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Waterline Example Design Report

Project Number: 0407225

Prepared by:

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July 2020

Example Waterline Project
Arizona Department of Environmental Quality

Date: July 2020

I. Introduction

The Galaxy is a new residential subdivision located in Gilbert, Arizona. The site is south of the South 202 Loop within Maricopa county (i.e. See Figure 1 for vicinity map and site location). The proposed 980 linear feet of 6-inch PVC water main will serve 28 residential lots. Running north and south along Milky Wave Lane, the waterline connects to the existing 6-inch water main at the intersection of Milky Wave Lane and Neptune Drive. In addition to the 6-inch PVC waterline, two fire hydrants, shut-off valves and additional appurtenances will be added. The waterline was designed in accordance with the Engineering Bulletin No. 10.

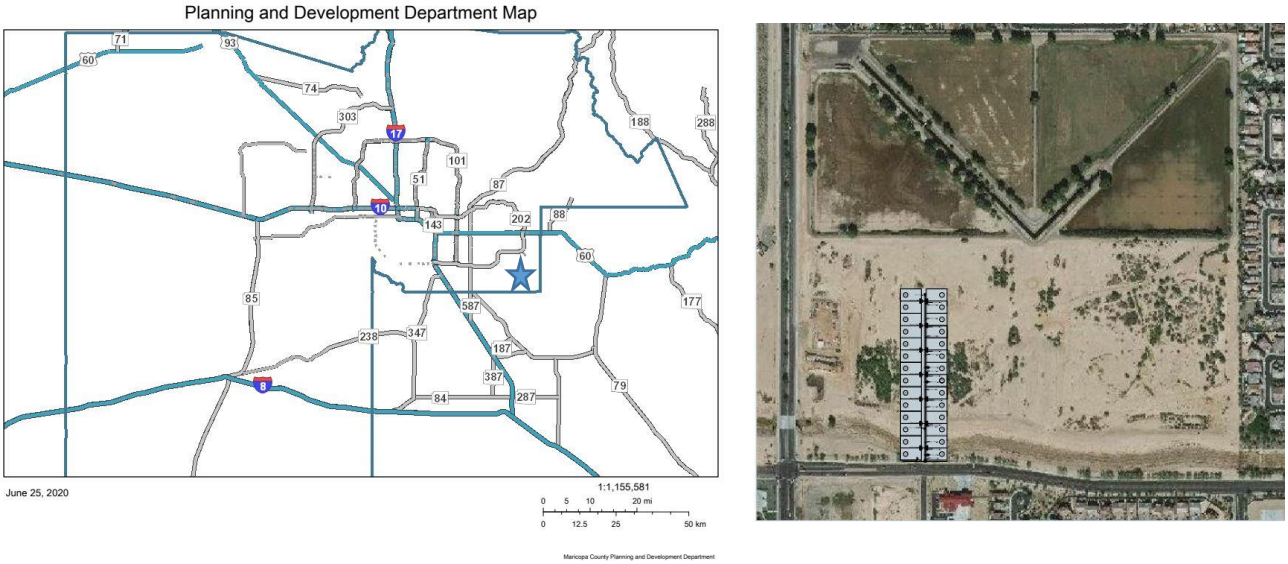

Figure 1: Left: Vicinity Map (Star represents the site location), Right: Site Location

II. Project

According to the Census report for Gilbert, AZ, there are 3.14 persons per a household. However, for an additional factor of safety, the average daily demand used was 360 gallons per a day with a peak factor of 1.7, based on the City of Phoenix Design Standards (2017). The daily demand is based on 3.6 persons per a household and 100 gallons per day per person. The fire flow is 1000 gallons per a minute with a minimum duration of 1 hour in accordance to the National Fire Protection Association, NFPA. Given the 28 lots served by the waterline, the total average and peak demand was found to be 10,080 and 17,136 gallons per a day respectively (i.e. See Table 1). For more detailed calculations, reference Appendix A.

Table 1: Demand and Fire Flow

Description	Value	Units
Persons per a household[1]	3.6	persons
Demand per a person per a day[1]	100	gpd
Average Demand[1]	360	gpd
	0.25	gpm
Peak Factor[1]	1.7	
Peak Demand	612	gpd
	0.425	gpm
Number of Lots	28	lots
Total Average Demand	10,080	gpd
	7	gpm
Total Peak Demand	17,136	gpd
	11.9	gpm
Fire Flow[2]	1,000	gpm
Peak Demand + Fire Flow	1,011.9	gpm

[1] City of Phoenix Design Standards Manual for Water and Wastewater Systems (2017)
[2] NFPA 1142 Standard A.4.4, minimum duration of 1 hour (2017)

The proposed waterline for the new subdivision will connect an existing 6-inch water main located on Neptune Drive. Fire flow analysis was conducted on a nearby existing fire hydrants and used to develop the boundary conditions for the water pressure model. (See Appendix B for fire flow analysis). The waterline was designed and analyzed in EPANET (See Appendix C for water pressure modeling). For each flow condition, the minimum pressure exceeded 20 psi and the maximum pressure was below 100 psi. Thus, the demand and pressure criteria were satisfied. The flow conditions where maximum and minimum pressure occurred can be referenced in Table 2.

Table 2: Maximum and Minimum Pressures

Case	Description	Demand (gpm)	Pressure (psi)
1	Average flow	7	76.28
6	Peak Flow	11.9	76.28
9	Peak Flow and Fire Flow from 1 hydrant	1011.9	37.8
10	Peak Flow and Fire Flow from 2 fire hydrants	2011.9	36.94

Case 9 meets the minimum fire flow of 1000 gallons per a minute with a pressure over 20 psi. However, the system can handle fire flow for multiple fire hydrants and still meet the minimum pressure as seen in case 10. The waterline meets and exceeds the fire flow criteria.

