Water Supply

Simulation of Water Distribution Networks
The Use of EPANET

Mohammad N. Almasri

Introduction

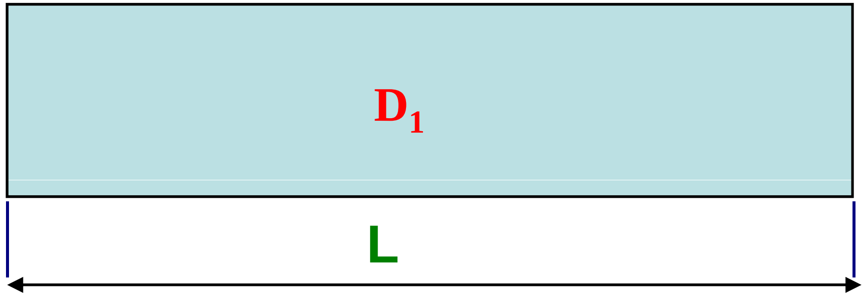
This presentation focuses on two issues:

- The simulation of water distribution networks (WDNs) using EPANET
- The optimal design of water distribution networks

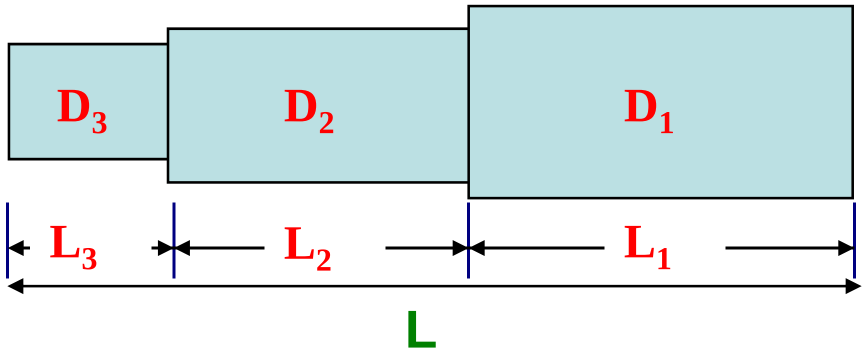
Definitions

- A WDN is comprised of a number of links connected together to form loops or branches
- These links contain pumps, fittings, valves, etc..
- Links: A link is a segment of the network that has a constant flow and no branches. Each link may contain one or more pipes (with different diameters) connected in series
- Pipes: A pipe is a segment of a link that has a constant flow, constant diameter, and no branches

