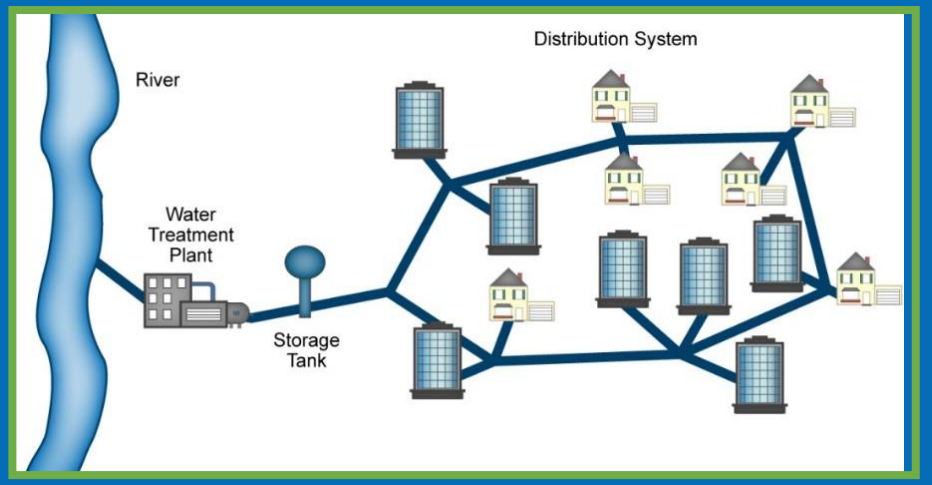
United States Environmental Protection Agency

EPA Tools & Resources Webinar: Drinking Water Models and Tools

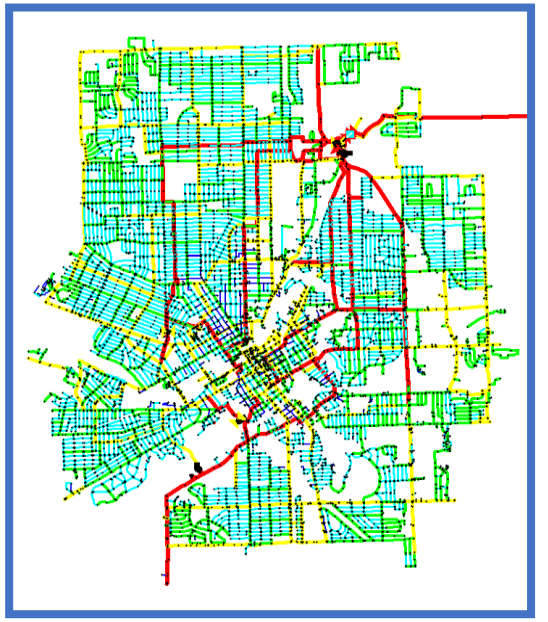
Regan Murray, PhD
US EPA Office of Research and Development

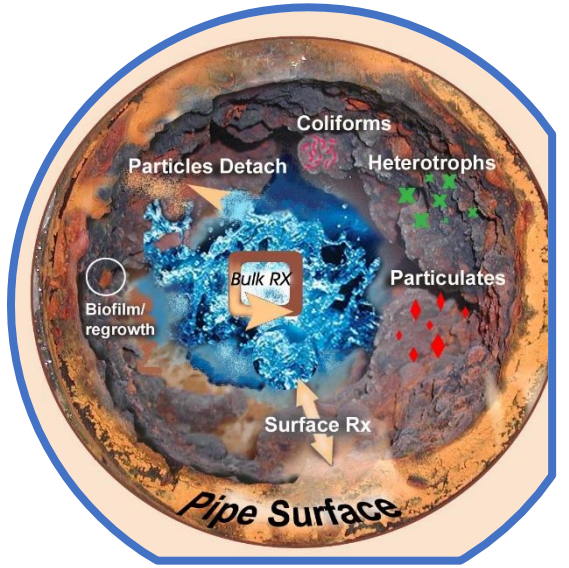
November 18, 2020



Background and Motivation

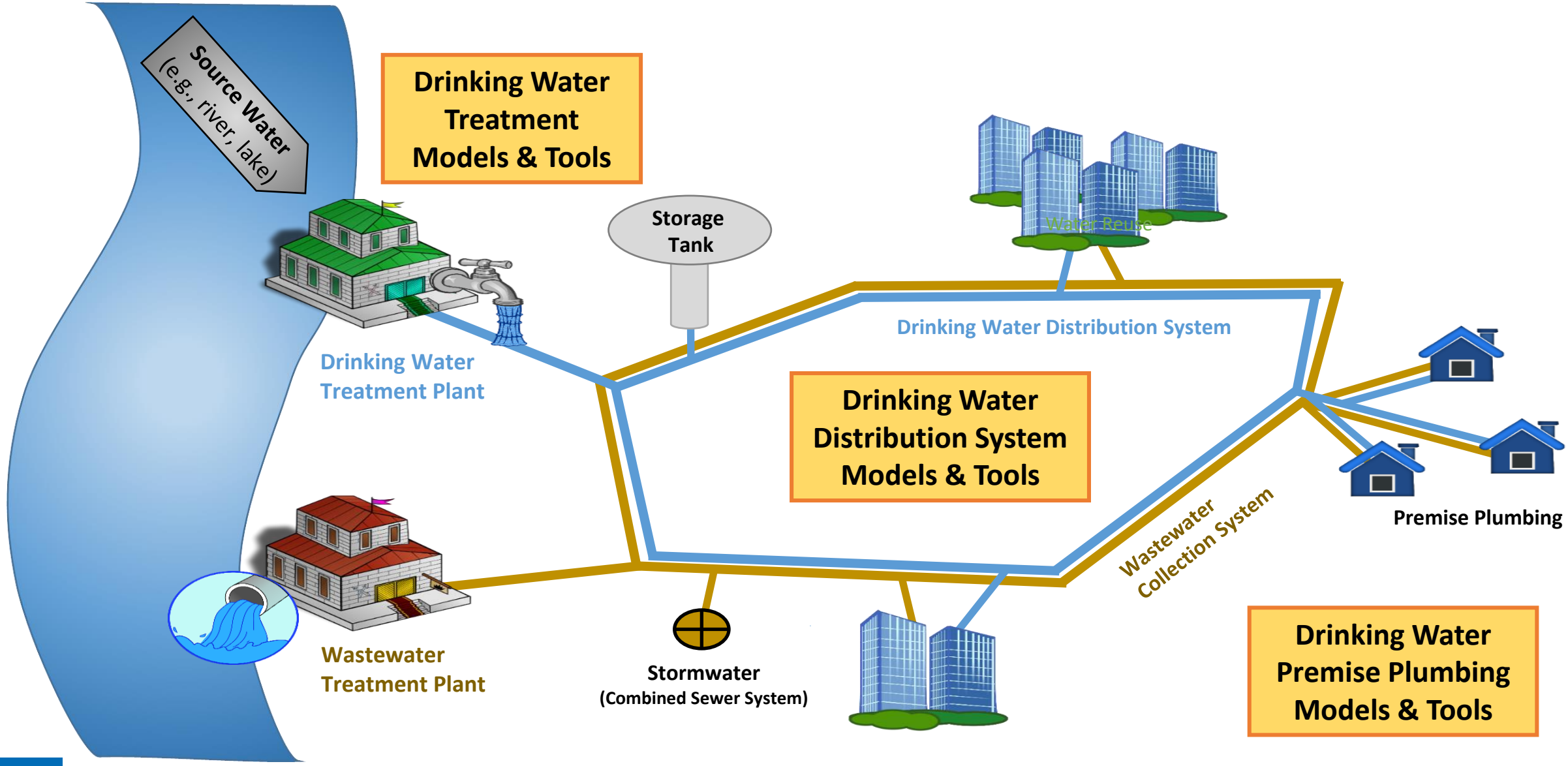
- Drinking water systems are large and complex.
- Changes to treatment processes or distribution systems can affect water quality downstream in unforeseen ways.
- Modeling is a powerful, cost-effective tool to predict and evaluate the effects of such changes prior to implementing them in the real system.



