

CE 3372 Water Systems Design
Fall 2016¹

1. (1 pts.) 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
2. (5 pts.) The rational runoff coefficient for a 14.31 acre parcel property is 0.85. The rainfall intensity is 6.54 inches per hour. The peak discharge from this property is anticipated to be about
 - (A) 23.82 cfs
 - (B) 28.41 cfs
 - (C) 33.01 cfs
 - (D) 48.18 cfs
 - (E) 57.86 cfs
 - (F) 65.90 cfs
 - (G) 80.18 cfs
3. (8 pts.) A storm sewer (reinforced concrete pipe) is 400-feet long and 36-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 0.015 for all flow depths, the sewer maximum flow capacity without surcharge is about
 - (A) 17.8 cfs
 - (B) 19.2 cfs
 - (C) 20.6 cfs
 - (D) 22.1 cfs
 - (E) 28.9 cfs
 - (F) 31.2 cfs
 - (G) 33.4 cfs
 - (H) 35.9 cfs

¹For partial credit show work

4. (8 pts.) What is the discharge in the storm sewer above if it is flowing at $\frac{3}{4}$ full?
- (A) $Q_{75\%} = 16.2$ cfs
 - (B) $Q_{75\%} = 18.7$ cfs
 - (C) $Q_{75\%} = 22.6$ cfs
 - (D) $Q_{75\%} = 23.6$ cfs
 - (E) $Q_{75\%} = 24.3$ cfs
 - (F) $Q_{75\%} = 26.4$ cfs
 - (G) $Q_{75\%} = 29.9$ cfs
 - (H) $Q_{75\%} = 30.4$ cfs
5. (11 pts.) A pipe with a diameter of 2.4 meters is depicted in Figure 1. The pipe is flowing partially full.

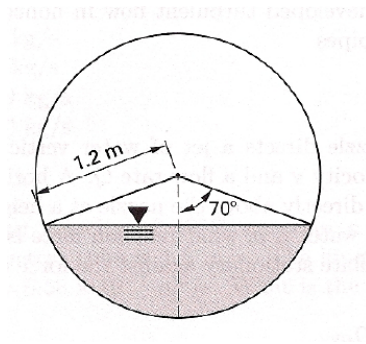


Figure 1: Circular channel flowing partially full.

What is the hydraulic radius of flow in the circular section?

- (A) 0.21 m
- (B) 0.44 m
- (C) 1.30 m
- (D) 1.39 m
- (E) 1.44 m
- (F) 1.68 m
- (G) 1.80 m
- (H) 2.80 m

6. (12 pts.) A smooth concrete channel ($n=0.012$) is depicted in Figure 2. The channel's dimensionless slope in the direction of flow is 0.005. If the flow width at the surface is 2-meter, what is the flow rate in the channel using Manning's equation?

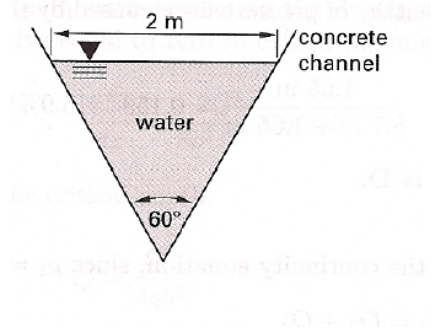


Figure 2: Triangular channel.

- (A) 0.24 cms (cubic meters per second)
- (B) 0.31 cms
- (C) 3.52 cms
- (D) 3.91 cms
- (E) 4.41 cms
- (F) 4.45 cms
- (G) 5.83 cms
- (H) 6.66 cms

7. (19 pts.) 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 3.

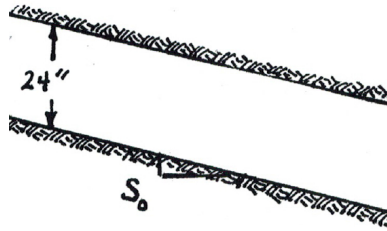


Figure 3: Sewer pipe sketch

Use Manning's equation and the depth-area, and the depth-perimeter equations on the equation sheet to complete Table 1.

Table 1: 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				
2.00				

8. (8 pts.) Figure 4 is a sketch of a 24 inch line with Manning's n of 0.015, on a slope of 0.01, connecting to a 48 inch line (also at 0.01) at a junction box. The flowlines (invert elevations) match at the junction box. The downstream boundary conditions cause the flow depth in the 48-inch line to be 12-inches deep.