Pipes and Links



A pipe



A link

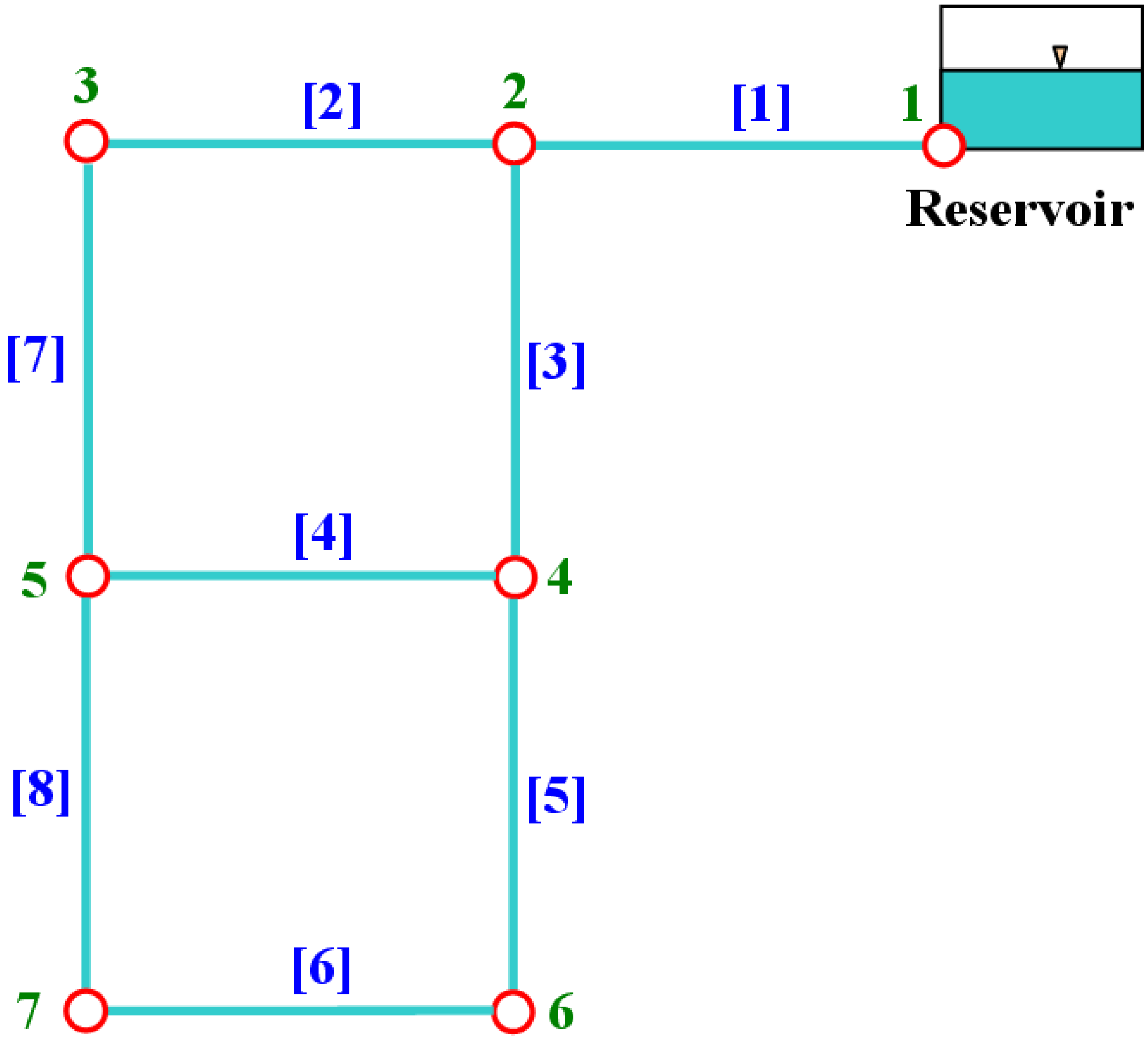
Definitions

- Nodes: They are the end points of the pipe sections where two or more links are joined. Water can enter or leave the network at these nodes

- Loops: The loop is a closed circuit consists of a series of links in which the demand nodes are supplied from more than one pipe

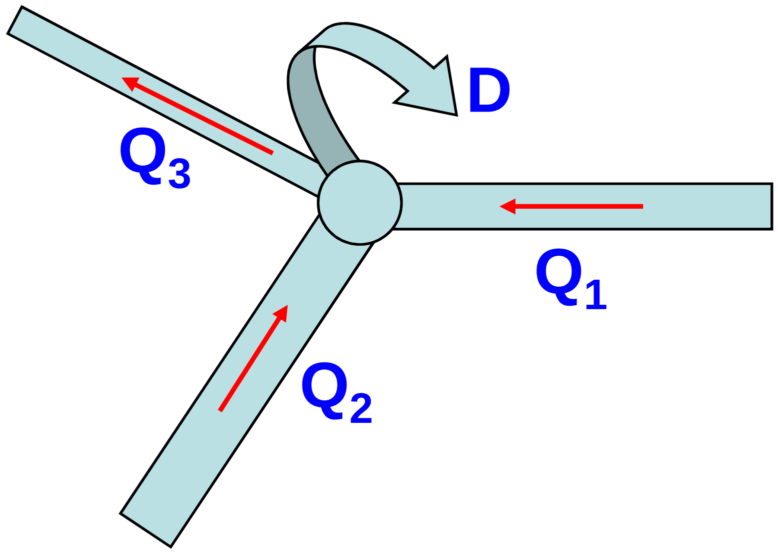
- The path: It represents the way or the route through which the demand nodes are reached from the source nodes

Example of a Water Distribution Network



Main Principles of Network Analysis

Continuity: The algebraic sum of the flow rates in the pipes meeting at a node together with any external flows is zero



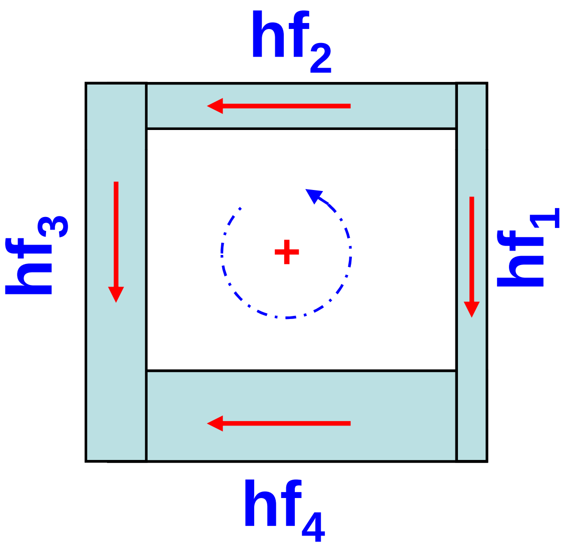
$$Q_1 + Q_2 = Q_3 + D$$

$$D = Q_1 + Q_2 - Q_3$$

A demand node
The node is connected to three supplying pipes

Main Principles of Network Analysis

Energy conservation: For all paths around closed loops and between fixed grade nodes, the accumulated energy loss including minor losses minus any energy gain or heads generated by pumps must be zero