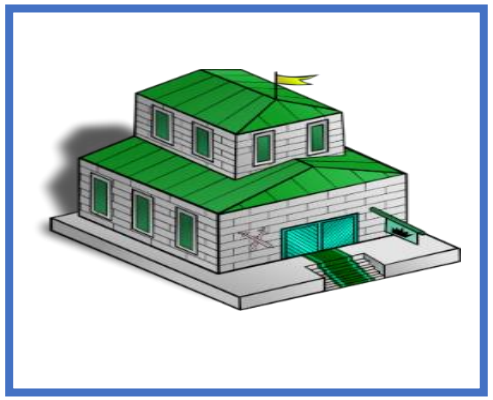


EPA United States Environmental Protection Agency

Water Infrastructure

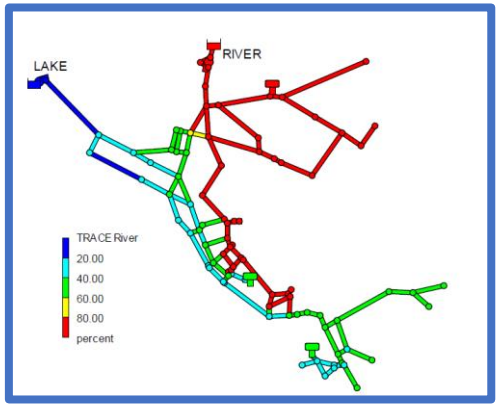


Drinking Water Models and Tools



Drinking Water Treatment Models & Tools

- CFD
- CBCS
- FCCAS
- FCEDTS
- WTM
- ETDOT
- Treatability DB



Drinking Water Distribution System Models & Tools

- EPANET
- EPANET-MSX
- EPANET-RTX
- RTX:LINK
- TEVA-SPOT
- CANARY
- WNTR

Drinking Water Premise Plumbing Models & Tools

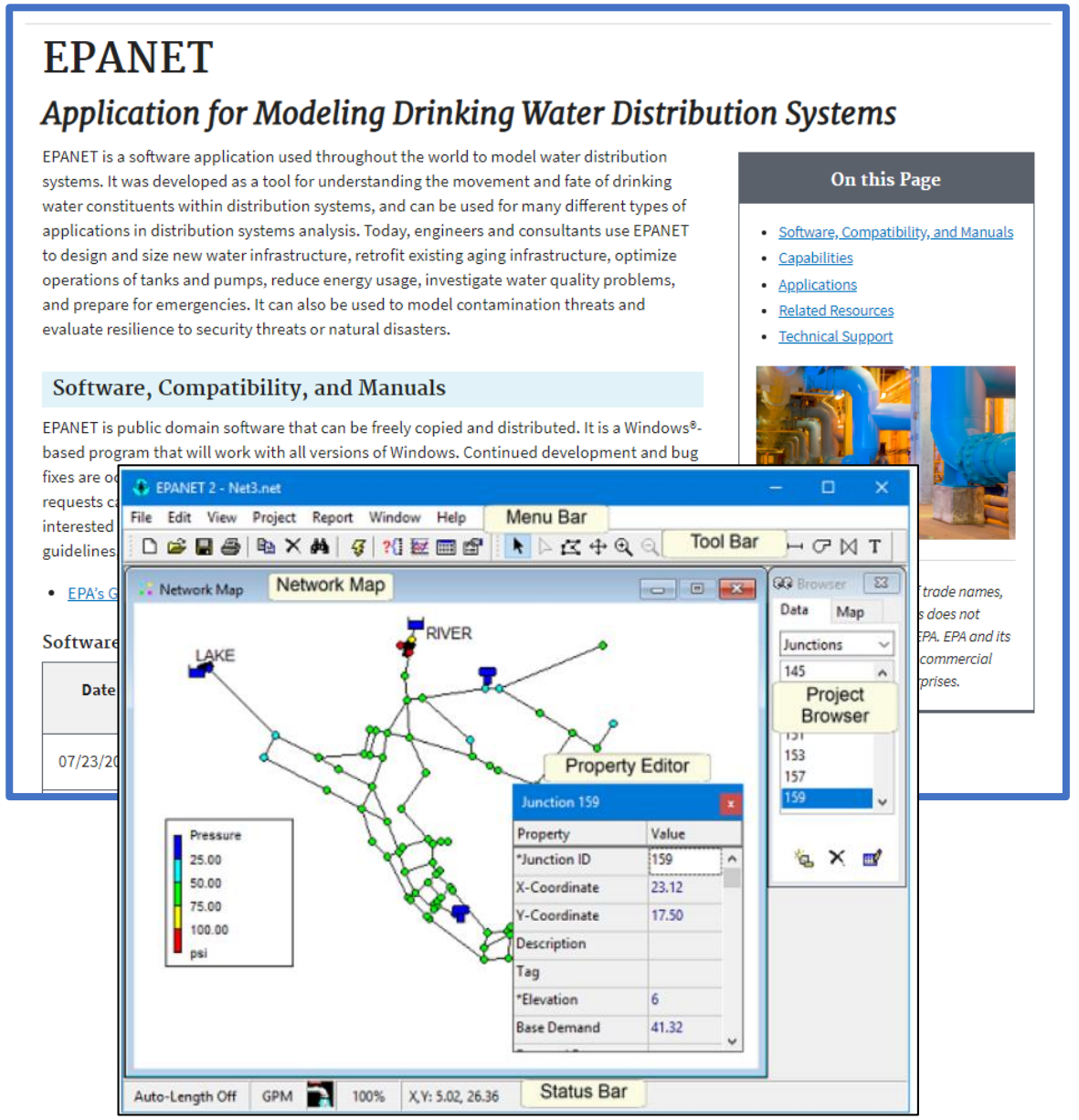
- PPM Tools

Access these models and tools through EPA's Science Models and Research Tools (SMaRT) Search

Distribution System Model: EPANET

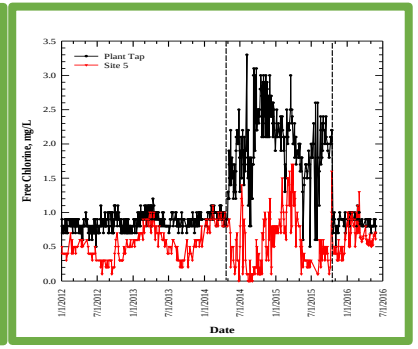
- Simulates hydraulics within a water distribution network.
- Models decay/growth of a single substance.
- More than 50,000 downloads per year.
- Components utilized for multiple commercial software packages.
- Latest official release: version 2.2 in July 2020.

