

An aerial photograph of a landscape. On the left, there's a dark, dense forest. In the center, a large, irregularly shaped body of water, possibly a reservoir or a large pond, is visible. To the right of the water, there's a large area of reddish-brown trees, likely a forest. Further right, a road or path winds through a green, grassy area. The overall scene is a mix of natural and possibly developed areas.

N|V|5

# When Water Doesn't Flow Downhill:

Integration of urban stormwater networks with  
elevation derived hydrography

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# Topics for discussion

- Why am I talking about subsurface flow networks?
- When do subsurface networks matter?
- Simple features... culverts
- **Complex networks... pipes, treatments facilities, etc**
- **Levels of network integration**
- Methods of network integration
- Sewersheds vs Watershed
- Limitations
  
- Questions/Discussion?

# Why am I talking about subsurface flow networks?

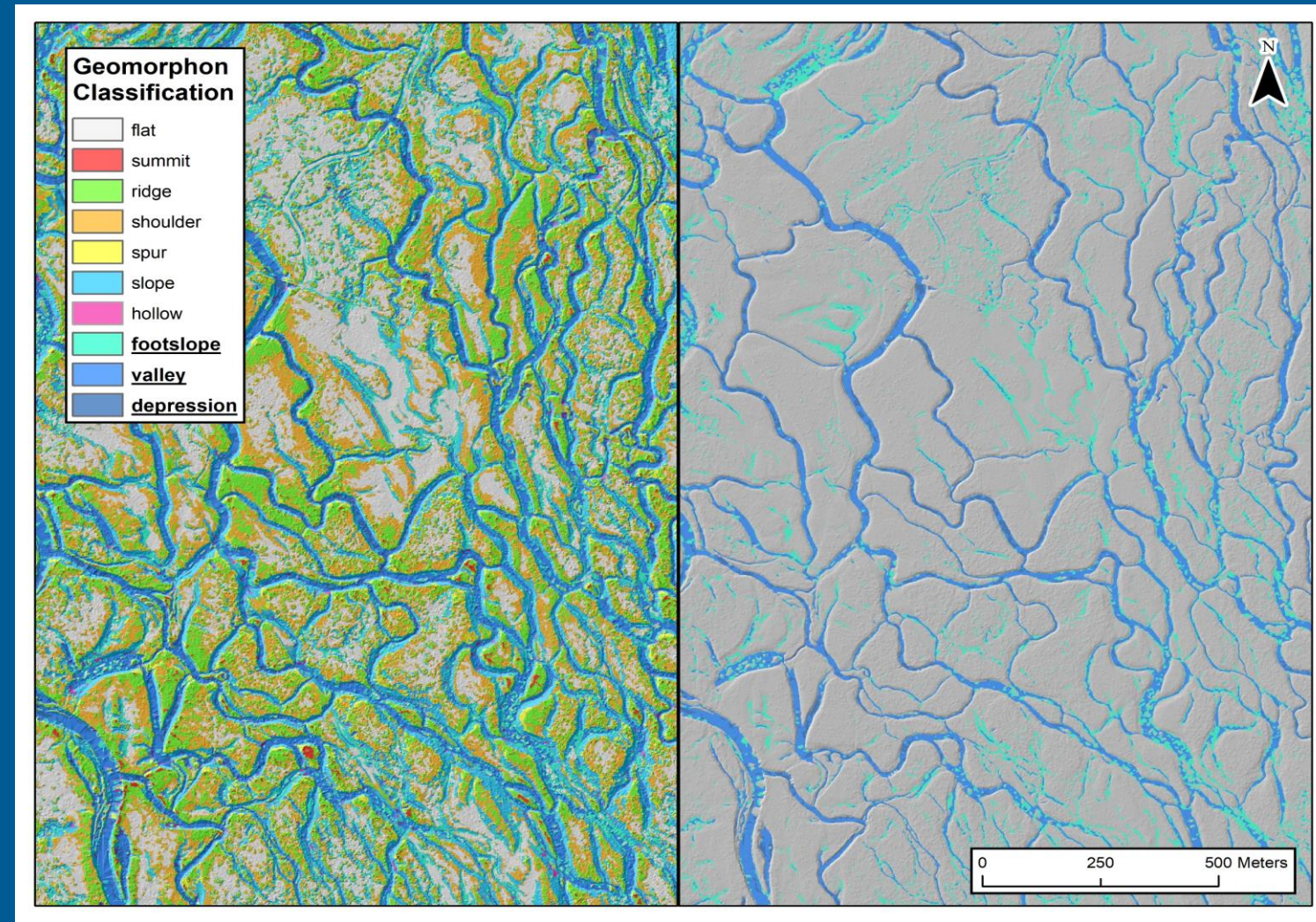
- 3D Hydrography Program (USGS)
  - Leverages high resolution elevation data (LiDAR/IF SAR)
  - Reliant on geomorphic channel detection and flow accumulation
  - Remote sensing can't see underground!
- Surface flow is often not the primary hydrologic driver in urban environments
  - Analysis of surface flow doesn't accurately map flow paths
  - Urban areas can be "hydrographic deserts" even with significant precipitation
- Integrating subsurface networks provides more accurate hydrography
  - Network capacity planning
  - Pollution tracking
  - Flooding/inundation risk

# When do subsurface networks matter?

- Density of urbanization / stormwater networks
  - How much water is moving underground?
  - How far is water moving underground?
- Desired application of hydrography mapping
  - Rough understanding of connectivity?
  - Precise flow accumulation for inundation?
  - Pollution tracking?
  - Urban basin delineation?

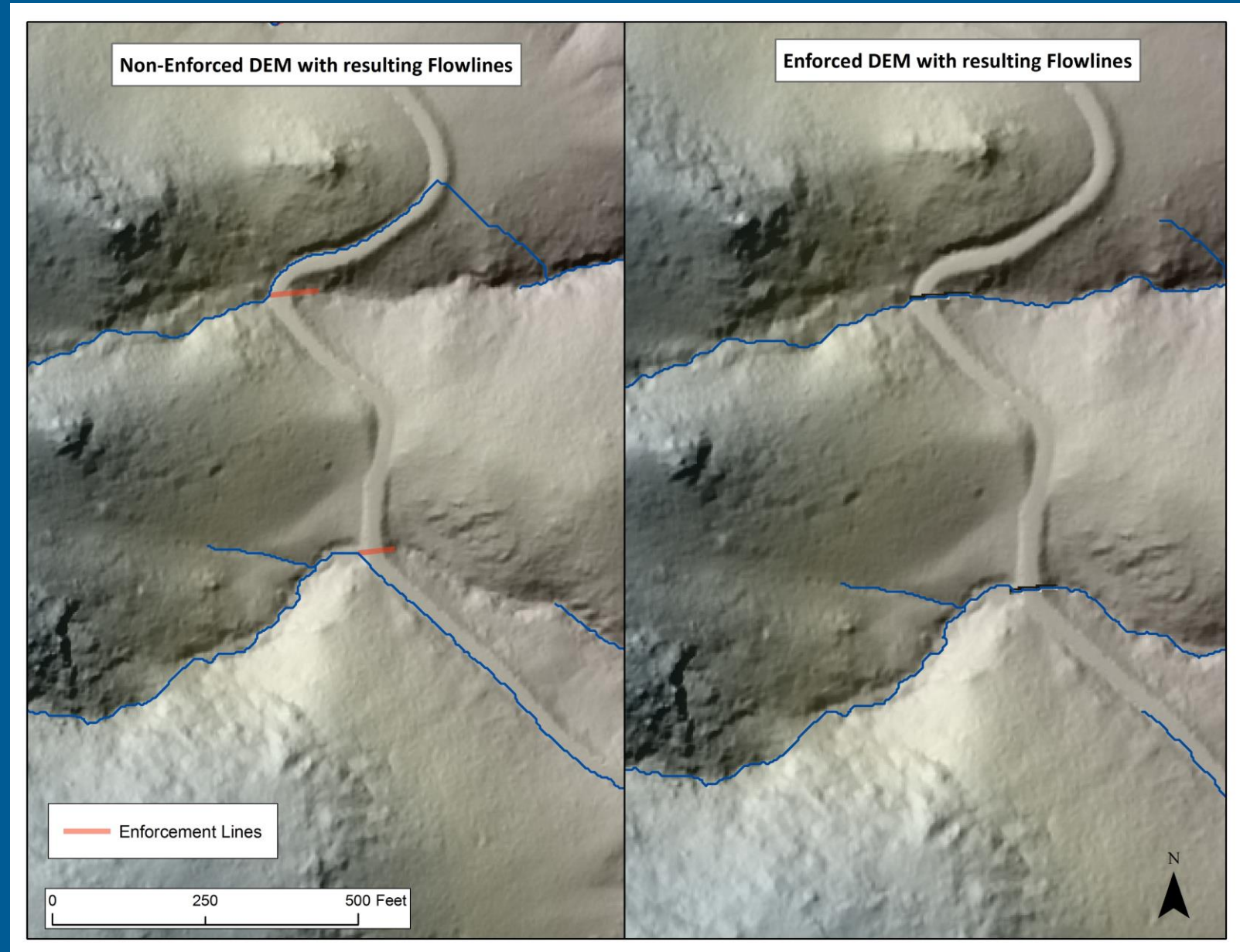
# Simple features... culverts

- Often culverts can be mapped through geomorphic channel detection... “hydro enforcement”
- Ideally precise culvert inventories collected in the field are available.
- Neither of these processes are perfect in reality...



