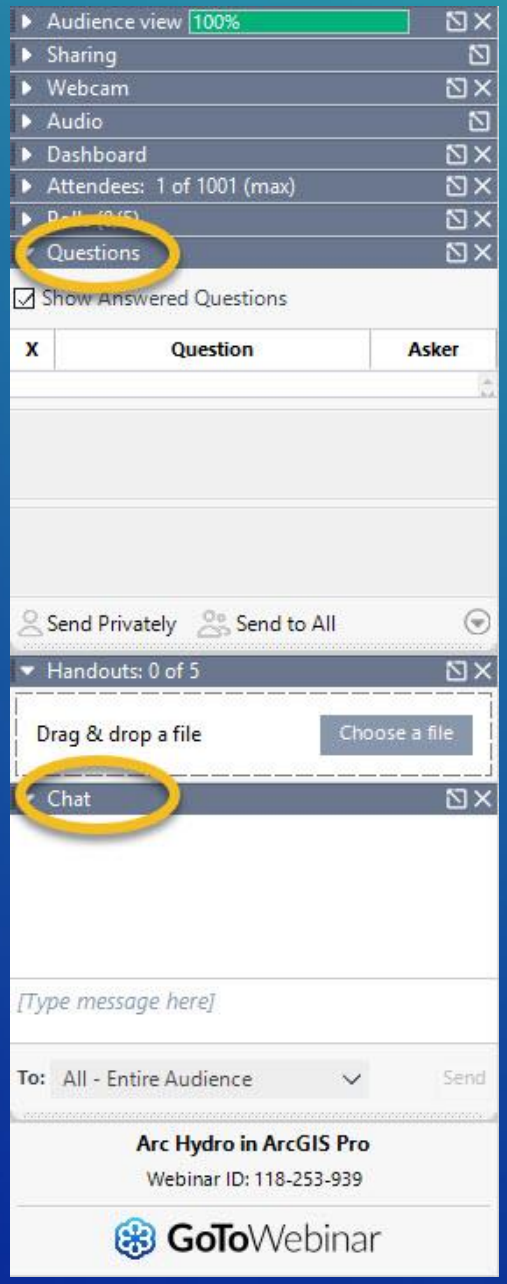
Arc Hydro: Advances in Hydro Feature Extraction

Dean Djokic, Finn Swann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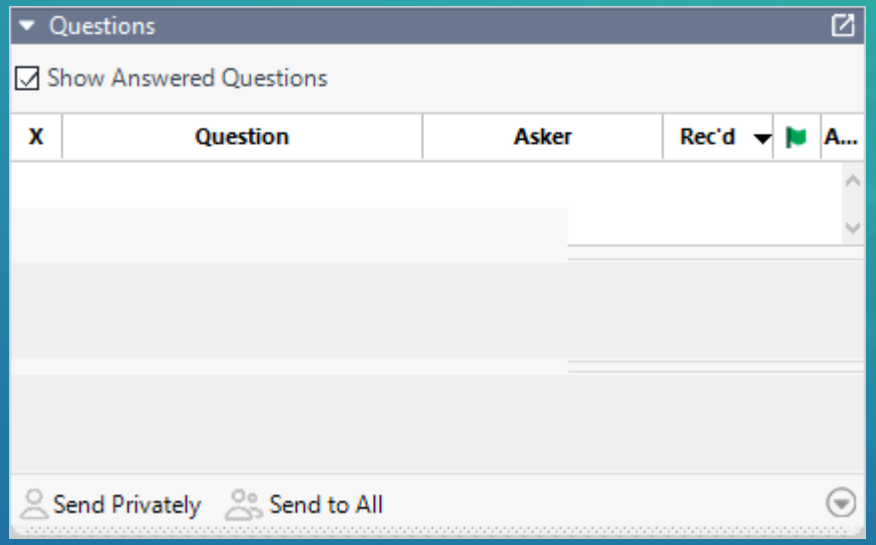
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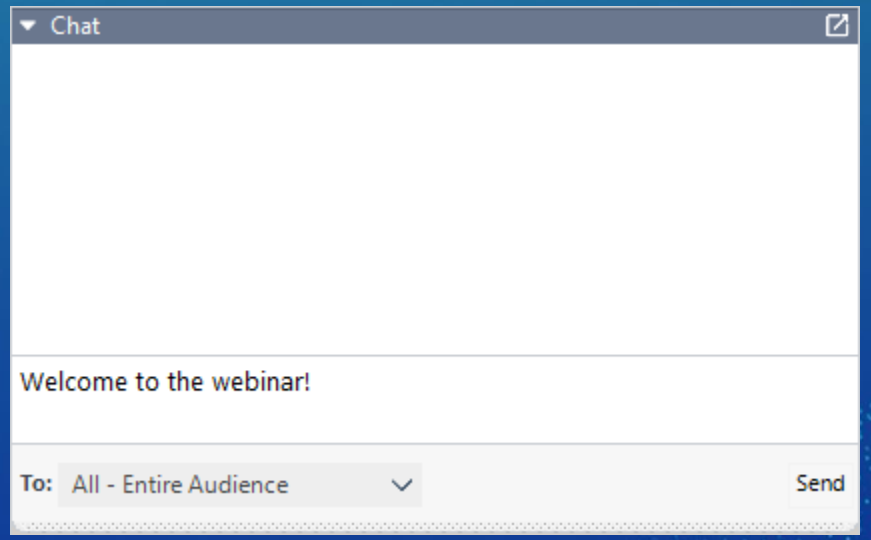

Chat
Welcome to the webinar!
To: All - Entire Audience
Send

Have you attended one of our Arc Hydro webinars in the last 3 years?

What ArcGIS Software are you using?

Connecting with Esri Water Resources

Finn Swann

Water Resources Team

Industry Solutions

Christa Campbell

Mariah Salazar

Finn Swann

Ciera Patti

Core Development

Tania Lopez-Cantu

Steve Kopp

Nawajish Noman

Living Atlas

Caitlin Scopel

Gonzalo Espinoza

Professional Services

Dean Djokic

Gina O'Neil

Christine Dartiguenave

Zichuan Ye

Ezra Bosworth-Ahmet

Paul Burgess

Jordyn Miller

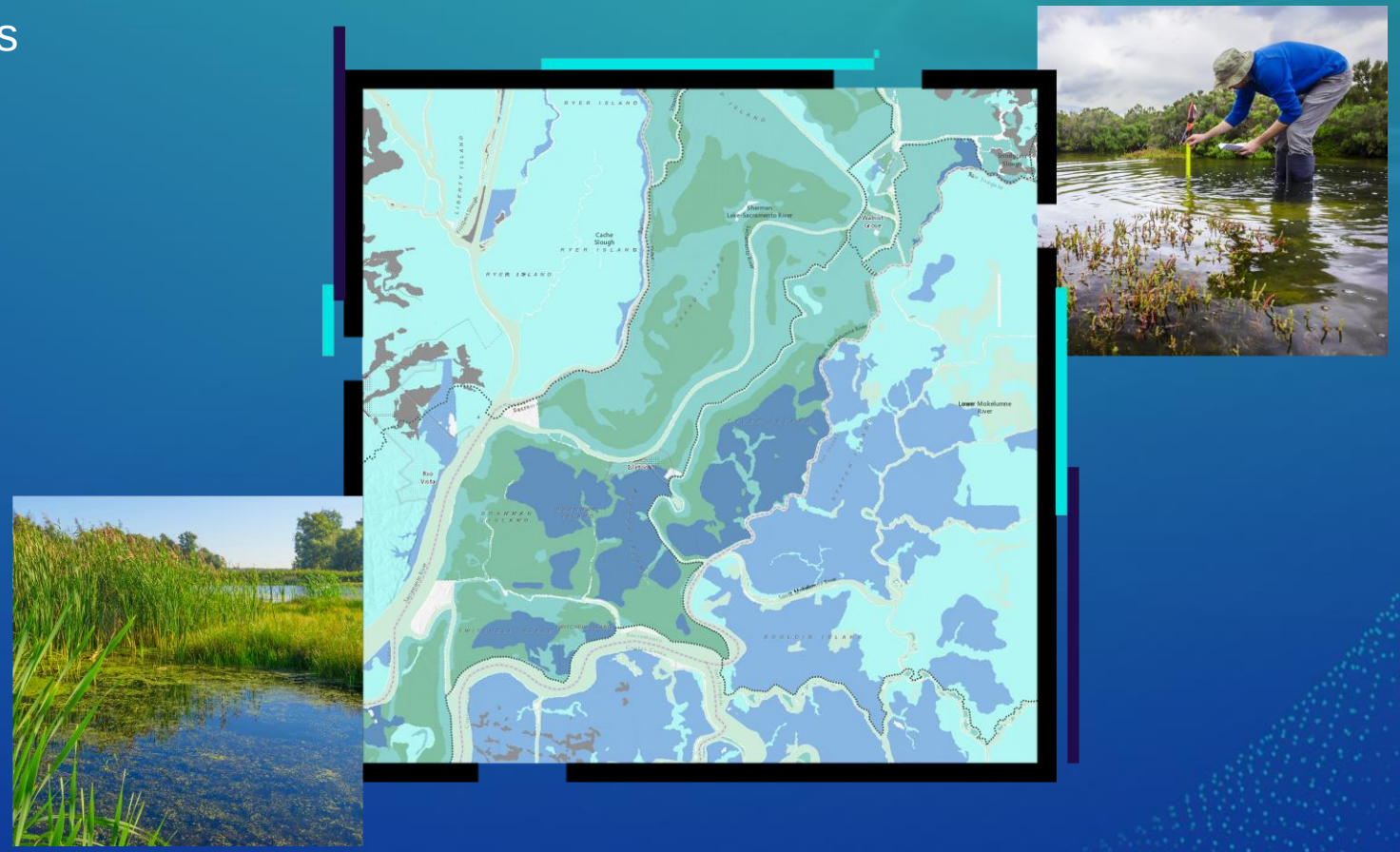
Jakob Drozd

Training Services, Business Development, Account Management, …

Navigating Esri Web Sites

Finding information on Esri websites

- Water Resources
- Arc Hydro



Water Resources web page

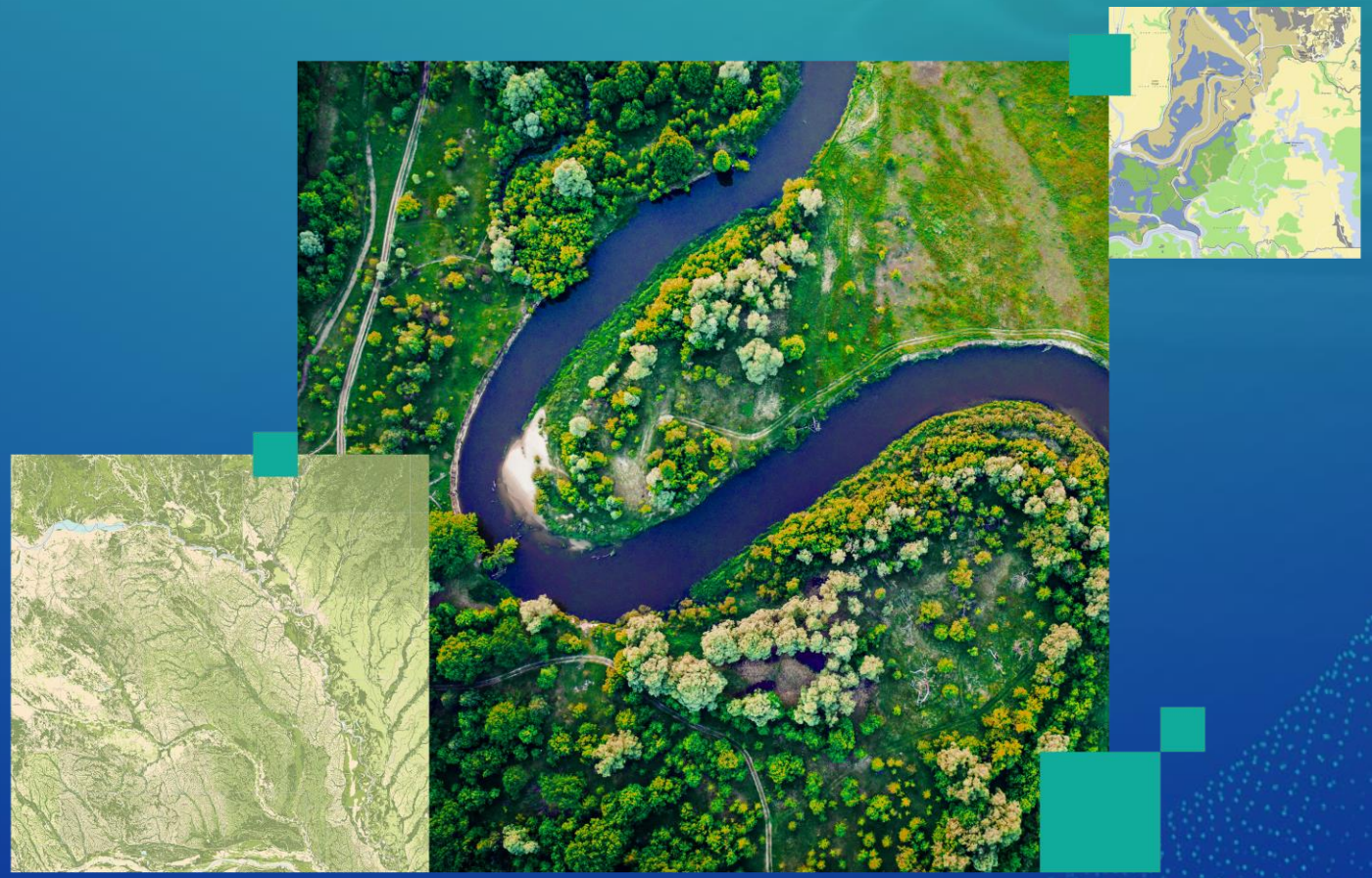
Arc Hydro web page

Esri Water Resources Community

Connecting with industry professionals

- Online Q&A
- Blogs
- Videos
- Technical documents

Water Resources Community



Industry Events

FFMA

- April 23-26, 2024, Miramar Beach, FL

Webinar: Flood Simulation

- June 26, 2024

WEFTEC

- October 5-9, 2024, New Orleans, LA

AWRA Annual Water Resources Conference

- September 30- October 2, 2024, St. Louis, MO

Connect with our team to ask questions and share your work.

Esri UC: Hydro Meeting

Sunday, July 14, 2024

- New Hydro Functionality in ArcGIS
- ArcGIS Living Atlas of the World Updates
- Arc Hydro Updates
- Streamflow Instant App
- NASA SWOT Updates
- FEMA – HAZUS for ArcGIS Pro
- …

Esri Water Meetup

Water Resources Office Hours (Virtual)

Esri's hydro experts host virtual office hours to discuss common water resources workflows and answer questions.

Join us to ask questions, contribute to the community,
and vote on Office Hour topics.

Next scheduled on May 2nd

Esri Office Hour
Registration Page

Stay Connected with Esri's Water Team

@EsriWater

Esri Water Resources

Esri Water Meetup

Esri Water eNewsletter

Dean Djokic

27 years Redlands, CA

Hydroinformatics

Principal Consultant

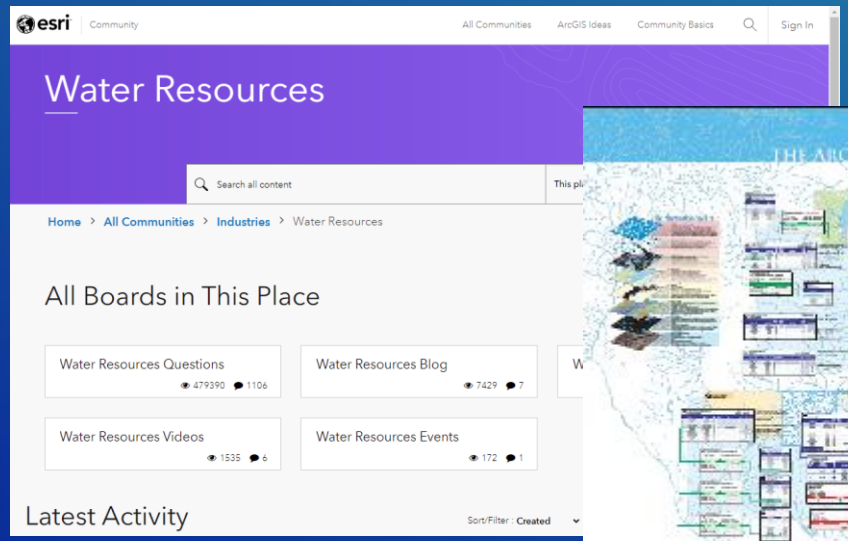
Arc Hydro Team Lead

Introduction to Arc Hydro and 2024 Webinar Series

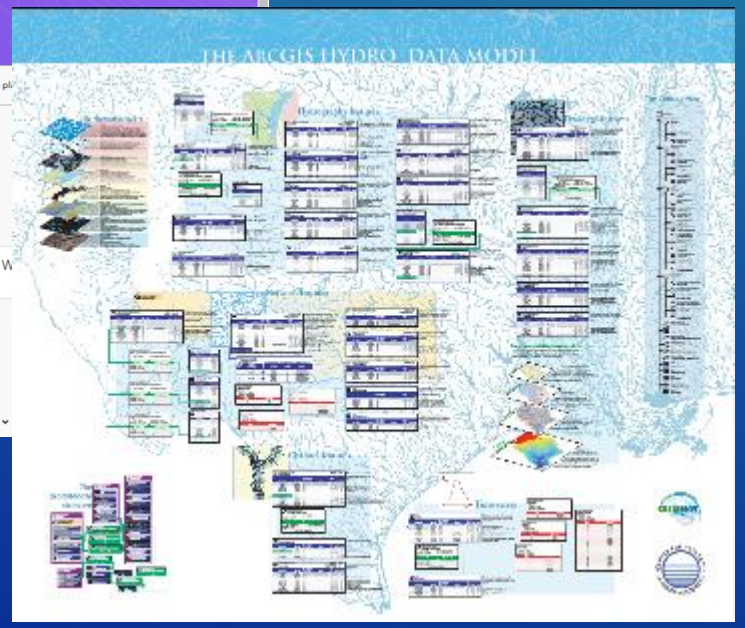
Dean Djokic

Arc Hydro - Vision

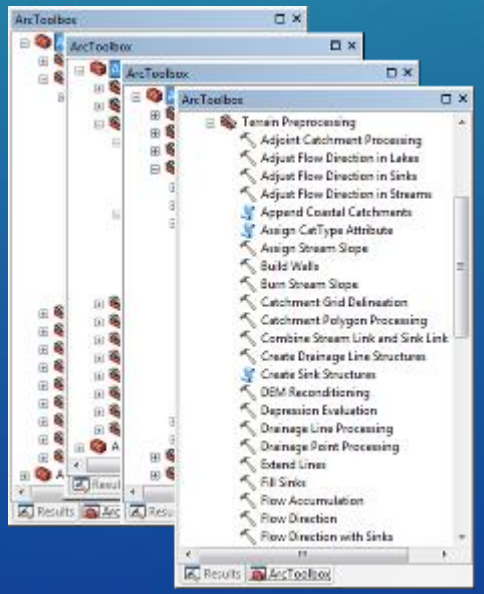
"Provide practical GIS framework for development of integrated analytical systems for water resources market."