epa.gov/water-research/epanet



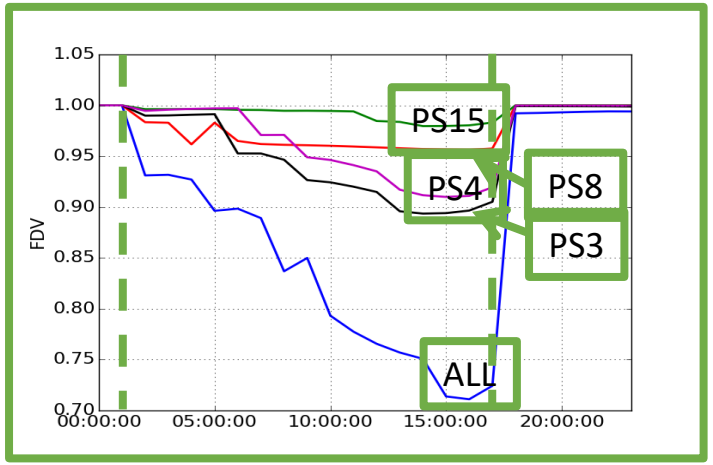
EPANET Typical Uses and Applications

Solving Regulatory Problems

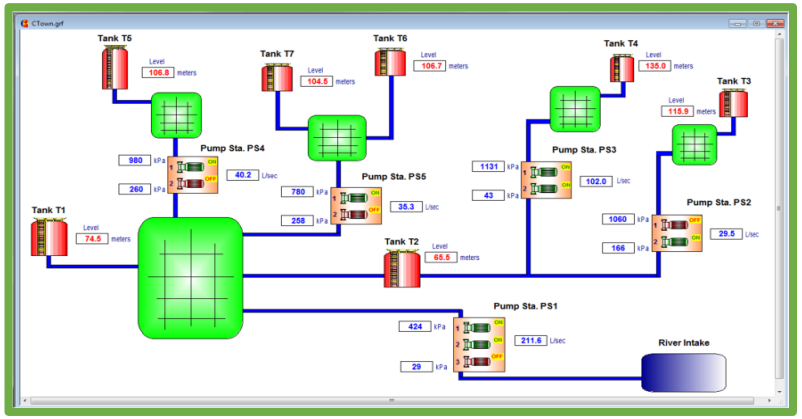


Designing and Replacing Aging Infrastructure

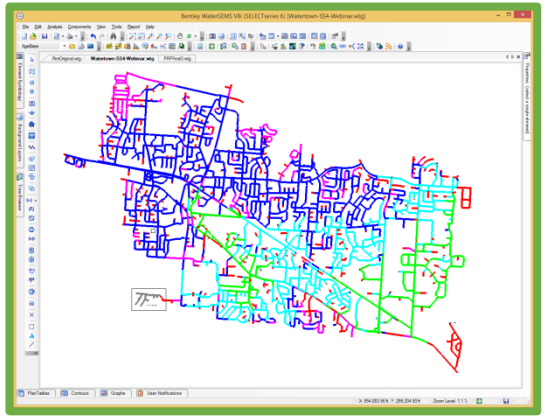
Preparing for Emergencies



Optimizing Operations to Improve Water Quality

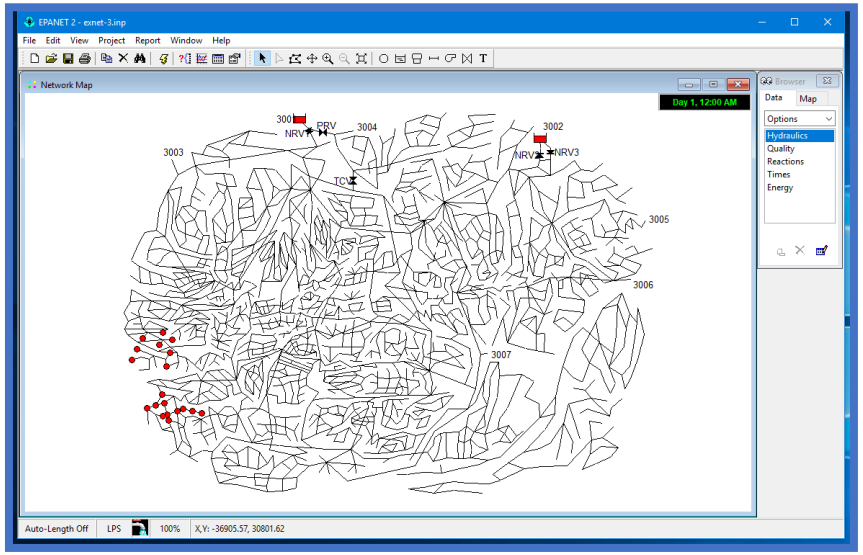


Real-time Operations and Decision Making



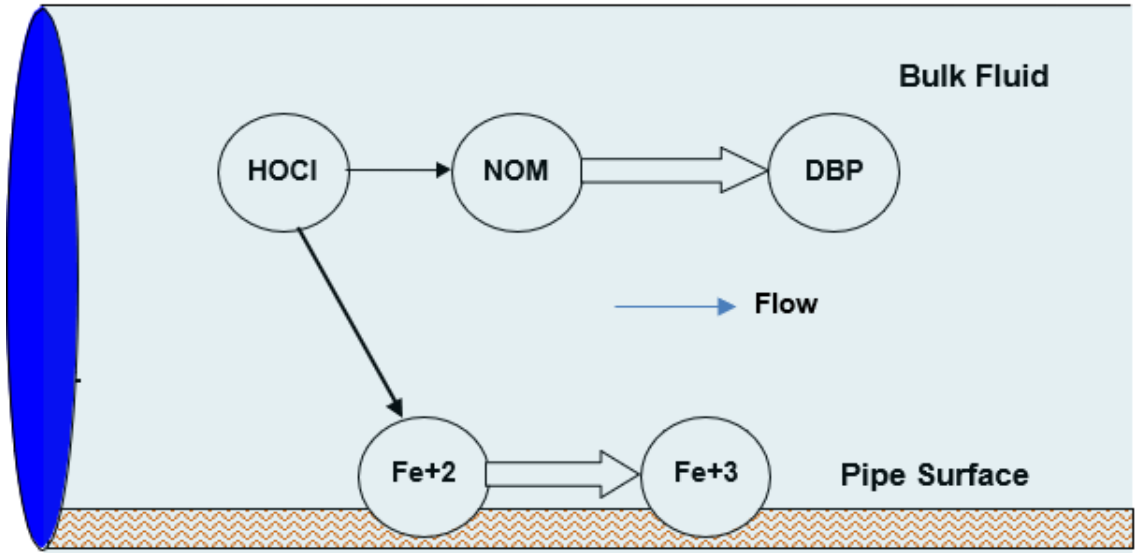
EPANET Recent Updates *(version 2.2)*

- Online User Manual
- Testing and QA
- User interface
- Improved solution performance and accuracy
  - Pressure dependent demand analysis
  - Water quality mass balance
  - Handling of low flows
  - Convergence criteria
- External contributors



Distribution System Model: EPANET-MSX

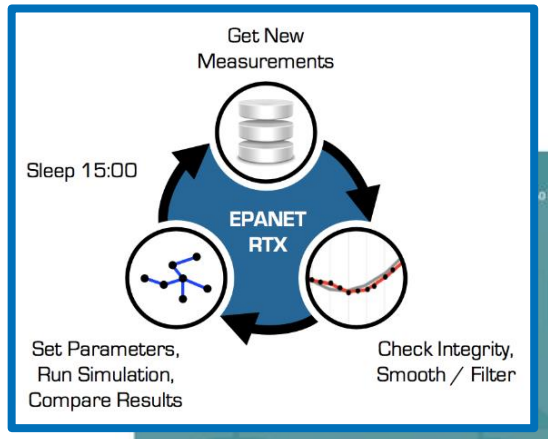
- EPANET-MSX can model the following:
  - Adsorption/desorption on pipe walls
  - Attachment to biofilms
  - Chemical reactions
  - Biological growth and decay
- Planned features:
  - Graphical user interface
  - Dispersion modeling
  - Parcel tracking
  - Built in contaminant fate and transport models

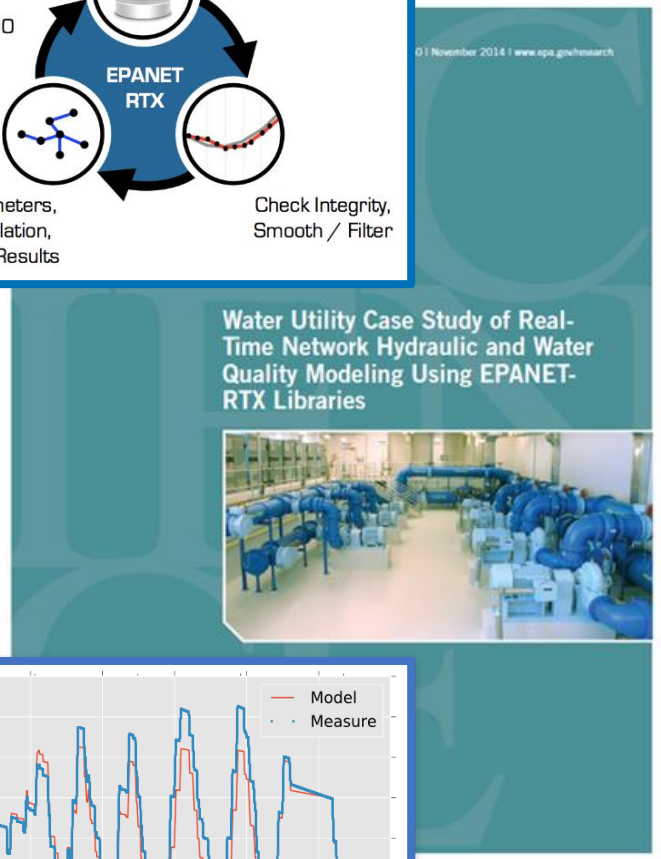


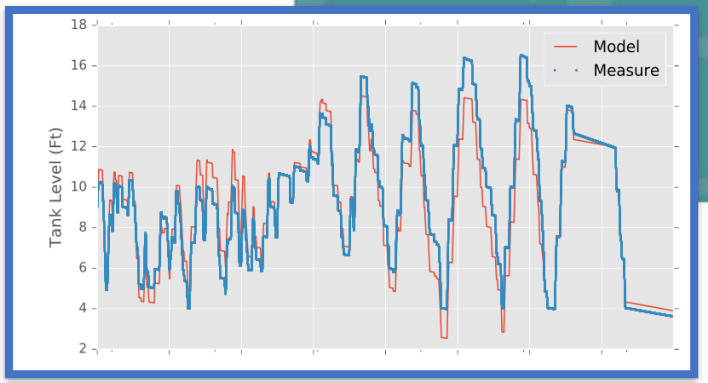
epa.gov/water-research/epanet

Distribution System Model: EPANET-RTX

- EPANET in real-time.
- Suite of software libraries to integrate EPANET model with SCADA operational data.
- Real-time analytics for automated:
  - Forward and hind cast
  - Model calibration
  - Simulate and compare operational decisions
- Continuous comparison and analysis between model and SCADA outputs allowing for more accurate predictions.



