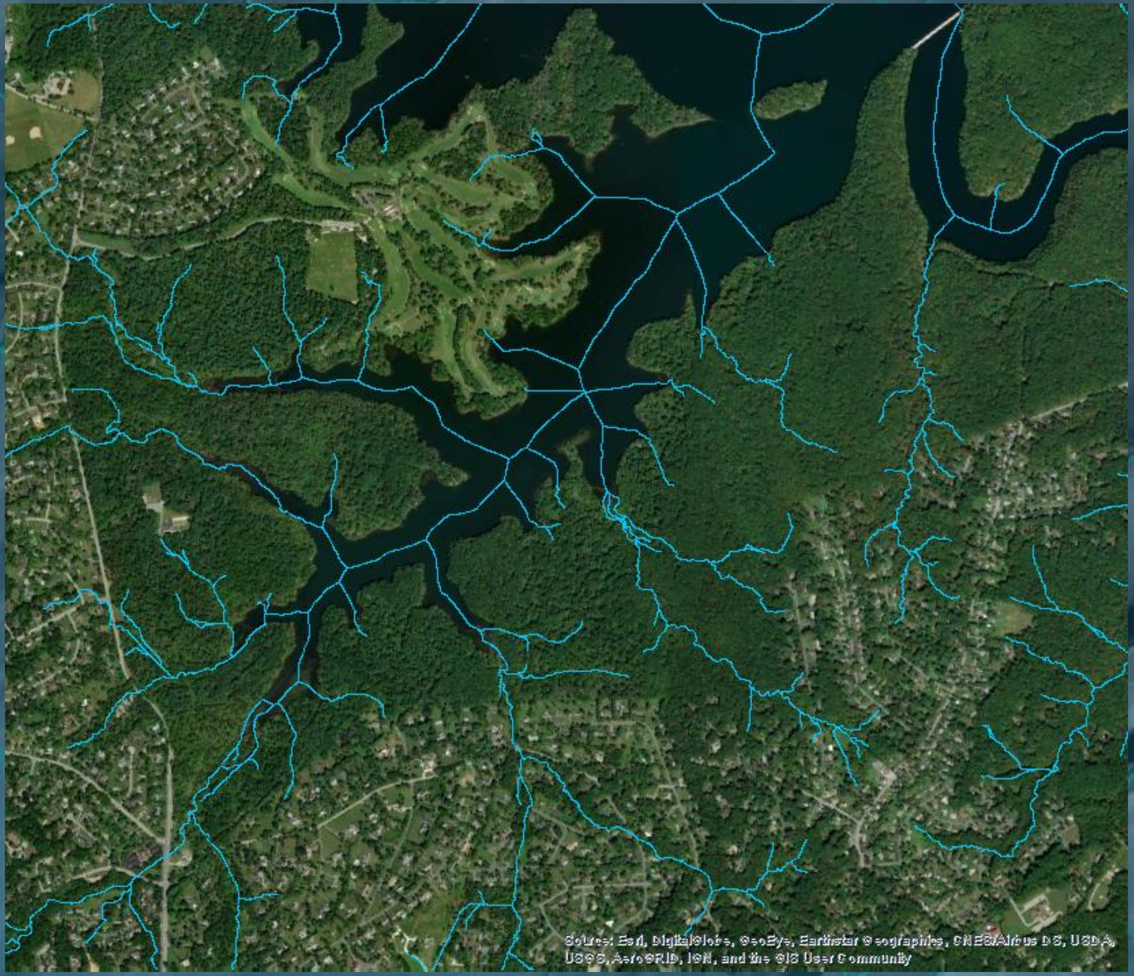
- High population density
- Highly modified landscape
- History of human manipulation of water
- Consider challenges of
  - Man made vs natural features
  - Road crossings/Dams
  - Open water
  - Whatever happens around major highways
- Channel skeleton and open water pixels provide breadcrumbs for connections



