18th Annual EPA Drinking Water Workshop

Small Systems Challenges and Solutions | Aug 30 - Sep 2, 2021

SESSION T2: Introduction to EPANET and Example Applications

Presentation Slides: Located under "Handouts" in the right navigation bar on your screen.

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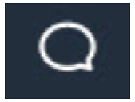
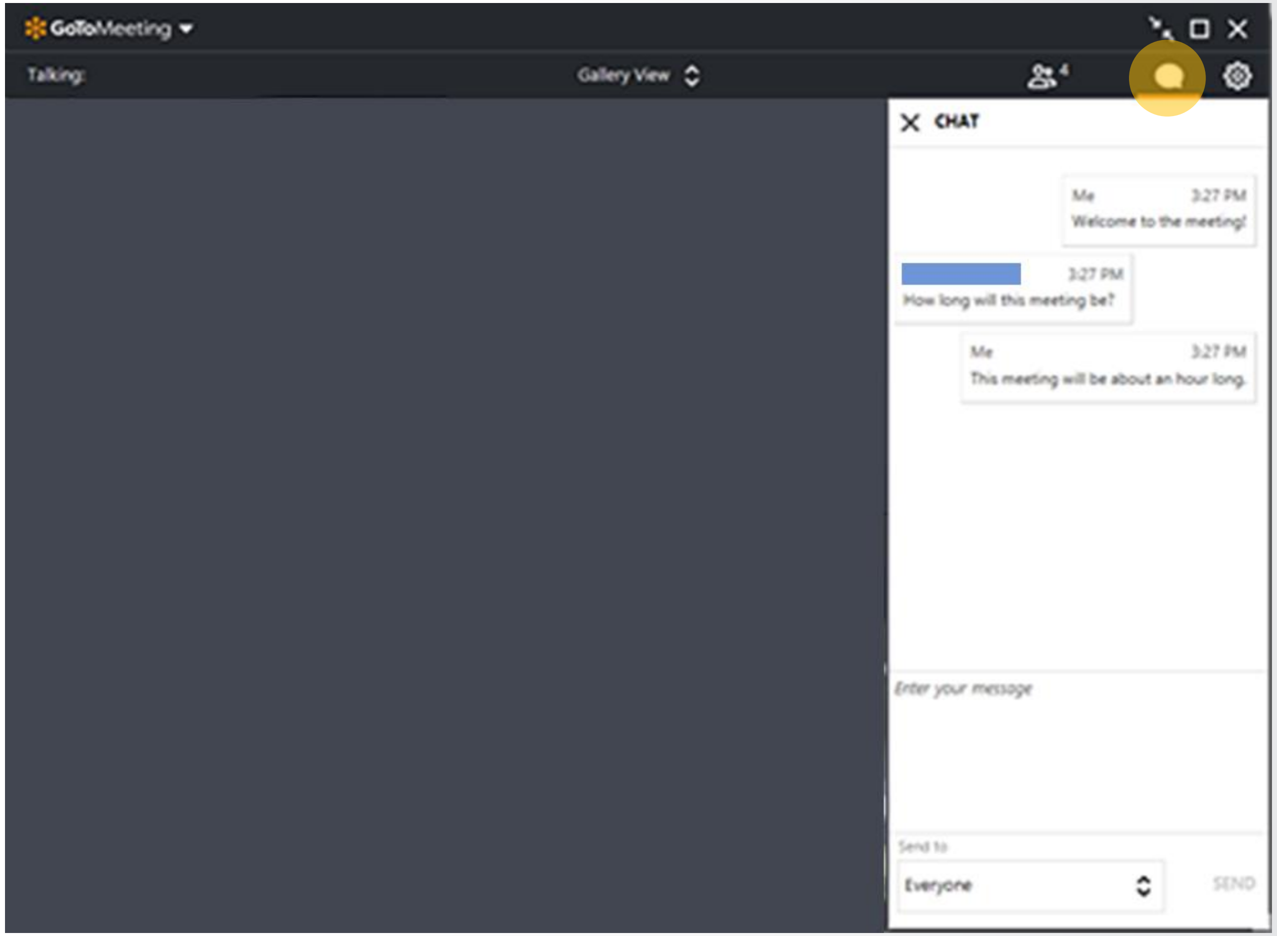
- Click the speech chat icon 
- Type & submit your questions at anytime
- We'll take time to answer them at the end of each section



18th Annual EPA Drinking Water Workshop

Introduction to EPANET and Example Applications

Center for Environmental Solutions and Emergency Response

US EPA Office of Research and Development

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EPANET Presenters (I)

TERRA HAXTON has a B.S. in civil engineering from Rose-Hulman Institute of Technology and M.S. and Ph.D. in environmental engineering from Vanderbilt University. Since joining EPA in 2007, Terra's research has focused on modeling the fate and transport of contaminants in drinking water distribution systems. Past research areas have included using modeling tools to help detect contamination, identify the source of contamination, determine grab sample locations to outline contaminated areas, and evaluate flushing strategies for contamination incidents. Her current research area is developing and applying modeling and simulation tools to assess the resilience of drinking water systems to disasters (e.g., earthquakes, power outages, pipe breaks, loss of source water).

FENG SHANG received his bachelor’s and master’s degrees in environmental engineering from Tsinghua University in China. Feng completed his PhD at the University of Cincinnati in the Environmental Engineering program. After getting his PhD degree, Feng worked briefly as a postdoc for the EPA, during which time he wrote the initial code for the multiple species extension (MSX) to EPANET. Feng joined the engineering software company Innovyze in 2008 and worked there as a principal software engineer until 2019. Feng joined EPA’s Water Infrastructure Division as an environmental engineer in April 2019. His focus at EPA is on researching hydraulic and water quality issues in water infrastructure systems.

EPANET Presenters (2)

BEN BURKHART received his bachelor's degree in Mechanical Engineering from the University of Cincinnati. Ben joined the EPA in 2020 as an ORAU contractor. Prior to joining the EPA, Ben spent his last 3 co-ops at Wayne Water Systems designing and testing residential water pumps. Ben's research at the EPA has focused on water age and EPANET. Ben provides technical support for EPANET, including responding to users' questions and producing presentations and papers to help EPANET to be easier to learn and use.

JONATHAN BURKHARDT earned his Ph.D., master's and bachelor's degrees in Chemical Engineering from the University of Cincinnati. Jon joined U.S. EPA in 2013 as an ORISE postdoctoral fellow, and more permanently in 2015. Jon's research at EPA has focused on modeling contaminant fate and transport in water distribution systems and more recently in premise plumbing systems. Jon has supported EPANET, EPANET-MSX, WNTR and PPMtools development to support research related to these systems. Jon also leads research efforts associated with understanding water treatment with granular activated carbon.

EPANET Presenters (3)

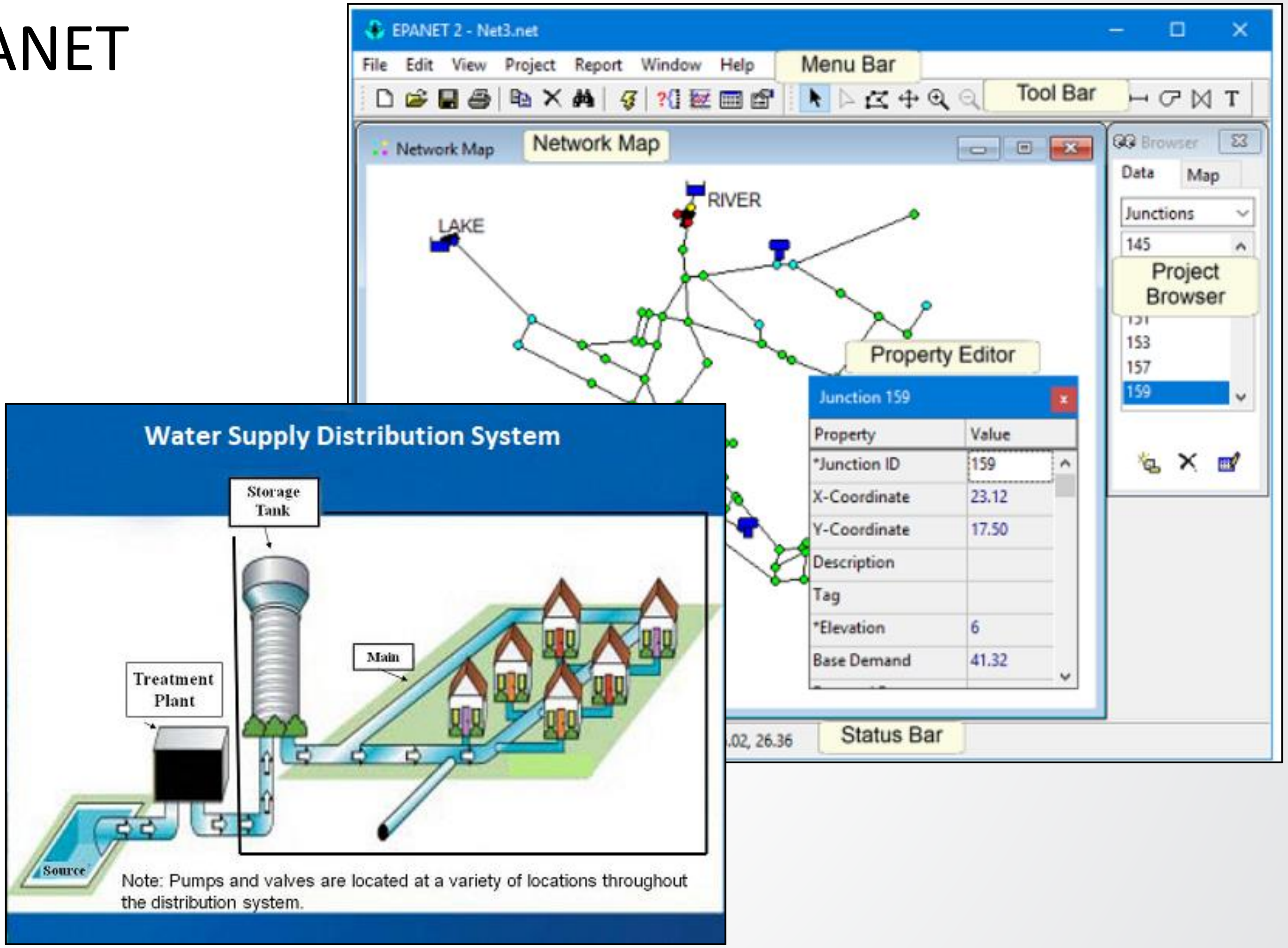
ROBERT JANKE earned his bachelor's degree in Chemistry and a master's degree in Health Physics from the University of Cincinnati. Rob joined U.S. EPA in 2003. Prior to joining EPA, Rob spent 12 years with the Department of Energy overseeing a large-scale remediation while focused on developing real-time radiological survey instrumentation and procedures. Rob's research at EPA has focused on understanding and dealing with contaminant threats to drinking water distribution systems (TEVA-SPOT) and developing the tools for real-time modeling. Rob helped coordinate the establishment of the EPANET-RTX open-source project that helped lead to the community open-source software project for EPANET.

Summary

- This workshop on EPANET will be structured as two parts. Part 1 will provide an overview and introduction to EPANET. Part 2 will consist of presenting and discussing four example EPANET applications that participants can follow to get familiar with and use EPANET. The four applications will be in the form of exercises and will include (1) building an EPANET model, (2) performing a hydraulic simulation using demand dependent and pressure dependent demands, (3) performing a water age analysis, and (4) performing a water quality, chlorine analysis.

Outline for Workshop

- Overview & Introduction to EPANET
- EPANET Modeling Capabilities
- EPANET Applications
  - Model Building
  - Hydraulic Modeling
  - Water Age Modeling
  - Chlorine Modeling
- Application sections:
  - Lecture
  - Demonstration
  - DIY Exercise

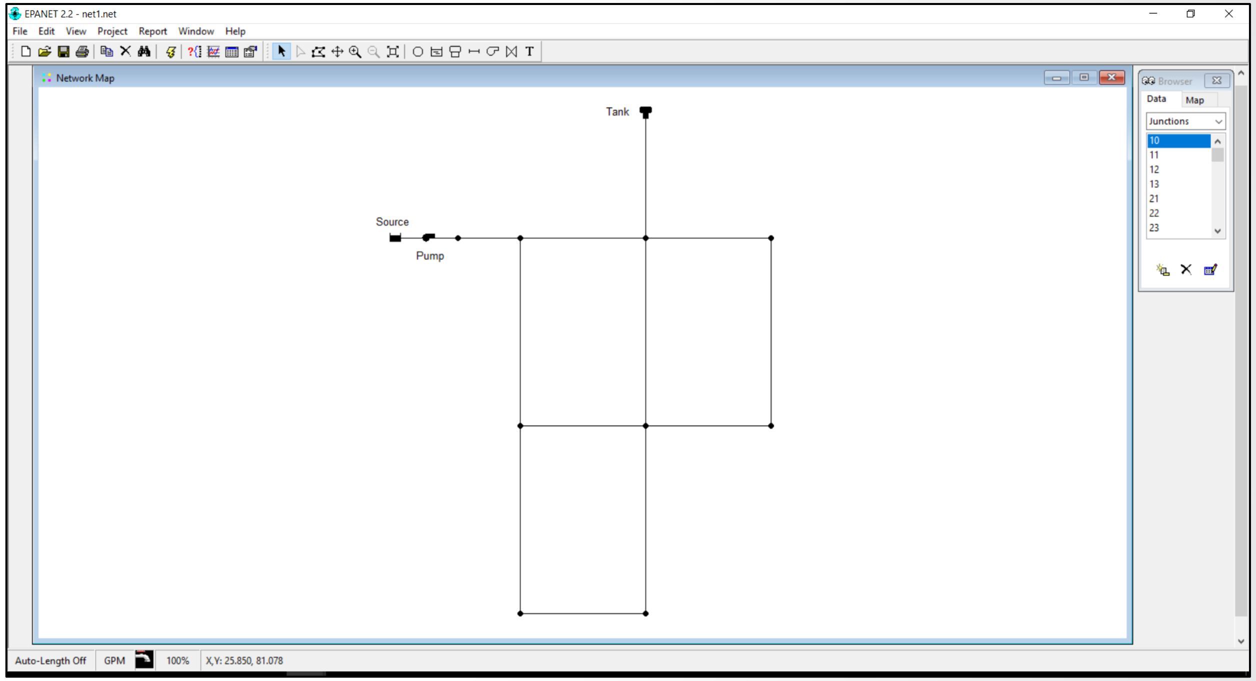


Overview & Introduction to EPANET

Terra Haxton

What is EPANET?

- What is EPANET?
  - Not acronym or initialism!
  - Computer program
    - Graphical user interface (GUI)
      - Microsoft Window Compatible
    - Command line & toolkit versions
- Used to model and analyze a water distribution system network
  - Input:
    - Pipe network layout
  - Outputs:
    - Hydraulics (e.g., pipe flows and pressures)
    - Water quality (e.g., disinfectant concentrations and water age)



EPANET is open-source software that is free for anyone to use!

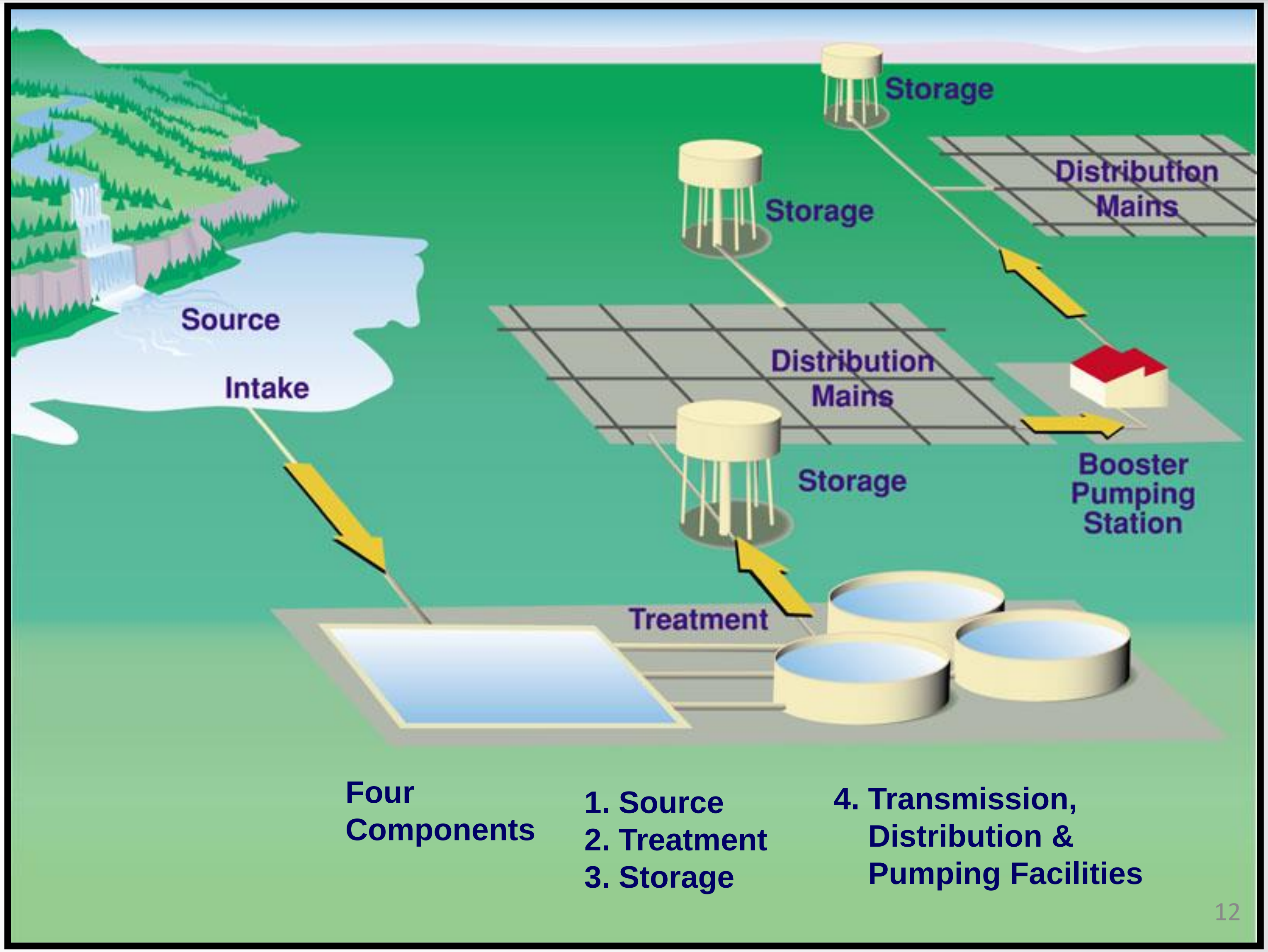
Knowledge Check I

What does EPANET stand for?

A. Environmental Protection Agency Network
B. It’s not an acronym
C. Environmental Protection Agency National Emission Trends
D. Energy Partnership Agreement National Employee Training

Drinking Water System

- Major components:
  - Source water
  - Treatment
  - Storage
  - Transmission, Distribution, and Pumping Facilities



Terms & Definitions (I)

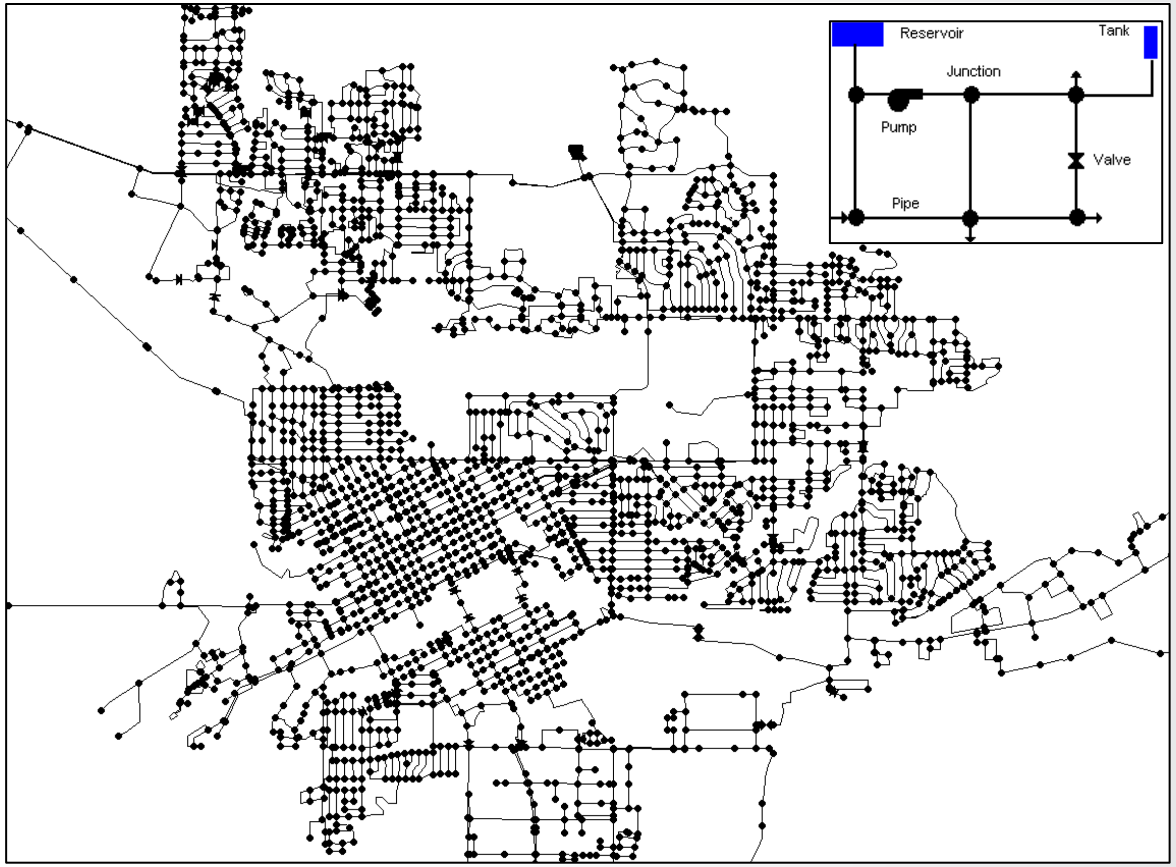
- Water distribution system (WDS)
  - Collection of pipes, tanks, pumps, valve control systems, and other components that work together to move water from water source or treatment plant to individual users or customers’ taps
- Network model (text file with .inp extension or binary file with .net)
 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

Terms & Definitions (2)

- Steady state simulation
  - Network analyzed as snap-shot in time, time zero in EPANET
- Extended period simulation
  - Network analyzed over time
- Water distribution system modeling is process to help understand:
  - How water distribution system is designed and how designs can be improved
  - How water distribution system is operating and how operations can be improved
- Water distribution system modeling is mathematical process
  - Formulas are used to convert physical (infrastructure) model into form able to calculate hydraulics and chemical properties of water quality to represent or model the behavior of water system

Reasons to Develop Model

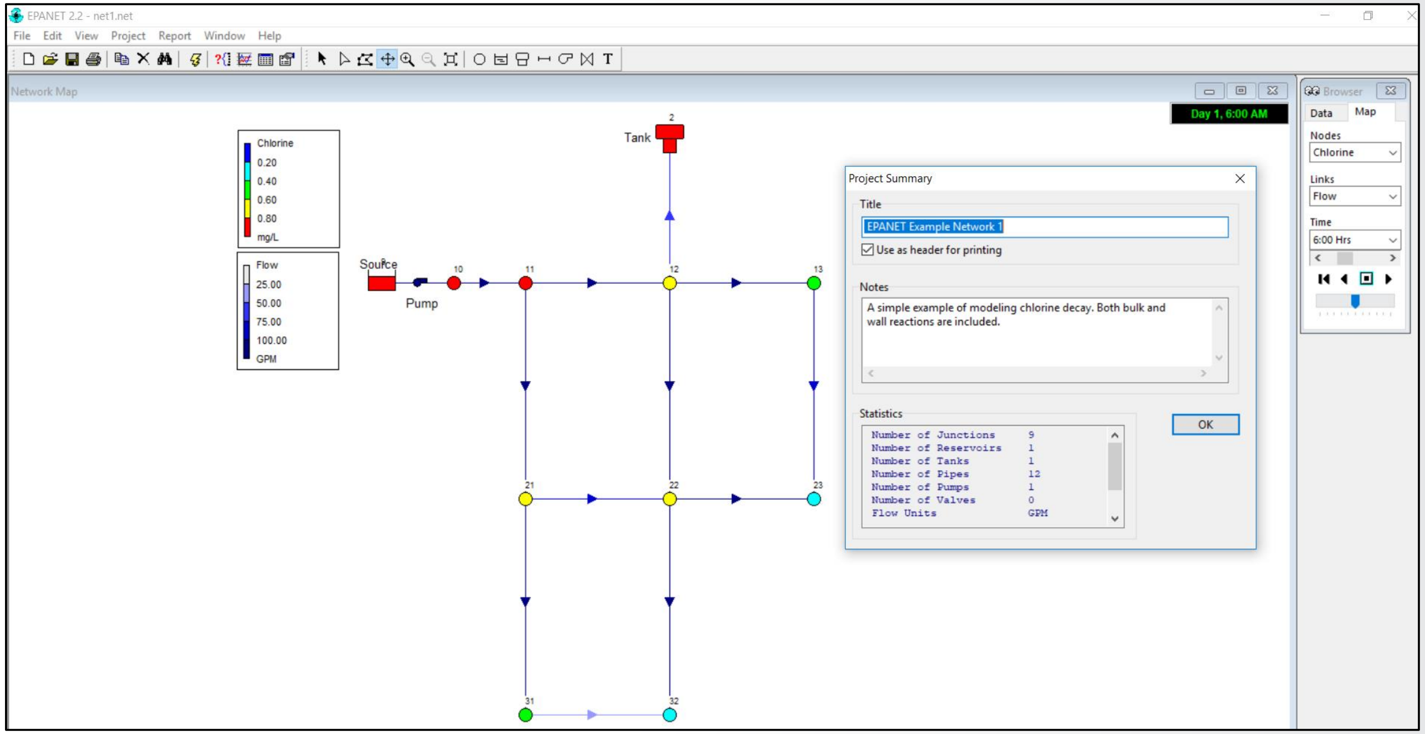
- Planning
  - Capital improvements
  - Water usage and conservation
  - Replacement and upgrade program
- Design
  - Facility sizing
  - Fire flow analysis
- Operations
  - Training
  - Hydraulic and water quality concerns
  - Emergencies



Network model

EPANET Modeling Types

- Hydraulic modeling
  - Evaluate operations
    - Current conditions
    - Test impact of changes to pumps, tanks, and valves
  - Design new water distribution systems or upgrade existing systems
- Quality modeling
  - Water age and disinfectant management
  - Contaminant transport, exposure, and risk analyses



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

History of EPANET

- EPANET was developed by Lewis A. Rossman (retired March 2014) working for U.S. EPA in 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 community collaboration at https://github.com/OpenWaterAnalytics/EPANET

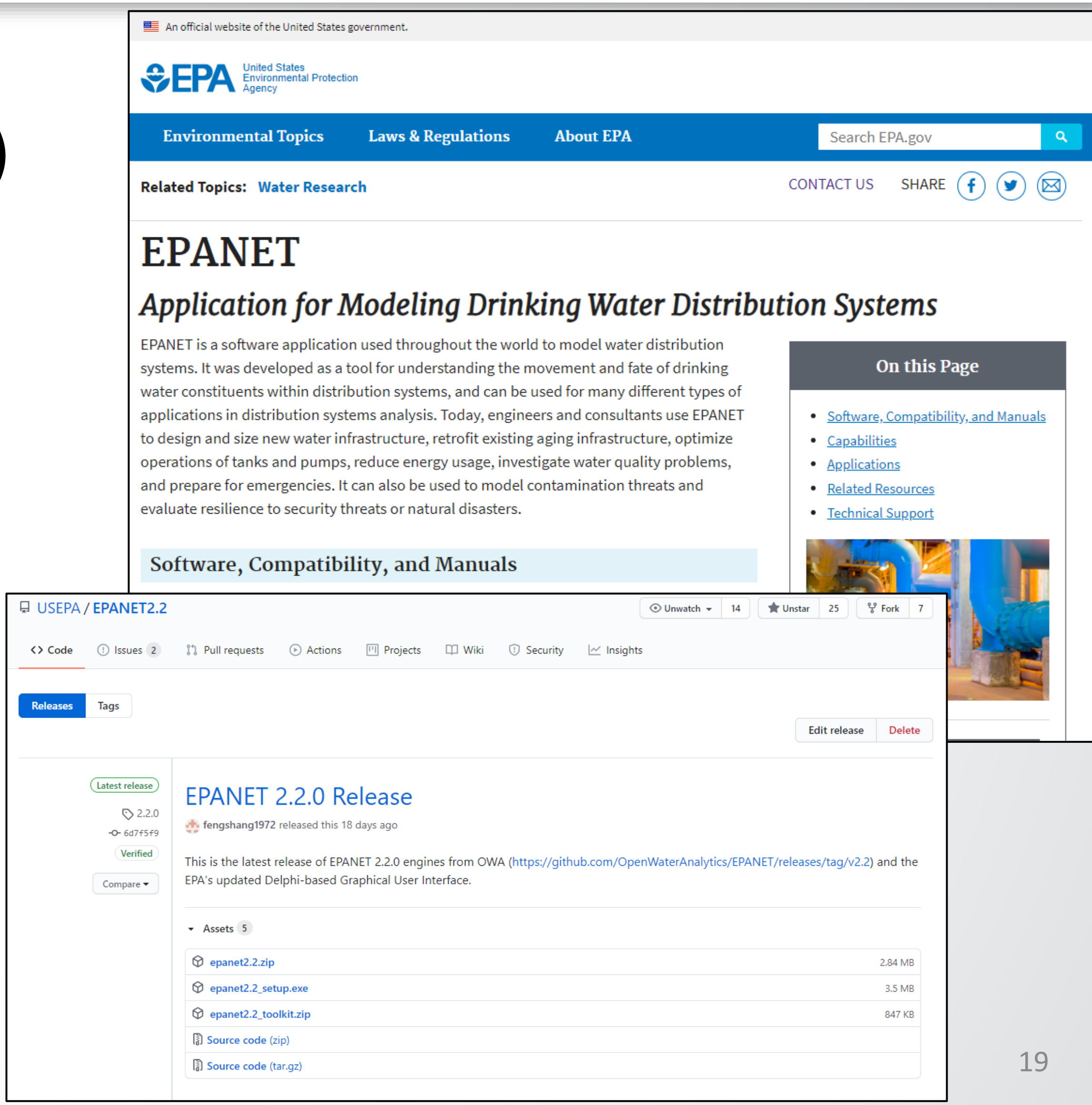
U.S. EPA’s latest release is version 2.2.0

Improvements in EPANET 2.2

- Ability to use pressure-dependent demands in hydraulic analyses
- Option to allow full tanks to overflow
- Options that ensure more accurate hydraulic analysis
- 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/)

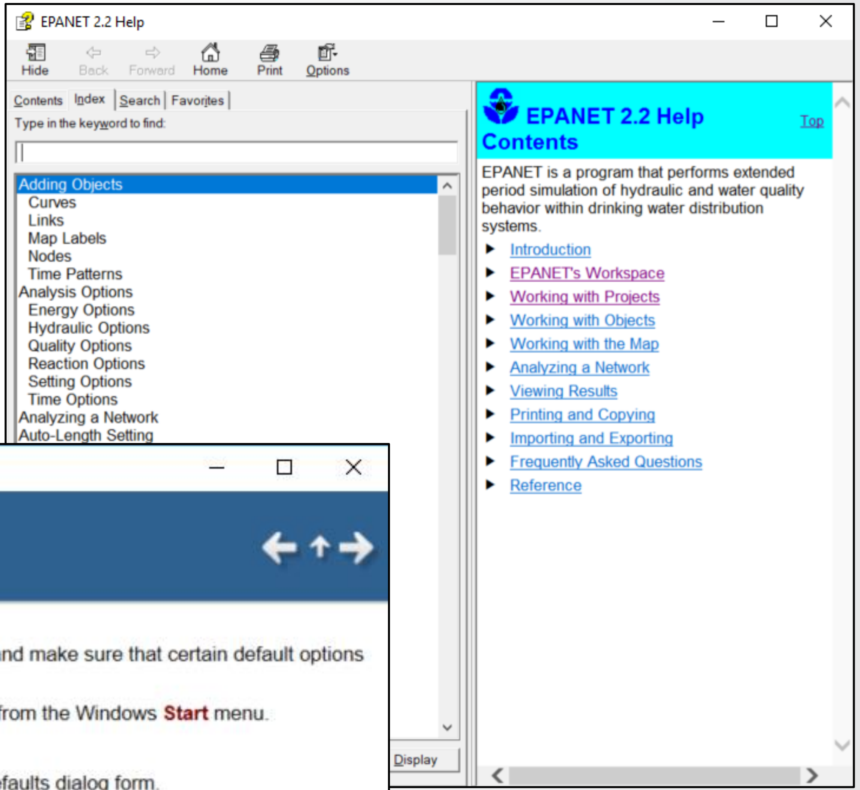
Downloading EPANET

- U.S. EPA's website (https://www.epa.gov/water-research/epanet)
  - Software (GUI)
    - 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/)
  - 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

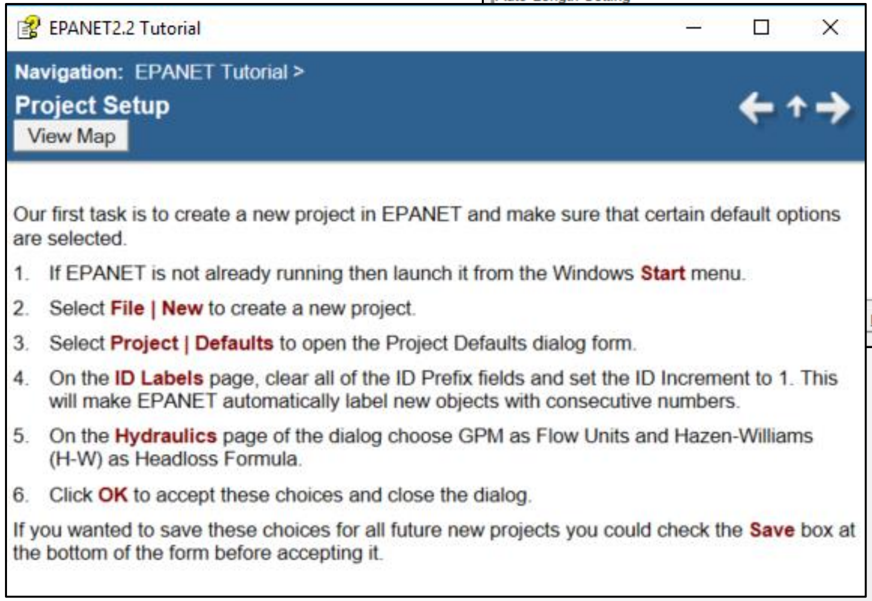


Installing & Running EPANET

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



EPANET's Integrated Help



EPANET's Tutorial

Running EPANET (non-installing)

- Non-installing software for EPANET 2.2 (epanet2.2.zip)
  - Notice everything is included – same as installed version
  - Can be saved anywhere on computer
  - Runs EPANET (Epanet2w.exe)
  - DOS command line EPANET (runepanet.exe)
  - This option does not require administrative rights!

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

EPANET Resources

- U.S. EPA website (General Information)
  - (https://www.epa.gov/water-research/epanet)
  - Questions - Email us at epanet@epa.gov

- USEPA Github.com repository (General Information & User Interface)
  - https://github.com/USEPA/EPANET2.2

- 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 https://github.com/OpenWaterAnalytics/EPANET/issues

Knowledge Check 2

If you have questions about EPANET, where can you find answers?

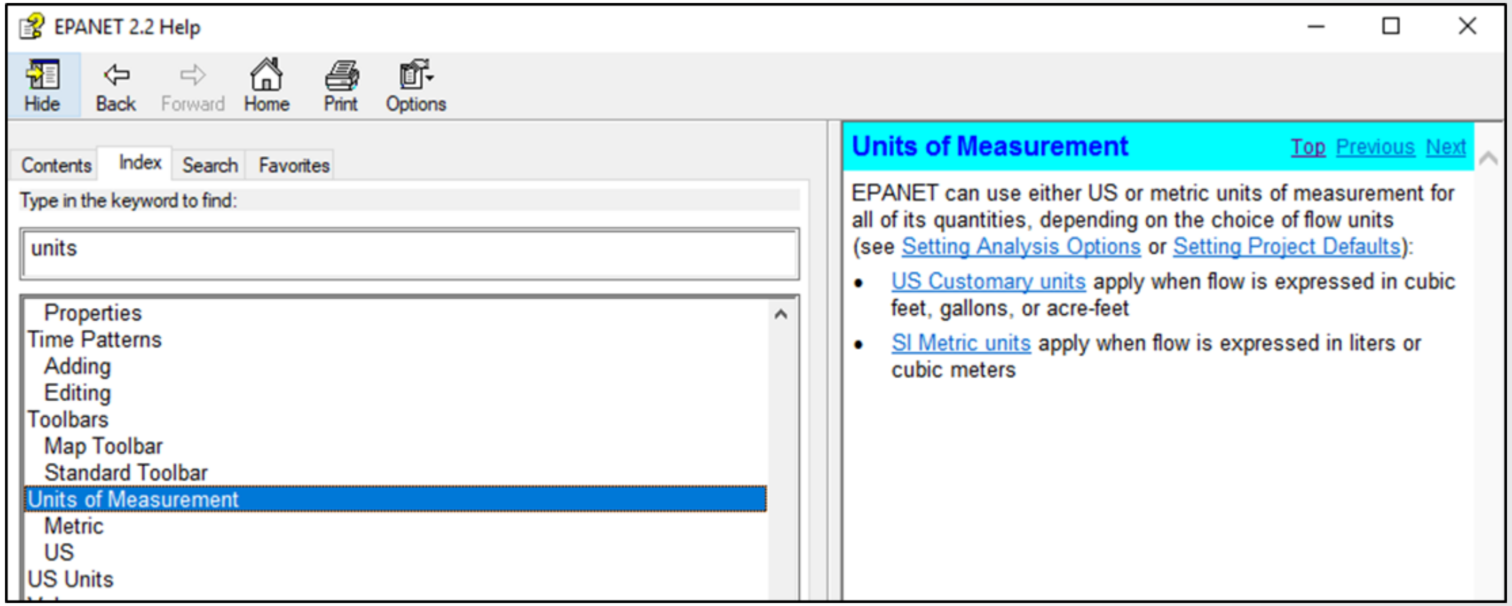
A. EPANET's Integrated Help feature
B. Email the question to EPANET@EPA.GOV
C. The EPANET User Manual's FAQ section
D. Ask the OWA community on GitHub
E. All the above

Brief Hydraulics Review

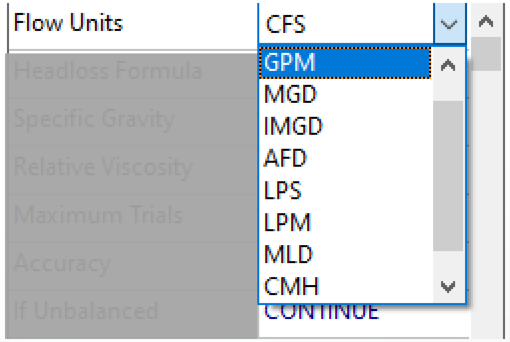
- EPANET's basic assumptions about flow
  - Incompressible flow
  - Laminar, transition, and turbulent flows
  - Closed pipe (e.g., contaminant injections are modeled as mass/time)
  - Full pipe
- For background, supporting information, and review of basic principles
  - Advanced Water Distribution Modeling 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

- U.S. Customary
  - Gallons per minute (GPM)
  - Million gallons per day (MGD)
  - 1 MGD = 646 GPM
- SI 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



EPANET's Integrated Help



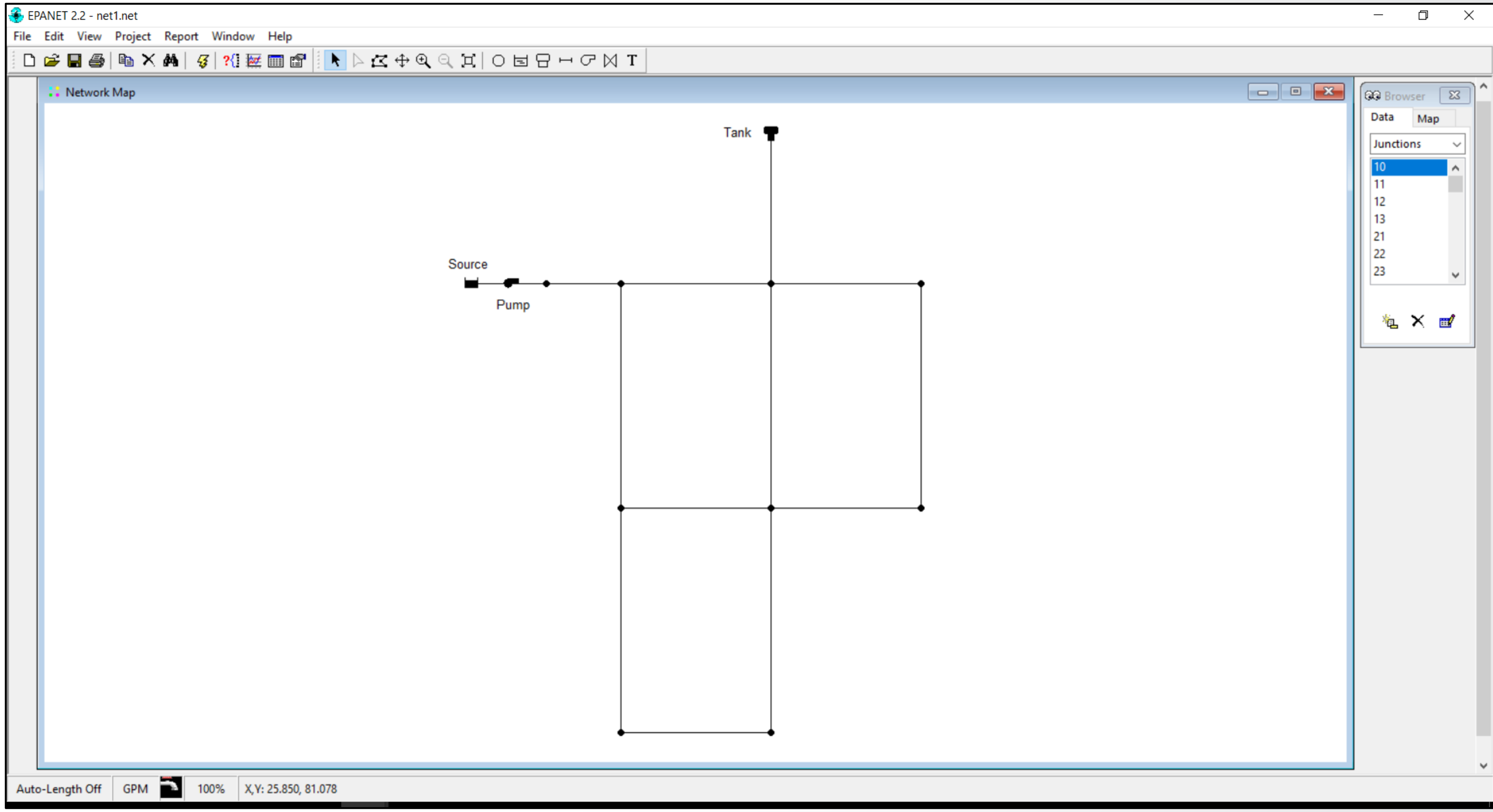
EPANET Units & Components

- Pressure
  - Pounds per square inch (psi) (U.S.)
  - Pascal (Pa) = N/m^2 (Metric)
  - 1 foot H_2O = 2.31 psi
- Normal operating range of pressures in drinking water systems
  - 20 psi (minimum)
  - 80-100 psi (maximum)
- Nodes
  - Junctions
  - Tanks
  - Reservoirs - infinite external source or sink of water to network
- Links
  - Pipes
  - Pumps (modeled with zero volume)
  - Valves (modeled with zero volume)

