17th Annual EPA Drinking Water Workshop: Small System Challenges and Solutions

# EPANET: An Introduction and Example Applications

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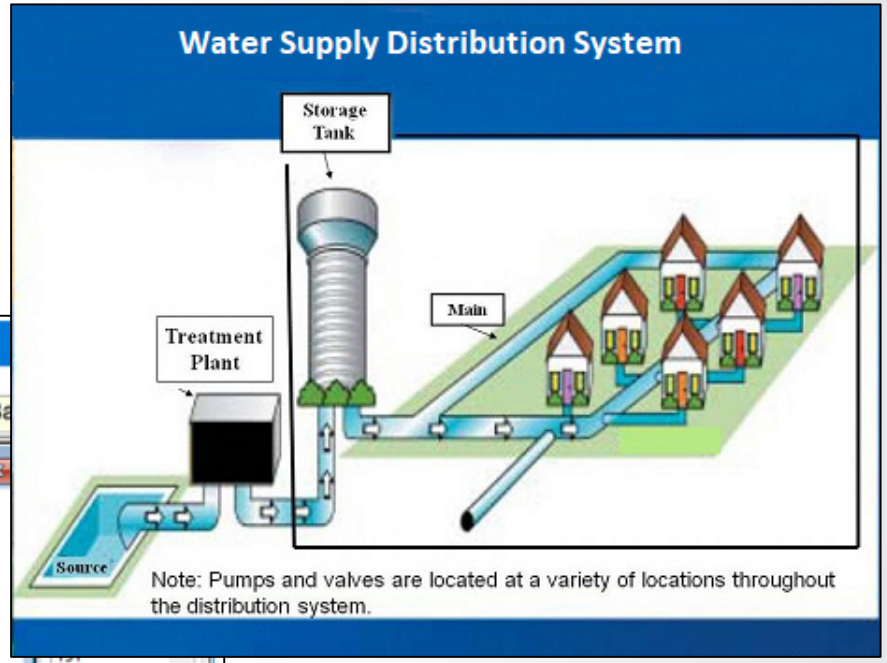
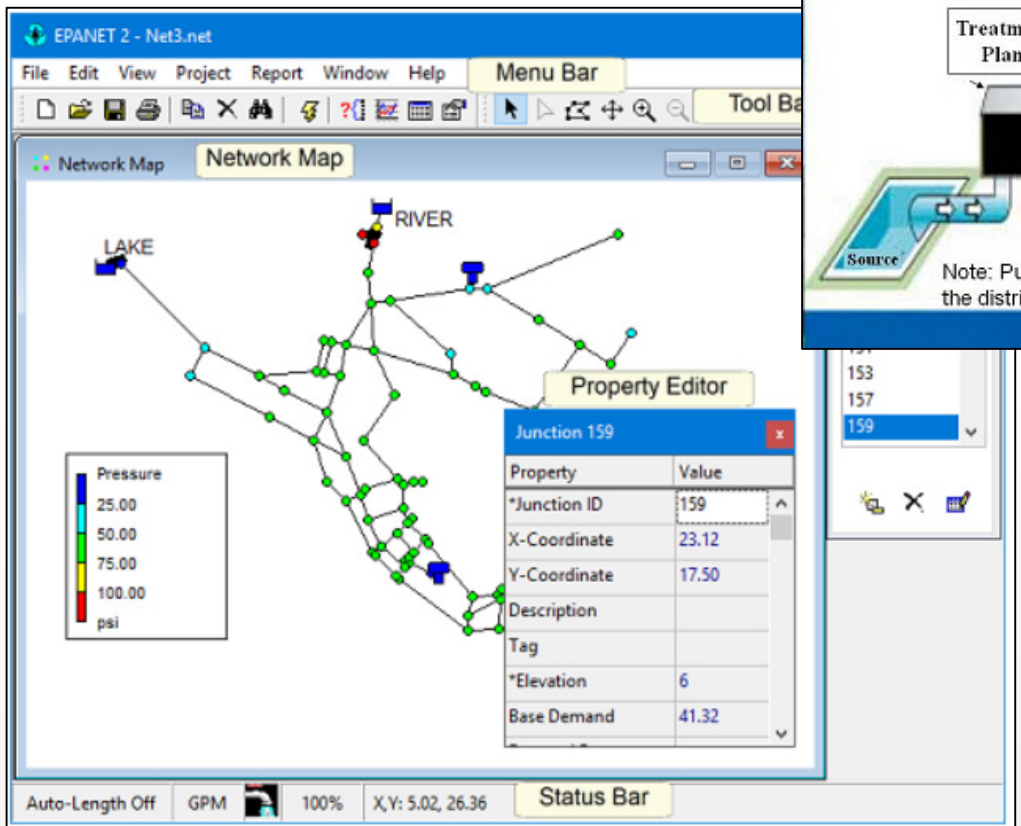
# Outline

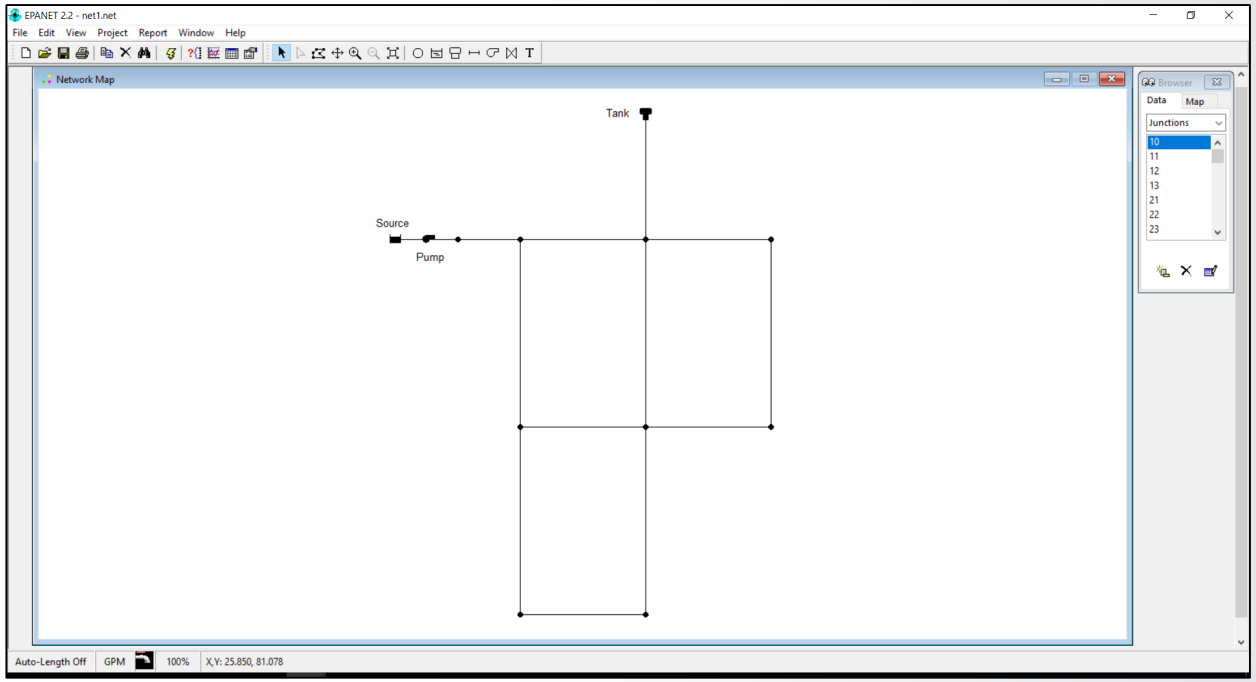
- Introduction to EPANET
- EPANET applications



# What is EPANET?

- What is EPANET?
  - Not an acronym!
  - Computer program (Microsoft Windows desktop or laptop software application)
    - Graphical user interface
    - Command line & Toolkit versions
  - Used for modeling and analyzing a water distribution system
  - Input is a pipe network layout
  - Output are hydraulic (e.g., pipe flows and pressures) and water quality (e.g., disinfectant and contaminant concentrations) parameters




EPANET Graphical User Interface

***EPANET is open source software that is free to anyone to use!***

# Some terms and definitions

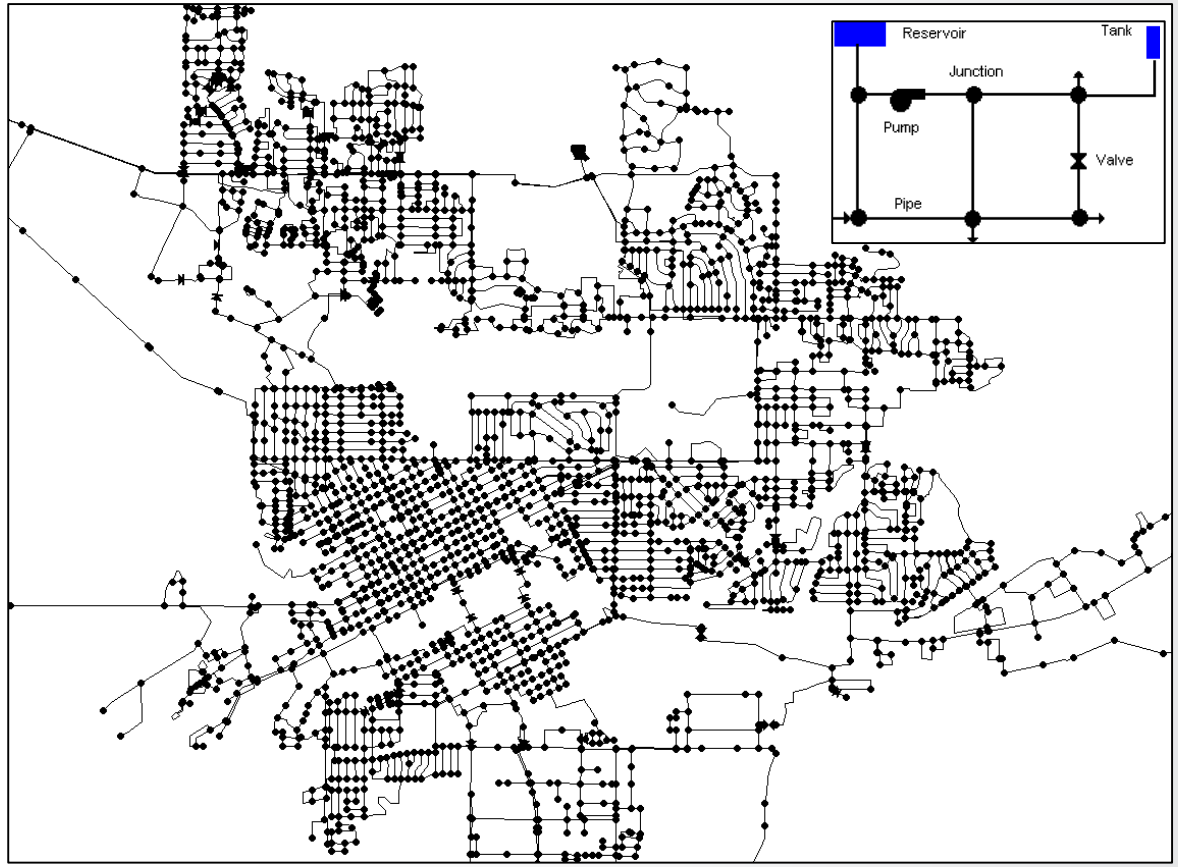
- Water Distribution System
  - Collection of pipes, tanks, pumps, valve control systems, and other components that work together to move water from a water source or treatment plan to individual users or customers' taps
- Network model (text file with .inp extension)
  - Water distribution system representation!
  - Pipe network layout (infrastructure map) including tanks, pumps, valve control systems and other components needed to describe a water distribution system
- Hydraulic model
  - Network model simulated in EPANET for hydraulics
- Water quality model
  - Network model simulated in EPANET for water quality

# Some terms and definitions cont'd

- Water distribution system modeling is a process for understanding:
  - How a water distribution system should be designed?
  - How a water distribution system is operating and how operations can be improved?
- Water distribution system modeling is a mathematical process
  - Connects a physical (infrastructure) model with mathematical processes of hydraulics and chemical properties of water quality to represent or model the behavior of a water system
- Steady state simulation
  - Network analyzed as a snap-shot in time, time zero in EPANET
- Extended period simulation
  - Network analyzed over time.

