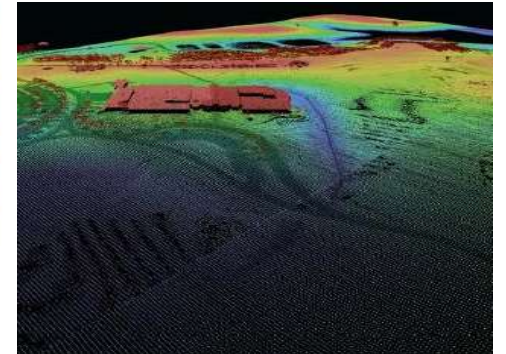
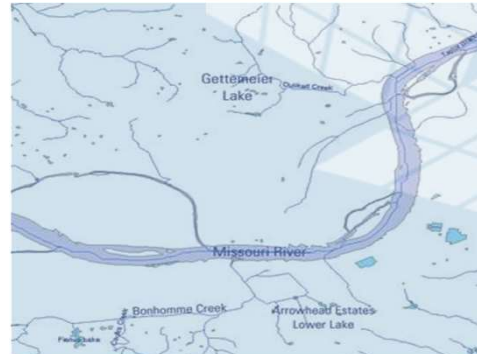
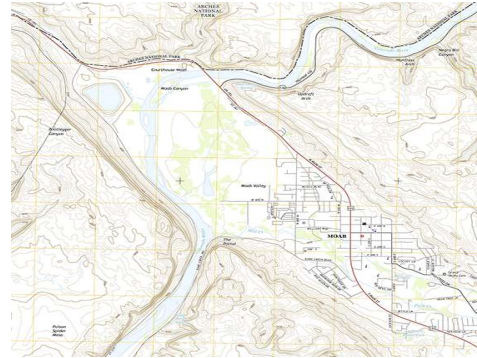




Uncharted Waters: Finding water in elevation data



Steve Aichele
USGS National Geospatial Program

May 2022



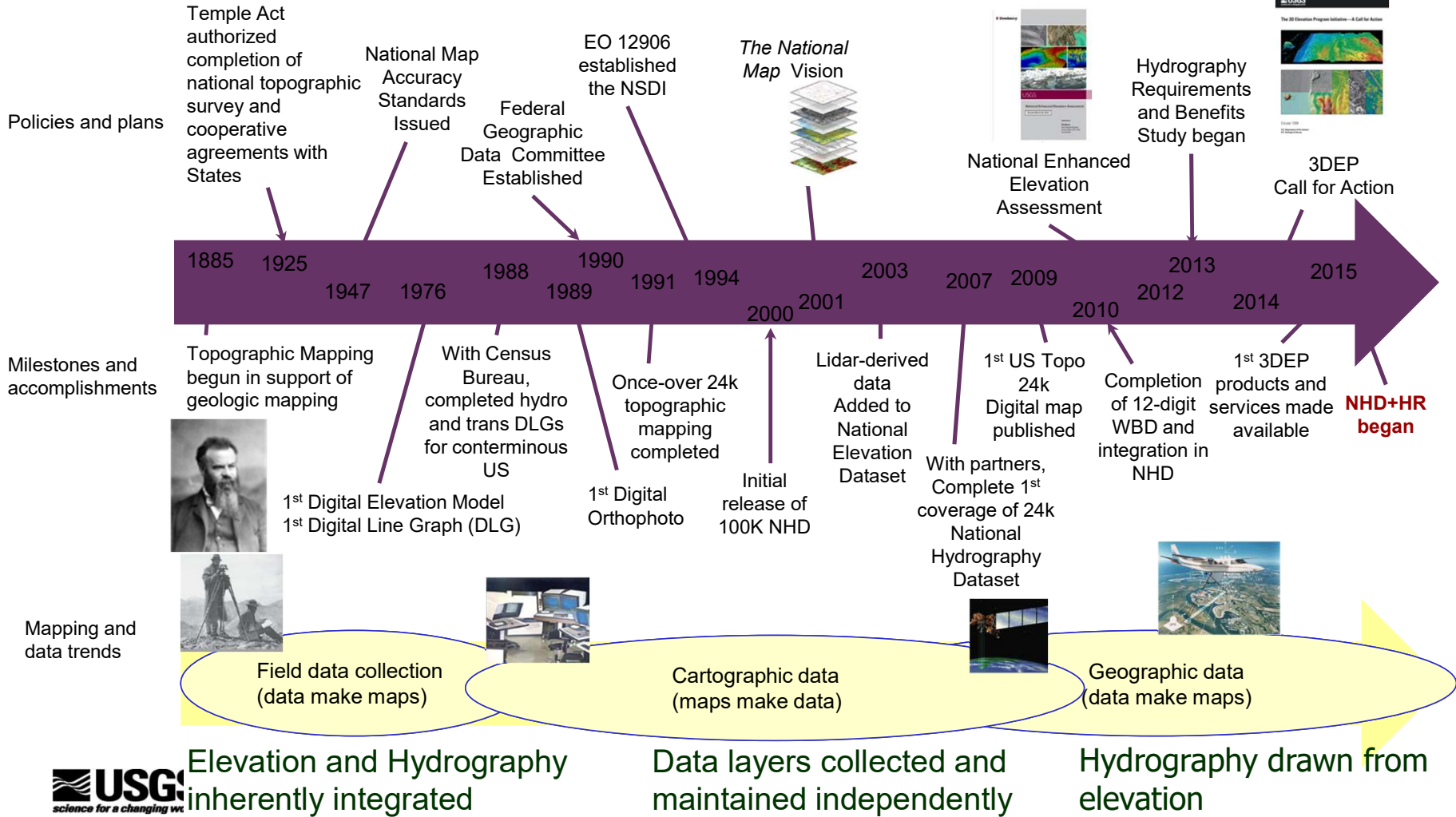
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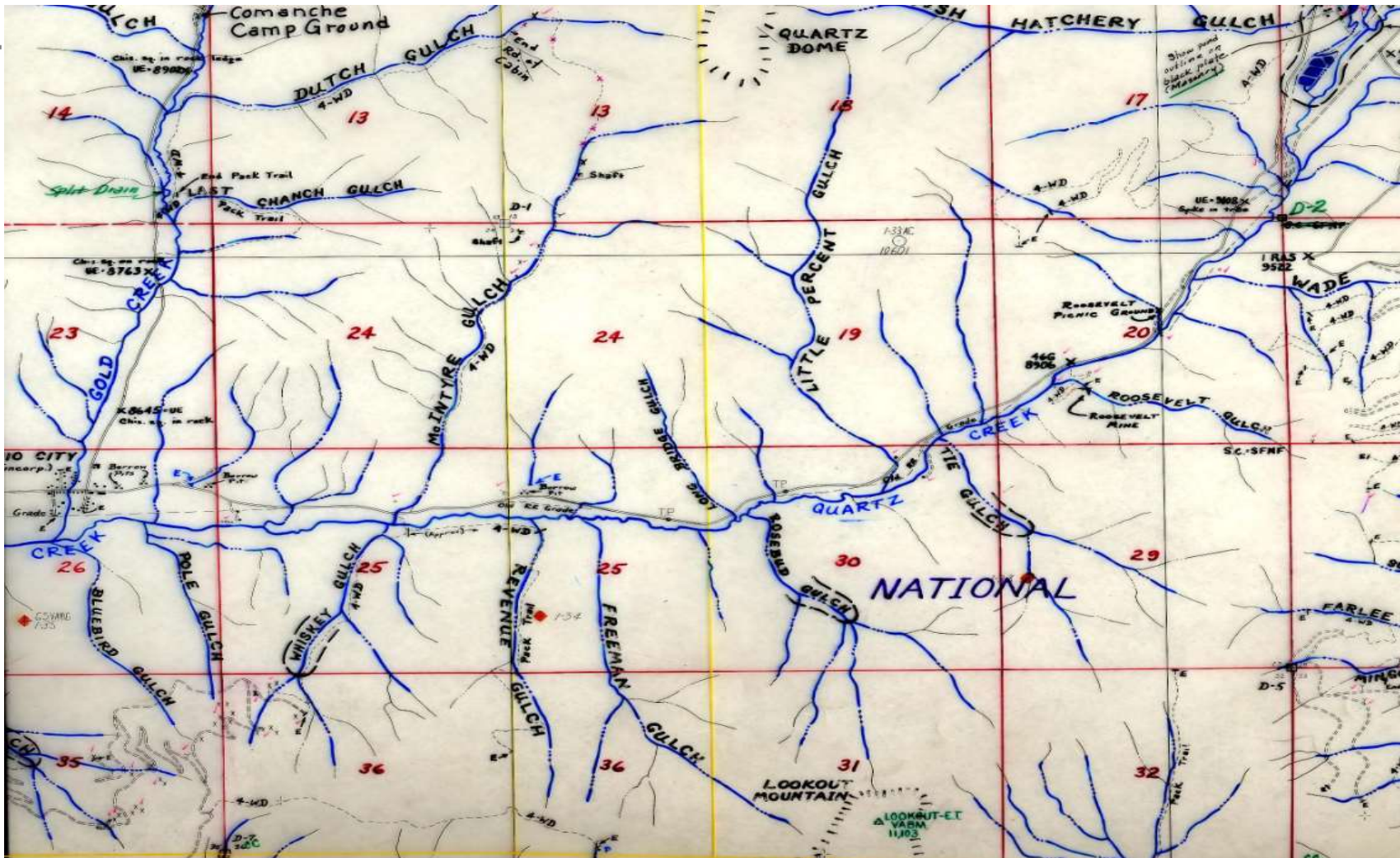
Agenda

- How we got here
- Where we are
- What's next



An Abridged History of USGS Topographic Mapping





This shows the results of the field classification of the streams in the same area. Notice that some of the drainage lines were determined to not have any water at least part of the year – they don't have "blue lines".

+

6

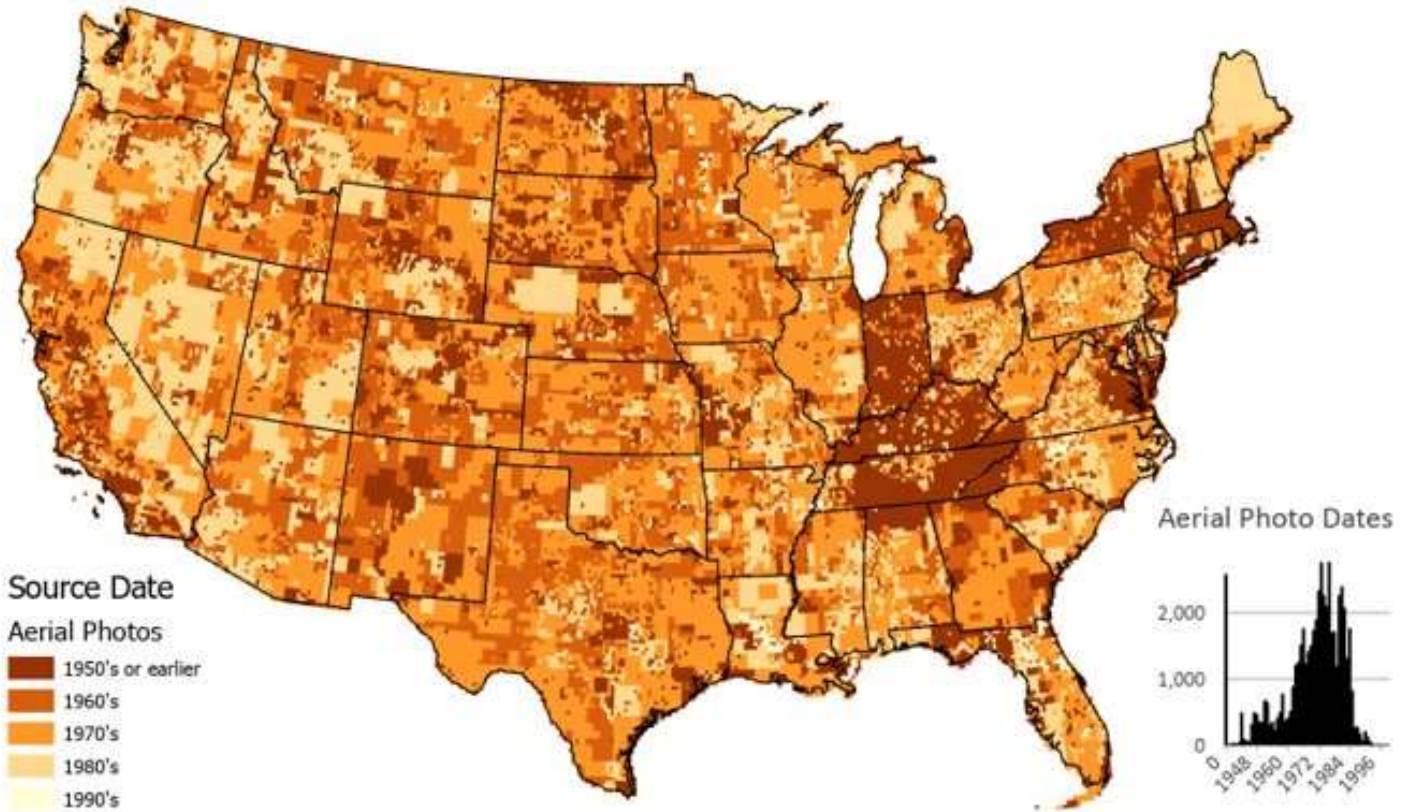


Original compilation manuscript for the Pitkin, CO USGS topo map.

