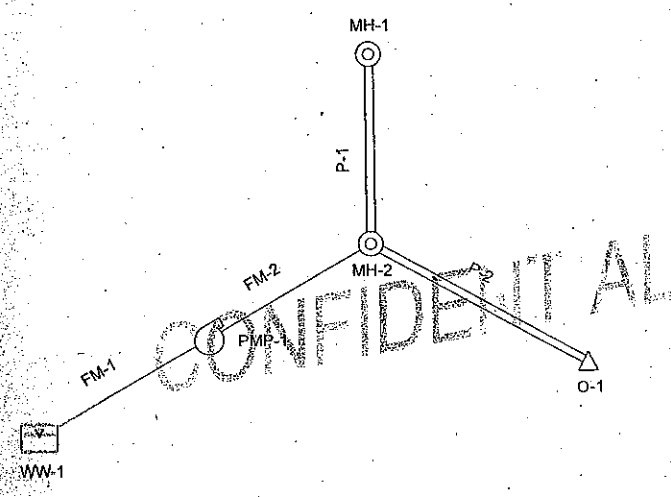
Chapter 7
Sanitary Sewer Design

Problem 7-1

In the sanitary sewer represented below, a load from a development of high-rise apartments (at wet well WW-1) with 10,000 residents is pumped to the top of a hill, where it is then transported via a circular gravity line to a treatment plant (represented by O-1). At manhole MH-1 is a resort apartment with 300 guests. The load generated here flows down a circular gravity pipe to the same gravity line mentioned above. A bar that serves, on average, 50 people per day and 2 large cafeterias with 20 employees each are located near manhole MH-2.



Schematic for Problem 7-1

Pipe Data for Problem 7-1

Pipe	Pipe Type	Material	Diameter (mm)	Length (m)	Upstream Invert (m)	Downstream Invert (m)
P-1	Gravity	PVC $n = 0.010$	200	100	98.90	97.62
P-2	Gravity	PVC $n = 0.010$	375	200	97.62	96.62
FM-1	Pressure	Ductile Iron $C = 130$	300	1	70.00	70.00
FM-2	Pressure	Ductile Iron $C = 130$	350	1,000	70.00	97.62

Node Data for Problem 7-1

Node	Ground Elevation (m)	Rim Elevation (m)	Sump Elevation (m)	Structure Diameter (m)
MH-1	100.30	100.30	98.90	1.00
MH-2	99.10	99.10	97.62	1.00
O-1	100.00	100.00	96.62	N/A
WW-1	74.00	--	--	--

The base and minimum elevations for the wet well are both 70 m. The initial elevation is 73 m and the maximum elevation is 73.5 m. The diameter of the circular wet well is 3 m.

The tailwater elevation at outlet O-1 is 98 m.

The three defining points of the pump curve are: 0 m^3/min at 33.33 m; 5.00 m^3/min at 25.00 m; and 10 m^3/min at 0 m. The pump's elevation is 70 m.

a) What is the total peak sanitary outflow if no peaking factor method is applied to the four unit sanitary loads mentioned above? If Babbitt's peaking factor method is applied? If Harmon is applied? Which peaking factor method is the most conservative?

No Peaking Factor Load = 2,688,000 l/d
Babbitt Peaking Factor Applied = 8,352,812 l/d
Harmon Peaking Factor Applied = 7,839,006 l/d

The most conservative peaking factor method is Babbitt.

b) With the Harmon peaking factor applied to each of the four unit dry loads, what is the hydraulic grade at MH-2? How does this peaking factor change the hydraulic load and the flow velocity of pipe P-1 from when no peaking factor was applied?

The hydraulic grade at MH-2 is 98.29 m. The velocity in pipe P-1 is slightly higher when the Harmon peaking factor method is applied.

