 worked solutions

CE 3372 Water Systems Design
Exam 2
Spring 2025

1. (46 Points) Consider the pipe network portion shown in Figure 1.

   The reservoir has a pool elevation of 1310 meters

   Node 1 elevation is 200.0 meters; Node 2 elevation is 150.0 meters
   Node 3 elevation is 150.0 meters; Node 4 elevation is 100.0 meters
   Node 5 elevation is 100.0 meters; Node 6 elevation is 50.0 meters

   P1 roughness is $e = 0.045$ mm; P2 roughness is $e = 0.045$ mm
   P3 roughness is $e = 0.045$ mm; P4 roughness is $e = 0.090$ mm
   P5 roughness is $e = 0.045$ mm; P6 roughness is $e = 0.045$ mm
   P7 roughness is $e = 0.045$ mm; P8 roughness is $e = 0.045$ mm

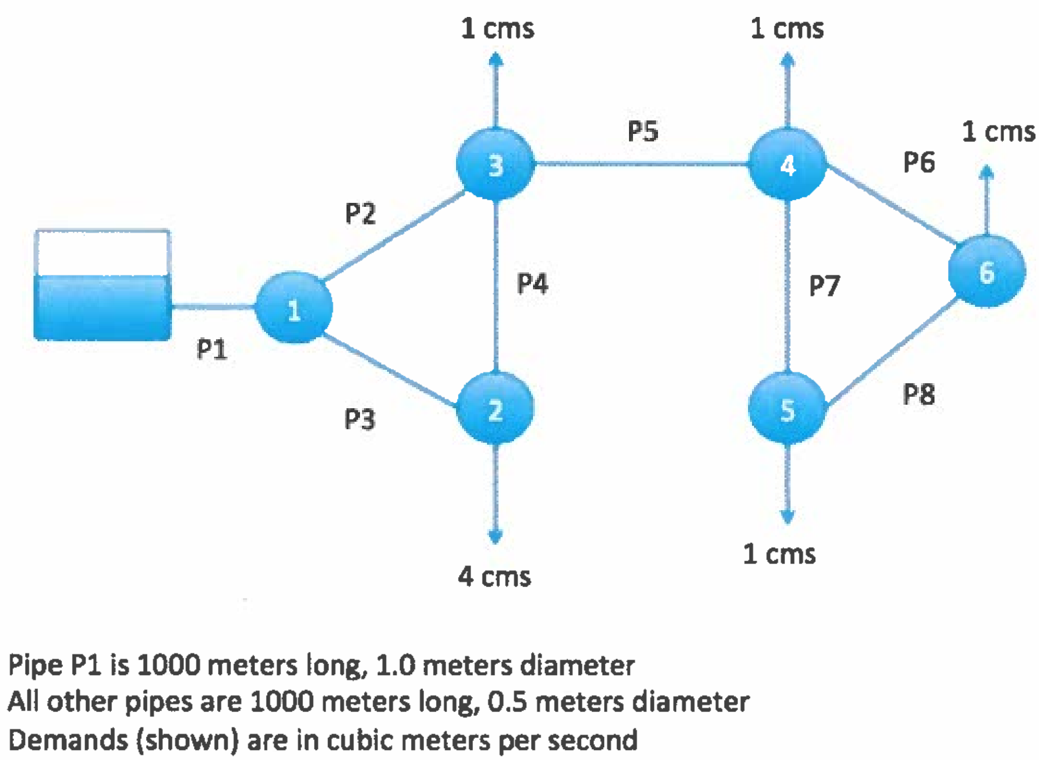


Figure 1. Pipe Network.

a) Use EPANET to determine the discharge, velocity, and head loss in each pipe and populate Table 1

Table 1. Estimated Q, V, and Δh in each pipe in Figure 1

Pipe ID	Discharge (m^3/s)	Velocity (m/s)	Head Loss (m)
1	8	10.2	56.8
2	4	20.4	507.2
3	4	20.4	507.2
4	∅	∅	∅
5	3	15.3	287.0
6	1	5.1	33.2
7	1	5.1	33.2
8	∅	∅	∅

b) Use EPANET to determine the total head and pressure at each node and populate Table 2 below.

