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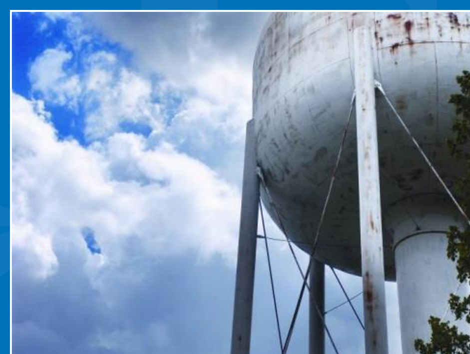
Small and Large Water Systems are Piloting Real-Time Data Analytics to Improve Water Quality and Preparedness

Homeland Security Research Program Webinar Series
March 12, 2018



Robert Janke
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Office of Research and Development
National Homeland Security Research Center

Our Drinking Water Distribution Systems Modeling Team

- U.S. EPA
  - Regan Murray, Terra Haxton, Michael Tryby, and Jonathan Burkhardt
- CitiLogics
  - Jim Uber and Sam Hatchett
- Pegasus
  - Hyoungmin Woo
- DeRisk Center – University of Colorado
- Partnering water utilities

Outline

- Problems drinking water utilities face
- What is really needed for drinking water utility preparedness and response?
- Using drinking water utility data and information
- Real-time analytics technologies
- Water utility case studies
- Preparedness and response tools

Problems Water Systems Face

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Water Loss

Cross Connections

Pump Failure

Loss of Water Quality

Pipe Breaks

Loss of Pressure

Contamination Incidents

Valve Maintenance

Tank Management

Chlorine Management

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Contamination Incidents

Two examples:

- **<u>1980, Pittsburgh, PA:</u>** Intentional contamination with the pesticide chlordane. 10,500 people affected. One month without service and 9 months of flushing and cleanup. Cleanup costs exceeded $200K (Welter et al. 2009)
- **<u>2014, Charleston, WV:</u>** An industrial spill results in 300,000 customers and many business not having tap water to use for any purpose – drinking, flushing toilets, food prep, etc, some for over a week. Weeks later, many still do not trust the tap water's safety. (Scientific American online, Feb. 05, 2013)

Example of an Operational Emergency

- Emergency occur following:
  - Replacement of a 24-inch main to tank
  - Monitored pressure and noticed pressure spike
- But could not prevent water hammer and customer's loss of pressure

"In the summer of 2005, our water department was supporting a contractor who was swapping over a 24-inch water main associated with a new storage tank. We had staff on site and were also monitoring system pressures and wells. At 5:30 pm, one of our operators noticed a pressure spike at a monitoring station. We later determined that we experienced a water hammer in the system. Within 15 minutes of the initial notification, phone calls started coming in from all over the city. Calls ranged from water bubbling in the, to a geyser in a front yard, loss of pressure, and asphalt lifting…."

Excerpt of J-AWWA article about emergency preparedness

Real-Time Analytics Applications

- Examples of companies that use real-time analytics in their operations

For example, every step of your ordering is understood

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What can be achieved if this level of understanding was brought to drinking water systems' operations?

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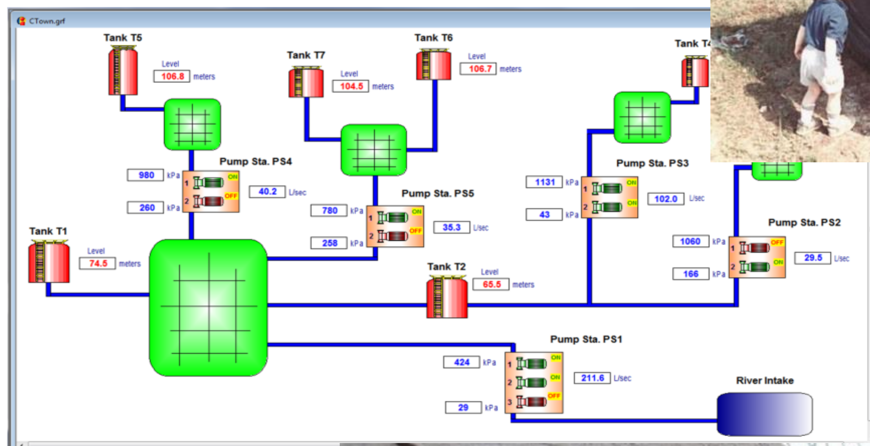
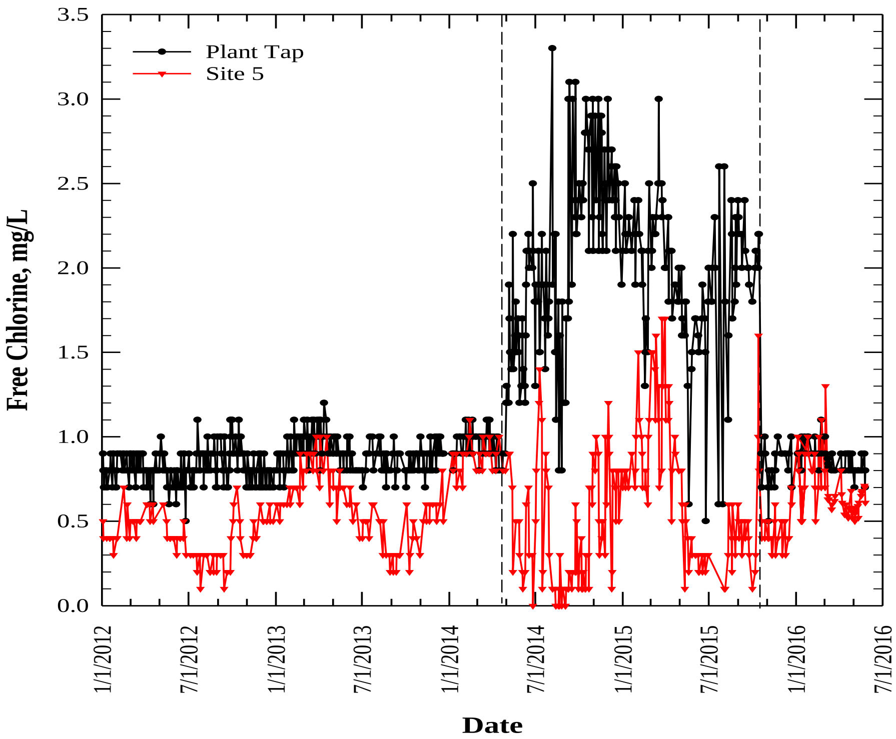
Planning and Operations

- Better planning for the future
- Replacement of aging infrastructure
- Optimizing operations



Preparedness and Response

- Solving water quality problems ahead of time
- Preparing better for emergencies
- During emergencies implement decision-making to reduce consequences



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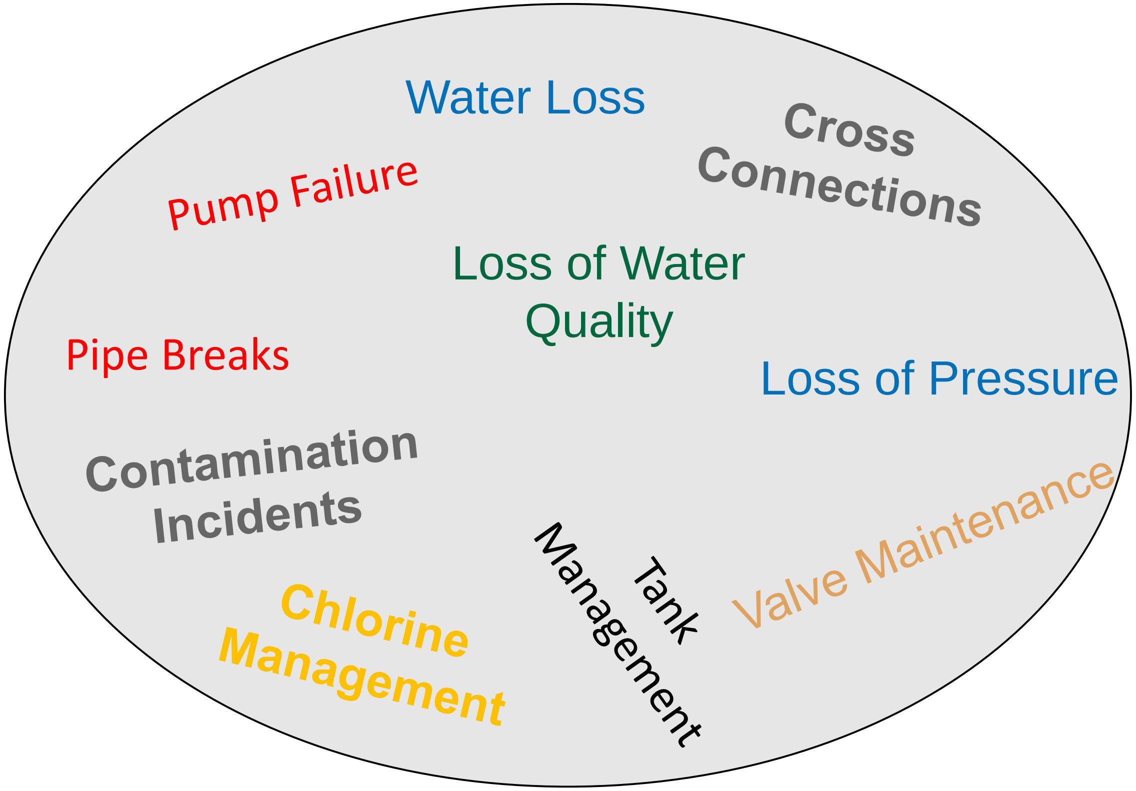
What do these water utility problems have in common?

- Operational problems
- Can be solved with data and information



Information Needed for Preparedness and Response

Automated and routine capability to understand what is happening at the treatment plant and in the distribution system, being able to analyze what has happened in the past (historical record), and predict what can happen in the future – in terms of complete system hydraulics (e.g., pressures, flows) and water quality (e.g., disinfectant, water age).

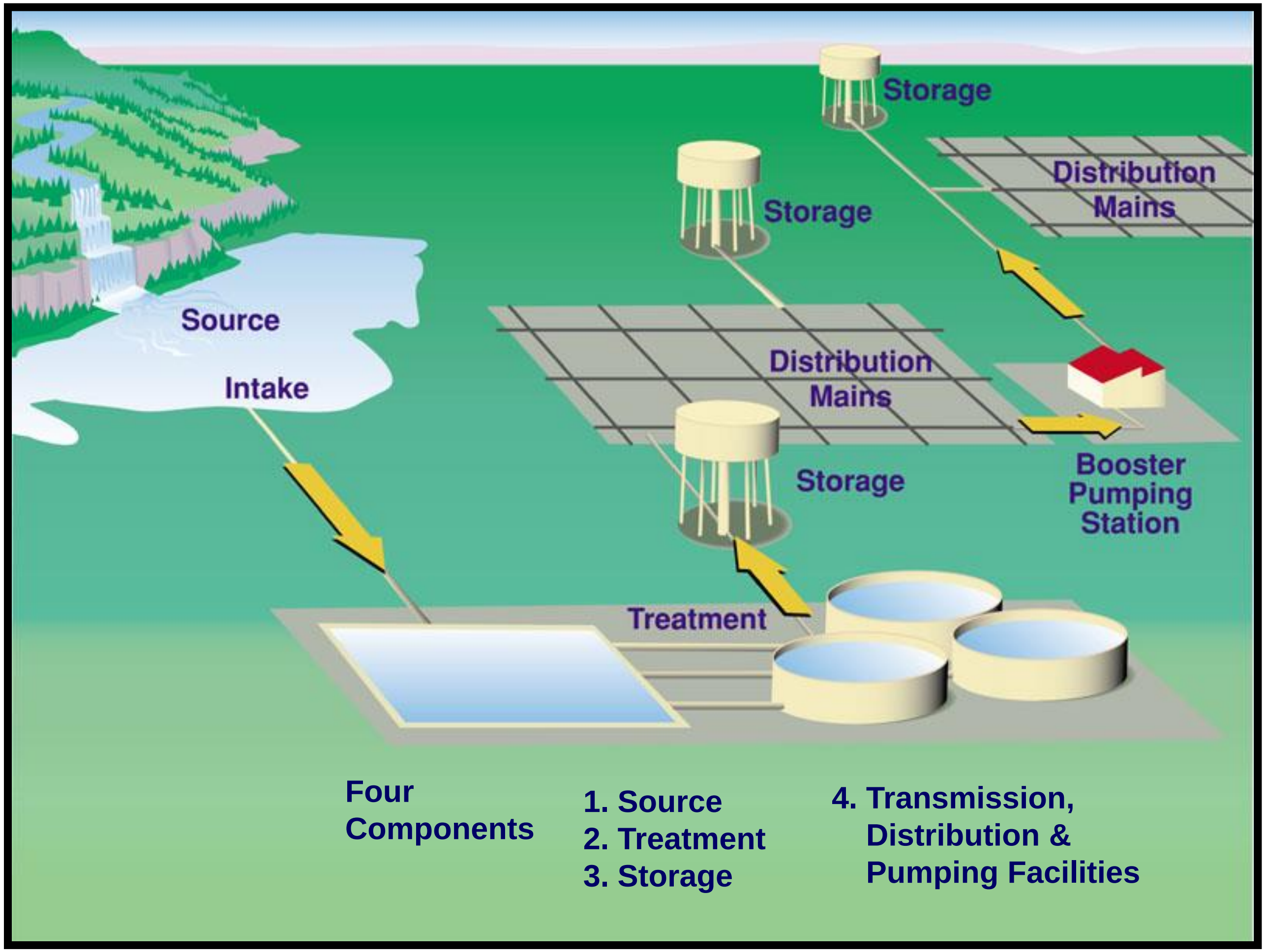
What information and tools are needed?