  * Links require start and end nodes

Getting Started

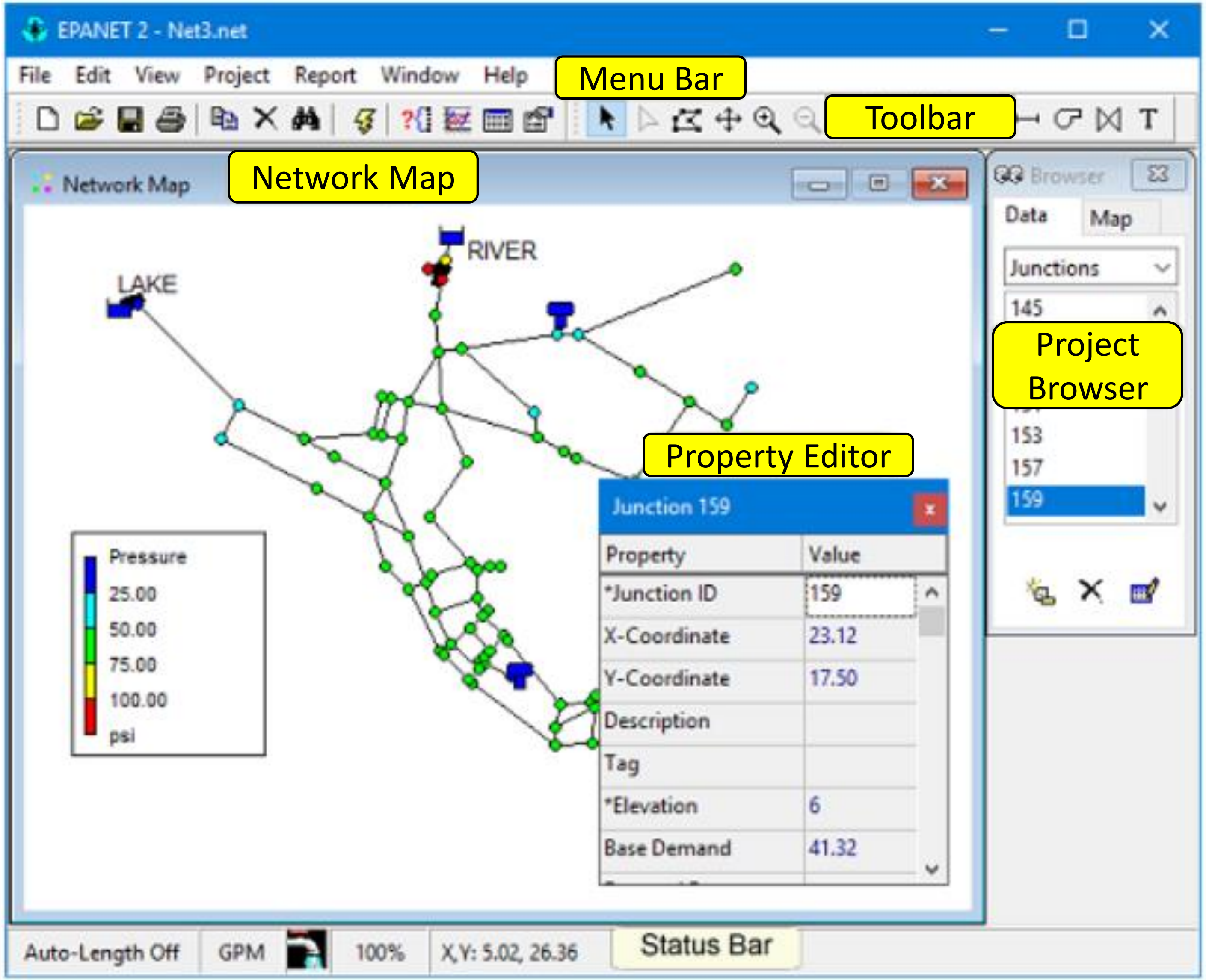
- Tutorial
  - Compiled HTML tutorial file and integrated help file
- User’s manual
  - Opening existing network
- Example networks
  - Experiment with example networks provided



Example Net 1 Opened in EPANET 2.2

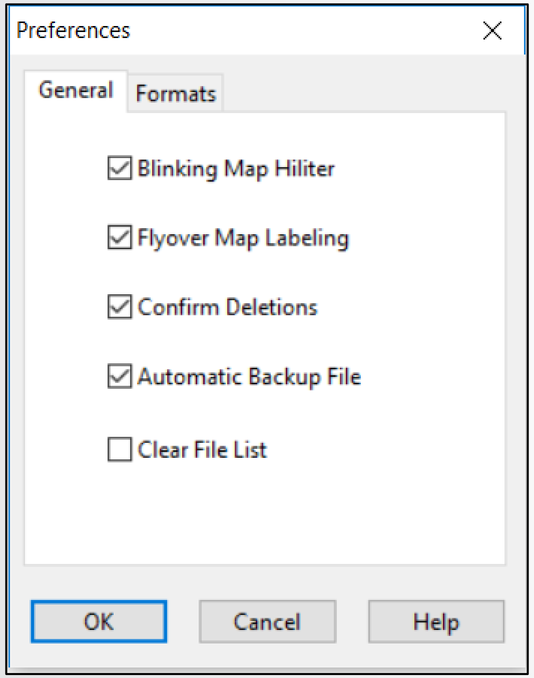
EPANET's Workspace

- EPANET's GUI
  - Menu Bar
  - Toolbar
  - Network Map
  - Project Browser
  - Property Editor
- User's manual chapter 4 "EPANET's Workspace"
- Questions?
  - Integrated Help (in Menu Bar or by pressing F1 key)



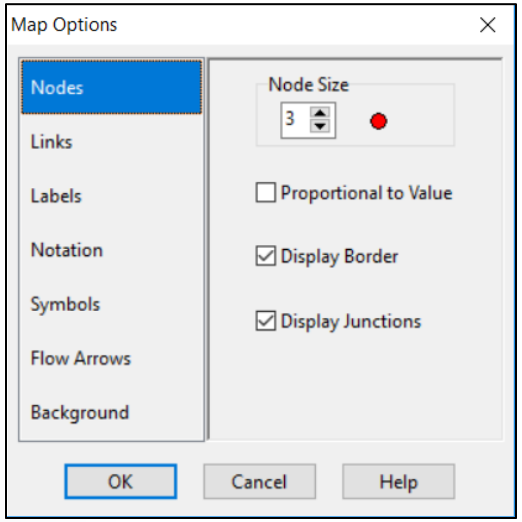
Menu Bar

File >> Preferences



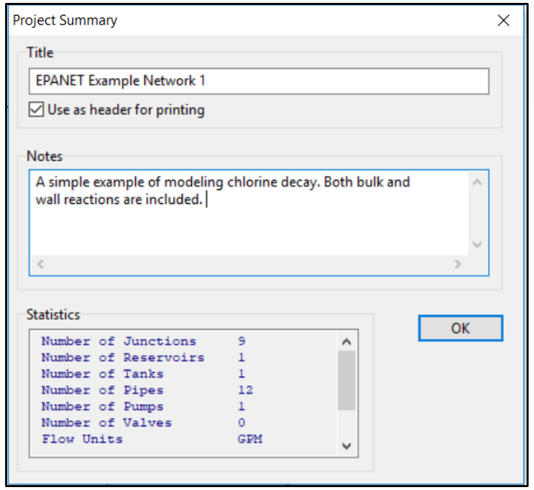
(set preferences e.g., decimal places)

View >> Options

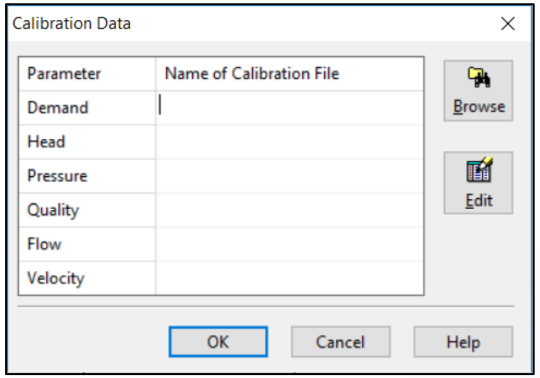


(set map viewing options)

Project >> Summary

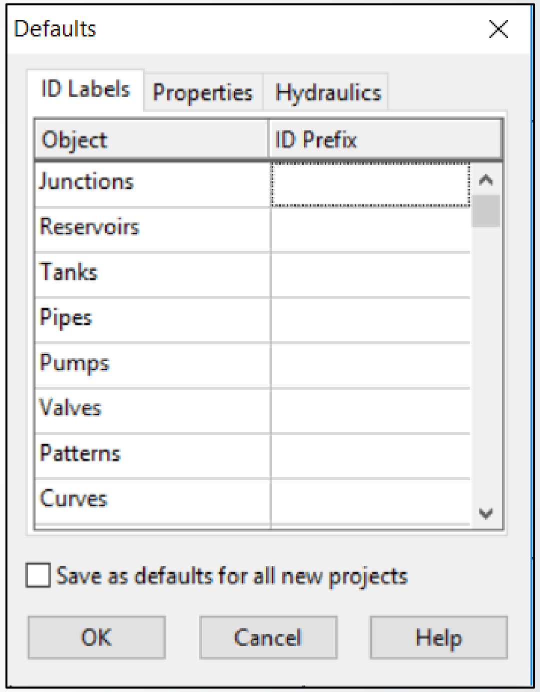


Project >> Calibration Data



(upload calibration data)

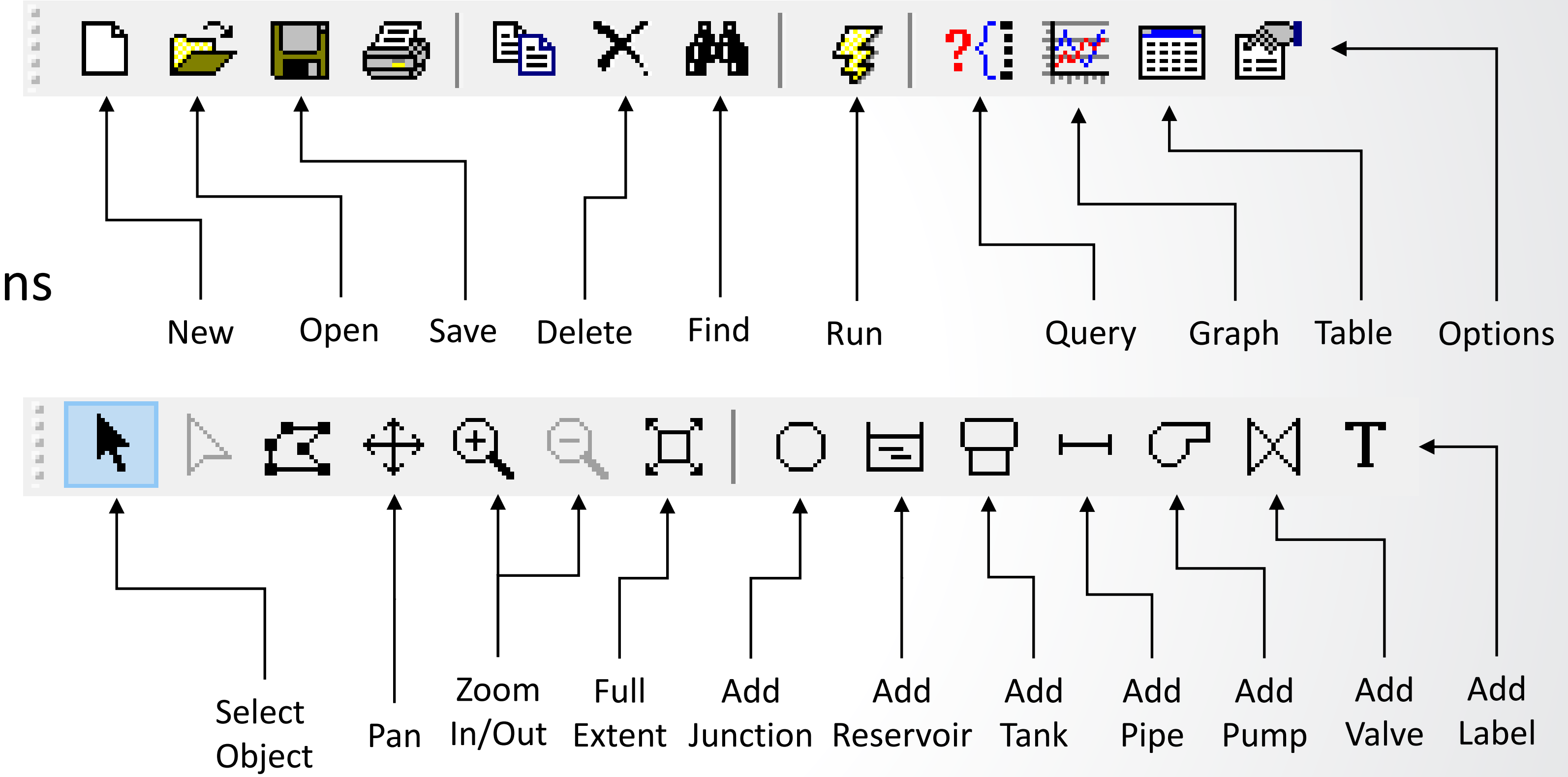
Project >> Defaults



(set project defaults)

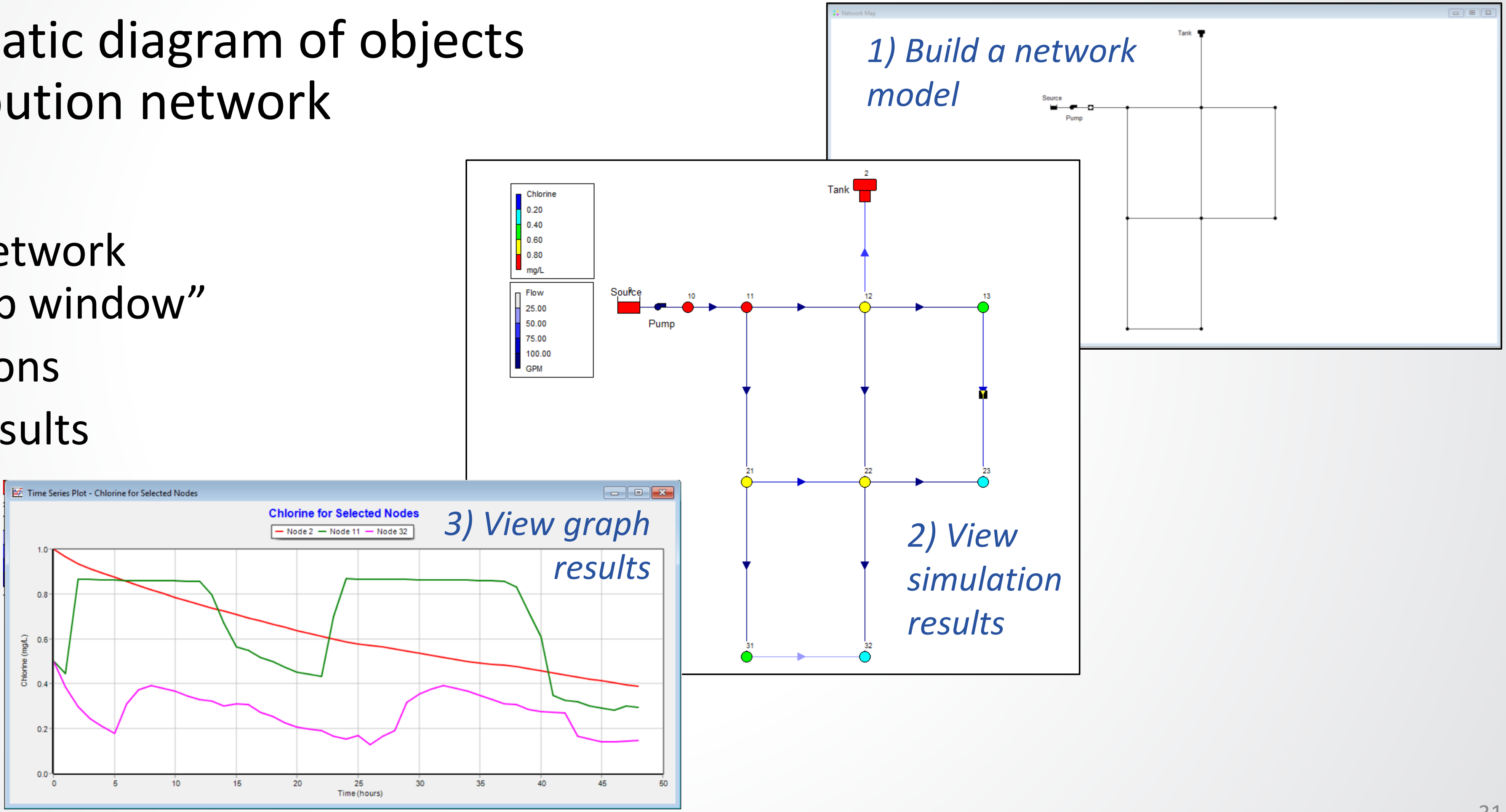
Toolbar

- Standard Toolbar
  - New, Open, Save, Print
  - Copy, Delete, Find
  - Run
  - Query, Graph, Table, Options
- Map Toolbar
  - Select
    - Object, Vertex, Region
  - Pan
  - Zoom In/Out
  - Full Extent
  - Add
    - Junction, Reservoir, Tank
    - Pipe, Pump, Valve
    - Label



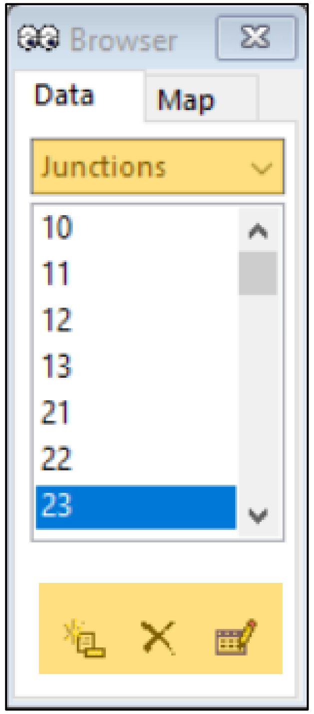
Network Map

- Displays schematic diagram of objects of water distribution network
- Examples
  - Build water network model in “map window”
  - View simulations
  - View graph results

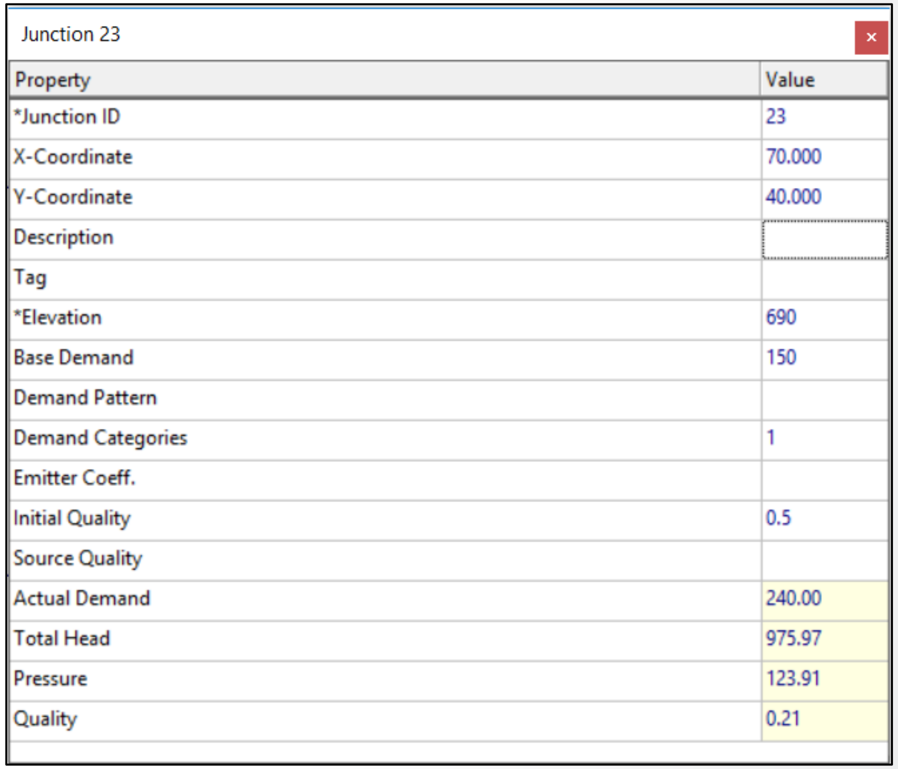


Project Browser

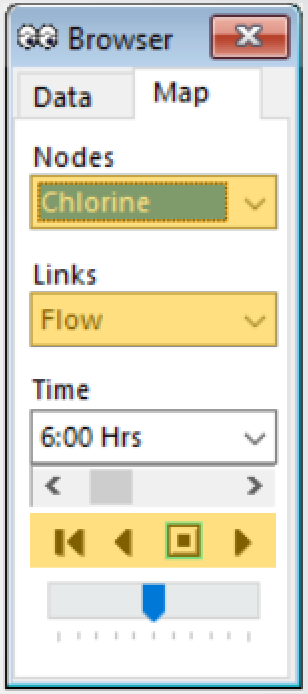
- Data Browser
  - Gives access to objects, by category
  - Buttons at bottom to add, delete, and edit objects
- Map Browser
  - Selects parameters and time period that are viewed in Network Map
  - Starts and stops the animation



Data Browser



Double-clicking object (Junction 23) in Data Browser brings up Property Editor above



Map Browser

Property Editor

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

Note: Property Editor looks different depending on type of component selected

- (Junction vs Tank vs Reservoir vs Pipe vs Pump vs Valve)

Component Properties

- Double-Click Component >> Properties marked “*” are required
  - Yellow highlighted properties are required
  - Blue highlighted properties are not required, but are still commonly used

Junction 101

Property	Value
*Junction ID	101
X-Coordinate	13.810
Y-Coordinate	22.940
Description	
Tag	
*Elevation	42
Base Demand	189.95
Demand Pattern	
Demand Categories	1
Emitter Coeff.	

Reservoir Lake

Property	Value
*Reservoir ID	Lake
X-Coordinate	8.000
Y-Coordinate	27.530
Description	
Tag	
*Total Head	167.0
Head Pattern	
Initial Quality	
Source Quality	
Net Inflow	#N/A

Tank 3

Property	Value
*Tank ID	3
X-Coordinate	29.410
Y-Coordinate	27.270
Description	
Tag	
*Elevation	129.0
*Initial Level	29.0
*Minimum Level	4.0
*Maximum Level	35.5
*Diameter	164

Pipe 101

Property	Value
*Pipe ID	101
*Start Node	10
*End Node	101
Description	
Tag	
*Length	14200
*Diameter	18
*Roughness	110
Loss Coeff.	0
Initial Status	Open

Pump 10

Property	Value
*Pump ID	10
*Start Node	Lake
*End Node	10
Description	
Tag	
Pump Curve	1
Power	
Speed	
Pattern	
Initial Status	Closed

Valve 1

Property	Value
*Valve ID	1
*Start Node	Lake
*End Node	103
Description	
Tag	
*Diameter	12
*Type	PRV
*Setting	
Loss Coeff.	0
Fixed Status	None

Knowledge Check 3

Which part of the EPANET workspace would you use to view simulation results?

A. Menu Bar

B. Toolbar

C. Network Map

D. Project Browser

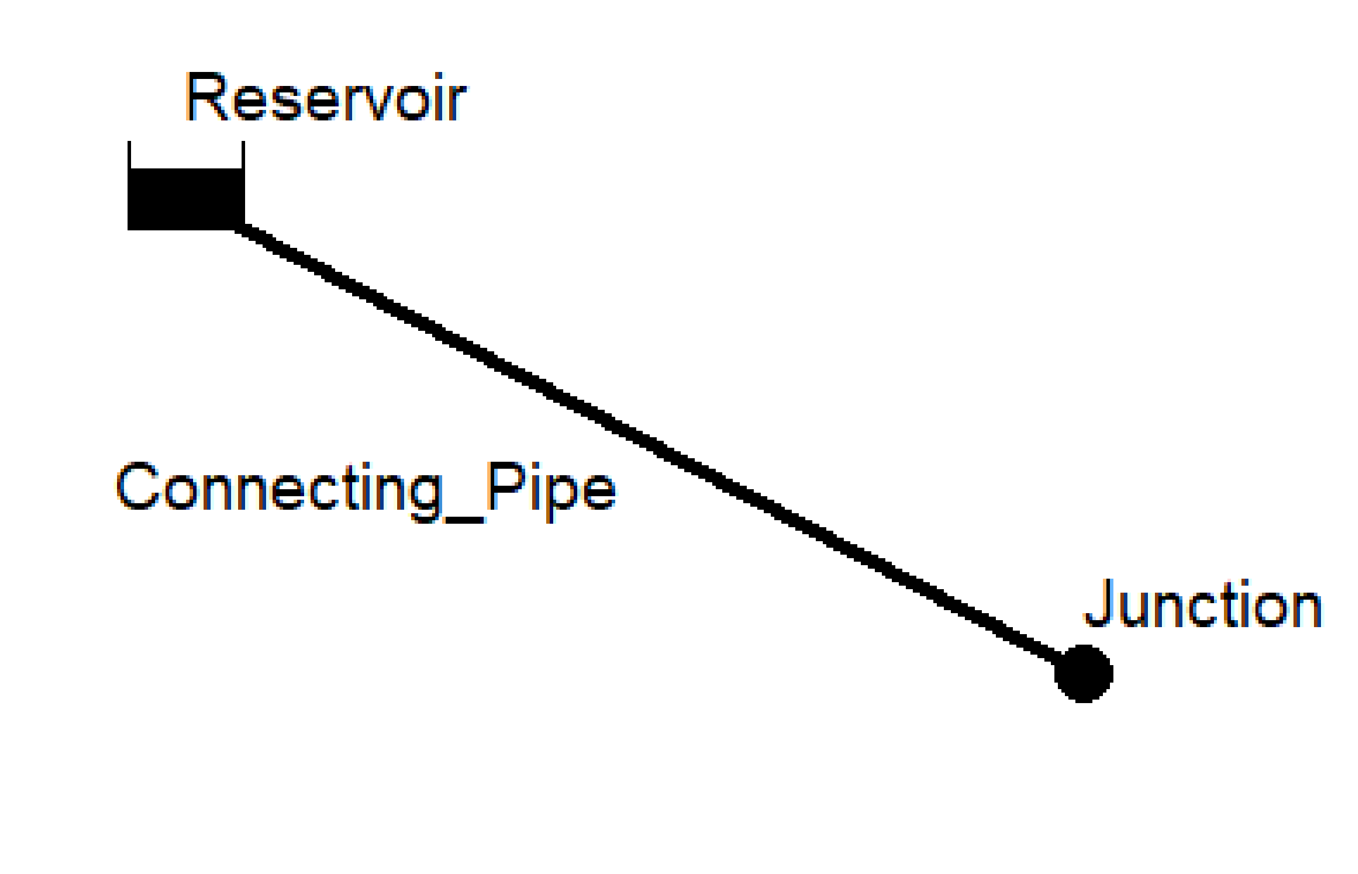
E. Property Editor

EPANET Modeling Capabilities

Feng Shang

EPANET Model

- EPANET model can be very simple
  - One reservoir to provide water
  - One pipe to transfer water
  - One junction to consume water



EPANET Hydraulics

- EPANET models hydraulic conditions over one period or multiple periods
- No transient/water hammer analysis in EPANET
- Demands needs to be assigned
- Pipes, pumps, and valves transfer water from sources to consumer nodes
- Steady state analysis
  - Fixed demand
  - Snapshot analysis
- Extended period simulation (EPS)
  - Changing demand over time (through Patterns)
  - Typically simulates a few days, e.g., seasonal peak days

Hydraulic Factors in WDS

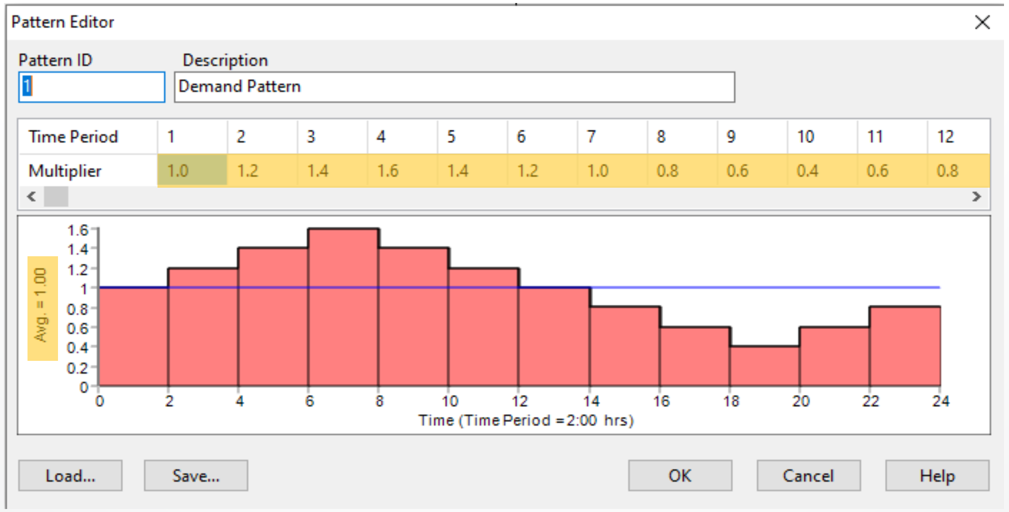
- Demands
- Dynamic head
- Elevations
- Patterns & controls
- Pipe properties (diameter, length, roughness)
- Tanks, pumps, & valves

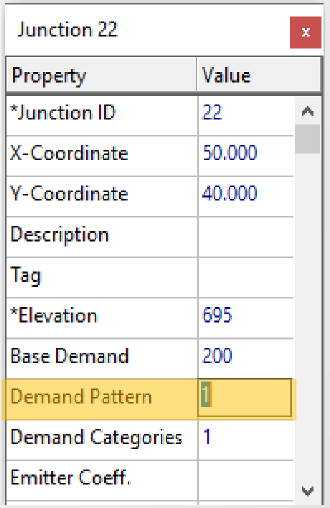
Extended Period Simulation

- Pattern Time Step usually set to 1 or 2 hours
  - Can be set very small (e.g., 1 minute)
- Each node has its own Base Demand
  - Base Demand is usually average demand
- Pattern multipliers are applied to Junctions' Base Demand
  - e.g., Base Demand = 1.0 GPM & Pattern Multiplier = 0.5 $\rightarrow$ Actual Demand = 0.5 GPM
- Patterns can be set to multiple nodes
  - Default Pattern is assigned to all junctions without specified pattern

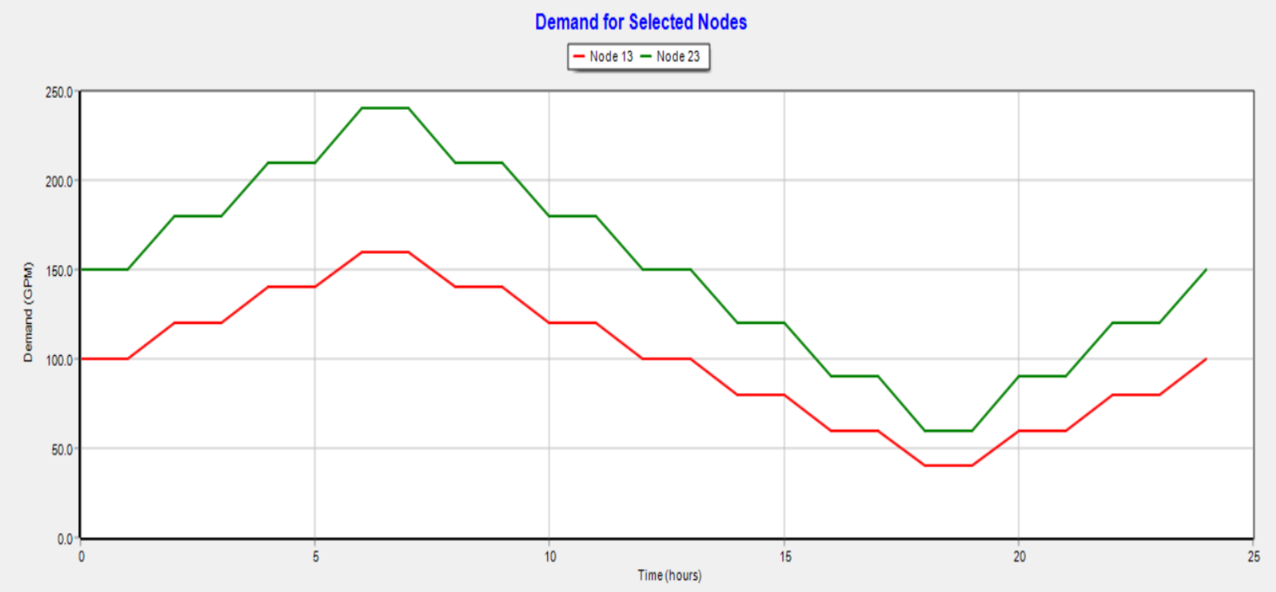
Patterns

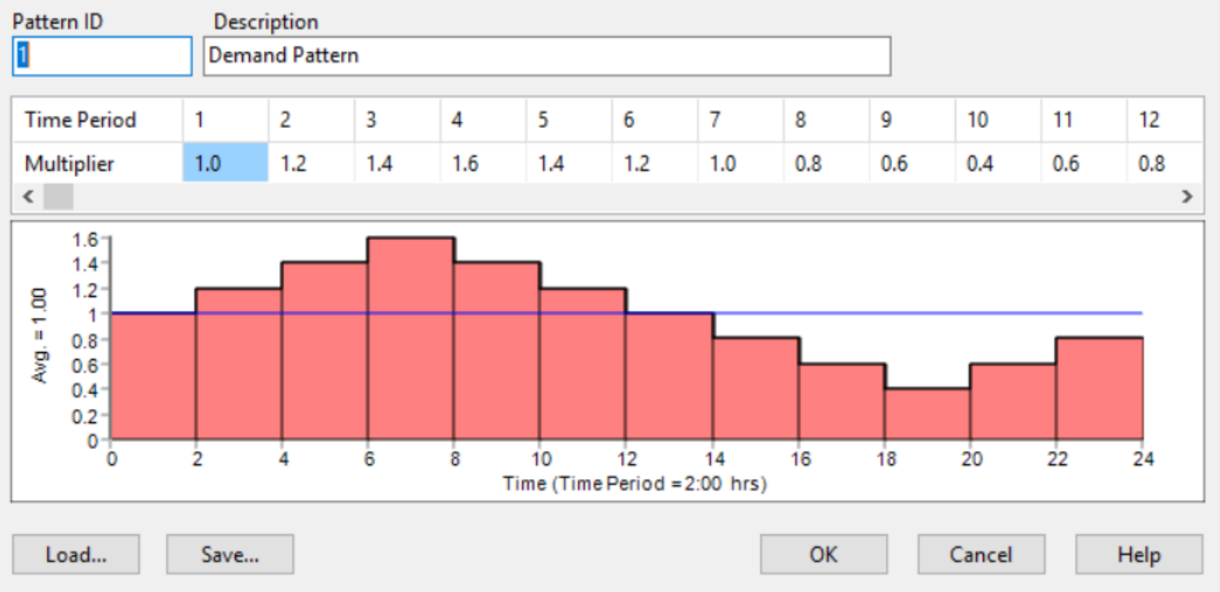
- Simulate changes over time
- Repeat for each time period (typically 1 day)
- Pattern ID is name & how it is assigned in properties
- Multiplies the Base Demands of Junctions (or Heads for Reservoirs or Prices for Pumps) by specified amounts
  - Typically, multipliers average 1.0 so base value (demand, head, or price) is average



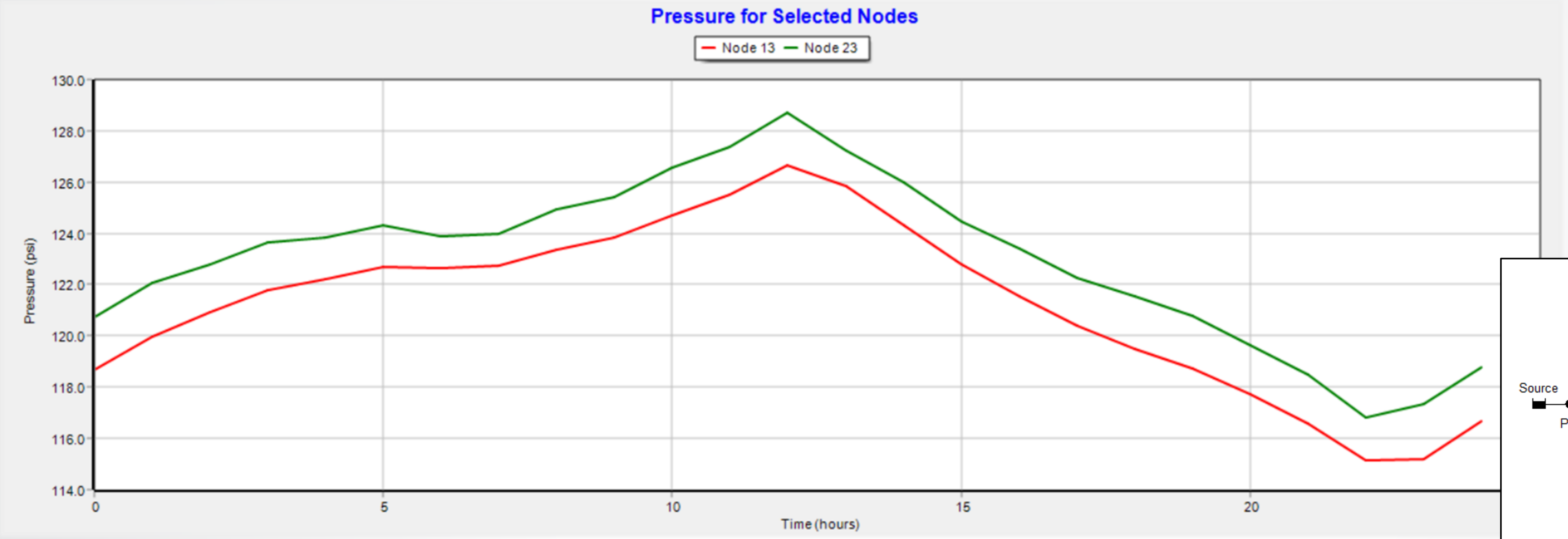


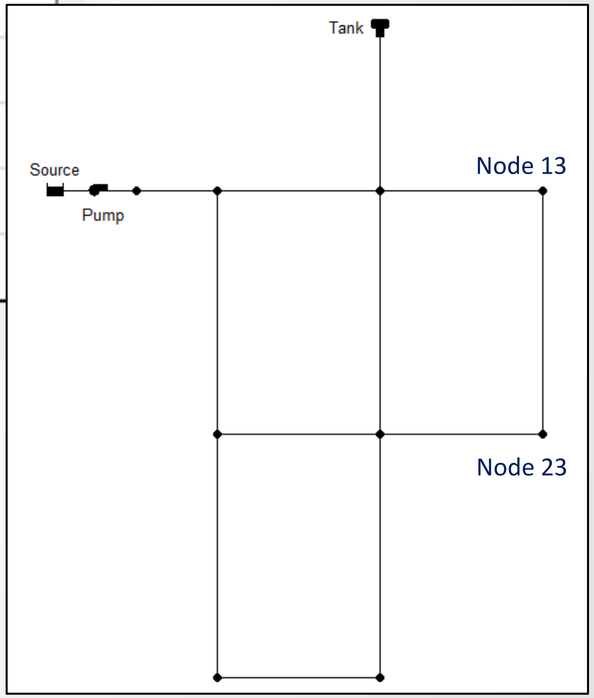
Demand Patterns



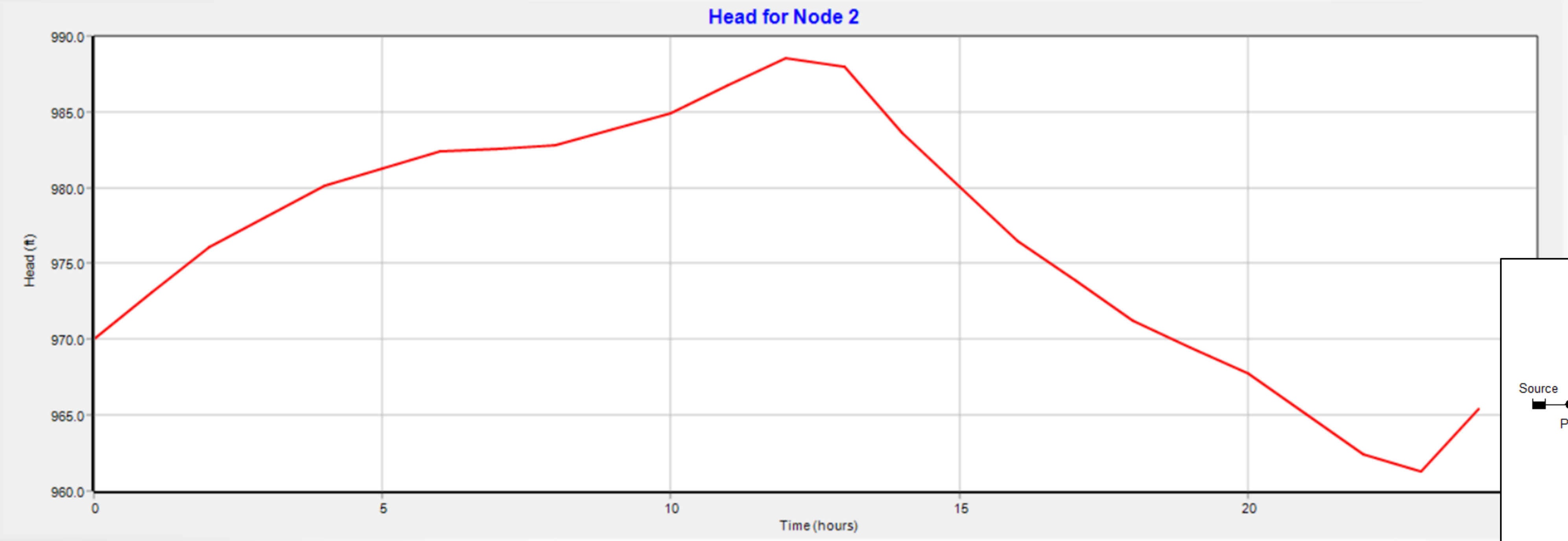


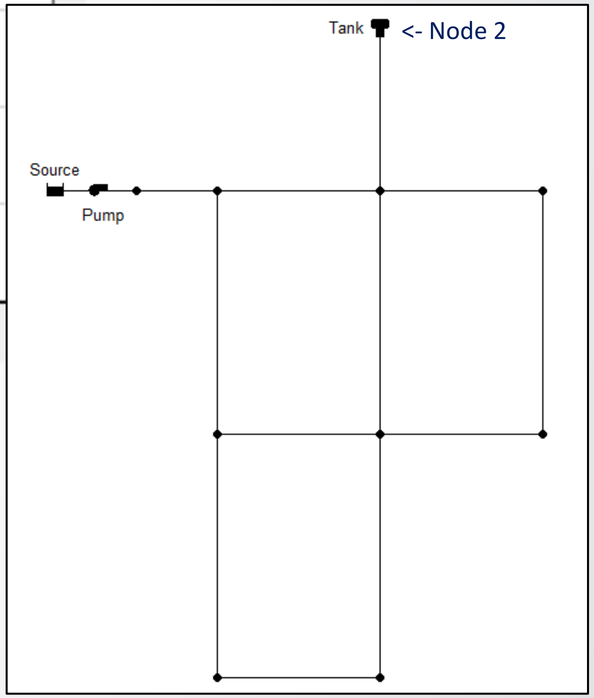
EPS Results – Node Pressure



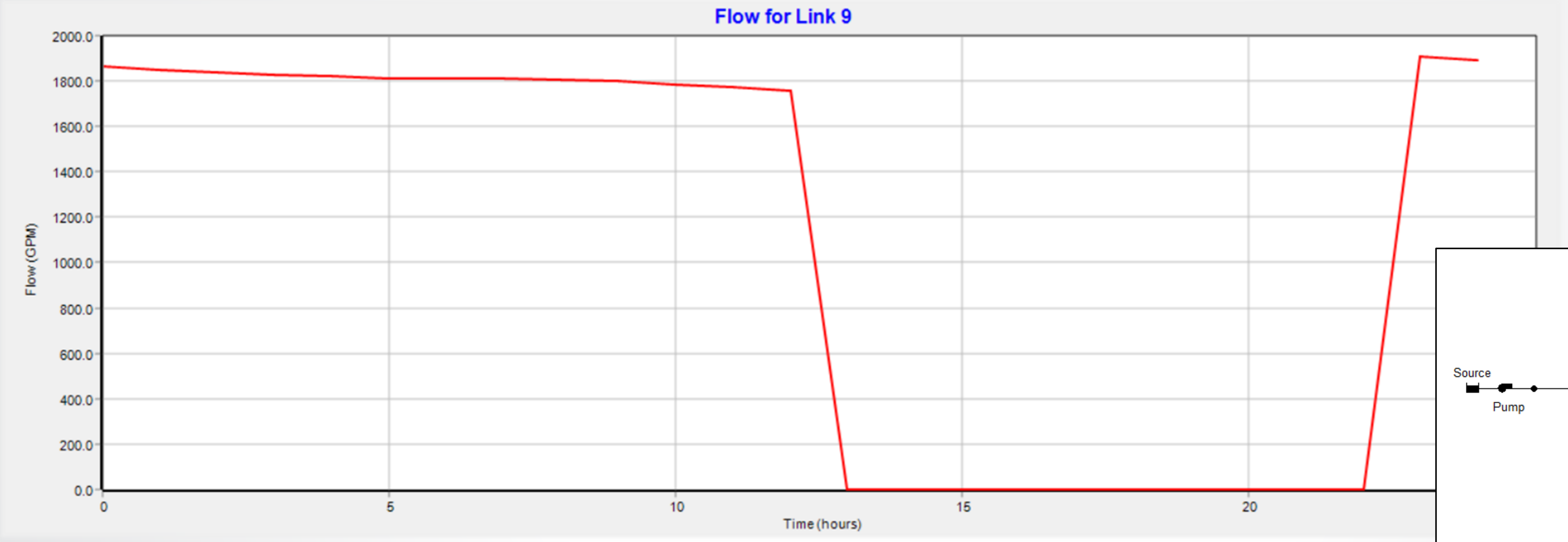


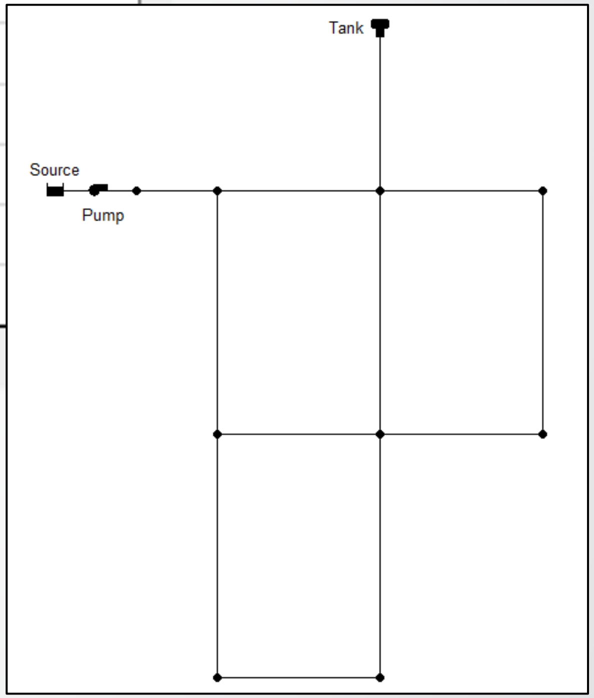
EPS Results – Tank Operation





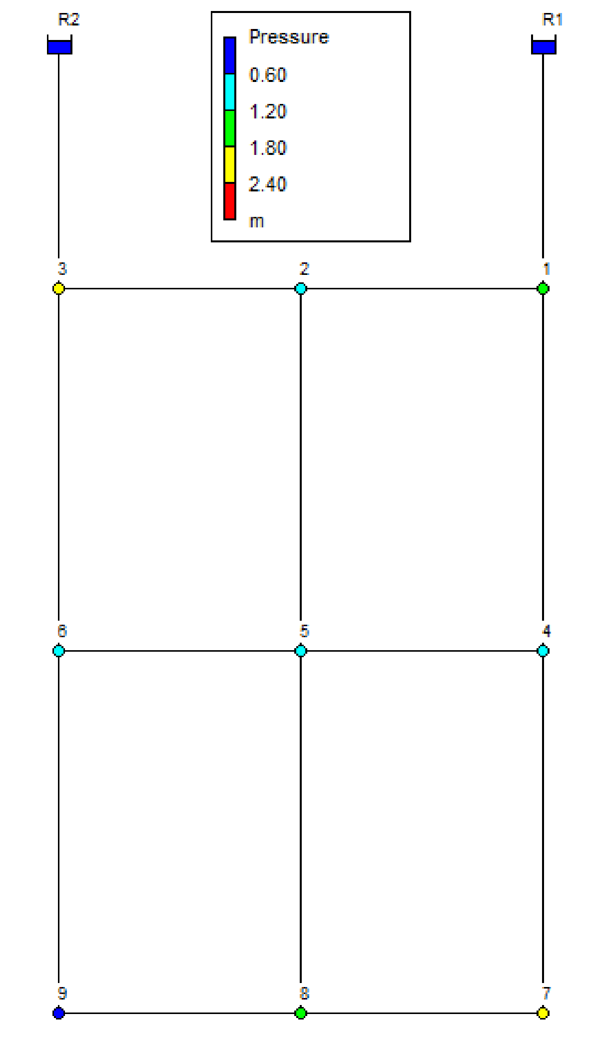
EPS Results – Pump Operation





EPANET Pressures

- Negative pressure
  - Why negative pressure warnings?
  - What should we do?
- Pressure dependent analysis (PDA)
  - User assigned demand is delivered if pressure is high enough (Pressure > Required Pressure)
  - Actual demand is lower than user assigned demand if pressure is not high enough (Pressure < Required Pressure)
  - Zero flow if pressure is too low (Pressure < Minimum Pressure)



