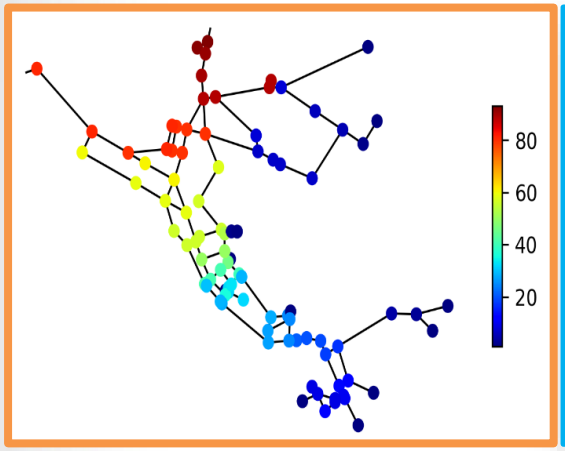
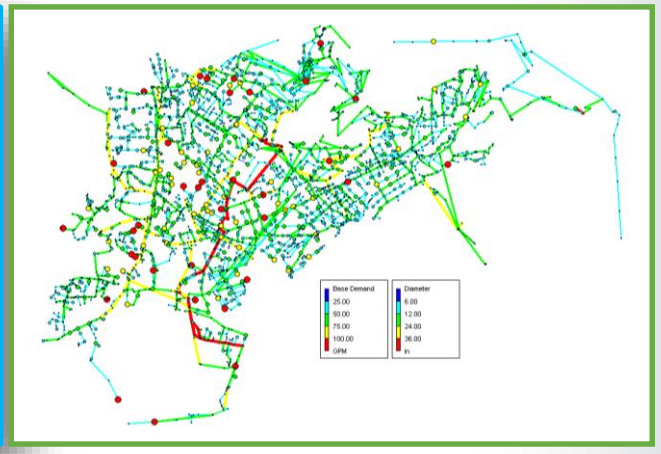
US EPA Office of Research and Development

HOMELAND SECURITY RESEARCH PROGRAM





WATER SECURITY SYSTEMS MODELING TOOLS TO SUPPORT DECONTAMINATION EFFORTS

Terra Haxton

U. S. Environmental Protection Agency

Decontamination Research And Development Conference

5/10/18

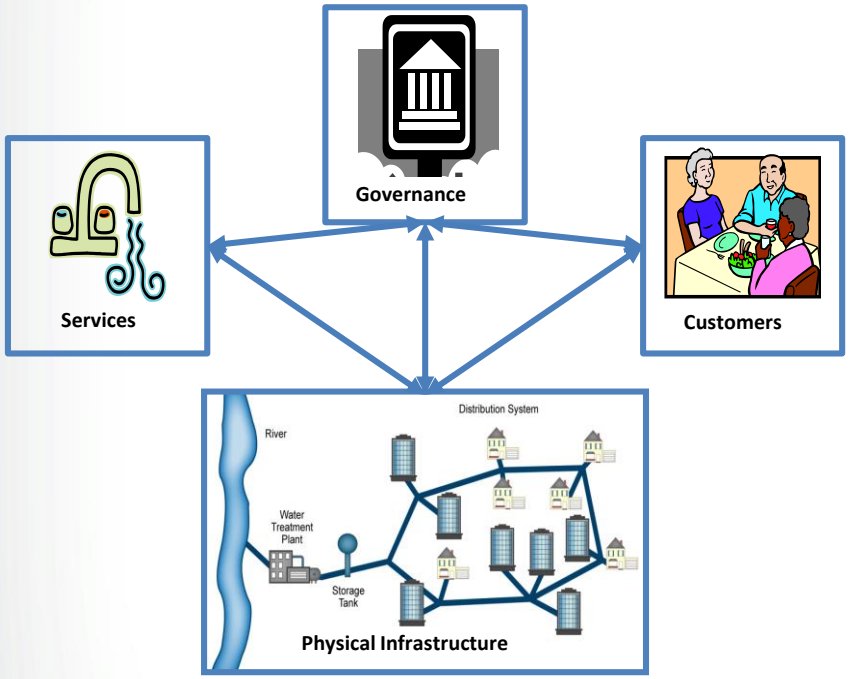
Drinking Water Utilities

- More than 50,000 community water systems around the U. S. supply high quality drinking water to customers
- Drinking water distribution systems face a variety of challenges
  - Solving water quality problems
  - Replacing aging infrastructure
  - Optimizing operations
  - Managing emergencies
  - Planning for the future

Hydraulic modeling is an effective and efficient tool to address all of these!

What is Hydraulic Modeling?

