CE 3372 WATER SYSTEMS DESIGN

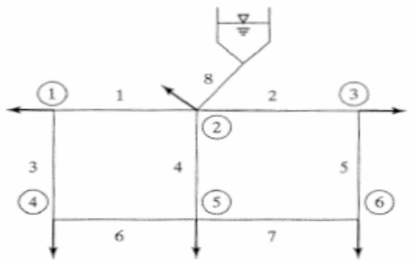
LESSON 10: PUMPS IN EPANET FALL 2020

OVERVIEW

- EPANET NETWORK SIMULATION (WITHOUT PUMP)
  - APPLICATION OF MODELING PROTOCOL
- EPANET PUMP SIMULATION
  - APPLICATION OF MODELING PROTOCOL
- EPANET NETWORK SIMULATION (WITH PUMP)
  - APPLICATION OF MODELING PROTOCOL

PROBLEM STATEMENT

Compute the discharge in each pipe and the pressure at each junction node for the 8-pipe system shown in Figure 1. The water surface elevation in the storage tank is 315.0 ft. Prepare your solution using EPA-NET. Report your results in U.S. Customary units. Identify the node with the lowest pressure in your solution. Include a transmittal letter with the solution.



Pipe Data

Pipe no.	Length m	Length ft	Diameter mm	Diameter in.	Friction factor
1	1,220	4,000	254	10	0.024
2	1,829	6,000	254	10	0.024
3	1,829	6,000	305	12	0.022
4	1,982	6,500	610	24	0.018
5	2,134	7,000	254	10	0.024
6	915	3,000	457	18	0.020
7	1,524	5,000	254	10	0.024
8	91	300	305	12	0.022

Junction Data

Junction node	Ground elevation m	Ground elevation ft	Demand ℓps	Demand gpm
1	51.8	170	31.5	500
2	54.9	180	31.5	500
3	50.3	165	31.5	500
4	47.3	155	94.6	1,500
5	45.7	150	63.1	1,000
6	44.2	145	94.6	1,500

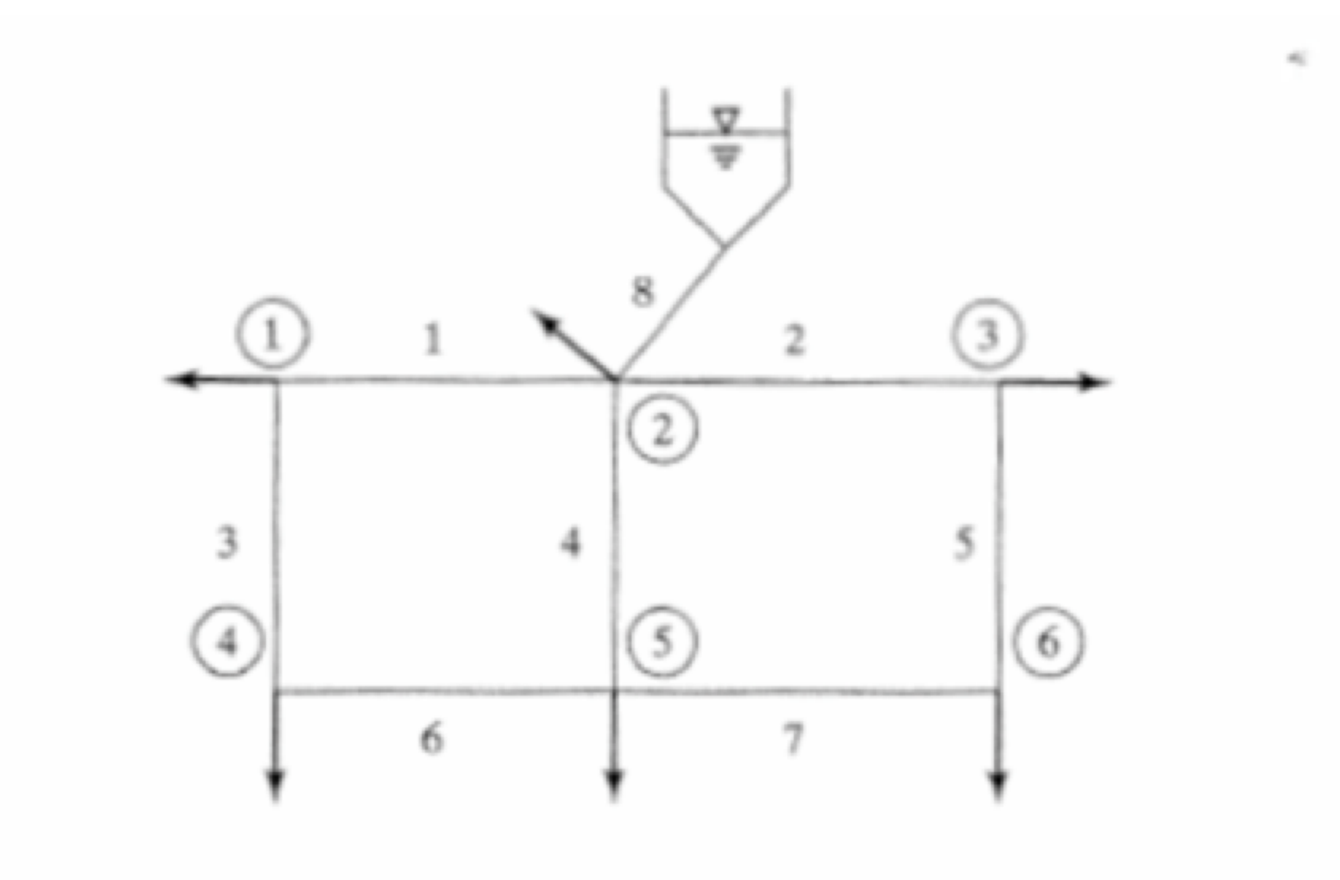
Figure 1: Network and Data for Problem 1

MODELING PROTOCOL

- SKETCH A LAYOUT ON PAPER
- IDENTIFY PIPE DIAMETERS; LENGTH; ROUGHNESS VALUES
- IDENTIFY NODE ELEVATIONS; DEMANDS
- SUPPLY RESERVOIR (OR TANK); IDENTIFY RESERVOIR POOL ELEVATION
- IDENTIFY PUMPS; PUMP CURVE IN PROBLEM UNITS

SKETCH A LAYOUT

- SKETCH A LAYOUT ON PAPER



PIPES

- IDENTIFY PIPE DIAMETERS; LENGTH; ROUGHNESS VALUES

Pipe no.	Length ft	Diameter in.	Friction factor
1	4,000	10	0.024
2	6,000	10	0.024
3	6,000	12	0.022
4	6,500	24	0.018
5	7,000	10	0.024
6	3,000	18	0.020
7	5,000	10	0.024
8	300	12	0.022

Adjust roughness values to match these.