Example: Loch Raven Reservoir

Appalachian Terrain

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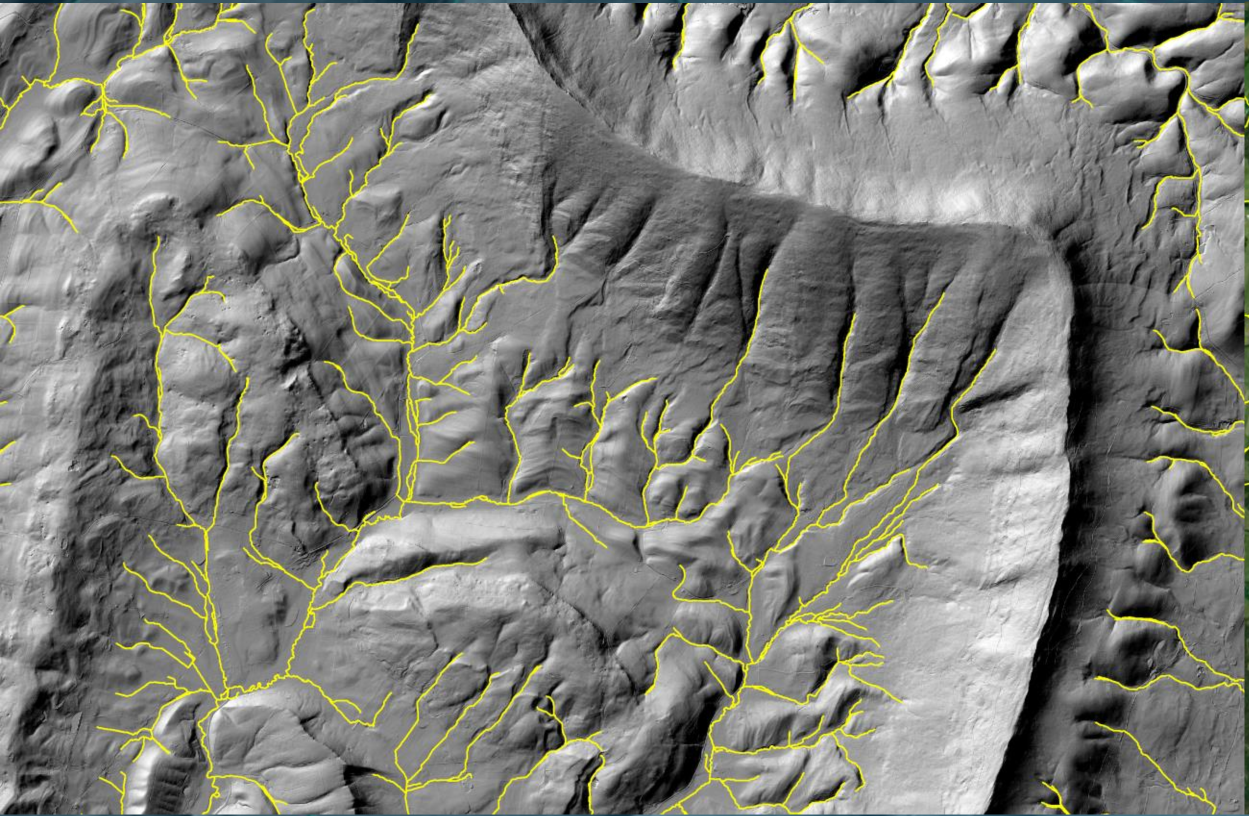
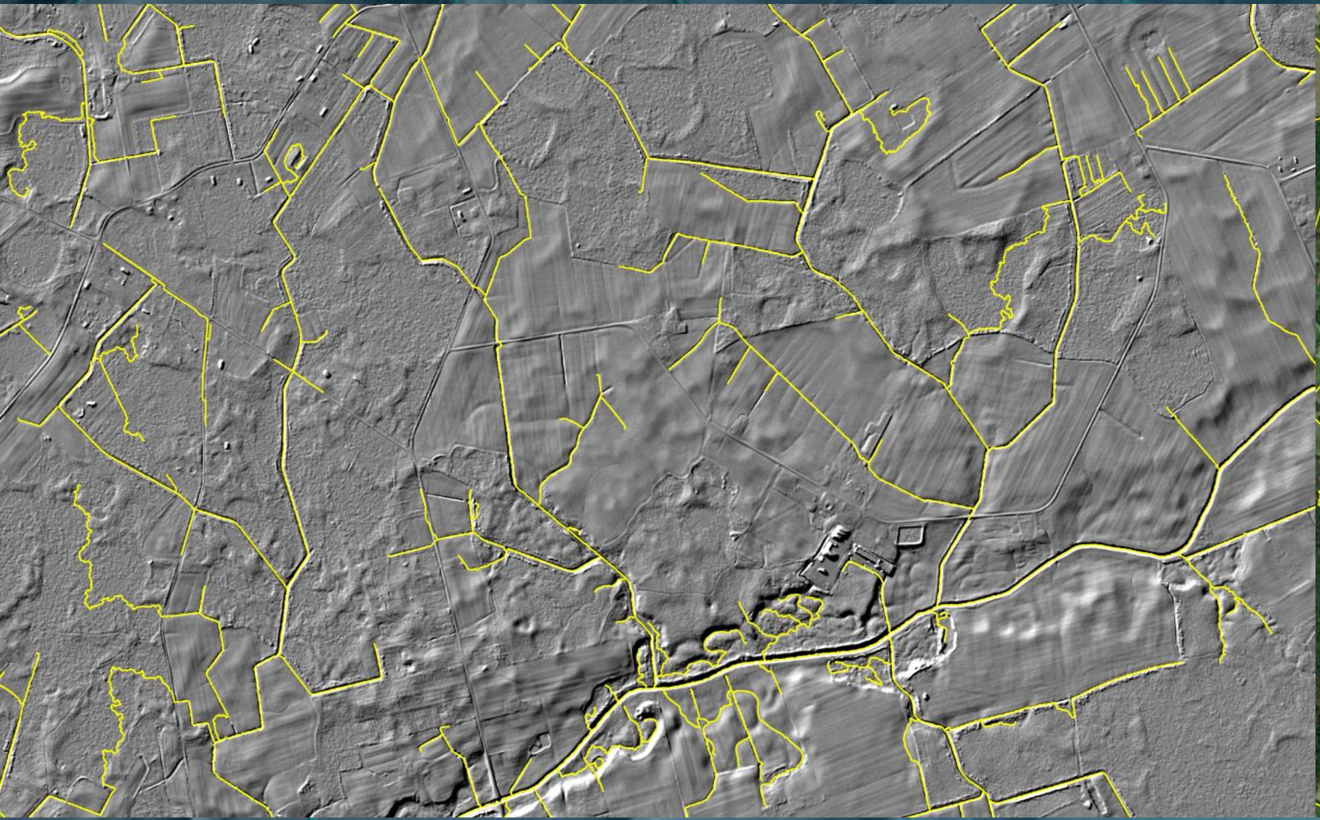
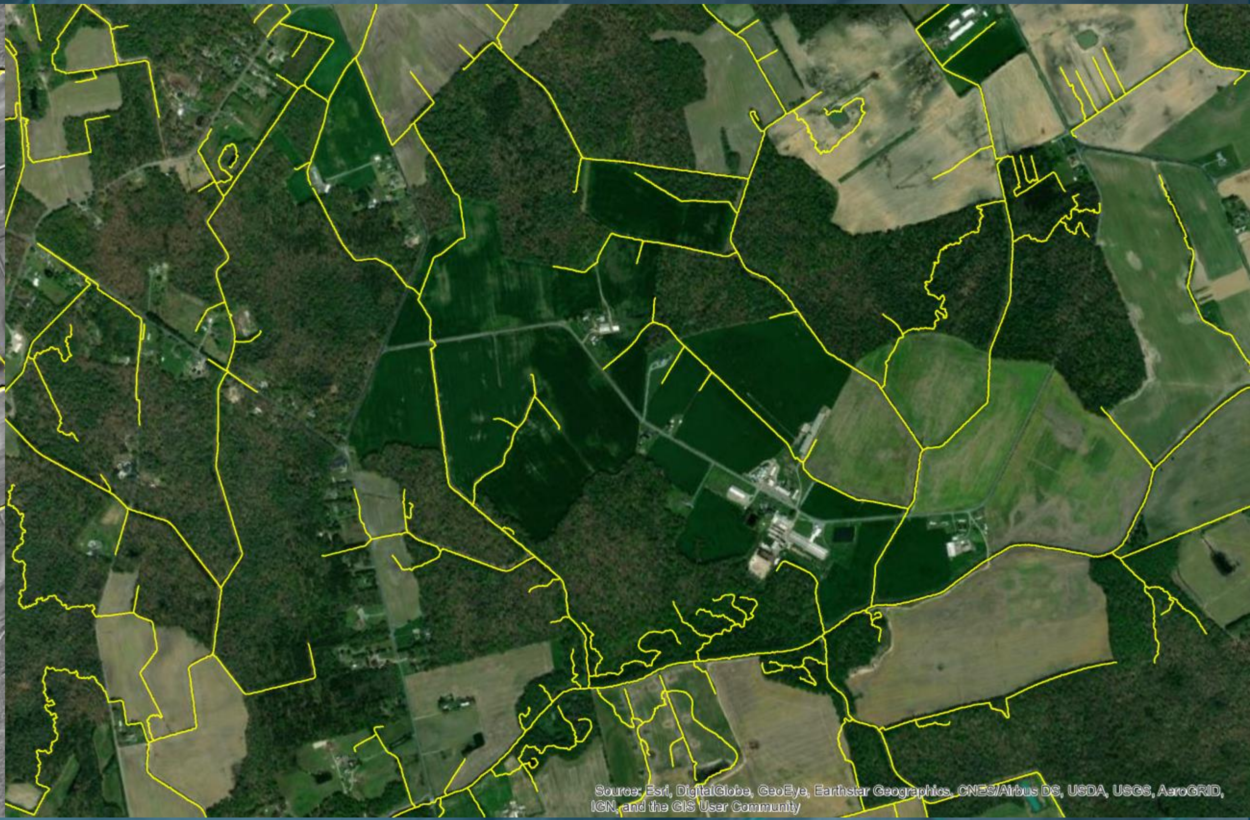