+

Age of NHD

How old is NHD?



+ Key takeaways

- Completing CONUS coverage of 1:24,000 scale maps took about 45 years
- Methods varied as technology improved
- Most work done by USGS staff
- Costs of collecting the hydrography data not tracked explicitly
- Geospatial information from the 1:24,000 scale maps was converted to Digital Line Graphs (1990s)
- USGS and state partners attributed DLG data (usually) to create National Hydrography Dataset (2007)
- Most features in NHD trace back to original 1:24,000 scale maps
- Hydrography and elevation were mapped together, and enforced each other

+

Hydrography Requirements and Benefits Study

“HRBS” to its friends

9

Hydrography Requirements and Benefits Study (HRBS) content requirements met by 3DHP Datasets		% Mission Critical Activities required/ addressed
Level of detail	Highest level of detail available maintained, build generalization functionality	100%
Spatial accuracy	Spatial features horizontal positional accuracy - +/- 2 meters, 90 percent CE	64%
Elevation data integration	Elevation and hydrography integrated – 3DHP Datasets derived from 3DEP data	65%
More complete hydrologic cycle	Groundwater models linked to 3DHP Datasets	21%
	NWI wetland features data spatially aligned with 3DHP Datasets	64%
	Engineered hydrology (e.g. stormwater systems) connected (potentially generalized)	51%
	Culverts included / linked to 3DHP Datasets; bridges spatially aligned	55%
Streamflow permanence	Streamflow permanence attributed as modeled values that can be classed by users	51%
Network connectivity	On-network discovery supported (multiple requirements)	47-68%
	Network analysis supported (multiple requirements)	59-66%
Maintenance	Features reviewed / updated as needed on 4-5 year schedule (dependent on 3DEP)	41%
	Known errors corrected within 1-2 months from reporting	64%

+

Elevation-Derived Hydrography (EDH)

Deriving hydrography from elevation is a key future direction for USGS hydrography

- Hydrography (streams, lakes, hydrologic units) synthetically derived using algorithms to process elevation data to identify channels and depressions that may carry surface flow
- Deriving synthetic streams and lakes from DEMs can be tricky...
 - There are plenty of algorithms to choose from - which is right for your landscape or area?
 - Where are the bridges and culverts, etc.?
 - How far is far enough in headwater areas?
- Deriving hydrography from elevation greatly improves accuracy, precision, and detail of hydrography data and ensures necessary data integration for modeling and analysis

10

+

Known unknowns

What we knew we didn't know

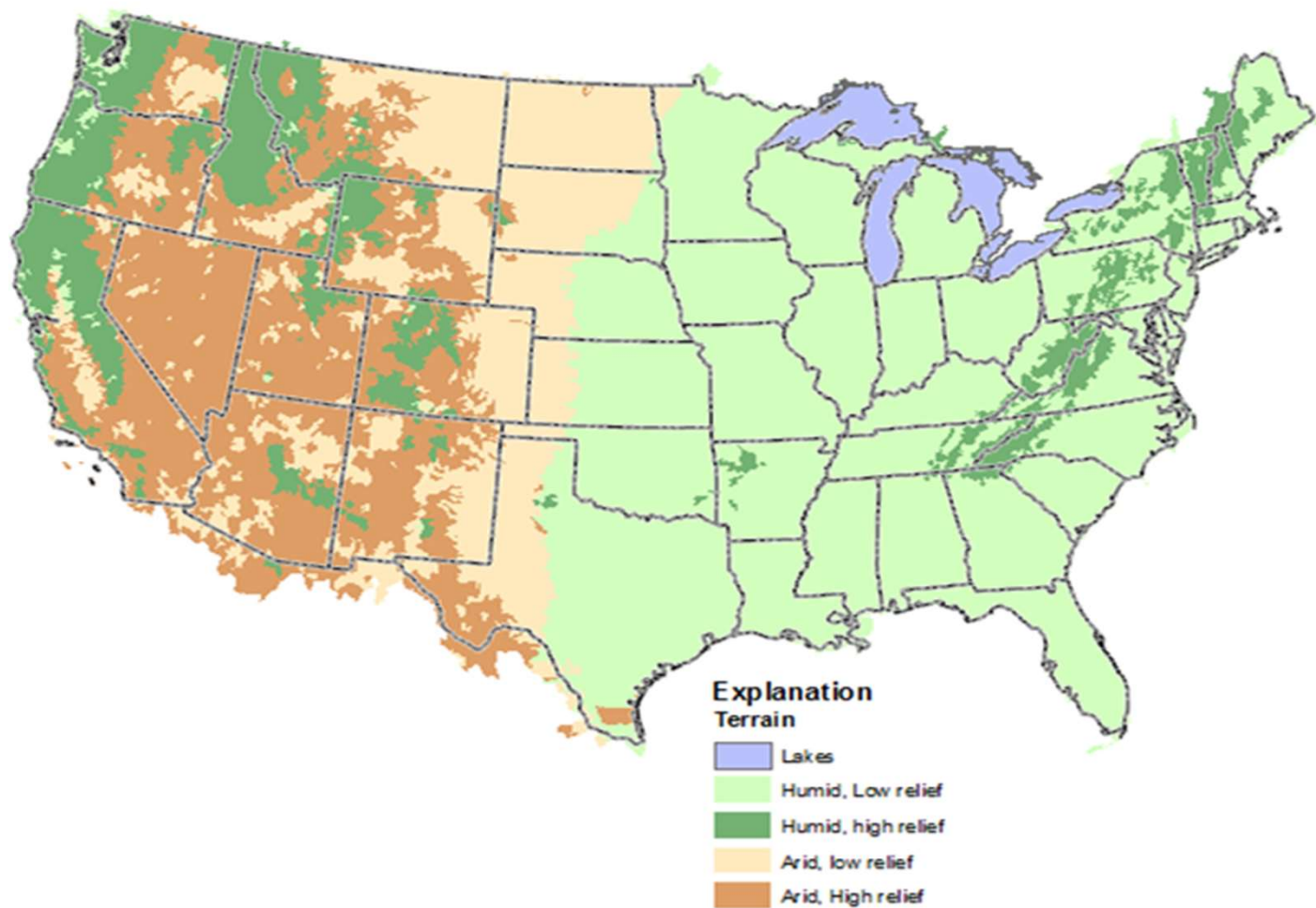
- Acquisition process
- Contractor ability and capacity
- Project timelines
- Inspection process
- Costs
- Unknown unknowns

+ 2016 Pilots

- Pilot efforts
 - Five landscapes – humid, arid, flat, mountainous, coastal
 - Three levels of improvement
 - Improve positional accuracy of 24K feature content
 - Improve positional accuracy of 24K feature content AND add local-res (~1:4800) content
 - Attribution of linework/conflation
 - Level of effort reported for each step, and each landscape
- Understand contracting process
- Evaluate contractor performance
- Understand scenario costs