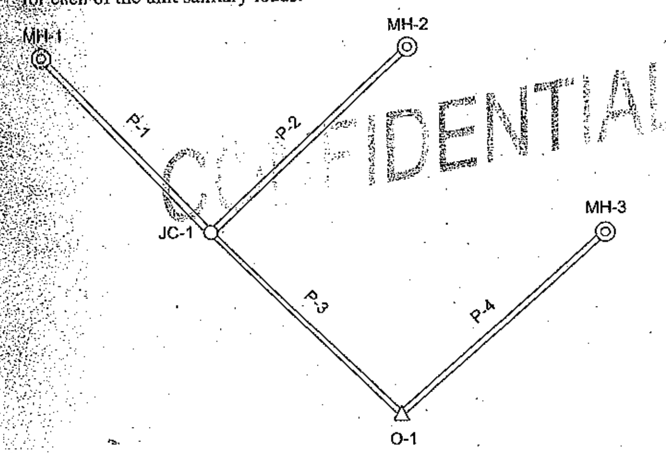
c) Identify and describe any problems for each of the three scenarios from part (a).

With no peaking factor applied, the velocities in pipes P-1 and P-2 violate the minimum default velocity constraint of 0.5 m^3/s. If the flow velocity is too low, the solids in the flow will settle in the pipe. With Babbitt and Harmon, only pipe P-1 violates the default velocity constraint. There is a hydraulic jump in pipe P-1 for all three flow conditions.

Problem 7-2

The estimated infiltration rate for the concrete gravity pipes in the proposed sanitary sewer system represented below is 20 l/d per mm-km. The estimated inflow into each of the manholes during a 5-yr storm event is approximately 75 l/d. The ground elevations for MH-1, MH-2, MH-3, JC-1 and O-1 are 12.10 m, 12.10 m, 11.20 m, 11.80 m, and 10.25 m, respectively. The top of junction chamber JC-1 is 11.8 m. The tailwater condition is a free outfall.

Use SewerCAD's Automatic Design feature to calculate the inverts and sizes of concrete pipes in the proposed sanitary sewer. The design constraints and pipe lengths are given in the tables below. Apply both the wet-weather (given above) and dry-weather sanitary loads (given in the table below). Use Federov's equation to calculate the peaking factor for each of the unit sanitary loads.



Schematic for Problem 7-2

Pipe and Constraint Data for Problem 7-2

Pipe	Length (m)
P-1	200
P-2	150
P-3	200
P-4	300

Constraint	Minimum	Maximum
Velocity (m/s)	0.5	3.0
Cover (m)	1.0	3.0
Slope (m/m)	0.005	0.1

Node Data for Problem 7-2

Node	Unit Sanitary Load	Loading Unit	Loading Unit Count
MH-1	Hospital (Medical) per Bed	Bed	400
	Cafeteria per Employee	Employee	20
	Apartment Resort	Guest	100
MH-2	Apartment	Resident	400
	Shopping Center per Employee	Employee	100
	Laundromat per Wash	Wash	200
MH-3	School (Boarding)	Student	500

a) List the diameter and slope for each newly designed pipe. Are there any problems with the designed system?

P-1 diameter = 200 mm; Slope = 0.005
P-2 diameter = 200 mm; Slope = 0.007
P-3 diameter = 200 mm; Slope = 0.007
P-4 diameter = 200 mm; Slope = 0.005

In P-2, the flow velocity violates the predefined minimum velocity constraint, and a hydraulic jump occurs.

b) What percentage of the total flow is wet-weather flow? Which pipe has the most infiltration?

3,679.40 l/d ÷ 1,218,091.52 l/d × 100% = 0.3 %
Pipe P-4 has the most infiltration; infiltration rate = 1,200 l/d

c) For a larger magnitude storm, the inflow rate into each manhole is estimated at 100 l/d. Analyze the model using the previously designed system and apply the larger wet-weather loading. What percentage of the total flow is wet-weather loading?

3,754.4 l/d ÷ 1,218,166.52 l/d × 100% = 0.3 %

d) Do you consider the amount of wet-weather flow into the system significant? What are some methods for alleviating infiltration?