- Valley bottom agriculture
- Note discontinuous scars on ridges: should they be included?

Delmarva Terrain





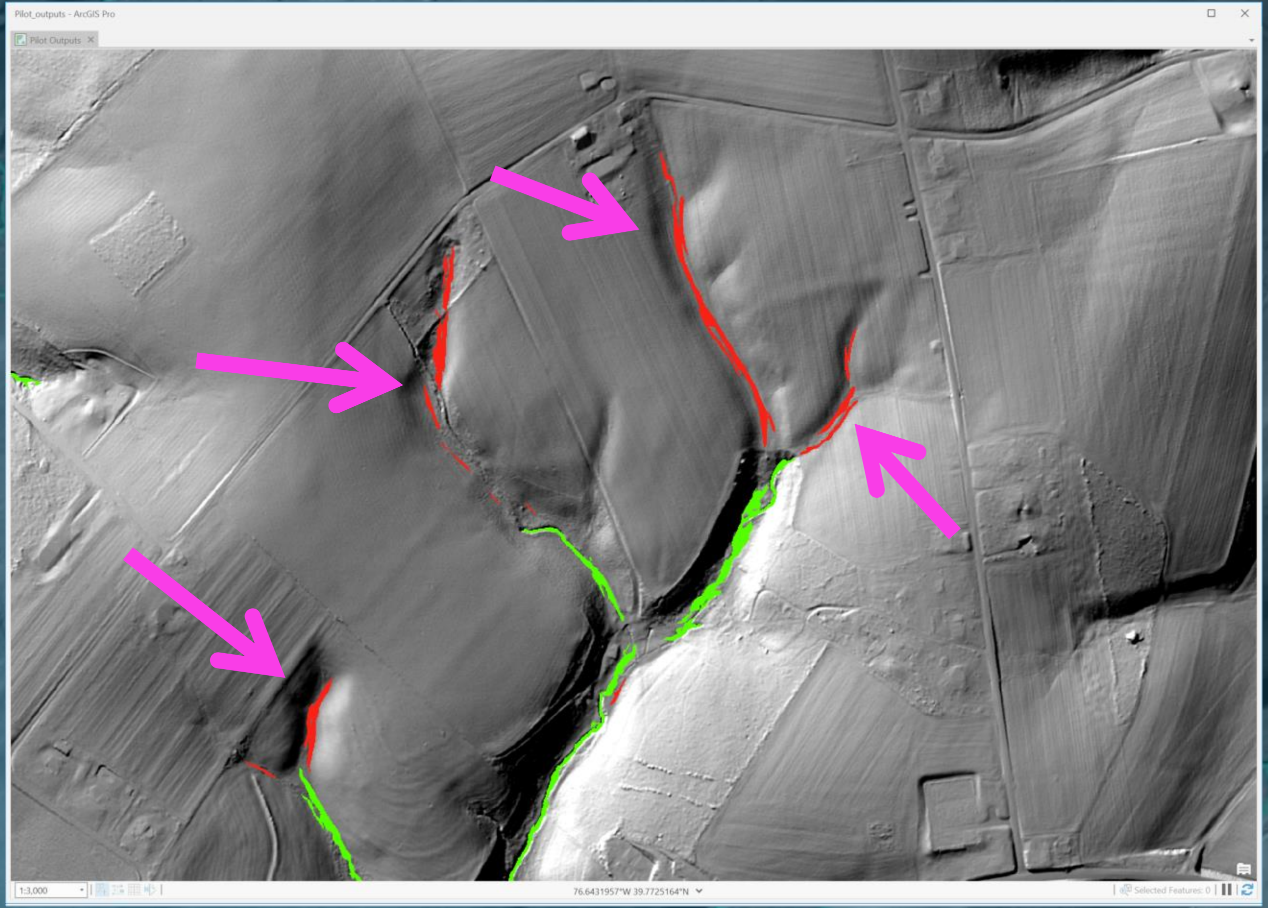
- Ditching and draining widespread
- Combination of modern drainage and remnant landforms

A Paradigm Shift

- A new challenge is distinguishing features that belong in "*stream*" map

- Other conveyance features morphologically similar to stream channels:
  - Rills and gullies
  - Roadside ditches
  - Agricultural ditches/swales
  - Detention features/ponds
  - Floodplain depressions
  - Other (e.g., anthropogenic features, crevice, slide scars, washes)