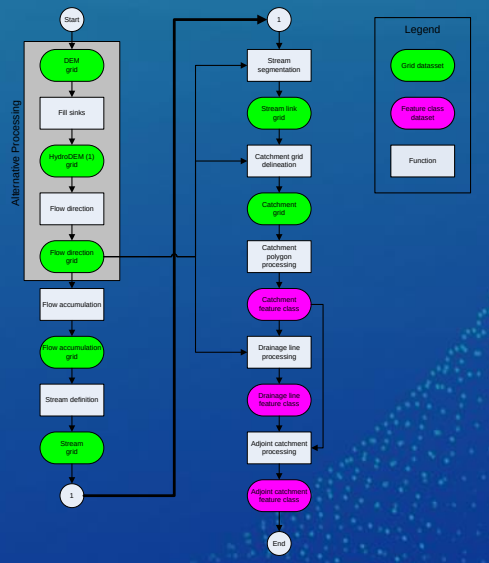
Community



Data Model



Tools

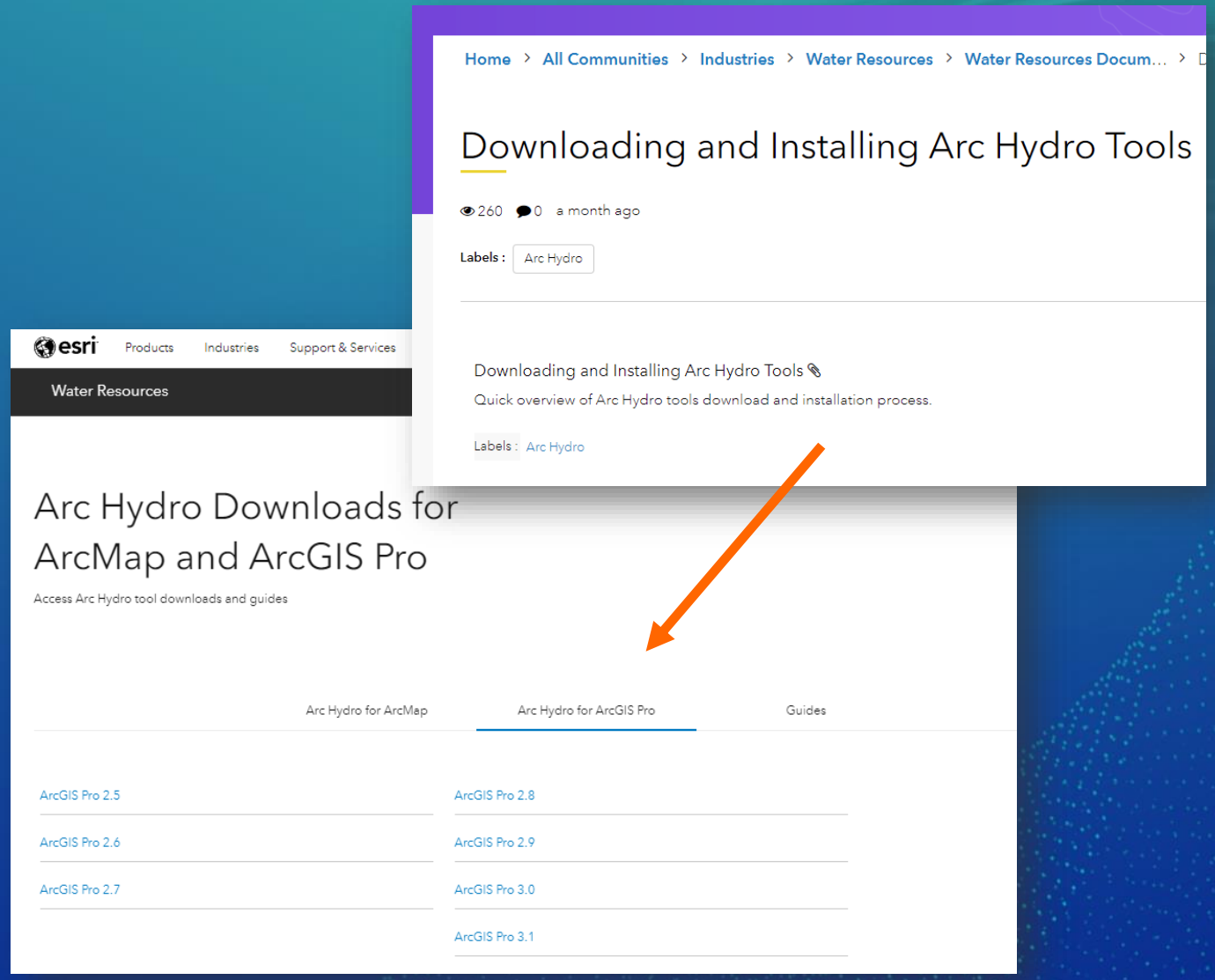


Workflows

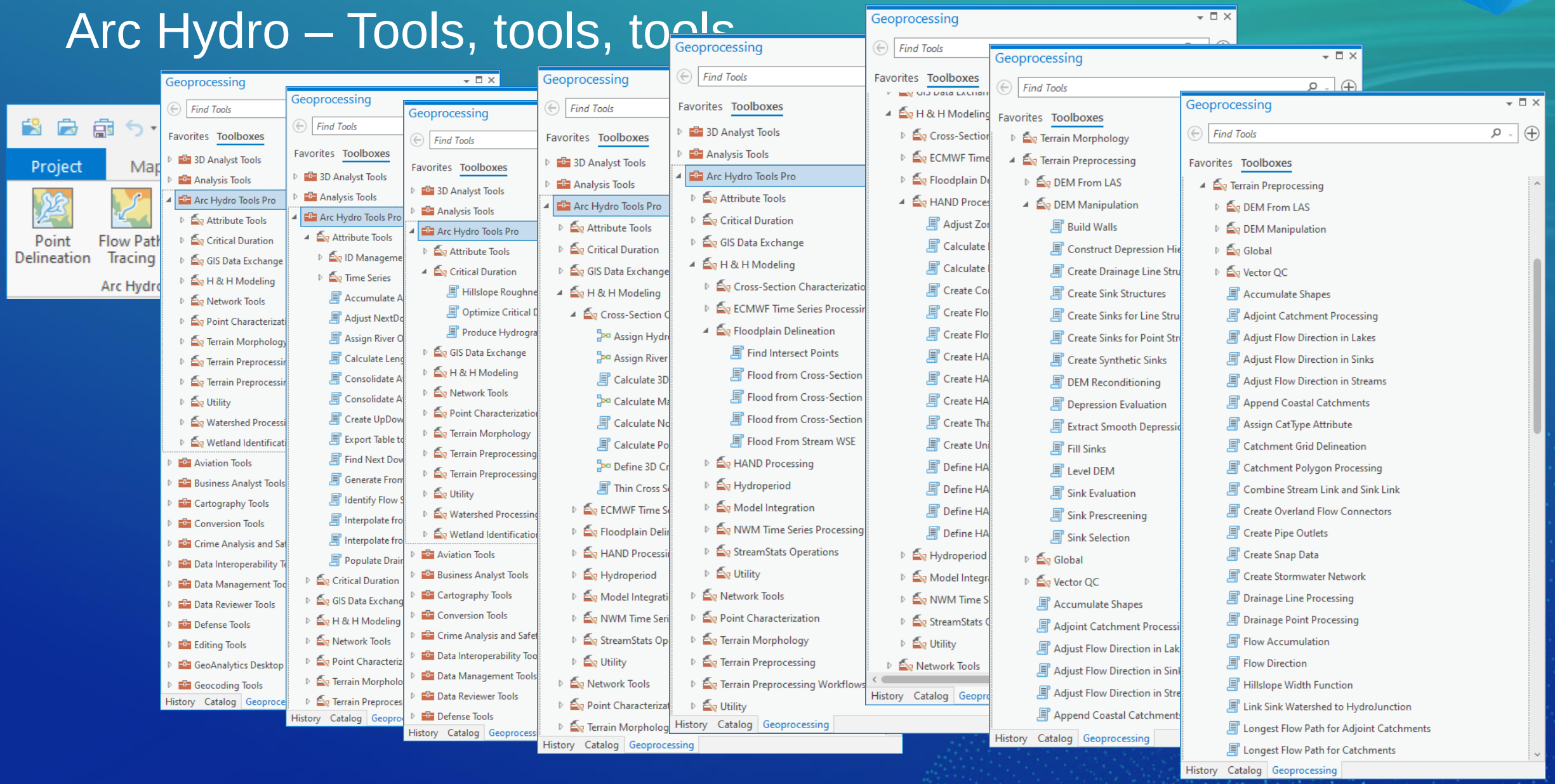
Arc Hydro - Product \ Capability Summary

- "No fee" downloadable offerings:
  - Data model
  - Tools
  - Workflows
  - Documentation
  - Available now :
    - Pro tools - all versions up to 3.2
    - ArcMap tools - all versions up to 10.8.2
    - Web services in the Living Atlas

- Optional offerings:
  - Training (paid)
  - Consulting (paid)



Arc Hydro – Tools, tools, tools



Have you used Arc Hydro?

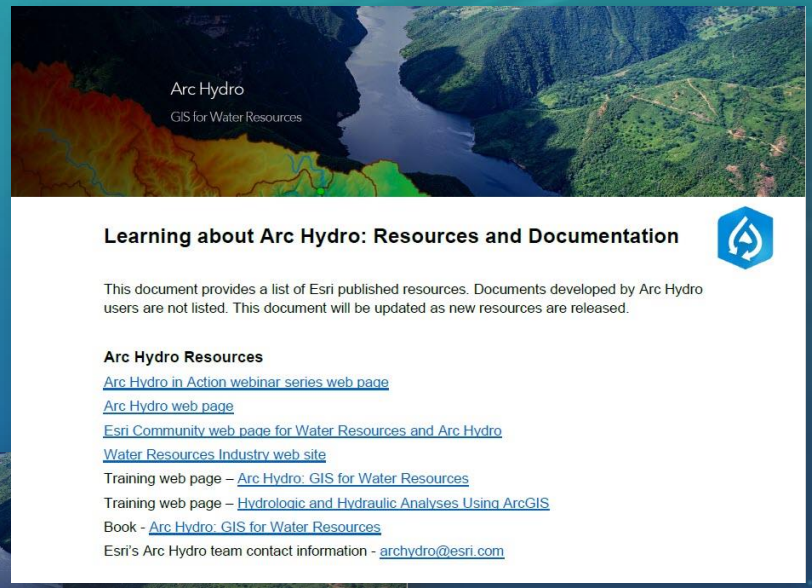
Arc Hydro: Getting Started

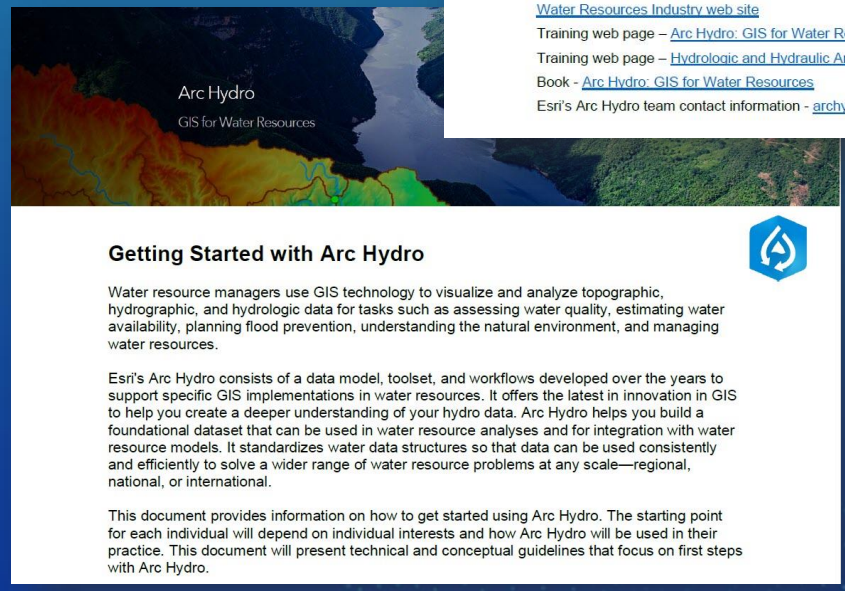
Learning about Arc Hydro: Resources and Documentation

- https://go.esri.com/AH_Resources

Getting Started with Arc Hydro

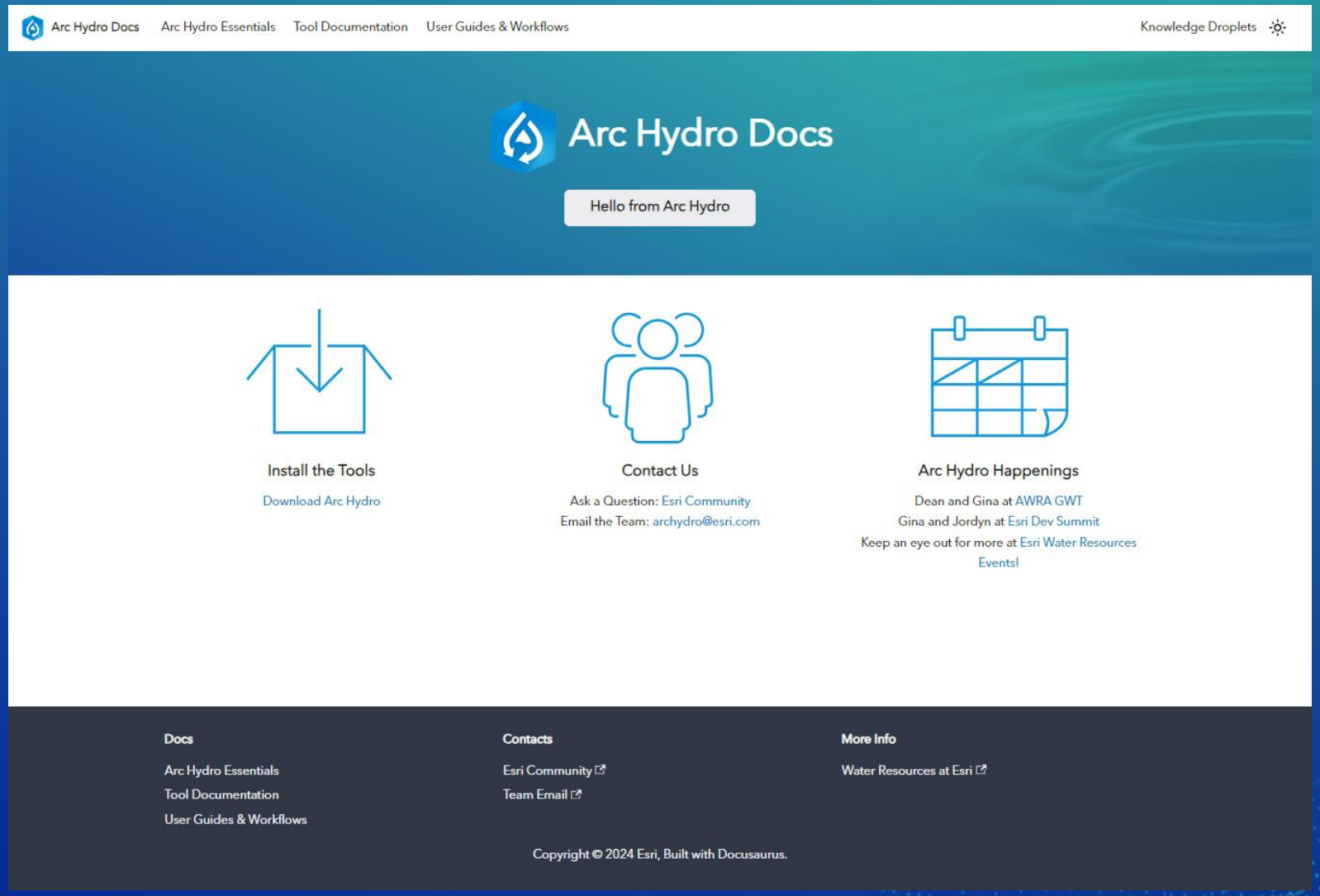
- https://go.esri.com/AH_Getting_Started





Arc Hydro Docs

https://esrips.github.io/ah-docs/



Arc Hydro Webinars (2021, 2022, 2023)

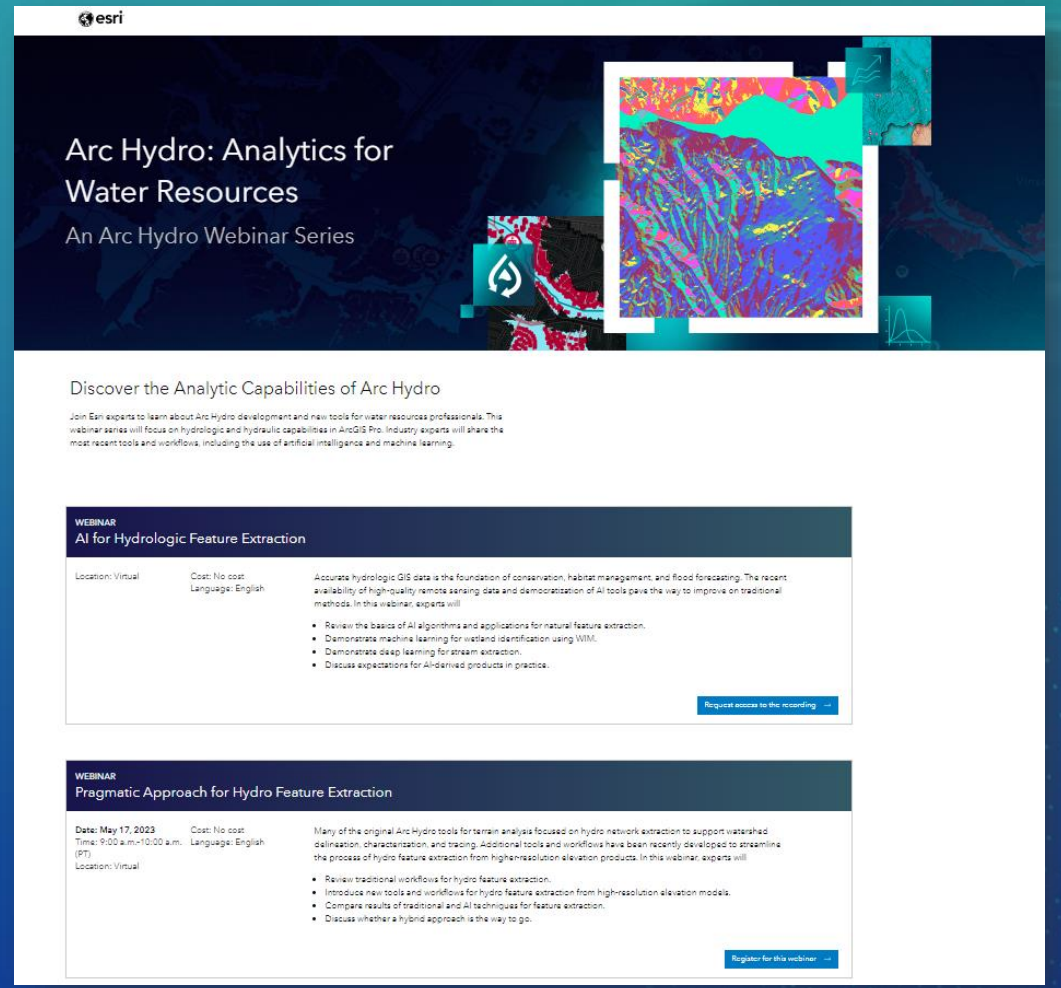
- All webinar recordings are available on demand.

2024 Webinar Series

- All webinar recordings will be available on demand.
- 2 more in making.
  - June 26th (Flood Simulation)
  - One in late fall.

2023 Webinar Series

- 2 webinars related to today's topic:
  - AI for Hydro Feature Extraction
  - Pragmatic Approach for hydro Feature Extraction



Arc Hydro: Advances in Hydro Feature Extraction

Dean Djokic

Topics

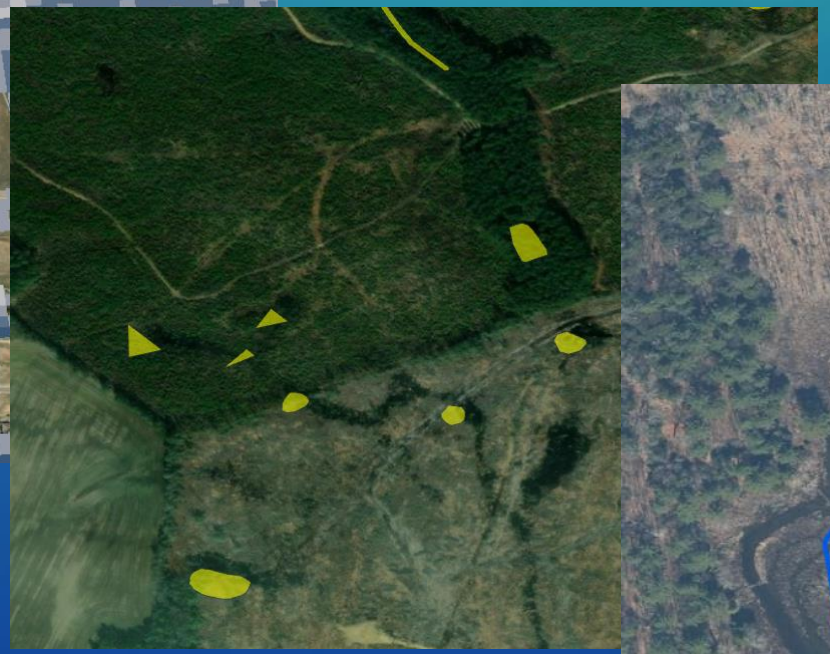
- Quick review of “Pragmatic Approach for Hydro Feature Extraction”
  - Why automated “hydro feature extraction” (HFE)
  - Key concepts and data for HFE analyses
- Workflows
  - Purpose
  - Available data
  - Iterative
- Tools
- Discussion / conclusion

Motivation: Why Hydro Feature Extraction?

- **Need data to conserve, manage, and plan.**

We can do better than the data we've been using…

Impervious surface



Wetlands

Streams

Motivation

- Data, data, data – high resolution digital elevation (DEM) derived from Lidar (laser) or Ifsar (radar) sensors – sub-meter cell sizes.
  - Volume of data to process.
  - Frequency of updates.
- Traditional methods are costly, can’t be automated.
  - Elevation / photointerpretation.
  - Data refinement and attribution.
  - Manual confirmation of characteristics.

Motivation

- Techniques, techniques, techniques
- Consistent methodology for consistent results
  - Data driven (“same input data should produce the same output data”)
  - How to minimize “human intervention”
    - Data/interpretation – allow user interpretation to drive the process
      - User controlled; parameter driven process
      - Capture and store user “control” (as parameters or actual features) for reuse
    - Methodology – no change in methodology, change input data and parameters
- And as a technology developer – can we build the required tech to support “production” as opposed to “research”
  - Scalability
  - Performance
  - Maintenance

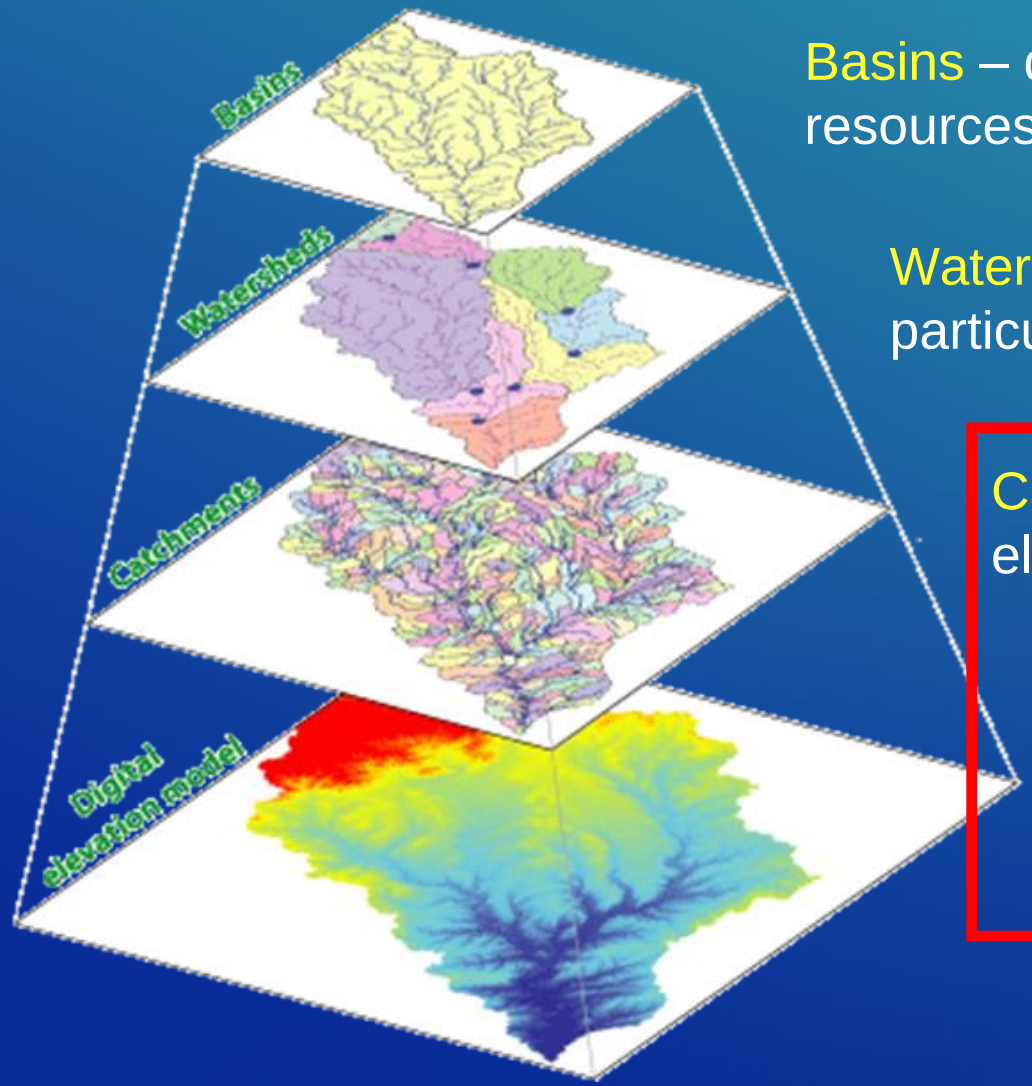
Automated hydro feature extraction in Arc Hydro context

- Any technique used to derive “hydro features” from digital elevation model. Primary types are:
  - Streams.
  - Lakes – water gets in and gets out from a known lake outlet (e.g. stream).
  - Sinks – water gets in but does not get out.
  - Drainage areas – areas draining into other type of hydro feature
  - Wetlands – can be either lake or sink.
- Hydro features are defined by their type and geometry NOT their properties.
- Scale and problem dependency:
  - Scale dependency – what is sink at one scale might be a lake at another.
  - Problem dependency – what is a sink for one hydro problem “flows” in another (e.g. drought vs. flood analysis).