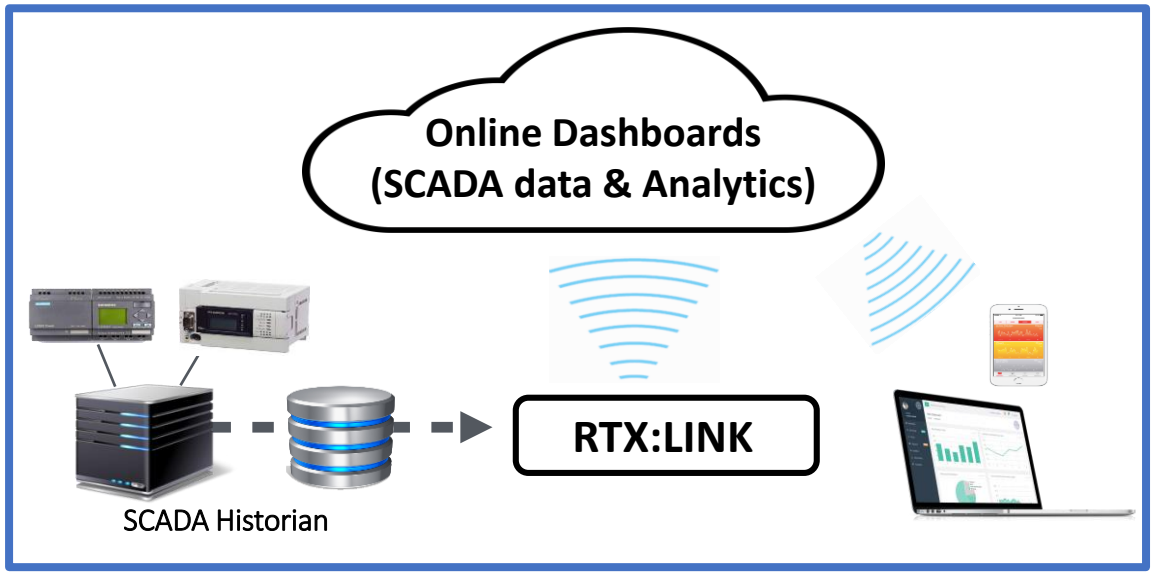


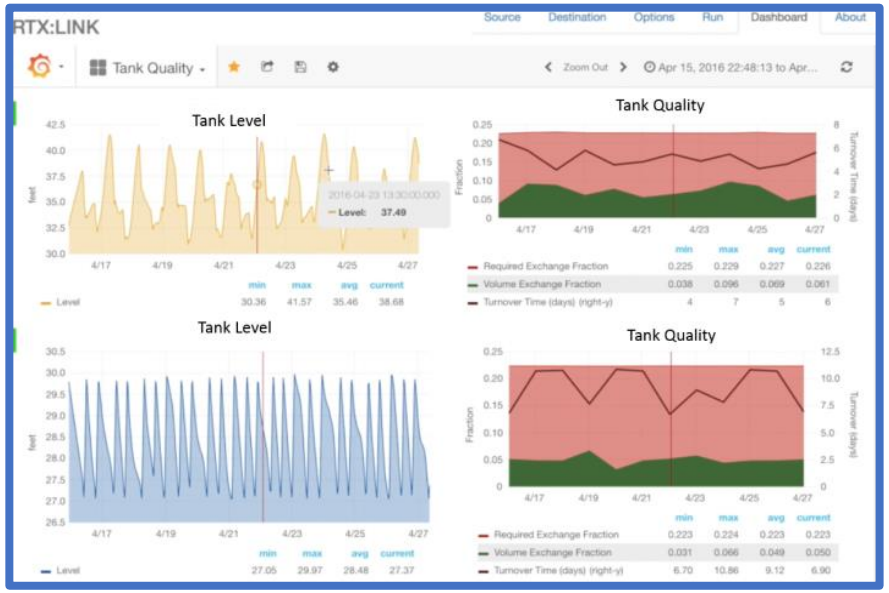


Distribution System Tool: RTX:LINK

RTX:LINK provides the technology to view water system data and simple analytics on smart phones and mobile devices.

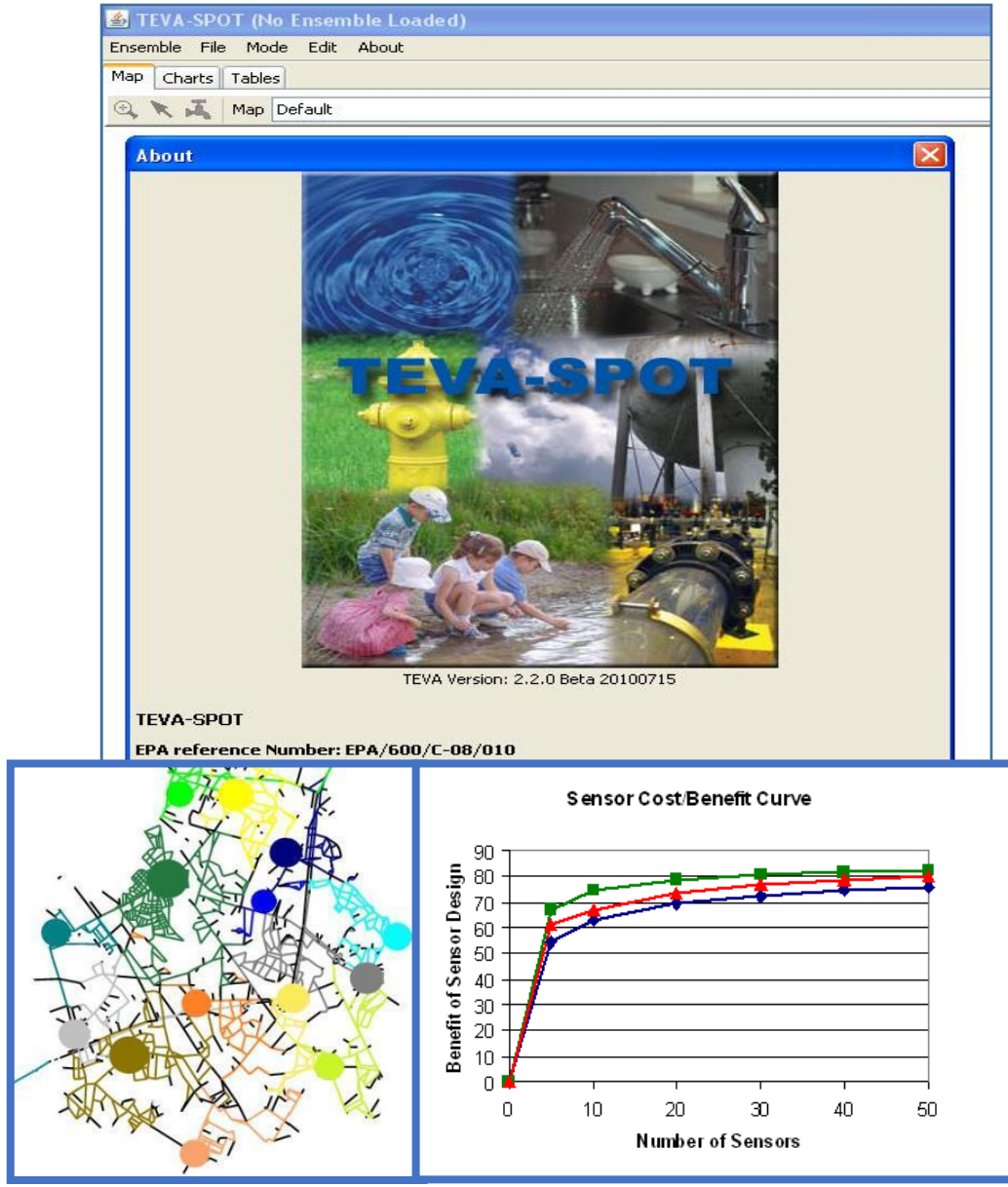
- Available for free on EPA's website.
- Shows real-time statistics and trends, water age, tank turnover time, tank degree of mixing, energy usage and system demand.
- Can alert based on min/max (set point) levels or other methods.
- Helps support rapid and accurate decision making at water utilities.





Distribution System Model: Sensor Placement

- TEVA-SPOT:
  - Threat Ensemble Vulnerability Assessment
  - Sensor Placement Optimization Tool
- Assess impacts of contamination incidents.
- Optimize sensor network designs.
- Evaluate/compare the performance of different sensor layouts.
- Command line (research) and Graphical User Interface (end user) versions available.

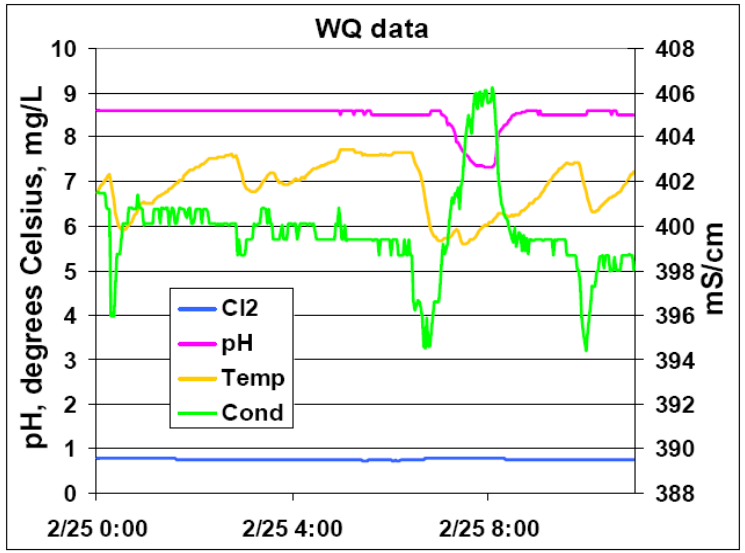


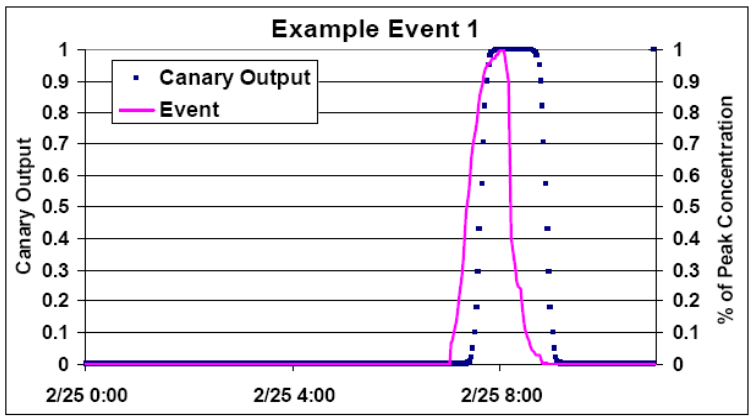
Distribution System Tool: CANARY

CANARY is a water quality event detection software.