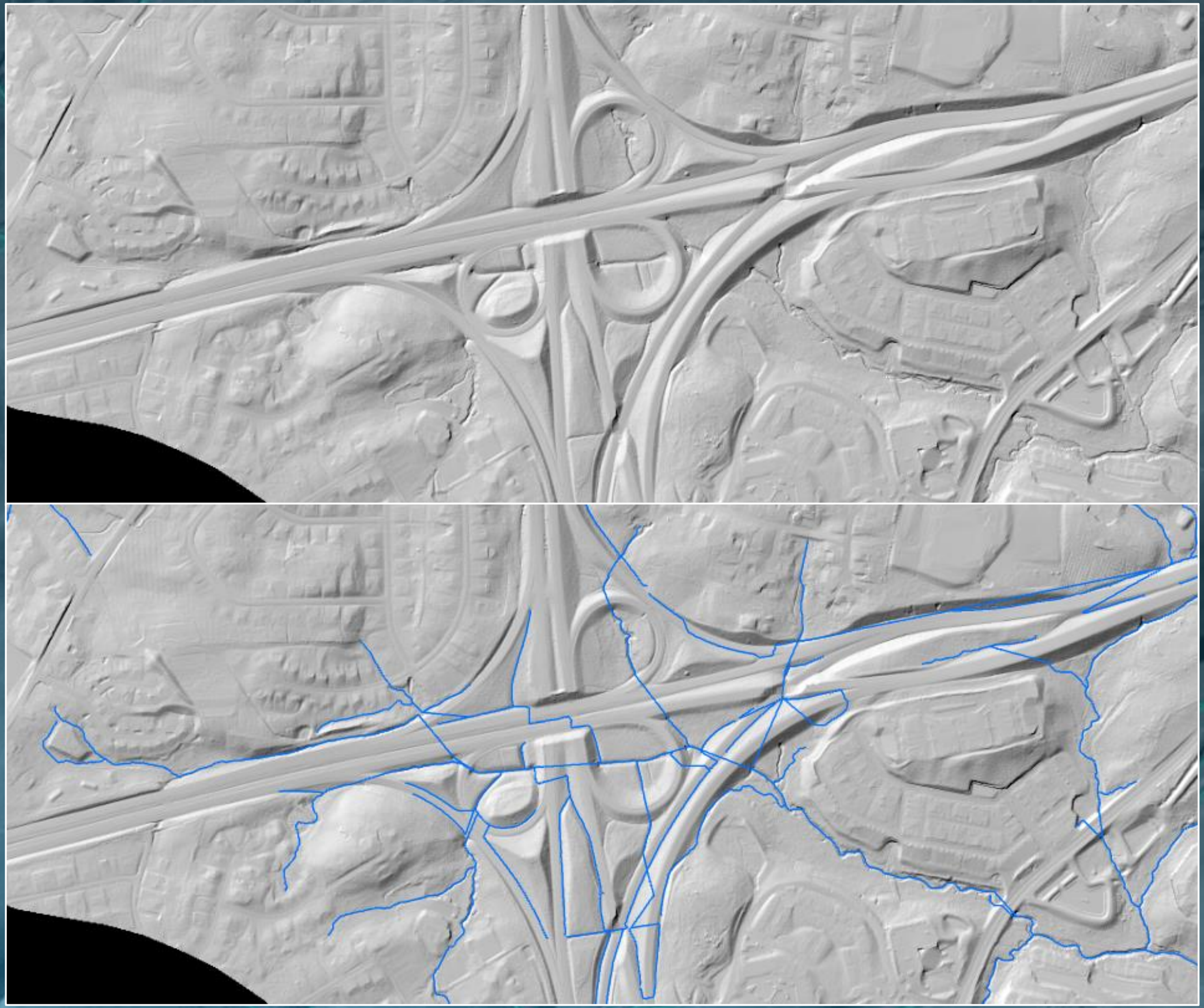
- Effective discrimination and handling of features for different map uses, terrains, changes in time



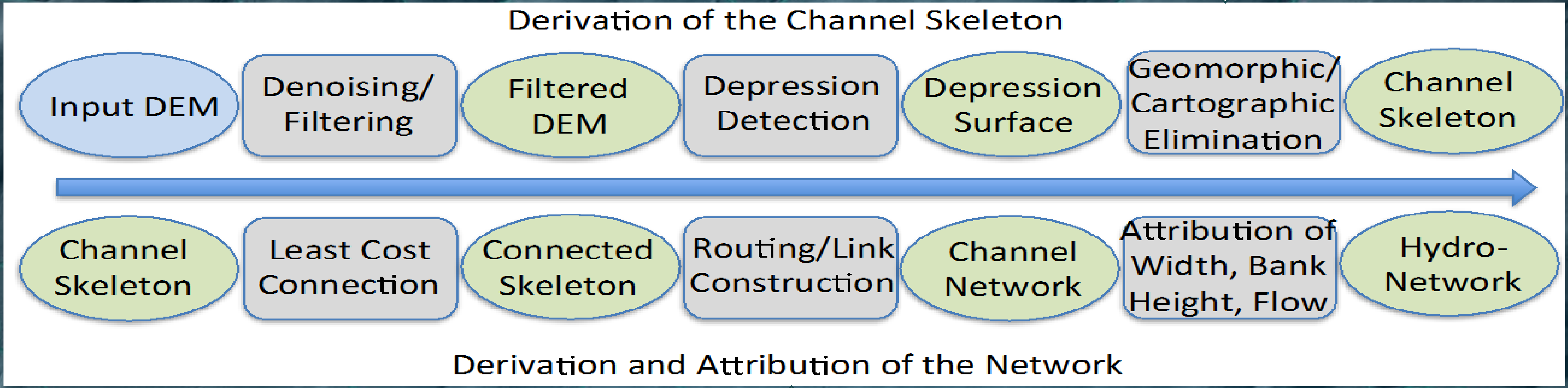
Contiguous and Discontinuous Features

Complexity of Terrain Modifications

- Anthropogenic modification can be extreme, especially around transportation infrastructure
- Sometimes involve multiple layers of drainage modification
- Can yet pose a challenge for automation