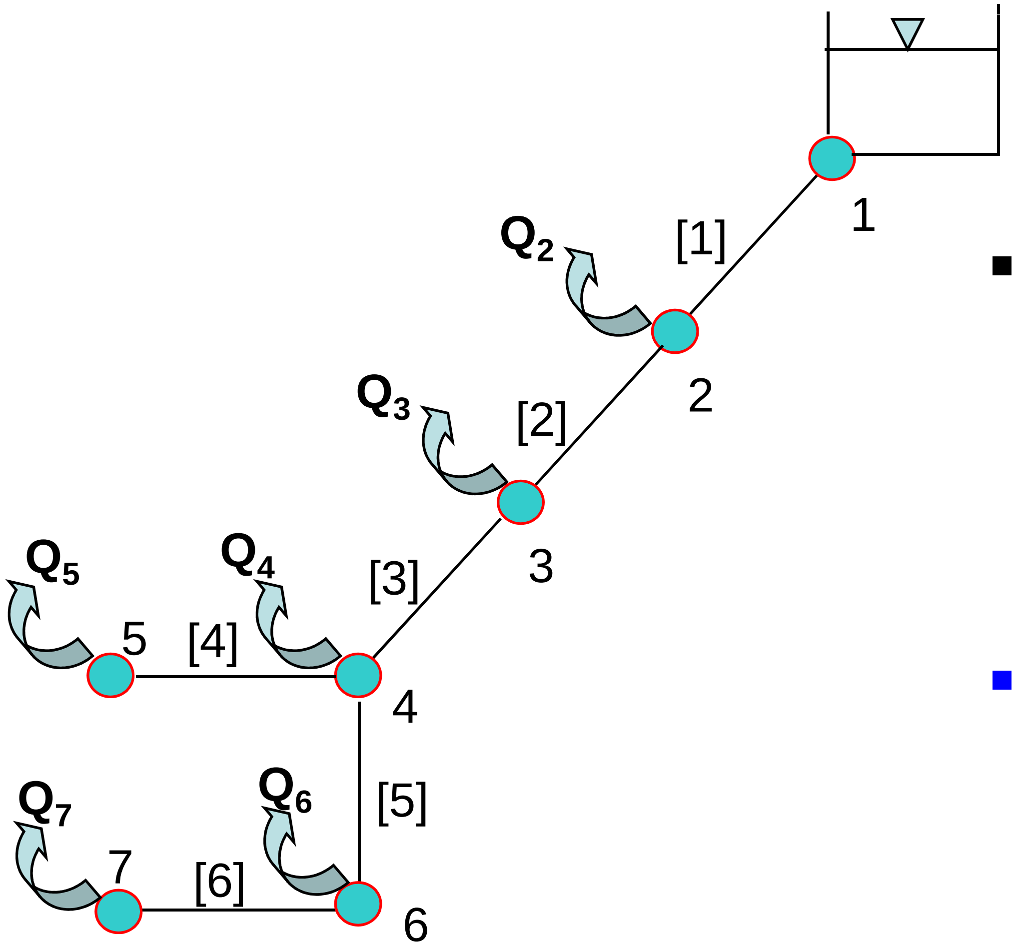


A part of a looped network
Closed loop
Given total headloss for each link (pipe) as h_f