- Monitors water quality data at multiple sensor locations continuously.
- Recognizes recurring water quality patterns.
- Ignores data during periods of sensor malfunction or hardware alarms.
- Analyzes data using multiple statistical algorithms.
- Alerts during periods of anomalous water quality.
- Produces graphics for analysis.

https://github.com/USEPA/CANARY/releases/tag/v4.3.3

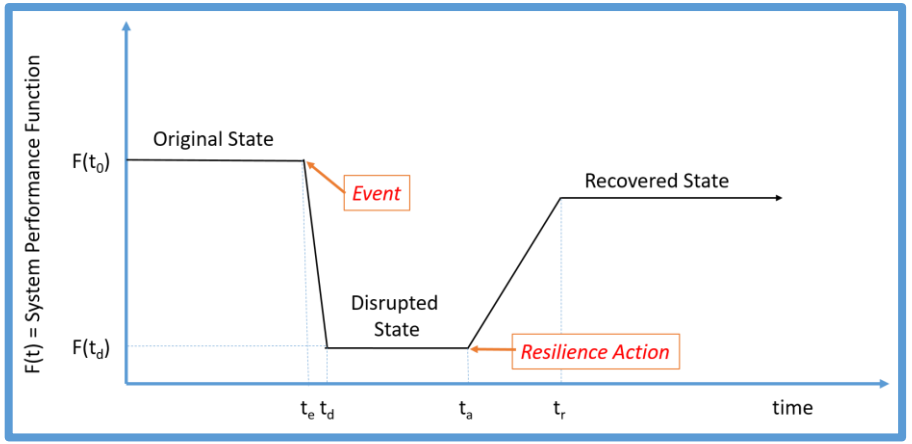


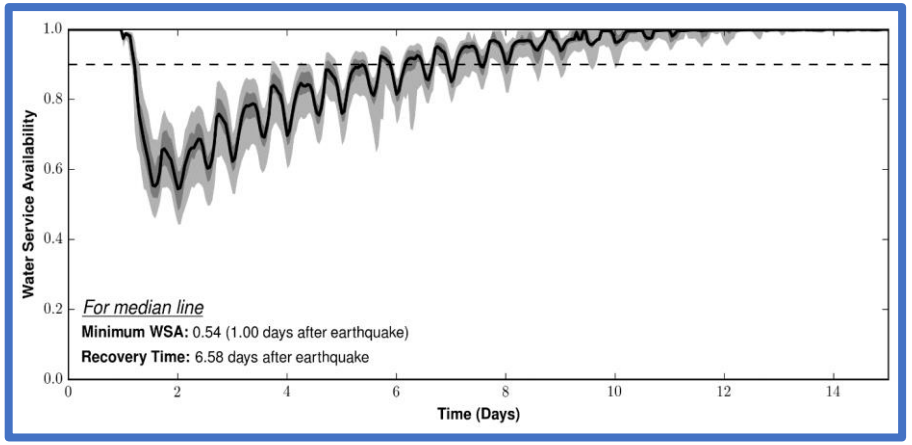


Distribution System Tool: WNTR

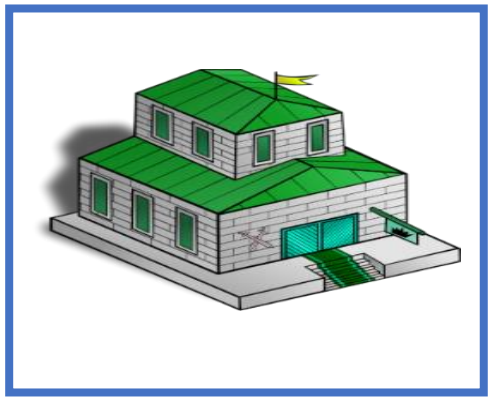
- Simulates disaster scenarios such as earthquakes, power outages, floods, and contamination incidents.
- Predicts damage to infrastructure.
- Calculates resilience metrics.
- Evaluates response and mitigation strategies to improve resilience.

https://github.com/USEPA/WNTR





Drinking Water Models and Tools



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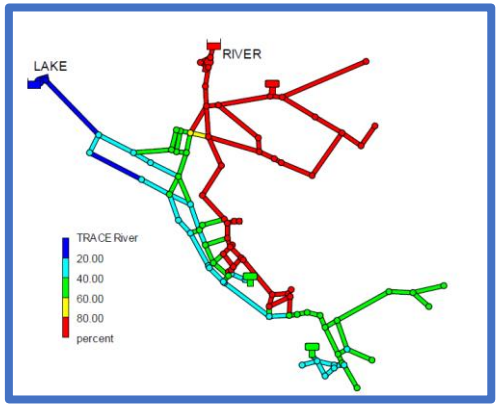

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Drinking Water Premise Plumbing Models & Tools

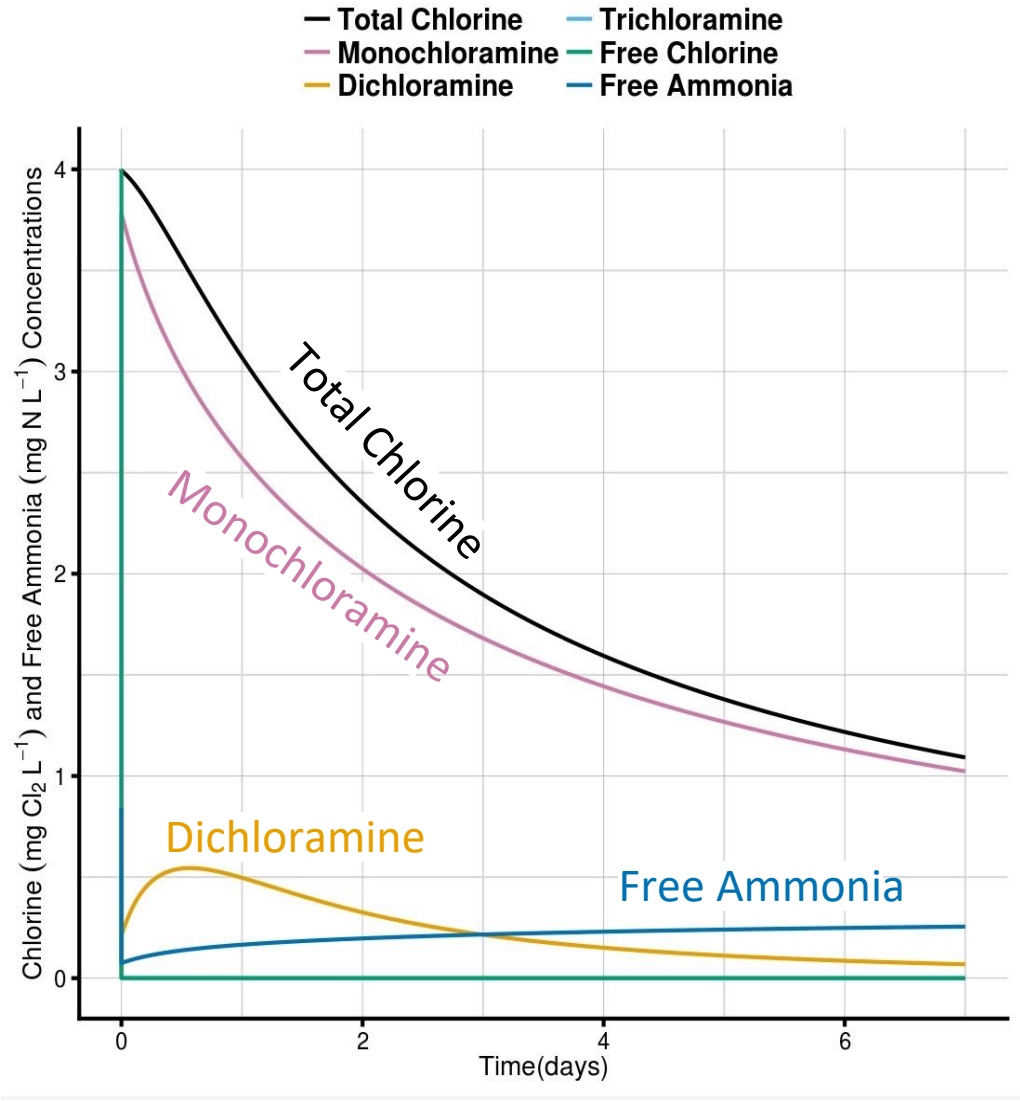
- PPM Tools

Access these models and tools through EPA's Science Models and Research Tools (SMaRT) Search

