HW5: Water Systems Network Analysis

Anna Fetter

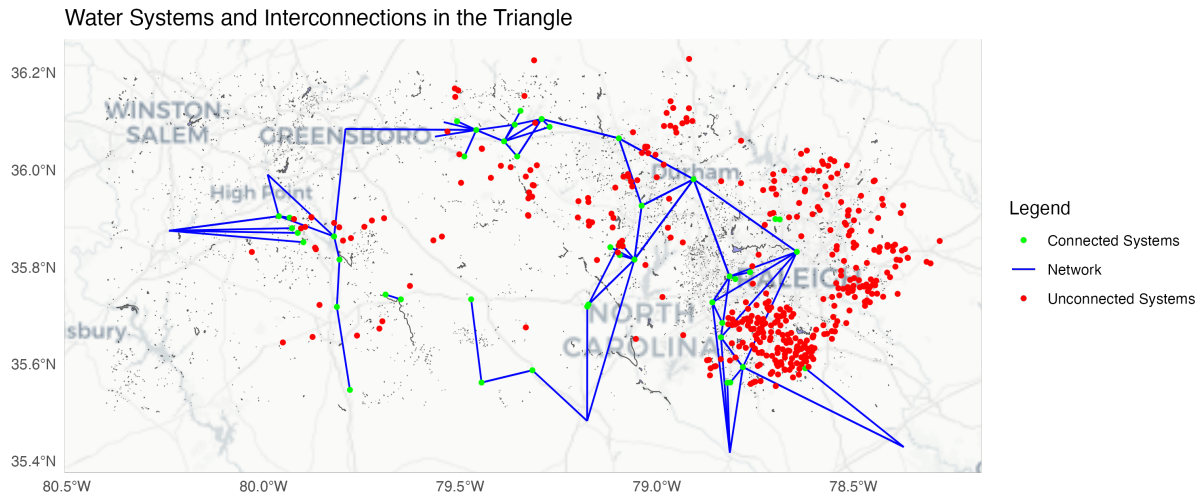
2025-04-08

Github repo with source code & dataset: https://github.com/aefetter/plan372-water-networks

1. Summary

In this report, I analyzed water systems across the Triangle using spatial network tools in R. I looked at how systems are connected, identified which towns are most central to the network, and mapped the shortest paths for moving water between cities. I compared options for Chapel Hill (OWASA) to buy water from Cary or Raleigh and explored what it would take for Liberty to connect to the larger system. The analysis highlights which towns and pipes matter most, and where regional planning efforts could focus.

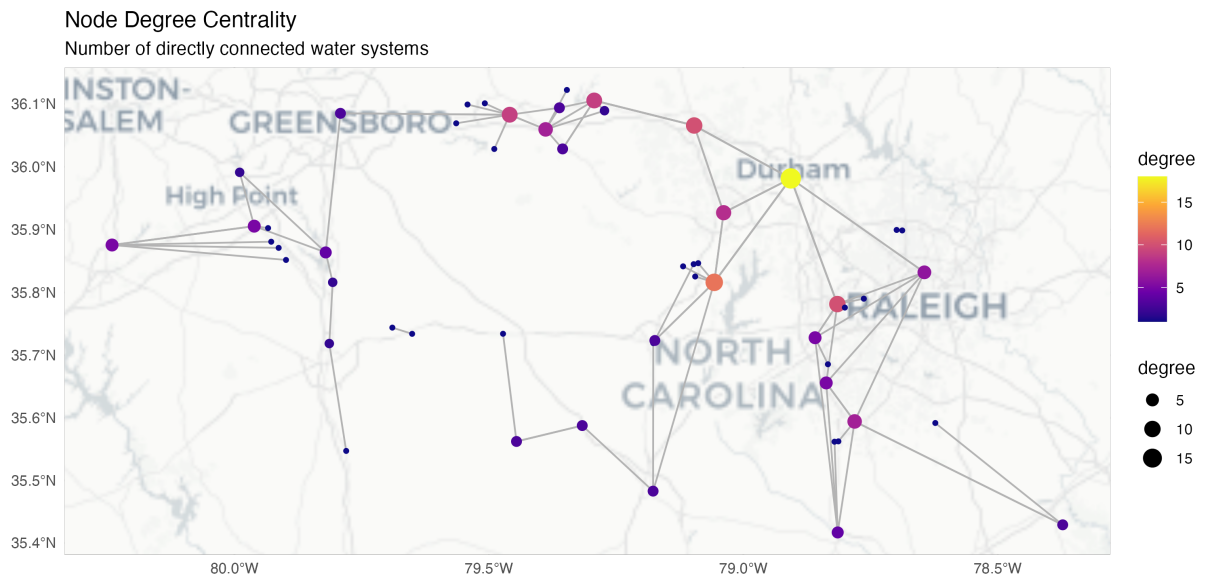
Here is a preliminary chart mapping the connected and unconnected parts of the broader Triangle area's water supply in North Carolina.