# Why develop a model?

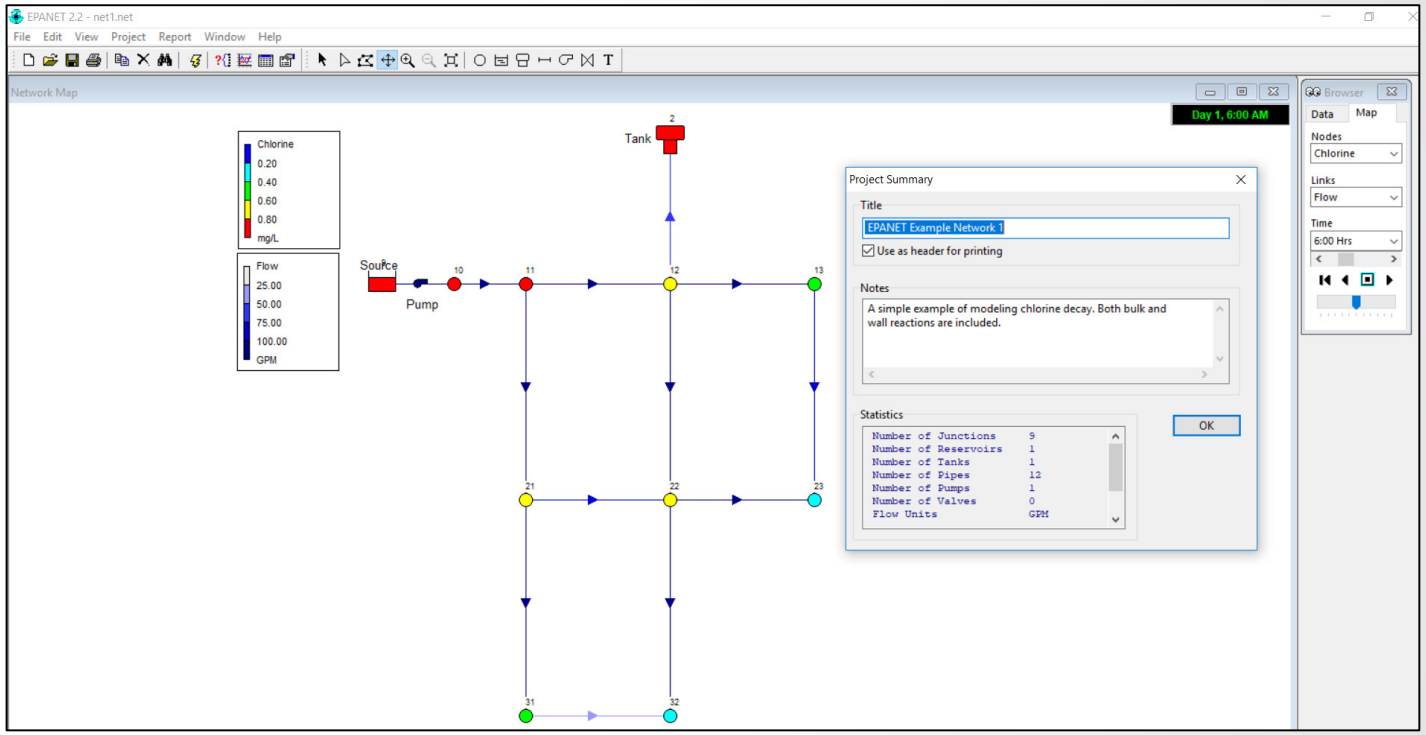
- Planning
  - Capital improvements
  - Water usage and conservation
  - Replacement and upgrade program
- Design
  - Facility sizing
  - Fire flow analysis
- Operations
  - Training
  - Hydraulic and water quality concerns
  - Emergencies




Creating a network model

# EPANET Supports…

- Hydraulic Modeling
  - Design new water distribution systems or upgrade existing systems
  - Evaluate operations (e.g., pump, tank and valve operations)
- Water Quality Modeling
  - Water age and disinfectant management
  - Contaminant transport, exposure and risk analyses




Hydraulic & water quality (chlorine) modeling for Example Net 1

# EPANET – A brief history

- EPANET was developed by Lewis A. Rossman (retired March 2014) working for U.S. EPA in the early 1990's
- First non-beta release of EPANET was in 2000, version 2.00.00
- U.S. EPA's last release of version 2.00 was in 2008 with 2.00.12
- Maintenance and advancement of EPANET is now through a community collaboration at https://github.com/OpenWaterAnalytics/EPANET

***U.S. EPA's latest release is version 2.2.0 and was made possible by the U.S. EPA and community collaboration at OpenWaterAnalytics***

# EPANET: Community Collaboration

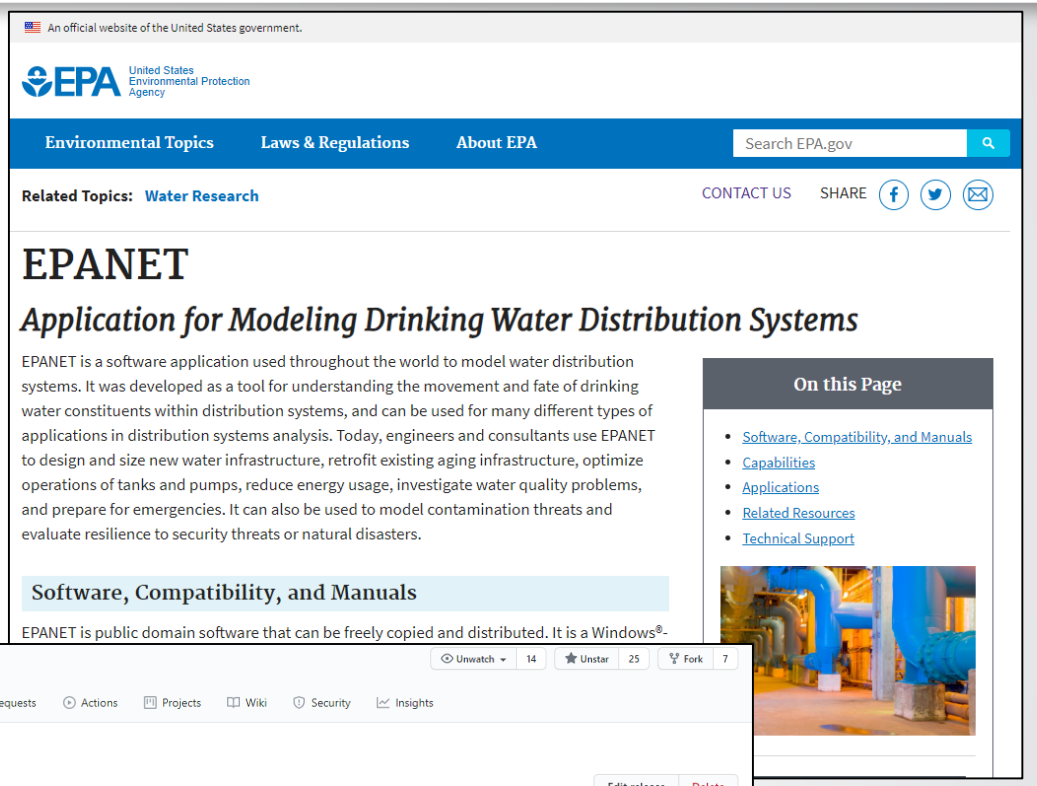
- Announcement of Open Source EPANET Initiative – June 7, 2015 http://community.wateranalytics.org/t/announcement-of-an-open-source-epanet-initiative/117
  - Open letter to the international Water Distribution Systems Analysis (WDSA) community
  - Established **Steering Committee, Development Committee, and Discussion Forum**

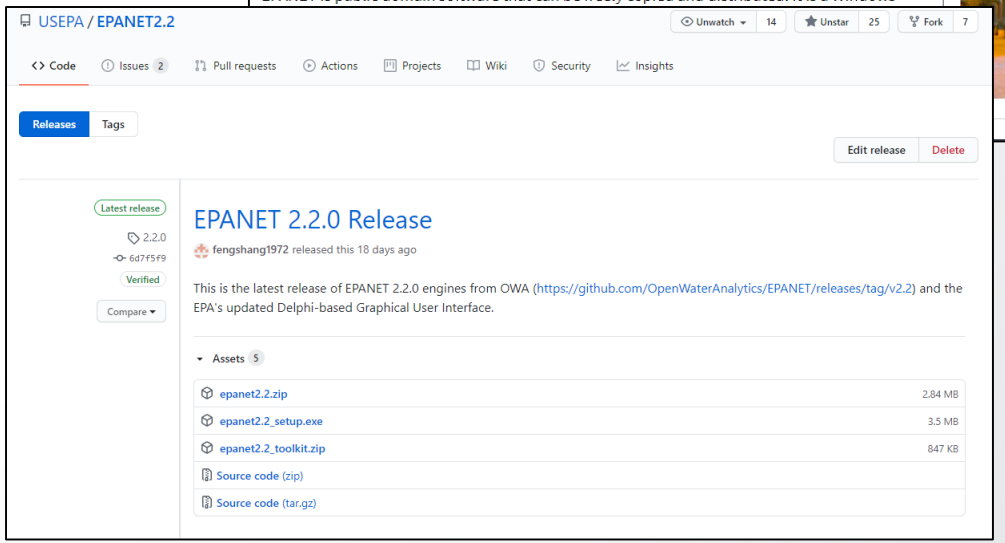
- EPANET hydraulic and water quality engines repository:
  - https://github.com/OpenWaterAnalytics/EPANET

- OWA-EPANET is an open-source version of the EPANET Toolkit
  - https://github.com/OpenWaterAnalytics/EPANET/wiki
  - OWA EPANET Toolkit – User's Manual: http://wateranalytics.org/EPANET/

# Obtaining EPANET

- U.S. EPA's website (https://www.epa.gov/water-research/epanet)
  - Software (GUI and DOS command line)
  - Toolkit and extensions
- U.S. EPA's Github.com site (https://github.com/USEPA/EPANET2.2)
  - Mirror of the website
  - Easier to maintain & keep updated