Start at 0.26, use D-W head loss model

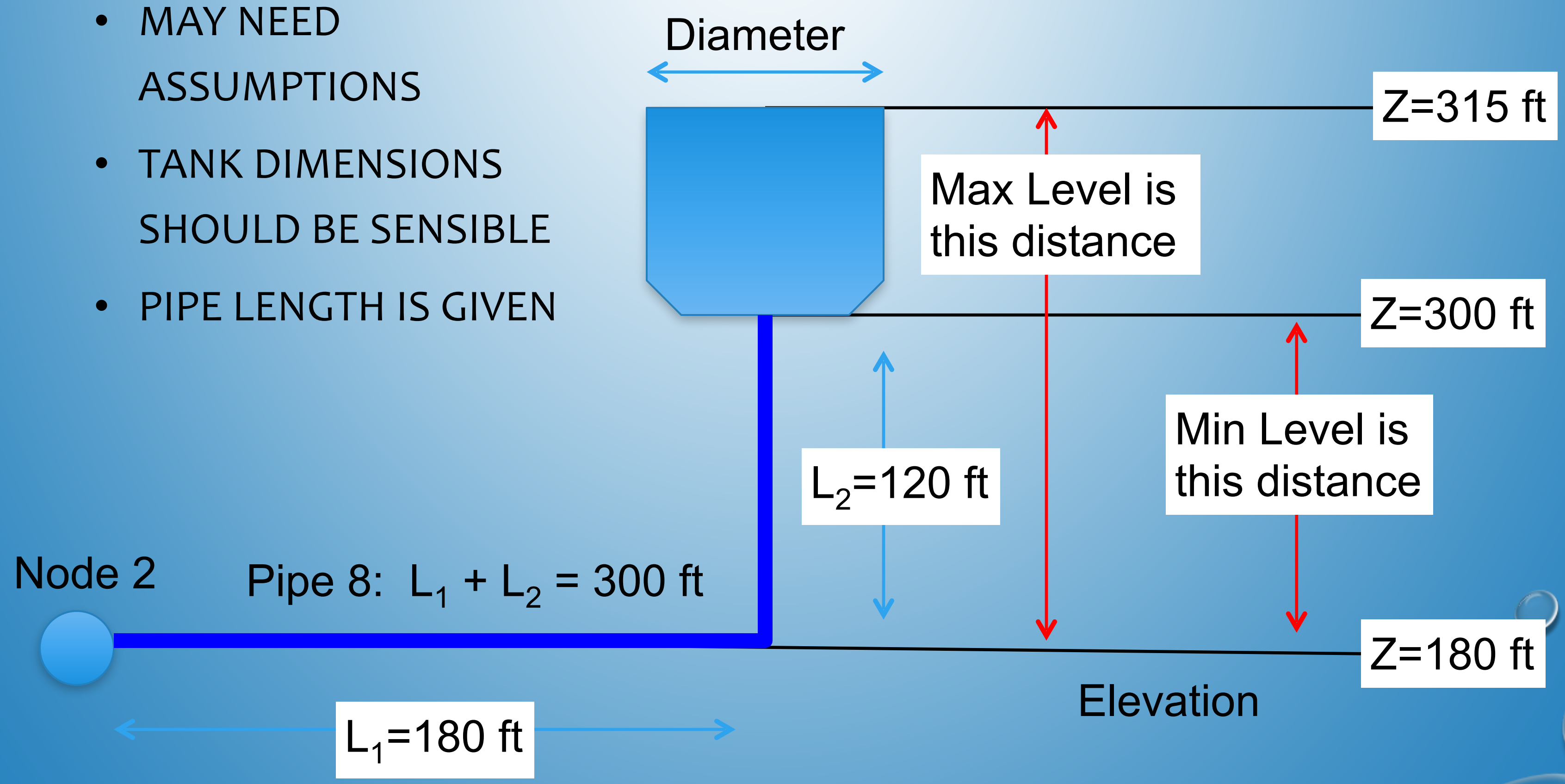
NODES

- IDENTIFY NODE ELEVATIONS; DEMANDS

Junction node	Ground elevation	Demand
	ft	gpm
1	170	500
2	180	500
3	165	500
4	155	1,500
5	150	1,000
6	145	1,500

TANK

- SUPPLY RESERVOIR (OR TANK); IDENTIFY RESERVOIR POOL ELEVATION
  - MAY NEED ASSUMPTIONS
  - TANK DIMENSIONS SHOULD BE SENSIBLE
  - PIPE LENGTH IS GIVEN



PUMPS

- IDENTIFY PUMPS; PUMP CURVE IN PROBLEM UNITS
  - NONE THIS PROBLEM!

