

## Flocculation Example Calculations

### Flocculation Basins

Hydraulic Retention Time Equation

$$t = \frac{V}{Q}$$

where

$t$  = theoretical detention time, min

$V$  = volume of fluid in reactor,  $ft^3$

$Q$  = flow rate into reactor,  $ft^3/min$

Design Criteria		Units
Detention Time	25	Minutes
Depth	>1	Meter
L/W Ratio	5 to 20	N/A
Given/Assumed Values		Units
Flow Rate, Q	4757	$ft^3/min$
# of Flocculation Basins	4	Basins
Depth per Basin	7	feet
Width	17	ft
$f_D$	0.025	-
Hydraulic Diameter	9.9	ft
Velocity	0.67	ft/s
Gravity	32.2	$ft/s^2$
Flow Rate, Q	79.3	$ft^3/s$
Minor Loss	0.0207	ft
Paddle Flocculator Loss	0.25	ft

$$25 \text{ min} = \frac{V}{4757 \frac{ft^3}{min}}$$

Solve for  $V$

$$V = 118924 \text{ ft}^3$$

Volume per Flocculation Basin:

$$\frac{\text{Total Volume}}{\# \text{ of Flocculation Basins}} = \frac{118924 \text{ ft}^3}{4} = 29731 \text{ ft}^3$$

Area per Basin:

$$\frac{\text{Volume per Basin}}{\text{Depth per Basin}} = \frac{29731 \text{ ft}^3}{7 \text{ ft}} = 4247 \text{ ft}^2$$

Length per Basin:

$$\frac{\text{Area per Basin}}{\text{Width per Basin}} = \frac{4247 \text{ ft}^2}{17 \text{ ft}} = 250 \text{ ft}$$

L/W Ratio:

$$\frac{\text{Length}}{\text{Width}} = \frac{250 \text{ ft}}{17 \text{ ft}} = 15$$

Flow Rate per Basin:

$$\frac{\text{Flow Rate}}{\# \text{ of Flocculation Basins}} = \frac{4757 \frac{\text{ft}^3}{\text{min}}}{4} = 1189 \text{ ft}^3/\text{min}$$

Compartment Volume per Basin:

$$\frac{\text{Volume per Basin}}{3 \text{ Compartments}} = \frac{29731 \text{ ft}^3}{3} = 9910 \text{ ft}^3$$

**Head Loss Calculations per Basin:**

$$h_f = f_D \frac{L V^2}{D 2g}$$

where:

$h_f, \text{ft} = \text{headloss}$

$f_D = \text{Darcy's friction factor}$

$L = \text{Length, ft}$

$D = \text{Hydraulic diameter, ft}$

$V = \text{Velocity, ft}^2/\text{s}$

$g = \text{Gravity, ft/s}^2$

$$h_f = (0.025) \left( \frac{250 \text{ ft}}{9.9 \text{ ft}} \right) \left( \frac{(0.67 \frac{\text{ft}^2}{\text{s}})^2}{32.2 \frac{\text{ft}}{\text{s}^2}} \right)$$

Solve for  $h_f$

$$h_f = \mathbf{0.0043 \text{ ft}}$$

Total Head Loss:

$$h_f + \text{minor loss} + \text{paddle flocculator} = \text{total headloss}$$

$$0.0043 \text{ ft} + 0.0207 \text{ ft} + 0.25 \text{ ft} = \mathbf{0.3 \text{ ft}}$$

## Bar screen Initial Screening

$$H_L = k \frac{[(V_{thru})^2 - (V_{approach})^2]}{2g} \quad \text{Removal Efficiency}$$

$$H_L = \text{Headloss, m}$$

$k$  = empirical discharge coefficient

$V_{thru}$  =

$V_{approach}$  = approach velocity, m/s

$g$  = gravitational acceleration =  $9.81 \text{ m/s}^2$

Initial flow  $Q_i = 1.8 \text{ MGD}$

$$Q = VA \quad v = \frac{Q}{A}$$

$$Q = 1.8,000,000 \frac{\text{gal}}{\text{day}} \cdot \frac{3.78 \text{ Liters}^3}{1 \text{ gallon}} \cdot \frac{0.035 \text{ ft}^3}{1 \text{ liter}} \cdot \frac{1 \text{ day}}{24 \text{ hrs}} \cdot \frac{1 \text{ hr}}{3600 \text{ sec}}$$

