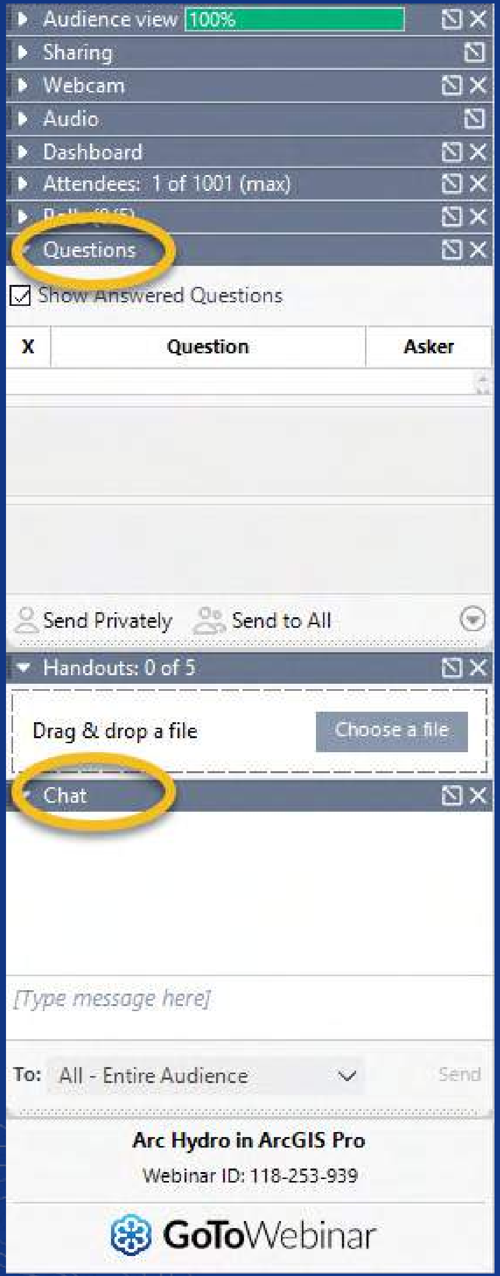
Arc Hydro in Action Webinar Series

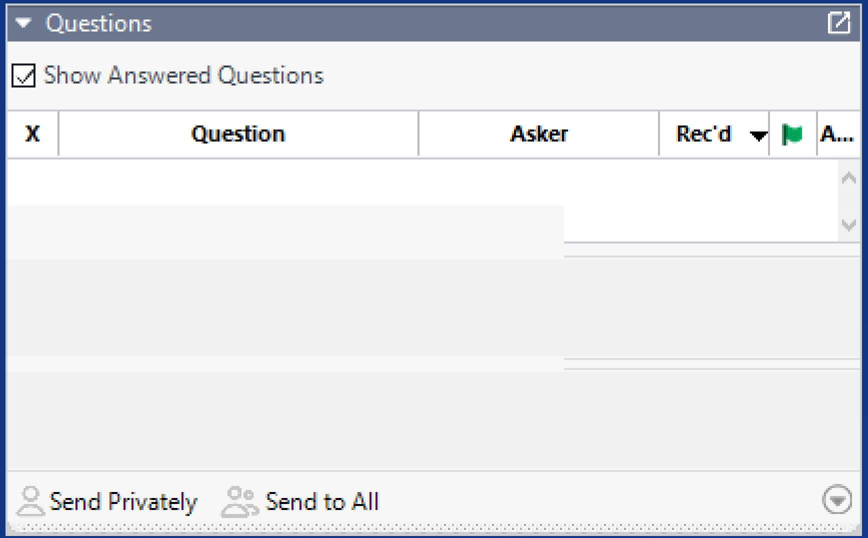
2/25/21: Arc Hydro in ArcGIS Pro

3/11/21: Arc Hydro: Flooding & Forecasting

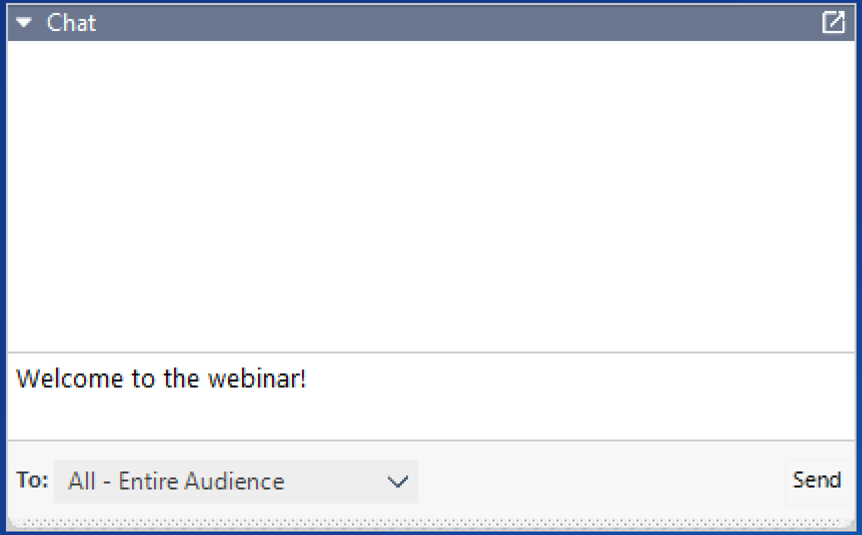
3/25/21: **Arc Hydro: Hydrology & Hillslope**

4/15/21: Arc Hydro: Support for Hydrologic and Hydraulic Modeling


Audience view 100%
Sharing
Webcam
Audio
Dashboard
Attendees: 1 of 1001 (max)
Questions
Show Answered Questions
X
Question
Asker
Send Privately
Send to All
Handouts: 0 of 5
Drag & drop a file
Choose a file
Chat
[Type message here]
To: All - Entire Audience
Send
Arc Hydro in ArcGIS Pro
Webinar ID: 118-253-939
GoToWebinar


Questions
Show Answered Questions
X
Question
Asker
Rec'd
A...
Send Privately
Send to All

QR Code


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

Announcements

Watch webinar one and two at your convenience

- Arc Hydro in ArcGIS Pro
- Arc Hydro: Flooding & Forecasting

- Applied Meteorology Using ArcGIS (webinar series)

Polling Questions

Did you attend or watch the first two webinars?

- Yes, Arc Hydro in ArcGIS Pro
- Yes, Arc Hydro: Flooding and Forecasting
- No

Presenters:

Dana Lapides, PhD

Postdoctoral Scholar

UW-Madison Aquatic Sciences Center

Annelise Sytsma

PhD Candidate

University of California, Berkeley

Gina O'Neil, PhD

Technical Consultant

Esri

Dean Djokic, PhD

Water Resources Practice Manager

Esri

Arc Hydro: Hydrology and Hillslope

2021 “Arc Hydro in Action” Webinar Series

Webinar 3 Topics

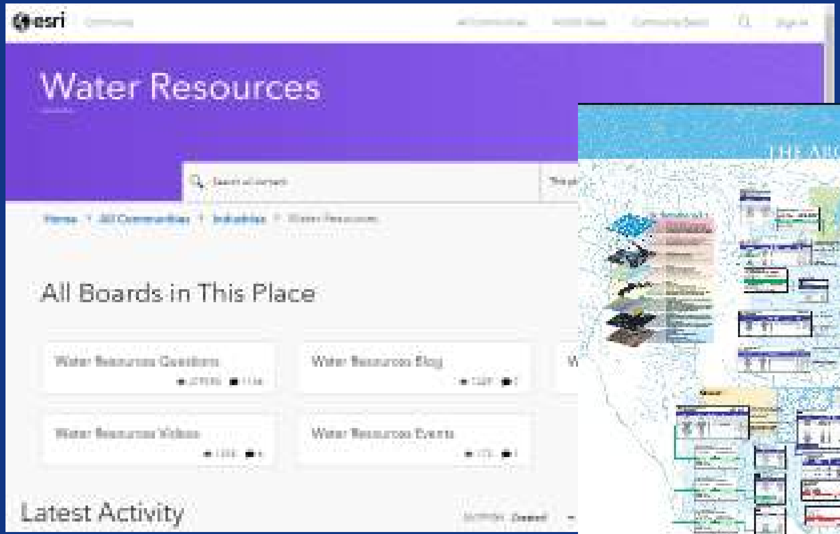
- Quick review of Webinars #1 & #2
- Statistical hydrology.
  - Terrain preprocessing, characterization, and streamflow statistics
- Hillslope Hydrology and Critical Duration tools.
  - Theory and practice
- Distributed hydrologic modeling
- Questions

Review of Webinars #1 and #2

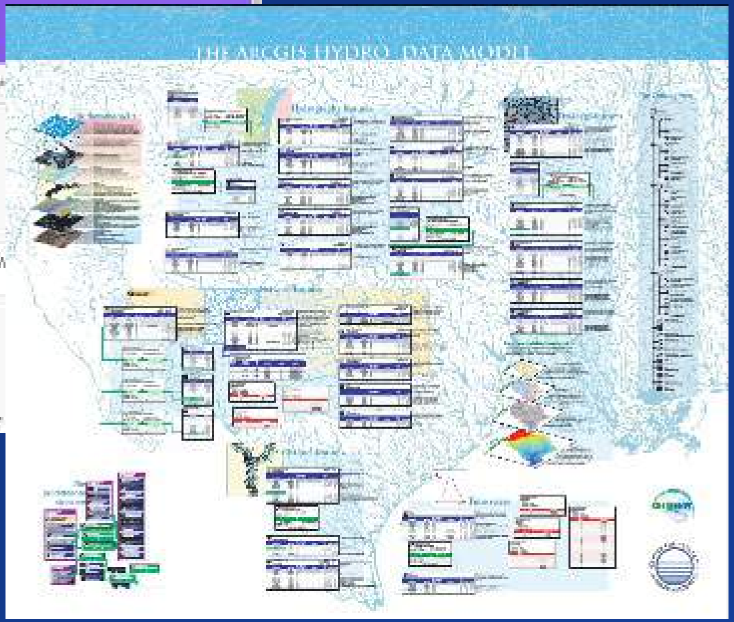
Dean Djokic

Arc Hydro: Vision

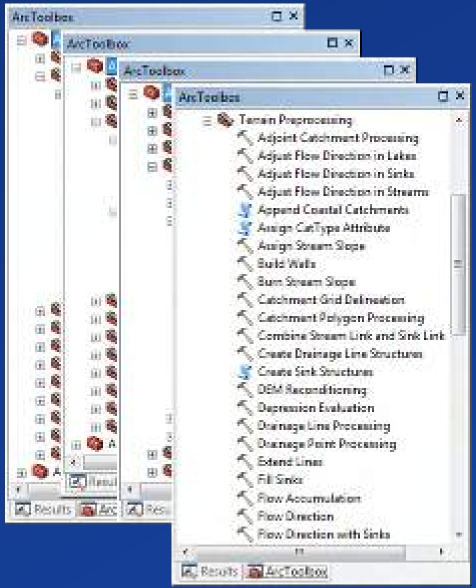
"Provide practical GIS framework for development of **integrated analytical systems** for water resources market."



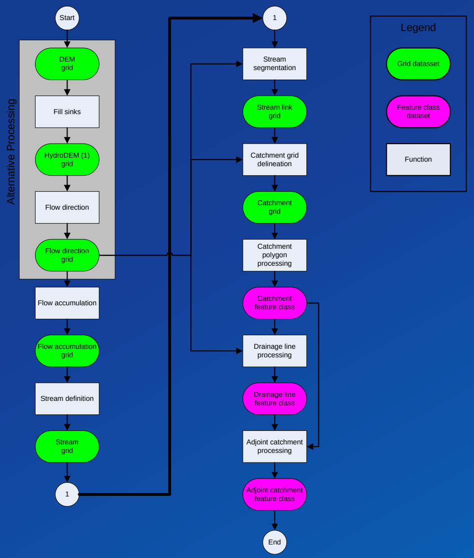
Community



Data Model



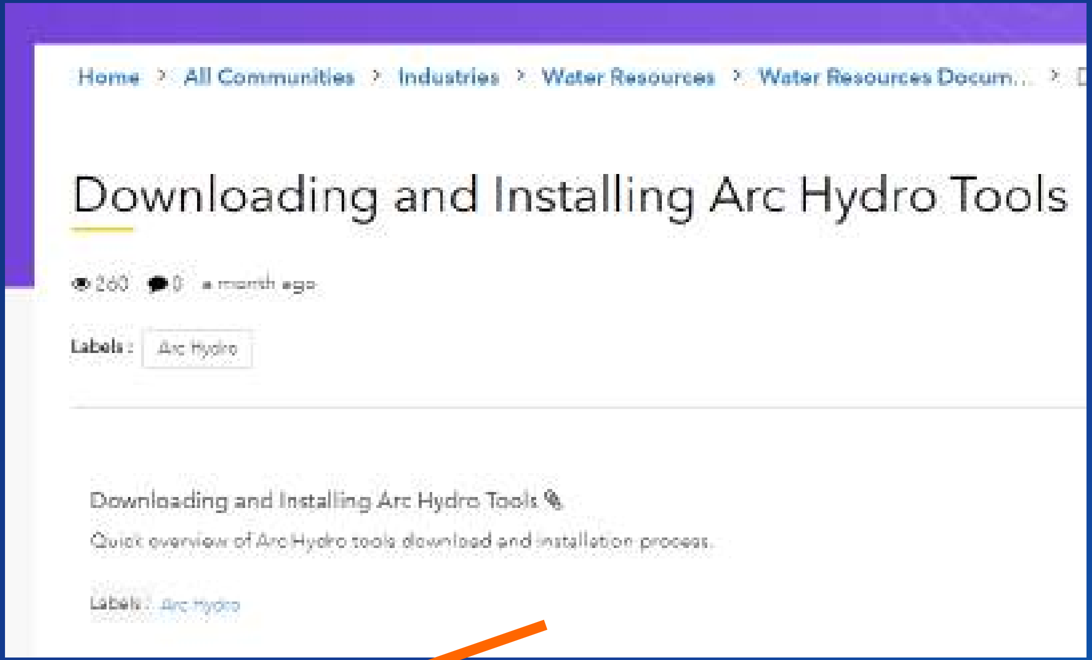
Tools



Workflows

Product \ Capability Summary

- “No fee” downloadable offerings:
  - Data model
  - Tools
  - Workflows
  - Documentation
  - Available now :
    - ArcMap tools - all versions up to 10.8
    - Pro tools - all versions up to 2.7
    - Web services in the Living Atlas



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

- Average of 1000 views per month of the download page

Arc Hydro Tools Summary

Functionality Grouping

Foundation

Administration

- ID mgmt.
- QA
- Configuration

Terrain preprocessing

- Streams
- Sinks
- Flow patterns

Specific implementations

Living Atlas

- Watershed delineation
- Downstream tracing
- Floodplain delineation

Customer Specific

- Nebraska DNR
- USFS GRAIP-Lite
- Illinois DNR

Scientific model integration

- HEC-HMS
- HEC-RAS
- ICPR

General implementation domains

Watershed delineation

- Watershed
- Sub-watershed
- Batch processing

Watershed characterization

- Pollutant loads
- Impervious areas
- Runoff characteristics

Floodplain delineation

- Streams
- Lakes
- Forecast

Stormwater

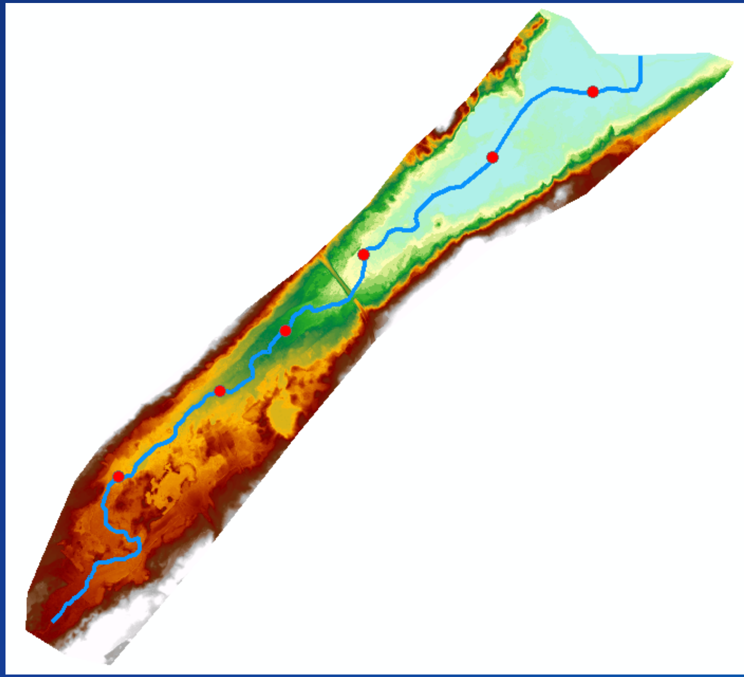
- Built infrastructure
- Surface drainage
- Connectivity

Arc Hydro "Required" Reading

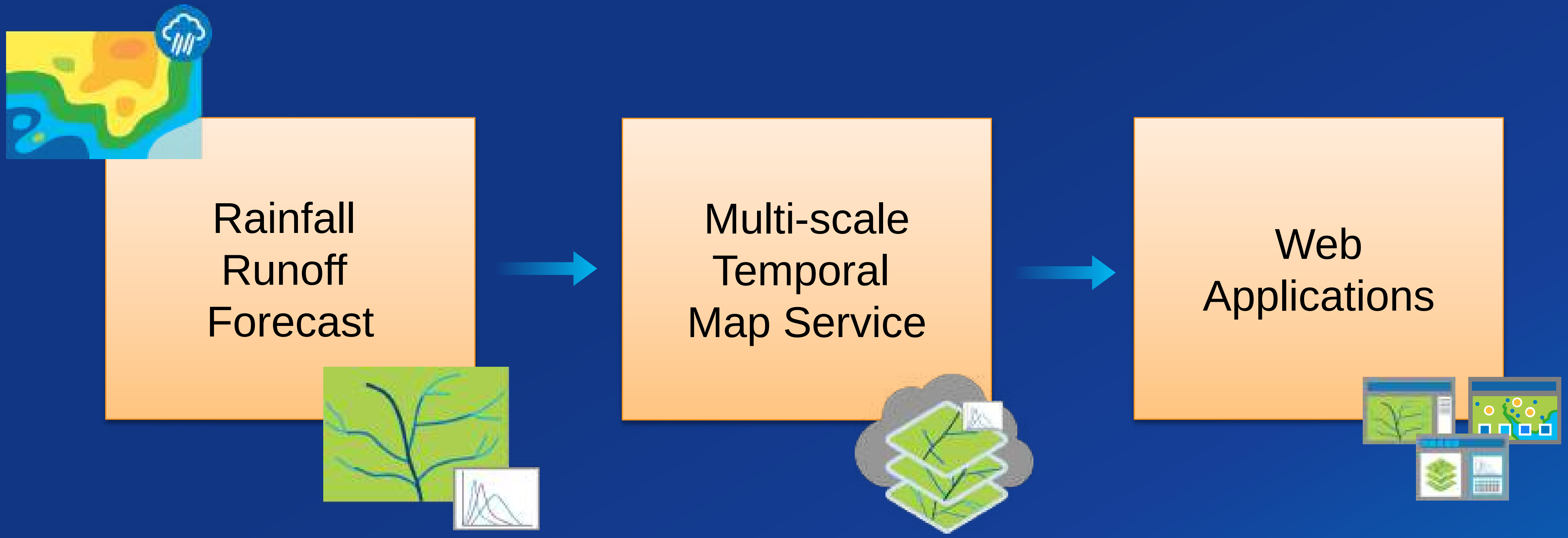
- Arc Hydro - Project Development Best Practices (general)
- Arc Hydro - ArcGIS Pro Project Startup Best Practices (Pro)
- Arc Hydro - Overview of Terrain Preprocessing Workflows (workflow)
- Arc Hydro - HydroPeriod Tool (toolset / workflow)
- Arc Hydro - Wetland Identification Toolset (Pro / toolset / workflow)
- Arc Hydro - Stormwater Processing (toolset / workflow)
- Arc Hydro - Identifying and Managing Sinks (workflow)
- Arc Hydro - Support for Hydrologic Modeling (workflow)
- Arc Hydro - Calling Arc Hydro Tools in Python (developers)