Assume counterclockwise to be positive

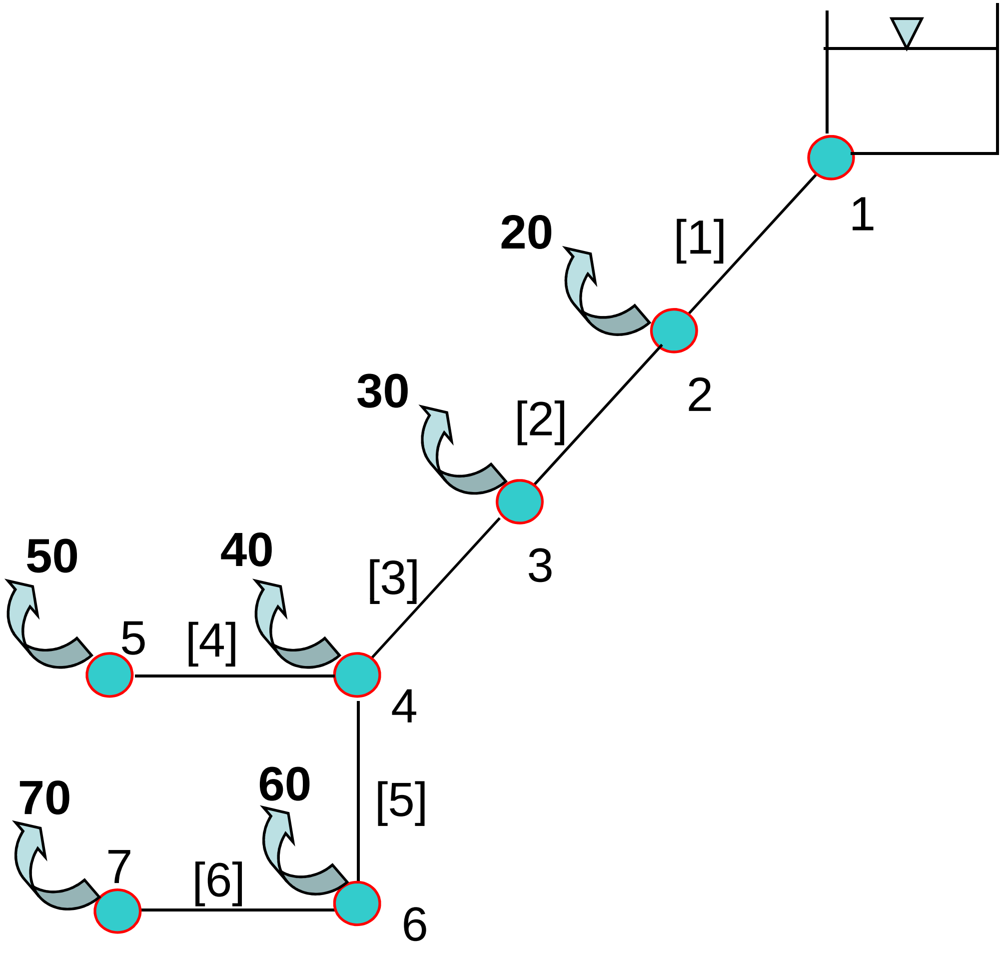
$$-hf_1 - hf_4 + hf_3 + hf_2 = 0$$

Branched WDNs



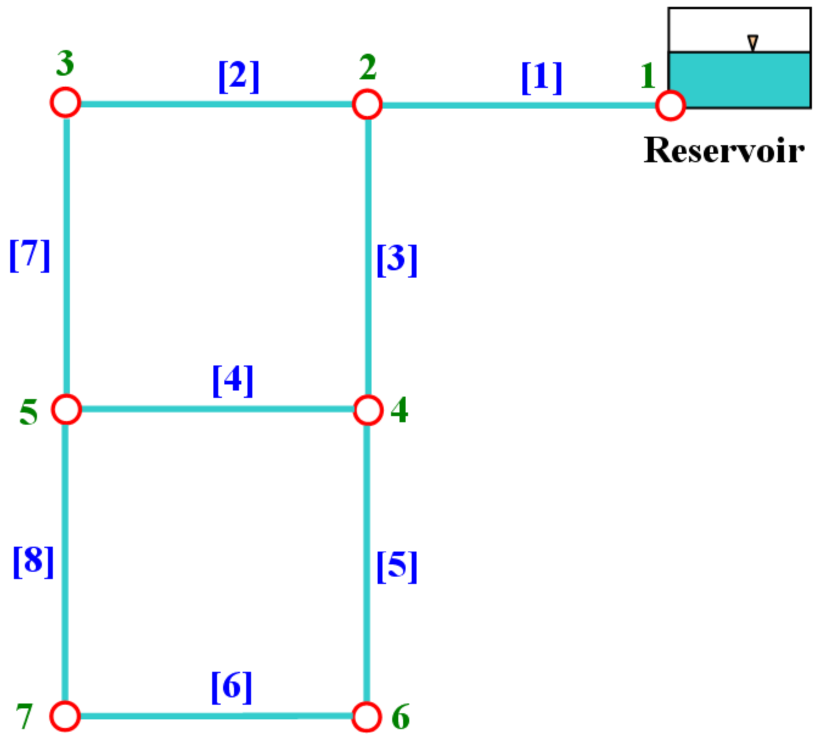
- In branched WDNs, there is only one path (route) from the source node to each node
- How can we compute the flow in each link?

Branched WDNs



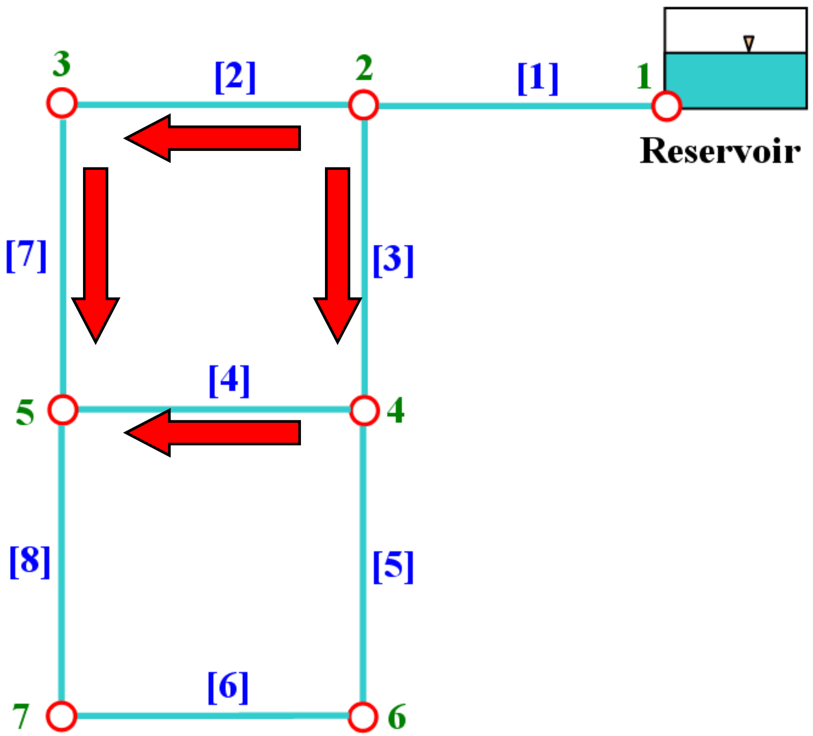
What is the flow in each link?

Looped WDNs



- More than one path to each node
- In looped network, how can we compute the flow in each link?

Main Principles of Network Analysis



Link	Head Loss (m)
1	6.753
2	13.238
3	4.504
4	18.728
5	3.737
6	4.998
7	9.994
8	9.992

Energy Loss in Pipelines – Hazen Williams Formula

$$h_f = 162.5\left(\frac{Q}{C_{HW}}\right)^{1.852} D^{-4.87} L$$

h_f: head loss (m);

L: pipe length (m)

D: pipe diameter (in)

Q: is flowrate in the pipe (m^3/h)

C_{HW}: Hazen Williams coefficient (-)

- Cast Iron:
  - New: 130
  - 5 year old: 120
  - 10 year old: 110
- Plastic: 150

What is EPANET?