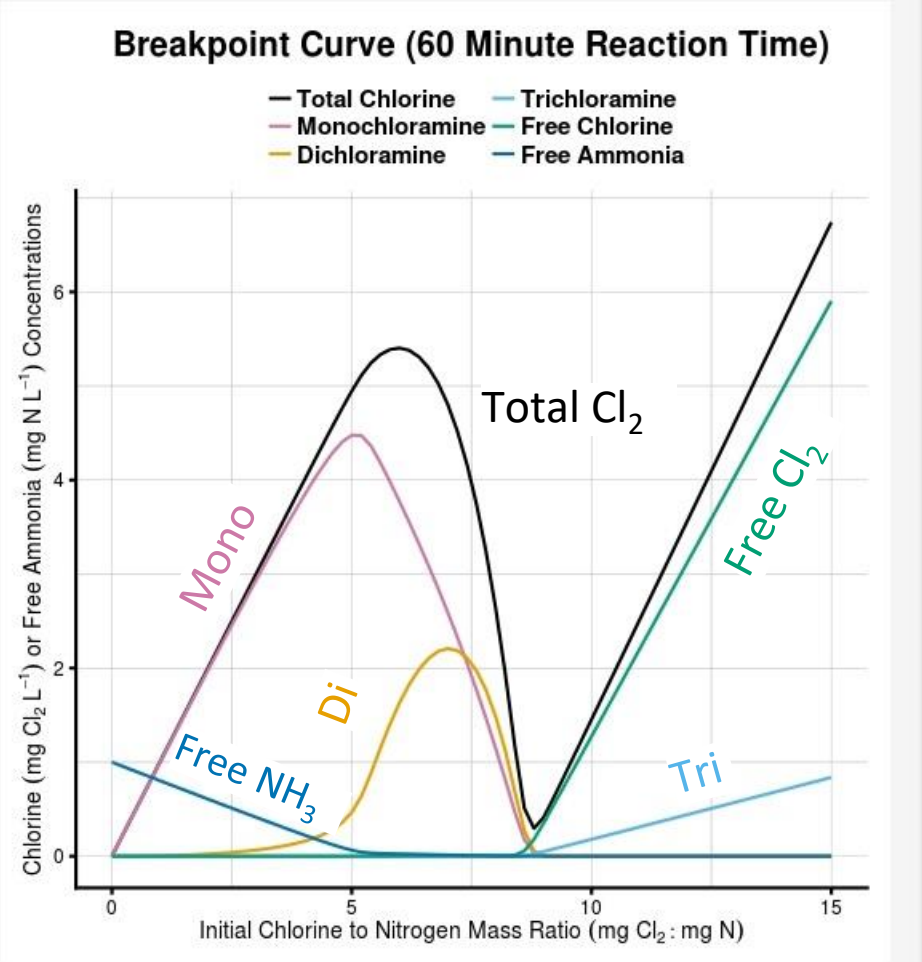
Treatment Models: Chloramine Formation/Decay

- Chloramine formation and decay
- Batch (plug flow) reactor
- Allows comparison of input choices:
  - Free chlorine, free ammonia
  - pH, alkalinity, temperature, Total Organic Carbon (TOC)
  - Simultaneous addition, booster chlorination, or preformed chloramines

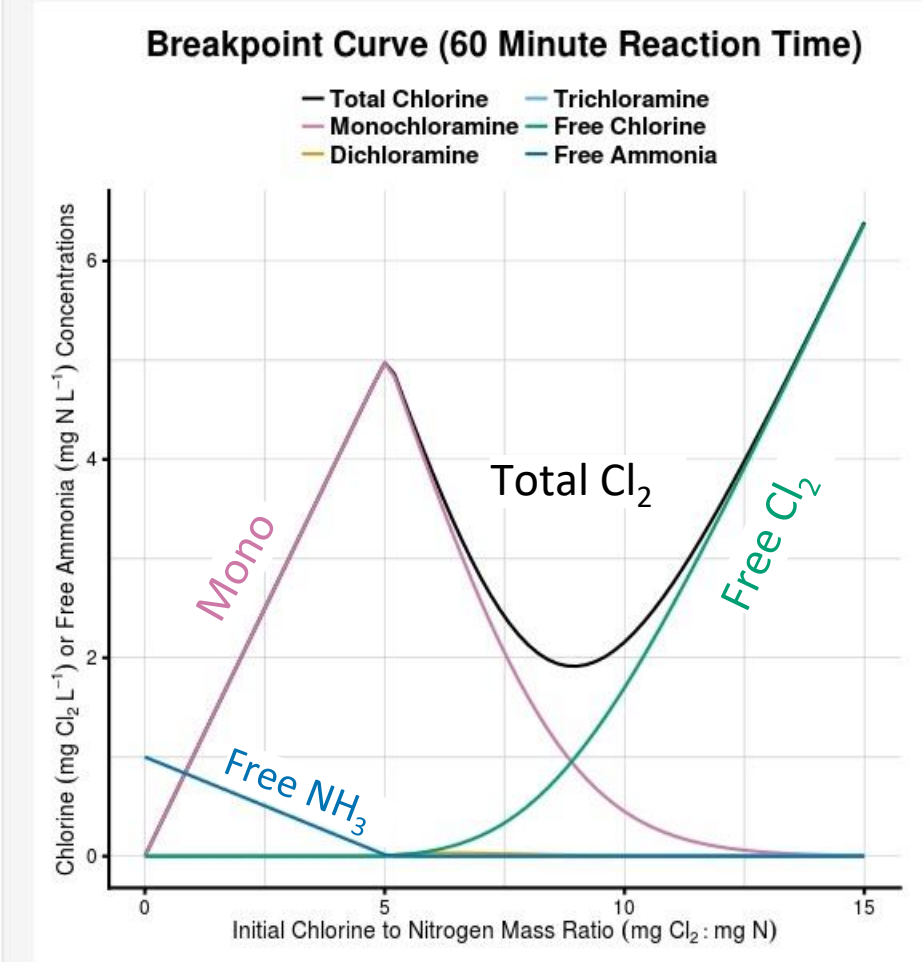
https://shiny.epa.gov/cfd/



Treatment Models: Chlorine Breakpoint Curve



pH 7

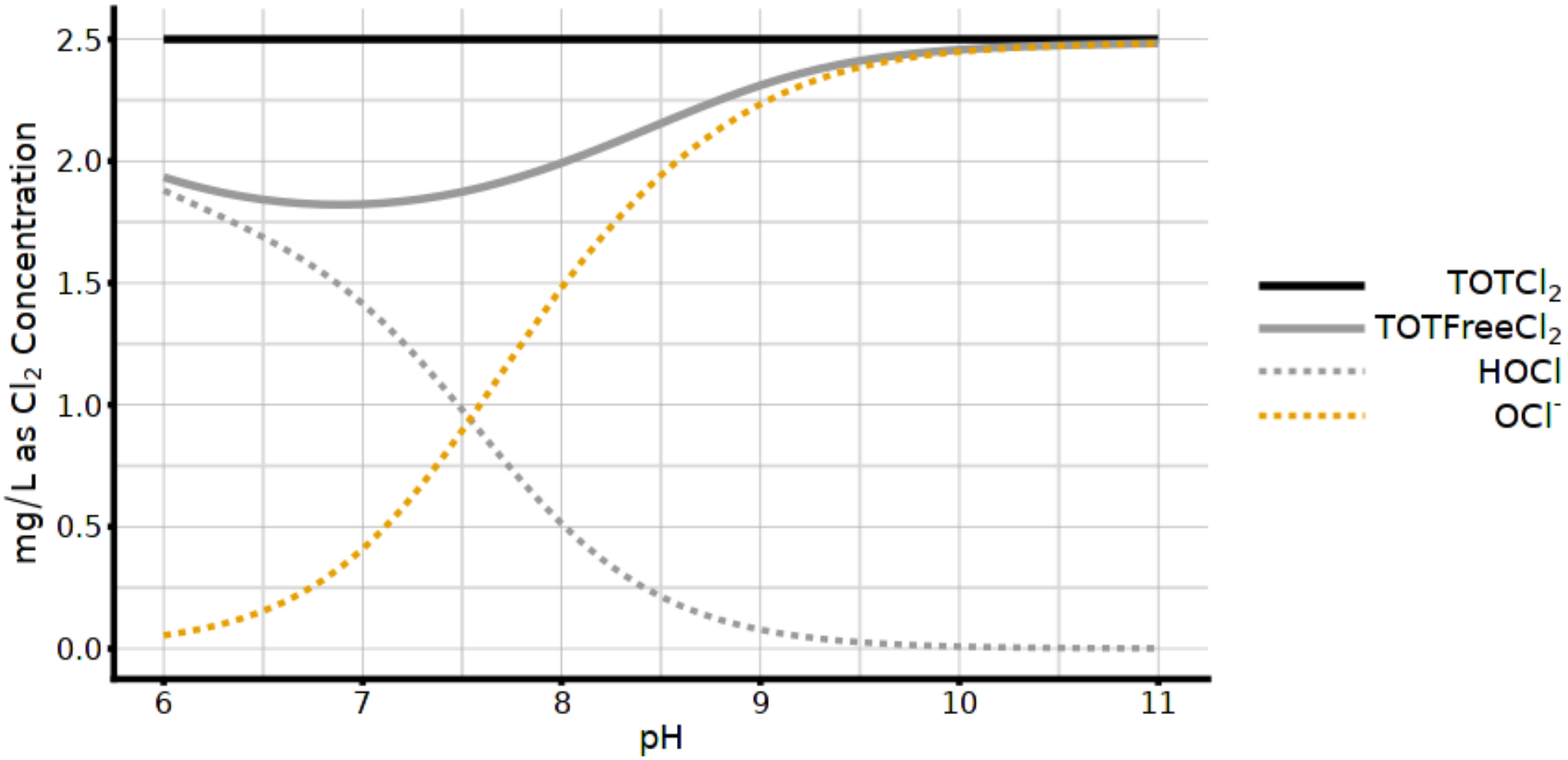


pH 9

https://shiny.epa.gov/cbcs/

Treatment Models: Free Chlorine and Cyanuric Acid

Predicts chlorine chemistry for various initial conditions when using Dichlor or Trichlor as the free chlorine source.