Floodplain Delineation Solutions Matrix

- **Different levels of complexity are possible/needed to determine flood extents**
- **Simple, based on terrain and observations only:**
  - **"Flooding out" based on DEM, stream centerline, and point data**
  - **HAND approach (constant depth of flooding per reach)**
- **Complex, based on hydraulic modeling (using external hydraulic models):**
  - **1D**
  - **2D**
  - **Full or simplified equations (Navier-Stokes / Saint-Venant / …)**



Flood Impact Forecasting

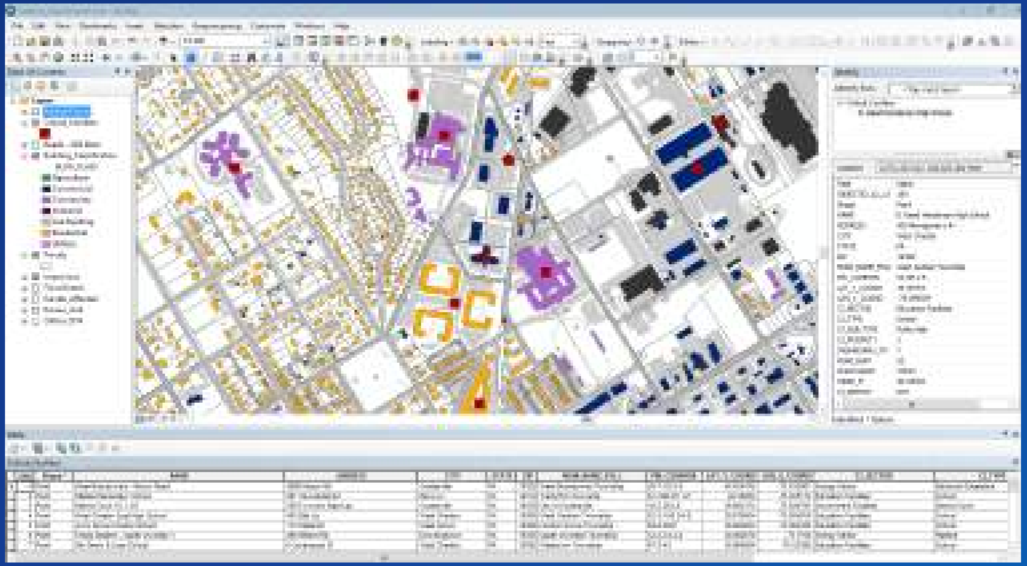


Flood Impact Forecasting

WHEN:
National Water Model

WHERE:
Arc Hydro Tools

WHO:
Local County GIS Data



Dave Sekkes, Chester County EOC

Quotes of the day/month/year/…

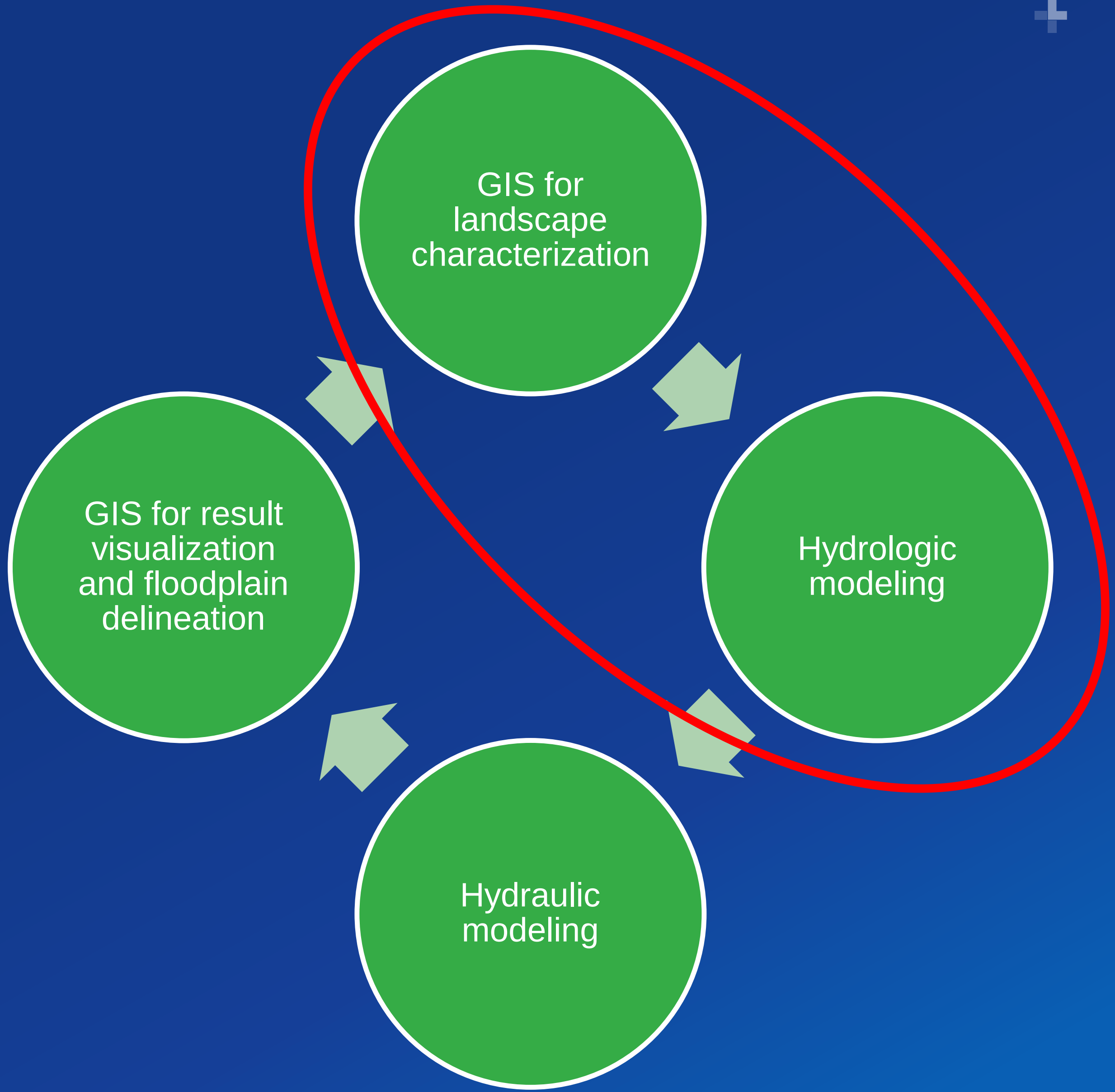
- “All models are wrong, but some are useful” (George Box ~1976)
- “Perfect is the enemy of the good” (Voltaire ~1770)
- “A fool with a tool is still a fool”
  - (reported by Ken Lanfear, USGS ret.)

Statistical Hydrology

Dean Djokic

GIS for Hydro Modeling “Cycle”

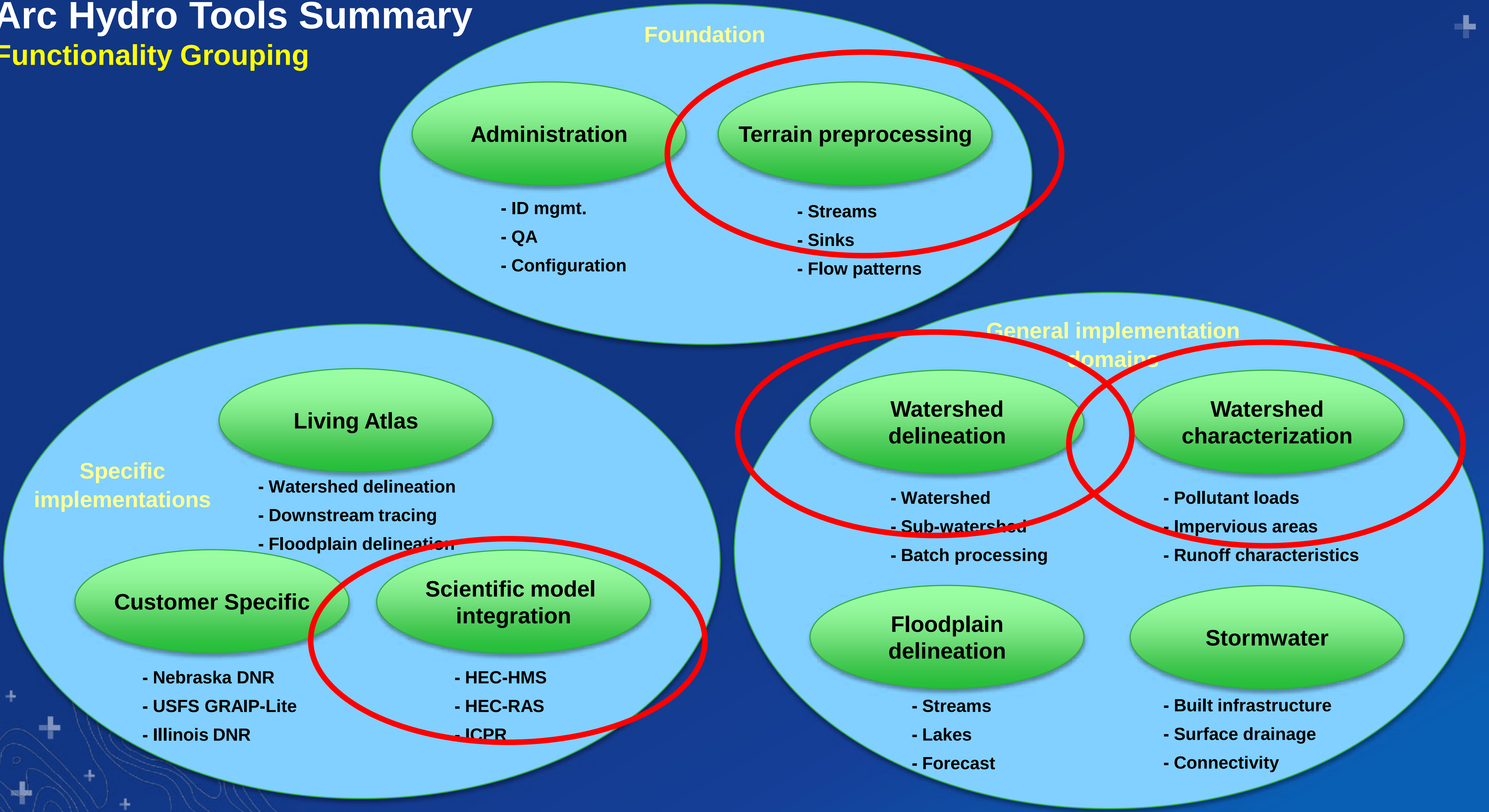
- **GIS is used for landscape characterization and model parametrization.**
- **Hydrology and Hydraulics (H&H) is used for determination of flows, depths and velocities.**
- **GIS is used for result postprocessing and visualization.**
- **GIS and H&H modeling are closely connected as one impacts the other**



… and many arrows in between

Arc Hydro Tools Summary

Functionality Grouping



Regression Equations – USGS StreamStats

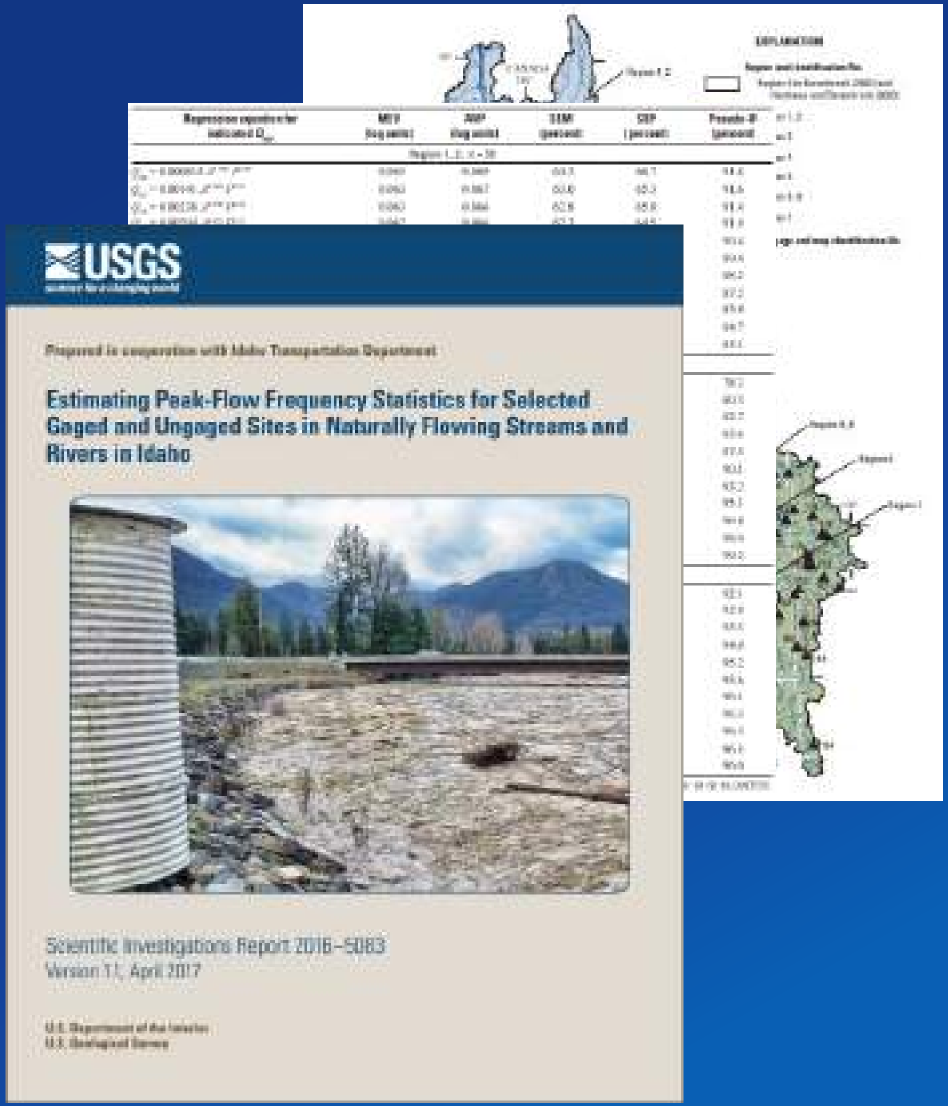
- Used to estimate streamflow statistics, both high and low flows, for ungaged sites (in uncontrolled flow environment)
- Relate streamflow statistics to measured basin characteristics
- Developed by all 48 USGS districts on a state-by-state basis through the cooperative program (usually sponsored by DOT)

Example Regression Equation

- Regression equations take the form:

$$Q_{100} = 0.471 * A^{0.715} * E^{0.827} * SH^{0.472}$$

- Where
  - A is drainage area, in square miles
  - E is mean basin elevation, in feet
  - SH is a shape factor, dimensionless



Basin Characteristics Used for Peak Flows

Basin characteristic	# of States using this (including PR)
Drainage area or contributing drainage area (square miles)	51
Main-channel slope (feet per mile)	27
Mean annual precipitation (inches)	19
Surface water storage (Lakes, ponds, swamps)	16
Rainfall amount for a given duration (inches)	14
Elevation of watershed	13
Forest cover (percent)	8
Channel length (miles)	6
Minimum mean January temperature (degrees F)	4
Basin shape ($(length)^2$ per drainage area)	4
Soils characteristics	3
Mean basin slope (feet per foot or feet per mile)	2
Mean annual snowfall (inches)	2
Area of stratified drift (percent)	1
Runoff coefficient	1
Drainage frequency (number of first order streams per sq. mi.)	1
Mean annual runoff (inches)	1
Normal daily May-March temp (degrees F)	1
Impervious Cover (percent)	1
Annual PET (inches)	1

. . . and many others

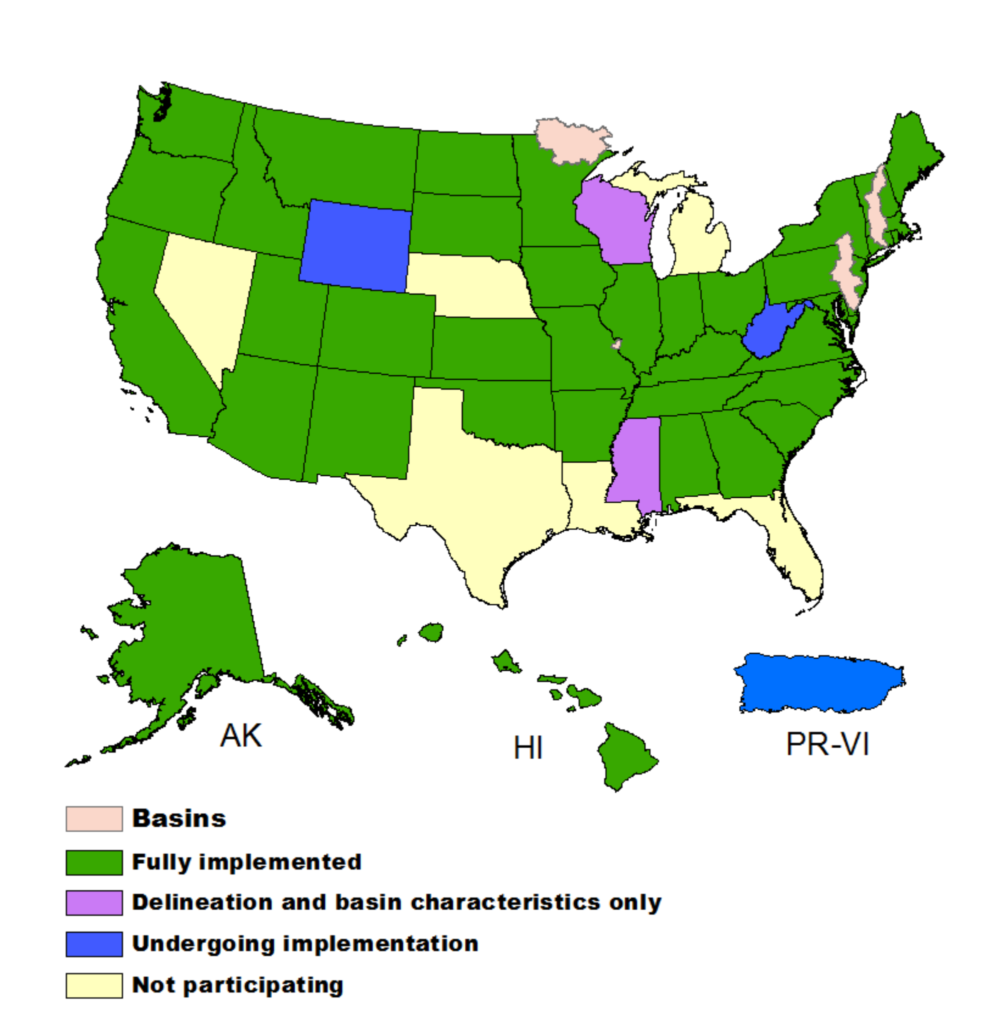
Role of GIS

- Systematize methodology and datasets used in the process (repeatability).
- Provide better tools for deriving characteristics for regression equation determination.
- Provide a common (single) access to the methodology (for users and maintenance).
- Provide a map-based user interface.
- Speed up the process (instead of hours, minutes).
- Web and desktop implementation are based on Arc Hydro.