# Simple features... culverts

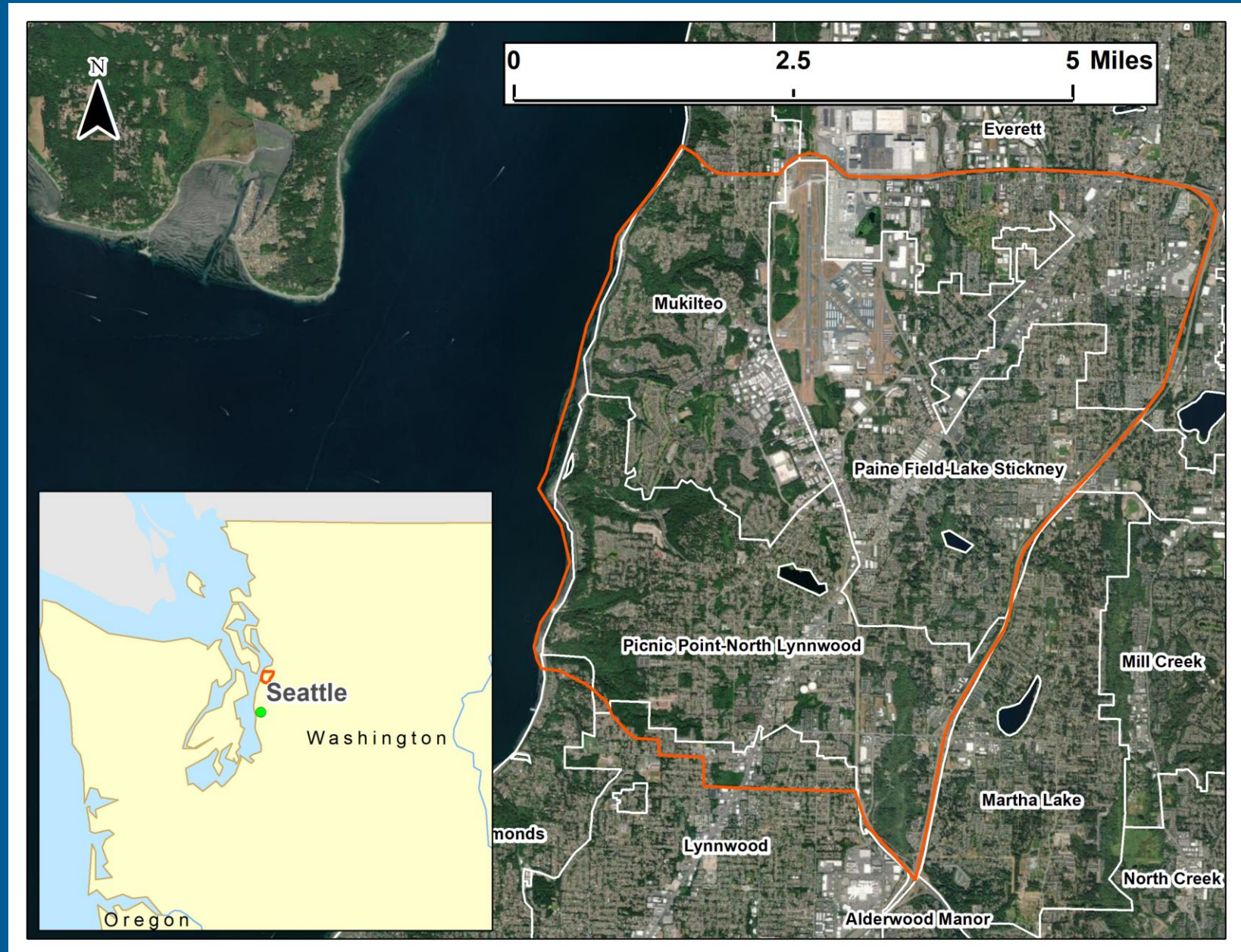
- Enforced in DEM
- Not the case for longer connectors
- Requirement for basin delineation



# Complex networks... pipes, treatments facilities, etc

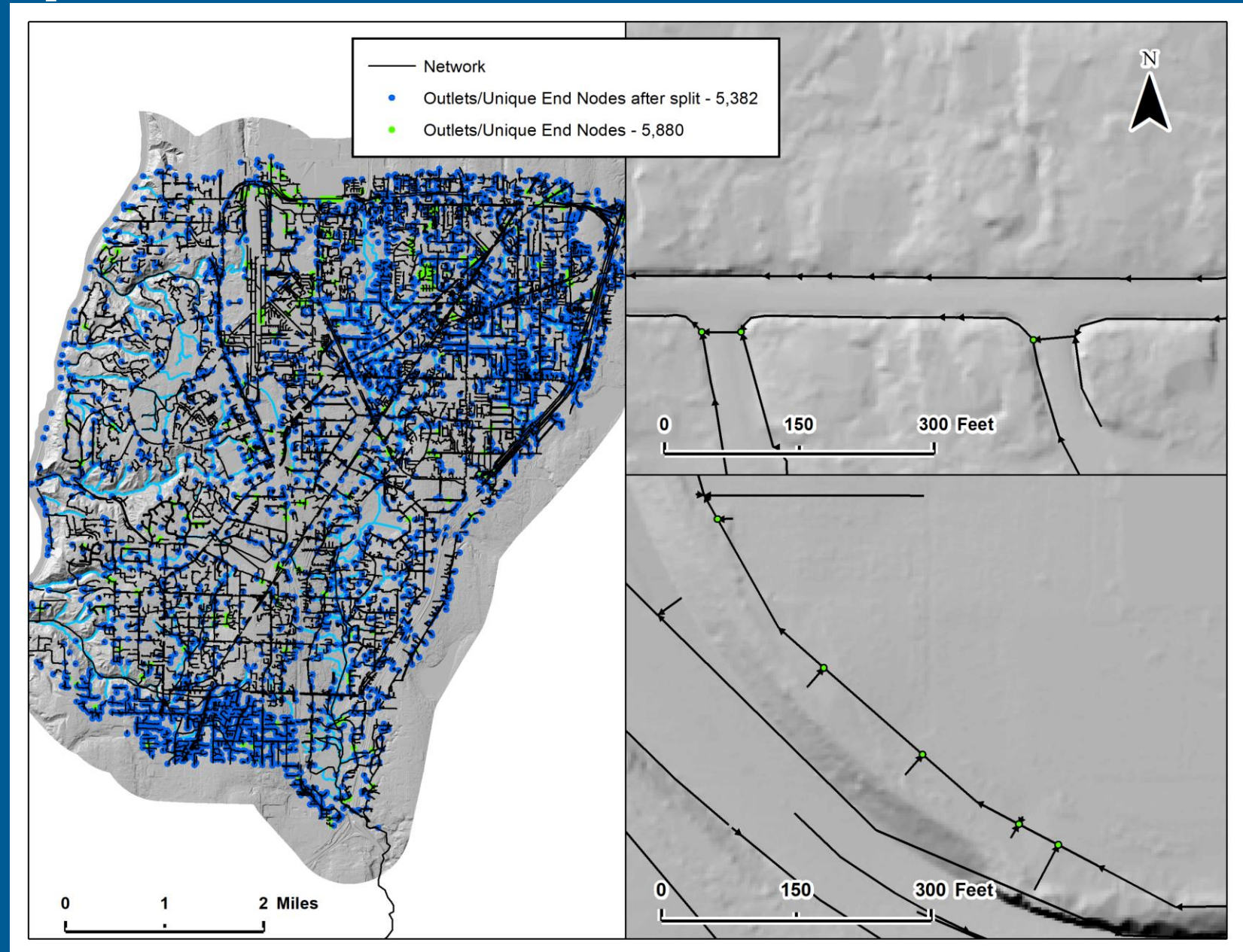
- Longer and more complex subsurface networks require different analysis, treatment and integration.
  - Topological correction
  - Positional correction and alignment
  - Not enforced in DEM
  - Often surface flowpaths (typically canals/ditches) are integral components of stormwater network
  - Can transport water over long distances with no surficial agreement

