Modeling Water Supply Reliability following a major earthquake

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San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

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Agenda

- AWSS and Background
- Level Of Service (LOS) Goals
- Modeling
  - Ignitions and Demands
  - SynerGEE
  - GIRAFFE
- Project Development and Assessment
- Program Recommended to SFPUC
- Next Steps

AWSS and Background

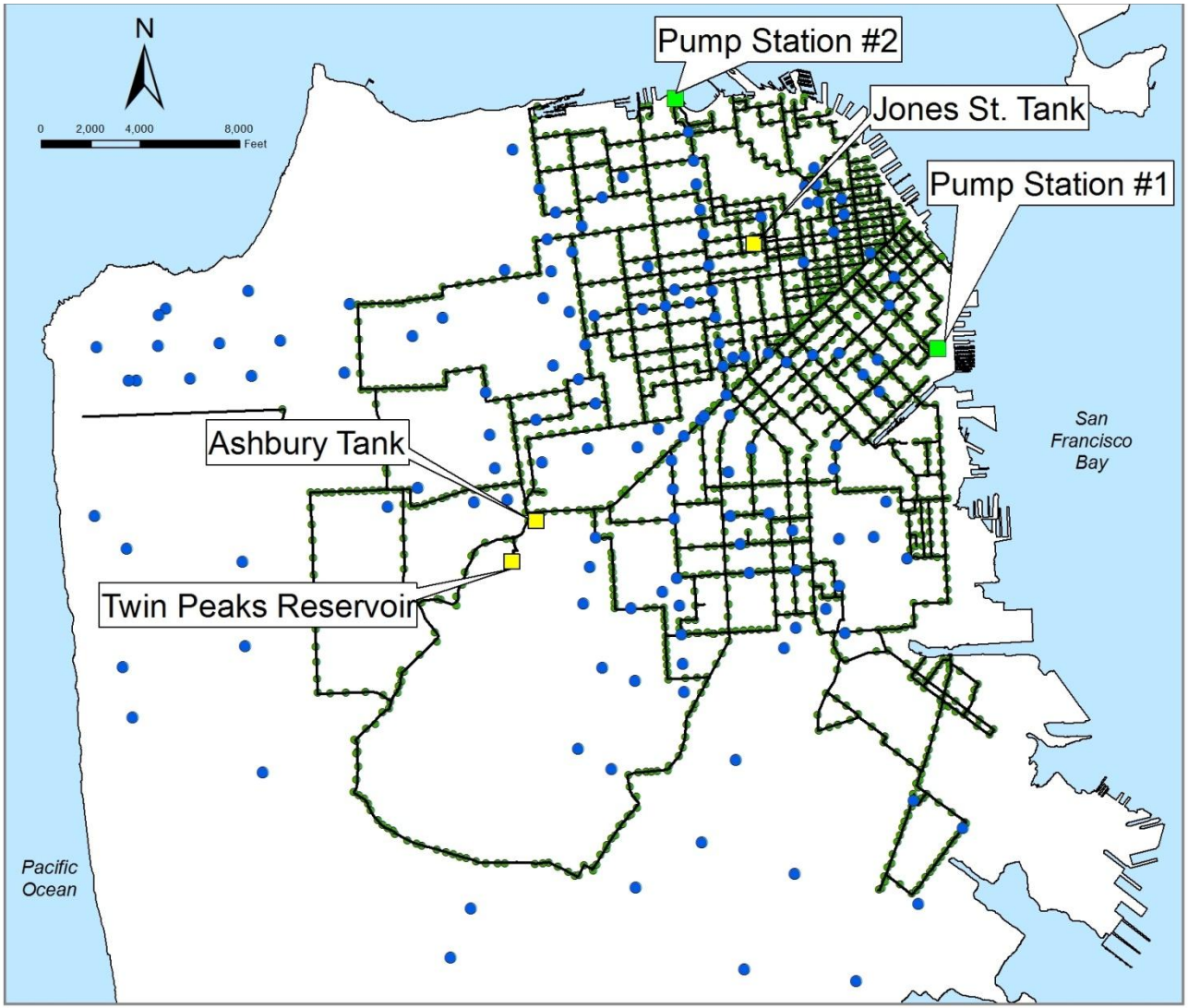
San Francisco Following the 1906 Earthquake and Fires

AWSS Overview

- Separate high pressure water system originally constructed in 1910 -1913
  - 77 Miles of 10 inch and larger Cast Iron Pipe
  - Two Salt Water Pump Stations
  - Three gravity storage facilities fed by domestic system
- Total system consists of high pressure pipe, cisterns, suction connections, saltwater pumps, fireboats, reservoir and storage tanks
- Pipe construction with extra thick walls
- Double lead and restrained joints
- Limited connections

Image Source: www.flickr.com

AWSS System Map



AWSS Operations

- Over time has been extended to cover more of the City, now 135 miles, 80% cast iron pipe
- Used by the San Francisco Fire Department (SFFD) and owned and maintained by the SFPUC City Distribution Division (CDD)
- Normally operates in three pressure zones
- Designed to allow one pressure zone with pressures up to 340 psi

Modeling Process

AWSS Capital Planning Study (CS-199)

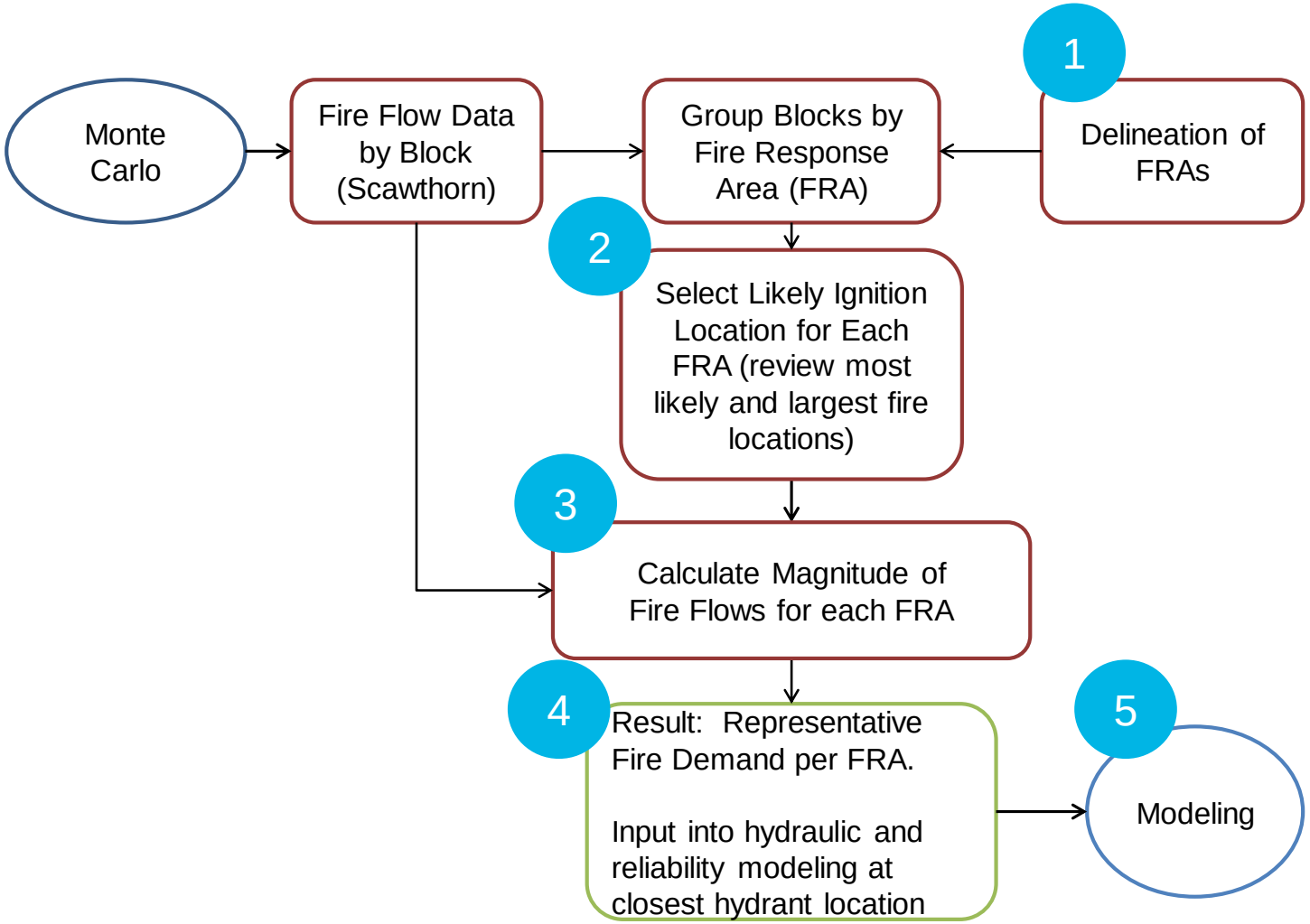
- Goal:
  - To maximize the likelihood that the AWSS will effectively provide required fire fighting capabilities after a major seismic event.
- Recommended LOS Objectives:
  - "AWSS will reliably provide water to supply the "probable fire demands" after a M7.8 San Andreas earthquake"
    - Each fire response area will be XX% reliable in supplying probable demands.
    - AWSS will be YY% reliable in supplying probable demands City-wide.