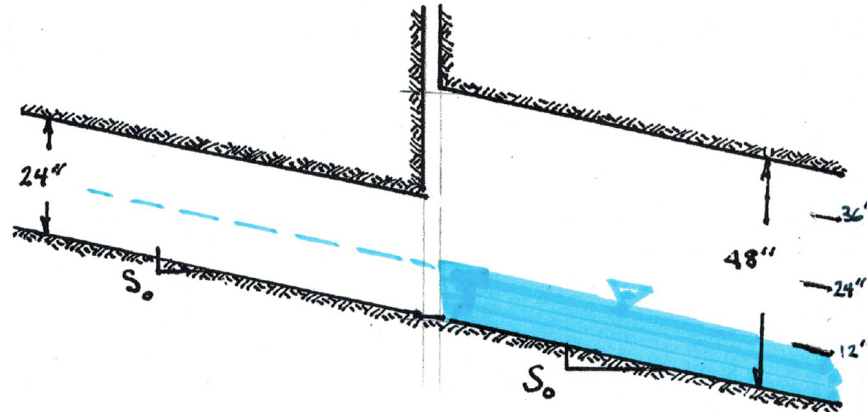


Figure 4: Sewer pipes connected at a junction box. Matching flow line elevations.

- (A) The likely flow depth in the 24 inch line (at the junction box) is
- i) 12.0-inches
 - ii) 18.0-inches
 - iii) 24.0-inches
 - iv) 36.0-inches
 - v) 48.0-inches
- (B) The discharge in the 24 inch line, assuming normal flow at the flow depth in the junction box is
- i) 0.00 cfs
 - ii) 2.45 cfs
 - iii) 4.92 cfs
 - iv) 9.83 cfs
 - v) 19.66 cfs
 - vi) 39.32 cfs

(C) The full-pipe discharge in the 24 inch line, assuming normal flow, is

- i) 0.00 cfs
- ii) 2.45 cfs
- iii) 4.92 cfs
- iv) 9.83 cfs
- v) 19.66 cfs
- vi) 39.32 cfs

(D) What is the unused flow capacity (in cfs) in the 24 inch line?

9. (8 pts.) Figure 5 is a sketch of a 24 inch line with Manning's n of 0.015, on a slope of 0.01, connecting to a 48 inch line (also at 0.01) at a junction box. The soffit(crown) elevations match at the junction box. The downstream boundary conditions cause the flow depth in the 48 line to be 36 inches deep.

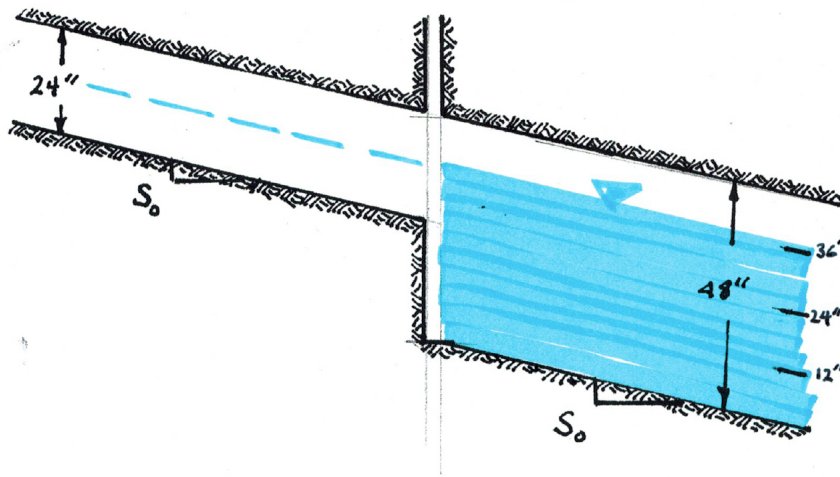


Figure 5: Sewer pipes connected at a junction box. Matching soffit elevations.

- (A) The likely flow depth in the 24 inch line (at the junction box) is
- i) 12.0-inches
 - ii) 18.0-inches
 - iii) 24.0-inches
 - iv) 36.0-inches
 - v) 48.0-inches
- (B) The discharge in the 24 inch line, assuming normal flow at the flow depth in the junction box is
- i) 0.00 cfs
 - ii) 2.45 cfs
 - iii) 4.92 cfs
 - iv) 9.83 cfs
 - v) 19.66 cfs
 - vi) 39.32 cfs

(C) The full-pipe discharge in the 24 inch line, assuming normal flow, is

- i) 0.00 cfs
- ii) 2.45 cfs
- iii) 4.92 cfs
- iv) 9.83 cfs
- v) 19.66 cfs
- vi) 39.32 cfs

(D) What is the unused flow capacity (in cfs) in the 24 inch line?

10. (8 pts.) Figure 6 is a sketch of a 24 inch line with Manning's n of 0.015, on a slope of 0.01, connecting to a 48 inch line (also at 0.01) at a junction box. The soffit(crown) elevations match at the junction box. The downstream boundary conditions cause the flow depth in the 48 line to be 36 inches deep.