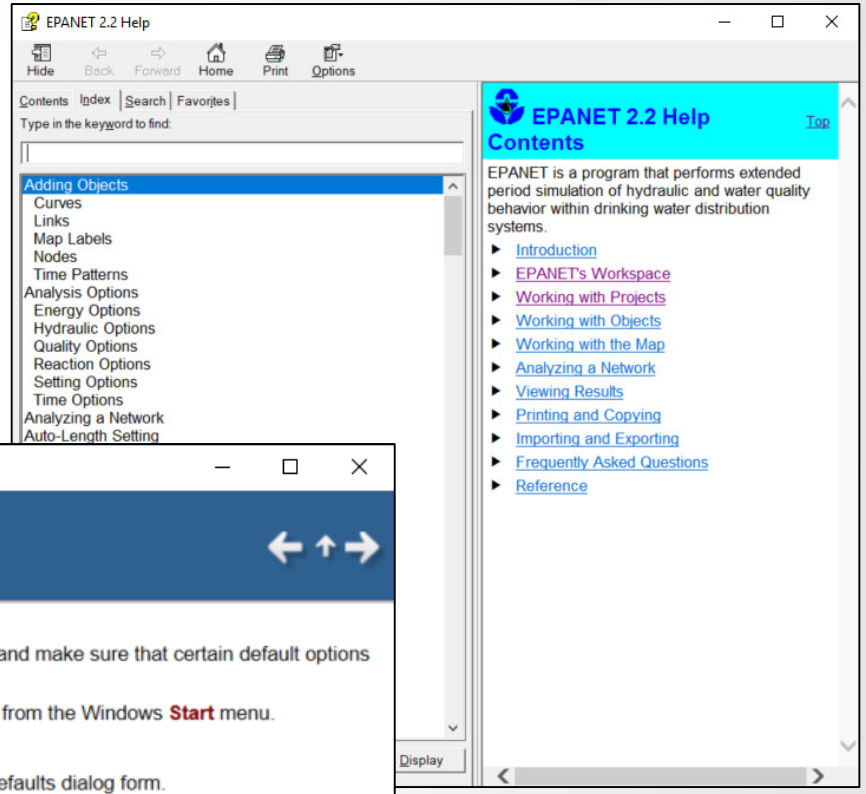



# U.S. EPA website for EPANET

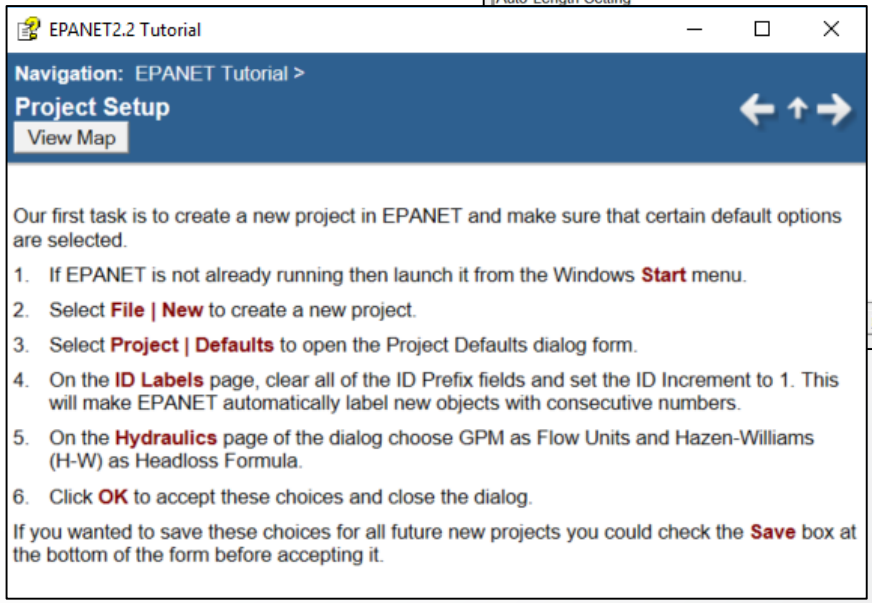
- Website (https://www.epa.gov/water-research/epanet)
  - Software
    - Self-extracting installation program for EPANET 2.2 ("epanet2.2_setup.exe" file)
    - Non-installing software for EPANET 2.2 ("epanet.zip" file)
  - User's Manual
    - Pdf version
    - Read-the-Docs (https://epanet22.readthedocs.io/en/latest/)
- More information:
  - Click on the link "https://github.com/USEPA/EPANET2.2"

# Installing and running EPANET

- Self-extracting installation program for EPANET 2.2 (epanet2.2_setup.exe)
  - May require administrative privileges for installation
  - Installs EPANET program, Help, Tutorial, and Release Notes in the Microsoft Windows Start Menu
  - Example networks may be hard to find:
    - Placed in a sub-folder named "EPANET Projects\Examples" in your Documents folder



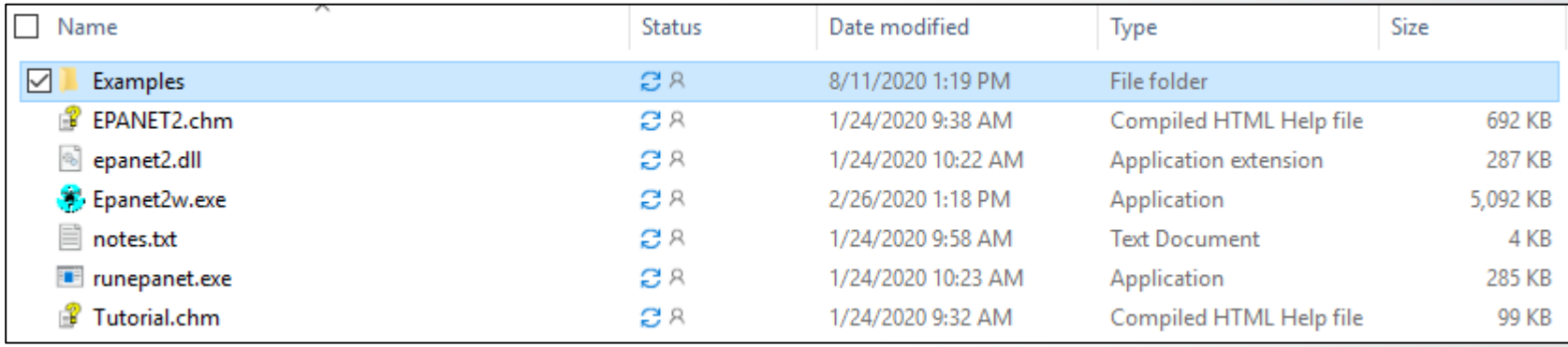

EPANET's Integrated Help




EPANET's Tutorial

# Running EPANET un-installed

- Non-installing software for EPANET 2.2 (epanet2.2.zip)
  - Notice everything is included
  - Runs EPANET (Epanet2w.exe)
  - DOS command line EPANET (runepanet.exe)



| Name | Status | Date modified | Type | Size |
|---|---|---|---|---|
| Examples | | 8/11/2020 1:19 PM | File folder | |
| EPANET2.chm | | 1/24/2020 9:38 AM | Compiled HTML Help file | 692 KB |
| epanet2.dll | | 1/24/2020 10:22 AM | Application extension | 287 KB |
| Epanet2w.exe | | 2/26/2020 1:18 PM | Application | 5,092 KB |
| notes.txt | | 1/24/2020 9:58 AM | Text Document | 4 KB |
| runepanet.exe | | 1/24/2020 10:23 AM | Application | 285 KB |
| Tutorial.chm | | 1/24/2020 9:32 AM | Compiled HTML Help file | 99 KB |

After extraction of epanet2.2.zip file contents

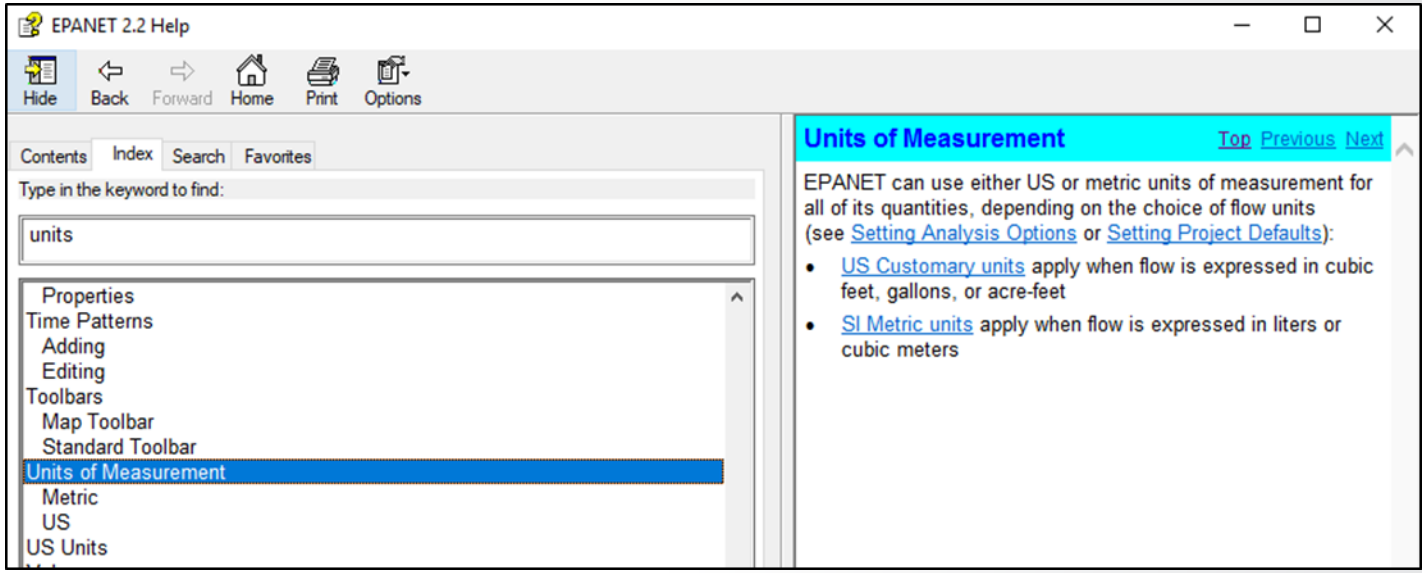
# Brief hydraulics review

- EPANET's basic assumptions about flow:
  - Incompressible flow
  - Turbulent flow
  - Closed pipe (e.g., contaminant injections are modeled as mass/time)
  - Full pipe

- For background, supporting information, and review of basic principles:
  - Advanced Water Distribution Modeling and Management, Haestad Methods, T. Walski, D. V. Chase, D. A. Savic, W. M. Grayman, S. Beckwith, and E. Koelle
  - Water Distribution Systems Handbook, McGraw-Hill Handbooks, L. W. Mays editor

# EPANET units

- English units (adapted for U.S.)
  - Gallons per minute (GPM)
  - Million gallons per day (MGD)
  - 1 MGD = 646 GPM
- Metric
  - Liters per second (l/s)
  - Cubic meters per second ($m^3/s$)
  - 1 $m^3/s$ = 1000 l/s
- EPANET supports both unit systems



