Phase 7 WSM Development – Updates on CalCAST Hydrology

Modeling Workgroup Quarterly Meeting – April 2021

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Presentation Outline

1. NHDplus Catchments, Streams, and Topology
2. CalCAST Hydrology

Presentation Outline

1. NHDplus Catchments, Streams, and Topology
   - Introduction
   - Stream routing and divergence
   - Unconnected stream features
   - Outside of the watershed linkages
   - Tidal and Non-Tidal classification
2. CalCAST Hydrology
   - Development considerations
   - Data (prototype)
   - Results (initial)
   - Calibration and verification
   - Issues and Next steps

CalCAST

- Finer scale characterization of sources and sinks
- Time-averaged model of finer NHDplus 1:100K (medium resolution) scale with calibration capabilities
- Testing of new data and development of meta parameters

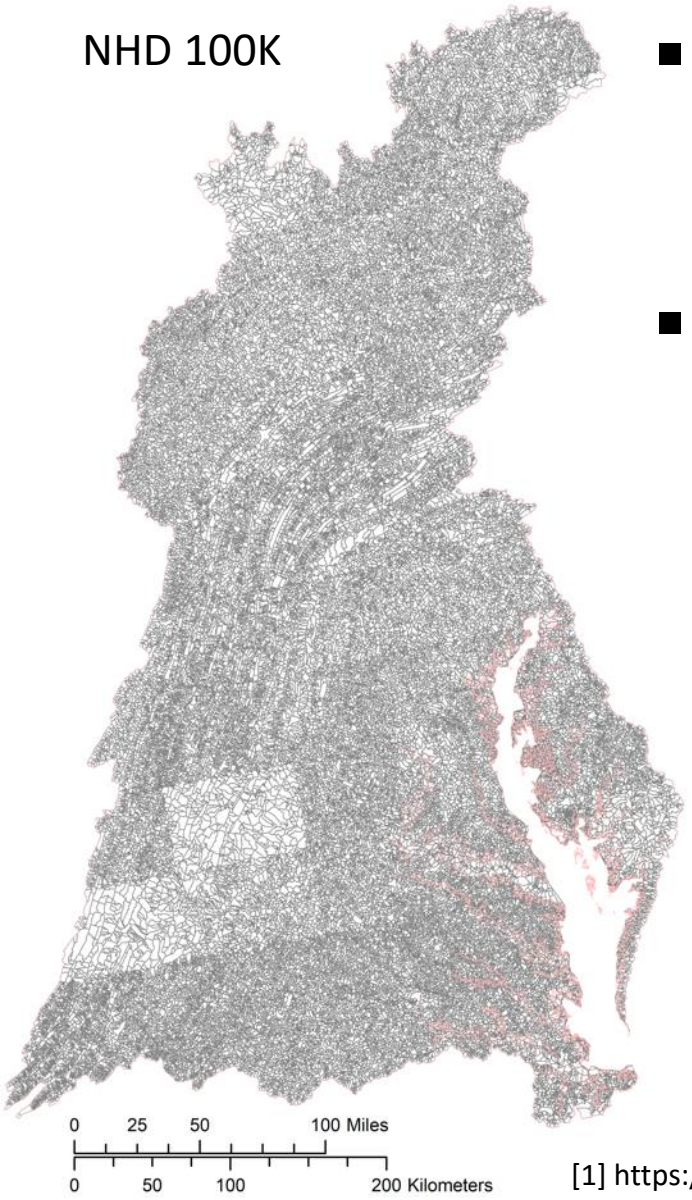
CalCAST – Hydrology

- Hydrology model plays an important role in supporting water quality model.
- CalCAST – Hydrology presents an opportunity for incorporating additional/new high-resolution data in the hydrology model.
- In addition to initial development and testing of the CalCAST infrastructure, improvements to the hydrology model could range from scale, inputs, explainability of model parameters/responses, and downscaling (e.g., differential crediting of BMPs, hydrology data for nutrients & sediment models).

NHDplus 100K Catchments – Version 2.1

Phase 6

NHD 100K

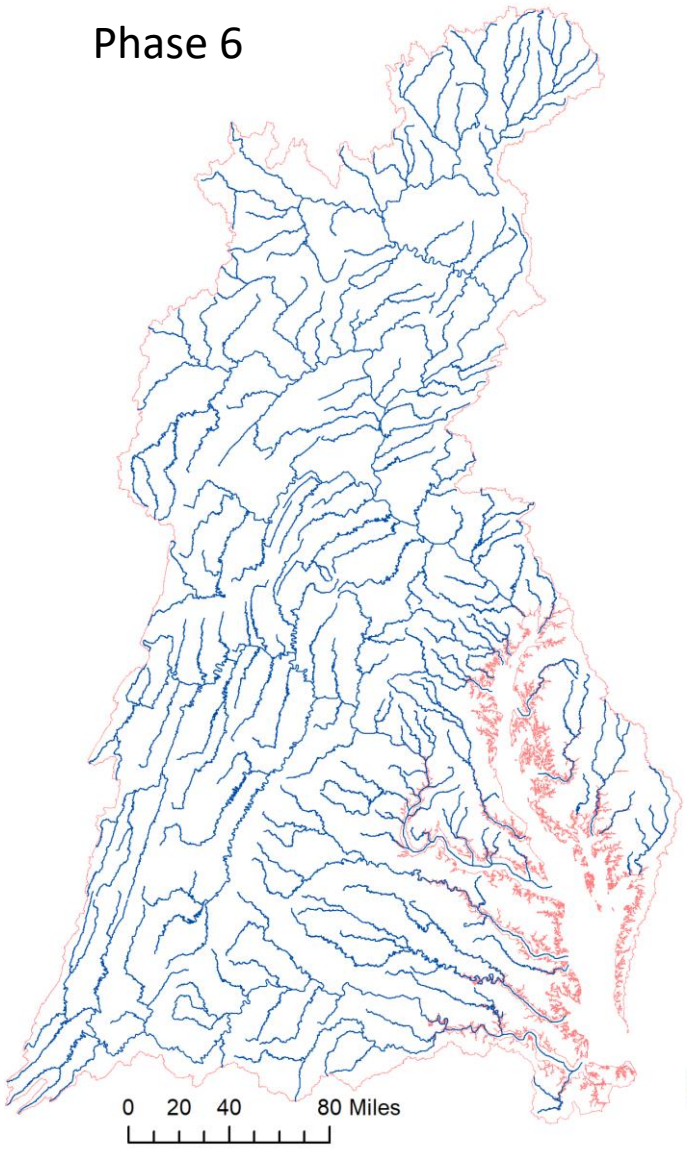


- NHD 100K reach catchments are significantly finer than Phase 6 sub-watersheds.
- NHD 100K reach catchments for the Region 02a[1] was used.
  - A total of 83628 reach catchments in the Chesapeake Bay Watershed.
  - Unlike Phase 6, currently it does not extend beyond the watershed.
  - Several reach catchments either completely or partially overlap with the Bay tributaries.

[1] https://nhdplus.com/NHDPlus/NHDPlusV2_02.php

NHDplus 100K Streams – Version 2.1

Phase 6



NHD 100K

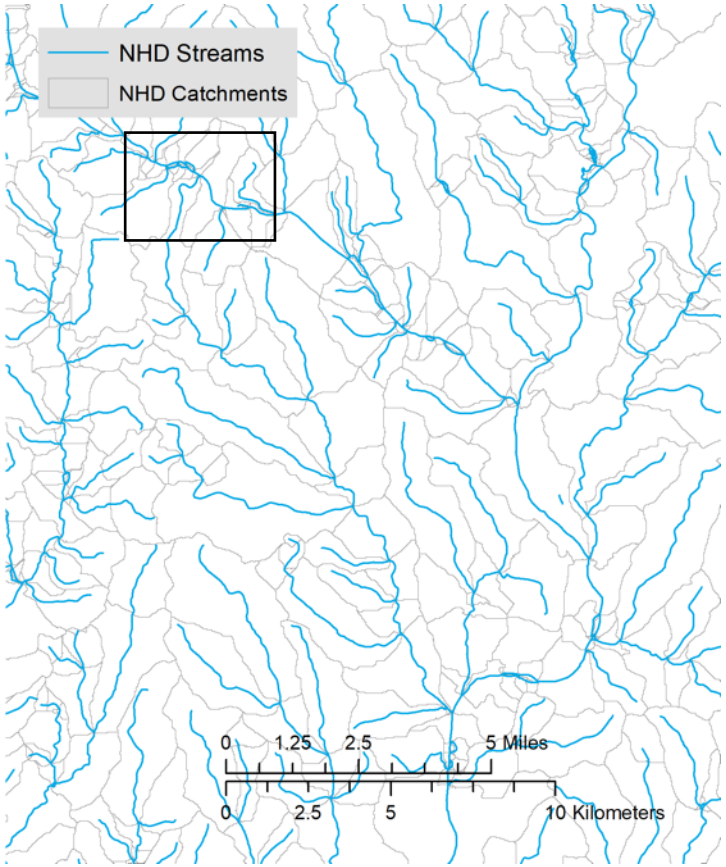
- Geospatial analysis was used for selecting NHD 100K reach network
  - A total of 86796 stream reach were identified in the Chesapeake Bay Watershed.
  - Every NHD catchment has a stream reach but the opposite is not always true.
  - There are a few cases when reach extend beyond the watershed boundary.

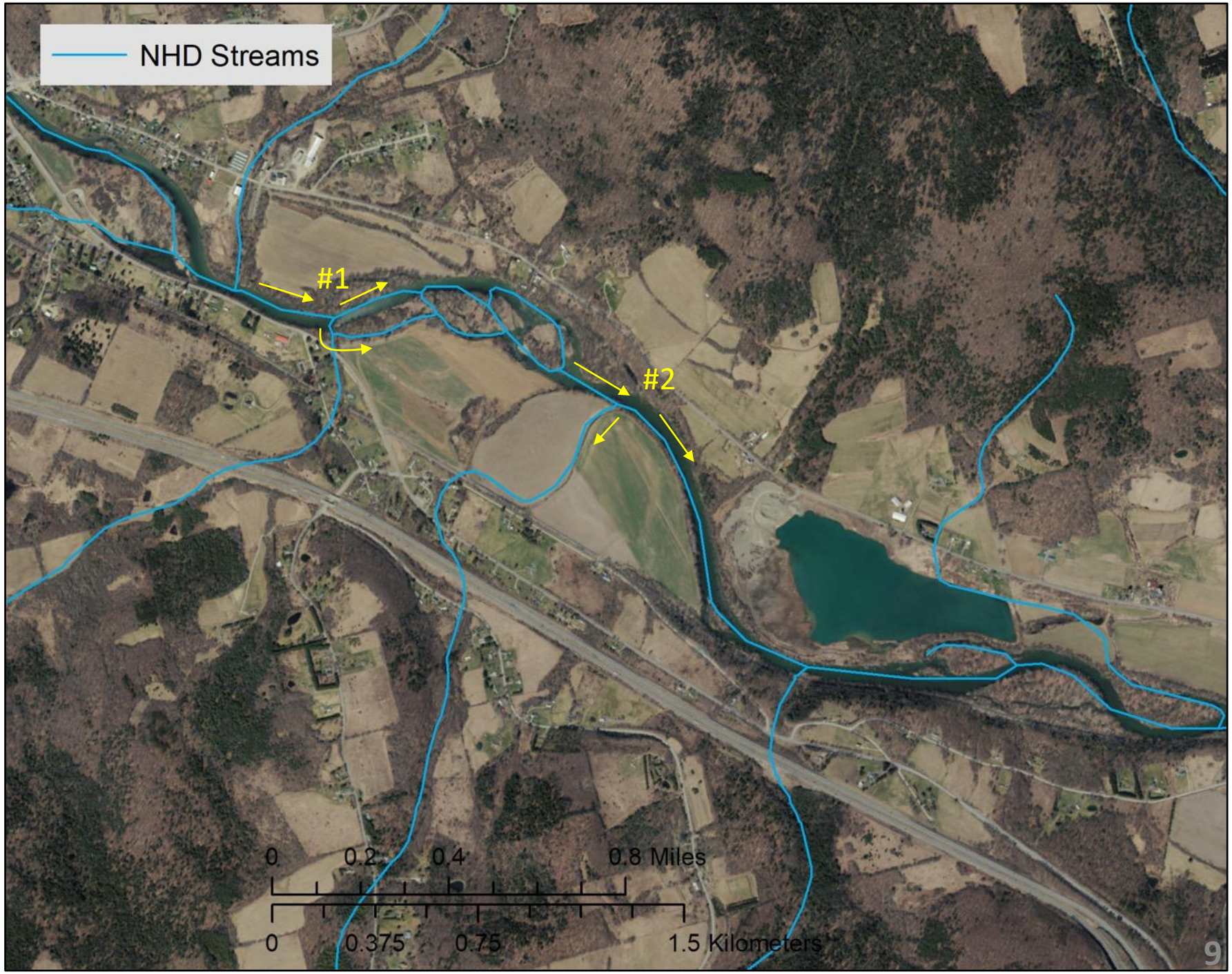
Stream Routing

- PlusFlow[1] NHD database provides reach topology data (i.e., From and To COMIDs or stream reaches)
  - Headwater reaches have “0” as the “From COMID” (38,701 reaches)
  - There a total of 3211 segments with more than one downstream reach.
  - There are as many as 3 downstream branching for a few reaches (9 reaches).
  - Divergence fractions[2][3] quantifying flow partition is being used for flow routing.

[1] NHDPlusAttributes – https://nhdplus.com/NHDPlus/NHDPlusV2_02.php
[2] E2NHDPlusV2_us: https://www.sciencebase.gov/catalog/item/5d16509ee4b0941bde5d8ffe
[3] Schwarz, G.E., 2019, E2NHDPlusV2_us: Database of Ancillary Hydrologic Attributes and Modified Routing for NHDPlus Version 2.1 Flowlines: U.S. Geological Survey data release, https://doi.org/10.5066/P986KZEM.