Automated hydro feature extraction in Arc Hydro context

- Integrated raster and vector representation of the features with respect to the underlying DEM.
  - Concept of “Hydrofabric”.
  - No “raster vs. vector” wars
- Primary role to identify flow patterns within the landscape and support various “hydro” analyses.
  - Watershed delineation and characterization
  - Flooding
  - Hydrography
  - …
- NOT a specific product with specific product specifications (e.g. USGS’ EDH or 3DHP) but more general constructs that can SUPPORT derivation of specific products.

Drainage system representations – Arc Hydro



Basins – drainage areas for water resources management

Watersheds – subdivision of land surface for a particular hydrologic purpose

"Program"
- EDH
- 3DHP

Catchments – subdivision of land surface into elementary drainage areas by physical rules

"Nature"

Digital Elevation Model – land surface terrain grid cells

Source: "Arc Hydro: GIS For Water Resources", Esri Press, 2002

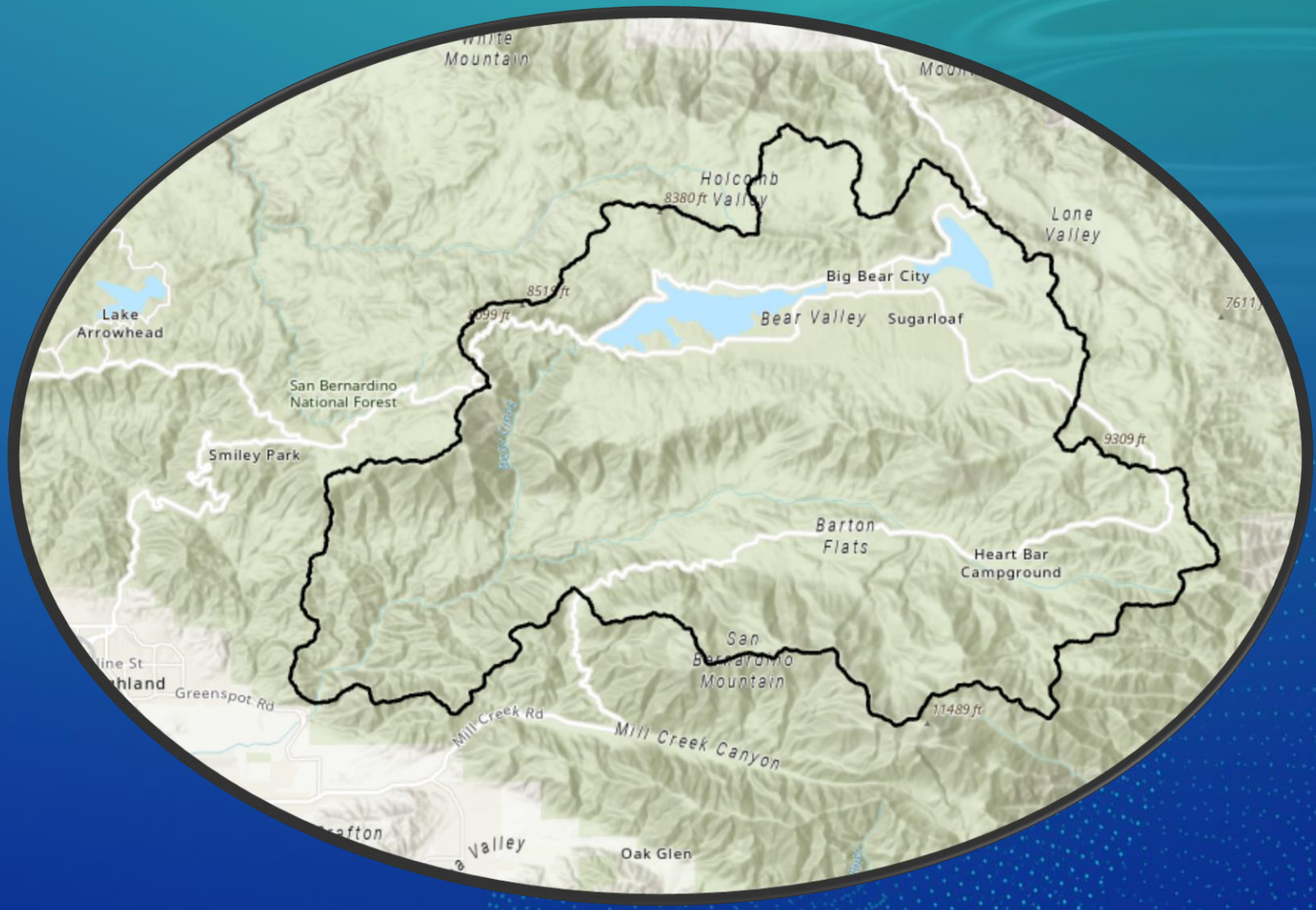
Reality check / Myth busters

- Lidar-derived DEMs are NOT that great.
  - Often a blend of different source flights (age, resolution, vendor/processing methodology, …).
  - Horizontal/vertical accuracy, registration, projection, ...
  - Interpretation of Lidar point cloud and processing into DEM.
    - Removal of bridges, culverts, buildings, vegetation, …
    - Removal/insertion of water bodies (hydro-flattening).
    - Vendor-specific methods (some are better than others).
- Your other input data are NOT that great.
  - Existing hydrography, built infrastructure (bridges, culverts, …).
  - Scale, temporal issues, completeness, ...
- Interpretation can be important.
  - “Automation” still needs human touch.
  - Iterative process.

Workflows

Hydro Feature Extraction: In a perfect world …

- Using 10m NHDPlus HR DEM.
- Seven Oaks Dam watershed in Southern California. Upper portion of Santa Ana River including the Big Bear Lake.
  - Area: ~ 550 km2
  - Elevation range: ~ 600 - 3,500 m
  - Cells: ~ 2,600 by 3,900 (rows by columns)
  - SR: National Albers

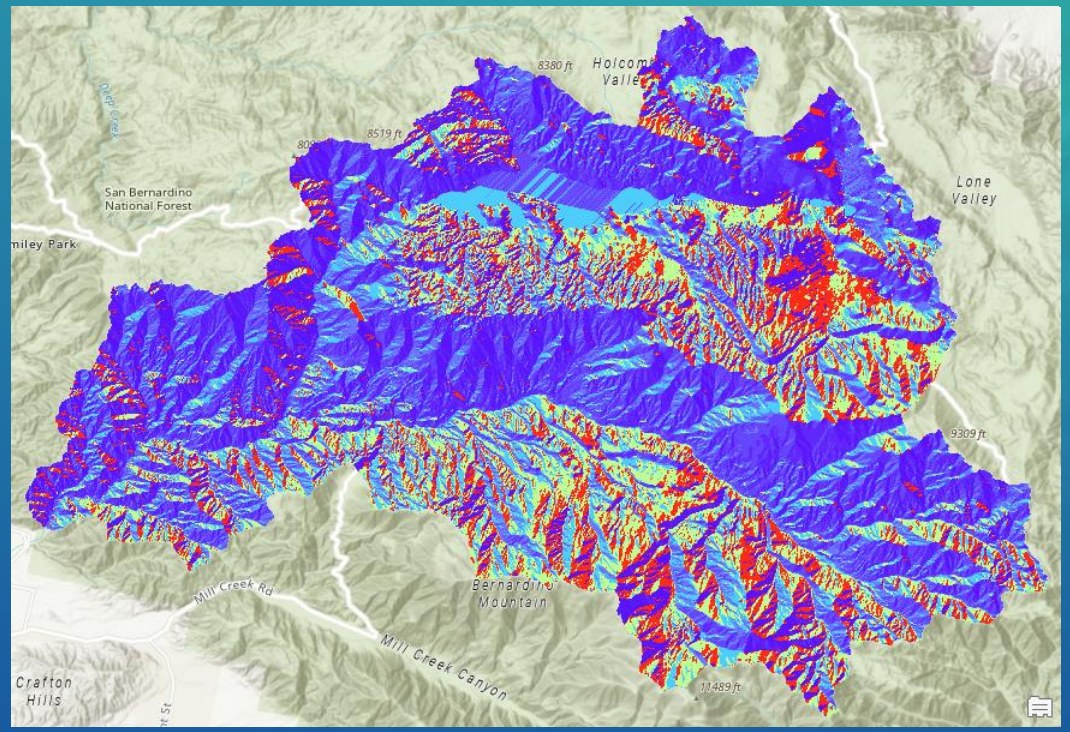


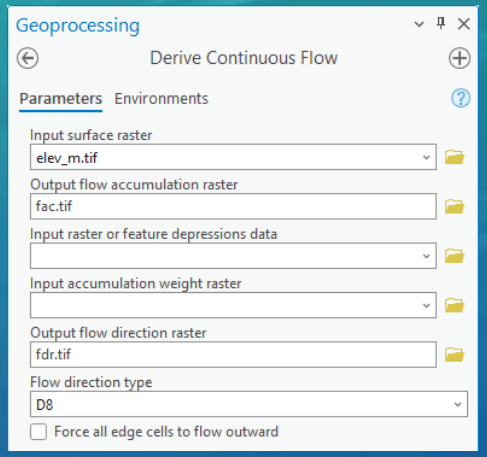
Hydro Feature Extraction: In a perfect world …

1. Use “raw” DEM to derive flow direction
2. Use “few” parameters to derive base drainage network
3. Finalize drainage system

1

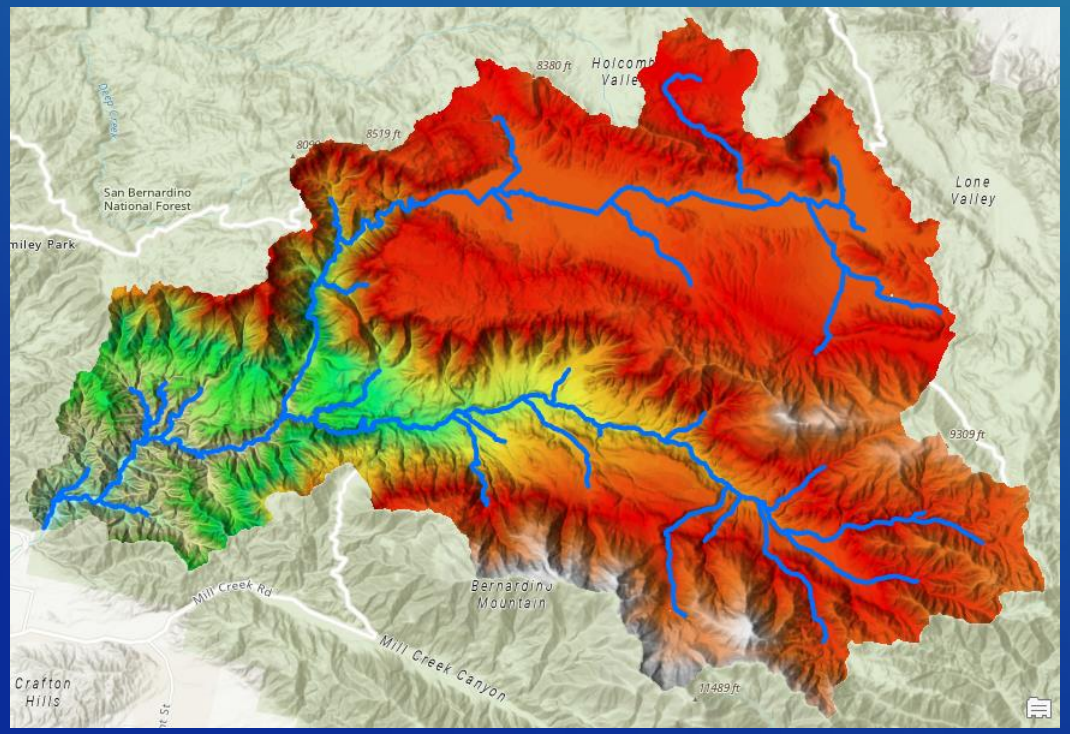
Use “raw” DEM to derive flow direction

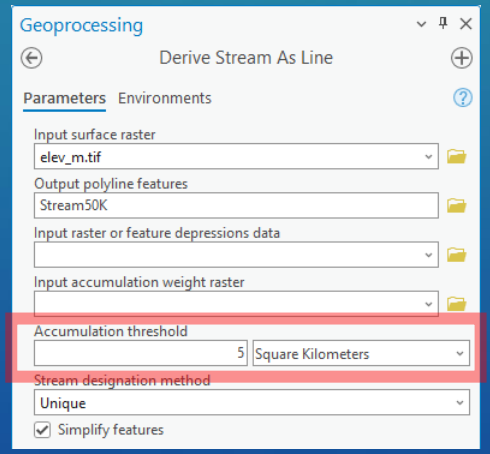




Hydro Feature Extraction: In a perfect world …

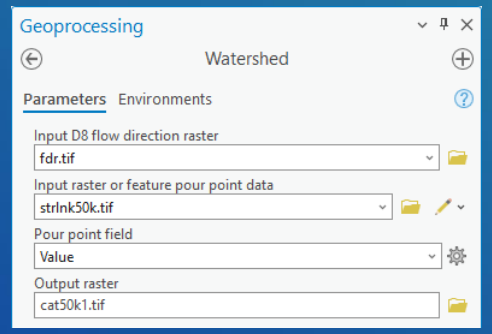
Hydro Feature Extraction: In a perfect world …

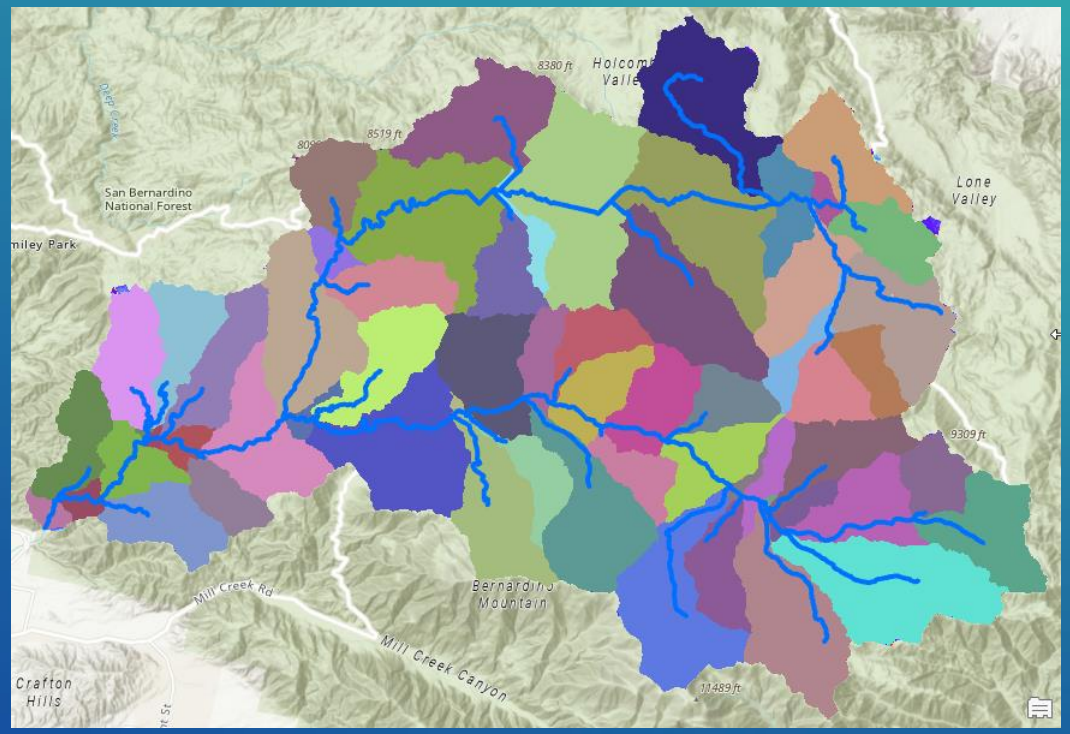




2

Use “few” parameters to derive base drainage network





3

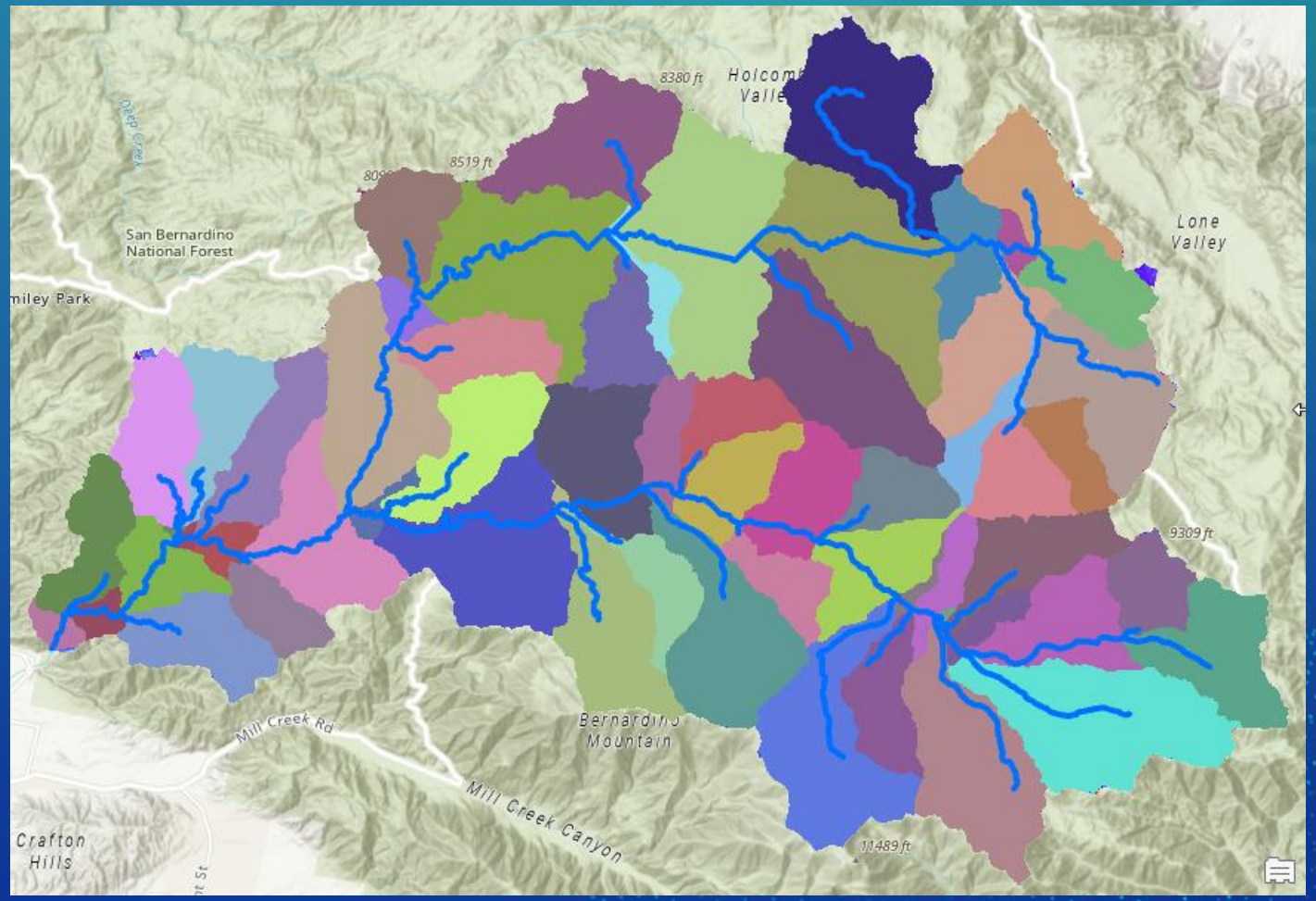
Finalize drainage system

Hydro Feature Extraction: In a perfect world …

In a perfect world …

One physical parameter controls it all (but few would be OK too)

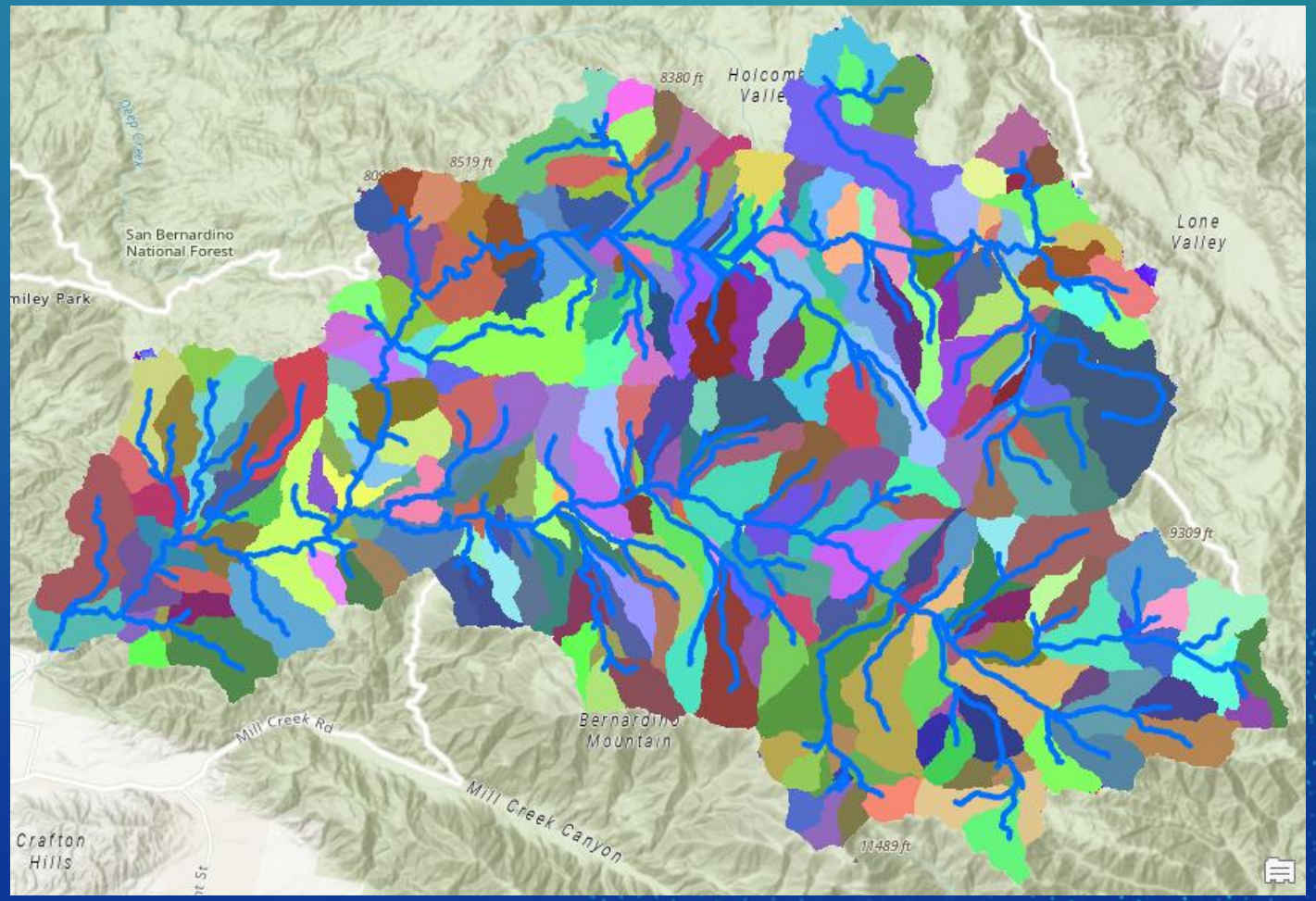
Stream threshold = 5 km sq.