$$Q = 66 \text{ ft}^3/\text{s}$$

$$v = \frac{66 \text{ ft}^3/\text{s}}{2(4 \times 20)} = 0.4125 \text{ ft/s}$$

Using graph from cutsheet

0.3 inches

$$\frac{0.3}{12} = 0.025 \text{ ft in headloss}$$

## Fine screening calculations

$$Q = 61 \text{ ft}^3/\text{s} \quad \# \text{ units} = 10$$

$$A = 32 \text{ ft}^2$$

$$\text{Effective open area} = 128 \text{ ft}^2$$

$$v = \frac{61 \text{ ft}^3/\text{s}}{32 \text{ ft}^2} \cdot 128 \text{ ft}^2 = 0.4766 \text{ ft/s}$$

Johnsons Wedge wire

$$k = 0.76$$

$$H_c = \frac{k \cdot v \cdot \sqrt{\text{Particle thickness}} \cdot \text{Discharge coeff.}}{2g} = \frac{(0.76) \cdot (0.4766 \text{ ft/s})}{2 \cdot (2.2174 \text{ ft/s}^2)} = 0.0027 \text{ ft}$$

Solid removal efficiency = 96%

$$\text{TSS} = 4.3 \text{ mg/L}$$

$$4.33 - (4.33)(0.96) = 0.177 \text{ mg/L}$$

## Coagulation Example Calculations

### In-Line Mechanical Mixer

Hydraulic Retention Time Equation

$$t = \frac{V}{Q}$$

where

$t$  = theoretical detention time, s

$V$  = volume of fluid in reactor,  $m^3$

$Q$  = flow rate into reactor,  $m^3/s$

Velocity Gradient Equation:

$$G = \left( \frac{P}{\mu V} \right)^{1/2}$$

where

$G$  = Global RMS velocity gradient,  $s^{-1}$

$P$  = Power of mixing input to vessel,  $W$

$\mu$  = dynamic viscosity of water,  $Pa \cdot s$

$V$  = Volume of liquid,  $m^3$

Design Criteria		Units
Global RMS Velocity Gradient, G	3,000-5,000	$s^{-1}$
Detention Time	0.5	$s^{-1}$
Head Loss	1.0-3.0	ft
Given Values		Units
Dynamic Viscosity of Water, $\mu$	8.9E-4	$Pa \cdot s$
Flow Rate, Q	50,000,000	gall/d
Radius of Pipe	1.75	ft
Specific Weight of Water, $\gamma$	62.4	$lb/ft^3$

Flow Rate (Q) Conversion

$$50,000,000 \frac{\text{gall}}{\text{d}} \times \frac{0.134 \text{ ft}^3}{\text{gall}} \times \frac{1 \text{ d}}{24 \text{ hrs}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 77.5 \frac{\text{ft}^3}{\text{s}}$$

### Hydraulic Detention Time Calculation:

$$2 \text{ s} = \frac{V}{77.5 \frac{\text{ft}^3}{\text{s}}}$$

Solve for  $V$

$$V = 155 \text{ ft}^3$$

Volume ( $V$ ) Conversion:

$$155 \text{ ft}^3 \times \frac{0.0283 \text{ m}^3}{1 \text{ ft}^3} = 4.39 \text{ m}^3$$

Velocity Gradient Calculation:

$$4,000 \text{ s}^{-1} = \left( \frac{P}{(8.9 \times 10^{-4} \text{ Pa} \cdot \text{s}) \times (4.39 \text{ m}^3)} \right)^{1/2}$$

Solve for  $P$

$$P = 62,501.1 \text{ Watts}$$

### Pipe Length for Coagulation Calculation:

Equation for Volume of Cylinder

$$V = \pi r^2 h$$

where

$r = \text{radius, ft}$

$h = \text{height, ft}$

$$155 \text{ ft}^3 = \pi \times (1.75 \text{ ft})^2 \times h$$

Solve for  $h$

$$\text{height} = 16.1 \text{ ft}$$

## Headloss Calculation:

Power Conversion:

$$62501.1 \text{ Watts} \times \frac{1 \text{ kW}}{1000 \text{ W}} \times \frac{737.56 \frac{\text{ft} - \text{lb}}{\text{s}}}{1 \text{ kW}} = 46098.3 \frac{\text{ft} - \text{lb}}{\text{s}}$$