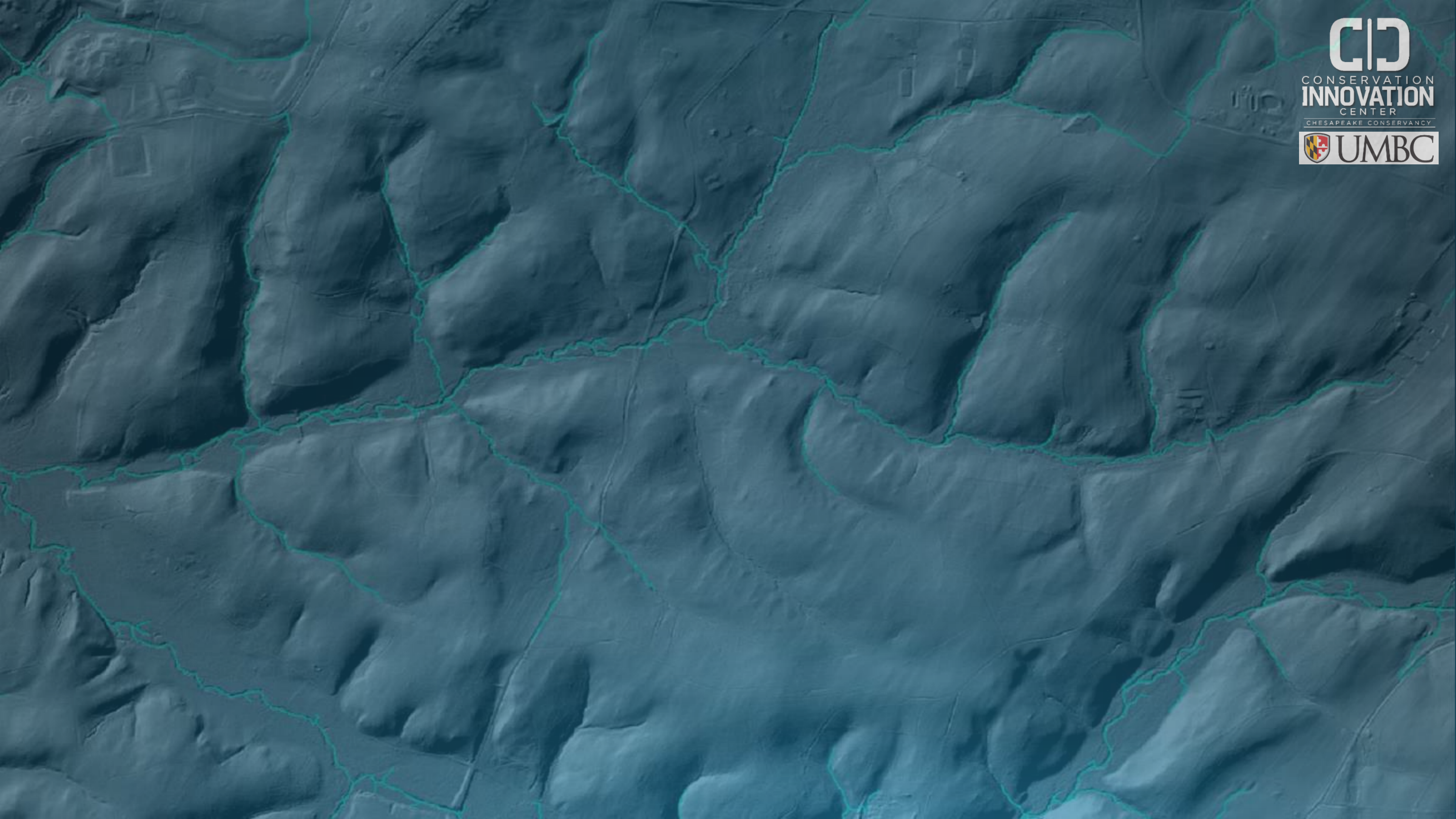


Potential Improvements in Workflow



Summary

- New data release (late Sept 2024)
- New applications enriching hydrographic data models, enable rapid mapping over broad landscapes
- High resolution elevation data provide an opportunity to rethink:
  - how we approach stream delineation
  - what features we map
  - which attributes are important