CONSTRUCT MODEL – RUN SIMULATION

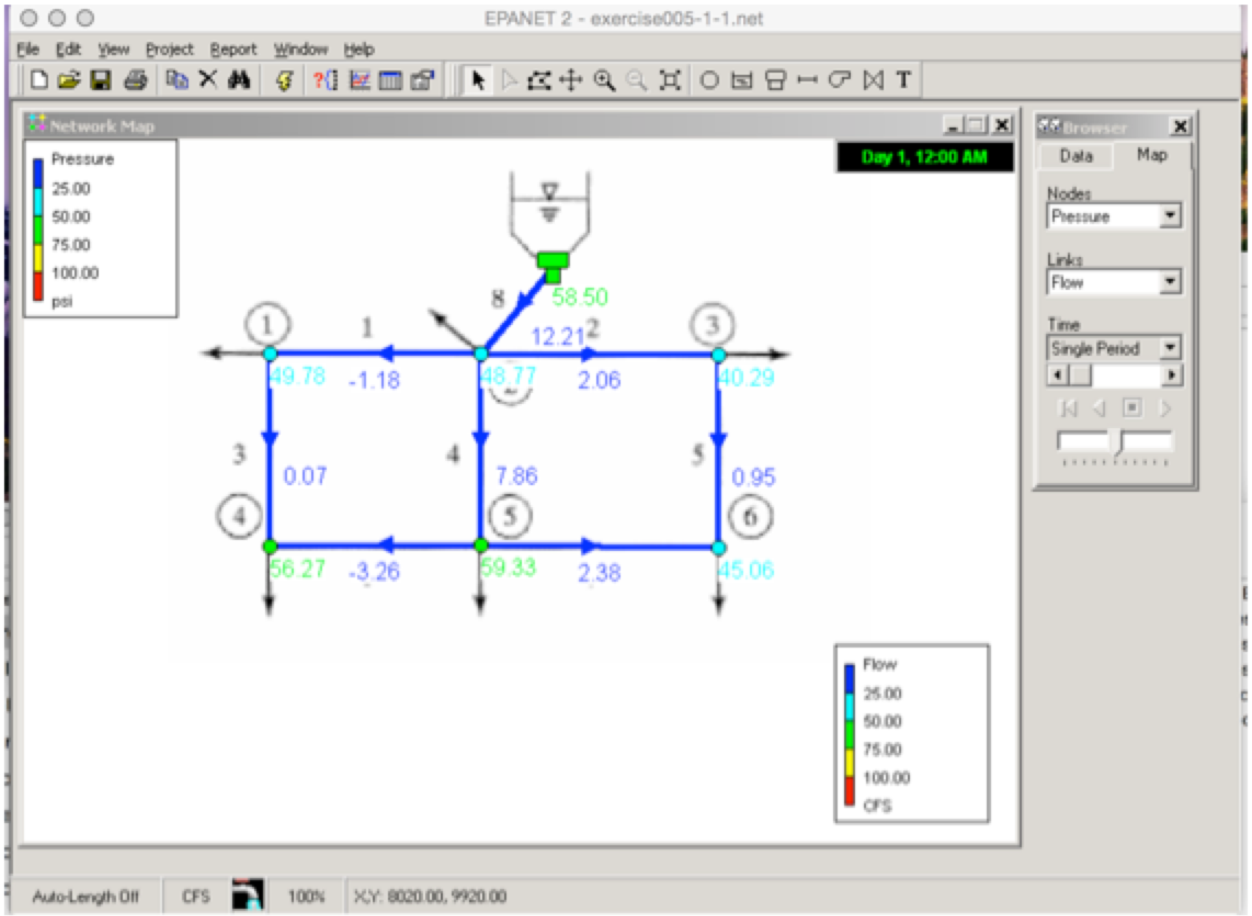


Figure 2. Screen Capture Completed EPANET simulation showing node pressures in pounds per square inch, and pipe discharge in cubic feet per second.

RUNS TO MATCH FRICTION FACTORS

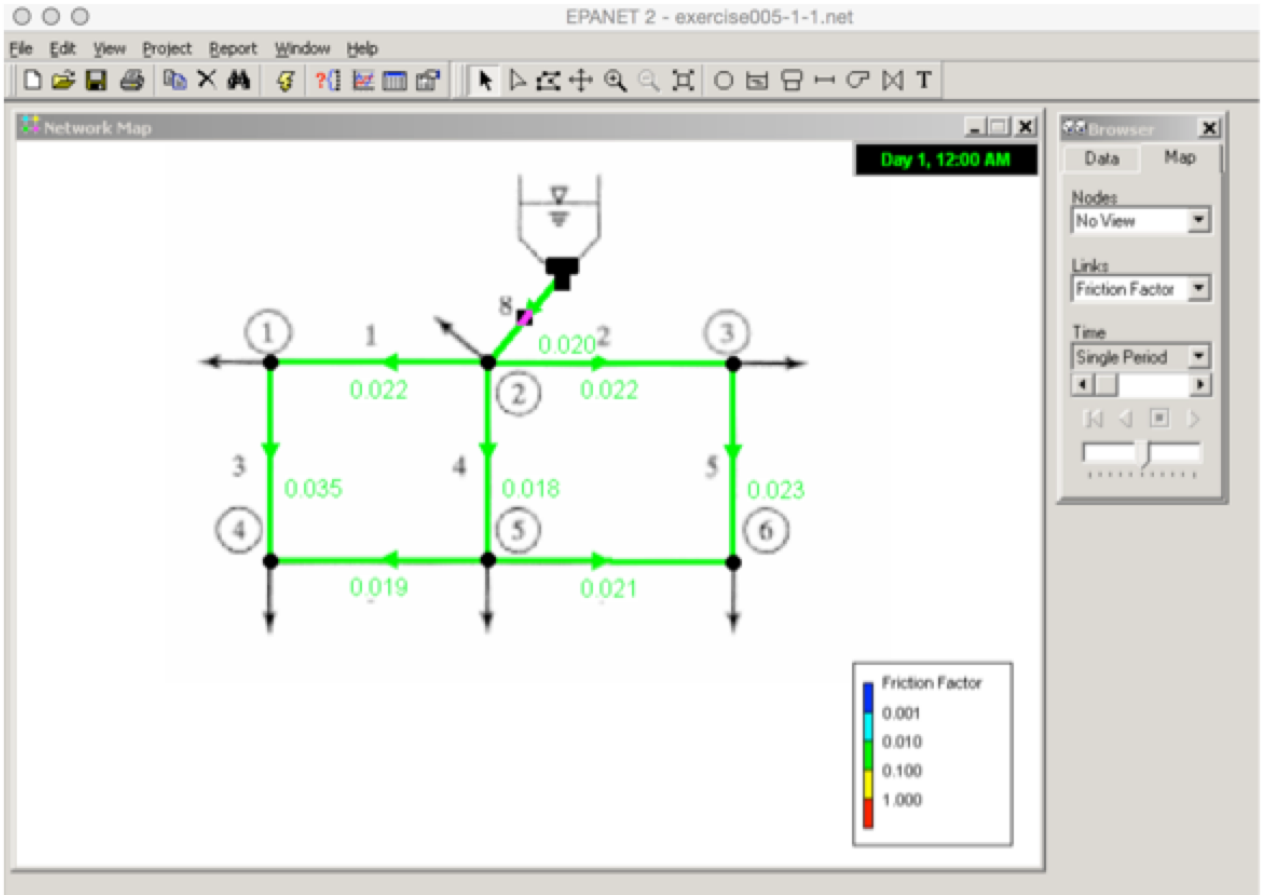


Figure 3. Screen capture of EPANET simulation showing computed friction factors for each pipe.