Modeling Overview

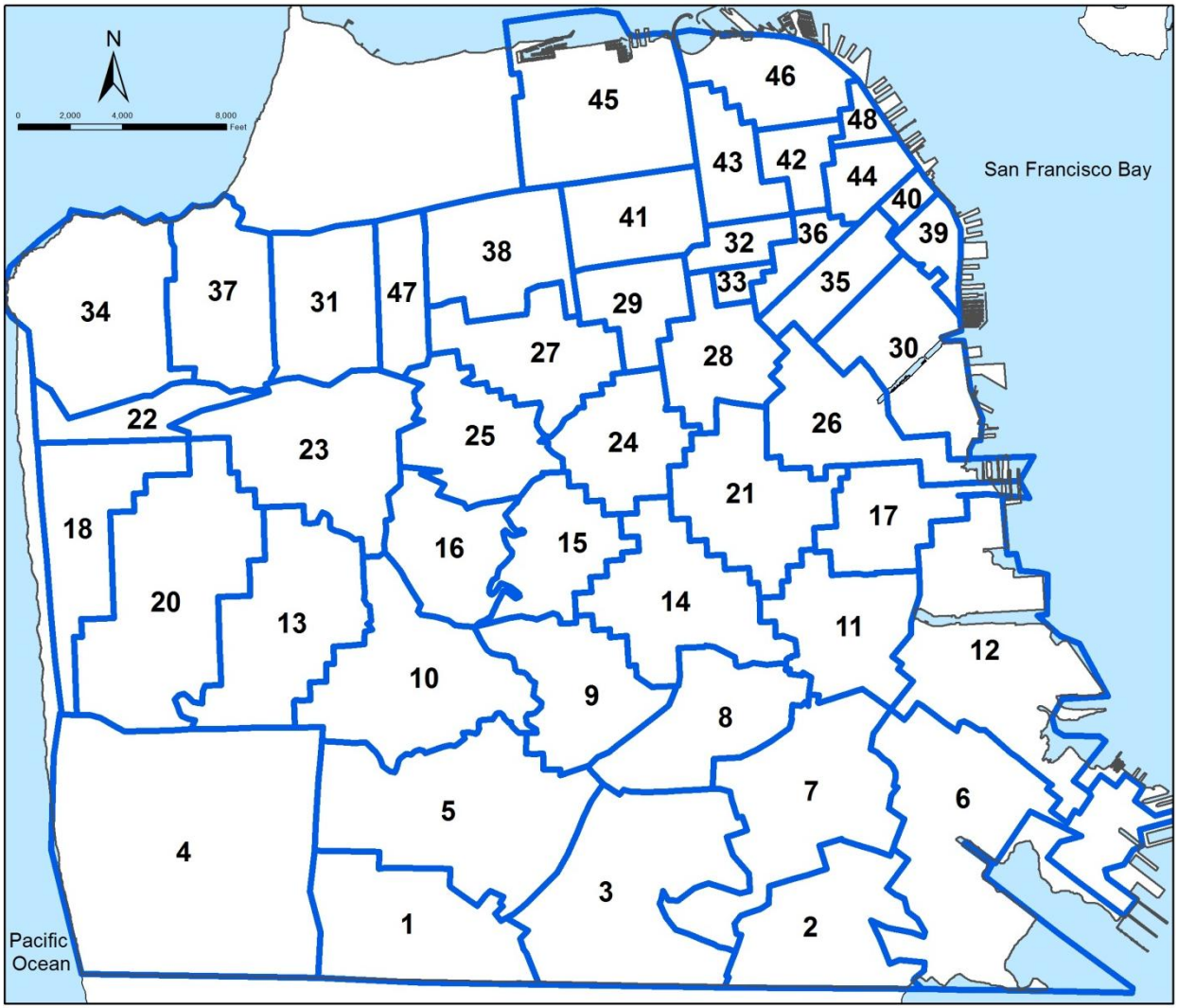
- Modeling objective:
  - To determine the amount of water the AWSS can deliver given a set of demands
- Hydraulic and reliability modeling to determine project hydraulic benefits
- Tools used:
  - SynerGEE
  - GIRAFFE (Cornell University)
  - EPANET
  - ArcGIS
  - R script

