1) $Q = 2Lh^{1.5}$ when $h = 0$, $Q = 0$.

Elevation (m)	56.4	57.9	59.4
Surface area (ha)	28.5	32.7	37.2
h (m)	0	1.5	3.0
Surface area (m^2)	285,000	327,000	372,000
Q (m^3/s)	0	88.2	249.4
Δ storage (m^3)	0	459,000	983,000
$2S/\Delta t + Q$ (m^3/s)	0	598.2	1341

$$Q = (2)(24)h^{1.5} = 48h^{1.5}$$

$$\Delta S = \left(\frac{28.5 + 32.7}{2}\right)(1.5) = 45.9 \text{ ha}\cdot\text{m} = 459{,}000 \text{ m}^3$$

$$\Delta S = \left(\frac{32.7 + 37.2}{2}\right)(1.5) = 52.4 \text{ ha}\cdot\text{m} = 524{,}000 \text{ m}^3$$

$$\Sigma = 983{,}000 \text{ m}^3$$

$$\frac{2S}{\Delta t} + Q = \frac{2(459{,}000)}{(30 \text{ min})(60 \text{ s/min})} + 88.2 = 598.2 \text{ m}^3/\text{s}$$

$$\frac{2S}{\Delta t} + Q = \frac{2(983{,}000)}{(30 \text{ min})(60 \text{ s/min})} + 249.2 = 1341 \text{ m}^3/\text{s}.$$

From table next page:

Maximum outflow = $\underline{104.6 \text{ m}^3/\text{s}}$.

$$\left.\begin{array}{l} 104.6 - 88.2 = 16.4 \\ 249.4 - 88.2 = 161.2 \end{array}\right\} \text{Interpolation from height outflow relationship}$$

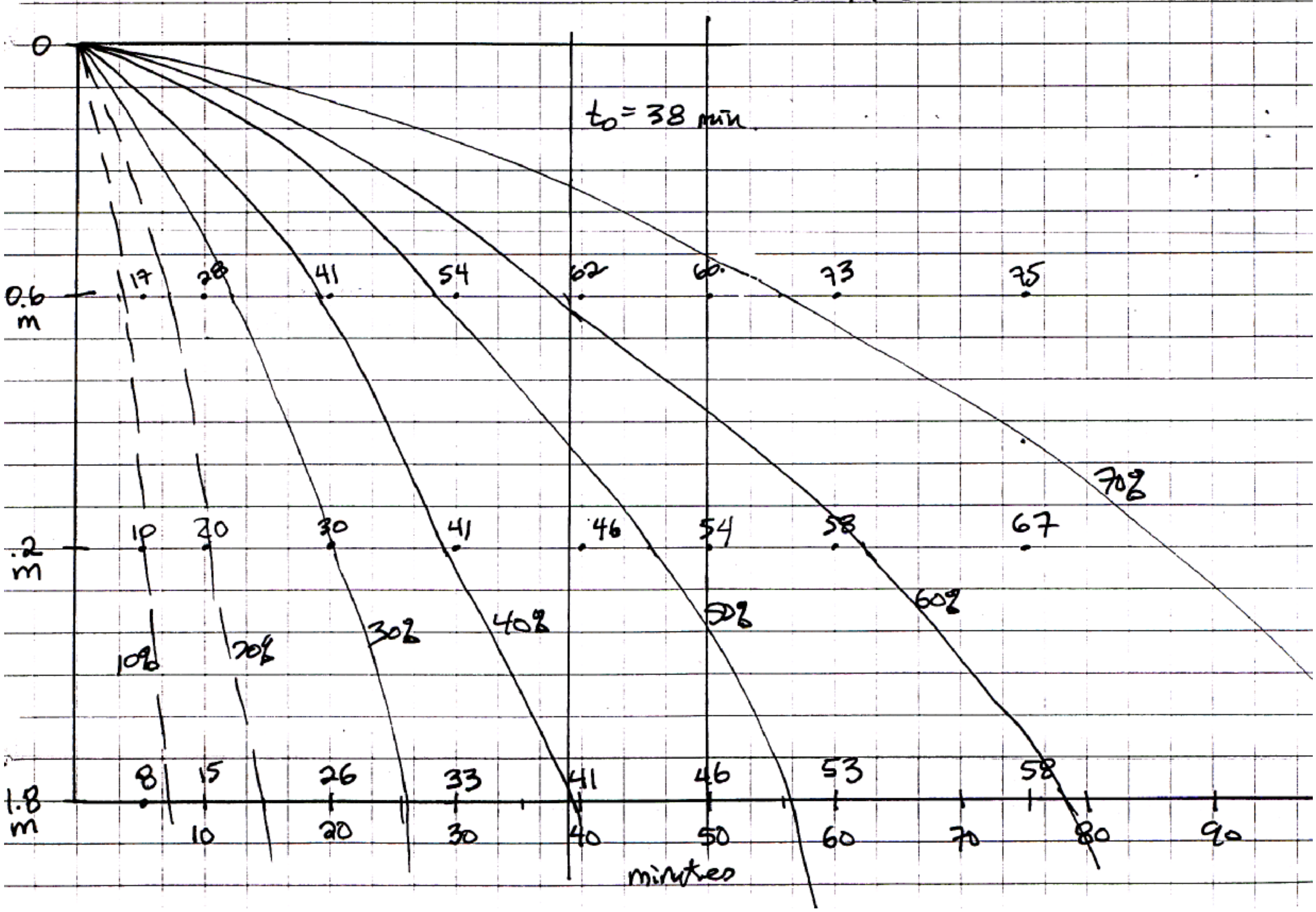
$$\frac{16.4}{161.2} = 0.102 \qquad 0.102 \times 1.5 = 0.153$$

