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17th Annual EPA Drinking Water Workshop: Small System Challenges and Solutions EPANET: An Introduction and Example Applications

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Center for Environmental Solutions and Emergency Response US EPA Office of Research and Development

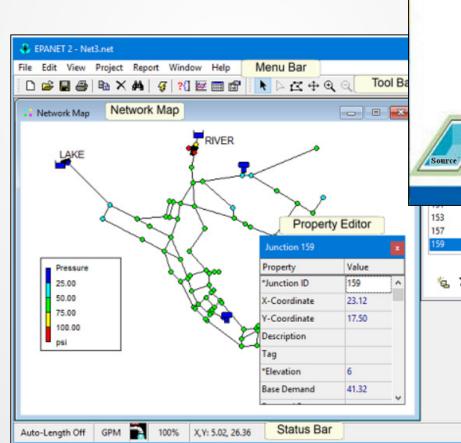
August 31, 2020



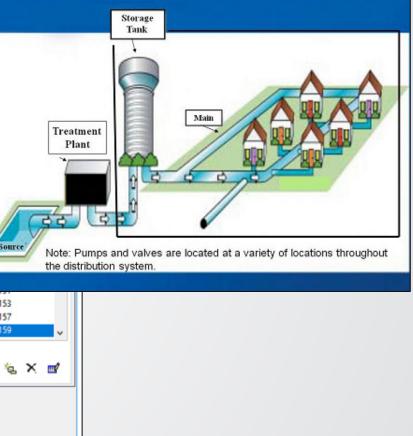
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Outline

- Introduction to EPANET
- EPANET applications



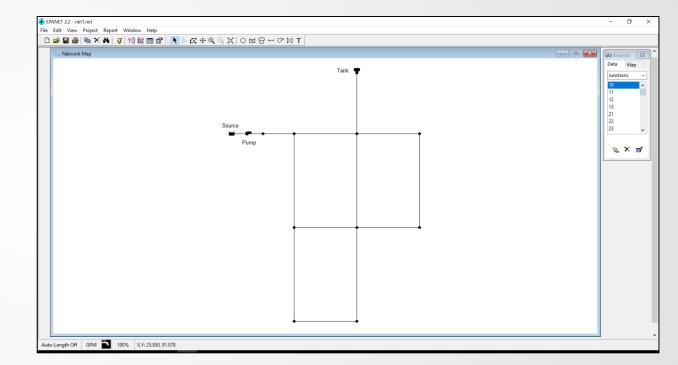
Water Supply Distribution System



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

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Some terms and definitions

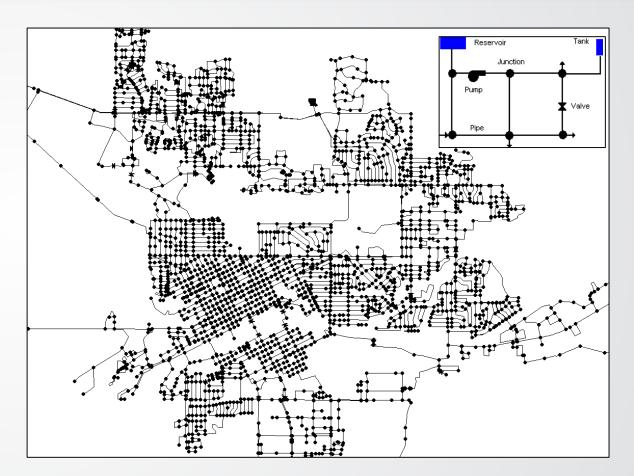
- Water Distribution System
 - Collection of pipes, tanks, pumps, valve control systems, and other components that work together to move water from a water source or treatment plan to individual users or customers' taps
- Network model (text file with .inp extension)
 - Water distribution system representation!
 - 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