Estimating Fire Demands

Fire Demand Formulation

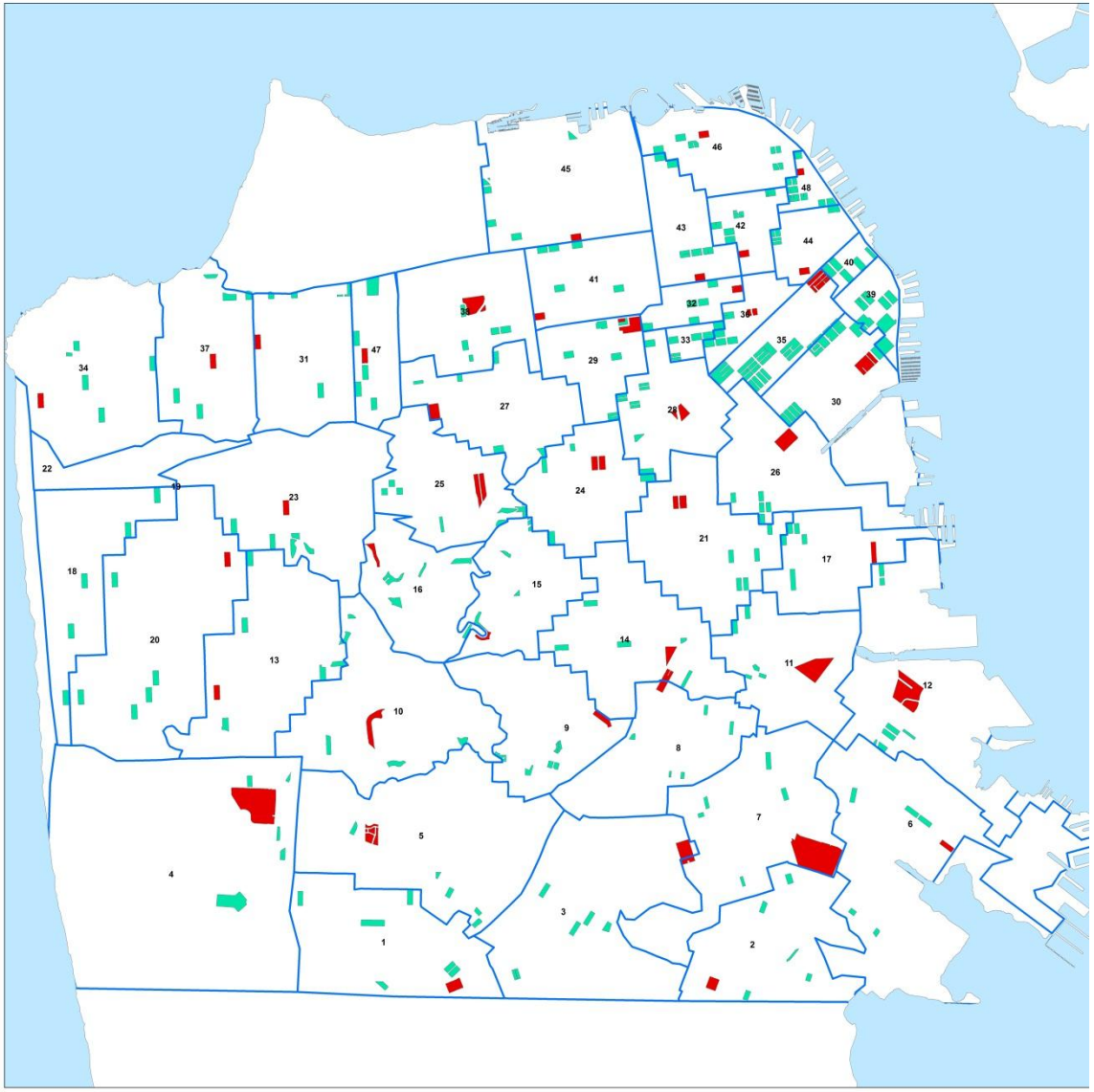


1 Delineation of Fire Response Areas



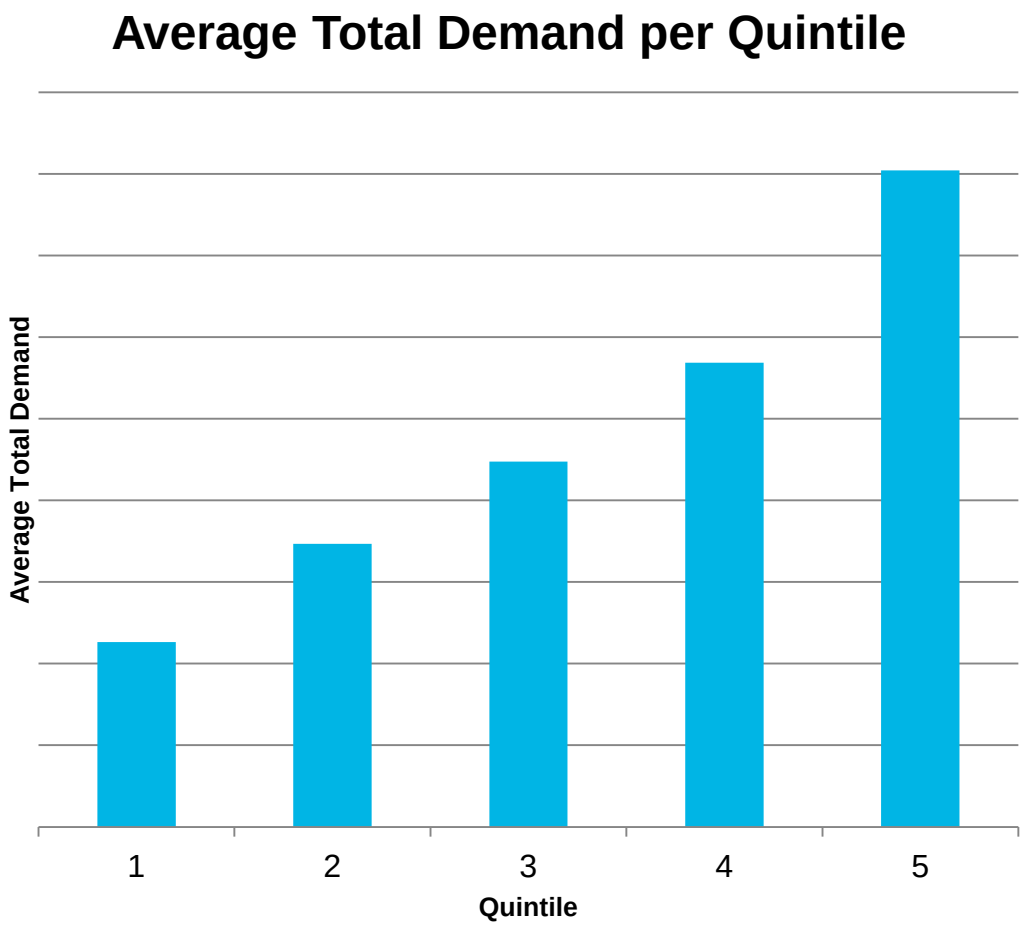
- Based on SFFD Response Districts
- Further refined based on fire density

2 Ignition Location Selection



- Red – Block with Highest Occurrence of Ignitions
- Blue – Top 5 Demands per FRA