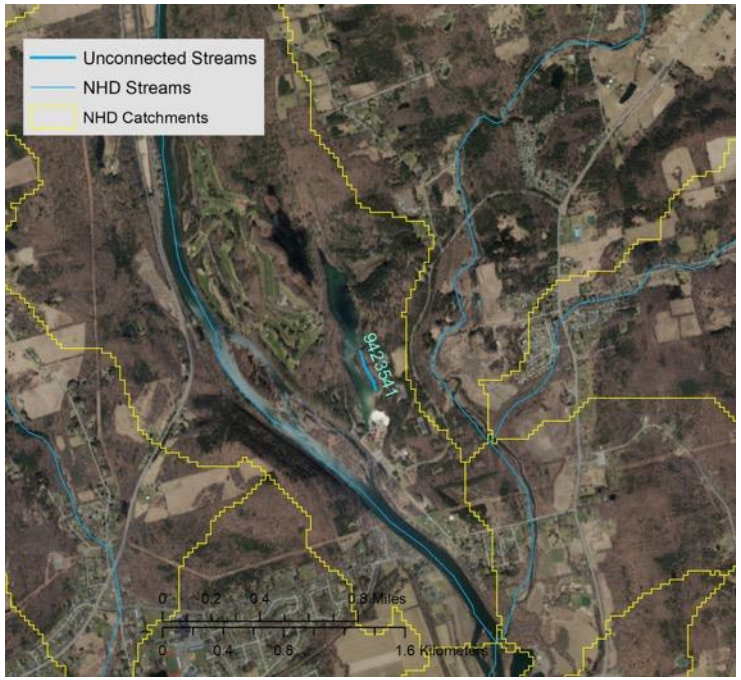
Divergence

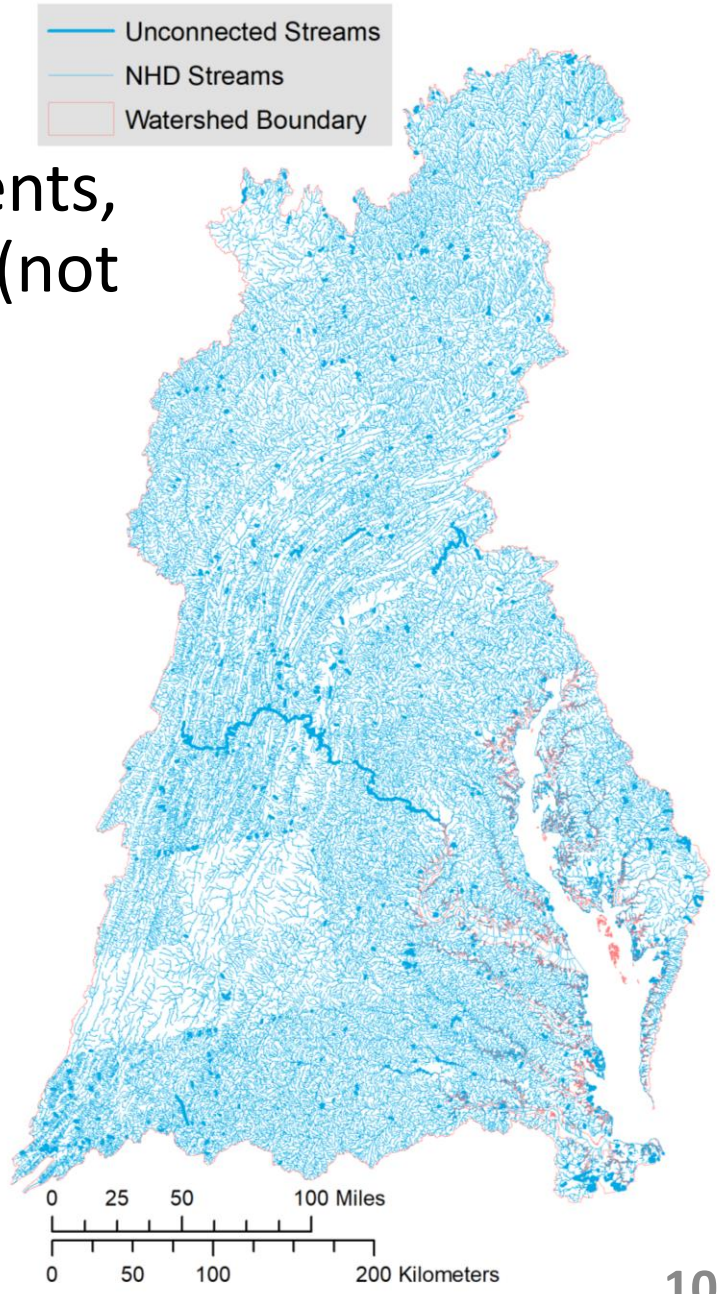

NHD Streams
NHD Catchments
0 1.25 2.5 5 Miles
0 2.5 5 10 Kilometers


NHD Streams
#1
#2
0 0.2 0.4 0.8 Miles
0 0.375 0.75 1.5 Kilometers

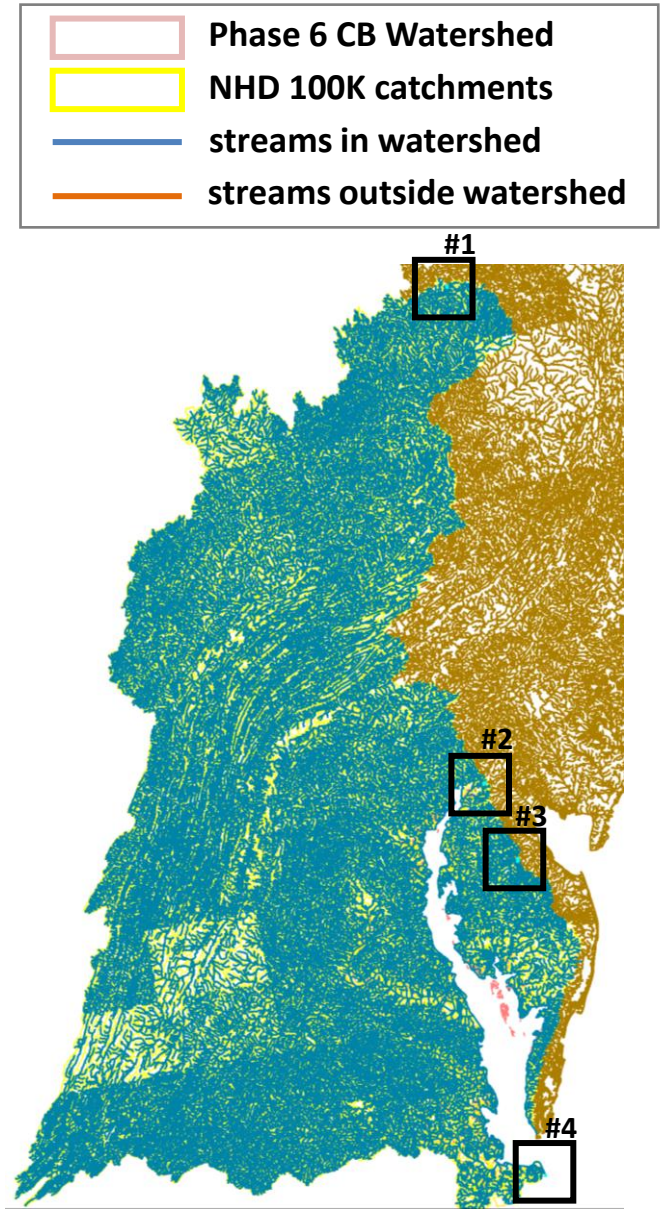
Unconnected Stream Features

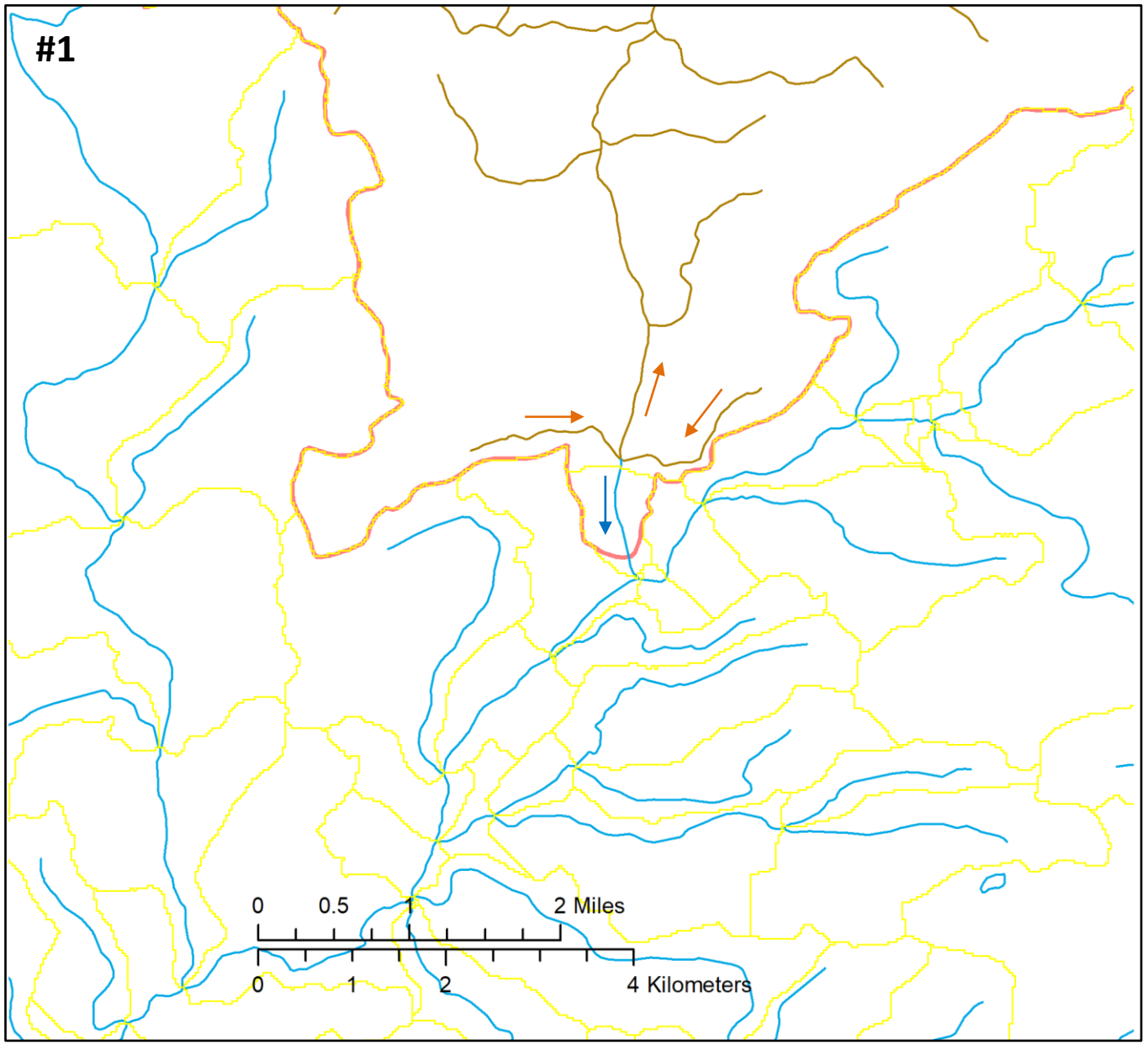
- There are a total of 1173 unconnected reach segments, i.e., without “From COMID” or “TO COMID” entries (not to be confused with Divergence Fraction = 0)
  - It was verified that none of these reaches have corresponding catchments. Suggesting that they may be intermittently connected hydrologic features/flowlines.