- Water utility infrastructure data
- Hydraulic and water quality modeling
- Real-time analytics and real-time modeling

Typical Drinking Water System

Major components:

- Source water
- Treatment
- Storage
- Transmissions, Distribution, and Pumping Facilities



Water Utility Infrastructure Data

- SCADA (supervisory control and data acquisition) data
- Geographical information system (GIS) data
- As-built drawings for piping and infrastructure
- Billing and customer information
- Network model

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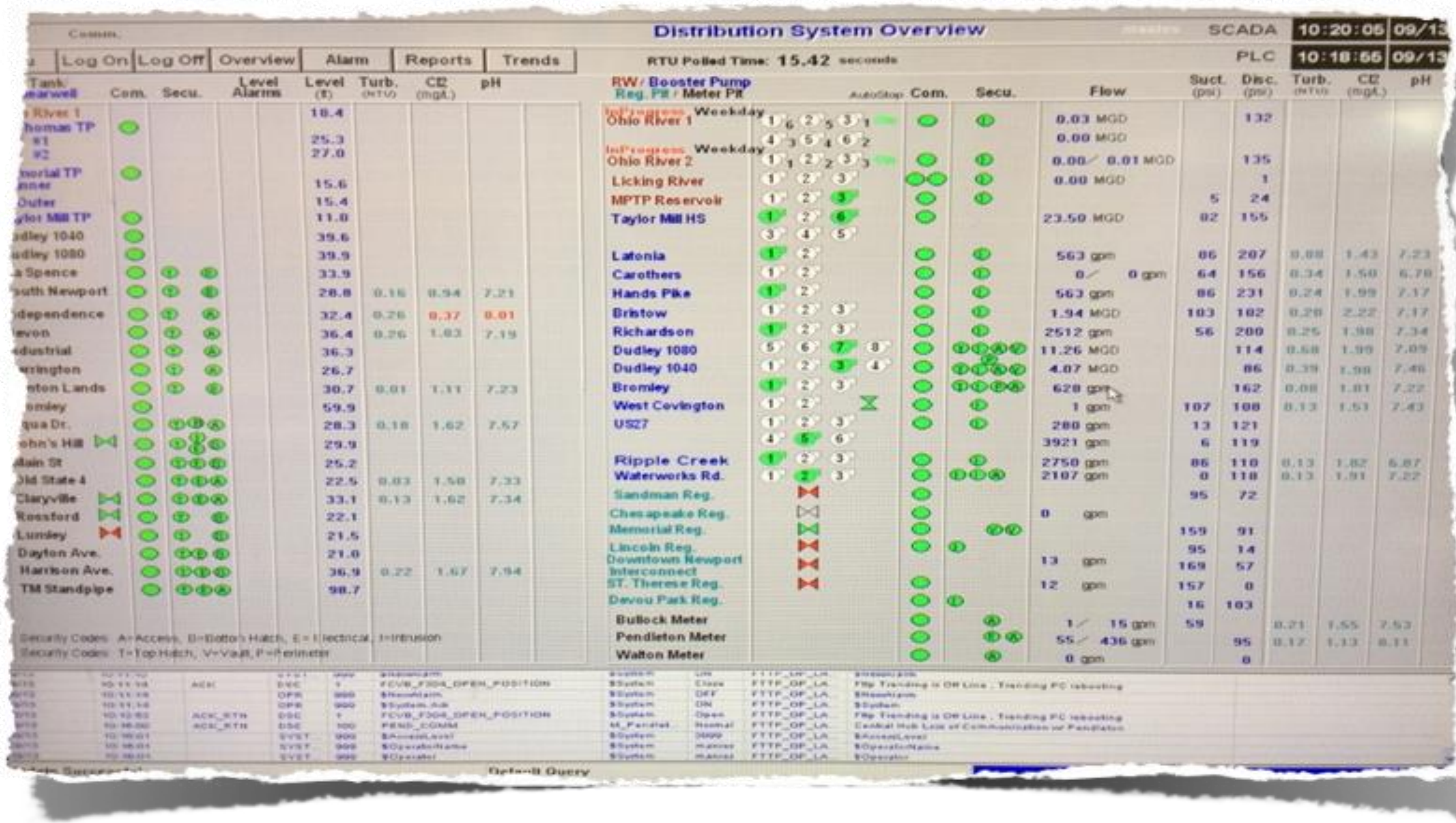
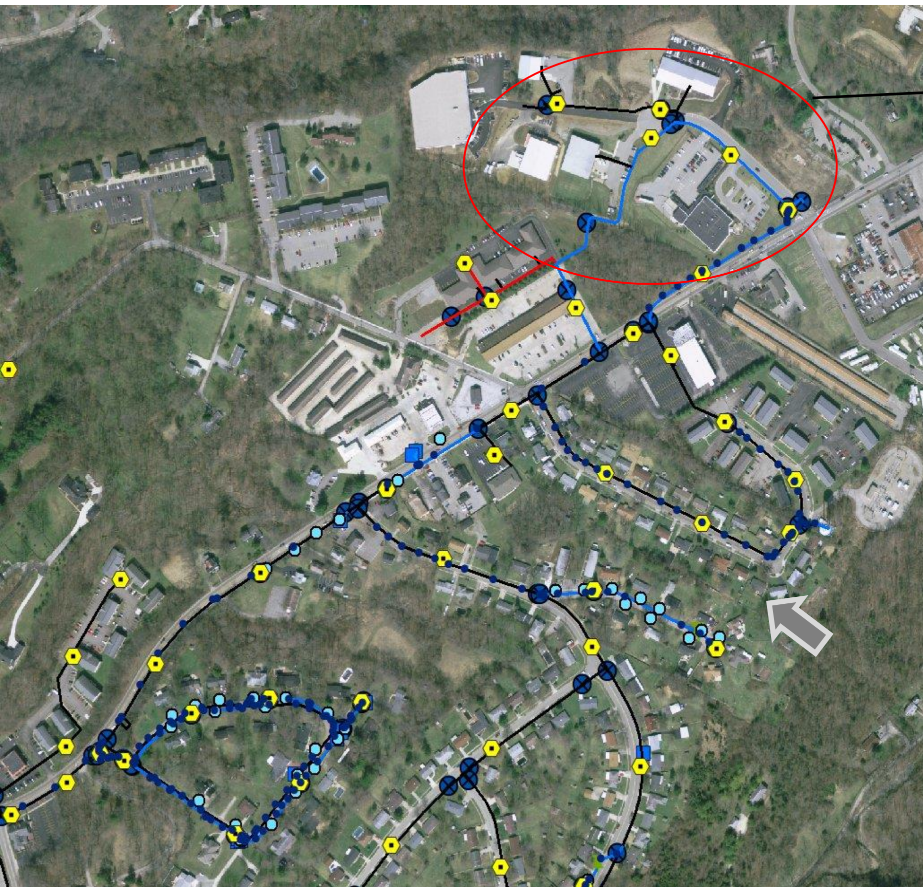
SCADA

- Can monitor what is going on in the plant and the distribution system
- Most utilities have a SCADA system

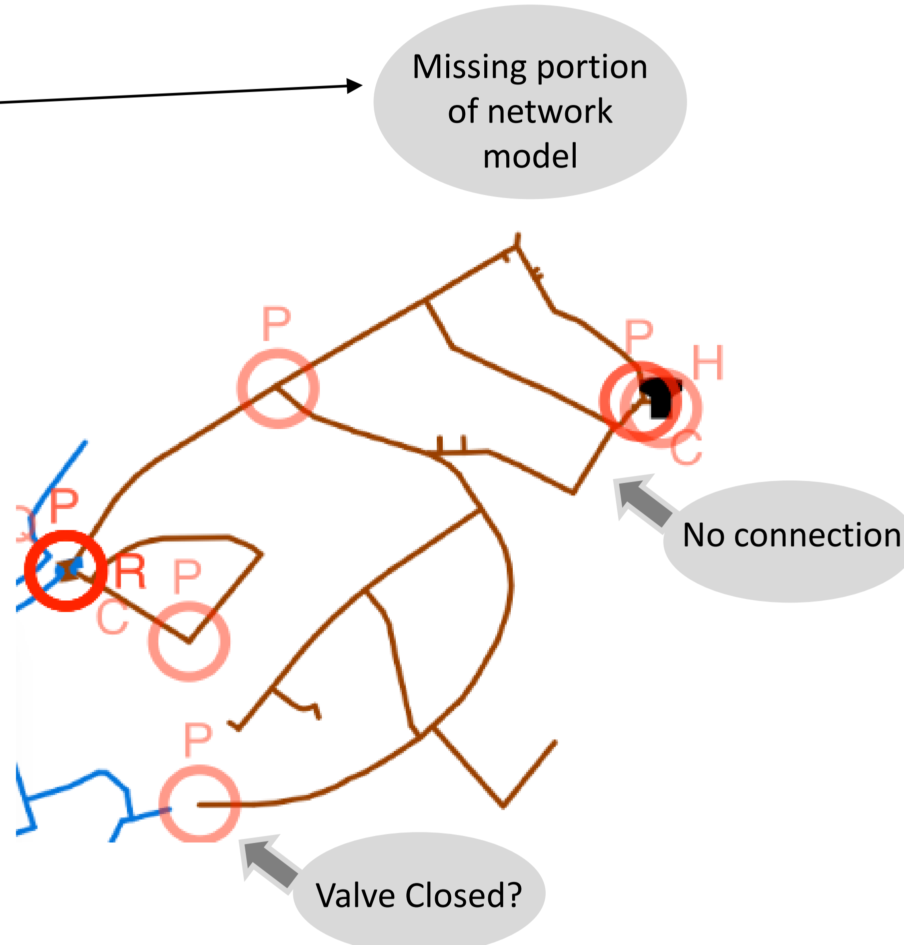
Example Photo of Utility SCADA Terminal



Geographical Information System Data



GIS Data

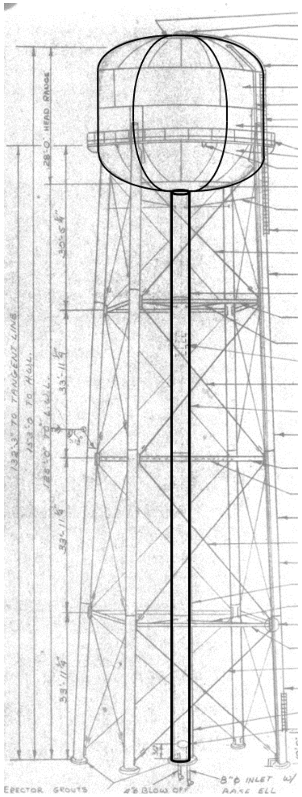


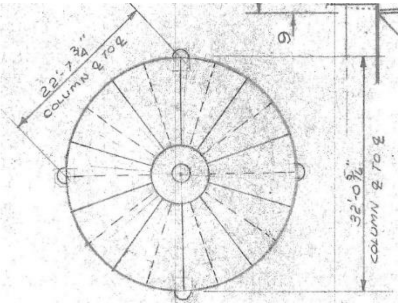
Configuring model and SCADA monitoring points

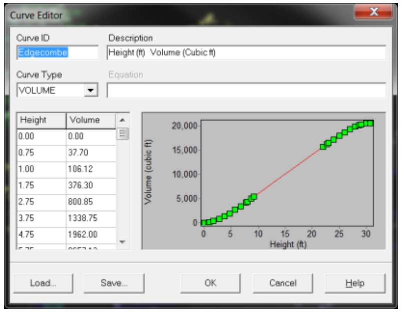
As-built Drawings

Tank volume curve is wrong in model – as-built drawings are used to correct the problem