In a perfect world …

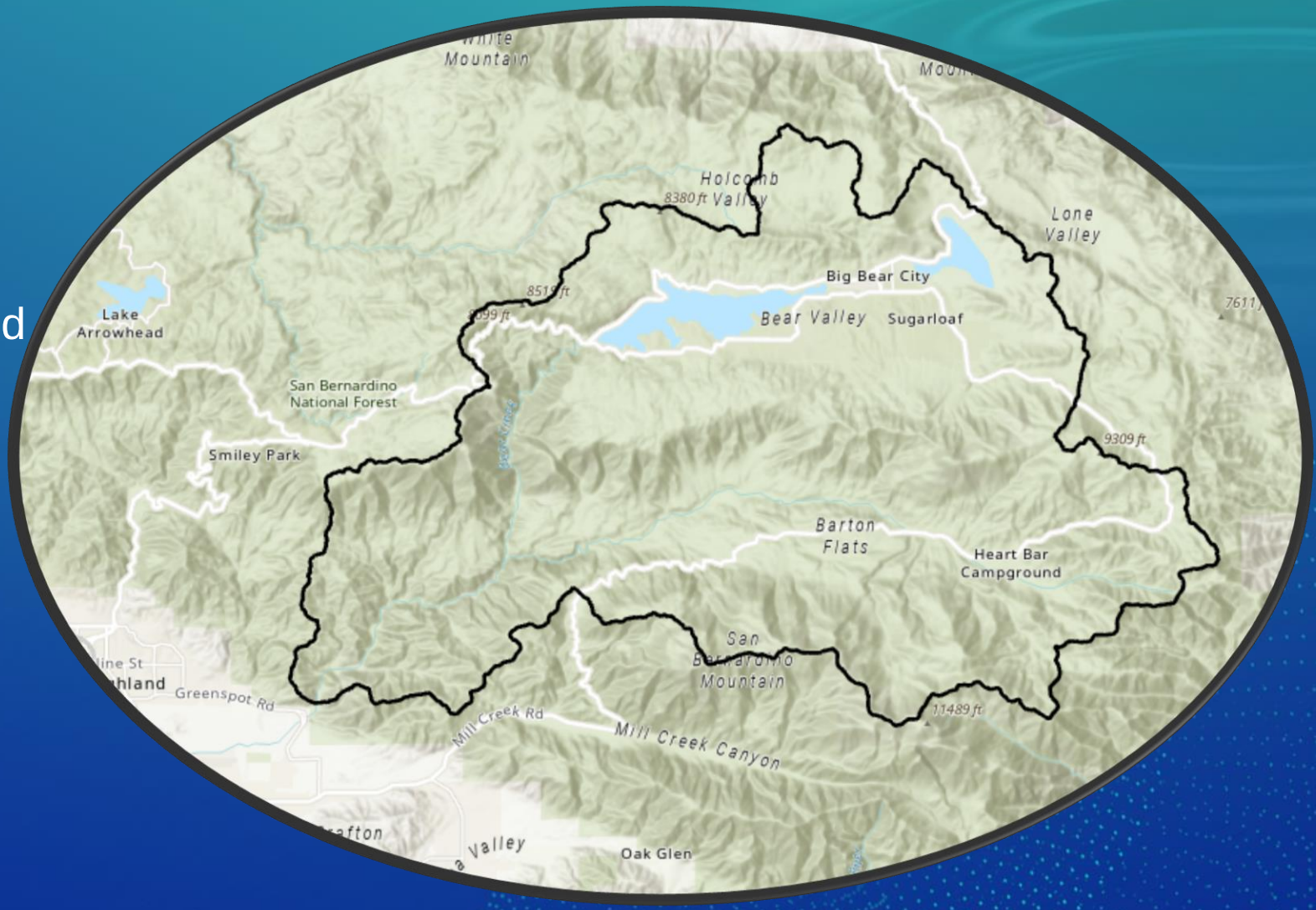
One physical parameter controls it all (but few would be OK too)

Stream threshold = 1 km sq.



In a perfect world – using different DEM

- Using 1m Lidar-derived DEM.
- 2018, consistent collection effort (post fires).
- 13 tiles from USGS 3DEP clipped to the AOI.
  - Cells: ~ 25,000 by 39,000 (rows by columns)
  - ~ 100 times bigger than the 10m DEM
  - SR: UTM Zone 11N



In a perfect world – using different DEMs

5 km^2 stream origination threshold

Metrics \ DEM	10m DEM	1m DEM
Cells (rows by columns)	2,600 by 3,900	25,000 by 39,000
Stream threshold (cells)	50,000	5,000,000
Flow direction (time)	9”	10’ 14”
Stream definition (time)	9“	9’ 16”
Catchment (time)	2”	5‘ 55”
Number of features	61	67

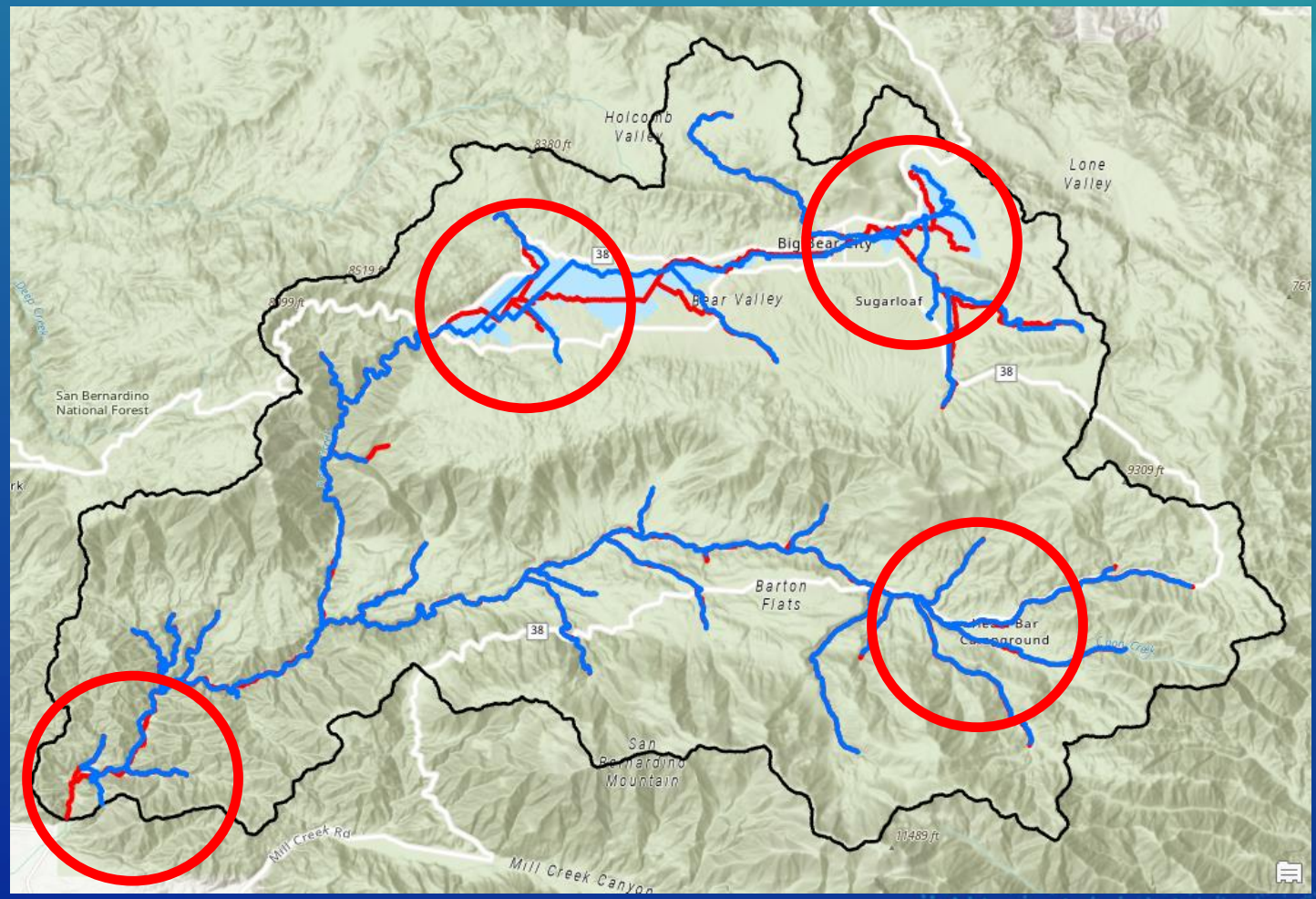
In a perfect world – using different DEMs

5 km^2 stream origination threshold

Streams

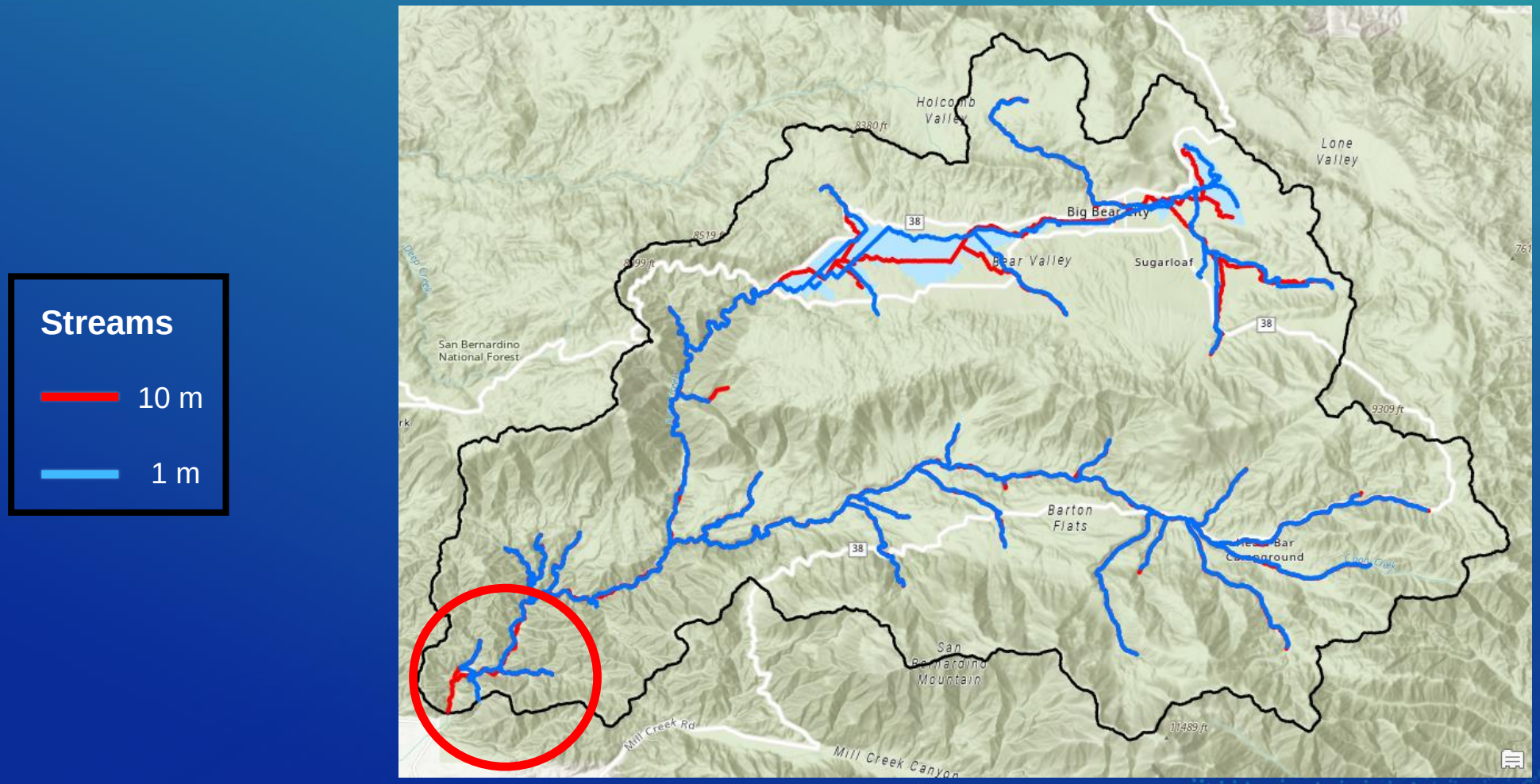
10 m

1 m



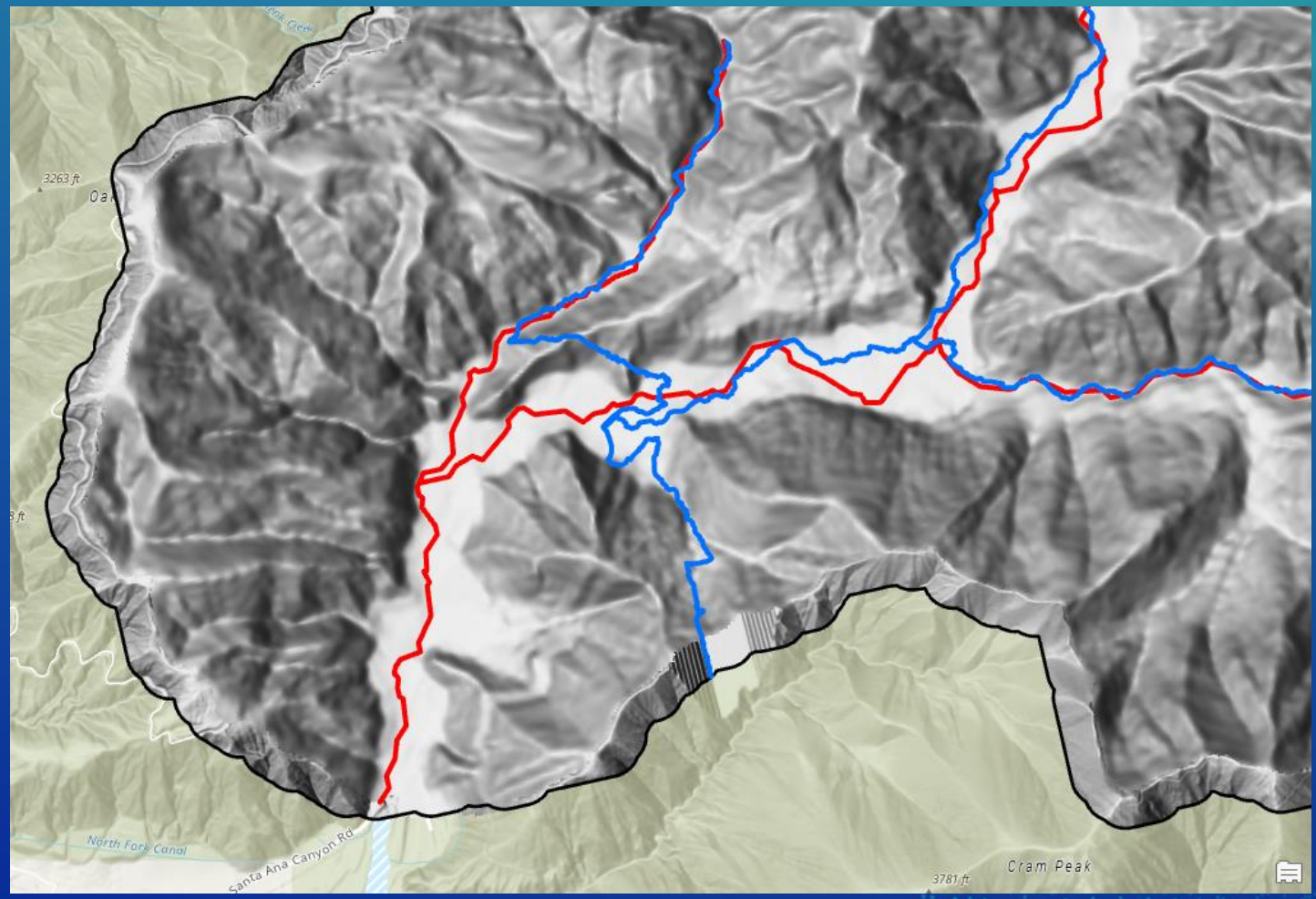
In a perfect world – using different DEMs

5 km^2 stream origination threshold



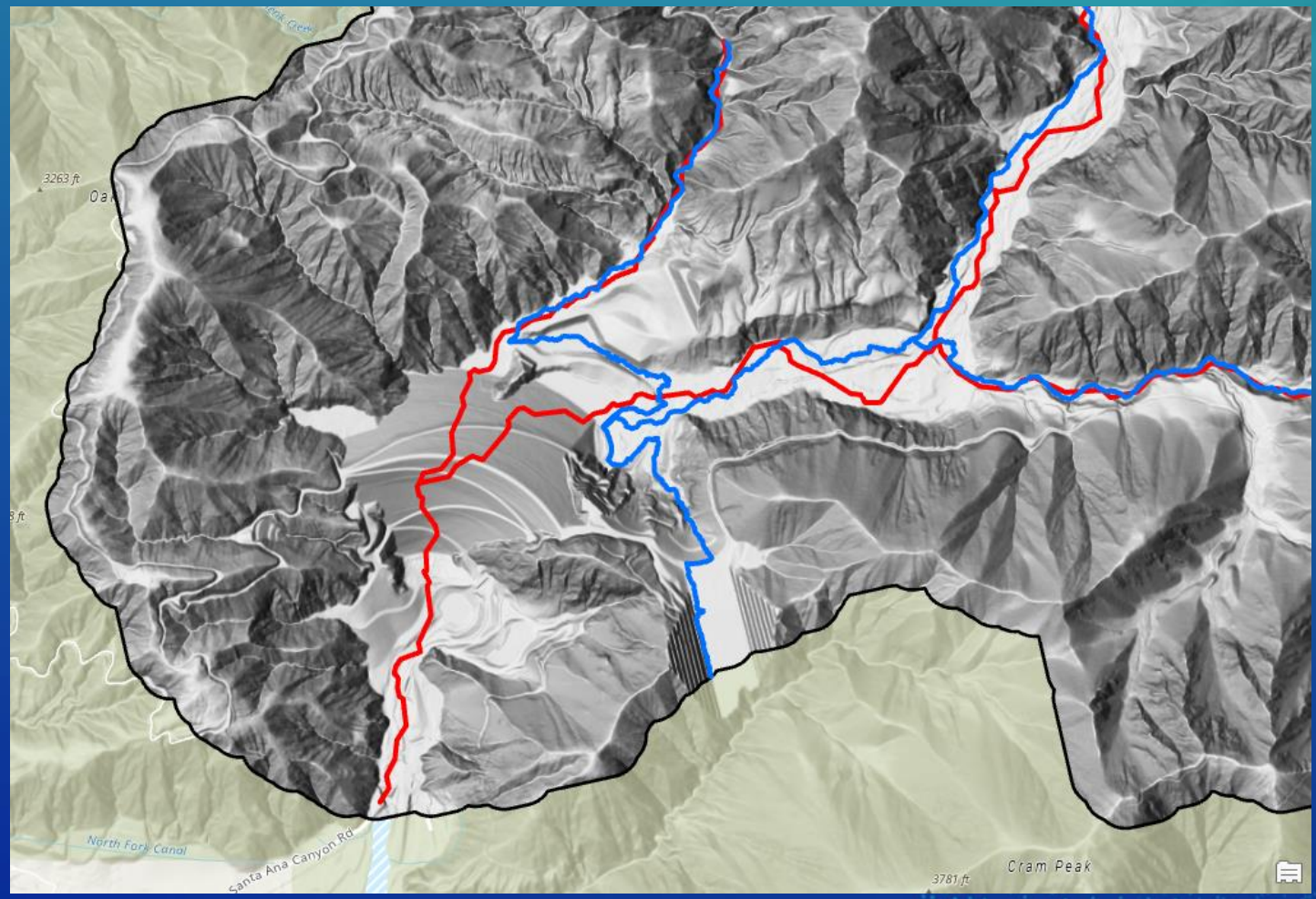
In a perfect world – using different DEMs