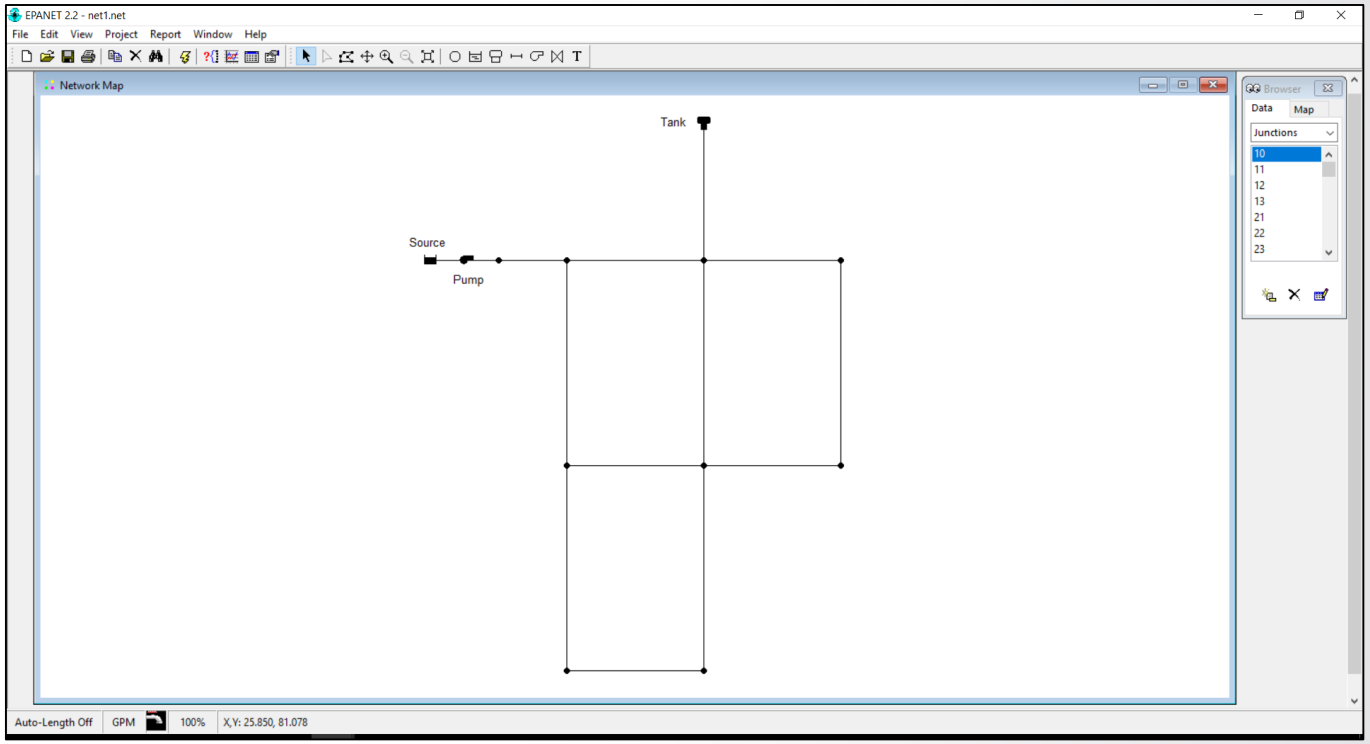

Taken from EPANET's Integrated Help – from Windows Start Menu

# EPANET definitions

- Nodes
  - Junctions, tanks and reservoirs
- Links
  - Pipes, pumps and control valves
  - Links must have start and end nodes
- Reservoirs
  - Nodes with infinite external source or sink of water to the network
- Pressure
  - Pounds per square inch (psi) (U.S.)
  - Pascal (Pa) = Newton/ square meter (Metric)
- Normal range of allowable pressures in drinking water systems:
  - 20 psi (minimum)
  - 80-100 psi (maximum)
- Pressure:  psi to feet
  - 1 foot = 2.31 psi

# Getting started!

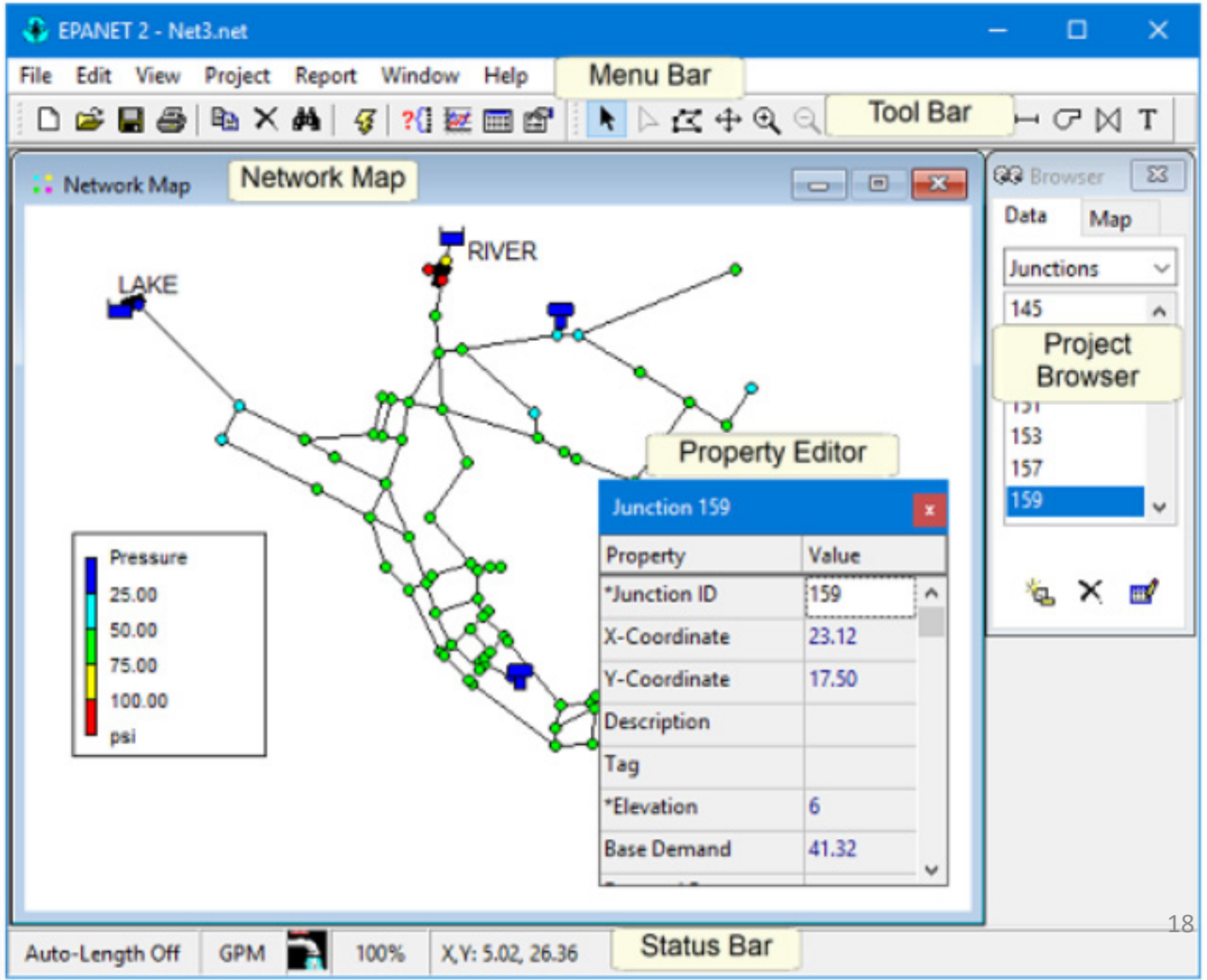
- Tutorial
  - Compiled HTML tutorial file and integrated help file
- User's Manual
  - Opening an existing network
- Example networks
  - Experiment with example networks provided




Example Net 1 Opened in EPANET 2.2

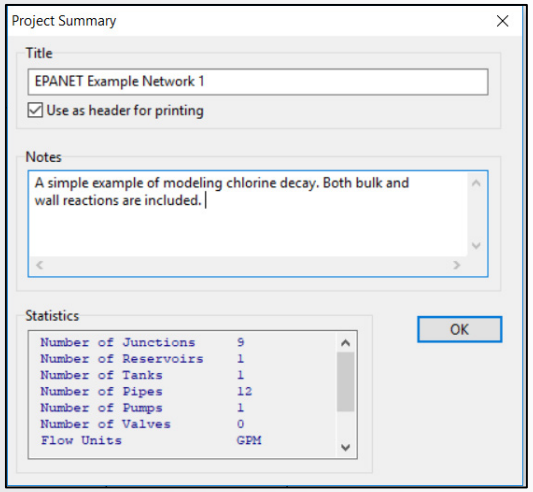
# EPANET's workspace

- EPANET's Graphical User Interface
  - Menu Bar
  - Network Map
  - Project Browser
  - Property Editor
- See Chapter 4 "EPANET's Workspace"
- Questions?
  - Integrated Help (in the Menu Bar) or by pressing F1 key

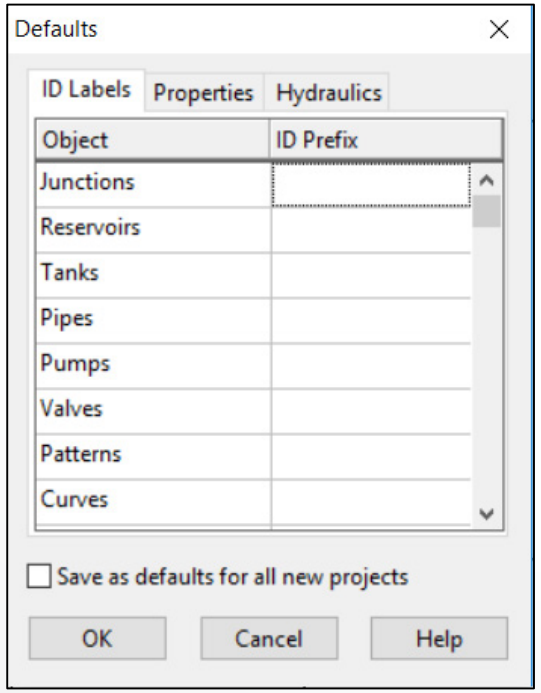


# Menu bar

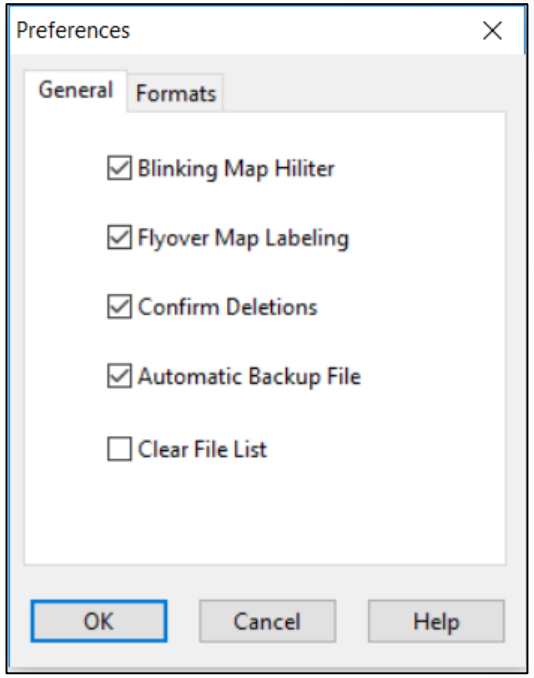
- Some menu items to highlight:



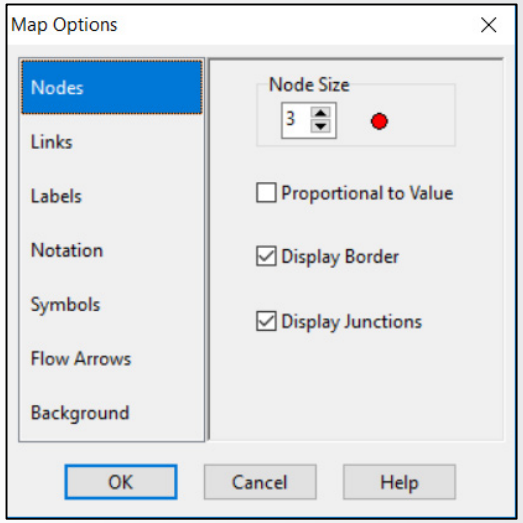

Project Summary



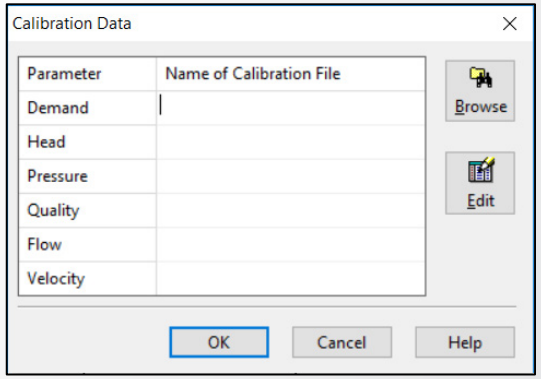

Interface for setting project defaults




Interface for setting preferences e.g., decimal places




Interface for setting map viewing options




Interface for uploading calibration data

# Property editor

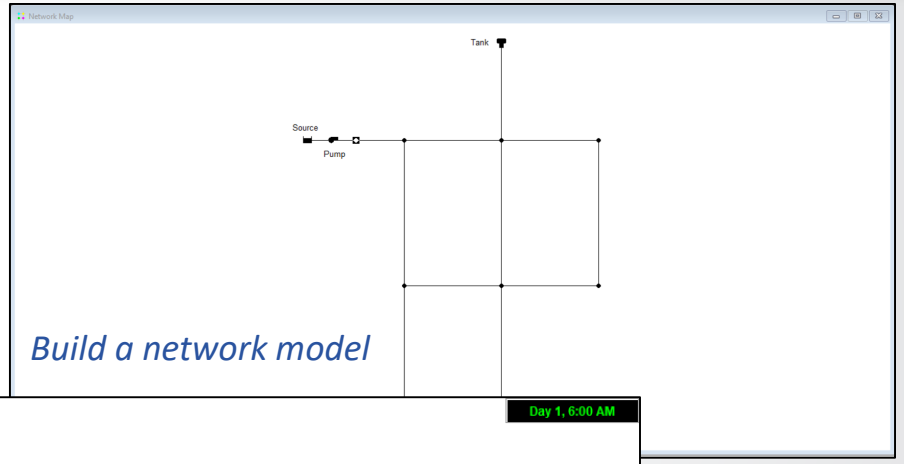
- Edit properties of nodes, links, labels, analysis options

Junction 10

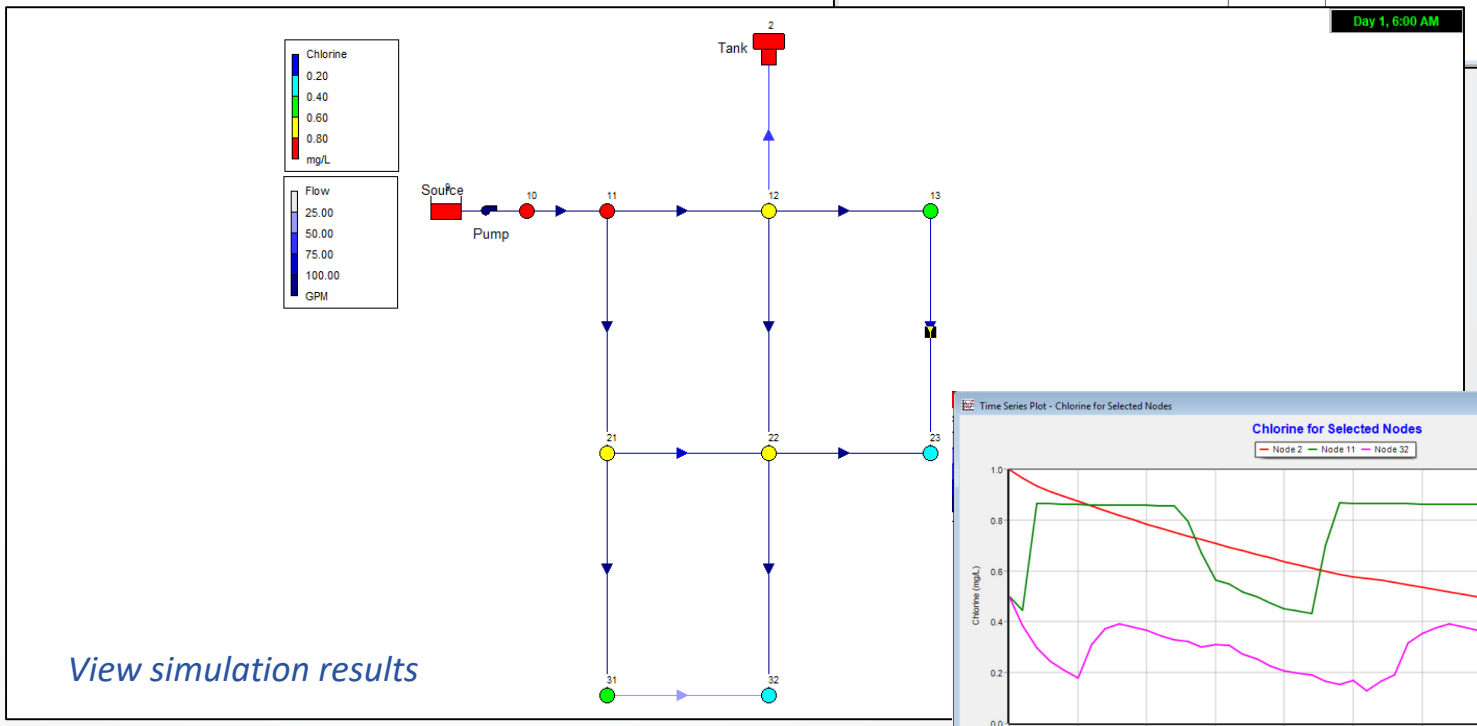
| Property | Value |
|---|---|
| *Junction ID | 10 |
| X-Coordinate | 20.000 |
| Y-Coordinate | 70.000 |
| Description | |
| Tag | |
| *Elevation | 710 |
| Base Demand | 0 |
| Demand Pattern | |
| Demand Categories | 1 |
| Emitter Coeff. | |
| Initial Quality | 0.5 |
| Source Quality | ... |
| Actual Demand | #N/A |
| Total Head | #N/A |
| Pressure | #N/A |
| Quality | #N/A |

# Network map

- Displays schematic diagram of the objects of the water distribution network, for example:
  - Build a water network model in the “map window”
  - View simulations
  - View graph results



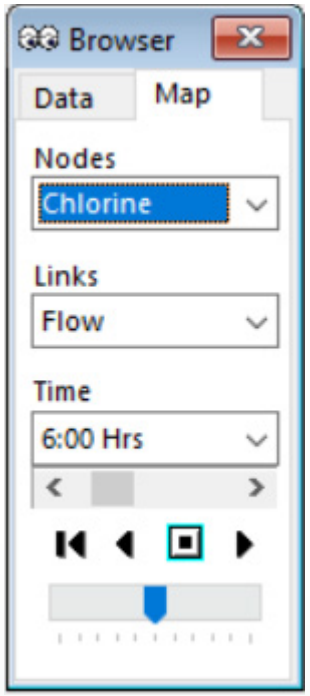

*Build a network model*



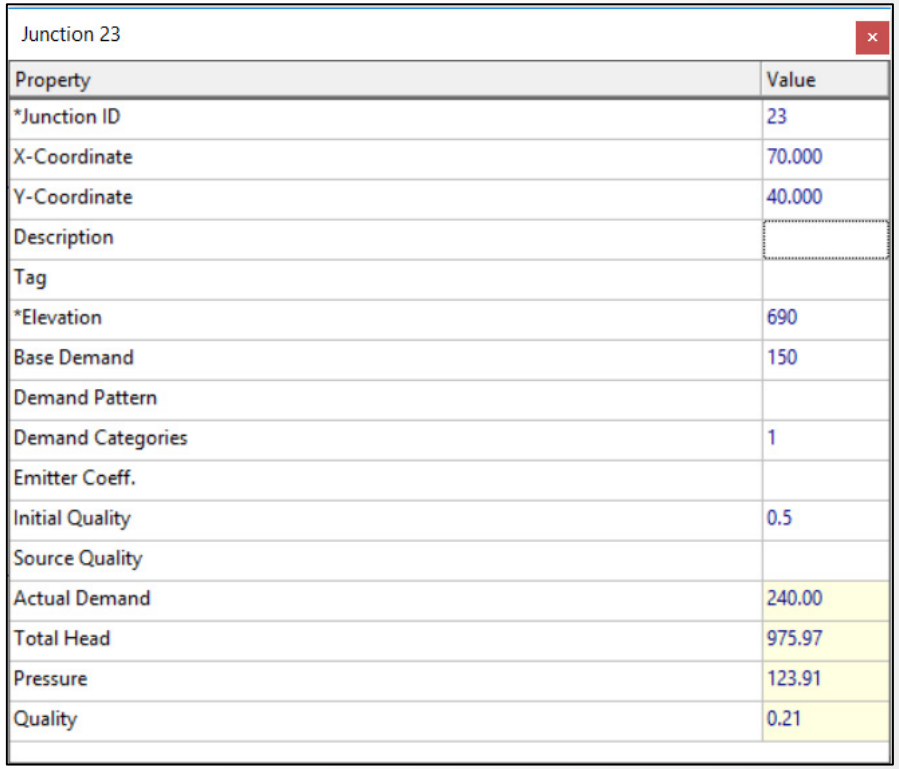

*View simulation results*

# Project browser

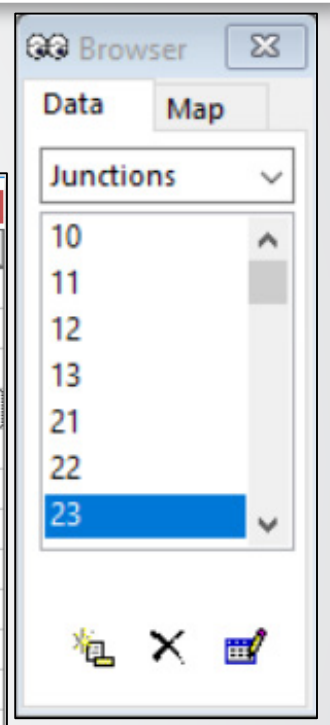
- Data browser
  - Gives access to objects, by category
  - Buttons at bottom allow add, delete and edit objects
- Map browser
  - Selects parameters and time period that are viewed in the Network Map
  - Allows animation through




Map Browser view




Double-clicking object (junction 23) in Data Browser brings up property editor above




Data Browser view

# Improvements in EPANET 2.2

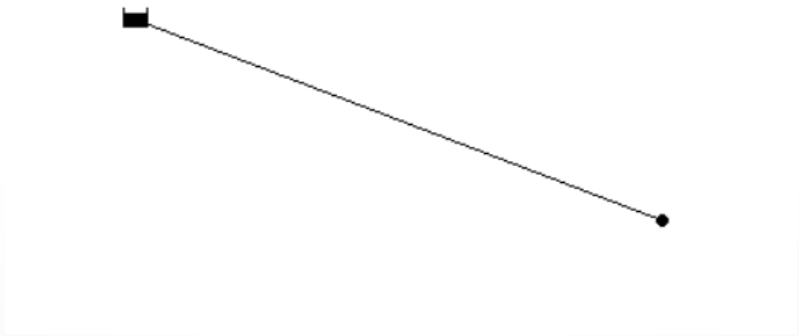
- The ability to use pressure-dependent demands in hydraulic analyses
- An option to allow full tanks to overflow
- Options that insure a more accurate hydraulic analysis is made
- More robust handling of low and zero flow hydraulic conditions
- Faster solution times for single period hydraulic analyses
- Improved mass balance results for water quality analyses
- An enhanced API function library for customizing EPANET (see http://wateranalytics.org/EPANET/)

# Where do you go for help?

- U.S. EPA website (General Information)
  - Bottom of website page – Technical Support:  Contact us link
- USEPA Github.com repository (General Information & User Interface)
  - Contact email:  epanet@epa.gov
- EPANET community at OpenWaterAnalytics (Hydraulic & Water Quality Engines)
  - https://github.com/OpenWaterAnalytics/EPANET/wiki
  - Community forum http://community.wateranalytics.org/
- If you want to contribute to EPANET - please go to https://github.com/OpenWaterAnalytics/EPANET/issues

# EPANET Application

- An EPANET model can be very simple:
  - One reservoir to provide water
  - One pipe to transfer water
  - One node to consume water



# EPANET Application - Hydraulics

- EPANET models hydraulic conditions over one or more than one period.
- No transient/water hammer analysis in EPANET.
- Demands needs to be assigned to each period.
- Pipes, pumps and valves transfer water from sources to consumer nodes.