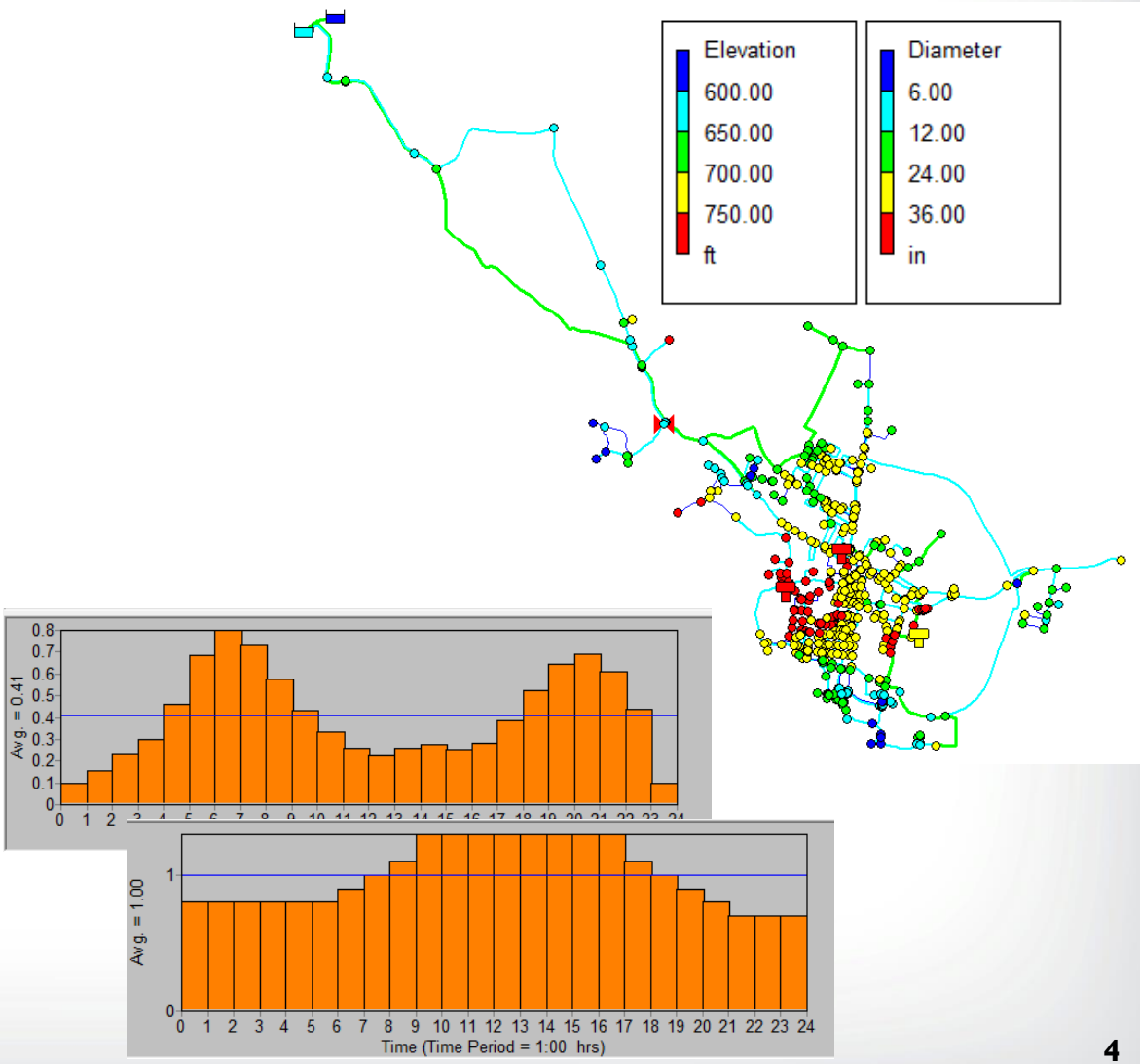
- Hydraulic modeling is a systems-based approach to solving problems



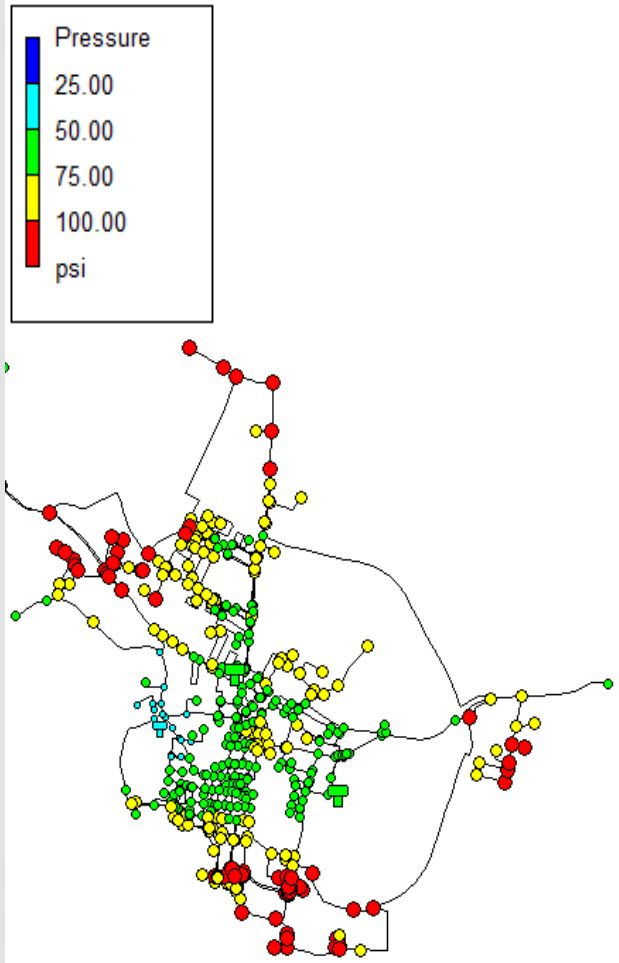
EPANET or other software: Simulates flow, pressure and water quality in distribution system.