Pressure Dependent Analysis

- Data Browser Window >> Options >> Hydraulics >> Demand Model
- Minimum Pressure: Demand = 0 if Pressure < Minimum Pressure
- Required Pressure: full Demand if Pressure ≥ Required Pressure
  - Set to at least 0.1 psi or m above Minimum Pressure
- Pressure Exponent: used to calculate partial demand
  - Suggested value is 0.5

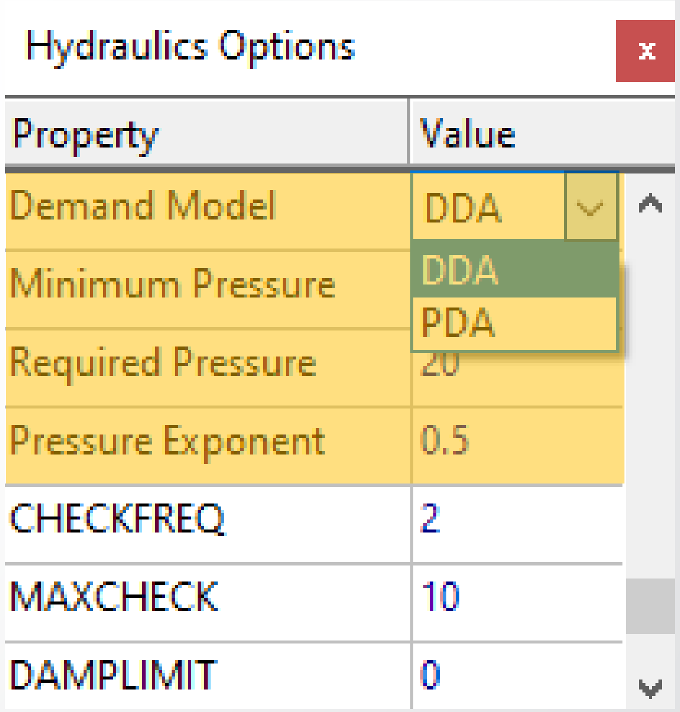
$$y = ax^k$$

y = Demand Delivered

x = Calculated Pressure / Required Pressure

a = Requested Demand

k = Pressure Exponent



Pressure-Dependent Analysis (PDA)

Without PDA

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

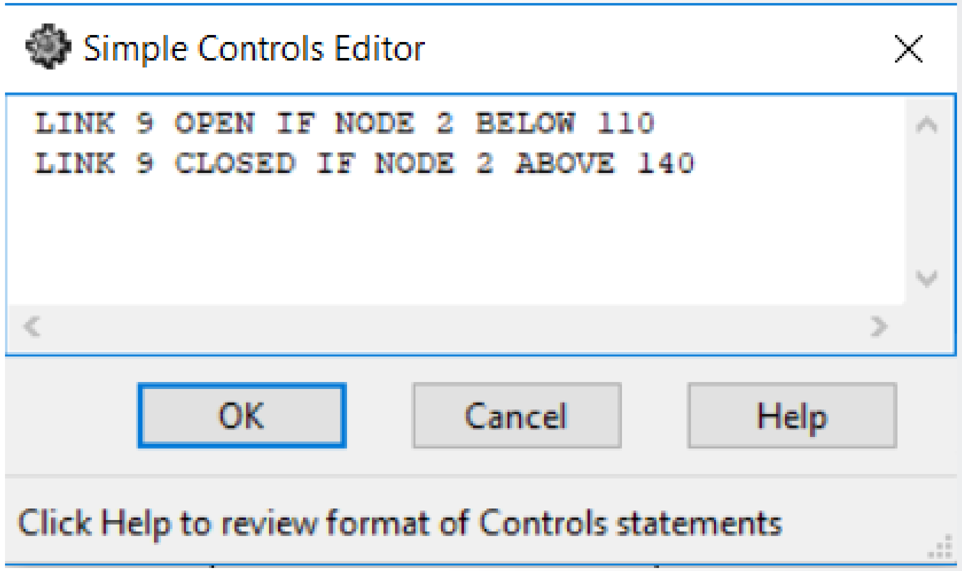
With PDA

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 Hydraulic Functionalities

- Controls
  - Simple
  - Rule-Based
- Pumps
  - Pump Curves
  - Pump Efficiency analysis
  - Pump Energy analysis
- Valves
  - Pressure Relief Valve (PRV)
  - Pressure Sustaining Valve (PSV)
  - Pressure Breaker Valve (PBV)
  - Flow Control Valve (FCV)
  - Throttle Control Valve (TCV)
  - General Purpose Valve (GPV)



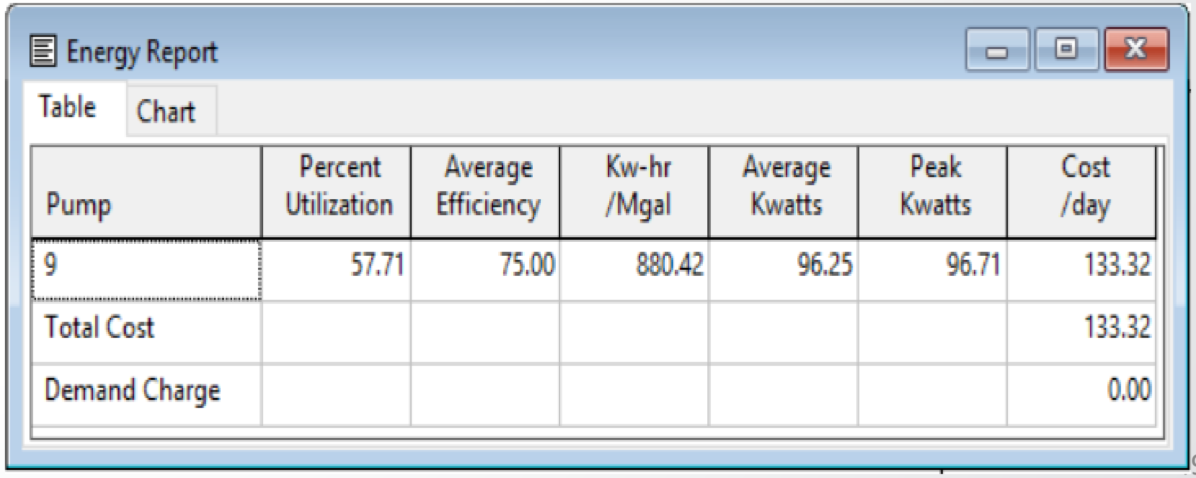

Energy Report

Table | Chart

Pump	Percent Utilization	Average Efficiency	Kw-hr /Mgal	Average Kwatts	Peak Kwatts	Cost /day
9	57.71	75.00	880.42	96.25	96.71	133.32
Total Cost						133.32
Demand Charge						0.00

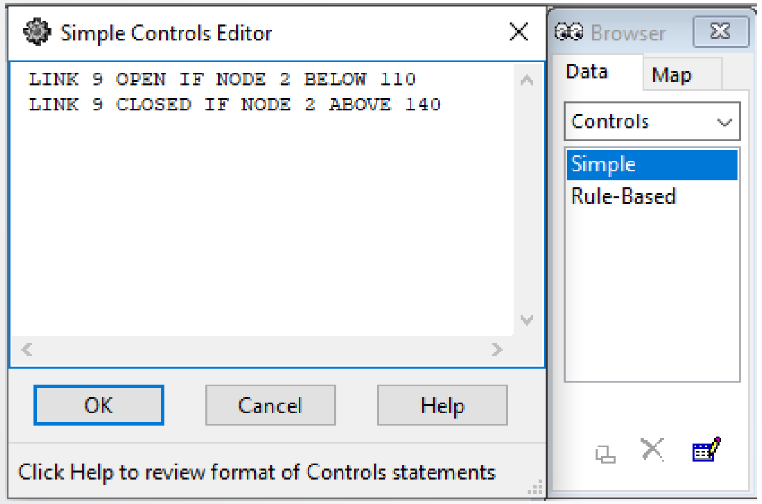
Knowledge Check 4

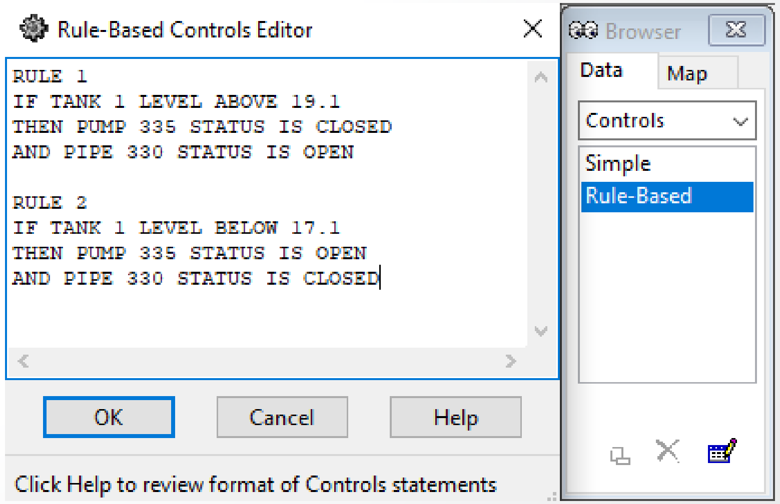
Which of these can EPANET NOT do?

A. Steady State Analysis
B. Transient State Simulation
C. Extended Period Simulation
D. Trick Question; EPANET can do all of these

Introduction to Controls

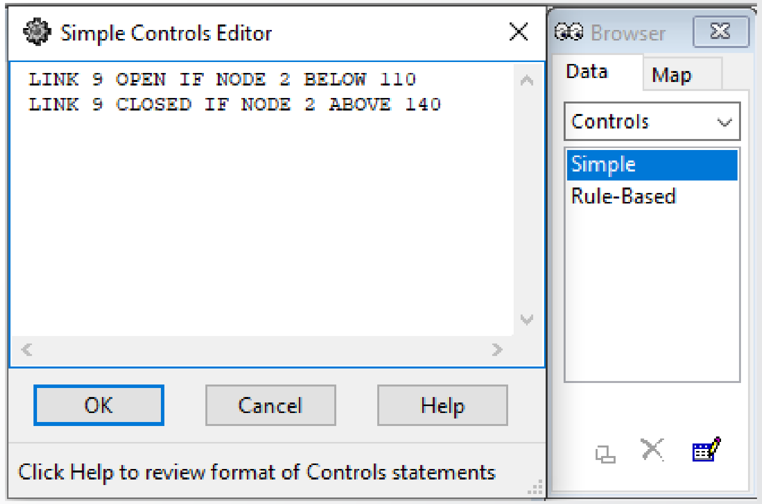
- Statements that determine how the network is operated over time.
- Controls can be either Simple Controls or Rule-Based Controls
  - Simple Controls modify links based on a single condition
  - Rule-Based Controls modify links based on a combination of conditions





Simple Controls

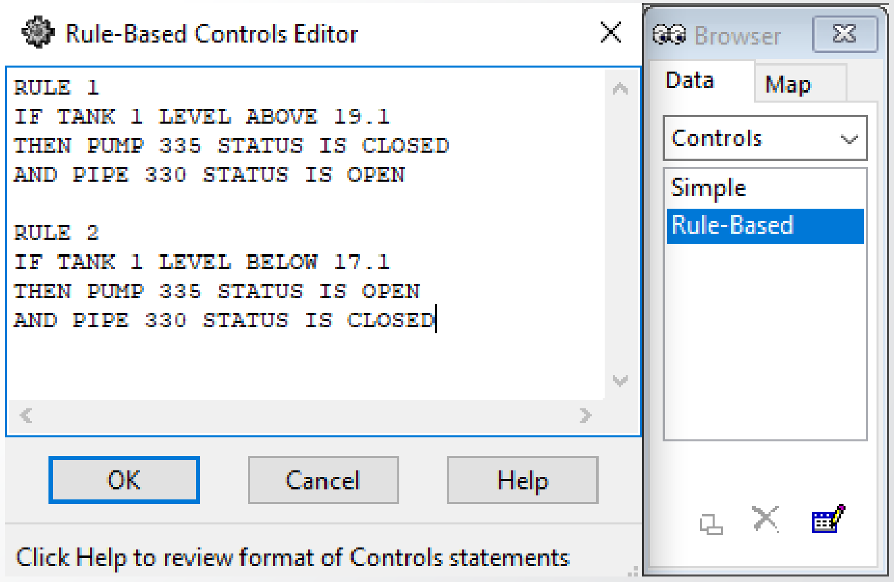
- Change status of links based on
  - Water level in tank
    - Format: **LINK** *linkID status* **IF NODE** *tankID* **ABOVE/BELOW** *value*
  - Pressure at junction
    - Format: **LINK** *linkID status* **IF NODE** *junctionID* **ABOVE/BELOW** *value*
  - Time into simulation
    - Format: **LINK** *linkID status* **AT TIME** *time*
  - Time of day
    - Format: **LINK** *linkID status* **AT CLOCKTIME** *clocktime* **AM/PM**



Rule-Based Controls

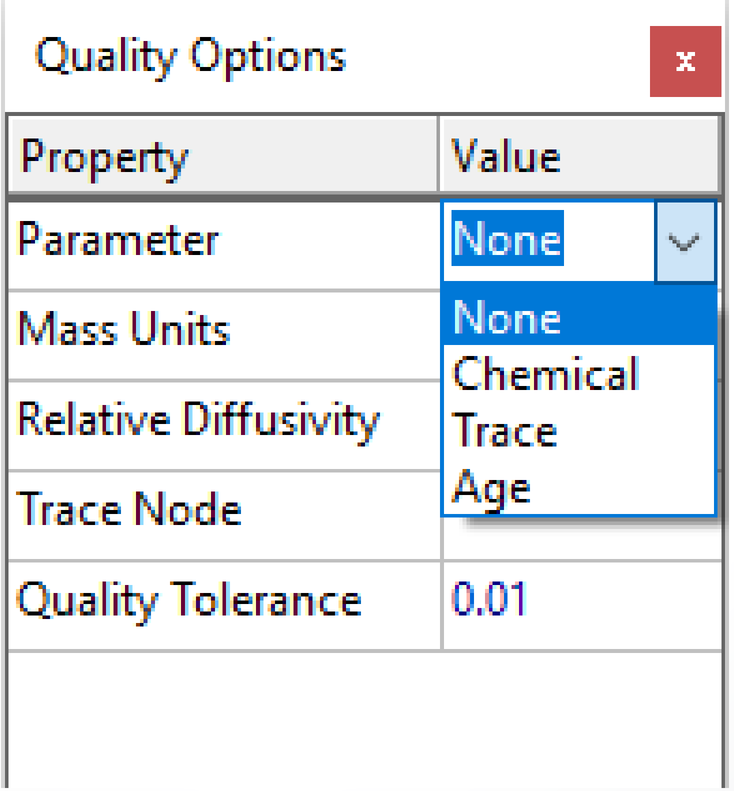
- Change status of links and settings based on combinations of conditions that might exist in network over extended period simulation
- Use combinations of “IF” & “IF, THEN” statements, and “AND” and “OR” clauses/operators
  - Statements are in form of
    - **RULE** *ruleID*
    - **IF** condition_1
    - **AND** condition_2
    - **OR** condition_3
    - Etc…
    - **THEN** action_1
    - **AND** action_2
    - Etc…
    - **ELSE** action_3
    - **AND** action_4
    - Etc…
    - **PRIORITY** *priority*

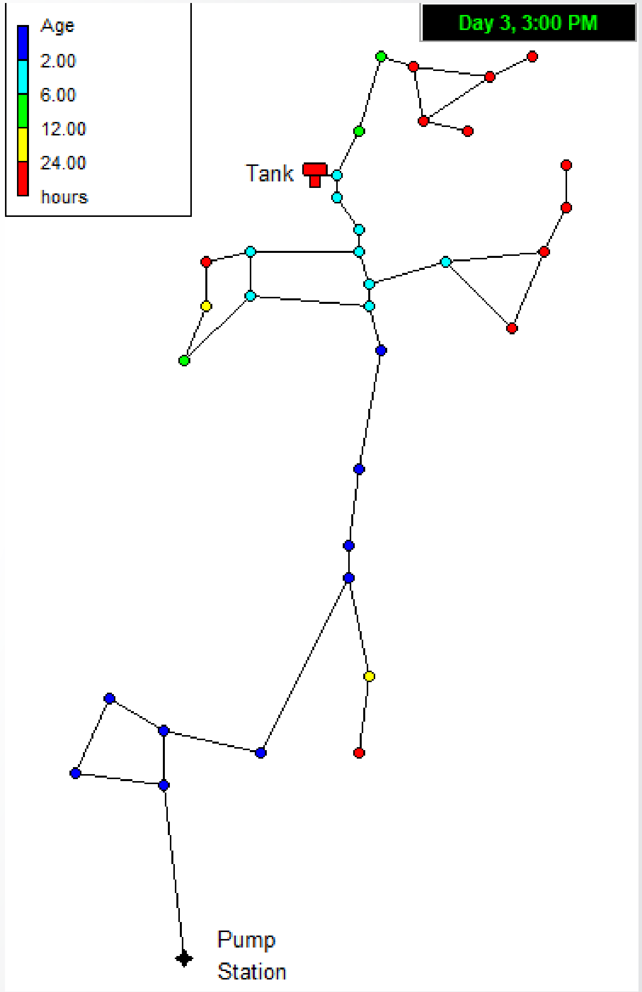
`ruleID`	=	an ID label assigned to the rule
`conditon_n`	=	a condition clause
`action_n`	=	an action clause
`priority`	=	a priority value (e.g., a number from 1 to 5)



EPANET Water Quality Options

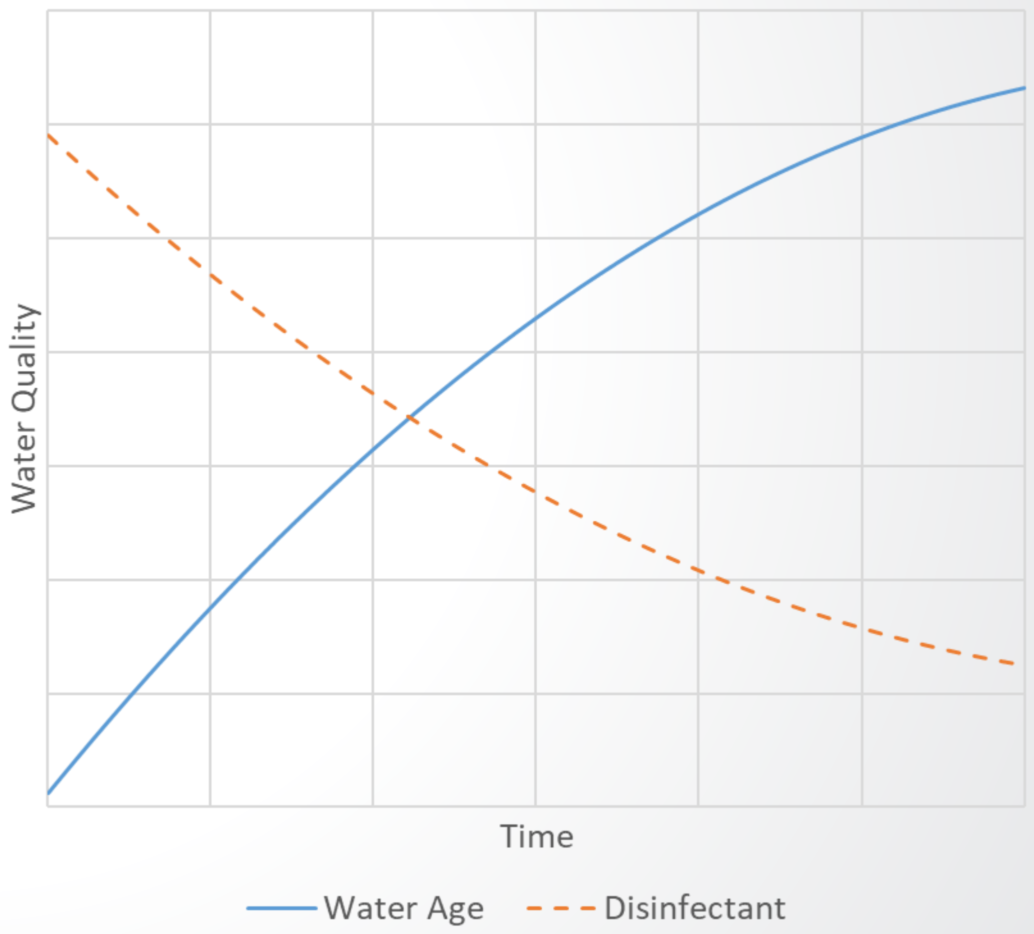
- Parameters
  - Age
    - Ex: water age
  - Trace
    - Ex: source tracing
  - Chemical
    - Ex: chlorine decay





Water Age – Definition

- Non-explicit measurement of water quality and consists of quantity of time that parcel of water exists before being consumed
- Measured from time water leaves treatment plant or well until it is used/consumed by water user

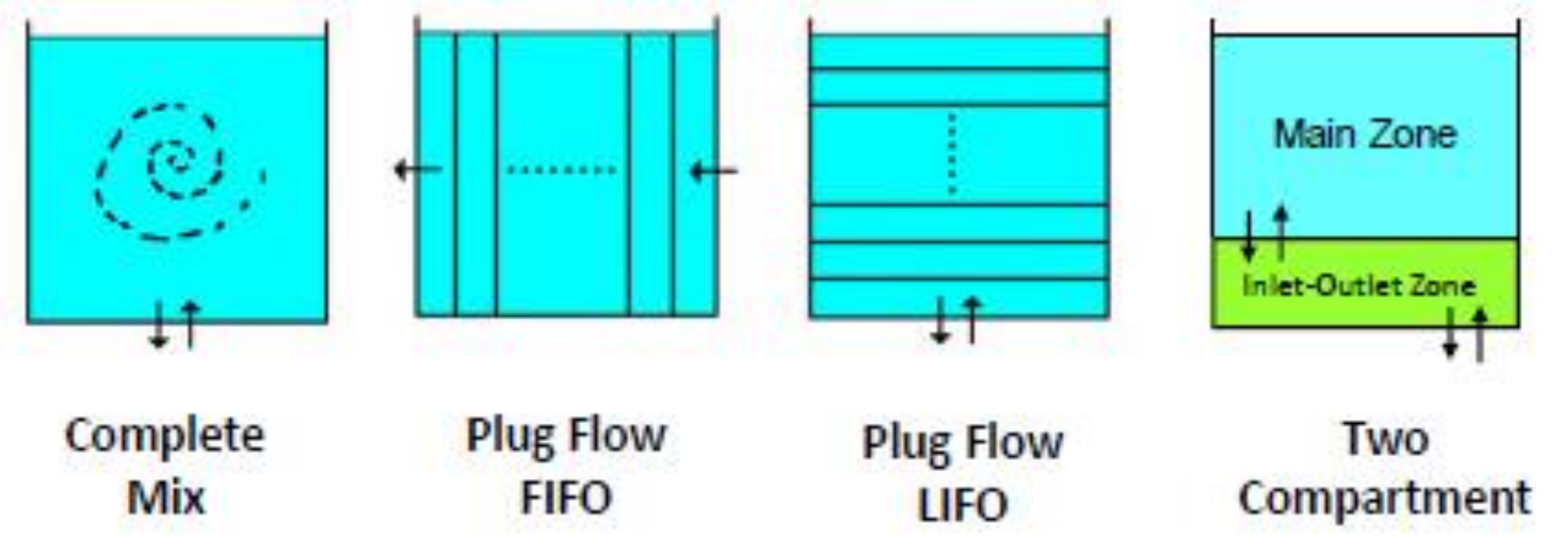


Water Age – Simple Explanation

- Represents time water has been in WDS after leaving source and until it is used at junctions
- Frequently used as surrogate for water quality
  - New water → good
  - Old water → bad
- Influenced by residence times in tanks and travel times through pipes
- Typically highest in dead ends, downstream of series of tanks, and at nodes at far end of distribution network

Tank Mixing Methods

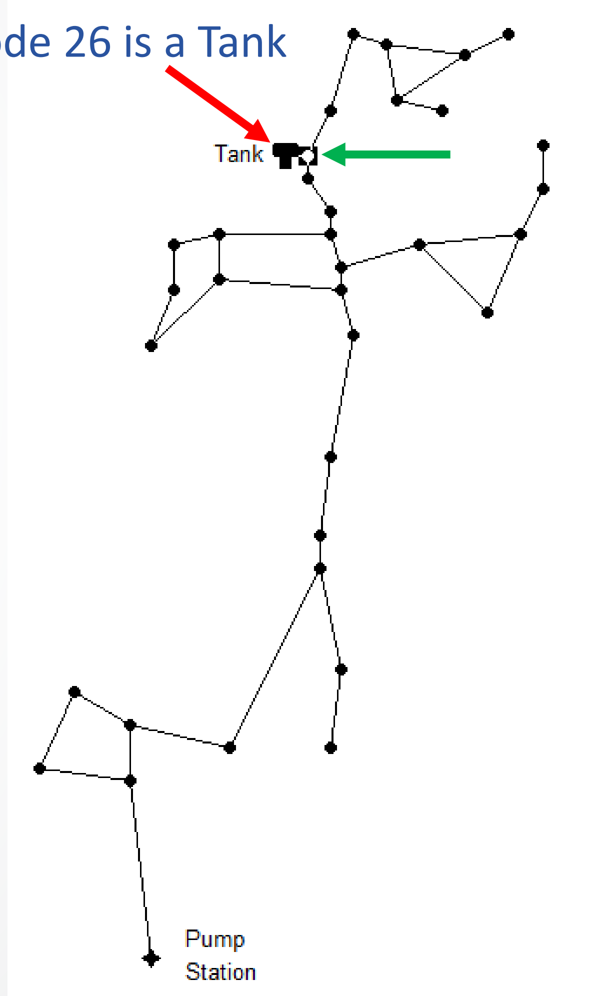
- Four choices to simulate theoretical tank mixing
- Theoretical tanks models are unlikely to represent any tank perfectly
  - But may be close!



Water Age – Plot

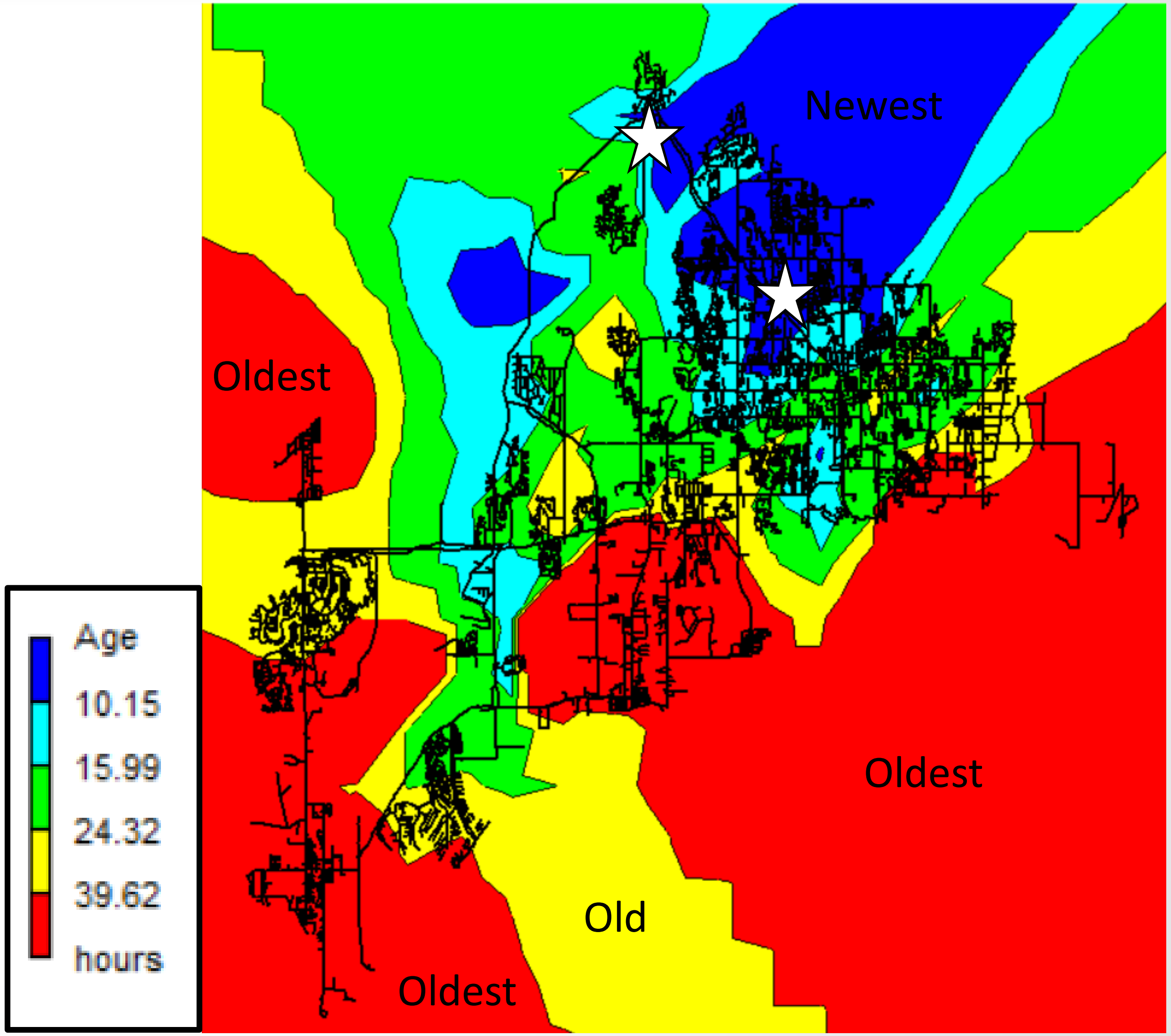
Water is old in the tank

Note: Node 26 is a Tank



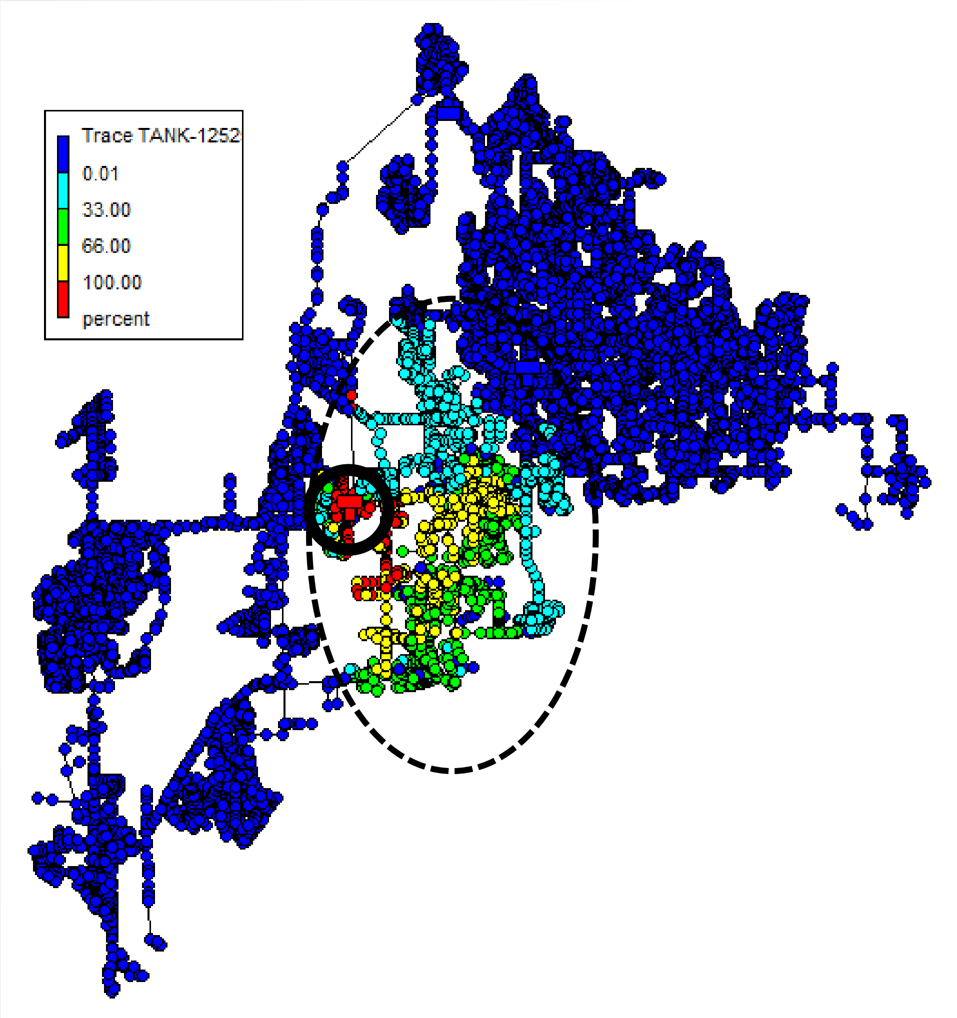
Water Age – Distance

- Graph >> Contour Plot >> Age
  * EPANET example networks do not have enough nodes to make Contour Plot
- Water takes time to flow, especially at dead-ends and low-demand nodes
- Typically, nodes farther from treatment plants have higher water age