FULL STATUS REPORT (1 OF 3)

```
Input File: exercise005-1-1.net

Link - Node Table:

----------------------------------------------------------------------

Link          Start          End                  Length   Diameter

ID            Node           Node                    ft          in
----------------------------------------------------------------------

1             2              3                     4000          10
2             3              4                     6000          10
3             2              5                     6000          12
4             3              6                     6500          24
5             4              7                     7000          10
6             5              6                     3000          18
7             6              7                     5000          10
8             9              3                      300          12
```

FULL STATUS REPORT (2 OF 3)

```
Node Results:

----------------------------------------------------------------------

Node                    Demand      Head   Pressure    Quality

ID                         CFS        ft        psi
----------------------------------------------------------------------

2                         1.11    284.88      49.78       0.00
3                         1.11    292.57      48.77       0.00
4                         1.11    258.00      40.29       0.00
5                         3.33    284.86      56.27       0.00
6                         2.22    286.92      59.33       0.00
7                         3.33    249.00      45.06       0.00
9                       -12.21    315.00      58.50       0.00 Tank
```

FULL STATUS REPORT (3 OF 3)

Link Results:

Link ID	Flow CFS	VelocityUnit fps	Headloss ft/Kft	Status
1	-1.18	2.15	1.92	Open
2	2.06	3.79	5.76	Open
3	0.07	0.08	0.00	Open
4	7.86	2.50	0.87	Open
5	0.95	1.75	1.29	Open
6	-3.26	1.85	0.69	Open
7	2.38	4.36	7.58	Open
8	12.21	15.55	74.78	Open

ASSESS RESULTS

- PROBLEM IS GIVEN IN GPM, SO CHANGING TO CFS IS UNNECESSARY COMPLICATION
- VELOCITY IN THE PIPE FROM THE TANK IS 15 FT/SEC – HIGHER THAN TYPICALLY DESIRED; CONSIDER LARGER PIPE OR FLOW CONTROL VALVE

PUMPS IN EPA-NET

- PUMPS ARE MODELED AS LINKS BETWEEN TWO NODES THAT HAVE PUMPING CURVE PROPERTIES.
- EACH NODE MUST HAVE APPROPRIATE ELEVATIONS.
  - A PUMP IS ADDED AS A LINK, THEN THE **PUMP CURVE** IS SPECIFIED FOR THAT PUMP.
  - THE PROGRAM WILL OPERATE THE PUMP OUT-OF-RANGE BUT ISSUE WARNINGS TO GUIDE THE ANALYST TO ERRORS.