Hydraulic Power Equation:

$$h_f = \frac{P}{\gamma Q}$$

where

$h_f = \text{Headloss, ft}$

$\gamma = \text{specific weight, } \frac{\text{lb}}{\text{ft}^3}$

$P = \text{Power, } \frac{\text{ft} - \text{lb}}{\text{s}}$

$$h_f = \frac{46098.3 \frac{\text{ft} - \text{lb}}{\text{s}}}{\left(62.4 \frac{\text{lb}}{\text{ft}^3}\right) \left(77.5 \frac{\text{ft}^3}{\text{s}}\right)}$$

Solve for  $h_f$

$$\mathbf{h_f = 10 \text{ ft}}$$

## Plate Settler Calculations:

*Equation 1: Total Plate Settler Surface Area*

$$A_s = \frac{Q}{V_o}$$

Where:

$A_s$  = Total Surface Area of all Plate Settlers ( $m^2$ )

$Q$  = Flow Rate (MGD,  $m^3/day$ ,  $m^3/s$ )

$V_o$  = Overflow Velocity ( $m^3/d \cdot m^2$ )

*Equation 2: Surface Area of Tank*

$$A_{Tank} = \frac{A_s}{n}$$

Where:

$A_{Tank}$  = Surface Area of Tank ( $m^2/tank$ )

$A_s$  = Total Surface Area of all Plate Settlers ( $m^2$ )

$n$  = # of tanks (tanks)

*Equation 3: Length of Settler*

$$L_{Settler} = \frac{A_{Tank}}{W}$$

Where:

$L_{Settler}$  = Length of Settler (m)

$A_{Tank}$  = Surface Area of Tank ( $m^2/tank$ )

$W$  = Width (m)

*Equation 4: Length of Basin*

$$L_{Basin} = L_{Settler} \times \frac{1}{0.75}$$

Where:

$L_{Basin}$  = Length of Basin (m)

$L_{Settler}$  = Length of Settler (m)

*Equation 5: Side Water Depth*

$$SWD = Settler\ Depth + Launder\ Depth + Sludge\ Zone$$

Where:

SWD = Side Water Depth (m)

*Equation 6: Total Tank Depth*

$$Total\ Tank\ Depth = SWD + Freeboard$$

*Equation 7: Area of Approach*

$$A_{Approach} = W \times SWD$$

Where:

$A_{Approach}$  = Area of Approach (m<sup>2</sup>)

W = Width (m)

SWD = Side Water Depth (m)

*Equation 8: Velocity of Approach*

$$V_A = \frac{Q}{n \times A_{Approach}}$$

Where:

$V_A$  = Approach Velocity (m/s)

$Q$  = Flow Rate (m<sup>3</sup>/s)

$n$  = # of tanks

$A_{Approach}$  = Area of Approach (m<sup>2</sup>)

*Equation 9: Velocity in Settler*

$$V_{fc} = \frac{Q}{A \times \sin\theta}$$

Where:

$V_{fc}$  = Velocity in Settler (m/s)

$A$  = Area per tank (m<sup>2</sup>)

$\theta$  = Plate Angle (°)

*Equation 10: Reynold's Multiplier*

$$R_H = \frac{D_H}{4}$$

Where:

$R_H$  = Reynold's Multiplier (m)

$D_H$  = Plate Settler Diameter (mm)

Equation 11: Reynold's Equation

$$R_e = \frac{V_{fc} \times R_H}{\nu}$$

Where:

$R_e$  = Reynold's Number (unitless)

$V_{fc}$  = Velocity in Settler (m/s)

$R_H$  = Reynold's Multiplier (m)

$\nu$  = Viscosity (Pa · s)

Equation 12: Froude's Number Equation

$$F_R = \frac{V_{fc}^2}{g \times R_H}$$

Where:

$F_R$  = Froude's Number (unitless)

$V_{fc}$  = Velocity in Settler (m/s)

$g$  = gravity (m/s<sup>2</sup>)

$R_H$  = Reynold's Multiplier (m)

Equation 13: Launder Width

$$LW = 3 \text{ Launder} \times \frac{2 \text{ sides}}{\text{Launder}} \times L_{\text{Settler}}$$

Where:

LW = Launder Width (m)

$L_{\text{Settler}}$  = Length of Settler (m)

Equation 14: Loading Rate

$$WL = \frac{Q}{n \times A_s}$$

Where:

WL = Loading Rate (m<sup>3</sup>/d • m<sup>2</sup>)

Q = Flow Rate (m<sup>3</sup>/s)

n = # of tanks

A<sub>s</sub> = Total Surface Area of all Plate Settlers (m<sup>2</sup>)