# EPANET Application - Hydraulics

- Steady state analysis
  - Fixed demand
  - A snapshot analysis

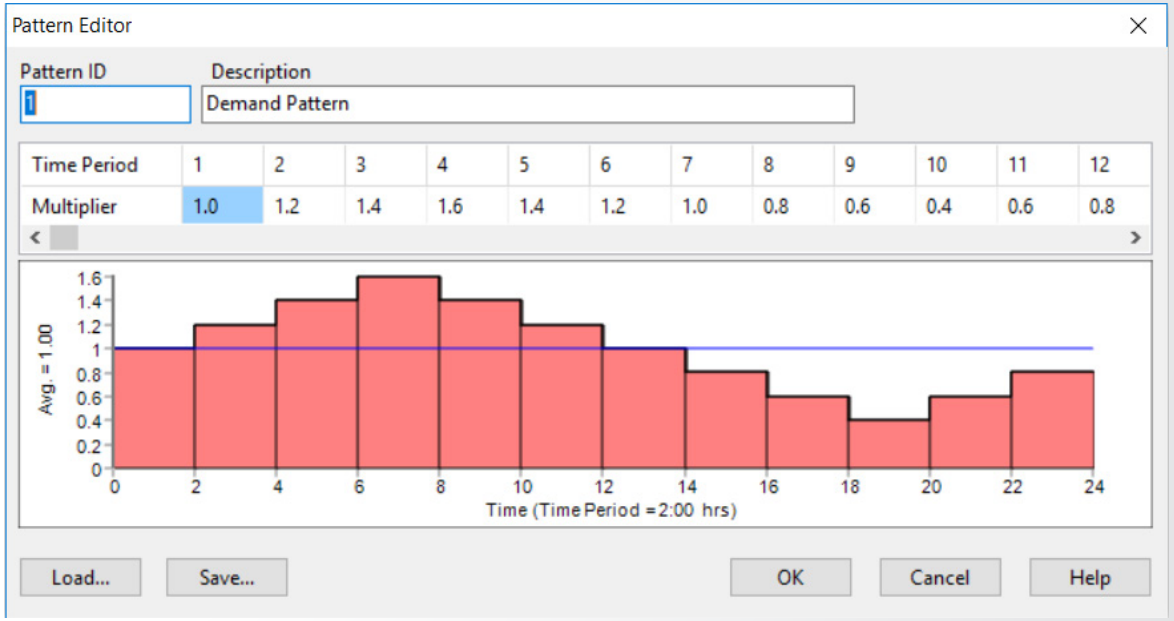
- Extended Period Simulation
  - Changing demand over time
  - Typically, at least a couple of days, e.g., seasonal peak days

# EPANET Application - Hydraulics

- Extended Period Simulation
  - Pattern time step can be set very small (1 minutes), usually 1 or 2 hours.
  - Each node has its own base demand which is usually the average demand.
  - Multiple nodes can share the same demand variation pattern.

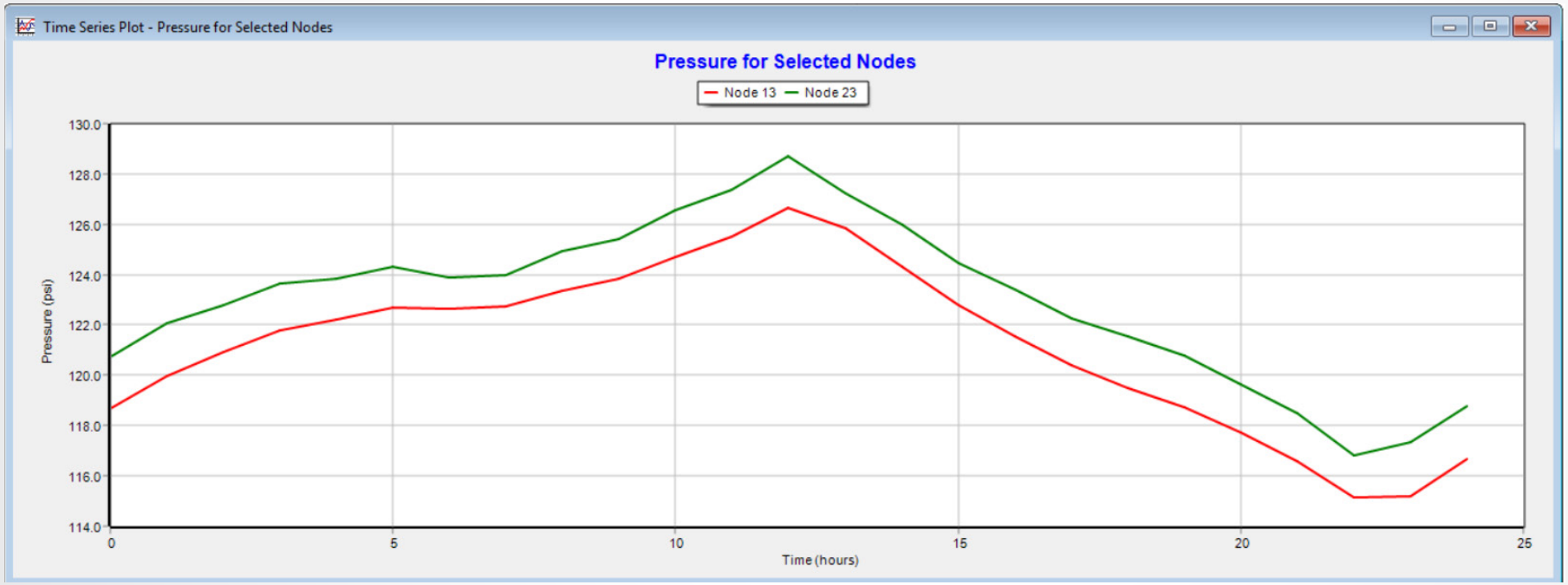
# EPANET Application - Hydraulics

- Extended Period Simulation

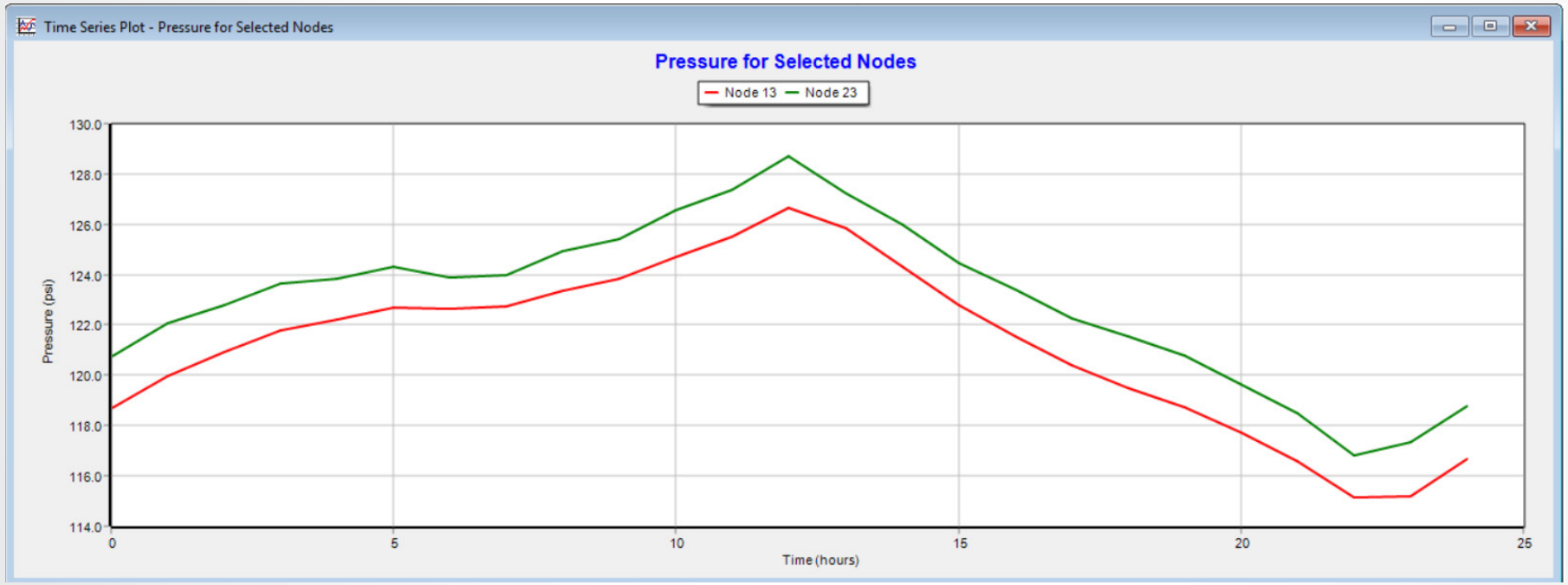
# EPANET Application - Hydraulics

- Extended Period Simulation Results



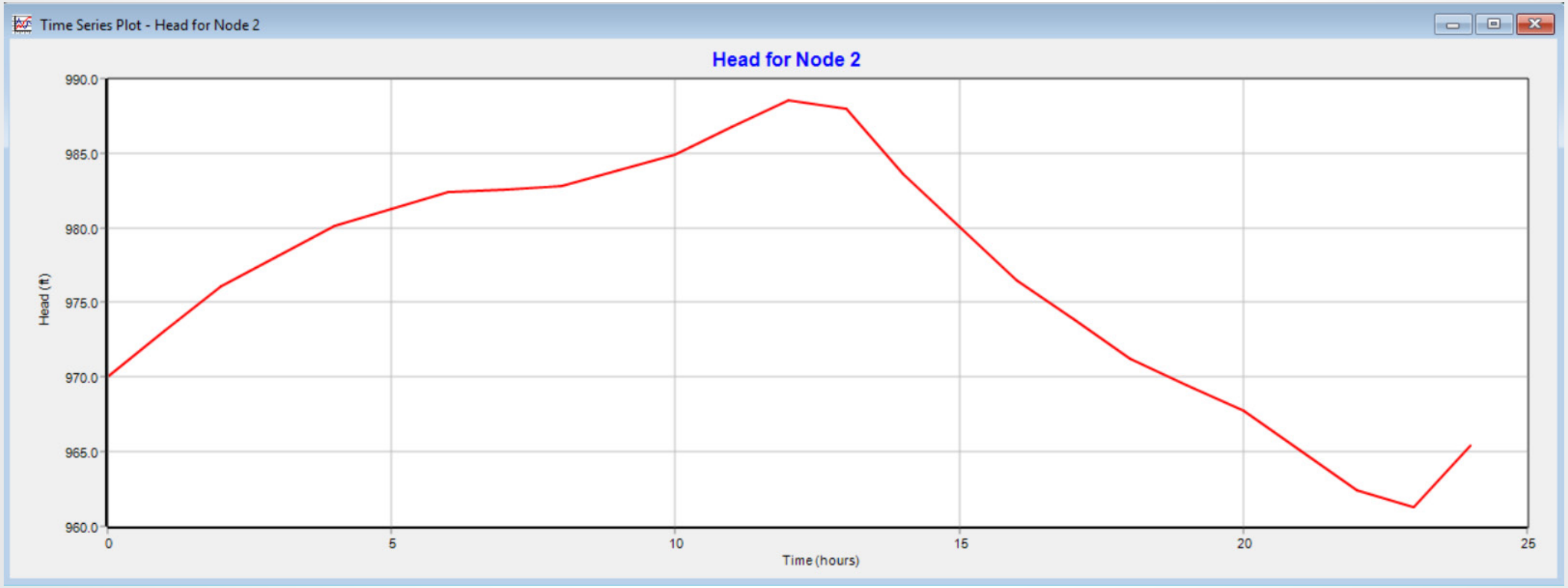
# EPANET Application - Hydraulics

- Extended Period Simulation Results: node pressure



# EPANET Application - Hydraulics

- Extended Period Simulation Results: tank operation



# EPANET Application - Hydraulics

- Negative pressure
  - Why negative pressure warnings?
  - What we should do?

