CE 3372 Water Systems Design
Fall 2017 [1]

1. (1 pts.) The hydraulic radius in a conduit containing a flowing liquid is

   (A) the ratio of the cross-sectional area of flow and the wetted perimeter

   (B) the mean radius from the center of flow to the wetted side of the conduit

   (C) the ratio of the cross-sectional area of the conduit and the wetted perimeter

   (D) the ratio of the wetted perimeter and the cross-sectional area of the conduit

2. (5 pts.) The rational runoff coefficient for a 14.81 acre parcel property is 0.35. The rainfall intensity is 4.56 inches per hour. The peak discharge from this property is anticipated to be about

   (A) 23.82 cfs

   (B) 33.01 cfs

   (C) 48.18 cfs

   (D) 57.86 cfs

   (E) 65.90 cfs

   (F) 80.18 cfs

   (G) 97.81 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 0.013 for all flow depths, the full-sewer flow is about

   (A) 17.8 cfs

   (B) 19.2 cfs

   (C) 22.1 cfs

   (D) 28.9 cfs

   (E) 31.2 cfs

   (F) 33.4 cfs

   (G) 35.9 cfs

   (H) 36.4 cfs

[1] For partial credit show work

4. (8 pts.) The storm sewer in the question above is flowing at $\frac{3}{4}$ full. What is the discharge in the sewer?

   (A) $Q_{75\%} = 16.9$ cfs

   (B) $Q_{75\%} = 18.2$ cfs

   (C) $Q_{75\%} = 20.1$ cfs

   (D) $Q_{75\%} = 27.5$ cfs

   (E) $Q_{75\%} = 32.3$ cfs

   (F) $Q_{75\%} = 31.7$ cfs

   (G) $Q_{75\%} = 34.1$ cfs

   (H) $Q_{75\%} = 34.5$ cfs

5. (8 pts.) A triangular V-shaped channel is depicted in Figure 1. The channel's dimensionless slope in the direction of flow is 0.008. Manning's N for the channel is $n = 0.012$. The flow width at the surface is $T = 2$ meters.[2]

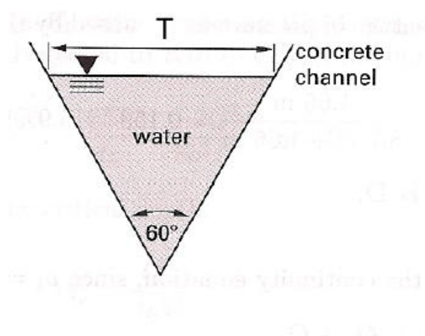

Figure 1: Triangular channel.

A) What is the flow width?

(A) 1 m	(E) 5 m
(B) 2 m	(F) 6 m
(C) 3 m	(G) 7 m
(D) 4 m	(H) 8 m

B) What is the flow depth?

(A) 1 m	(E) 5 m
(B) 2 m	(F) 6 m
(C) 3 m	(G) 7 m
(D) 4 m	(H) 8 m

C) What is the wetted perimeter?

(A) 2 m	(E) 10 m
(B) 4 m	(F) 12 m
(C) 6 m	(G) 14 m
(D) 8 m	(H) 16 m

D) What is the flow area?

A) 111 m^3/s	E) 111 m^3/s
B) 111 m^3/s	F) 111 m^3/s
C) 111 m^3/s	G) 111 m^3/s
D) 111 m^3/s	H) 111 m^3/s

[2] Show your work on the next page for full credit.

E) What is the flow rate using Manning's equation?

A) 111 m^3/s
B) 111 m^3/s
C) 111 m^3/s
D) 111 m^3/s
E) 111 m^3/s
F) 111 m^3/s
G) 111 m^3/s
H) 111 m^3/s

Show work for Problem 5 below:

6. (11 pts.) A partially-full pipe with a radius of r meters is depicted in Figure 2. The angle shown is $\alpha = 70^o$

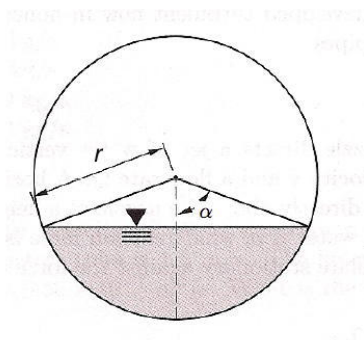

Figure 2: Circular channel flowing partially full.

A) What is the angle in radians?

(A) 1 m
(B) 2 m
(C) 3 m
(D) 4 m
(E) 5 m
(F) 6 m
(G) 7 m
(H) 8 m

B) What is the flow depth?

(A) 1 m
(B) 2 m
(C) 3 m
(D) 4 m
(E) 5 m
(F) 6 m
(G) 7 m
(H) 8 m

C) What is the wetted perimeter?

(A) 2 m
(B) 4 m
(C) 6 m
(D) 8 m
(E) 10 m
(F) 12 m
(G) 14 m
(H) 16 m

D) What is the hydraulic radius?

(A) 2 m
(B) 4 m
(C) 6 m
(D) 8 m
(E) 10 m
(F) 12 m
(G) 14 m
(H) 16 m

E) What is the flow area?

A) 111 m^3/s
B) 111 m^3/s
C) 111 m^3/s
D) 111 m^3/s
E) 111 m^3/s
F) 111 m^3/s
G) 111 m^3/s
H) 111 m^3/s

F) What is the flow rate using Manning's equation?

A) 111 m^3/s
B) 111 m^3/s
C) 111 m^3/s
D) 111 m^3/s
E) 111 m^3/s
F) 111 m^3/s
G) 111 m^3/s
H) 111 m^3/s

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

(A) 0.44 m

(B) 0.88 m

(C) 1.30 m

(D) 1.80 m

(E) 0.44 m

(F) 0.88 m

(G) 1.30 m

(H) 1.80 m

Show work for Problem 6 below:

7. (46 pts.) An EPA-NET simulation model for a reservoir-pump-network was constructed and operated for four (4) different operational scenarios. Figure 3 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 3.