# Snohomish example





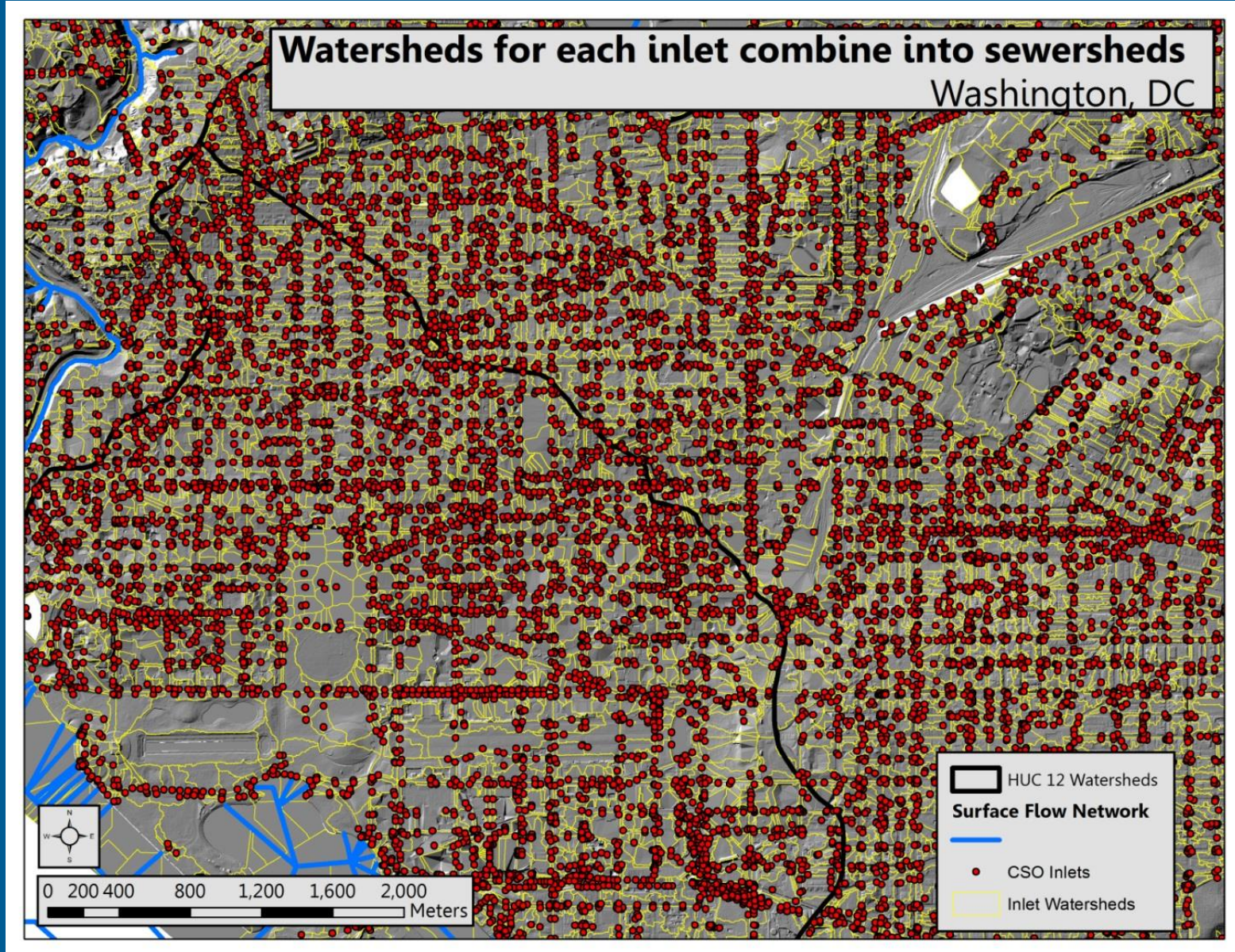
# Snohomish example



# Washington DC example

~33k inlets in DC

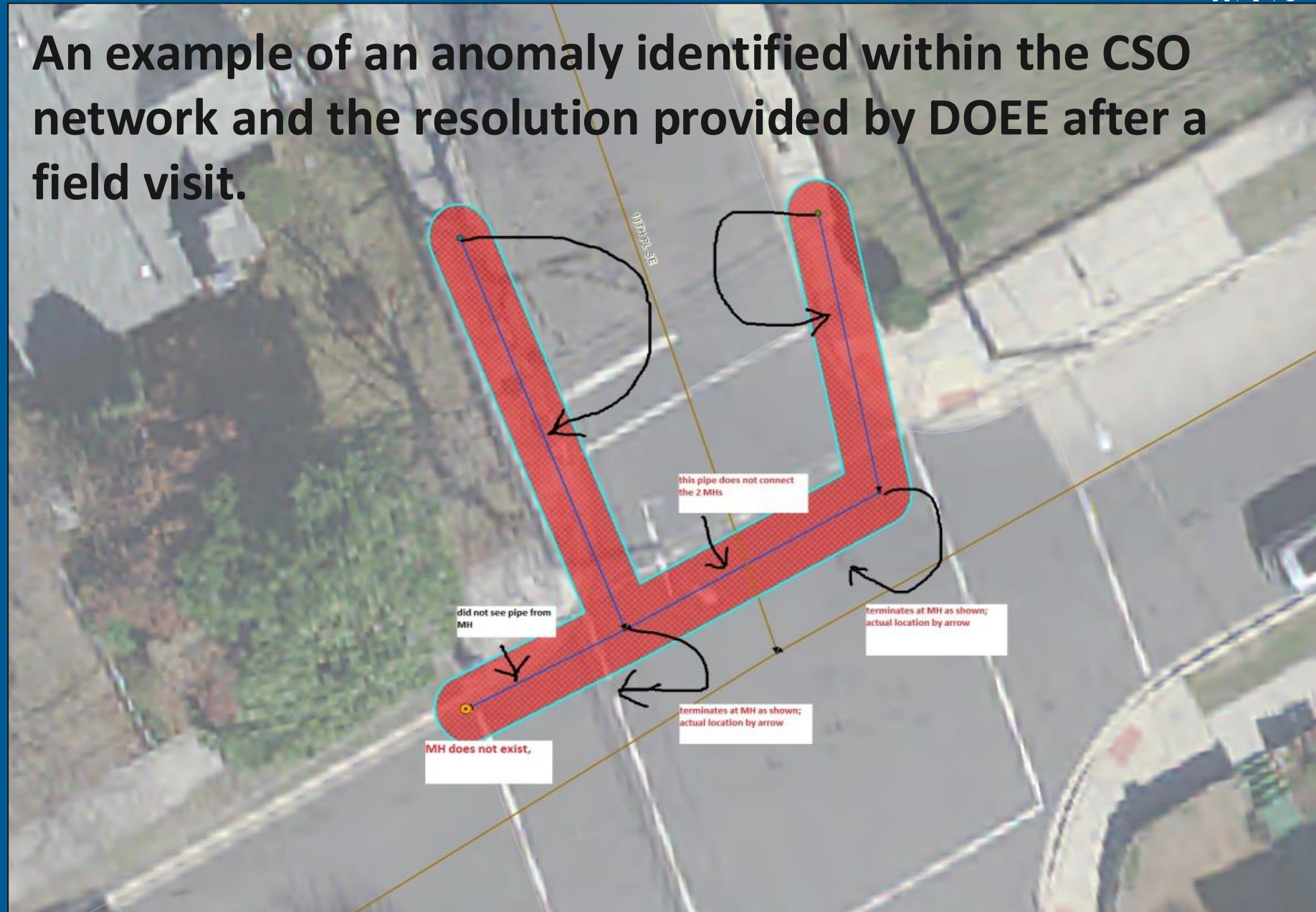
Not all jurisdictions!



