Vulnerability Analysis of the Bay Area's Water Supply Network

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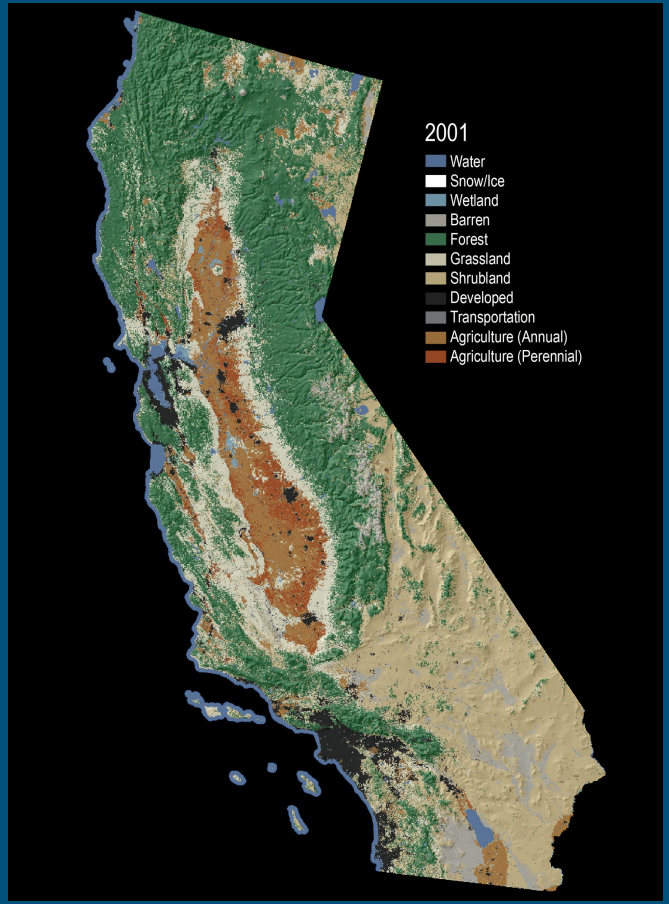
Motivation

Global Water Crisis - Effects very apparent in California

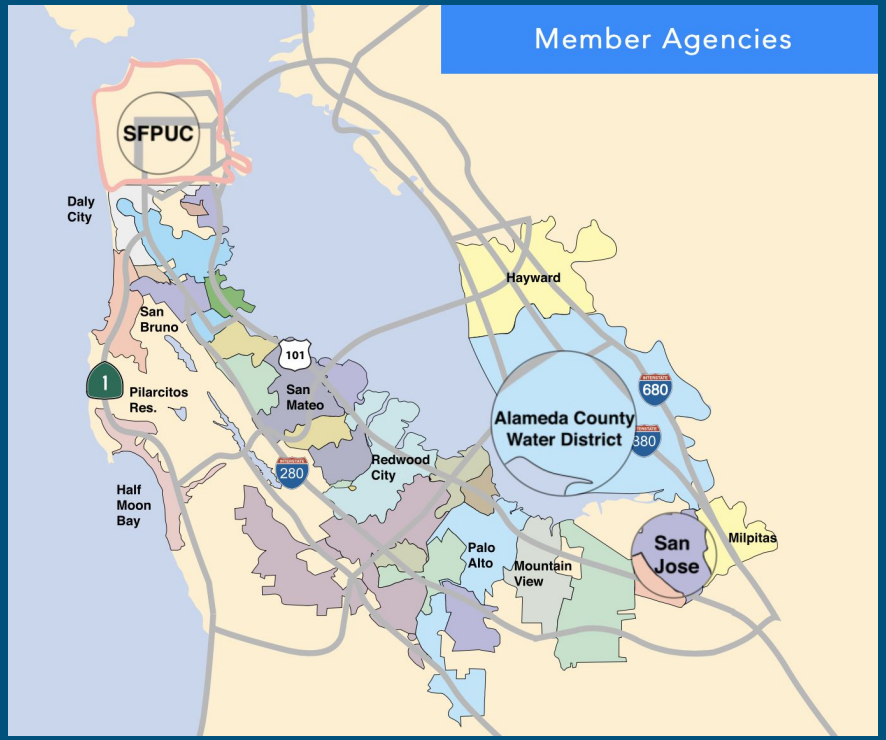
- Climate Change
  - Rising temperatures
  - Increased drought
  - Decreased reliability of snowpack
- Source Depletion
  - Anthropogenic desiccation
  - Groundwater depletion