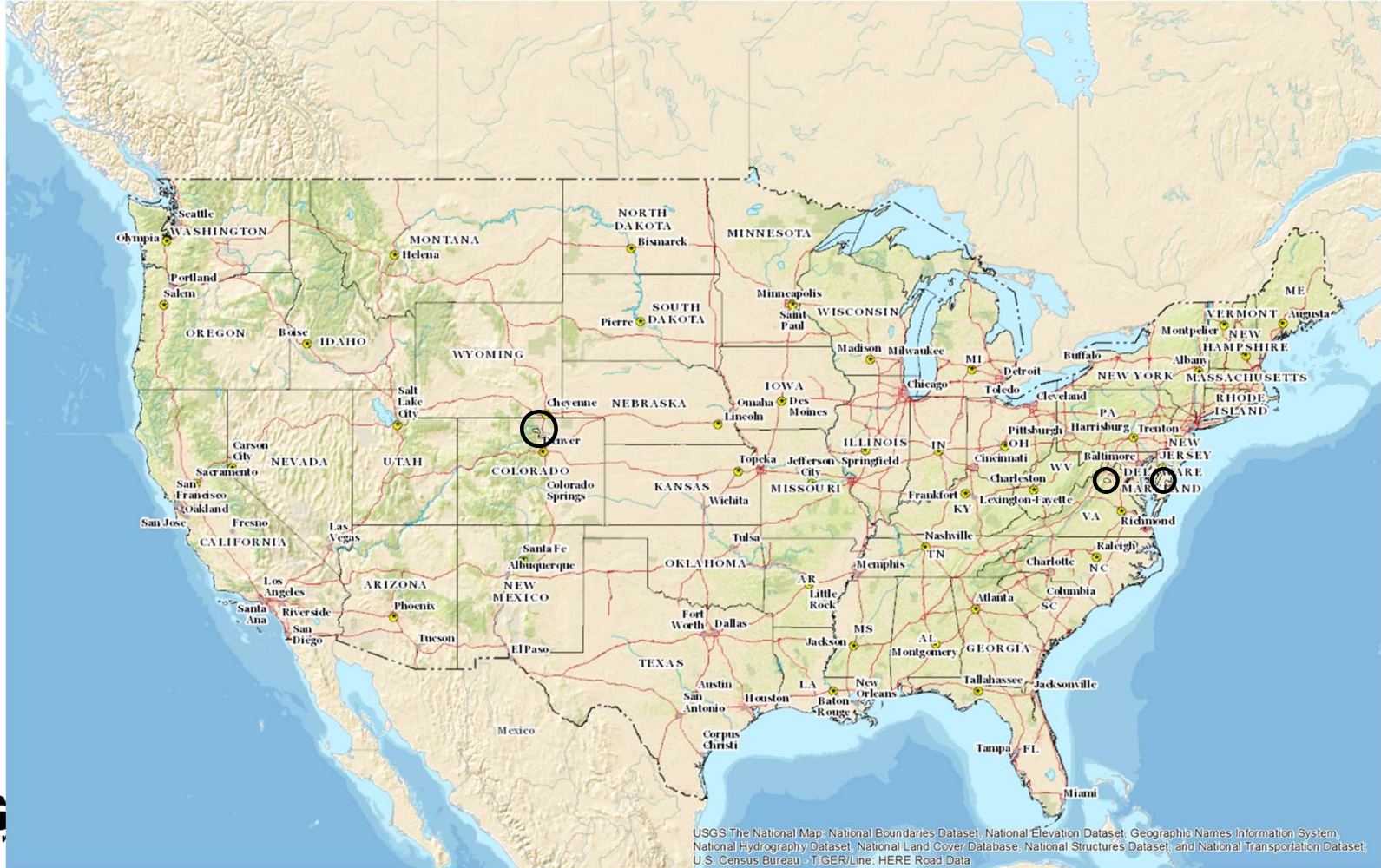
+ Terrain regions

13

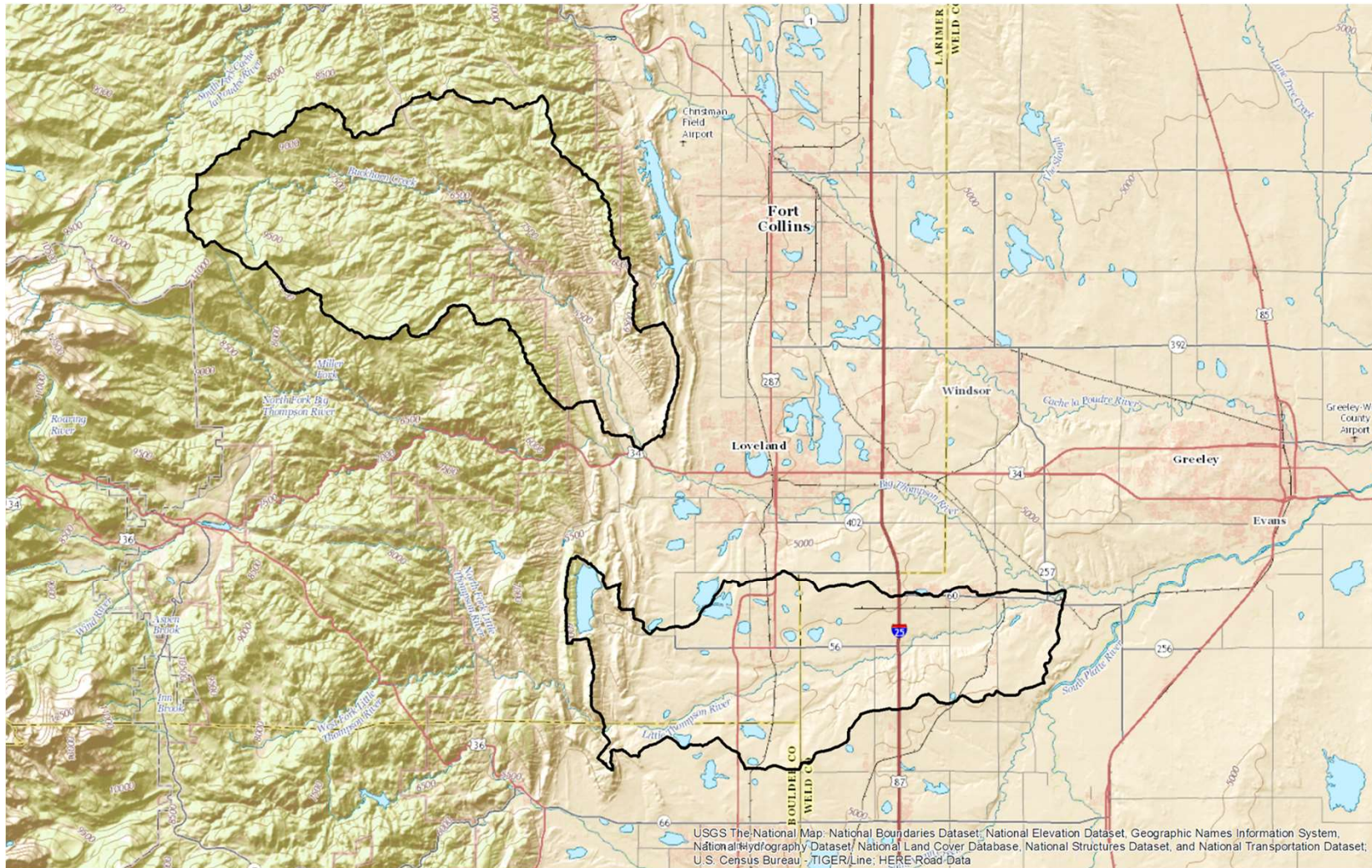


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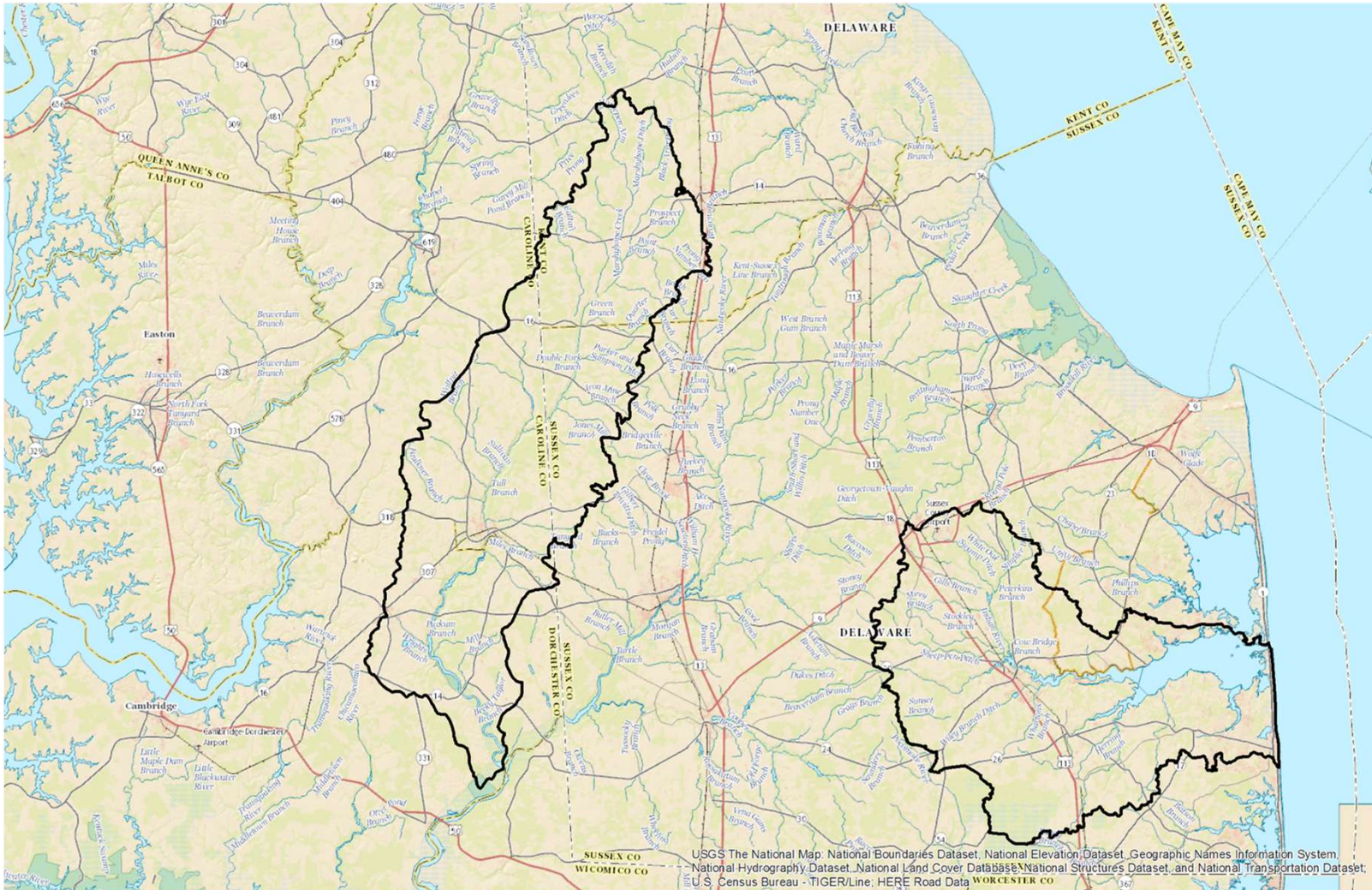
Pilot Areas