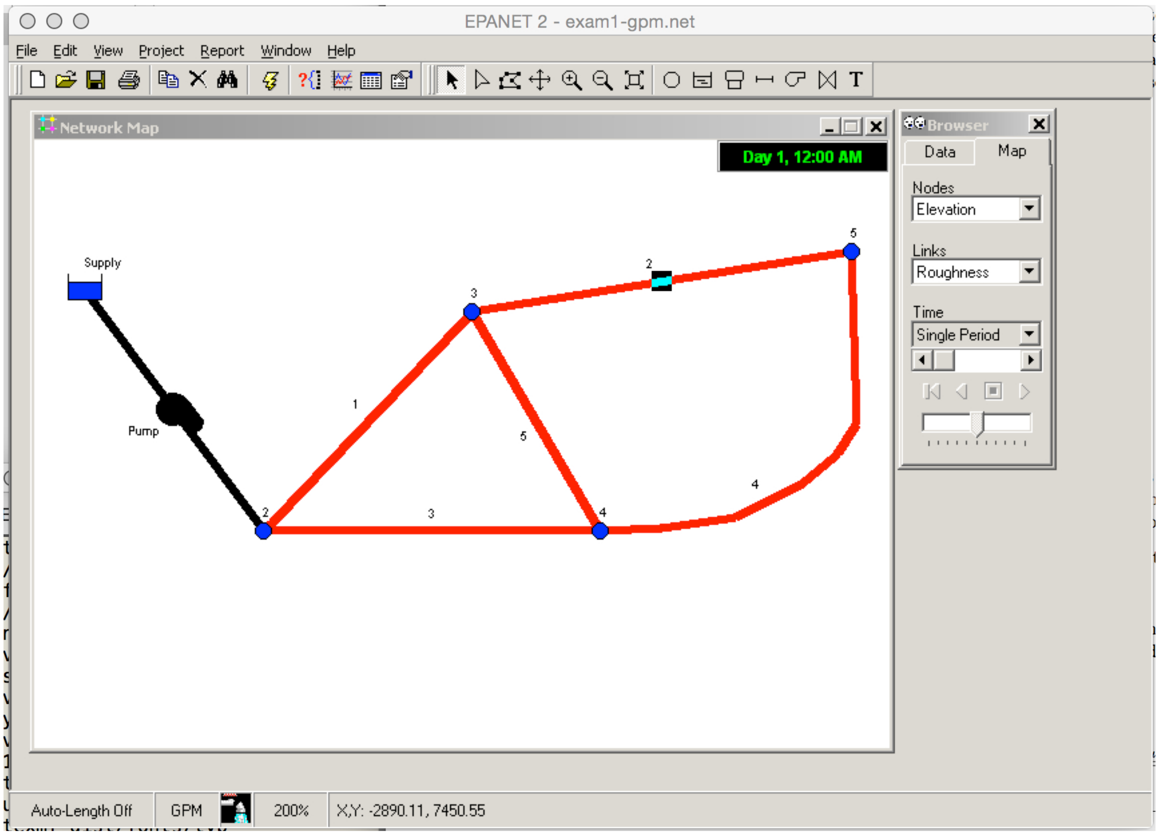

Figure 3: EPA-NET system topology.

Figure 6 is an output report for simulation 1.
Figure 7 is an output report for simulation 2.
Figure 8 is an output report for simulation 3.
Figure 9 is an output report for simulation 4.

These four simulation represent different demand scenarios for the same system. Interpret these reports, to answer the following questions:

a) Which of the four simulations most closely represents a shut-off (zero discharge) condition?

A) Simulation #1.

B) Simulation #2.

C) Simulation #3.

D) Simulation #4.

b) What is the total head at the supply reservoir for each simulation?

A) $\approx$ 0 ft.

B) $\approx$ 31 ft.

C) $\approx$ 100 ft.

D) $\approx$ 100 m.

c) What is the total head at node #2 for simulation #1?

A) $\approx$ 113 ft.

B) $\approx$ 117 ft.

C) $\approx$ 118 ft.

D) $\approx$ 120 ft.

d) What is the total head at node #2 for simulation #2?

A) $\approx$ 113 ft.

B) $\approx$ 117 ft.

C) $\approx$ 118 ft.

D) $\approx$ 120 ft.

e) What is the total head at node #2 for simulation #3?

A) $\approx$ 113 ft.

B) $\approx$ 117 ft.

C) $\approx$ 118 ft.

D) $\approx$ 120 ft.

f) What is the total head at node #2 for simulation #4?

A) $\approx$ 113 ft.

B) $\approx$ 117 ft.

C) $\approx$ 118 ft.

D) $\approx$ 120 ft.

g) 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 $\Delta H_{pump} = H_{Node2} - H_{Supply}$ is the added head supplied by the pump.

Table 1: Pump Discharge and Supplied Head

Simulation #	Q_{pump}	H_{Supply}	H_{Node2}	ΔH_{pump}
1				
2				
3				
4				

h) 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 2: System Discharge and Head Loss

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

i) Sketch and the pump curve on Figure 4 below.