- Terrain-based mapping cannot map what it cannot see
- Highlighting new concepts, challenges, and potential for improved conservation and management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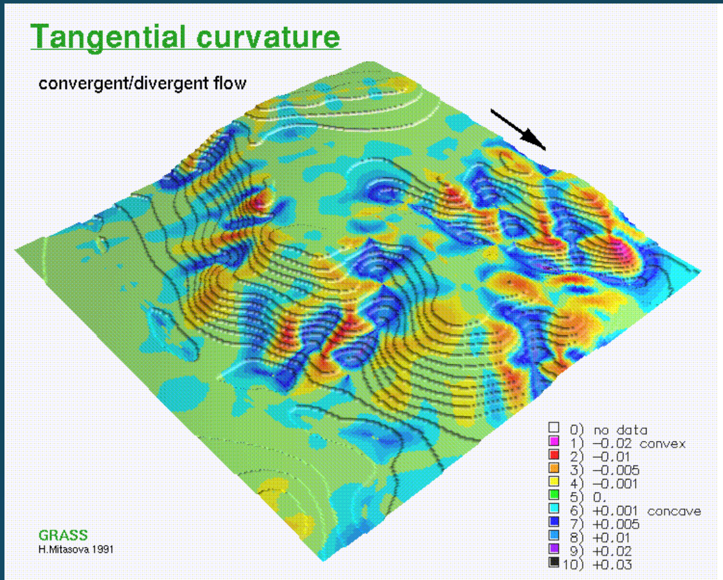
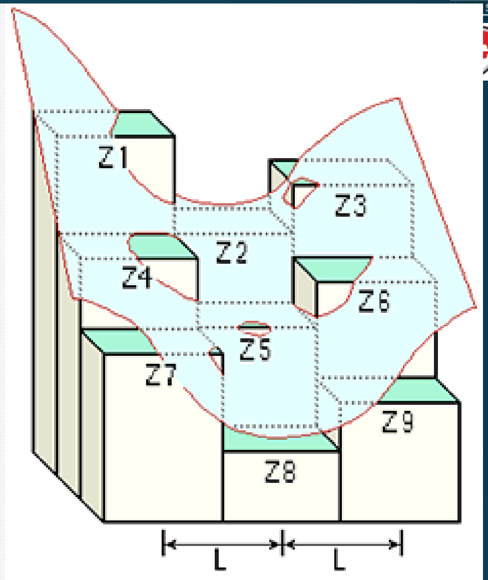
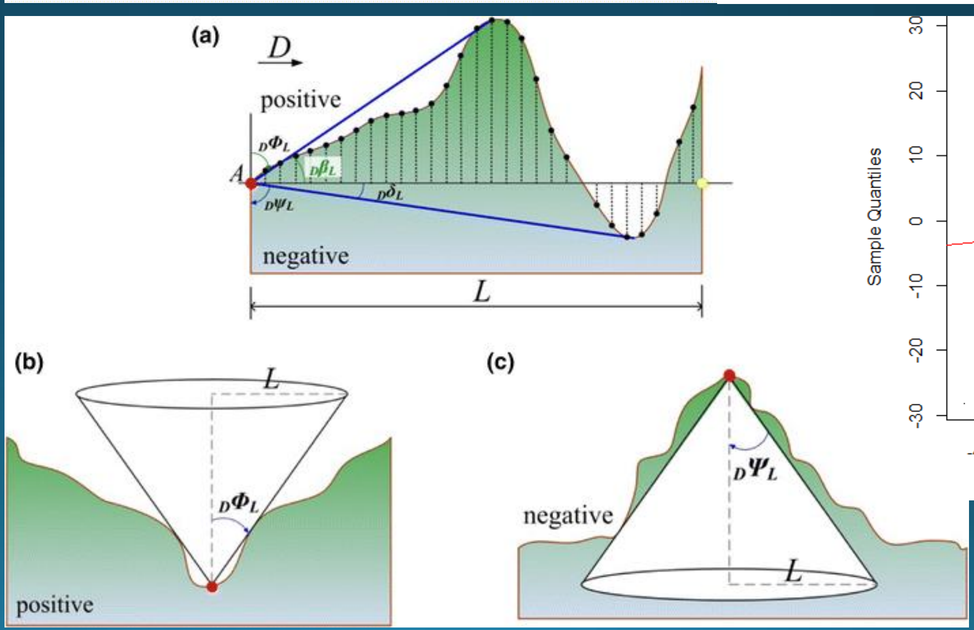
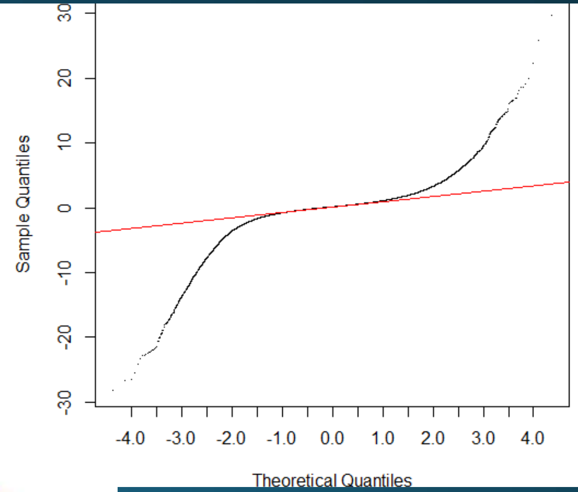
Depressions as channel indicators