+ CO Pilots – Arid, mountainous and flat

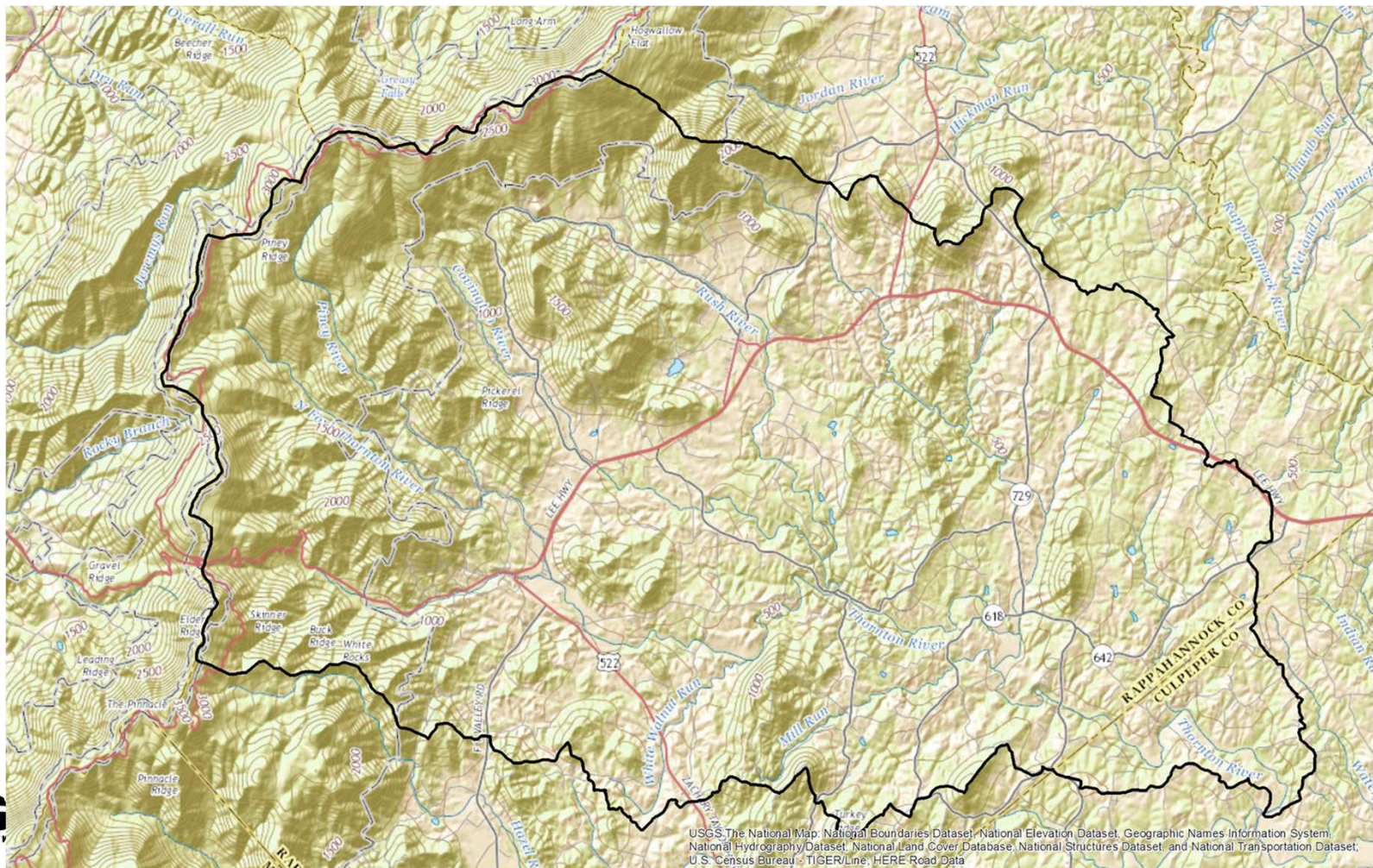


+ DE/MD pilots – humid, flat and coastal



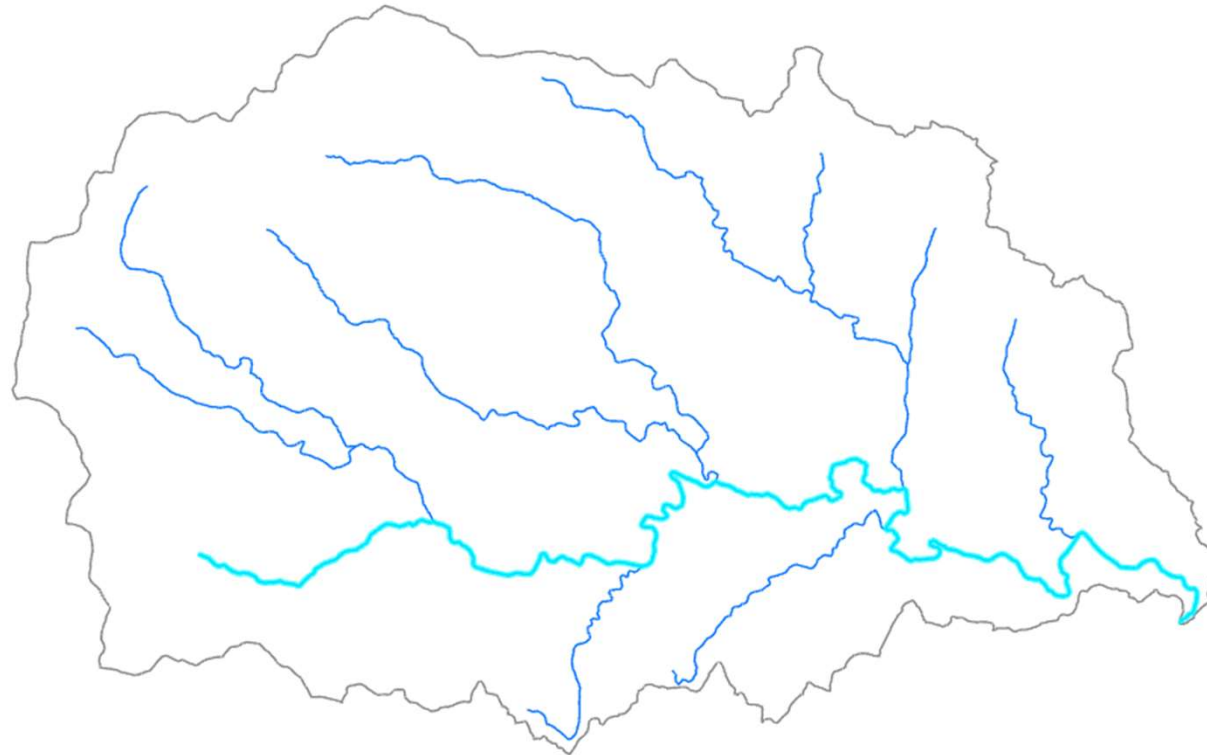
+

VA Pilot



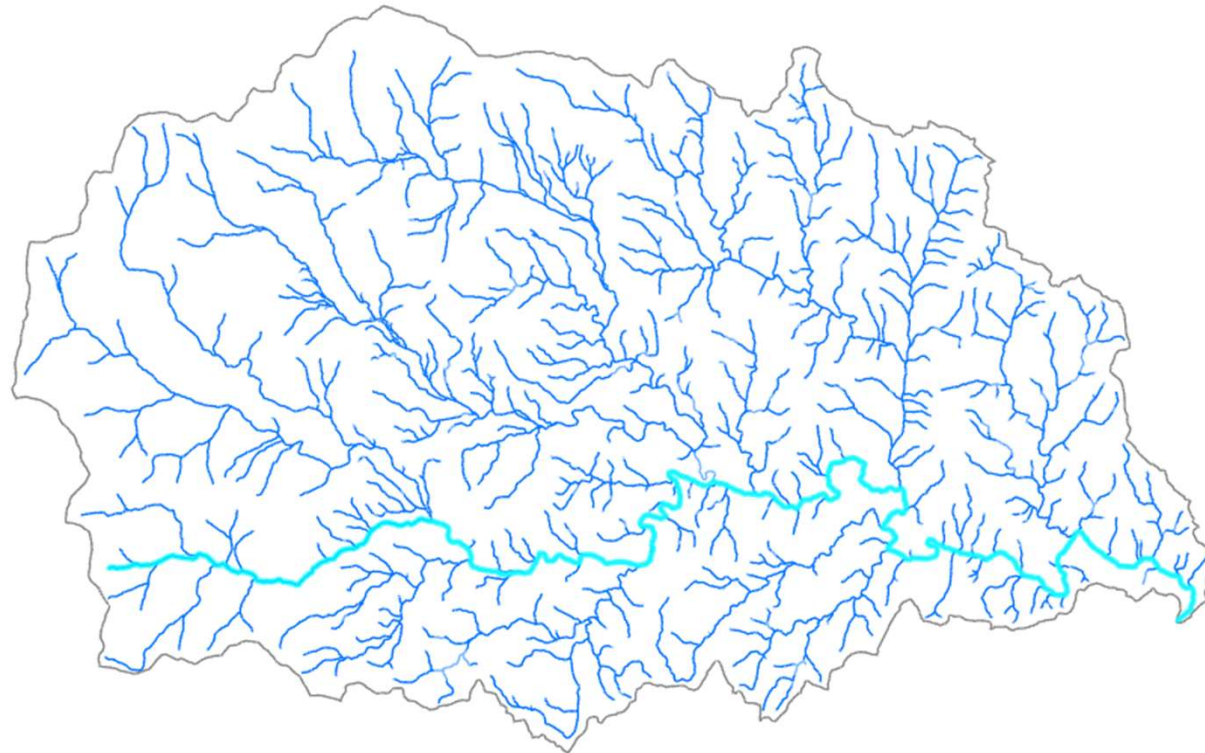
+ Thornton River

NHD, medium resolution stream network



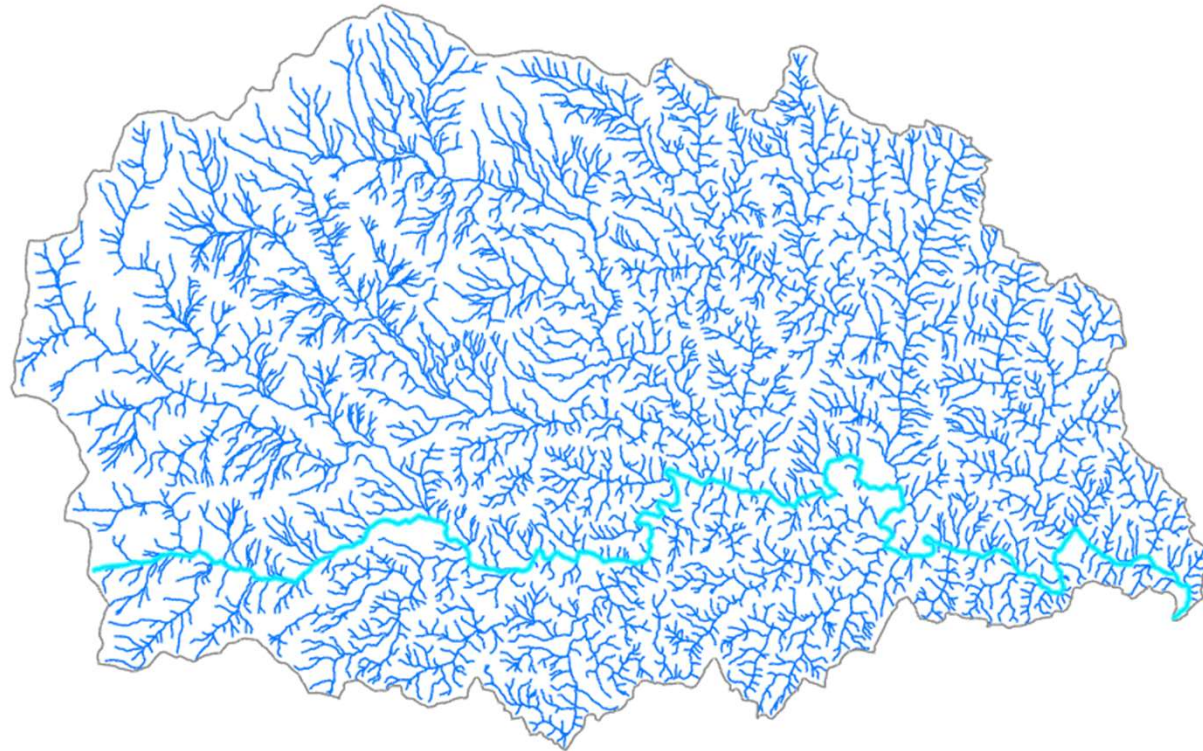
+ Thornton River

NHD, high resolution stream network



+ Thornton River

Elevation-derived hydrography



+ Technical findings from pilots

- Specifications were inadequate – need to revise and expand elehydro data dictionary (eventually became the new EDH Specifications and READ rules)
- Need to develop standards for z-values
- Need to develop standards and automated processes for inspection
- Need to develop common language with contractors

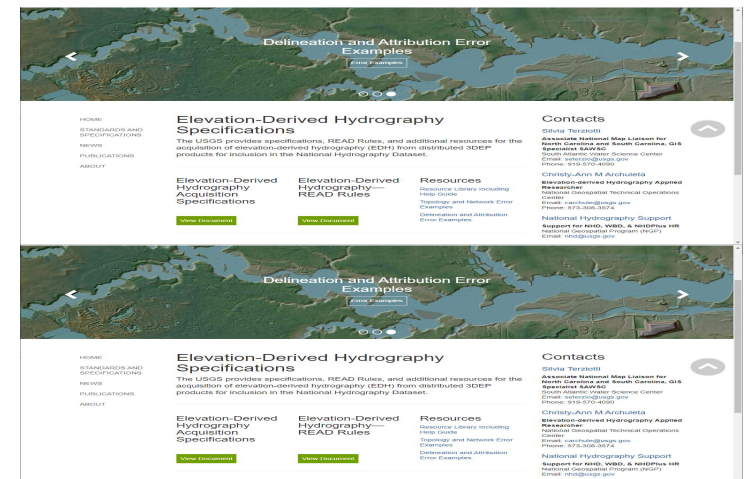
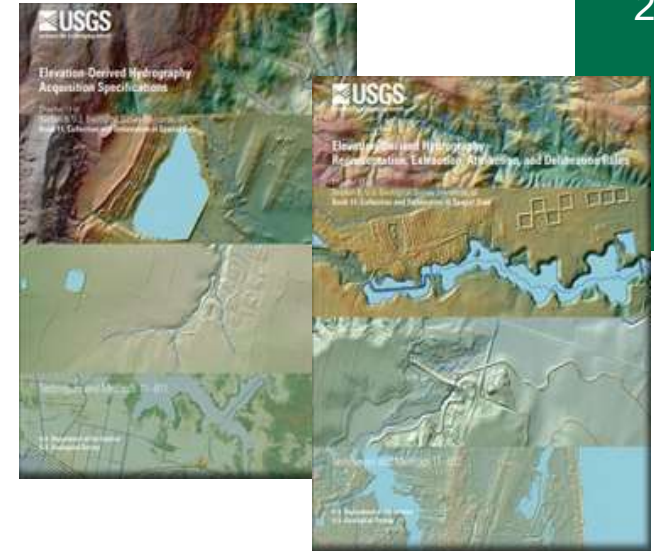
Back to the drawing board



Specifications

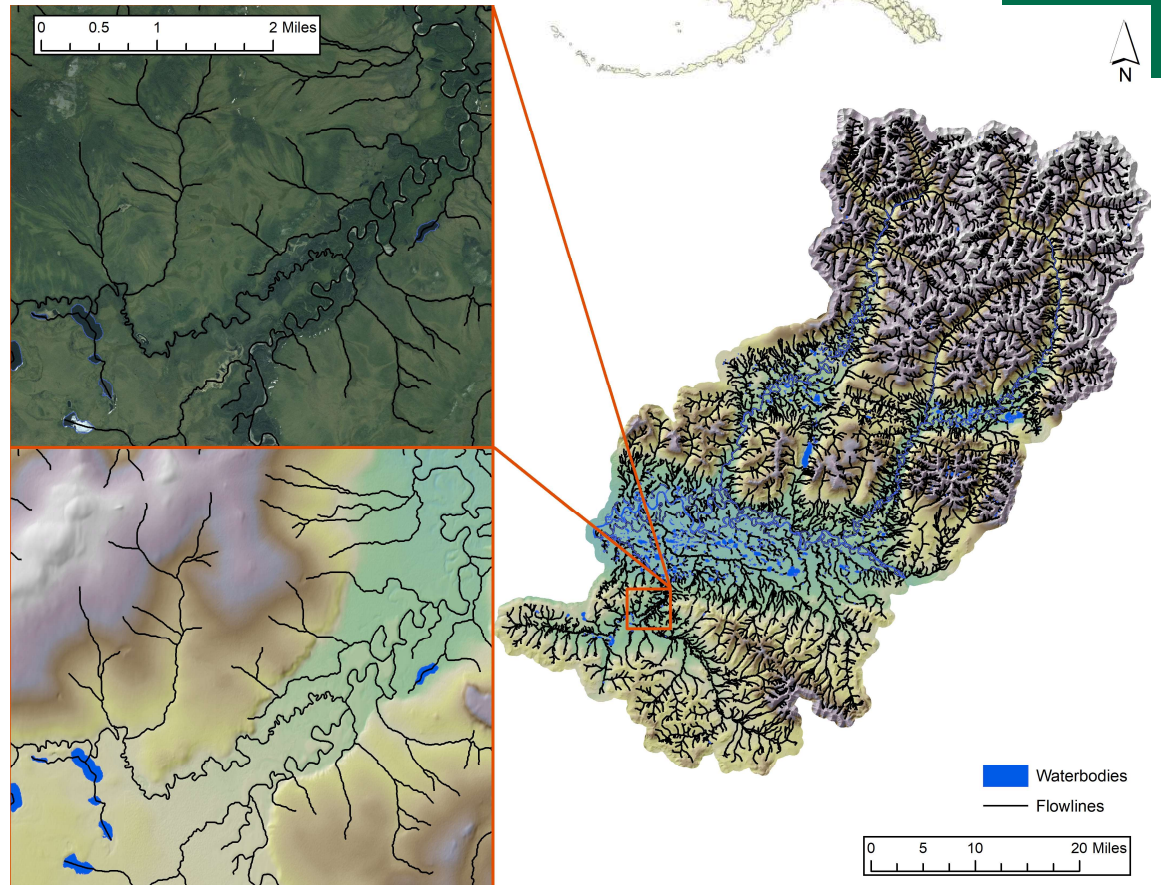
Published July 2020

- USGS Techniques and Methods 11–B11: Elevation-Derived Hydrography Acquisition Specifications
 - Suggested citation: Terziotti, S., and Archuleta, C.M., 2020, Elevation-Derived Hydrography Acquisition Specifications: U.S. Geological Survey Techniques and Methods, book 11, chap. B11, 74 p., <https://doi.org/10.3133/tm11B11>.
- USGS Techniques and Methods 11–B12: Elevation-Derived Hydrography—Representation, Extraction, Attribution, and Delineation Rules
 - Suggested citation: Archuleta, C.M, and Terziotti, S., 2020, Elevation-Derived Hydrography—Representation, Extraction, Attribution, and Delineation Rules: U.S. Geological Survey Techniques and Methods, book 11, chap. B12, 60 p., <https://doi.org/10.3133/tm11B12>.
- Specification resources online
 - <https://www.usgs.gov/core-science-systems/ngp/ss/elevation-derived-hydrography-specifications>