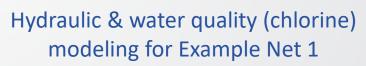


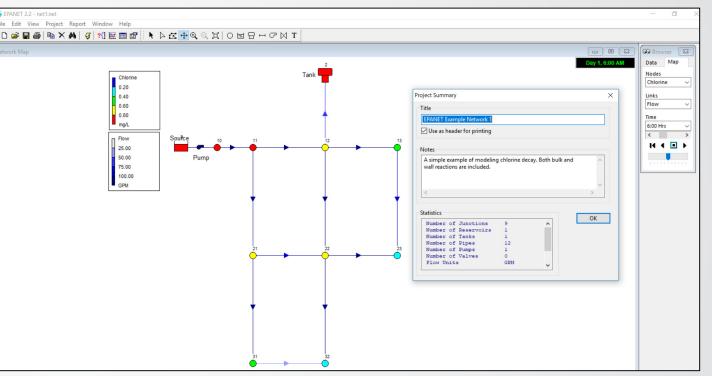
Creating a network model

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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





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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 <u>https://github.com/OpenWaterAnalytics/EPANET</u>

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 <u>http://community.wateranalytics.org/t/announcement-of-an-open-source-epanet-initiative/117</u>
 - 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:
 - <u>https://github.com/OpenWaterAnalytics/EPANET</u>
- OWA-EPANET is an open-source version of the EPANET Toolkit
 - <u>https://github.com/OpenWaterAnalytics/EPANET/wiki</u>
 - OWA EPANET Toolkit User's Manual: http://wateranalytics.org/EPANET/



Obtaining EPANET

USEPA / EPANET2.2

Tags

(Latest releas

S 2.2

🕅 epanet2.2 toolkit.zij

Source code (zin Source code (tar.oz

<> Code ① Issues 2 11 Pull red

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

Environmental Topics	Laws & Regulations	About EPA	Search EPA.gov
Related Topics: Water Res			CONTACT US SHARE (F) (S) (S)
EPANET			
Application for	r Modeling Drinl	king Water Distribu	tion Systems
systems. It was developed a water constituents within di applications in distribution to design and size new wate operations of tanks and pun and prepare for emergencie evaluate resilience to securi Software, Compat	systems analysis. Today, engine r infrastructure, retrofit existing nps, reduce energy usage, inves s. It can also be used to model o ty threats or natural disasters. ibility, and Manuals	novement and fate of drinking used for many different types of eers and consultants use EPANET g aging infrastructure, optimize stigate water quality problems,	On this Page • Software, Compatibility, and Manuals • Capabilities • Applications • Related Resources • Technical Support
) Pull requests 🕑 Actions 🔟 Projects	🖽 Wiki 🕕 Security 🗠 Insights	5	
		Edit release	Delete
FANET 2.2.0 Release fengshang1972 released this 18 days ago his is the latest release of EPANET 2.2.0 engin PA's updated Delphi-based Graphical User Int	1 1 1 1 P	nWaterAnalytics/EPANET/releases/tag/v2.2) ar	id the
fengshang1972 released this 18 days ago	1 1 1 1 P	nWaterAnalytics/EPANET/releases/tag/v2.2) ar	id the

847 KB

U.S. EPA website for EPANET

- Website (<u>https://www.epa.gov/water-research/epanet</u>)
 - 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 "<u>https://github.com/USEPA/EPANET2.2</u>"

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 2.2 Help	- 0
		편 수 수 쇼 프 한- Hide Back Forward Home Print Options	
		Contents Index Search Favorites	EPANET 2.2 Help
			Contents
		Adding Objects Curves Links Map Labels Nodes Time Patterns Analysis Options Energy Options Hydraulic Options Quality Options Reaction Options Setting Options Time Options Time Options Analyzing a Network Auto-Length Setting	EPANET is a program that performs extended period simulation of hydraulic and water quality behavior within drinking water distribution systems. Introduction EPANETs Workspace Working with Projects Working with Objects Working with the Map Analyzing a Network Viewing Results Printing and Copying Importing and Exporting
😵 EPA	NET2.2 Tutorial	– 🗆 X	Frequently Asked Questions
Naviga	tion: EPANET Tutorial >		<u>Reference</u>
Projec	ct Setup	← ↑ →	
View I	Мар		
Our first are sele	t task is to create a new project in EPANET a acted.	nd make sure that certain default options	
1. If E	PANET is not already running then launch it f	rom the Windows Start menu.	
2. Sel	ect File New to create a new project.	Displa	
. Sel	ect Project Defaults to open the Project De	faults dialog form.	
	the ID Labels page, clear all of the ID Prefix make EPANET automatically label new object		EPANET's
	the Hydraulics page of the dialog choose GI	² M as Flow Units and Hazen-Williams	
5. On	W) as Headloss Formula.		
5. On (H-)	W) as Headloss Formula. ck OK to accept these choices and close the o	tialog.	Integrated Help

