5.16 BOD5=180mg/L, k=0.22/day, TKN=30mg/L:

a. $CBOD = L_0 = \frac{BOD_t}{\left(1-e^{-kt}\right)} = \frac{180}{\left(1-e^{-0.22x5}\right)} = 270\,mg/L$

b. $NBOD = 4.57xTKN = 4.57x30\,mg/L = 137\,mg/L$

c. $BOD_{remaining} = (270 + 137) - 180 = 227$ mg/L

5.18 $2\ CH_2(NH_2)COOH + 3\ O_2 \rightarrow 4\ CO_2 + 2\ H_2O + 2\ NH_3$

mol wt glycine = 2x12 + 5x1 + 1x14 +2x16 = 75 g/mol

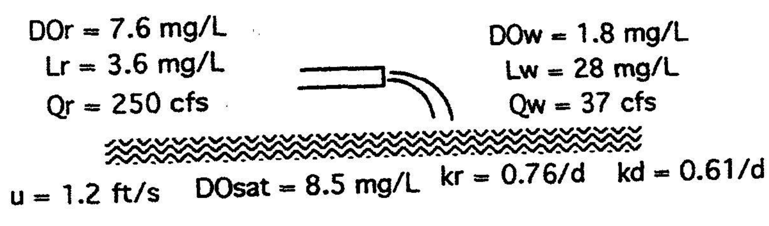
a. $CBOD = \frac{3mol\ O_2}{2mol\ glycine} x \frac{32g\ O_2/mol}{75g\ glycine/mol} x \frac{200mg\ glycine}{L} = 128mg/L$

b. Nitrogenous portion: $NH_3 + 2\ O_2 \rightarrow NO_3^- + H^+ + H_2O$

$$NBOD = \frac{2mol\ O_2}{1mol\ NH_3} x \frac{2mol\ NH_3}{1mol\ glycine} x \frac{32g/mol\ O_2}{75g/mol\ glycine} x \frac{200mg\ glycine}{L} = 171mg/L$$

c. Total theoretical oxygen demand = 128 + 171 = 299 mg/L

5.30



a. initial conditions:

$$DO = \frac{37cfs\ x\ 1.8mg/L\ +\ 250cfs\ x\ 7.6mg/L}{37\ +\ 250\ cfs} = 6.85mg/L$$

Initial deficit $= D_0 = 8.5mg/L - 6.85mg/L = 1.65mg/L$

$$Initial\ BOD = L_0 = \frac{37cfs\ x\ 28mg/L\ + 250cfs\ x\ 3.6mg/L}{37\ +\ 250\ cfs} = 6.75mg/L$$

b. critical point:

$$t_c = \frac{1}{k_r - k_d} \ln\left(\frac{k_r}{k_d}\left[1 - \frac{D_0(k_r - k_d)}{k_d L_0}\right]\right)$$

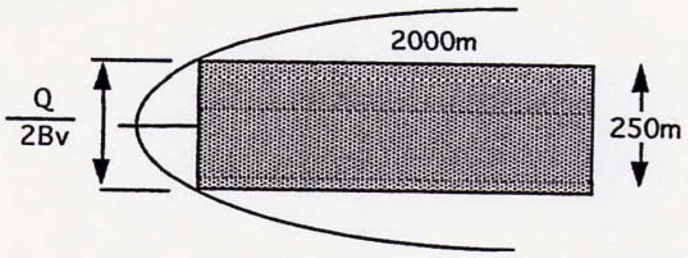
5.50 0.1m^3 TCE plume, B=10m, 2000m x250m , grad=0.001, K=0.001m/s, h=0.4:

a. Can it dissolve? Using the specific gravity given in Table 5.15, the concentration C of TCE in the plume (if it could all dissolve) would be

$$C = \frac{0.1\text{m}^3 \text{ x } 1.47 \text{ kg/L x } 10^3 \text{L/m}^3 \text{ x } 10^6 \text{mg/kg}}{2000\text{m x } 250\text{m x } 10\text{m x } 0.40 \text{ x } 10^3 \text{L/m}^3} = \frac{1.47\text{x}10^8 \text{mg}}{2\text{x}10^9 \text{L}} = 0.073 \text{mg/L}$$

Since the solubility (Table 5.15) is 1100 mg/L, YES it could all dissolve.

b. Try a single well:



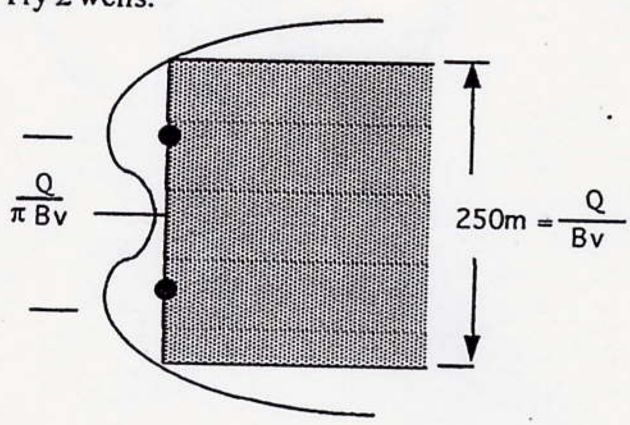
$$\frac{Q}{Bv} = 250\text{m}$$

$$v = K\frac{dh}{dL} = 0.001\text{m/s x } 0.001 = 1\text{x}10^{-6}\text{m/s}$$

$$Q = 250 \text{ x } 2Bv = 250\text{m x } 2 \text{ x } 10\text{m x } 1\text{x}10^{-6}\text{m/s} = 0.005\text{m}^3\text{/s}$$

this exceeds the maximum pumping rate, which is given as 0.003 m^3/s.