# Topological correction

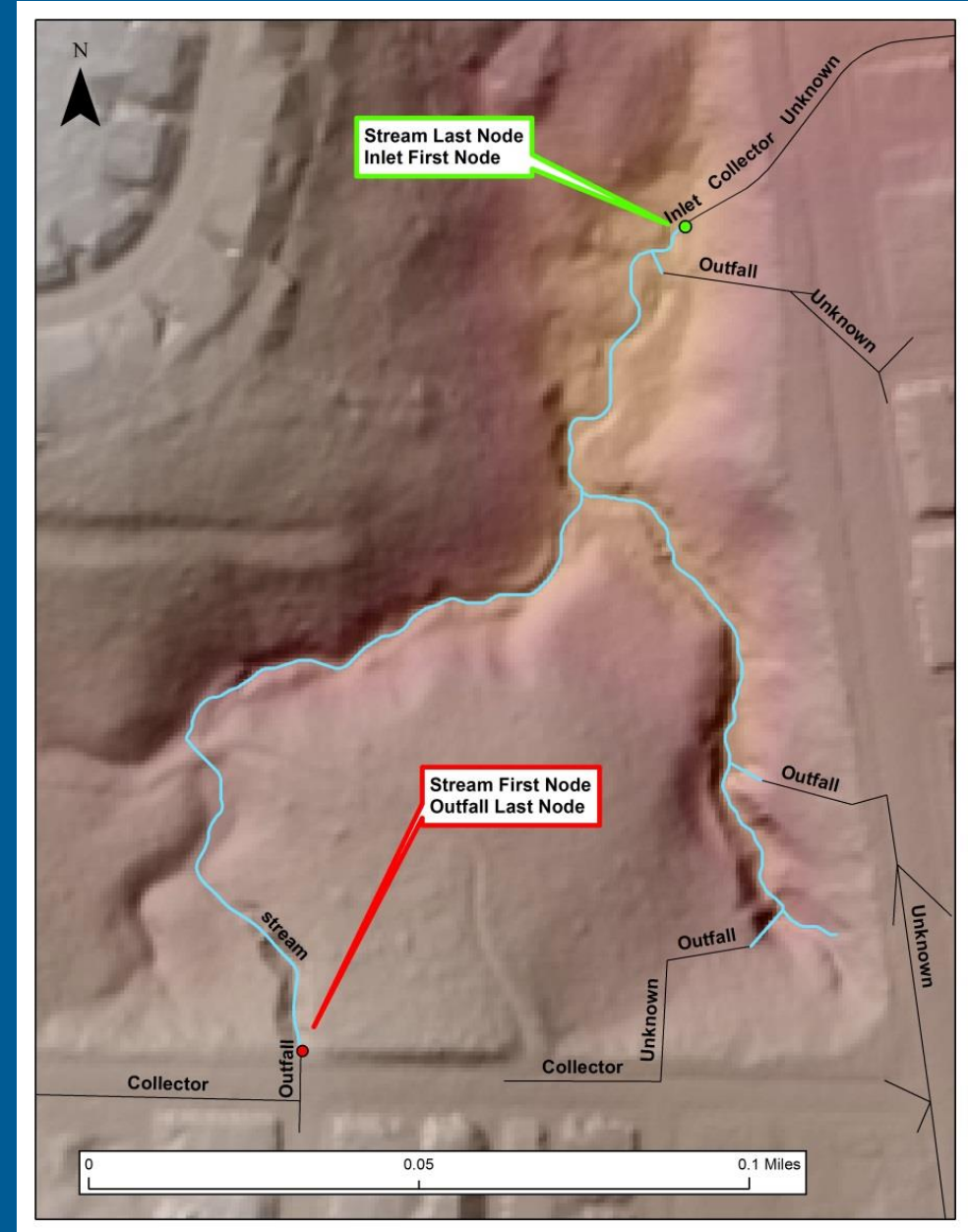
- Loops
- Conflicts
- Missing Vertices
- Wrong Vertices
  
- Clean geometric network required!

An example of an anomaly identified within the CSO network and the resolution provided by DOEE after a field visit.



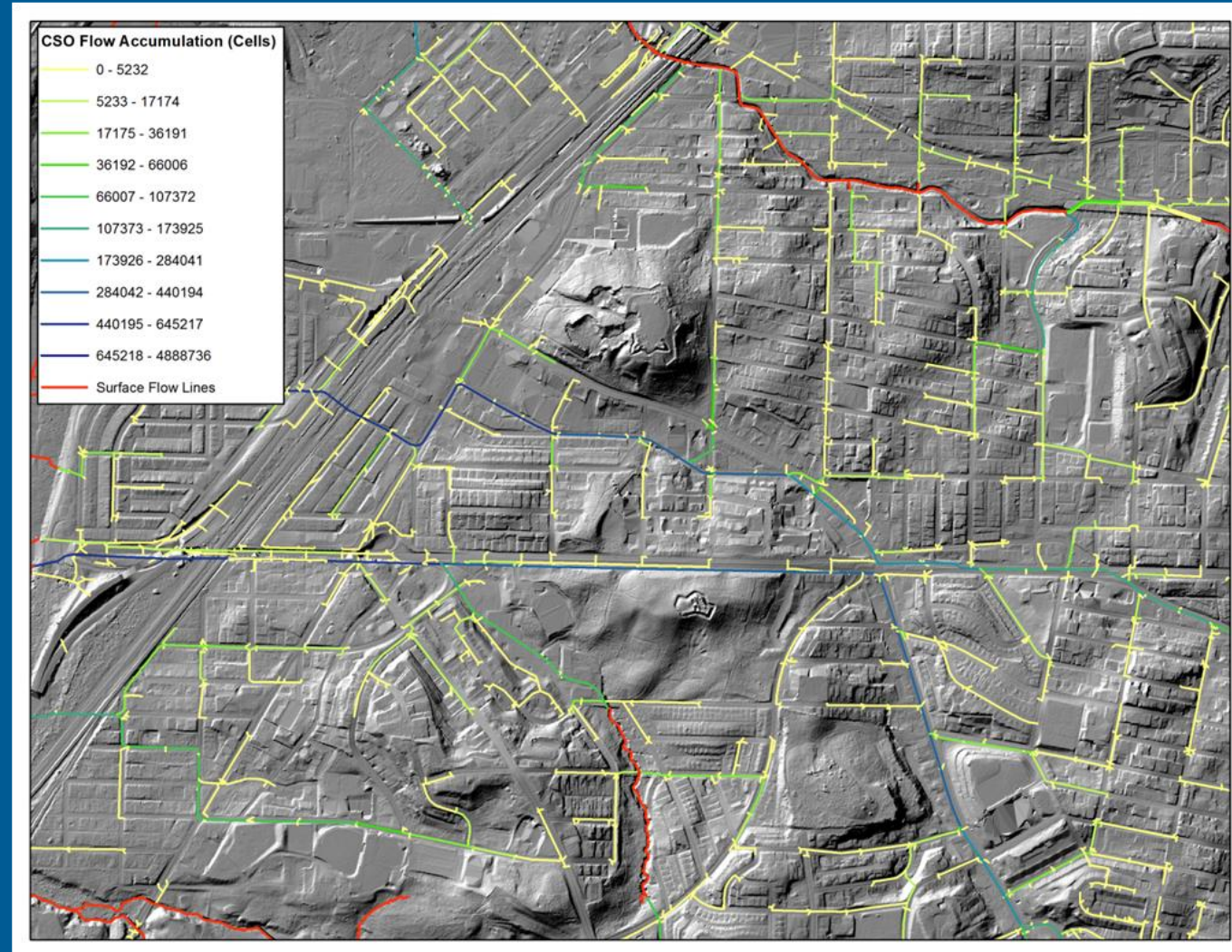
# Positional correction and alignment

- So much snapping!
  - Snap network vertices
  - Snap inlets to low point in DEM
  - Snap subsurface lines to surface or verse vica
- Alternative to some snapping is very short line segments
- Bad catchment delineation