132’
153’
125’







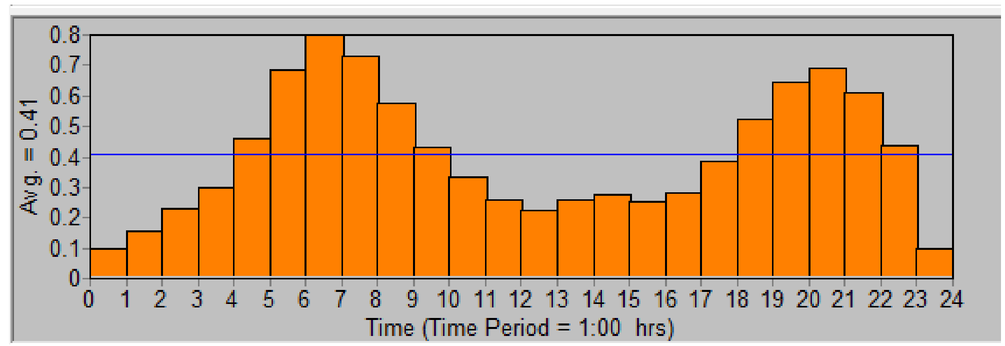
Ground E.L.: 826.56’(=699’+3.3’(frost line)+124.25’)
(closest node J-1 EL: 699.0694)
Riser to LWL: 125’
Riser to tank bottom: 124’ 3”
Ground EL: 704’ (from contour line)
H.W.L: 28’9” (153’ from Ground)
L.W.L: 9” (125’ from Ground)
Total Volume: 150000 gallon (Dia 32’ 5/16”)
Diameter: 32’-5/16”
Foundation Diameter: 43’-9/16”

Volume Depth Curve

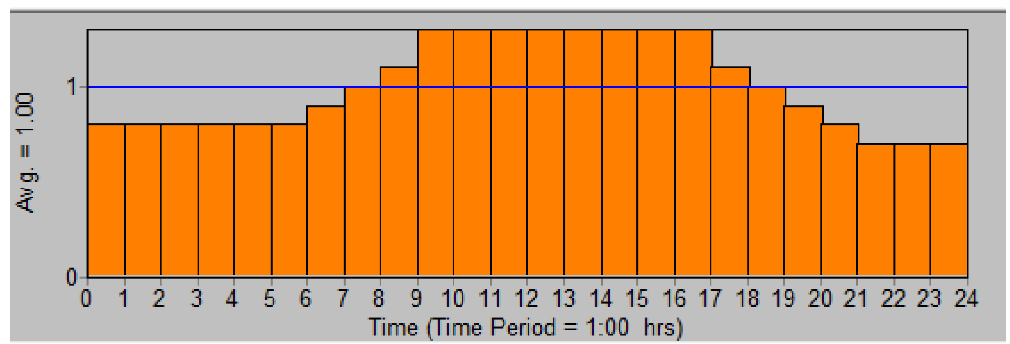
Height (ft)	Volume (Cubic ft)
0.00	0.00
0.75	37.70
1.00	106.12
1.75	376.30
2.75	800.85
3.75	1338.75
4.75	1962.00
5.75	2657.13
6.75	3408.00
7.75	4185.83
8.00	4384.39
8.75	4987.57
9.25	5389.70
22.00	15643.86
22.75	16247.04
23.00	16445.60
24.00	17223.43
25.00	17974.30
26.00	18669.43
27.00	19292.68
28.00	19830.58
28.75	20192.45
29.00	20255.13
30.00	20531.25
30.75	20568.95

Billing and Customer Information

- Water usage or demand drives water movement
- Water usage is described by demand patterns
  - 3,000 customers
  - 60% Residential Use
  - 25% Commercial Use



Residential pattern

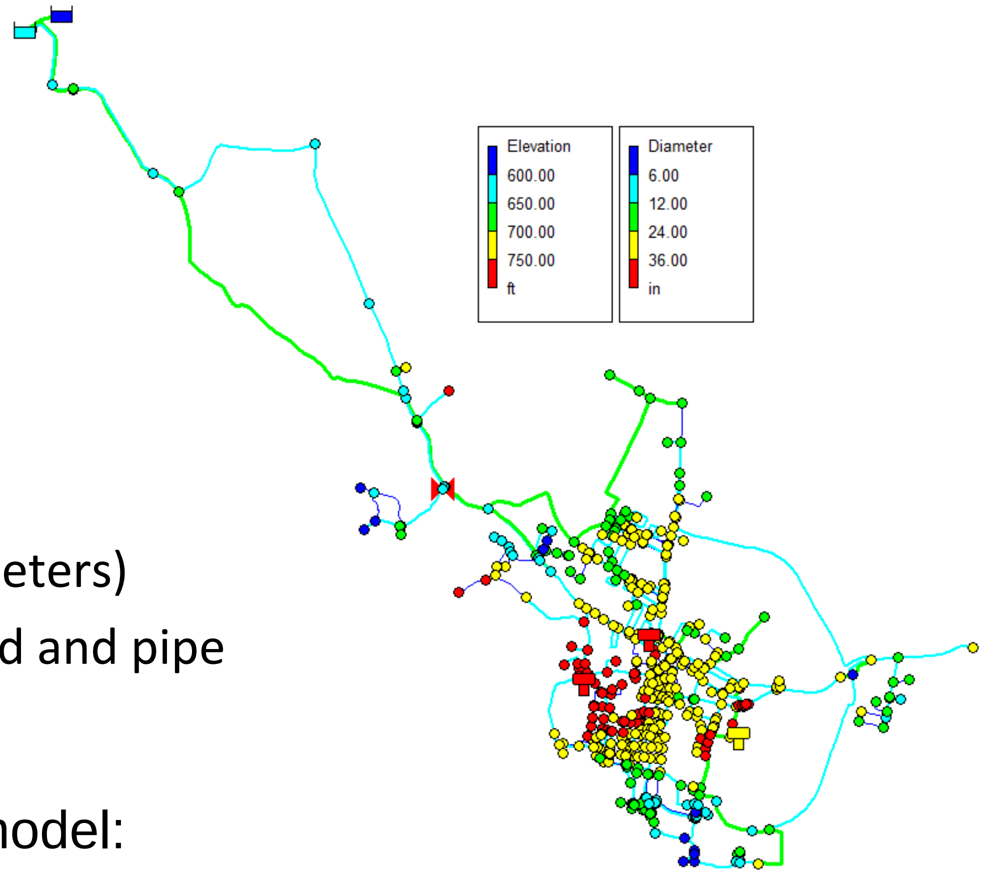


Commercial pattern

Network Model

Example system:

- 1.5 MGD
- 3,000 customers
- 2 reservoir sources
- 2 pumps
- 2 tanks
- 60 miles of pipe
- 645 pipes (varying lengths & diameters)
- 545 junctions (where water is used and pipe connections)

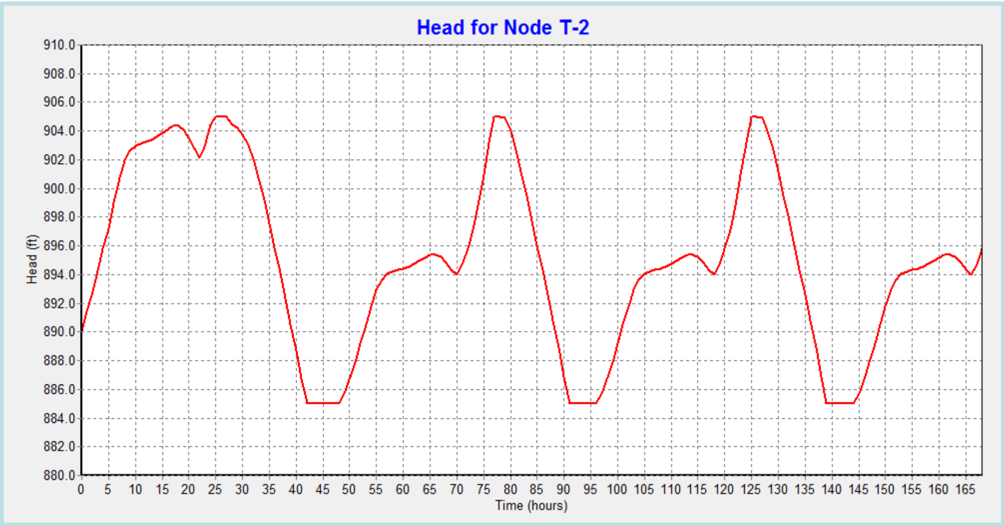


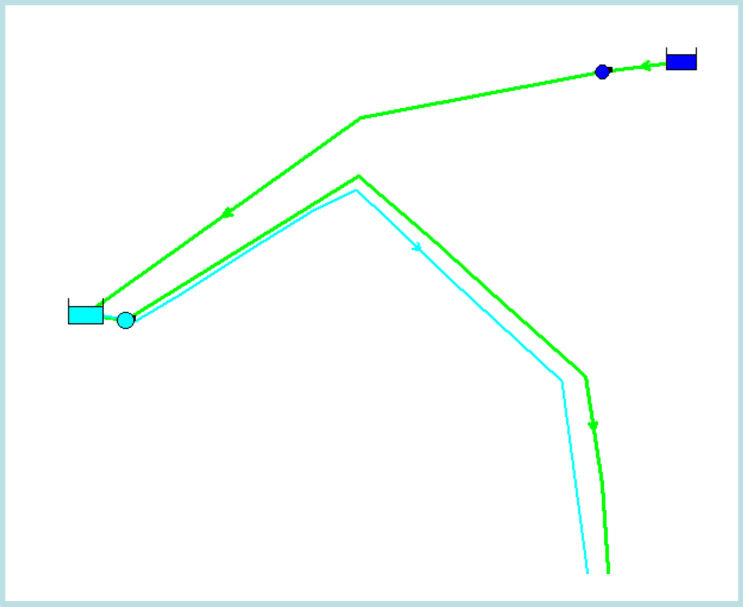
EPANET software uses a network model:

https://www.epa.gov/water-research/epanet

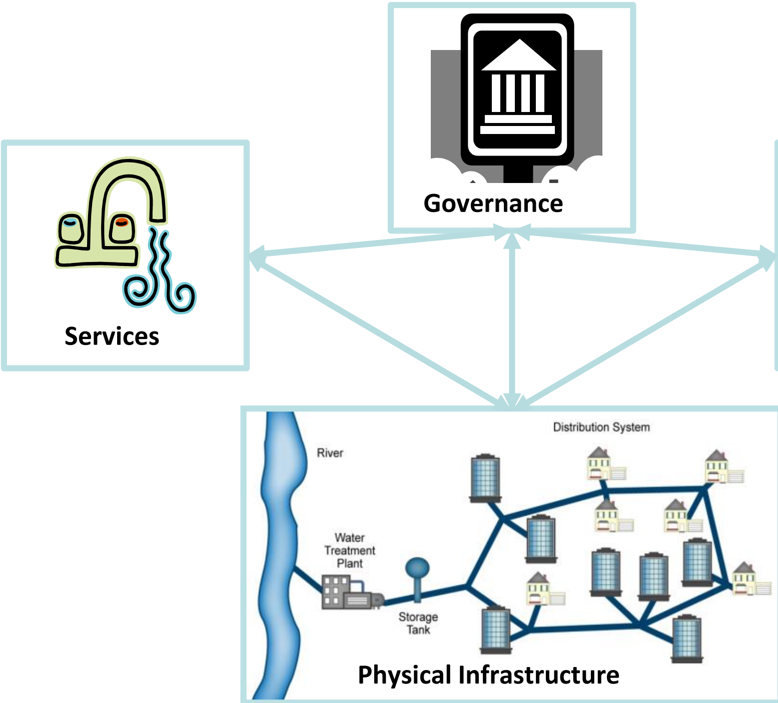
Operations are Described in the Network Model

- PUMP Open [*turns on*] If TANK (T-2) Below 5 ft (888)
- PUMP Closed [*turns off*] If TANK (T-2) Above 19 ft (904 ft)