Equation 15: Number of Orifices per Tank

$$Orifices = \frac{LW}{D_o}$$

Where:

LW = Launder Width (m)

D<sub>o</sub> = Diameter of Orifices (m)

Equation 16: Flow Rate

$$Q_{Tank} = \frac{Q}{n}$$

Where:

Q<sub>Tank</sub> = Flow Rate per Tank (m<sup>3</sup>/s)

Q = Total Flow Rate (m<sup>3</sup>/s)

n = # of Tanks

Equation 17: Flow Rate per Orifice

$$Q_{Orifice} = \frac{Q_{Tank}}{N}$$

Where:

Q<sub>Orifices</sub> = Flow Rate per Orifice (m<sup>3</sup>/s)

Q<sub>Tank</sub> = Flow Rate per Tank (m<sup>3</sup>/s)

N = # of Orifices

*Equation 18: Area per Orifice*

$$A = \frac{\pi D^2}{4}$$

Where:

A = Area per Orifice (m<sup>2</sup>)

D = Diameter of Orifice (m)

*Equation 19: Headloss*

$$h = \frac{1}{2g} \times \frac{Q_{Orifice}}{K \times A}$$

Where:

h = Headloss (m)

g = Gravity (m/s<sup>2</sup>)

Q<sub>Orifices</sub> = Flow Rate per Orifice (m<sup>3</sup>/s)

K = Coefficient (unitless)

A = Area per Orifice (m<sup>2</sup>)

*Equation 20: Minor Loss*

$$Minor Loss = K \frac{v^2}{2g}$$

Where:

K = Coefficient (unitless)

v = Viscosity (Pa • s)

g = Gravity (m/s<sup>2</sup>)

### Plate settler Headloss calculation

$$Q = 40 \text{ MGD} = 1.753 \text{ m}^3/\text{s}$$

$$D_{\text{orifices}} = 50 \text{ mm}$$

$$\text{Placement} = 1 \text{ m}$$

$$n = 6 \text{ tanks}$$

$$L = 34 \text{ m}$$

estimating # of orifices per tank:

$$(34 \text{ m})(3 \text{ launders}) \left( \frac{2 \text{ sides}}{1 \text{ launder}} \right) = 201.84 \text{ m}$$

$$\frac{201.84 \text{ m}}{1 \text{ m/orifice}} = 201.84 \rightarrow \text{round up} = 202 \text{ orifices}$$

flow rate determination:

$$\frac{(1.753 \text{ m}^3/\text{s})}{(6 \text{ tanks})} = 0.292 \text{ m}^3/\text{s per tank}$$

estimating flow rate per orifices:

$$\frac{Q}{N} = \frac{(0.292 \text{ m}^3/\text{s per tank})}{(202 \text{ orifices})} = 1.45 \times 10^{-3} \text{ m}^3/\text{s} \cdot \text{orifices}$$

area of orifice:

$$A = \frac{\pi D^2}{4} = \frac{\pi (0.05 \text{ m})^2}{4} = 1.93 \times 10^{-3} \text{ m}^2$$

headloss calculation using coeff. of 0.6:

$$h = \frac{1}{2g} \left( \frac{Q/N}{A} \right)^2 = \frac{1}{2(9.81)} \left( \frac{(1.45 \times 10^{-3})}{(0.6)(1.93 \times 10^{-3})} \right)^2 = 0.0036 \text{ m}$$

$$\text{minor loss: } \text{minor loss} = k \left( \frac{v^2}{2g} \right) = 0.0714 \times 12 = 0.8412 \text{ inches}$$

→ 2.5 inches of headloss

$$\text{Total head loss} = 2.5 \text{ in} + 0.8412 \text{ in} = \boxed{3.3412 \text{ inches}}$$

# Plate settlers calculations

\* GRUND guidance was used to check if values were to standards

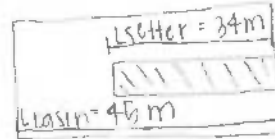
$Q = 40 \text{ MGD} = 1.753 \text{ m}^3/\text{s} = 151417.728 \text{ m}^3/\text{d}$   
 $T = 25^\circ\text{C}$   $D_H = 60 \text{ mm}$   $\theta = 59^\circ$   $\bar{v}_0 = 150 \text{ m}^3/\text{d}\cdot\text{m}^2$

