Homework #8 Wastewater Characteristics & Sewer Hydraulics

5 points total for entire homework

1. A municipal wastewater treatment plant receives a seasonal discharge from a fruit processing company. Influent flows to the municipal wastewater treatment plant and wastewater concentrations when the company operates and when it is not in operation are shown in the table. Note that these are total values which include sanitary WW and industrial WW.

Municipal Wastewater Flows and Concentrations

Parameter	Company Operating	Company Not Operating
Flow (m^3/d)	18,750	13,275
BOD_5 (mg/L)	300	215
SS (mg/L)	420	240
NH_3 as N (mg/L)	64	15
Cl^- (mg/L)	29	41
Alkalinity (mg/L as $CaCO_3$)	57	125

a. Determine the contribution (or loading) of each wastewater constituent in both kg/day and lb/day for both cases of the company in operation and when it is not operating.

2 points for #1

Loading is usually in units of mass per time, and may be calculated as the product of flow times concentration.

$$W = QC$$

This frequently requires units conversion, recognizing, for example that 1 Kg equals 2.2046 pounds.

	Load while Operating		Load Not Operating	
Parameter	**(kg/day)**	**(lb/day)**	**(kg/day)**	**(lb/day)**
BOD5 (mg/L)	5,625	12,401	2,854	6,292
SS (mg/L)	7,875	17,361	3,186	7,024
NH3 as N (mg/L)	1,200	2,646	199	439
Cl (mg/L)	544	1,199	544	1,200
Alkalinity (mg/L as CaCO3)	1,069	2,356	1,659	3,658

b. Also, determine the flow and constituent concentrations for the fruit processing wastewater by mass balance analysis (assume all parameters behave conservatively).

The presumption here is that the fruit processing company wastewater is entirely responsible for the differences in flow and loading as calculated above. So both flows and loadings from the fruit company are determined by the difference (operating minus not operating). The concentrations are then back calculated:

$$C = \frac{W}{Q}$$

Parameter	Industry alone
Flow (m3/d)	5,475
BOD5 (mg/L)	506.1
SS (mg/L)	856.4
NH3 as N (mg/L)	182.8
Cl (mg/L)	-0.1
Alkalinity (mg/L as CaCO3)	-107.9

Note that chloride shows a tiny negative concentration. This is, of course, impossible. It is probably just a result of error in estimating flows and concentrations and the fact that the real concentration from the fruit industry is near zero

Alkalinity is negative, which is quite possible, as negative alkalinity just reflects positive acidity.

2. A town has a population of 7500 and a domestic per capita wastewater flow of 100 gpcd. The municipal wastewater plant receives the domestic flow and industrial wastewater discharges of 65,000 gpd from a cheese processing plant and 90,000 gpd from a brewery. The BOD loads of the domestic wastewater and brewery wastes are 0.20 lbs/cap-day and 450 lb/day, respectively. The BOD concentration of the cheese wastewater is 1400 mg/L. Calculate:

a. The total (domestic plus industrial) wastewater flow in MGD

1 point for #2

$$Q_{domestic\ WW} = 7{,}500\ people\ \left(100\frac{gal}{cap-day}\right) = 750{,}000\frac{gal}{d} = 0.75MGD$$

$$Q_{total\ WW} = 750{,}000\frac{gal}{d} + 65{,}000\frac{gal}{d} + 90{,}000\frac{gal}{d} = 905{,}000\frac{gal}{d} = \mathbf{0.905}\boldsymbol{MGD}$$

b. The BOD in mg/L of the total wastewater, and

determine individual load for domestic & cheese, add to brewery load, then divide by the total flow

$$Loading_{domestic\ BOD} = 7{,}500\ people\left(0.2\frac{lb}{cap-day}\right) = 1{,}500\frac{lb}{d}$$

$$Loading_{cheese\ WW\ BOD} = 65{,}000\frac{gal}{d}\left(\frac{MG}{10^6 gal}\right)\left(\frac{3.785L}{gal}\right)1{,}400\frac{mg}{L}\left(\frac{1lb}{453.6g}\right)\left(\frac{1g}{1000mg}\right) = 759\frac{lb}{d}$$

$$Loading_{total\ BOD} = 1{,}500\frac{lb}{d} + 759\frac{lb}{d} + 450\frac{lb}{d} = 2{,}709\frac{lb}{d}$$

$$BOD_{total} = \frac{Loading_{total\ BOD}}{Q_{total\ WW}} = \frac{2{,}709\frac{lb}{d}\left(\frac{453.6\ g}{lb}\right)}{905{,}000\frac{gal}{d}\left(\frac{3.785L}{gal}\right)} = 0.359\frac{g}{L} = \mathbf{359\frac{mg}{L}}$$

c. The BOD equivalent population for the total wastewater.