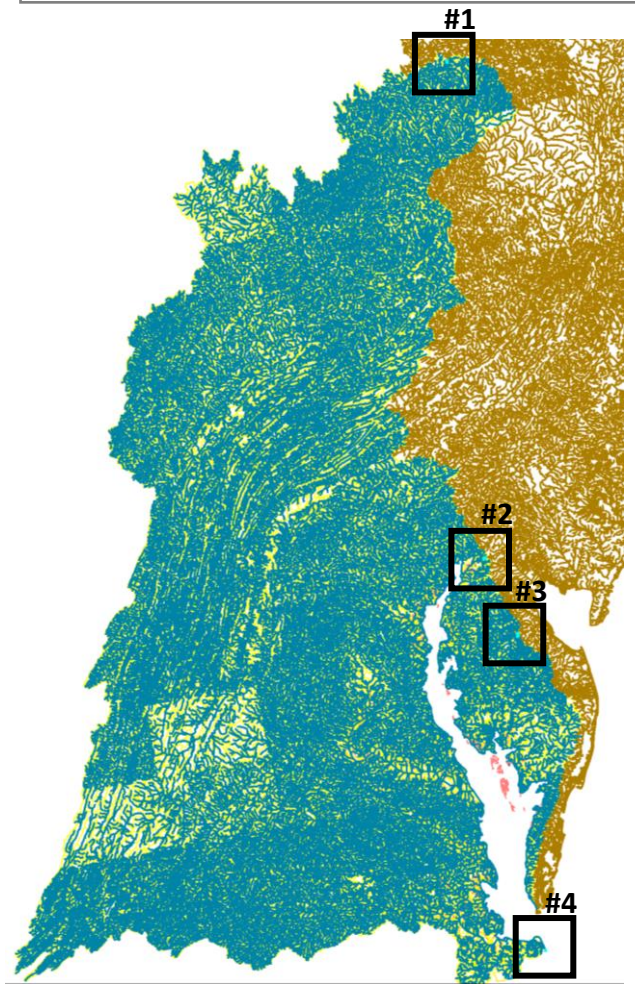
Outside of the Watershed Linkages

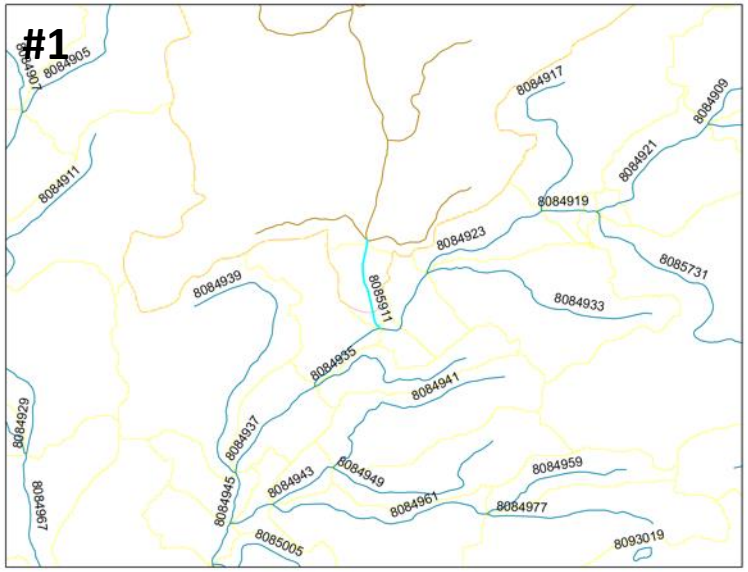


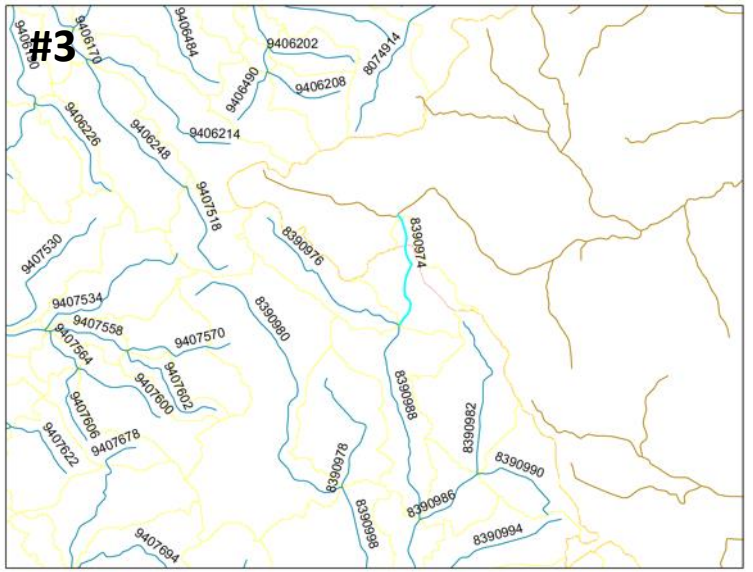


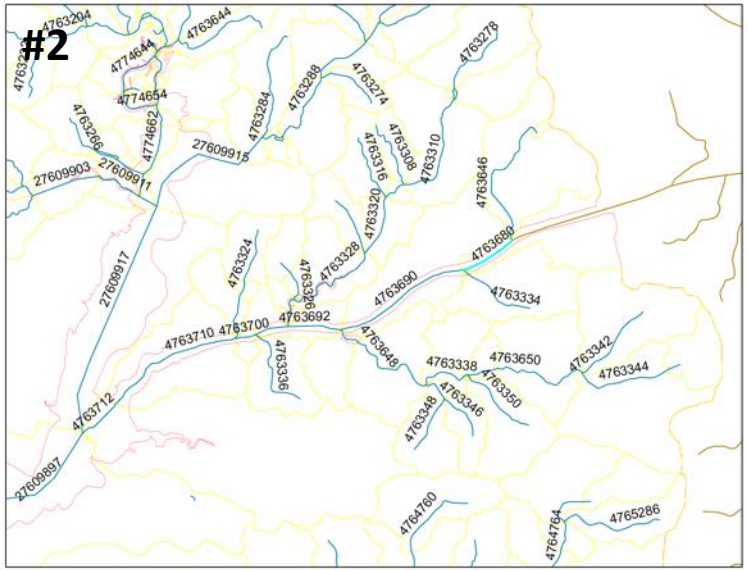
Outside of the Watershed Linkages

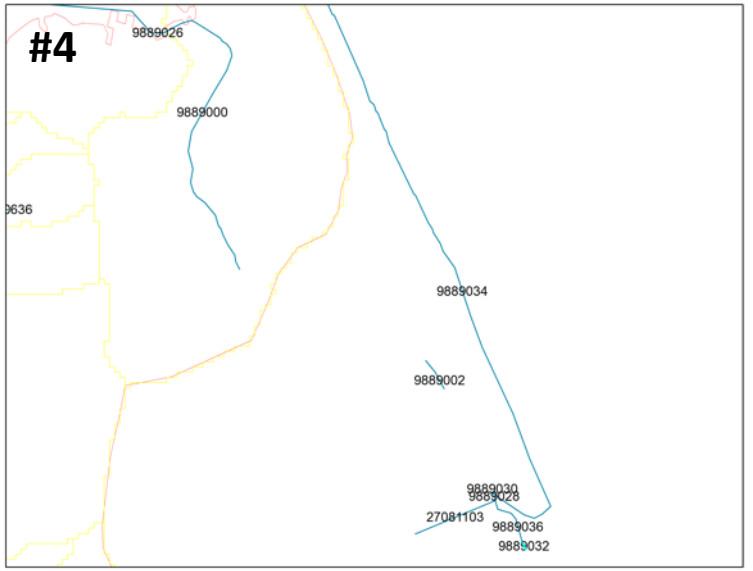
Phase 6 CB Watershed
NHD 100K catchments
streams in watershed
streams outside watershed



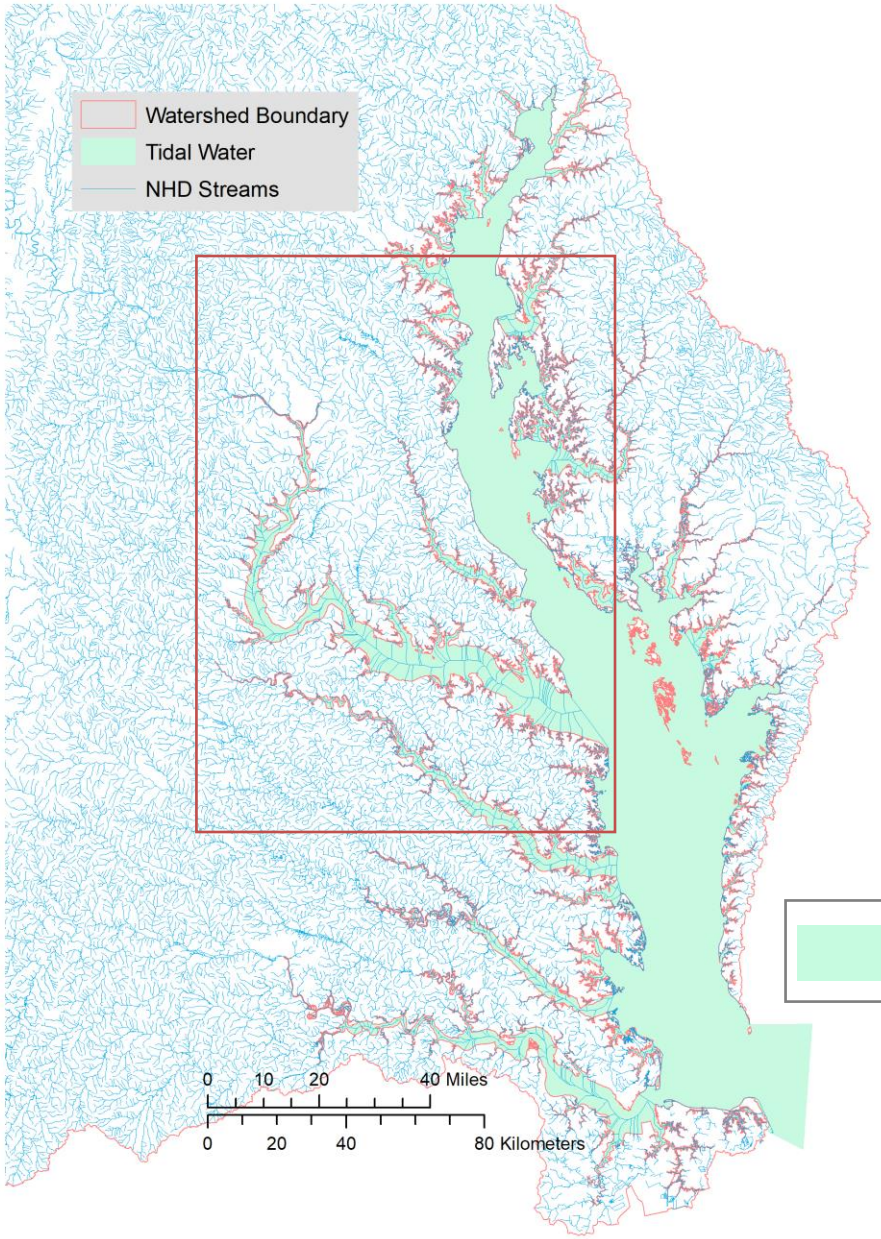






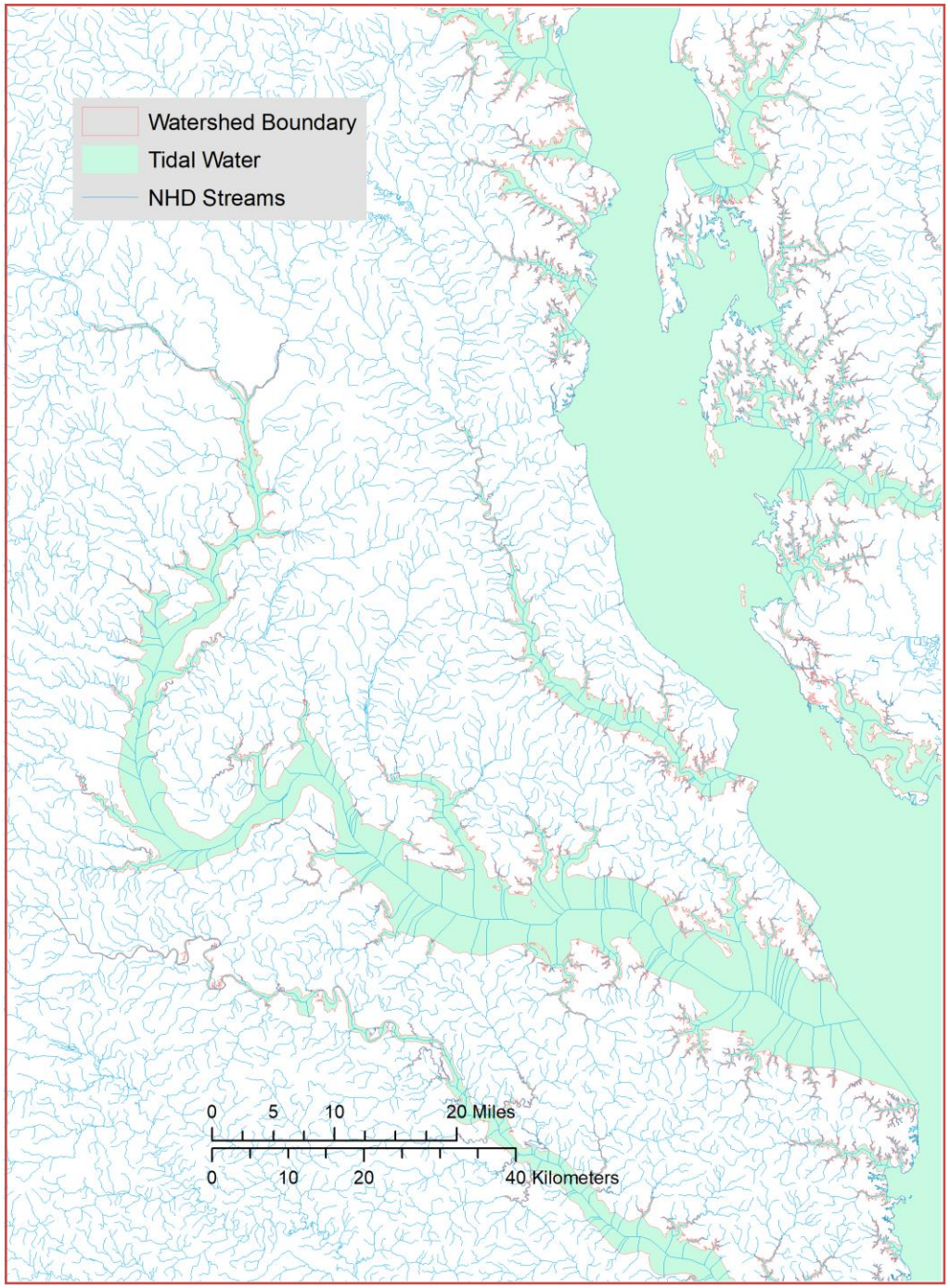


Tidal and Non-Tidal Classification



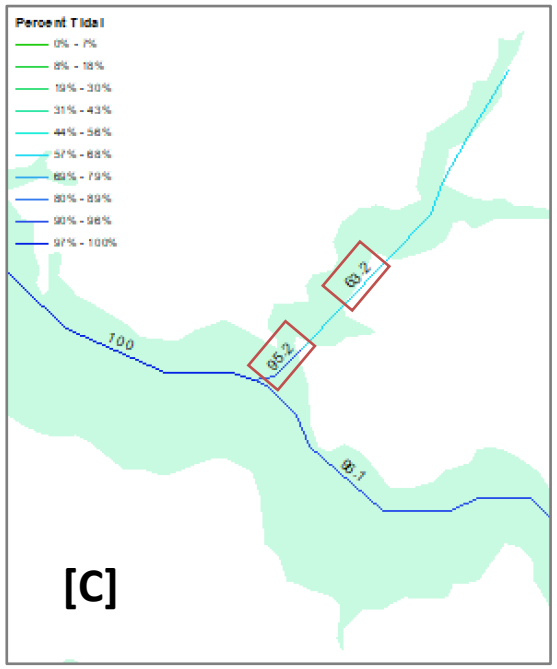
NHD streams either fully or partially in the tidal water