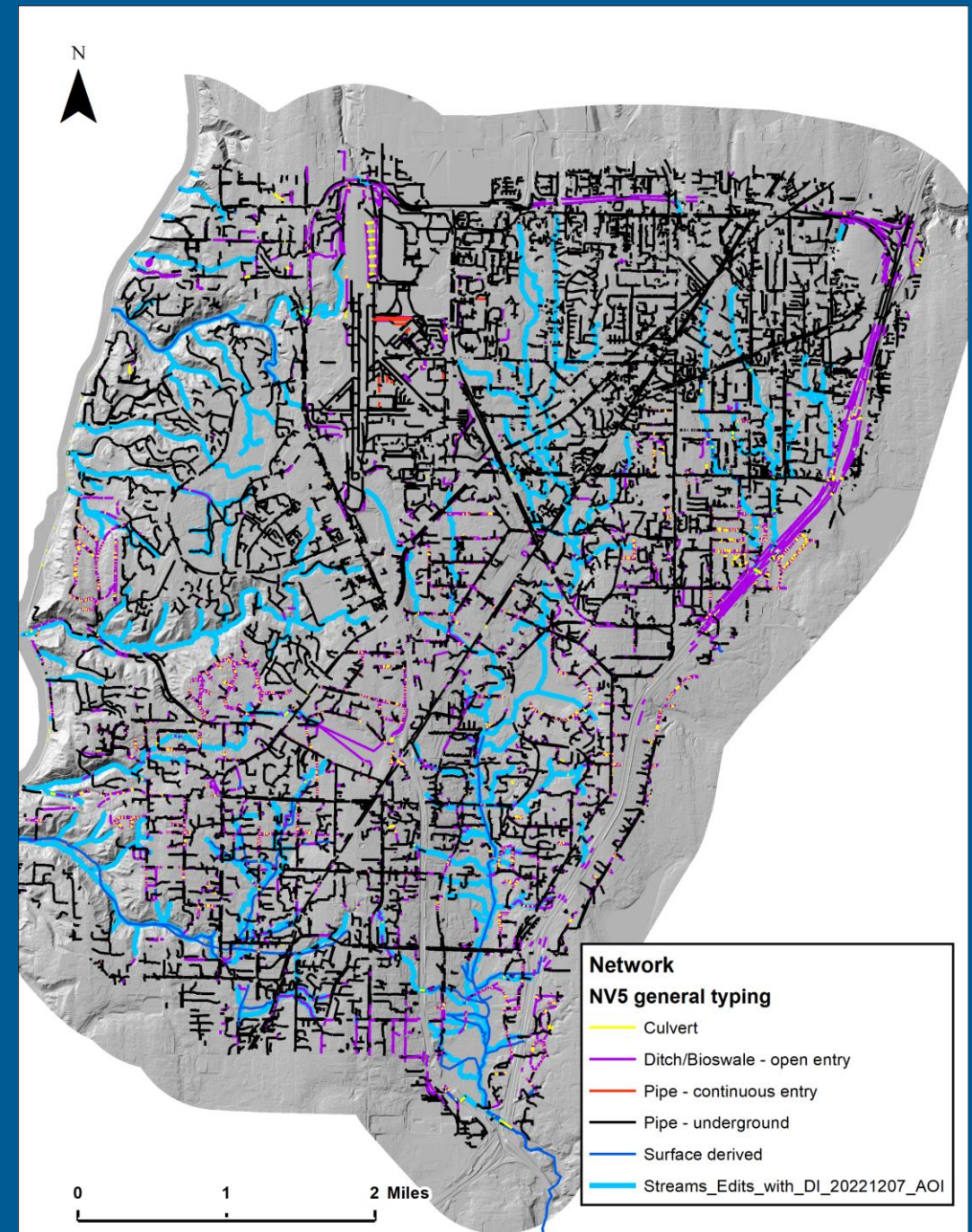
# NETWORK/TOPOLOGY ACCURACY

- Stormwater networks contain many XY crossings that may or may not represent a transfer of flow between the pipes.
- For correct flow accumulation need...
  - Accurate topology
  - Nodes only exist where flow is exchanged
  - Line direction correctly represents flowpaths
- Flow input only at inlets not pipeline.

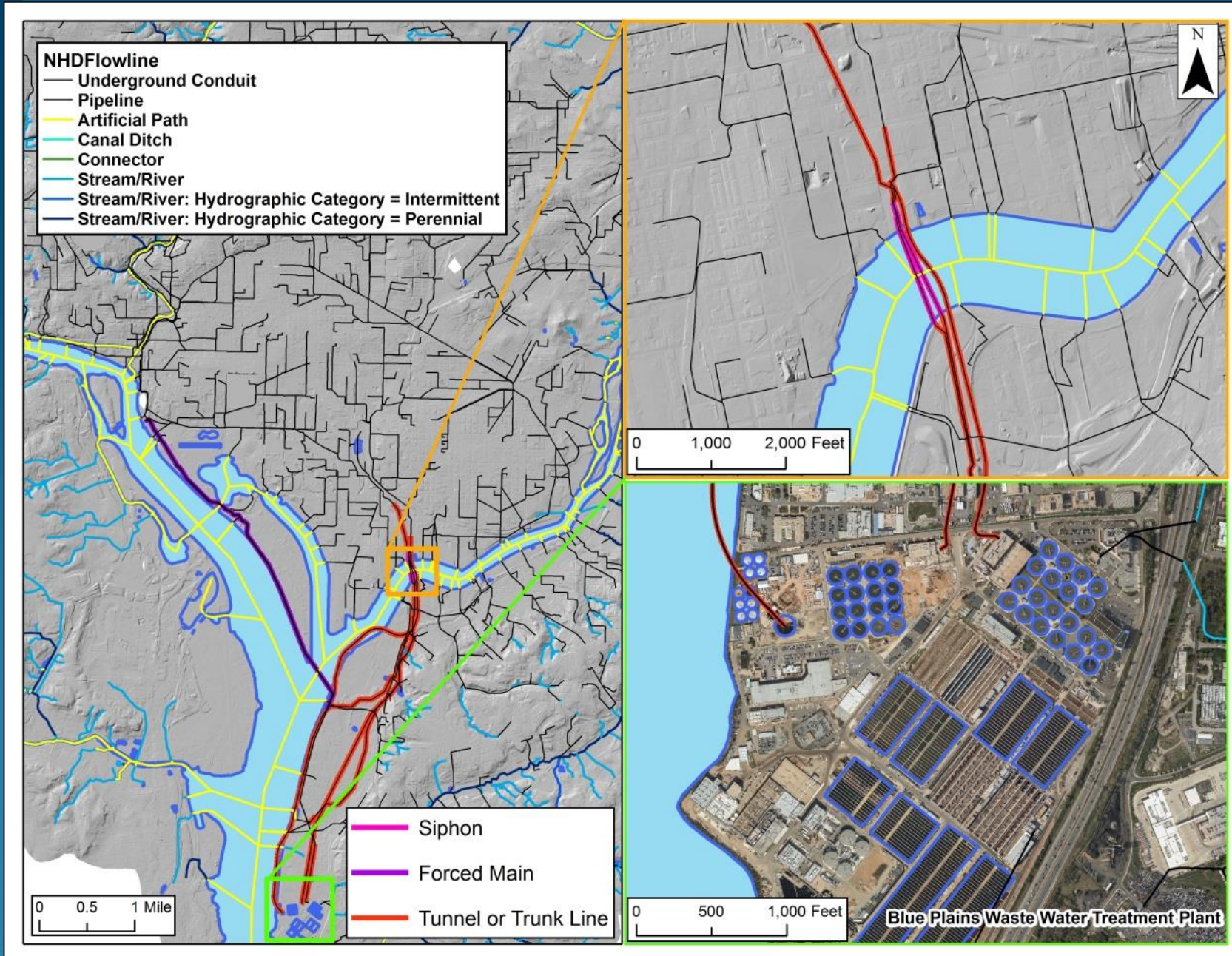


# Feature Types

- Culvert
- Ditch
- Pipe (Continuous Entry)
- Pipe (Underground)
- Surface connectors
- Surface flow (terrain derived)
  
- True engineered sinks
  
- Each of the above may require different treatment and classification!