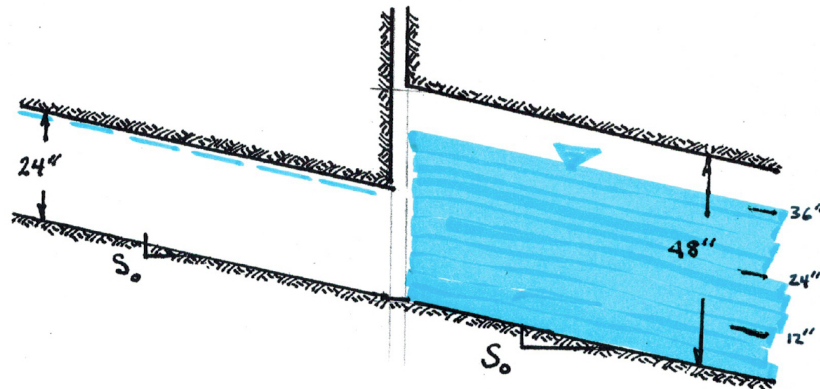


Figure 6: Sewer pipes connected at a junction box. Matching flow line elevations.

- (A) The likely flow depth in the 24 inch line (at the junction box) is
- i) 12.0-inches
 - ii) 18.0-inches
 - iii) 24.0-inches
 - iv) 36.0-inches
 - v) 48.0-inches
- (B) The discharge in the 24 inch line, assuming normal flow at the flow depth in the pipe is
- i) 0.00 cfs
 - ii) 2.45 cfs
 - iii) 4.92 cfs
 - iv) 9.83 cfs
 - v) 19.66 cfs
 - vi) 39.32 cfs
 - vii) 49.32 cfs

(C) The full-pipe discharge in the 24 inch line, assuming normal flow, is

- i) 0.00 cfs
- ii) 2.45 cfs
- iii) 4.92 cfs
- iv) 9.83 cfs
- v) 19.66 cfs
- vi) 39.32 cfs
- vii) 49.32 cfs

(D) What is the unused flow capacity (in cfs) in the 24 inch line?

11. (46 pts.) An EPA-NET simulation model for a reservoir-pump-network was constructed and operated for four (4) different operational scenarios. Figure 7 is a depiction of the network. The numbers next to the nodes are Node_ID values in the reports that follow, and the numbers next to the pipes are the Link_ID values. The network is supplied from a reservoir through a booster pump, both are depicted on Figure 7.

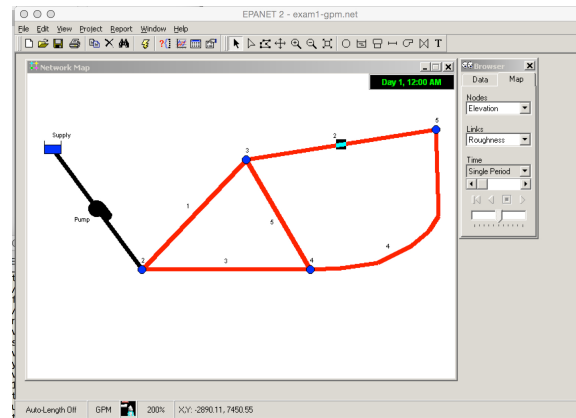


Figure 7: EPA-NET system topology.

Figure 8 is the a portion of the summary report for simulation 1. Figure 9 is the a portion of the summary report for simulation 2. Figure 10 is the a portion of the summary report for simulation 3. Figure 11 is the a portion of the summary report for simulation 4.

These four simulation represent different demand scenarios for the same system.

Interpret these reports, to answer the following questions:

- (a) Complete the table below. Q_{pump} is the discharge in gallons-per-minute through the pump station, H_{Supply} is the head at the supply reservoir, H_{Node2} is the head at Node 2, and ΔH_{pump} is the added head supplied by the pump.

Table 2: Pump Discharge and Supplied Head				
Simulation #	Q_{pump}	H_{Supply}	H_{Node2}	ΔH_{pump}
1				
2				
3				
4				

- (b) Complete the table below. Q_{pump} is the discharge in gallons-per-minute through the pump station, $\Delta H_{Node2-to-5}$ is head loss in the system from Node 2 to Node 5.

Table 3: System Discharge and Head Loss

Simulation #	Q_{pump}	H_{Node2}	H_{Node5}	$\Delta H_{Node2-to-5}$
1				
2				
3				
4				

- (c) If the pump performance curve has the mathematical structure:
 $H_{pump} = H_{shutoff} - K_{pipe} \times Q^2$, estimate the values of $H_{shutoff}$ and K_{pipe} .

- (d) If the system frictional loss curve has the mathematical structure: $H_{pipe} = K_{loss} \times Q^2$, estimate the value of K_{loss}

- (e) What effect would removing the pipe joining nodes 3 and 4 have on the system performance? Explain your reasoning.
- (f) Estimate the flow distribution and head losses the the system if the the pipe joining nodes 3 and 4 are removed, and the pipe joining node 4 and 5 is removed if the nodal demands are the same as SIMULATION 2.