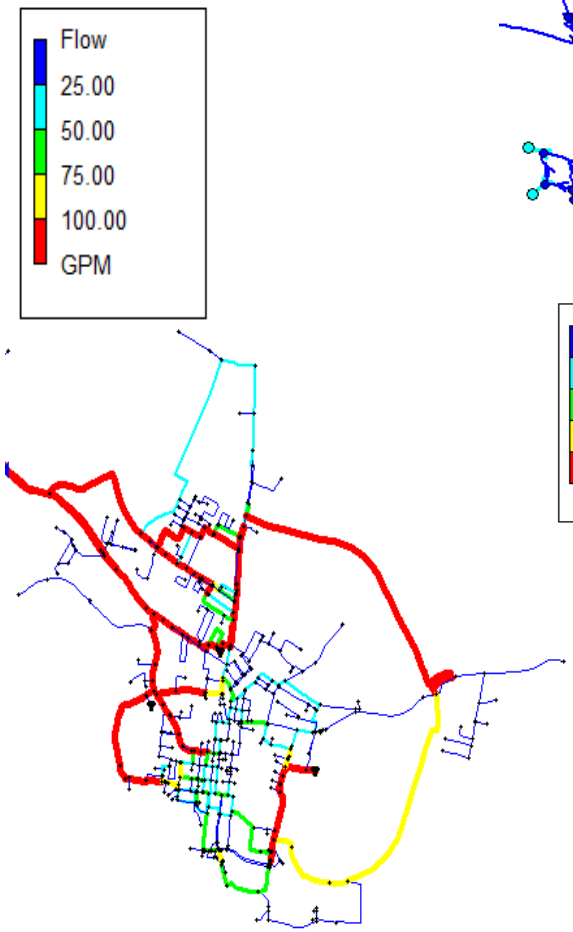
Water Distribution Models

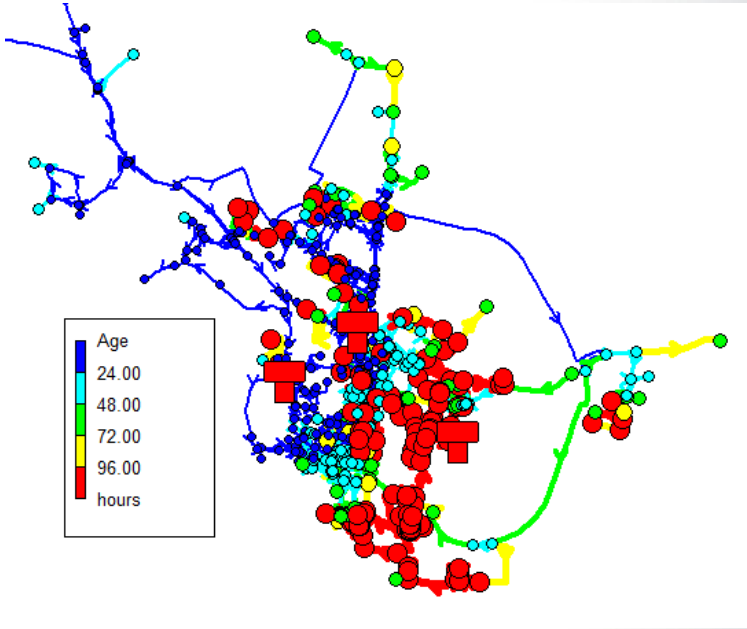
- Infrastructure
  - 2 reservoir sources
  - 2 pumps
  - 2 tanks
  - 60 miles of pipe
- Customer usage
  - 3,000 customers
  - 60% residential use
  - 25% commercial use
- Operations



Predicts Pressure, Flow, Quality



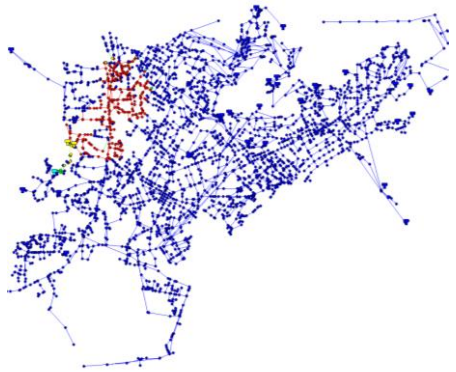


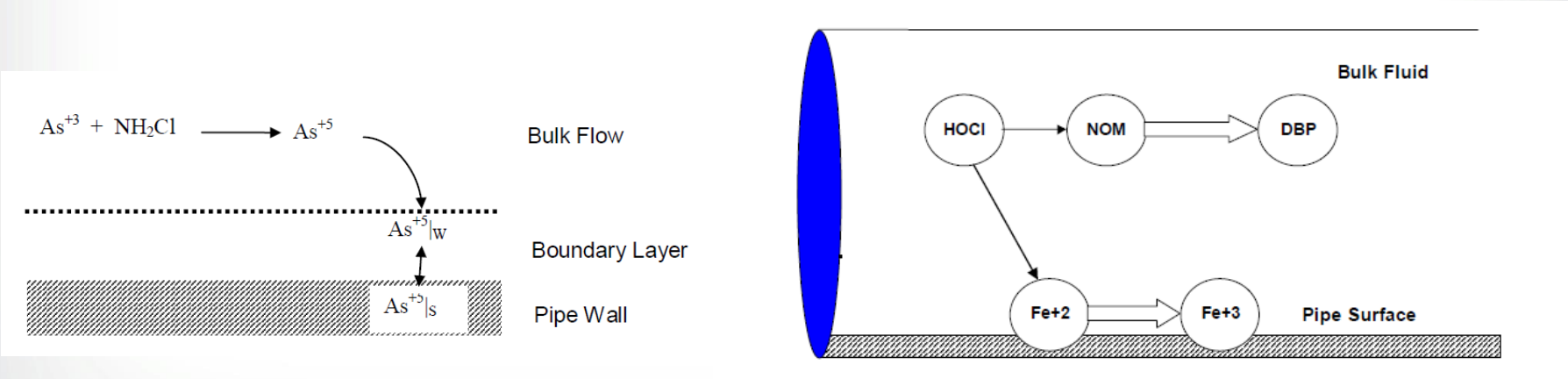


Water age can be a surrogate for declining water quality.