Running EPANET un-installed

 Non-installing software for EPANET 2.2 (epanet2.2.zip)

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- Notice everything is included
- Runs EPANET (Epanet2w.exe)
- DOS command line EPANET (runepanet.exe)

Name	Status	Date modified	Туре	Size
🗹 📜 Examples	2 8	8/11/2020 1:19 PM	File folder	
🔐 EPANET2.chm	<mark>2</mark> 8	1/24/2020 9:38 AM	Compiled HTML Help file	692 KB
epanet2.dll	<mark>2</mark> 8	1/24/2020 10:22 AM	Application extension	287 KB
蹇 Epanet2w.exe	<mark>2</mark> 8	2/26/2020 1:18 PM	Application	5,092 KB
notes.txt	<mark>2</mark> 8	1/24/2020 9:58 AM	Text Document	4 KB
📧 runepanet.exe	<mark>2</mark> 8	1/24/2020 10:23 AM	Application	285 KB
🔐 Tutorial.chm	<mark>2</mark> 8	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

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- 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 (m³/s)
 - 1 m³/s = 1000 l/s
- EPANET supports both unit systems

😰 EPANET 2.2 Help	- 🗆 ×
Hide Back Forward Home Print Options	
Contents Index Search Favorites	Units of Measurement <u>Top</u> Previous Next
Type in the keyword to find:	EPANET can use either US or metric units of measurement for all of its quantities, depending on the choice of flow units
units	(see <u>Setting Analysis Options</u> or <u>Setting Project Defaults</u>):
	US Customary units apply when flow is expressed in cubic
Properties	feet, gallons, or acre-feet
Time Patterns	SI Metric units apply when flow is expressed in liters or
Adding	cubic meters
Editing	
Toolbars	
Map Toolbar	
Standard Toolbar Units of Measurement	
Metric	
US	
US Units	

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

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EPANET definitions

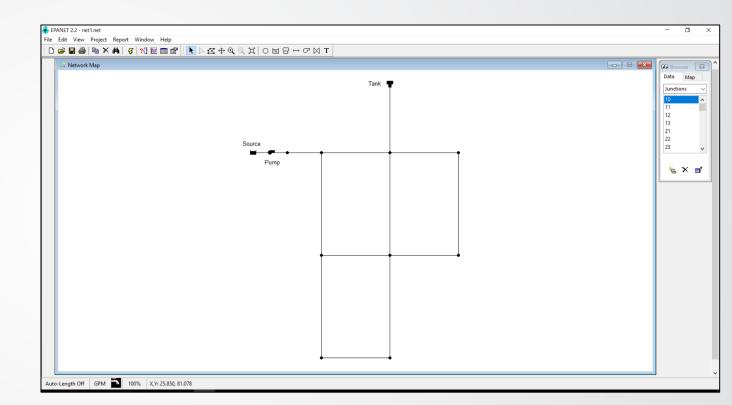
- Nodes
 - Junctions, tanks and reservoirs
- Links
 - Pipes, pumps and control valves
 - Links must have start and end nodes
- Reservoirs
 - Nodes with infinite external source or sink of water to the network

- 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

Set EPA

Getting started!