StreamStats Implementation Activities

March 2021

- USGS lead effort
- State-based
- ArcGIS Server technology (10.7.1)
- Hosted in Denver
- Extended functionality

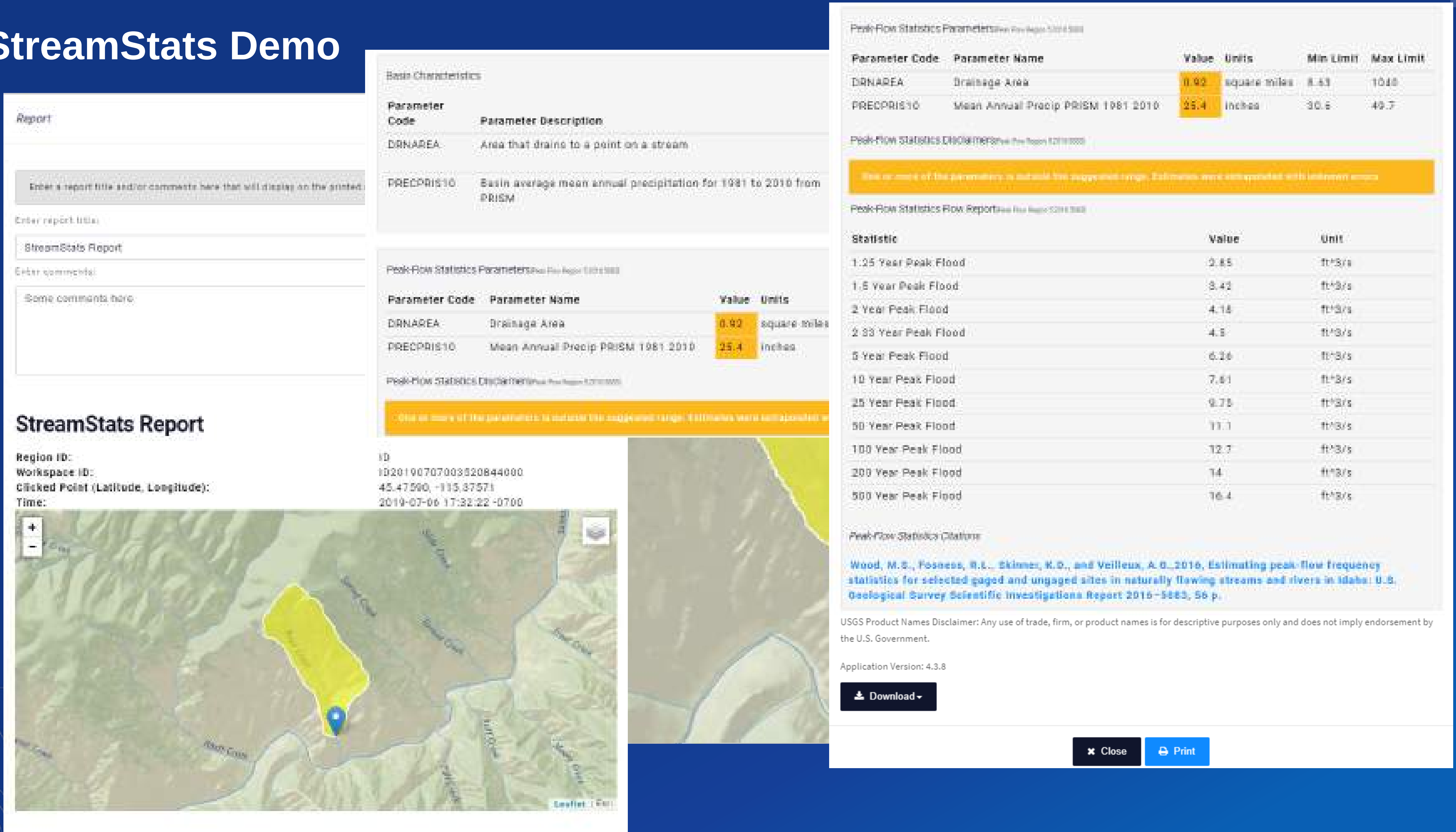


Source: https://streamstats.usgs.gov/ss/

StreamStats Demo

https://streamstats.usgs.gov/ss/

StreamStats Demo

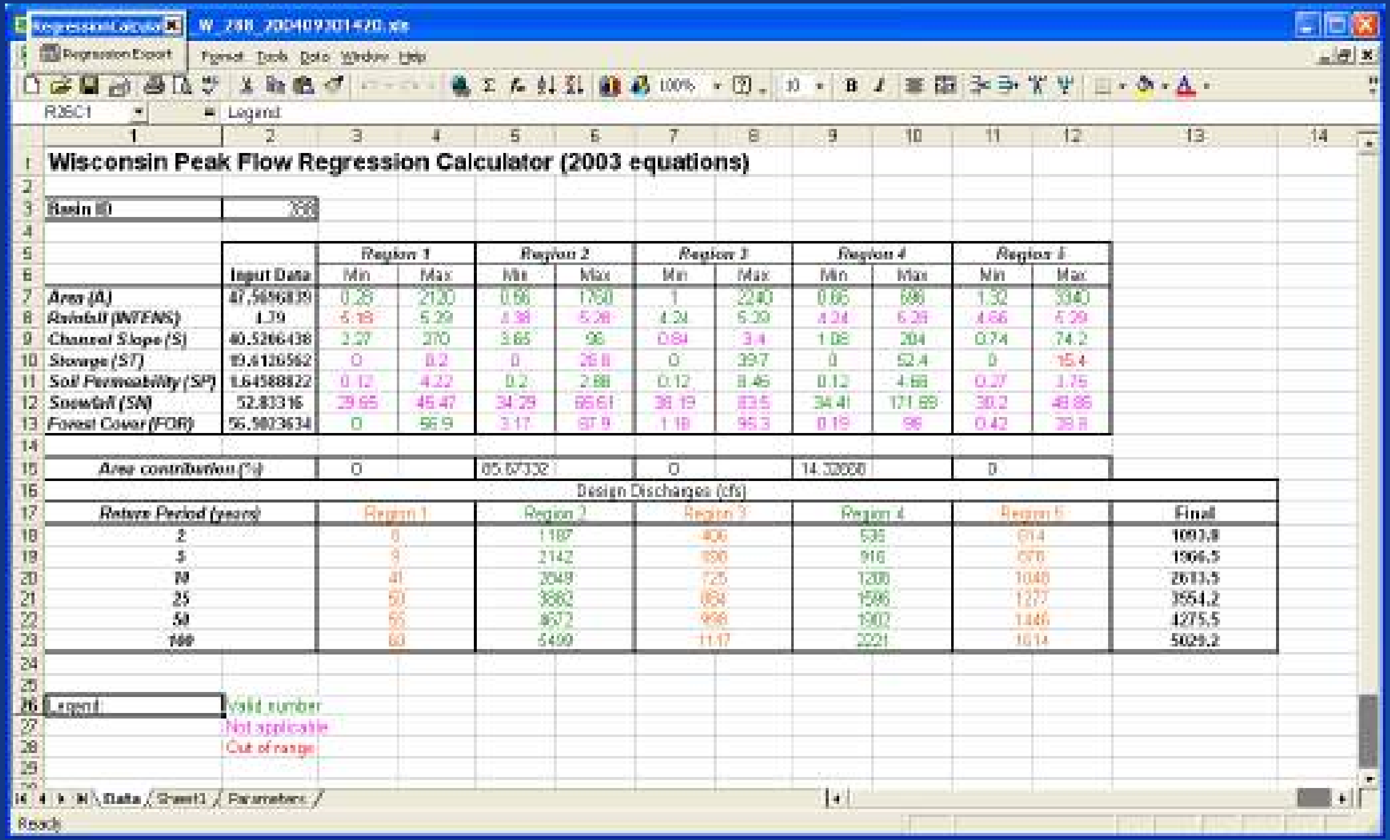


Desktop Implementation

- StreamStats or any similar methodology can be implemented within desktop environment.
- Need:
  - Data.
  - Equations (hopefully with well defined GIS parameter extraction methodology).
- Implementation:
  - Local watershed delineation and characterization.
  - “Regression calculator”
    - External app.
    - Python
    - Excel

Desktop Implementation

- **Pre-StreamStats for Wisconsin was done in ArcView 3 and Excel.**



Wisconsin Peak Flow Regression Calculator (2003 equations)

Basin ID	288

	Input Data	Region 1 Min	Region 1 Max	Region 2 Min	Region 2 Max	Region 3 Min	Region 3 Max	Region 4 Min	Region 4 Max	Region 5 Min	Region 5 Max
Area (A)	47.5696839	0.28	2120	0.66	1760	1	2240	0.06	696	1.32	3340
Rainfall (INTENS)	1.79	5.18	5.29	4.38	5.28	4.24	5.39	4.24	6.28	4.66	5.29
Channel Slope (S)	40.5206438	2.27	270	3.65	96	0.84	3.4	1.08	204	0.74	74.2
Storage (ST)	19.6126562	0	0.2	0	26.8	0	39.7	0	52.4	0	15.4
Soil Permeability (SP)	1.64588822	0.12	4.22	0.2	2.88	0.12	8.46	0.12	4.68	0.27	3.75
Snowfall (SN)	52.83316	29.65	45.47	34.29	65.61	38.19	83.5	34.41	171.69	30.2	48.85
Forest Cover (FOR)	56.5023634	0	56.9	3.17	87.9	1.18	95.3	0.19	96	0.42	39.8
Area contribution (%)		0		85.67332		0		14.32668		0	

Design Discharges (cfs)

Return Period (years)	Region 1	Region 2	Region 3	Region 4	Region 5	Final
2	6	1187	406	535	614	1093.8
5	9	2142	590	916	870	1966.5
10	41	2849	725	1200	1040	2613.5
25	50	3882	864	1596	1277	3554.2
50	[illegible]	4672	998	1902	1446	4275.5
100	[illegible]	5499	1117	2221	1614	5029.2

Legend: Valid number / Not applicable / Out of range

Arc Hydro Hillslope: an Arc Hydro tool for hillslope-scale runoff analysis

Anneliese Sytsma and Dana Lapides

In collaboration with: Gina O'Neil, Dean Djokic, Mary Nichols, and Sally Thompson

Polling question

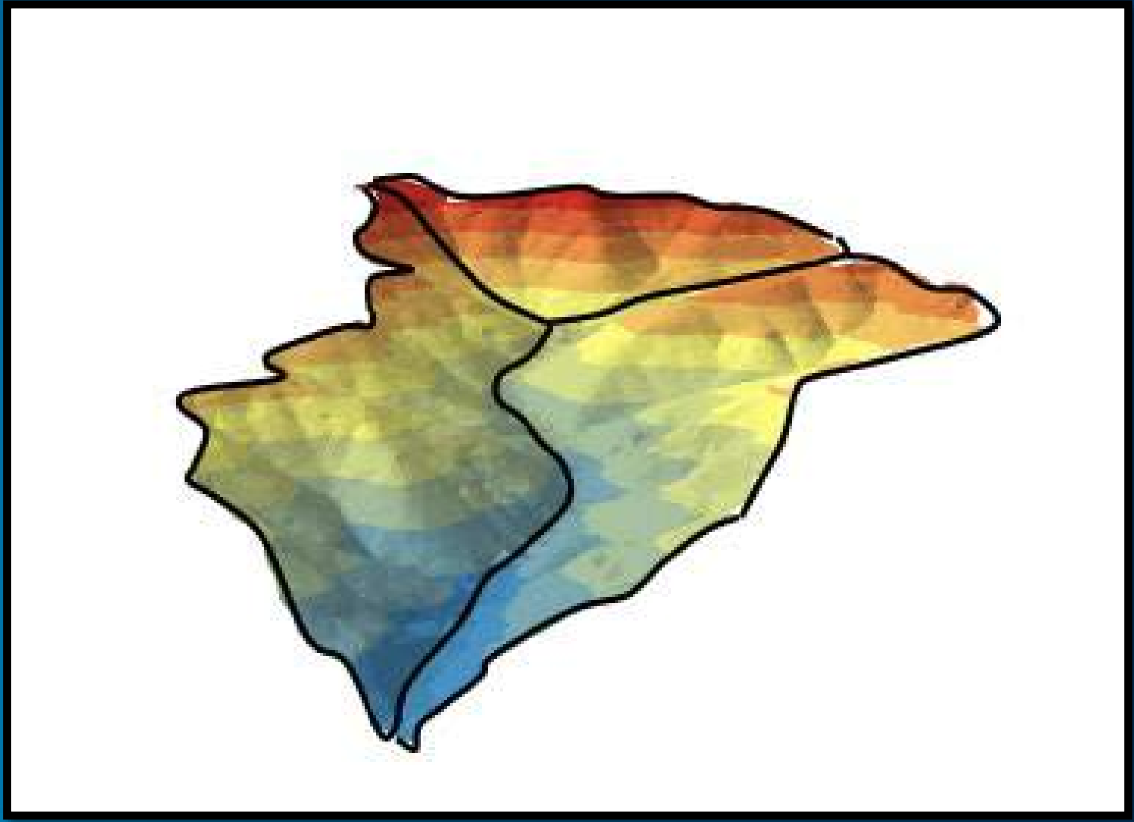
- Have you used the Rational Method for peak flow prediction?
  - Yes
  - Yes, but only in an educational course
  - No

Background and Motivation: Hillslopes and Curvature

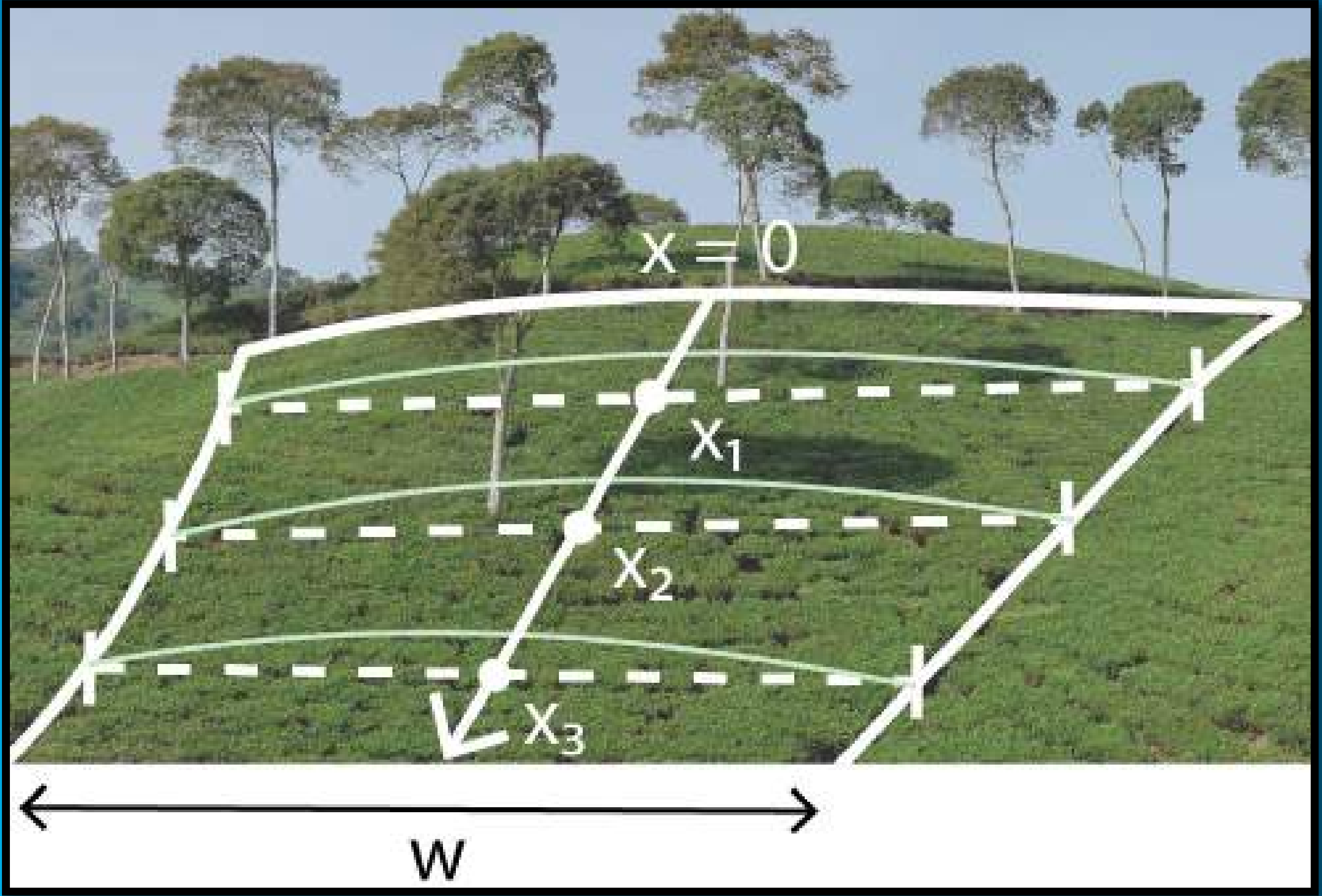
Dana Lapides

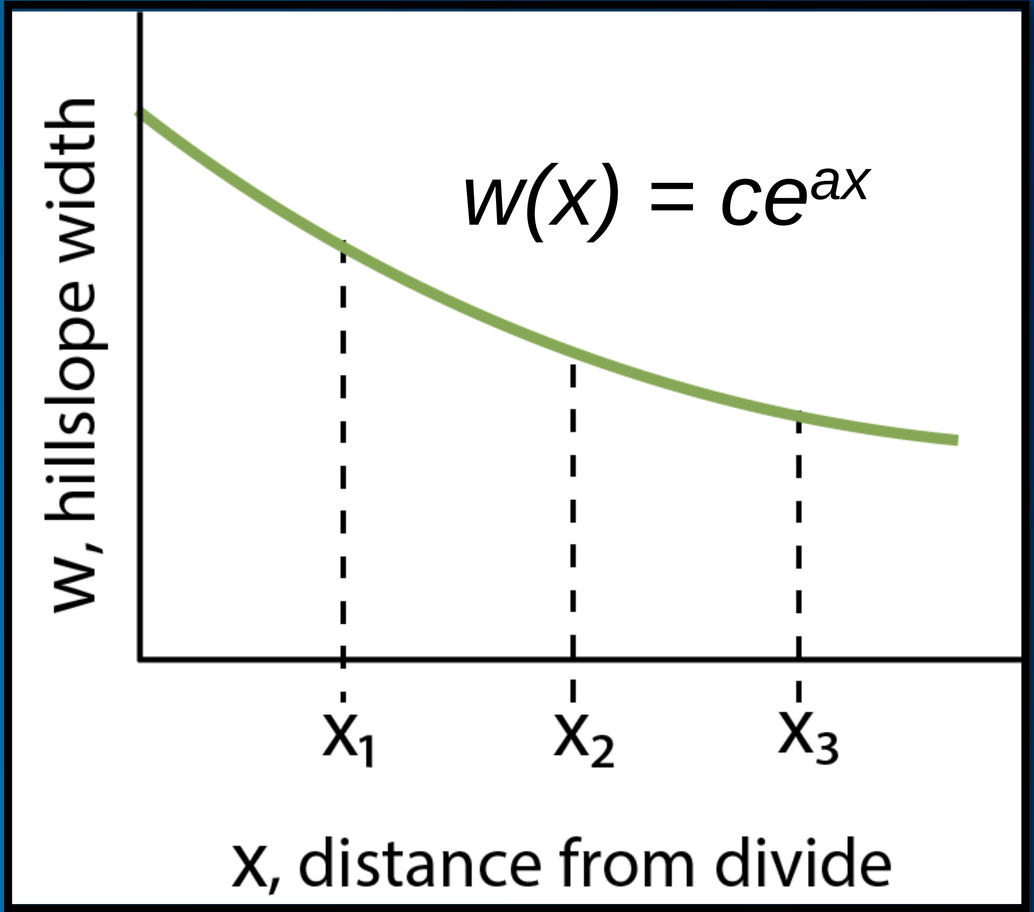
Hillslopes

- Deliver water and sediment to streams
- Can be used as a hydrologic response unit
- Allow for analysis of important questions related to hydrology and morphology