EPANET-MSX

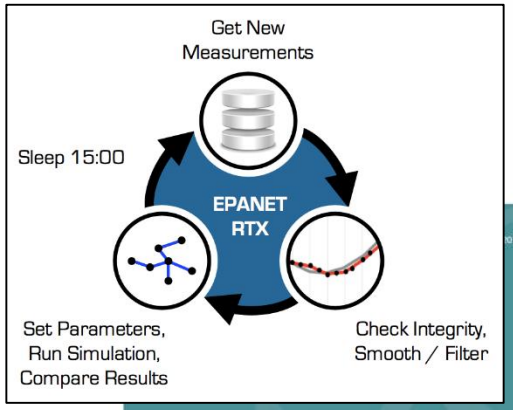
- Models and simulates complex reactions between water constituents
  - Adsorption/desorption on pipe walls
  - Attachment to biofilms
  - Chemical reactions
  - Biological growth and decay

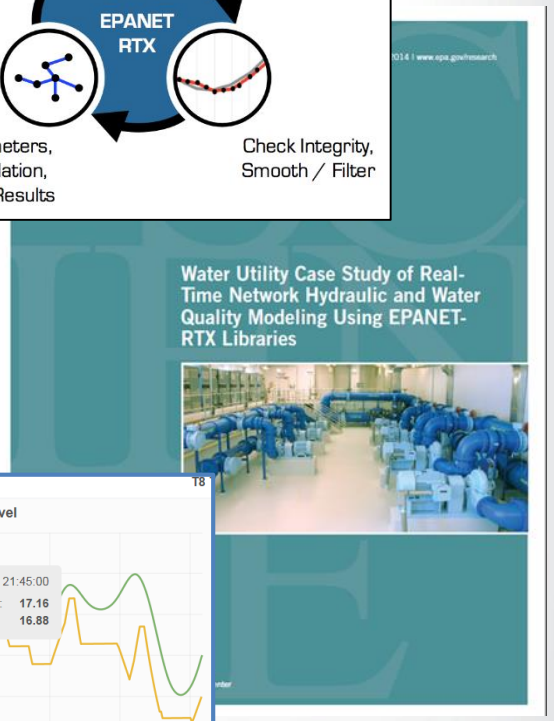


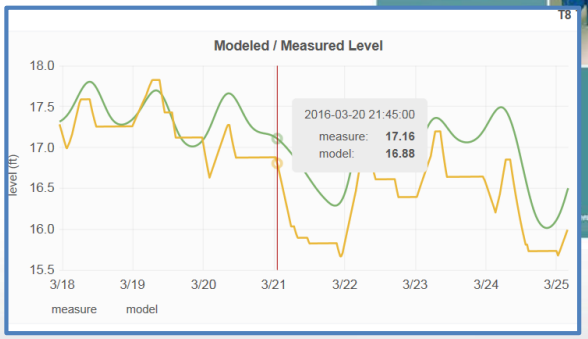


EPANET-RTX

- Real-time hydraulic modeling
- Integrates hydraulic model with SCADA operational data
  - Flow, pressure, pump status, valve position, chlorine residual
  - Real-time situational awareness of flow, pressure, and chlorine residual throughout the distribution system
  - Continuous graphical data comparison and analysis between model and SCADA outputs