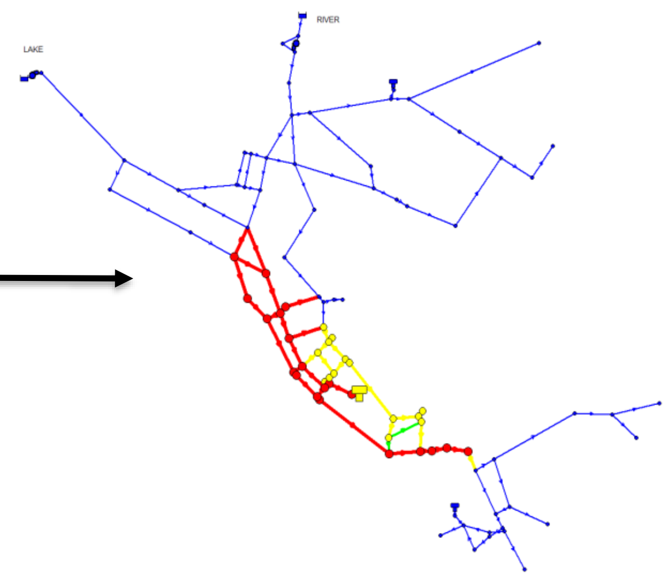




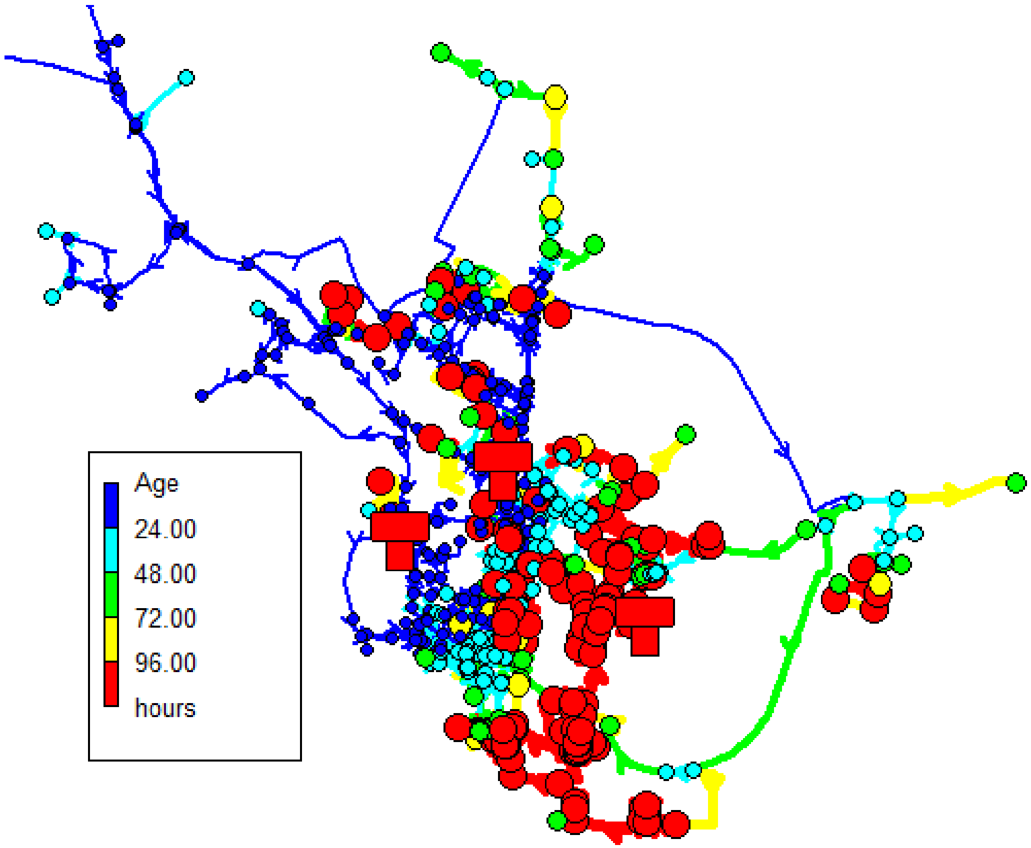
Hydraulic and Water Quality Modeling



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



Water Age can be Predicted by Network Model (flow and pressure too)



Life Cycle of the Hydraulic and Water Quality Network Model

- Construction
  - Planning, data collection, infrastructure model development, customer demands, operational data
- Calibration
  - Fire flow tests, hydraulic gradient tests, C factor tests, pressure monitoring, meter calibration, establishing correct elevation data, tracer studies
- Maintenance
  - Establish regular schedule for updating model components, ideally link model to databases, perform periodic calibration

What are real-time analytics?

“**Real-time analytics** is the use of, or the capacity to use, data and related resources as soon as the data enters the system.
... **Real-time analytics** is also known as dynamic analysis, **real-time** analysis, **real-time** data integration and **real-time** intelligence.”

Source: Google – “Real-time analytics”

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What is real-time modeling?
(defined for a water system)

An integration of network hydraulic and water quality models with operations data collected and stored via SCADA, providing for an automated and routine capability to hind-cast, now-cast, and forecast complete system pressures, flows, and water quality, in support of operational, emergency response, and water system planning goals.

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Examples of Companies Using Real-Time Analytics and Modeling

FedEx

Exxon

ebay

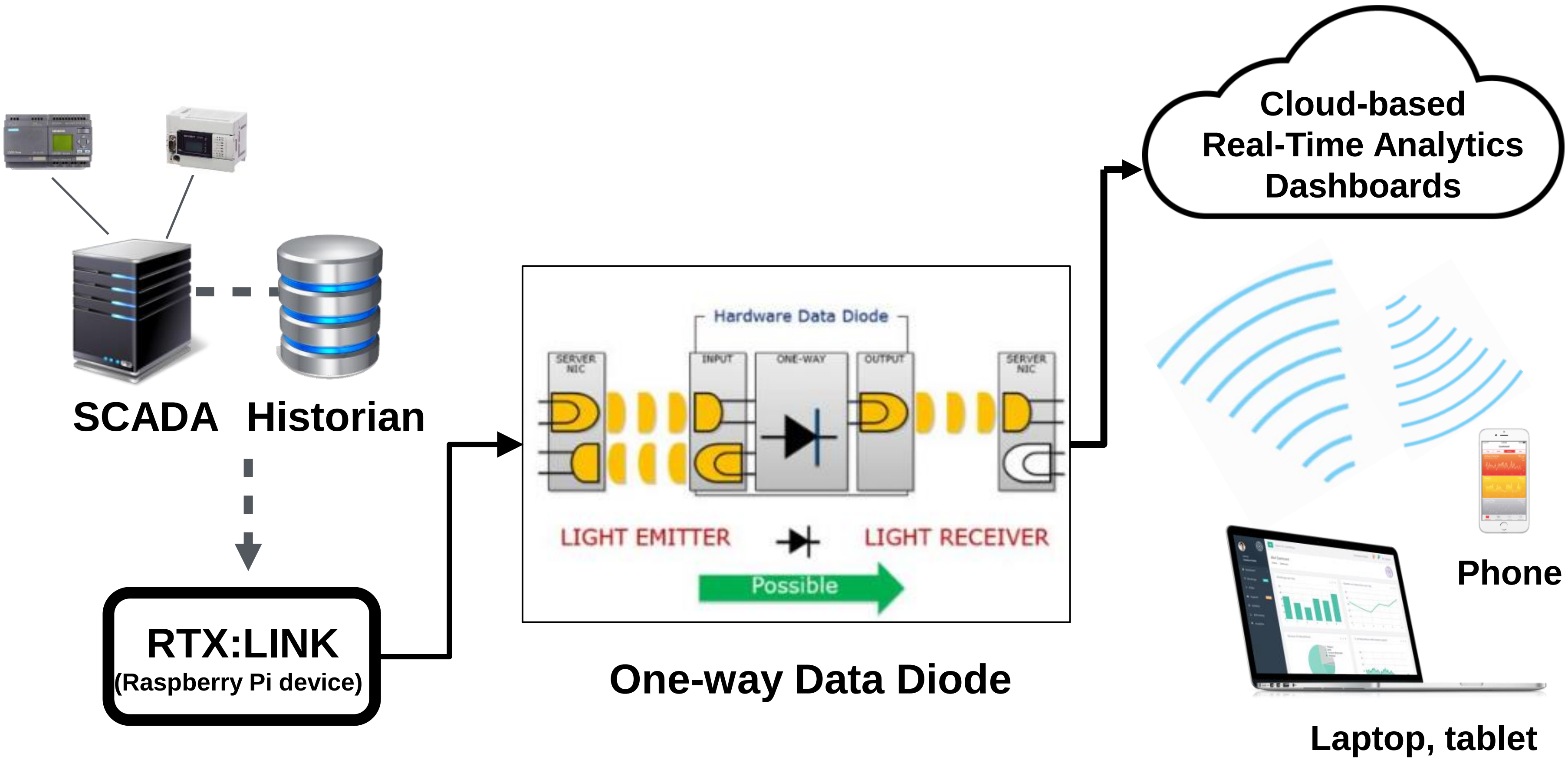
DELTA

amazon

Real-Time Analytics Technologies

- RTX:LINK
- EPANET-RTX

RTX:LINK – Data Access



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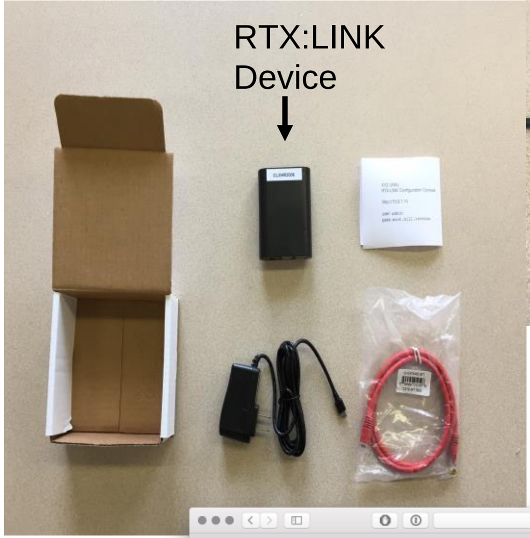
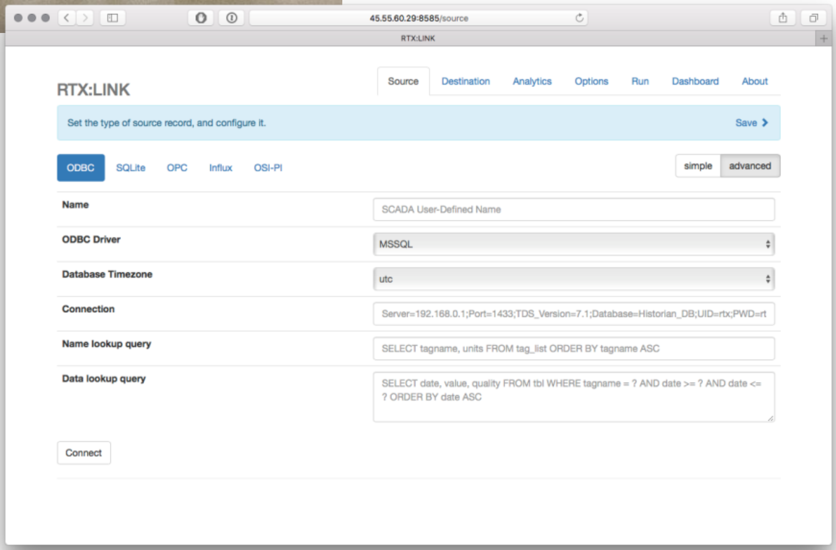
RTX:LINK

Hardware & Software Package

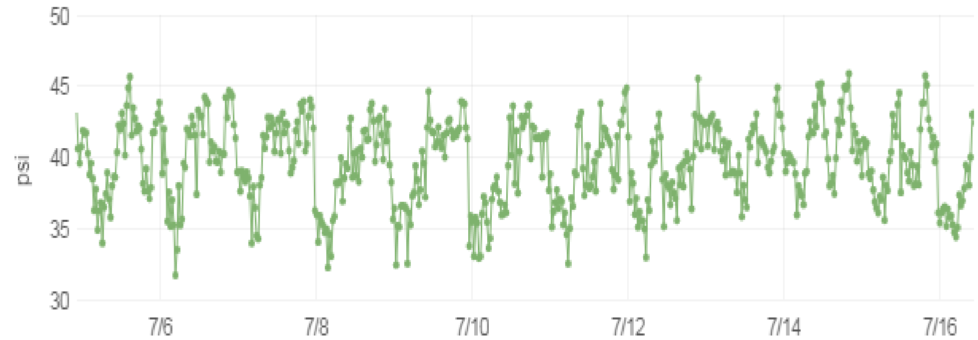
- Package delivery
- Self-configure via web browser
- Completely open-source
- Connects to variety of SCADA systems
- Runs continuously, little maintenance