Hillslope Width Functions

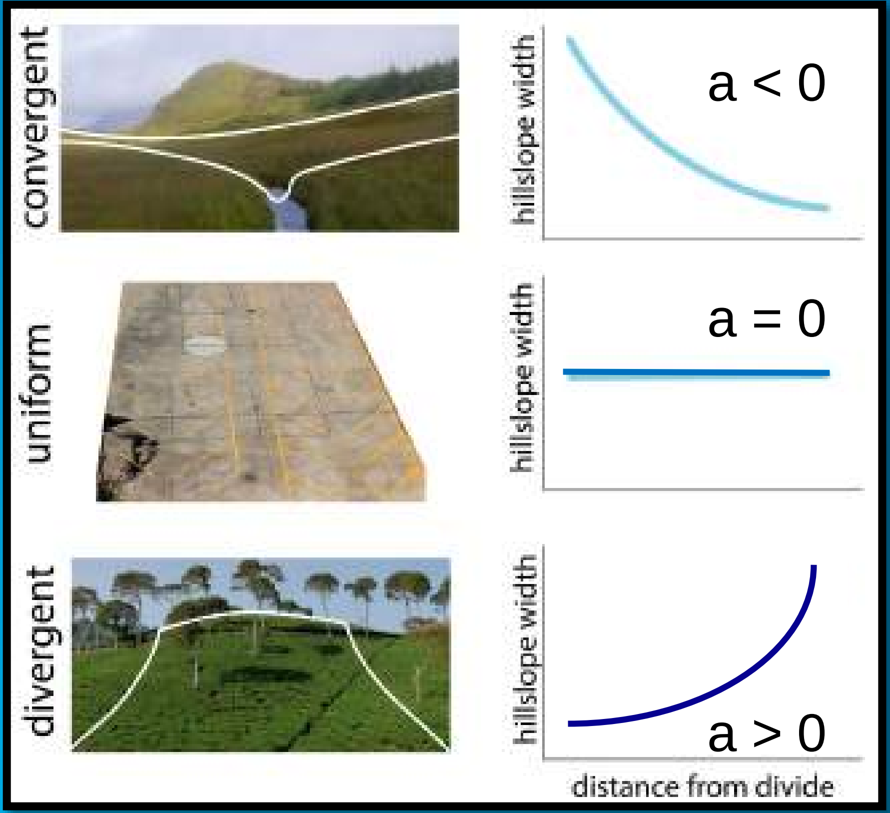


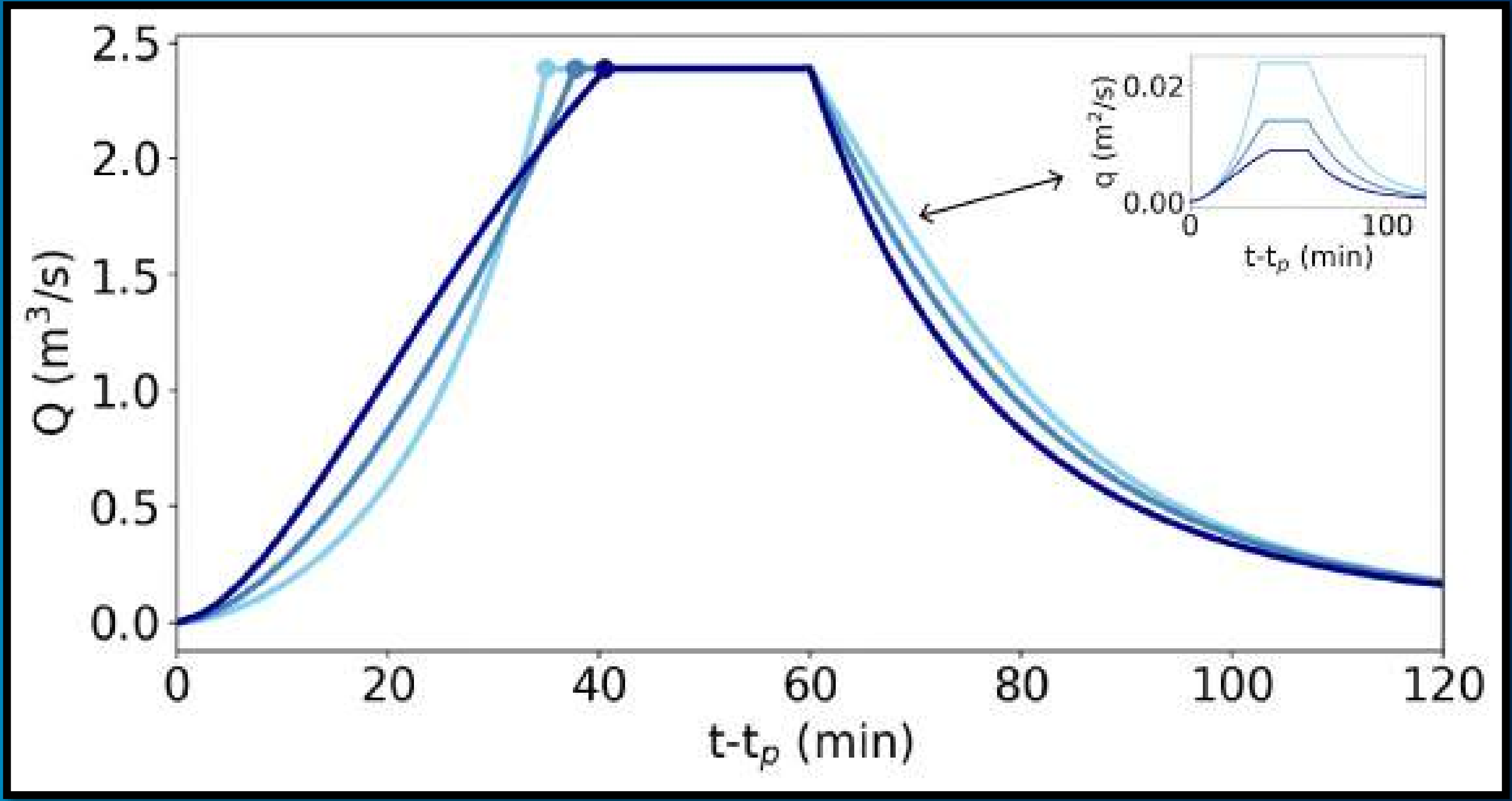


Overland flow with Hillslope Width Functions

$w(x) = ce^{ax}$

$q = \alpha h^m$





- Lapides, Dana A., et al. "Analytical solutions to runoff on hillslopes with curvature: numerical and laboratory verification." Hydrological Processes 34.24 (2020): 4640-4659 https://onlinelibrary.wiley.com/doi/abs/10.1002/hyp.13879 .

Using HWF to explore curvature impacts on design peak flows

Dana Lapides

The Rational Method

$$Q_{max} = CAI$$

Design peak flow [L^3/T]

Design storm intensity [L/T]

Contributing Area [L^2]

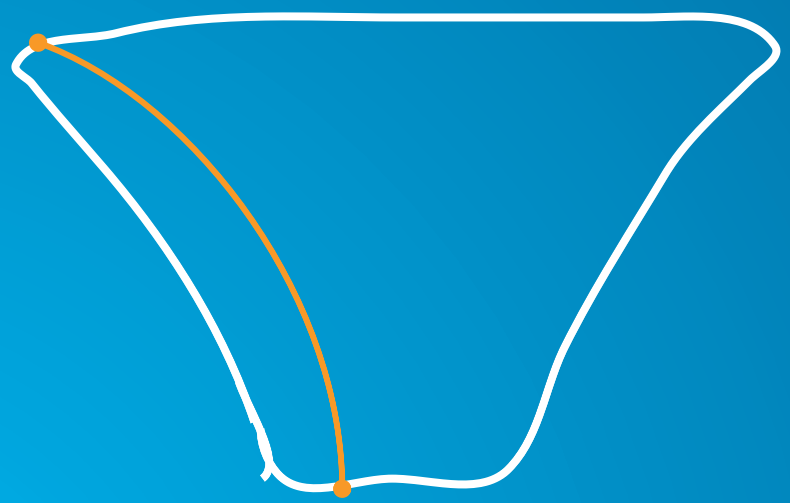
Runoff Coefficient

Kuichling, E. (1889). “The relation between the rainfall and the discharge of sewers in populous districts.” *Trans. Am. Soc. Civil Eng.*, 20(1), 1–56.
Mulvany, T. (1851). “On the use of self-registering rain and flood gauges in making observations of the relation of rainfall and flood discharges in given catchment.” *Trans. Instit. of Civil Eng. Ireland*, 4, 18–33.

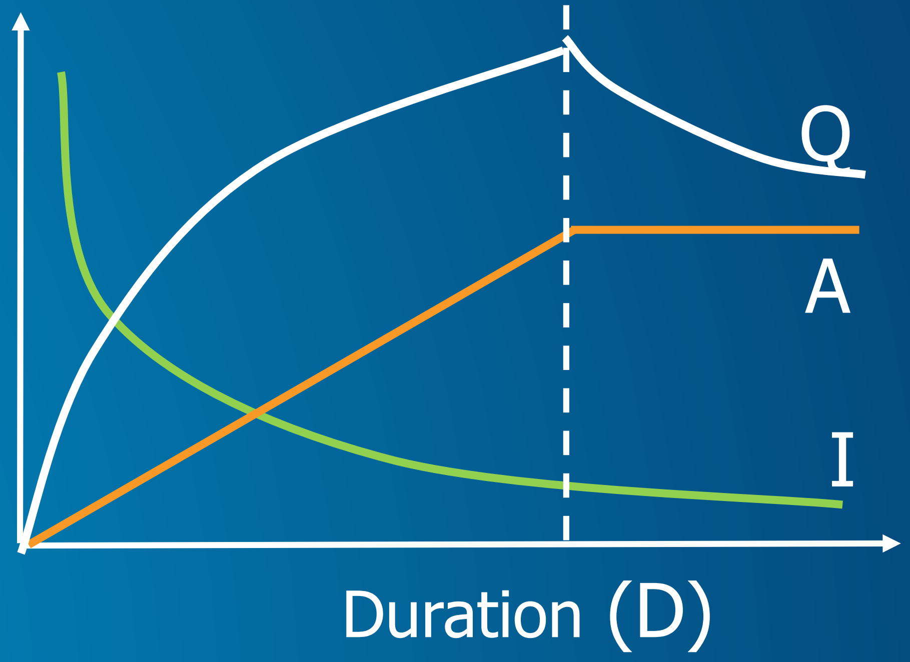
Timescales

$$Q_{max} = CAI$$

- Time of Concentration
  - Travel time to outlet from furthest point in landscape

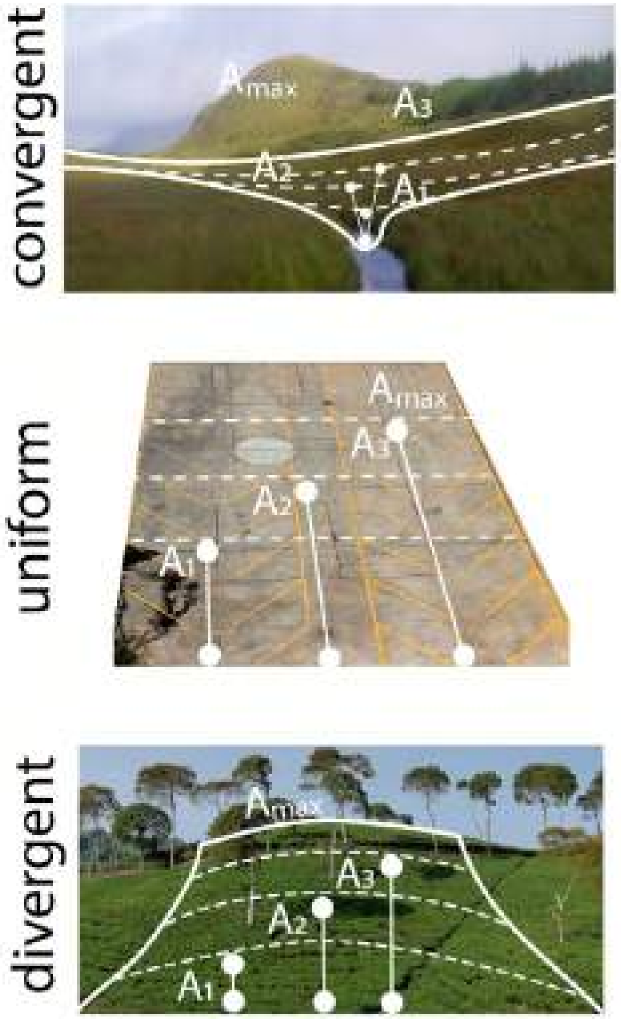


- Critical Duration
  - Storm duration that maximizes peak flow for a given IFD curve and hillslope



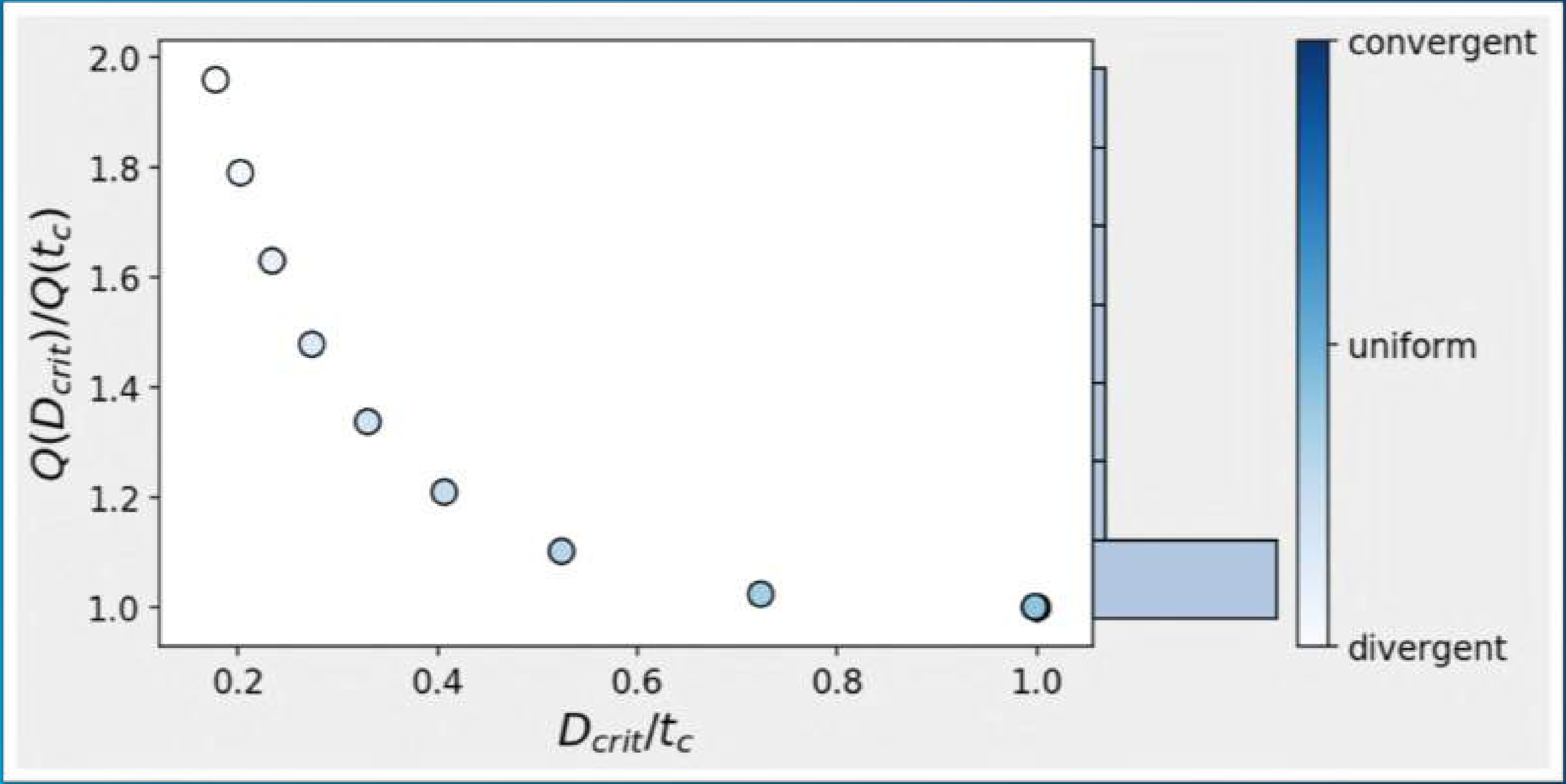
Grimaldi, S., et al. "Time of concentration: a paradox in modern hydrology." *Hydrological Sciences Journal* 57.2 (2012): 217-228.
McCuen, Richard H. "Uncertainty analyses of watershed time parameters." *Journal of Hydrologic Engineering* 14.5 (2009): 490-498.