Table 2. TDH, z, and P at each node in Figure 1

Node ID	Total Head (m)	Elevation (m)	Pressure (kPa)
Reservoir	1310	N/A	0
1	1253.2	200 ✓	10319
2	746.0	150 ✓	5840
3	746.0	150 ✓	5840
4	459.0	100 ✓	3518
5	425.8	100 ✓	3685
6	425.8	50 ✓	3685

i) Attach a **screen capture** of your EPANET simulation here

ii) Attach the EPANET **summary report** here

To convert p in meters of head

$kPa = meters_{H_2O} * 9.80665$

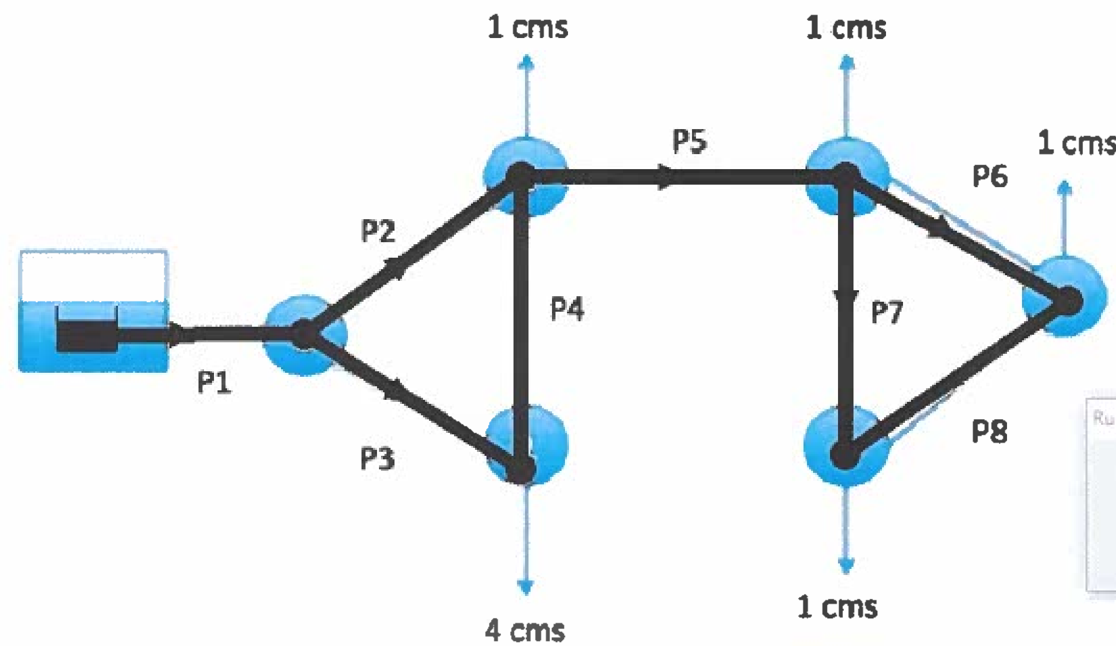
For example node 1 (drawing) is Junc 2 (model) and has reported pressure

$$1053.18\,meters \left(\frac{9.80665\ kPa}{1\,meters_{H_2O}} \right) = 10319\ kPa$$

EPANET 2.2 - ex2.net

File Edit View Project Report Window Help

Network Map



Run Status

Run was successful.