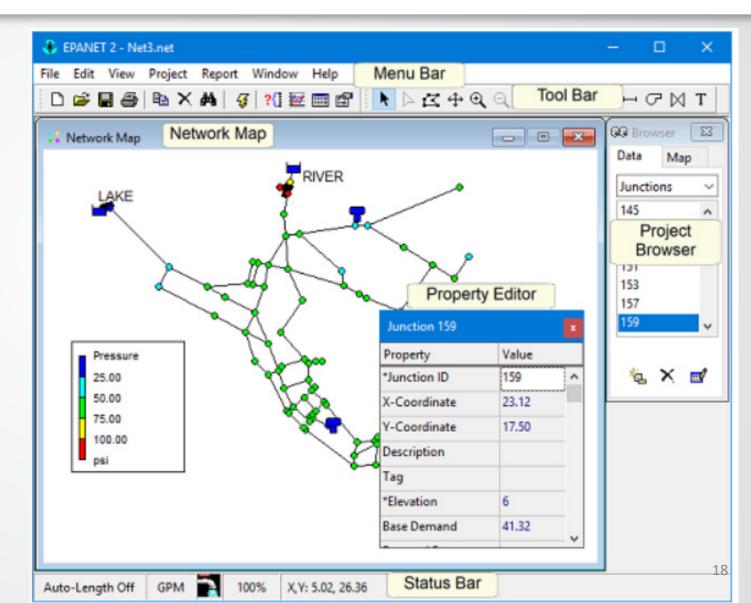
- Tutorial
 - Compiled HTML tutorial file and integrated help file
- User's Manual
 - Opening an existing network
- Example networks
 - Experiment with example networks provided



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





 Some menu items to highlight:

oject Summary			
Title			
EPANET Example Network 1			
Use as header for printing			
Notes			
	chlorine dec	av. Both bulk a	and A
A simple example of modeling wall reactions are included.	, chionne dec		>
wall reactions are included.			>
wall reactions are included.	9		~
wall reactions are included.			>
vall reactions are included.	9		>
wall reactions are included.	9		>
Vall reactions are included.	9 1 1		>
<pre>wall reactions are included. </pre> Statistics Number of Junctions Number of Reservoirs Number of Tanks Number of Pipes	9 1 1 12		>

Project Summary

ID Labels	Properties	Hydraulics	
Object		ID Prefix	
Junctions			
Reservoirs			
Tanks			_
Pipes			
Pumps			
Valves			
Patterns			
Curves			



Preferences	×
General Formats	
Blinking Map Hiliter	
Flyover Map Labeling	
Confirm Deletions	
Automatic Backup File	
Clear File List	

OK	Cancel	Help

Interface for setting preferences e.g., decimal places

Nodes	Node Size
inks	3 💭 🔶
abels	Proportional to Value
Notation	🗹 Display Border
ymbols	Display Junctions
Flow Arrows	
Background	

Interface for setting map viewing options

Parameter	Name of Calibration File	- 🖓
Demand		Browse
Head		
Pressure		E E
Quality		Edit
Flow		
Velocity		

Interface for uploading calibration data 19

Property editor

 Edit properties of nodes, links, labels, analysis options

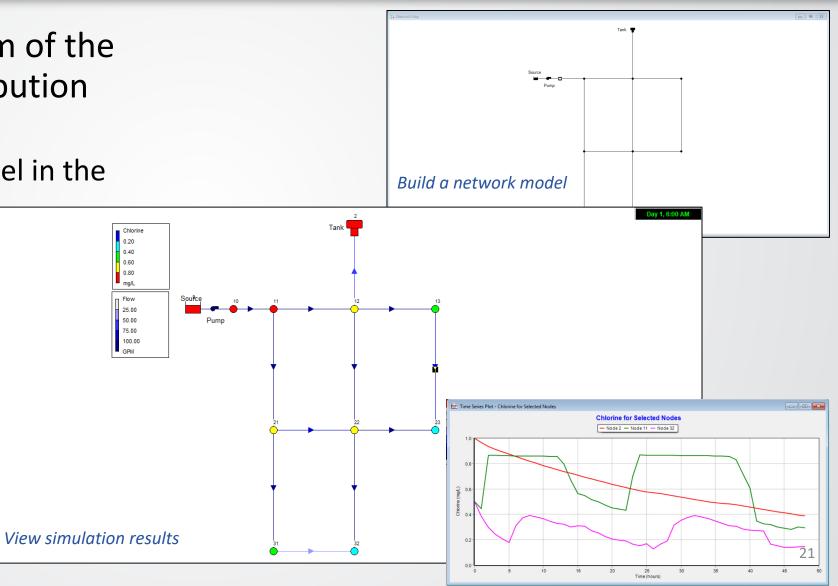
Property	Value	
*Junction ID	10	
X-Coordinate	20.000	
Y-Coordinate	70.000	
Description		
Tag		
*Elevation	710	
Base Demand	0	
Demand Pattern		
Demand Categories	1	
Emitter Coeff.		
Initial Quality	0.5	
Source Quality		
Actual Demand	#N/A	
Total Head	#N/A	
Pressure	#N/A	
Quality	#N/A	