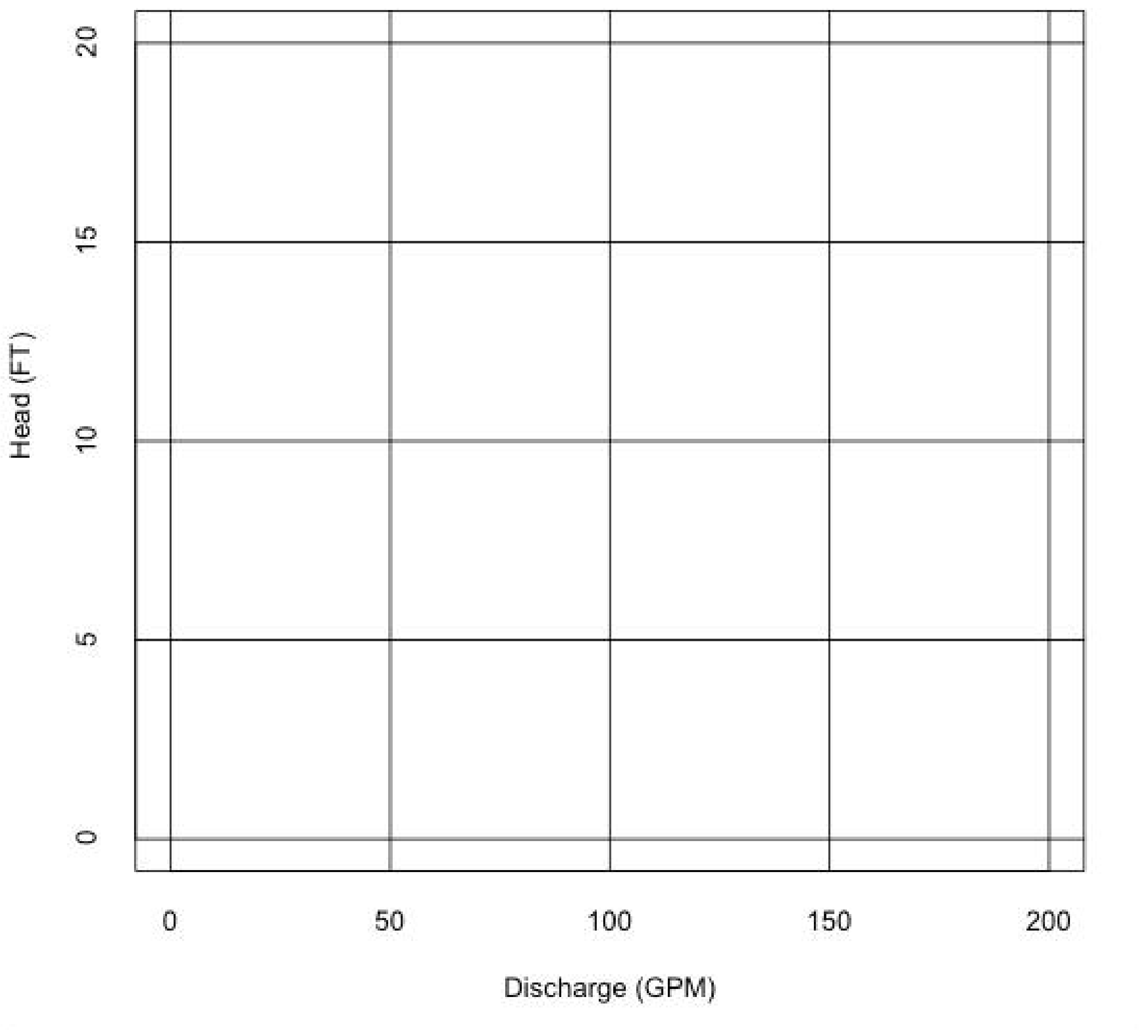

Figure 4: Pump Performance Curve

j) Estimate the value of K_{system} if the pump performance curve has the mathematical structure: $\Delta H_{pump} = H_{shutoff} - K_{system} \times Q^2_{pump}$,

k) Estimate the value of K_{loss} if the system loss curve has the mathematical structure: $\Delta H_{Node~2-to-5} ~ = K_{loss} \times Q^2_{pump}$,

l) Estimate the discharges, head losses, and nodal heads if pipes 4 and 5 are removed and the nodal demands are as shown on Figure 5. (Same demand as Simulation # 2.)[3]

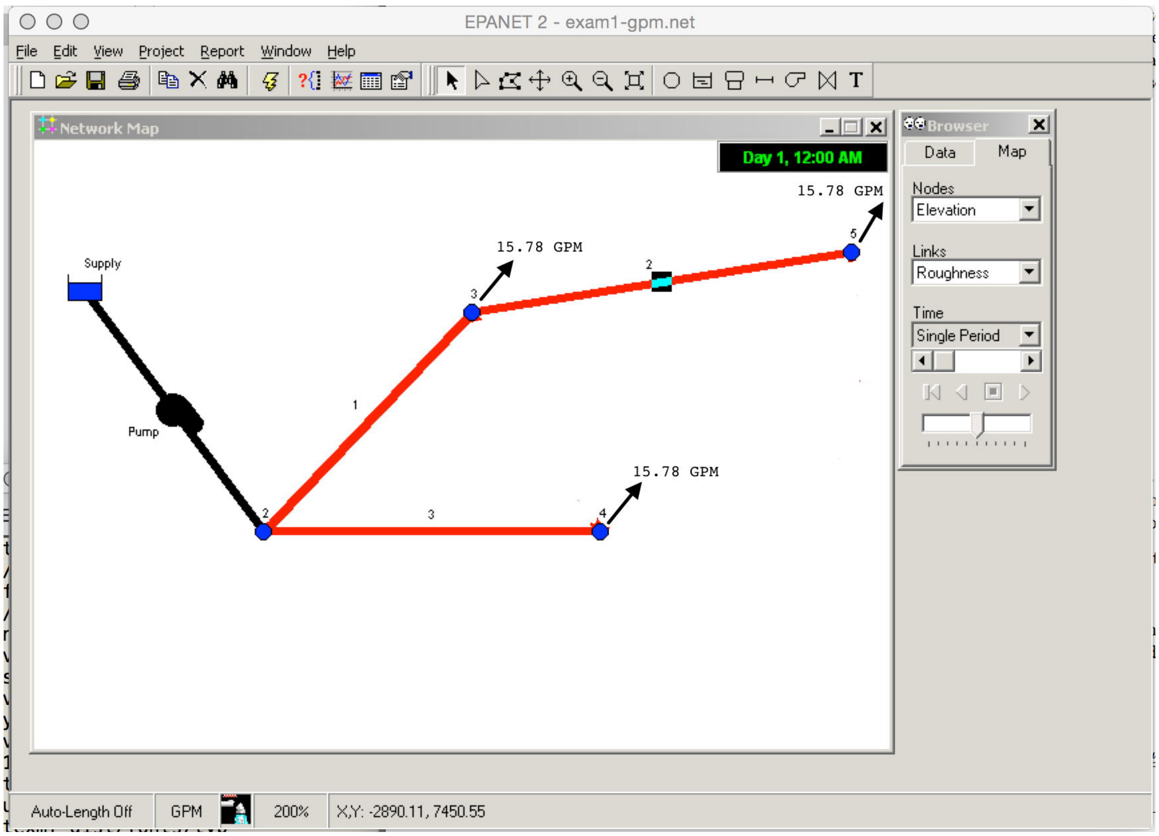

Figure 5: EPA-NET system topology.

A) Pipe #1 Discharge = ______________ GPM.

B) Pipe #2 Discharge = ______________ GPM.

C) Pipe #3 Discharge = ______________ GPM.

[3] Most, but not all, answers appear in the simulation reports – you will have to interpolate one head loss value from different simulation reports to complete the problem.

D) Pipe #1 Head Loss = ______________ FT.