- EPANET is a program for analyzing the hydraulic and water quality behavior of WDNs
- Developed by the US Environmental Protection Agency
- It is a public domain software that may be freely copied and distributed
- A complete Users Manual as well as full source code and other updates can be downloaded from: www.epa.gov/ORD/NRMRL/wswrd/epanet.html

What Does EPANET Do?

- Analyzing WDNs. This means mainly the following:
  - Determination of the flow in each link
  - Determination of pressure head at each node
- Additional outcome includes the simulation of chlorine concentration in each link and at each node

Elements

- Source reservoir
- Pumps
- Pipes
- Nodes
- Tanks
- Valves

EPANET Elements – Reservoirs

- Reservoirs are nodes that represent an external source or sink of water to the network. They are used to model lakes, rivers, and groundwater aquifers. Reservoirs can also serve as water quality source points

- The primary input properties for a reservoir are its hydraulic head and initial water quality

- Because a reservoir is a boundary point to a network, its head and water quality cannot be affected by what happens within the network. Therefore it has no computed output properties. However its head can be made to vary with time by assigning a time pattern to it

EPANET Elements – Tanks

- Tanks are nodes with storage capacity, where the volume of stored water can vary with time during a simulation

- The primary input properties for tanks are:
  - Bottom elevation
  - Diameter (or shape if non-cylindrical)
  - Initial, minimum and maximum water levels
  - Initial water quality

- The principal computed outputs are:
  - Total head (water surface elevation)
  - water quality

- Tanks are required to operate within their minimum and maximum levels

EPANET Elements – Pipes

- Pipes convey water from one point in the network to another
- EPANET assumes that all pipes are full at all times
- The principal hydraulic input parameters for pipes are: Diameter, Length, Roughness coefficient, and Initial status (open, closed, or contains a check valve)
- The water quality inputs for pipes consist of:
  - Bulk reaction coefficient
  - Wall reaction coefficient

EPANET Elements – Pipes

- Computed outputs for pipes include: Flow rate, Velocity, Headloss, Friction factor, Reaction rate, and Water quality

- The hydraulic head lost by water flowing in a pipe due to friction with the pipe walls can be computed using three different formulas: Hazen-Williams Formula, Darcy-Weisbach Formula, and Chezy-Manning Formula

- Minor losses caused by bends and fittings can also be accounted for by assigning the pipe a minor loss coefficient

EPANET Elements – Pumps

- The principal input parameter for a pump is its pump curve
- Pumps can be turned on and off at preset times
- Variable speed pumps can be considered
- EPANET can also compute the energy consumption and cost of a pump