III. Conclusion

The proposed 980 linear feet of 6-inch water main, fire hydrants, shut-off valves and additional appurtenances will support 28 residential lots in the new subdivision, Galaxy. The proposed 6-inch PVC waterline meets the minimum design criteria. For each demand scenario, inclusive of average demand, peak demand and fire flow, the pressure exceeds 20 psi.

IV. References

Arizona Department of Environmental Quality . (1978, May). Engineering Bulletin No. 10 Guildlines for the Construction of Water Systems.

City of Phoenix Water Services Department. (2017). *Design Standards Manual for Water and Wastewater Systems.* Retrieved from City of Phoenix Water Services Home: https://www.phoenix.gov/waterservicessite/Documents/Design%20Standards%20Manual%20for%20Water%20and%20Wastewater%20Systems%20-%202017.pdf

National Fire Protection Association. (n.d.). NFPA 1142 Standard on Water Supplies for Suburban and Rural Fire Fighting. *2017*.

United States Census Bureau. (2018). *QuickFacts Gilbert town, Arizona*. Retrieved from United States Census Bureau: https://www.census.gov/quickfacts/fact/table/gilberttownarizona/HSD310218#HSD310218

IV. Appendices

Appendix A: Demand Calculations

Average Demand

$$Average\ Daily\ Demand = 3.6\frac{persons}{household} * 100\frac{gallons}{person * day} = 360\frac{gallons}{household * day}$$

$$Average\ demand = 360\frac{gallons}{household * day} * \frac{1\ day}{24\ hrs} * \frac{1\ hr}{60\ min} = 0.25\frac{gallons}{household * min}$$

$$Total\ Average\ Daily\ Demand = 360\frac{gallons}{household * day} * 28\ lots = 10{,}080\ gpd$$

$$Total\ Average\ Demand = 0.25\frac{gallons}{household * min} * 28\ lots = 7\ gpm$$

Peak Daily Demand

$$Peak\ Daily\ Demand = Peak\ Factor * Average\ Daily\ Demand$$
$$= 1.7 * 360\frac{gallons}{household * day} = 612\frac{gallons}{household * day}$$

$$Peak\ demand = 612\frac{gallons}{household * day} * \frac{1\ day}{24\ hrs} * \frac{1\ hr}{60\ min} = 0.425\frac{gallons}{household * min}$$

$$Total\ Peak\ Daily\ Demand = 612\frac{gallons}{household * day} * 28\ lots = 17{,}136\ gpd$$

$$Total\ Peak\ Demand = 0.425\frac{gallons}{household * min} * 28\ lots = 11.9\ gpm$$

Example Fire Flow and Peak Demand Calculation – 1 Fire Hydrant

$$Fire\ Flow = 1000\ gpm$$

$$Total\ Demand = Peak\ Flow + Fire\ Flow = 11.9\ gpm + 1000\ gpm = 1011.9\ gpm$$

Appendix B: Fire Flow Analysis

Time, Date, Location of Flow Test	Reason for Flow Test
09:15, 08-04-2020, 4922 S. Neptune Dr.	New Construction
Location of Flow Hydrant(s) #5	
Location of Control Hydrant #3	

Diameters Squared	2''	2 1/4''	2 1/2''	4''	4 1/4''	4 1/2''
d2	4	5.0625	6.25	16	18.0625	20.25

FH coefficients	into		square		round	
C	0.7		0.8		0.9	

	static	diameter	**residual**	coefficient	pitot	**fire flow**	
Fire Hydrant #1		4		0.7	55.12	1200	
Control Hydrant	73.66	4	66.30	0.7			
Total Available Flow at 20 psi		3508.153	gpm				

This test is not to be taken out of context of known conditions during the time of the test.

Test Conducted by – J. Doe

Appendix C: EPANET Model

Using EPANET, a model was created to represent the waterline, as seen in Figure 2. Using the boundary conditions calculated from the fire flow analysis, a reservoir with 170 feet of head was used to stimulate water flow and pressure in the existing waterline. In the model, the existing fire hydrant is located at Junction 5 and the new fire hydrants are located at Junctions 6 and 8. Shut-off valves and T-joints are accounted for as the energy loss coefficient for respective pipes. A total of 10 different cases were modeled representing average flow, peak flow and fire flow. For each case, the demand was met and the pressure exceeded 20 psi and was below 100 psi.

Case 1:

Table 3: Average Flow

Case 1			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	170	73.66
Junc 4	0	170	74.11
Junc 5	0	170	75.02
Junc 6	2	170	75.09
Junc 7	1	170	74.02
Junc 8	4	169.99	76.28
Resvr 1	-7	170	0

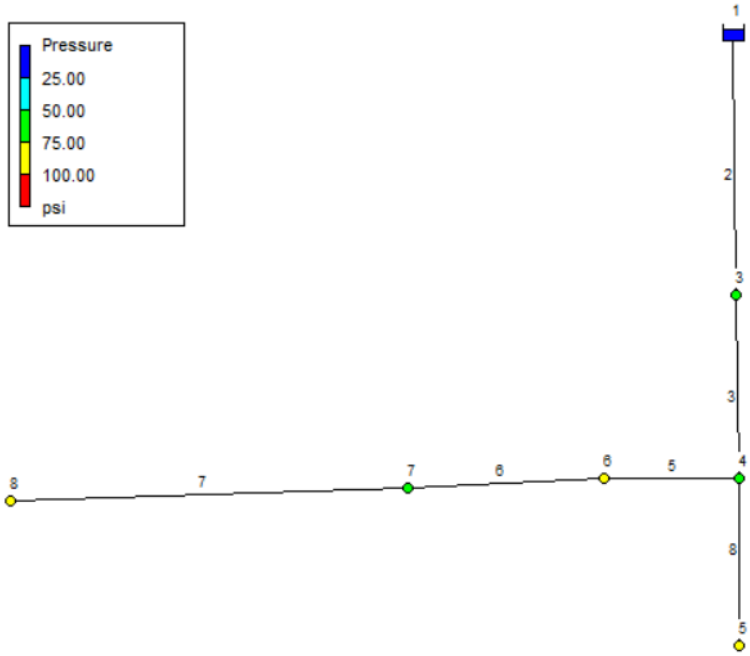

Figure 2: EPANET Model with Average Flow

Case 2:

Table 4: Average Flow and Fire Flow at Junction 5

Case 2			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	157.72	68.34
Junc 4	0	151.59	66.13
Junc 5	1000	137.07	60.75
Junc 6	2	151.59	67.12
Junc 7	1	151.58	66.05
Junc 8	4	151.58	68.3
Resvr 1	-1007	170	0

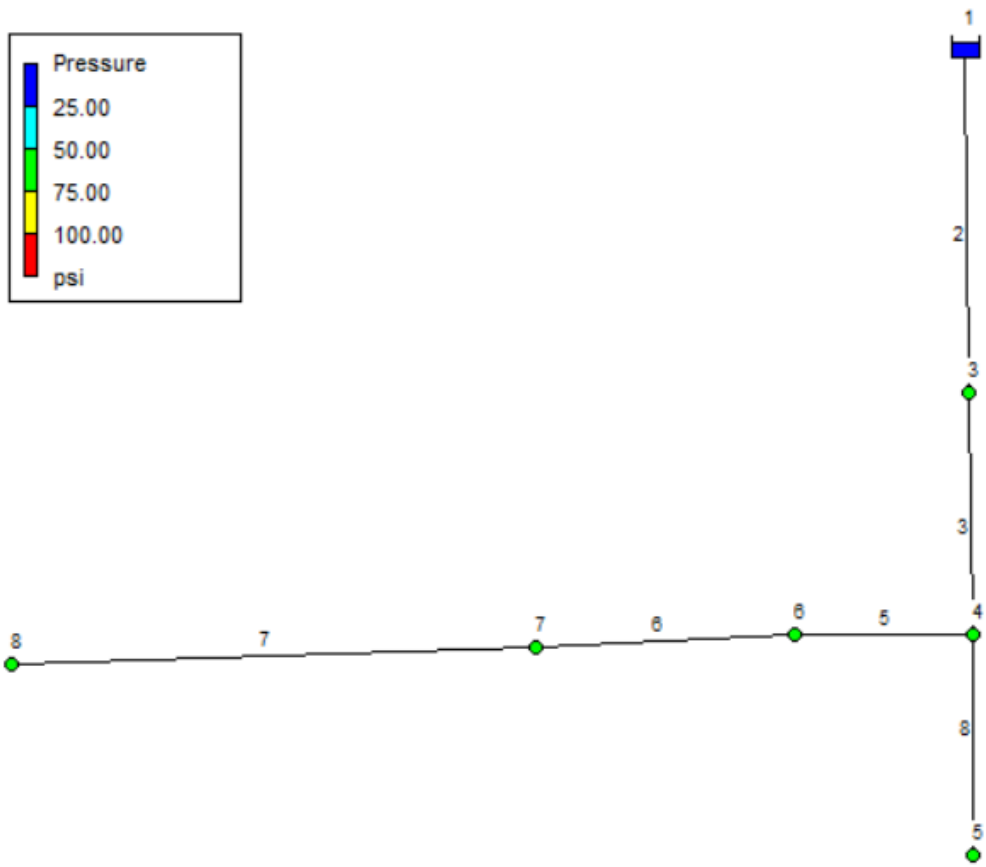

Figure 3: EPANET Model with Average Flow and Fire Flow at Junction 5

Case 3:

Table 5: Average Flow and Fire Flow at Junction 6

Case 3			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	157.72	68.34
Junc 4	0	151.59	66.13
Junc 5	0	151.59	67.04
Junc 6	1002	132.53	58.86
Junc 7	1	132.53	57.79
Junc 8	4	132.53	60.05
Resvr 1	-1007	170	0