E) Pipe #2 Head Loss = ______________ FT.

F) Pipe #3 Head Loss = ______________ FT.

G) Node #2 Head = ______________ FT.

H) Node #3 Head = ______________ FT.

I) Node #5 Head = ______________ FT.

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Page 1                                     Thu Mar 23 15:44:27 2017

******************************************************************
*                           E P A N E T                          *
*                   Hydraulic and Water Quality                  *
*                   Analysis for Pipe Networks                   *
*                         Version 2.00.12                        *
******************************************************************

Analysis begun Thu Mar 23 15:44:27 2017


Hydraulic Status:
-----------------------------------------------------------------------
   0:00:00: Balanced after 7 trials
   0:00:00: Reservoir 1 is closed


Node Results:
--------------------------------------------------------
                Elevation    Demand       Head  Pressure
Node                   ft       gpm         ft       psi
--------------------------------------------------------
2                  100.00      0.00     120.00      8.67
3                  100.00      0.01     120.00      8.67
4                  100.00      0.01     120.00      8.67
5                  100.00      0.01     120.00      8.67
1                  100.00     -0.03     100.00      0.00  Reservoir


Link Results:
----------------------------------------------------------------------------
                   Length  Diameter       Flow  Velocity  Headloss  F-Factor
Link                   ft        in        gpm       fps   /1000ft
----------------------------------------------------------------------------
1                 3280.00      5.00       0.07      0.00      0.00     0.279
2                 3280.00      5.00      -0.05      0.00      0.00     0.271
3                 3280.00      5.00      -0.04      0.00      0.00     0.840
4                 3280.00      5.00       0.06      0.00      0.00     0.189
5                 1000.00      5.00       0.11      0.00      0.00     0.000
6                    0.00     12.00       0.03      0.00    -20.00     0.000  Pump

Analysis ended Thu Mar 23 15:44:27 2017
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Figure 6: EPA-NET Report, Simulation #1

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Page 1                                    Thu Mar 23 15:45:45 2017

******************************************************************
*                           E P A N E T                          *
*                   Hydraulic and Water Quality                  *
*                   Analysis for Pipe Networks                   *
*                         Version 2.00.12                        *
******************************************************************

Analysis begun Thu Mar 23 15:45:45 2017


Hydraulic Status:
-----------------------------------------------------------------------
   0:00:00: Balanced after 5 trials
   0:00:00: Reservoir 1 is emptying


Node Results:
--------------------------------------------------------
                Elevation    Demand      Head  Pressure
Node                   ft       gpm        ft       psi
--------------------------------------------------------
2                  100.00      0.00    118.74      8.12
3                  100.00     15.78    118.15      7.86
4                  100.00     15.78    118.15      7.86
5                  100.00     15.78    118.06      7.83
1                  100.00    -47.34    100.00      0.00  Reservoir


Link Results:
----------------------------------------------------------------------------
                   Length  Diameter      Flow  Velocity  Headloss  F-Factor
Link                   ft        in       gpm       fps   /1000ft
----------------------------------------------------------------------------
1                 3280.00      5.00     23.67      0.39      0.18     0.032
2                 3280.00      5.00      7.89      0.13      0.03     0.041
3                 3280.00      5.00     23.67      0.39      0.18     0.032
4                 3280.00      5.00      7.89      0.13      0.03     0.041
5                 1000.00      5.00      0.00      0.00      0.00   408.583
6                    0.00     12.00     47.34      0.00    -18.74     0.000  Pump

Analysis ended Thu Mar 23 15:45:45 2017
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Figure 7: EPA-NET Summary Report, Simulation #2

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Page 1                                      Thu Mar 23 15:49:29 2017

******************************************************************
*                           E P A N E T                          *
*                   Hydraulic and Water Quality                  *
*                   Analysis for Pipe Networks                   *
*                         Version 2.00.12                        *
******************************************************************

Analysis begun Thu Mar 23 15:49:29 2017


Hydraulic Status:
-----------------------------------------------------------------------
   0:00:00: Balanced after 5 trials
   0:00:00: Reservoir 1 is emptying


Node Results:
--------------------------------------------------------
                Elevation    Demand      Head  Pressure
Node                   ft       gpm        ft       psi
--------------------------------------------------------
2                  100.00      0.00    117.12      7.42
3                  100.00     31.56    114.98      6.49
4                  100.00     31.56    114.98      6.49
5                  100.00     31.56    114.69      6.37
1                  100.00    -94.68    100.00      0.00  Reservoir


Link Results:
----------------------------------------------------------------------------
                   Length  Diameter      Flow  Velocity  Headloss  F-Factor
Link                   ft        in       gpm       fps   /1000ft
----------------------------------------------------------------------------
1                 3280.00      5.00     47.34      0.77      0.65     0.029
2                 3280.00      5.00     15.78      0.26      0.09     0.035
3                 3280.00      5.00     47.34      0.77      0.65     0.029
4                 3280.00      5.00     15.78      0.26      0.09     0.035
5                 1000.00      5.00      0.00      0.00      0.00   702.884
6                    0.00     12.00     94.68      0.00    -17.12     0.000  Pump

Analysis ended Thu Mar 23 15:49:29 2017
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Figure 8: EPA-NET Summary Report, Simulation #3

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Page 1                                    Thu Mar 23 15:51:16 2017

******************************************************************
*                           E P A N E T                          *
*                   Hydraulic and Water Quality                  *
*                   Analysis for Pipe Networks                   *
*                         Version 2.00.12                        *
******************************************************************

Analysis begun Thu Mar 23 15:51:16 2017


Hydraulic Status:
-----------------------------------------------------------------------
   0:00:00: Balanced after 4 trials
   0:00:00: Reservoir 1 is emptying


Node Results:
--------------------------------------------------------
                Elevation    Demand      Head  Pressure
Node                   ft       gpm        ft       psi
--------------------------------------------------------
2                  100.00      0.00    113.52      5.86
3                  100.00     47.34    108.91      3.86
4                  100.00     47.34    108.91      3.86
5                  100.00     47.34    108.32      3.60
1                  100.00   -142.02    100.00      0.00  Reservoir


Link Results:
----------------------------------------------------------------------------
                   Length  Diameter      Flow  Velocity  Headloss  F-Factor
Link                   ft        in       gpm       fps   /1000ft
----------------------------------------------------------------------------
1                 3280.00      5.00     71.01      1.16      1.41     0.028
2                 3280.00      5.00     23.67      0.39      0.18     0.032
3                 3280.00      5.00     71.01      1.16      1.41     0.028
4                 3280.00      5.00     23.67      0.39      0.18     0.032
5                 1000.00      5.00      0.01      0.00      0.00   180.889
6                    0.00     12.00    142.02      0.00    -13.52     0.000  Pump

Analysis ended Thu Mar 23 15:51:16 2017
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Figure 9: EPA-NET Summary Report, Simulation #4

8. (30 pts) Figures 10,11, and 12 are screen captures of an EPANET extended period simulation for water quality in a pipeline distribution network. The chemical parameter of interest is Chloramine. Interpret the figures to answer the following questions:

A) What is the Chloramine value (dosage) in the supply reservoir?