EXAMPLE 4

- EXAMPLE 4 – LIFTING WITH A PUMP

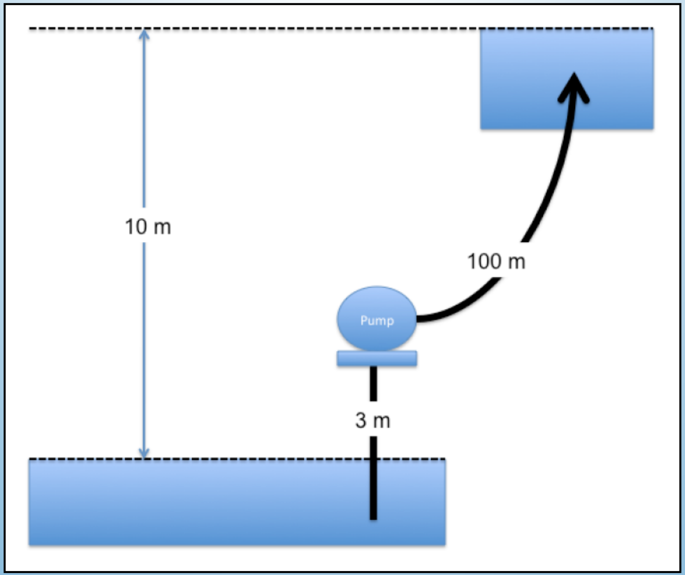


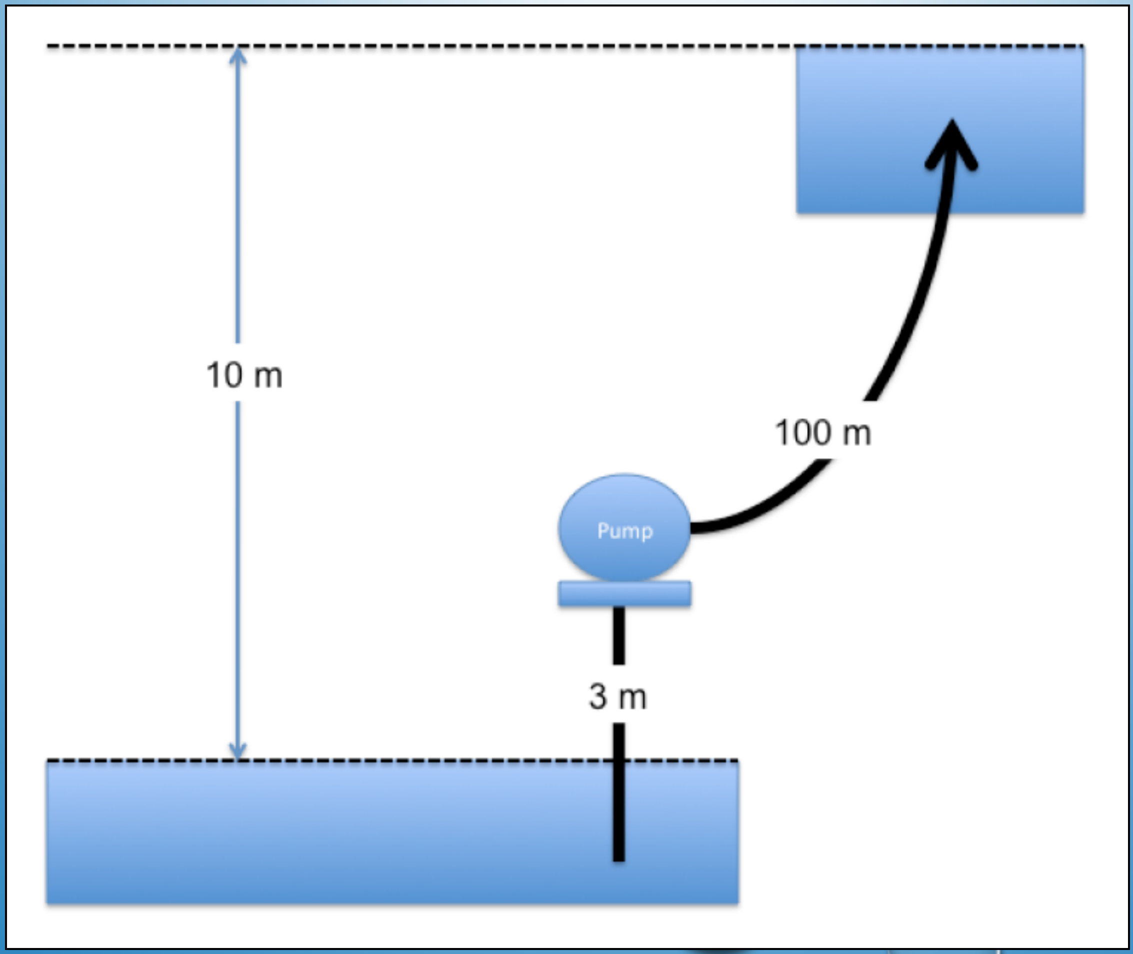
Figure 15 is a conceptual model of a pump lifting water through a 100 mm diameter, 100 meter long, ductile iron pipe from a lower to an upper reservoir. The suction side of the pump is a 100 mm diameter, 4-meter long ductile iron pipe. The difference in reservoir free-surface elevations is 10 meters. The pump performance curve is given as

$$h_p = 15 - 0.1Q^2 \tag{1}$$

where the added head is in meters and the flow rate is in liters per second (Lps). The analysis goal is to estimate the flow rate in the system.

EXAMPLE 4

- EXAMPLE 4 – LIFTING WITH A PUMP



EXAMPLE 4

- EXAMPLE 4 – LIFTING WITH A PUMP

Figure 15 is a conceptual model of a pump lifting water through a 100 mm diameter, 100 meter long, ductile iron pipe from a lower to an upper reservoir. The suction side of the pump is a 100 mm diameter, 4-meter long ductile iron pipe. The difference in reservoir free-surface elevations is 10 meters. The pump performance curve is given as

$$h_p = 15 - 0.1Q^2 \tag{1}$$

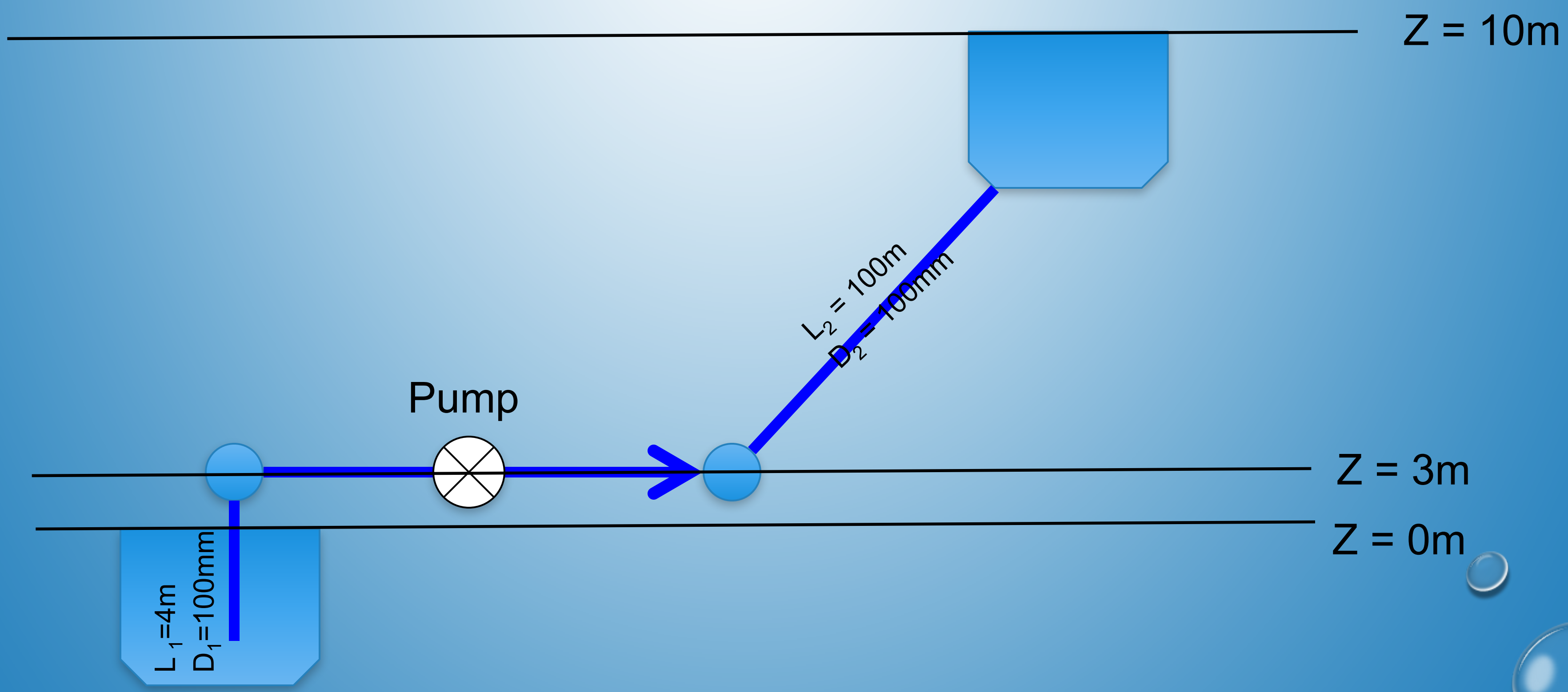
where the added head is in meters and the flow rate is in liters per second (Lps). The analysis goal is to estimate the flow rate in the system.