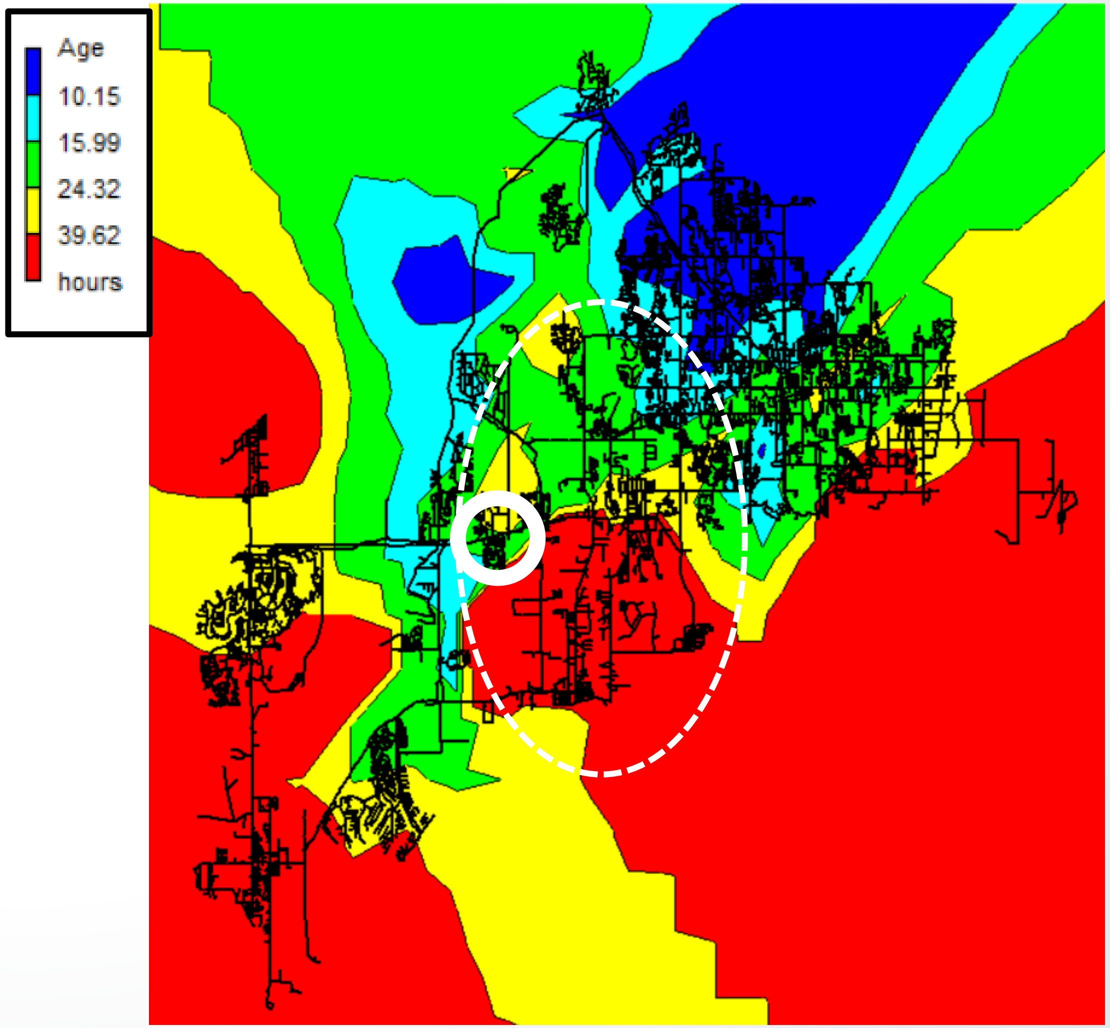


Water Age – Tank Influence

600h EPS Max Tracer Test

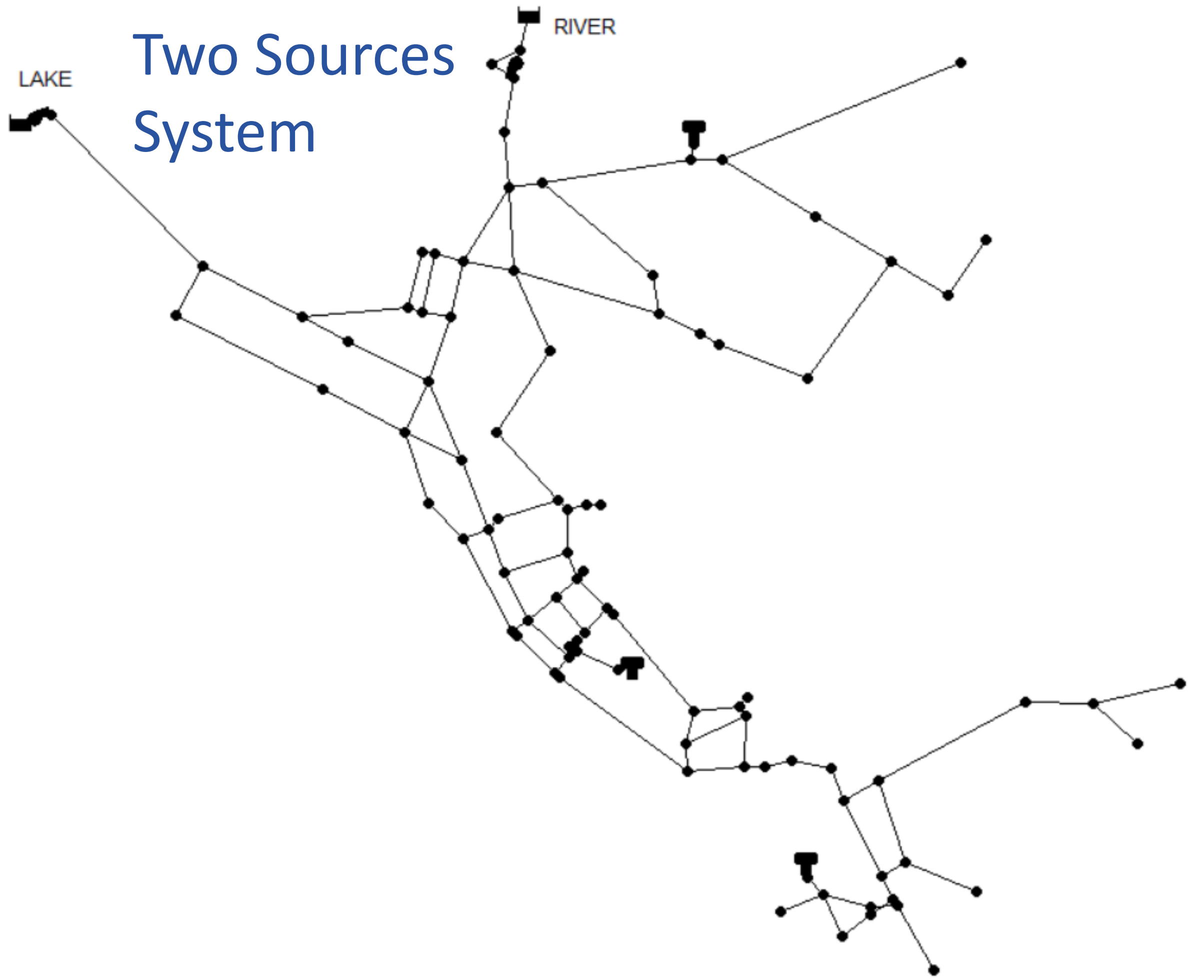


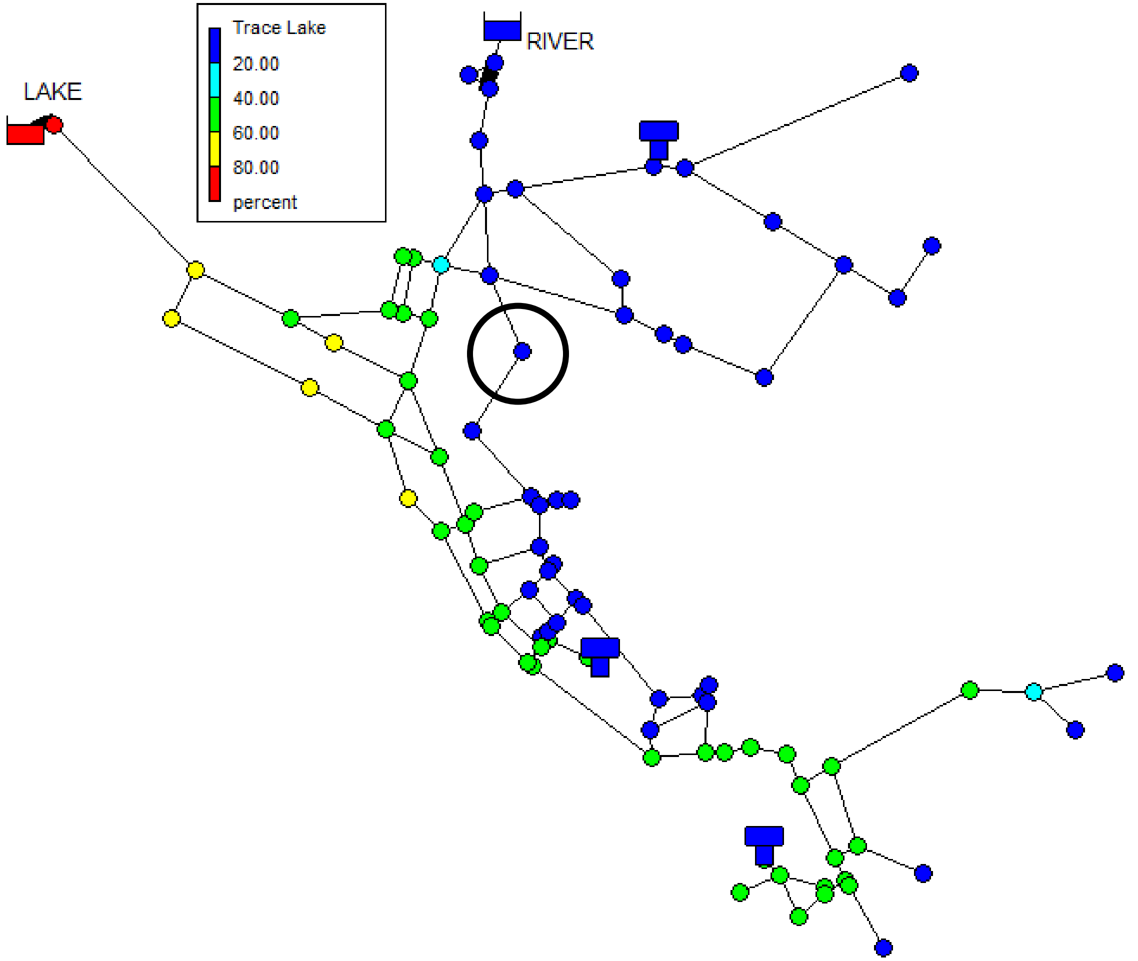
600h EPS Average Water Age



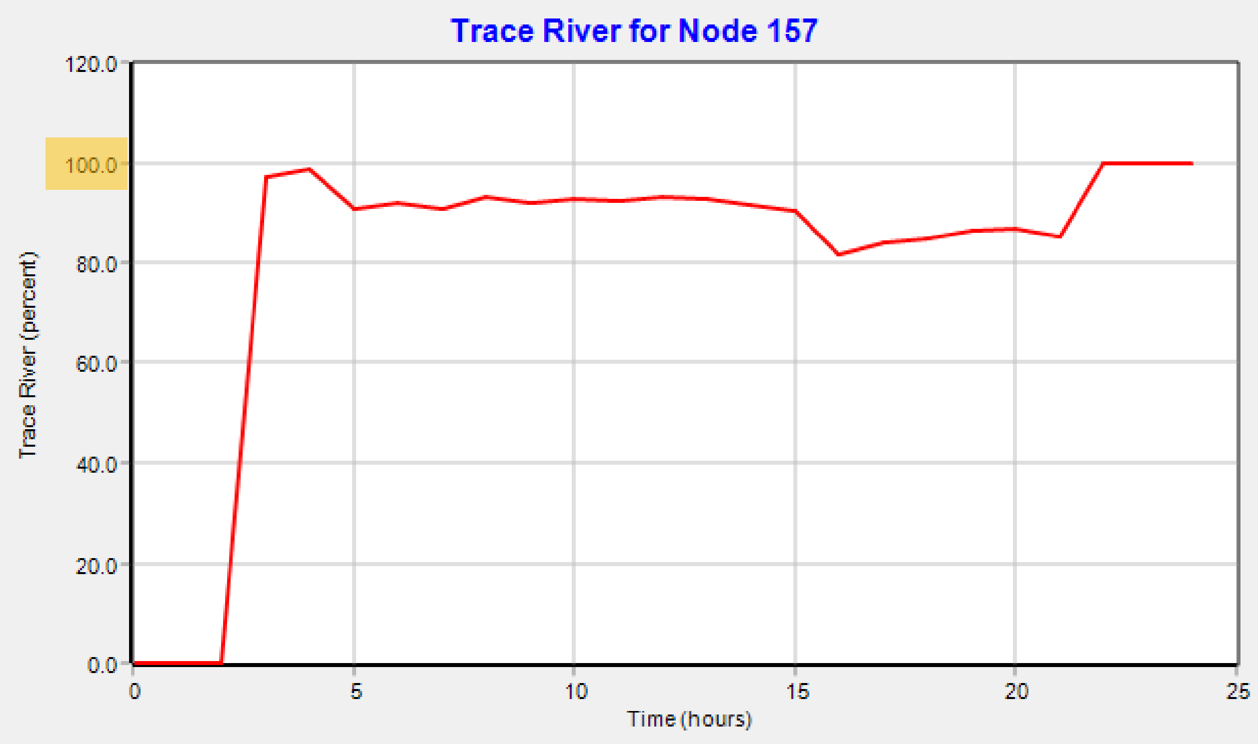
EPANET Application – Water Quality

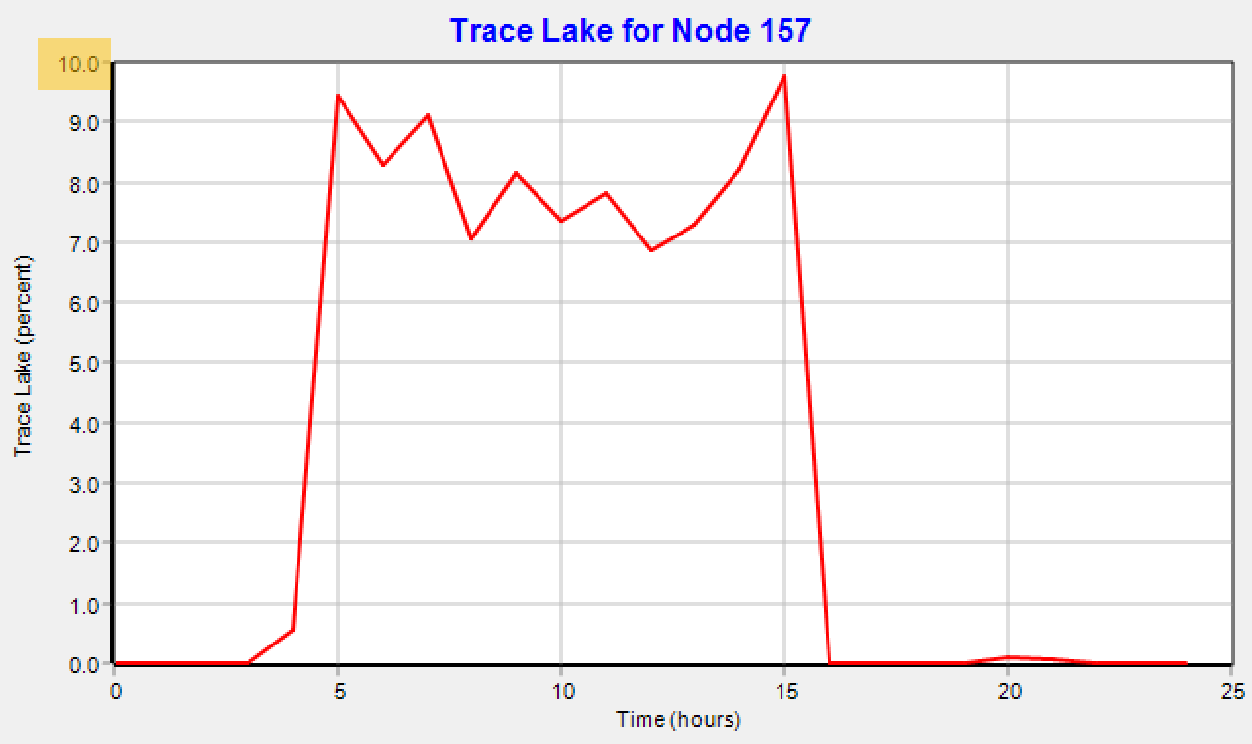
- Trace Analysis: where the water comes from?





Trace Analysis





Knowledge Check 5

Which of the following best explains what a EPANET's tracer test is, using a Trace Node?

A. A periodic measurement to track changes in fluoride levels in the physical WDS

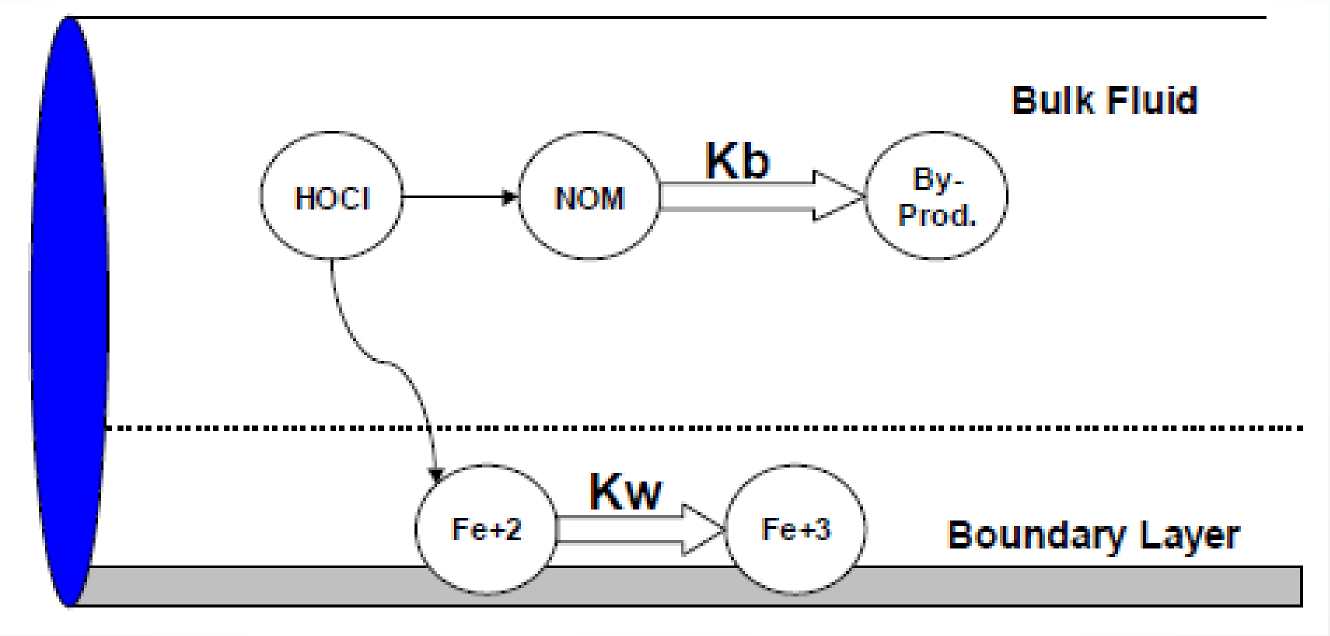
B. A hydraulic simulation that calculates where the water from one point in the model ends up

C. A water quality simulation of an unreactive chemical in each of the water sources

D. A superimposed layer on the Network Map that lets you copy part of the model by following the pipes with your cursor

Chlorine Modeling

- Chlorine is most common water quality constituent modeled
- Modeling predicts chlorine residual throughout distribution system
- Chlorine & chlorine residual varies significantly during day & over time



Chlorine – First Order Decay

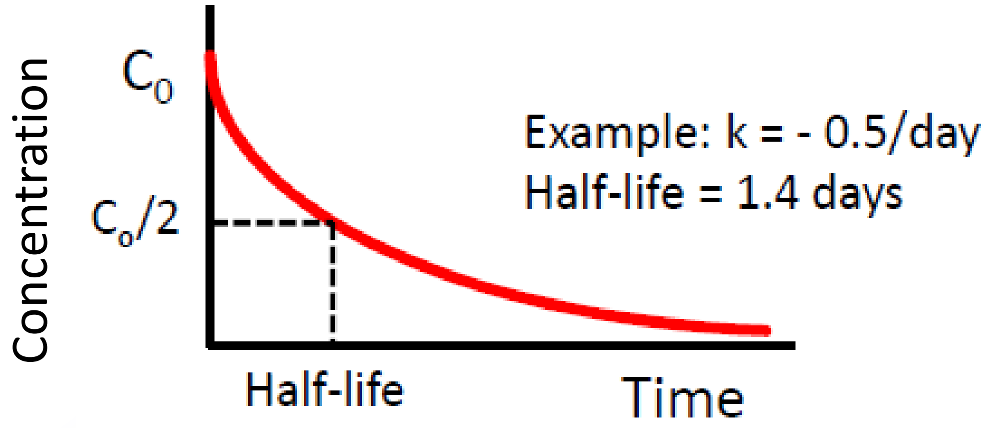
- Chlorine residual usually follows 1st order decay
- Chlorine decays proportionally to its concentration

$$\frac{dC}{dt} = kC$$

- Exponential decay:

$$C_t = C_0 e^{kt}$$

  - C_0 = Initial Concentration
  - t = Time
  - k = Decay Coefficient
    - Usually expressed per day (e.g., -0.5/day)



- Half-life: Time to decay to 50% of initial concentration

Chlorine – Bulk Decay

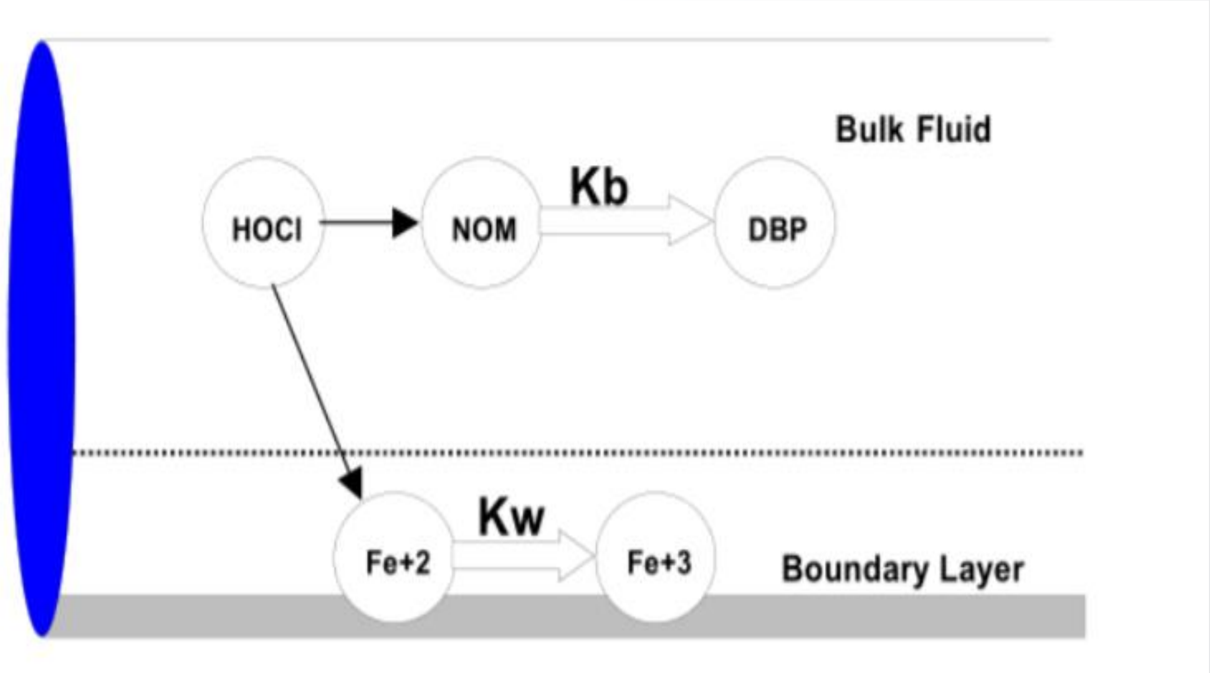
- Bulk decay is decay in flowing water
- Usually represented as first order reaction: $C_t = C_0 e^{kt}$
- Decay rate
  - Depends on water quality characteristics
  - Is independent of pipe material
- Negative k (e.g., $C_0 e^{kt}$) indicates decay
- Typically, between -0.2 & -1.0 per day
  - Equivalent to half life of 3.5 to 0.7 days (16.8 hours)
- Bottle tests in treatment plants can help determine bulk decay coefficient

Chlorine – Wall Decay

- Wall decay is interaction of water with pipe walls
  - Due to corrosion, biofilm, etc. at wall
  - Determined by pipe material (Copper, PVC, Concrete, Steel, etc.)
- Rate of loss of chlorine at wall depends upon
  - Wall decay coefficient
  - Rate at which mass is transferred to wall
- Wall decay coefficient cannot be measured directly, instead it is determined through field studies or chosen from literature values

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

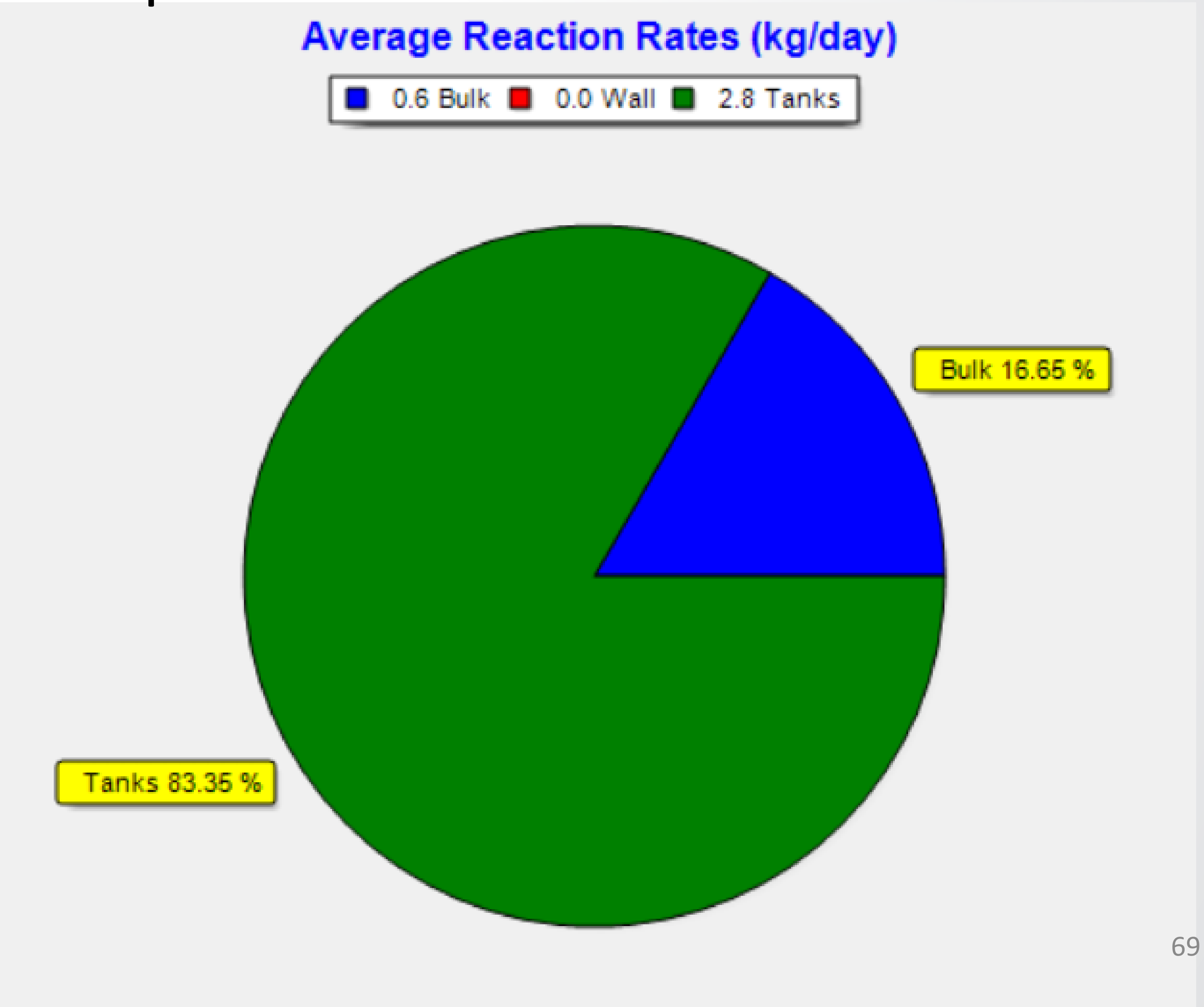


Chemical Analysis Results (I)

Reactions Options

Property	Value
Bulk Reaction Order	1
Wall Reaction Order	First
Global Bulk Coeff.	-.5
Global Wall Coeff.	0
Limiting Concentration	0.0
Wall Coeff. Correlation	0.0

- Report >> Reactions

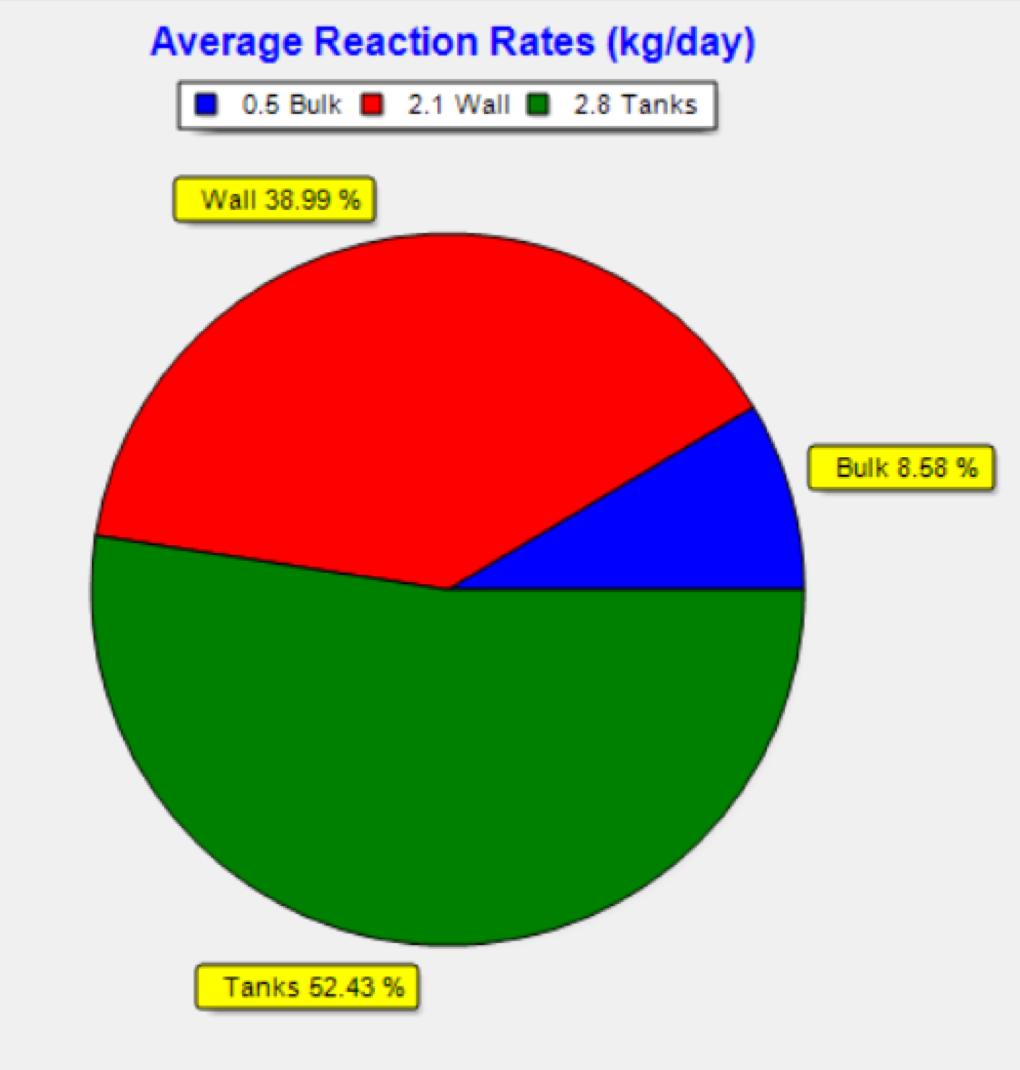


Chemical Analysis Results (2)

- Report >> Reactions

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



Knowledge Check 6

Where in the WDS is chlorine usually used up the most?

A. Treatment plants

B. Tanks

C. Bulk

D. Wall

Lunch Break

Download & launch EPANET

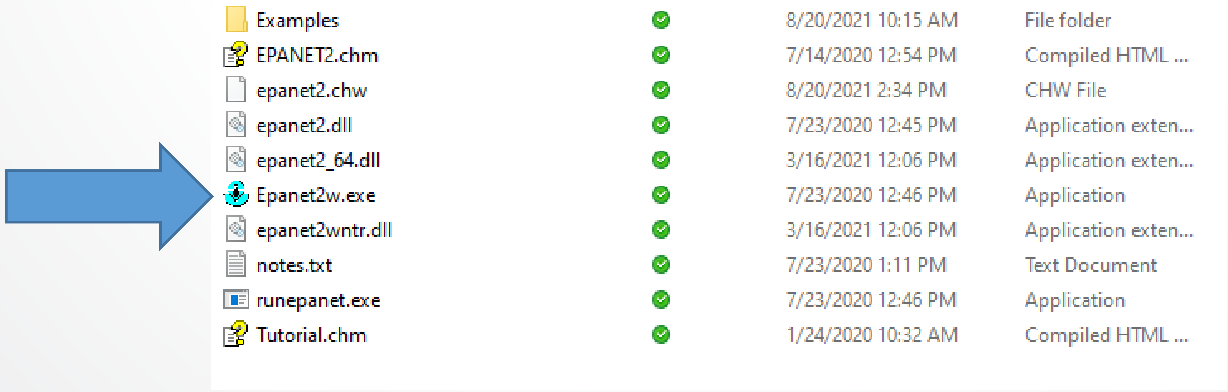
Enjoy your lunch

Join us for the walkthrough sessions at 1:00PM EST

Download and Run EPANET

EPANET 2.2 can be downloaded from: https://github.com/USEPA/EPANET2.2/releases/download/2.2.0/epanet2.2.zip

- Download and open non-installing version of EPANET
  - Non-installing software for EPANET 2.2 (epanet2.2.zip)
    - Double click (Epanet2w.exe) and run EPANET
    - This option does not require administrative rights!



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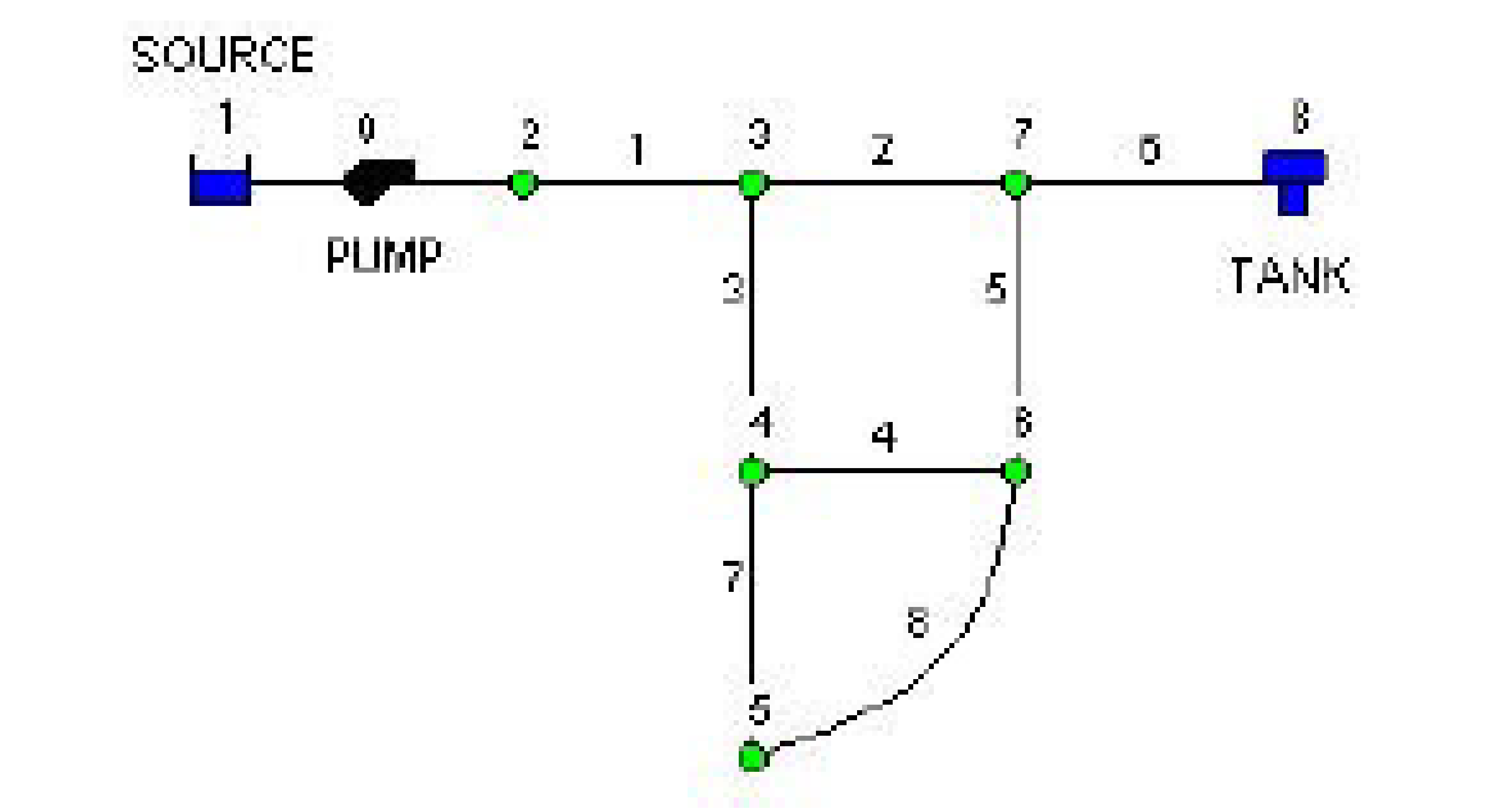
epanet2.dll	7/23/2020 12:45 PM	Application exten...
epanet2_64.dll	3/16/2021 12:06 PM	Application exten...
Epanet2w.exe	7/23/2020 12:46 PM	Application
epanet2wntr.dll	3/16/2021 12:06 PM	Application exten...
notes.txt	7/23/2020 1:11 PM	Text Document
runepanet.exe	7/23/2020 12:46 PM	Application
Tutorial.chm	1/24/2020 10:32 AM	Compiled HTML ...

Model Building Application

Ben Burkhart

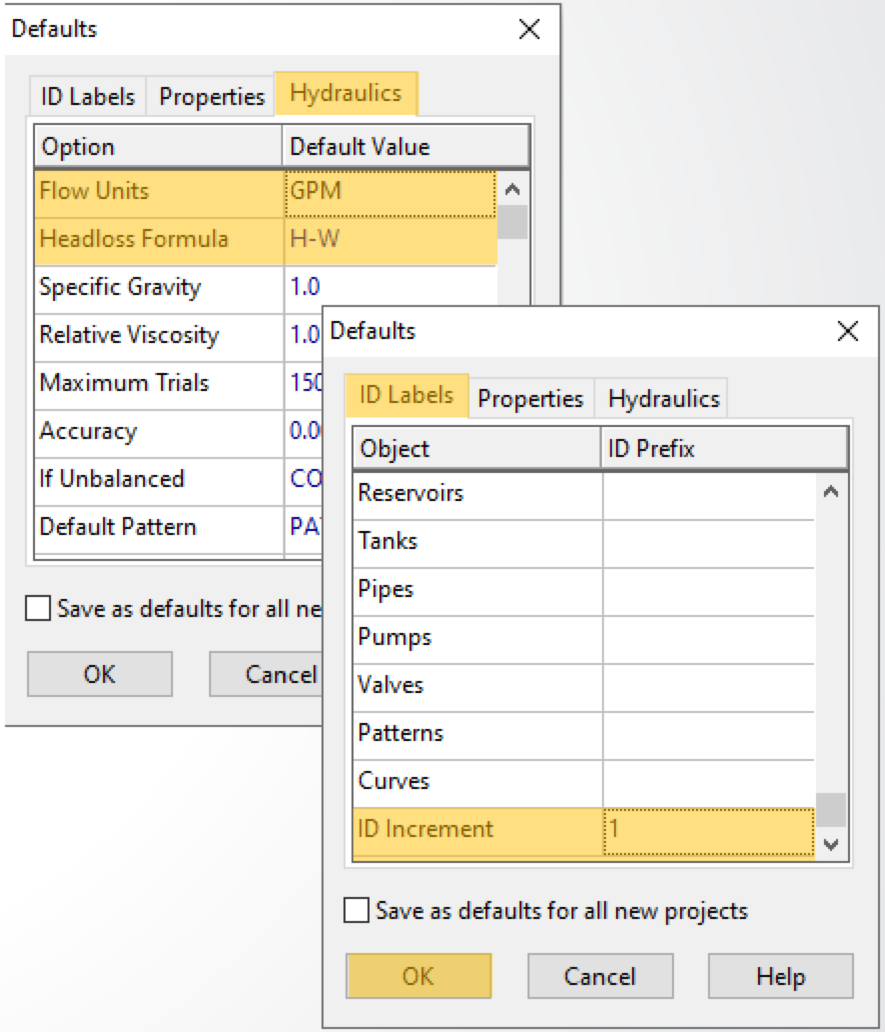
Tutorial Example Network

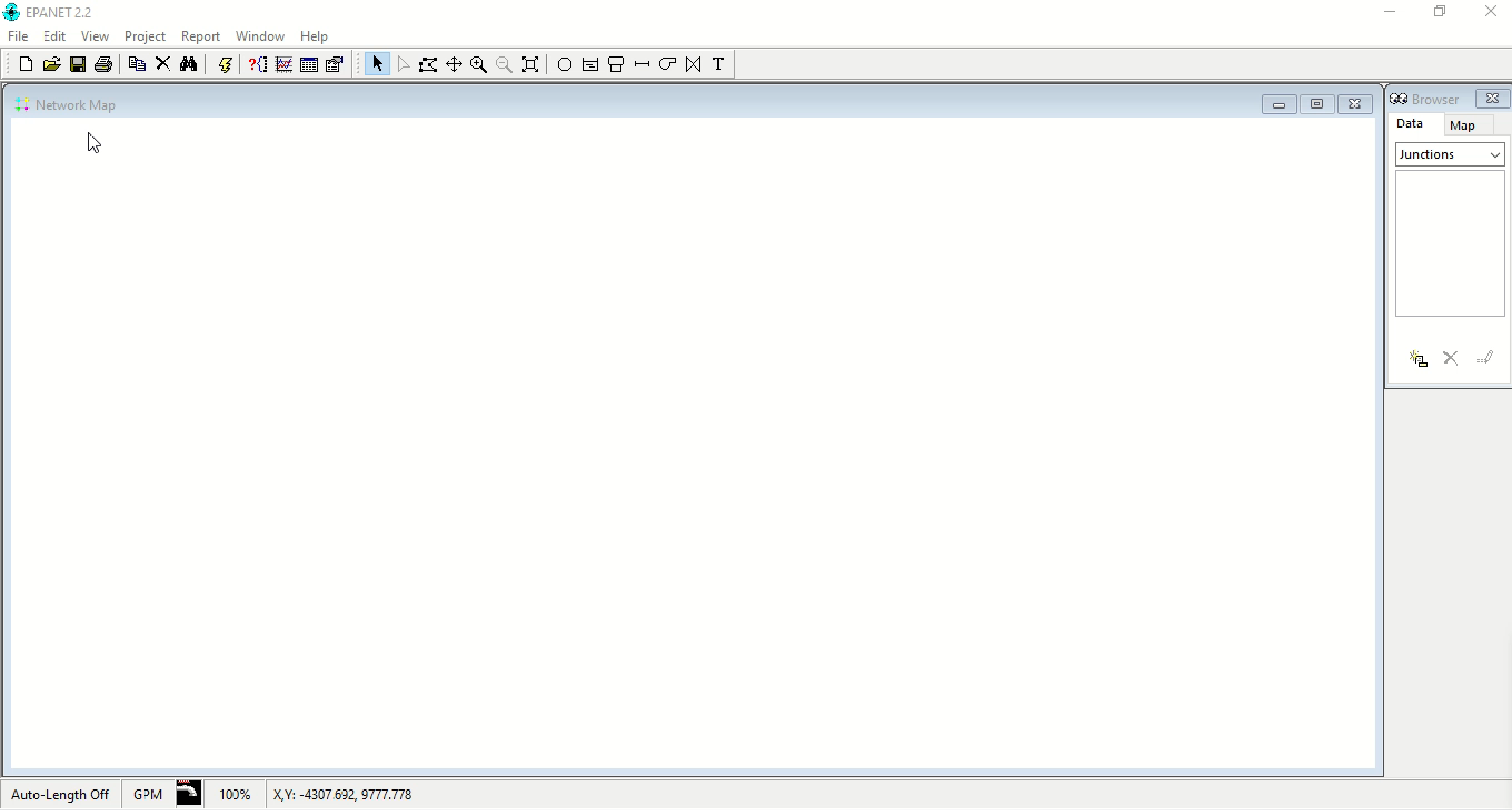
- Will eventually look like



Project Setup - Defaults

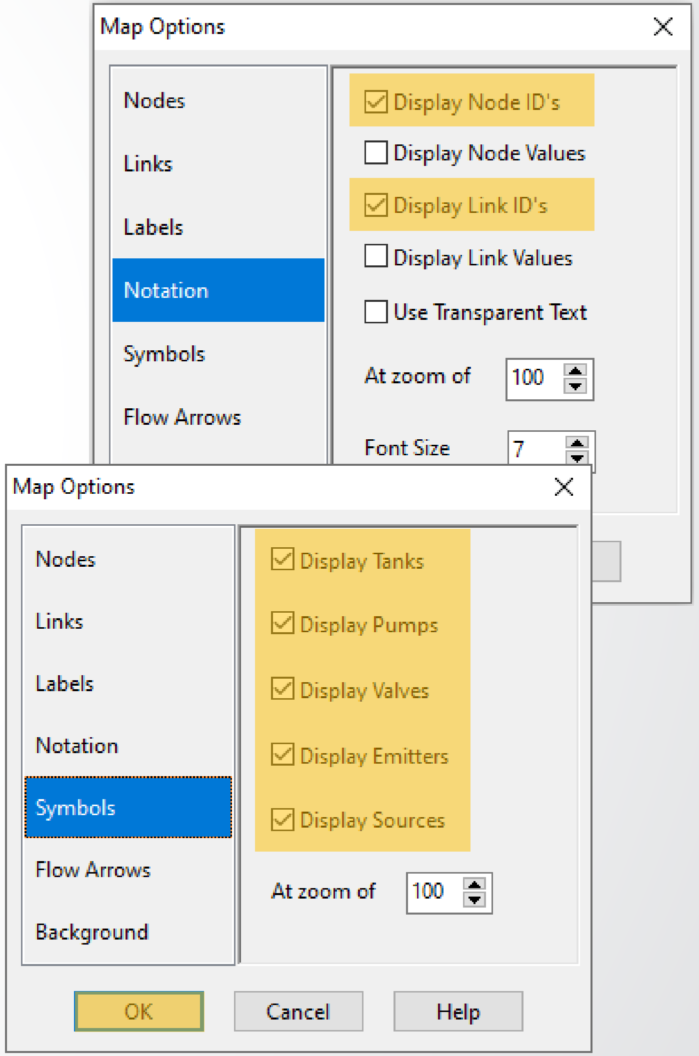
- Launch EPANET, or if it is already running select File >> New
- Select Project >> Defaults >> Hydraulics tab
  - Set choice of Flow Units to GPM
  - Set Headloss Formula to H-W
- Select ID Labels
  - Clear all ID Prefix fields
  - Set ID Increment to 1
- Can save these Default values and settings between projects
  - Good practice to set Defaults early on

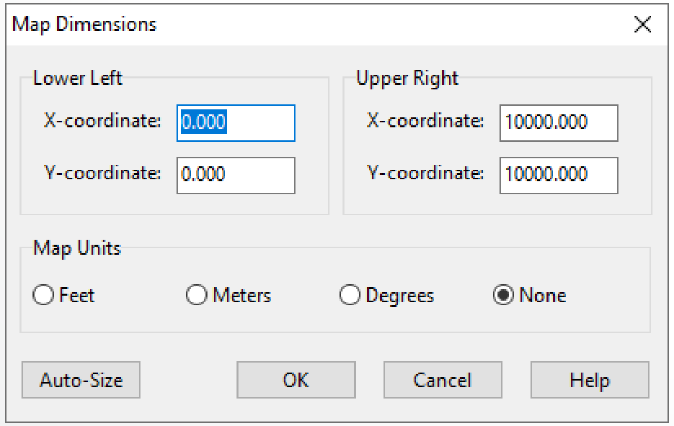


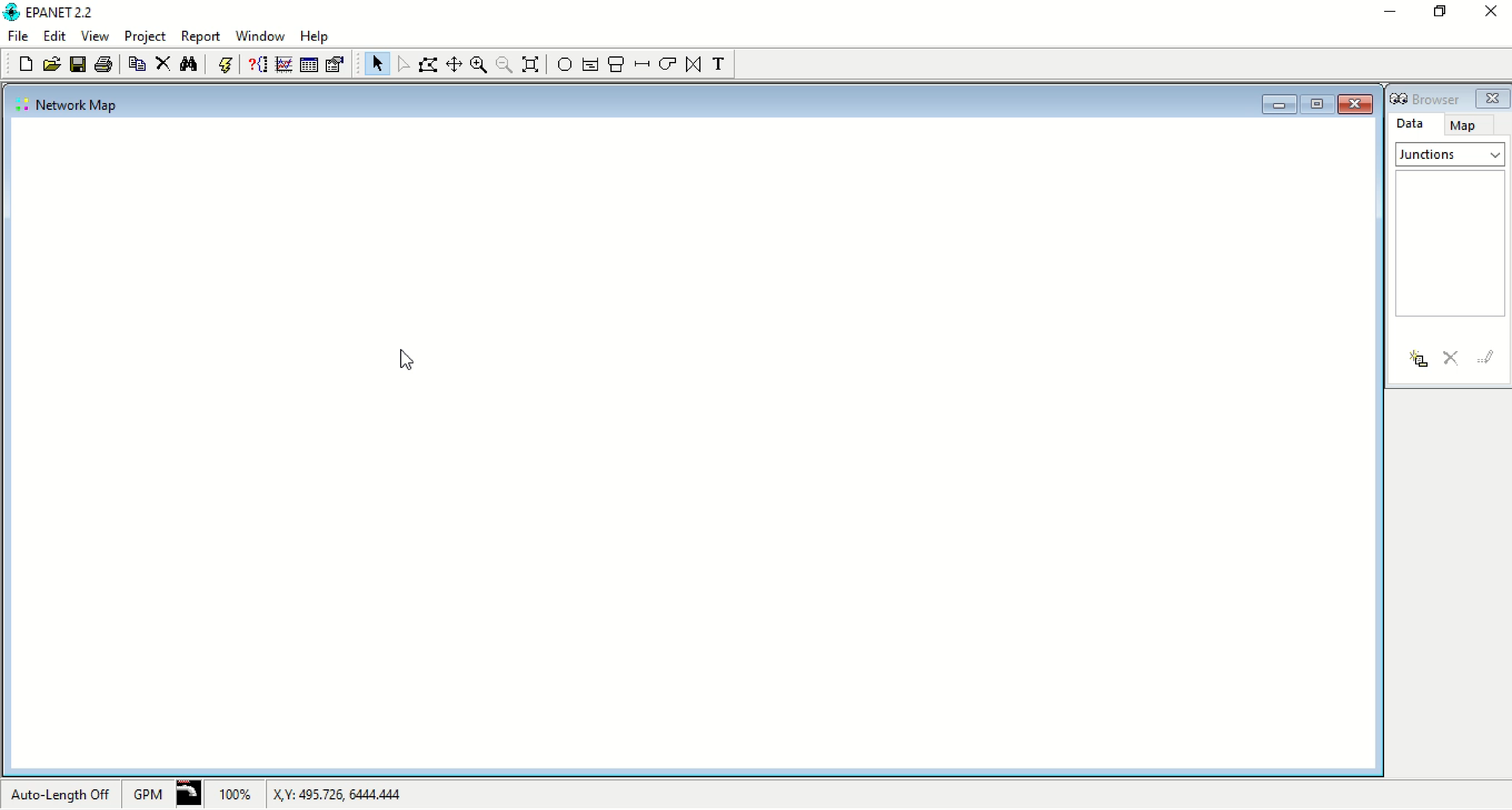

EPANET 2.2
File Edit View Project Report Window Help
Network Map
Browser
Data
Map
Junctions
Auto-Length Off
GPM
100%
X,Y: -4307.692, 9777.778