B) What is the simulation time, in hours, of the first arrival of chloramine to Node 6?

C) What is the distance, in feet, from the supply reservoir to Node 6 along the path that involves Link 11 $->$ Link 1 $->$ Link 4 $->$ Link 7?

D) What is the travel time, in hours, along the path above? (Show your calculations)

E) What is the distance, in feet, from the supply reservoir to Node 6 along the path that involves Link 11 − > Link 3 − > Link 6 − > Link 7?

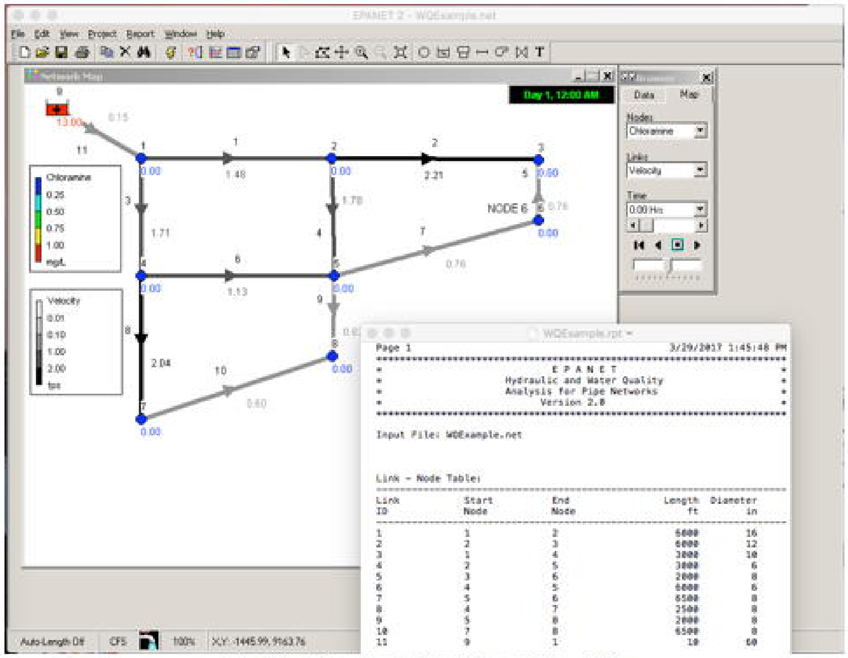
F) What is the travel time, in hours, along the path above? (Show your calculations)

G) Are these two times less than 6 hours?

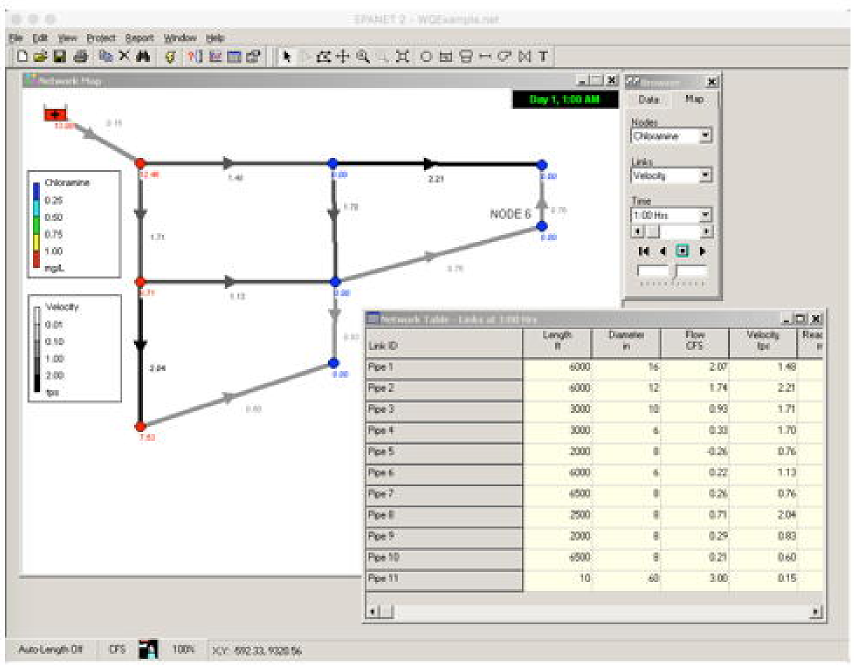
H) What is your estimate of the concentration at Node 6 at simulation hour 6:00?

I) What is your estimate of the concentration at Node 6 at simulation hour 12:00?

J) Explain your reasoning for the two answers above.