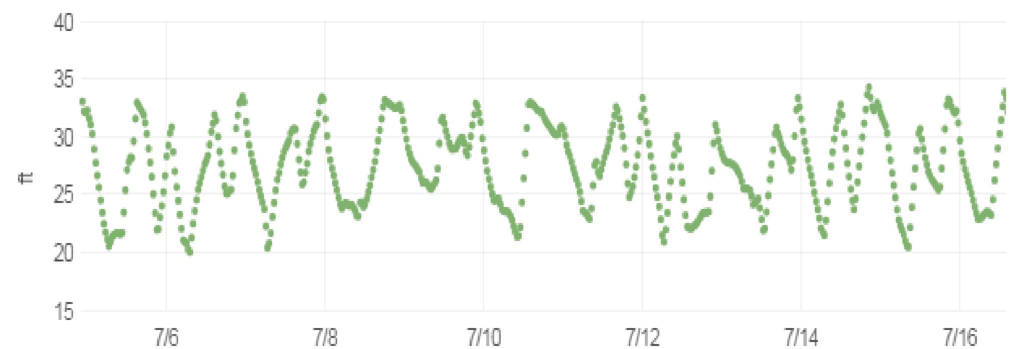


RTX:LINK Analytics

- Access and view raw SCADA data on web browsers, mobile devices, or desktops
- Data analytics including real-time statistics and trends (pressure, flows, chlorine), water age, tank turnover time, tank degree of mixing, energy usage, and system demand
- Alerts based on min/max (set point) levels or other methods

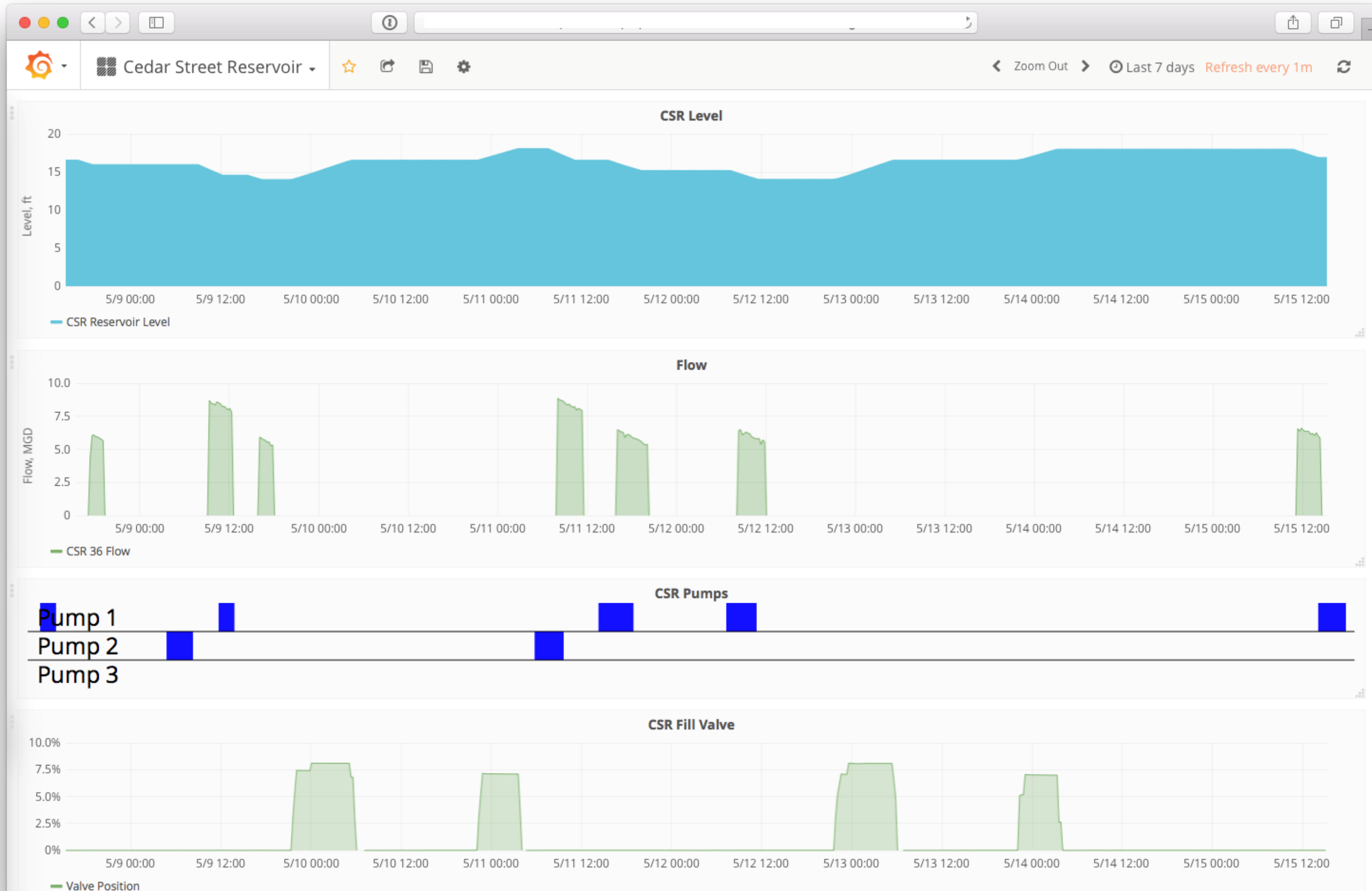


System pressure vs time



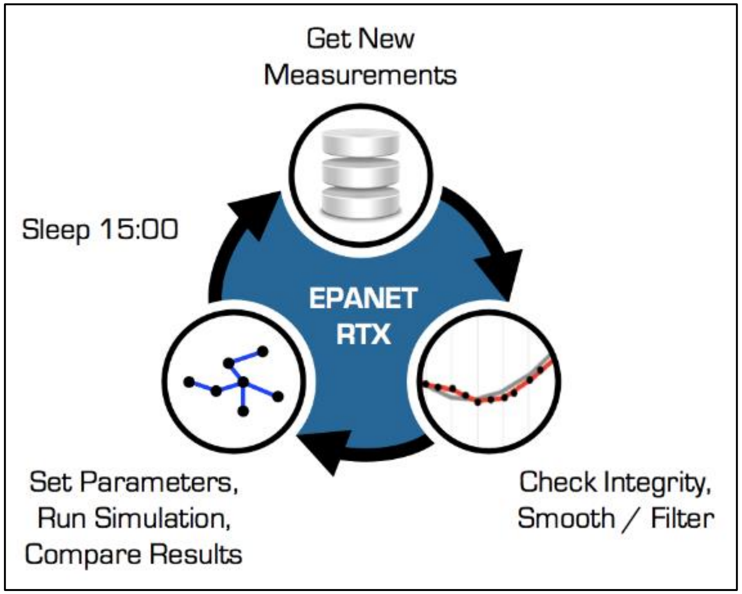
Tank level vs time

RTX:LINK - Utility Data & Analytics to Smart Phone



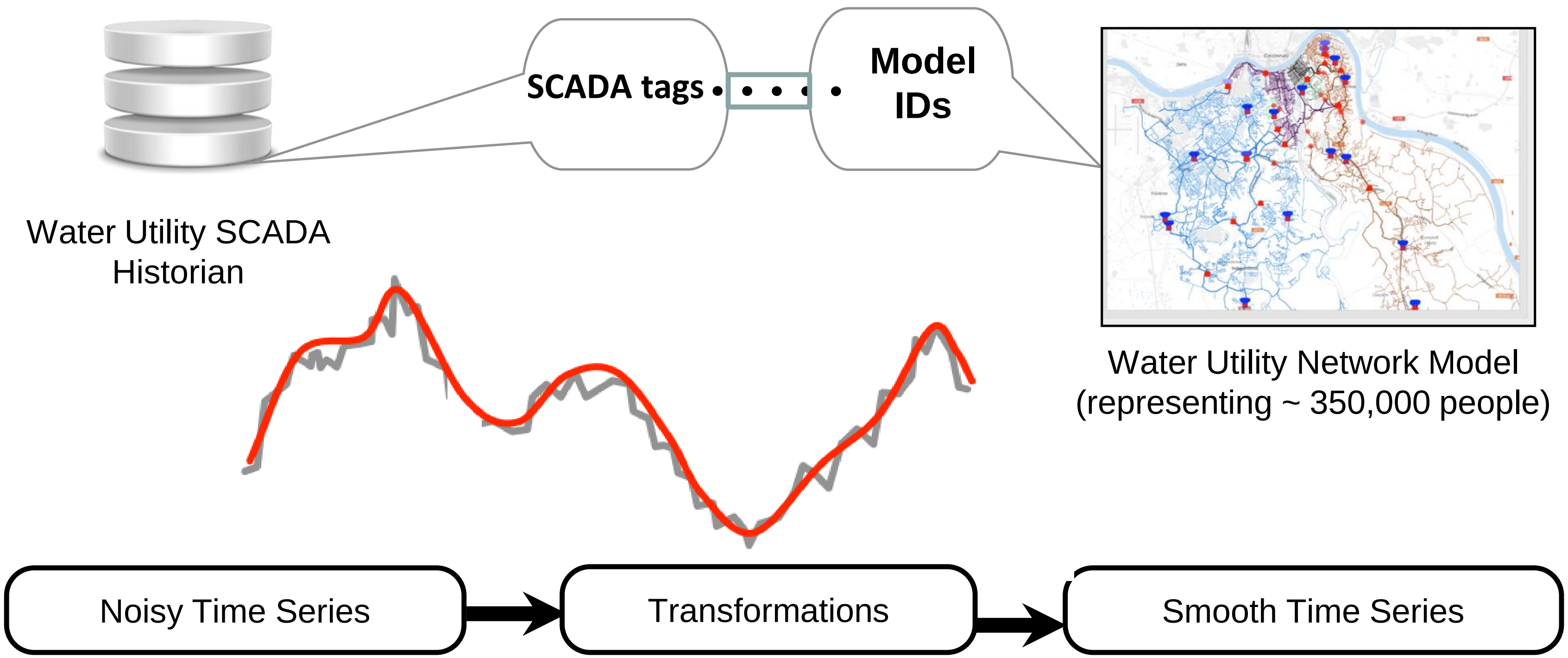
EPANET-RTX

- EPANET-RTX software brings together modeling and data in a new and powerful way
- Analytical software to integrate network model with utility SCADA operational data
- Real-time analytics for automated and routine capability to
  - Analyze problems
  - Better prepare
  - Implement response actions to mitigate consequences
- Open source project (http://openwateranalytics.github.com/epanet-rtx/)