- Pressure Dependent Analysis
  - User assigned demand if the pressure is high enough
  - Less than user assigned demand if the pressure is not high enough
  - Zero flow if the pressure is too low.

# EPANET Application - Hydraulics

- Pressure Dependent Analysis is an option in EPANET

Network Table - Nodes

| Node ID | Demand LPS | Pressure m |
|---|---|---|
| Junc 1 | 25.00 | 0.40 |
| Junc 2 | 25.00 | -0.44 |
| Junc 3 | 25.00 | 1.25 |
| Junc 4 | 25.00 | -0.58 |
| Junc 5 | 25.00 | -0.70 |
| Junc 6 | 25.00 | -0.71 |
| Junc 7 | 25.00 | 0.32 |
| Junc 8 | 25.00 | -0.19 |
| Junc 9 | 75.00 | -2.73 |
| Resvr R1 | -124.23 | 0.00 |
| Resvr R2 | -150.77 | 0.00 |

Network Table - Nodes

| Node ID | Demand LPS | Pressure m |
|---|---|---|
| Junc 1 | 25.00 | 1.40 |
| Junc 2 | 25.00 | 0.69 |
| Junc 3 | 25.00 | 2.28 |
| Junc 4 | 25.00 | 0.79 |
| Junc 5 | 25.00 | 0.73 |
| Junc 6 | 25.00 | 0.74 |
| Junc 7 | 25.00 | 1.92 |
| Junc 8 | 25.00 | 1.60 |
| Junc 9 | 61.63 | 0.07 |
| Resvr R1 | -117.04 | 0.00 |
| Resvr R2 | -144.59 | 0.00 |

# EPANET Application - Hydraulics

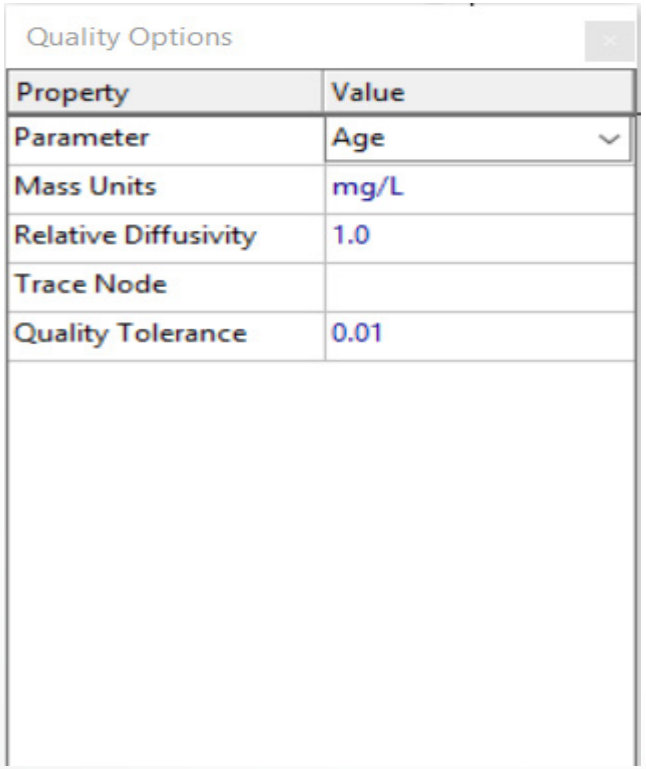
- Other more advanced functionalities:
  - Controls
  - Pump Curves
  - Pressure Reducing/Sustaining Valves
  - Flow Control Valve
  - Pump Efficiency and Energy Analysis

# EPANET Application – Water Quality

- Water age analysis
- Tracing analysis
- Chemical (chlorine decay)