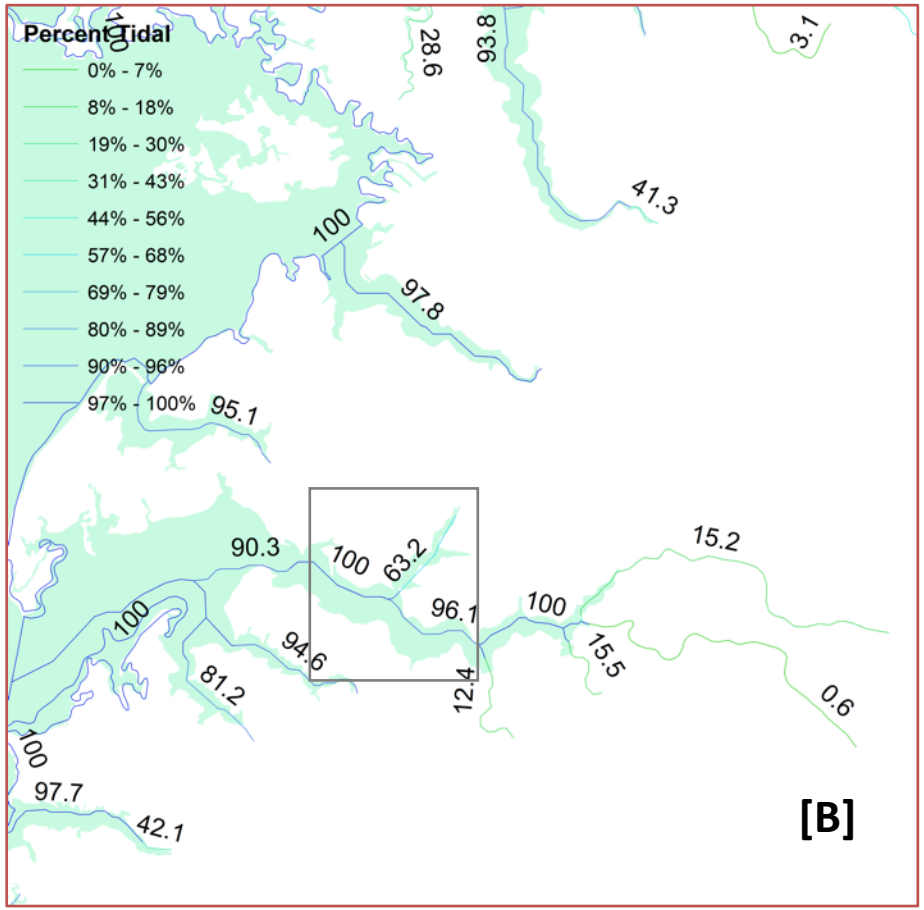
outside the watershed

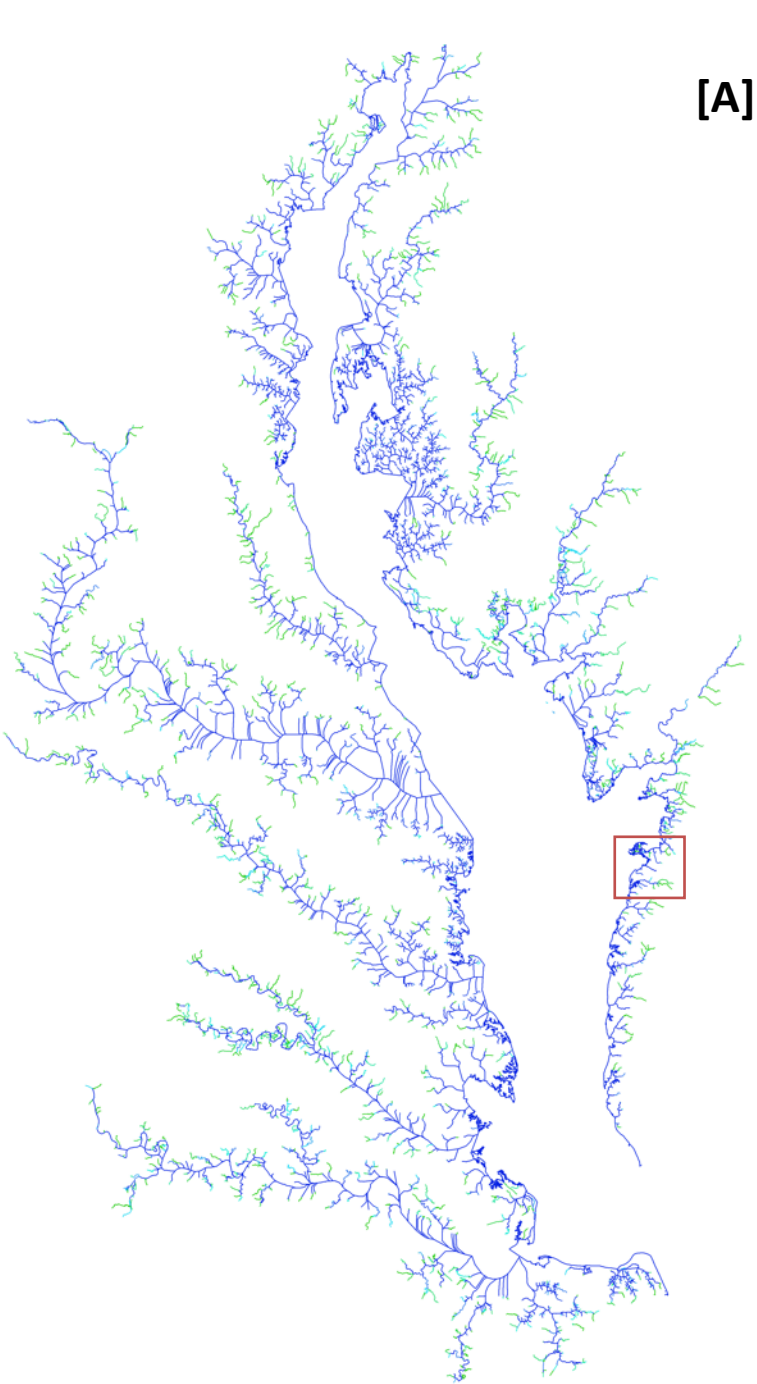


Tidal and Non-Tidal Classification

Percent of the stream reach length that fall outside the P6 watershed boundary



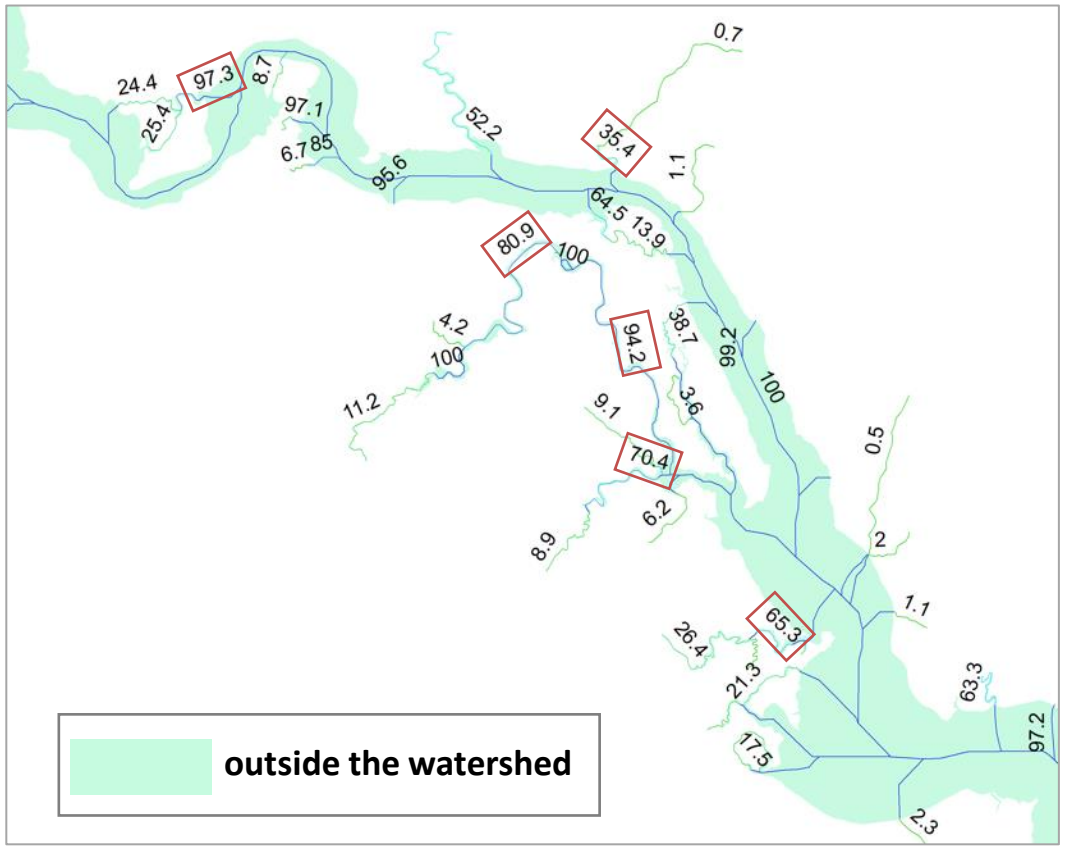


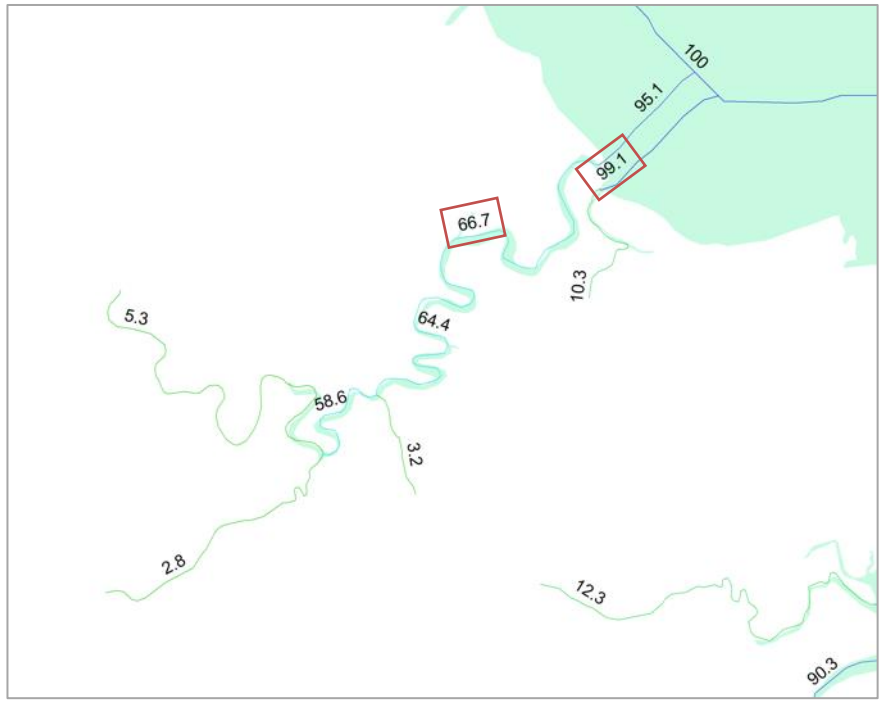


outside the watershed

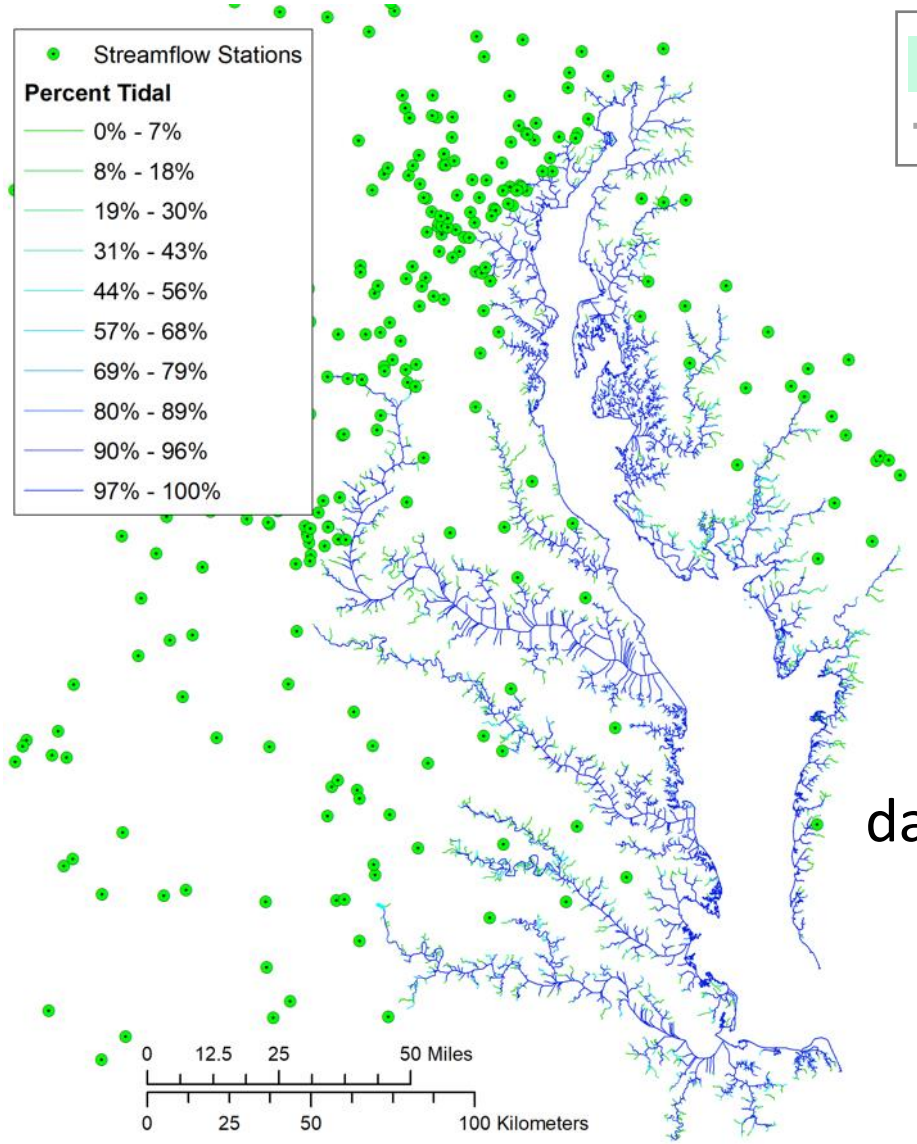
Tidal and Non-Tidal Classification

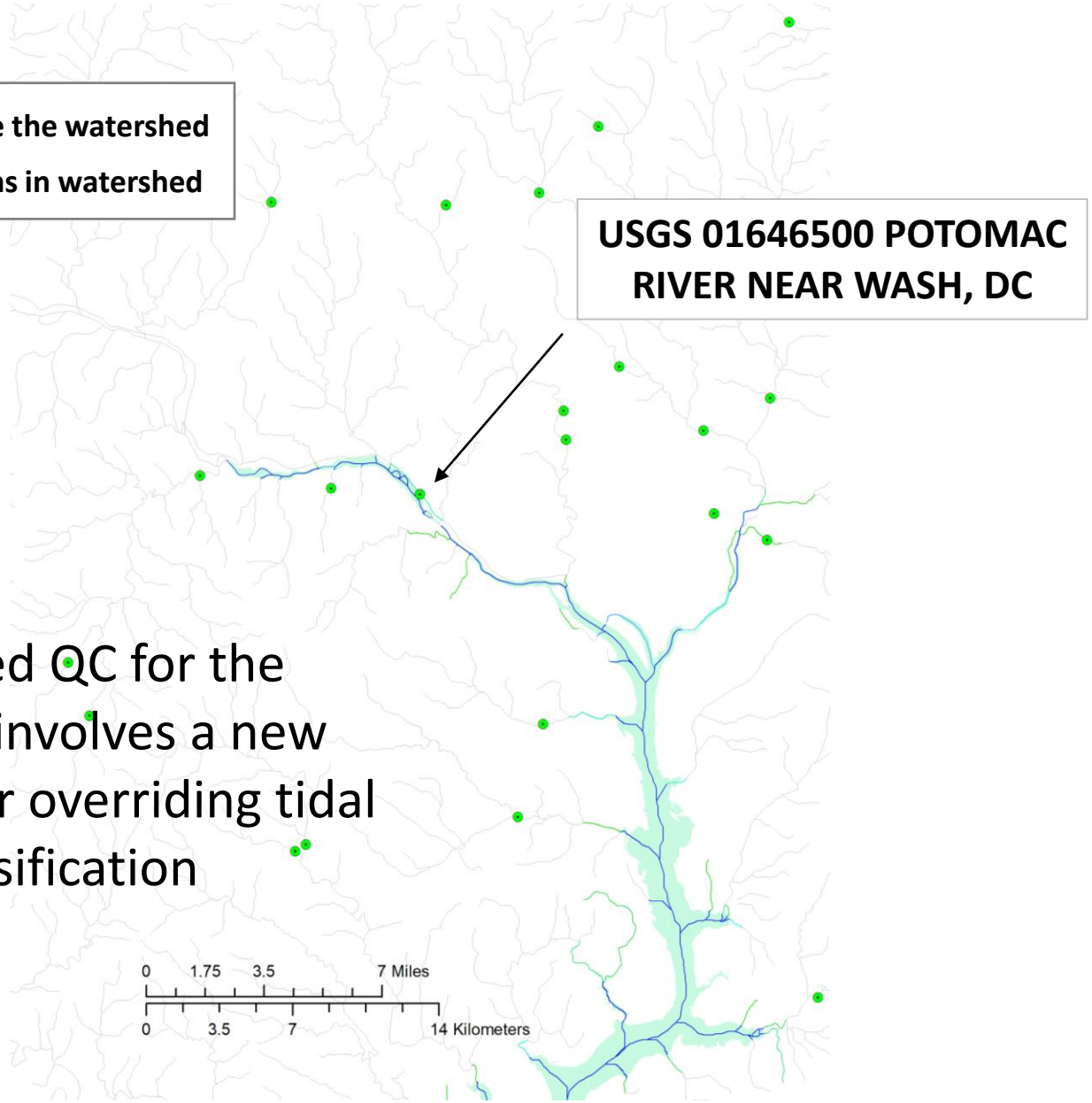
Quality Control: For a stream reach, if any of its upstream reaches were non-zero % tidal then the segment was set to 100% tidal