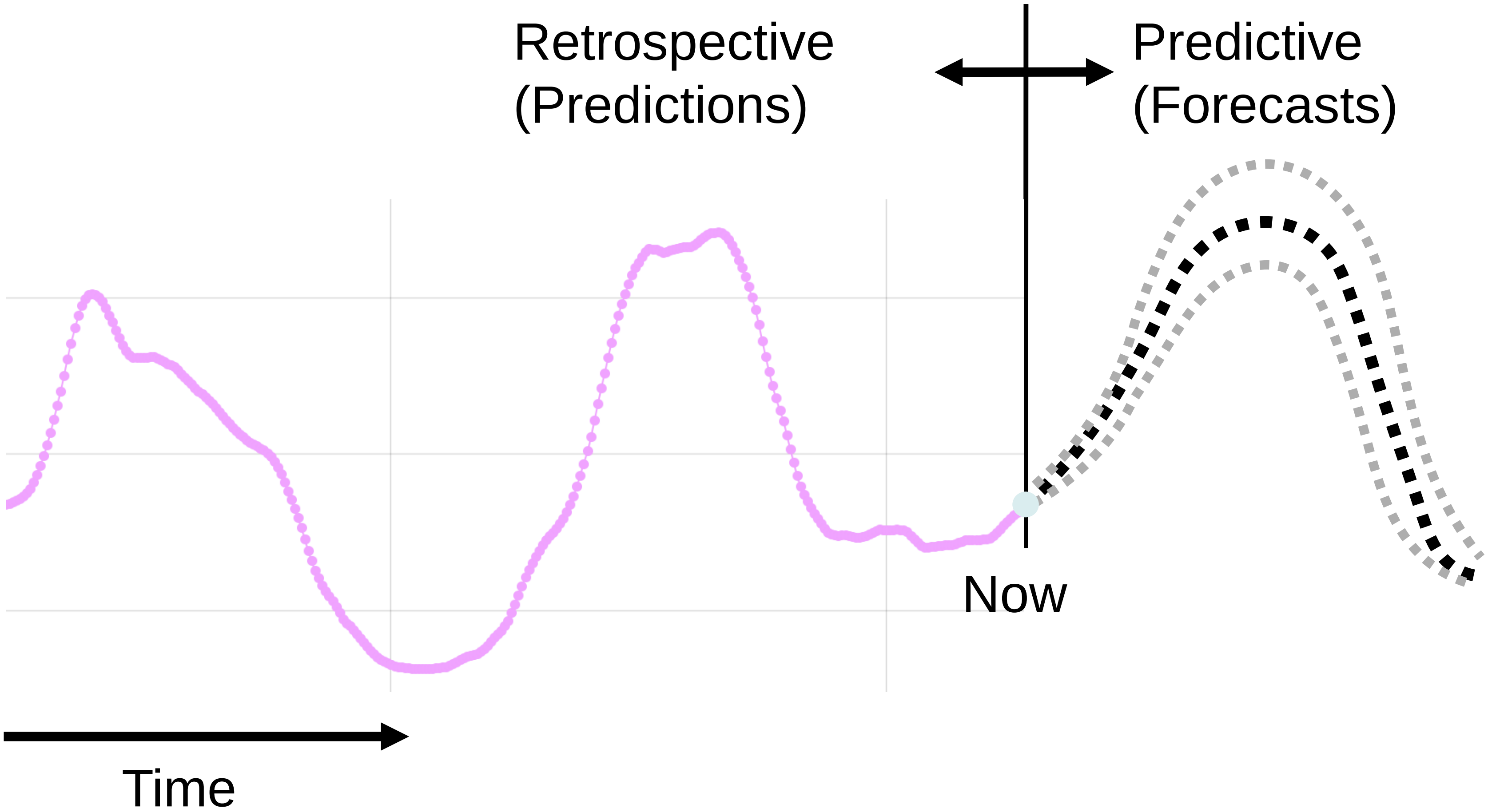


EPANET-RTX logo

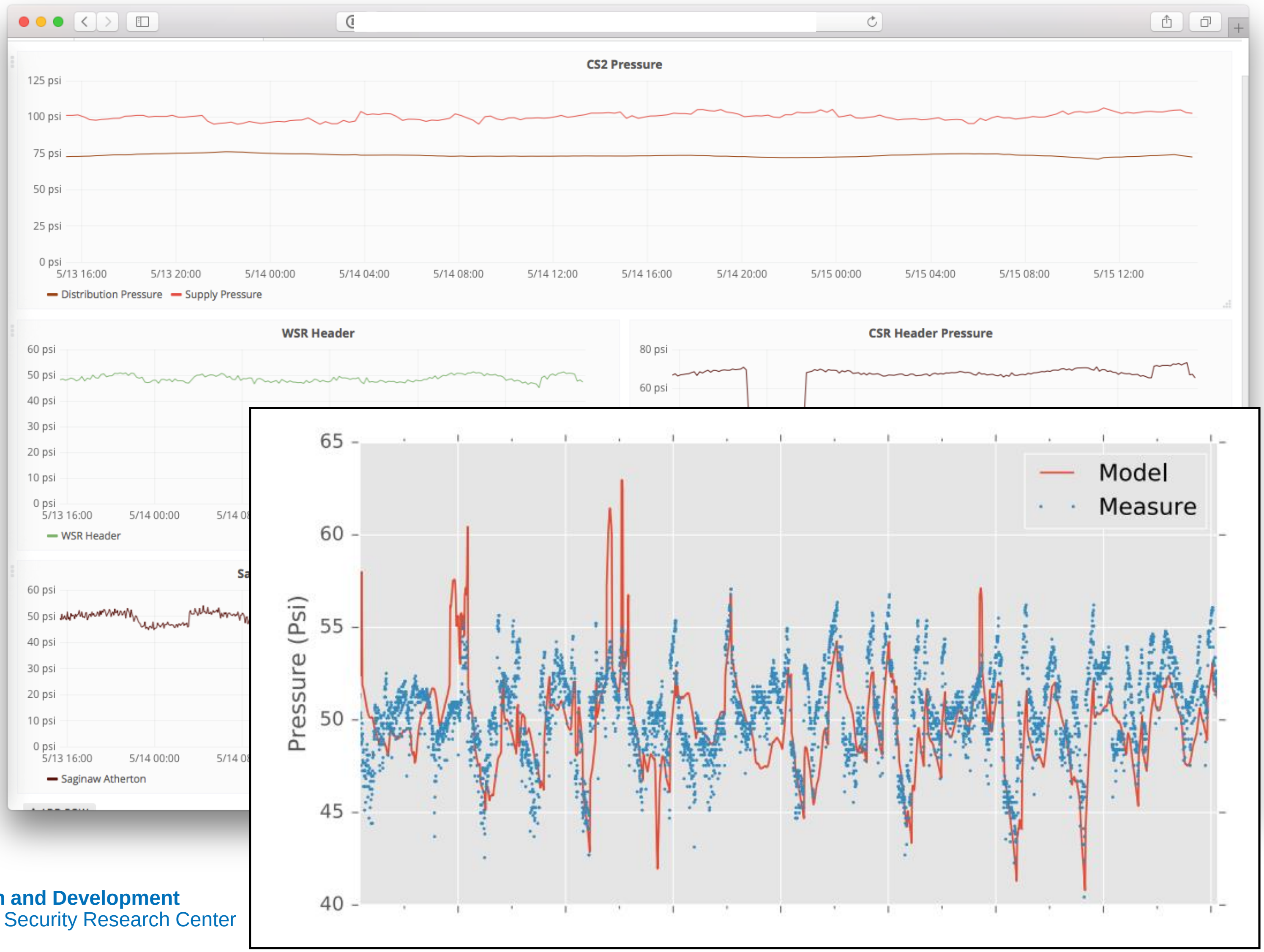
Building EPANET-RTX Network Model



Predicting System Behavior

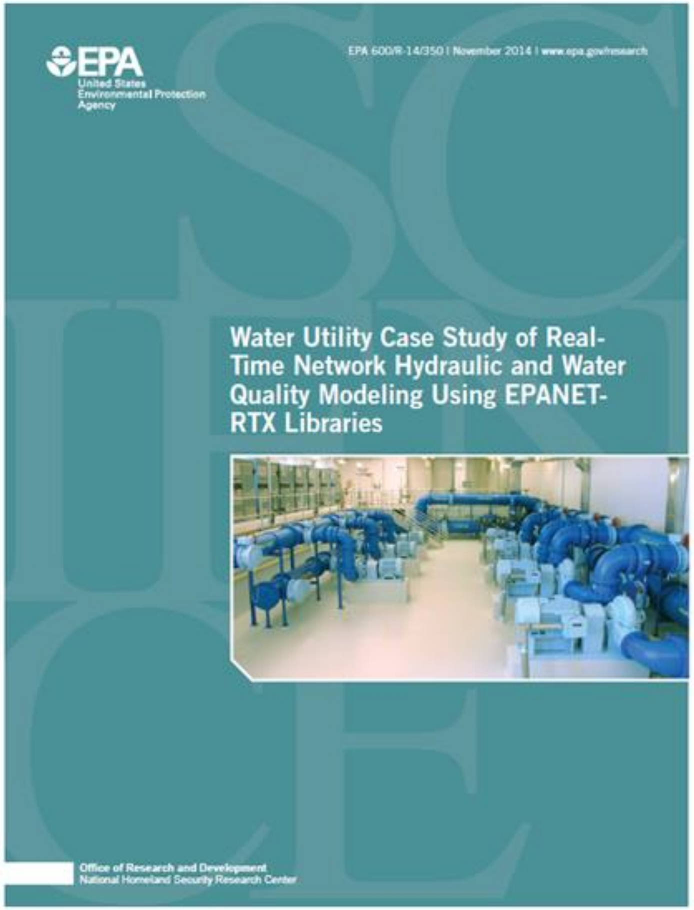


Real-Time Network Model Accuracy Dashboards



Water Utility Examples

- Northern Kentucky Water District
  - Showed real-time modeling can provide substantive benefits to operations
  - Identified potential valve problem and excessive water pumping
- City of Milford, OH
  - RTX:LINK demonstration
  - Real-time analytics for improved water quality management
- City of Flint, MI
  - Model calibration and assessment
  - Help improve operations and water quality management



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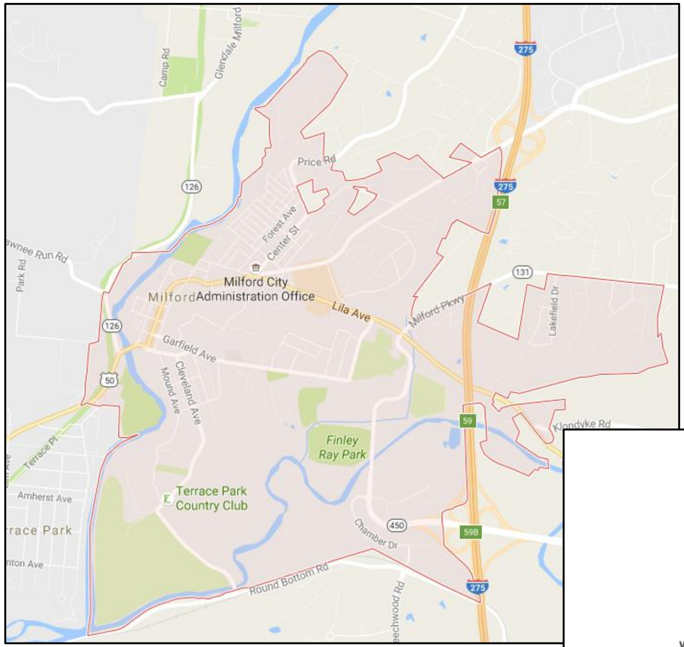
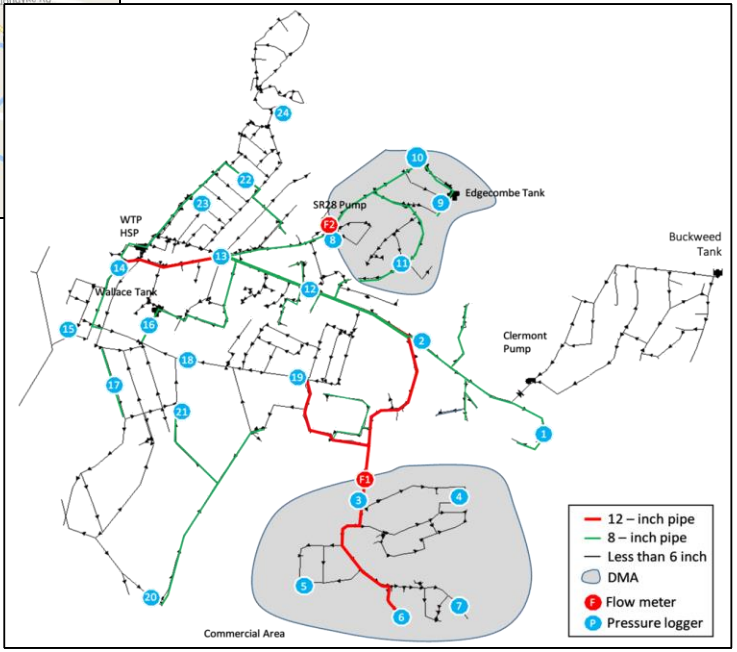
City of Milford, Ohio

- Approximately 7,000 customers
- 4 groundwater wells
- 6 pumps
- 4 tanks
- 900 pipes
- 4 square miles service area