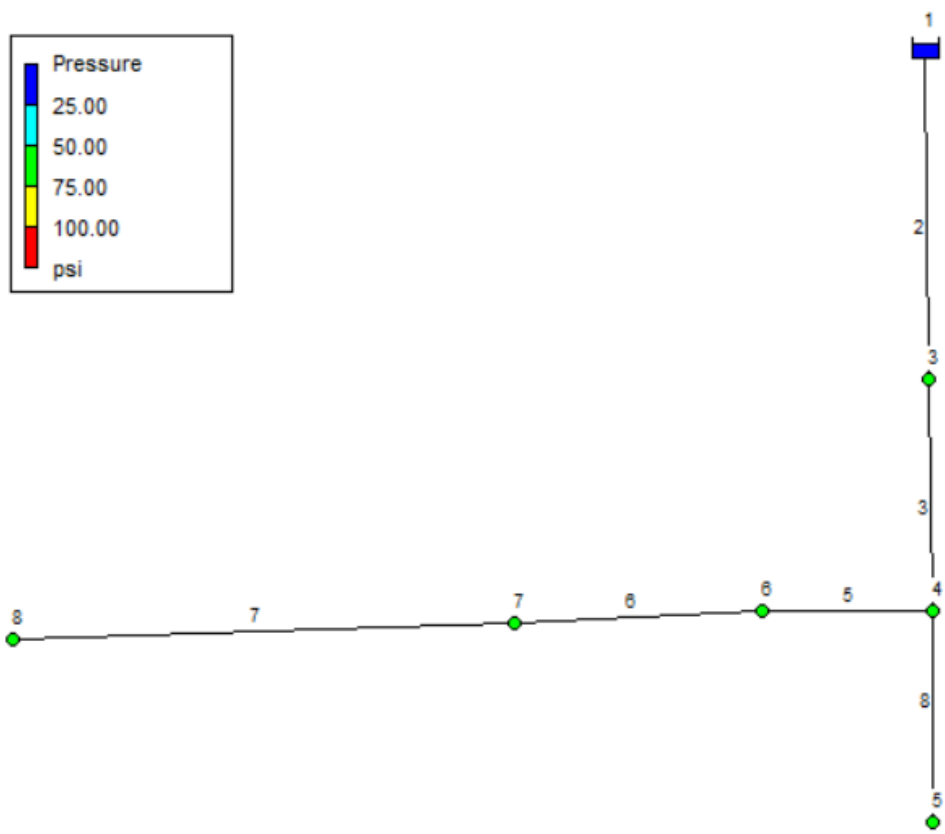

Figure 4: EPANET Model Average Flow and Fire Flow at Junction 6

Case 4:

Table 6: Average Flow and Fire Flow at Junction 8

Case 4			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	157.72	68.34
Junc 4	0	151.59	66.13
Junc 5	0	151.59	67.04
Junc 6	2	132.53	58.86
Junc 7	1	117.98	51.48
Junc 8	1004	81.82	38.07
Resvr 1	-1007	170	0

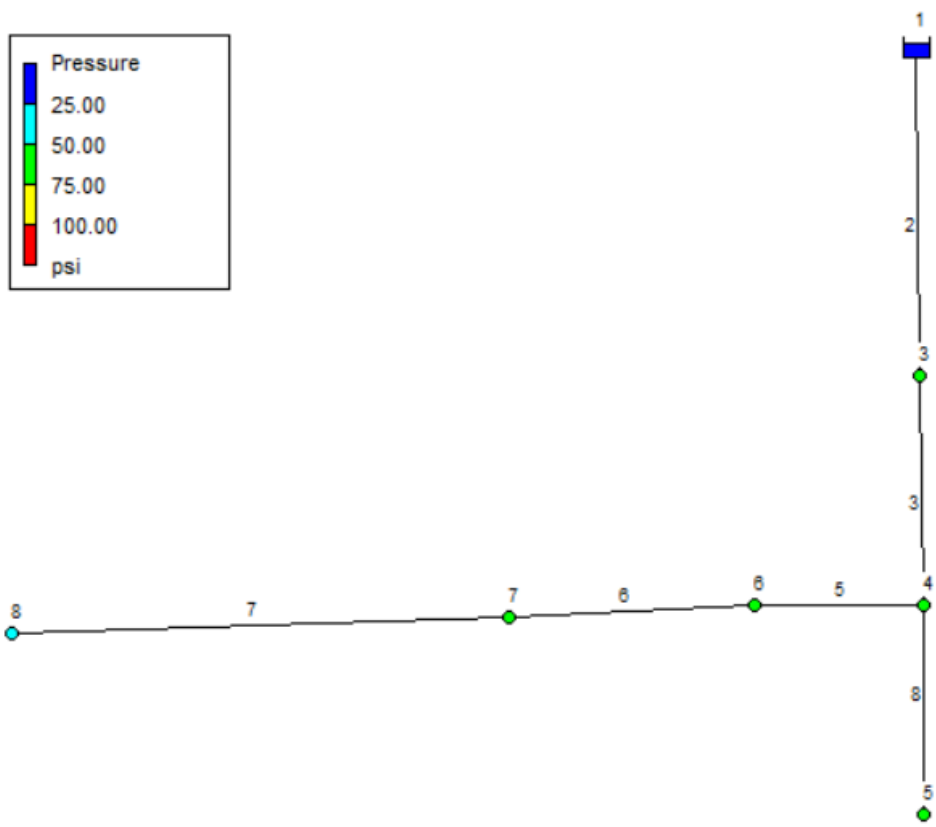

Figure 5: EPANET Model Average Flow and Fire Flow at Junction 8

Case 5:

Table 7: Average Flow and Fire Flow at Junctions 5 and 6

Case 5			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	125.97	54.58
Junc 4	0	103.96	45.49
Junc 5	1000	89.44	40.11
Junc 6	1002	84.9	38.22
Junc 7	1	84.9	37.15
Junc 8	4	84.9	39.41
Resvr 1	-2007	170	0