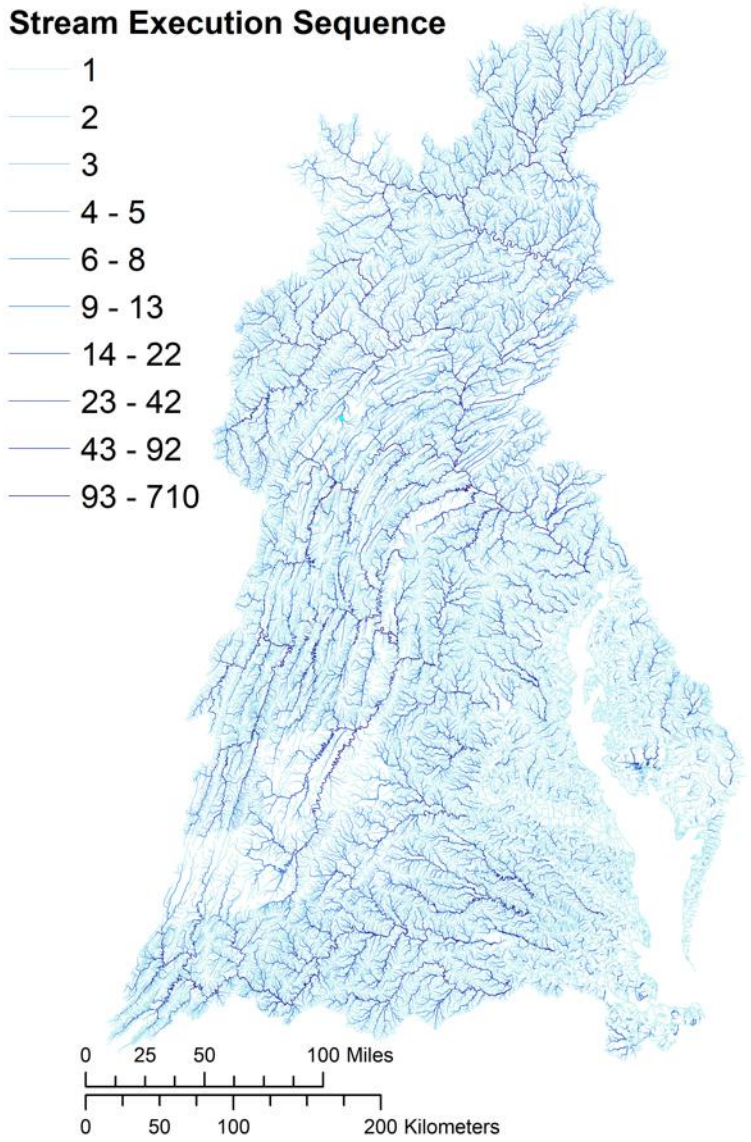
Tidal and Non-Tidal Classification





Proposed QC for the Potomac involves a new database for overriding tidal classification

Combined topology – Stream Execution Sequence

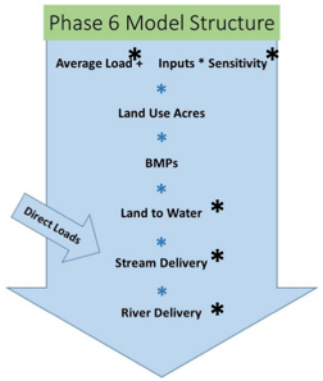


- Maximum execution depth of 710 (it was 45 in Phase 6)

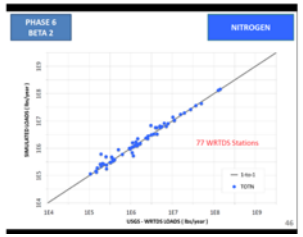
Sequence	Number of Segments
1	37,090
2	13,646
3	6,568
4-5	6,933
6-8	5,082
9-13	3,983
14-22	3,457
23-42	3,392
43-92	3,335
93-710	3,310

CalCAST Hydrology Model Development

- Average annual streamflow *(Q)* is the difference of Rainfall and Actual Evapotranspiration *(AET)*, where *AET* can be estimated from Potential Evapotranspiration *(PET)* and/or other watershed properties.



Calibration of meta-parameters to spatial loads

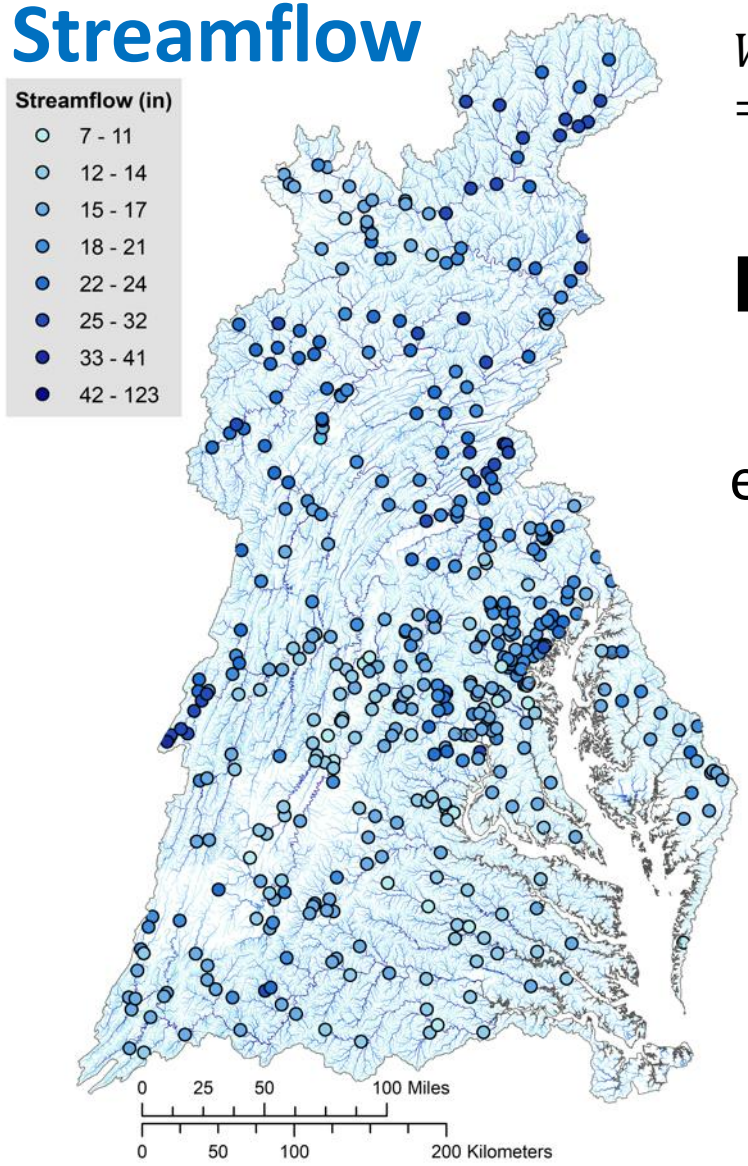


$$Q = \sum_{\substack{upstream \\ geography}} Precipitation - PET \times f_{LU} \sout{\times Fn(watershed\ properties)}$$

$$e.g., Fn(watershed\ properties) = a + f_w \times Wetness + f_s \times Slope$$

CalCAST Hydrology Model Development

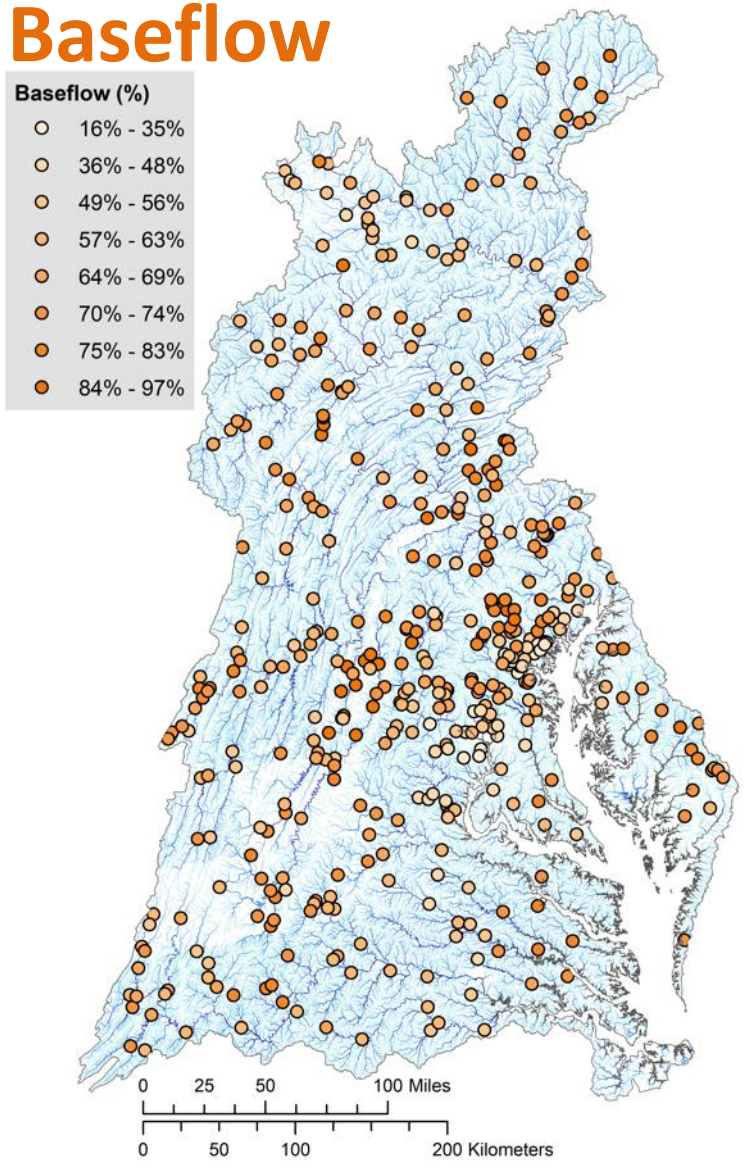
Streamflow



$$Watershed\ Response = Fn(Inputs, Watershed\ Properties)$$

This framework can be extended to other hydrology endpoints, e.g., baseflow response, peakiness etc.

Baseflow

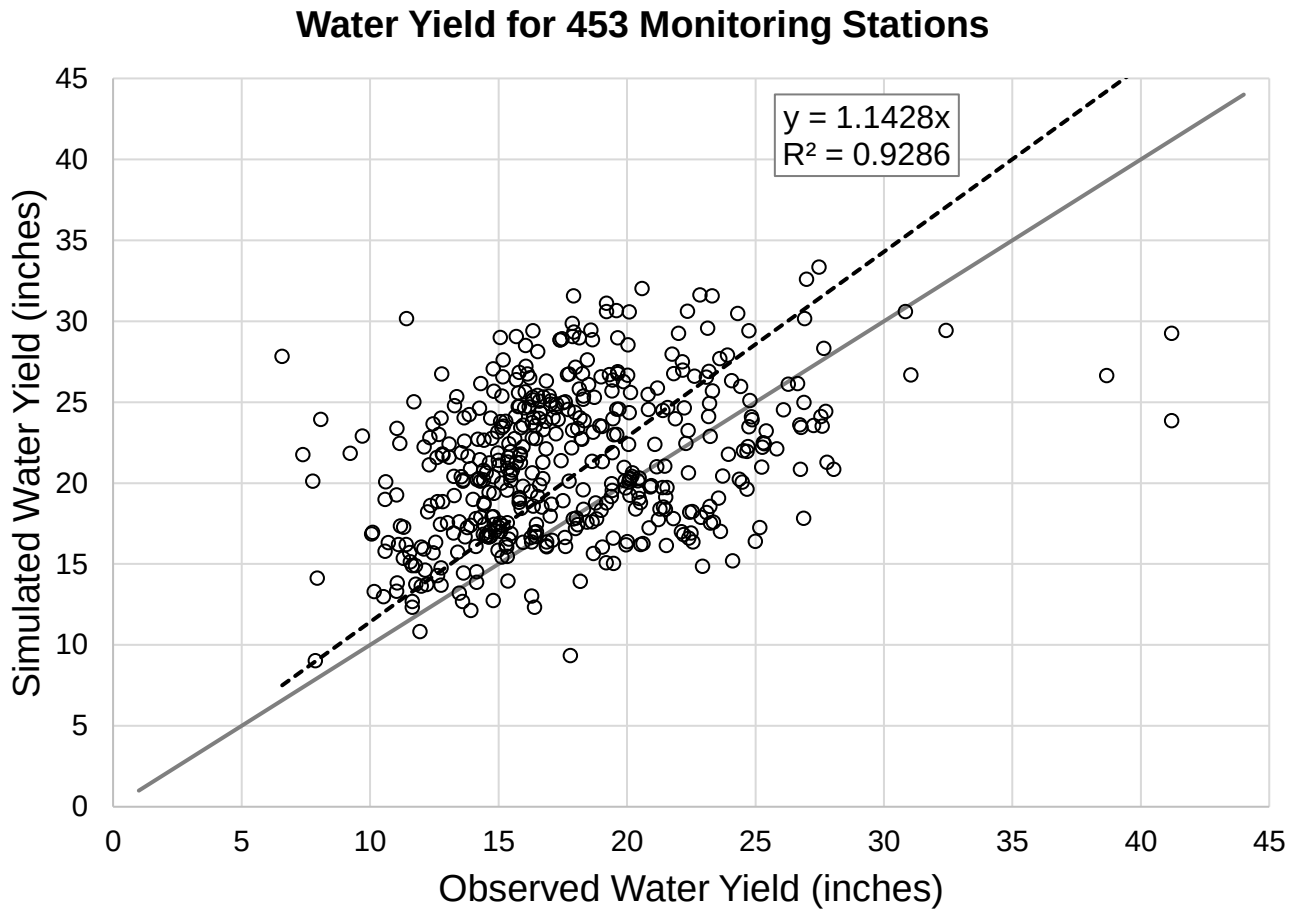


Data (CalCAST Hydrology – an initial, simplified prototype)