$$0.153 + 57.9 = \underline{\underline{58.05}} \text{ max. height}$$

1		2	3	4	5	6
Time (min)	j	Inflow Ij+1 m3/s	Ij+Ij+1 m3/s	2Sj/dt-Qj m3/s	2Sj+1/dt+Qj+1 m3/s	Outflow Q_{j+1} m3/s
0	0	0				
30	1	7.6	7.6	0	7.6	1.12
60	2	32	39.6	5.36	44.96	6.629007
90	3	101.3	133.3	31.70199	165.001986	24.32828
120	4	162.2	263.5	116.3454	379.8454324	56.00529
150	5	147.4	309.6	267.8348	577.4348435	85.13834
180	6	119.4	266.8	407.1582	673.9581695	$\boxed{104.6408}$
210	7	76.4	195.8	464.6766	660.4765946	101.7151
240	8	37.9	114.3	457.0465	571.3464733	84.24065
270	9	16.7	54.6	402.8652	457.4651662	67.44973
300	10	4.2	20.9	322.5657	343.465709	50.64138
330	11	0	4.2	242.1829	246.3829422	36.32727
			0	173.7284	173.7283936	25.61492
				122.4986	122.4985564	18.06147
				86.37561	86.37561195	12.73542
				60.90477	60.90476951	8.979941
				42.94489	42.94488763	6.331894
				30.2811	30.2810993	4.464716
				21.35167	21.35166781	3.14814
				15.05539	15.05538864	2.219802
				10.61579	10.61578557	1.565216
				7.485353	7.485353315	1.103658

2) $C_0 = 430$ mg/L
$V_0 = 0.0475$ m/min.
values in table are C_i values.

Time (min)	60 cm		120 cm		180 cm	
5	357	17%	387	10%	396	8
10	310	28	346	20	366	15
20	252	41	299	30	316	26
30	198	54	254	41	288	33
40	163	62	230	46.	252	41
50	144	66	196	54	232	46
60	116	73	179	58	204	53
75	108	75	143	67	181	58
	C_i	$\left(\frac{C_0 - C_i}{C_0}\right) \times 100\%$ = % removed	C_i	$\left(\frac{C_0 - C_i}{C_0}\right) \times 100\%$ = % removed	C_i	$\left(\frac{C_0 - C_i}{C_0}\right) \times 100\%$ = % removed