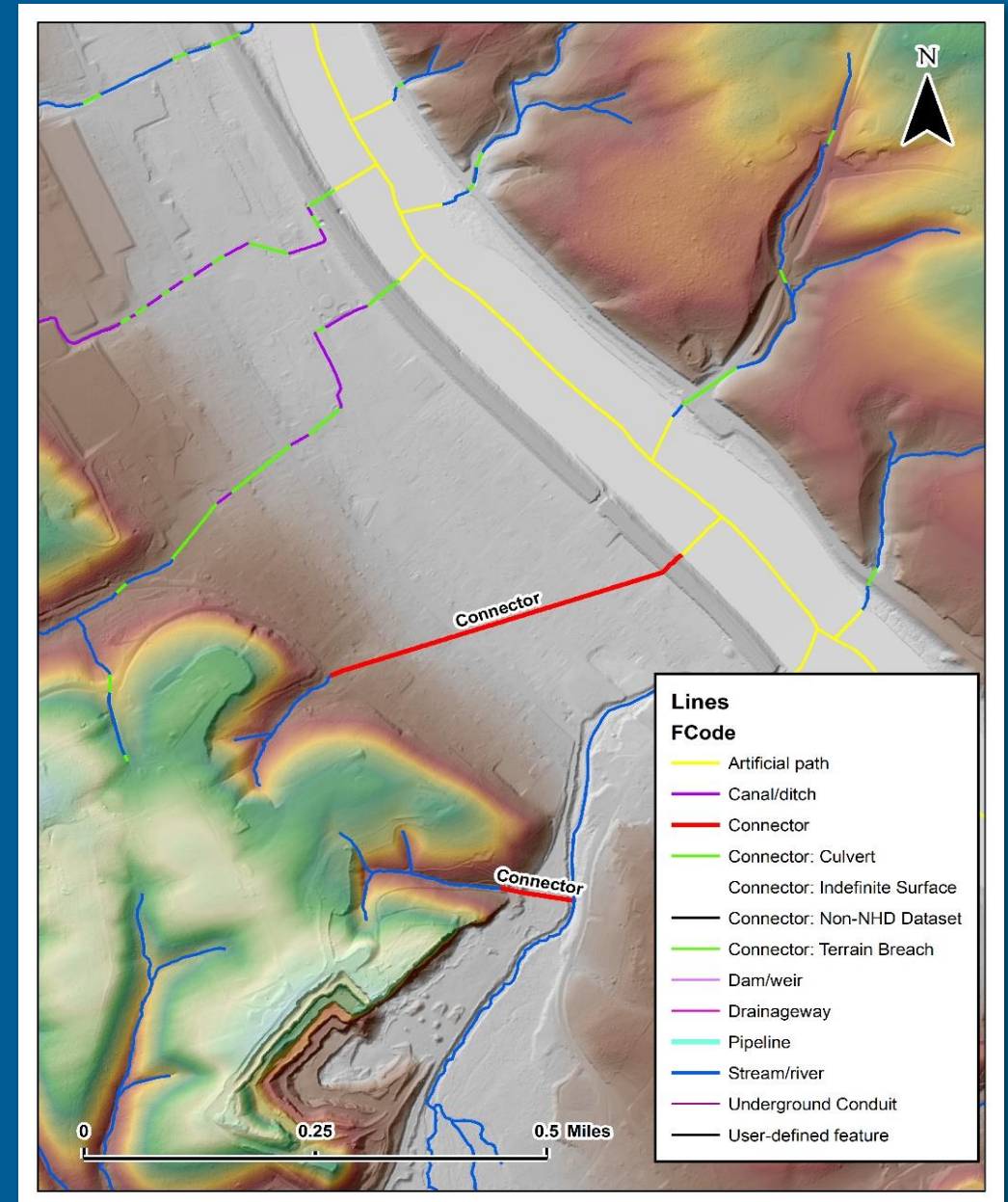


# Treatment facilities



# Levels of network integration

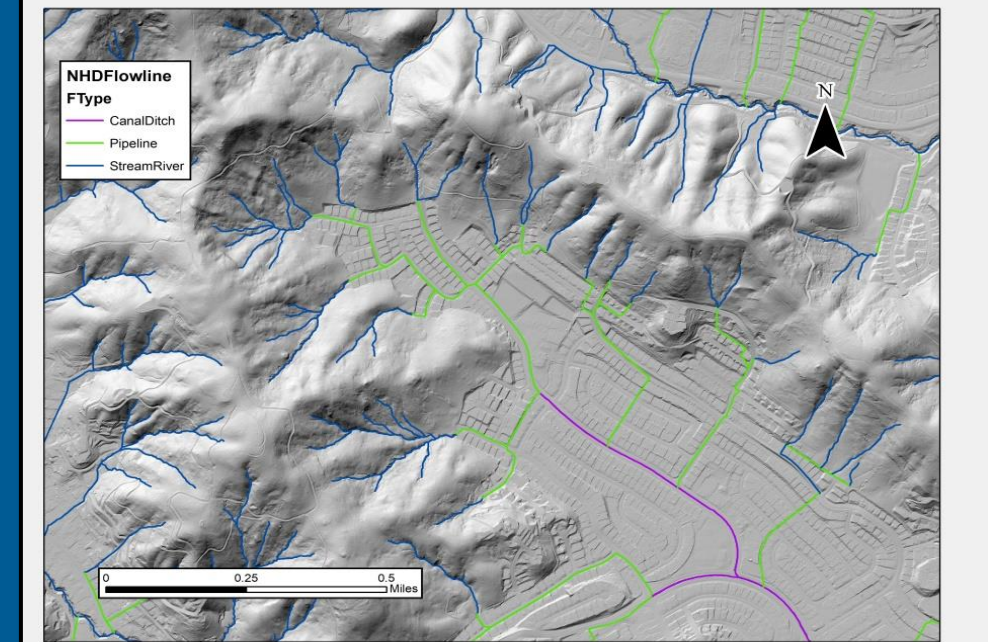
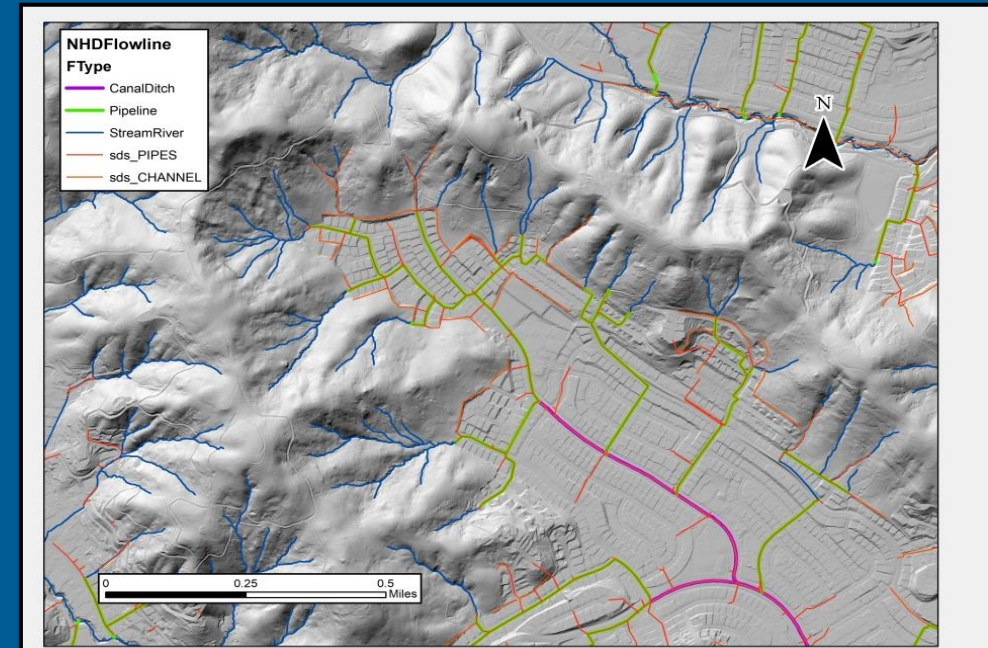
- Level 1: No integration
- Connector features are created as best guess in areas where connection should or must exist.
- Suitable for low density short connections.