MODELING PROTOCOL

- SKETCH A LAYOUT ON PAPER
- IDENTIFY PIPE DIAMETERS; LENGTH; ROUGHNESS VALUES
- IDENTIFY NODE ELEVATIONS; DEMANDS
- SUPPLY RESERVOIR (OR TANK); IDENTIFY RESERVOIR POOL ELEVATION
- IDENTIFY PUMPS; PUMP CURVE IN PROBLEM UNITS

MODELING PROTOCOL

- SKETCH A LAYOUT ON PAPER



MODELING PROTOCOL

- IDENTIFY PIPE DIAMETERS; LENGTH; ROUGHNESS VALUES

L_1=4m
D_1=100mm
k_s~ 0.85

L_2 = 100m
D_2 = 100mm
k_s~0.85

Table 3.2 Roughness Coefficients for New Pipe

Material	*Hazen-Williams C (unitless)*	*Darcy-Weisbach ε (feet x 10^{-3})*	*Manning's n (unitless)*
Cast Iron	130 – 140	0.85	0.012 - 0.015
Concrete or Concrete Lined	120 – 140	1.0 - 10	0.012 - 0.017
Galvanized Iron	120	0.5	0.015 - 0.017
Plastic	140 – 150	0.005	0.011 - 0.015
Steel	140 – 150	0.15	0.015 - 0.017
Vitrified Clay	110		0.013 - 0.015

MODELING PROTOCOL

- IDENTIFY NODE ELEVATIONS; DEMANDS
  - NODE 1 = 3M
  - NODE 2 = 3M
  - NO DEMANDS AT NODES (NEEDED FOR CONNECTION TO PUMP)

MODELING PROTOCOL

- SUPPLY RESERVOIR (OR TANK); IDENTIFY RESERVOIR POOL ELEVATION
  - LOWER RESERVOIR POOL ELEV. = 0M
  - UPPER RESERVOIR POOL ELEV. = 10M

MODELING PROTOCOL

- IDENTIFY PUMPS; PUMP CURVE IN PROBLEM UNITS
  - ONE PUMP – CONNECTS FROM NODE 1 TO NODE 2

E8

	A	B
1	Pump Curve Builder	
2		
3	Head (M)	Flow (LPS)
4	15	0
5	12.5	5
6	5	10

$$h_p = 15 - 0.1Q^2$$

EXAMPLE 4

- BUILD AND RUN MODEL

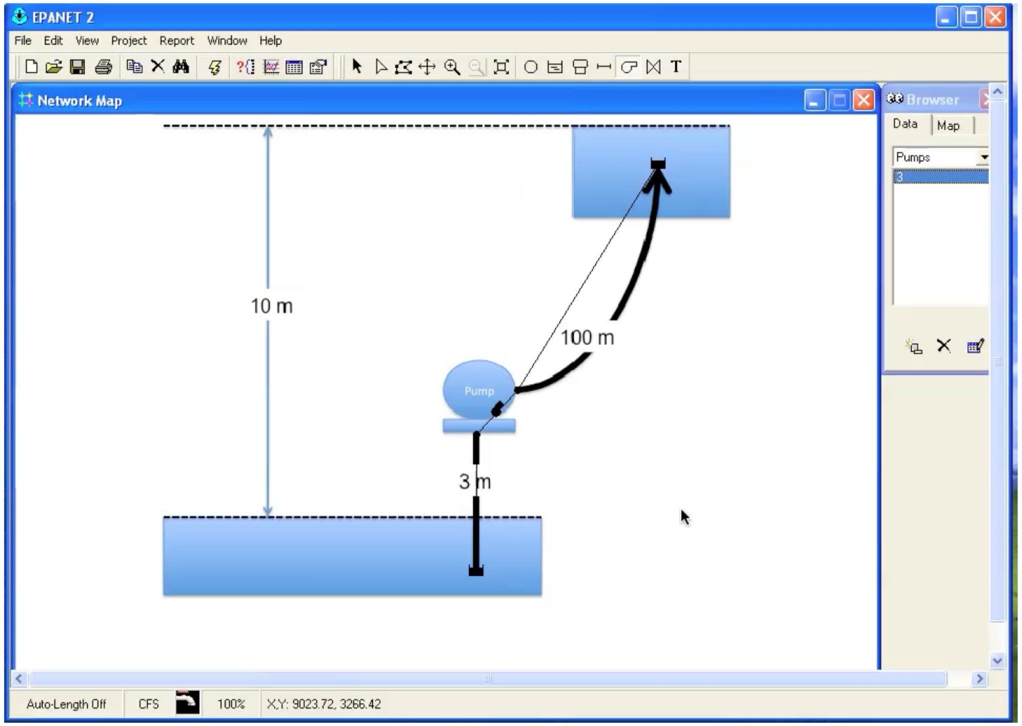


Figure 18: Example 5 place the nodes, pipes, and the pump link.

NETWORK SIMULATION

AN EXAMPLE – WITH A PUMP

PROBLEM STATEMENT

- STARTING WITH THE SAME SYSTEM AS IN THE FIRST EXAMPLE ADD A PUMP AND ITS SUPPLY TO THE SYSTEM

A pump is installed in the 18-inch diameter pipe extending 500 feet from the ground-level reservoir (WSE = 155 ft.) to junction node 4. The booster pump pushes water into the network; three points on the pump curve are listed on the figure. Determine the discharge and flow direction in each line and the pressure at each junction node. Try to match the reported friction factors (in the figures), but do not expect to obtain an exact match, within 20 percent is sufficient. Report your results in U.S. Customary units.