5 km^2 stream origination threshold



In a perfect world – using different DEMs

5 km^2 stream origination threshold

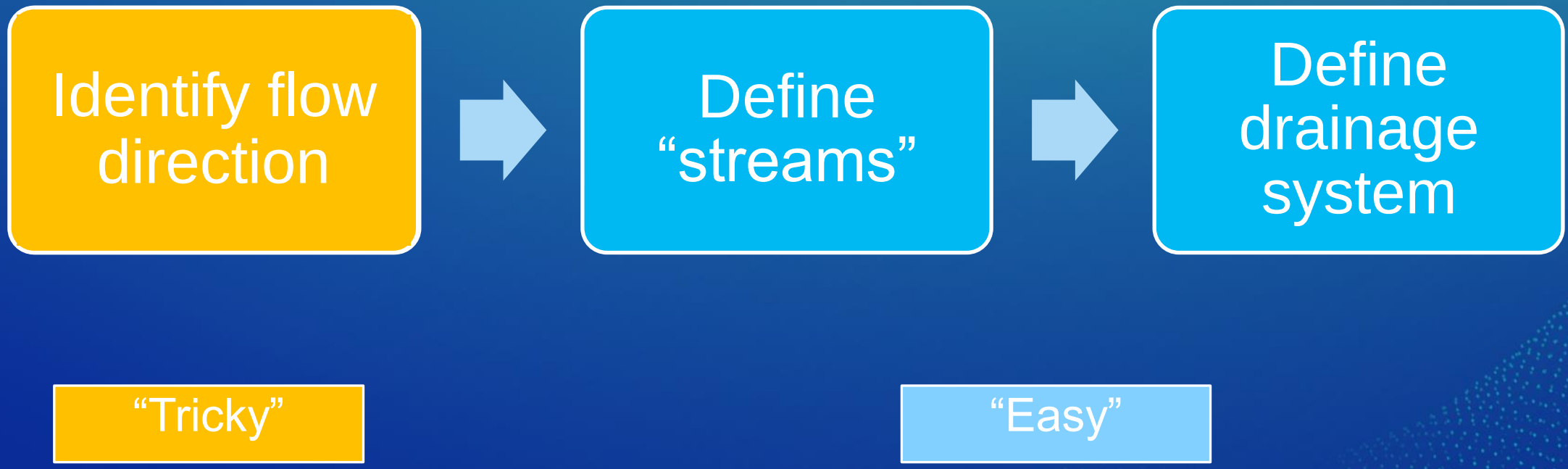


In a perfect world …

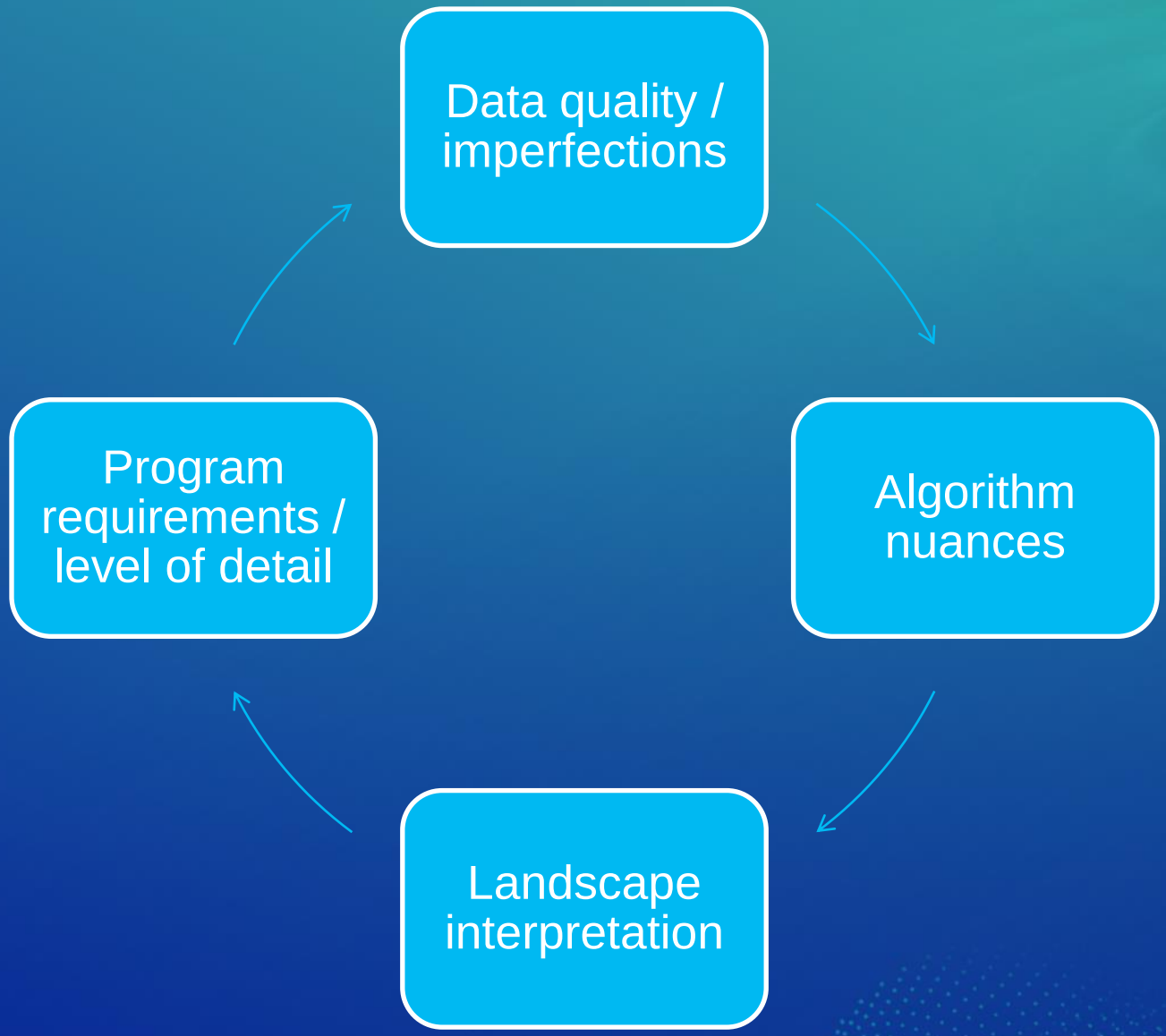
… but that is not the world we live in

Hydro Feature Extraction: In a not so perfect world …

Basic workflow

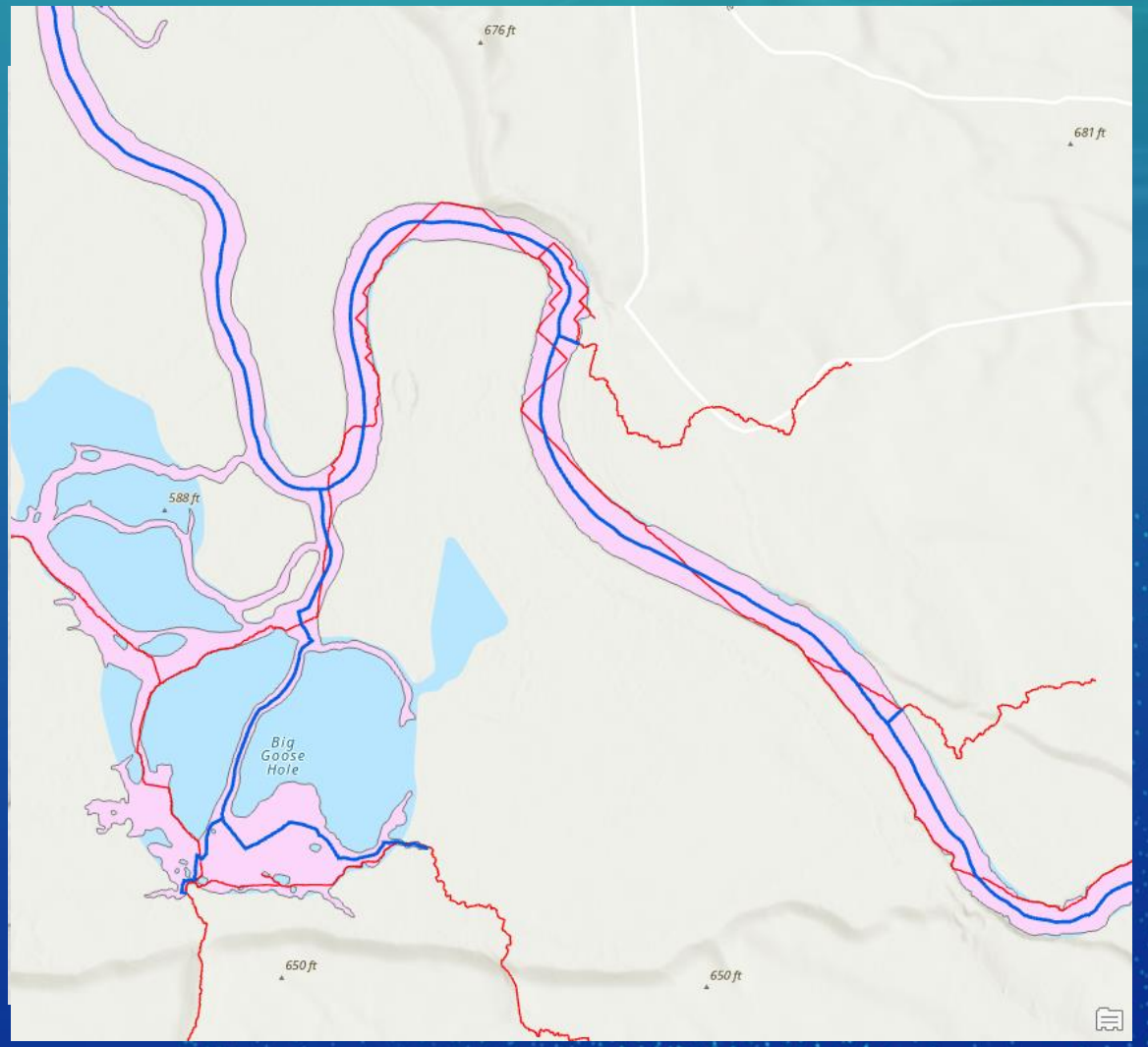


Reality


Data quality / imperfections
Algorithm nuances
Landscape interpretation
Program requirements / level of detail

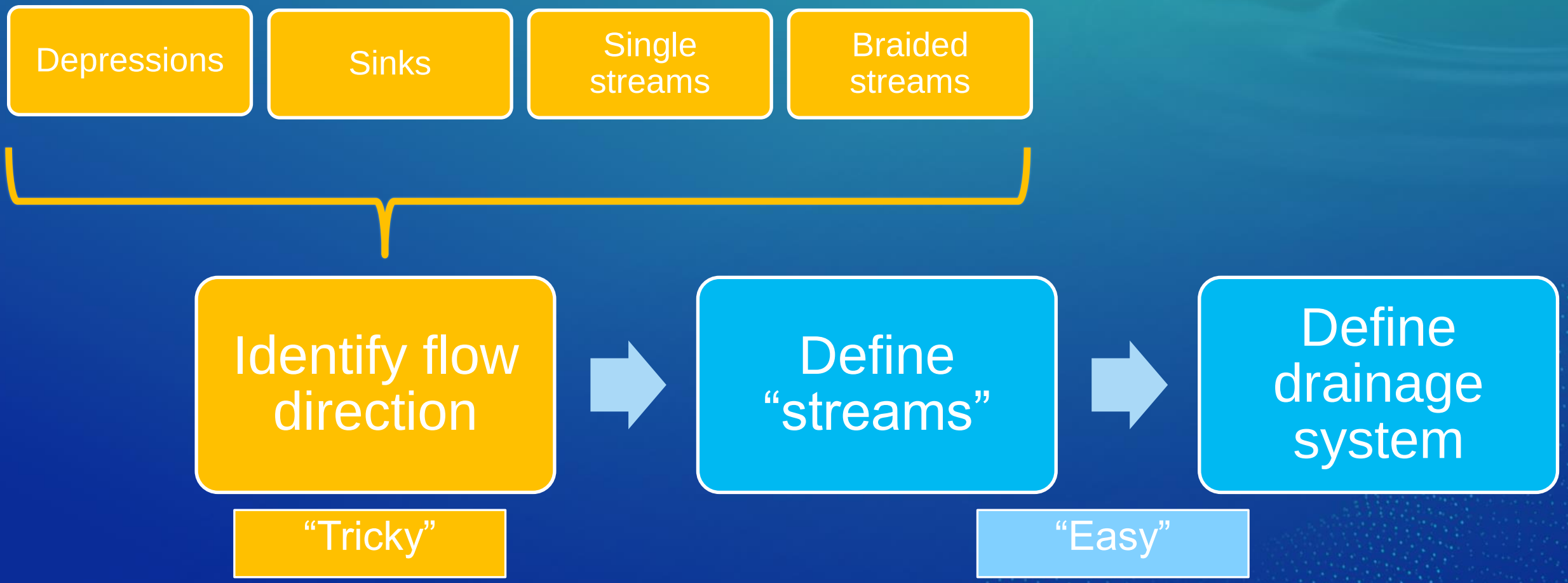
Help thy algorithm

- Some algorithms are better than others depending on the ultimate analysis goal.
- But do not change the algorithm each time something goes wrong. Instead:
  - Control through parameters.
  - Control through data.
- Depressions.
- Flat areas.



Hydro Feature Extraction: In a not so perfect world …

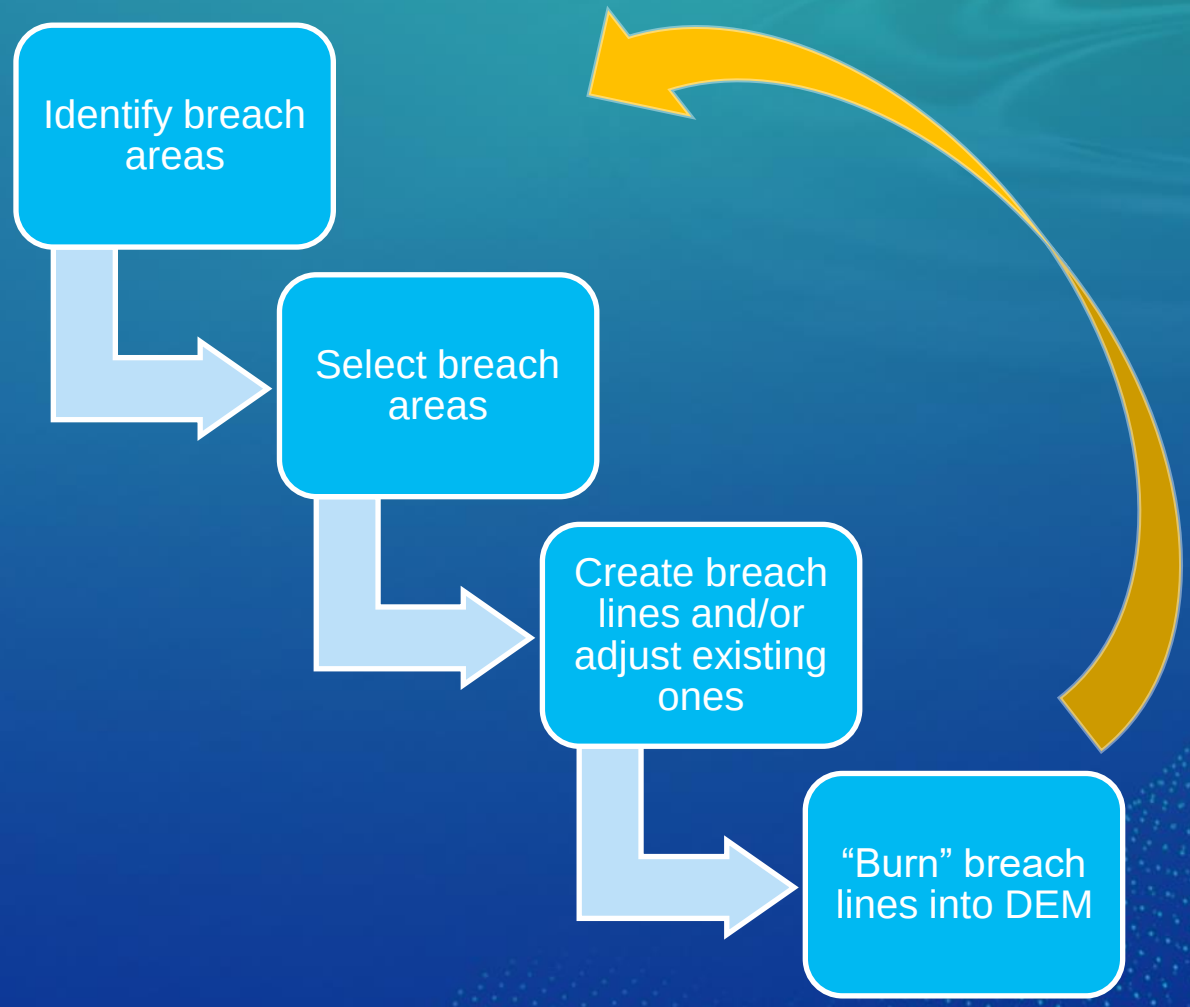
Extended workflows



Tools

Depression adjustments: tools

- Depressions – real (keep them) or not (breach)?
  - Known structures
  - Leverage other sources
    - Roads, railroads, imagery, …
  - Hydrography vs. hydrology
- Breaching process
  - Straight line
  - Something else?

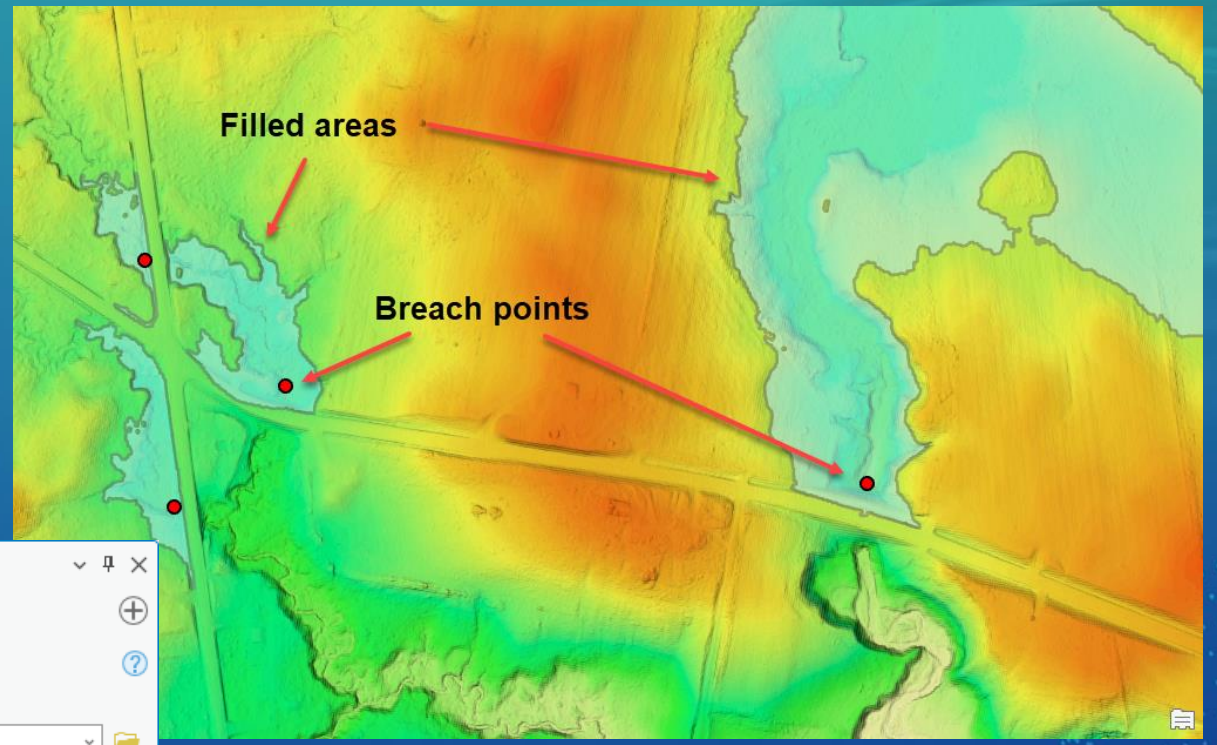


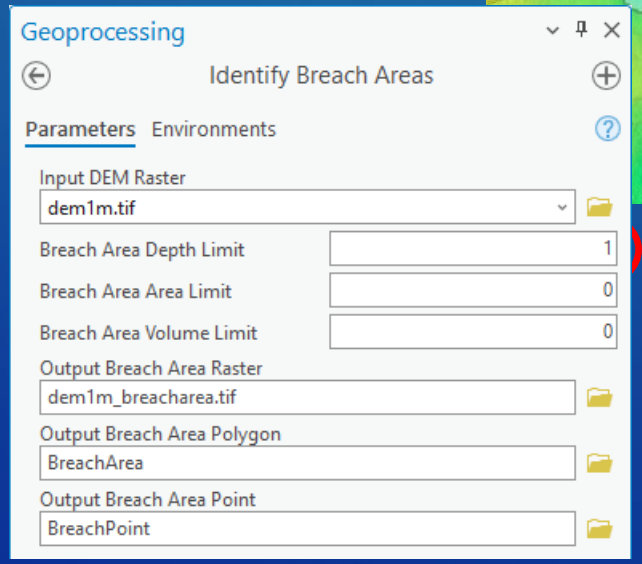
Depression adjustments: overview of steps

1. Identify potential areas needed to be breached
2. Select areas that need to be breached
3. Create breach lines
4. Adjust alignment for existing structures (optional)
5. “Burn” culverts into DEM
6. Run “stream” extraction on “burned” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Identify potential areas needed to be breached

- Arc Hydro tool “Identify Breach Areas”
- Only DEM as input
- Ability to do initial sub-selection based on:
  - Area
  - Depth
  - Volume
  - Area “shape” factors (as a separate analysis)





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2. Select areas that need to be breached
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4. Adjust alignment for existing structures
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6. Run “stream” extraction on “burned” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Select areas that need to be breached

- Use standard GIS selection methods
- Leverage additional data such as:
  - Roads
  - Railroads
  - Known sinks and lakes (that do not have to be breached)
  - Soils
  - …
- Potential for statistical analysis of existing structures w/r to their topographic indicators
  - Would add new rules to “real” depression area selection

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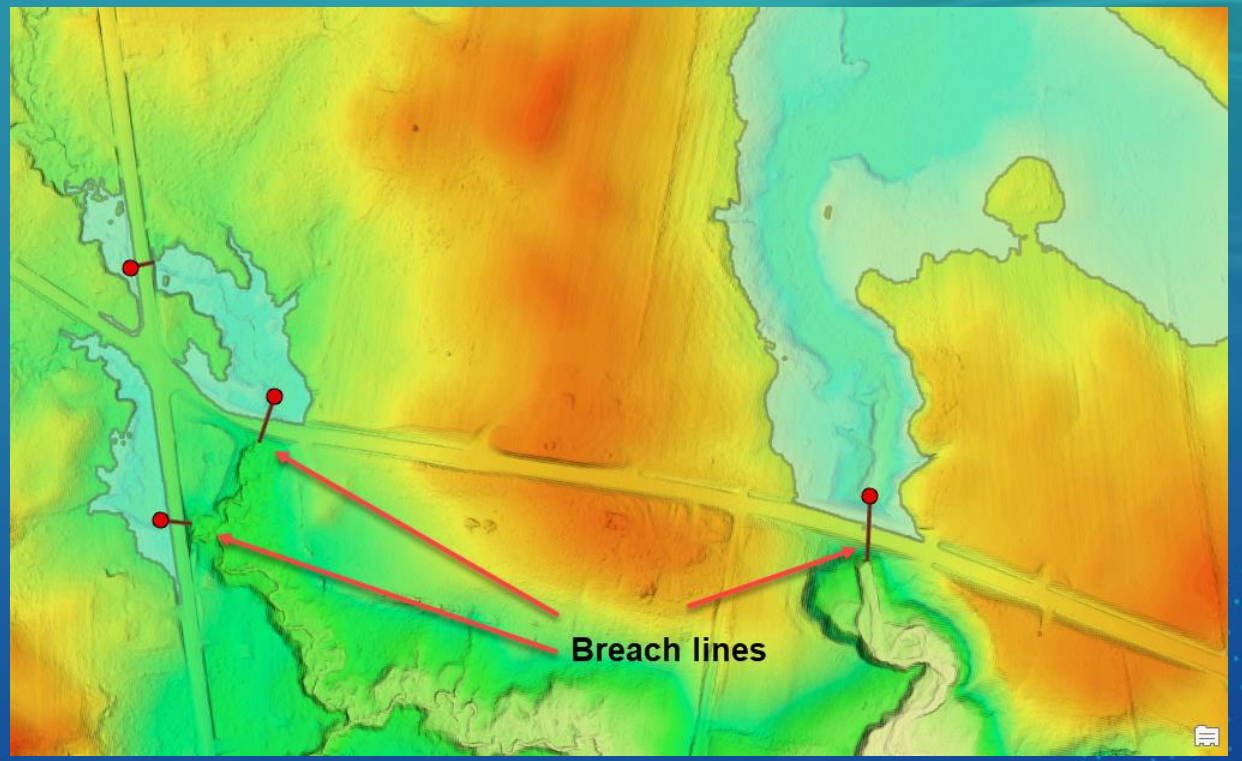
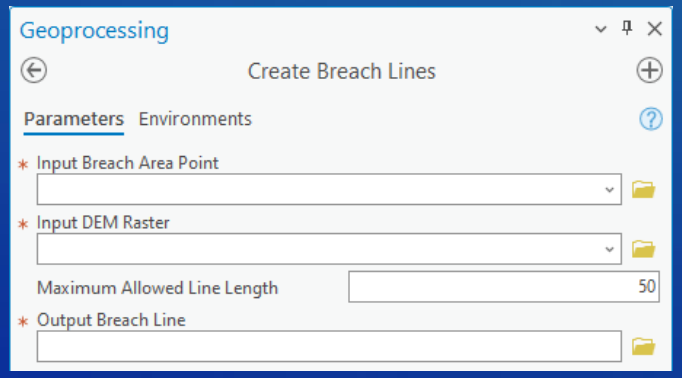
Create breach lines

- Arc Hydro tool “Create Breach Lines”
  - Looking for a closest, lower point within specified buffer distance.
- Possible enhancement to implement variable breach length.