Project Setup – Map Options

- View >> Options to bring up Map Options
  - Notation >> check Display Node IDs & Display Link IDs
  - Symbols >> check all boxes
  - Click “OK” to accept and close
- View >> Dimensions to bring up Map Dimensions
  - Note default dimensions assigned for new project.
  - These settings will suffice for this example, so click “OK”



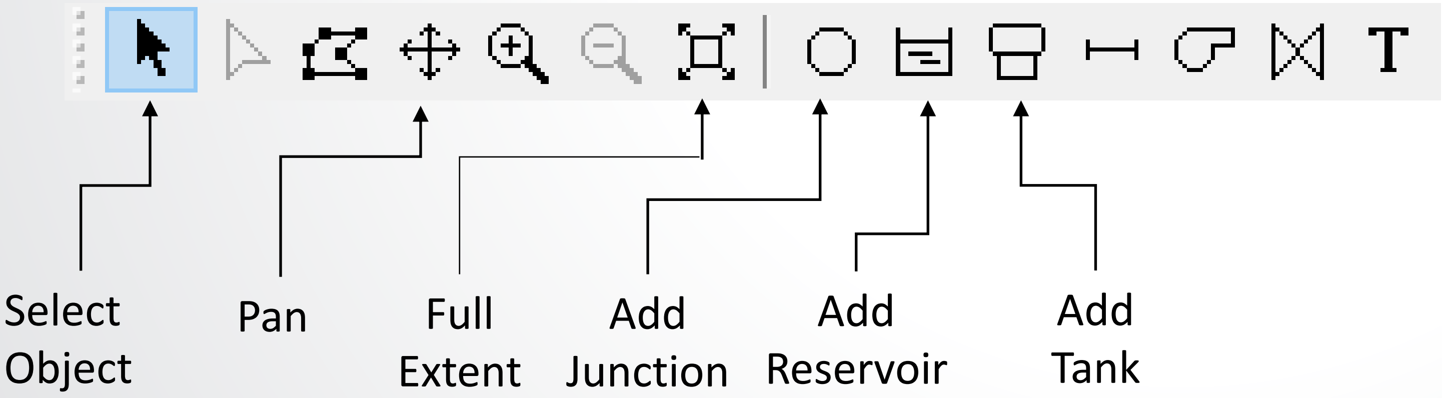


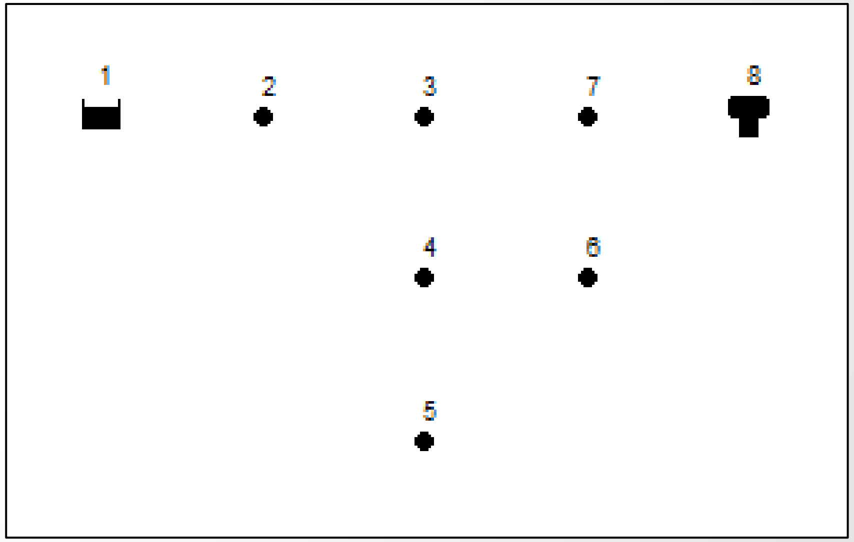

EPANET 2.2
File Edit View Project Report Window Help
Network Map
Browser
Data
Map
Junctions
Auto-Length Off
GPM
100%
X,Y: 495.726, 6444.444

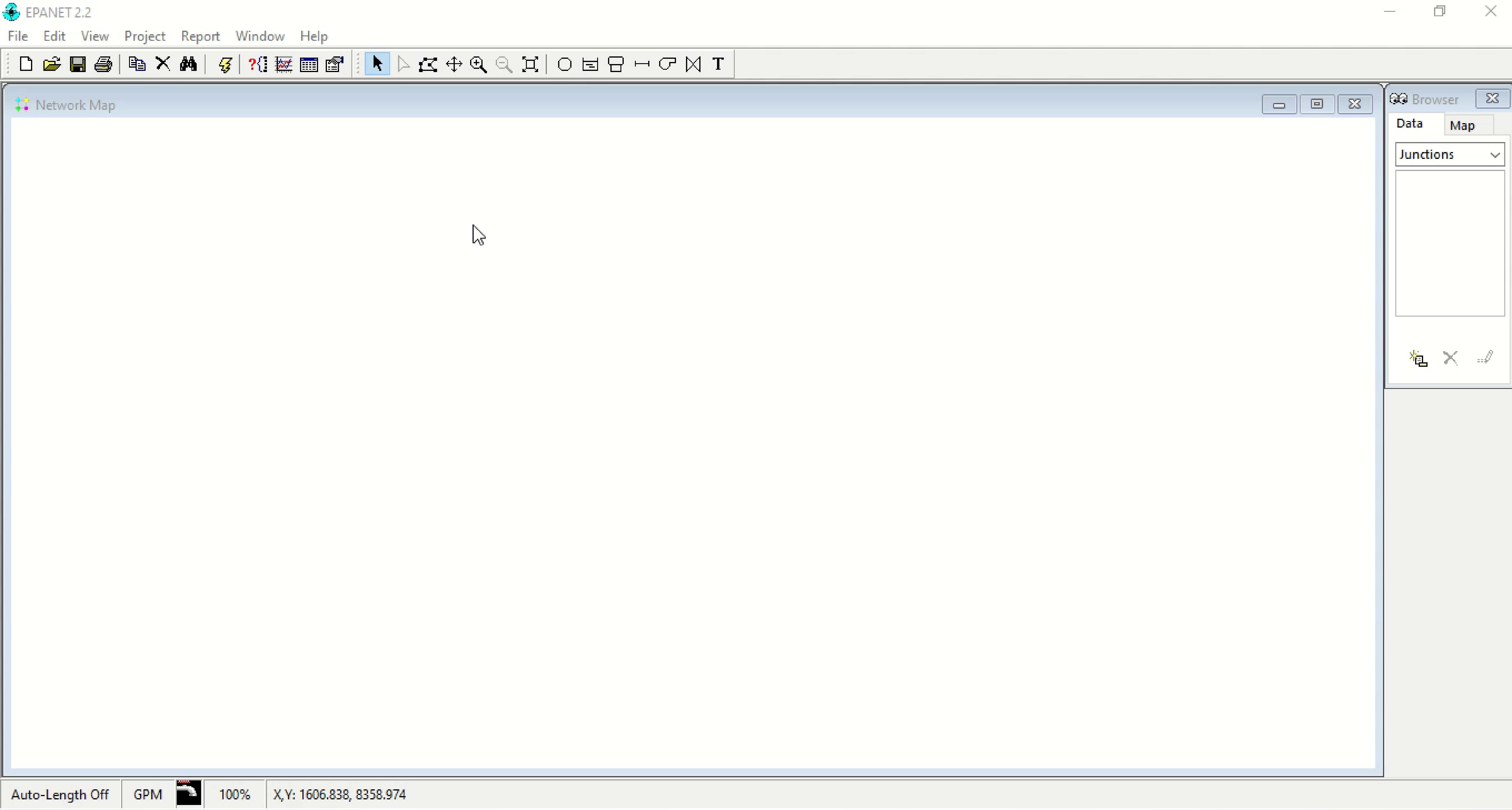
Placing the Nodes

- Click Reservoir button then click mouse on map at location of reservoir
- Click Junction button and then click on map at locations of nodes 2 through 7
- Add tank by clicking Tank button and clicking map where tank is located

*If this toolbar is not visible, then select View >> Toolbars >> Map

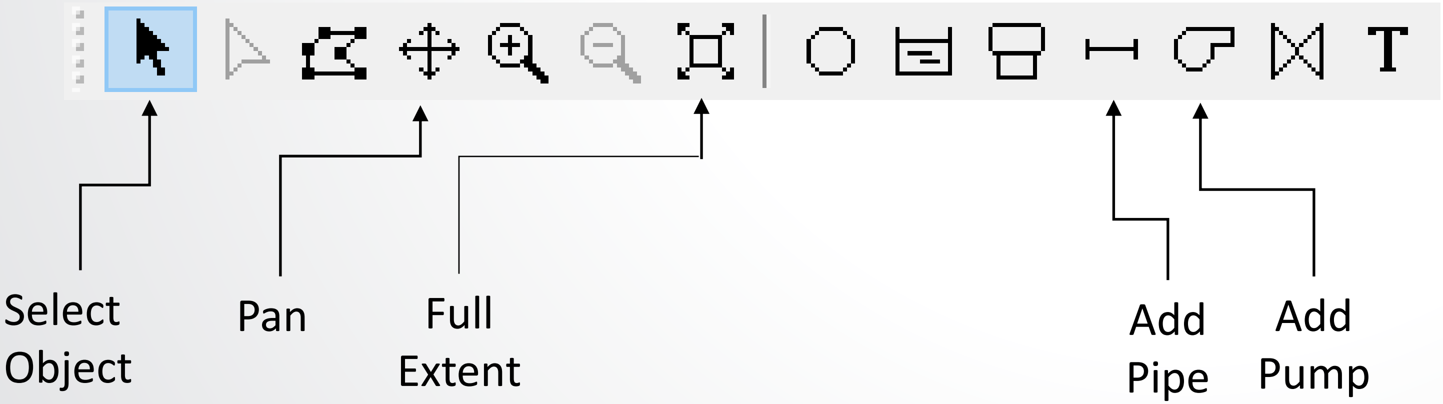


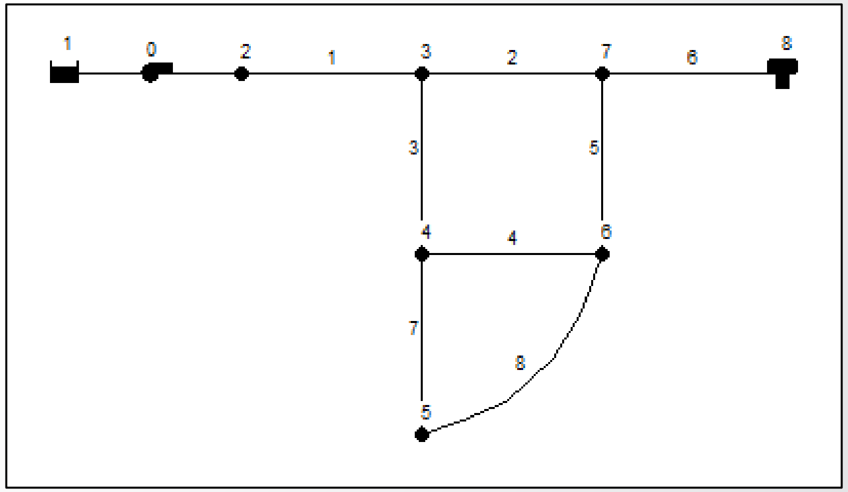


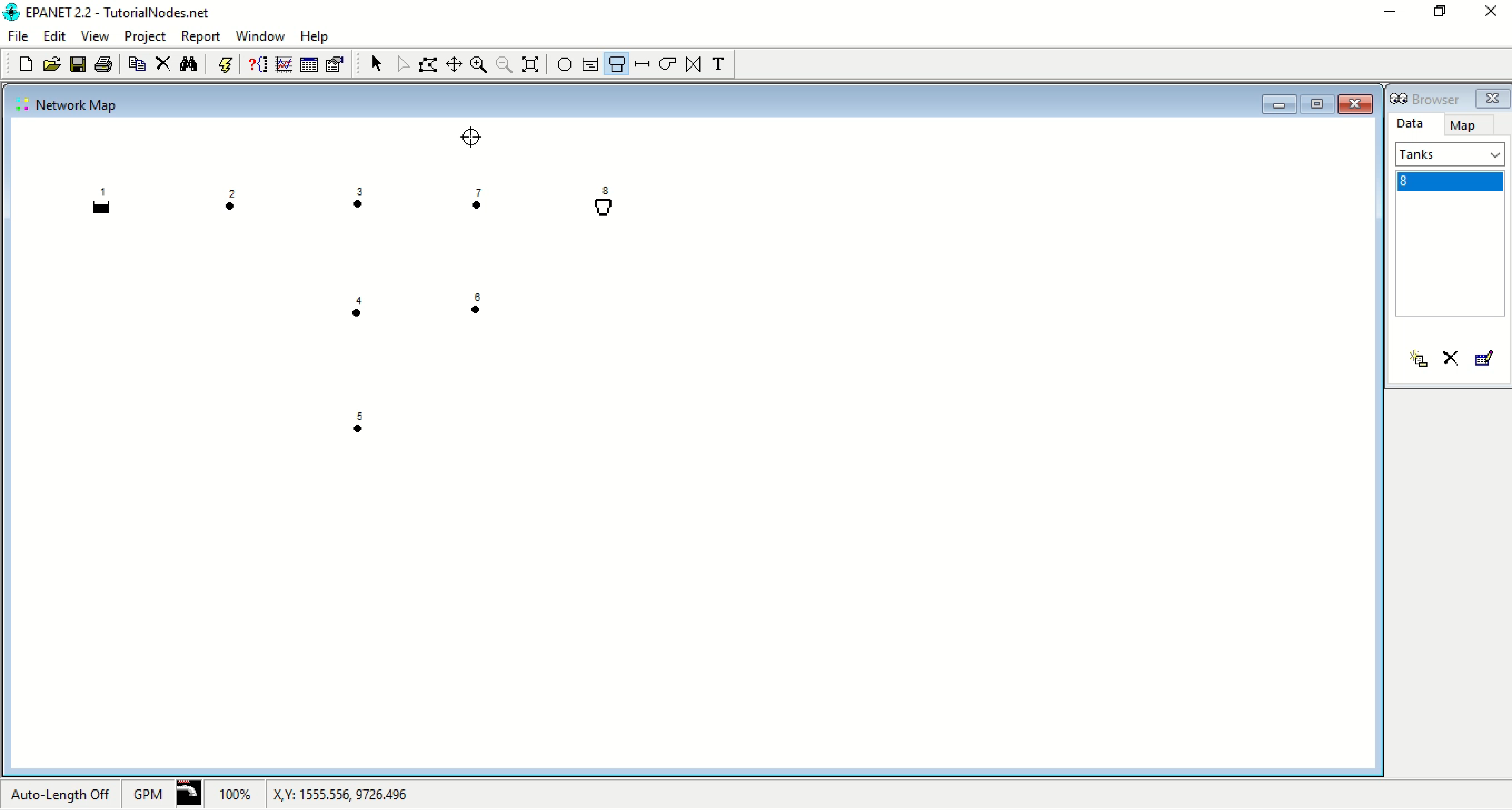

EPANET 2.2
File
Edit
View
Project
Report
Window
Help
Network Map
Browser
Data
Map
Junctions
Auto-Length Off
GPM
100%
X,Y: 1606.838, 8358.974

Connecting the Links

- Next add pipes using Pipe button on Toolbar
- Pipe 8 is curved, so to draw it
  - Click on Node 5
  - Click at points before Node 6 to change direction & maintain desired shape
  - Complete process by clicking on Node 6
- Click Pump button , click on node 1 and then on node 2

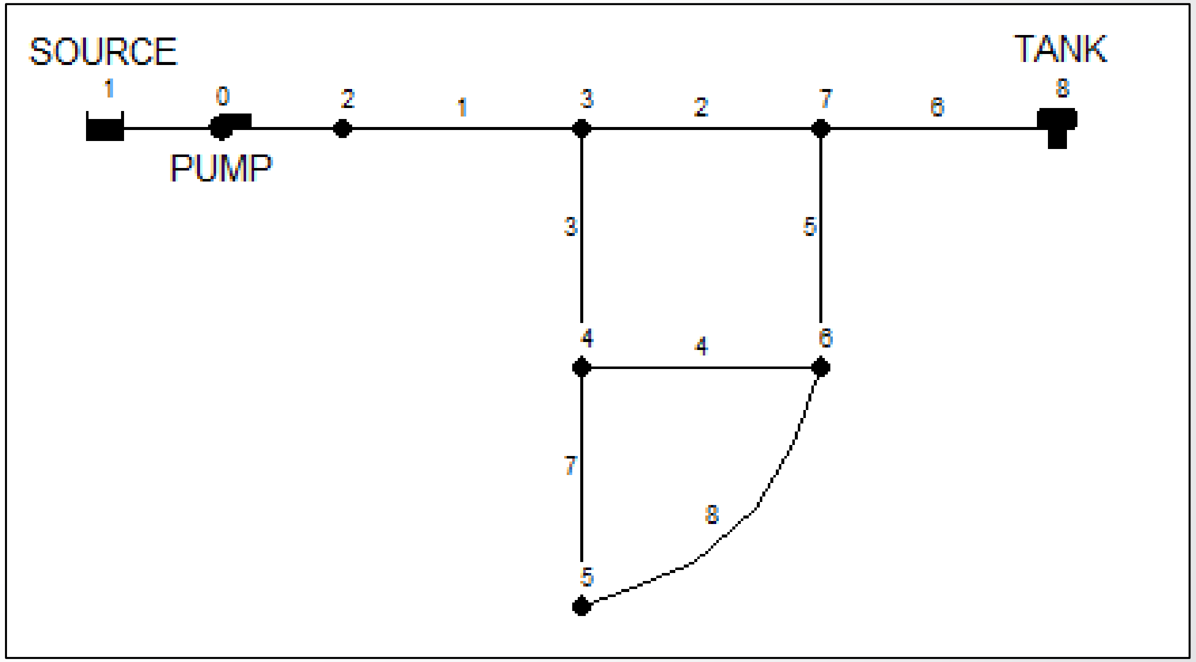


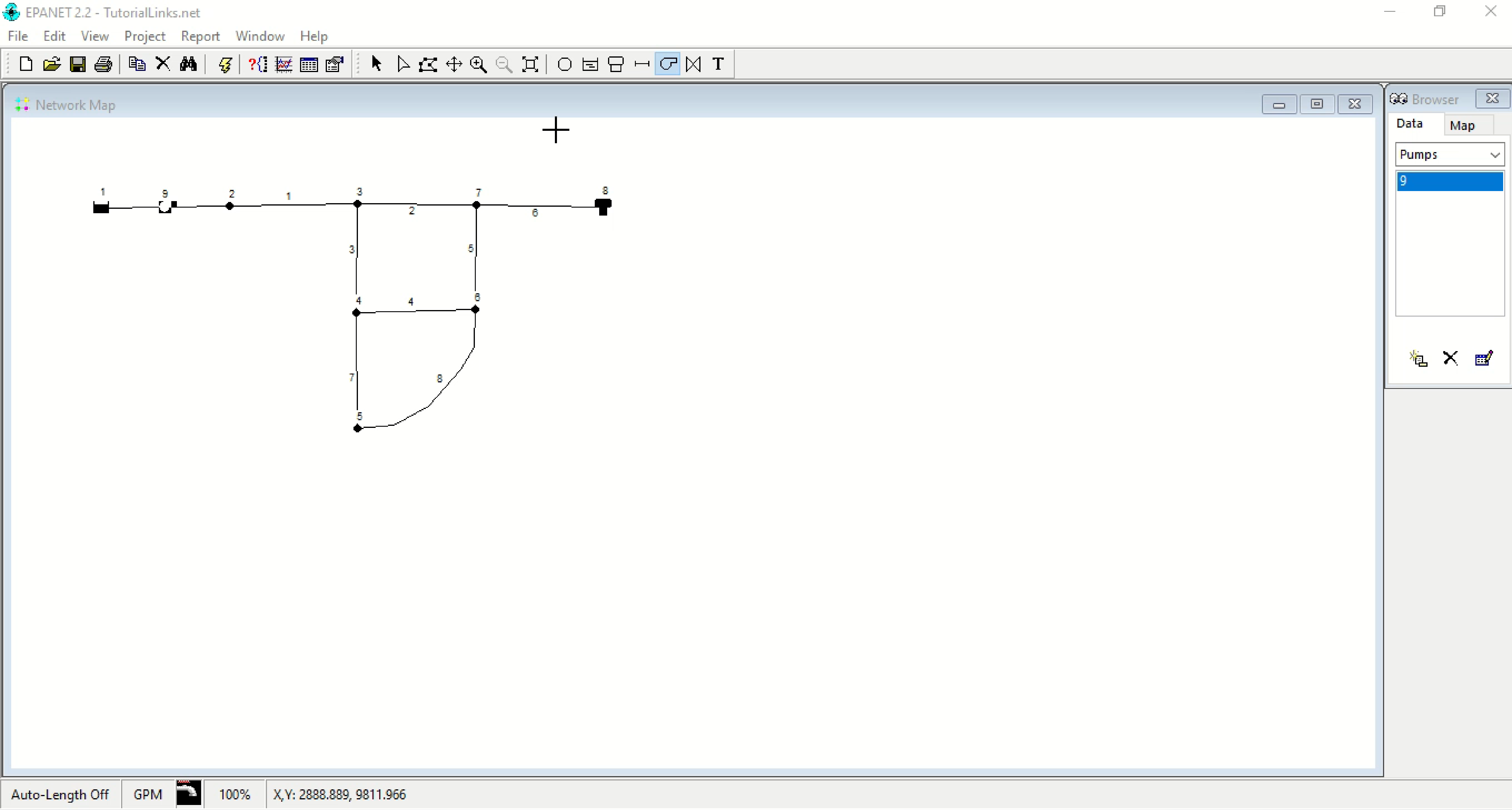



EPANET 2.2 - TutorialNodes.net
File
Edit
View
Project
Report
Window
Help
Network Map
1
2
3
7
8
4
6
5
Browser
Data
Map
Tanks
8
Auto-Length Off
GPM
100%
X,Y: 1555.556, 9726.496

Adding the Labels

- Select Text button **T** on Map Toolbar
- Click in Network Map & edit box will appear
  - Click near reservoir (Node 1) & type word “SOURCE”, then hit Enter key
  - Click next to pump and enter its label
  - Repeat steps for tank




EPANET 2.2 - TutorialLinks.net
File Edit View Project Report Window Help
Network Map
Browser
Data
Map
Pumps
9
Auto-Length Off
GPM
100%
X,Y: 2888.889, 9811.966

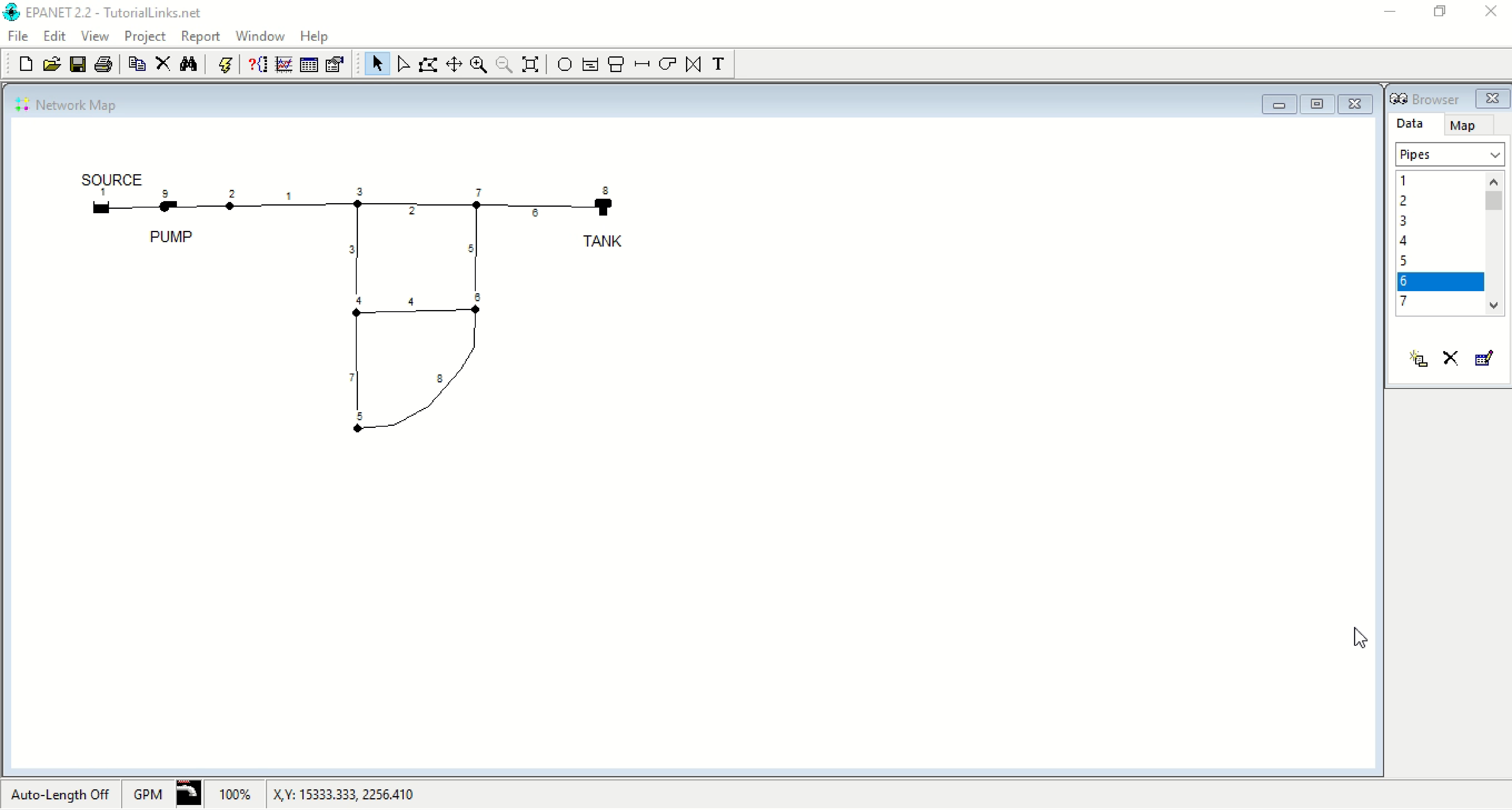
Using Property Editors

- Use Property Editor to change value of object's properties
- Open Property Editor by either
  - Double-click object on map
  - Right-click on object and select Properties
- Select object from Data page of Browser window and then click Edit button

* Note: You can change a node's coordinates here, but that has no effect on calculations

Junction 1

Property	Value
*Junction ID	1
X-Coordinate	5000
Y-Coordinate	5000
Description	
Tag	
*Elevation	0
Base Demand	0
Demand Pattern	
Demand Categories	1
Emitter Coeff.	

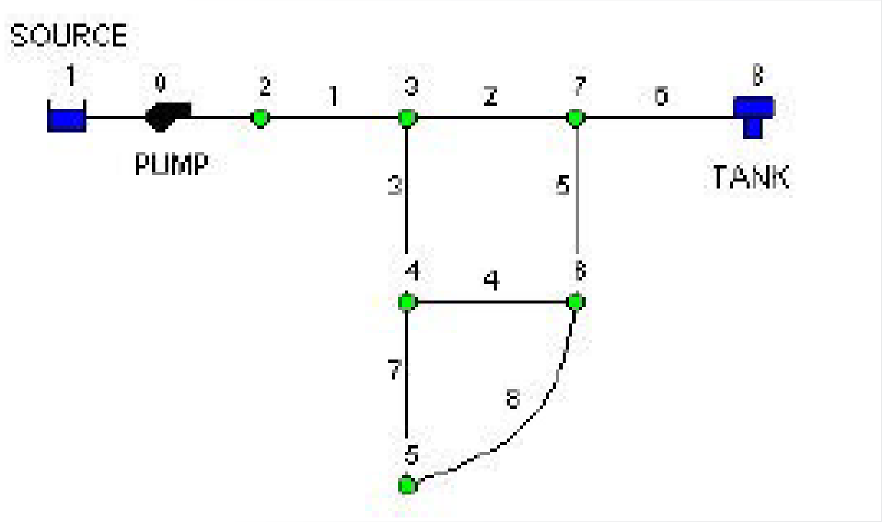

EPANET 2.2 - TutorialLinks.net
File Edit View Project Report Window Help
Network Map
SOURCE
PUMP
TANK
Browser
Data
Map
Pipes
1
2
3
4
5
6
7
Auto-Length Off
GPM
100%
X,Y: 15333.333, 2256.410

Setting Properties

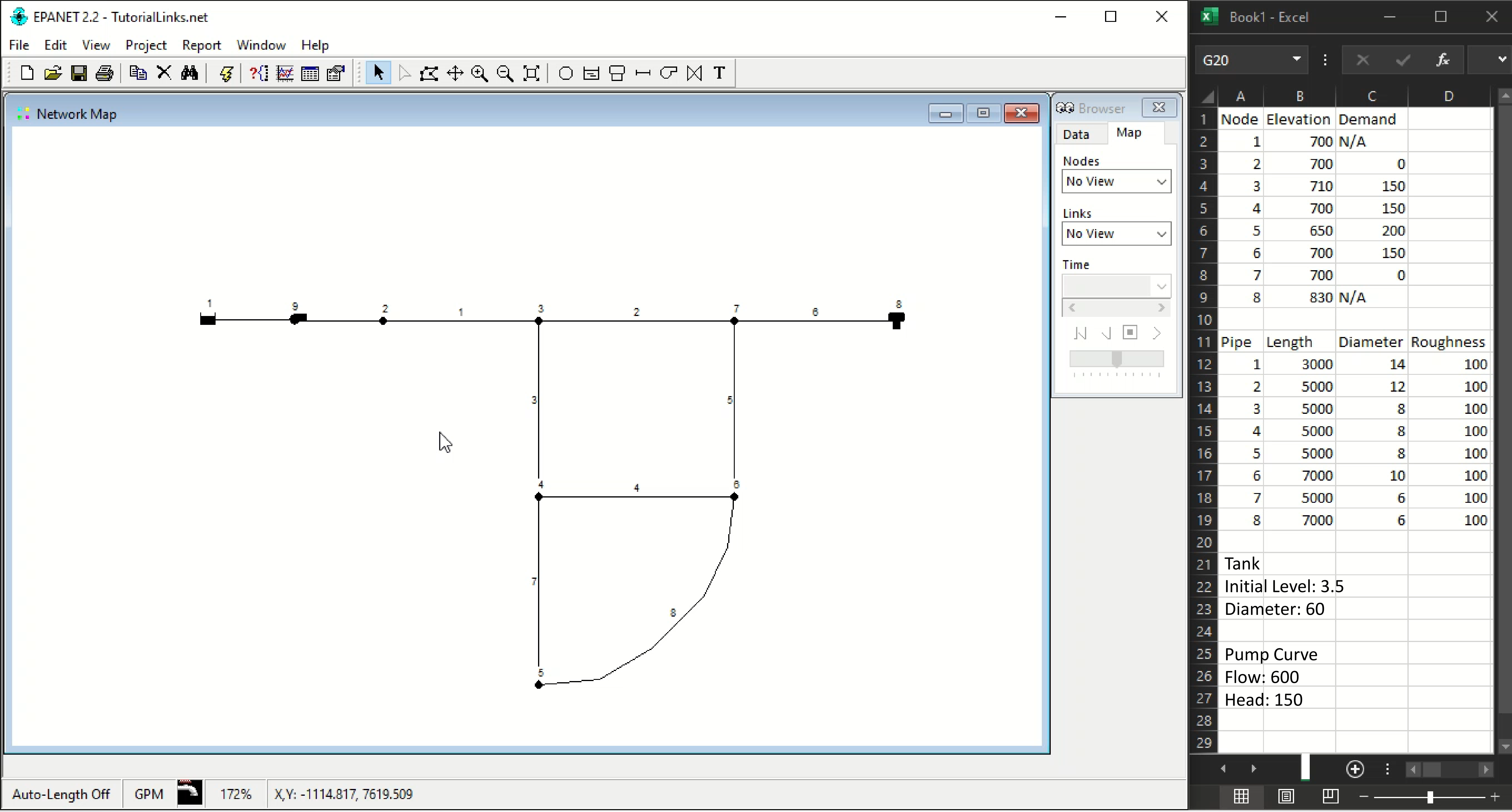
- Use tables to set properties of nodes and pipes

Node	Elevation (ft)	Demand (GPM)
1	700 (Total Head)	N/A
2	700	0
3	710	150
4	700	150
5	650	200
6	700	150
7	700	0
8	830	N/A

Pipe	Length (ft)	Diameter (inches)	Roughness
1	3000	14	100
2	5000	12	100
3	5000	8	100
4	5000	8	100
5	5000	8	100
6	7000	10	100
7	5000	6	100
8	7000	6	100

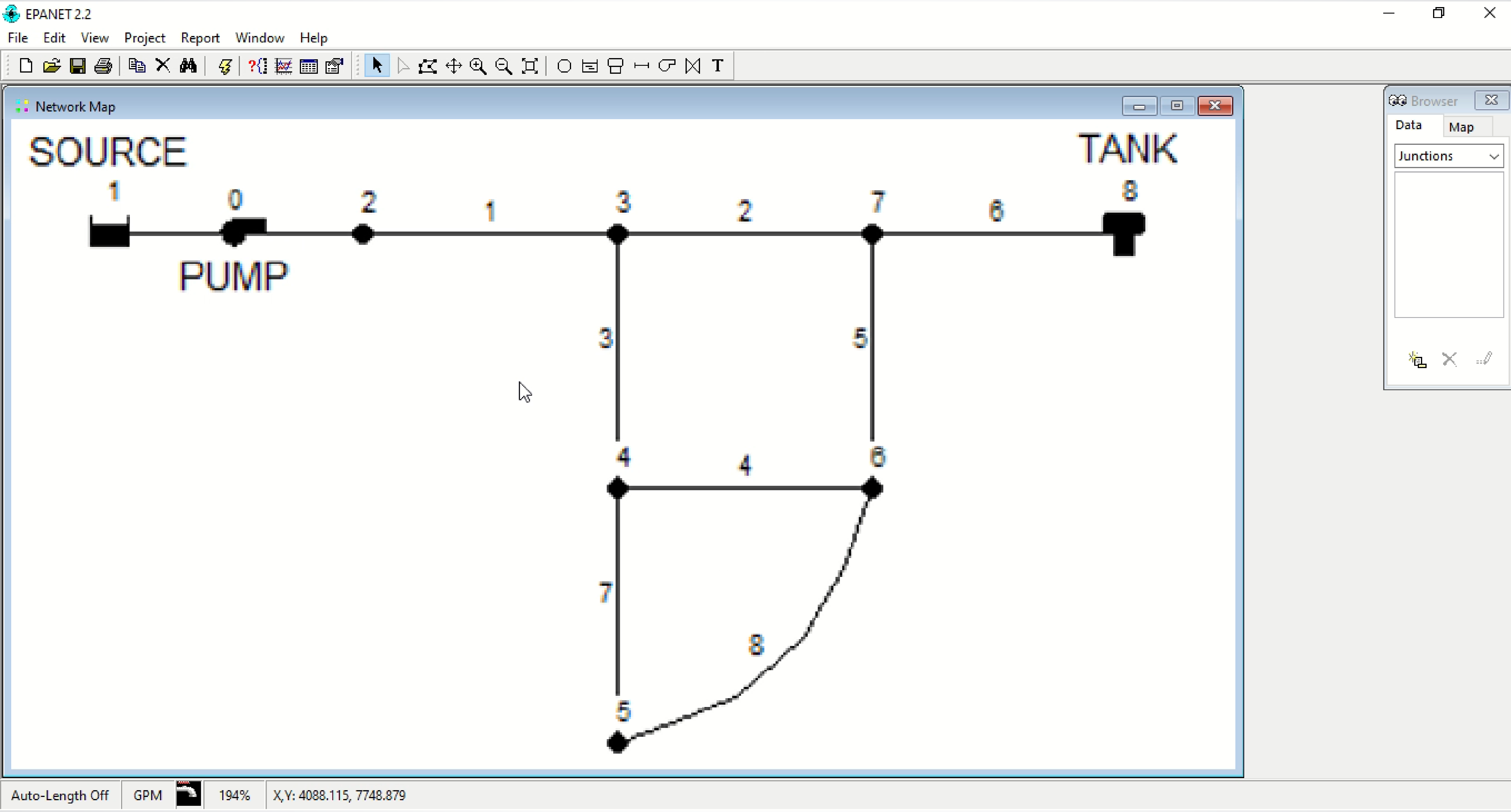


- Set tank (Node 8) properties as
  - Diameter to 60 feet, Initial Water Level to 3.5 feet, & Maximum Level to 20 feet
- Make Curve with one point; Head = 150 ft & Flow = 600 GPM
  - For pump (Link 9), set Pump Curve to “1”


EPANET 2.2 - TutorialLinks.net
File Edit View Project Report Window Help
Network Map
1
9
2
1
3
2
7
6
8
3
5
4
4
6
7
8
5
Browser
Data Map
Nodes
No View
Links
No View
Time
Auto-Length Off
GPM
172%
X,Y: -1114.817, 7619.509
Book1 - Excel
G20
Node Elevation Demand
1 700 N/A
2 700 0
3 710 150
4 700 150
5 650 200
6 700 150
7 700 0
8 830 N/A
Pipe Length Diameter Roughness
1 3000 14 100
2 5000 12 100
3 5000 8 100
4 5000 8 100
5 5000 8 100
6 7000 10 100
7 5000 6 100
8 7000 6 100
Tank
Initial Level: 3.5
Diameter: 60
Pump Curve
Flow: 600
Head: 150

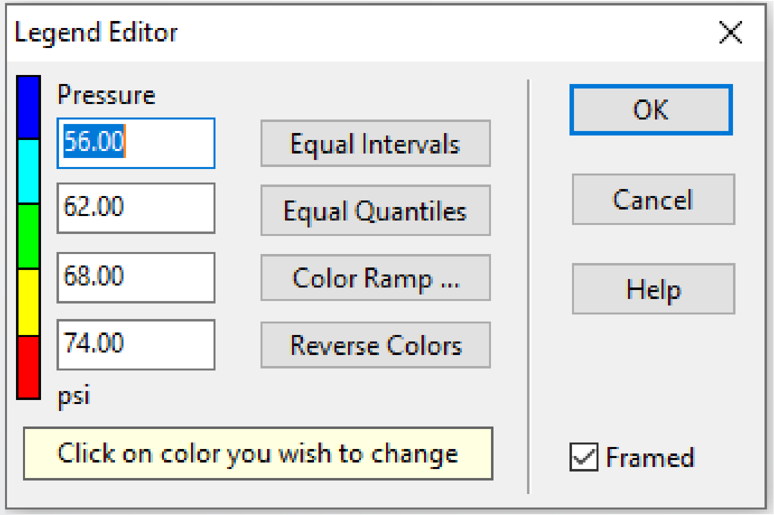
Saving and Opening Projects

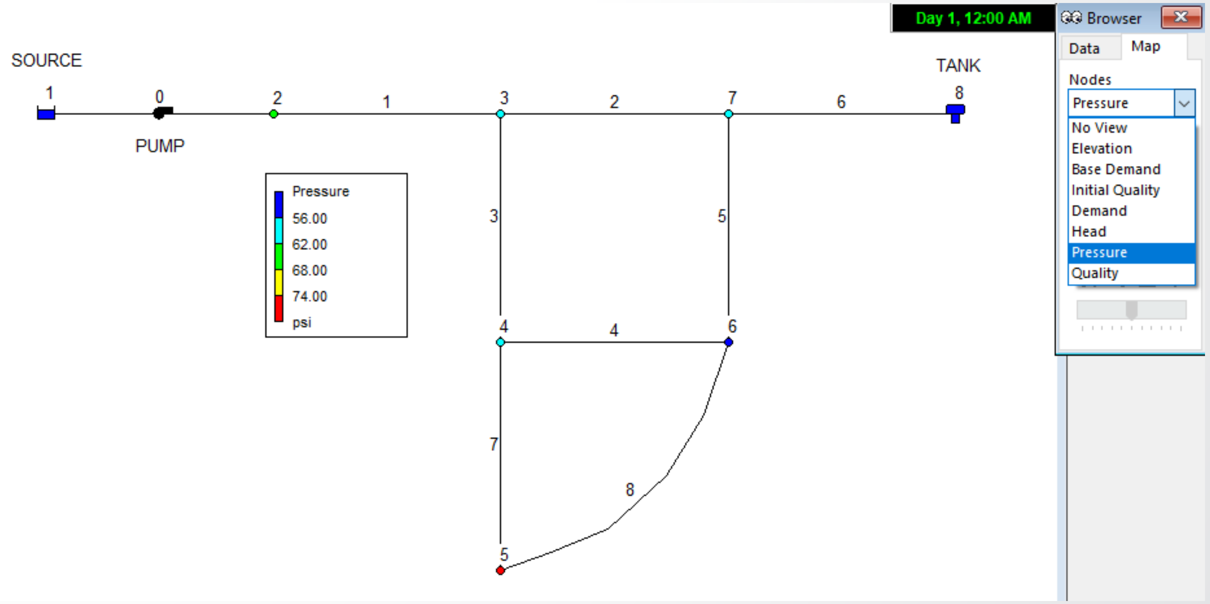
- Save file using File >> Save As
- Select folder to save this project & name the file **Tutorial.net**
  - File extension of .net is added to file name if one is not supplied
  - NET files are in special binary format
- Click “OK” to save project
- Use File >> Export >> Network to save network data as a readable text file with extension .inp

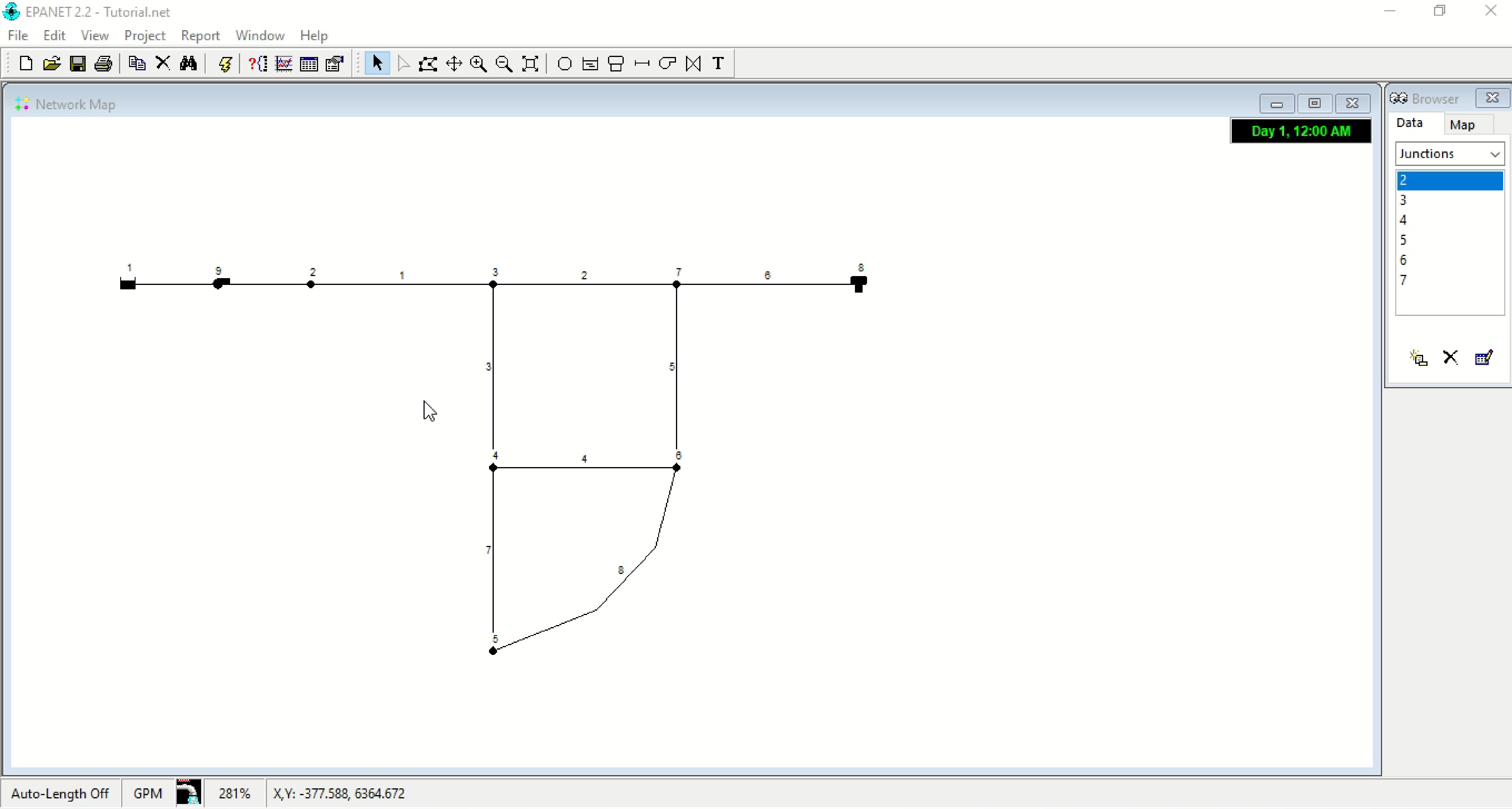

EPANET 2.2
File
Edit
View
Project
Report
Window
Help
Network Map
SOURCE
TANK
PUMP
1
0
2
1
3
2
7
6
8
3
5
4
4
6
7
8
5
Browser
Data
Map
Junctions
Auto-Length Off
GPM
194%
X,Y: 4088.115, 7748.879