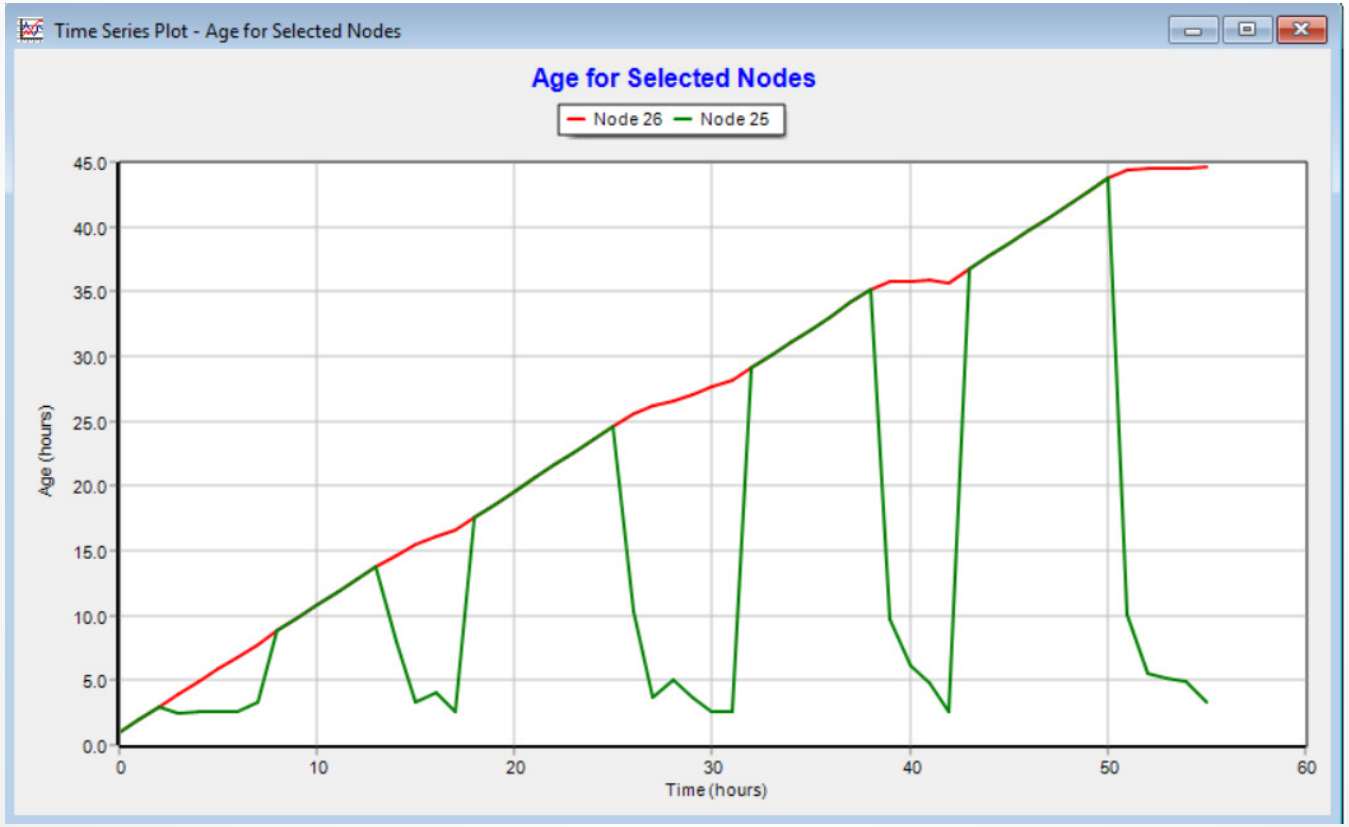
# EPANET Application – Water Quality

- Water age modeling is very easy to do



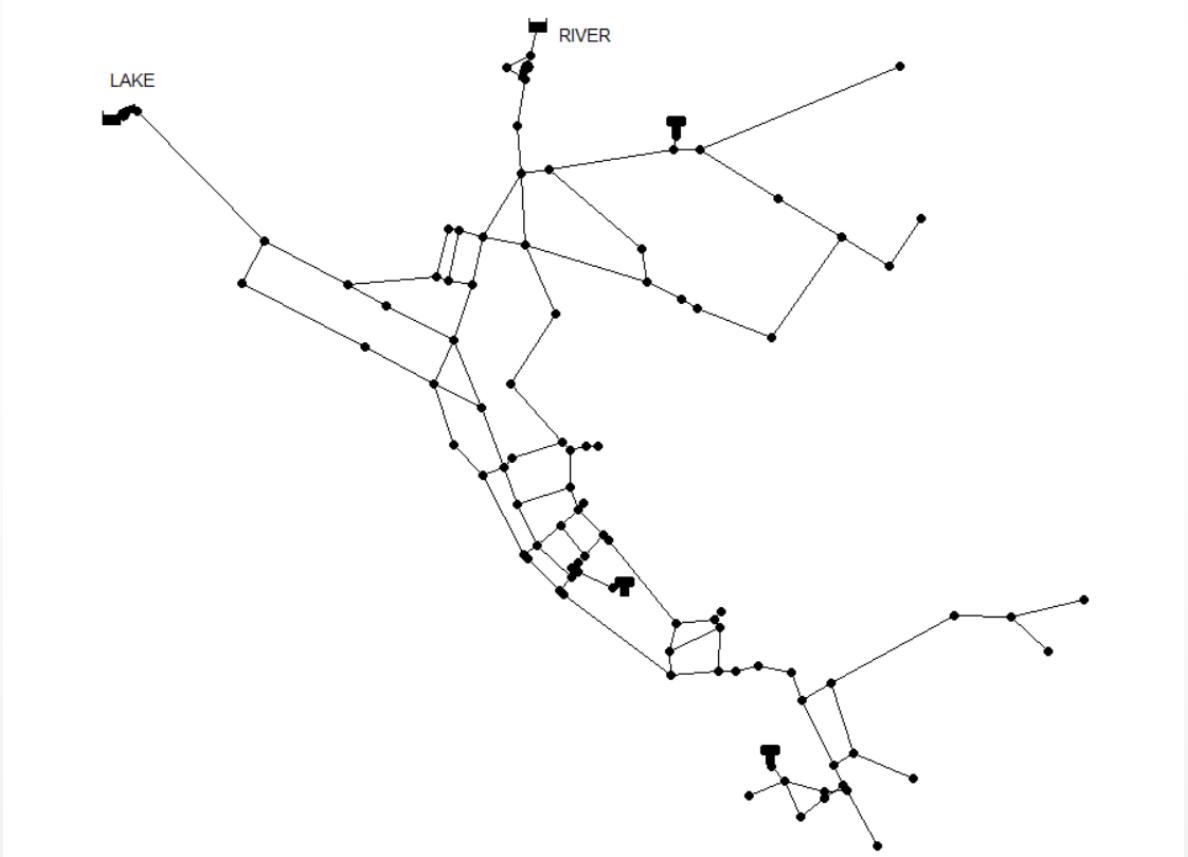
# EPANET Application – Water Quality

- Water age can tell you a lot

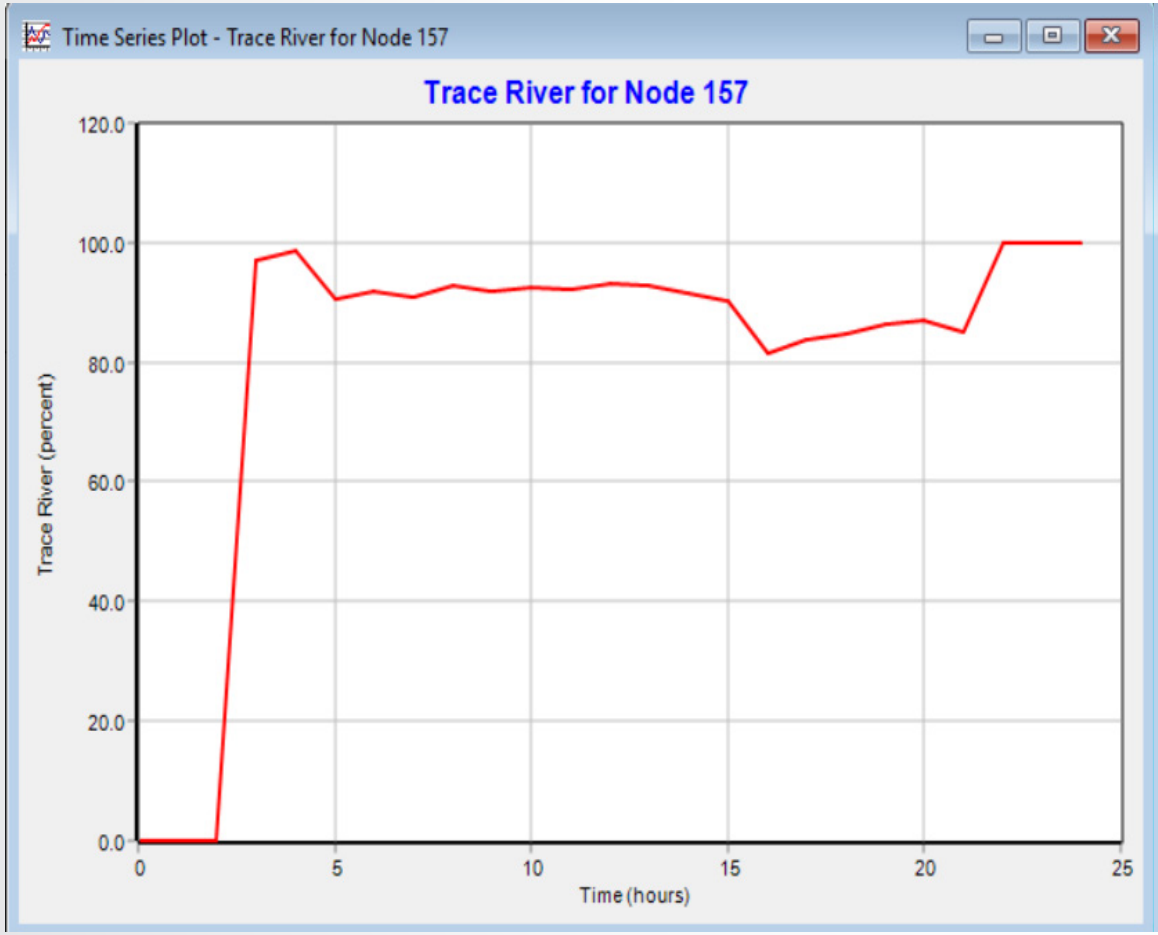


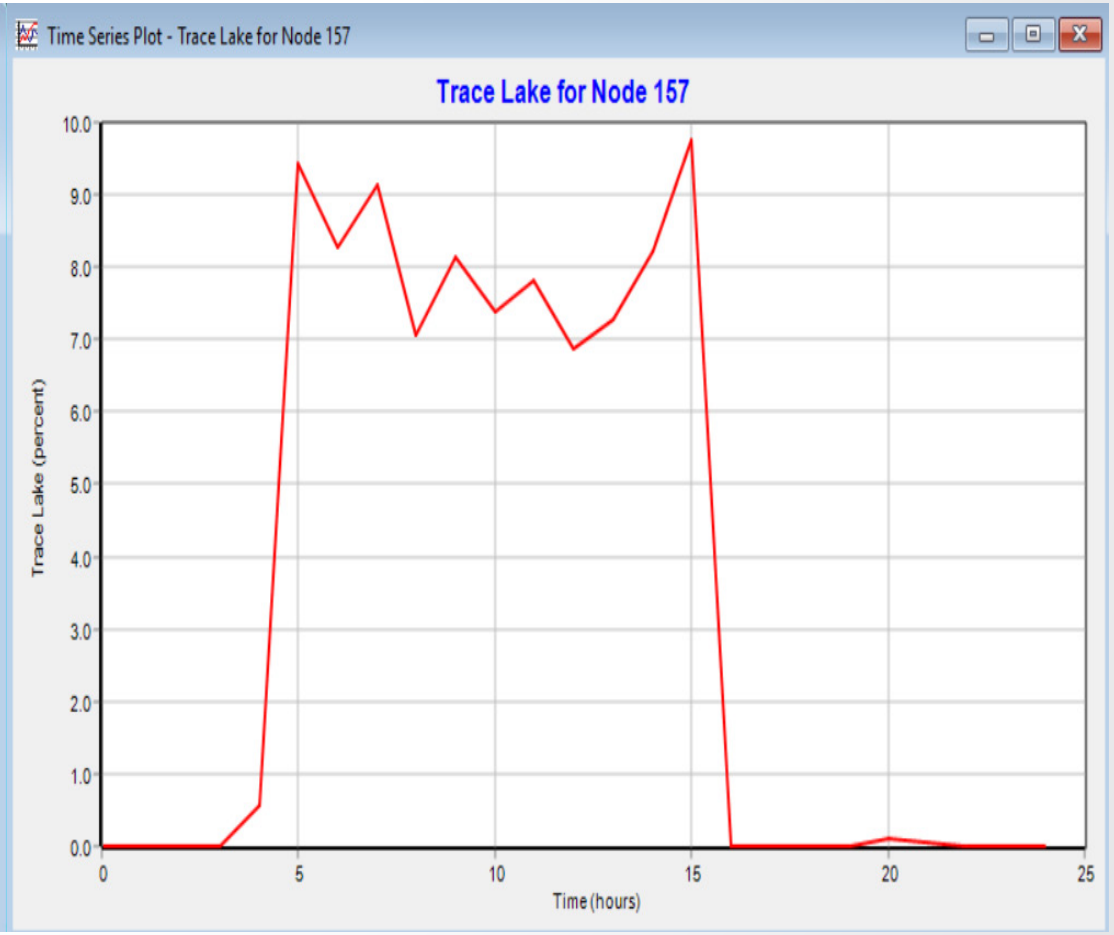
# EPANET Application – Water Quality

- Trace Analysis: where the water comes from?



# EPANET Application – Water Quality



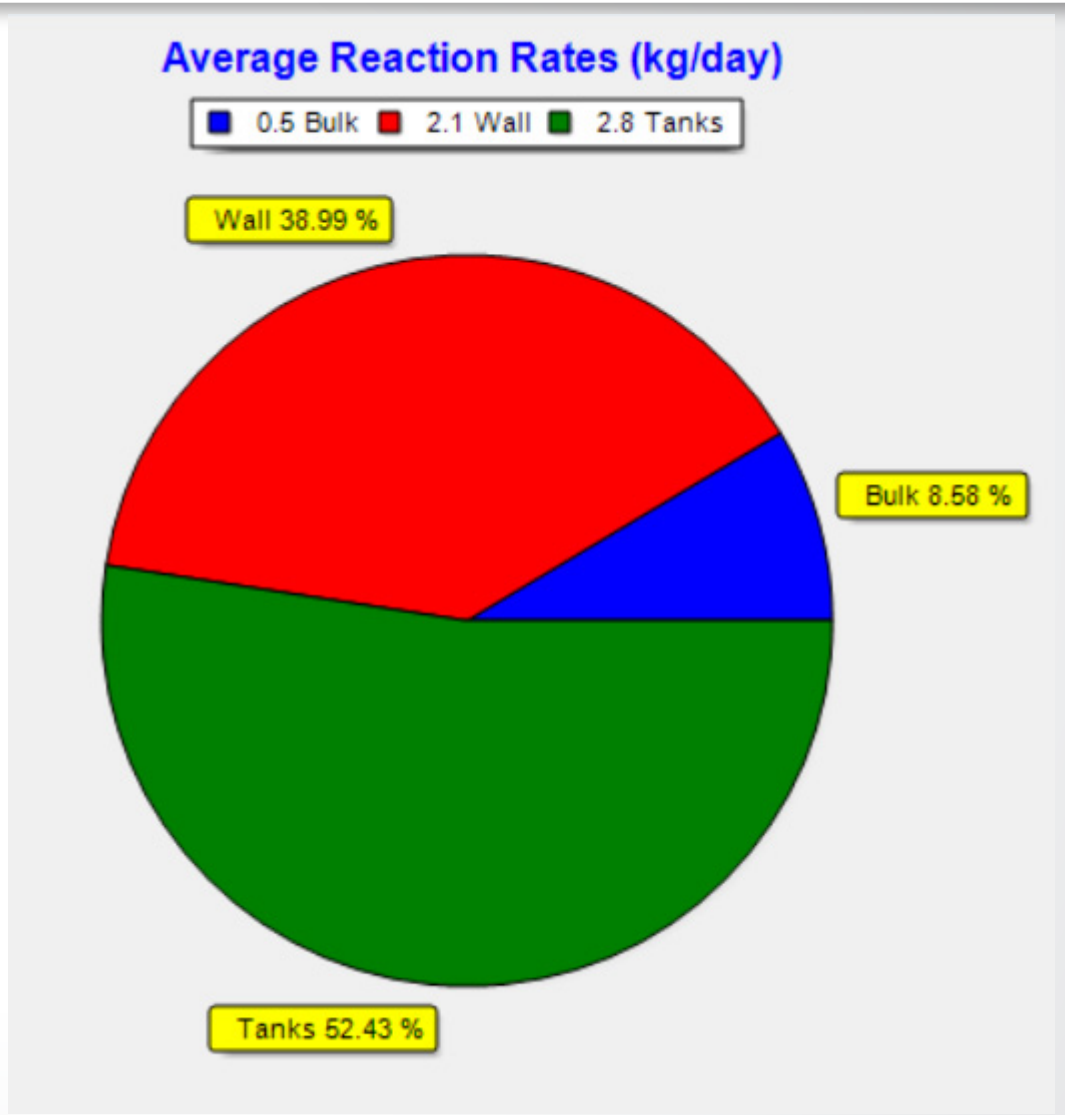
# EPANET Application – Water Quality

- Chemical Analysis: chlorine decay
- Relatively complicated analysis compared to water age and trace analysis.
- Water chemistry
  - Reaction/decay in bulk
  - Reaction/decay on pipe wall

# EPANET Application – Water Quality

Reactions Options

| Property | Value |
|---|---|
| Bulk Reaction Order | 1 |
| Wall Reaction Order | First |
| Global Bulk Coeff. | -.5 |
| Global Wall Coeff. | -1 |
| Limiting Concentration | 0.0 |
| Wall Coeff. Correlation | 0.0 |



# EPANET Application

- Both hydraulic and water quality issues need to be considered for water distribution system analysis.
- Improving hydraulic reliability may hurt water quality (large tanks with low turn over rate).
- EPANET is a convenient tool to do simulation analysis.
- Much effort is required to develop a good model!

# Disclaimer

*Disclaimer: This presentation has been subjected to the Agency's review and has been approved for presentation. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Any mention of trade names, manufacturers, or products does not imply an endorsement by EPA. EPA and its employees do not endorse commercial products, services, or enterprises.*