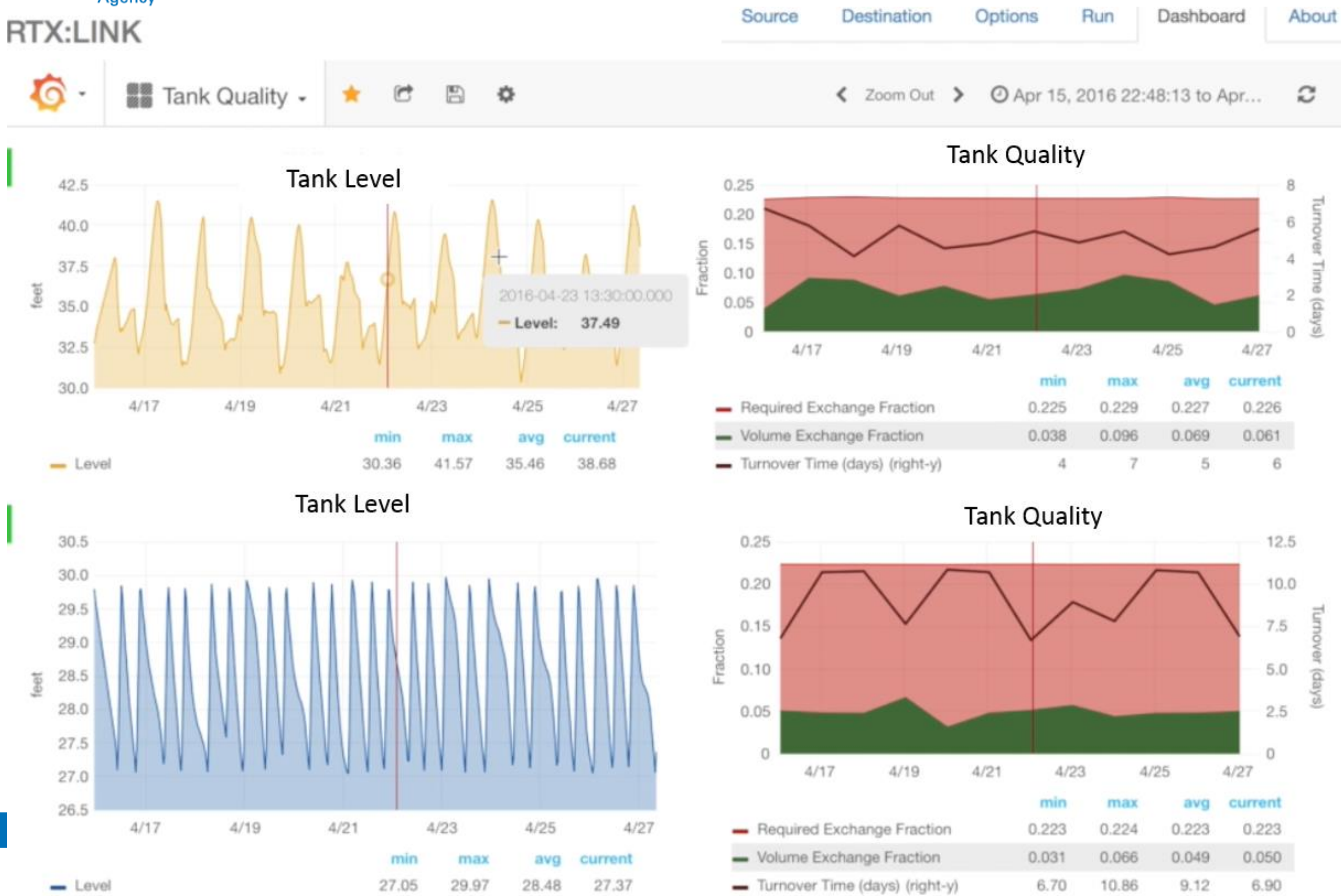


Googlemaps – City of Milford Outline



Network Model

Milford Real-Time Analytics



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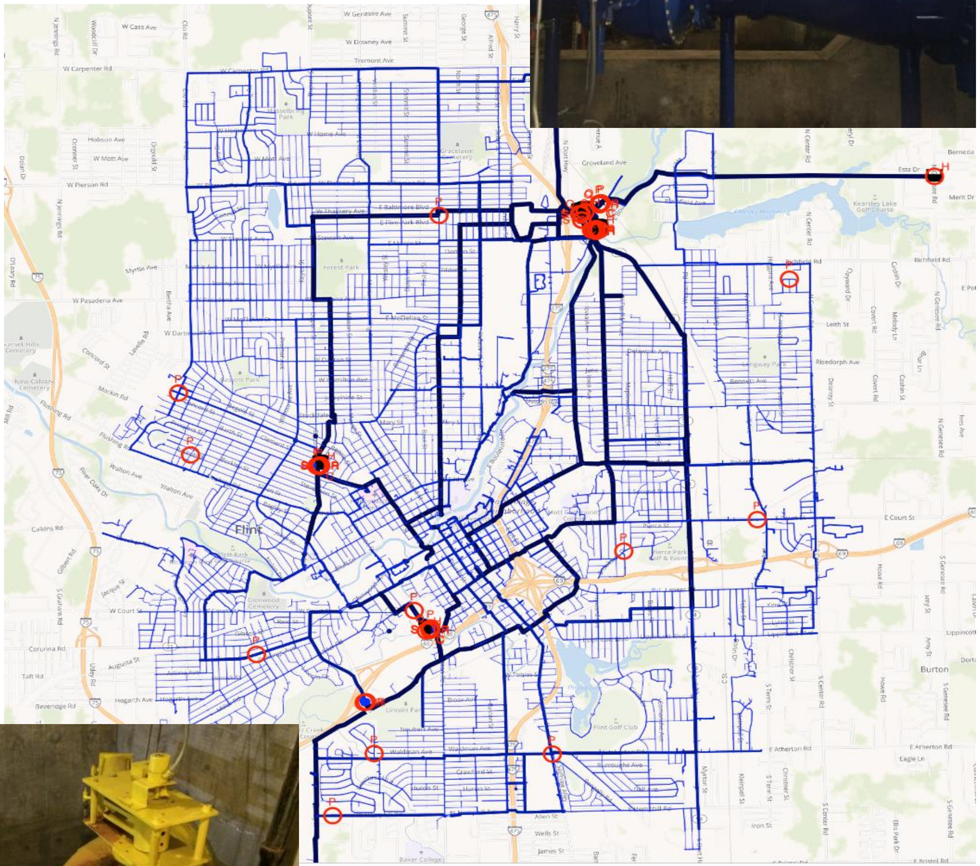
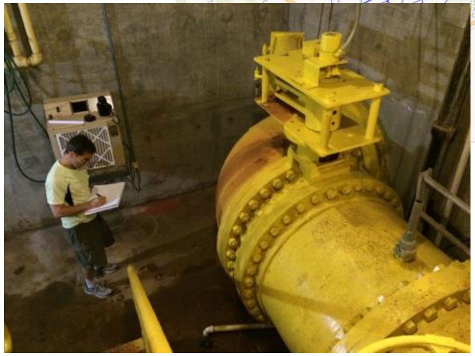
City of Flint, Michigan

- Network model update & calibration
  - Started with historical model
  - As-built drawings
  - Data from in-house studies
  - SCADA data
  - Customer billing data
  - Field visits & data collection





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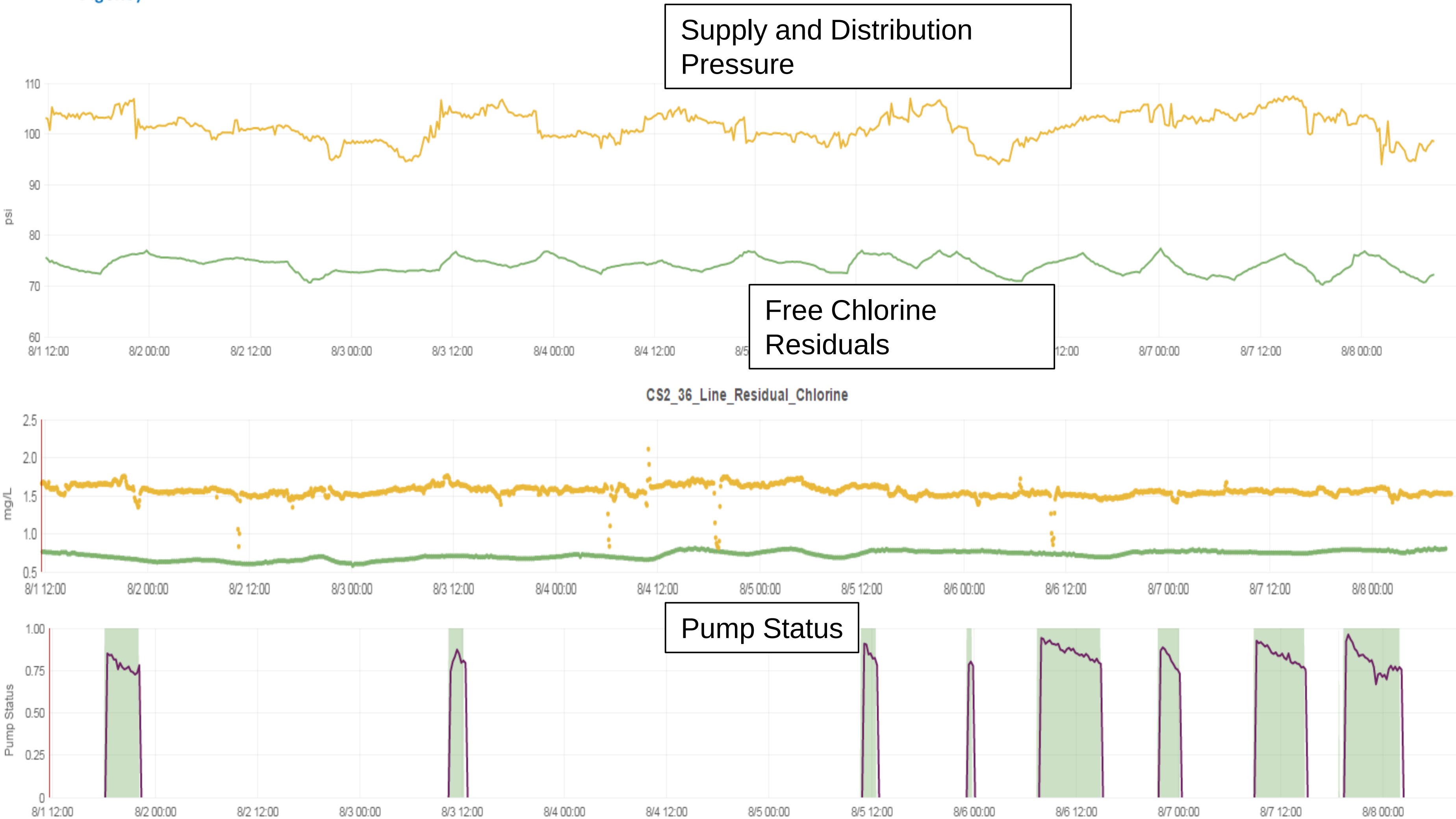
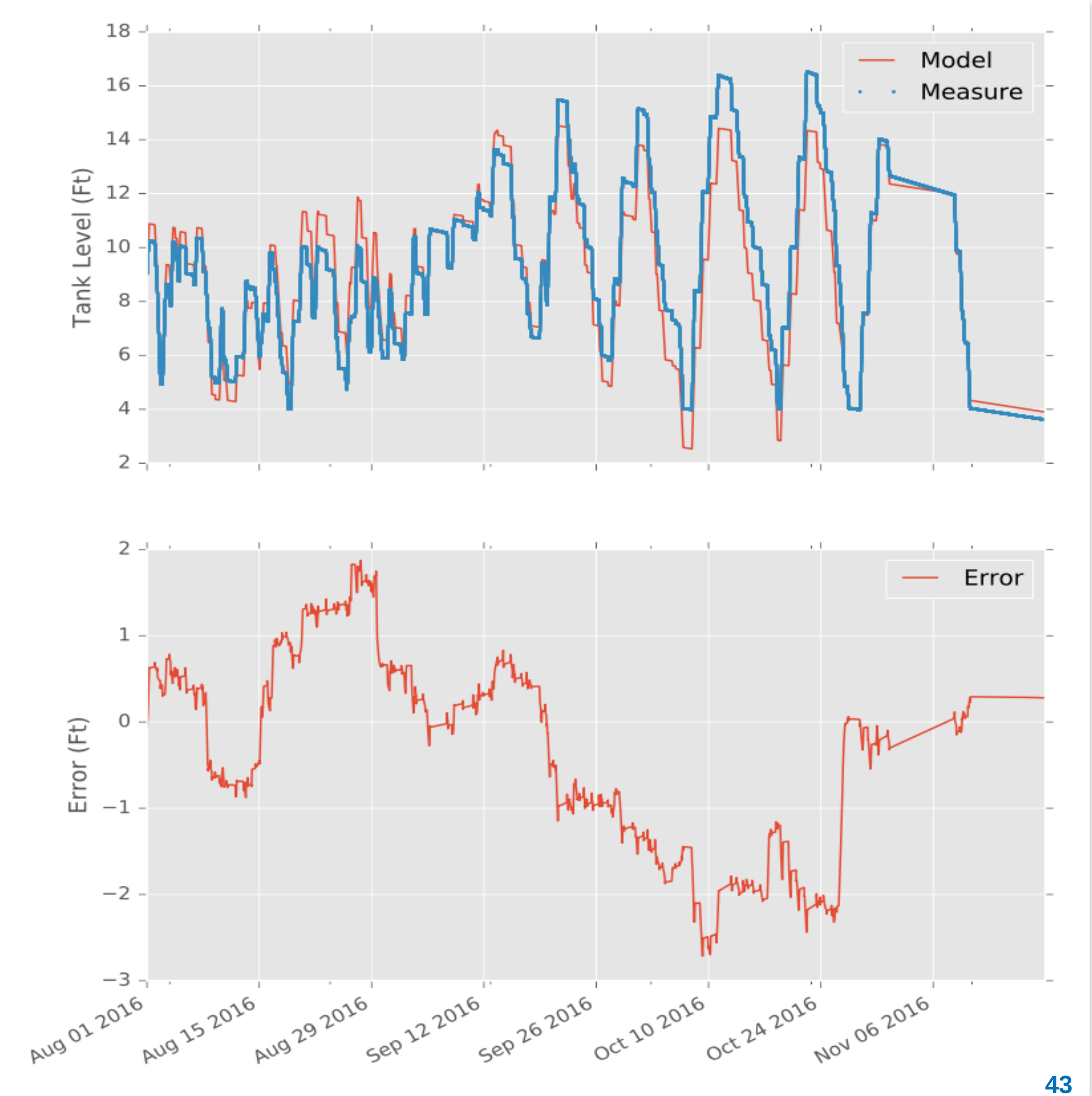
Flint RTX:LINK Analytics