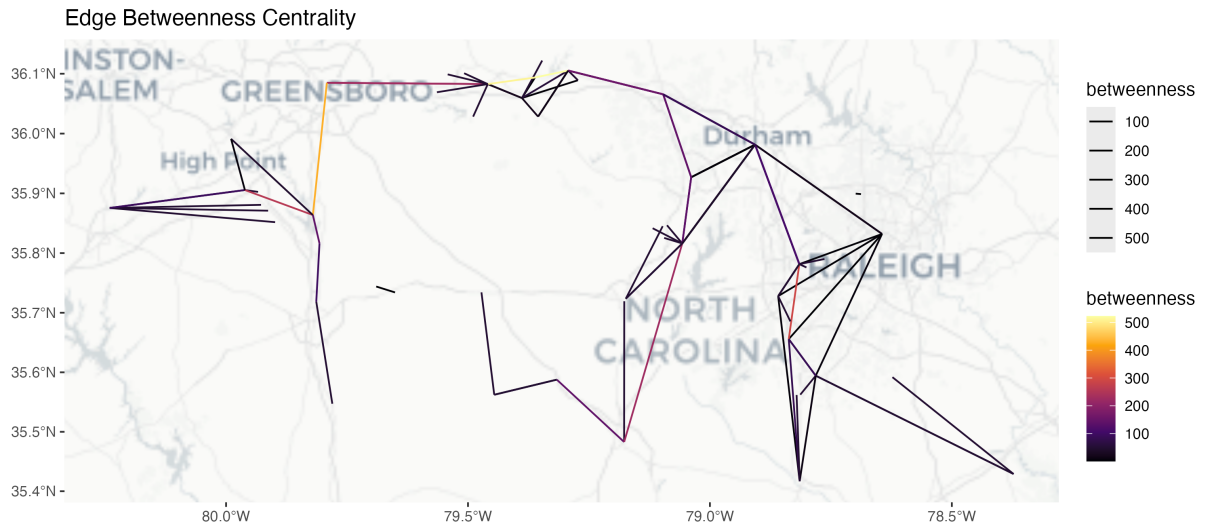
2. Degree centrality & Betweenness

Calculating degree and betweenness centrality allows us to visualize how connected certain water systems are within North Carolina's water grid and to identify infrastructure that may play a crucial role in water distribution.