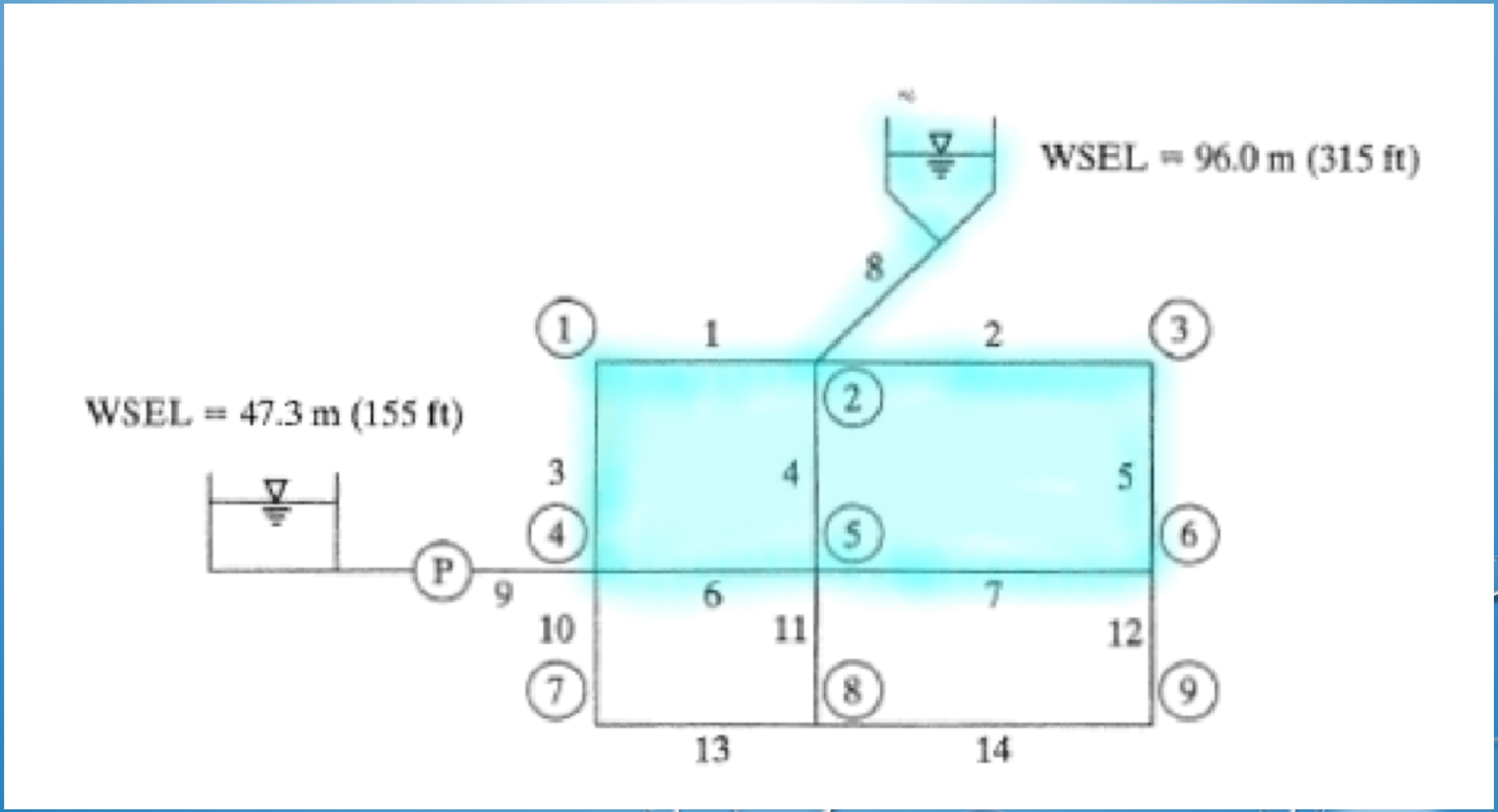
Observe that the pump curves are provided in cubic feet per second, while the nodal demands are in gallons per minute – so you need to convert units (either the pump units or the demand units – pump units are easier!)

MODELING PROTOCOL

- SKETCH A LAYOUT ON PAPER
- IDENTIFY PIPE DIAMETERS; LENGTH; ROUGHNESS VALUES
- IDENTIFY NODE ELEVATIONS; DEMANDS
- SUPPLY RESERVOIR (OR TANK); IDENTIFY RESERVOIR POOL ELEVATION
- IDENTIFY PUMPS; PUMP CURVE IN PROBLEM UNITS

SKETCH A LAYOUT

- SKETCH A LAYOUT ON PAPER



PIPES

- IDENTIFY PIPE DIAMETERS; LENGTH; ROUGHNESS VALUES
  - ADD TO PREVIOUS SYSTEM TO BUILD MODEL

Pipe Data

Pipe no.	Length m	Length ft	Diameter mm	Diameter in.	Friction factor
9	152	500	457	18	0.020
10	1,220	4,000	254	10	0.024
11	1,220	4,000	610	24	0.018
12	1,220	4,000	305	12	0.022
13	915	3,000	203	8	0.026
14	1,524	5,000	305	12	0.022

NODES

- IDENTIFY NODE ELEVATIONS; DEMANDS
  - ADD TO PRIOR SYSTEM TO BUILD MODEL

Junction Data

Junction no.	Ground elevation		Demand	
	m	ft	ℓps	gpm
7	50.3	165	31.5	500
8	51.8	170	63.1	1,000
9	50.3	165	31.5	500