Running a Single Period Simulation

- To run analysis, select Project >> Run Analysis or click Run button
- Map Browser >> Node >> Pressure then nodes are color-coded by pressure
  - To view legend for color-coding, select View >> Legends >> Node (or right-click on map >> Node Legend)
  - Right-click legend to open Legend Editor
    - Change legend intervals and colors






EPANET 2.2 - Tutorial.net
File Edit View Project Report Window Help
Network Map
Day 1, 12:00 AM
Browser
Data
Map
Junctions
2
3
4
5
6
7
1
9
2
1
3
2
7
6
8
3
5
4
4
6
7
8
5
Auto-Length Off
GPM
281%
X,Y: -377.588, 6364.672

Analyzing Results

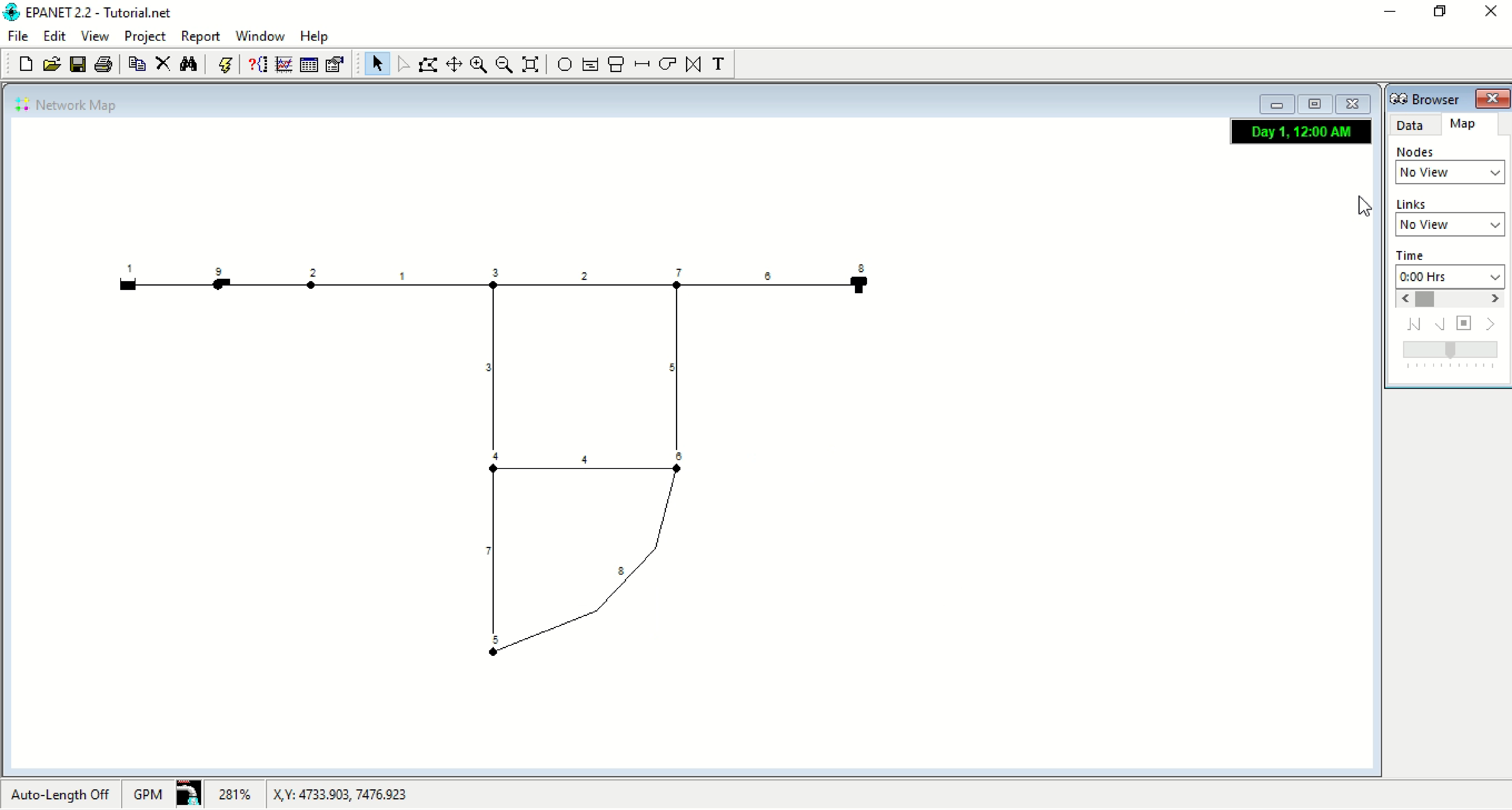
- Open Property Editor (double-click any node/link)
  - Note computed results are displayed at end of property list
- Create tabular list of results
  - Report >> Table (or click Table button)

Junction 6

Property	Value
Initial Quality	
Source Quality	
Actual Demand	150.00
Total Head	828.75
Pressure	55.79
Quality	5.00

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi	Quality hours
Junc 2	0.00	843.89	62.35	5.00
Junc 3	150.00	841.37	56.92	5.00
Junc 4	150.00	829.81	56.25	5.00
Junc 5	200.00	828.75	77.45	5.00
Junc 6	150.00	828.75	55.79	5.00
Junc 7	0.00	839.97	60.65	5.00
Resvr 1	-635.62	700.00	0.00	0.00
Tank 8	-14.39	840.00	4.33	0.00


EPANET 2.2 - Tutorial.net
File Edit View Project Report Window Help
Network Map
Day 1, 12:00 AM
Browser
Data
Map
Nodes
No View
Links
No View
Time
0:00 Hrs
1
9
2
1
3
2
7
6
8
3
5
4
4
6
7
8
5
Auto-Length Off
GPM
281%
X,Y: 4733.903, 7476.923

Modeling Knowledge Check

T/F: Junctions must be placed at the exact coordinates and distances from each other to simulate the correct pipe lengths

- True
- False

Hydraulic Modeling Application

Ben Burkhart

Running a Hydraulic Model

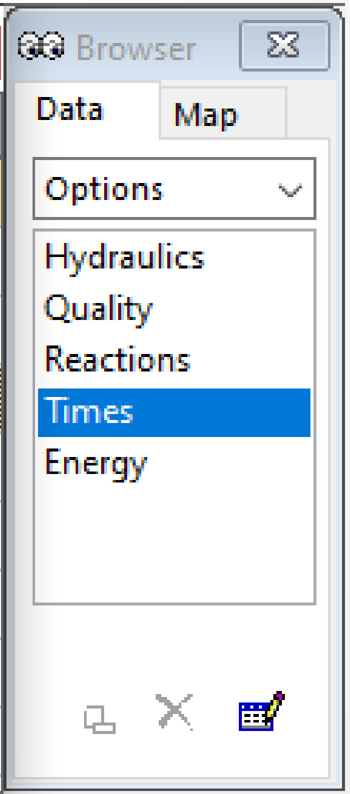
- Start with model with appropriate components & layout
- Set all relevant/required component properties
  - Base Demand, Elevation, Head, Mixing Method, etc.
- Set Total Duration of simulation (set to 0 for SPS)
- Make and assign any Patterns (EPS only)
- Optional: Set and sort Controls
- Optional: Set initial conditions (tank Initial Levels)
- Run model and look at results

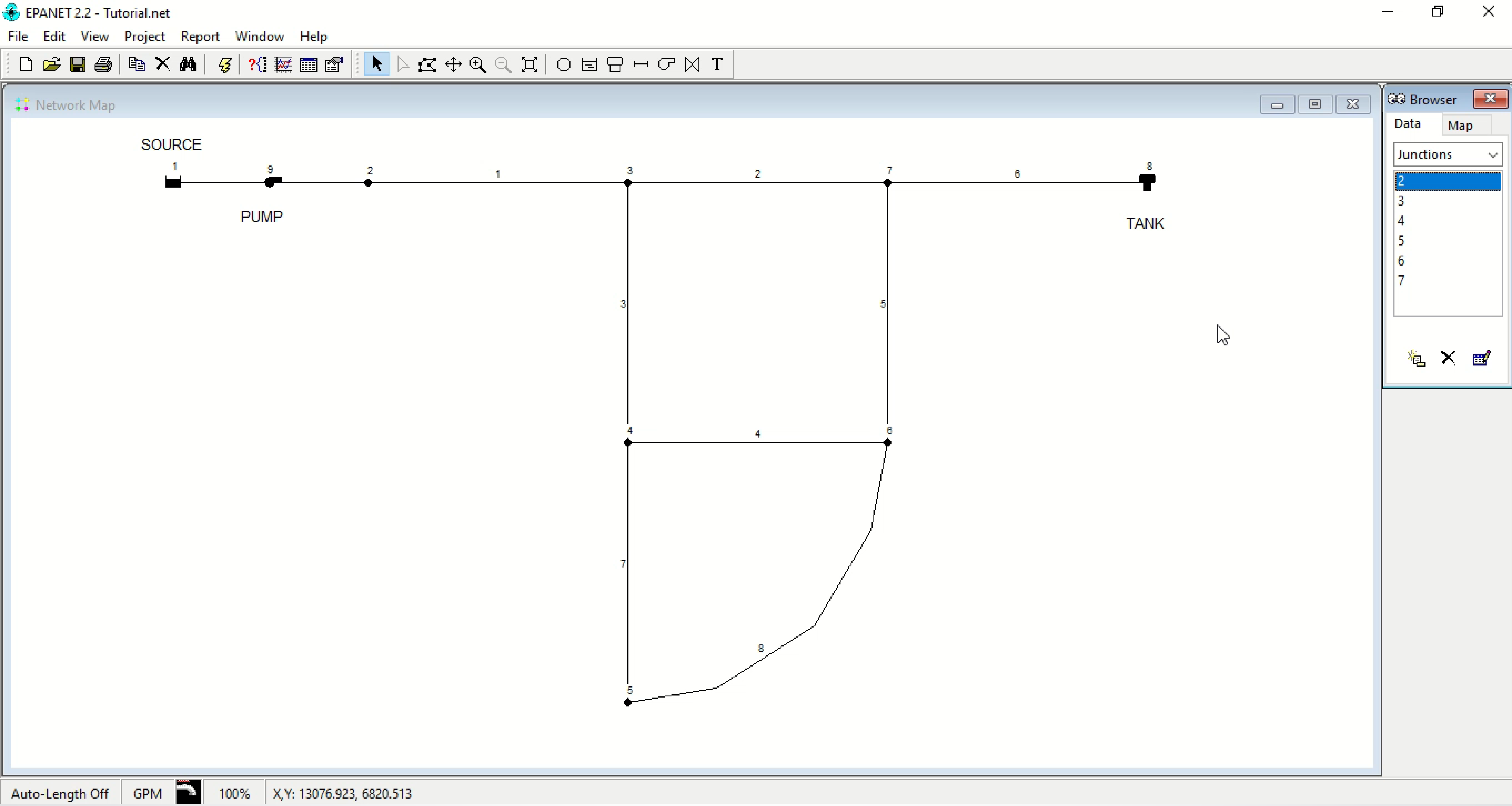
Hydraulics – Time Options

- Browser Window >> Data Tab >> Options >> Time
  - Total Duration = 72
  - Pattern Time Step = 6

Times Options

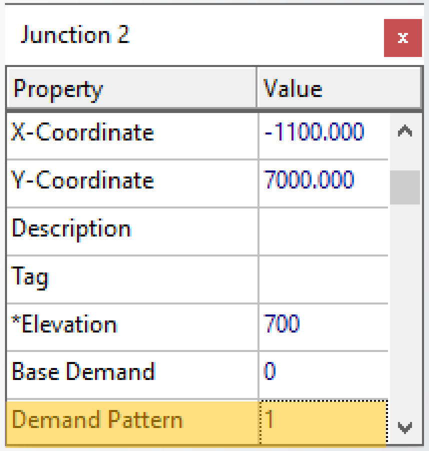
Property	Hrs:Min
Total Duration	72
Hydraulic Time Step	1:00
Quality Time Step	0:05
Pattern Time Step	6
Pattern Start Time	0:00
Reporting Time Step	1:00
Report Start Time	0:00
Clock Start Time	12 am
Statistic	None

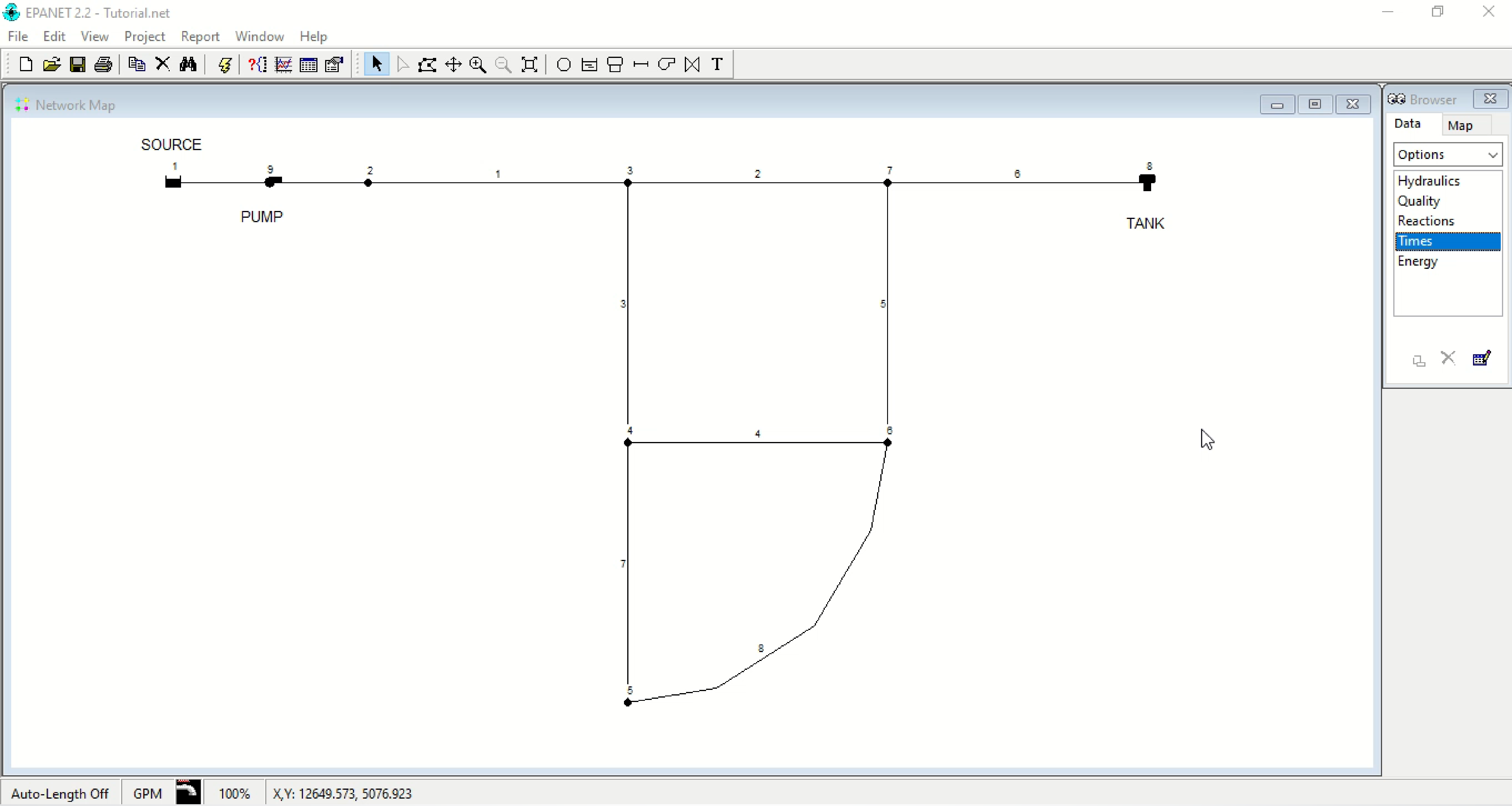



EPANET 2.2 - Tutorial.net
File Edit View Project Report Window Help
Network Map
SOURCE
PUMP
TANK
1
9
2
1
3
2
7
6
8
3
5
4
4
6
7
8
5
Browser
Data
Map
Junctions
2
3
4
5
6
7
Auto-Length Off
GPM
100%
X,Y: 13076.923, 6820.513

Hydraulics – Patterns

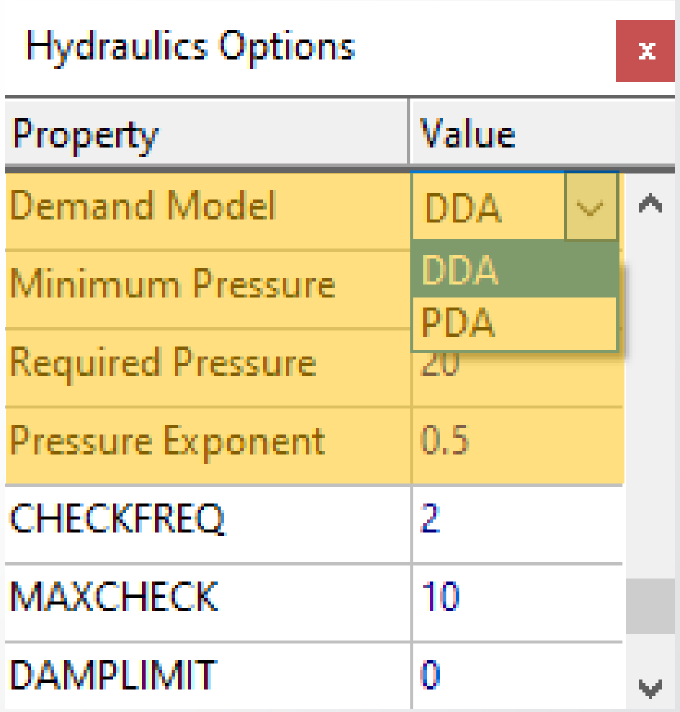
- Data Browser Window >> Patterns >> New
- Create Pattern below & assign it to each Junction using Property Editor

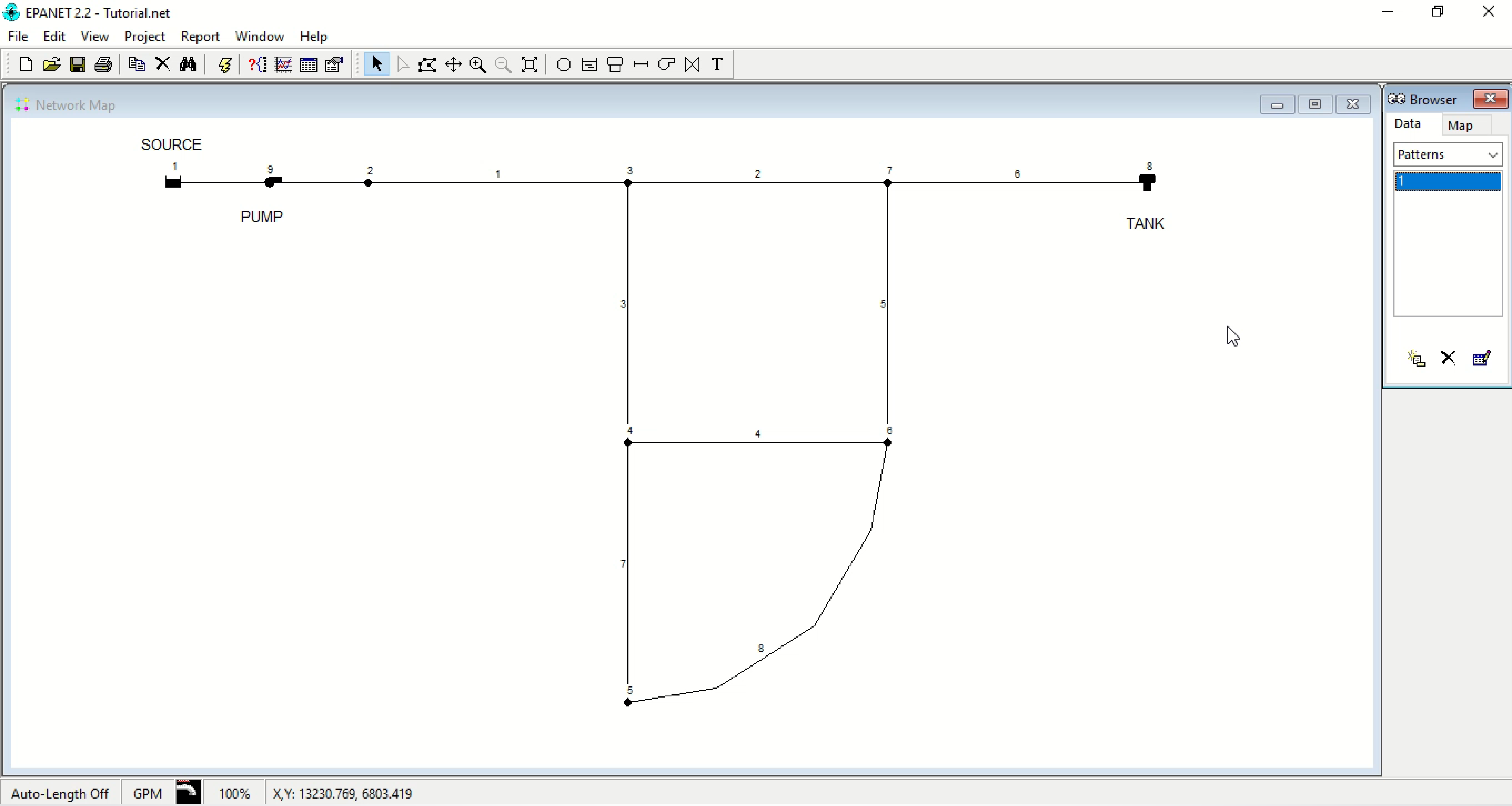



EPANET 2.2 - Tutorial.net
File Edit View Project Report Window Help
Network Map
SOURCE
PUMP
TANK
1
9
2
1
3
2
7
6
8
3
5
4
4
6
7
8
5
Browser
Data
Map
Options
Hydraulics
Quality
Reactions
Times
Energy
Auto-Length Off
GPM
100%
X,Y: 12649.573, 5076.923

Hydraulic Options - PDA

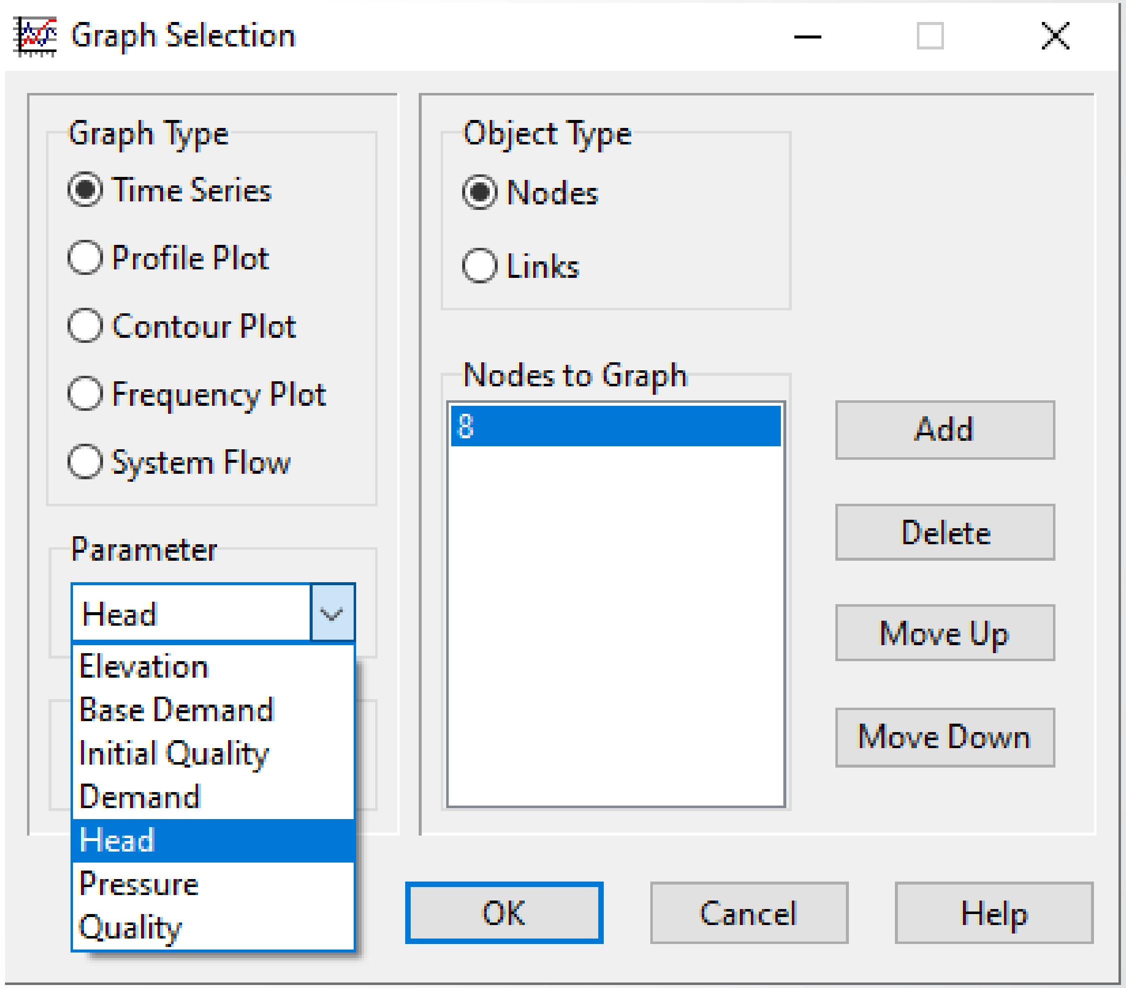
- Data Browser Window >> Options >> Hydraulics >> Demand Model
- Minimum Pressure: Demand = 0 if Pressure < Minimum Pressure
- Required Pressure: full Demand if Pressure ≥ Required Pressure
  - Set to at least 0.1 psi or m above Minimum Pressure
- Pressure Exponent: used to calculate partial demand
  - Suggested value is 0.5

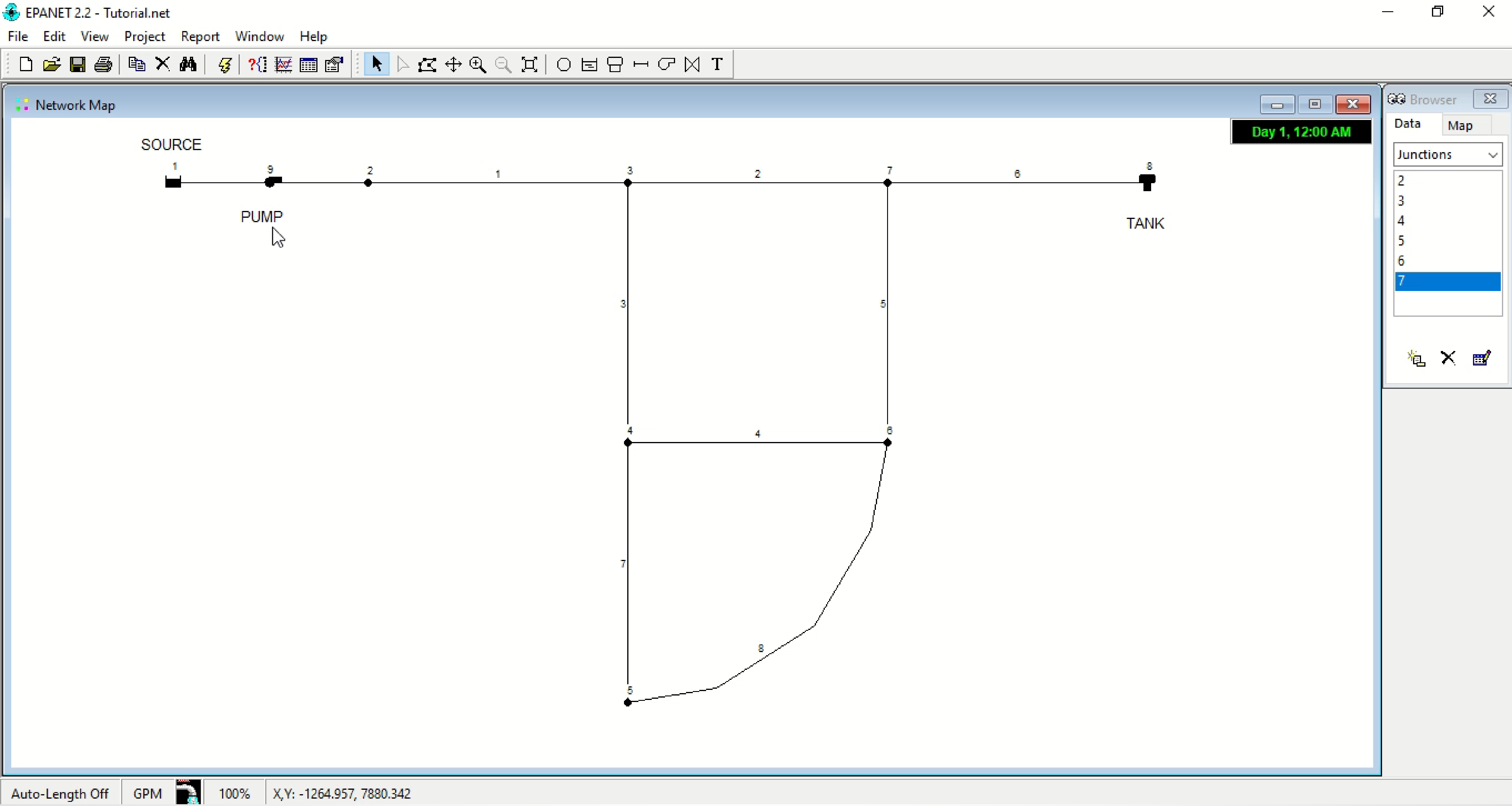



EPANET 2.2 - Tutorial.net
File
Edit
View
Project
Report
Window
Help
Network Map
SOURCE
PUMP
TANK
1
9
2
1
3
2
7
6
8
3
5
4
4
6
7
8
5
Browser
Data
Map
Patterns
1
Auto-Length Off
GPM
100%
X,Y: 13230.769, 6803.419

Hydraulics – Time Series (Head)

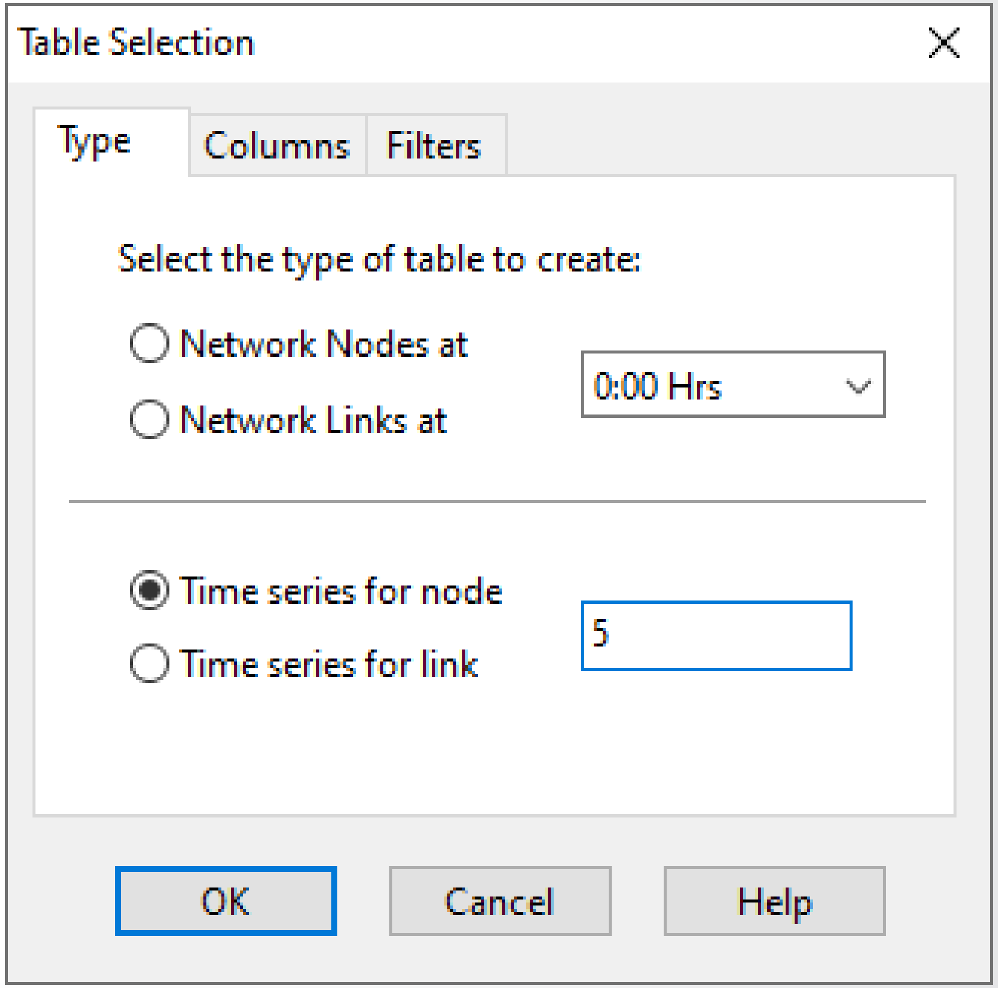
- Report >> Graph (or just Graph button)
  - Graph Type: Time Series
  - Parameter: Head
  - Nodes to Graph: 8 (Tank)
    - Move Graph Selection window until Tank is visible in Network Map
    - Click Tank so it is blinking (selected)
    - Click Add

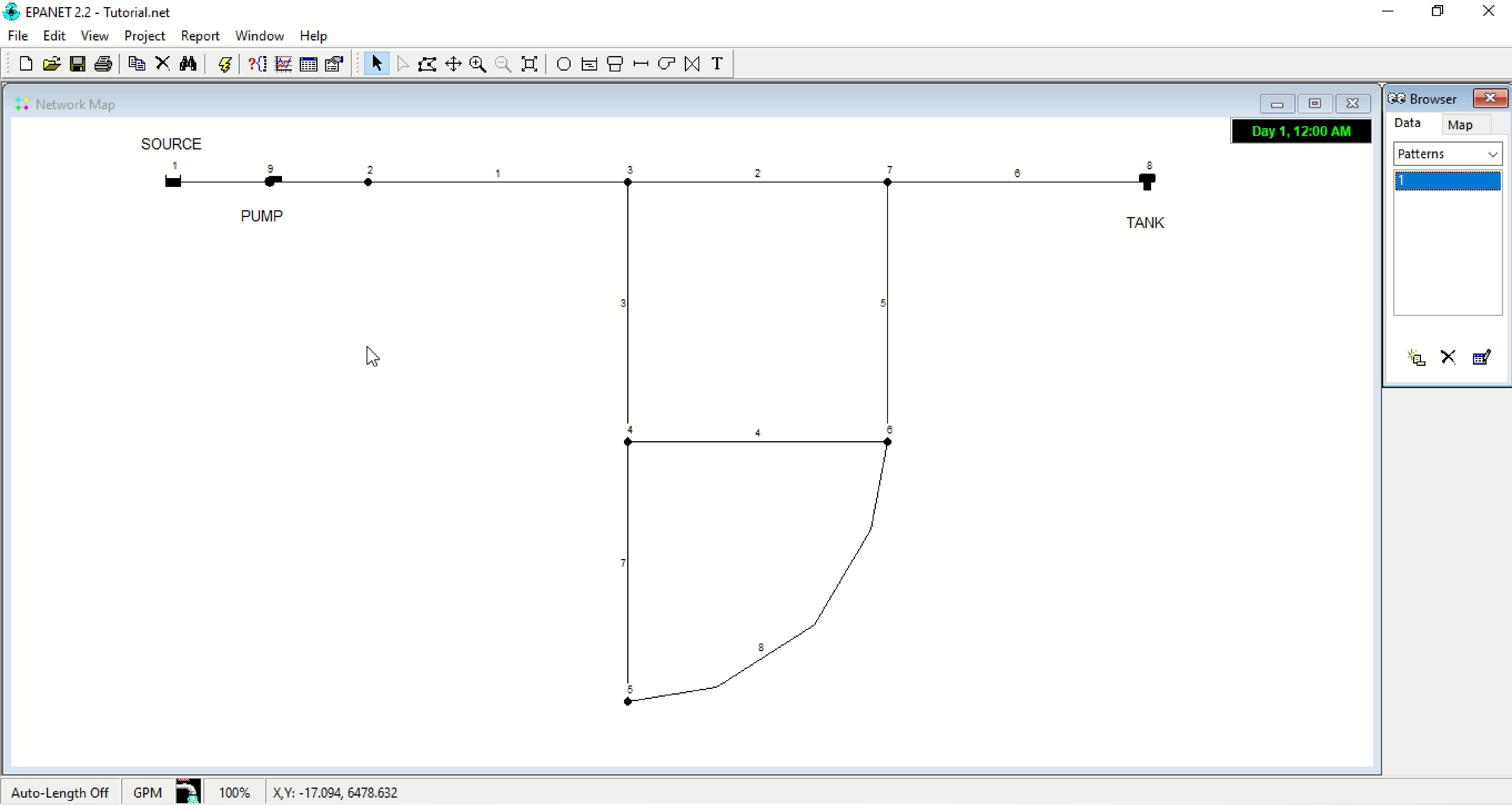



EPANET 2.2 - Tutorial.net
File
Edit
View
Project
Report
Window
Help
Network Map
Day 1, 12:00 AM
SOURCE
PUMP
TANK
1
9
2
1
3
2
7
6
8
3
5
4
4
6
7
8
5
Browser
Data
Map
Junctions
2
3
4
5
6
7
Auto-Length Off
GPM
100%
X,Y: -1264.957, 7880.342

Hydraulics - Table

- Report >> Table (or just Table button)
  - Select type of table to create: Time series for node
  - Type "5" in box for Node/Junction 5

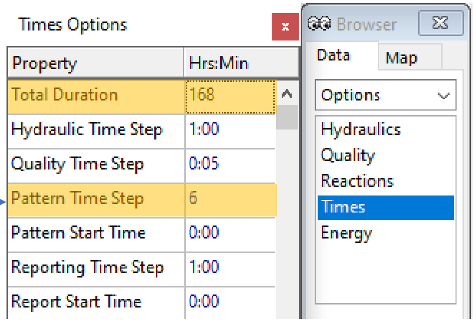



EPANET 2.2 - Tutorial.net
File Edit View Project Report Window Help
Network Map
Day 1, 12:00 AM
SOURCE
PUMP
TANK
Browser
Data
Map
Patterns
1
Auto-Length Off
GPM
100%
X,Y: -17.094, 6478.632

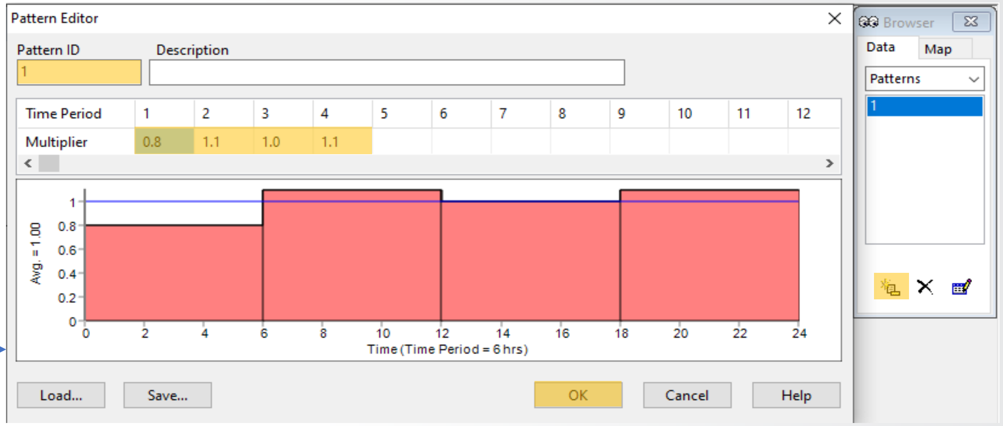
Hydraulics Modeling Exercise

Set-Up - Exercise

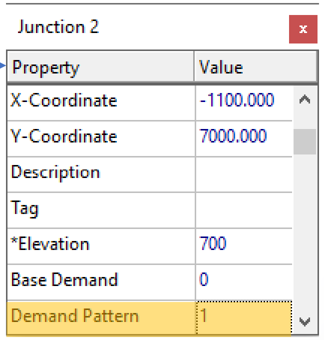
- Use input file: **Tutorial.net**



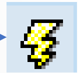
- Set Times Options



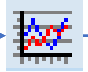
- Create a Pattern

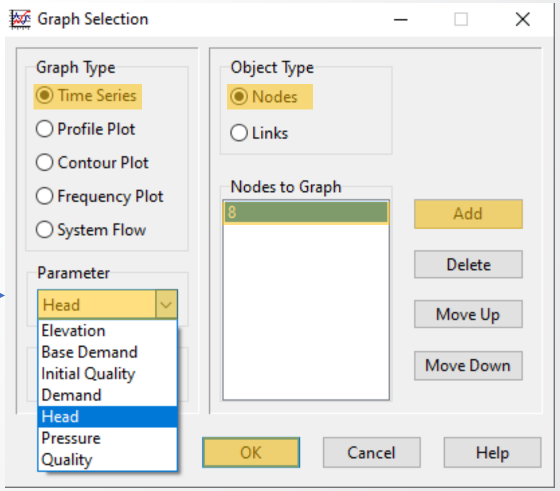


- Set Demand Pattern for each Junction
- Run Analysis



- Graph Head in Tank 8

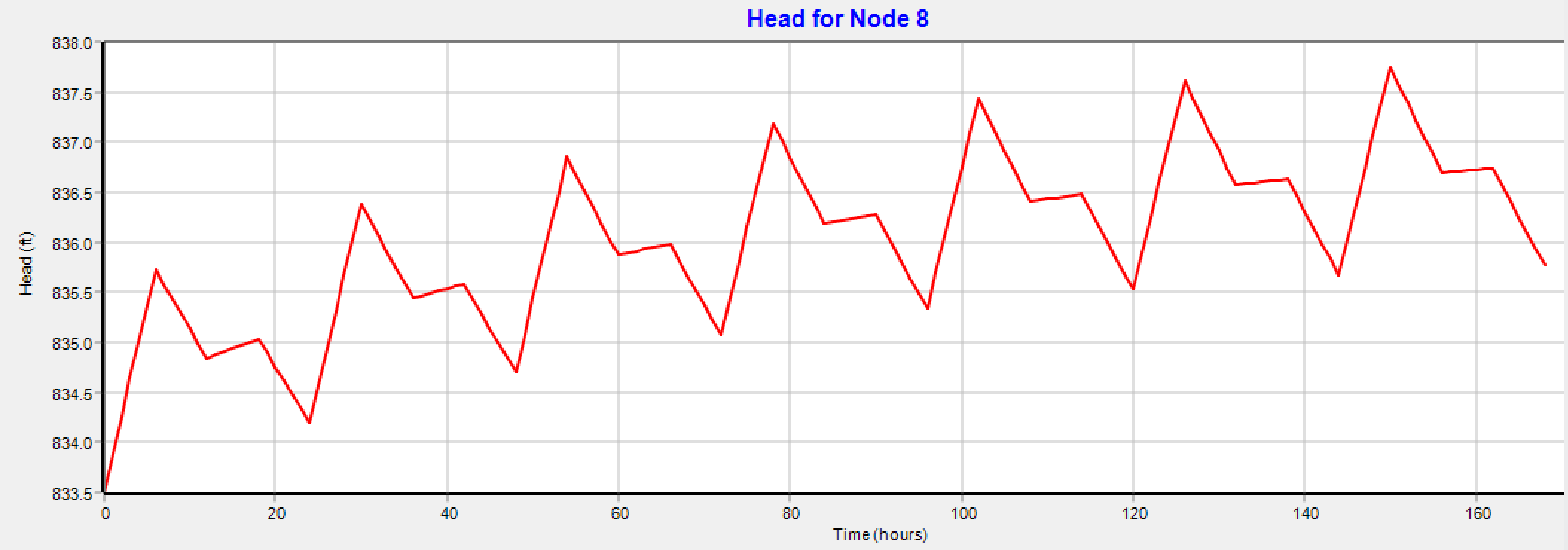




- Save As: **Tutorial Hyd1.net**

Set-Up - Results

- What do we see? Has the tank reached a cyclic equilibrium?