Impact of hillslope curvature on timing of peak flows



Lapides, Dana A., et al. “Rational Method time of concentration can underestimate peak discharge on hillslopes" *Journal of Hydraulic Engineering.* (2021)

Impact of curvature on timescales and peak flow



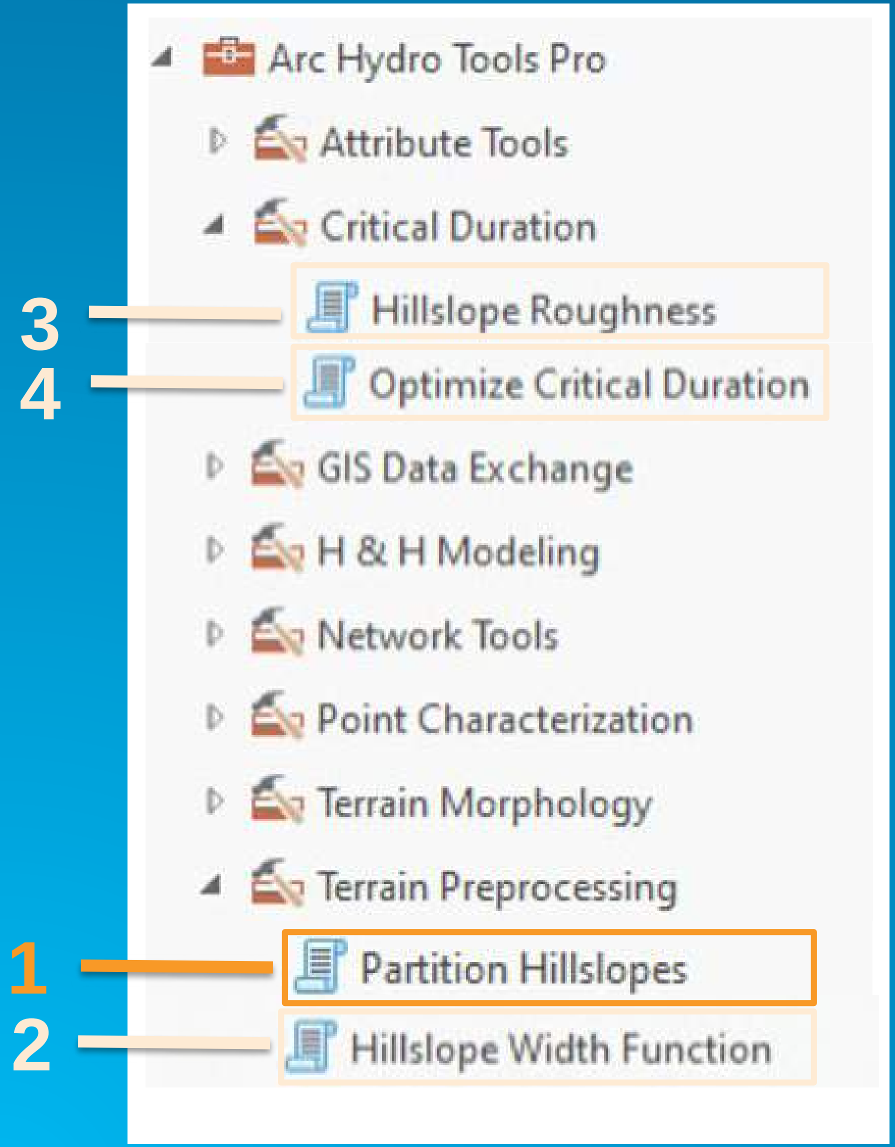
Lapides, Dana A., et al. "Rational Method time of concentration can underestimate peak discharge on hillslopes" *Journal of Hydraulic Engineering.* (2021)

Arc Hydro Hillslope and Critical Duration toolbox

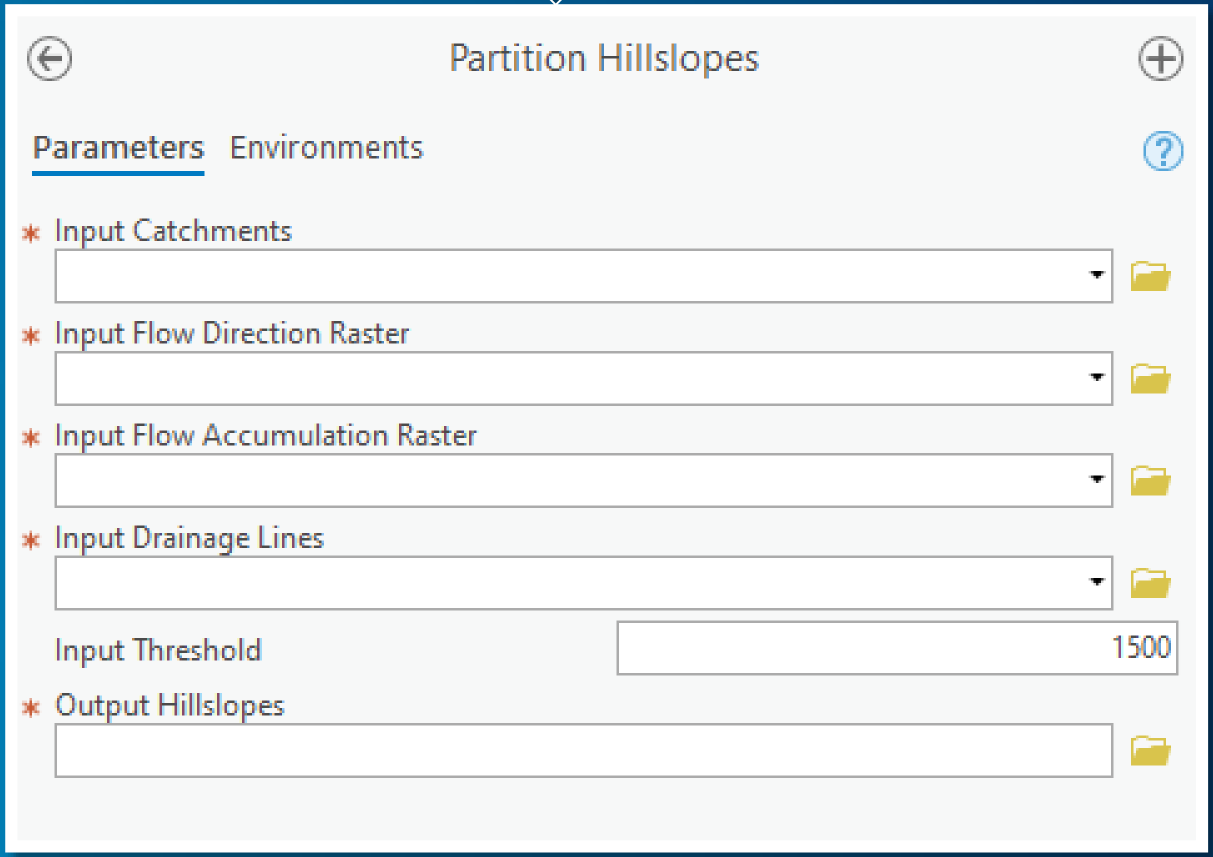
Anneliese Sytsma

Toolbox overview

Partition hillslopes

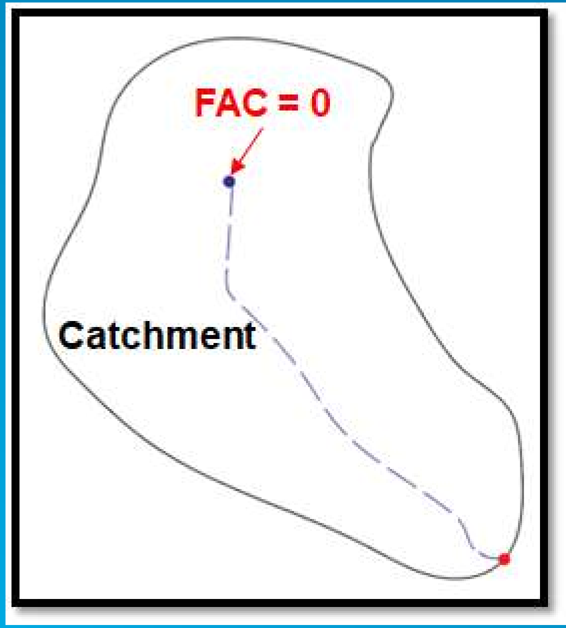


- Prerequisite steps:
  1) Fill DEM
  2) Basic dendritic terrain processing

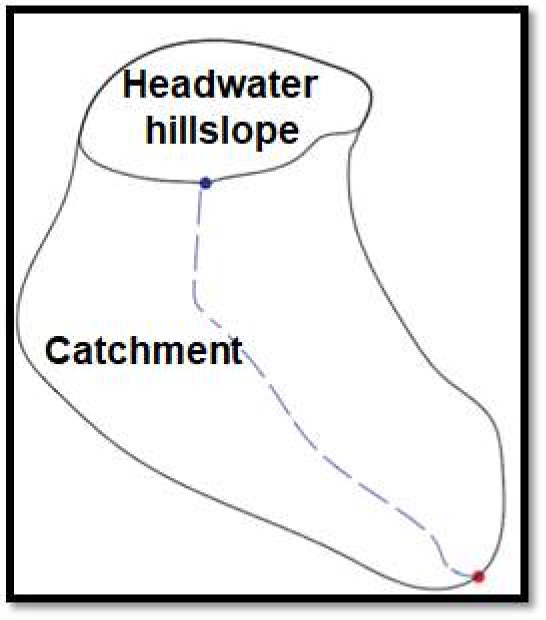


Partition hillslopes

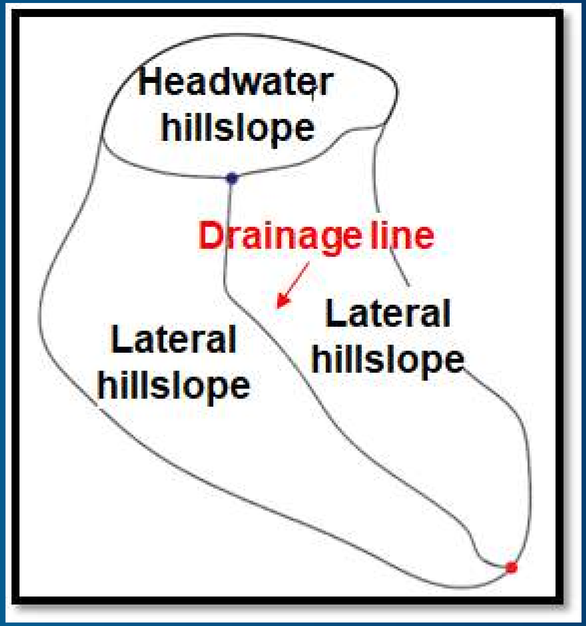
Identifies catchment initiation point (headwater hillslope outlet)



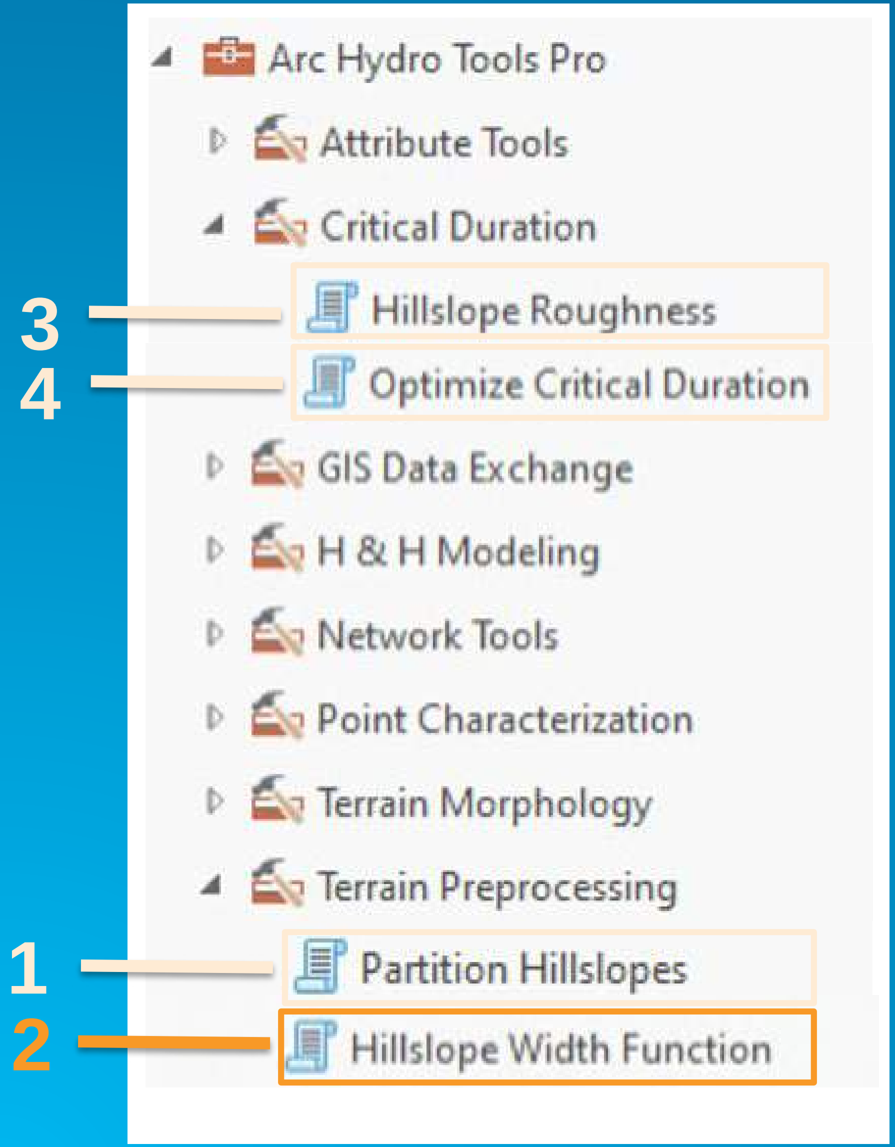
Delineates headwater hillslopes draining to headwater outlet