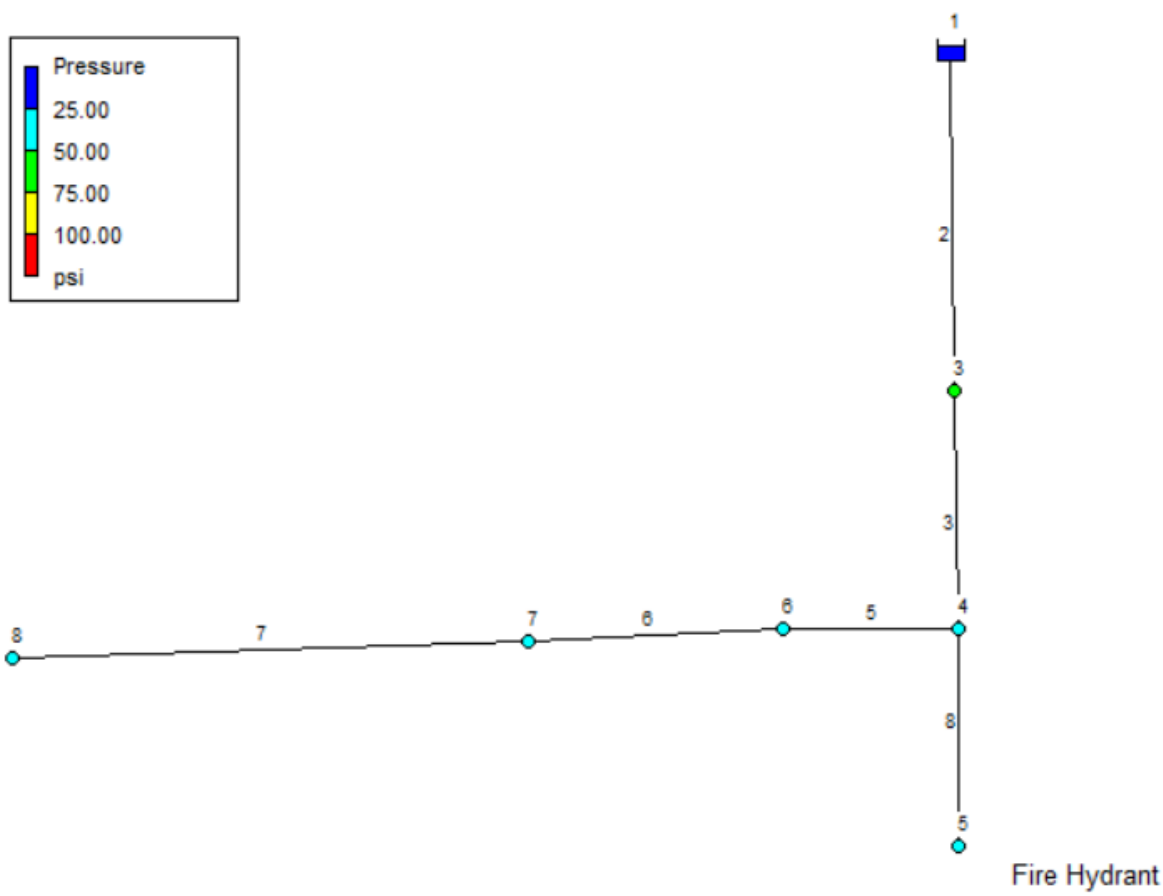

Figure 6: EPANET Model Average Flow and Fire Flow at Junctions 5 and 6

Case 6:

Table 8: Peak Flow

Case 6			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	170	73.66
Junc 4	0	170	74.11
Junc 5	0	170	75.02
Junc 6	3.4	169.99	75.09
Junc 7	1.7	169.99	74.02
Junc 8	6.8	169.99	76.28
Resvr 1	-11.9	170	0

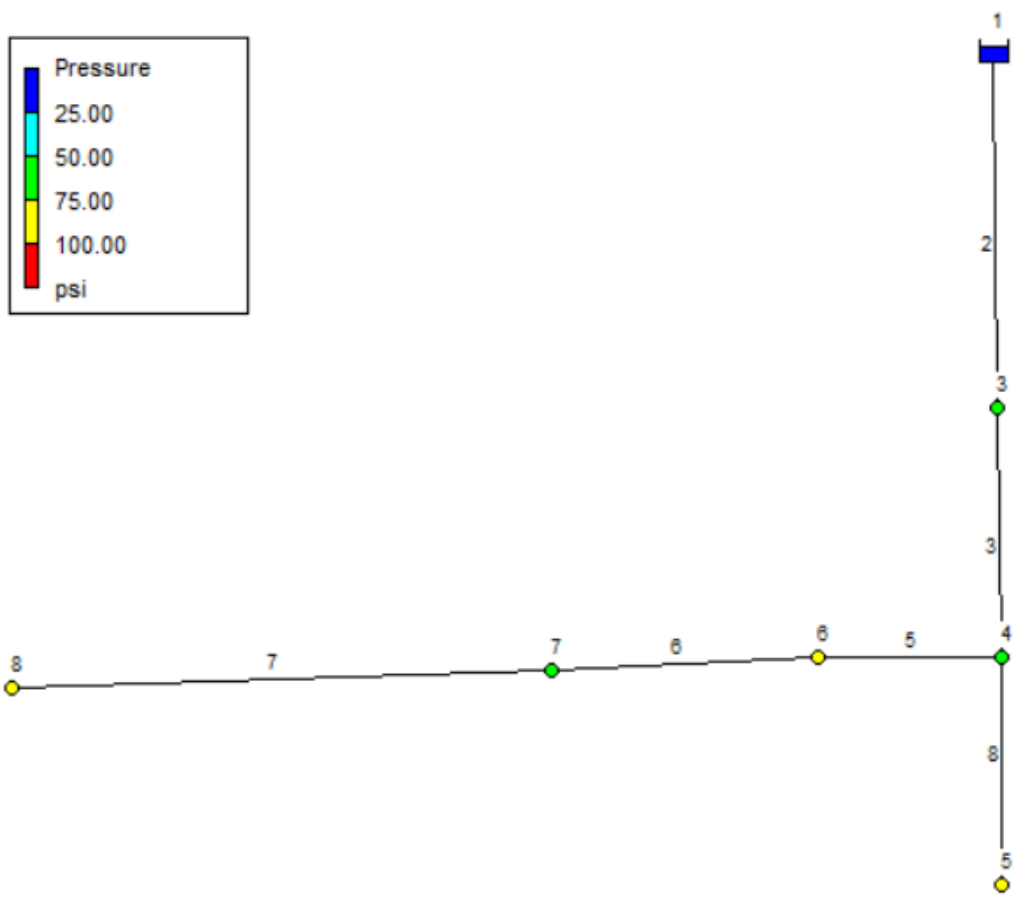

Figure 7: EPANET Model Peak Flow

Case 7:

Table 9: Peak Flow and Fire Flow at Junction 5

Case 7			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	157.61	68.29
Junc 4	0	151.42	66.06
Junc 5	1000	136.9	60.68
Junc 6	3.4	151.42	67.04
Junc 7	1.7	151.41	65.97
Junc 8	6.8	151.41	68.23
Resvr 1	-1011.9	170	0

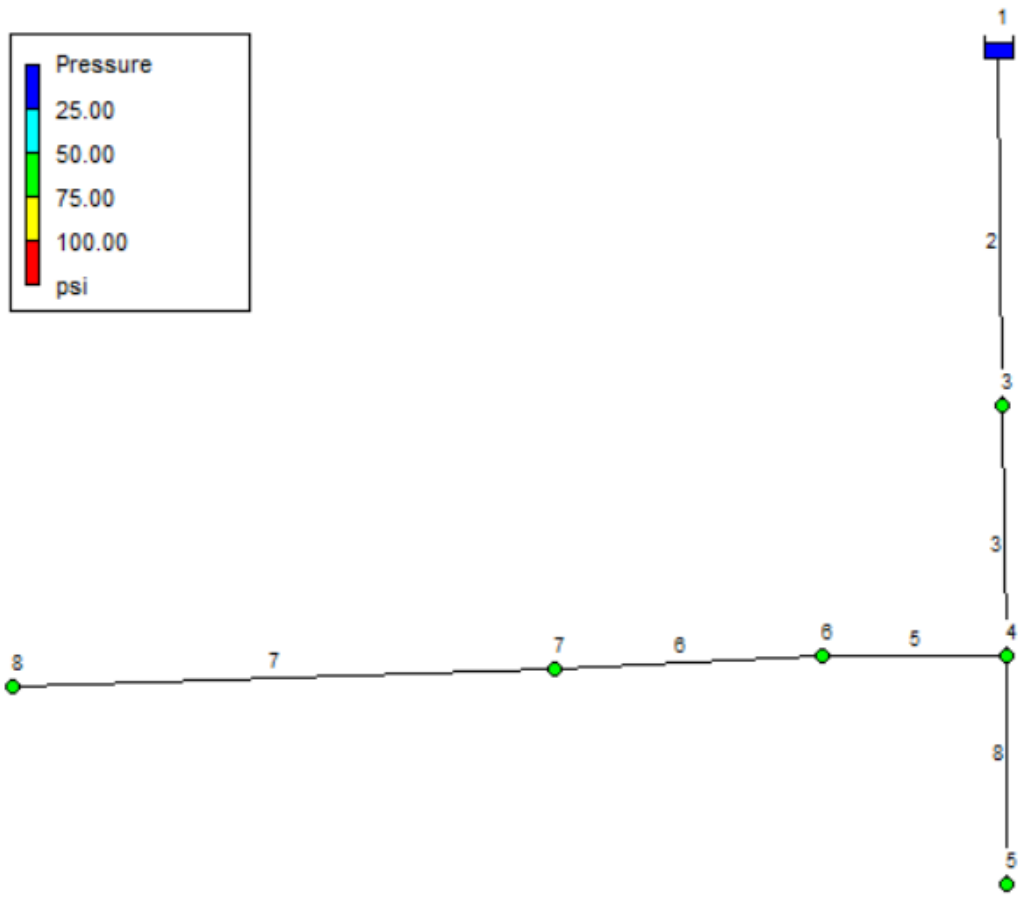

Figure 8: EPANET Model Peak Flow and Fire Flow at Junction 5

Case 8:

Table 10: Peak Flow and Fire Flow at Junction 6

Case 8			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	157.61	68.29
Junc 4	0	151.42	66.06
Junc 5	0	151.42	66.97
Junc 6	1003.4	132.19	58.71
Junc 7	1.7	132.19	57.64
Junc 8	6.8	132.18	59.9
Resvr 1	-1011.9	170	0

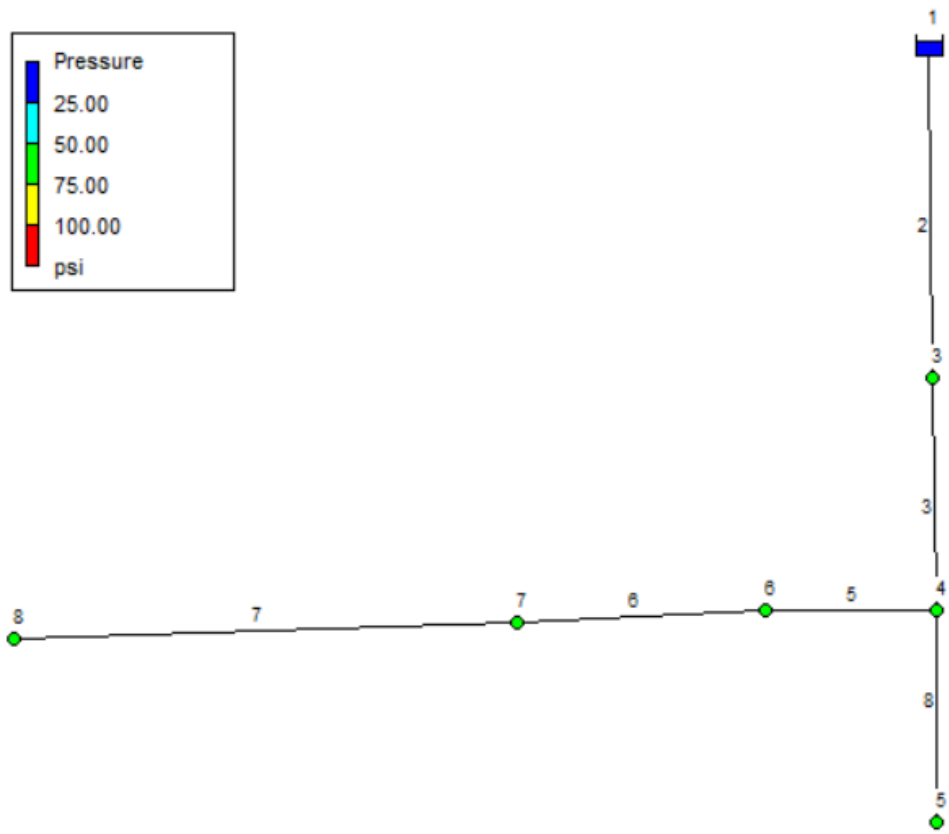

Figure 9: EPANET Model Peak Flow and Fire Flow at Junction 6

Case 9:

Table 11: Peak Flow and Fire Flow at Junction 8

Case 9			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	157.61	68.29
Junc 4	0	151.42	66.06
Junc 5	0	151.42	66.97
Junc 6	3.4	132.19	58.71
Junc 7	1.7	117.54	51.29
Junc 8	1006.8	81.19	37.8
Resvr 1	-1011.9	170	0

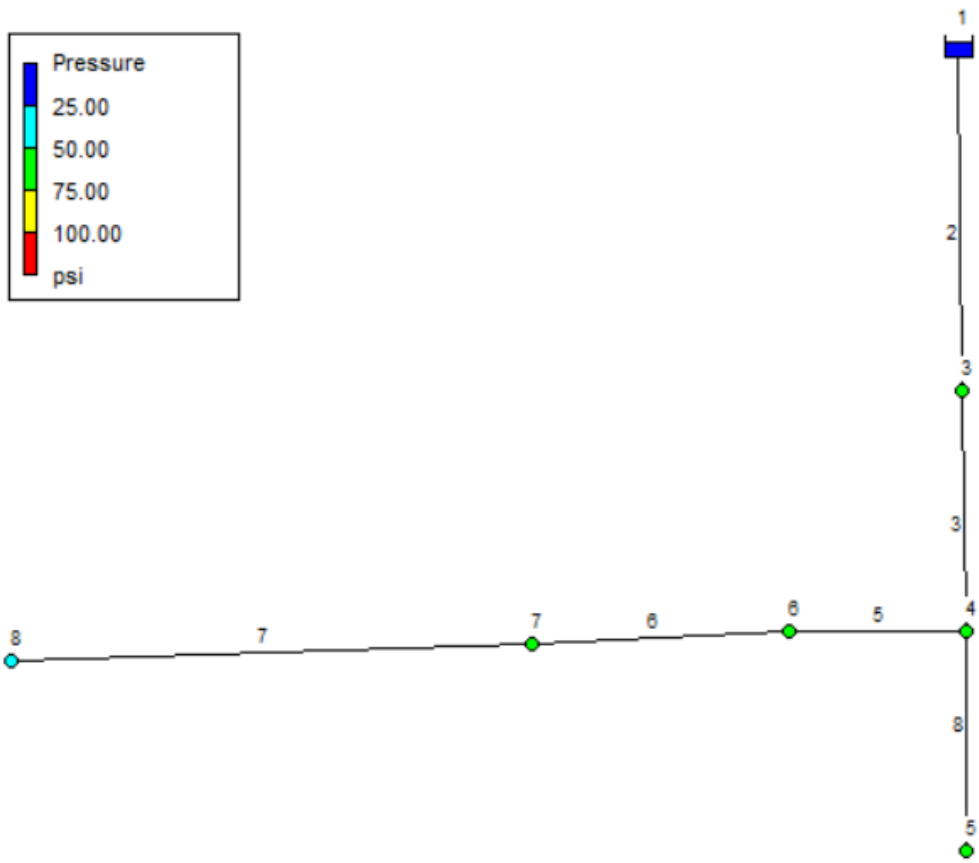

Figure 10: EPANET Model Peak Flow and Fire Flow at Junction 8

Case 10:

Table 12: Peak Flow and Fire Flow at Junctions 5 and 6

Case 10			
Node ID	Demand (gpm)	Head (ft)	Pressure (psi)
Junc 3	0	125.77	54.5
Junc 4	0	103.66	45.37
Junc 5	1000	89.14	39.98
Junc 6	1003.4	84.43	38.02
Junc 7	1.7	84.42	36.94
Junc 8	6.8	84.42	39.2
Resvr 1	-2011.9	170	0