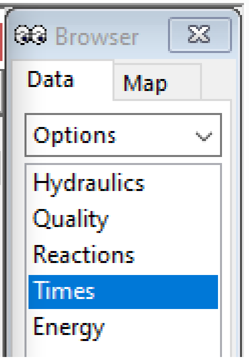


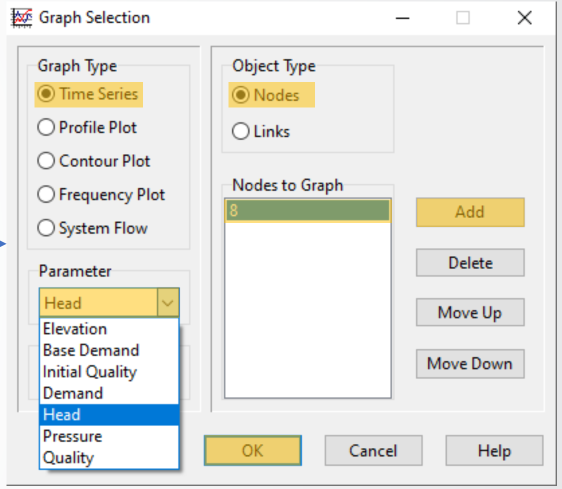
Tank Initial Conditions - Exercise

- Use input file: **Tutorial Hyd1.net**
- Change Times Options
- Run Analysis
- Re-graph tank's Head
- Determine minimum head [Value] at cyclic equilibrium
- Set Tank's Initial Level
  - Use "Value – Elevation (830') = Initial Level"
- Run Analysis
- Save As: **Tutorial Hyd2.net**

Times Options

Property	Hrs:Min
Total Duration	504
Hydraulic Time Step	1:00
Quality Time Step	0:05
Pattern Time Step	1:00
Pattern Start Time	0:00



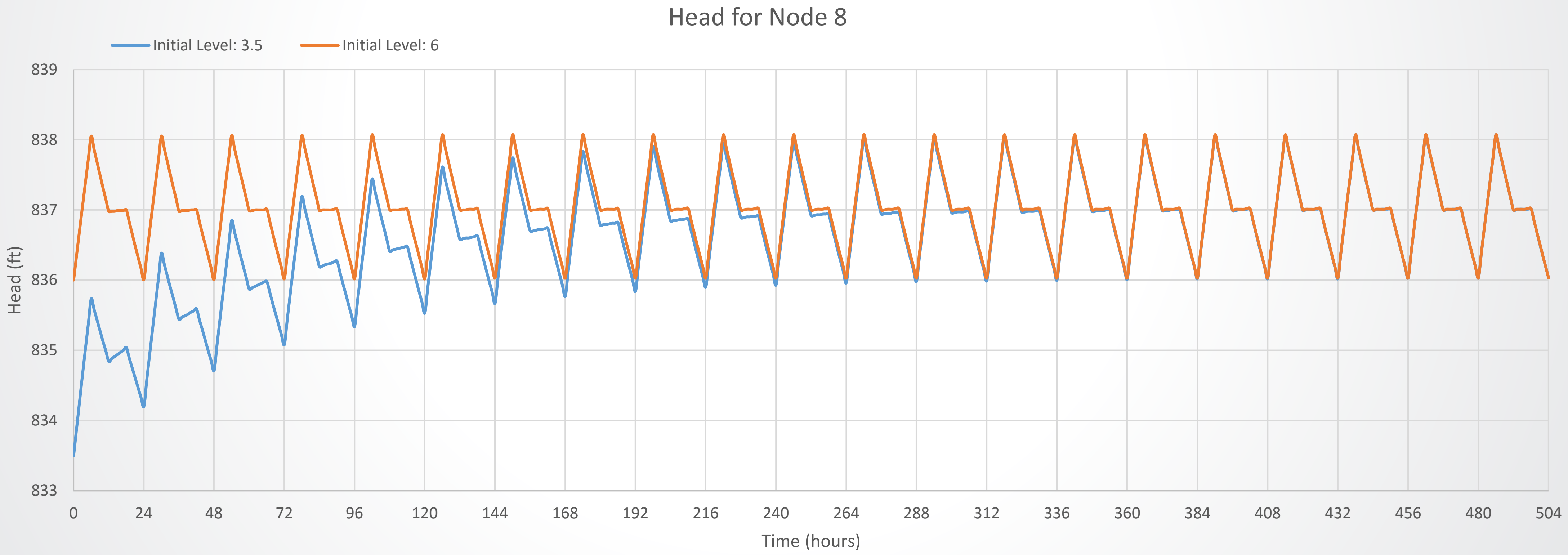


Tank 8

Property	Value
*Elevation	830
*Initial Level	6
*Minimum Level	0
*Maximum Level	20
*Diameter	60

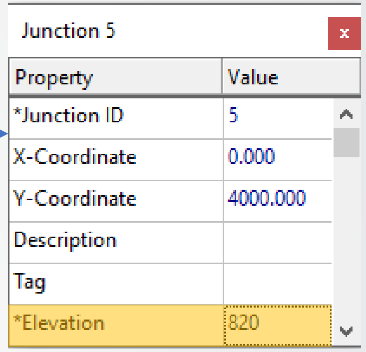
Tank Initial Conditions - Results

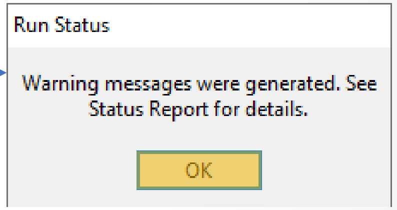
- How long did it take for tank(s) to reach cyclic equilibrium? (Before & after changing Tank 8's Initial Level)

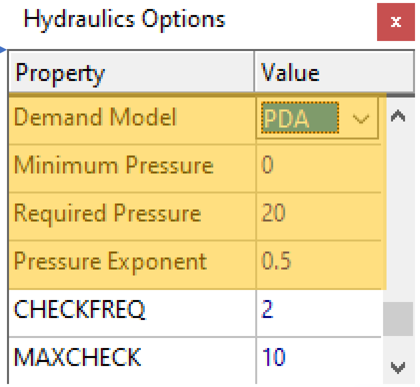


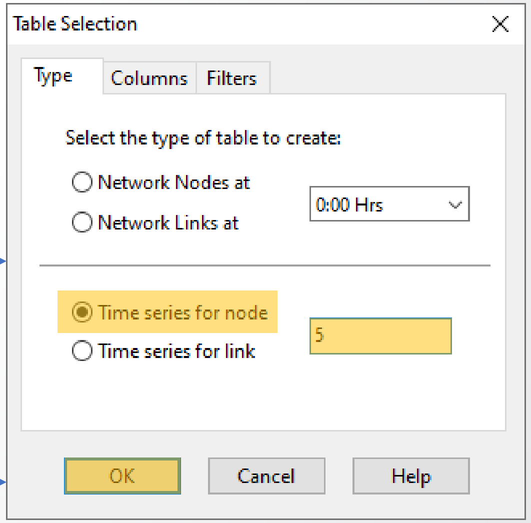
PDA - Exercise

- Use input file: **Tutorial Hyd1.net**
- Change Junction 5's Elevation
- Run Analysis
  - Negative Pressure Warnings (that's ok)
- Create Table
  - Notice negative pressures & requested demands
- Change Hydraulics Options
- Run Analysis
- Create Table
- Save As: **Tutorial HydPDA.net**









PDA - Results

- DDA: Demands are assigned demands (220 GPM), but pressures are negative at those times (e.g., 6:00-23:00)
- PDA: Demands are less than assigned demands, but pressures are positive

DDA

Time Series Table - Node 5

Time Hours	Demand GPM	Head ft	Pressure psi
0:00	160.00	824.47	1.94
1:00	160.00	824.78	2.07
2:00	160.00	825.08	2.20
3:00	160.00	825.38	2.33
4:00	160.00	825.68	2.46
5:00	160.00	825.97	2.59
6:00	220.00	812.67	-3.17
7:00	220.00	812.50	-3.25
8:00	220.00	812.34	-3.32
9:00	220.00	812.17	-3.39
10:00	220.00	812.01	-3.46
11:00	220.00	811.85	-3.53

PDA

Time Series Table - Node 5

Time Hours	Demand GPM	Head ft	Pressure psi
0:00	85.55	833.20	5.72
1:00	86.64	833.53	5.86
2:00	87.69	833.87	6.01
3:00	88.72	834.19	6.15
4:00	89.72	834.51	6.29
5:00	90.70	834.83	6.43
6:00	96.94	828.96	3.88
7:00	97.37	829.04	3.92
8:00	97.79	829.12	3.95
9:00	98.20	829.20	3.99
10:00	98.61	829.27	4.02
11:00	99.00	829.35	4.05

Hydraulics Knowledge Check

EPANET can use a ________-driven or _______-driven approach to solve hydraulic simulations. (Fill in the blank.)

A. Demand & Head

B. Pressure & Demand

C. Power & Pressure

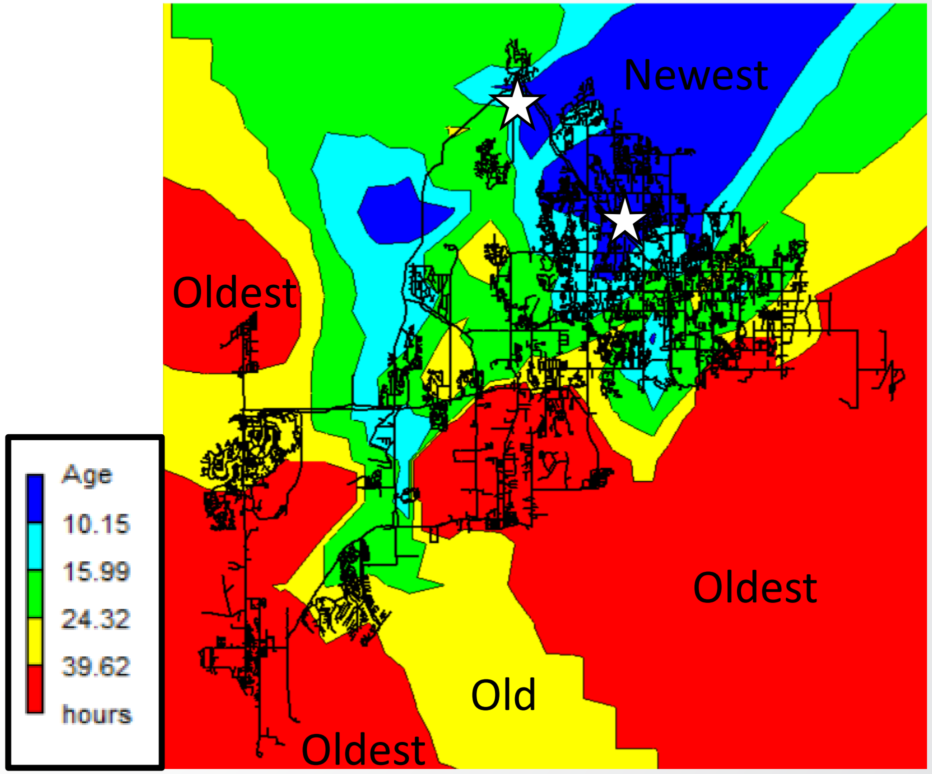
D. Head & Power

Water Age Modeling Application

Ben Burkhart

Uses of Water Age Models

- Operation
  - Indicate general water quality
  - Insight without modeling complex disinfection process
- Design
  - Evaluate impacts of new tank
  - Evaluate impacts from skeletonization



Running a Water Age Model

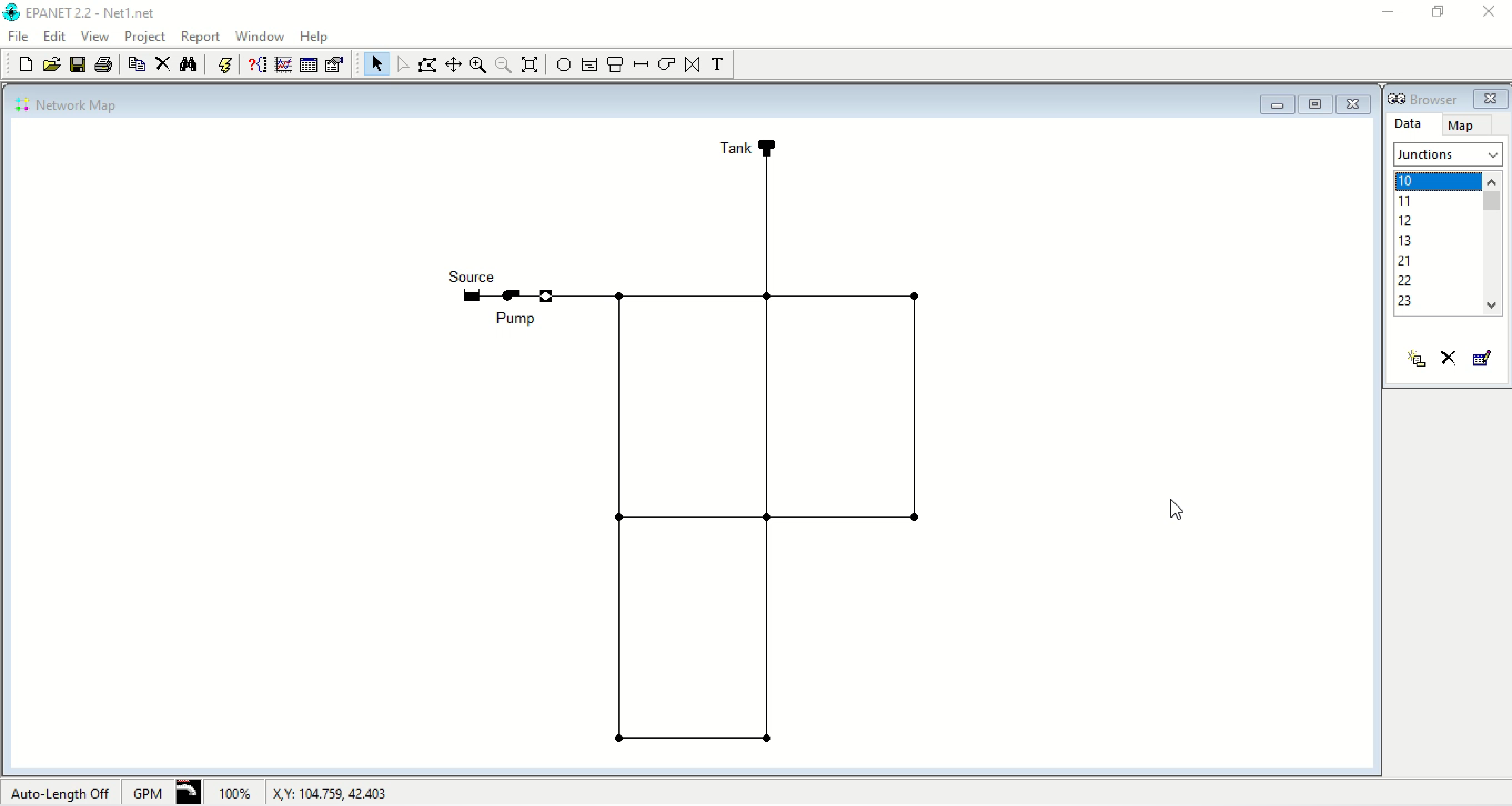
- Start with (calibrated) hydraulic model
- Set Total Duration & Quality Time Step of simulation
- Set Quality Parameter to "Age" for water age
- Choose best Mixing Model (Mixed, FIFO, LIFO, or 2Comp) for each tank
- Optional: Set initial conditions (tank Initial Levels & nodal Initial Quality)
- Run model and analyze results

Water Age – Time Options

- Browser Window >> Data Tab >> Options >> Time
  - Total Duration = 240
  - Report Time Start = 168
    - Setting Report Start Time removes results from earlier times (usually prior to reaching/approaching steady state) and ‘cleans up’ results, making them easier to analyze

Times Options

Property	Hrs:Min
Total Duration	240
Hydraulic Time Step	1:00
Quality Time Step	0:05
Pattern Time Step	2:00
Pattern Start Time	0:00
Reporting Time Step	1:00
Report Start Time	168
Clock Start Time	12 am
Statistic	None


EPANET 2.2 - Net1.net
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Browser
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Junctions
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23
Auto-Length Off
GPM
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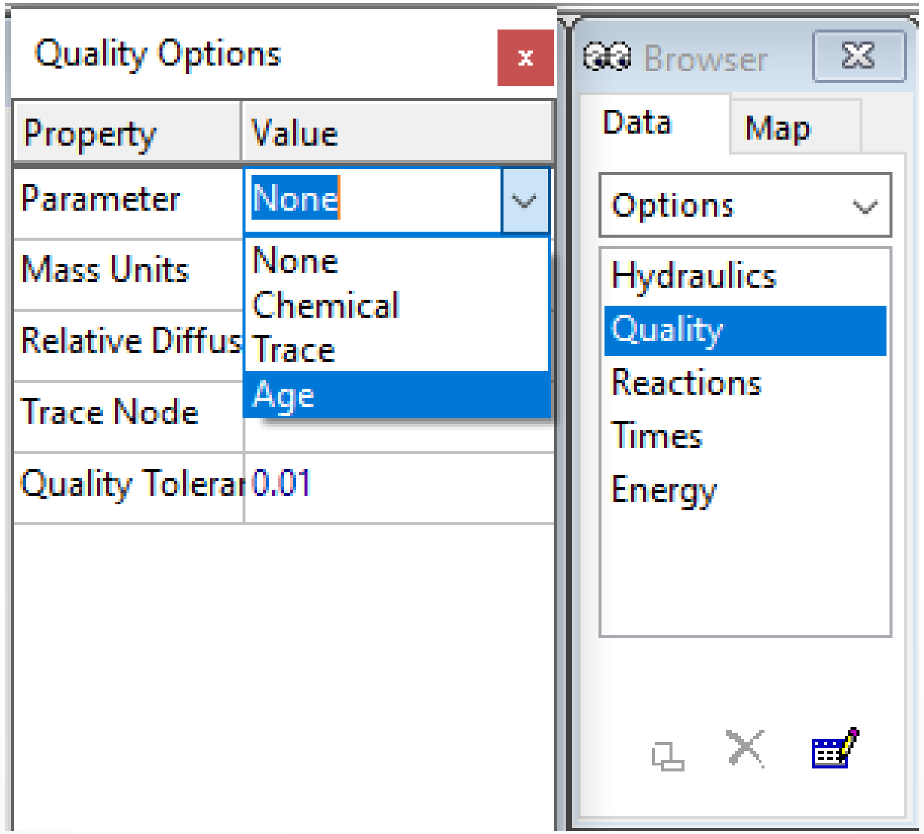
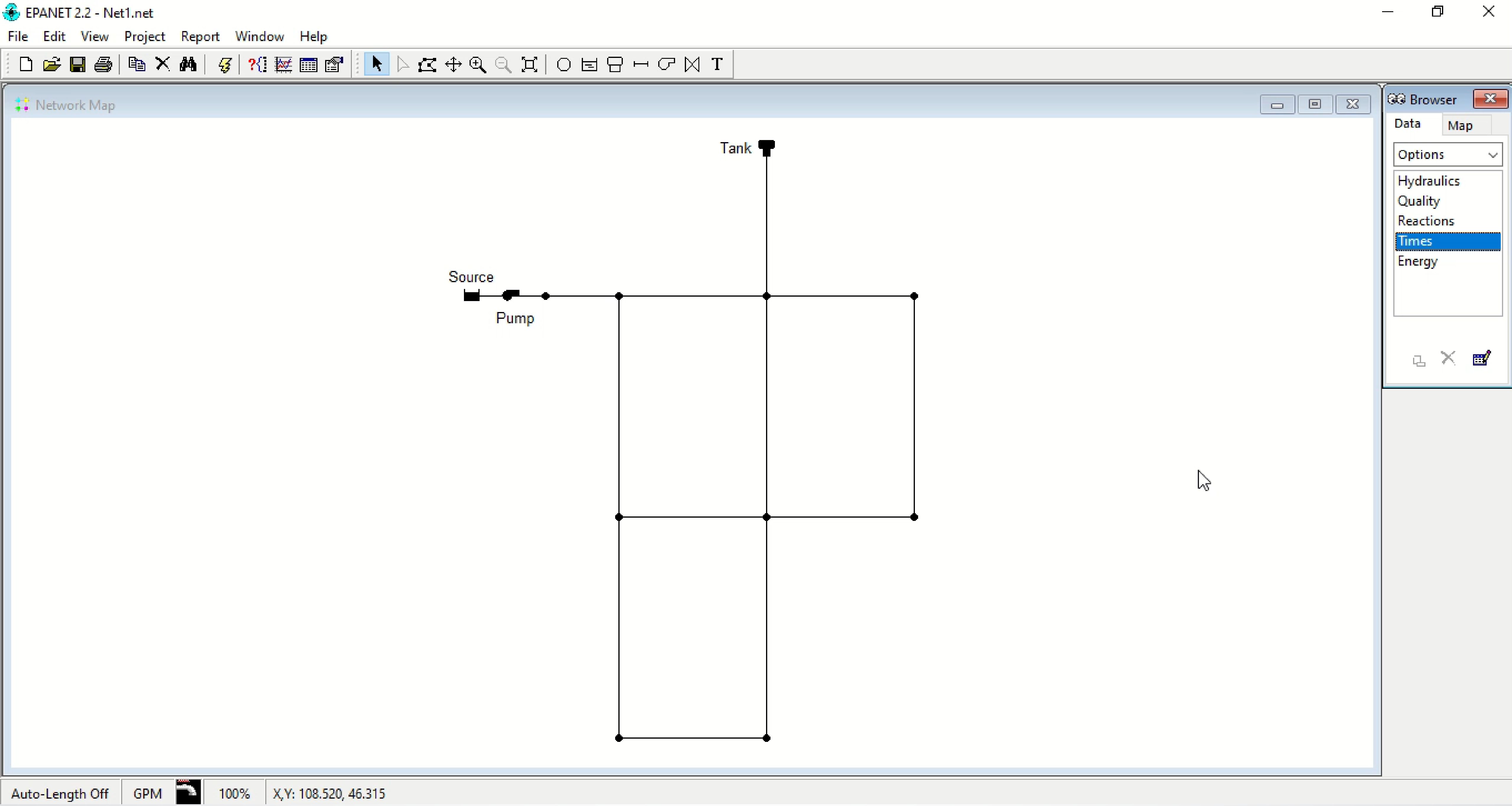
X,Y: 104.759, 42.403

Water Age – Quality Parameter

- Browser Window >> Data Tab >> Options >> Quality >> Parameter to Age

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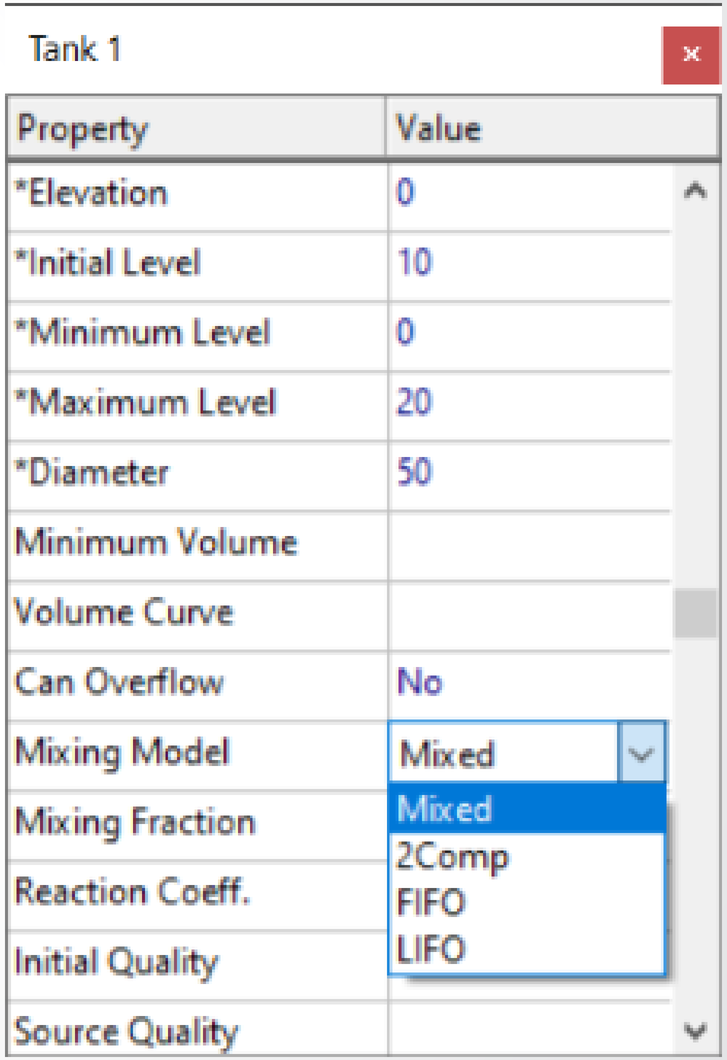
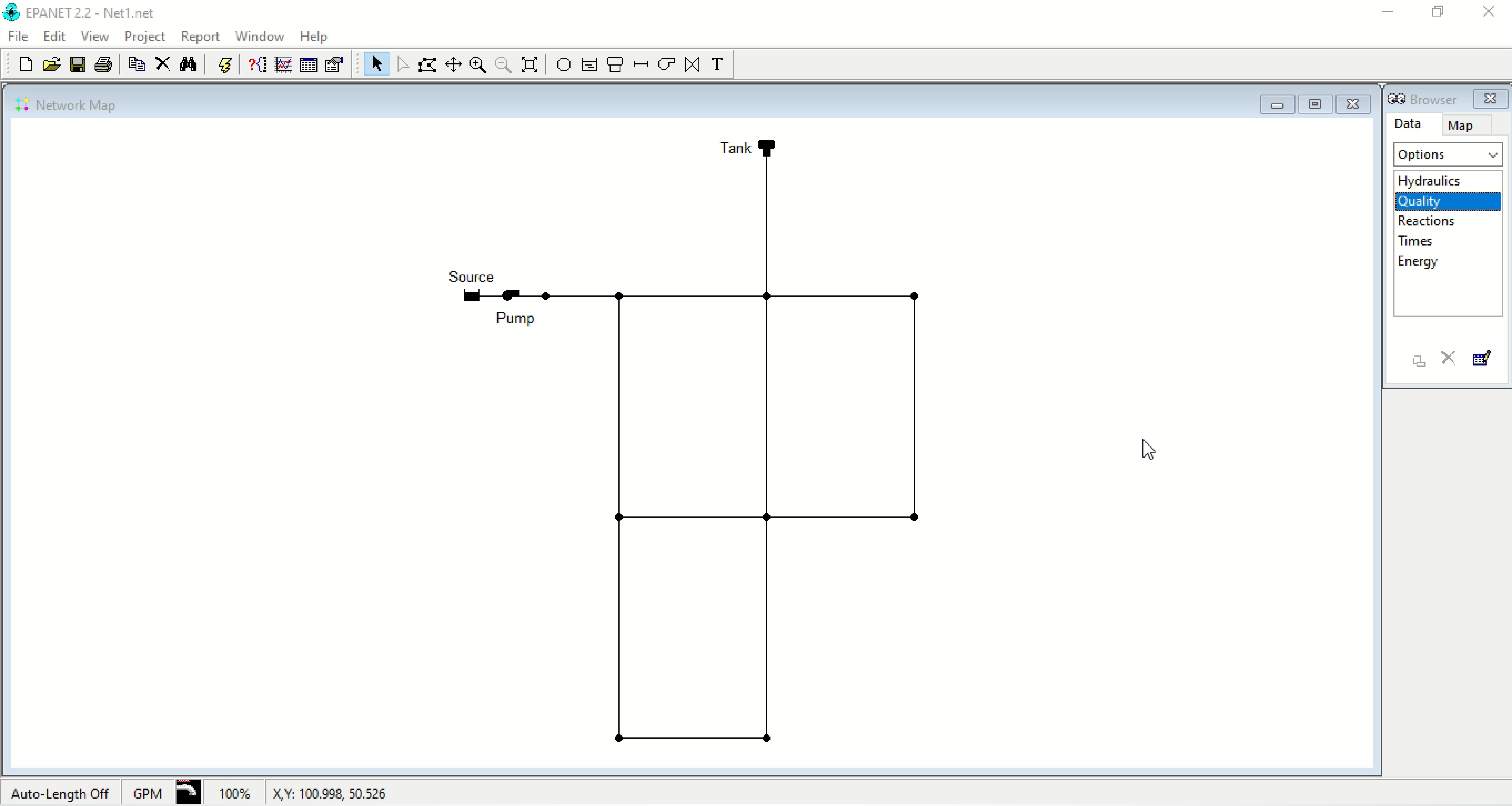
Hydraulics
Quality
Reactions
Times
Energy
Auto-Length Off
GPM
100%
X,Y: 108.520, 46.315

Water Age – Tank Mixing Models

- Open tank properties table (double click Tank)
- Set most appropriate Mixing Model from drop-down list (Mixed, FIFO, LIFO, or 2Comp)
  - Only 2-compartment method requires value for Mixing Fraction

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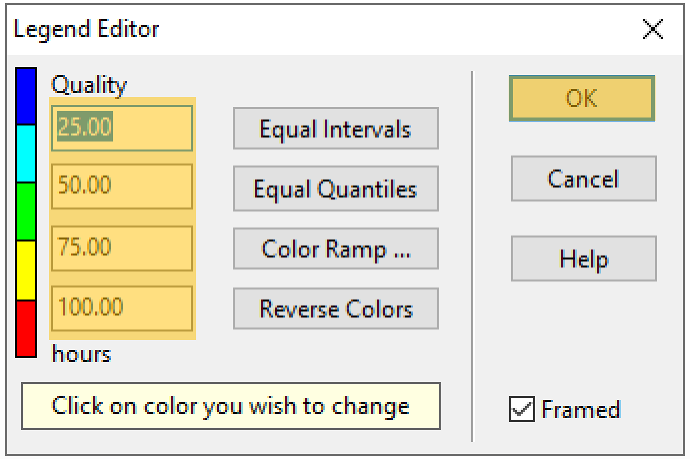
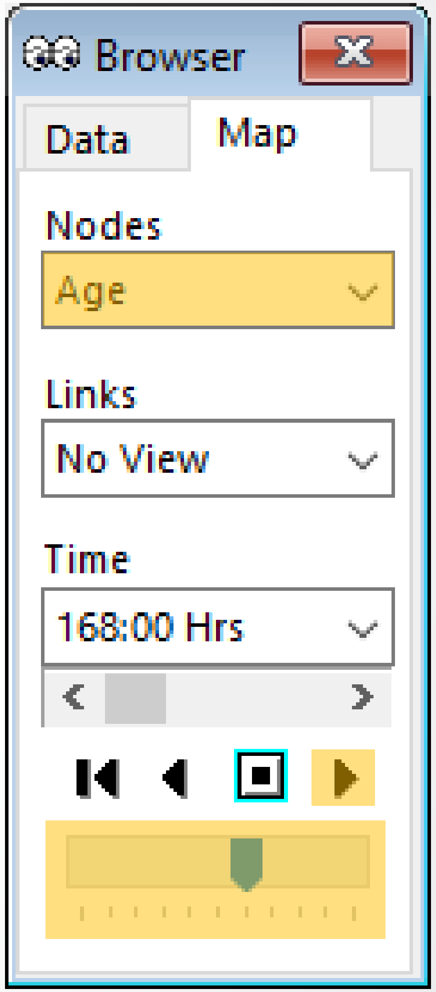
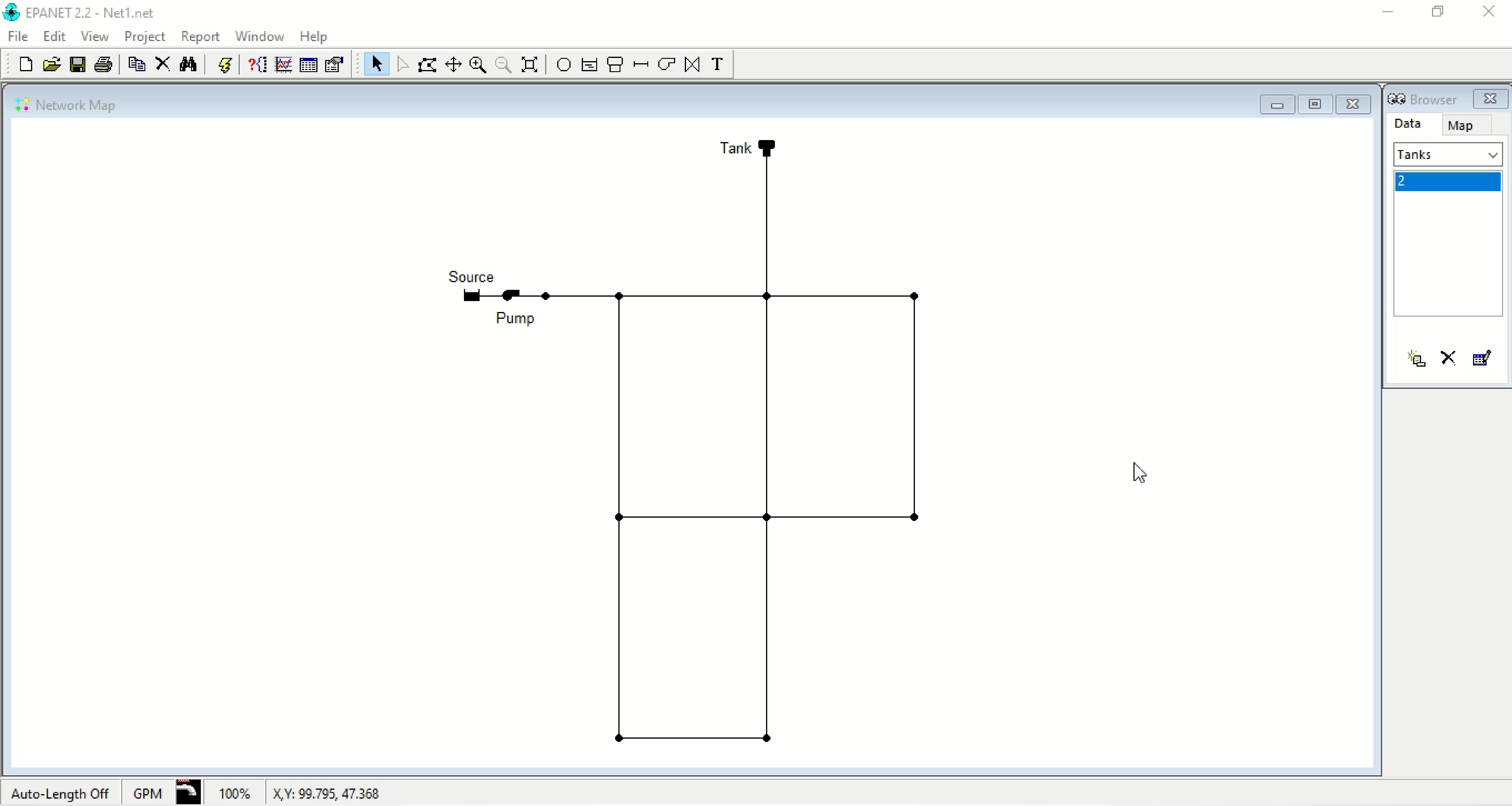
Reactions
Times
Energy
Auto-Length Off
GPM
100%
X,Y: 100.998, 50.526

Water Age – Map Animation

- Map Browser
  - Nodes: Age
  - Click Play
  - Adjust bottom bar to change animation speed






EPANET 2.2 - Net1.net
File Edit View Project Report Window Help
Network Map
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Browser
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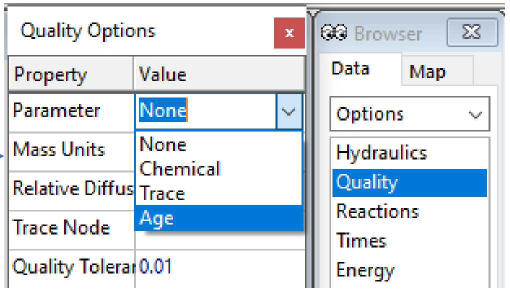
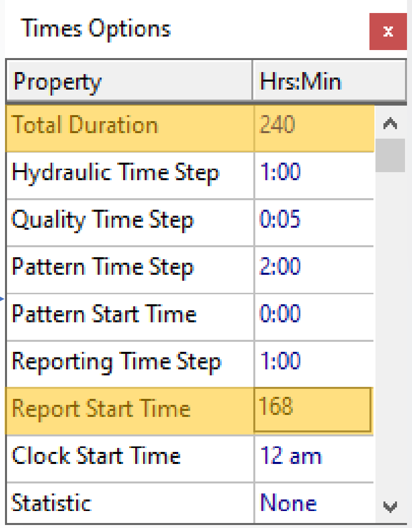
Map
Tanks
2
Auto-Length Off
GPM
100%
X,Y: 99.795, 47.368

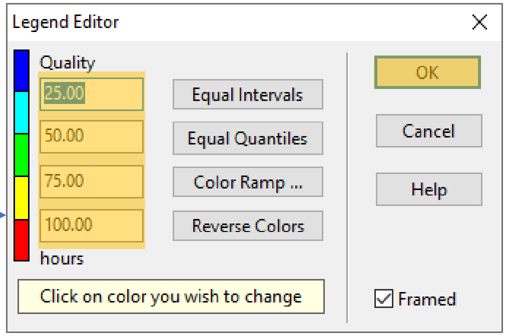
Water Age Modeling Exercise

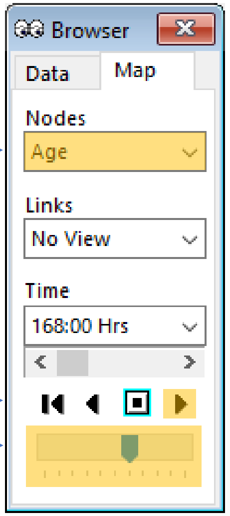
Set-Up & Mixed Water Age Exercise

- Use input file: **Net1.net**
- Change Quality Options
- Change Times Options
- Run Analysis
- Set Map Browser
- Open Legend Editor
- Play Animation
  - (Feel free to increase *Animation Speed*)
  - Note times that tank's color is red
- Save As: **Net1 Age1.net**



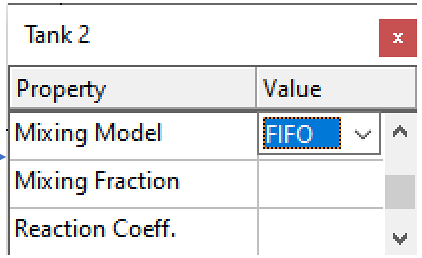




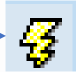


FIFO/LIFO Water Age Exercise

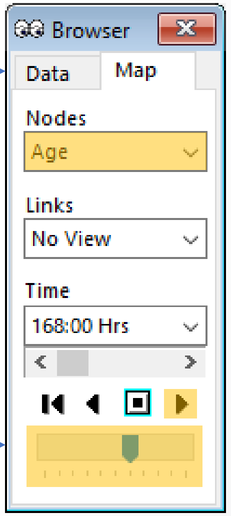
- Use input file: **Net1 Age1.net**
- Set Tank’s Mixing Model



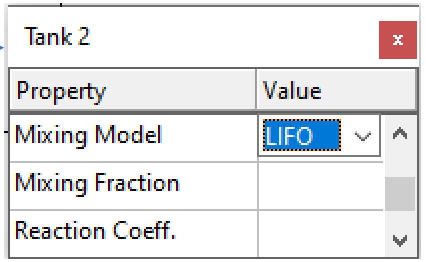
- Run Analysis



- Play Animation
  - Note tank's color is different



- Set Tank’s Mixing Model

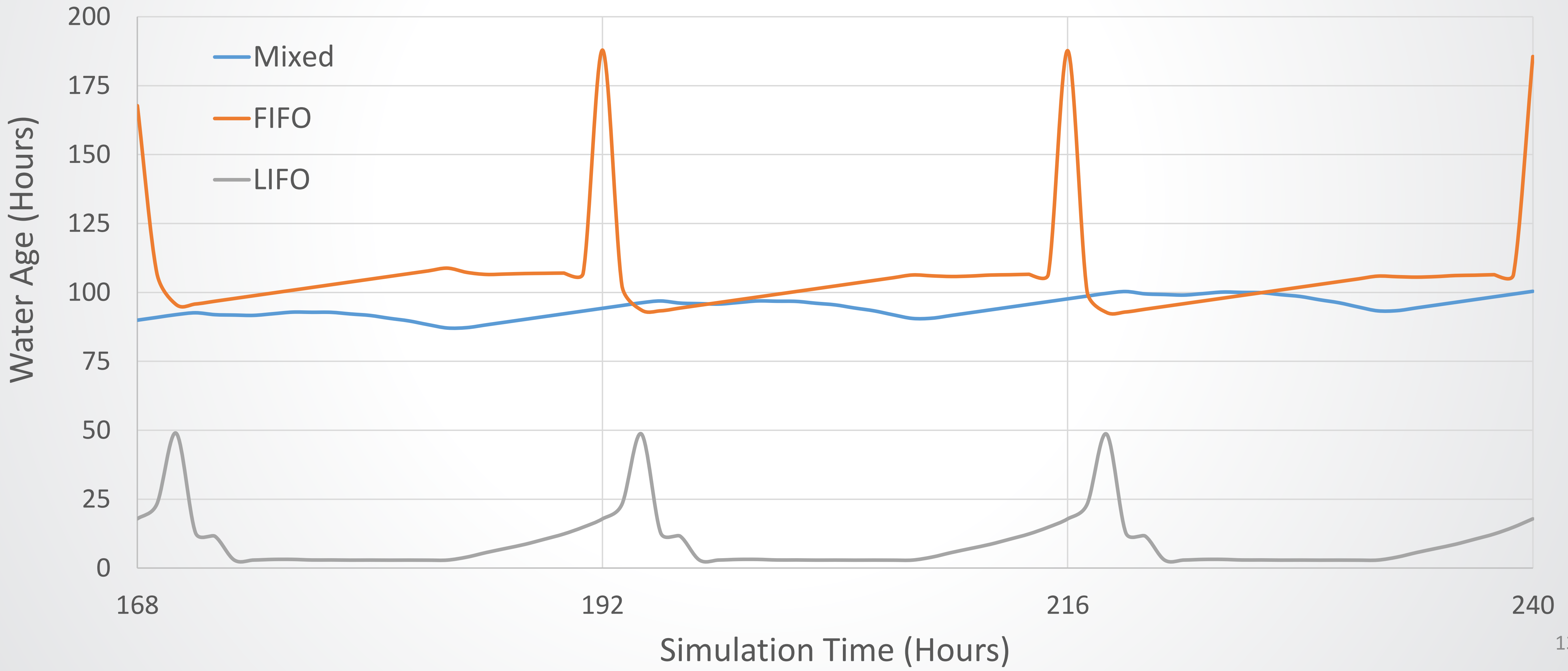


- Run Analysis

- Play Animation
  - Note tank's color is different
- Save As: **Net1 Age2.net**

Tank Mixing Model Results

Did changing the Mixing Model improve (lower) or worsen (raise) the water age in the system? Why?



Water Age Knowledge Check

Which of these does NOT affect water age?