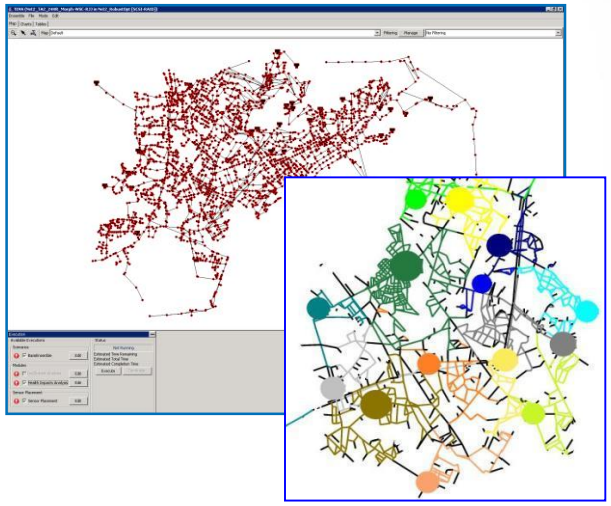


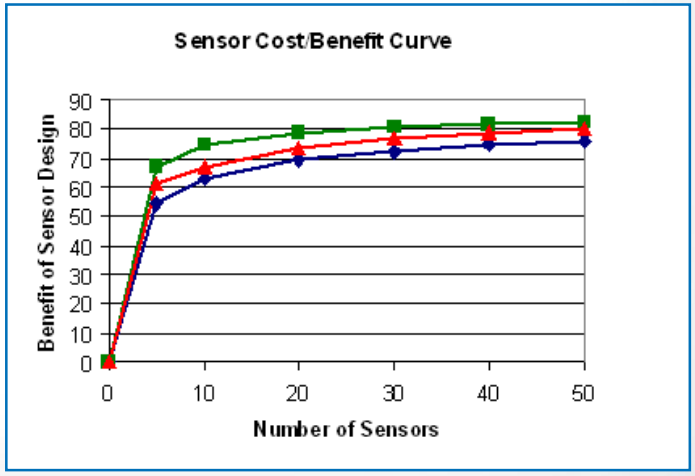




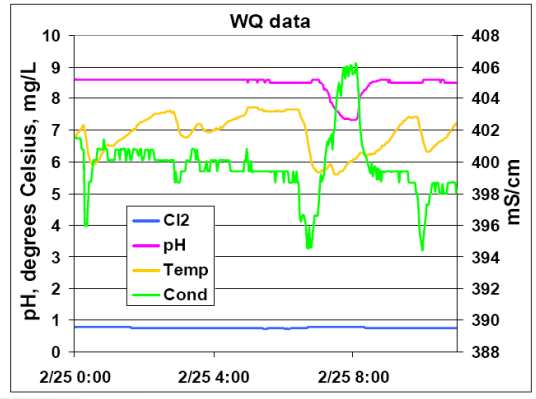
TEVA-SPOT

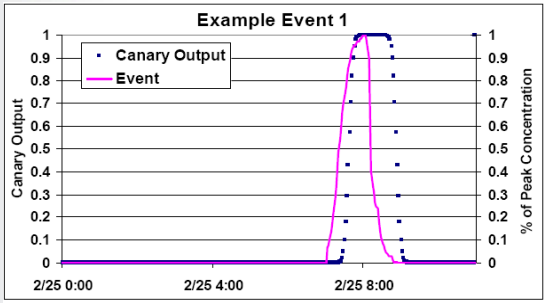
- Evaluates contamination based threats and their consequences to drinking water distribution systems
- Probabilistically analyze water customers' behaviors to determine exposure, dose, and consequences from ingestion, inhalation during showering, and inhalation from humidifier use
- Sensor placement optimization to minimize the number of people impacted, the extent of contamination, or the detection time



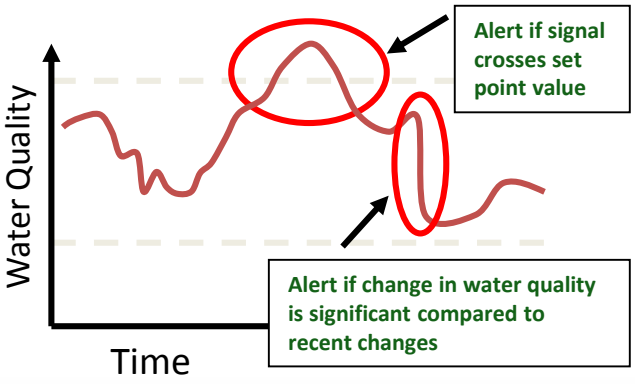


CANARY



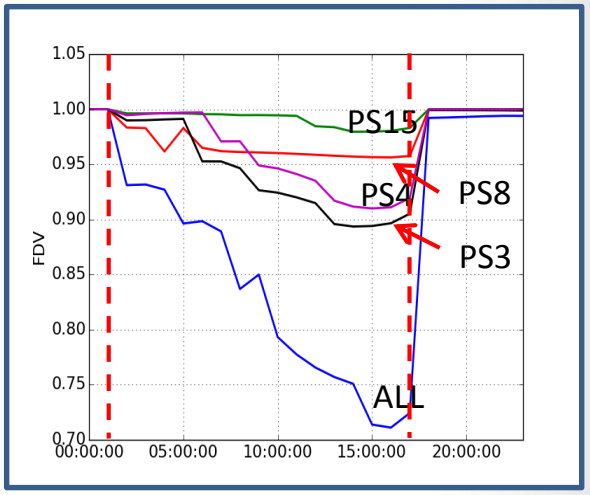


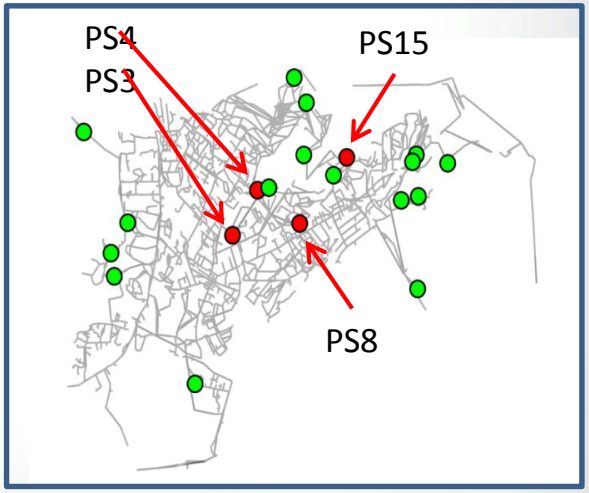
- Evaluates water quality data collected continuously from multiple sensor locations
- Ignores data during periods of sensor malfunction or hardware alarms
- Analyzes data using multiple statistical algorithms
- Alerts during periods of anomalous water quality



Water Network Tool for Resilience

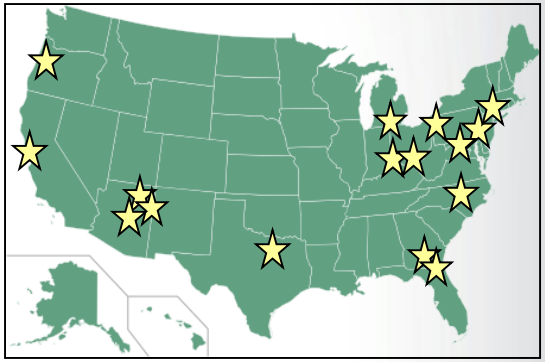
- Simulates disaster scenarios
- Calculates impacts (number of people without full access to water)
- Predicts benefits of utility response actions (fixing pipes, restoring power)
- Measures quantitative resilience indicators over time
- Evaluates improvement in resilience due to changes in system operation or design