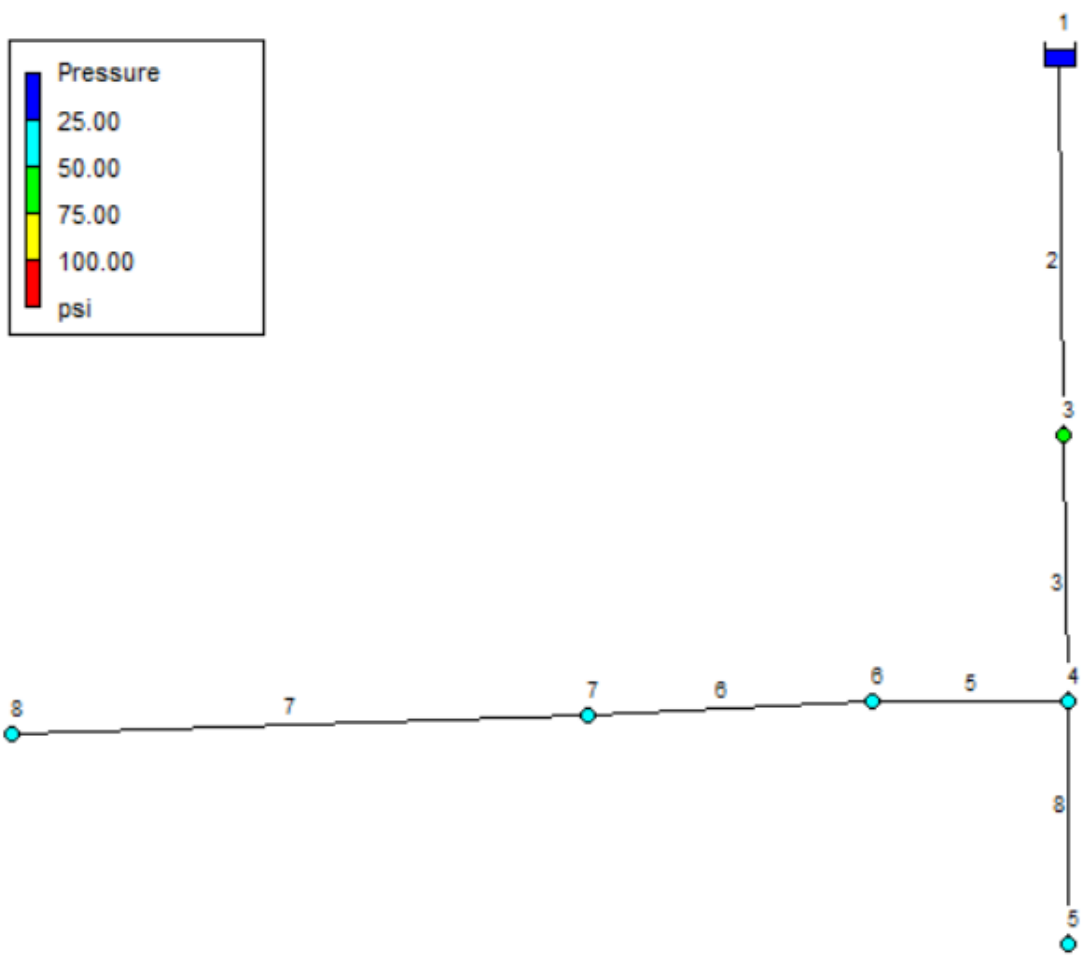

Figure 11: EPANET Model Peak Flow and Fire Flow at Junctions 5 and 6

Appendix D: EPANET Model and Calculations

The model uses energy equations for steady state flow and accounts for head loss to determine the pressure at each junction. The energy balance can be seen below, where both the major and minor head losses are included.

$$z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + H_f + H_L$$

Where

$$z = Elevation$$
$$p = Pressure$$
$$\gamma = Unit\ Weight\ of\ Water$$
$$v = Velocity$$
$$g = Gravity$$
$$H_f = Major\ Head\ Loss$$
$$H_L = Minor\ Head\ Loss$$

The Hazen-Williams formula was used compute the major head loss as follows:

$$H_f = \frac{4.72LQ^{1.85}}{C^{1.85}d^{4.87}}$$

Where

$$L = Length\ of\ Pipe$$
$$Q = Flow$$
$$C = Roughness\ \ Coefficient\ (Hazen - Williams)$$
$$d = internal\ diamter\ of\ the\ pipe$$

The minor head loss was computed as follows

$$H_L = \sum K_L \frac{v^2}{2g}$$

Where

$$K_L = Loss\ Cofficient$$

An example calculation between the reservoir and Junction 3 (junction immediately after reservoir) to compute the pressure at Junction 3 is shown below. The calculation is based on case 7, where there is peak flow and fire flow from the existing fire hydrant. Assuming the reservoir is very large and the surface is at atmospheric pressure, both the velocity and the pressure are negligible at the reservoir. Since, the total head of the reservoir is 170 ft, the sum of the elevation head, velocity head and pressure head for the reservoir is 170 ft.

$$z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + H_f + H_L$$

Rearranging the energy equation, the pressure at Junction 3 (p_2) can be solved.

$$\frac{p_2}{\gamma} = H_r - z_2 - \frac{v_2^2}{2g} - H_f - H_L$$

Where

$$H_r = z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} = Reservoir\ head = 170\ ft$$

$$\gamma = 62.4\frac{lbf}{ft^3}$$

$$g = 32.2\frac{ft}{s^2}$$

$$z_2 = 0\ ft$$

$$p_2 = unknown$$

The velocity at Junction 3 (v_2) can be computed based on flow and the area of the pipe.

$$Q = 1011.9\ gpm * \frac{1\ ft^3}{7.48\ gal} * \frac{1\ \text{min}}{60\ \text{s}} = 2.25\frac{ft^3}{s}$$

$$v_2 = \frac{Q}{A} = \frac{Q}{0.25\pi d^2} = \frac{2.25\frac{ft^3}{s}}{0.25\pi(0.5\ \text{ft})^2} = 11.48\ ft/s$$

Using Hazen-Williams, the major head loss was determined as follows, where the length of the pipe is 200 feet and roughness coefficient is 145 (plastic pipe).

$$H_f = \frac{4.72LQ^{1.85}}{C^{1.85}d^{4.87}} = \frac{4.72(200\ ft)(2.25\frac{ft^3}{s})^{1.85}}{(145)^{1.85}(0.5)^{4.87}} = 12.36\ ft$$

The minor head loss was assumed to be zero. The pressure at Junction 3 can then be computed as follows.

$$\frac{p_2}{\gamma} = 170\ ft - 0ft - \frac{\left(11.48\frac{ft}{s}\right)^2}{2\left(32.2\frac{ft}{s^2}\right)} - 12.36\ ft - 0\ ft$$

$$p_2 = 155.58\ ft * 62.4\frac{lbf}{ft^3} * \frac{1\ ft^2}{12^2 in^2} = 67.4\ psi$$

The pressure at Junction 3 was calculated to be 67.4 psi, which is close to the model's pressure calculation of 68.29 psi. The slight difference can be accounted to rounding errors.