Animation from: USGS

Dataset

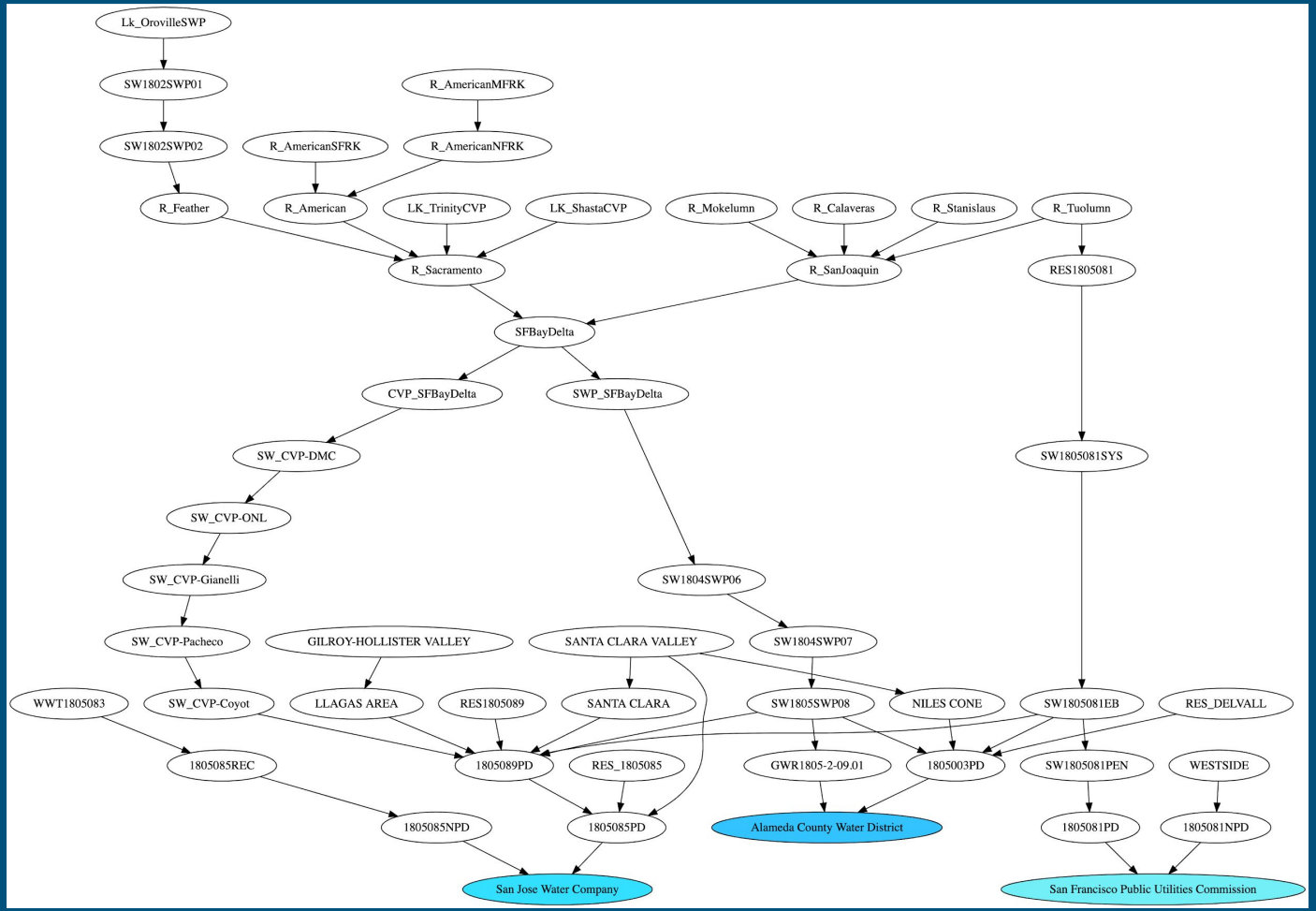
- Aggregation of 2010 CA UWMP data
  - Utilized **2020** projections
- Data attributes
  - **Consumption** & transmission **volumes**
  - Transmission & treatment electricity consumption
- Selected 3 **Bay Area** water systems
  - SFPUC, ACWD, SJWC



Network

Bay Area Water Supply Network:

- **SFPUC**: San Francisco Public Utilities Commission
- **ACWD**: Alameda County Water District
- **SJWC**: San Jose Water Company