Now divide the total BOD load by the per-capita load

$$BOD\ equivalent\ population = \frac{Loading_{total\ BOD}}{per - capita\ loading} = \frac{2{,}709\frac{lb}{d}}{0.2\frac{lb}{cap-d}} = \mathbf{13{,}545\ people}$$

This is almost twice the actual population

3. What is the flowing full capacity (Q, in gpm) and velocity (V, in ft/s) for a 12 inch diameter sewer at a slope of 0.0060 ft/ft for:

1 point for #3

Recall that for Manning's equation:

$$Q = \frac{1.49}{n} AR^{0.67} S^{0.5}$$

When the pipe is flowing full, and the diameter is 1 ft, the hydraulic radius becomes:

$$R = \frac{A}{wp} = \frac{\pi\left(D/2\right)^2}{\pi D} = \frac{D}{4} = 0.25\,ft$$

a) Manning's n of 0.013 and,

$$Q = \frac{1.49}{0.013}(3.1415ft^2)(0.25ft)^{0.67}(0.0060)^{0.5} = 2.75\frac{ft^3}{s}$$

$$Q = 2.75\frac{ft^3}{s}\left(\frac{1gal}{0.13368ft^3}\right)\left(\frac{60s}{min}\right) = \mathbf{1236\frac{gal}{min}}$$

$$V = \frac{Q}{A} = \frac{2.75\frac{ft^3}{s}}{\pi\left(\frac{6}{12}\right)^2} = \mathbf{3.51\frac{ft}{s}}$$

b) n of 0.011?

$$Q = \frac{1.49}{0.011}(3.1415ft^2)(0.25ft)^{0.67}(0.0060)^{0.5} = 3.26\frac{ft^3}{s}$$

$$Q = 3.26\frac{ft^3}{s}\left(\frac{1gal}{0.13368ft^3}\right)\left(\frac{60s}{min}\right) = \mathbf{1461\frac{gal}{min}}$$

$$V = \frac{Q}{A} = \frac{3.26\frac{ft^3}{s}}{\pi\left(\frac{6}{12}\right)^2} = \mathbf{4.14\frac{ft}{s}}$$

4. Use the pipe flow graphic reproduced below (from Viessman & Hammer text; Figure 6.2 or 7.2 depending on edition) to answer the following. A 33 inch sewer is placed on a slope of 0.40 ft/100 ft. Manning's n is 0.013.

1 point for #4

a) At what depth of flow is the velocity equal to 2.0 ft/sec?

so the velocity version of the Manning equation is:

$$V = \frac{1.49}{n} R^{0.67} S^{0.5}$$

first find V_{full} from this:

as before, for a full pipe, the hydraulic radius is 0.25*D, so using the Manning equation:

$$V_{full} = \frac{1.49}{0.013}\left(\frac{33in}{4}\frac{1ft}{12in}\right)^{0.67}\left(\frac{0.40ft}{100ft}\right)^{0.5} = 5.63\frac{ft}{s}$$

Now determine the ratio

$$\frac{V}{V_{full}} = \frac{2\frac{ft}{s}}{5.63\frac{ft}{s}} = 0.35 \ or \ 35\%$$

Then go to the attached figure, and read the d/D axis position where the velocity curve hit V/V_{full} of 35%

$$\frac{depth}{D} = 12\% \ or \ 0.12$$

$$depth = 0.12(33in) = \mathbf{4.0in}$$

b) If the depth of flow is 18 in, what is the flow rate? (in gpm).