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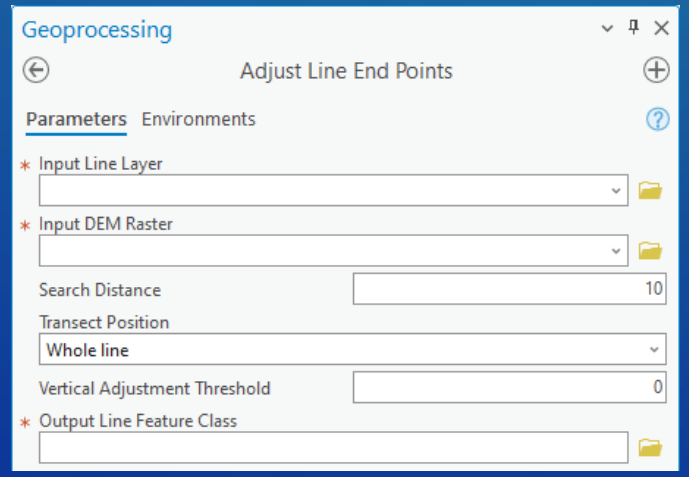
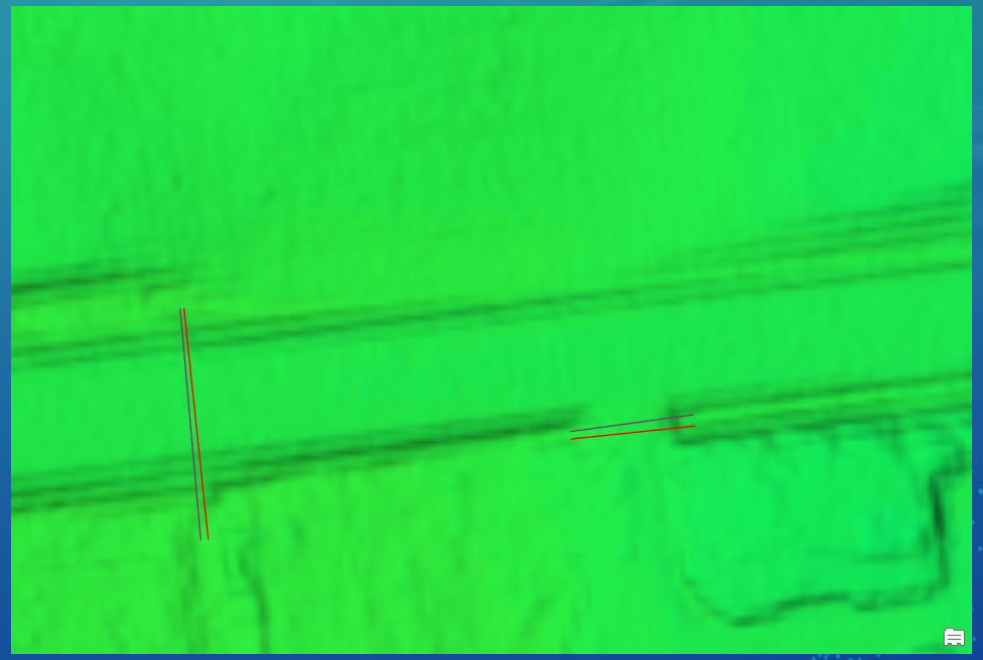
Adjust alignment for existing structures

- Arc Hydro tool “Adjust Line End Points”
- Used when culverts have not been derived from current DEM (e.g. digitized) or using different automation techniques that do not guarantee proper alignment of culvert end points.





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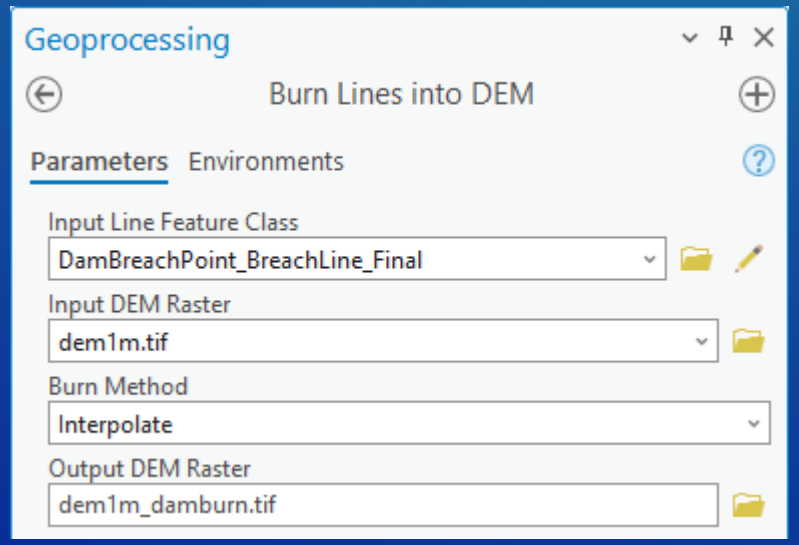
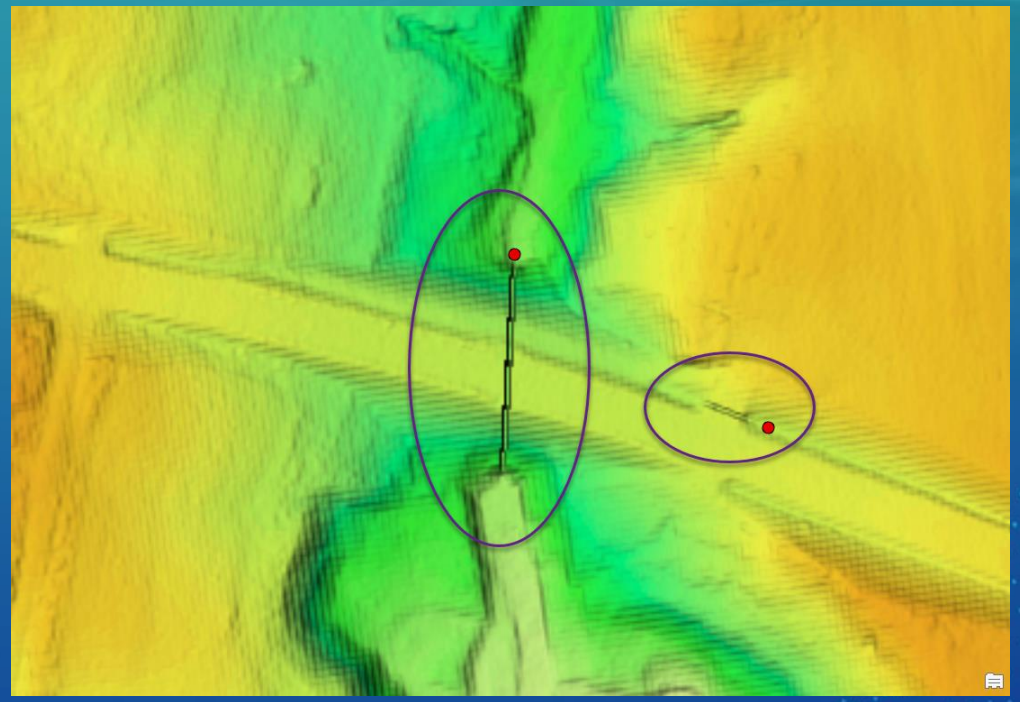
“Burn” culverts into DEM

- Arc Hydro tool “Burn Lines into DEM”
- Locally enforce culverts into DEM
- This could be optional, depending on the approach to manage infrastructure (focus on overall flow patterns or explicit management of stormwater infrastructure)





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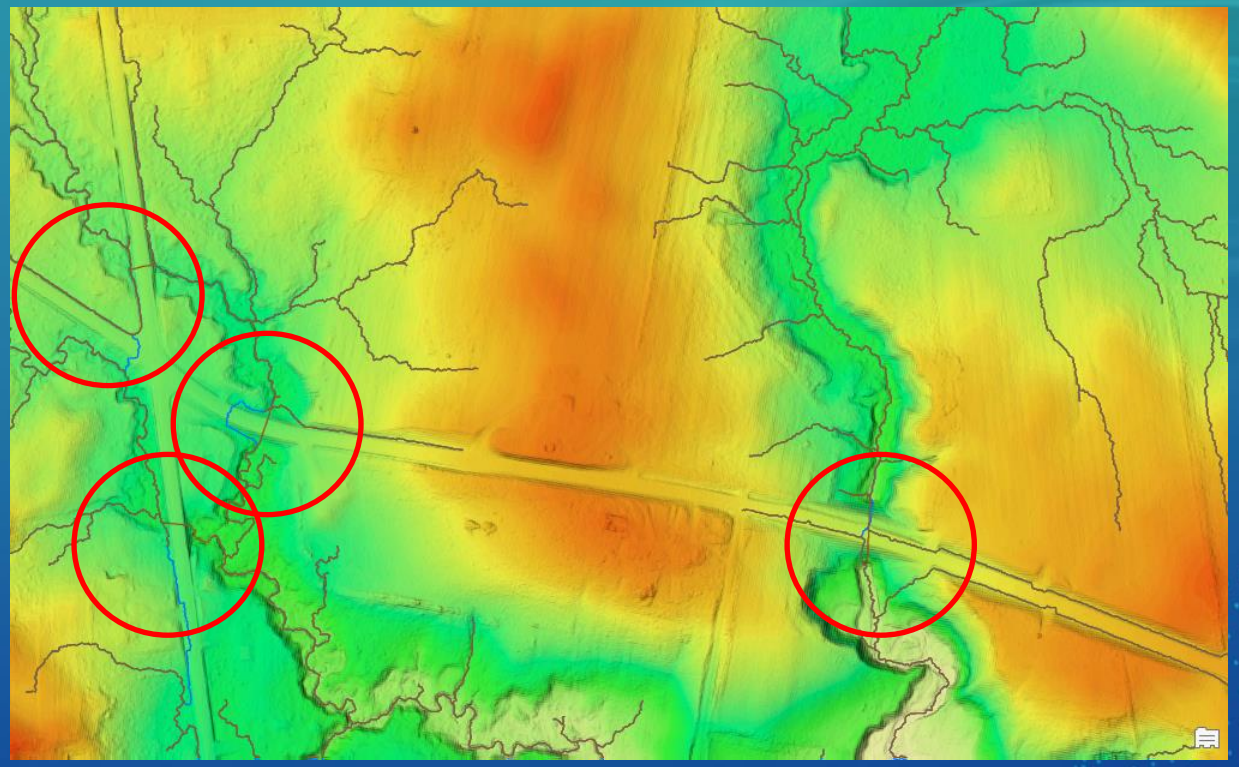
Run “stream” extraction on “burned” DEM

- This should be combined with other AH tools/workflows (e.g. for flat area flow enforcement)
- Arc Hydro tools:
  - “Flow Direction and Accumulation Using CF”
  - “Stream Definition”
  - “Stream Segmentation”
  - “Drainage Line Processing”



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Check for remaining flow path issues

- Back to the “Big Picture” – look at overall flow pattern.
- Check if there are any remaining potential areas needed to be breached.
- Make any necessary adjustments.
- Rerun some aspects of the workflow as necessary.

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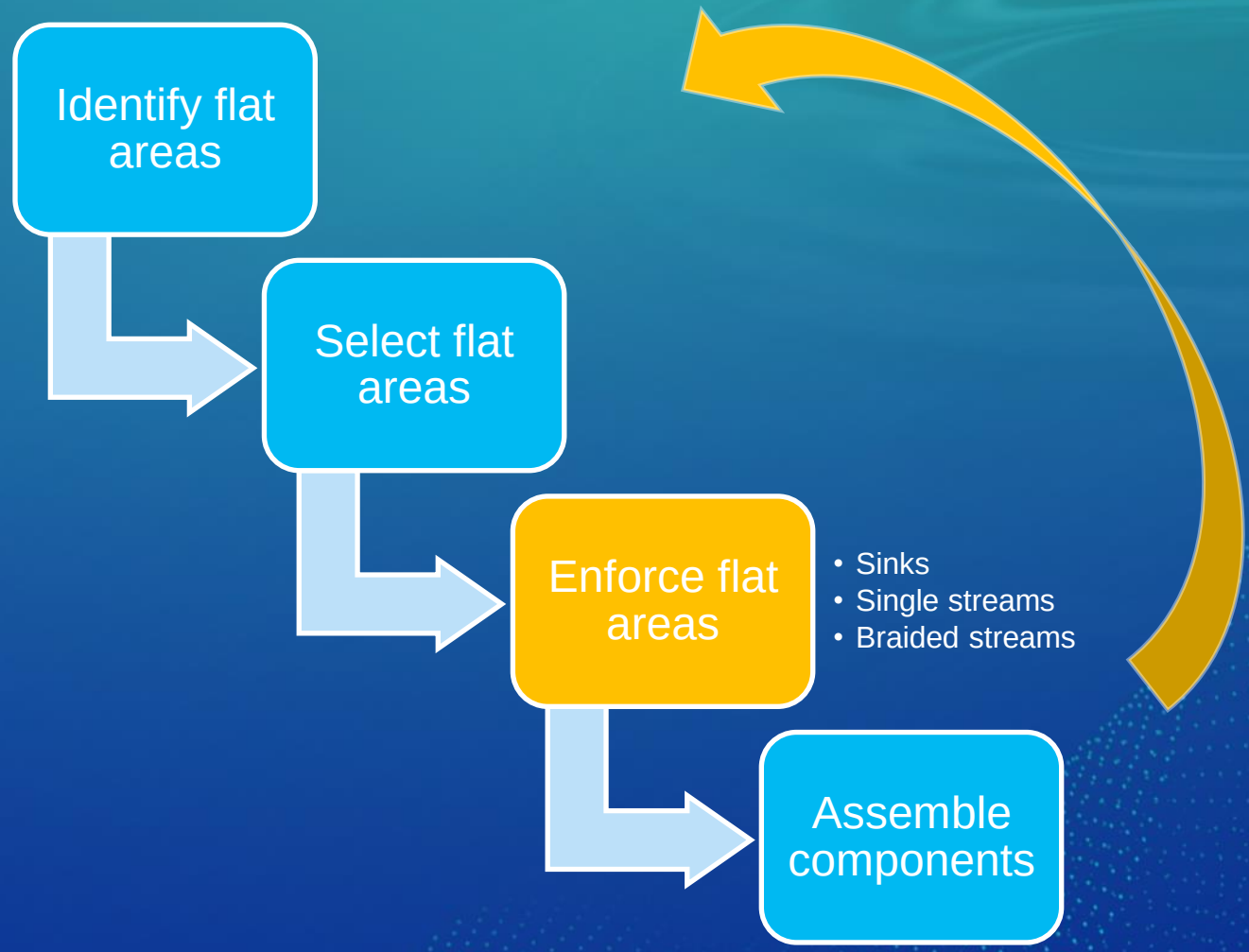
Flat area processing: tools

- Hydro-flattened DEM – where's water (and when)
  - Why don't we have bathymetry – and does it matter?
- Flat area processing
  - Identification
  - Processing
    - Sinks
    - Main stem enforcement
    - Braided system implementation
- Assembling components into a full drainage system



Flat area processing: overview of steps

1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
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6. Run “stream” extraction on “hydro-adjusted” DEM
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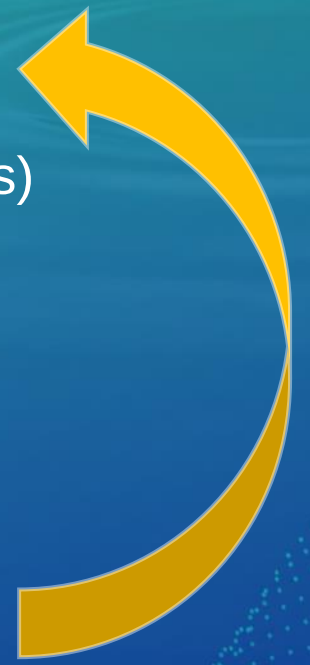
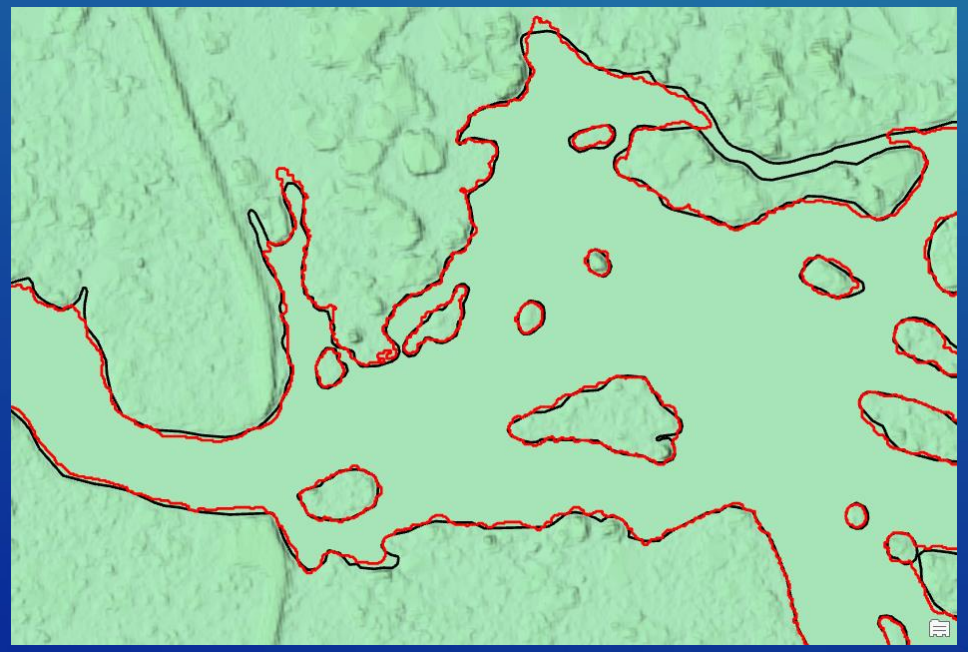
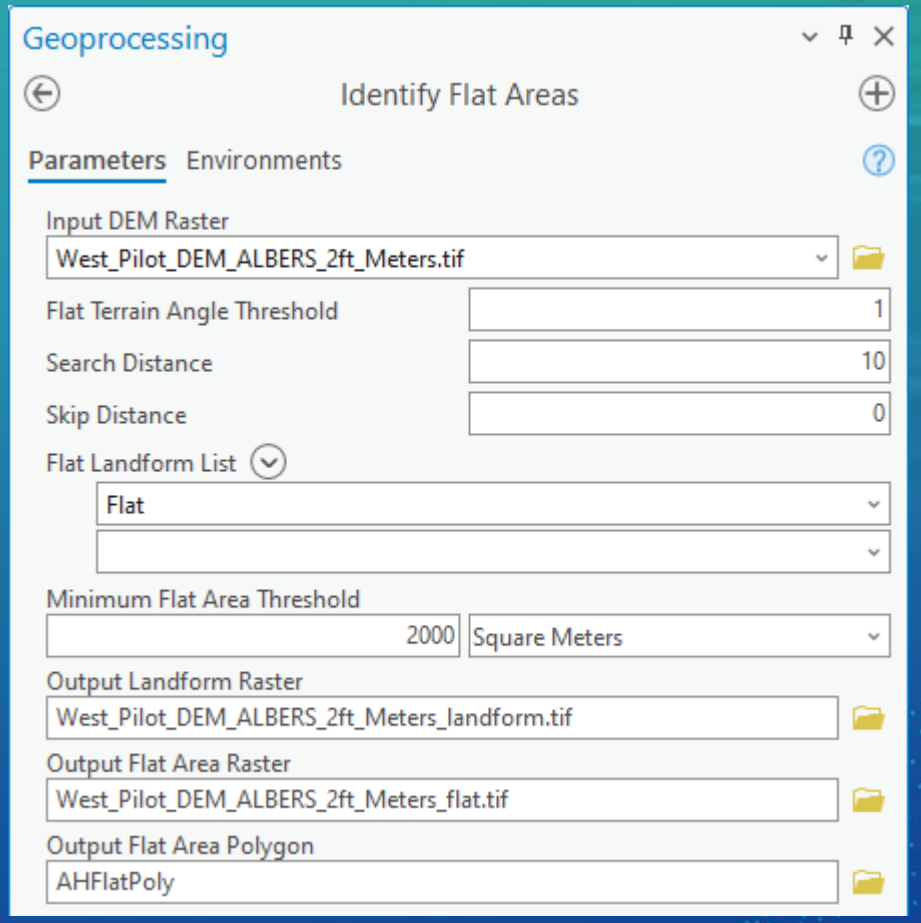


Identify potential flat areas

- Polygons might be provided with DEM
- Arc Hydro tool “Identify Flat Areas”
  - Leverage new geomorphon landform tool in Pro 3.1
  - Only DEM as input





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Select flat areas that need to be enforced

- Use standard GIS selection methods and understanding of type of terrain processing (dendritic, deranged, combined)
- Differentiate between:
  - Sinks (water comes in, but not out)
  - Lakes with single streams (water can come in from multiple places but exits from one place and there are no braids)
  - Lakes with braids (water can come in and out from multiple places and there can be braids)
- Might be beneficial to generate feature class for each category

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Enforce sinks – deranged and combined terrains

- Use sink feature class as “deranged” polygons in Arc Hydro tools/workflows.
  - Use in deranged and combined processing workflows.
- Also applicable to CF approach with flow direction adjustment in sinks.