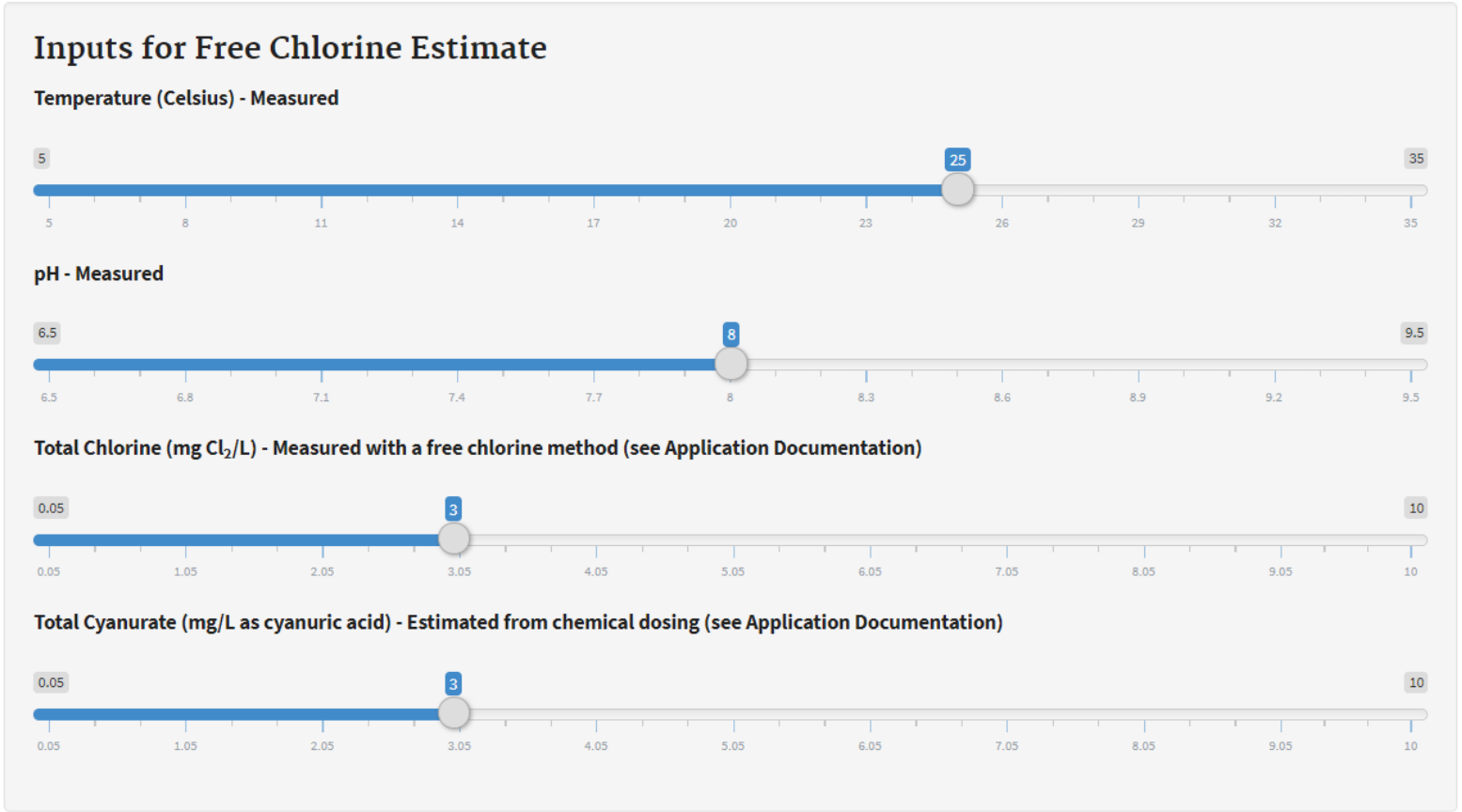


https://shiny.epa.gov/fccas/

Treatment Models: Free Chlorine Estimator for Dichlor and Trichlor Systems

- Calculates free chlorine concentration.
- Dichlor or trichlor are used as disinfectant.
- Uses measured free chlorine as an input.

https://shiny.epa.gov/fcedts



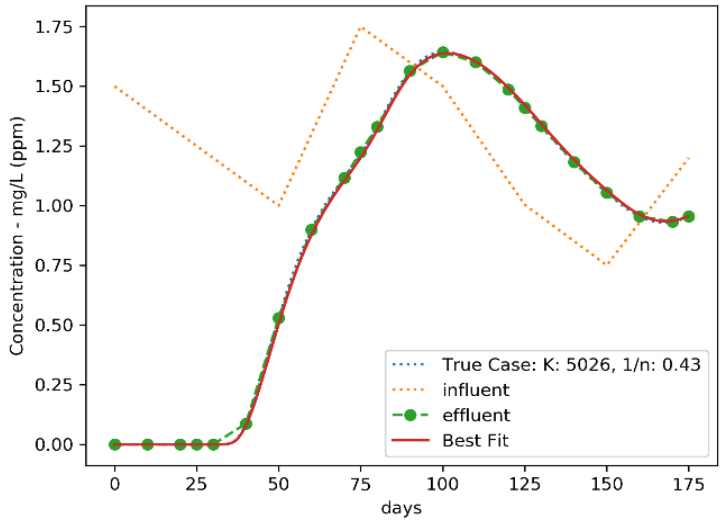
Estimated free chlorine concentration = 1.44 mg/L as chlorine

Treatment Models: WTM

Granular Activated Carbon Model

- Pore and Surface Diffusion Model (PSDM)
- Fouling related to natural organic matter
- Estimates model parameters
- Supports multiple component adsorption
- Estimates real-world operational bed replacement

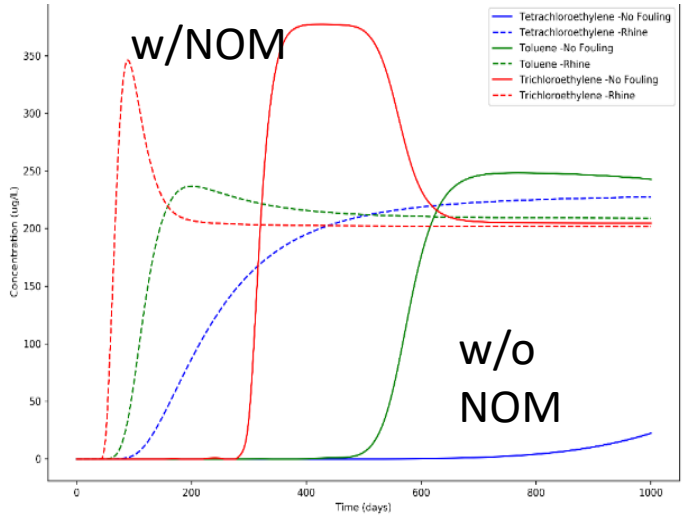
Parameter Estimation



Ion Exchange Media

- Supports gel-type ion exchange resins
- Planned support for macroporous resins (early 2021)
- Applicable to low natural organic matter waters
- Model competition from divalent ions, such as sulfate

Competitive Adsorption



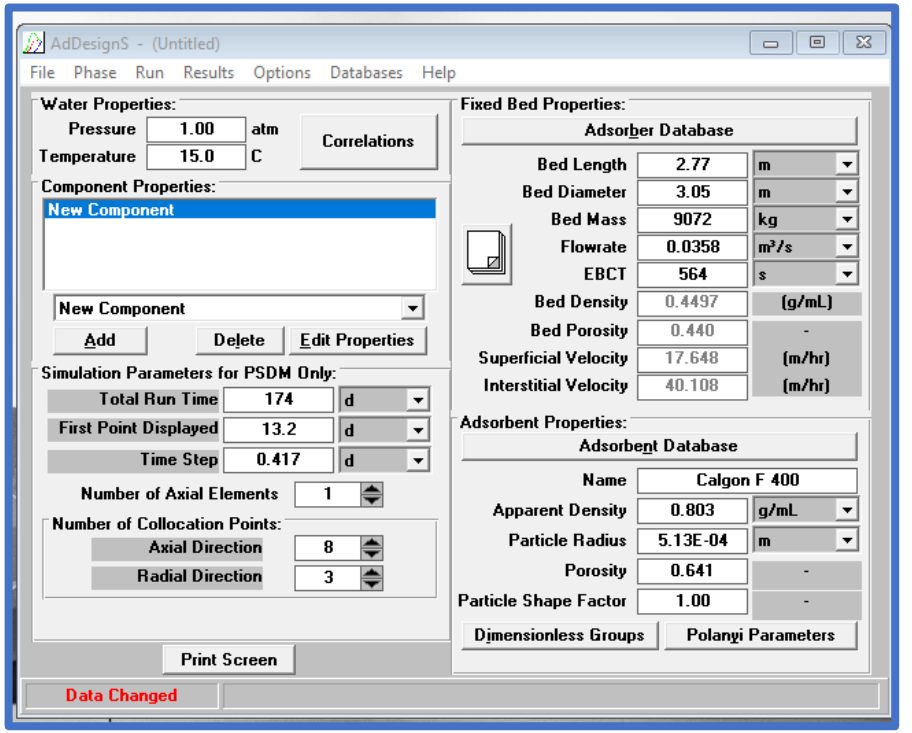
https://github.com/USEPA/Water_Treatment_Models

Treatment Models: ETDOT

Environmental Technologies Design Option Tool (ETDOT)

- Suite of software for modeling a variety of treatment technologies.
- Originally developed by Michigan Technological University (MTU).
- Now available on EPA's website.
- Includes models for adsorption, advanced oxidation, aeration, biofilters, PAC adsorption, ion exchange.