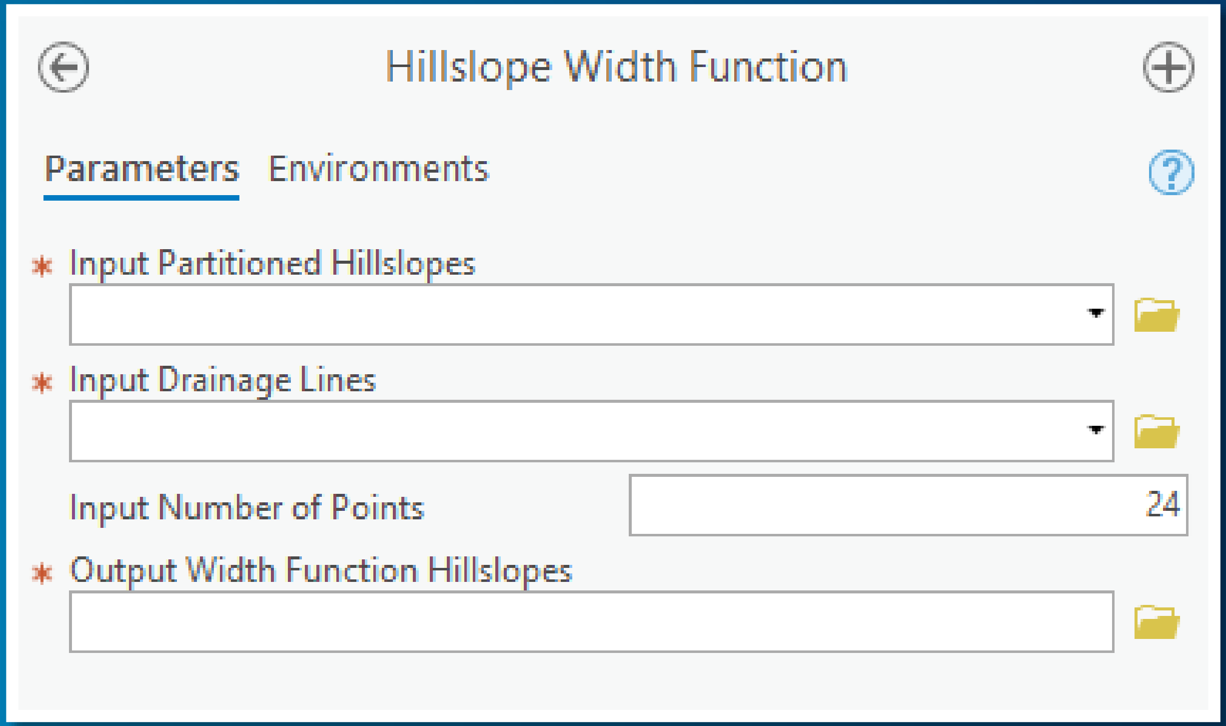


Bisects catchment with drainage line



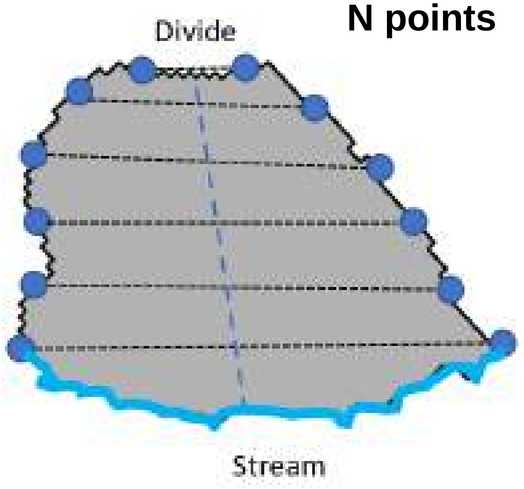
Hillslope Width Function



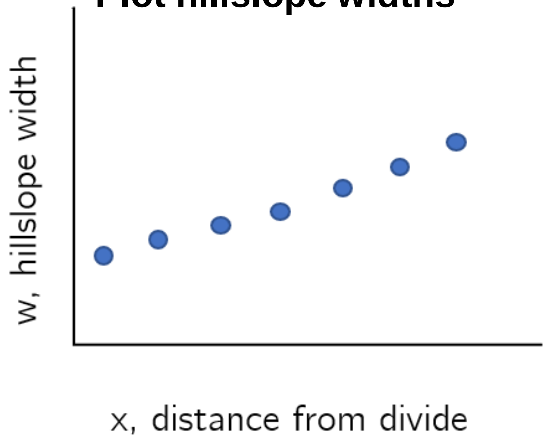


Hillslope Width Function

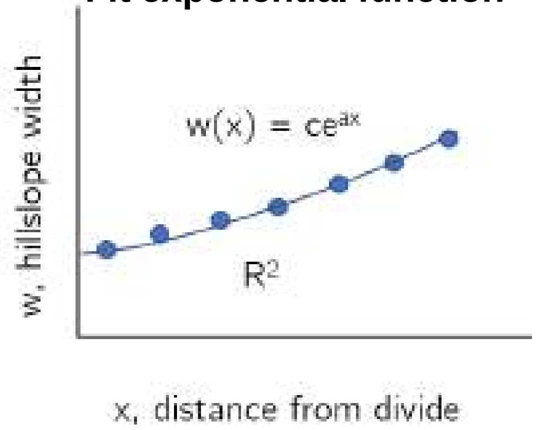
N points



Plot hillslope widths



Fit exponential function



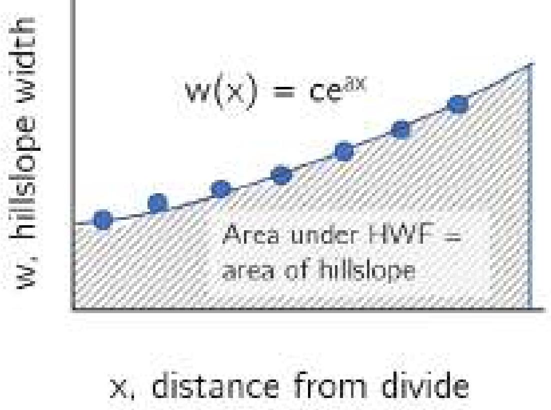
$$w(x) = ce^{ax}$$

Width at divide

Shape factor

a<0: convergent
a= 0: Uniform
a>0: divergent

Conservation of area

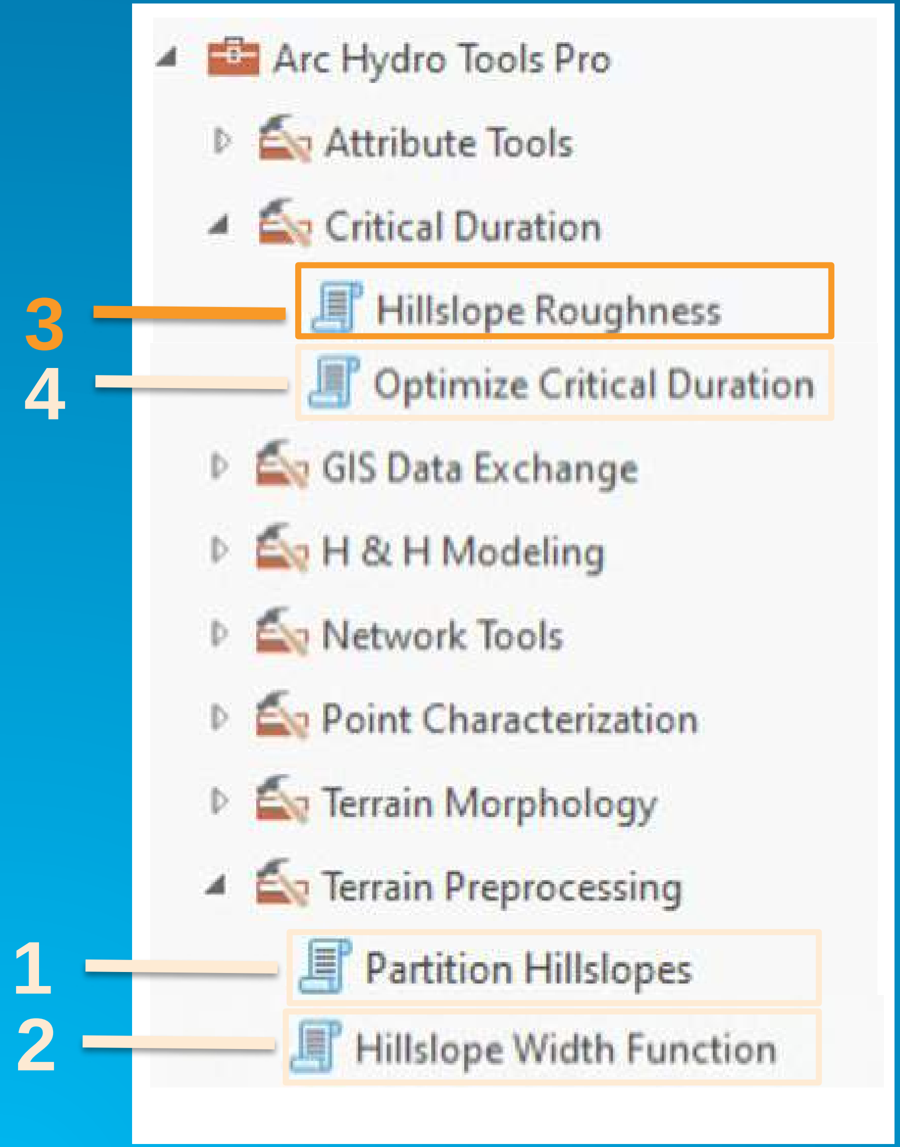


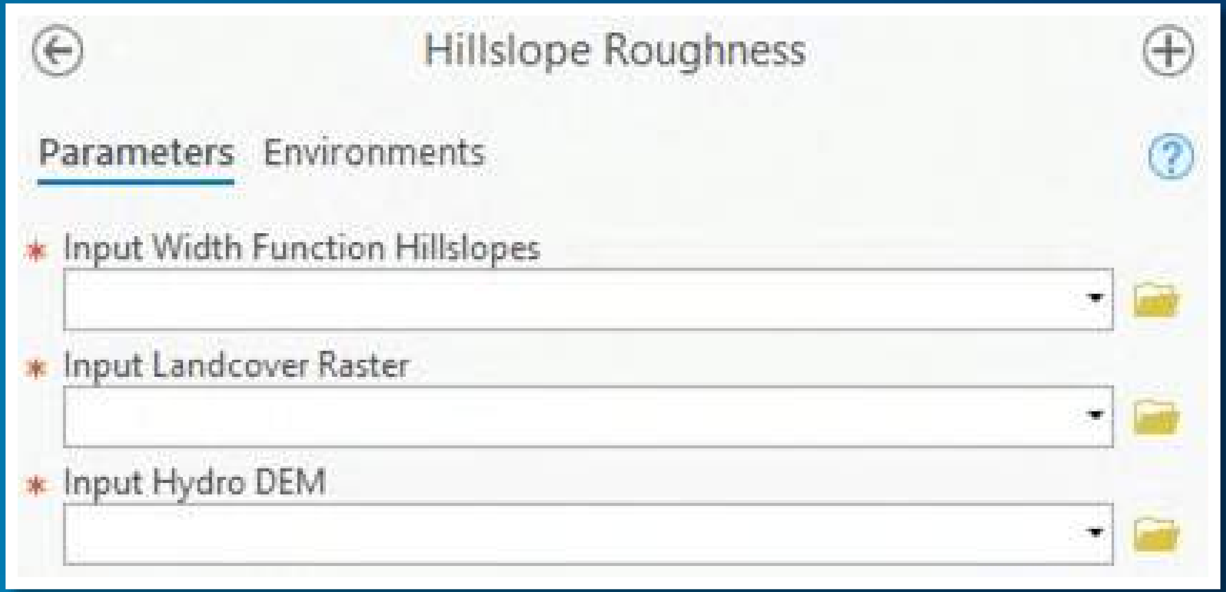
Error metrics

- R2 (exponential fit)
- Point error (how well do the points selected match the hillslope)

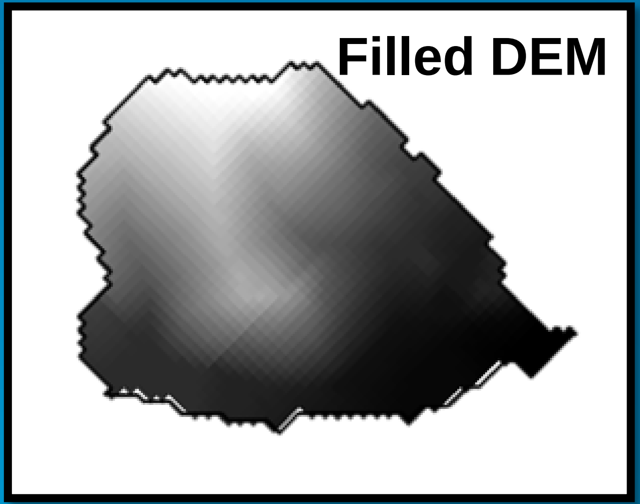
...And others

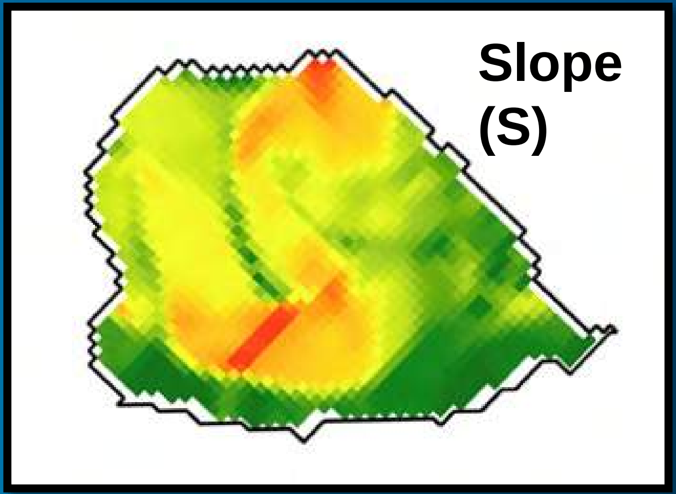
Hillslope roughness

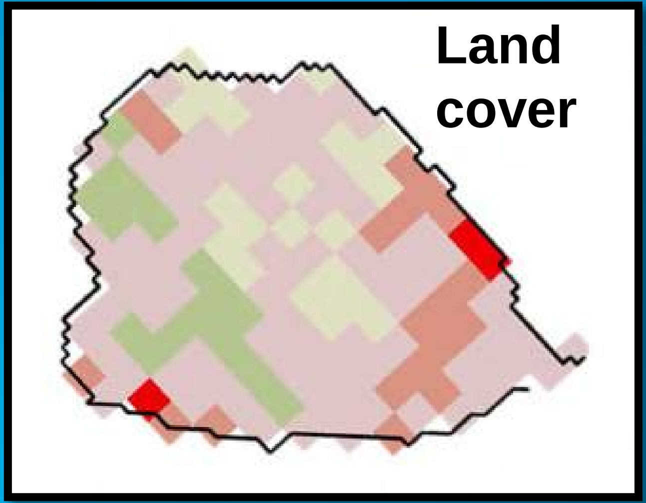




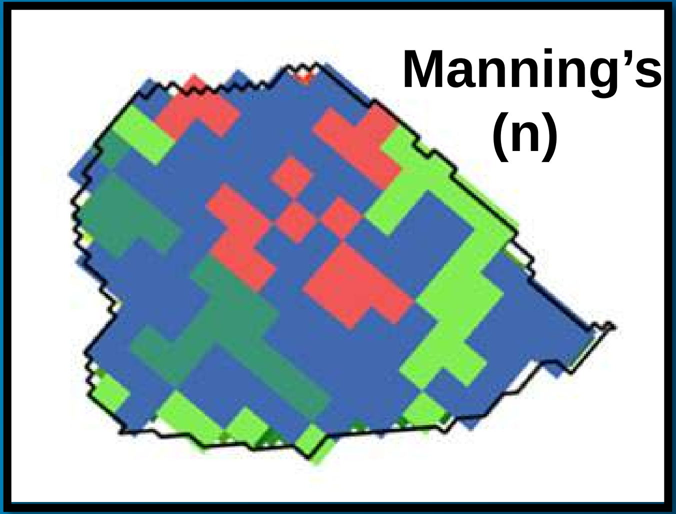
Hillslope roughness







Conversion factors from Kalyanapu, 2009

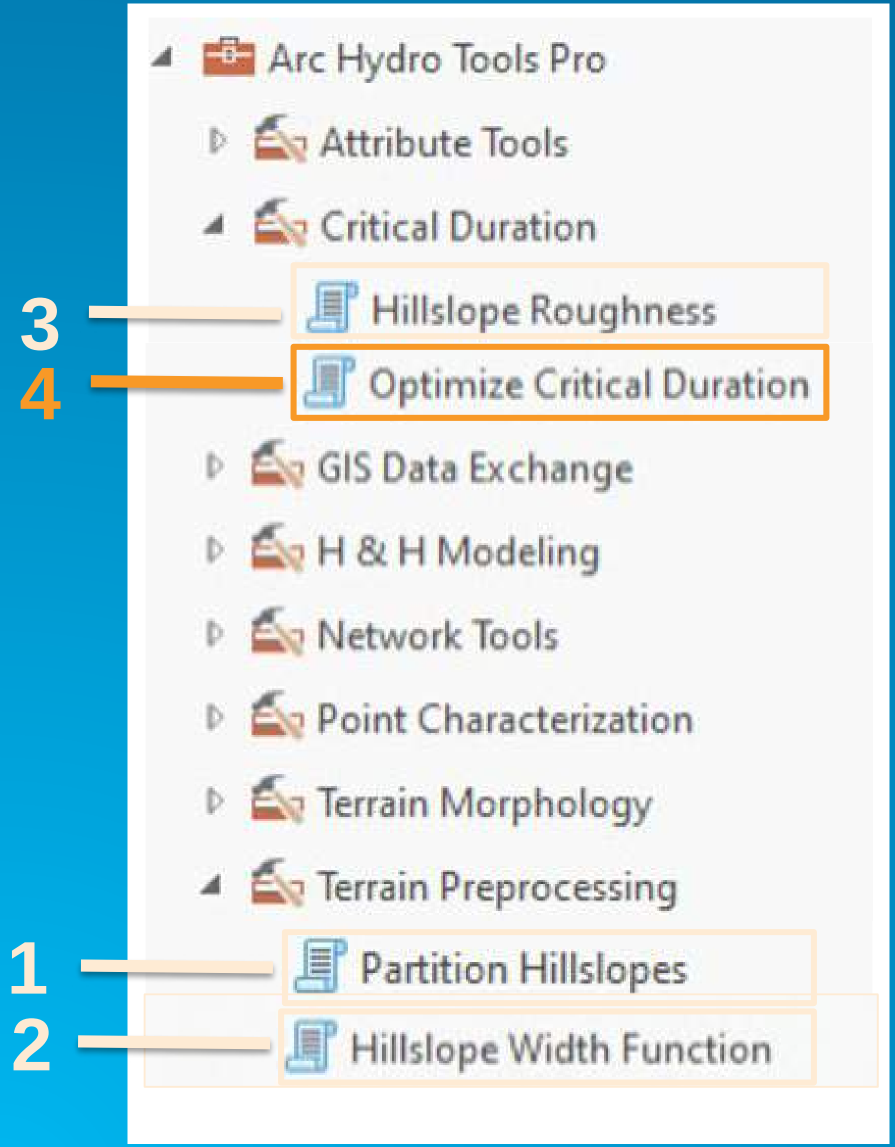


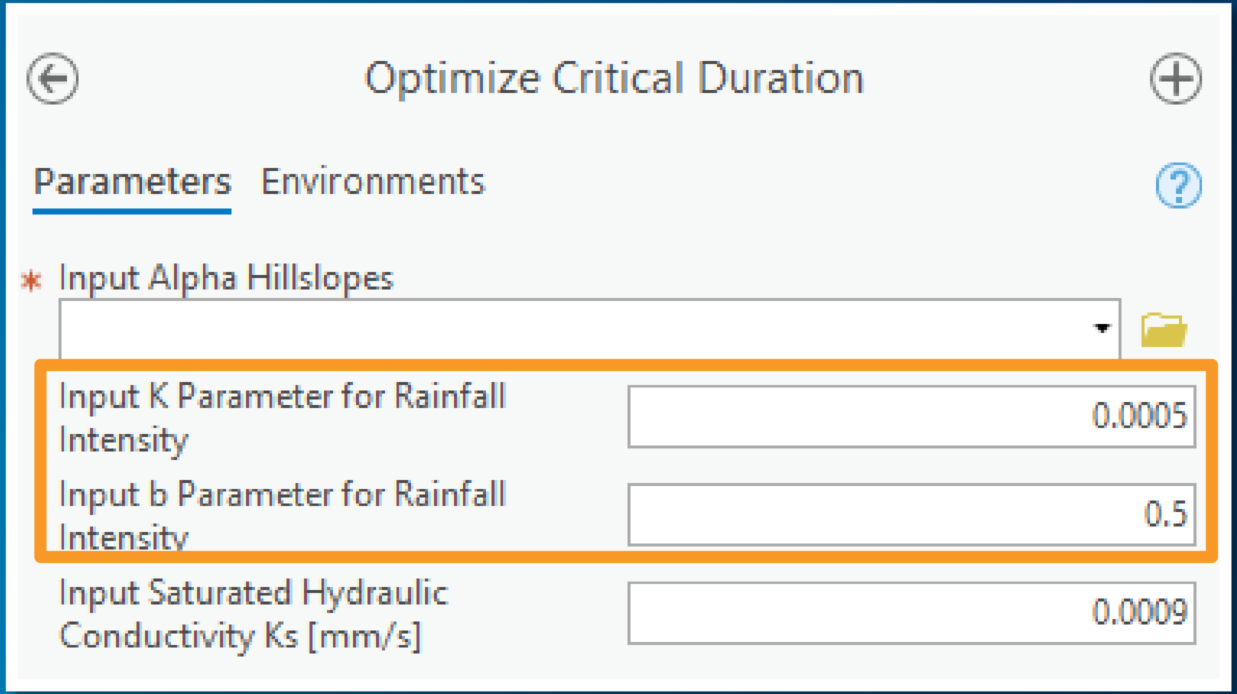
$$\alpha = \frac{\sqrt{S}}{n}$$

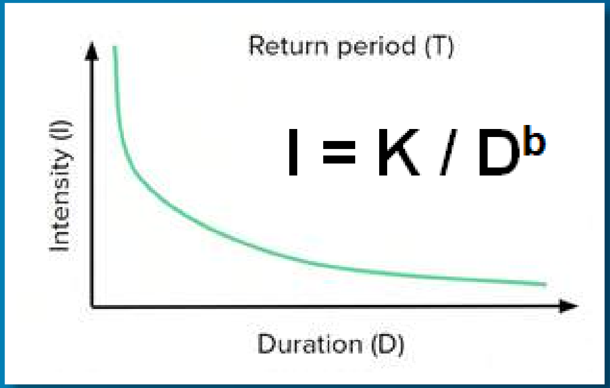
https://www.mrlc.gov/

Kalyanapu, A. J. (2009). Effect of land use-based surface roughness on hydrologic model output. *Journal of Spatial Hydrology*, *9*(2), 21.