- NHD 100K data/topology
- NLDAS Rainfall at county scale
- PET (Hamon) at county scale
- Land Cover at NHD 100K scale – 12 class (Peter Claggett)
- Municipal and Industrial discharges at NHD 100K scale (Rigelman, Devereux)
- Withdrawals (Phase 6 data at NHD 100K scale)
- USGS Observations for 452 stations

Results (CalCAST Hydrology – an initial, simplified prototype)

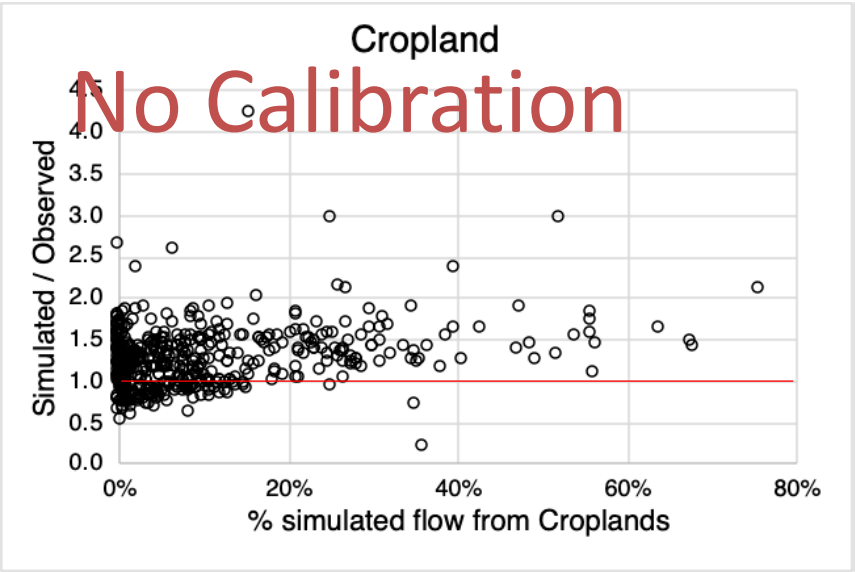
No Calibration

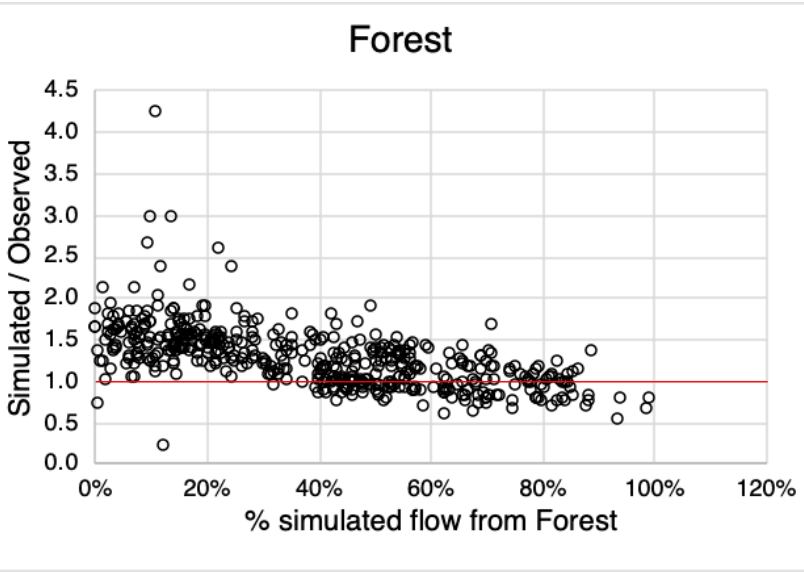


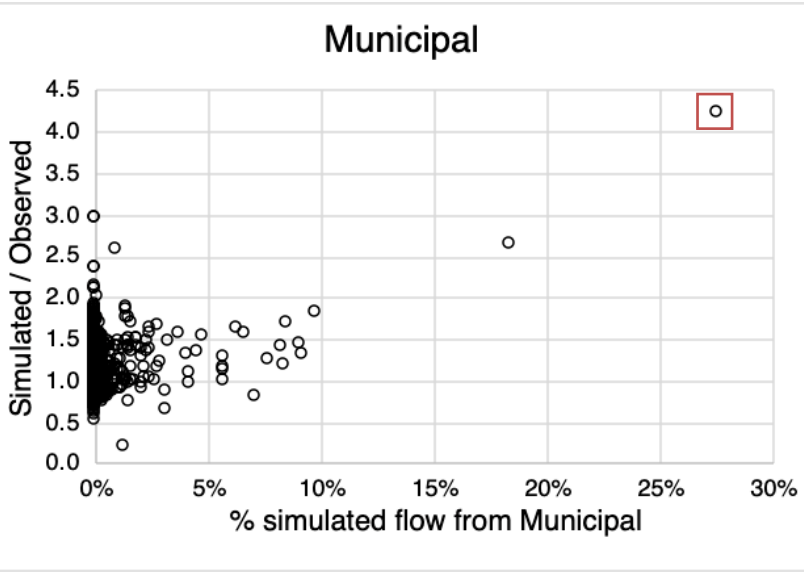
Run time is about 14 minutes using 4 Nodes (144 processors)

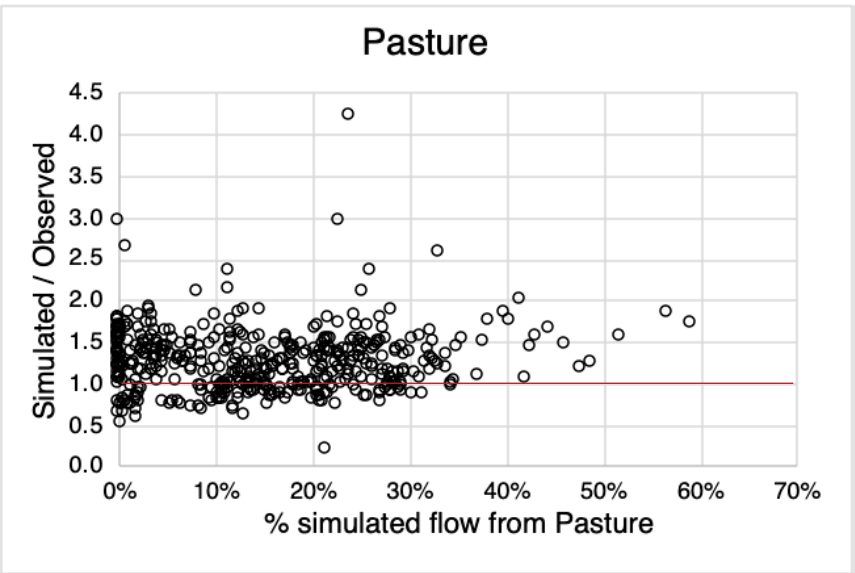
Results (CalCAST Hydrology – an initial, simplified prototype)