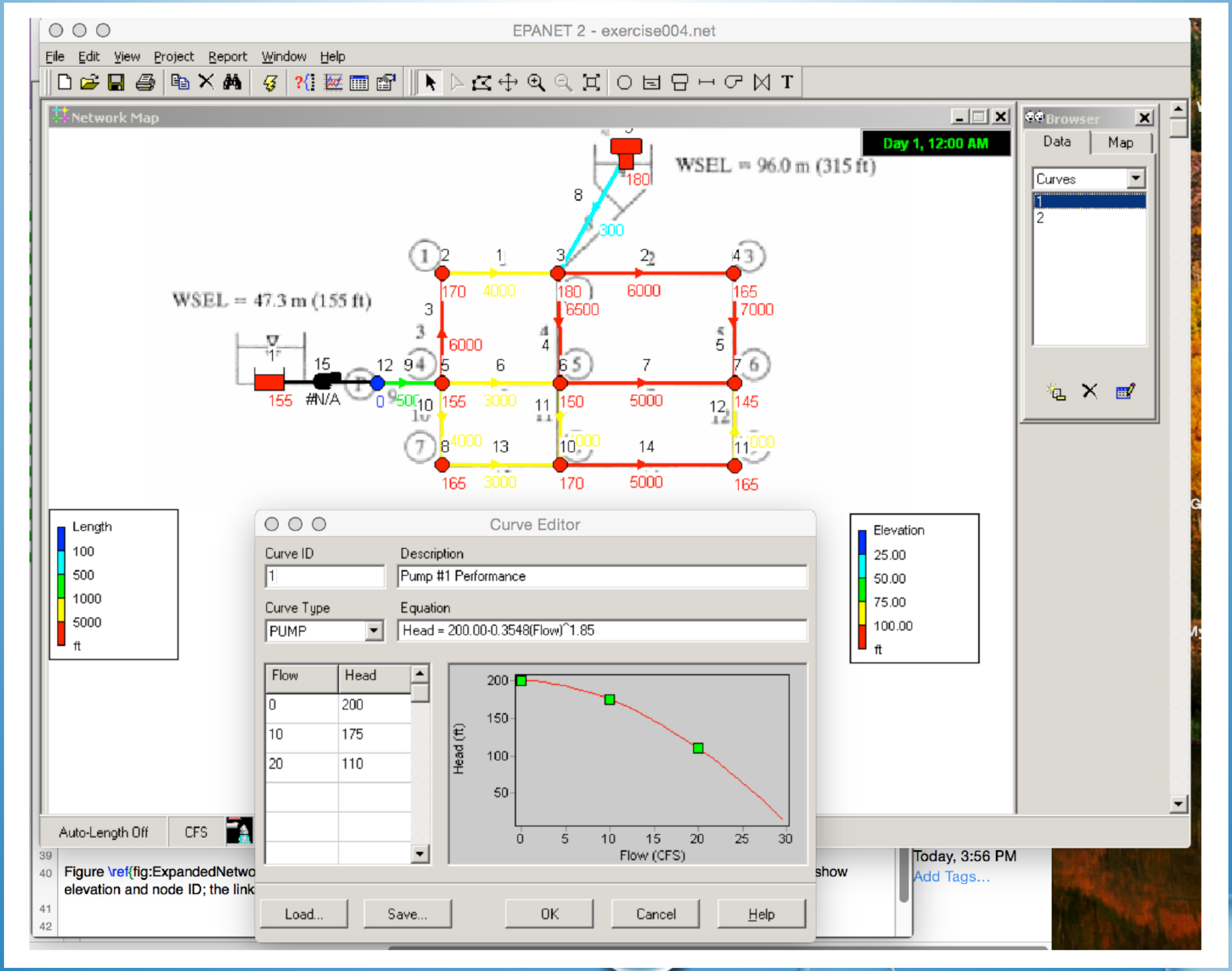
PUMPS

- IDENTIFY PUMPS; PUMP CURVE IN PROBLEM UNITS
  - ADD TO PRIOR SYSTEM TO BUILD MODEL

Pump Data

E_p		Q	
m	ft	cms	cfs
61.0	200	0	0
53.4	175	0.28	10.0
33.5	110	0.57	20.0

CONSTRUCT MODEL – RUN SIMULATION



STATUS REPORT

exercise004.rpt — Edited

Page 1 2/18/2016 4:46:39 PM
Input File: exercise004.net
Link - Node Table:

Link ID	Start Node	End Node	Length ft	Diameter in	
1	2	3	4000	10	
2	3	4	6000	10	
3	2	5	6000	12	
4	3	6	6500	24	
5	4	7	7000	10	
6	5	6	3000	18	
7	6	7	5000	10	
8	9	3	300	12	
9	12	5	500	18	
10	5	8	4000	10	
11	6	10	4000	24	
12	7	11	4000	12	
13	8	10	3000	8	
14	10	11	5000	12	
15	1	12	#N/A	#N/A	Pump

Node Results:

Node ID	Demand CFS	Head ft	Pressure psi	Quality	
2	1.11	311.58	61.35	0.00	
3	1.11	311.30	56.89	0.00	
4	1.11	292.89	55.42	0.00	LOW PRESSURE THIS NODE
5	3.33	317.21	70.29	0.00	
6	2.22	310.67	69.62	0.00	
7	3.33	291.30	63.39	0.00	
8	1.11	309.55	62.63	0.00	
10	2.22	309.47	60.43	0.00	
11	1.11	294.75	56.22	0.00	
12	0.00	321.41	139.27	0.00	
1	-11.73	155.00	0.00	0.00	Reservoir
9	-4.92	315.00	58.50	0.00	Tank

Link Results:

Link ID	Flow CFS	Velocity fps	Unit Headloss ft/Kft	Status	
1	0.20	0.38	0.07	Open	
2	1.50	2.74	3.07	Open	
3	-1.31	1.67	0.94	Open	
4	2.52	0.80	0.10	Open	
5	0.39	0.71	0.23	Open	
6	5.92	3.35	2.18	Open	
7	1.69	3.09	3.87	Open	
8	4.92	6.26	12.34	Open	
9	11.73	6.64	8.39	Open	
10	1.17	2.15	1.92	Open	
11	4.53	1.44	0.30	Open	
12	-1.26	1.60	0.86	Open	
13	0.06	0.18	0.03	Open	
14	2.37	3.02	2.94	Open	
15	PUMP DISCHARGE 11.73	0.00	-166.41 ADDED HEAD	Open	Pump

Figure 5: Network analysis report (annotated and edited for brevity)

NEXT TIME

- STORAGE CONSIDERATIONS
  - TANKS VS. RESERVOIRS
  - FLOW EQUALIZATION