Optimize Critical Duration



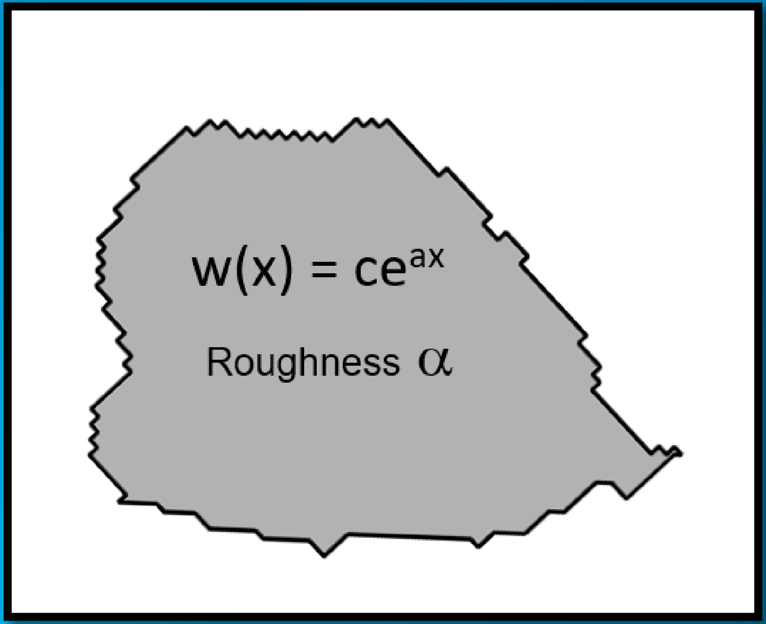




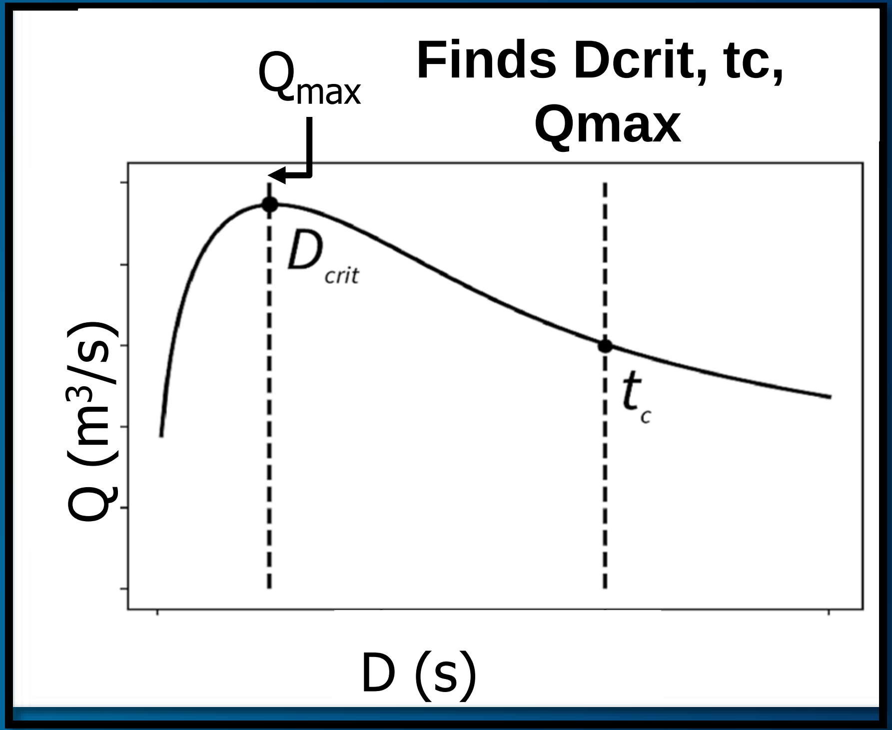
Optimize Critical Duration

$$Q_{max} = CAI$$

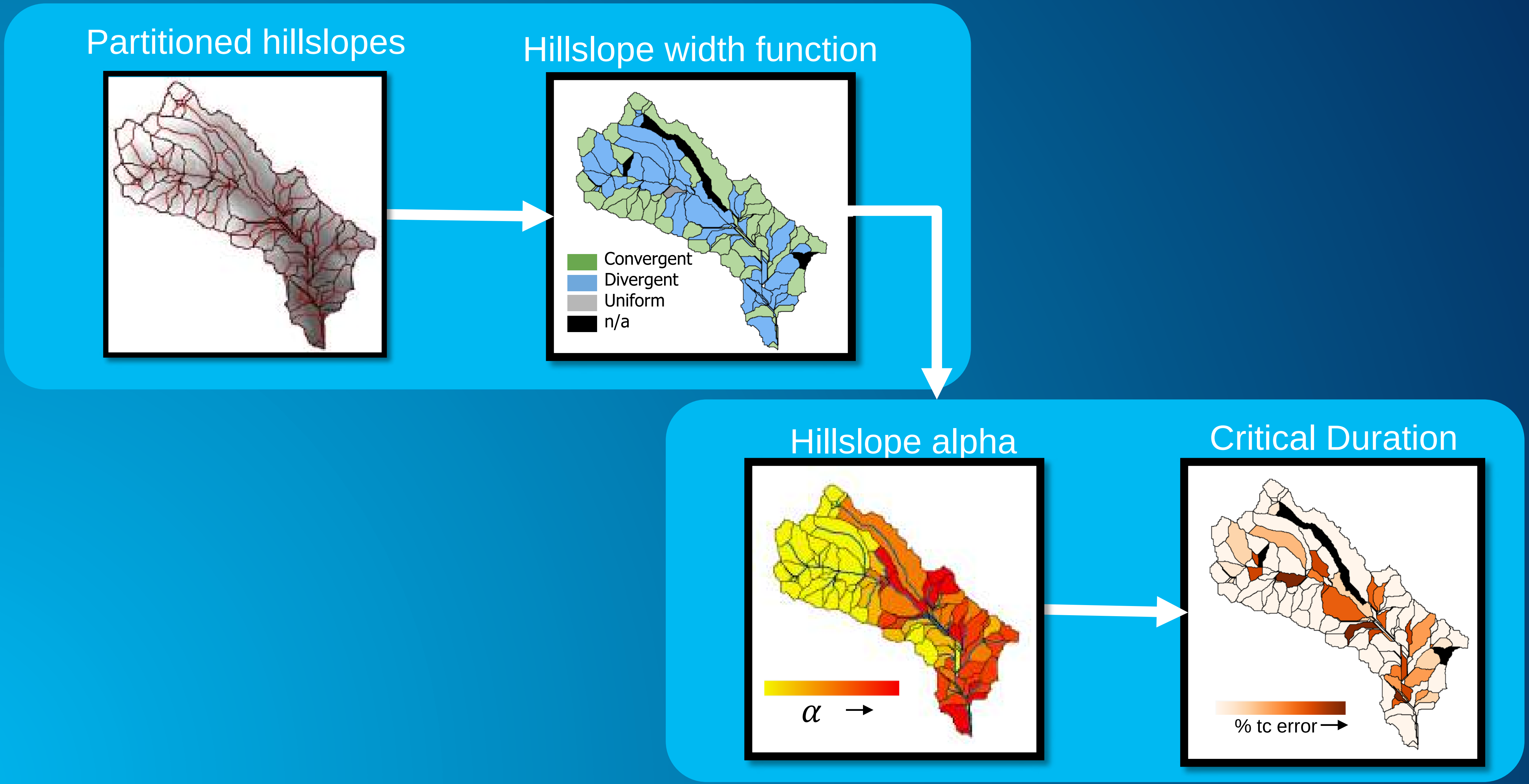
IFD parameters (K, b)
Soil Ks



Analytical solution for overland flow on hillslopes with curvature



Example outputs



Demonstration

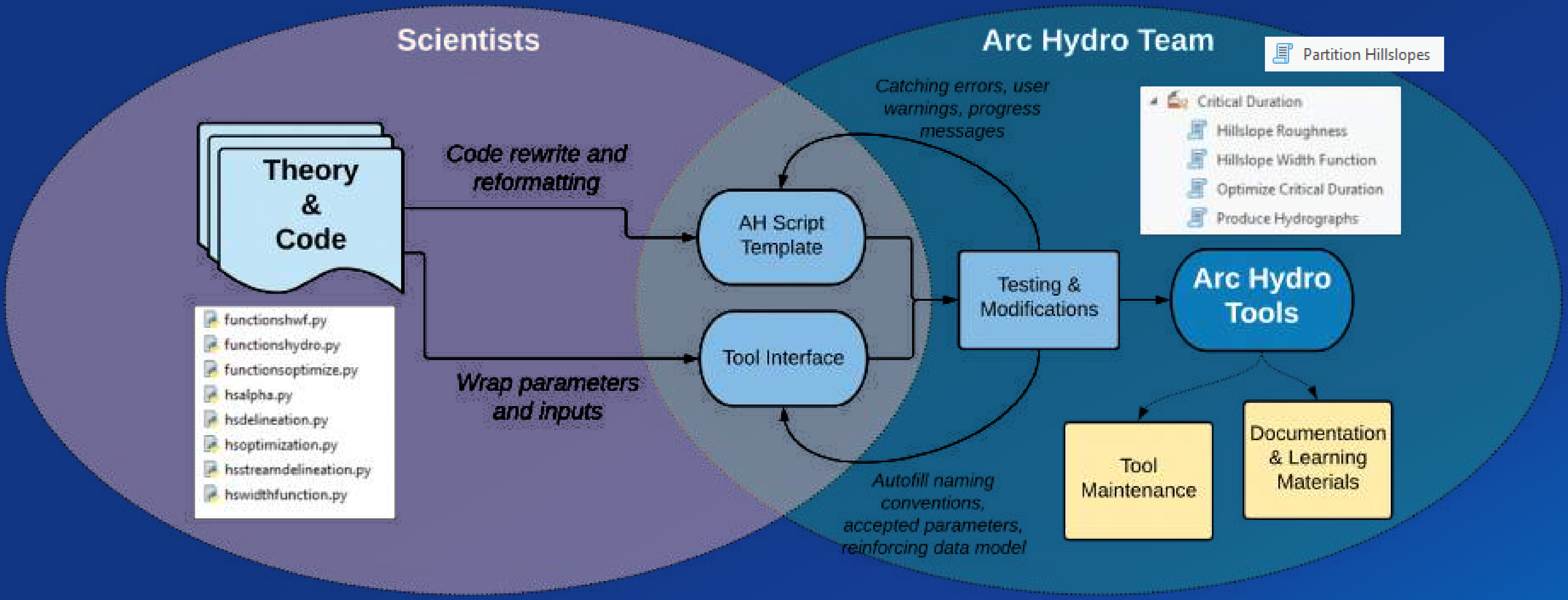
Anneliese Sytsma

Arc Hydro Hillslope + Critical Duration Tools: A Quick Demo

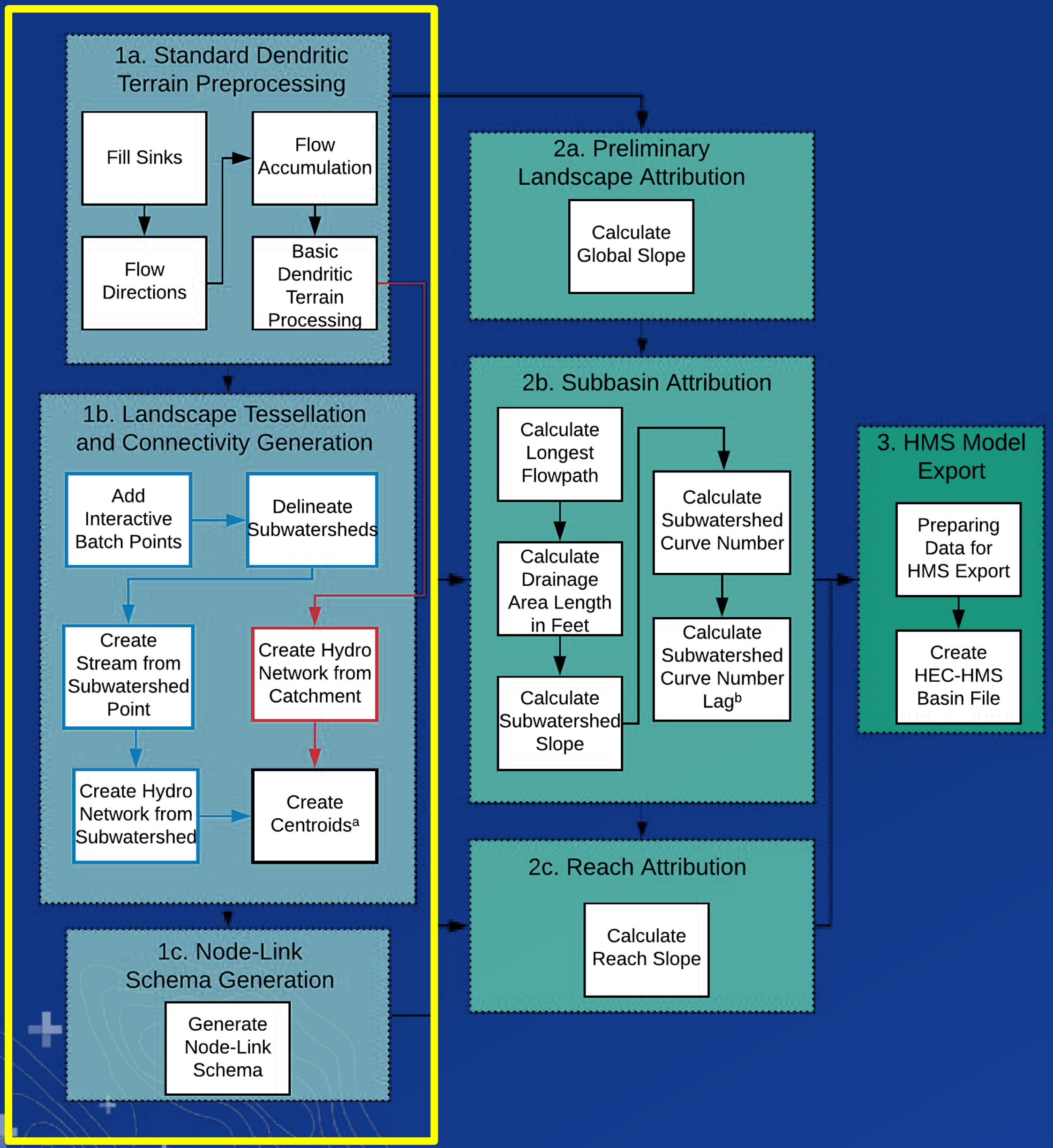
Distributed Modeling

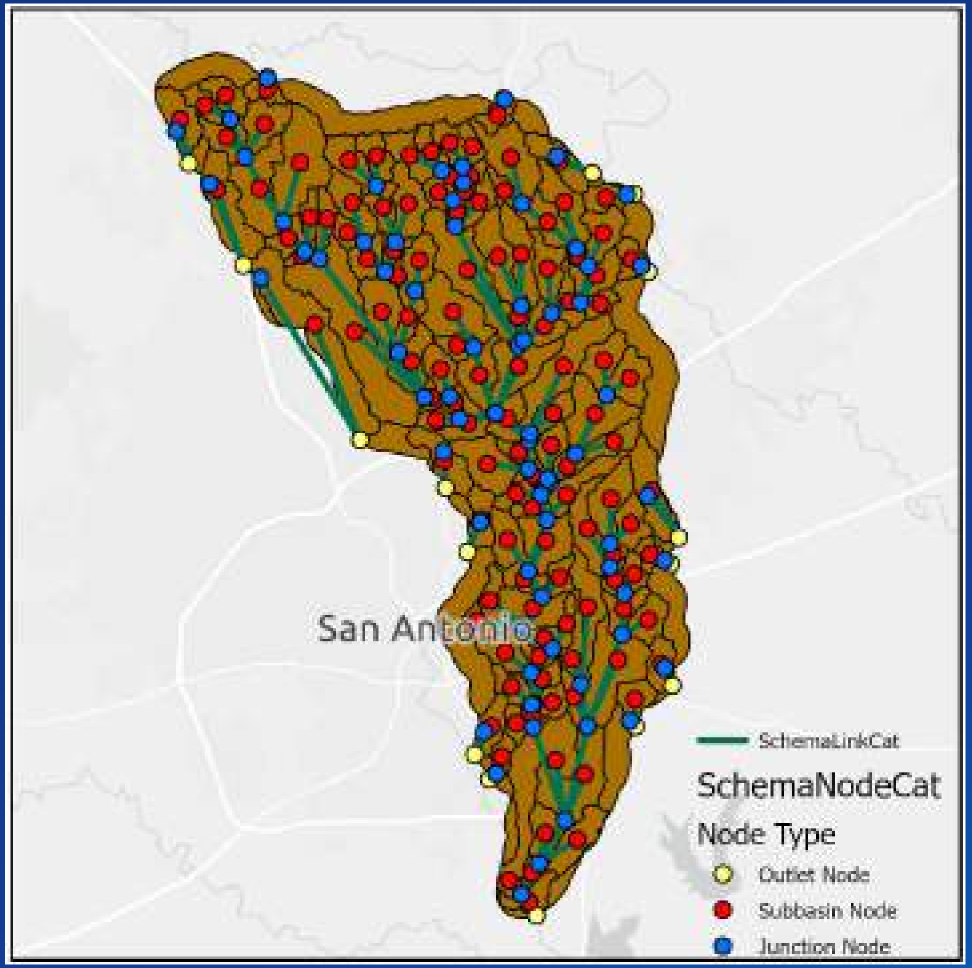
Gina O'Neil

Collaboratively Implementing the Science as an Arc Hydro tool

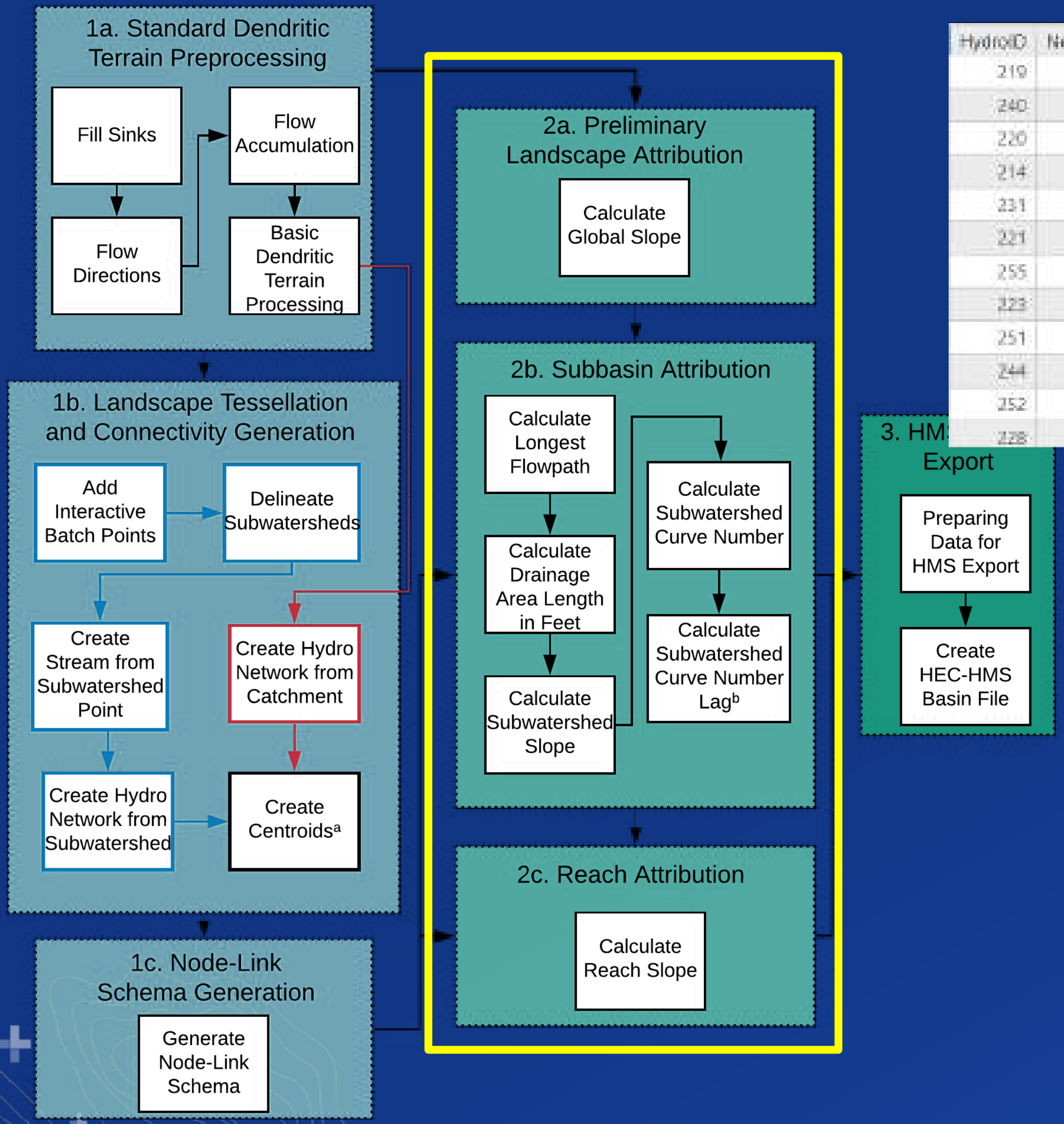


From Watershed Characterization to Simulating Hydrologic Processes

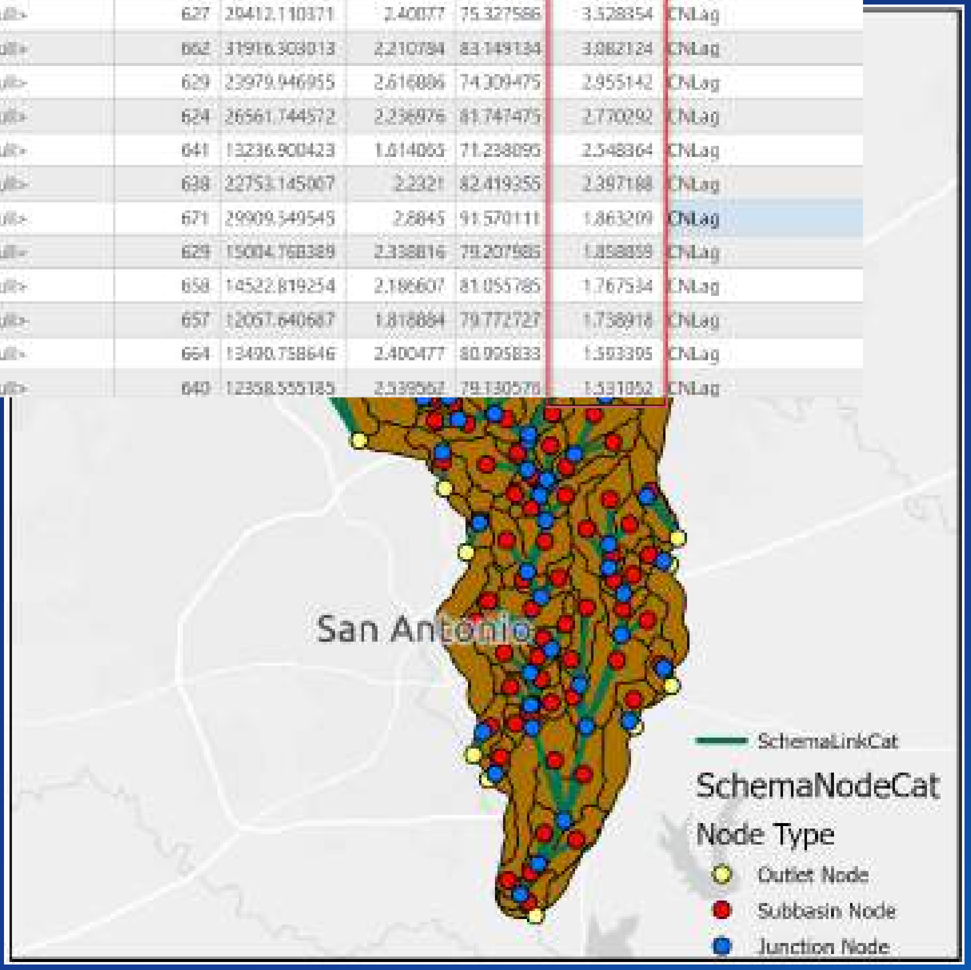




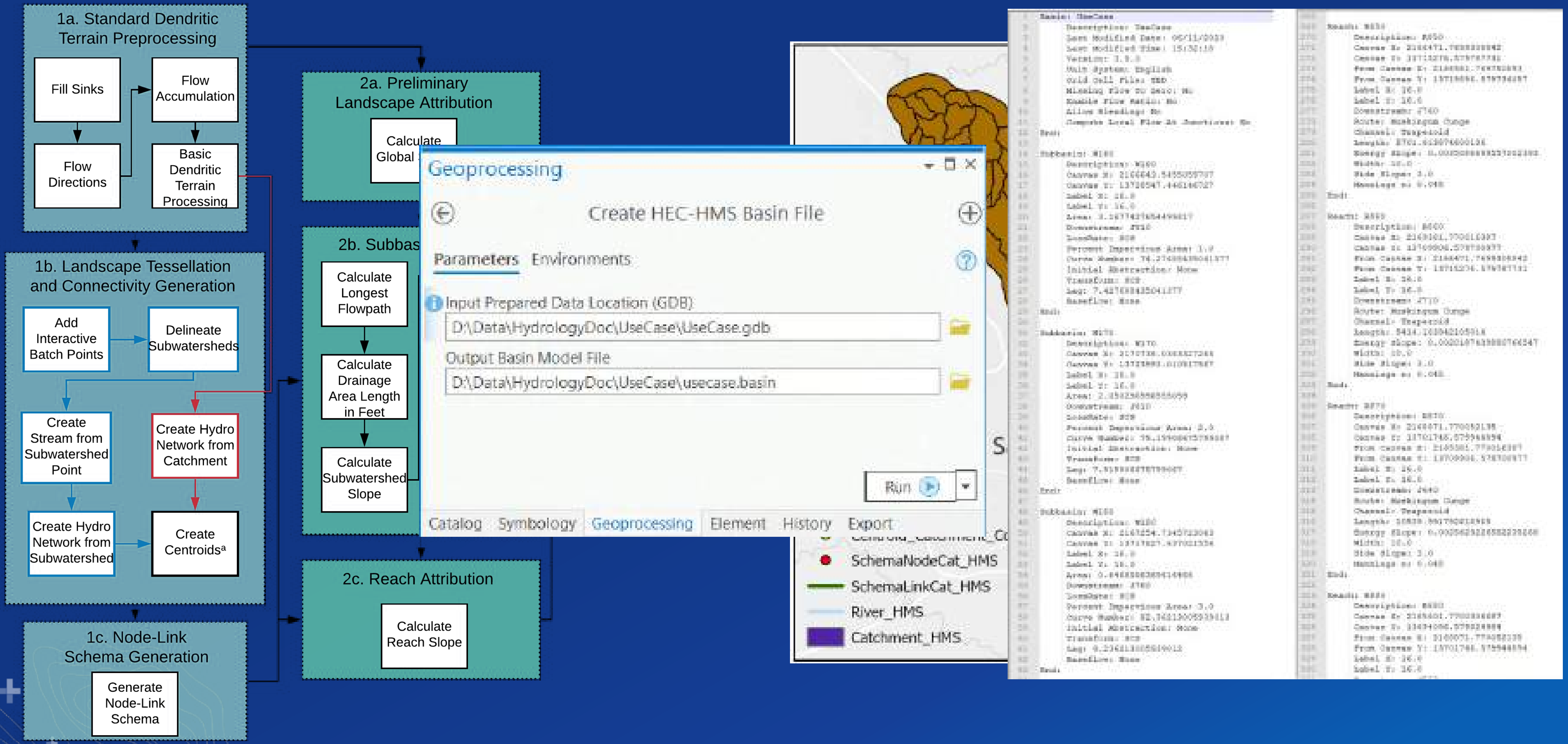
From Watershed Characterization to Simulating Hydrologic Processes



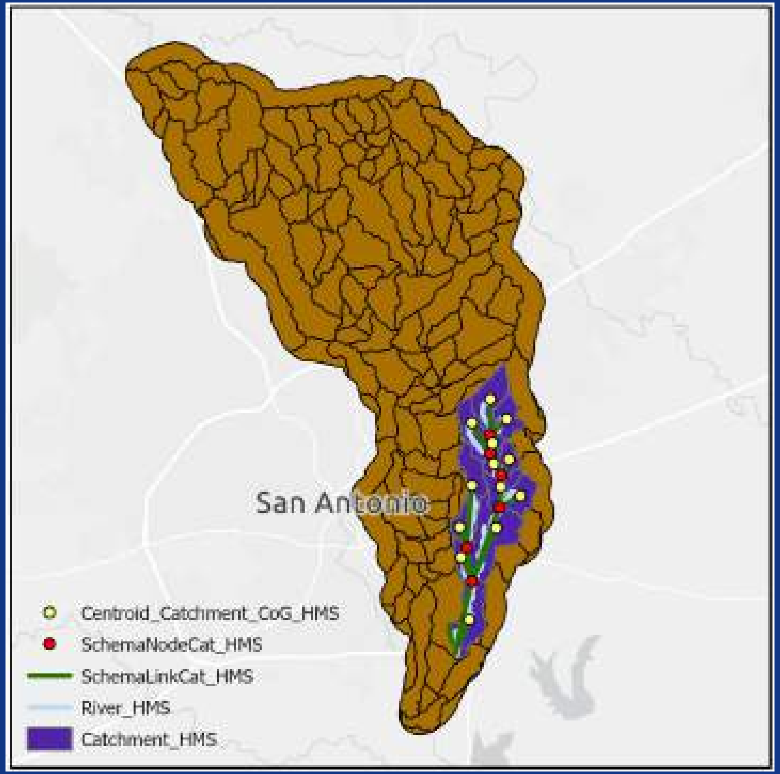
HydroID	NextDownID	CatType	JunctionID	LongestFLFt	BasinSlope	BasinCN	BasinLag	LagMethod
219	-1	<Null>	627	29412.110371	2.40077	75.327586	3.528354	CNLag
240	254	<Null>	662	31916.303013	2.210784	83.149134	3.082124	CNLag
220	226	<Null>	629	23979.946955	2.616886	74.309475	2.955142	CNLag
214	221	<Null>	624	26561.744572	2.236976	81.747475	2.770292	CNLag