3 Fireflow Magnitudes



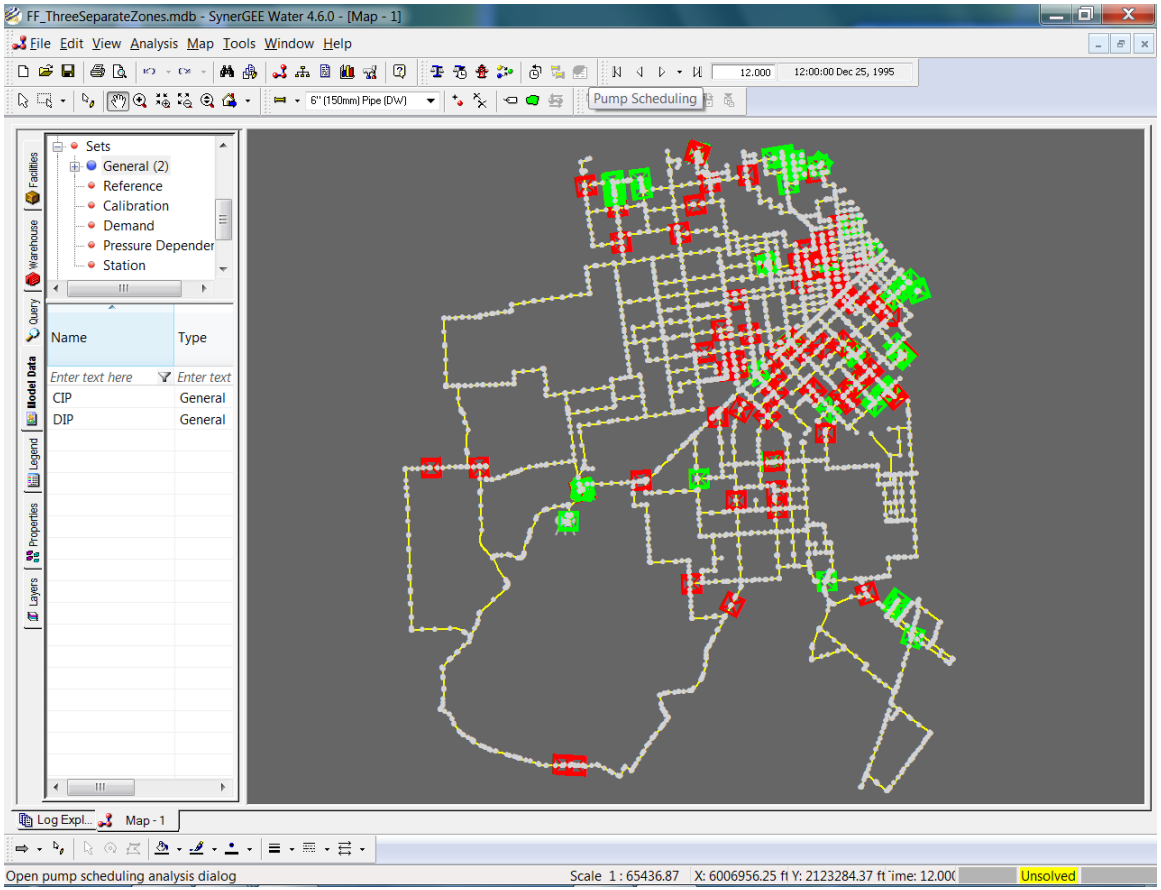
- Stochastic set of ignitions (1000 iterations)
- 60-minute 3rd quintile selected as representative demand set
- “Suppression” accounted for by removing all fires at first minute

4 Model Demand Locations

- Demand node highlighted in blue
- Location based on nearest network node to locations found in step 2

Estimating System Reliability

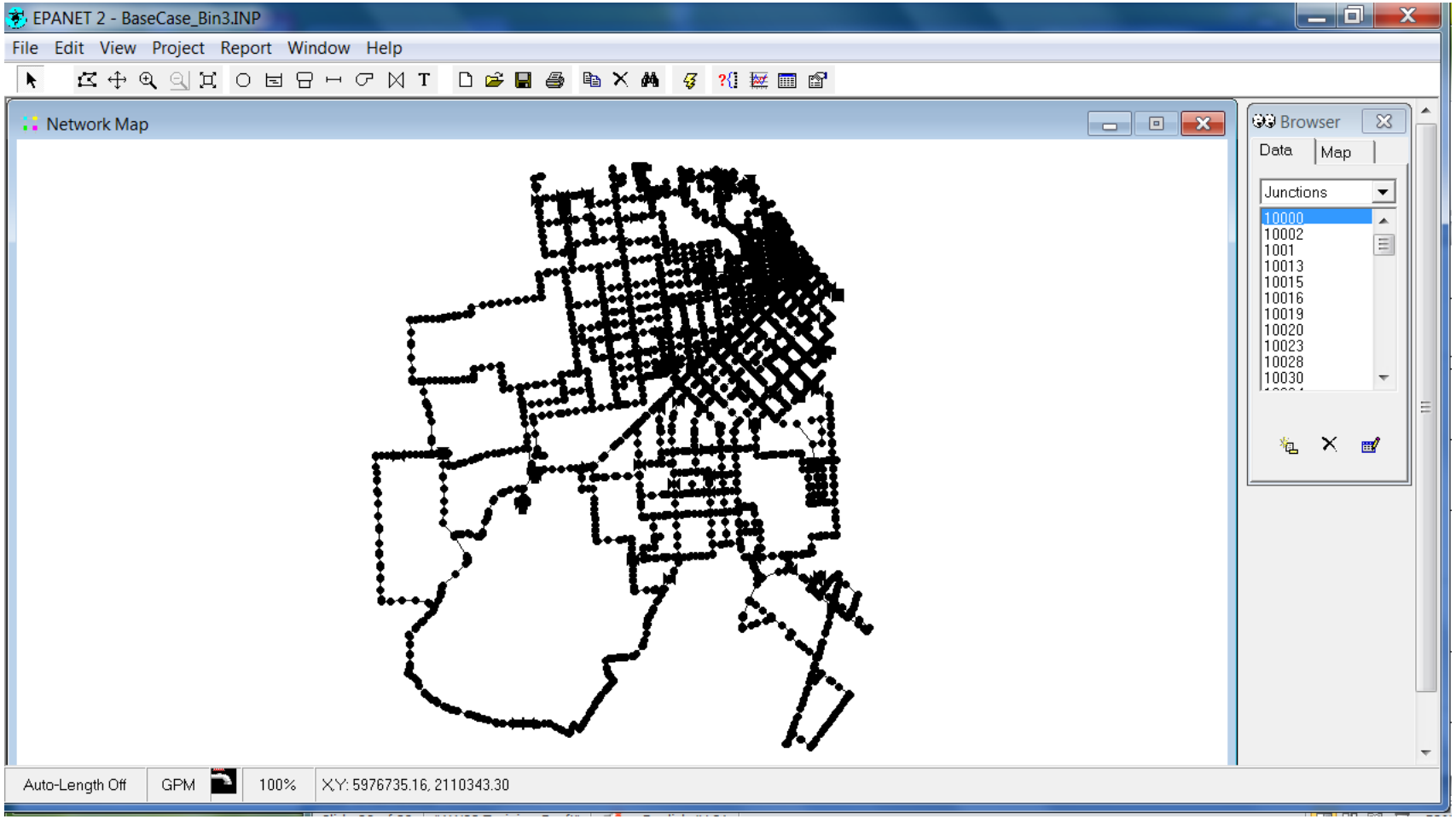
Hydraulic Model (SynerGEE)
AWSS Existing Condition Model



- 6,274 junctions
- 6,312 pipe segments
- 178 valves
- 10 pumps
- 5 tanks
- Model reviewed and calibrated with flow test data

SynerGEE Model Results

EPANET Model (Converted from SynerGEE)



Graphical Iterative Response Analysis for Flow Following Earthquakes (GIRAFFE)

GIRAFFE Overview

– Developed at Cornell University by Tom O'Rourke and colleagues

– Uses open source EPANET engine

– Deterministic and probabilistic simulations

– 5 modules:
  - System Definition [Input]
  - Seismic Damage [Input]
  - Earthquake Demand Simulation [Module]
  - Hydraulic Network Analysis [Computation]
  - Results Compilation [Output]