20



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



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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

	Data
Junction 23	Junctions
Property	Value 10
*Junction ID	23 11
X-Coordinate	70.000 12
Y-Coordinate	40.000 13
Description	21
Tag	
*Elevation	690 22
Base Demand	150 23
Demand Pattern	
Demand Categories	1
Emitter Coeff.	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Initial Quality	0.5
Source Quality	Data P
Actual Demand	240.00 Data Bi
Total Head	975.97 Vie
Pressure	123.91
Quality	0.21

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

Map Browser view

Brows

Data

Nodes Chlorine

Links

Flow

Time

6:00 Hrs

I4 -



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: <u>epanet@epa.gov</u>

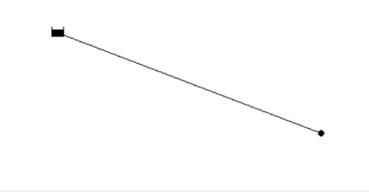
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- EPANET community at OpenWaterAnalytics (Hydraulic & Water Quality Engines)
 - <u>https://github.com/OpenWaterAnalytics/EPANET/wiki</u>
 - Community forum http://community.wateranalytics.org/
- If you want to contribute to EPANET please go to <u>https://github.com/OpenWaterAnalytics/EPANET/issues</u>

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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 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.



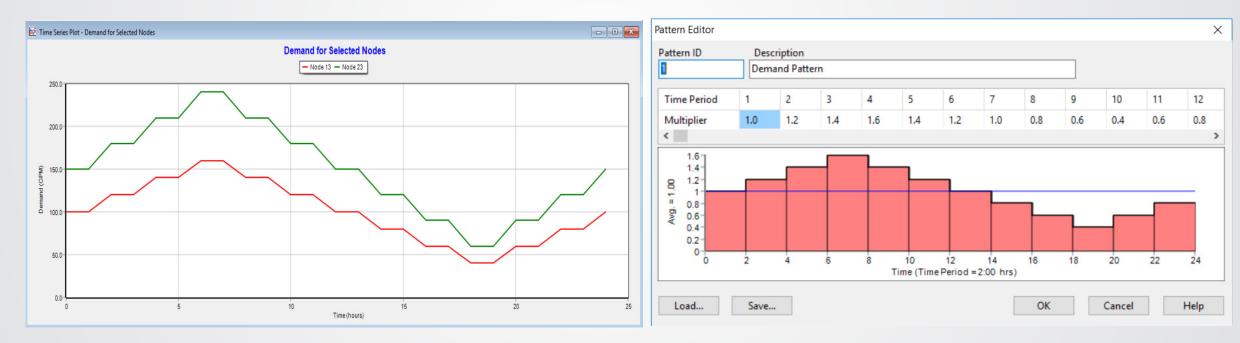
- Steady state analysis
 - Fixed demand
 - A snapshot analysis
- Extended Period Simulation
 - Changing demand over time
 - Typically, at least a couple of days, e.g., seasonal peak days



- 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.