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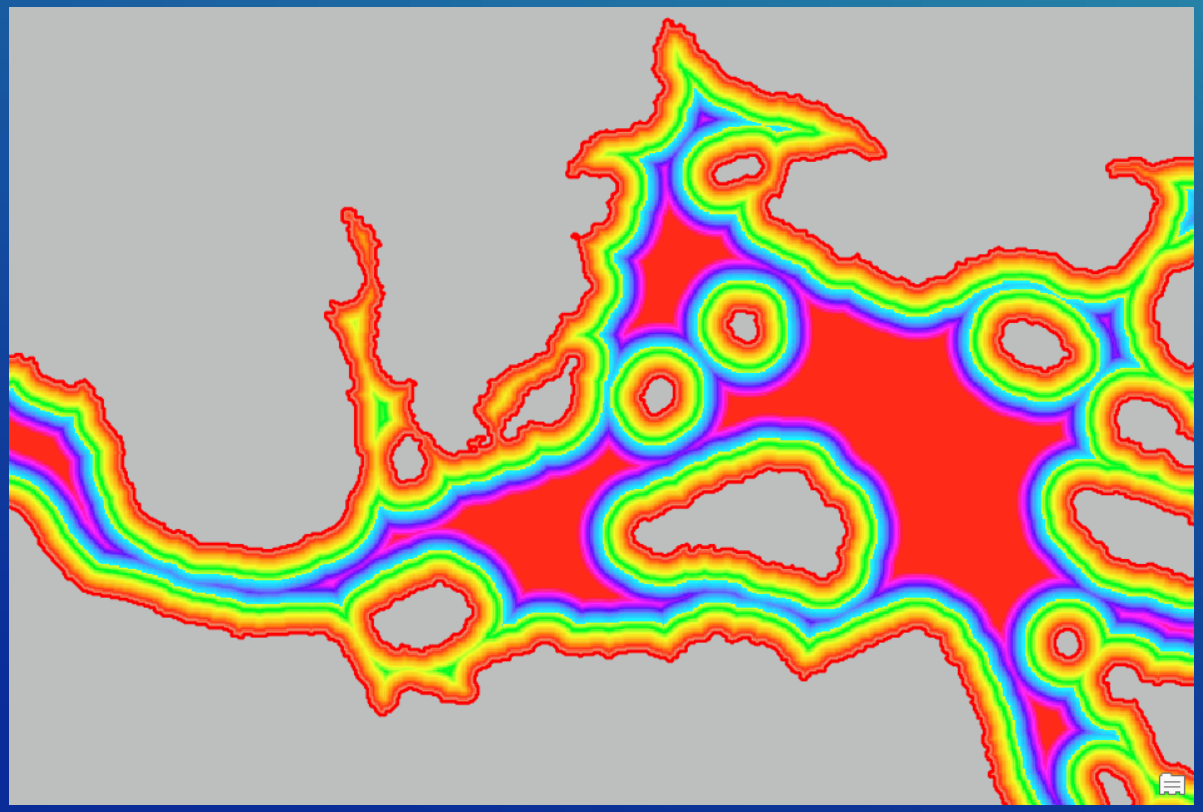
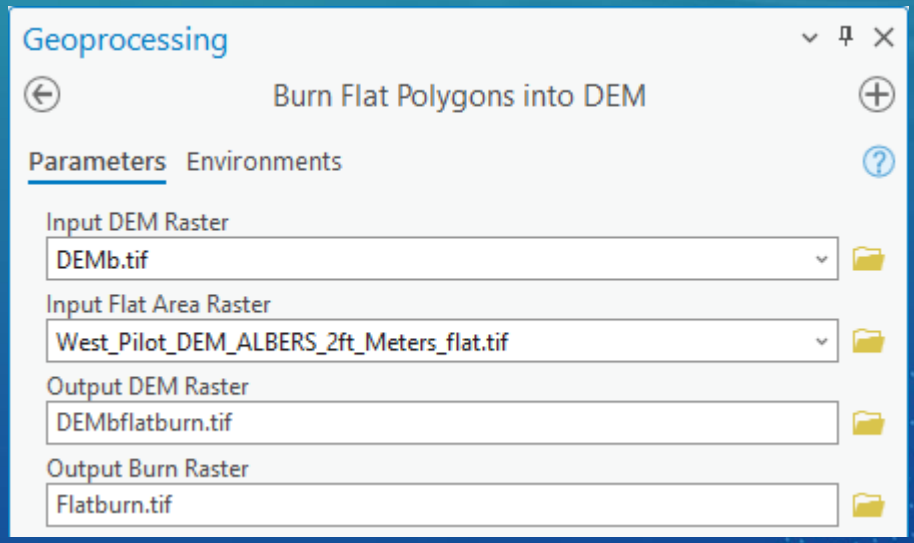
Enforce single streams - Burn Flat Polygons into DEM

- Arc Hydro tool “Burn Flat Polygons into DEM”
  - Use raster approach to “bowl” flat areas into DEM.





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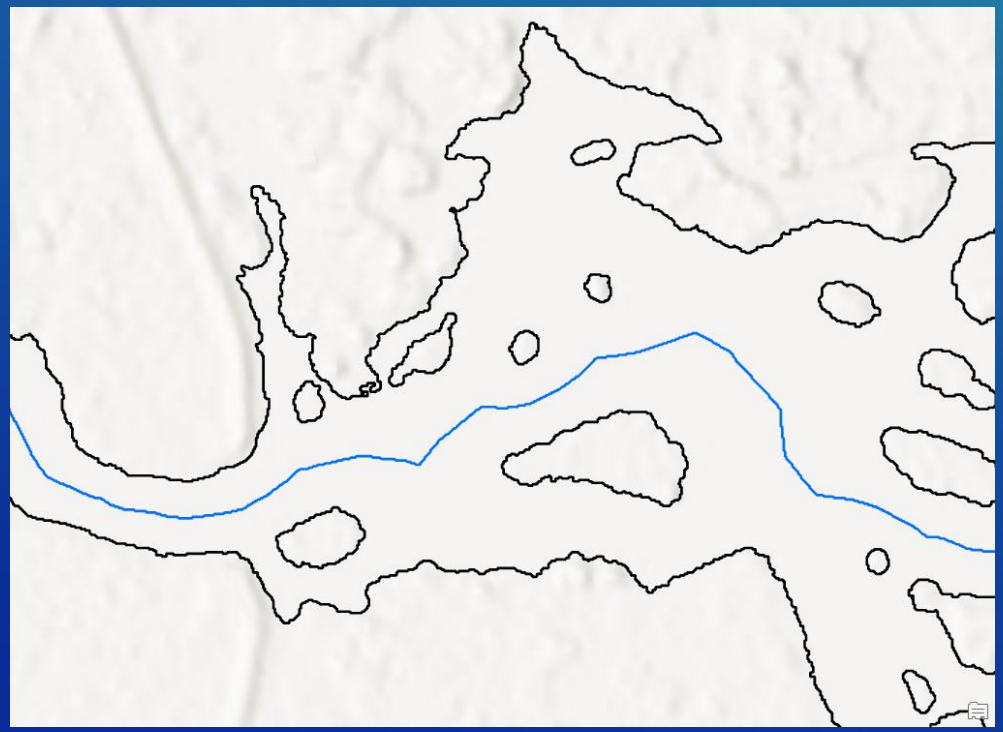
Enforce single streams – Continuous Flow approach

- Use SA tool “Derive Stream as Line” with “burned” DEM as input.
- Alternatively, use Arc Hydro stream derivation approach.



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Enforce braided streams – overall workflow

- Multi-step process with user input:
  - Tool “Derive Stream As Line” using “burned” DEM.
  - Arc Hydro tool “Create Flat Polygon Connectors”.
  - Arc Hydro tool “Define Flat Area Outlet Point”.
  - Tool “Collapse Hydro Polygon”.
  - Iterative process to refine loops/streams:
    - Arc Hydro tool “Remove Orphan Lines”.
    - Arc Hydro tool “Fix Line Orientation” (automated and manual).
    - Arc Hydro tool “Remove Line Pseudonodes” (optional).
    - Tool “Flip Line” (manual).
  - Arc Hydro tool “Burn Flat Polygons and Streams into DEM”.
  - Arc Hydro tool “Create Drainage Line Structures”.
  - Arc Hydro tool “Flow Direction and Accumulation Using CF”.
  - Arc Hydro tool “Adjust Flow Direction in Streams”.

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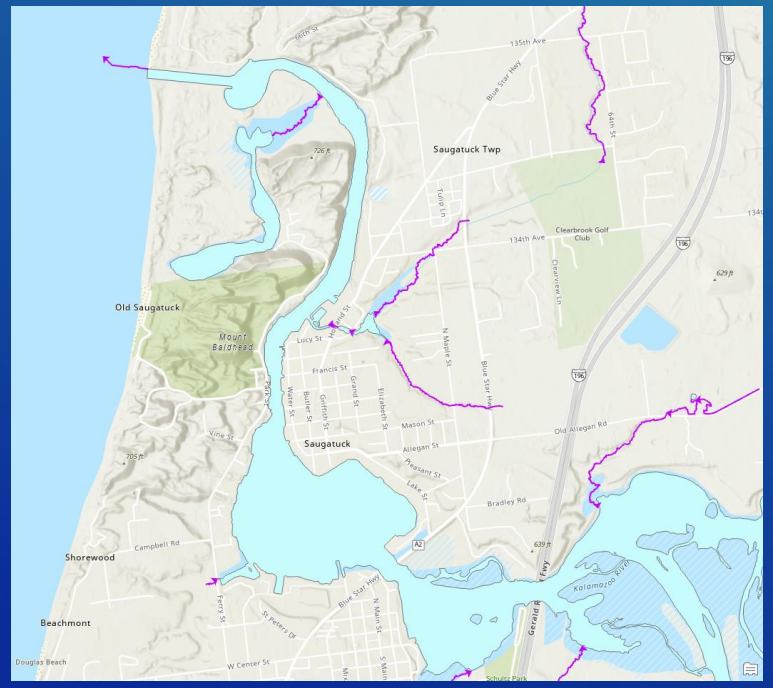
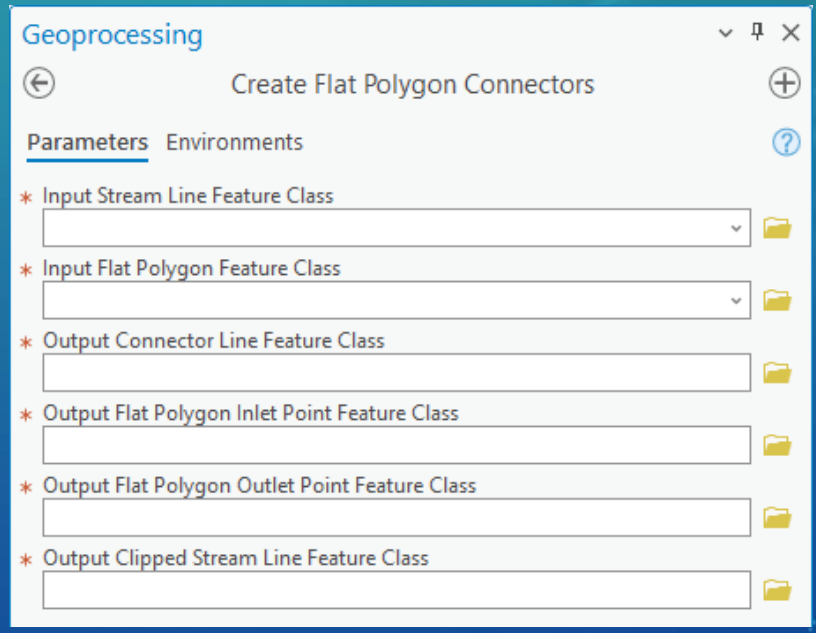
Enforce braided streams - Create Flat Polygon Connectors

- Arc Hydro tool “Create Flat Polygon Connectors”
  - Create lines outside of flat polygons
    - Must touch at least one flat polygon
  - Creates inlet and outlet points (into the polygons)





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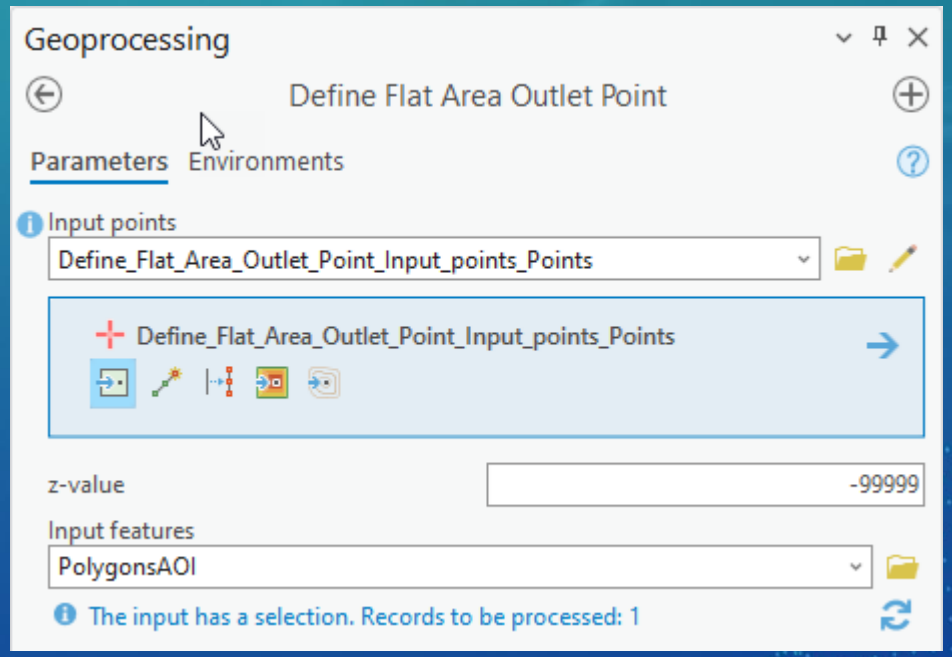
Enforce braided streams – Define Flat Area Outlet Point

- Arc Hydro tool “Define Flat Area Outlet Point”
  - New for Pro 3.2 and up.
- Define known most downstream point in the flat polygon system
  - Sets z value to -9999.0, for the vertex in the flat polygon under the outlet point
- Facilitates adjusting line orientation in downstream direction (performed by the next tool)



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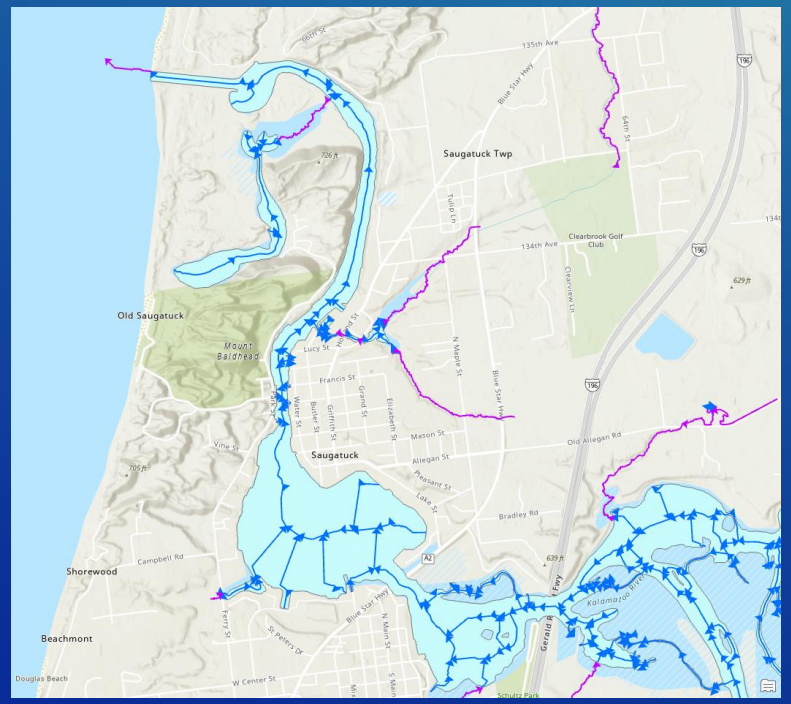
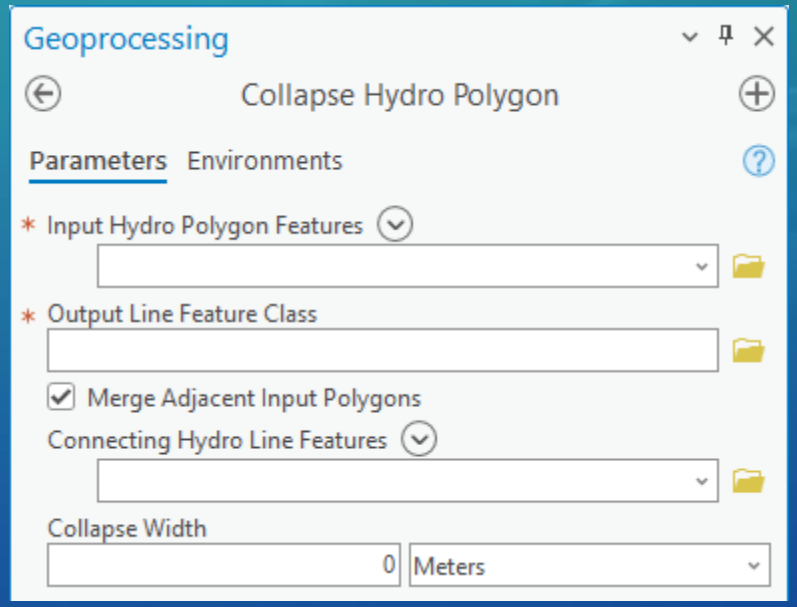
Enforce braided streams – Collapse Hydro Polygon

- Tool “Collapse Hydro Polygon”
  - New in Pro 3.2 - leverage z value of -9999.0 at the global outlet point.





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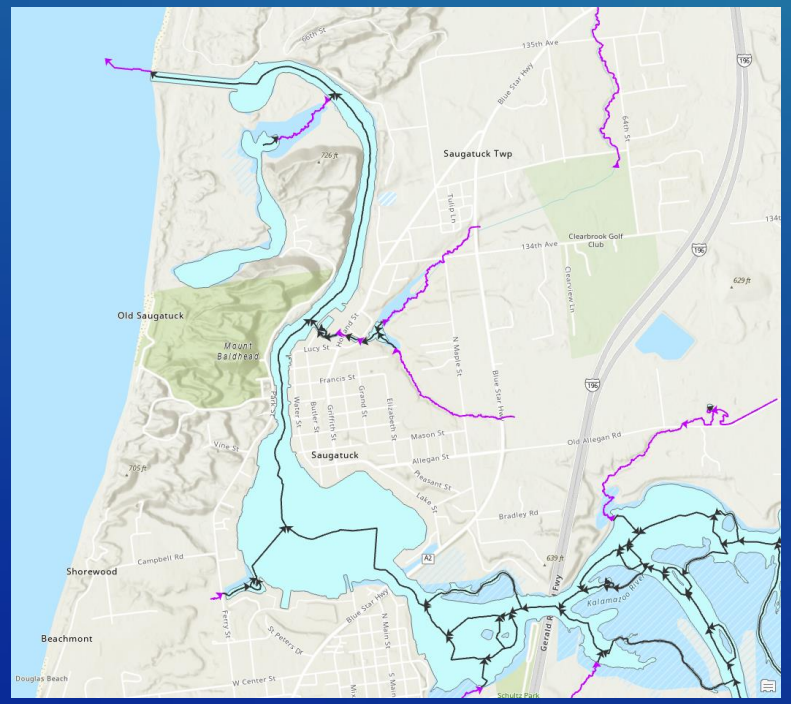
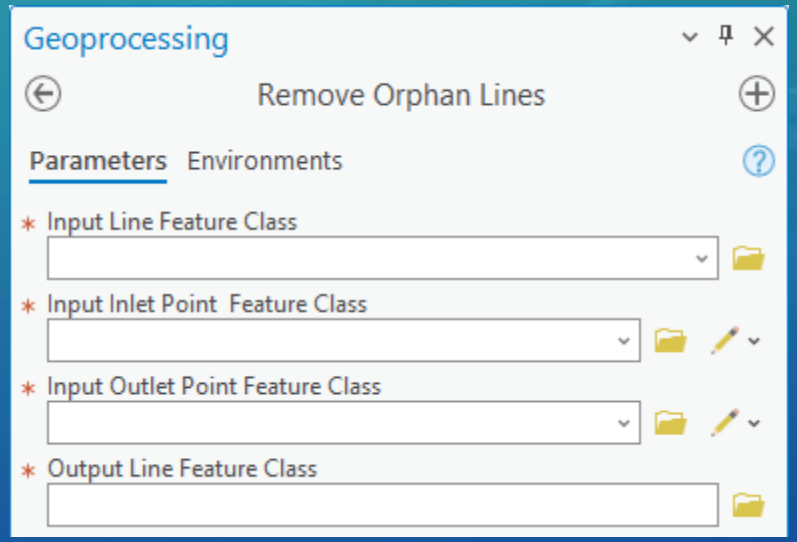
Enforce braided streams – Remove Orphan Lines

- Arc Hydro tool “Remove Orphan Lines”.
- Removes all lines not directly connected to inflow and outflow points or interconnected loops.
  - Isolated loops are removed.





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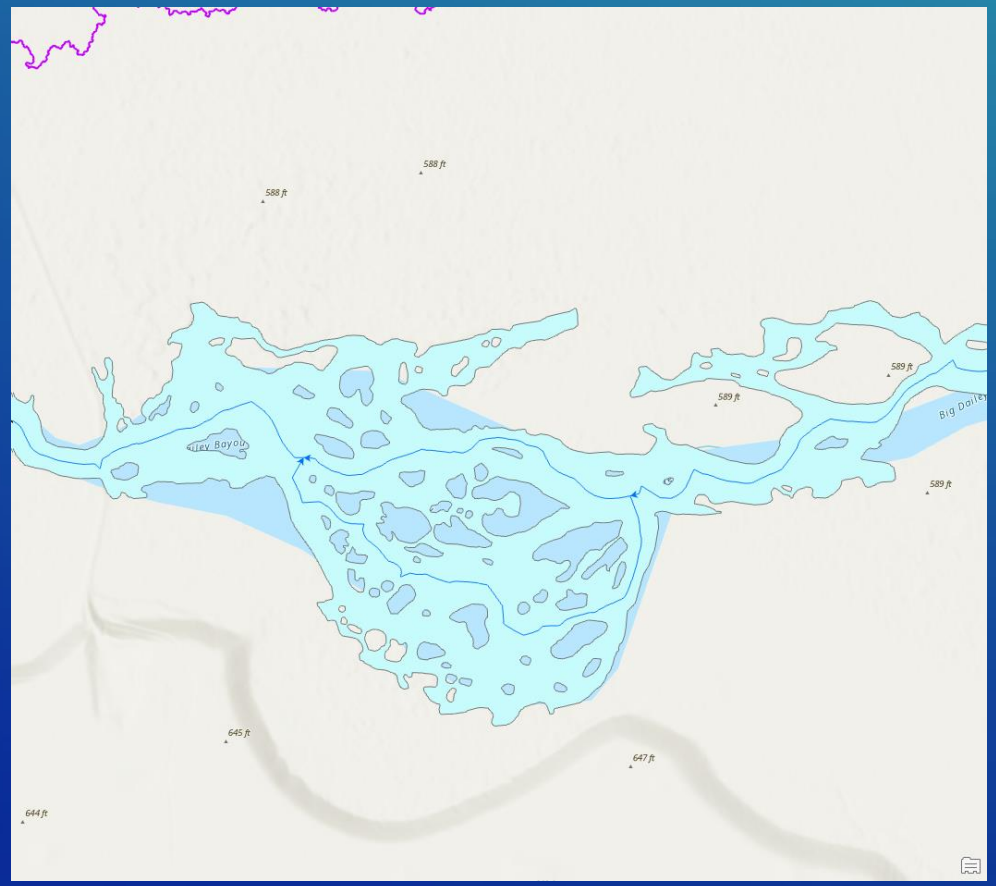
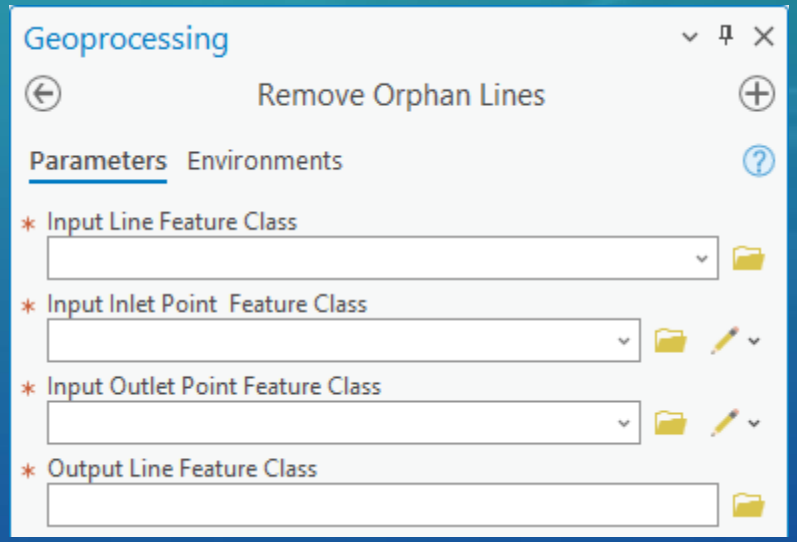
Enforce braided streams – Remove Orphan Lines

- Complex systems – additional “weeding” !?