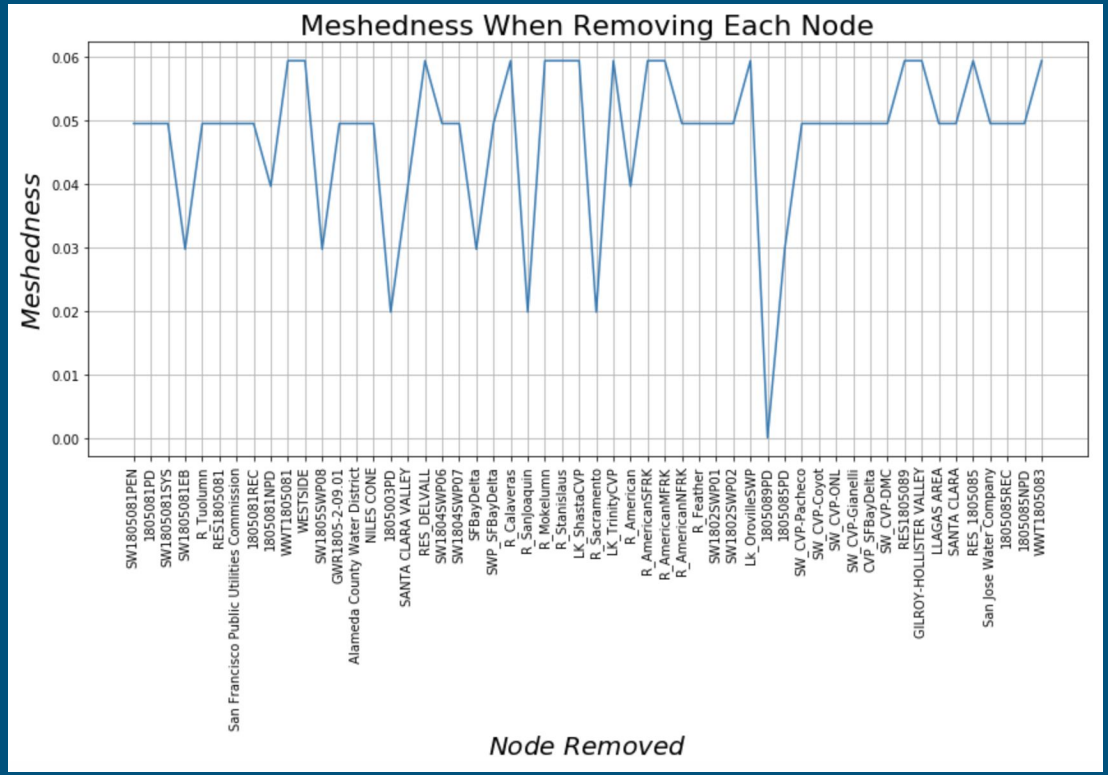
Methods & Metrics

- Selective network **fragmentation**
  - Determine each node's impact
- **Metrics** analysed

Metric	Meaning	Equation	Method of Calculation
Meshedness	Network connectivity & redundancy	$\alpha(r_m) = \frac{e-v}{2v-5}$	momepy.meshedness() from the momepy package
Average Path Length	Efficiency of mass transport	$L = \frac{1}{v(v-1)} \sum_{i \neq j} d_{ij}$	nx.averge_shortest_path_length() from Networkx
Average Clustering Coefficient	Node clustering & density	$C_N = \frac{1}{n} \sum_{i=1}^{n} \frac{e_i}{k_i(k_i-1)}$	nx.average_clustering() from Networkx
Average Node Centrality	Node's importance in bridging network	$C_b(v) = \sum_{s,t \in V} \frac{\sigma(s,t\|v)}{\sigma(s,t)}$	Average of nx.betweenness_centrality() from Networkx