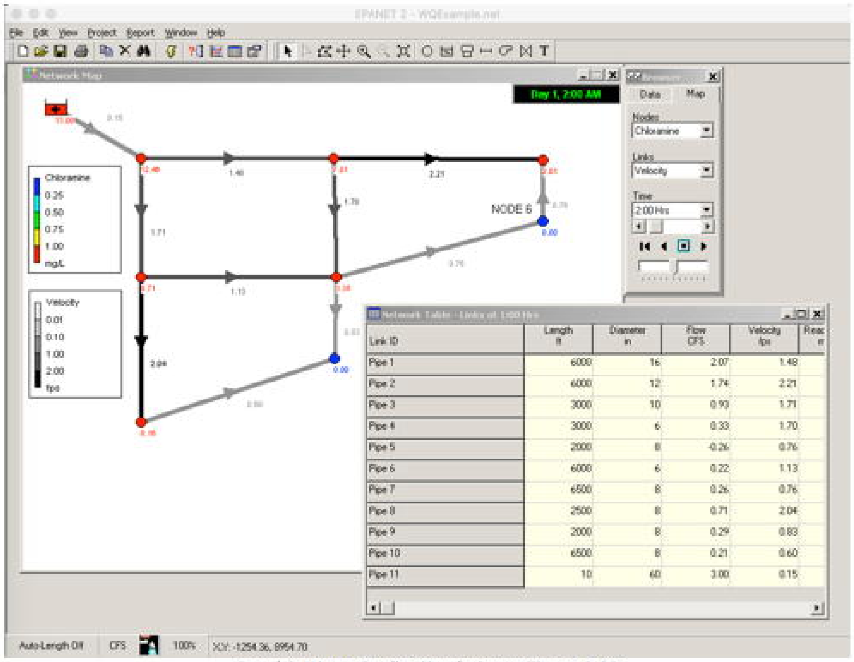


Panel A. Water Quality Simulation at Time = 0:00

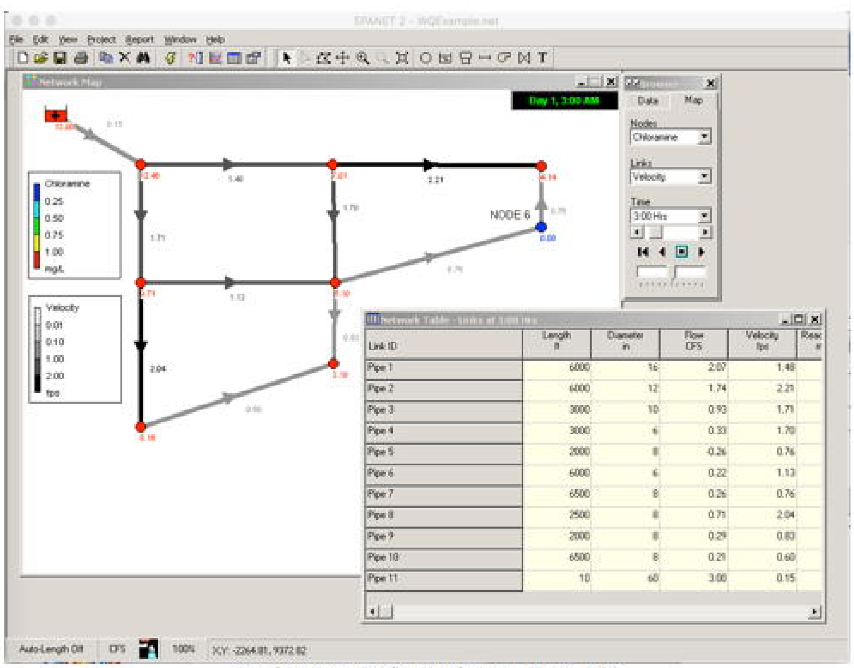


Panel B. Water Quality Simulation at Time = 1:00

Figure 10: EPA-NET Water Quality Simulation; Hours 0:00 and 1:00

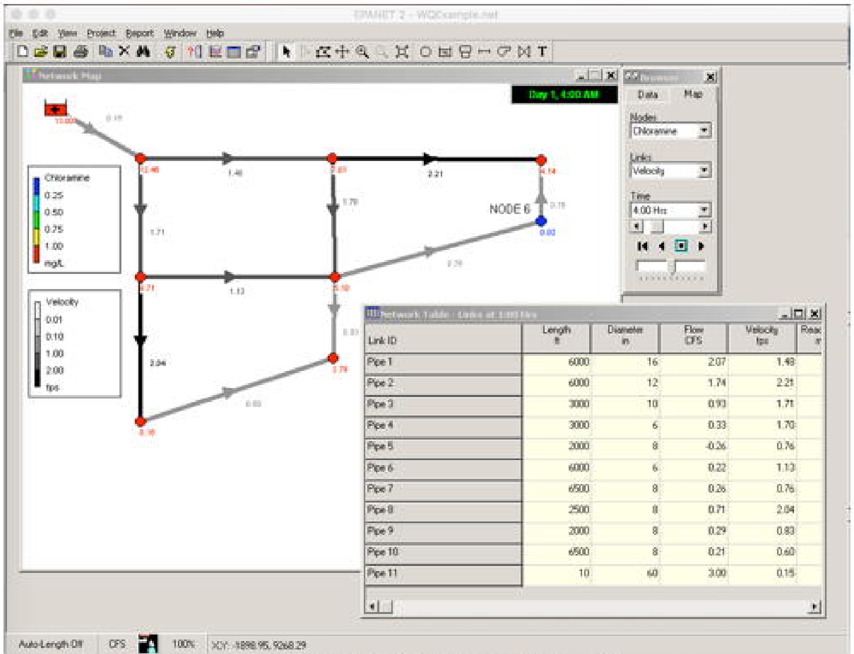


Panel C. Water Quality Simulation at Time = 2:00



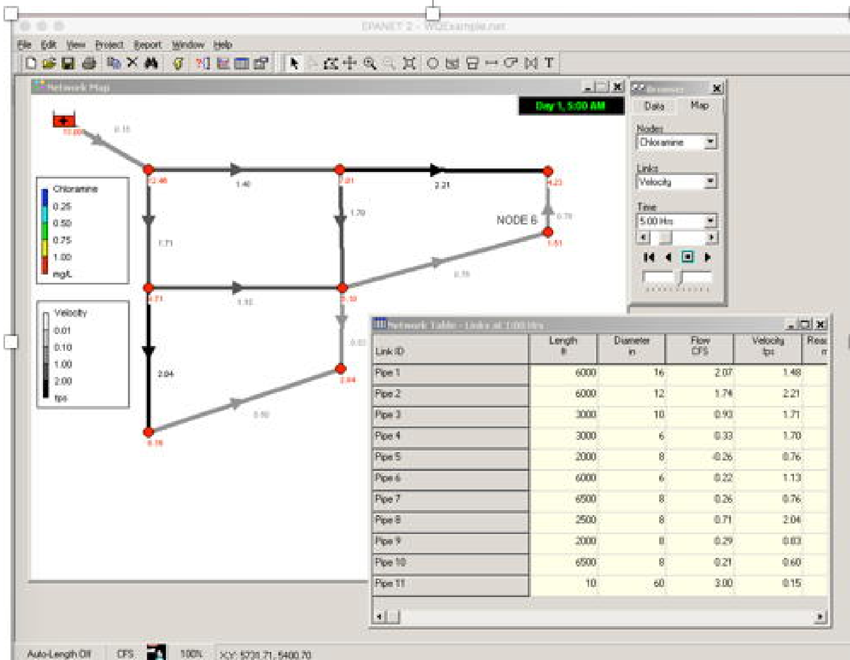
Panel D. Water Quality Simulation at Time = 3:00