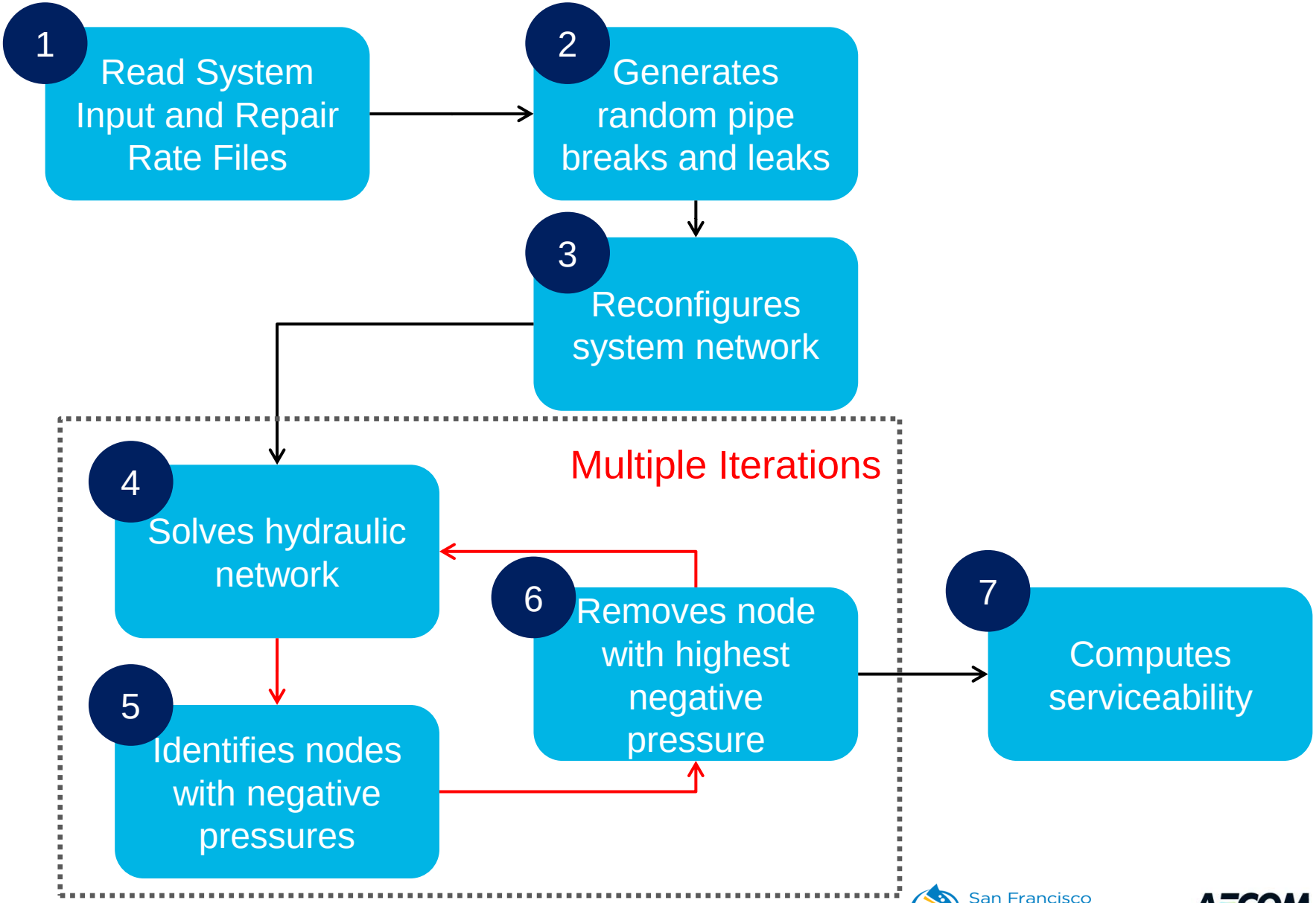
GIRAFFE GUI (Windows XP)

GIRAFFE Model Inputs

– Pipeline Fragilities
  - Based on PGV values by block
  - PGV estimated from regressions between block centroid distance to San Andreas fault and grouped by shear wave velocity (Vs30)

– System Information File (EPANET file)

GIRAFFE Process Flow



GIRAFFE Model Controls

- Simulation type:
  - Deterministic (single)
  - Monte Carlo Fixed
  - Monte Carlo Unfixed
- Convergence Criteria
- Break/Leak Ratio
- Leak type probabilities
- Random seed generator

