Question 1

$\frac{X_r}{X} = 6.5$ $\quad$ $K_s = 75 \text{ mg/L}$

$t_R = 2 \text{ hours}$ $\quad$ $\mu_{max} = 0.4 \text{ hr}^{-1}$

$S_{in} = 300 \text{ mg COD/L}$ $\quad$ $K_d = 0.004 \text{ hr}^{-1}$

$Q = 0.088 \text{ m}^3/\text{s}$ $\quad$ $Y = 0.4 \text{ mg VSS/mg COD}$

$Q_r = 0.013 \text{ m}^3/\text{s}$ $\quad$ $R = Q_r/Q = 0.15$

a. $$\Theta_c = \frac{t_R}{1 + R - R(X_r/X)} = \frac{2 \text{ hrs}}{1 + 0.15 - 0.15 \cdot 6.5}$$

$$= 11.4 \text{ hours} \simeq 11 \text{ hours}$$

b. $$S = \frac{K_s(1 + K_d \Theta_c)}{\mu_{max}\Theta_c - K_d\Theta_c - 1}$$

$$= \frac{75 \text{ mg/L}\,(1 + 0.004 \cdot 11)}{0.4 \cdot 11 - 0.004 \cdot 11 - 1} = 23.3 \text{ mg/L}$$

$$E = \frac{S_{in} - S}{S_{in}} = \frac{300 - 23}{300} = 0.92$$

c. $$\frac{1}{\Theta_{cw}} = \mu_{max}\frac{S_{in}}{K_s + S_{in}} - K_d$$

$$= 0.4 \text{ hr}^{-1} \frac{300}{75+300} - 0.004 \text{ hr}^{-1} = 0.316 \text{ hr}^{-1}$$

$$\Theta_{cw} = 3.2 \text{ hours}$$

Question 1 (con't)

d.
$$\frac{1}{\theta_c} = Y \frac{F}{M} E - k_d$$

$$0.043 = 0.4 \frac{F}{M} 0.92 - 0.004$$

$$\frac{F}{M} = \frac{0.043 + 0.004}{0.4 \; 0.92} = 0.13 \frac{mg\ COD}{mg\ VSS \cdot hr}$$

$$= 3.1 \frac{g\ COD}{g\ VSS \cdot day}$$

e.
$$\frac{F}{M} = \frac{S_{in}}{t_R X}$$

$$0.13 \frac{mg\ COD}{mg\ VSS \cdot hr} = \frac{300\ mg\ COD/L}{2\ hr \quad X}$$

$$\therefore\ X = 1150\ mg\ VSS/L = 1150\ g\ VSS/m^3$$

f.
$$P = \forall (\mu_g - k_d) X$$

$$\forall = t_R Q = 2\ hrs \cdot 0.088\ m^3/s \cdot 3600\ s/hr$$
$$= 634\ m^3$$

$$\mu_g = \mu_{max} \left(\frac{S}{K_s + S} \right)$$

$$= 0.4\ hr^{-1} \left(\frac{23.3}{75 + 23.3} \right) = 0.095\ hr^{-1}$$

$$P = 634\ m^3 \left(0.095 - 0.004 \right) hr^{-1}\ 1150 \frac{g\ VSS}{m^3}$$

$$= 66{,}000\ g\ VSS/hr = 66\ kg\ VSS/hr$$

Question 1 (con't)

h. This is a plant on the edge of disaster.

The F/M ratio at 3.1 g COD/g VSS·day is way off scale! This creates a real danger for operational problems with bulking sludge.

Likewise the sludge age is very low, which could lead to operating problems, including poor flocculation.

The F/M ratio needs to be reduced to $\sim 0.6 \frac{\text{g COD}}{\text{g VSS}\cdot\text{day}}$

Assuming we want the same E, then the sludge age becomes:

$$\frac{1}{\theta_c} = Y \frac{F}{M} E - k_d$$

$$= 0.12 \text{ day}^{-1}$$

$$\theta_c = 8 \text{ days}$$

This is more in the normal range

This however implies a new size aeration tank:

$$t_R = \theta_c \left[1 + R - R(X_r/X)\right]$$

$$= 8 \text{ days} \left[1 + 0.15 - 0.15(6.5)\right]$$

$$= 1.4 \text{ days}$$

$$\forall = t_R Q = 1.4 \text{ d} \cdot 0.088 \frac{m^3}{s} \cdot 86400 \frac{s}{d}$$

$$= 10{,}600 \text{ m}^3$$ <u>much</u> larger

Question 2

$Q = 7500 \ m^3/d$

$Y = 0.6 \ g \ VSS / g \ BOD$

$S_{in} = 90 \ mg \ BOD/L$

$k_d = 0.06 \ d^{-1}$

$S_e = 7 \ mg \ BOD/L$

$\theta_c = 10 \ d$

$X = 1400 \ mg \ VSS/L$

Calculate $\forall$:

From Lecture 17
Eqn 29

$$\frac{1}{\theta_c} = YU - k_d$$

$$0.1 \ d^{-1} = 0.6 \ \frac{g \ VSS}{g \ BOD} \ U - 0.06 \ d^{-1}$$

$$\rightarrow U = 0.267 \ \frac{g \ BOD}{g \ VSS \cdot d}$$

From Eq 24

$$U = \frac{S_{in} - S}{t_R X}$$

$$0.267 \ \frac{g \ BOD}{g \ VSS \cdot d} = \frac{(90 - 7) \ g \ BOD/m^3}{t_R \ 1400 \ g \ VSS/m^3}$$

$$0.267 \ day^{-1} = 0.059 / t_R$$

$$t_R = 0.22 \ d$$

$$\forall = Qd = 7500 \ \frac{m^3}{d} \cdot 0.22 \ d$$

$$= 1670 \ m^3$$

Question 2 (con't)

Or use Eq 12.75 from V & H:

$$\forall = \frac{\theta_c Y Q (S_{in} - S)}{X(1 + k_d \theta_c)} = 1670 \text{ m}^3$$

$$t_R = \frac{\forall}{Q} = 0.22 \text{ d} = 5.3 \text{ hr}$$

From Lecture 17, Eqn. 37

$$\frac{F}{M} = \frac{S_{in}}{t_R X} = \frac{90 \text{ g BOD/m}^3}{0.22 \text{ d} \cdot 1400 \text{ g VSS/m}^3}$$

$$= 0.29 \ \frac{\text{g BOD}}{\text{g VSS} \cdot \text{d}}$$

From Lecture 17, Eqn. 23

$$P = \forall (\mu_g - k_d) X$$

From Eqn 25 $\mu_g = YU$

$$P = \forall (YU - k_d) X$$

$$= 1670 \text{ m}^3 \left(0.6 \ \frac{\text{g VSS}}{\text{g BOD}} \cdot 0.267 \ \frac{\text{g BOD}}{\text{g VSS} \cdot \text{d}} - 0.06 \ \frac{1}{\text{d}}\right) 1400 \ \frac{\text{g VSS}}{\text{m}^3}$$

$$= 234 \text{ kg VSS/d}$$