Figure 11: EPA-NET Water Quality Simulation; Hours 2:00 and 3:00



Link ID	Length ft	Diameter in	Flow CFS	Velocity fps
Pipe 1	6000	16	2.07	1.48
Pipe 2	6000	12	1.74	2.21
Pipe 3	3000	10	0.93	1.71
Pipe 4	3000	6	0.33	1.70
Pipe 5	2000	8	-0.26	0.76
Pipe 6	6000	6	0.22	1.13
Pipe 7	6500	8	0.26	0.76
Pipe 8	2500	8	0.71	2.04
Pipe 9	2000	8	0.29	0.83
Pipe 10	6500	8	0.21	0.60
Pipe 11	10	60	3.00	0.15

Panel E. Water Quality Simulation at Time = 4:00



Link ID	Length ft	Diameter in	Flow CFS	Velocity fps
Pipe 1	6000	16	2.07	1.48
Pipe 2	6000	12	1.74	2.21
Pipe 3	3000	10	0.93	1.71
Pipe 4	3000	6	0.33	1.70
Pipe 5	2000	8	-0.26	0.76
Pipe 6	6000	6	0.22	1.13
Pipe 7	6500	8	0.26	0.76
Pipe 8	2500	8	0.71	2.04
Pipe 9	2000	8	0.29	0.83
Pipe 10	6500	8	0.21	0.60
Pipe 11	10	60	3.00	0.15

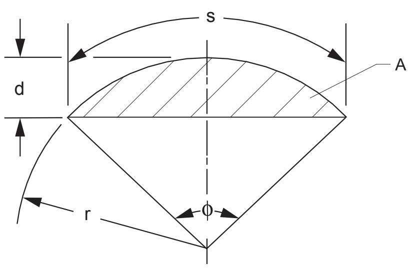
Panel F. Water Quality Simulation at Time = 5:00

Figure 12: EPA-NET Water Quality Simulation; Hours 4:00 and 5:00

MENSURATION OF AREAS AND VOLUMES (continued)

Circular Segment

♦

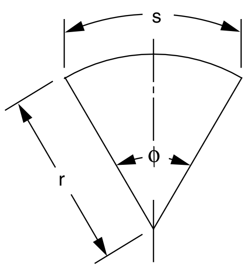


$$A = \left[r^2(\phi - \sin\phi)\right]/2$$

$$\phi = s/r = 2\left\{\arccos\left[(r - d)/r\right]\right\}$$

Circular Sector

♦

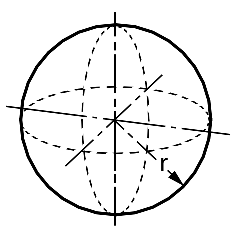


$$A = \phi r^2/2 = sr/2$$

$$\phi = s/r$$

Sphere

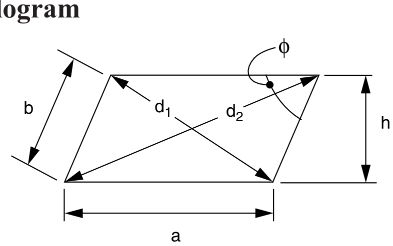
♦



$$V = 4\pi r^3/3 = \pi d^3/6$$

$$A = 4\pi r^2 = \pi d^2$$

Parallelogram



$$P = 2(a + b)$$

$$d_1 = \sqrt{a^2 + b^2 - 2ab(\cos\phi)}$$

$$d_2 = \sqrt{a^2 + b^2 + 2ab(\cos\phi)}$$

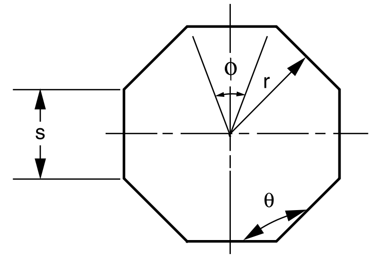
$$d_1^2 + d_2^2 = 2\left(a^2 + b^2\right)$$

$$A = ah = ab(\sin\phi)$$

If $a = b$, the parallelogram is a rhombus.

Regular Polygon (n equal sides)