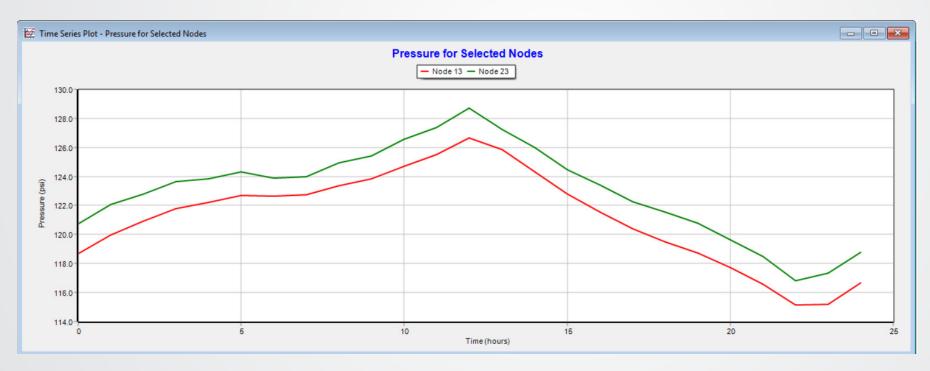


Extended Period Simulation



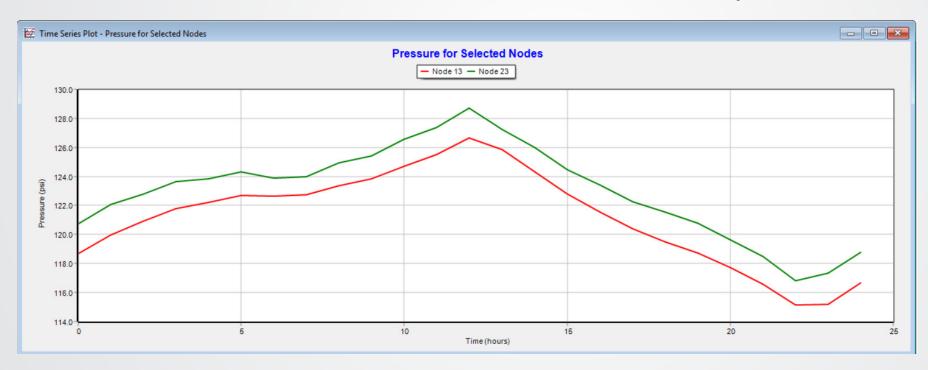


• Extended Period Simulation Results



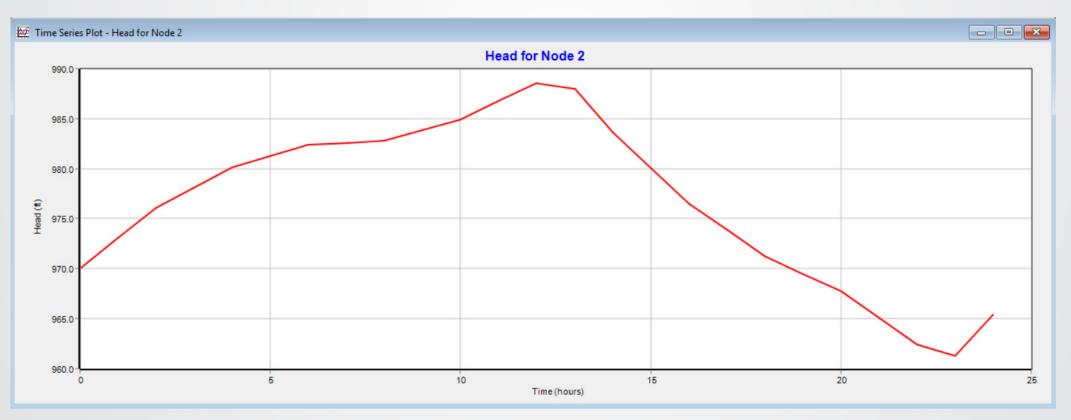


• Extended Period Simulation Results: node pressure





• Extended Period Simulation Results: tank operation





- 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.



Pressure Dependent Analysis is an option in EPANET

III 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

III 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



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



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

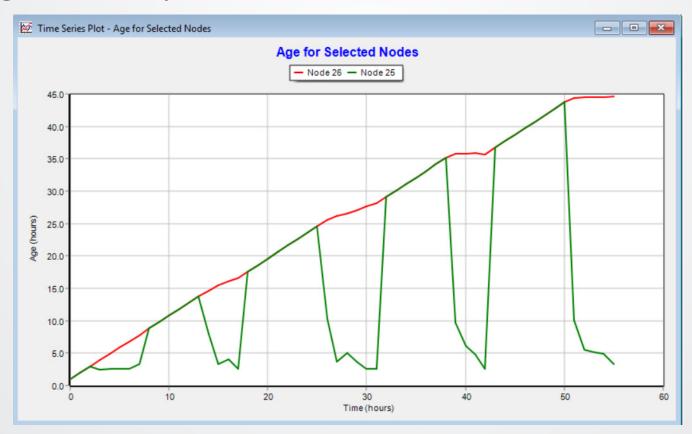


• Water age modeling is very easy to do

Property	Value
Parameter	Age ~
Mass Units	mg/L
Relative Diffusivity	1.0
Trace Node	
Quality Tolerance	0.01