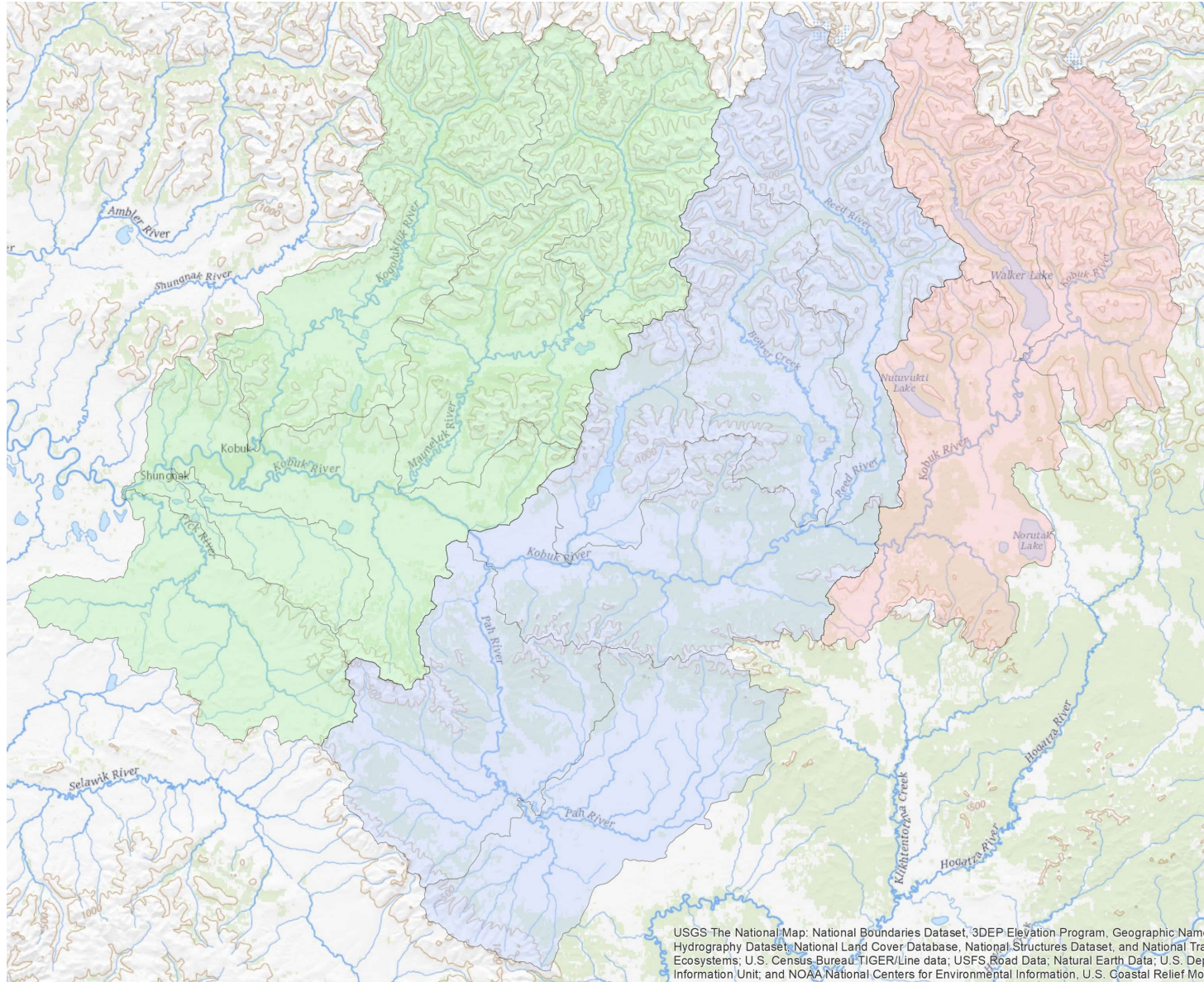
+ 2019-20 Alaska Hydro pilots – Kobuk River

- Total area of about 4700 sq. mi. (12,000 sq. km.)
- Roughly the size of Connecticut
- Mixed terrain
- High-interest because of a proposed road
- Very similar capture conditions to existing 1:24,000 scale data
- Customized elevation-derived hydrography specification and requirements
- z-enabled hydrography data that integrates with elevation data

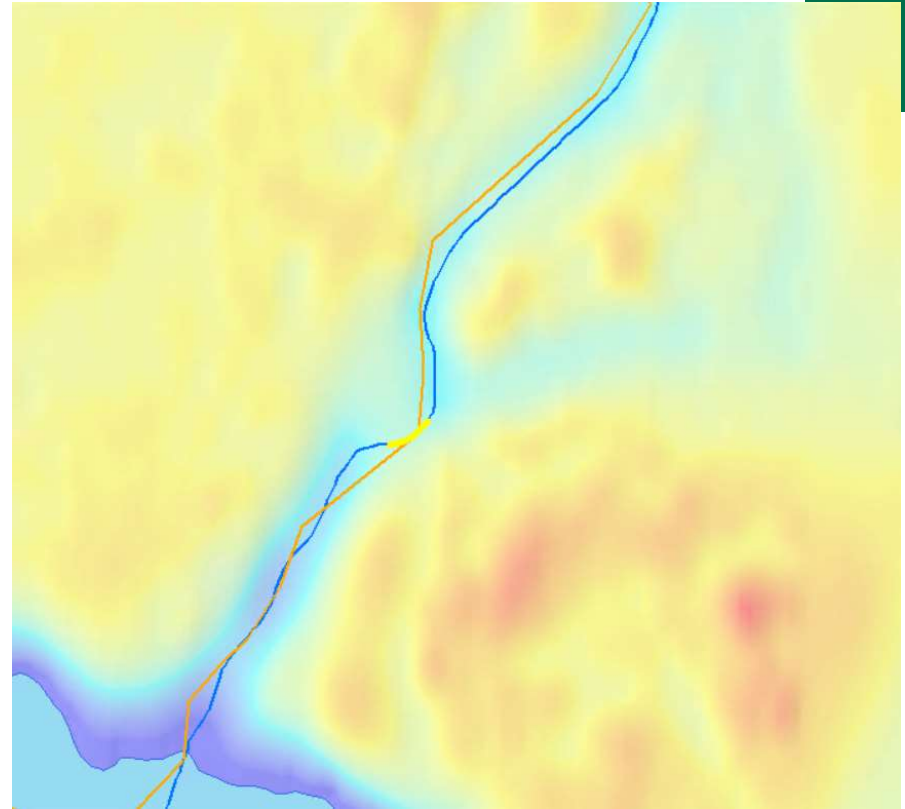


† Kobuk River - 19050302

- Three AOIs
- Three contractors
- Build understanding of what EDH really looks like
- Build capacity in contracting community and USGS process EDH
- Monthly meetings with contractors to review technical challenges, unexpected conditions
- Scaling up in 2021 – more than 40,000 square miles on contract



+ Specification improvement
Indefinite Surface and Subsurface Connections



- + Specification improvement
Indefinite Surface and Subsurface Connections
 Natural – underground conduits

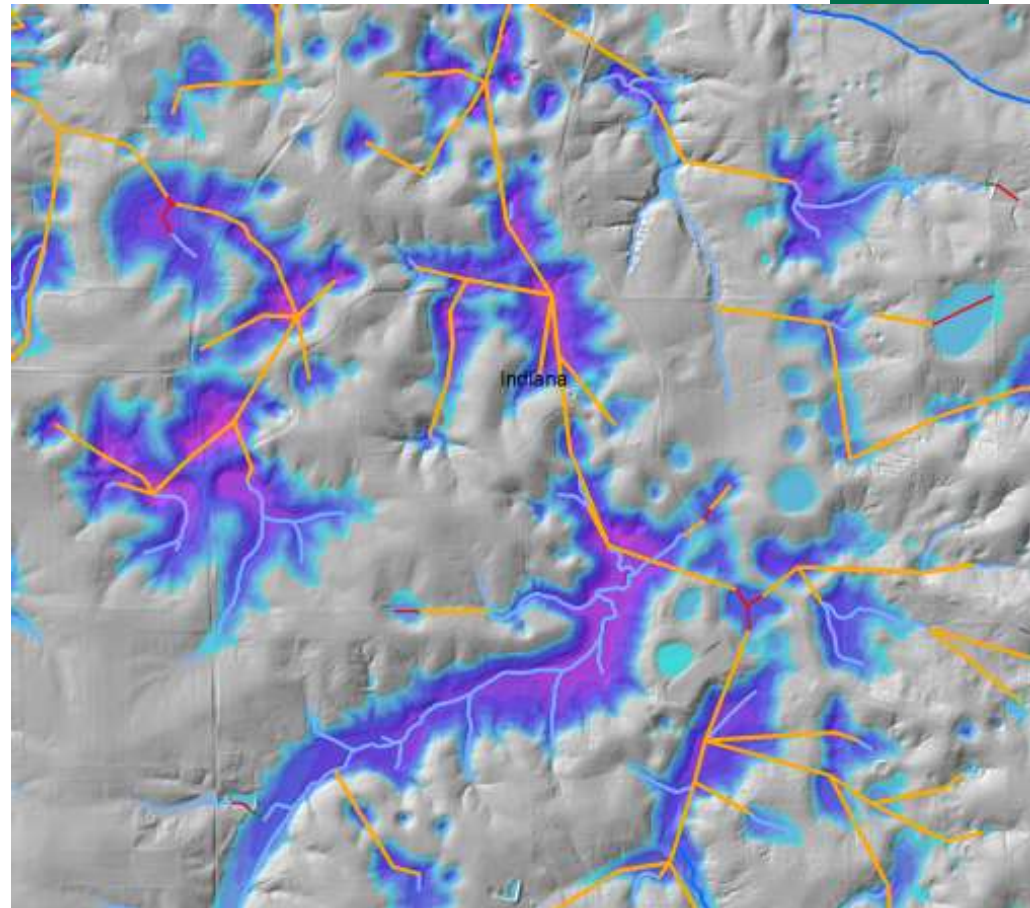
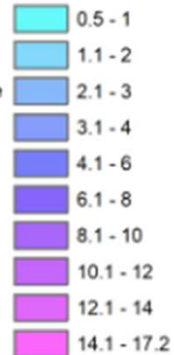
Underground conduits in Indiana

NHDFlowline selection

FCode

- Underground Conduit
- Underground Conduit: Positional Accuracy = Approximate
- Underground Conduit: Positional Accuracy = Indefinite