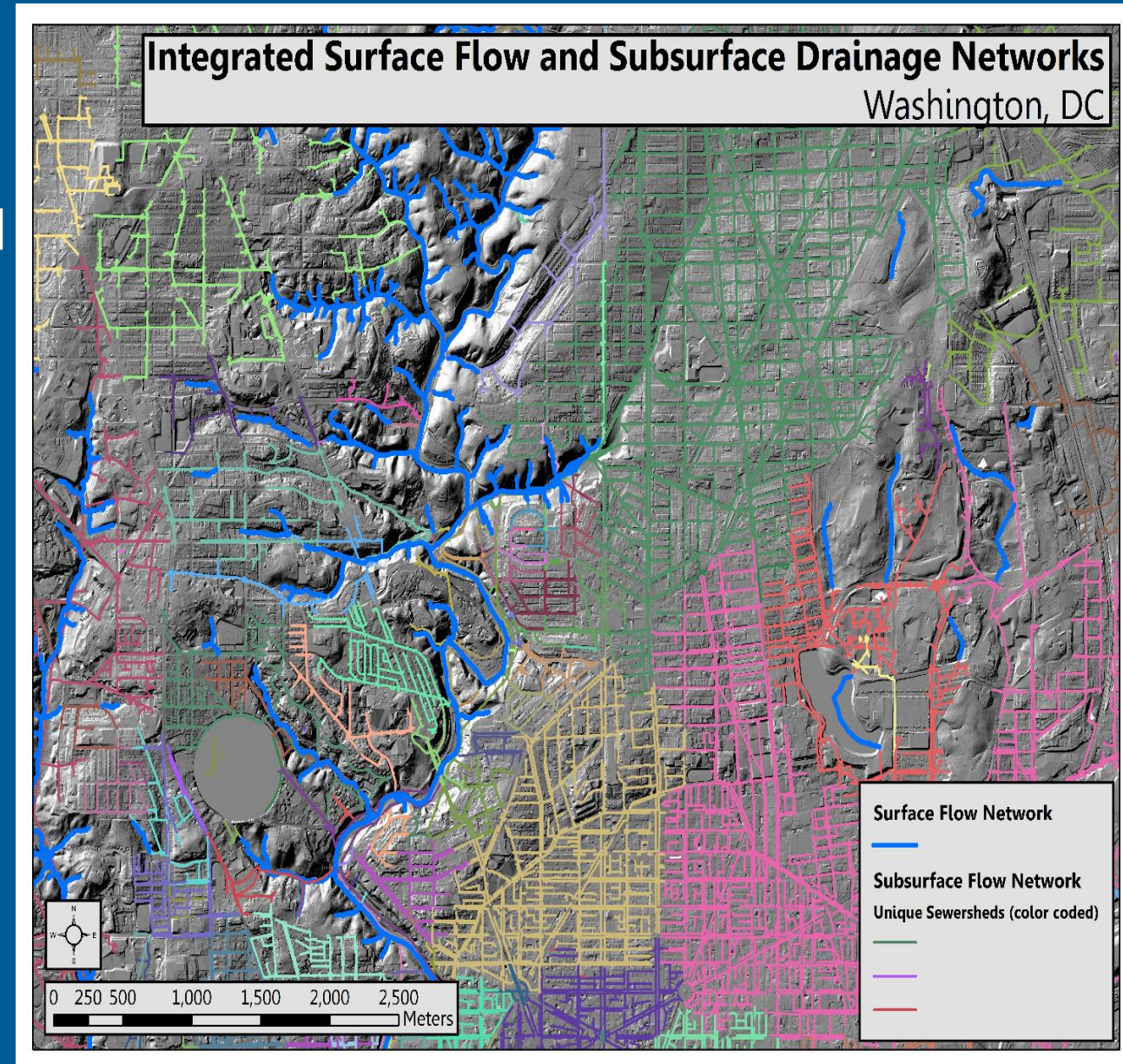
# Levels of network integration

- Level 2: Surficial integration
- Subsurface network features are provided to some degree.
- Connects surface derived flow paths with outlet to create connected network... single path.
- Suitable for small towns /medium density or where surface connection is primary goal.



# Levels of network integration

- Level 3 : Comprehensive integration
- Complete subsurface network required
- Entire landscape feeds complete network
- Suitable for cities or if inundation/capacity planning and pollution tracking a concern.