A. Distance from the treatment plant

B. Levels of disinfectants

C. Use of tanks

D. Use of loops or branches for pipe layouts

Chlorine Modeling Application

Ben Burkhart

Uses of Chlorine Models

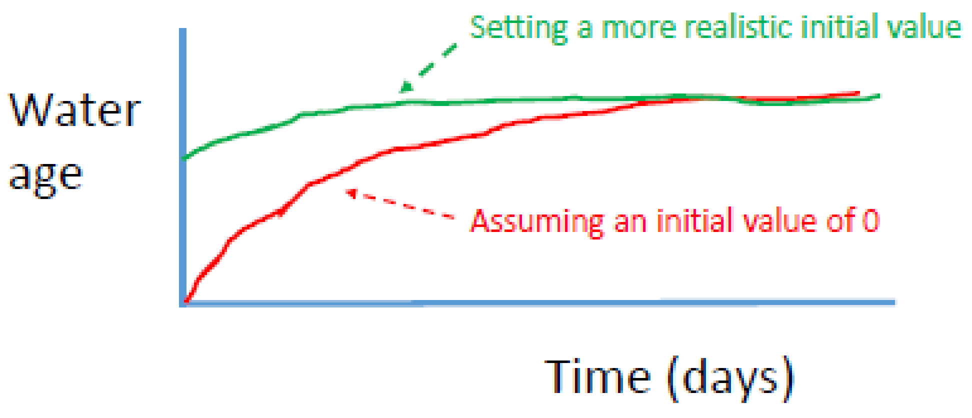
- Design
  - Evaluate impacts of new tank
  - Determine where booster stations are needed
- Operation
  - Adjust disinfectant feeds (source concentrations)
  - Select disinfectant type (free chlorine vs chloramine)
- Hindcasting
  - Recreate and investigate customer complaints
  - Evaluate and analyze litigation cases

Factors that Affect Chlorine in WDS

- Source water quality
- Operation of system
- Transport in distribution system
- Transformations
- Storage

Setting Initial Conditions

- Junctions & Tanks can optionally have Initial Quality set
  - Initial Quality is Chemical concentration (or water Age / Trace fraction) at t=0
- Reduces time to reach cyclical equilibrium
  - Allows for shorter Total Durations & shorter simulation run times
- Important for tanks because it might take days (or months) to reach a steady state



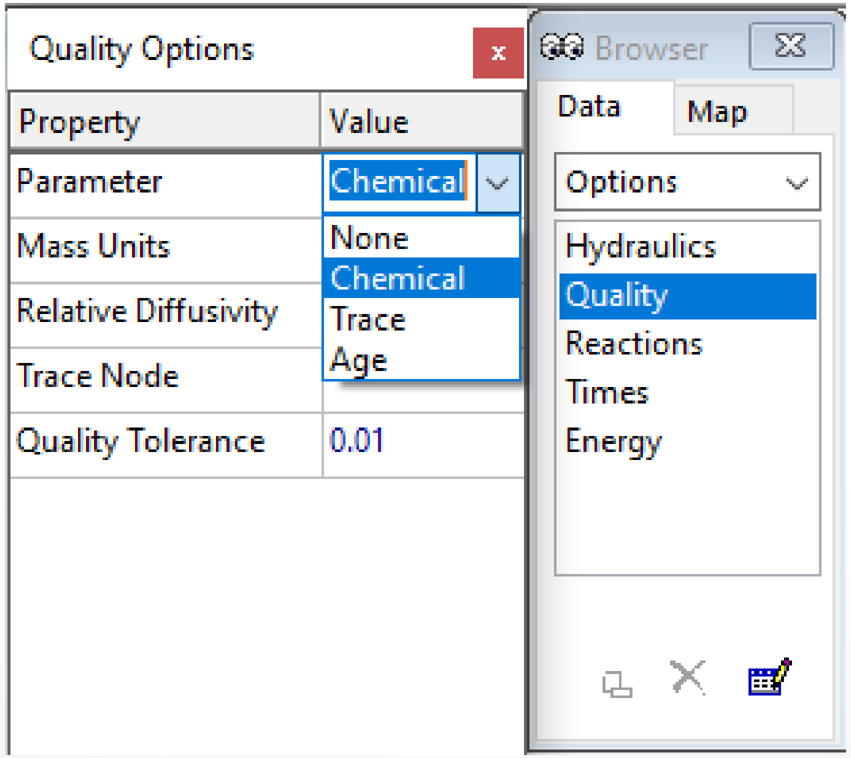
Example: setting an initial water age value in a tank

Running a Chlorine Model

- Start with (calibrated) hydraulic model
- Set Total Duration & Quality Time Step of simulation
- Set Quality Parameter to Chemical for chlorine
- Define Reaction parameters for chlorine
- Choose best mixing model (Mixed, FIFO, LIFO, or 2Comp) for each tank
- Set source concentrations (Initial Quality or Source Quality at Reservoirs)
- Optional: Set initial conditions (tank Initial Levels & nodal Initial Quality)
- Run model and look at results

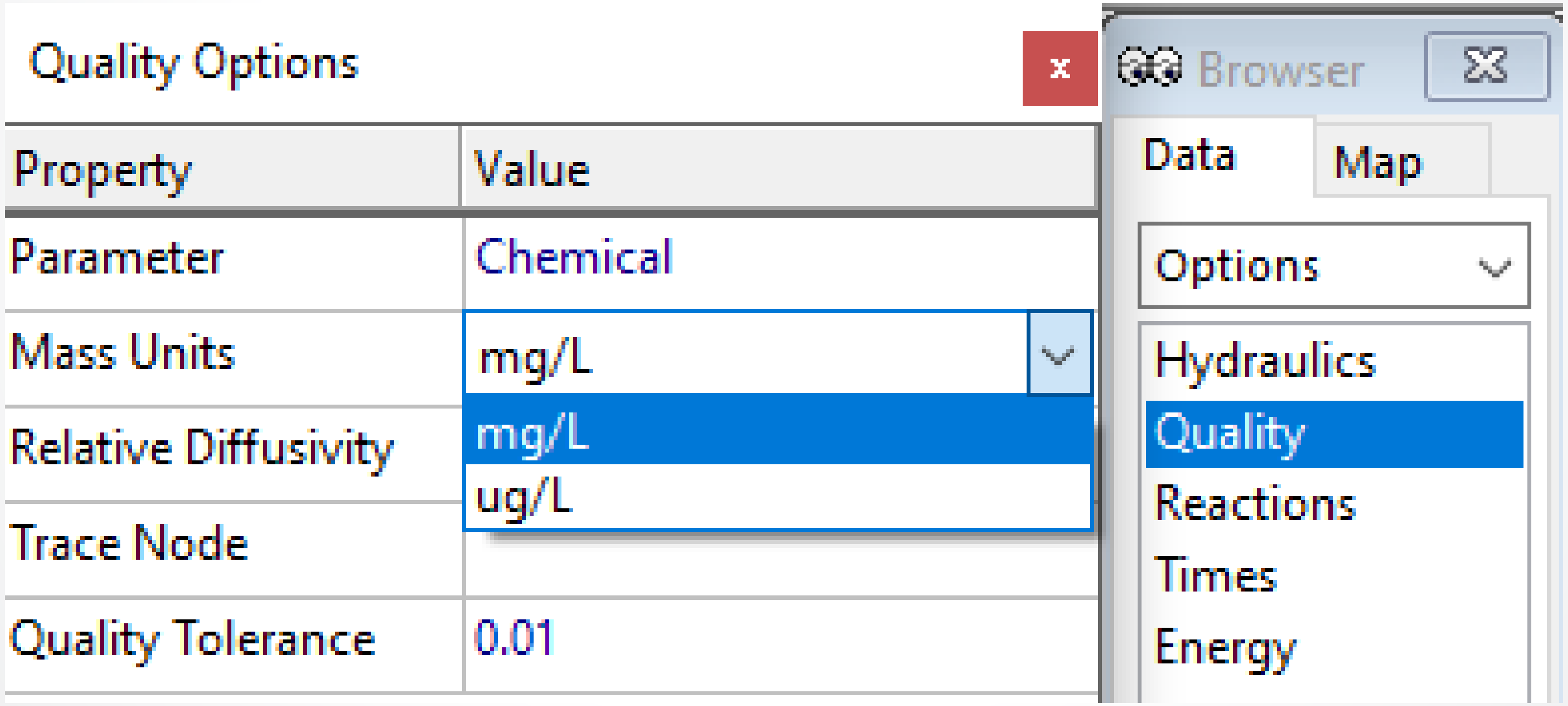
Chlorine – Quality Parameter

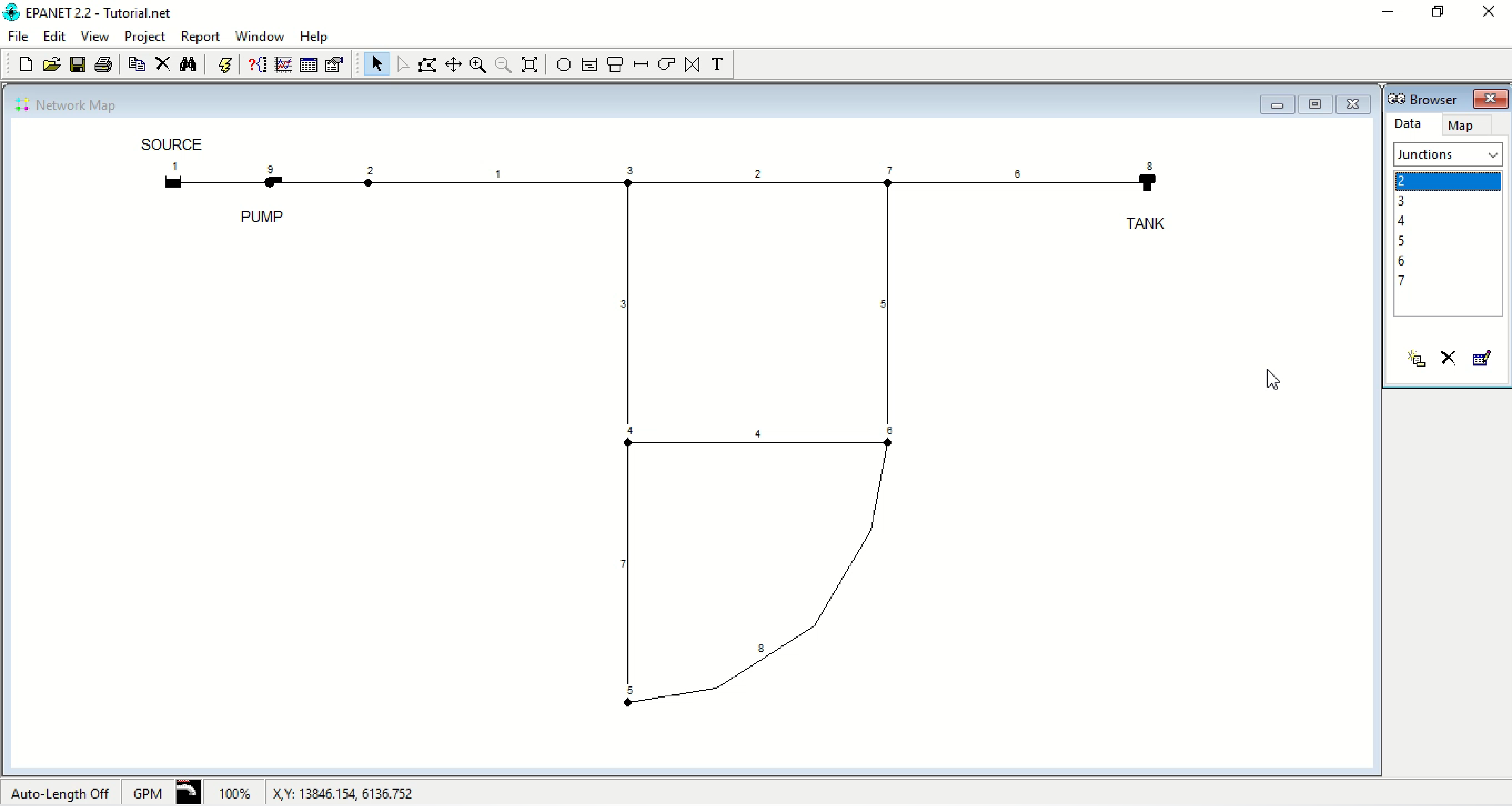
- Browser Window >> Data Tab >> Options >> Quality >> Parameter to "Chemical"
  - Can also type custom entry in Parameter (e.g., "Chlorine") & it will be same as Chemical but more identifiable



Chlorine – Mass Units

- Browser Window >> Data Tab >> Options >> Quality >> Mass Units to mg/L or µg/L

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Junctions
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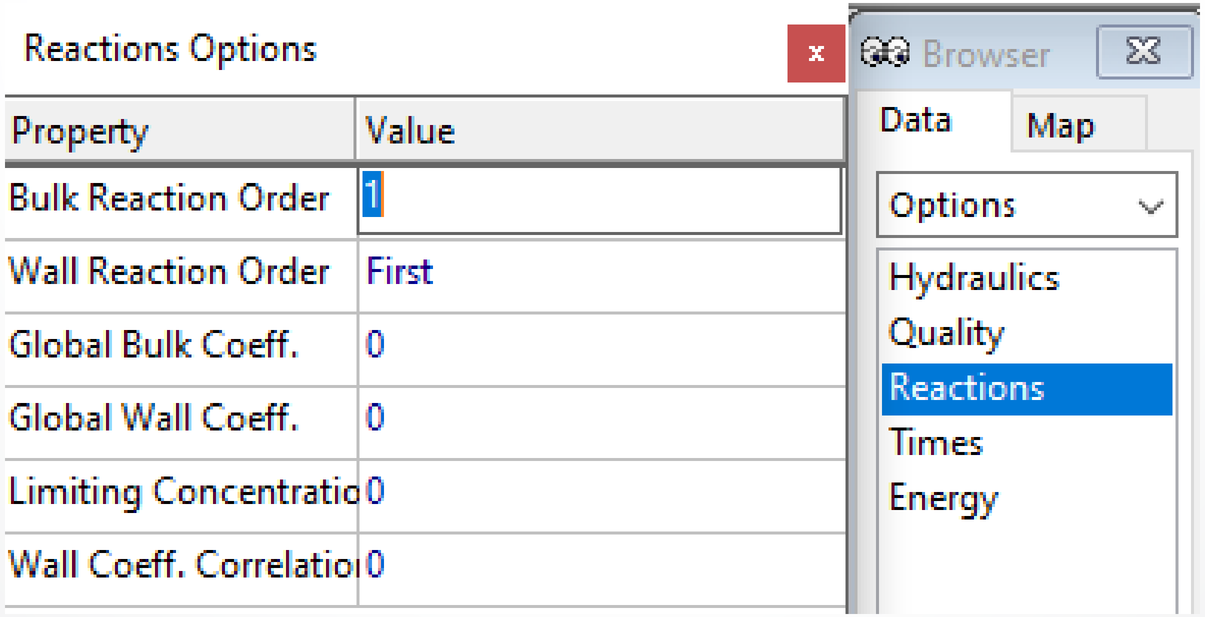
6
7
Auto-Length Off
GPM
100%
X,Y: 13846.154, 6136.752

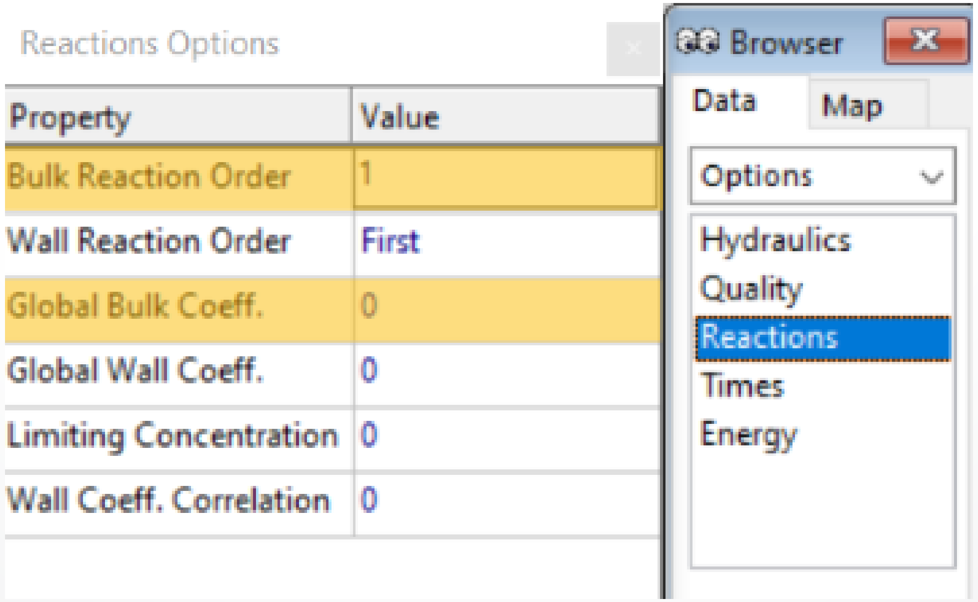
Chlorine – Reaction Order & Coefficients

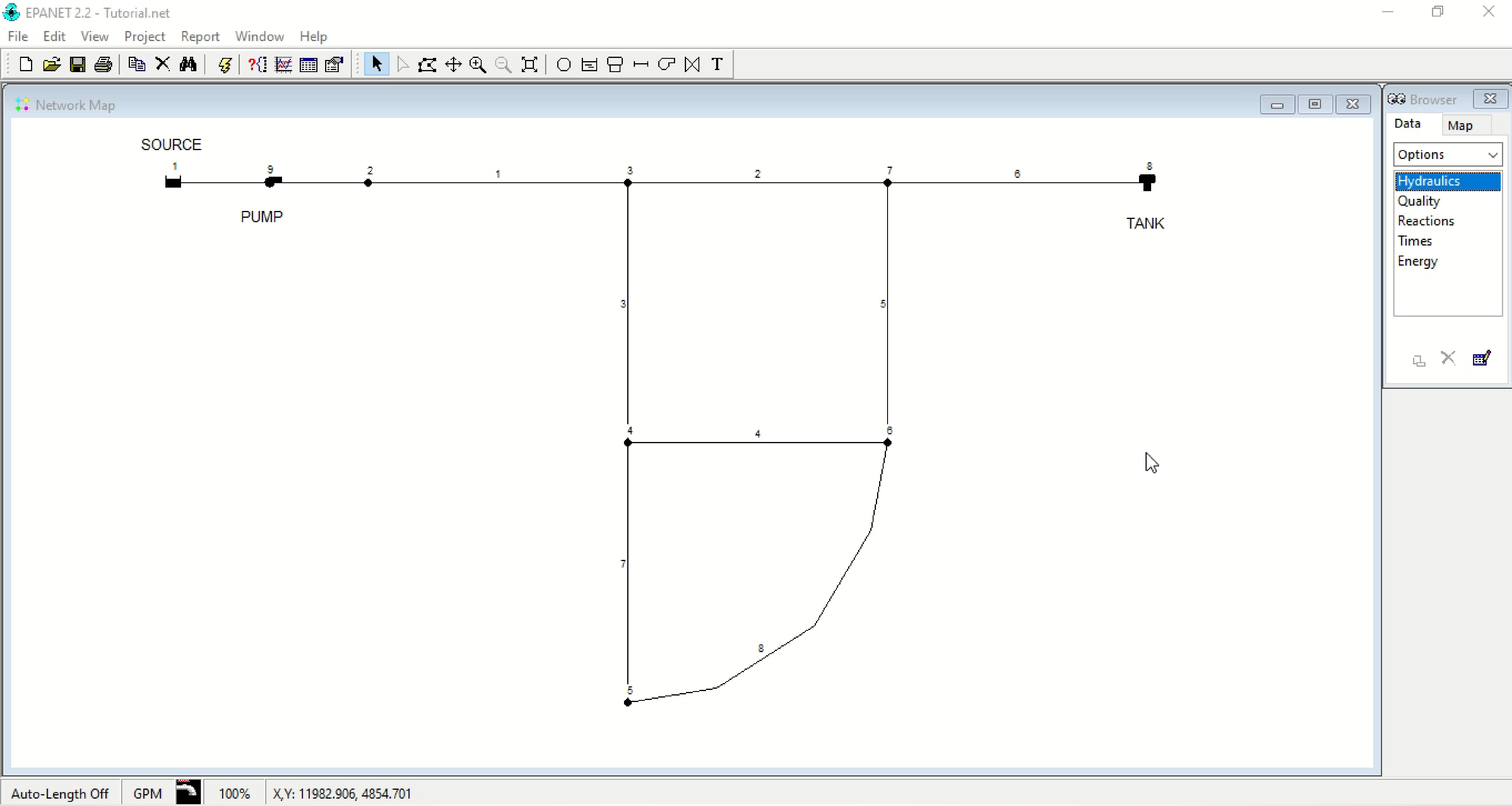
- Browser Window >> Data Tab >> Options >> Reaction
  - Set Global Bulk and Wall coefficients to 0 (usually the default values) for conservative chemicals
  - Values must be entered for several properties for non-conservative chemicals



Chlorine – Bulk Reactions

- Bulk Reaction Order & Global Bulk Coeff. must be set to define bulk reactions
  - Set Bulk Reaction Order to any number, but usually between 0 and 2
    - 1 is typically used for chlorine modeling
  - Enter a value for Global Bulk Coeff. depending on chemical and system
    - Use negative value for decay

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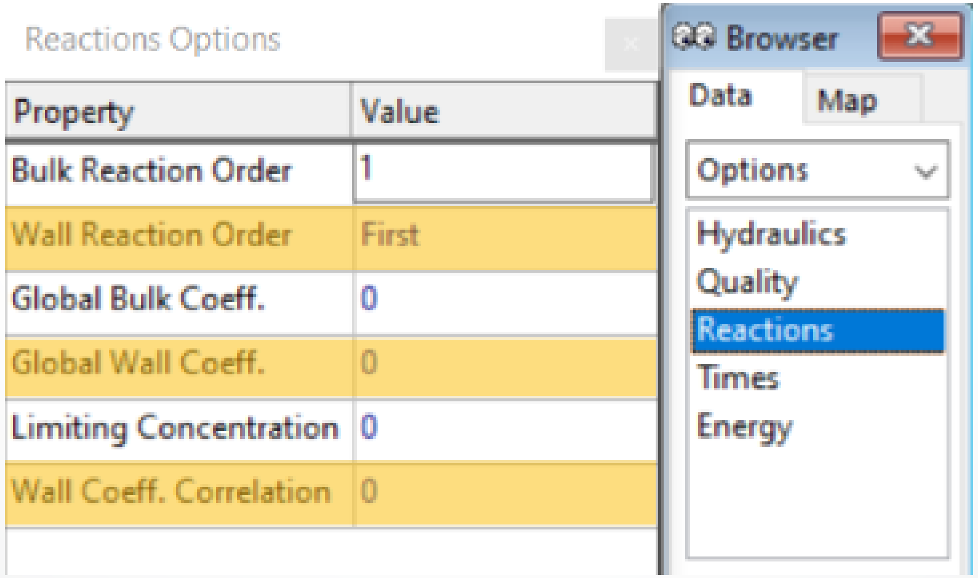
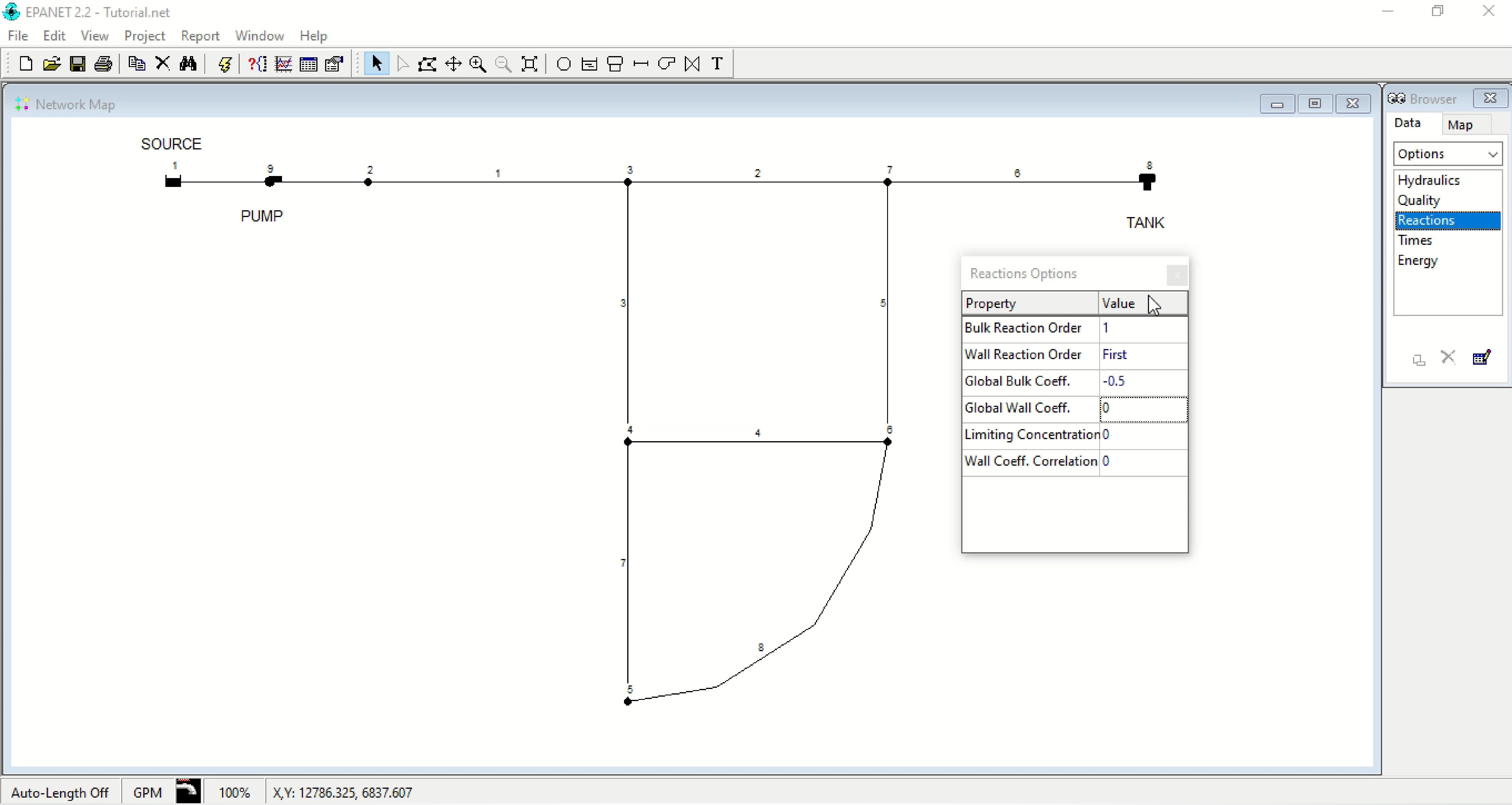
Times
Energy
Auto-Length Off
GPM
100%
X,Y: 11982.906, 4854.701

Chlorine – Wall Reactions

- Wall Reaction Order, Global Wall Coeff., & Wall Coeff. Correlation must be set to define bulk reactions
  - Wall Reaction Order can be set to Zero or First
    - Use First for chlorine
  - Enter value for Global Wall Coeff. depending on the chemical, pipes, and system
    - Use negative value for decay




EPANET 2.2 - Tutorial.net
File Edit View Project Report Window Help
Network Map
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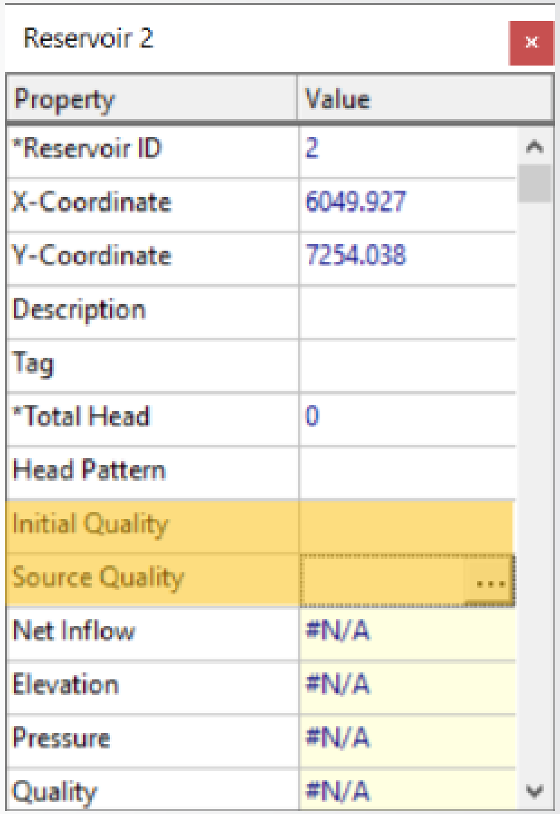
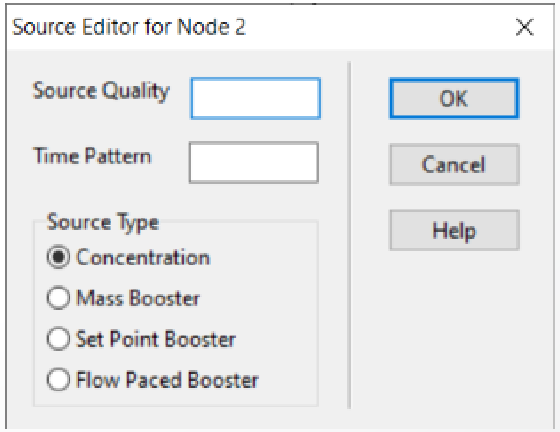
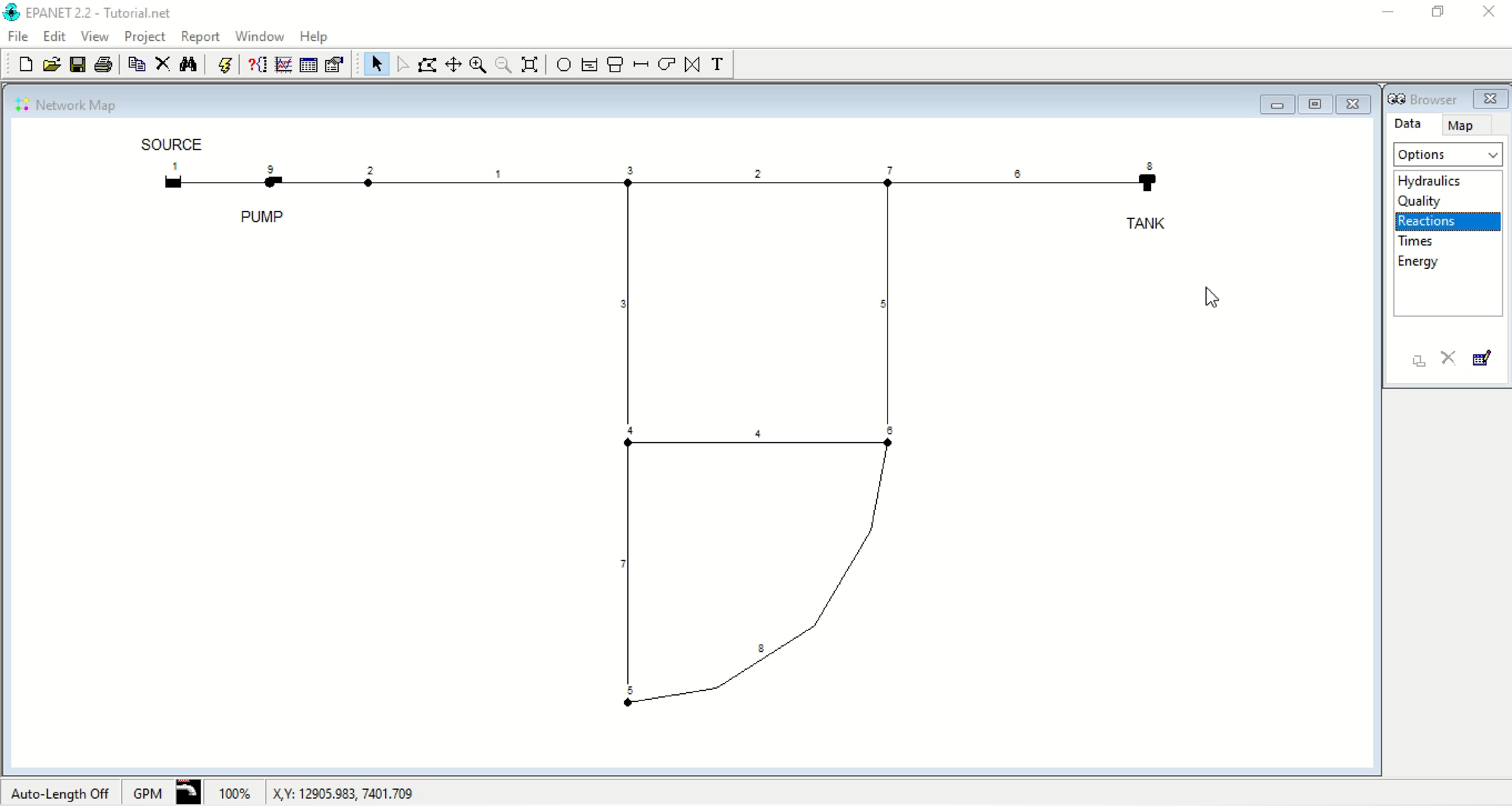
Hydraulics
Quality
Reactions
Times
Energy
Reactions Options
Property Value
Bulk Reaction Order 1
Wall Reaction Order First
Global Bulk Coeff. -0.5
Global Wall Coeff. 0
Limiting Concentration 0
Wall Coeff. Correlation 0
Auto-Length Off
GPM
100%
X,Y: 12786.325, 6837.607

Chlorine – Source Concentrations

- Initial Quality and Source Quality represents Chemical concentration at each Reservoir (treatment plant)
- Set only Initial Quality if Reservoir has a constant concentration
- Set Source Quality if Reservoir changes over time
  - Source Editor connects Source Quality & Time Pattern



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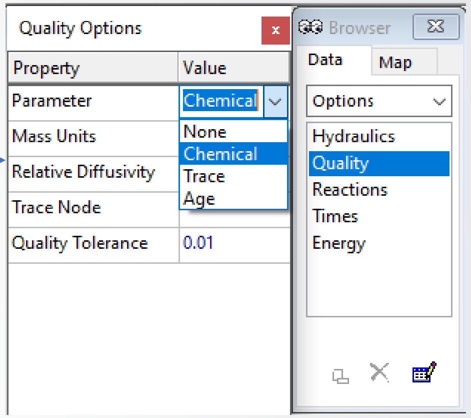
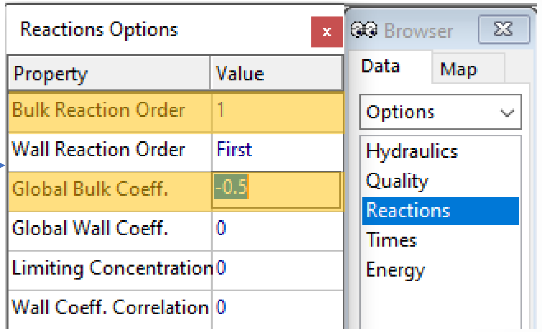
Hydraulics
Quality
Reactions
Times
Energy
Auto-Length Off
GPM
100%
X,Y: 12905.983, 7401.709

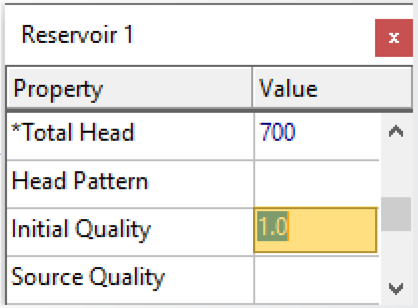
Chlorine Modeling Exercise

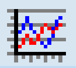
Bulk Chlorine Exercise

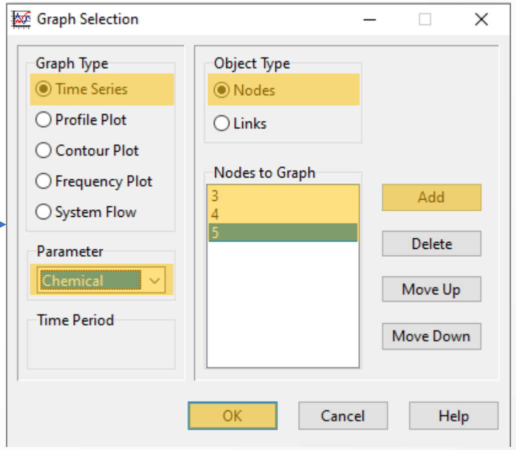
- Use input file: **Tutorial Hyd1.net**
- Set Quality Options
- Set Reactions Options
- Set Reservoir's Initial Quality
- Run Analysis
- Graph
- Save As: **Tutorial BulkOnly.net**





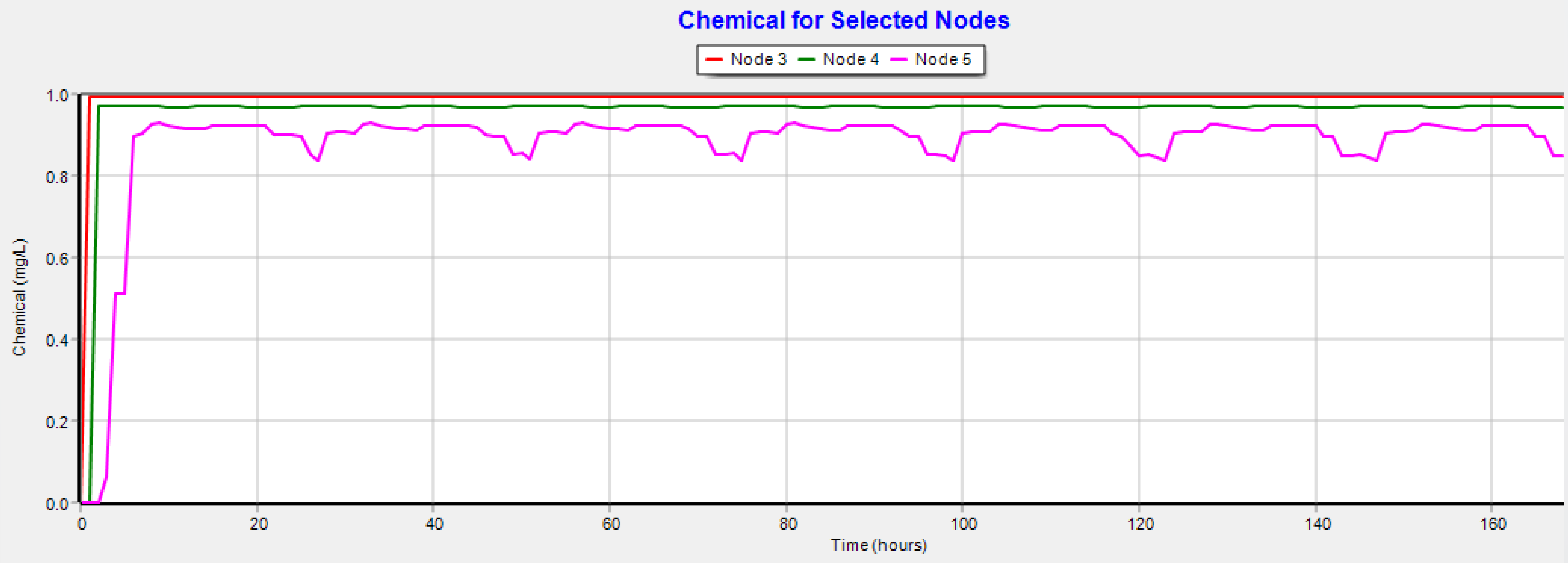






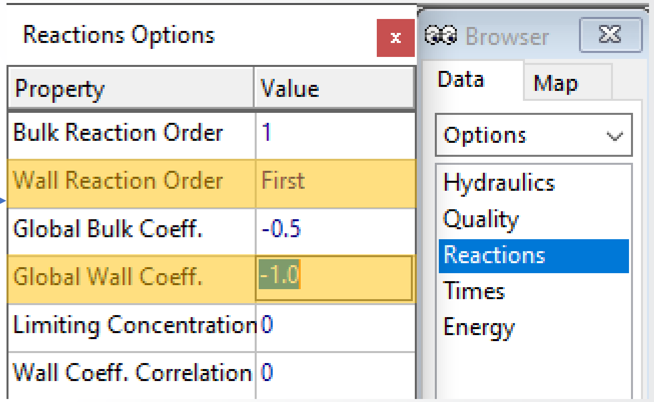
Bulk Chlorine Results

- Nodes 3, 4, & 5 are increasingly farther from the reservoir. How does that distance affect their chlorine concentrations?



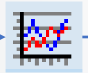
Bulk-Wall Chlorine Exercise

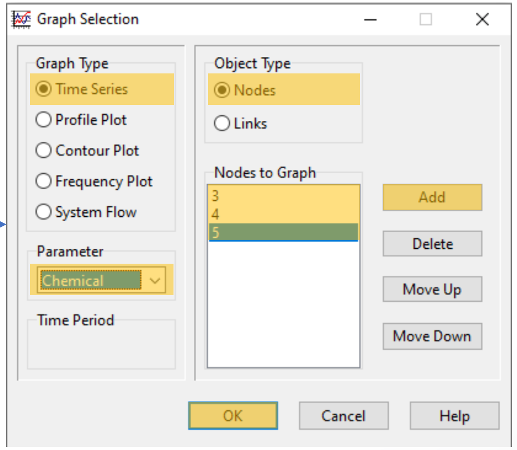
- Use input file: **Tutorial BulkOnly.net**
- Set Reactions Options



- Run Analysis

- Graph

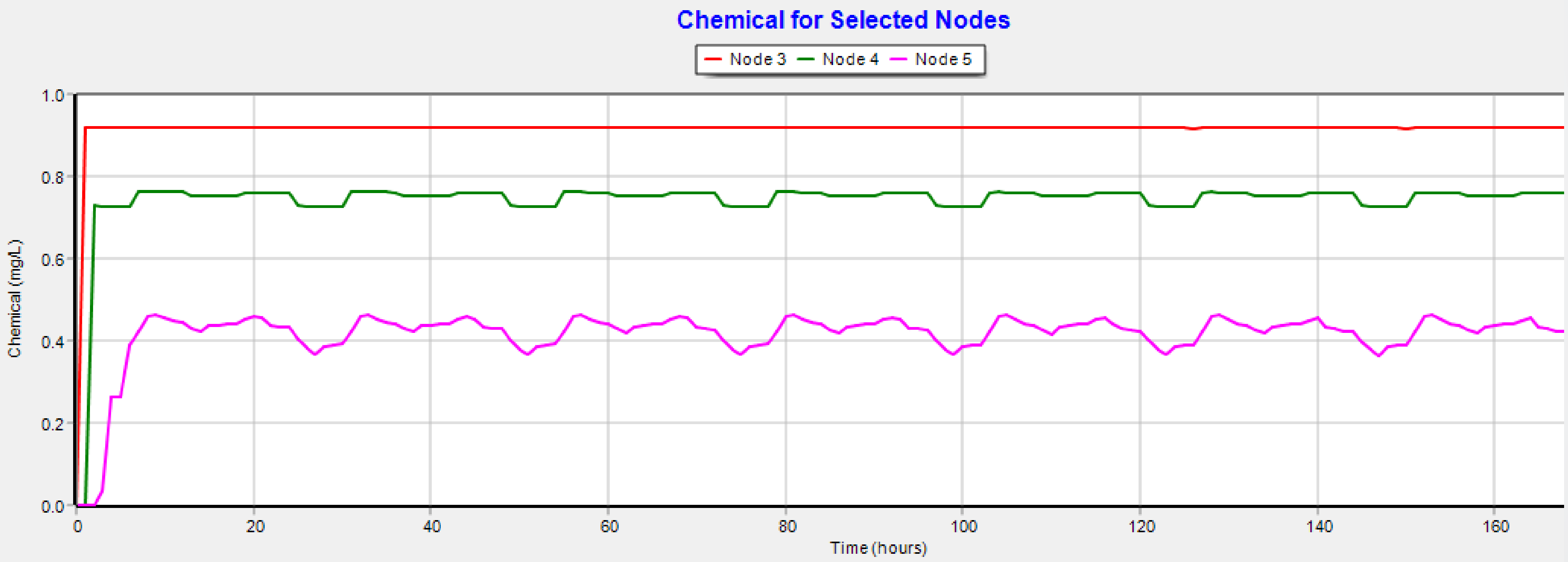




- Save As: **Tutorial Bulk-Wall.net**

Bulk-Wall Chlorine Results

- How did adding in the wall reaction change chlorine concentrations?



Chlorine Knowledge Check

Typically, within what range is the Global Bulk Coefficient for modeling chlorine decay?

A. Between -5.00 & -15 mg/L

B. Between -0.2 & -1.0

C. Between 3.5 & 0.7 days

D. Between 0.2 & 1.0

Need Help?

- U.S. EPA website (General Information)
  - (https://www.epa.gov/water-research/epanet)
  - Questions - Email us at epanet@epa.gov

- USEPA Github.com repository (General Information & User Interface)
  - https://github.com/USEPA/EPANET2.2

- 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 https://github.com/OpenWaterAnalytics/EPANET/issues

Contacts

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- **Jonathan Burkhardt -** Burkhardt.Jonathan@epa.gov
- **Robert Janke -** Janke.Robert@epa.gov

Concluding Knowledge Check

Y/N: Do you feel like you learned something about EPANET from this presentations?

- Yes
- No

Q&A Session

To Ask a Question:

Type in the "Questions" box located in right navigation bar on your screen.