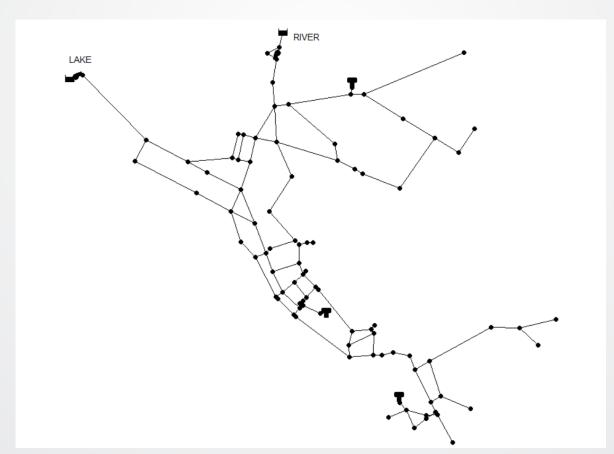


• Water age can tell you a lot

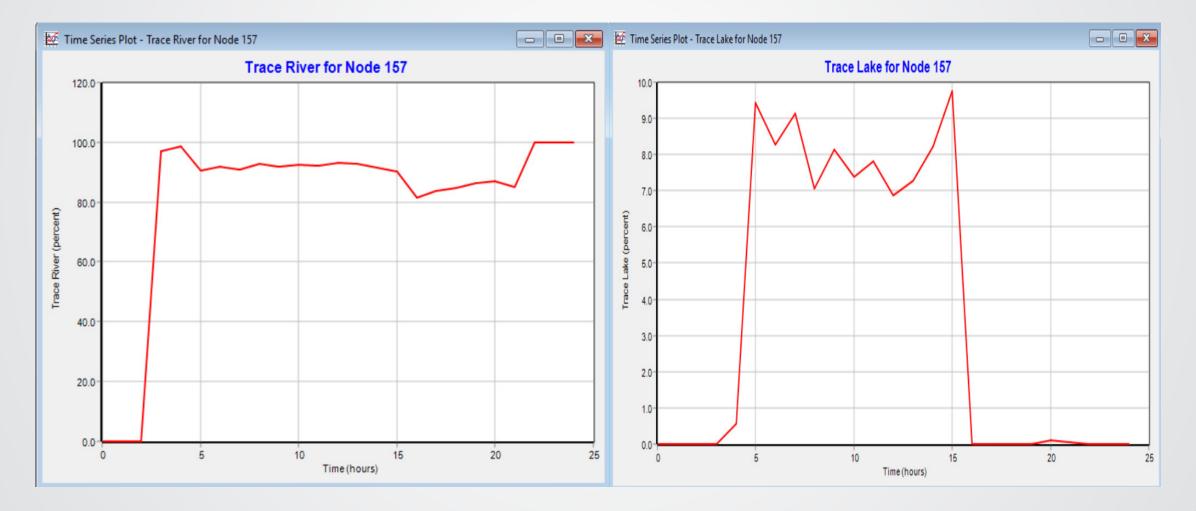




• Trace Analysis: where the water comes from?







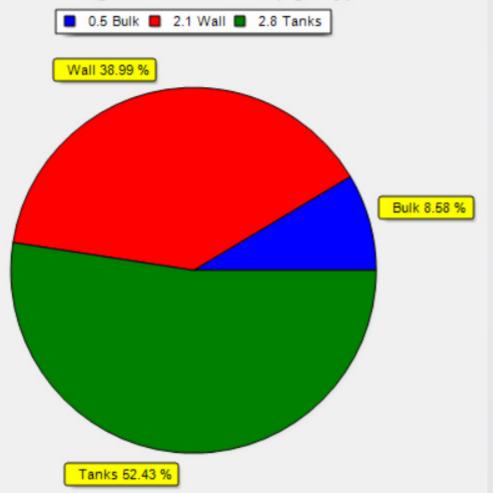


- Chemical Analysis: chlorine decay
- Relatively complicated analysis compared to water age and trace analysis.
- Water chemistry
 - Reaction/decay in bulk
 - Reaction/decay on pipe wall

EPANET Application – Water Quality

Reactions Options	x
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

Average Reaction Rates (kg/day)





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!



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