Example: AdDesignS



epa.gov/water-research/environmental-technologies-design-option-tool-etdot

Treatment Tools: Treatability Database

- Interactive searchable database.
- 123 regulated and unregulated contaminants.
- 35 treatment processes commonly employed or known to be effective.
- Referenced information gathered from thousands of literature sources.

epa.gov/water-research/drinking-water-treatability-database-tdb

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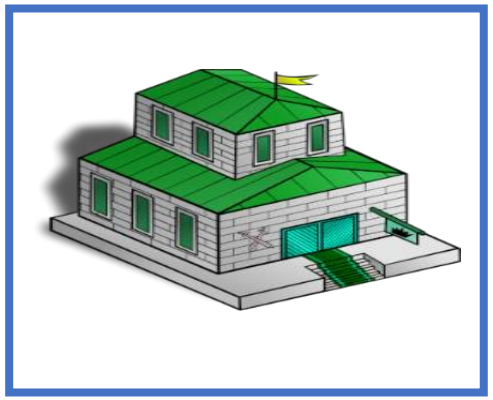

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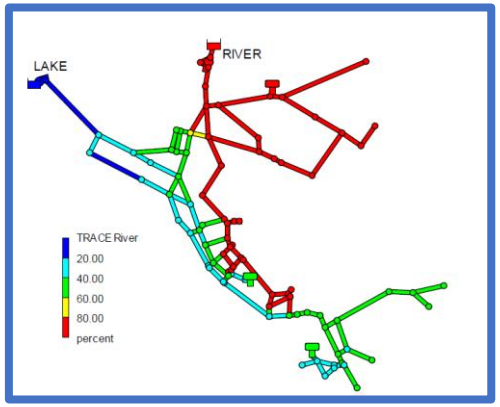

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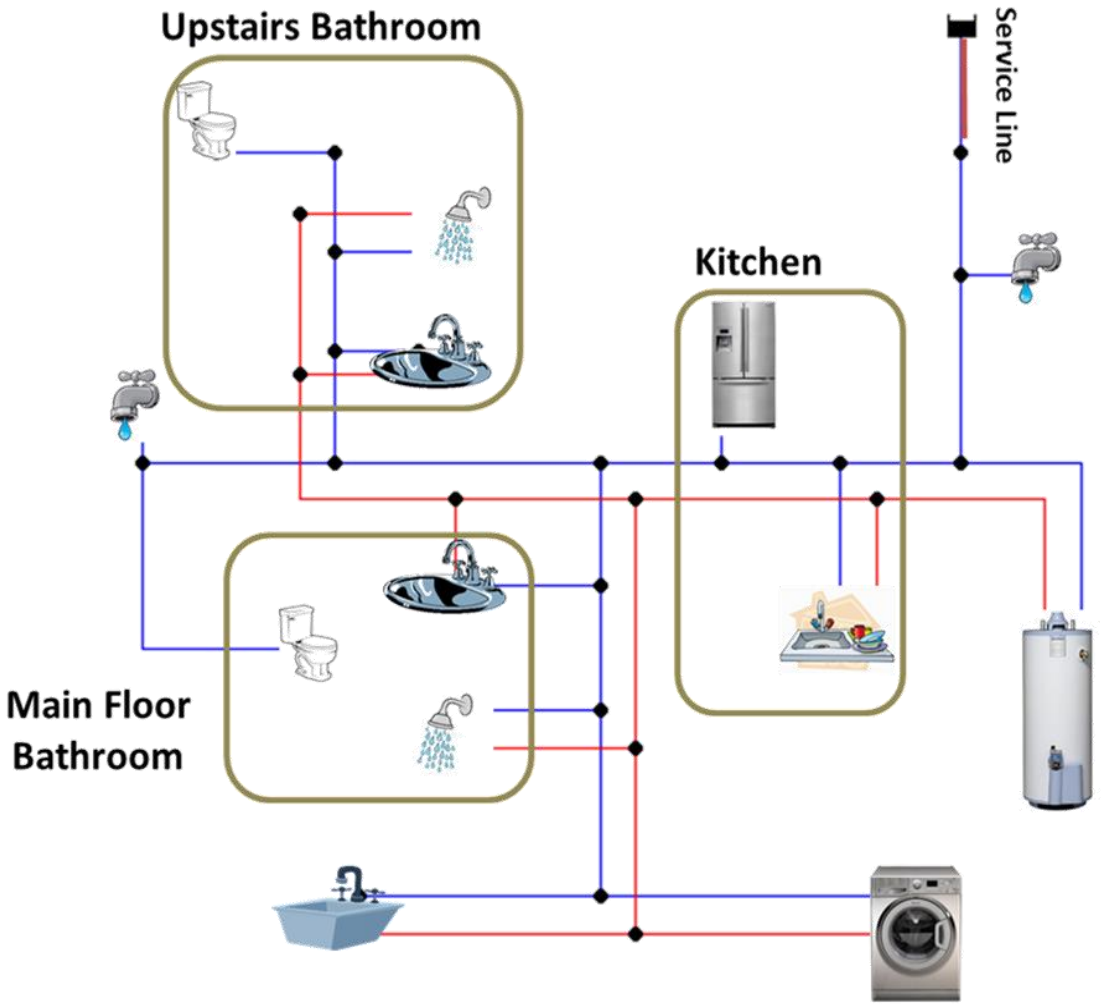
Premise Plumbing Tool: PPM Tools



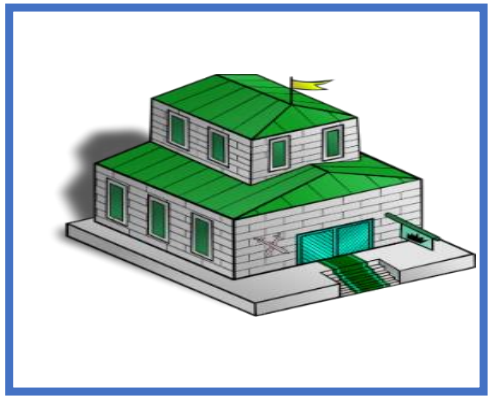
Premise Plumbing Modeling Tools (PPM Tools)

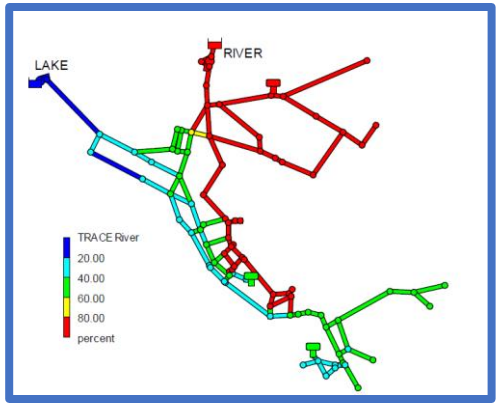
- Leverages EPANET and WNTR.
- Models real-world fixtures.
- Estimates realistic usage patterns.
- Generates and runs many scenarios.
- Predicts water quality information over time (e.g., water age, contaminant concentration).
- Simulates flushing to remove contaminants.
- Estimates exposure to contaminants.

https://github.com/USEPA/PPMtools

Summary

- Models and other tools can be used to help solve drinking water problems:
  - Water distribution systems design, vulnerability and resilience assessment, operational improvements.
  - Water treatment design, evaluation, assessment.
  - Premise plumbing design, contaminant exposure assessment, flushing.
- Tools and supporting documentation are available for free on the web and easily searchable from EPA's Science Models and Research Tools (SMaRT) Search.





Contacts

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US EPA Office of Research and Development
murray.regan@epa.gov
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Specific Models and Tools:

- **EPANET and EPANET-MSX:** Feng Shang (shang.feng@epa.gov)
- **EPANET-RTX, RTX:LINK and TEVA-SPOT:** Robert Janke (janke.robert@epa.gov)
- **WNTR:** Terra Haxton (haxton.terra@epa.gov)
- **CANARY, ETDOT, WTM and PPM Tools:** Jonathan Burkhardt (burkhardt.jonathan@epa.gov)
- **CFD, CBCS, FCCAS, FCEDTS:** David Wahman (wahman.david@epa.gov)
- **TDB:** Page Jordan (jordan.page@epa.gov)