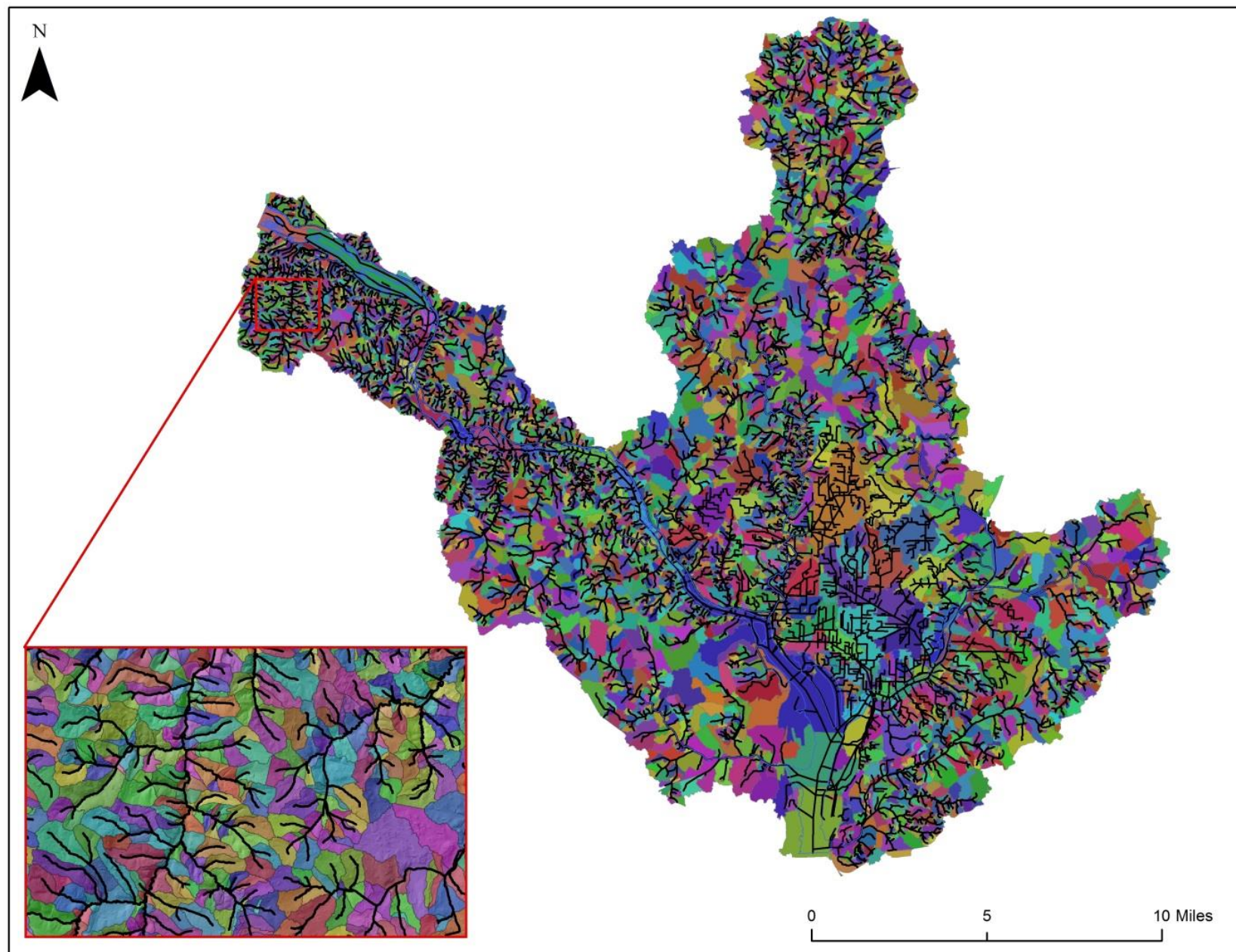


# Methods of network integration

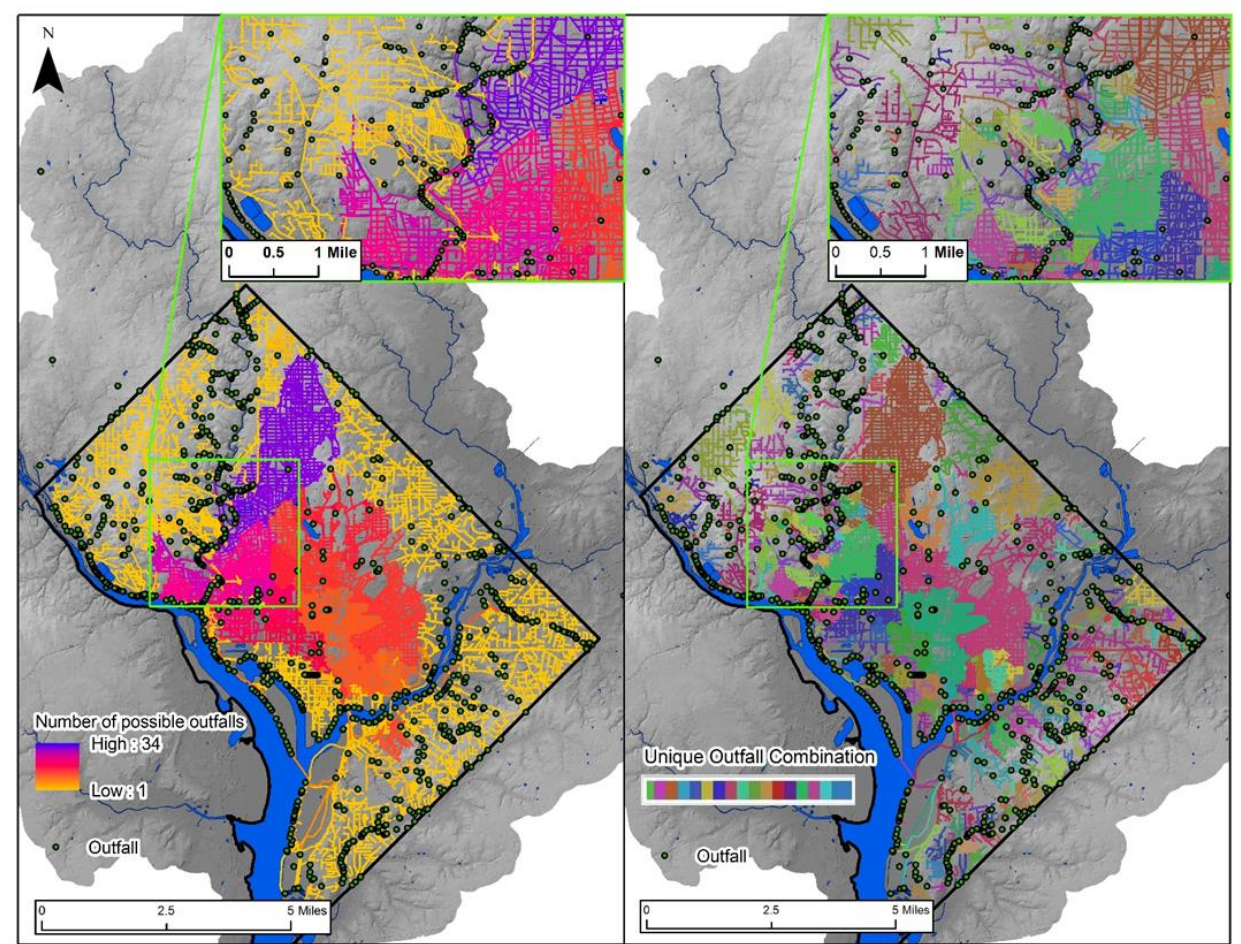
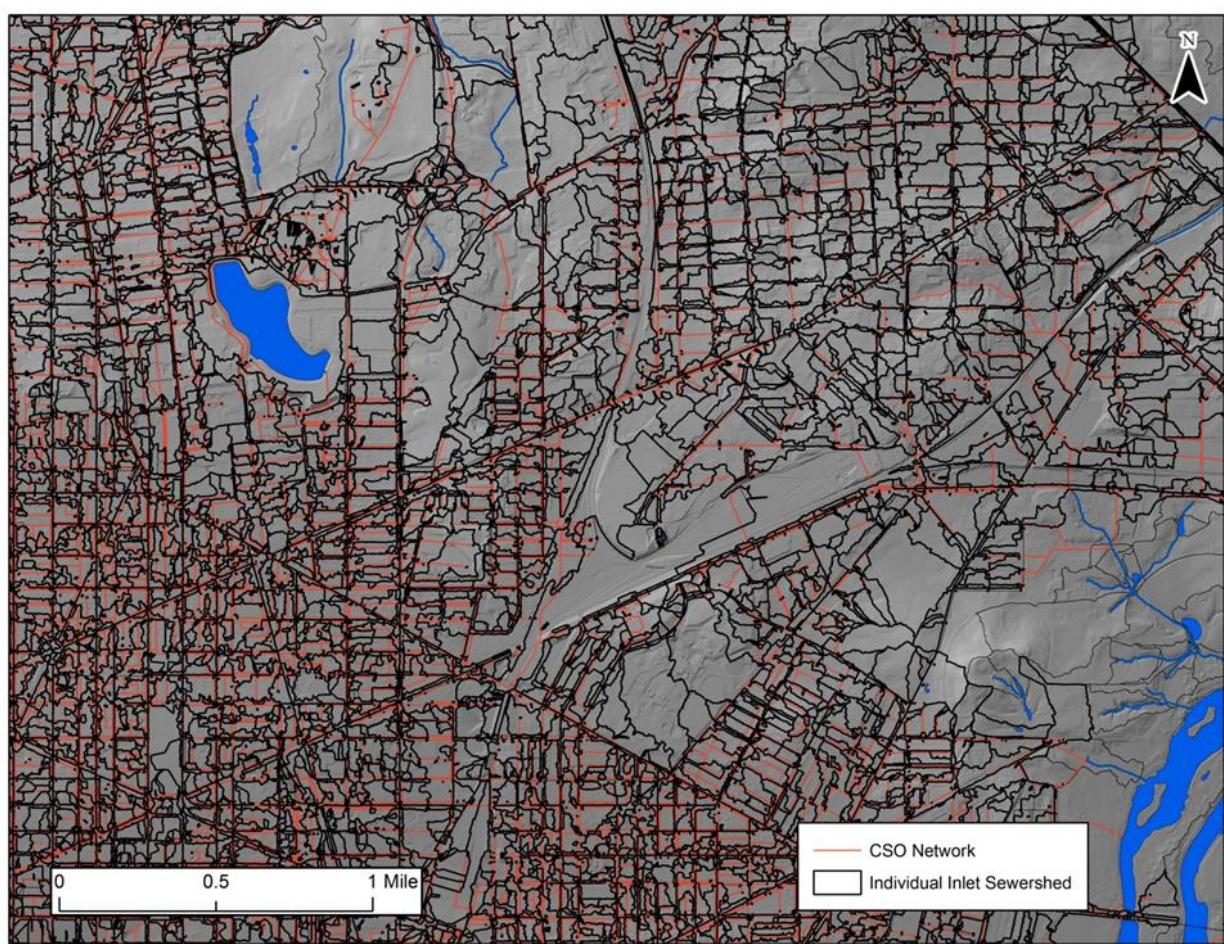
- Open features are treated differently than closed features
- Individual catchments for each inlet
- All water flowing to inlet catchment enters network
  - Rarely the case!
- Quantify flow accumulation
- Summarize accumulation throughout network leveraging network geometry.
- Cluster inlet catchments by outlets or combination of outlets.

# Watersheds

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# Sewersheds



# Limitations

- Typically no elevation available for subsurface network
- Assumes all water intersecting inlet enters inlet
- Typically, no pipe diameter to aid support hydraulic modeling

# Summary

- Requires involvement of local jurisdictions!
- Incorporation of subsurface network provides more accurate picture of water transport in urban landscape
- Valuable tool for estimating network capacity requirements and pollution source tracking... MS4 permitting?!?!



# THANK YOU

*Questions, Suggestions,  
Comments, Ideas?*

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