OK

Network Table - Links

Link ID	Flow LPS	Velocity m/s	Unit Headloss m/km
Pipe 1	8000.00	10.19	56.82
Pipe 2	4000.00	20.37	507.21
Pipe 3	4000.00	20.37	507.21
Pipe 4	0.00	0.00	0.00
Pipe 5	3000.00	15.28	286.99
Pipe 6	1000.00	5.09	33.16
Pipe 7	1000.00	5.09	33.16
Pipe 8	0.00	0.00	0.00

ters diameter
g, 0.5 meters diame
ers per second

Network Table - Nodes

Node ID	Elevation m	Head m	Pressure m
Junc 2	200	1253.18	1053.18
Junc 3	150	745.97	595.97
Junc 4	150	745.97	595.97
Junc 5	100	458.98	358.98
Junc 6	100	425.82	325.82
Junc 7	50	425.82	375.82
Resvr 1	1310	1310.00	0.00

Browser

Data Map

Pipes

1
2
3
4
5
6
7

Auto-Length Off | LPS | 100% | X,Y: 924.784, 9963.009

Full Report


```
**********************************************************************
*                           E P A N E T                              *
*                   Hydraulic and Water Quality                      *
*                   Analysis for Pipe Networks                       *
*                          Version 2.2                               *
**********************************************************************
```

Input File: ex2.net

Link - Node Table:

Link ID	Start Node	End Node	Length m	Diameter mm
1	1	2	1000	1000
2	2	4	1000	500
3	2	3	1000	500
4	4	3	1000	500
5	4	5	1000	500
6	5	7	1000	500
7	5	6	1000	500
8	6	7	1000	500

Node Results:

Node ID	Demand LPS	Head m	Pressure m	Quality	
2	0.00	1253.18	1053.18	0.00	
3	4000.00	745.97	595.97	0.00	
4	1000.00	745.97	595.97	0.00	
5	1000.00	458.98	358.98	0.00	
6	1000.00	425.82	325.82	0.00	
7	1000.00	425.82	375.82	0.00	
1	-8000.00	1310.00	0.00	0.00	Reservoir

Link Results:

Link ID	Flow LPS	VelocityUnit m/s	Headloss m/km	Status
1	8000.00	10.19	56.82	Open
2	4000.00	20.37	507.21	Open
3	4000.00	20.37	507.21	Open
4	0.00	0.00	0.00	Open
5	3000.00	15.28	286.99	Open
6	1000.00	5.09	33.16	Open

2. (1 points) The hydraulic radius in a conduit containing a flowing liquid is
   (A) the mean radius from the center of flow to the wetted side of the conduit
   (B) the ratio of the cross-sectional area of the conduit and the wetted perimeter
   (C) the ratio of the wetted perimeter and the cross-sectional area of the conduit
   (D) the ratio of the cross-sectional area of flow and the wetted perimeter
3. (4 points) The rational runoff coefficient for a 14.81 acre parcel property is 0.35. The rainfall intensity is 4.56 inches per hour. Determine the anticipated peak discharge from this property 23.82cfs
4. (4 points) The rational runoff coefficient for a $300X200$-meter property with a slope of 3% is 0.35. The rainfall intensity is 116 mm/hr. Determine the anticipated peak discharge from this property $0.677\ m^3/s$
5. (5 points) A storm sewer (reinforced concrete pipe) is 400-feet long and 30-inches in diameter. The sewer flows from a junction box (invert elevation 101.00 feet) to a lift station sump (invert elevation 100.00 feet). Assuming Manning's roughness coefficient is 0.013 for all flow depths, determine the maximum sewer flow capacity without surcharge 22.19 cfs
6. (5 points) The storm sewer in the question above is flowing at $\frac{3}{4}$ full. What is the discharge in the sewer? 19.32cfs
7. (5 points) A pipe with a diameter of 2.4 meters is depicted in Figure 2. The pipe is flowing partially full.

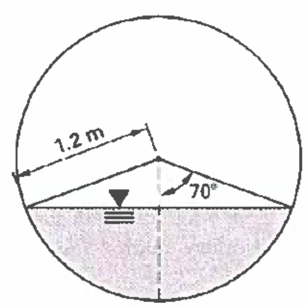


Figure 2. Circular channel flowing partially full..

Determine the hydraulic radius of flow in the circular section.