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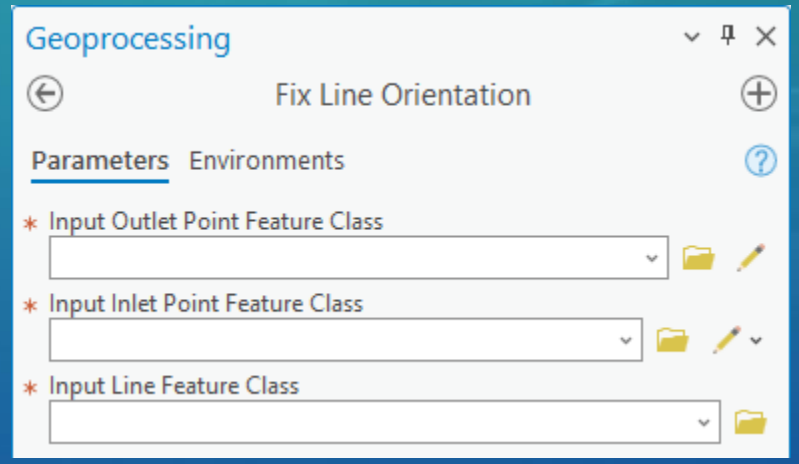
Enforce braided streams – Fix Line Orientation

- Arc Hydro tool “Fix Line Orientation”.
- Enforce orientation of lines in the system so they go from inflow to outflow points.
- Might need iterations through complex braided systems with multiple viable alternatives.
  - “DoNotProcess” field.
  - Operation on selected set.



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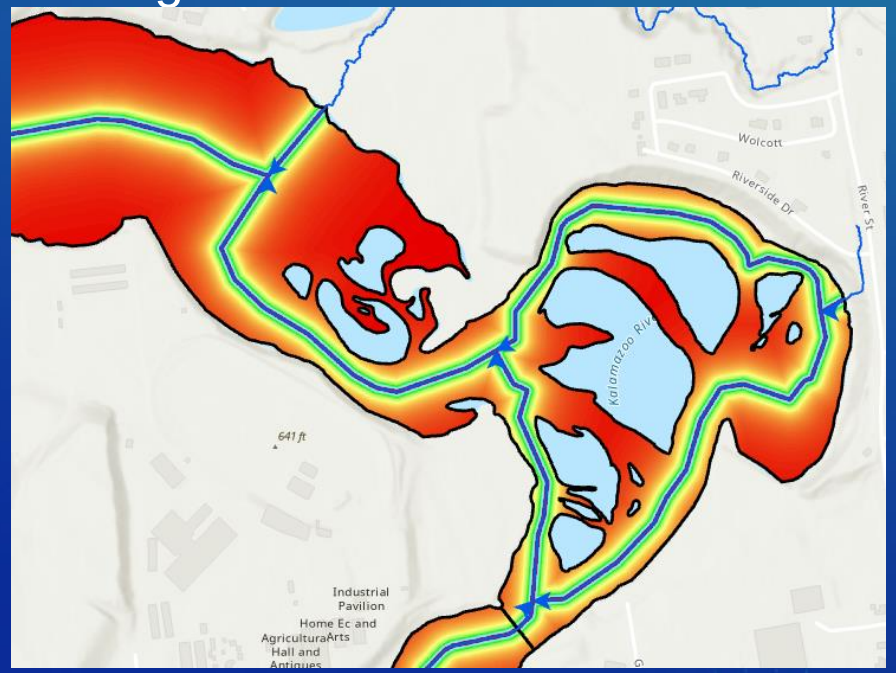
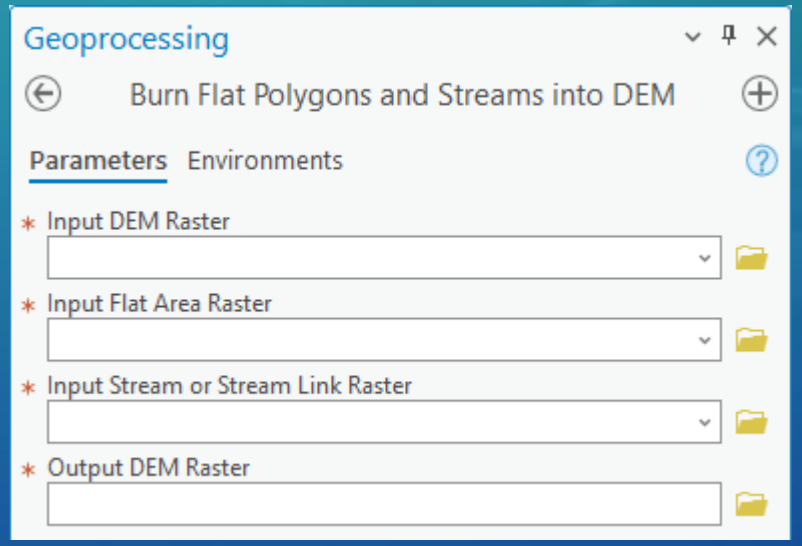
Enforce braided streams – “Bowl” elevation in flat areas

- Arc Hydro tool “Burn Flat Polygons and Streams into DEM”.
- Enforce elevation in flat areas so that the resulting flow direction flows from the flat area boundary into stream that is draining it.





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Enforce braided streams – final line enforcement

- Create connected network of stream elements outside flat areas and flat areas.
  - Standard data management operations.
- Arc Hydro tool “Create Drainage Line Structures”.
  - Creates raster and vector representation of the drainage system based on connected braided network.
- Arc Hydro tool “Flow Direction and Accumulation Using CF”.
  - Operating on “bowled” DEM.
- Arc Hydro tool “Adjust Flow Direction in Streams”.
  - Creates final flow direction that enforces braided streams.

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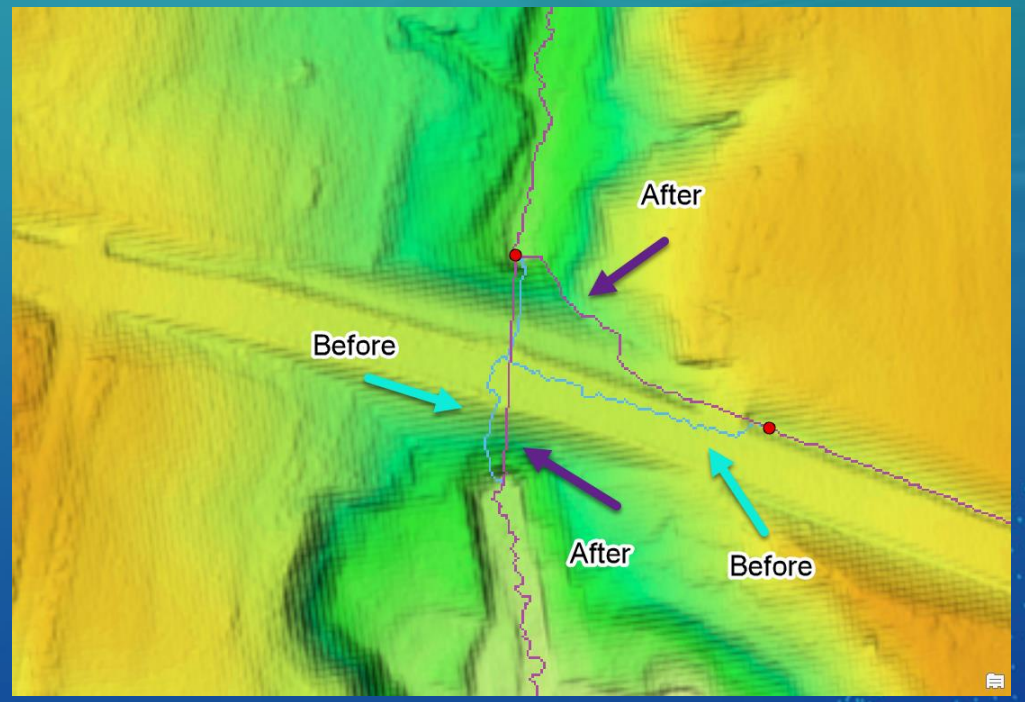
Run “stream” extraction on “hydro-adjusted” DEM

- Needed only for non-braided workflow – braided workflow already has final stream system identified.
- This should be combined with other AH tools/workflows.
- Arc Hydro tools:
  - “Flow Direction and Accumulation Using CF”
  - “Stream Definition”
  - “Stream Segmentation”
  - “Drainage Line Processing”



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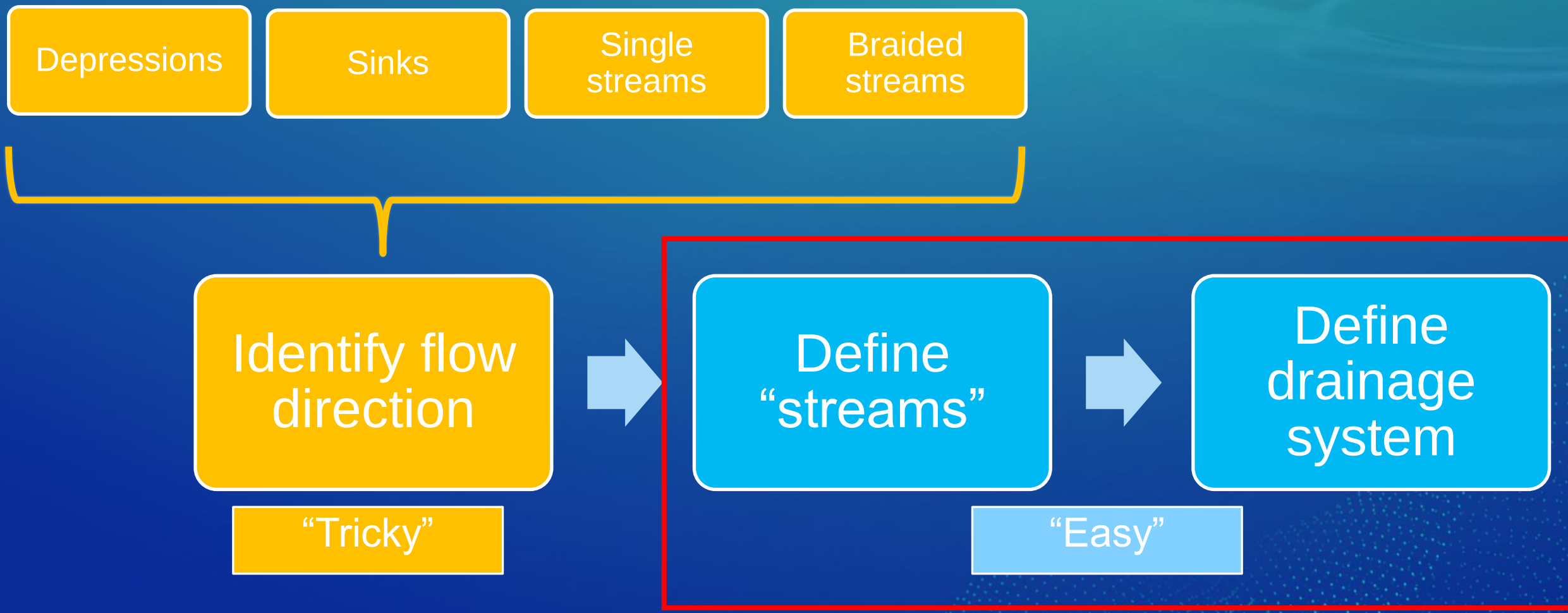
Hydro Feature Extraction: In a not so perfect world …

Extended workflows



Finalize drainage system

Extended workflow

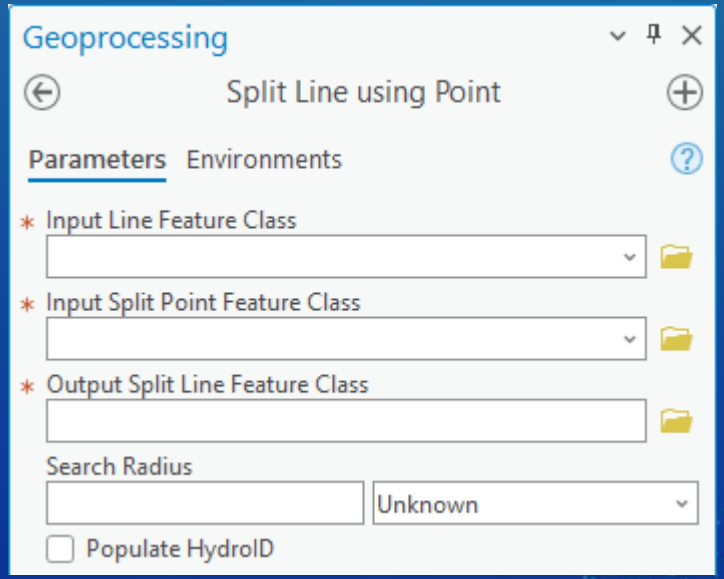
- Integrated vector and raster system (matching representation in both formats to maintain consistency and optimize performance of the analyses).

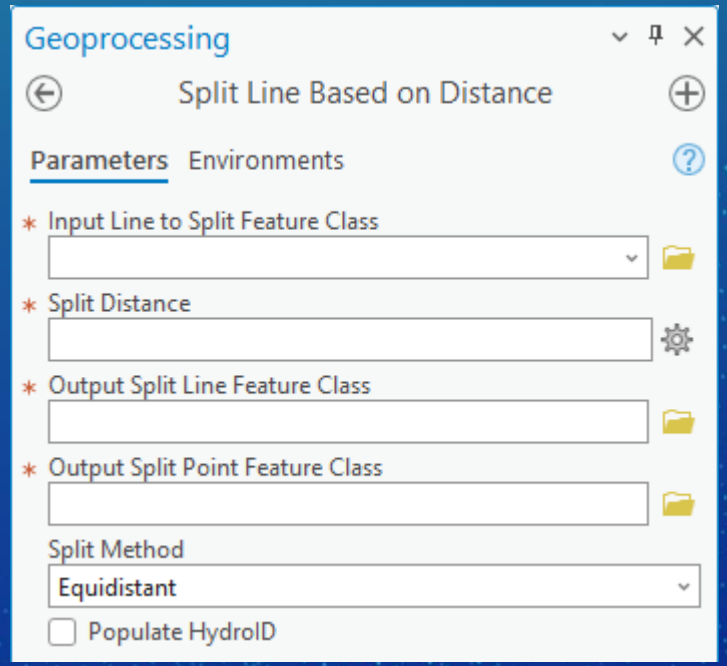
Physical NOT program rules (e.g. slopes, minimum drainage area, stream length, …)

Final stream partitioning

Optional – physically based

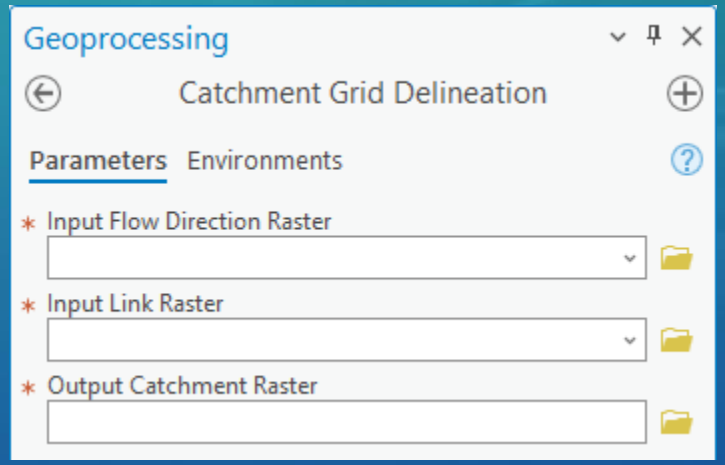
- Arc Hydro tools:
  - "Split Line using Point". (VIP)
  - "Split Line Based by Distance"
- Partition lines while maintaining the orientation and key identifiers (e.g. NextDownID").

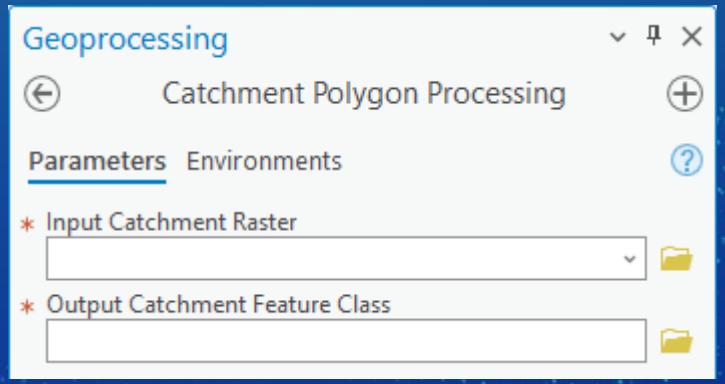




Defining catchments

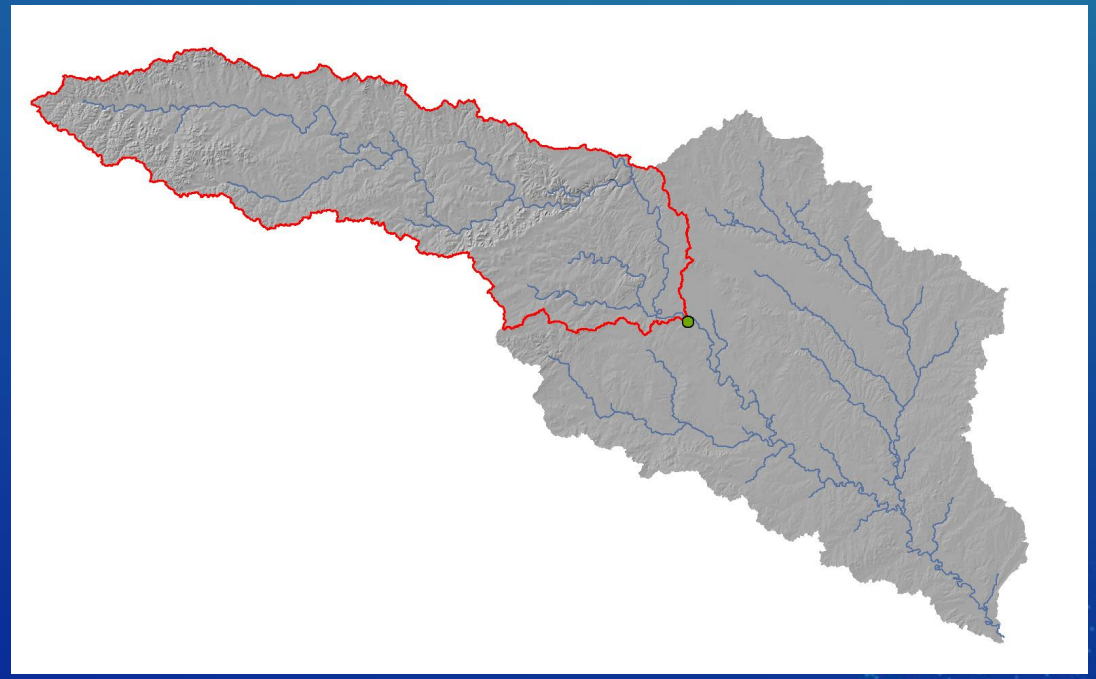
- Arc Hydro tools:
  - “Catchment Raster Processing”.
  - “Catchment Delineation”
- Identify drainage areas draining into stream segments and sinks.
  - Raster.
  - Vector.

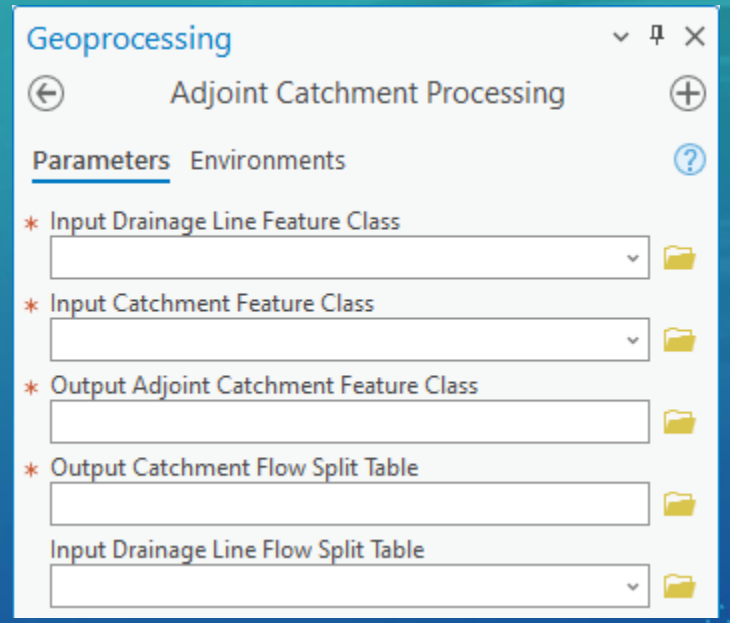




Defining adjoint catchments

- Arc Hydro tool “Adjoint Catchment Processing”.
- Identify upstream contributing area to each catchment/stream segment.
- Vector representation only.
- Performance “tool”.





Review and Summary

Review and Summary

- “Geofabric”.
  - Integrated vector/raster system.
- Foundation for support of specific “products” (e.g. USGS EDH/3DHP) and analyses.
- NOT a super button.

Review and Summary

- “Almost” done with individual tools and workflows.
  - Documentation (workflow document)
  - Line smoothing
  - Inflexion points

- R & D:
  - “Parameters”
  - “Culvert” selection (traditional, AI)
  - Automation
  - Performance

Questions?

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