$A_s = \frac{Q}{\bar{v}_0} = \frac{(151417.728 \text{ m}^3/\text{d})}{(150 \text{ m}^3/\text{d}\cdot\text{m}^2)} = 1,009.453 \text{ m}^2$

$A_{\text{tank}} = \frac{A_s}{n} = \frac{(1009.453 \text{ m}^2)}{(6 \text{ tanks})} = 168.242 \text{ m}^2/\text{tank}$

$L_{\text{settler}} \times W = A_{\text{tank}} \rightarrow L_{\text{settler}} = \frac{A_{\text{tank}}}{W} = \frac{168.242 \text{ m}^2}{5 \text{ m}} = 33.648 \text{ m}$

$L_{\text{basin}} = L_{\text{settler}} \times \frac{1}{0.75} = 44.865 \text{ m}$



Settler depth = 0.6m  
 Launder depth = 1.3m  
 Sludge zone = 3.0m  
 Freeboard = 0.6m  
 Total tank depth = 5.5m

$\uparrow$   
 approach depth = SWD = 4.90m  $\rightarrow 3\text{m} \leq 4.90\text{m} \leq 5\text{m} \checkmark$

$A_{\text{approach}} = W \times \text{SWD} = (5 \text{ m}) \times (4.90 \text{ m}) = 24.5 \text{ m}^2$   
 $\bar{v}_A = \frac{Q}{(n)(A_{\text{approach}})} = \frac{(1.753 \text{ m}^3/\text{s})}{(6 \text{ tanks})(24.5 \text{ m}^2)} = 0.01 \text{ m/s} \rightarrow 0.01 \frac{\text{m}}{\text{s}} \geq 0.01 \frac{\text{m}}{\text{s}} \checkmark$

Velocity in Settler  $\bar{v}_{fc} = \frac{Q}{A_s \sin \theta} = \frac{(1.753 \text{ m}^3/\text{s})}{(6 \text{ tanks})(168.242 \text{ m}^2)(\sin 59^\circ)} = 0.00273 \text{ m/s}$   
 $\bar{v}_{fc} = 0.0025 \text{ m/s} \leq 0.00273 \text{ m/s} \leq 0.0037 \text{ m/s} \checkmark$

$R_H = \frac{A}{WP} = \left(\frac{\pi D^2}{4}\right) \left(\frac{1}{\pi D}\right) = \frac{D_H}{4} = \frac{0.06 \text{ m}}{4} = 0.015 \text{ m}$

$Re = \frac{\bar{v}_{fc} R_H}{\nu} = \frac{(0.00273 \text{ m/s})(0.015 \text{ m})}{(8.927 \times 10^{-7} \text{ m}^2/\text{s})} = 45.814 \rightarrow 46 \rightarrow Re = 46 < 50 \checkmark$

$Fr = \frac{\bar{v}_{fc}^2}{g R_H} = \frac{(0.00273 \text{ m/s})^2}{(9.81 \text{ m/s}^2)(0.015 \text{ m})} = 5.052 \times 10^{-5} \rightarrow Fr = 5.052 \times 10^{-5} > 1 \times 10^{-5} \checkmark$

$LW = 3 \text{ launders} \times \frac{2 \text{ sides}}{\text{launder}} \times 34 \text{ m} = 201.840 \text{ m}$

distance between launder =  $\frac{W}{\#} = \frac{5 \text{ m}}{3} = 1.67 \text{ m}$

$WL = \frac{Q}{LW} = \frac{(151417.728 \text{ m}^3/\text{d})}{(201.840 \text{ m})} = 125 \text{ m}^3/\text{d}\cdot\text{m}^2$

$WL = 125 \text{ m}^3/\text{d}\cdot\text{m}^2 < 300 \text{ m}^3/\text{d}\cdot\text{m}^2 \checkmark$

$A_{\text{tank}} = 1811 \text{ ft}^2/\text{tank}$   
 $L_{\text{settler}} = 110 \text{ ft}$   
 $L_{\text{basin}} = 147 \text{ ft}$   
 Total tank depth = 18 ft  
 # of tanks = 6 tanks  
 Total Area = 3312 ft<sup>2</sup>