$R_h = 0.44m$

3) $C = 0.35$ $i = 4.56 \text{ in/hr}$ $A = 14.81 \text{ ac}$

$$Q_p = 1.008 C i A$$
$$= (1.008)(0.35)(4.56)(14.81) = \underline{\underline{23.82}} \text{ ft}^3/\text{s} \leftarrow$$

4) $C = 0.35$ $i = 116 \text{ mm/hr}$ $A = 60{,}000 \text{ m}^2$

- convert A to hectares

$$60{,}000 \text{ m}^2 \frac{1 \text{ ha}}{10{,}000 \text{ m}^2} = 6 \text{ ha}$$

$$Q_p = 0.00278 C i A$$
$$= (0.00278)(0.35)(116)(6) = \underline{\underline{0.6772}} \text{ m}^3/\text{s} \leftarrow$$

or 677 L/s

5) $n = 0.013$ $\Delta Z = 101.00 - 100.00 = 1.0 \text{ ft}$

$D = \frac{30}{12} \text{ ft}$ $L = 400 \text{ ft}$

1) $$Q_f = \frac{1.49}{n} A R^{2/3} S_o^{1/2}$$

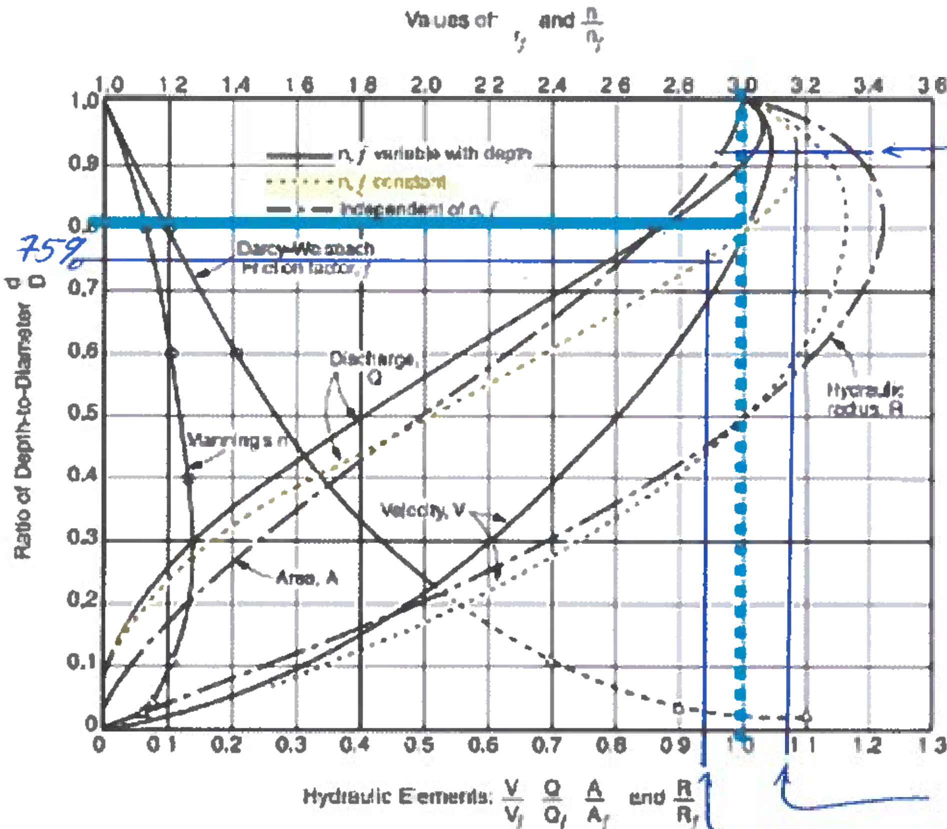
$$S_o = \frac{1.0}{400} = 0.0025$$

$$A = \frac{\pi D^2}{4} = \frac{\pi \left(\frac{30}{12}\right)^2}{4} = 4.908$$

$$P = \pi D = 7.854$$

$$R = \frac{A}{P} = \frac{4.908}{7.854} = 0.625$$

HYDRAULIC-ELEMENTS GRAPH FOR CIRCULAR SEWERS



max flow @ $0.93 \frac{d}{D}$

$\frac{Q}{Q_f} = 1.08$

Design and Construction of Sanitary and Storm Sewers. Water Pollution Control Federation and American Society of Civil Engineers. 1970.