♦



$$\phi = 2\pi/n$$

$$\theta = \left[\frac{\pi(n - 2)}{n}\right] = \pi\left(1 - \frac{2}{n}\right)$$

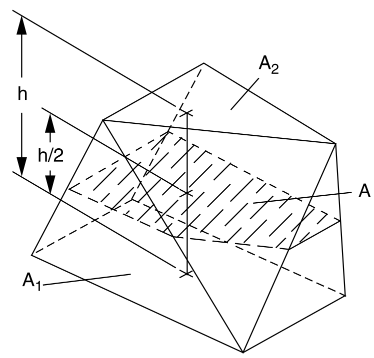
$$P = ns$$

$$s = 2r\left[\tan(\phi/2)\right]$$

$$A = (nsr)/2$$

Prismoid

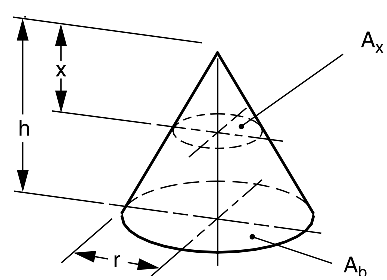
♦



$$V = (h/6)\left(A_1 + A_2 + 4A\right)$$

Right Circular Cone

♦



$$V = \left(\pi r^2 h\right)/3$$

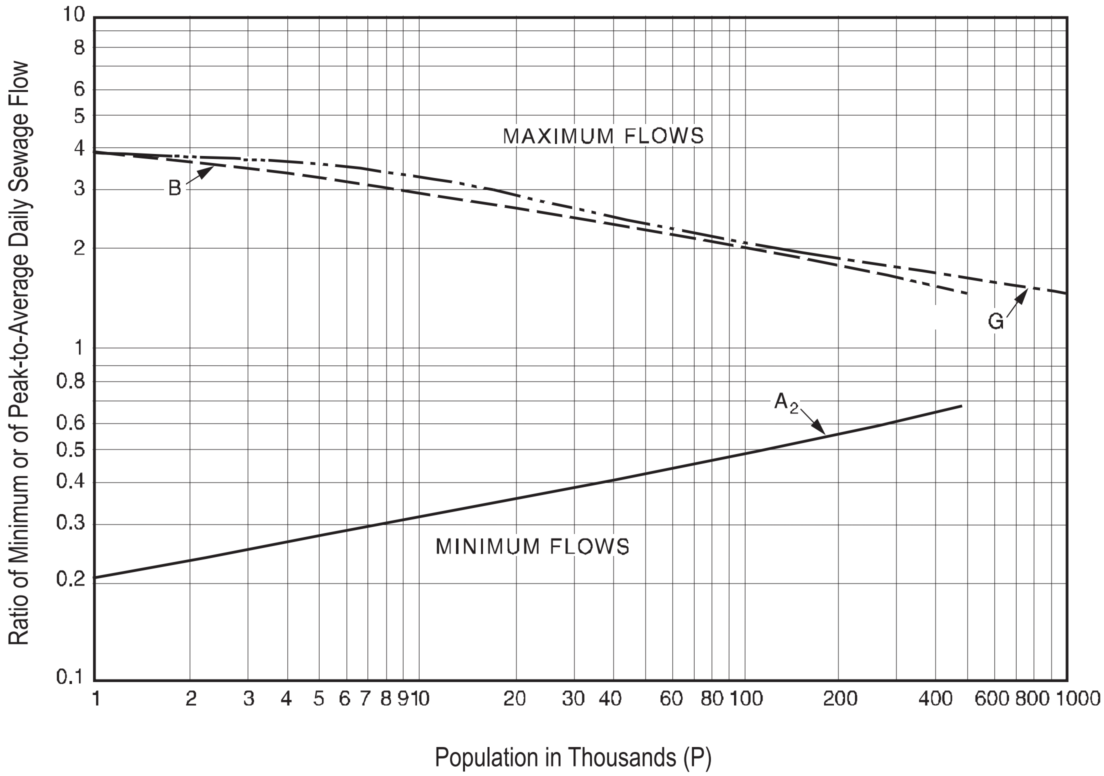
$$A = \text{side area} + \text{base area}$$

$$= \pi r\left(r + \sqrt{r^2 + h^2}\right)$$

$$A_x : A_b = x^2 : h^2$$

♦ Gieck, K., and R. Gieck, *Engineering Formulas*, 6th ed., Gieck Publishing, 1967.

♦ Sewage Flow Ratio Curves

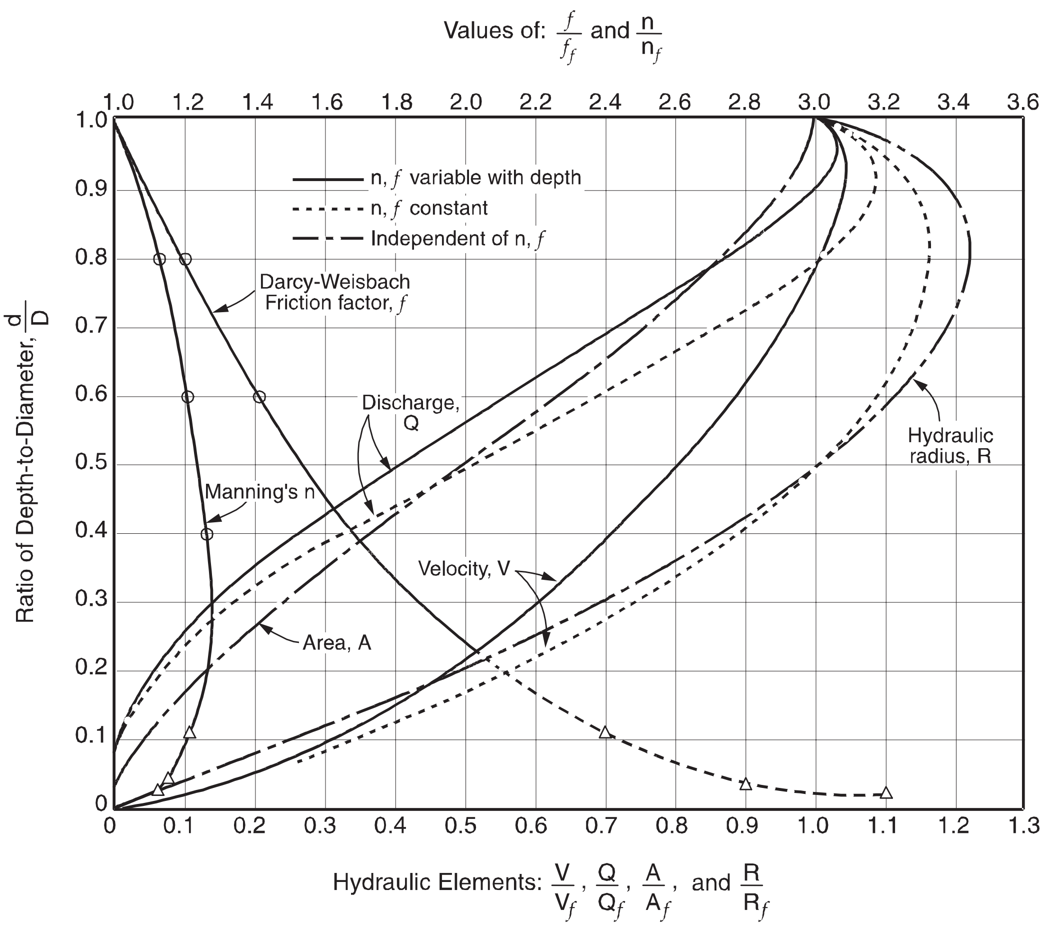


Curve A_2: $\frac{P^{0.2}}{5}$

Curve B: $\frac{14}{4+\sqrt{P}}+1$

Curve G: $\frac{18+\sqrt{P}}{4+\sqrt{P}}$

♦ Hydraulic-Elements Graph for Circular Sewers



♦ *Design and Construction of Sanitary and Storm Sewers*, Water Pollution Control Federation and American Society of Civil Engineers, 1970. Reprinted with permission from ASCE.