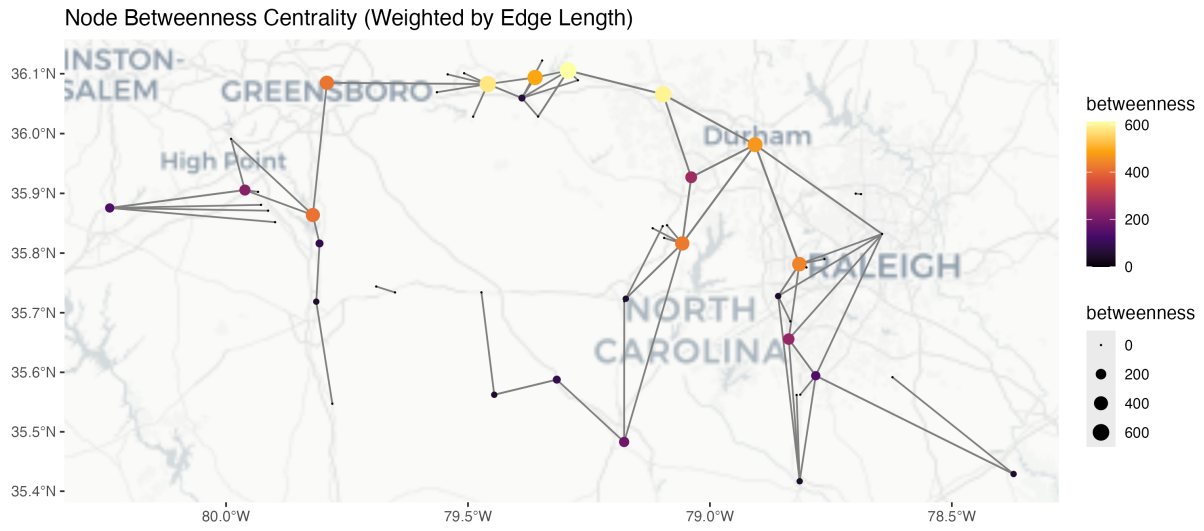
Map 1 "Node Degree Centrality" illustrates local connectivity. Nodes with high degrees are connected to many other systems. Lower degree nodes might only connect to one or two other nodes. Because degree centrality reflects only direct (one-hop) connections, it's most useful for identifying local hubs.



Map 2 “Edge Betweenness Centrality” highlights individual segments that are most frequently used in the shortest paths across the network. We weighted betweenness by distance to better reflect real-world water movement costs. The thicker and brighter edges, especially the yellow and orange ones, are critical conduits in the system. These brighter edges are most central in connecting distance edges of the network. In a practical sense, these edges represent where the infrastructure needs to be the most dependable. If one of these segments fail, it would disrupt many paths in the system.



Map 3 “Node Betweenness Centrality” shows which towns or intersections are most central to the overall network flow — not just locally. The larger, brighter dots are key system hubs that are critical connectors between regions. For example, Greensboro shows high betweenness, meaning that many towns rely on Greensboro as a transfer point. From a water planning standpoint, high betweenness nodes are important for reliability within the network.



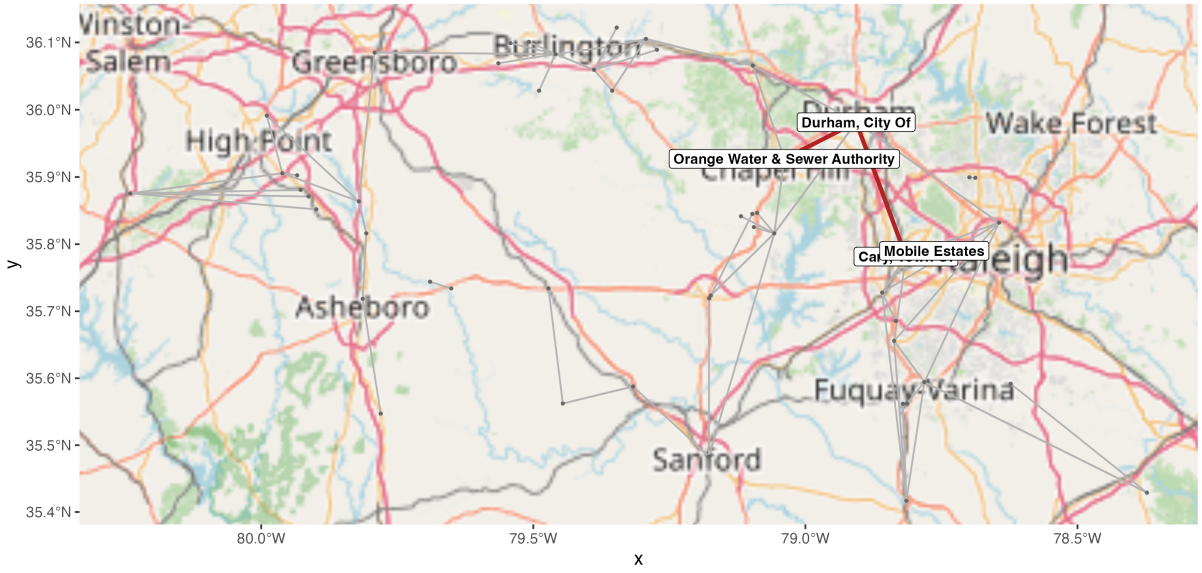
3. Augmenting Chapel Hill's Water Supply