Try 2 wells:



$$\frac{Q}{Bv} = 250\text{m}$$

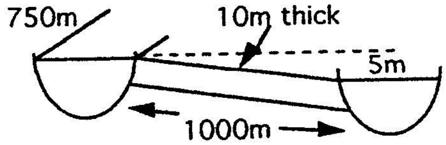
$$Q = 250\text{m x } 10\text{m x } 1\text{x}10^{-6}\text{m/s} = 0.0025\text{m}^3\text{/s} < 0.003\text{m}^3\text{/s}$$

so, 2 wells will work.

c. spacing for minimum pumping rate:

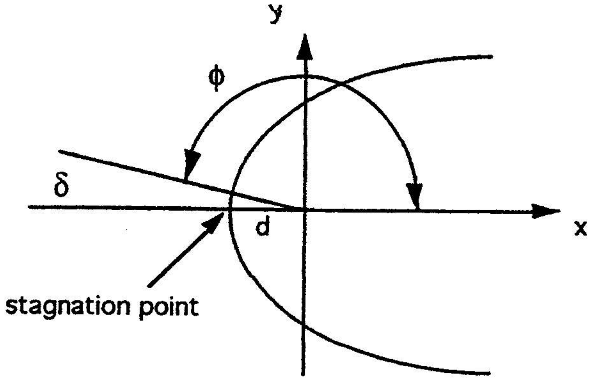
$$\text{spacing} = \frac{Q}{\pi Bv} = \frac{0.0025\text{m}^3\text{/s}}{\pi \text{ x } 10\text{m x } 10^{-6}\text{m/s}} = 79.6 \approx 80\text{m apart}$$

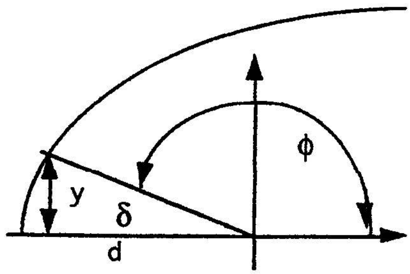
5.42



$$Q = KA\frac{dh}{dL} = 7.0\frac{m}{day}x(10m\ x\ 750m)x\frac{5m}{1000m} = 262.5m^3/day$$

5.49 Show $d = Q/(2Bv\pi)$





expanded view

$$y = \frac{Q}{2Bv}\left(1 - \frac{\phi}{\pi}\right) \qquad (5.60)$$

from expanded view,

$$y = \frac{Q}{2Bv}\left[1 - \left(\frac{\pi - \delta}{\pi}\right)\right] = \frac{Q\delta}{2Bv\pi}$$

$$\left(\frac{y}{d}\right) = \tan\ \delta \approx \delta \text{ for small values of } \delta$$

Therefore, for small δ, $y \approx \frac{Q}{2Bv\pi}\left(\frac{y}{d}\right)$

so, $d = \frac{Q}{2Bv\pi}$, that is, $x = -\frac{Q}{2Bv\pi}$ Q.E.D.

$$= \frac{1}{0.76 - 0.61/d} \ln\left(\frac{0.76}{0.61}\left[1 - \frac{1.65(0.76 - 0.61)}{0.61x6.75}\right]\right) = 1.05 \text{ days}$$

critical distance $= x_c = 1.2\frac{ft}{s}x3600\frac{s}{hr}x24\frac{hr}{d}x5280\frac{ft}{mi}x1.05day = 20.7miles$

c. minimum DO:

$$D_{max} = \frac{k_d L_0}{k_r - k_d}\left(e^{-k_d t} - e^{-k_r t}\right) + D_0 e^{-k_r t}$$

$$= \frac{0.61/d \text{ x } 6.75 \text{ mg/L}}{(0.76 - 0.61)/d}\left(e^{-0.61x1.05} - e^{-0.76x1.05}\right) + 1.65e^{-0.76x1.05} = 2.85 \text{ mg/L}$$

$DO_{min} = DO_{sat} - D_{max} = 8.5 - 2.85 = 5.6$ mg/L

d. 10 miles downstream:

$$t = \frac{10mi \text{ x } 5280ft/mi}{1.2ft/s \text{ x } 3600s/hr \text{ x } 24hr/d} = 0.51days$$

$$D = \frac{k_d L_0}{k_r - k_d}\left(e^{-k_d t} - e^{-k_r t}\right) + D_0 e^{-k_r t}$$

$$= \frac{0.61x6.75}{0.76 - 0.61}\left(e^{-0.61x0.51} - e^{-0.76x0.51}\right) + 1.65e^{-0.76x0.51} = 2.6mg/L$$

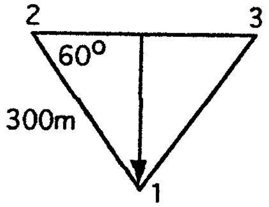
DO = 8.5 - 2.6 = 5.9 mg/L

5.41 From Prob. 5.39,
grad = 0.00115, hydraulic conductivity K = 1000m/d, porosity = 0.23

a. Darcy velocity $= v = K\frac{dh}{dL} = 1000m/d \text{ x } 0.00115 = 1.15$ m/day

b. avg. linear velocity $= v' = \frac{\text{Darcy velocity}}{\text{porosity}} = \frac{1.15m/day}{0.23} = 5.0m/day$

c.



without accounting for retardation, $t = \frac{\text{distance, d}}{\text{avg. velocity } v'} = \frac{300\sin 60°}{5.0m/day} = 52days$

with retardation factor of 2: t = R x 52d = 2 x 52 d = 104 days