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*****
*                      E P A N E T                      *
*          Hydraulic and Water Quality                    *
*          Analysis for Pipe Networks                     *
*          Version 2.0                                    *
*****
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Input File: exam1-gpm.net

Link - Node Table:

Link ID	Start Node	End Node	Length ft	Diameter in
1	2	3	3280	5
2	3	5	3280	5
3	2	4	3280	5
4	4	5	3280	5
5	3	4	1000	5
6	1	2	#N/A	#N/A Pump

Node Results:

Node ID	Demand GPM	Head ft	Pressure psi	Quality
2	0.00	65.60	28.42	0.00
3	0.00	65.60	28.42	0.00
4	0.00	65.60	28.42	0.00
5	0.00	65.60	28.42	0.00
1	0.00	0.00	0.00	0.00 Reservoir

Link Results:

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
1	0.06	0.00	0.00	Open
2	-0.06	0.00	0.00	Open
3	-0.06	0.00	0.00	Open
4	0.06	0.00	0.00	Open
5	0.11	0.00	0.00	Open
6	0.00	0.00	-65.60	Open Pump

Figure 8: EPA-NET Summary Report, Simulation #1

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*****
*                               E P A N E T                               *
*                               Hydraulic and Water Quality                 *
*                               Analysis for Pipe Networks                 *
*                               Version 2.0                               *
*****
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Input File: exam1-gpm.net

Link - Node Table:

Link ID	Start Node	End Node	Length ft	Diameter in
1	2	3	3280	5
2	3	5	3280	5
3	2	4	3280	5
4	4	5	3280	5
5	3	4	1000	5
6	1	2	#N/A	#N/A Pump

Node Results:

Node ID	Demand GPM	Head ft	Pressure psi	Quality
2	0.00	61.46	26.63	0.00
3	15.78	60.87	26.37	0.00
4	15.78	60.87	26.37	0.00
5	15.78	60.78	26.34	0.00
1	-47.34	0.00	0.00	0.00 Reservoir

Link Results:

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
1	23.67	0.39	0.18	Open
2	7.89	0.13	0.03	Open
3	23.67	0.39	0.18	Open
4	7.89	0.13	0.03	Open
5	0.00	0.00	0.00	Open
6	47.34	0.00	-61.46	Open Pump

Figure 9: EPA-NET Summary Report, Simulation #2

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*                               E P A N E T                               *
*                               Hydraulic and Water Quality                 *
*                               Analysis for Pipe Networks                   *
*                               Version 2.0                                *
*****
```

Input File: exam1-gpm.net

Link - Node Table:

Link ID	Start Node	End Node	Length ft	Diameter in
1	2	3	3280	5
2	3	5	3280	5
3	2	4	3280	5
4	4	5	3280	5
5	3	4	1000	5
6	1	2	#N/A	#N/A Pump

Node Results:

Node ID	Demand GPM	Head ft	Pressure psi	Quality
2	0.00	56.15	24.33	0.00
3	31.56	54.01	23.40	0.00
4	31.56	54.01	23.40	0.00
5	31.56	53.72	23.28	0.00
1	-94.68	0.00	0.00	0.00 Reservoir

Link Results:

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
1	47.34	0.77	0.65	Open
2	15.78	0.26	0.09	Open
3	47.34	0.77	0.65	Open
4	15.78	0.26	0.09	Open
5	0.00	0.00	0.00	Open
6	94.68	0.00	-56.15	Open Pump

Figure 10: EPA-NET Summary Report, Simulation #3

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*****
*                               E P A N E T                               *
*                               Hydraulic and Water Quality                 *
*                               Analysis for Pipe Networks                 *
*                               Version 2.0                               *
*****

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Input File: exam1-gpm.net

Link - Node Table:

Link ID	Start Node	End Node	Length ft	Diameter in
1	2	3	3280	5
2	3	5	3280	5
3	2	4	3280	5
4	4	5	3280	5
5	3	4	1000	5
6	1	2	#N/A	#N/A Pump

Node Results:

Node ID	Demand GPM	Head ft	Pressure psi	Quality
2	0.00	44.34	19.21	0.00
3	47.34	39.73	17.22	0.00
4	47.34	39.73	17.22	0.00
5	47.34	39.14	16.96	0.00
1	-142.02	0.00	0.00	0.00 Reservoir

Link Results:

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
1	71.01	1.16	1.41	Open
2	23.67	0.39	0.18	Open
3	71.01	1.16	1.41	Open
4	23.67	0.39	0.18	Open
5	0.01	0.00	0.00	Open
6	142.02	0.00	-44.34	Open Pump

Figure 11: EPA-NET Summary Report, Simulation #4