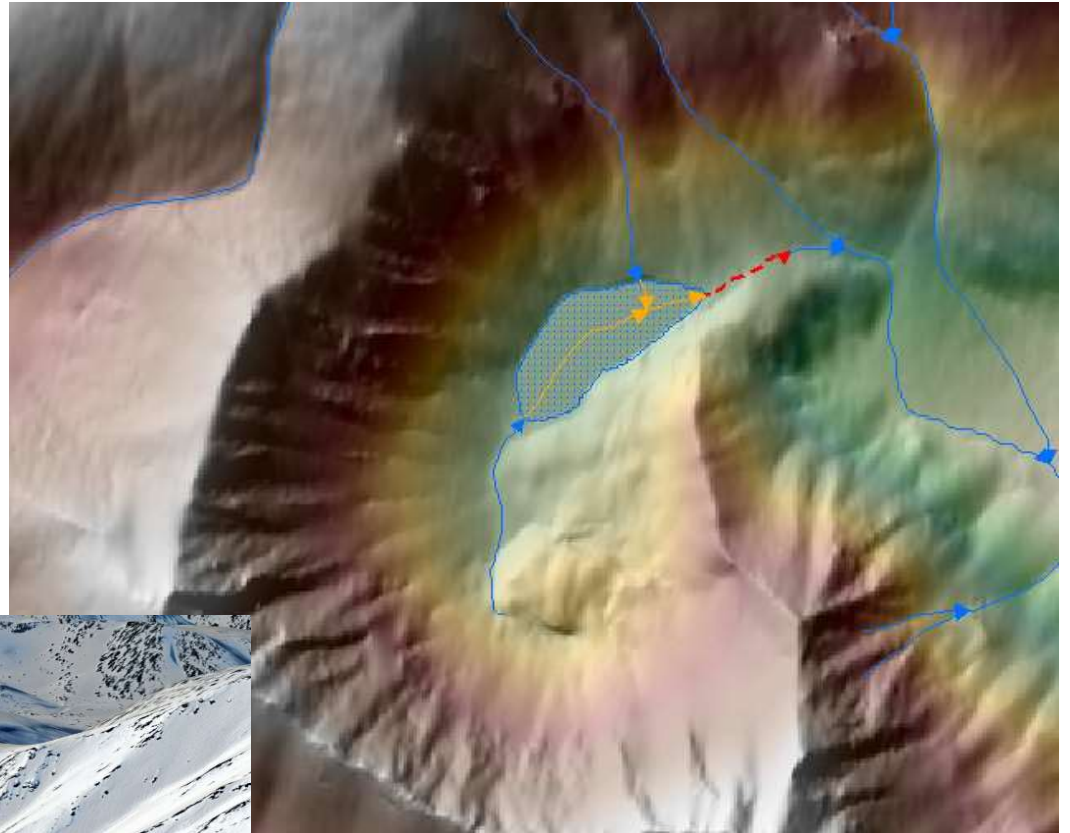
Depth of sinks, meters



+ Specification improvement *Indefinite Surface and Subsurface Connections*

DTM artifacts or possibly natural features
creating bulges near waterbodies

Either way we needed a way to route
through them

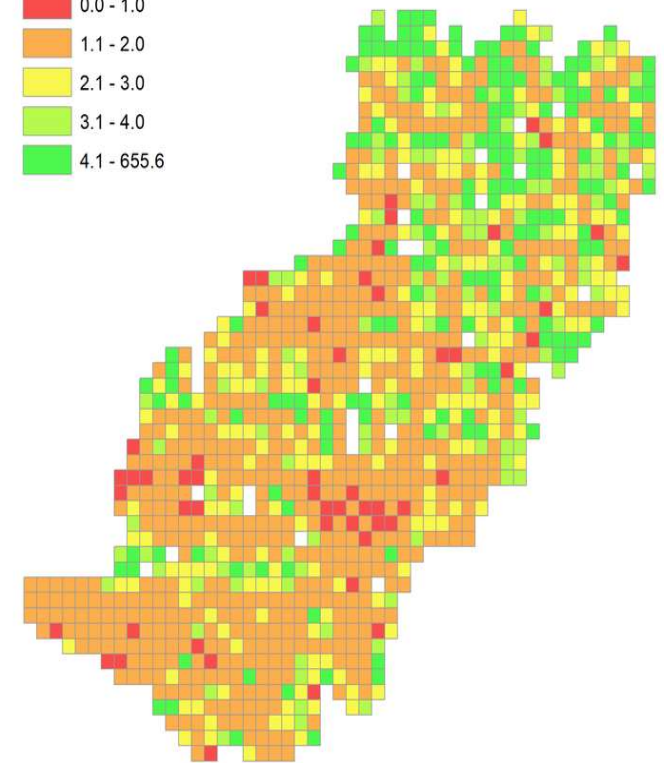
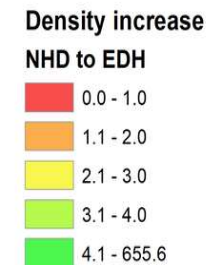




Inspection Process

Automated Prescreening

- Drainage density by HU12 based on guidance
- Artificial paths outside, or streams inside, polygons
- Monotonicity
- Vertex Spacing
 - Vertices must be no closer than 1.5 meters from another vertex
- Vertical Placement, above and below ground
 - No vertex z-values above DTM surface,
 - No vertex z-values more than 2 meters below DTM surface
- Horizontal Placement
- XYZ coordinates of intersections and waterbody vertices relative to hydroflattened surface
- Topology
- Geometric network



+ Geomorphic Indicators

Elevation derivatives developed from the source DEM that identify the most likely paths of water to flow or pool on the landscape

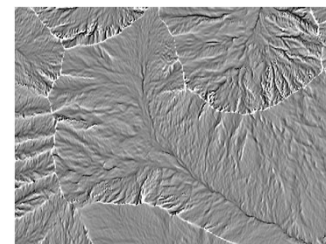
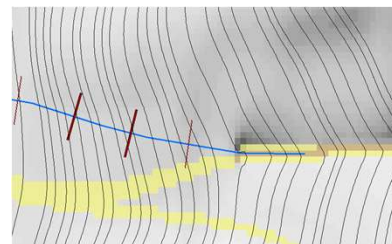
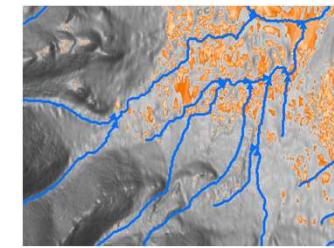
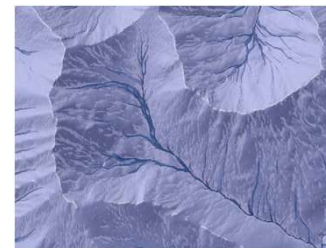
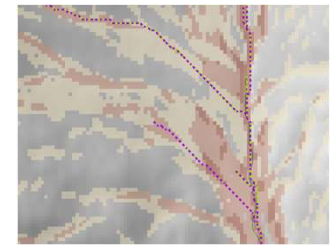
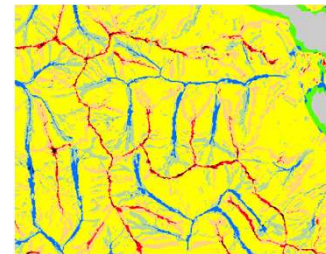
■ Derivatives

The primary derivatives used are:

- Geomorphon valleys and depressions
- BotHat channels
- Elevation percentile
- D-infinity flow paths

■ Additional layers

- D8 flow paths
- Low slope areas
- Sinks
- Contours
- Profiles





Inspection Process

Manual Inspection

- Some features will have a 100% inspection, and some will have a sample inspected
 - 100% inspection
 - Subsurface Connection Features: underground conduits, connectors, culverts
 - Glaciers
 - Features with new capture conditions: areas of complex channels, coastlines
 - Sample
 - Streams
 - Drainageways
 - Artificial Paths
 - Lake/pond, reservoir, and double line streams

+

Inspection Process

Manual Inspection

Completeness

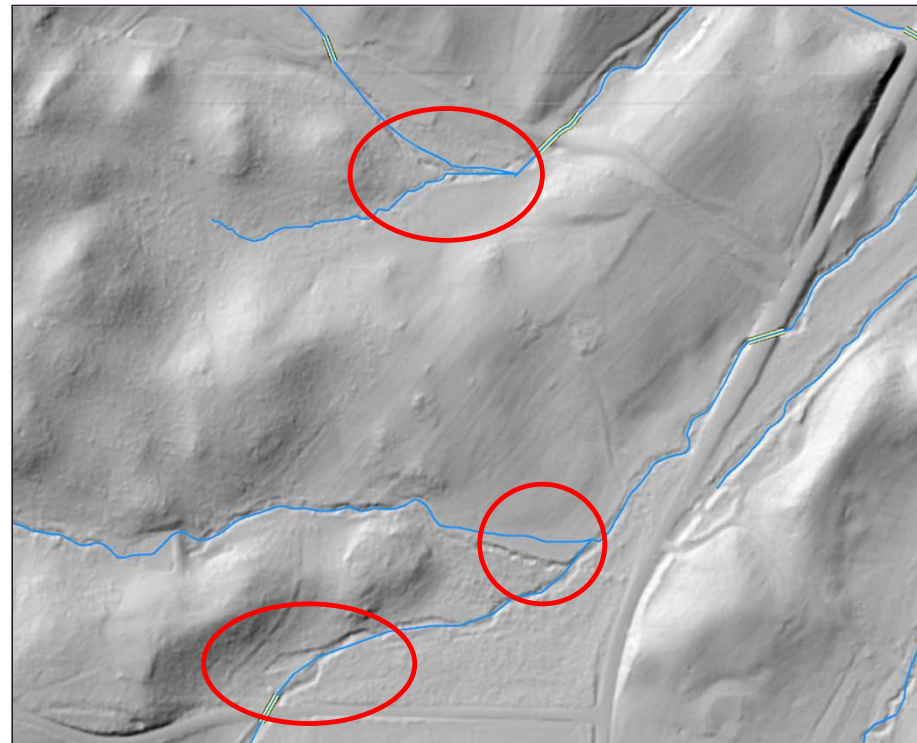
- Omission
- Commission

Integrity

- Schema and codes
- Hydrography types

Placement

- Horizontal
- Vertical



Horizontal Placement Errors

+ Inspection Process

Reporting

- Errors are compiled from Prescreening and Manual Inspection
 - Manual Inspection Errors are flagged spatially and categorized by Error Type
 - Summary Report is written

- Feedback is provided to Contractor

Vertical Placement		Delivery 2	Percent Error	Delivery 1	Percent Error
EDH UNINTEGRATED VERTEX REPORT 2020-06-04					
14:55:02.866000					
Z FLAGGING DISTANCE: 2.0 METERS					
	UNINTEGRATED VERTICES:	2734		1260	
	EDH LINES WITH AT LEAST ONE UNINTEGRATED VERTEX:	399		227	
	PERCENTAGE OF EDH LINES WITH AT LEAST ONE UNINTEGRATED VERTEX:		4.86%		4.26%
4.86% of features have vertical placement errors. The criterion for passing is less than 10% of all features shall have vertical placement errors.					

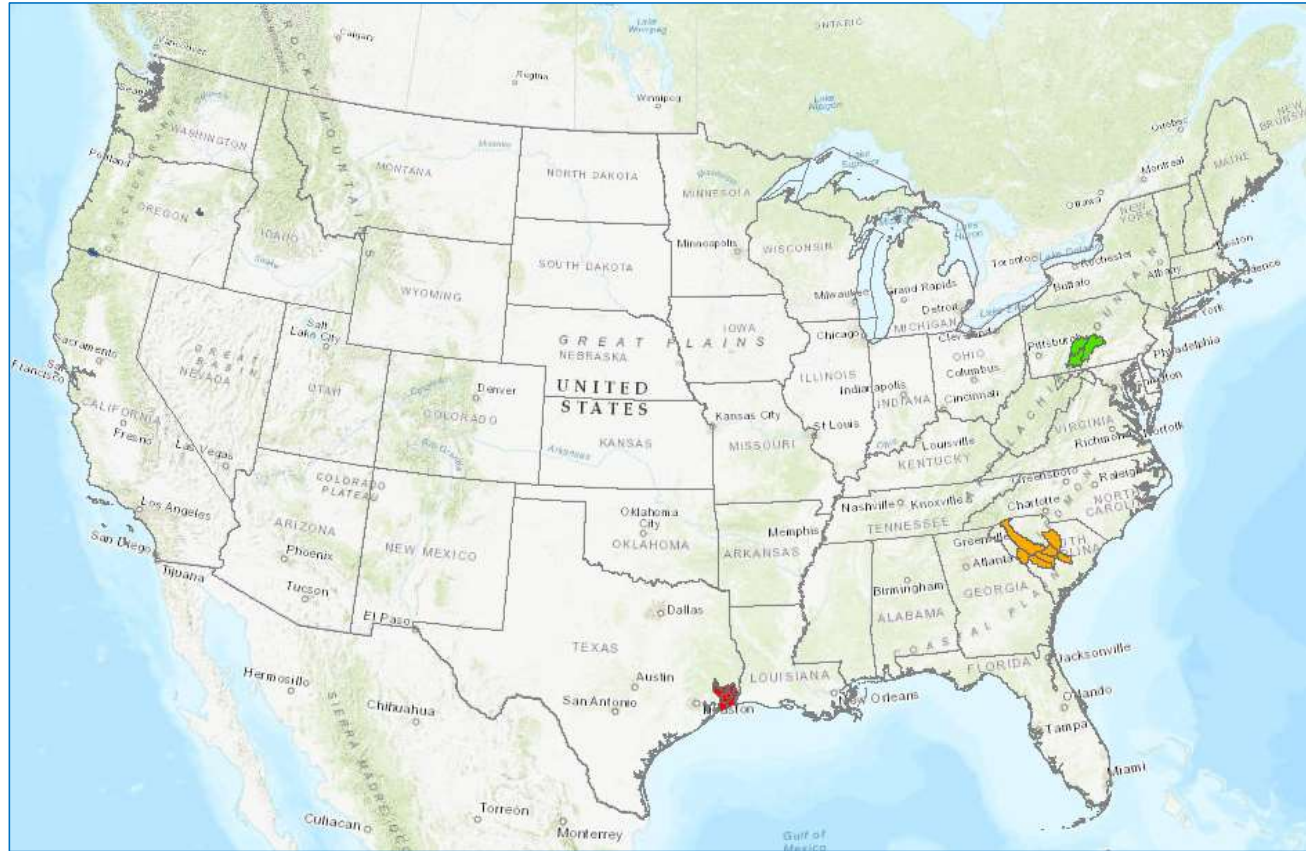
+ Alaska Transition to operational status - 2022