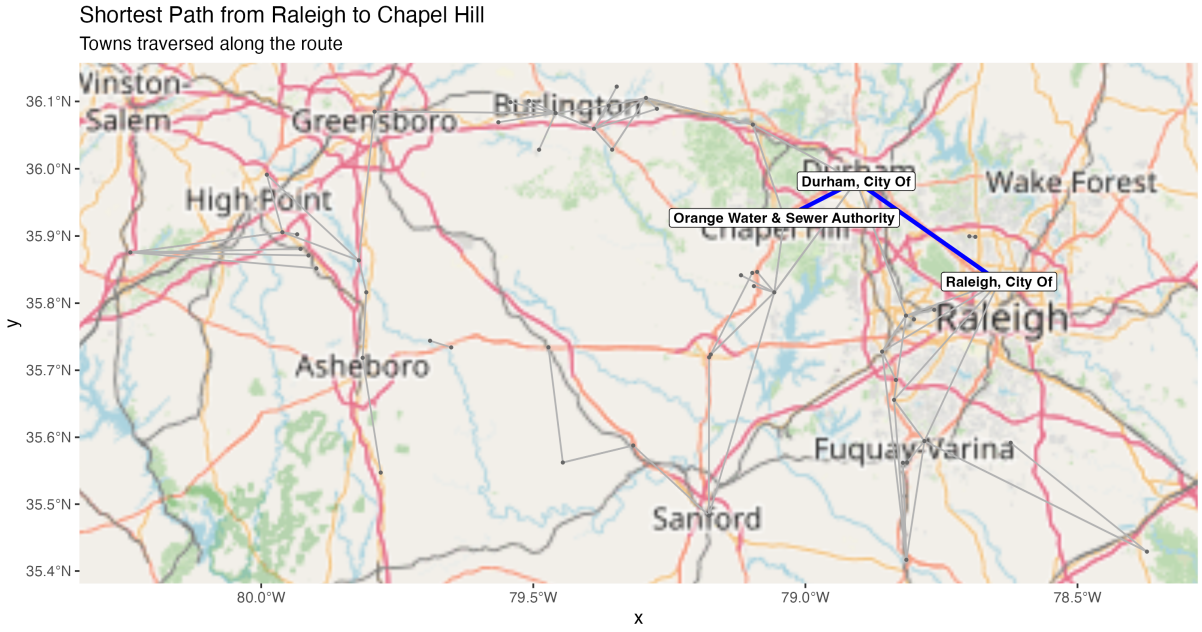
OWASA (the water system that serves Chapel Hill & Carrboro) needs to buy water. Cary has excess capacity that it is willing to sell. The cost of water depends on distance. Let's assume it costs What is the shortest path between Chapel Hill and Cary? What cities does the water need to pass through to get from Cary to Chapel Hill? Now assume, that OWASA is thinking of instead getting water from Raleigh. How far does water have to travel? What cities does the water have to go to?

OWASA, which serves Chapel Hill and Carrboro, is looking at augmenting its water supply from either Cary or Raleigh. Using a network graph of the Triangle's water systems, we calculated the shortest path by physical pipeline length from each city to Chapel Hill. The distance from Cary to Chapel Hill was slightly shorter, at 41840.74 meters. The route from Cary to Chapel Hill passed through Mobile Estates in Cary and Durham. The route from Raleigh to Chapel Hill was slightly longer, at 42232.69 meters, but only passed through one connection at Durham.