$$\frac{depth}{D} = \frac{18in}{33in} = 0.55 \ or \ 55\%$$

Then go to the attached figure, and read the Q/Q_{full} axis position where the discharge curve hits d/D of 55%

$$\frac{Q}{Q_{full}} = 57\% \ or \ 0.57$$

Now calculate Q_{full}

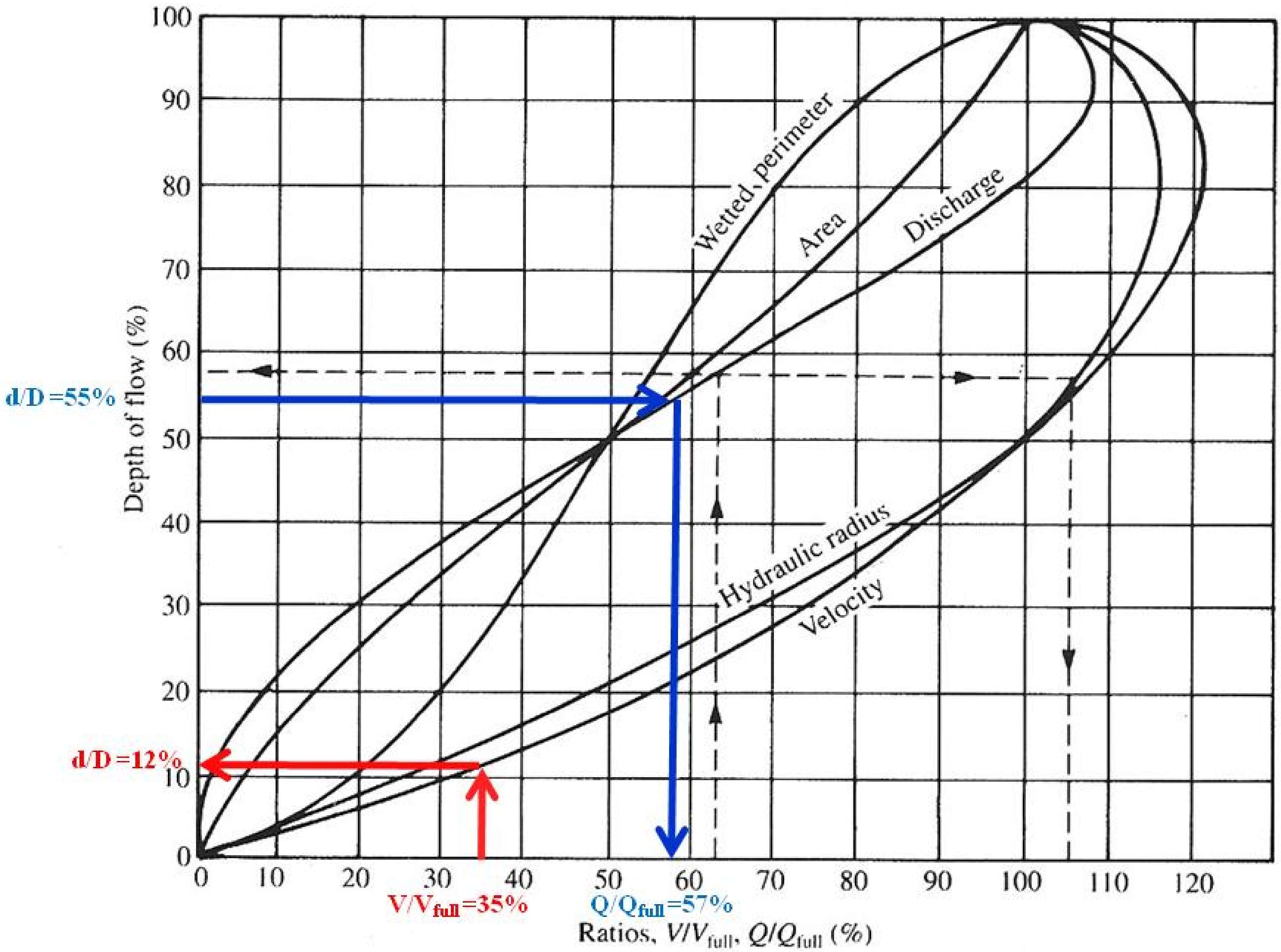
$$Q_{full} = V_{full}A_{full} = 5.63\frac{ft}{s}\pi\left(\frac{33in}{2x12\frac{in}{ft}}\right)^2 = 33.5\frac{ft^3}{s}$$

And now determine Q

$$Q = (0.57)33.5\frac{ft^3}{s} = 19.1\frac{ft^3}{s}$$

And in gpm this is

$$Q = 19.1\frac{ft^3}{s}\left(\frac{1gal}{0.13368ft^3}\right)\left(\frac{60s}{min}\right) = \mathbf{8570\frac{gal}{min}}$$



d/D =55%
d/D =12%
V/V_full =35%
Q/Q_full =57%
Wetted perimeter
Area
Discharge
Hydraulic radius
Velocity
Depth of flow (%)
Ratios, V/V_full, Q/Q_full (%)