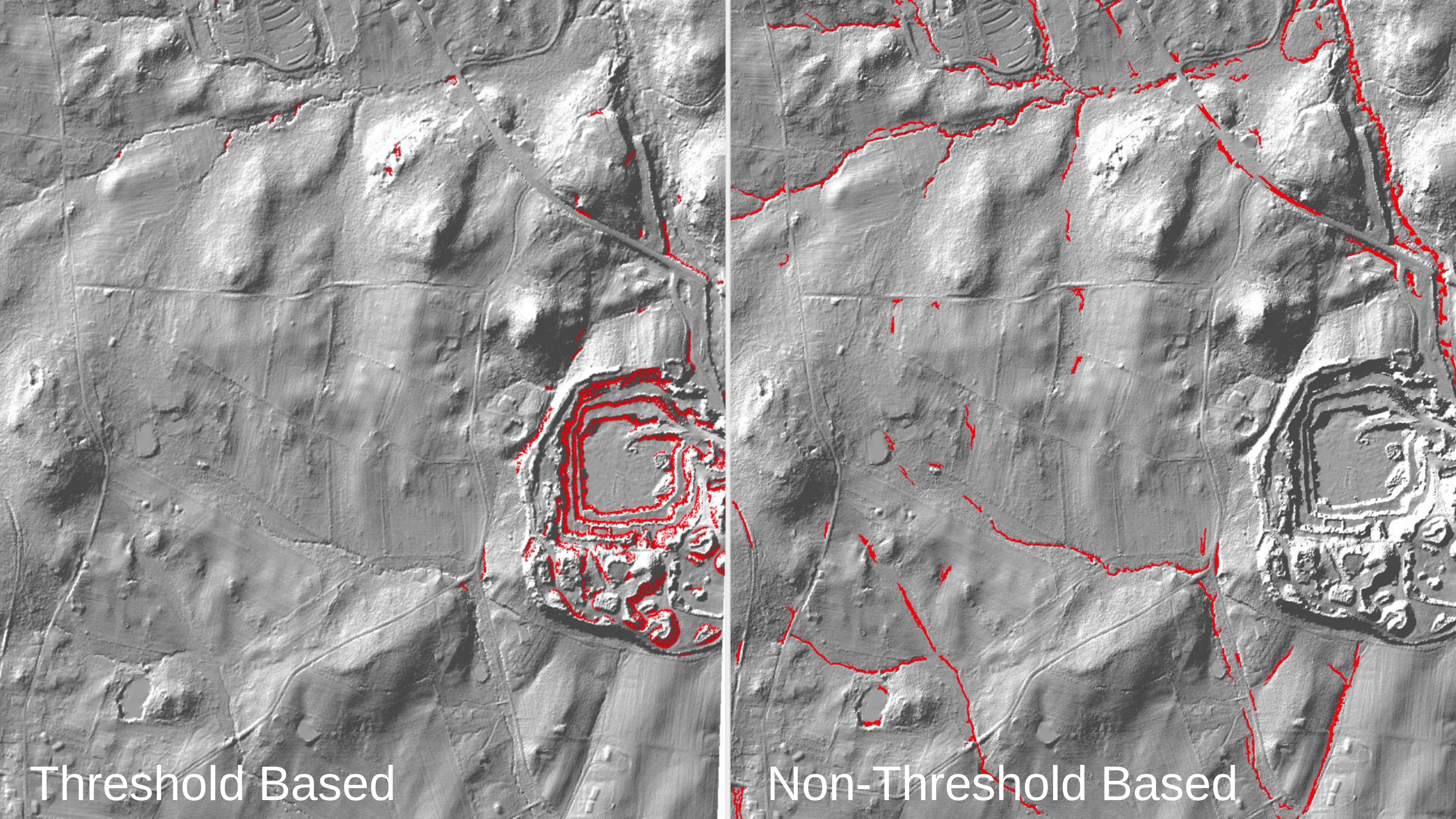
- Tangential/Planform Curvature
  - Most common approach
  - Areas of convergent flow
  - Known properties, canned functions
  - Local operation, fixed scale
  - Doesn't adapt well to all terrains
- Pos/Neg Topographic Openness
  - Line of sight, computer vision
  - Degree of enclosure/prominence
  - Scale independent, self adapting
  - Values not intuitive, hard to interpret
- Process Domains
  - Theory: where fluvial transport occurs
  - Practice: thresholds ID extreme outliers
  - Required for every regional domain










Threshold Based
Non-Threshold Based

Feature Extraction Comparison

- Most techniques produced reasonable results
  - Land use and physiography had distinct and significant effects

- However, curvature and openness involved *labor intensive* filtering techniques
  - Regional thresholding
  - Analysis of size distributions
  - Critical drainage area
  - Linear networking

- Geomorphons were as accurate or better using automated delineation and *Valley Network* filtering

- Geomorphons have <u>*attributes*</u> like dimension, shape, context, and other diagnostic information