Shortest Path from Cary to Chapel Hill

Towns traversed along the route

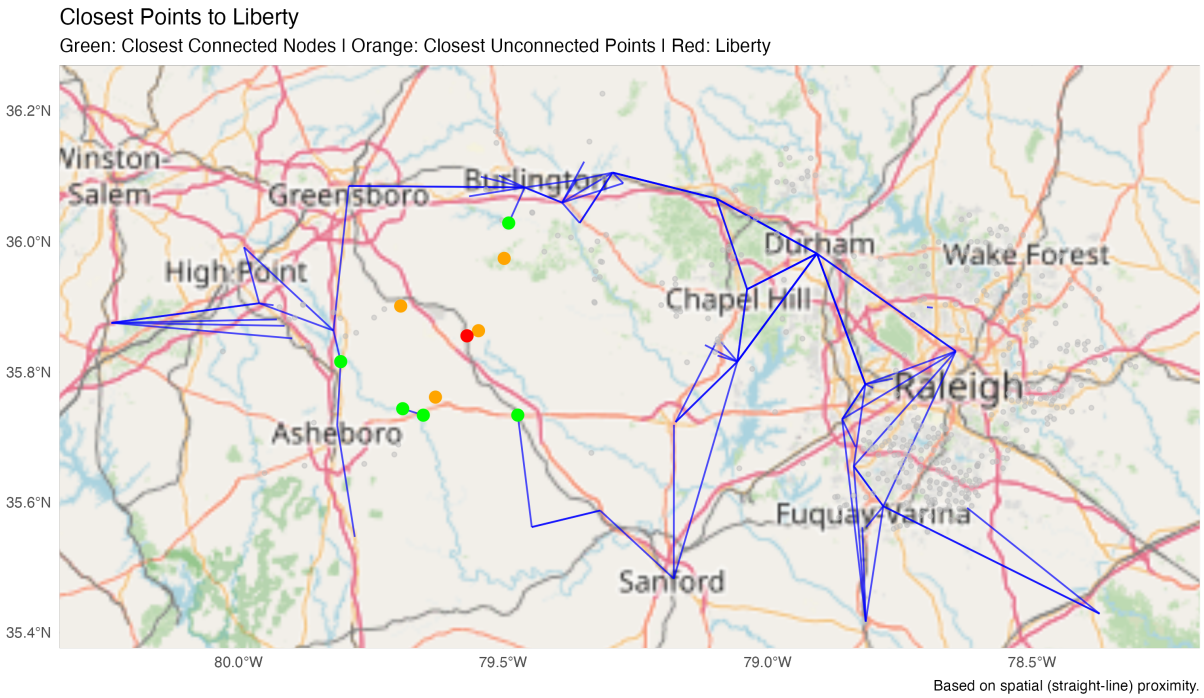




If the cost for water is based solely on distance traveled, it makes sense to get more water from Cary since the distance is slightly shorter, but this needs to be examined more based on water costs in the different municipalities and the risks associated with having to pass through one more connection on the way to Chapel Hill.

4. Connecting Liberty to the Network

Liberty, North Carolina is unconnected from North Carolina's larger water network. To address this, we calculated the spatial distance for the 5 closest unconnected and connected systems. The map below shows these points.



The graph shows that all of Liberty's closest connection points are also disconnected from the network. The five closest connection points are further away towards larger towns and cities.

	Town Name	Distance (miles)
1	Ramseur, Town Of	9.59
2	Siler City, City Of	9.97
3	Franklinville, Town Of	10.29
4	Village Of Alamance	12.71
5	Randleman, City Of	13.65

This chart shows the distance to Liberty's closest connections. Based on the analysis, Ramseur is the nearest option, located approximately 9.6 miles away, followed closely by Siler City and Franklinville.

However, proximity is only one factor to consider. Further analysis is needed to determine if these connections are viable connections due to geographic barriers, existing constraints on these water connection points, and government agreements and policies surrounding water.