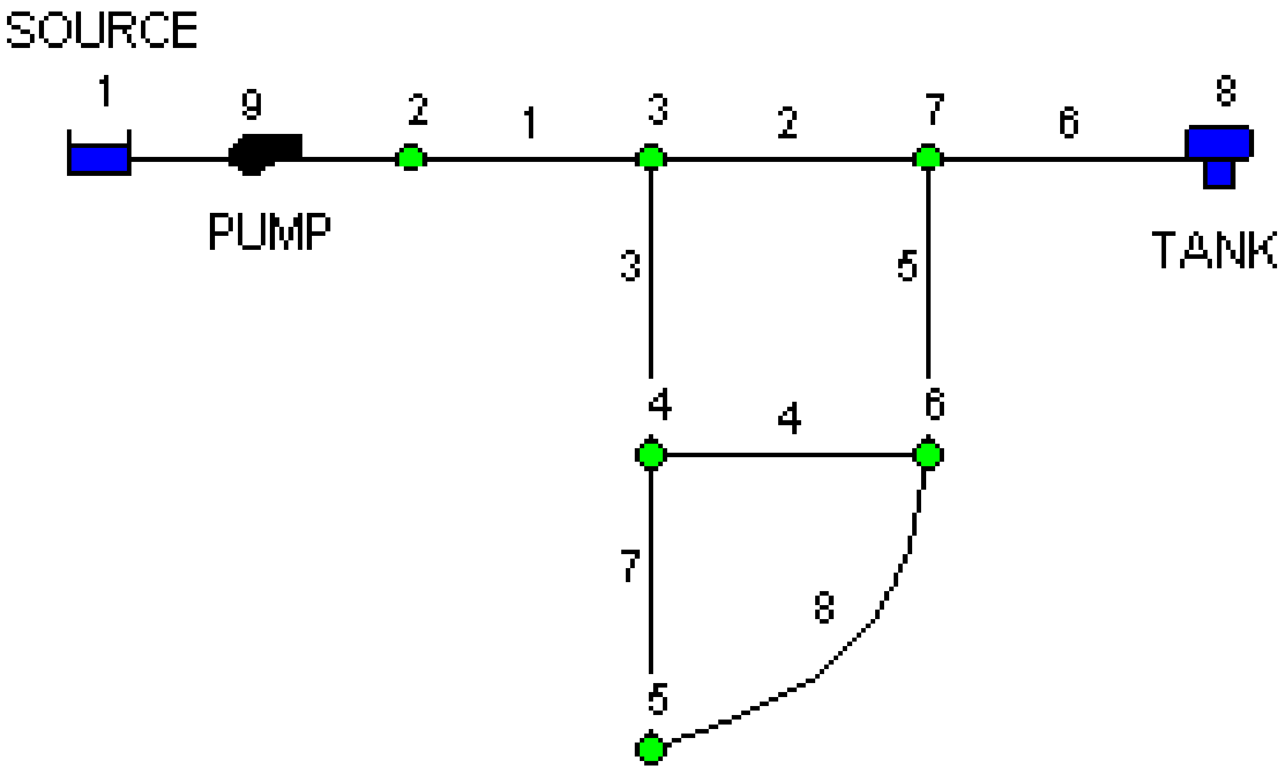
EPANET Elements – Valves

- Valves are used to control the pressure or flow at a specific point in the network

- The main different types of valves considered in EPANET include:

  - PRV (Pressure Reducing Valve): Used to limit pressure
  - PSV (Pressure Sustaining Valve): To maintain pressure at a certain value
  - PBV (Pressure Breaker Valve): Forces a specified pressure loss across the valve
  - FCV (Flow Control Valve): Used to control flow
  - GPV (General Purpose Valve): Can be used to represent a link where the flow – headloss relationship is supplied by the user

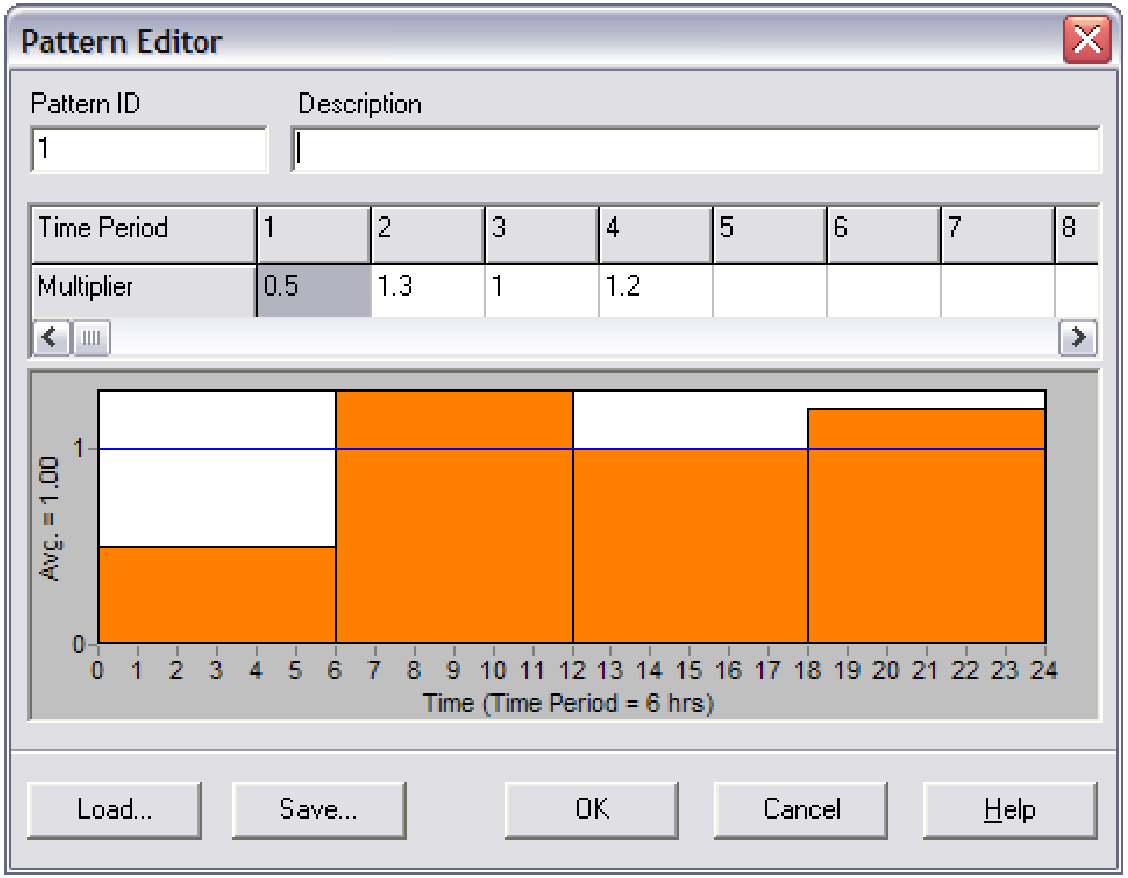
Network Layout



Time Pattern of Demands

- You can address the variability in demands through multipliers of the “Base Demand” at each node

- This is called in EPANET Time Pattern



General Results of EPANET

Nodes

Network Table - Nodes at 0:00 Hrs

Node ID	Elevation ft	Base Demand GPM	Demand GPM	Head ft	Pressure psi
Junc 2	700	0	0.00	847.05	63.72
Junc 3	710	150	75.00	844.67	58.35
Junc 4	700	150	75.00	839.69	60.53
Junc 5	650	200	100.00	836.83	80.95
Junc 6	700	150	75.00	839.47	60.43
Junc 7	700	0	0.00	841.19	61.18
Resvr 1	700	#N/A	-617.42	700.00	0.00
Tank 8	830	#N/A	292.42	834.00	1.73