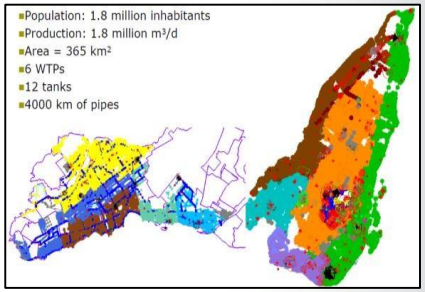




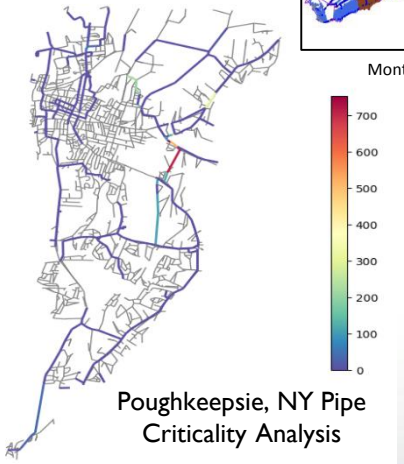
Water Utility Applications

- TEVA-SPOT
  - U.S. utilities (e.g., Cincinnati, OH; Arlington, TX [Super Bowl preparations])
  - International utilities (e.g., Montreal, Canada; China, South Korea, Israel)
- CANARY
  - Greater Cincinnati Water Works (17 sites since 2007)
  - Singapore Public Utility Board (70 sites since 2009)
- EPANET-RTX
  - Northern Kentucky Water District
  - Milford, OH
  - Flint, MI
- WNTR
  - Poughkeepsie, NY





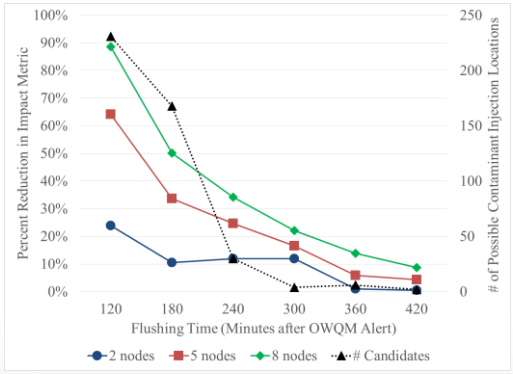
Montreal Canada Water System

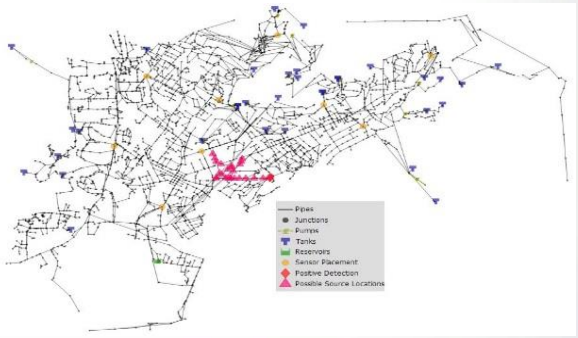


Poughkeepsie, NY Pipe Criticality Analysis

Water Security Toolkit (WST)

- Evaluates response actions that could be taken following a contamination incident, by identifying
  - Best hydrants to flush out contaminated water
  - Best injection location of chlorine to inactivate contaminant
  - Origin of contamination
  - Best sampling locations to confirm contamination or clean-up





Possible Origin of Contamination

Decontamination Questions

- When decontaminating after an incident, many questions arise

Where was the source of the contamination?

What was the contaminant?

Does it react with anything in the water or pipes?

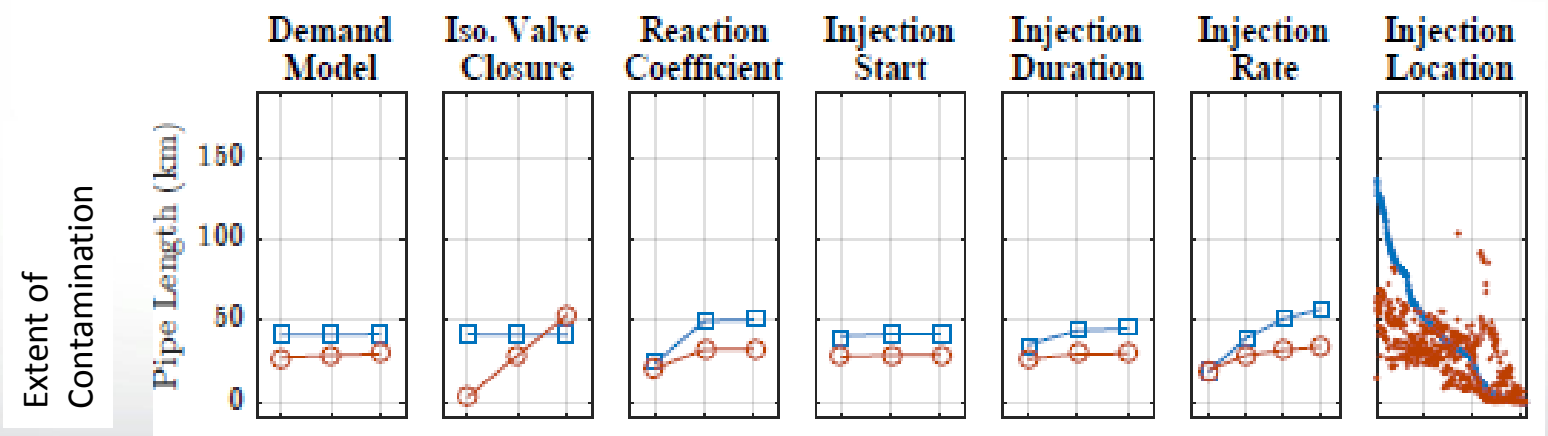
Where should samples be taken?