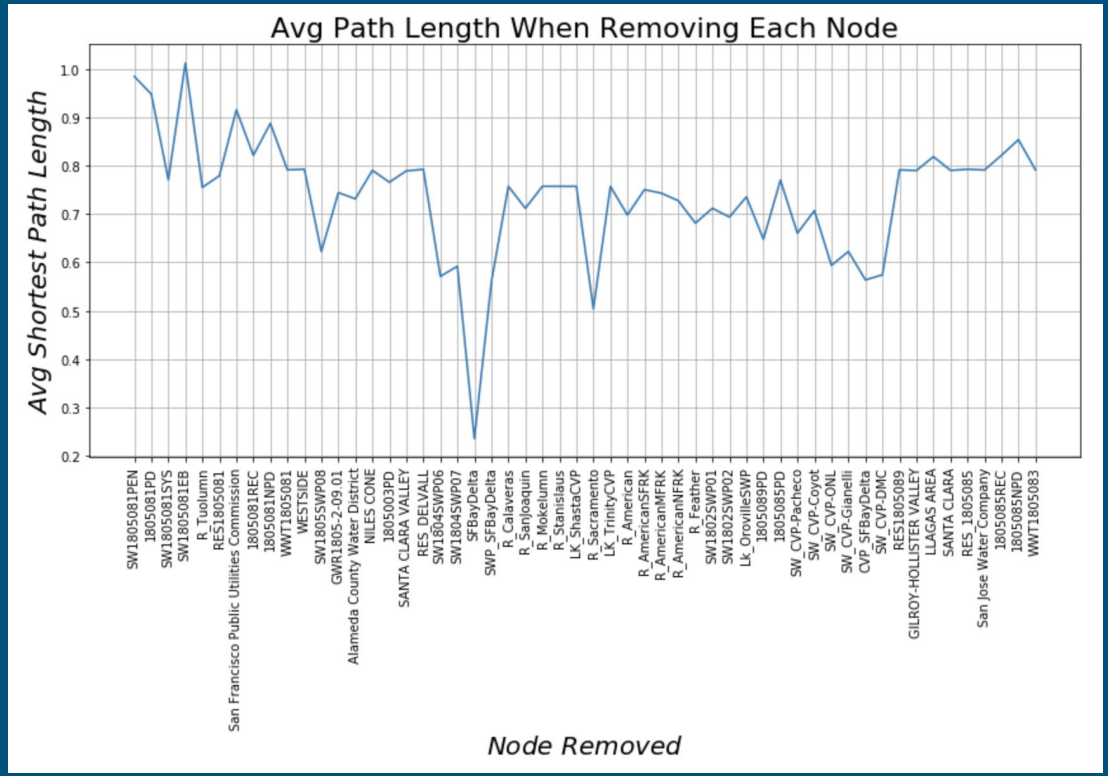
Meshedness

- Low values -> node removal caused decrease in network connectivity
- Most important nodes:
  - 1805003PD
  - San Joaquin River
  - Sacramento River
  - **1805089PD**



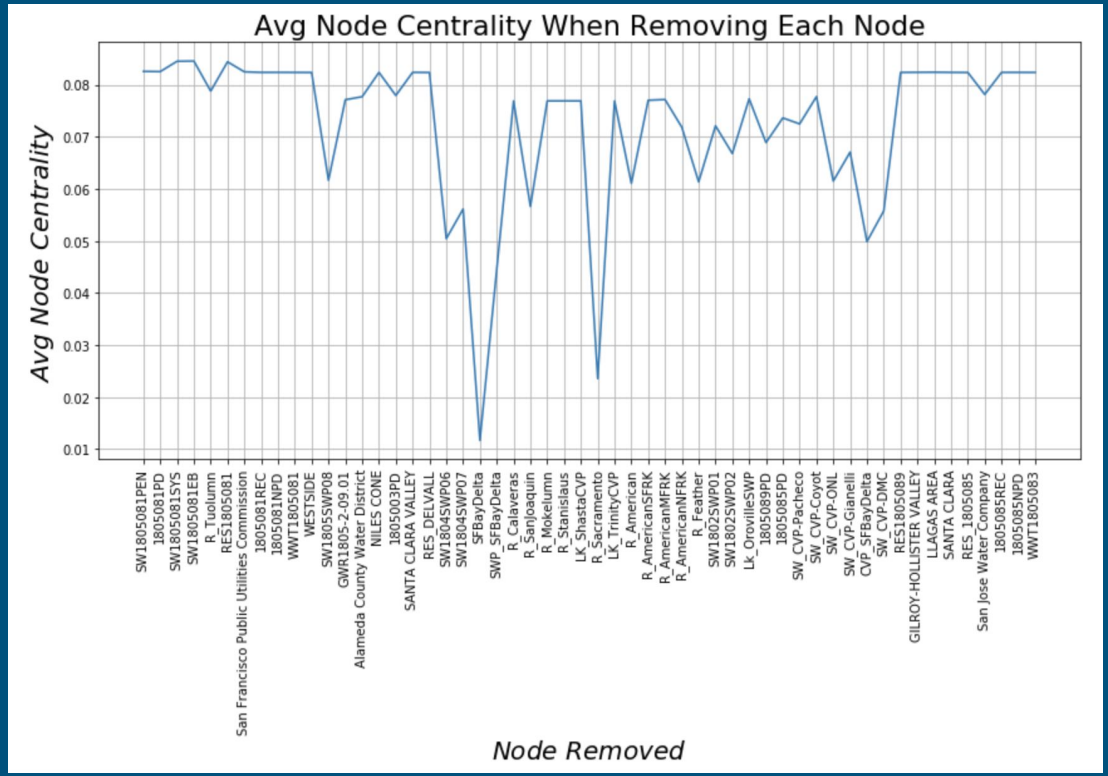
Average Shortest Path Length

- High value -> node removal negatively impacted mass transport ability
- Misleading result due to ill defined metric: San Francisco Bay Delta
- Important node:
  - **SW1805081EB**



Average Node Centrality

- Significantly lower value -> node removed was integral in bridging network
- Important nodes:
  - Sacramento River
  - San Francisco Bay Delta



Conclusions

- Important nodes based on analysis
  - San Francisco Bay Delta
  - San Joaquin and Sacramento Rivers
  - Certain reservoirs/storage of potable water
- Recommendations
  - Investment in upkeep and maintenance of identified important nodes
  - Consider alternatives if important nodes become unreliable
- Potential additional research areas
  - Additional research on weighting the network differently
  - Look into modeling different types of resilience