2) cont'd. with $V_o = 0.0475 \frac{m}{min} = \frac{1.80\ m}{t_o\ min}$; $t_o = 38$ mins.

$$R\% = \frac{0.33}{1.80}\left(\frac{100+70}{2}\right) + \frac{0.30}{1.80}\left(\frac{70+60}{2}\right) + \frac{0.32}{1.80}\left(\frac{60+50}{2}\right)$$
$$+ \frac{0.81}{1.80}\left(\frac{50+40}{2}\right) + \frac{0.04}{1.80}\left(\frac{40+39}{2}\right)$$

$$= 15.6 + 10.83 + 9.78 + 20.25 + 0.88$$

$$= \underline{\underline{57.34\%}}$$

Try $t_o = 50$ mins and interpolate between 2 values

$$R\% = \frac{0.50}{1.80}\left(\frac{100+70}{2}\right) + \frac{0.37}{1.80}\left(\frac{70+60}{2}\right) + \frac{0.50}{1.80}\left(\frac{60+50}{2}\right)$$
$$+ \frac{0.43}{1.80}\left(\frac{50+46}{2}\right)$$

$$= 23.61 + 13.36 + 15.27 + 11.47$$

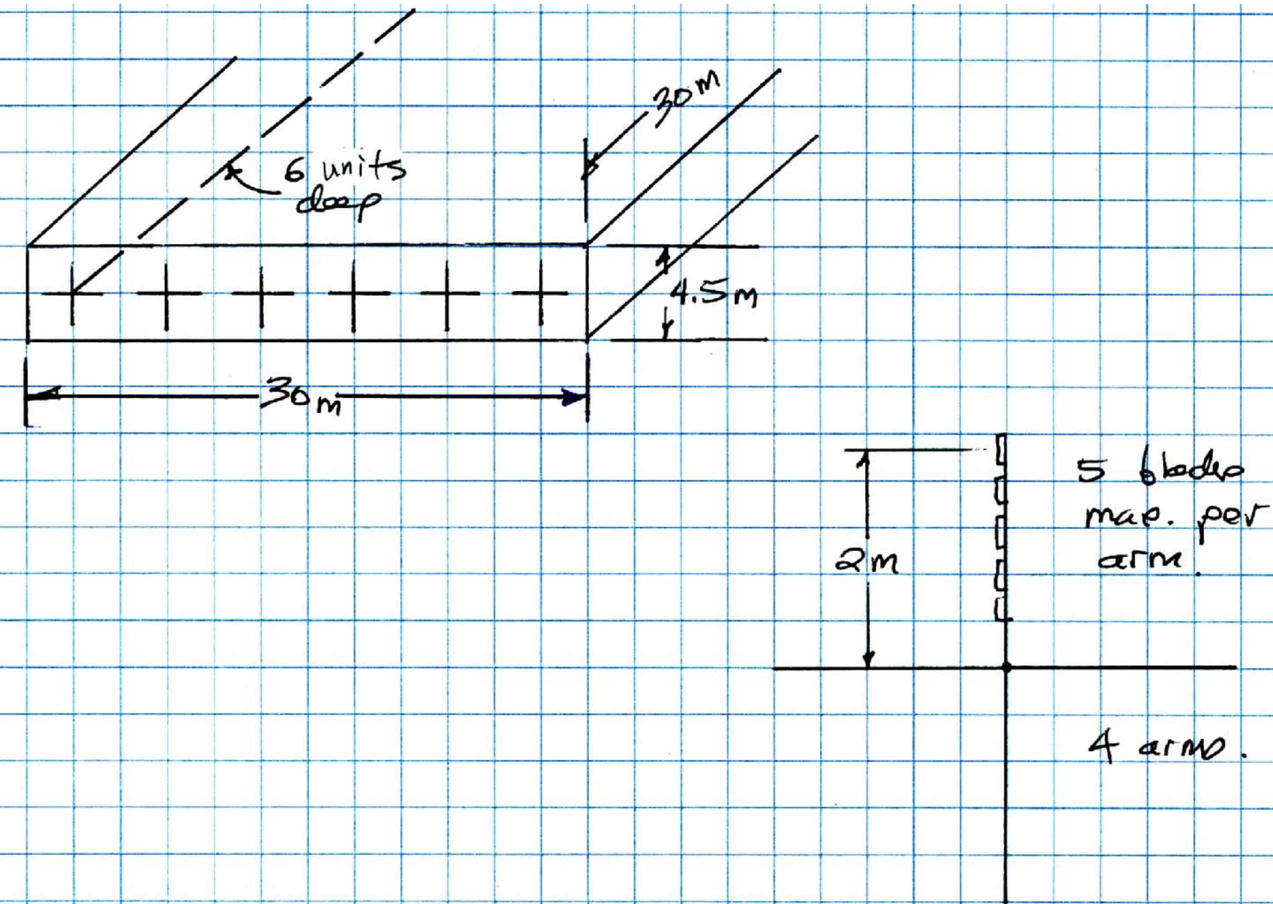
$$= 63.71\%$$

$2.66 + 3.71 = 6.37$, $\quad \frac{2.66}{6.37} \times (50 - 38\ mins) = 5.01$ mins.

So at $t = 38 + 5.01$ mins or $\doteq 43$ mins there will be 60% removed.

$$V_o = \frac{1.80\ m}{43\ min} = \underline{\underline{0.0419\ m/min.}}$$

3)



3) $Q = 200{,}000 \ m^3/day$
$T = 10°C$
$G = 60 \ s^{-1}$

$G = \sqrt{\frac{P}{\mu \forall}}$;

$P = \frac{C_d A \rho (1-k)^3 (2\pi n)^3}{2} (r_1^3 + r_2^3 + \ldots)$

at $T = 10°C$
$\rho = 999.7 \ kg/m^3$
$\mu = 1.307 \times 10^{-3} \ N \cdot s/m^2$

$\forall = 30 \ m \times 30 \ m \times 4.5 \ m = 4050 \ m^3$