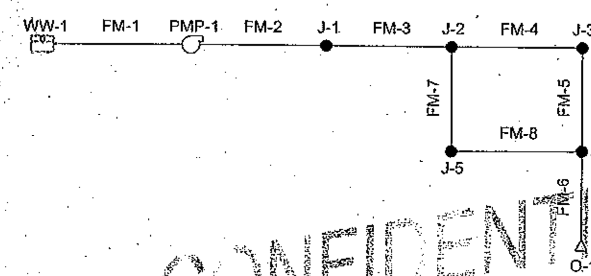
Wet weather flow in this system is negligible. However, in older systems, wet weather flow can be a large portion of the total flow.

To alleviate wet weather flow, which is especially necessary in older systems, the pipe joints could be resealed with a chemical grout, and defective pipes could either be lined with a plastic material or replaced.

Problem 7-3

The following network is an initial design for a system of force mains in a sanitary sewer. All pipes are ductile iron (Hazen Williams' $C = 130$). The pump, PMP-1, is at an elevation of 691 m. Enter the system data given in the tables below and answer the following questions. The ground elevation at the outlet is 715 m and the sump elevation is 712 m.

Hints: Make sure that the **Fixed Level in Steady State** box is checked under the Section tab of the Wet Well dialog. In addition, before running the model, make the following modification to the calculation options: within the GO dialog, click the **Options** button, scroll to the right, and in the **Pressure Hydraulics** tab check the **Use Pump Loads** box.



Schematic for Problem 7-3

Pump and Wet Well Data for Problem 7-3

Pump Curve Point	Head (m)	Flow (m^3/min)
Shut-Off	30	0
Design	20	4
Max Operating	5	6

Ground Elevation (m)	694.7
Maximum Elevation (m)	694.0
Initial Elevation (m)	691.5
Minimum Elevation (m)	688.5
Base Elevation (m)	687.0
Diameter (m)	3.0

Junction Data for Problem 7-3

Pressure Junction	Elevation (m)
J-1	698
J-2	701
J-3	703
J-4	705
J-5	703

Pipe Data for Problem 7-3

Pipe	Diameter (mm)	Length (m)	Upstream Invert (m)	Downstream Invert (m)
FM-1	400	2	687.00	691.00
FM-2	250	58	691.00	698.00
FM-3	350	45	698.00	701.00
FM-4	350	88	701.00	703.00
FM-5	350	71	703.00	705.00
FM-6	450	67	705.00	712.00
FM-7	450	39	701.00	703.00
FM-8	450	68	703.00	705.00

a) What is the head loss across the entire system?

$HL_{FM-1} + HL_{FM-2} + HL_{FM-3} + HL_{FM-4} + HL_{FM-5} + HL_{FM-6}$ = Total Head Loss

$1.34e^{-3} + 0.38 + 0.06 + 0.01 + 0.01 + 0.03 = 0.491$ m

b) Why is there more flow in FM-7 than FM-4?

There is more flow in FM-7 than FM-4 in order to satisfy Conservation of Energy.

c) Fill in the following table.

Answer Table for Part (c) of Problem 7-3

Pipe	Flow (m^3/s)	Velocity (m/s)	Head Loss (m)
FM-2	0.0623	1.27	0.38
FM-3	0.0623	0.65	0.06
FM-4	0.0183	0.19	0.01
FM-5	0.0183	0.19	0.01
FM-6	0.0623	0.39	0.03
FM-7	0.0439	0.28	0.01
FM-8	0.0439	0.28	0.01

d) If the minimum velocity required in the force main to keep particles from settling is 0.6 m/s, what areas are going to have problems?

Problems occur in FM-4, FM-5, FM-6, FM-7, and FM-8.