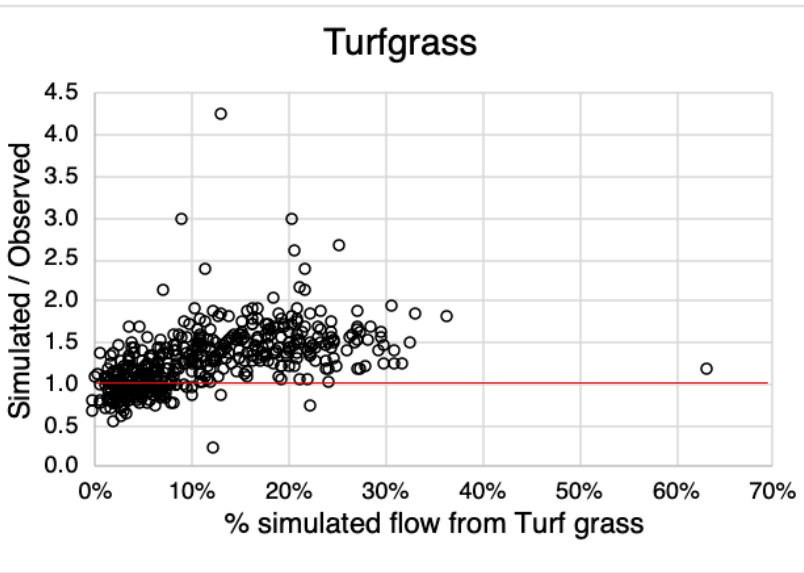
No Calibration

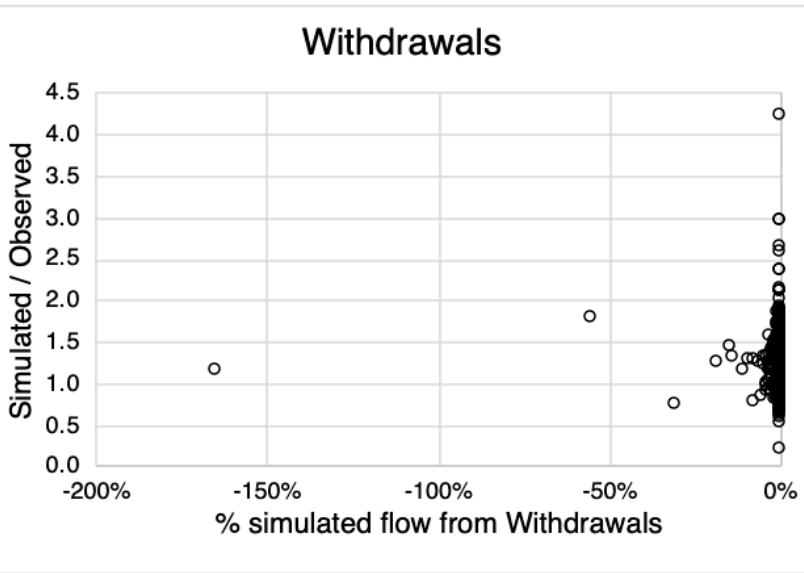








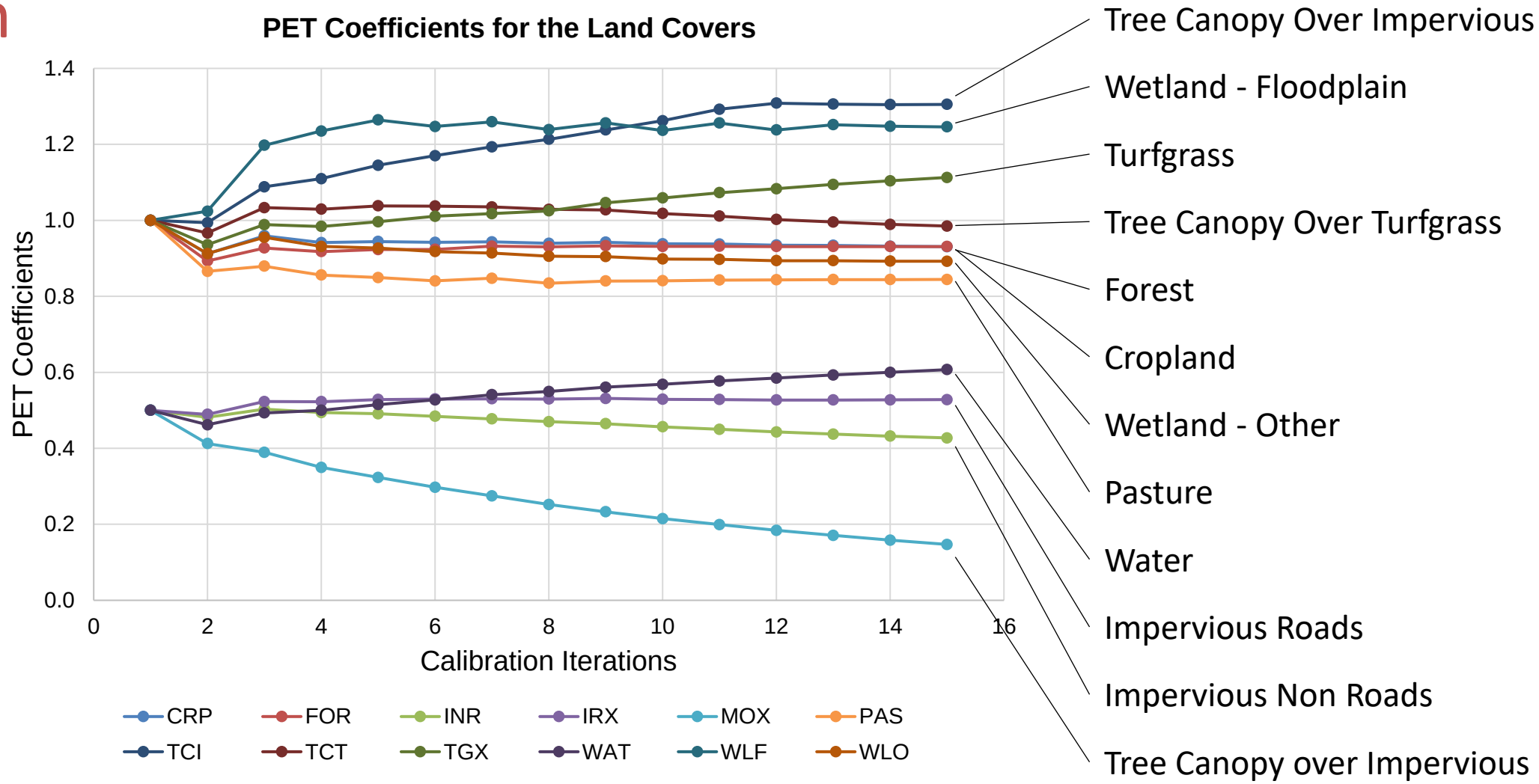




Calibration method; Potential data diagnostics

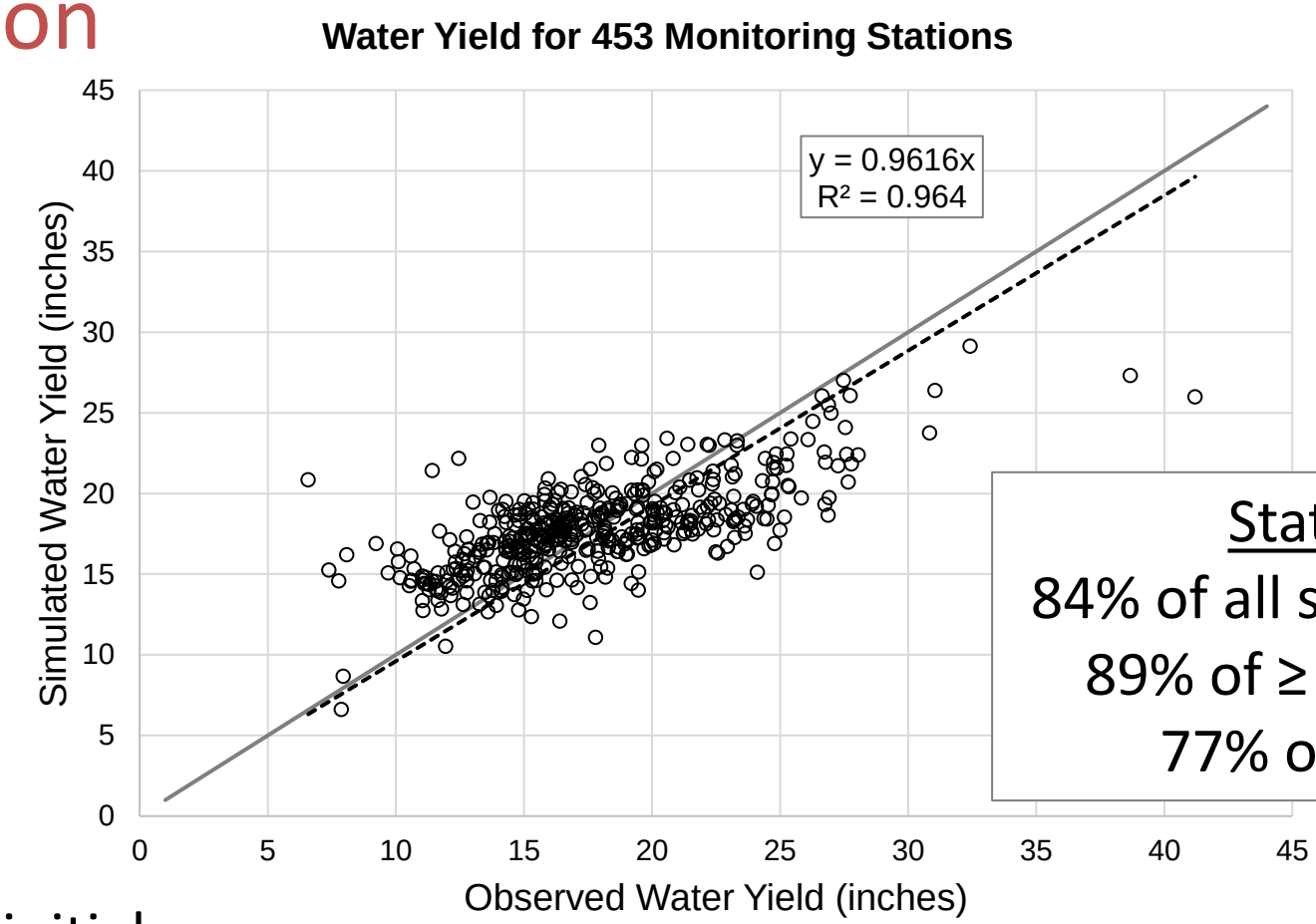
Results (CalCAST Hydrology – an initial, simplified prototype)

Calibration Iterations



Results (CalCAST Hydrology – an initial, simplified prototype)

After Calibration



Stats summary

84% of all station within ±25%

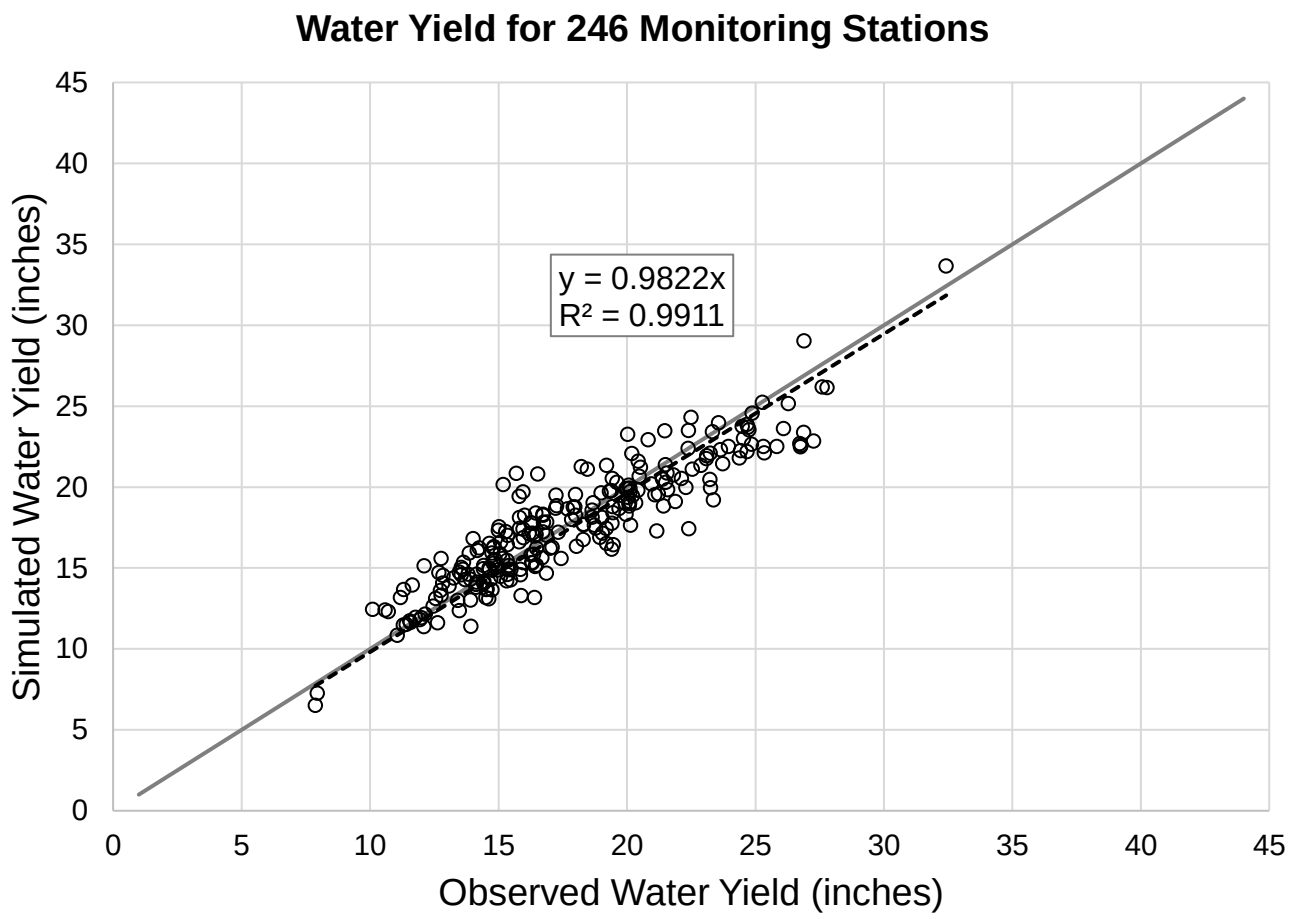
89% of ≥ 50cfs P6 stations

77% of new stations

Tests with different initial parameters, objective functions, etc. were conducted.

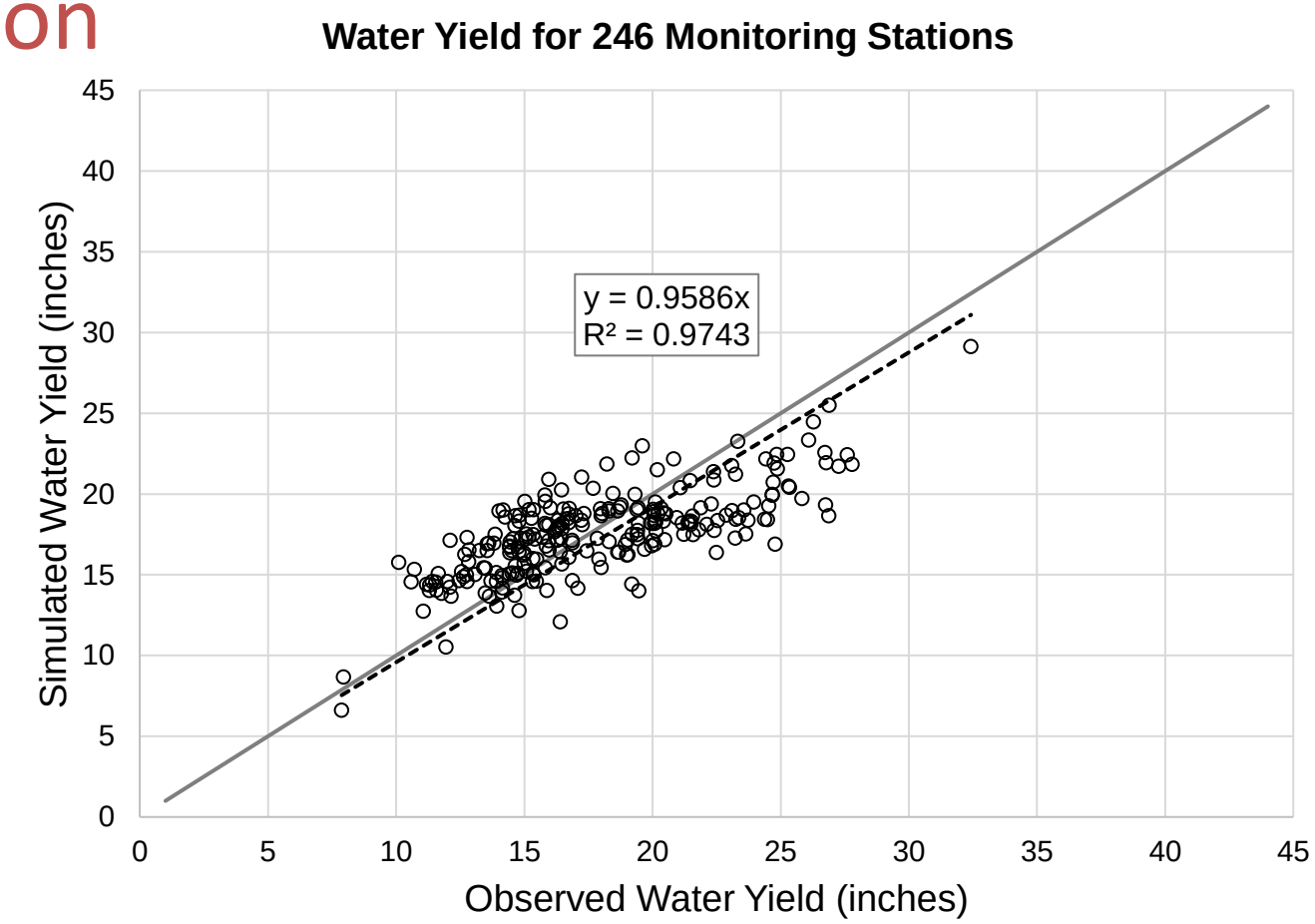
Results (CalCAST Hydrology – an initial, simplified prototype)

Phase 6 as a reference



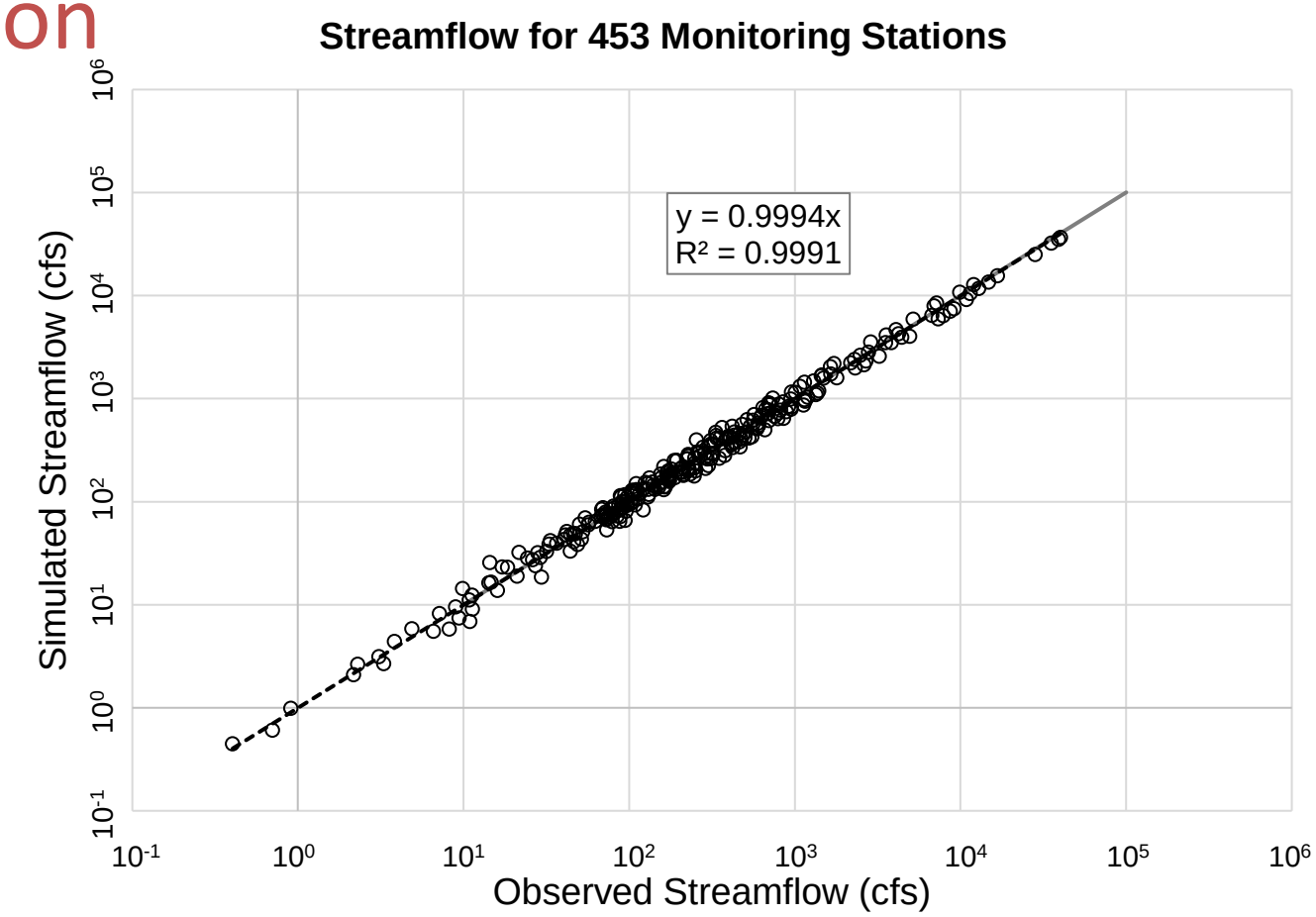
Results (CalCAST Hydrology – an initial, simplified prototype)

After Calibration



Results (CalCAST Hydrology – an initial, simplified prototype)

After Calibration



Verification of CalCAST setup, scale, and NHD topology

Other Issues & Next Steps

- Refinement of the CalCAST hydrology model
- Additional models targeting other hydrologic prediction endpoints
- Data Issues
  - CSO – incorporation would require adjustment of land cover data
  - Withdrawals – NHD (Additions/Removals) and/or USGS (John Brakebill)
  - A few monitoring stations (e.g., Big Spring, PA; James and Kanawha Canal, VA)

Other Issues & Next Steps

- Great progress has been made but we are in very early stages with our first quarter into this work.
- For the next quarter, we should continue to prioritize hydrology model and look for opportunities to make progress on time-averaged as well as dynamic hydrologic models.