$\frac{Q}{Q_f} = 0.94$

5) continued

$$Q_f = \frac{1.49}{0.013}(4.908)(0.625)^{2/3}(0.0025)^{1/2} = 20.553\ ft^3/s$$

$$Q_{93} = 1.08(Q_f) = \underline{\underline{22.19\ ft^3/s}}$$

6) Same as above, except 75% full

$$Q_{75} = 0.94(Q_f) = \underline{\underline{19.32\ ft^3/s}}$$

7) Using 0.79 meters as depth; formulas from readings

$$\alpha = \cos^{-1}\left(1 - \frac{2(0.79)}{2(1.2m)}\right) = 1.222\ rad\ \frac{90^\circ}{1.5708\ rad}$$

$$= 70.01^\circ \quad (\sim 0.014\%\ error)$$

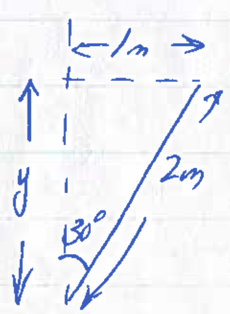
$$A = \frac{[2(1.2m)]^2}{4}(\alpha - \sin\alpha\cos\alpha) = 1.2974\ m^2$$

$$P = 2(1.2m)\alpha = 2.933\ m$$

$$R = A/P = \underline{\underline{0.4424\ m}} \longleftarrow$$

8) $S_0 = 0.005$ $\quad n = 0.013$ (concrete) $\quad T = 2m$

channel cross section is triangle (equilateral based on symmetry & supplied apex angle)



$$y = \sqrt{(2m)^2 - (1m)^2}$$

$$= \sqrt{3} = 1.73\ m$$

$$A = 2\left(\frac{1}{2}(2m)(1.73m)\right) = 1.73m^2$$

$$P = 4m$$

$$R = \frac{1.73m^2}{4m} = 0.433m$$

$$Q = \frac{1}{n}AR^{2/3}S^{1/2}$$

$$= \frac{1}{0.013}(1.73)(0.433)^{2/3}(0.005)^{1/2} = \underline{\underline{5.38\ m^3/s}}$$

8. (5 points) A smooth concrete channel is depicted in Figure 3. The channel's dimensionless slope in the direction of flow is 0.005. The flow width at the surface is 2-meters.

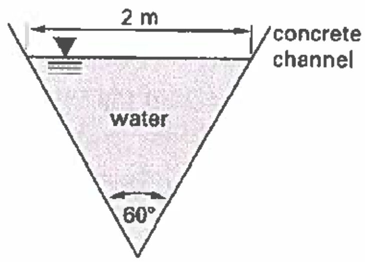


Figure 3. Triangular channel..

Determine the flow rate in the channel. 5.38 m^3/sec

9. (10 points) A 24-inch diameter sewer pipe, with Manning's n of 0.015 is laid on slope $S_0 = 0.01$ as shown in Figure 4.

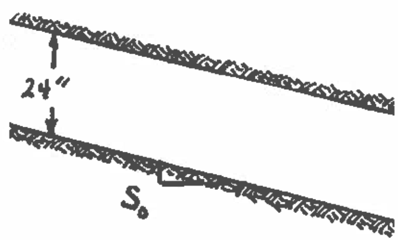


Figure 4. Sewer pipe sketch.

Use Manning's equation and the depth-area, and the depth-perimeter equations to complete Table 3.