How much of the system was affected?

What decontamination action would be most effective?

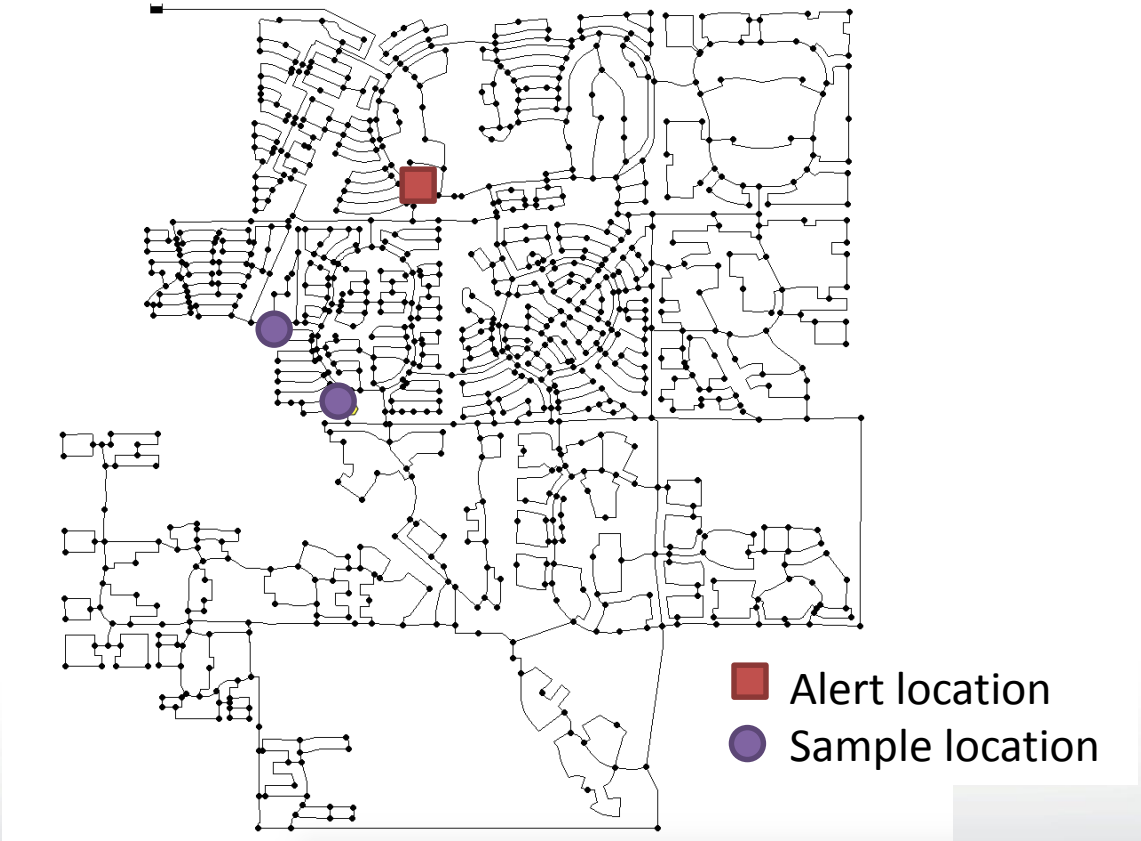
Sampling Application

- Investigate which model parameters affect contamination plume extent
- Varied parameters for
  - Customer demands
  - Valve status
  - Contaminant decay rate
  - Injection start time
  - Injection duration
  - Injection rate
  - Injection location
- Contaminant injection location was most dominant parameter
- Depending on contaminant injection location, other parameters affect the plume more