General Results of EPANET
Nodes

Network Table - Nodes at 23:00 Hrs

Node ID	Elevation ft	Base Demand GPM	Demand GPM	Head ft	Pressure psi
Junc 2	700	0	0.00	837.00	59.36
Junc 3	710	150	180.00	834.19	53.81
Junc 4	700	150	180.00	817.74	51.02
Junc 5	650	200	240.00	803.80	66.64
Junc 6	700	150	180.00	817.76	51.02
Junc 7	700	0	0.00	833.25	57.74
Resvr 1	700	#N/A	-673.52	700.00	0.00
Tank 8	830	#N/A	-106.48	834.36	1.89

General Results of EPANET

Pipes

Network Table - Links at 0:00 Hrs

Link ID	Length ft	Diameter in	Roughness	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor
Pipe 1	3000	14	100	617.42	1.29	0.80	0.036
Pipe 2	5000	12	100	382.51	1.09	0.69	0.038
Pipe 3	5000	8	100	159.91	1.02	1.00	0.041
Pipe 4	5000	8	100	29.34	0.19	0.04	0.053
Pipe 5	5000	8	100	-90.09	0.57	0.34	0.045
Pipe 6	7000	10	100	292.42	1.19	1.03	0.039
Pipe 7	5000	6	100	55.58	0.63	0.57	0.046
Pipe 8	7000	6	100	-44.42	0.50	0.38	0.048
Pump 9	#N/A	#N/A	#N/A	617.42	0.00	-147.05	0.000