Table 3. Depth-Area, Depth-Perimeter, Depth-Hyd. Radius, and Discharge for Circular Sewer.

y (ft)	A (ft^2)	P_w (ft)	R_h (ft)	Q (ft^3/sec)
1.00	1.57 ft^2	3.14 ft	0.5 ft	9.824 ft^3/s
2.00	3.14 ft^2	6.28 ft	0.5 ft	19.649 ft^3/s

10. (15 points)Consider the drainage area depicted in Figure 5. The 6.0 acre drainage area has a runoff coefficient of 0.65, and an inlet time (time of concentration to the inlet depicted in the figure) of 17 minutes. The pipes are concrete (Manning's $n = 0.013$). The initial invert elevations for the junction boxes (MH-1, MH-2, MH-3) are 323.2, 321.1, and 319.0 feet, respectively.

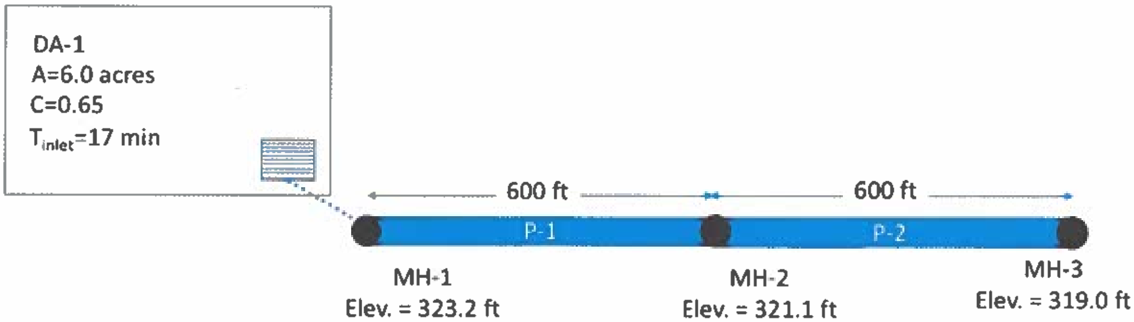


Figure 5. Drainage System Layout.

Equation 1 is the 10-year ARI intensity equation for the area, where I is intensity in inches-per-hour, and T_c is the characteristic time, in minutes.

$$I = \frac{56.6}{(T_c + 8.6)^{0.823}} \tag{1}$$

a) What is the dimensionless slope of the pipe run P1 (connecting MH-1 and MH-2)? $\Delta z = 323.2 - 321.1 = \frac{2.1 \text{ ft}}{600 \text{ ft}} = 0.0035$

b) What is the dimensionless slope of the pipe run P2 (connecting MH-2 and MH-3)? $\Delta z = 321.1 - 319.0 = \frac{2.1 \text{ ft}}{600 \text{ ft}} = 0.0035$

c) What is the CA value for drainage area DA-1?

$(0.65)(6.0) = 3.9$

d) What is the $\sum CA$ value (sum of the upstream products of runoff coefficients and contributing areas) at junction MH-1?

3.9

e) What is the $\sum CA$ value (sum of the upstream products of runoff coefficients and contributing areas) at junction MH-2?

3.9

f) What is the time of concentration to be used to compute the discharge leaving MH-1?

17min

g) What is the rainfall intensity for this time of concentration?

$$i = \frac{56.6}{(17 + 8.6)^{0.823}} = 3.92 \text{ in/hr}$$

h) What is the value of peak discharge leaving MH-1?

$(3.9)(3.92) = 15.28$ cfs

i) What is the pipe diameter for pipe P-1 required the carry the design flow at full pipe depth?

~ 25.2inches (not a common size!)

j) What is the flow velocity in pipe P-1? 4.41 ft/s

k) What is the pipe travel time for pipe P-1? $\frac{600 \text{ ft}}{4.41 \text{ ft/s}} = 136$ sec

l) What is the value of peak discharge leaving MH-2? (Explain your reasoning)

15.28cfs (same as MH1, no new sources)

m) What is the pipe diameter for pipe P-2 required the carry the design flow at full pipe depth?

~ 25.2inches

n) What is the flow velocity in pipe P-2?

4.41 ft/s

o) What is the pipe travel time for pipe P-2?

also 136 sec.