- Staffing a validation unit within NGTOC
- Standardized inspection process, including tools
- Standardized Inspection Feedback format
- Standardized Task Order Language
- Several guidance documents clarifying specifications or addressing unexpected conditions
- Bimonthly Technical Exchange Meetings with all GPSC Contractors
 - Alternating months EDH and 3DEP Topics
- Ad hoc Technical Discussions
- Planning on ~65,000 square miles per year for the next 7 years

+

Current (2021/2022) Pilot Projects

- Oregon
- SE Texas
- South Carolina
- Pennsylvania



+ Overall Goals

- Look at data development in differing physiographic regions and observe the challenges in data extraction
- SC and PA projects support stakeholder plans tied to broader collection. Emphasis on elevation-derivative products (e.g. hydro-enforced DEMs) and processes for modeling
- All projects will use 3DEP 1-meter sourced from QL2 or better data
- Delineate elevation-derived hydrography to update the National Hydrography Dataset
- Delineate polygon and linear streams, polygonal waterbodies, and raster products

+ Texas Pilot

“Southeast Texas” project

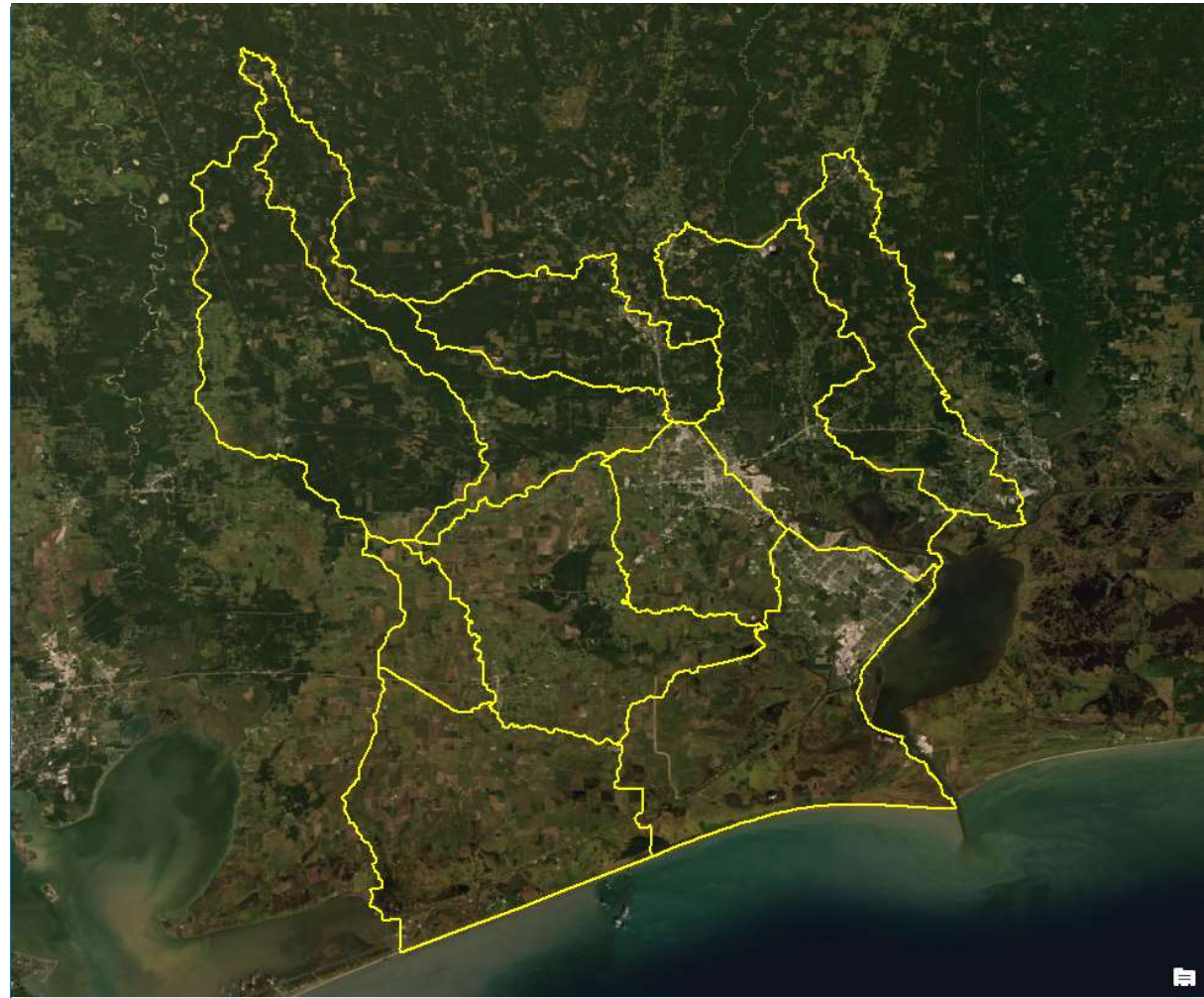
- Ten HU10 – Tenmile Creek-Neches River, Oyster Bayou, Spindletop Bayou, Cow Bayou, Pine Island Bayou, Little Pine Island Bayou, Boggy Creek, Hillebrandt Bayou, Lower Neches Valley Authority Canal, Salt Bayou
- 2,147 square miles
- Status: delivery of delineated hydrography and hydro enforced/conditioned DEMs; now in conflation process
- Includes WBD and bathymetry (topo-bathy)
- Partner: Multi-organization university, state, local, federal group
- Goal – understand issues in a flat, heavily engineered environment; understand DEM integration issues; support other research activities in the area.

+

Texas Pilot

Review of region

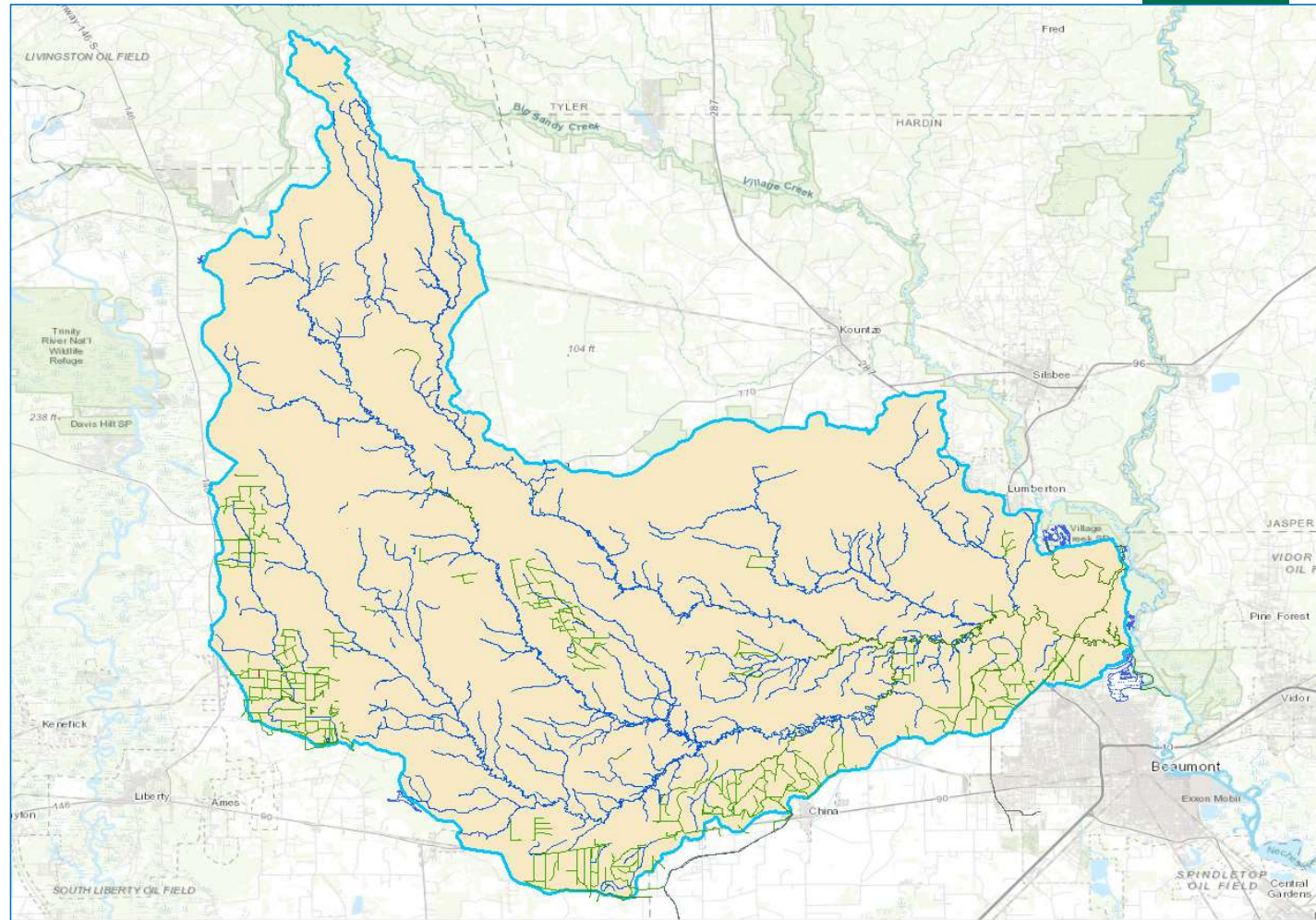
- Low relief and varying tree/shrub vegetation
- Numerous waterbodies, wetlands, canals, and stream/river flowlines
- NHD had been recently updated for part of the region (not elevation derived)





Texas Pilot

- Updating the NHD and WBD using 3DEP QL2 lidar 1m DEMs
- Part of a larger interagency project to create a seamless topography model above and below water
- Important for improving hydrologic and hydraulic networks and inform decision making on flood prediction and response