$6 \text{ compartments} \times \frac{6 \text{ flocculators}}{\text{compartment}} \times \frac{4 \text{ arms}}{\text{flocculator}} = 144$ paddles possible at each radius

$A = 144 \times 4.6 m \times 0.15 \ m = 99.36 \ m^2$

$k = \frac{\text{water velocity}}{\text{paddle velocity}} = 0.3$ (This means $v_p = 0.7$)

max. rotation at $r = 2.0 \ m$ is $0.8 \ m/s = 2\pi r n$
$= 2\pi (2.0 \ m) n$
$= 12.566 \ n$
$n = 0.06366 \ rps = 3.82 \ rpm$

$C_d = 1.80$

$G = \sqrt{\frac{P}{\mu \forall}} = \left(\frac{P}{\mu \forall}\right)^{\frac{1}{2}}$;

$G^2 = \frac{P}{\mu \forall}$

$P = G^2 \mu \forall = \frac{60^2}{s^2} \times 1.307 \times 10^{-3} \frac{N \cdot s}{\cancel{m^2}} \times 4050 \ m^{\cancel{3}}$
$= 19{,}056 \ \frac{N \cdot m}{s}$

3) cont'd. A trial and error process is required to determine the number of blades to be used throughout and at which radii.

Try blades at 2.0 m and at 1.40 m.

$$P = \frac{c_d A \rho (1-k)^3 (2\pi n)^3 (r_1^3 + r_2^3 \ldots)}{2}$$

$$P = \frac{(1.80)(99.36\ m^2)(999.7\ kg/m^3)\overset{0.343}{(0.7)^3}\overset{10.064}{(2\pi \times 0.06366)^3}}{2} \times (r_1^3 \ldots)$$

$$P = 1962 \times (r_1^3 + r_2^3)$$

$$= 1962 \times (2^3 + 1.4^3) = 21{,}079\ \frac{N.m}{s}$$

Try blades at 2.0 m and 1.10 m

$$P = 1962\,(2^3 + 1.10^3) = 18{,}307\ \frac{N.m}{s}.$$

At 2.0 m alone $P = 15696$ N·m/s
1.70 m $P = 9{,}639$ N·m/s
1.40 m $P = 5{,}384$ N·m/s
1.10 m $P = 2{,}611$ N·m/s
0.80 m $P = 1{,}004$ N·m/s.