GIRAFFE Output

– Pipe break/leak list

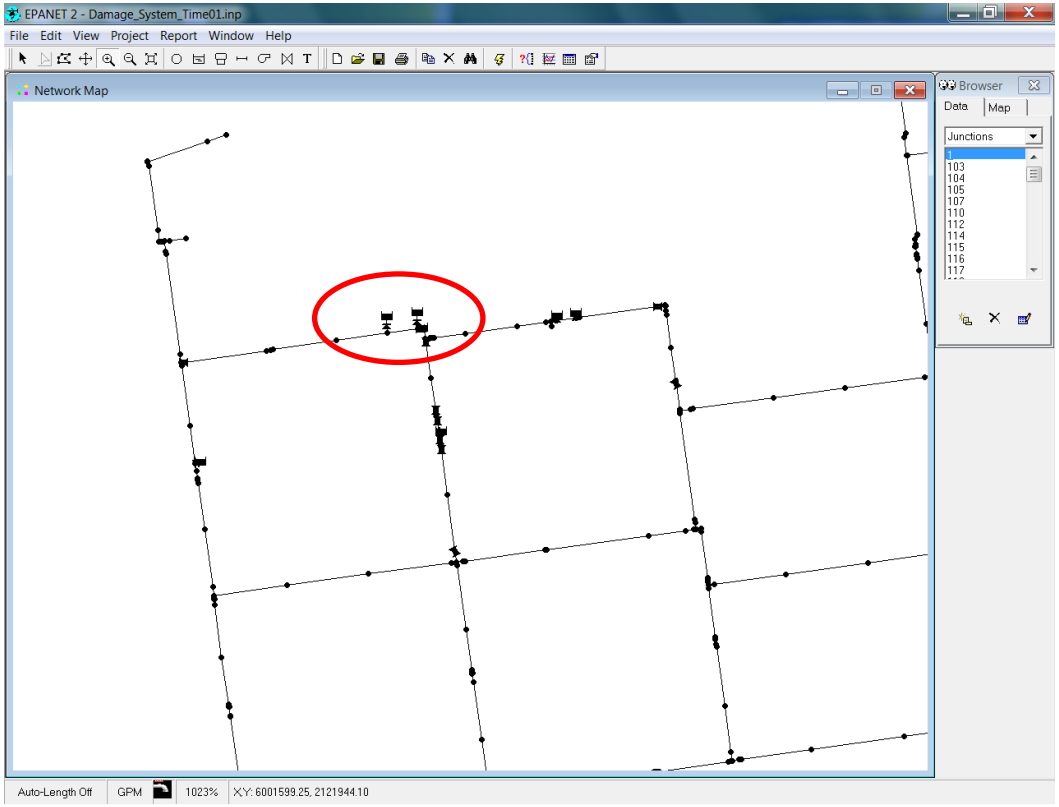
– System damage file

– Serviceability result

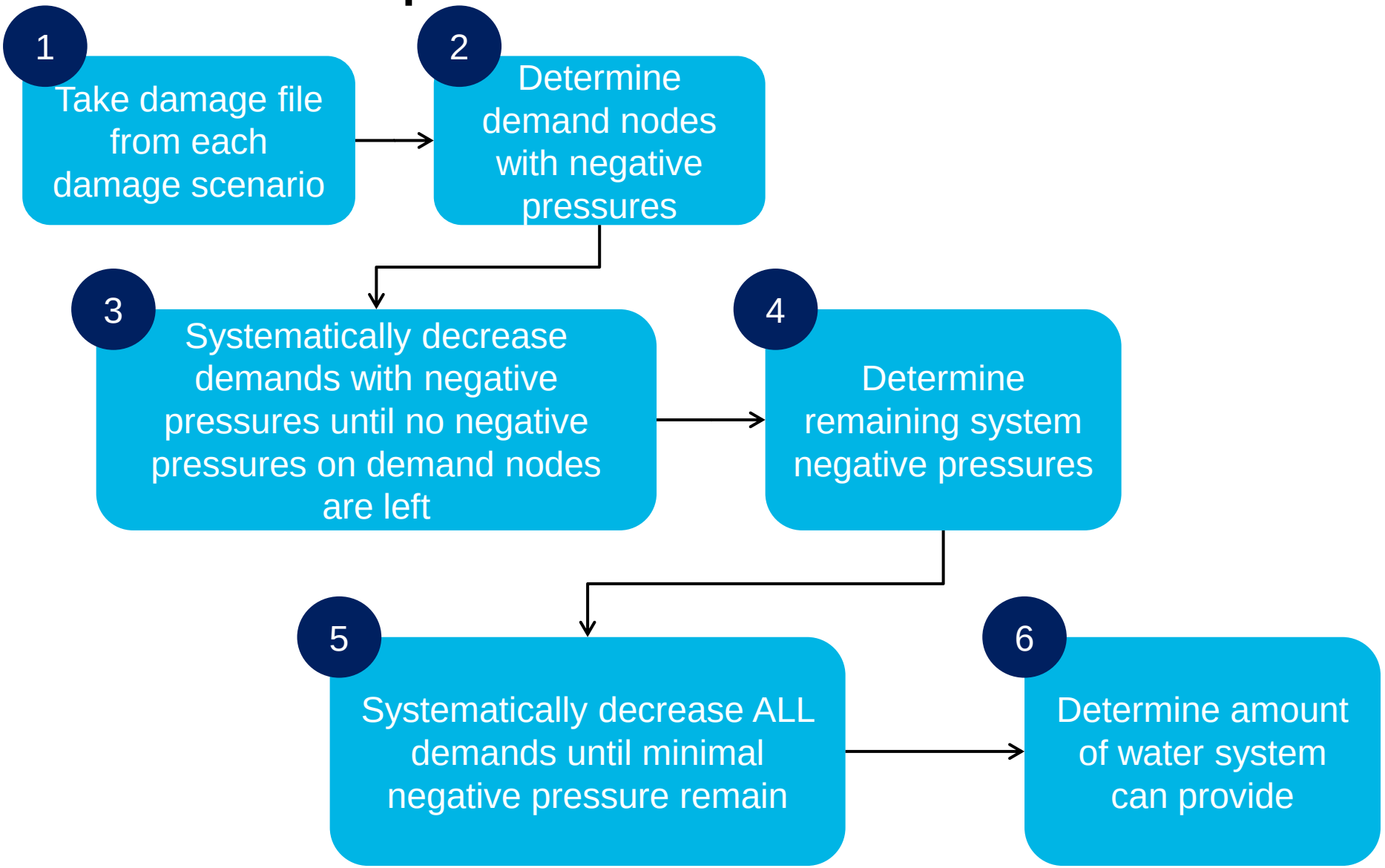
– Information by time-step for:

- Nodes
- Pipes
- Pump stations
- Valves
- Tanks

– Output summary



Solution to Output Limitation

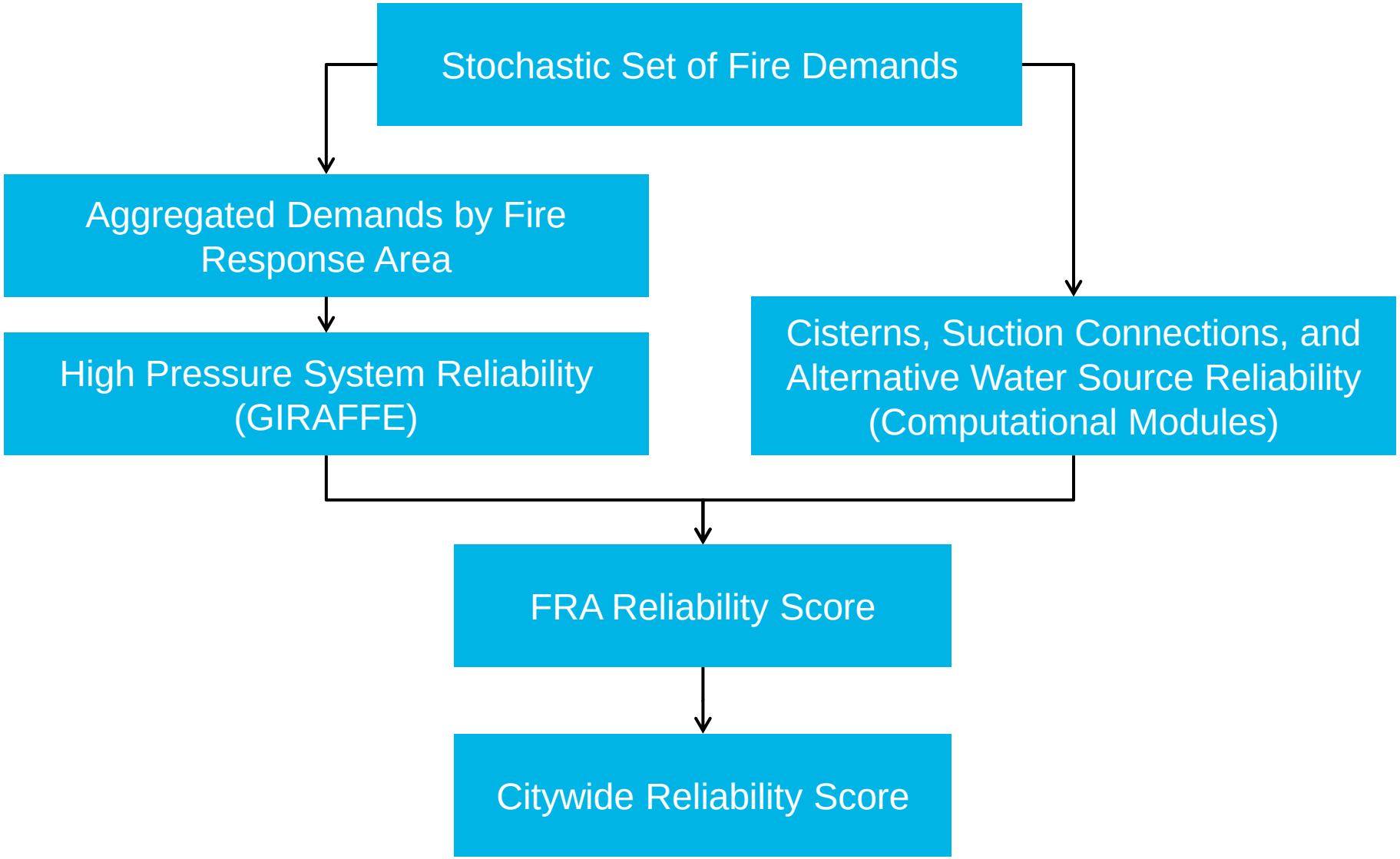


Sensitivity Analyses Performed

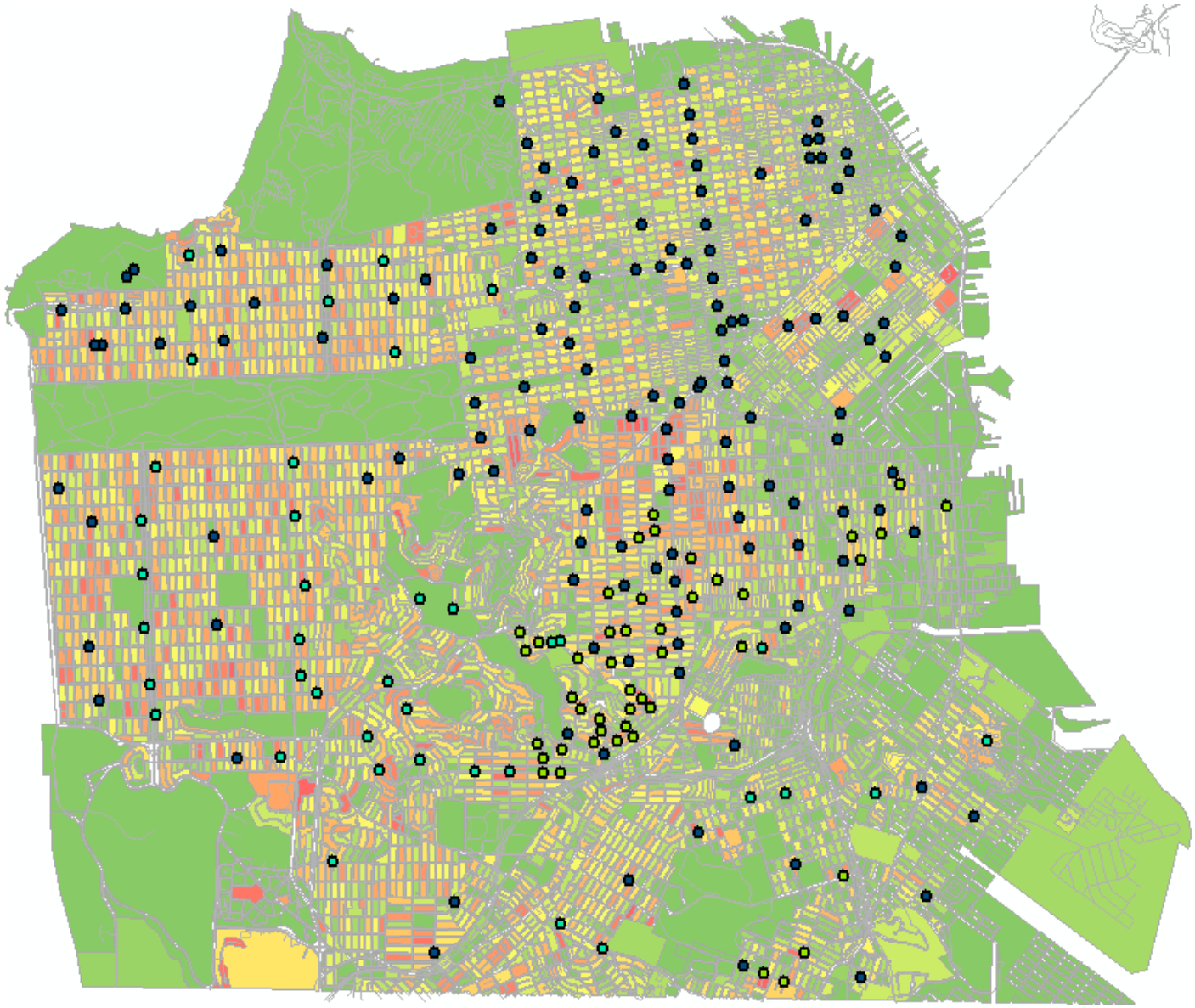
- Demand location and magnitudes
- Fireboat assumption
- Partial demands
- Infirm zones