+ Water crossing water



+ Everything crossing everything else



+

Oregon Pilot

“Applegate River” project

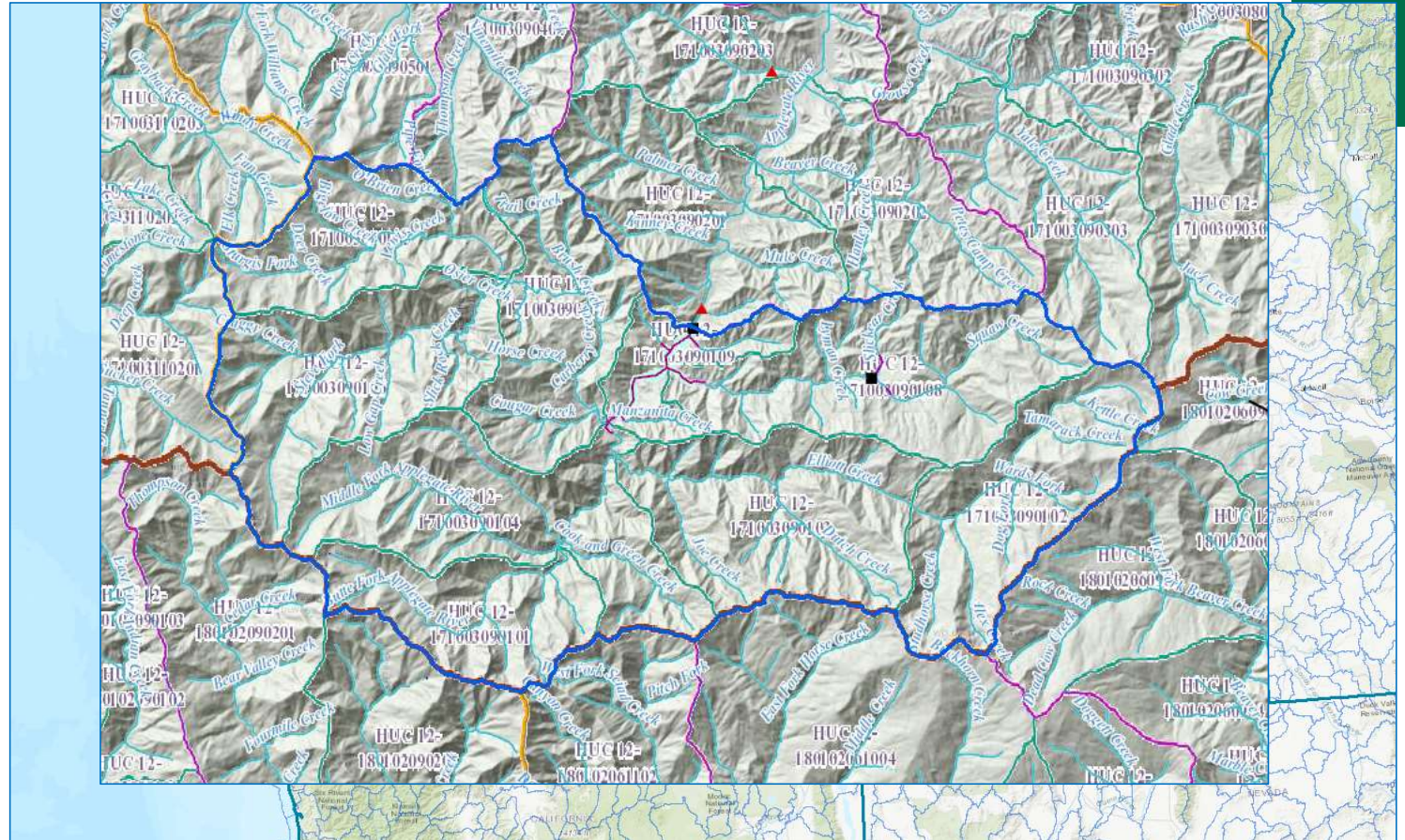
- Two HU10 - Headwaters Applegate River; Canyon Creek
- 337 square miles
- Status: all products delivered to USGS; in manual inspection by USGS
- Includes WBD as an additional requirement
- Partner: US Forest Service
- Goal: understand issues in a rugged, heavily forested environment

+

Oregon Pilot

Review of
region

Focus on
1710030901
“Headwaters
Applegate
River”



+ Pennsylvania Pilot

“Raystown” project

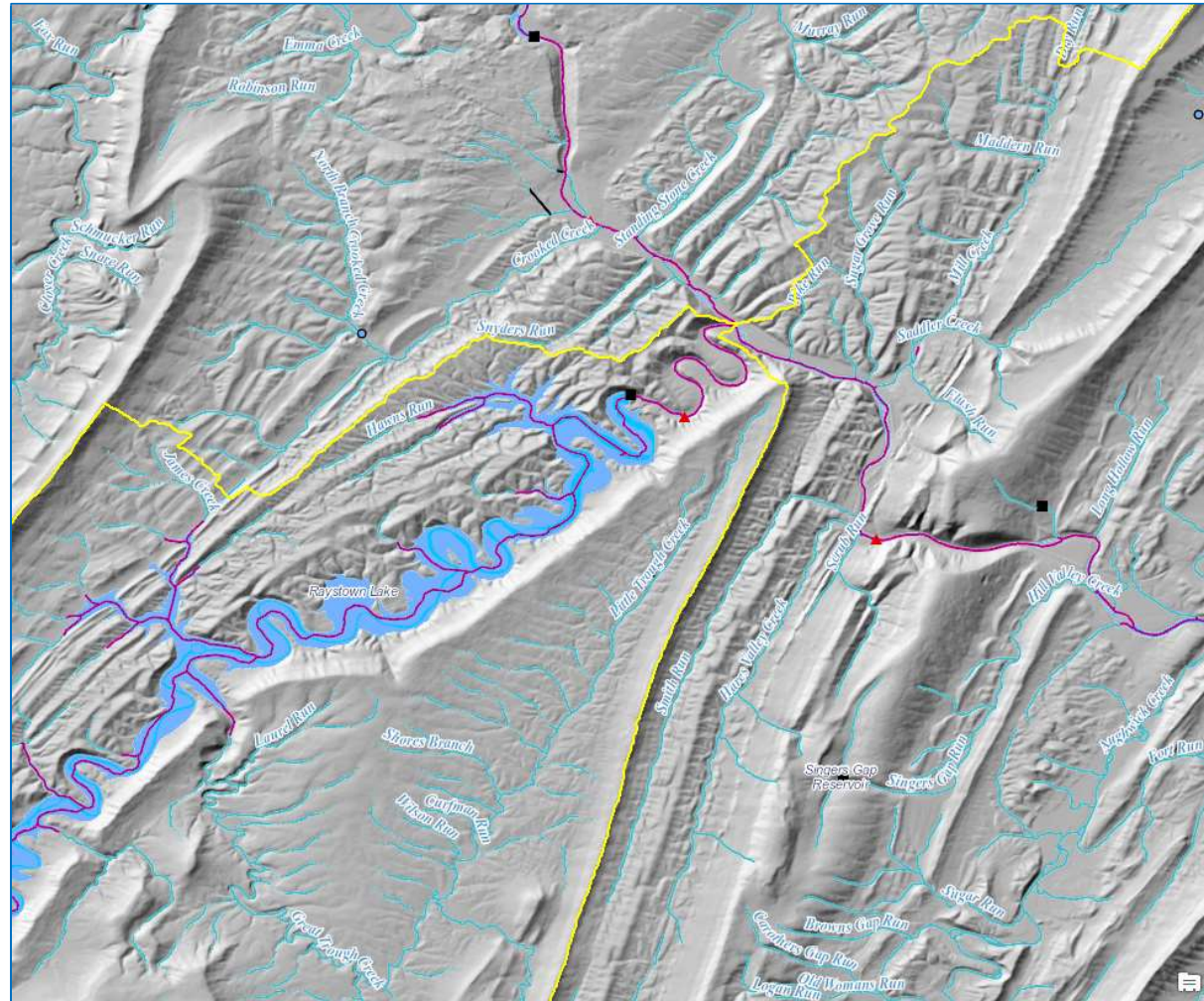
- Three HU8 – Upper Juniata River, Lower Juniata River, Raystown Lake
- 3,407 square miles
- Status: delineated elevation-derived hydrography and hydro enforced DEMs; in manual inspection by USGS
- Completion: early 2023
- Partner: NRCS



Pennsylvania Pilot

Review of region

- Appalachian Mountain physiographic region
- Ridge and valley terrain
- Karst landscape
 - Sinkholes
 - Disappearing streams
 - Isolated networks





South Carolina Pilot

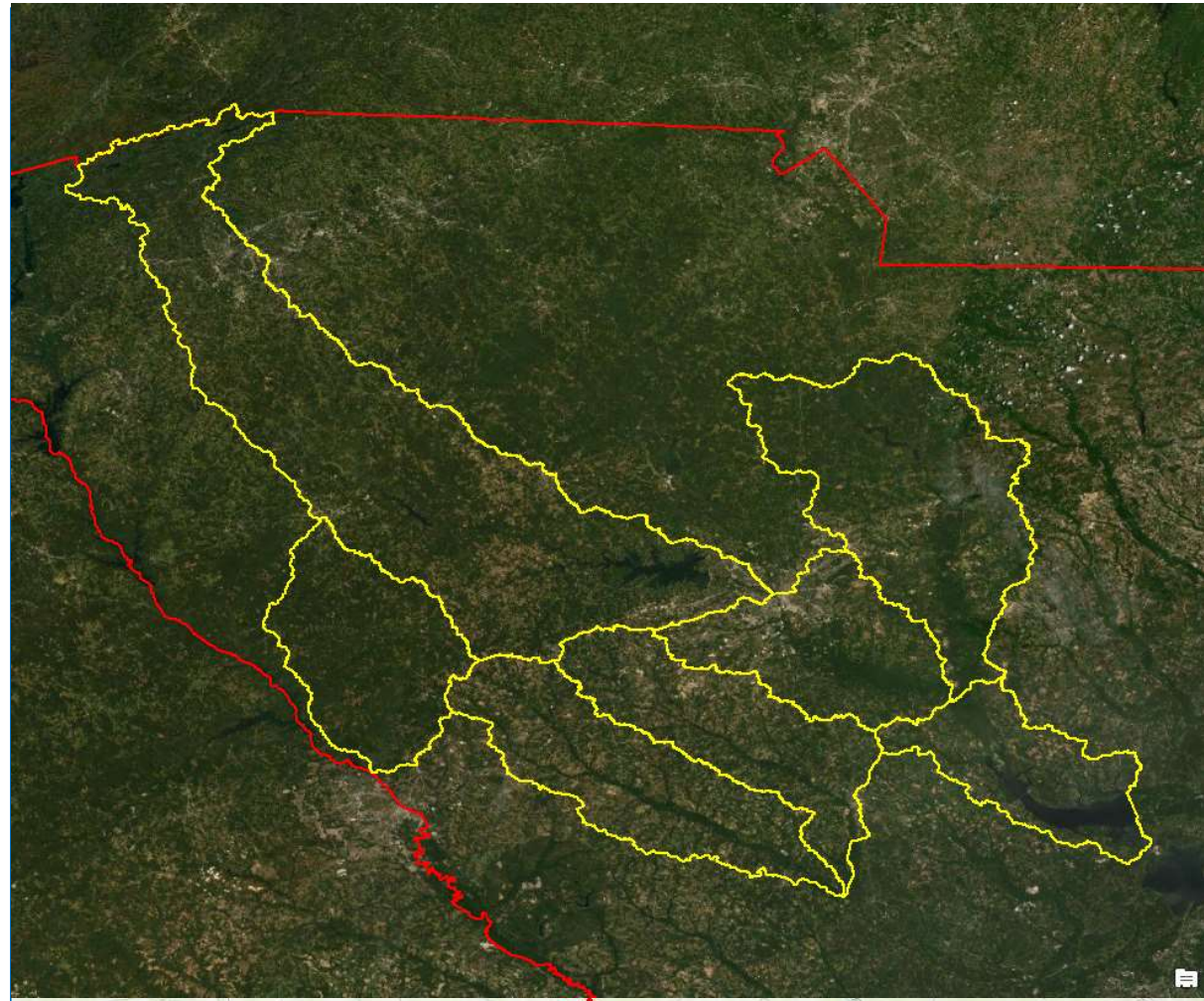
“Saluda” project

- Seven HU8 – Saluda River, Stevens River, Wateree River, Congaree River, Lake Marion, North Fork Edisto River, South Fork Edisto River
- 7,386 square miles
- Status: sample dataset Middle Saluda River delivered; initial flowline processing complete for all Lake Marion HU8; review of sample data
- Partner: NRCS

+ South Carolina Pilot

Review of region

- New lidar data sourced from 2021
- Broad mix of land uses (urban, rural, agricultural areas), terrain, and vegetation
- Coastal and uplands physiography



+ Derive Hydrography from Elevation

Summation

- Mix of HUC8 and HU10 units in four different environments
- Process considerations-
 - Likely costs for a nationwide program
 - Technical issues to be resolved
- Testing, testing, testing
 - Understanding of the requirements
 - Language and workflows for contracting
 - Quantifiable/testable standards and specifications
 - Tools and workflows for **inspection and testing**
 - Feedback and discussion with contractors
 - Automated processes



Next Steps

Complete CONUS pilots

- Evaluate utility of raster products
- Future Direction
 - USGS managed through Geospatial Products and Services Contracts
 - Projects under contract by other partners (local regional and state government, federal agencies)
 - BAA with hydrography coming – subject to funding
 - Review experiences in pilot projects
 - Review with USGS contractors
- Research
 - Conversion of elevation-derived data to eventual 3DHP model (will replace NHD)



THANK YOU!

Steve Aichele
USGS National Geospatial Program
saichele@usgs.gov



Bismarck, ND
3D Elevation Program (3DEP) data