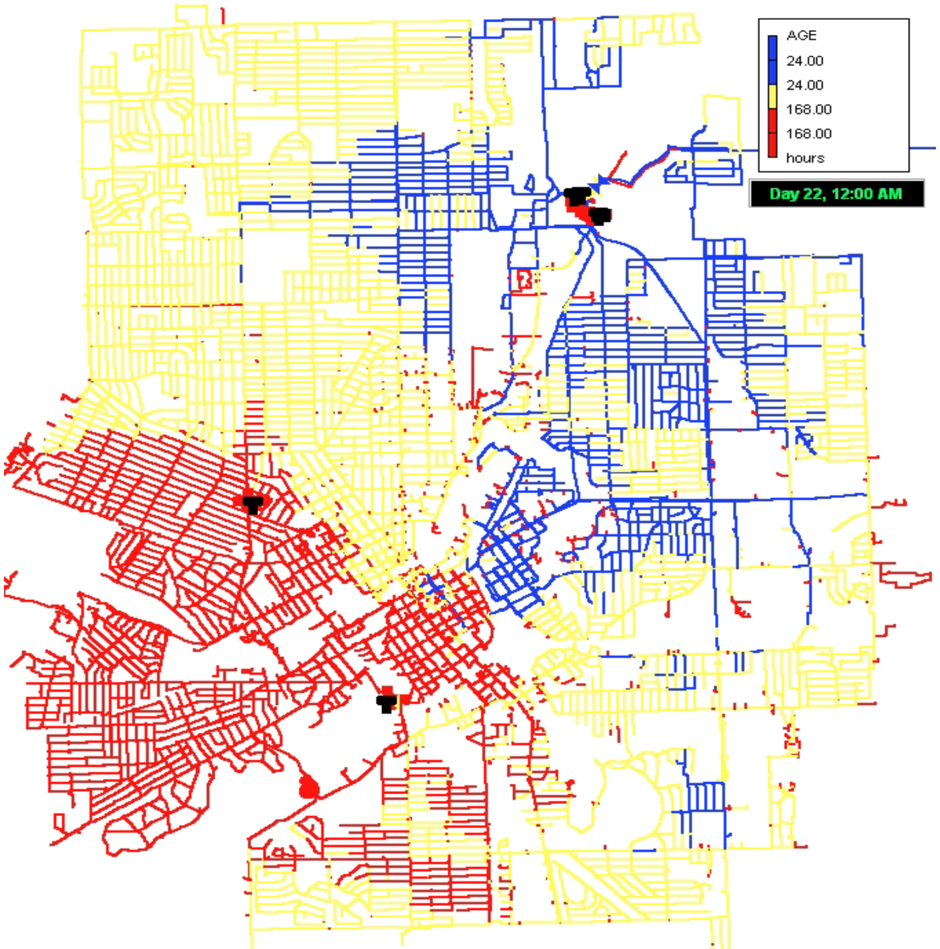
Flint Network Model Accuracy Assessment

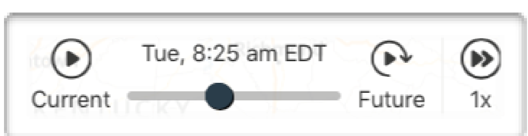
- Network model calibration assessment:
  - August-November, 2016
  - Rigorous 16-week continuous comparison
  - Distinct operational modes
- Network model accuracy assessment
  - August-November, 2017
  - Distinct operational mode
- Both assessments long compared to industry standards



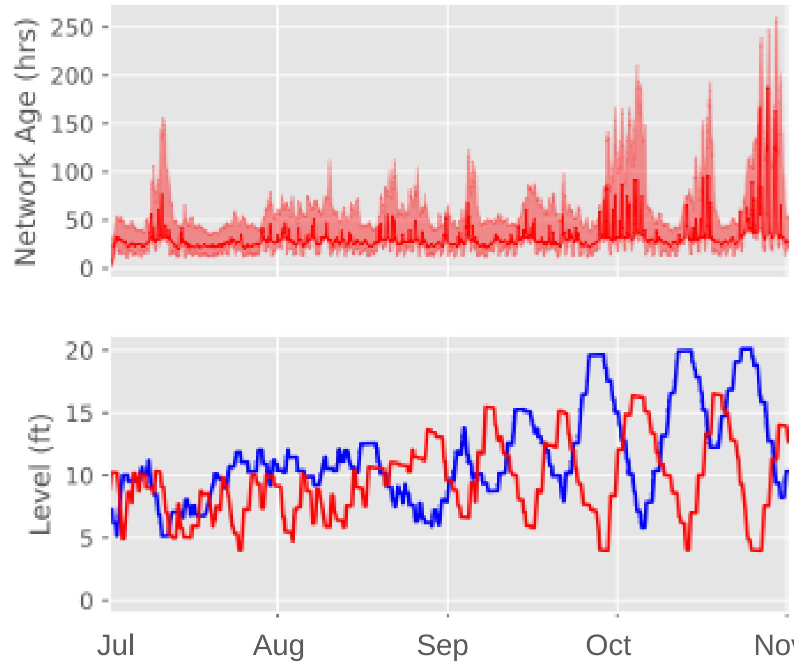
Prototype Real-Time Water Age Mapping for Flint

Day in Motion

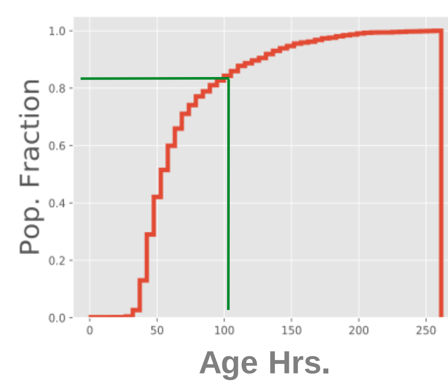




4 Month History



Day History



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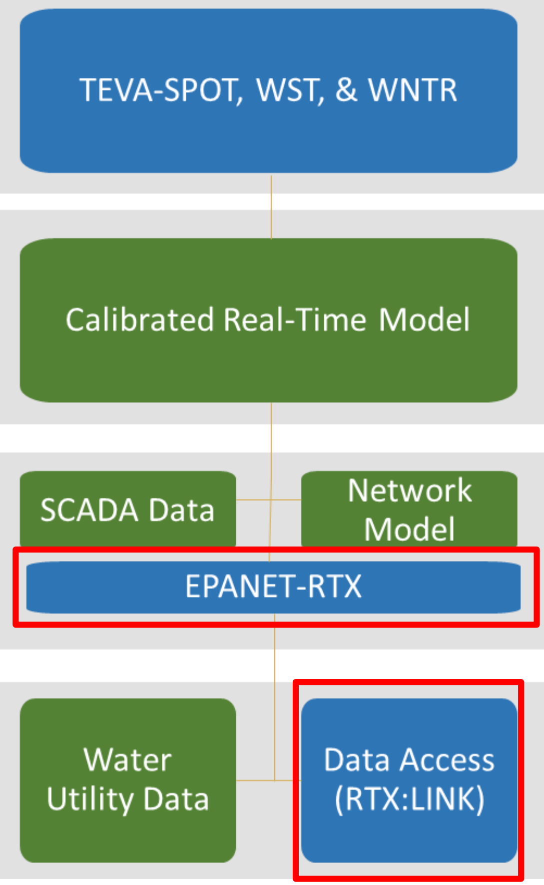
Preparedness and Response Tools

WATER SECURITY & RESILIENCE TOOLS

CALIBRATED UTILITY MODEL & DATA

DATA FUSION

DATA ACCESS



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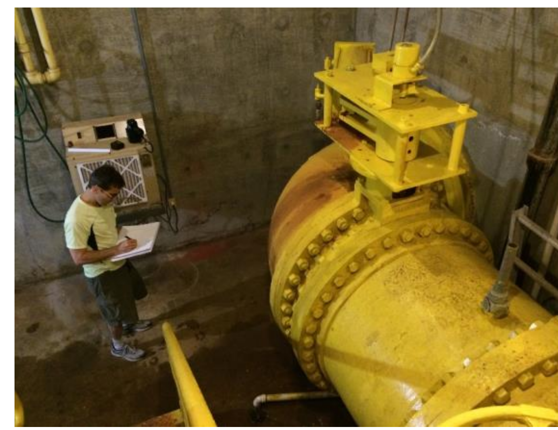
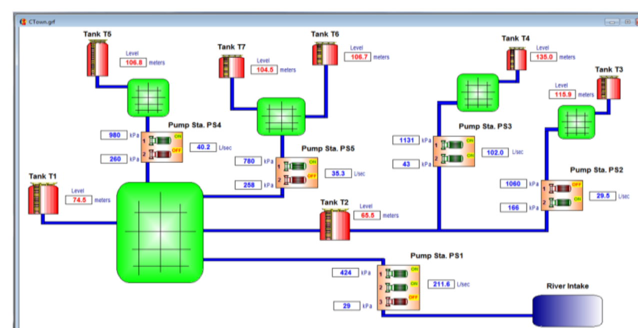
Planning and Operations

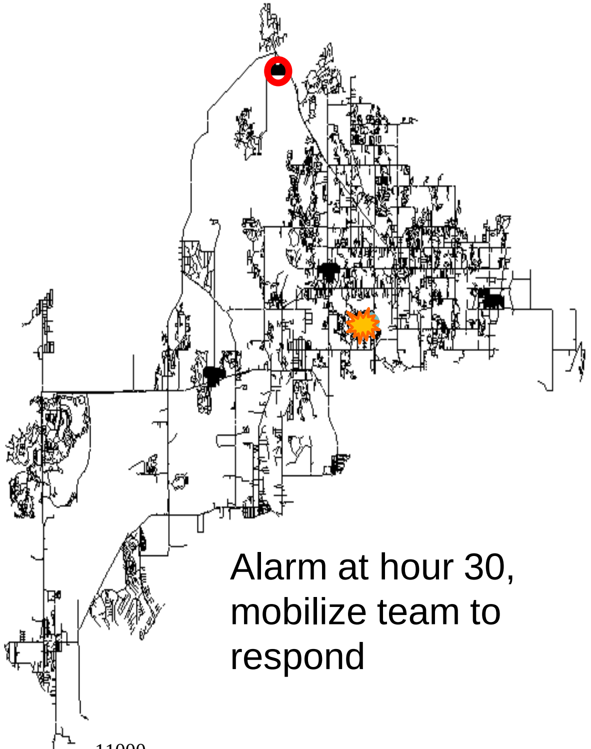
- Planning for the future
  - Sizing/locating new pipes & facilities, increasing/decreasing future demands, evaluating supplies, building resilience
- Replacing aging infrastructure
  - Main breaks, leaks and water loss, damaged infrastructure, prioritization/staging of repairs
- Optimizing operations
  - Pump schedules, tank cycling, pressure management, energy reduction



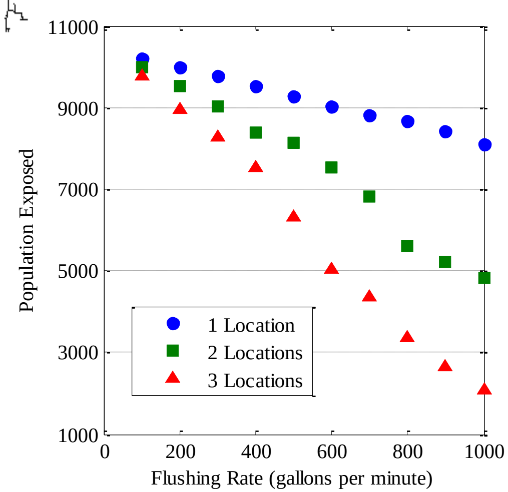


Preparedness and Response

- Real-time operations and decision-making requires
  - Integrating real-time SCADA data with network model
- Solve water quality problems
  - Customer complaints, low chlorine residuals, high water age, disinfection byproducts
- Prepare for and handle emergencies
  - Power outages, fires, source water spills, natural disasters, cyber attacks



Alarm at hour 30, mobilize team to respond



Questions

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Disclaimer

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- Partial support was provided by the USEPA DeRisk small systems research center at the University of Colorado – Boulder (R. Summers, PI)