Cistern, Suction Connection, Alternate Water Modules

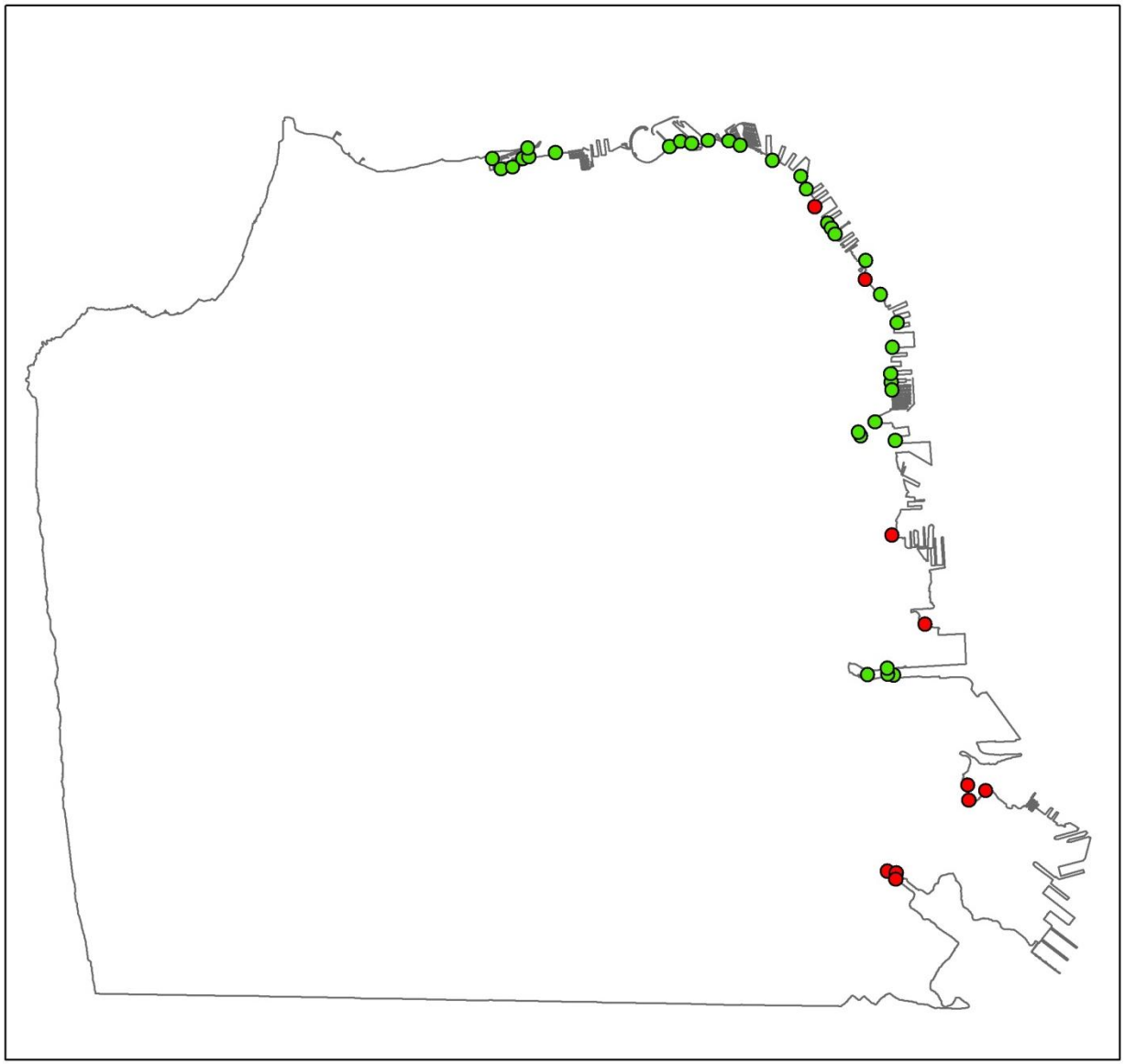
5 Modeling Summary



Cisterns

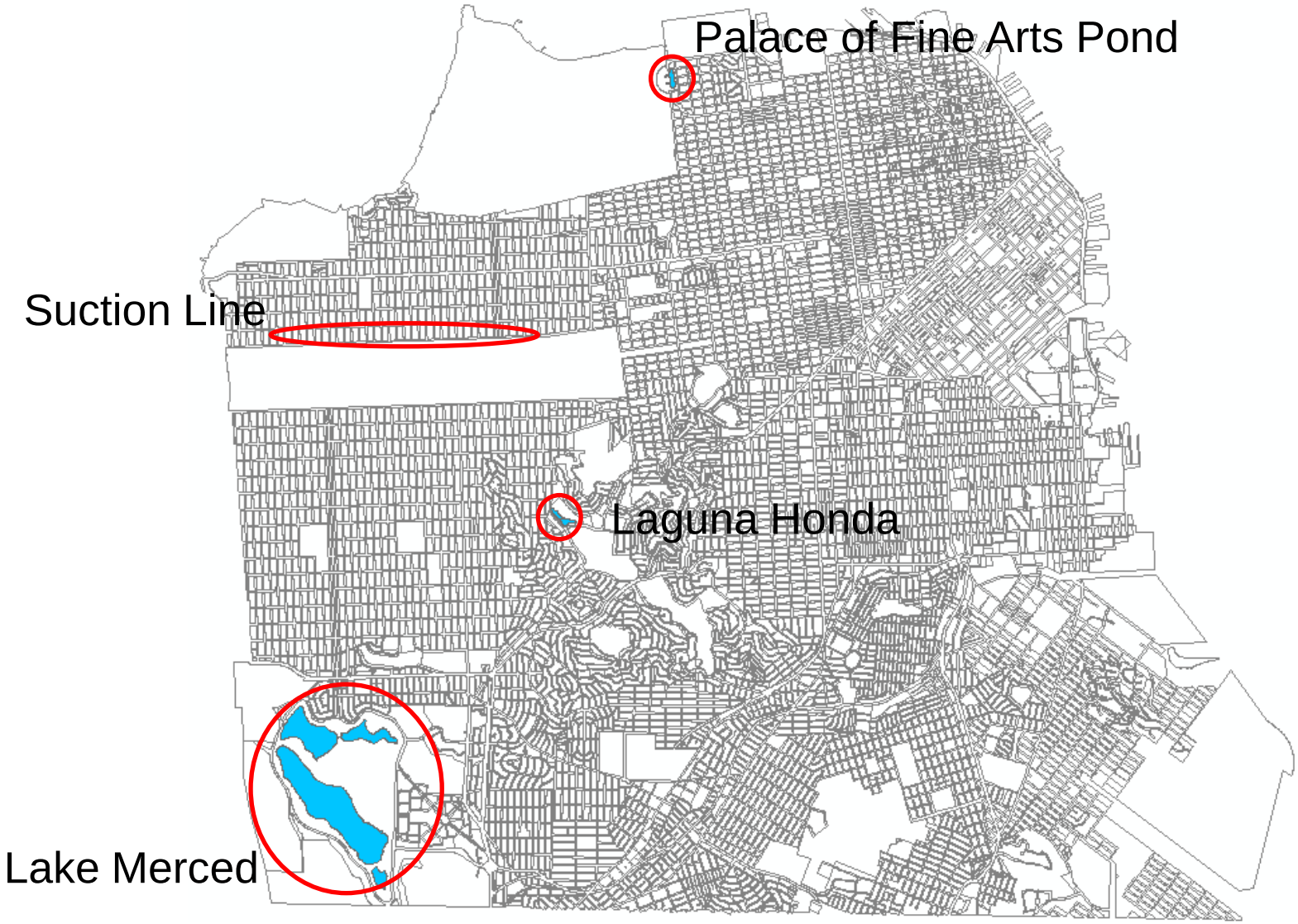


Suction Connections



- Green: existing suction connection
- Red: proposed suction connection (Alternative C only)

Alternate Water Sources



Reliability Scoring

Model Results Terminology

- Reliability:
  - Available supply / demand requested

- Citywide reliability:
  - Average of each Fire Response Area's reliability

Reliability Score Calculation

- Example FRA
- FRA demand: 5,000 gpm
- Total water available: 4,170
  - HPS contribution: 3,850 gpm (average from 15 iterations)
  - Cistern contribution: 320 gpm (average over 1000 sets)
  - Suction connection contribution: 0 gpm
  - Alternative water contribution: 0 gpm
- FRA reliability: 83% (4,170/5,000)

Reliability Score Context

- System tested at 3rd quintile demands with 46 simultaneous ignitions
- Considers initial fire department response but doesn't model response or resources required
- HPS evaluated with an aggregated demand for each FRA while other water sources are evaluated by block
- Reliability index scores are a relative representation of system performance

Alternative Programs and Assessment

Alternative Program Development

– Developed 3 Program Alternatives each composed of multiple projects

- Alternatives A & B: new pipe extensions and water supply and some cisterns
- Alternative C: all cisterns

– Performed Pairwise comparison of the Alternatives

– Recommended Preferred Alternative for further consideration

Program Alternative Scoring

Alternative		Ranking		
		1	2	3
Evaluation Criteria	Delivery Reliability	B	A	C
	Firefighting Capability	A/B tie		C
	Cost	B	A	C
	Schedule	A/B tie		C
	Operations and Maintenance	B	A	C
	Insurance Premiums	A/B/C tie		
	Environmental / Community Impacts	B	A	C
Final Ranking		**B**	**A**	**C**

Next Steps

Next Steps for AWSS

- Evaluation of other potential combinations of systems to meet potential fire demands
  - Improvements to Potable Water system
  - Construction of Multiuse or hybrid pipes
- Evaluation of relative risk of event
- Construction of projects funded by 2010 ESER bond
- Recommendations for future bond election

Thank You

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