231	233	<Null>	641	13236.900423	1.614065	71.238095	2.548364	CNLag
221	229	<Null>	638	22753.145007	2.2321	82.419355	2.397188	CNLag
255	259	<Null>	671	29909.549545	2.8845	91.570111	1.863209	CNLag
223	226	<Null>	629	15004.768389	2.338816	79.207985	1.858859	CNLag
251	249	<Null>	658	14522.819254	2.186607	81.055785	1.767534	CNLag
244	-1	<Null>	657	12057.640687	1.818884	79.772727	1.738918	CNLag
252	-1	<Null>	664	13490.758646	2.400477	80.995833	1.593395	CNLag
228	232	<Null>	640	12358.555185	2.539562	79.130576	1.531052	CNLag

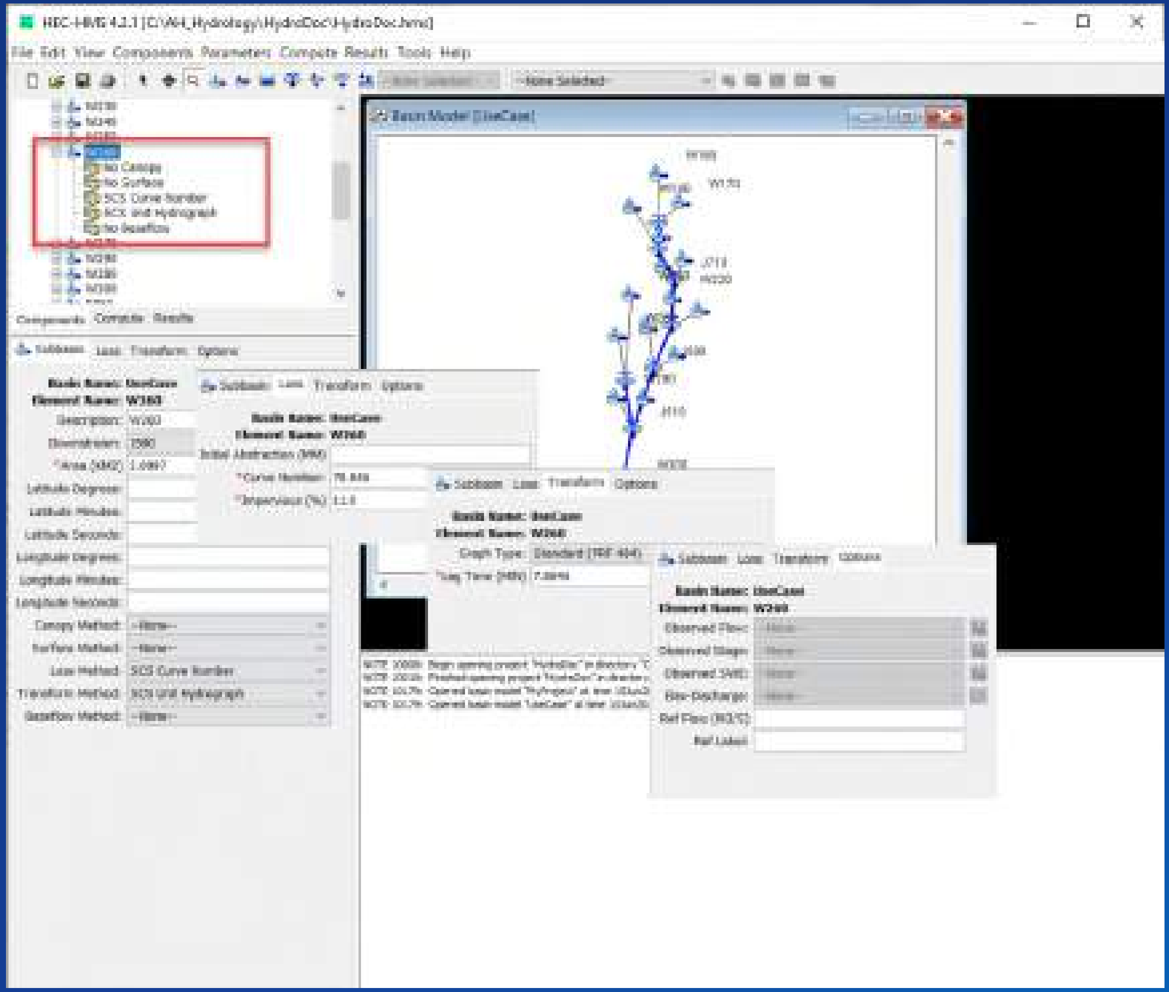


From Watershed Characterization to Simulating Hydrologic Processes



From Watershed Characterization to Simulating Hydrologic Processes





Final Thoughts

Dean Djokic

Arc Hydro in Action Webinar Series

2/25/21: **Arc Hydro in ArcGIS Pro**

3/11/21: **Arc Hydro: Flooding & Forecasting**

3/25/21: **Arc Hydro: Hydrology & Hillslope**

4/15/21: **Arc Hydro: Support for Hydrologic and Hydraulic Modeling**

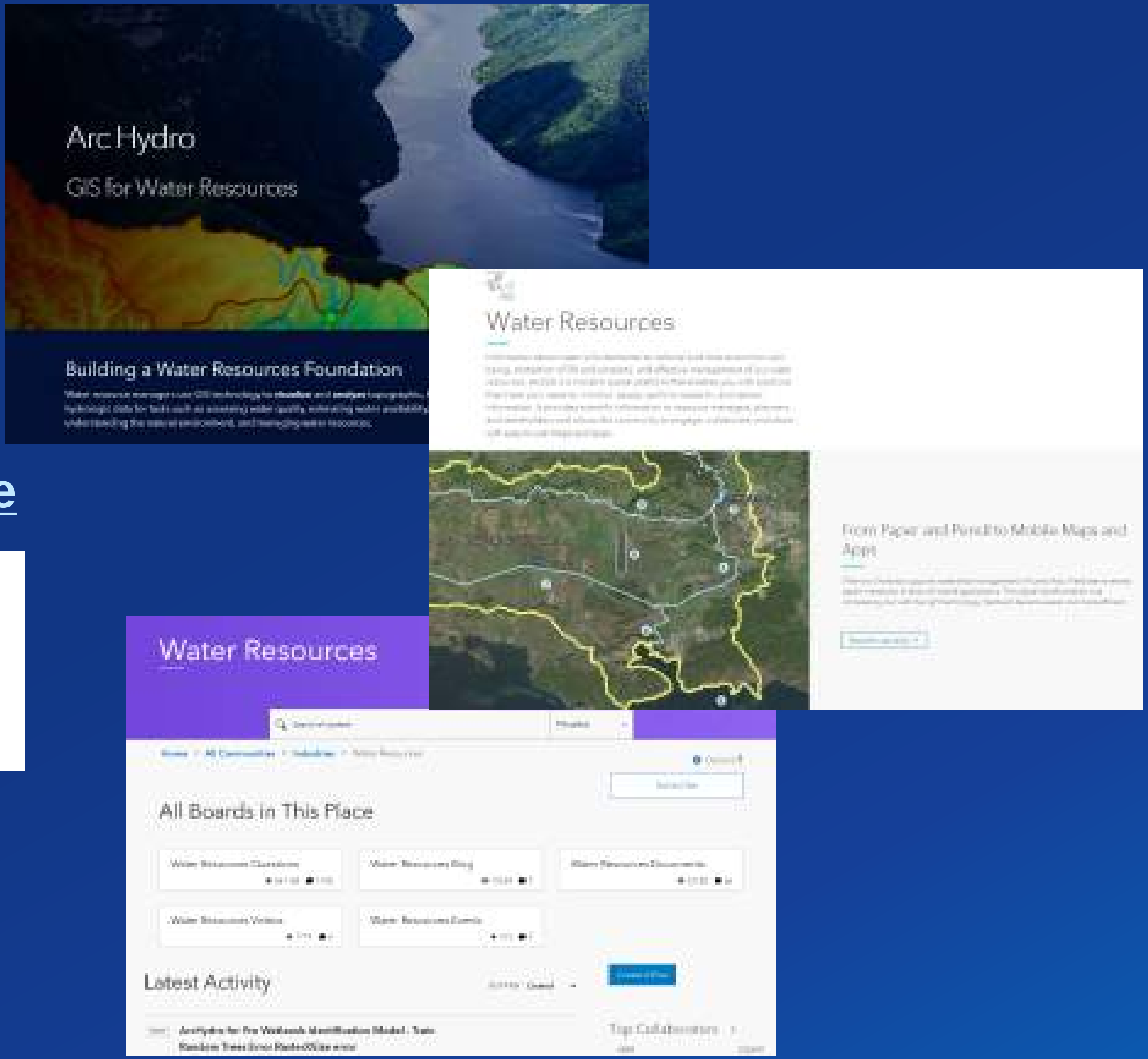
GIS for integrated H&H modeling.

Why GIS is not just model pre- and post-processor.

Questions?

Getting involved

- [Arc Hydro Web Page]
- [Water Resources Industry Web Page]
- [Arc Hydro Community]
  - archydro@esri.com
  - ddjokic@esri.com



@EsriWater | Esri Water Resources | @EsriWater | Esri Water Meetup | Esri Water eNewsletter