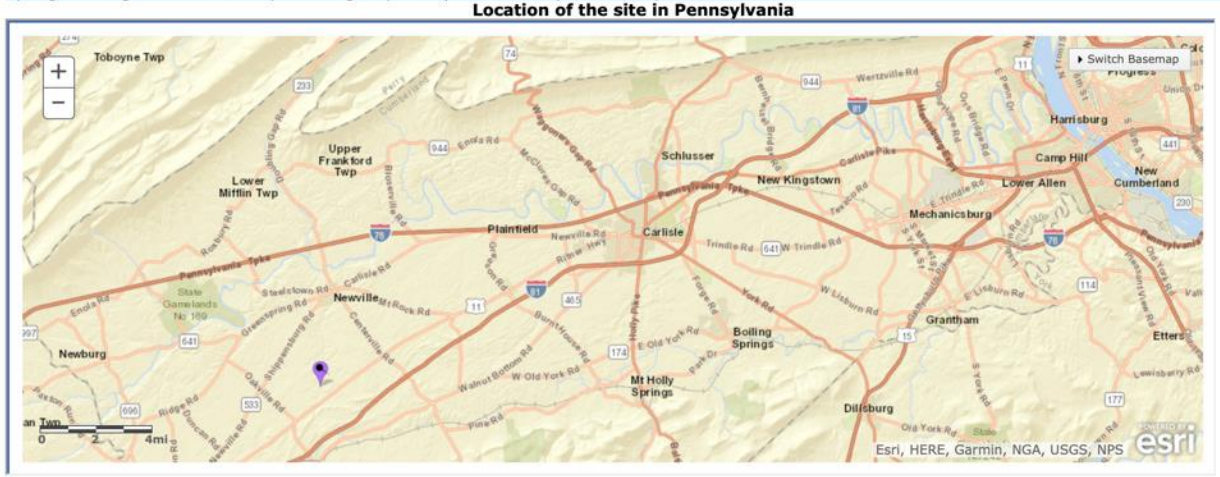
Big Spring Creek, PA

USGS 01569460 Big Spring Creek at Big Spring, PA

Available data for this site | Location map | GO

Cumberland County, Pennsylvania
Hydrologic Unit Code 02050305
Latitude 40°07'46", Longitude 77°24'27" NAD27
Land-surface elevation 510 feet above NGVD29
Spring discharges from the Valley and Ridge aquifers (N500VLYRDG) national aquifer.

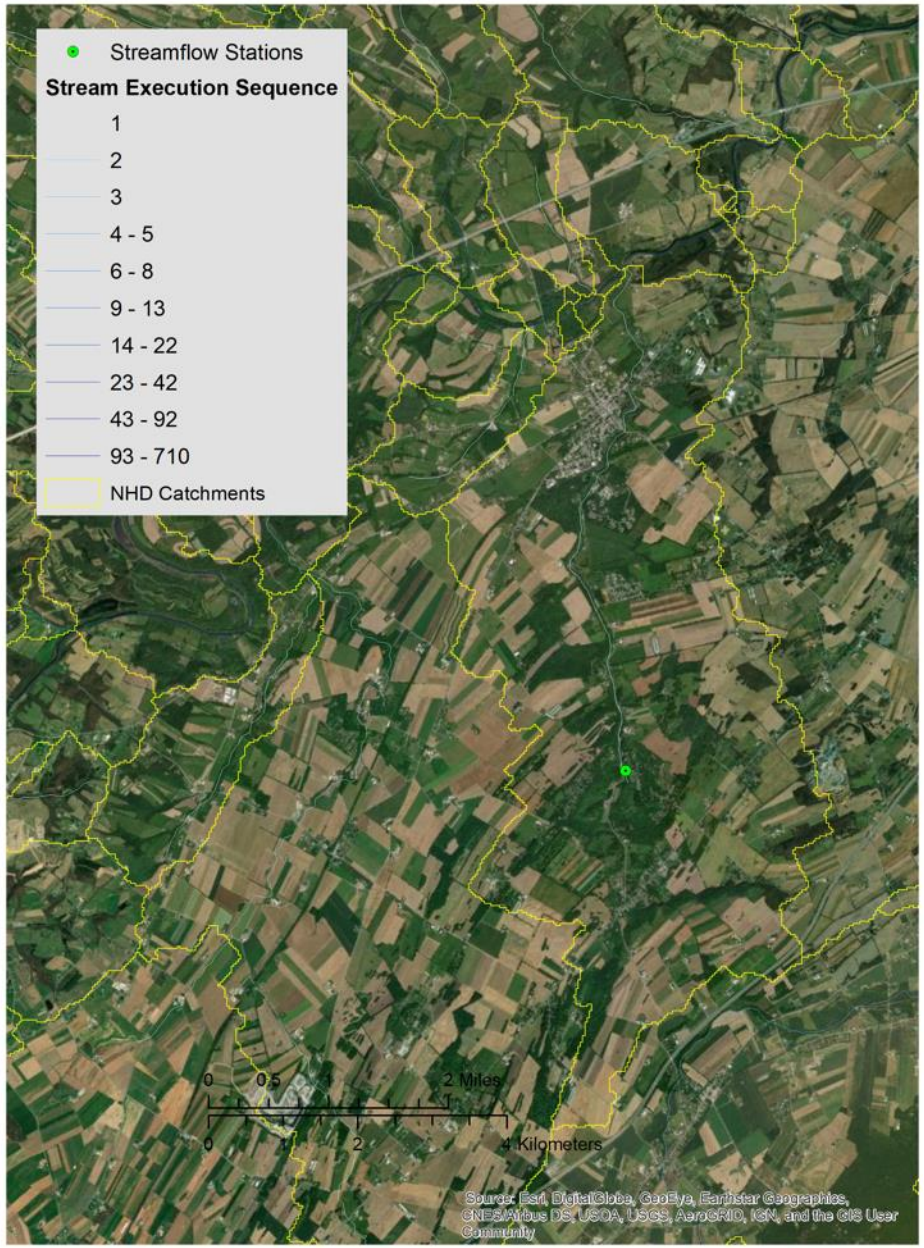
Location of the site in Pennsylvania



http://bigspringcreek.com

"Big Spring Creek near Newville [Cumberland], Pennsylvania is one of the most famous limestone spring creeks in the world. It is the fifth largest spring in Pennsylvania."

- Observations from Nov 2004 onwards
- Water yield of about **123 inches**
- Normal rainfall is about **43 inches**



DA = 2,182 acres; CA = 8.269 acres; Scaling factor = 3.8

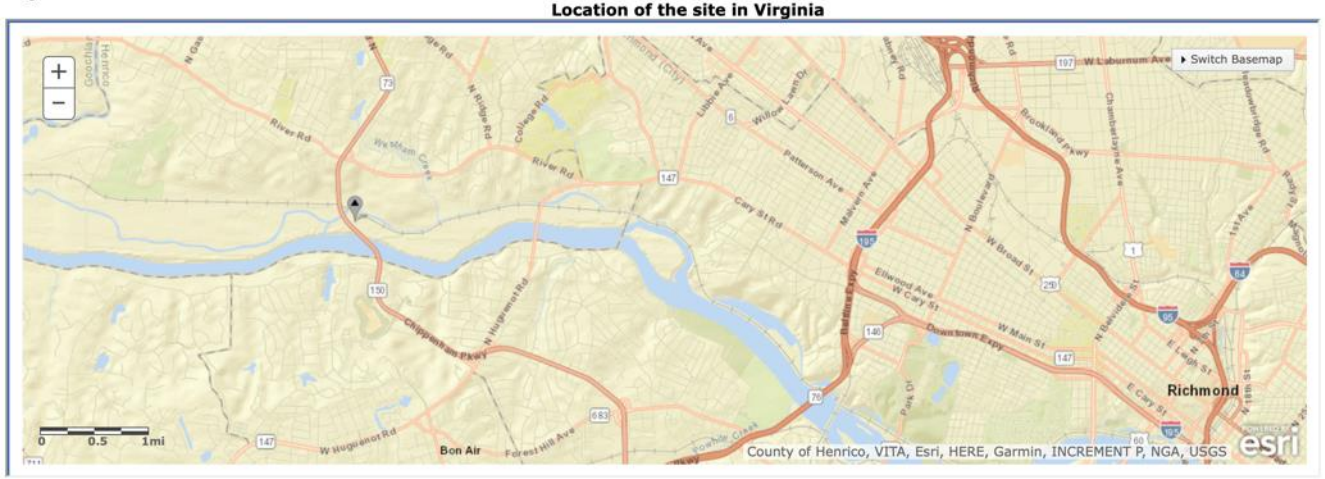
James River and Kanawha Canal

USGS 02037000 James River and Kanawha Canal, Richmond, VA

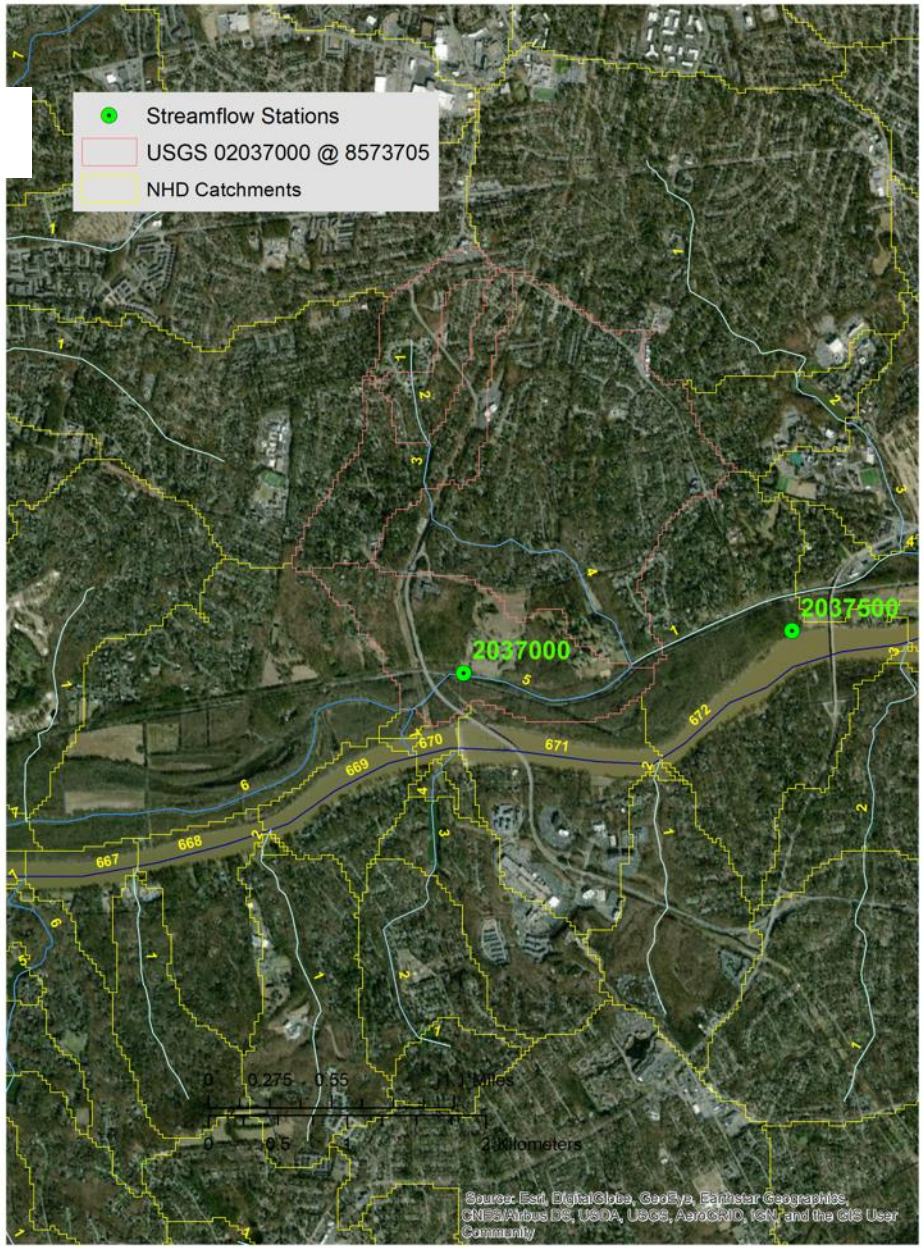
Available data for this site | Location map | GO

Henrico County, Virginia
Hydrologic Unit Code 02080205
Latitude 37°33'52", Longitude 77°34'28" NAD27
Drainage area 66.6 square miles
Gage datum 106.07 feet above NGVD29

Location of the site in Virginia



- Observations from Oct 1936 onwards
- Drainage Area **42,624 acres**
- NHD catchments provide **1,705 acres**



DA = 42,624 acres; CA = 1,705 acres; Scaling factor = 25