Blades at 2.0 m, 1.10 m and at 0.80 m gives
$P \doteq 19{,}311$ N·m/s.

This is closest to desired value.

4) Sedimentation Basin

5 m wide sludge equipment

$Q_{max} = 3.25\ m^3/s$

$V_0 = 2.0\ m/h$

$T = 5°C$

$Q_{avg} = Q_{max} \div 1.5 = 2.17\ m^3/s.$

Design basins and determine WOR

$$A_p = \frac{Q}{V_0} = \frac{3.25\ m^3/s}{2\ m/h \times 1h/3600\ s} = 5850\ m^2$$

Try width $= 2 \times 5m = 10\ m$

$L/W = 5/1 = 50/10$ so can use a $L = 50\ m$.

$$\frac{5850}{50 \times 10} = 11.7 \rightarrow \text{use } 12 \text{ basins.}$$

min $L/H = 50/H = 15/1$ $H = 3.33$ maximum.

Use $H = 3.30\ m$

$W/H = 10/3.3 = 3.03/1$ is acceptable

With $L = 50m$, $W = 10\ m$ and $H = 3.3\ m$

$$t = \frac{LHW}{Q} = \frac{50 \times 10 \times 3.3 \times 12 \text{ basins}}{3.25\ m^3/s \times 3600\ s/h} = 1.69\ hr.$$

at Q_{avg} $t = 1.69 \times 1.5 = 2.54$ hours.

at $5°C$ $\rho = 1{,}000\ kg/m^3$

$\mu = 1.519 \times 10^{-3}\ N \cdot s/m^2$

$= 0.001519\ kg/m \cdot s$

4) continued $L = 50\ m,\ W = 10\ m,\ H = 3.3\ m;$ 12 basins

$$V_H = \frac{Q}{HW} = \frac{3.5\ m^3/s \times 60\ s/min}{3.3\ m \times 10\ m \times 12\ basins} = 0.53\ m/min. = 0.00884\ m/s$$

$$R_h = \frac{A_x}{P_w} = \frac{10 \times 3.3}{3.3+3.3+10} = 1.99$$

$$R_e = \frac{\rho V_H}{\mu} R_h = \frac{1000\ kg/m^3 \times 0.00884\ m/s}{0.001519\ kg/m.s} \times 1.99 = 11,581$$

$< 20,000$ O.K

$$F_R = \frac{V_H^2}{g R_h} = \frac{0.00884^2}{9.81 \times 1.99} = 0.400 \times 10^{-5} \not> 1 \times 10^{-5}$$

not O.K.

A reduction in R_h increases F_R (and reduces R_e).

$$F_R = 0.00001 = \frac{(0.00884)^2}{9.81 \times R_H}$$

$$R_H = \frac{0.00884^2}{0.00001 \times 9.81} = 0.797 = \frac{A_x}{P_w} = \frac{3.3\ W}{W + 3.3 + 3.3}$$

$$0.797(W + 6.6) = 3.3W = 0.797W + 5.26 = 3.3\ W$$

$$2.503\ W = 5.26, \quad W = 2.10\ m$$

So 4 baffles (or 5 spaces) will just an adequate F_R.

$$\dot{W}oR = \frac{Q}{L_{weir}} = \frac{Q}{1.414\ W}$$

$$L_{weir} = \frac{Q_{max}}{WoR} = \frac{3.25\ m^3/s \times 3600\ s/h}{10.4\ m^3/m.h \times 12\ basins} = 93.75\ m$$

With 90° V-notch weir Horizontal width $= \frac{93.75}{1.414} = 66.3\ m.$

Basin $W = 10\ m$, so 7 weirs across each basin will work.

4) continued

Basin

4 channels with 7 weirs will satisfy WOR.

Seasonal changes may reduce Q and the number of basins online will need to be evaluated to maintain Re and Fr within acceptable levels.

9) longer detention times are required then basin dimensions or volumes will have to be reconsidered.