Keep in mind that 0.6 m^3/s is the ~~velocity~~ flow necessary to prevent solids in the flow from settling in the pipe. If the pump were to shut off and cause the velocity to drop below 0.6 m^3/s, then the velocity necessary to resuspend the solids in the flow would have to be significantly greater. An accepted value for a velocity necessary to resuspend solids is 1.1 m^3/s.

e) What are some possible changes to the design to fix the problem portions of the system?

The main solution would be to decrease the diameters of the pipes.

f) Implement a solution suggested in part (e). Describe the fix(es) and fill in the following chart.

A possible solution is provided in the following table.

Answer Table for Part (f) of Problem 7-3

Pipe	Diameter (mm)	Flow (m^3/s)	Velocity (m/s)	Head Loss (m)
FM-2	300	0.0617	0.87	0.15
FM-3	300	0.0617	0.87	0.12
FM-4	250	0.0366	0.74	0.21
FM-5	250	0.0366	0.74	0.17
FM-6	350	0.0617	0.64	0.08
FM-7	200	0.0252	0.80	0.14
FM-8	200	0.0252	0.80	0.25

Problem 7-4

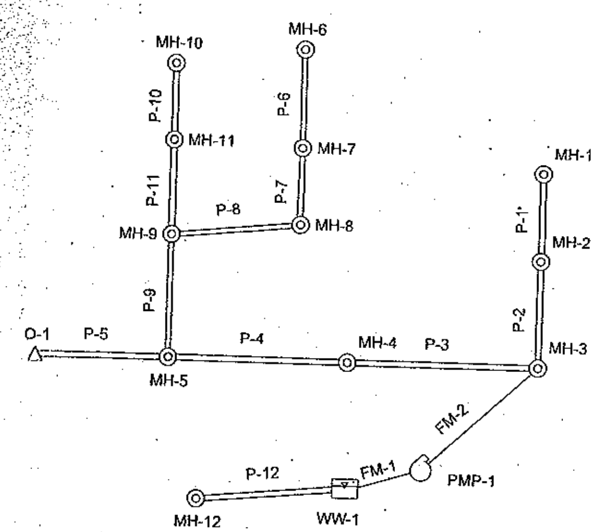
A major interceptor along a river collects laterals from subdivisions. The lower residential area loads are collected in a wet well and pumped to the major interceptor on the other side of a hill. The layout of the system is shown below. All pipes shown as double lines are circular, concrete, gravity-flow pipes ($n = 0.013$). The two pressure pipes (FM-1 and FM-2) are ductile iron (Hazen Williams $C = 130$). There is an overflow diversion at MH-5. All input data is given below.

To determine the performance of the system, set up and run three scenarios:

1. A steady state analysis of the average (base) sanitary loading only
2. An extended period analysis of the sanitary loading only
3. An extended-period analysis of both the sanitary and wet-weather loading

For the extended period analyses, use a 24-hour duration with a 1-hour hydraulic time step and a 0.1-hour hydrologic time step.

Hint: For this problem, it is only necessary to create one Sanitary Loading Alternative that will contain the base and pattern loads. During a steady-state analysis, SewerCAD will ignore the time-based pattern. However, it will be necessary to create two infiltration & inflow loading alternatives (one without the wet-weather loads and the other with the wet-weather loads) because Scenario 2 should not consider the wet-weather loads. Define the wet-weather loading pattern in the manhole prototype before laying out the network.



Schematic for Problem 7-4

Pipe Data for Problem 7-4

Pipe	Section Size (in)	Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Length (ft)
P-1	18	146.50	141.50	400
P-2	18	141.50	136.00	400
P-3	24	136.00	119.00	400
P-4	36	119.00	114.00	400
P-5	36	114.00	94.00	400
P-6	12	157.00	146.50	400
P-7	18	146.50	136.50	400
P-8	18	136.50	126.00	400
P-9	24	126.00	114.00	400
P-10	12	147.00	136.50	400
P-11	18	136.50	126.00	400
P-12	18	74.50	45.00	400
FM-1	24	45.00	45.00	2
FM-2	24	45.00	136.00	60