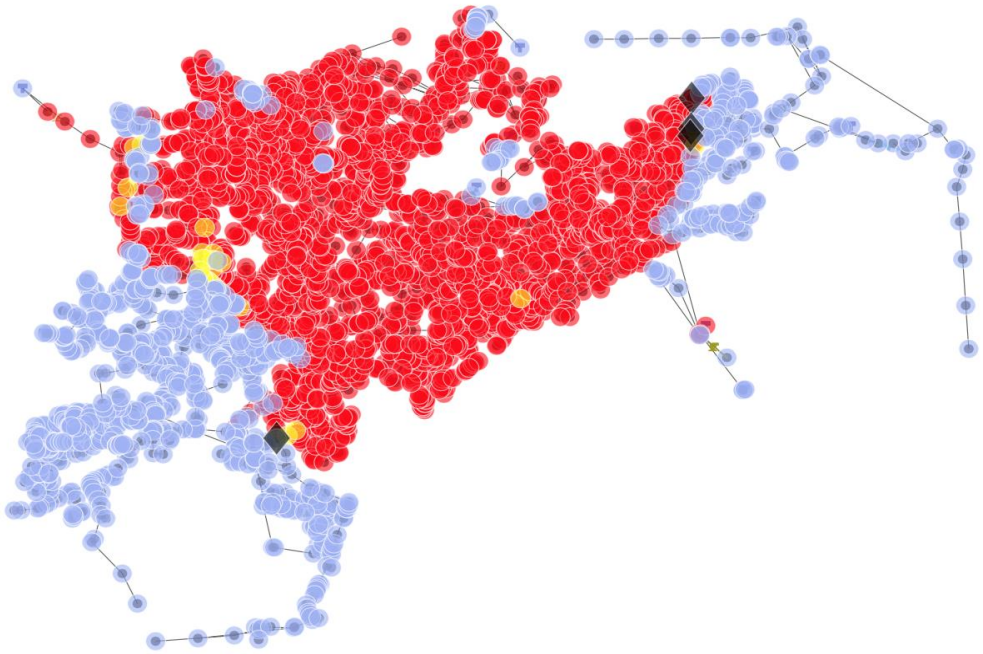


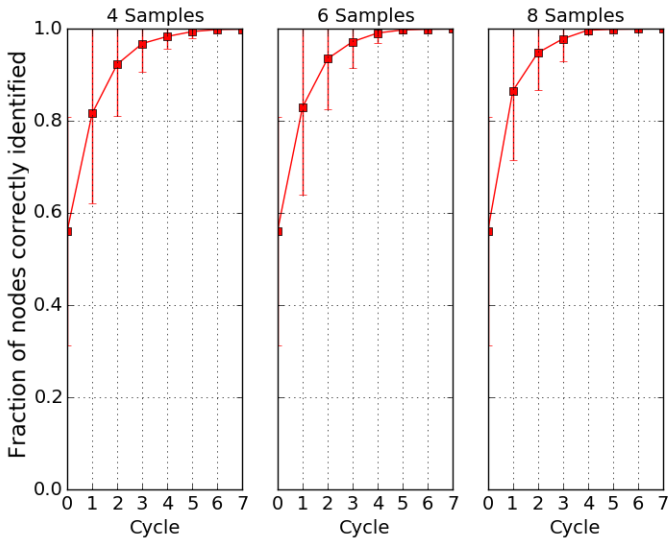
Sampling to Identify Plume

- Identify optimal sampling locations to reduce the uncertainty of the contamination plume
- Evaluate where, when, how many locations to samples



Number and Location of Samples





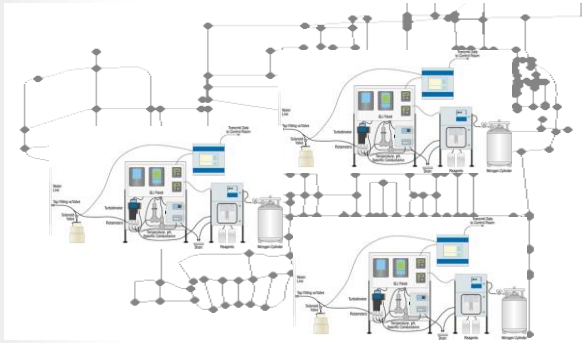
- Known contaminated location
- Unknown contaminated location
- Sampling location

Summary & Future Work

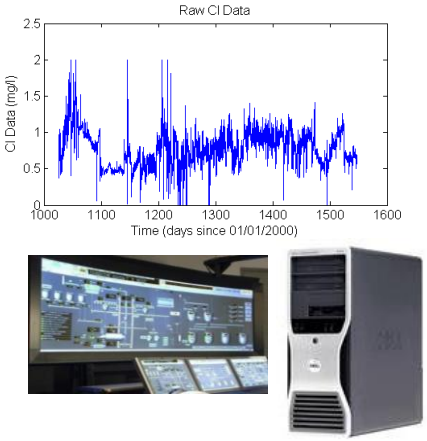
- Hydraulic modeling and data analytics can provide critical and scientifically-based information to support utility decision making to natural disasters, terrorist attacks, and traditional utility challenges (pipe breaks, water quality problems)
- Future research focuses on applying modeling and simulation tools to different case studies
  - Multiple distribution systems
  - Retrospective analysis of real incidents

Vision for Software Tools

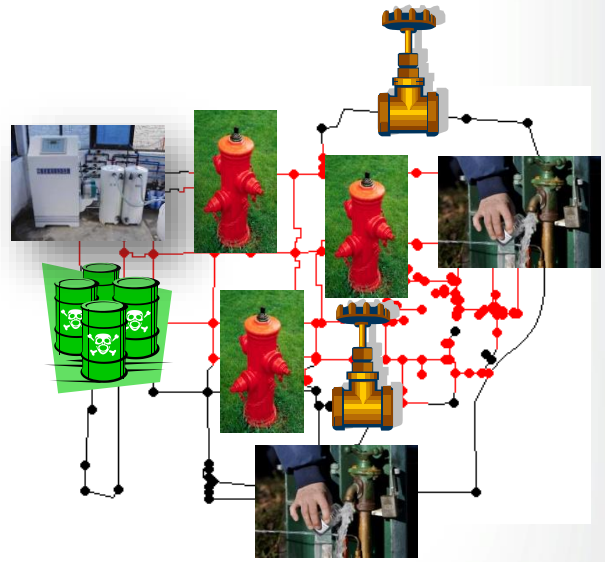
- Water utilities can use EPA tools to automatically detect water quality problems, predict real-time flow, pressure and chlorine residuals throughout the system, and identify and evaluate potential response actions.



Contamination Warning System



Data Analytics & Real-Time Modeling



Evaluation of Response Actions

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- Sandia National Laboratories
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Our software tools are being developed to support emergency response, design mitigation strategies, and improve daily operations at water utilities around the country.

The U.S. Environmental Protection Agency funded and collaborated in the work described here. It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.