General Results of EPANET

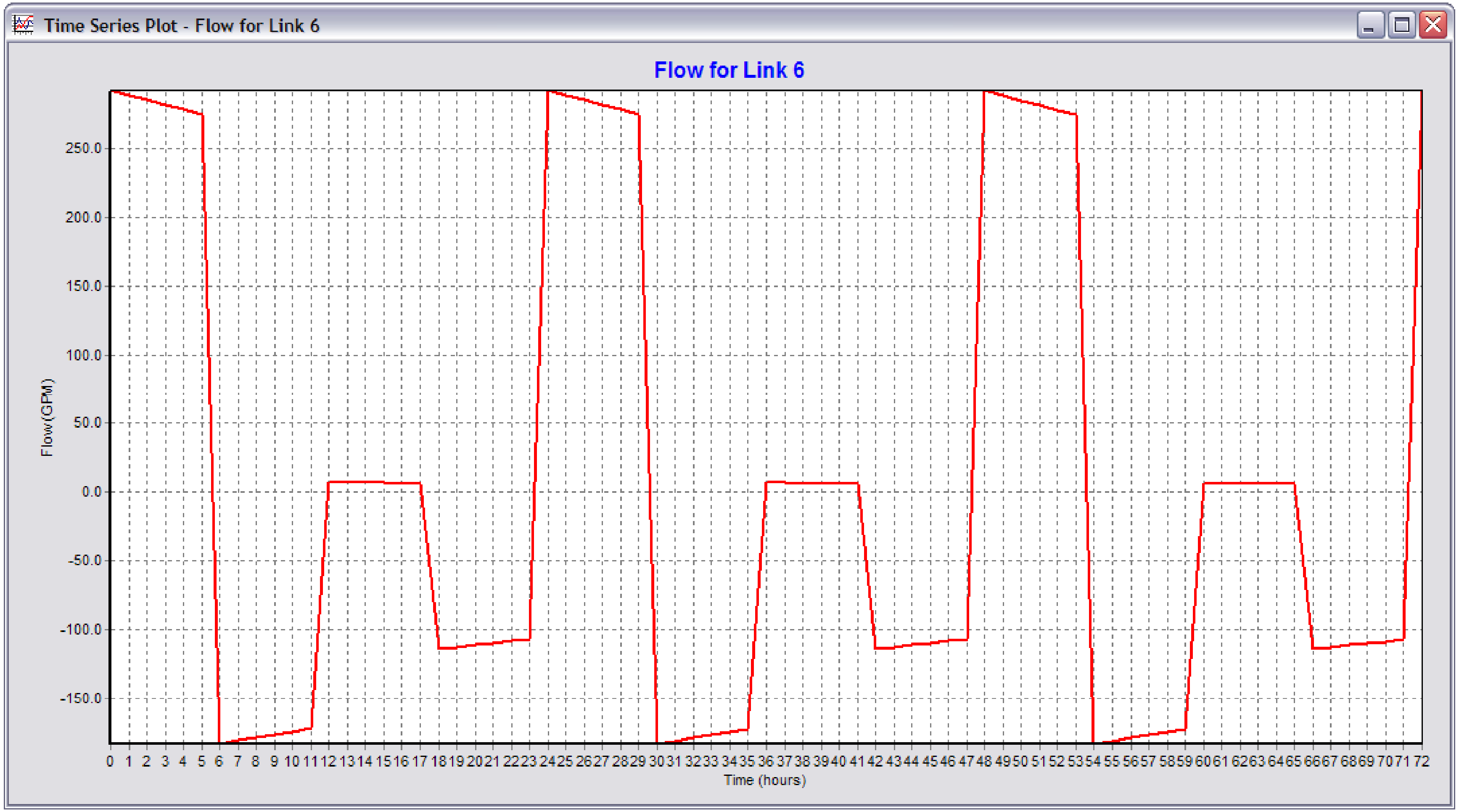
Pipes

Network Table - Links at 23:00 Hrs

Link ID	Length ft	Diameter in	Roughness	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor
Pipe 1	3000	14	100	673.52	1.40	0.94	0.036
Pipe 2	5000	12	100	188.70	0.54	0.19	0.042
Pipe 3	5000	8	100	304.82	1.95	3.29	0.037
Pipe 4	5000	8	100	-6.02	0.04	0.00	0.067
Pipe 5	5000	8	100	-295.18	1.88	3.10	0.037
Pipe 6	7000	10	100	-106.48	0.43	0.16	0.045
Pipe 7	5000	6	100	130.84	1.48	2.79	0.041
Pipe 8	7000	6	100	-109.16	1.24	1.99	0.042
Pump 9	#N/A	#N/A	#N/A	673.52	0.00	-137.00	0.000

General Results of EPANET

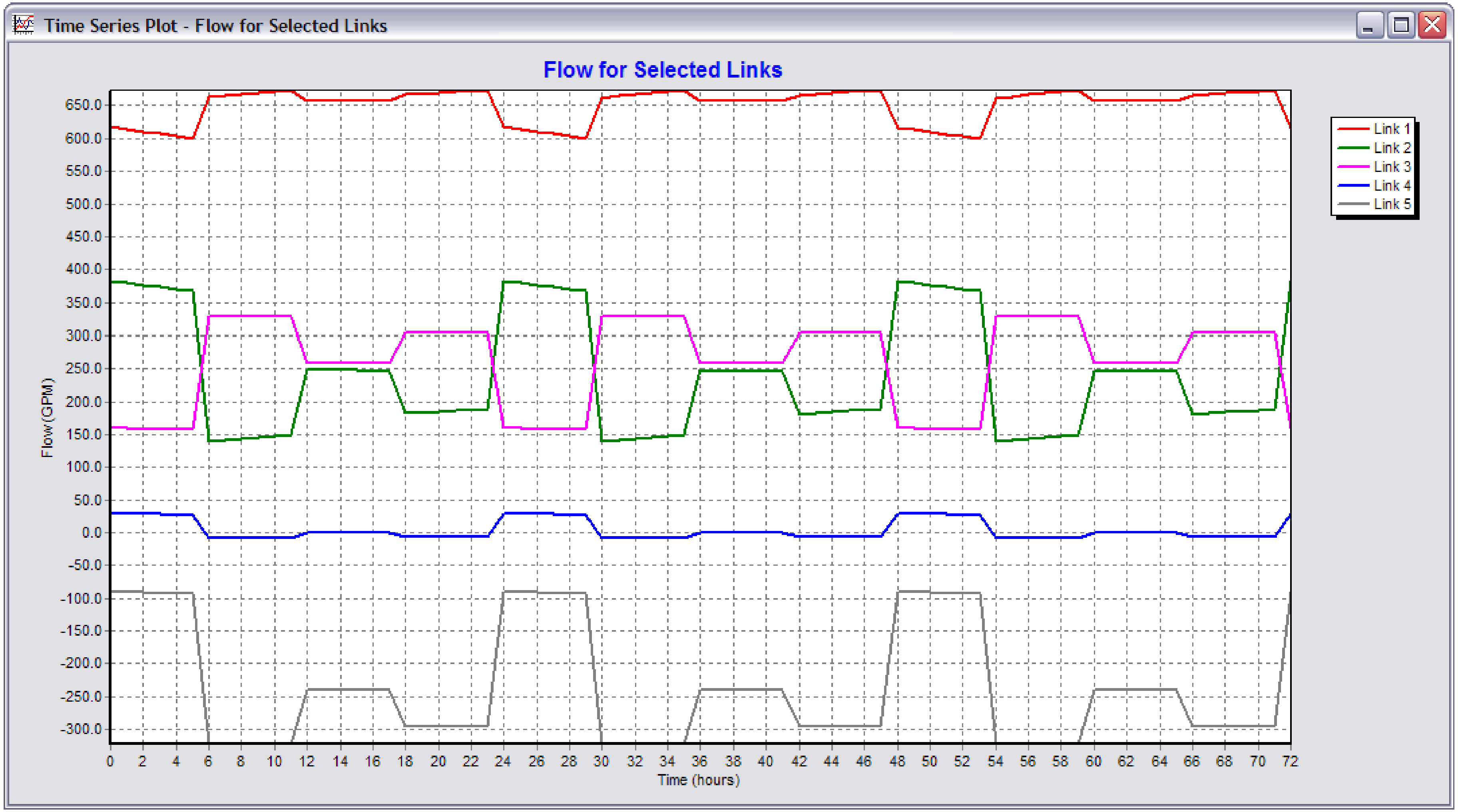
Time series



- Note the negative and positive values of flow
- What does this indicate?

General Results of EPANET

Time series



General Results of EPANET

Time series (Pump)