$A_{\text{Tank}} = 1,811 \text{ ft}^2/\text{tank}$

$L_{\text{Settler}} = 110 \text{ ft}$

$L_{\text{Basin}} = 147 \text{ ft}$

Total Tank Depth = 18 ft

# of Tanks = 6 tanks

Total Area = 3312ft<sup>2</sup>

Headloss = 2.50 in

Minor Headloss = 0.84 in

Total Headloss = 3.34 in

## Membrane Filter Calculations

$$\frac{Q}{A} = \frac{\Delta P}{(\mu)(R_m)}$$

where

$Q$  = flow rate of pure water

$A$  = surface area of clean membrane,  $m^2$

$\Delta P$  = transmembrane pressure, kPa

$\mu$  = dynamic viscosity of water,  $Pa \cdot s$

$R_m$  = membrane resistance coefficient

$$Q = 62 \text{ ft}^3/\text{s}$$

Using ePTFE Material

0.5-1  $\mu m$

$$R_m = \frac{8(\mu) L}{\pi r^4 P_{acc}}$$

$$kPa = 62$$

9105 cP

$$\frac{\Delta P}{A} = L$$

$$\Delta P = 62 \text{ kPa} = 9.213 \text{ PSI}$$

$$r = 0.1997$$

$$\frac{8}{A} R \frac{1}{\mu} = \frac{8}{\pi r^4}$$

Solubility

$$= 22.4352 \text{ ft}^2/\text{ft}^2$$

$$\frac{22.4352 \text{ ft}^2/\text{ft}^2}{0.999} = 22.4352$$

$$22.4352 = 22.5 \text{ ft}$$

$$0.999$$

## GAC Example Calculations

### Granular Activated Carbon Filter Beds

#### Hydraulic Retention Time Equation

$$t = \frac{V}{Q}$$

where

$t$  = theoretical detention time, s

$V$  = volume of fluid in reactor,  $m^3$

$Q$  = flow rate into reactor,  $m^3/s$

Design Criteria		Units
Empty Bed Contact Time, EBCT	30	min
Flow Rate	4757	$ft^3/min$
Given/Assumed Values		Units
Hydraulic Loading Rate	29.52	ft/hr
# of Filter Beds	7 (1 offline)	-
Width	20	ft

#### Hydraulic Detention Time Calculation:

$$30 \text{ min} = \frac{V}{4747 \frac{ft^3}{min}}$$

Solve for  $V$

$$\text{Carbon Bed Volume} = 142708 \text{ ft}^3$$

#### Area Calculation:

$$\frac{\text{Flow Rate (Q)}}{\text{Hydraulic Loading Rate}} = \frac{4757 \text{ ft}^3/\text{min}}{\text{ft/hr}} \times \frac{60 \text{ min}}{1 \text{ hr}} = 9669 \text{ ft}^2$$

#### Depth Calculation:

$$\frac{\text{Carbon Bed Volume, } V}{\text{Area}} = \frac{142708 \text{ ft}^3}{9669 \text{ ft}^2} = 14.76 \text{ ft}$$

**Area per Filter Calculation:**

$$\frac{\text{Area of Filter}}{\# \text{ of Filters}} = \frac{9669 \text{ ft}^2}{6} = \mathbf{1611.3 \text{ ft}^2}$$

**Length per Filter Calculation:**

$$\frac{\text{Area per Filter}}{\text{Width per Filter}} = \frac{1611.3 \text{ ft}^2}{20 \text{ ft}} = \mathbf{81 \text{ ft}}$$

## RO Calculations

Point BW30 PAO-400 / 34 Element

Max Flow = 75 GPM

$$75 \frac{\text{gal}}{\text{min}} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{24 \text{ hr}}{1 \text{ day}} = 108,000 \text{ GPD}$$

$$\frac{108,000 \text{ GPD}}{108,000 \text{ GPD}} = 3.70 \text{ RO Membranes}$$

Unit Size = 400 ft<sup>2</sup> with 34/m<sup>2</sup>  
400 ft<sup>2</sup> = 370 units / 43560 acres

$$\left[ \frac{108,000}{43560} = 2.48 \rightarrow 3 \text{ acres} \right]$$

Max Pressure Drop = 15 psi

## AOP Example Calculations

Advanced Oxidation Process: *UV/Ozone Basins*

### Ozone

Design Criteria		Units
Flow Rate, Q	4757	ft <sup>3</sup> /min
Flow Rate, Q	79.3	ft <sup>3</sup> /s
Flow Rate, Q	189,250,000	L/day
Ozone Dose	3	mg/L
Contact Time	10	(mg*min)/L
UV Dose	300	mJ/cm <sup>2</sup>
UV Contact Time	10	s
Velocity	0.5	ft/s
UV Depth	10	ft
UV Width	15.5	ft
UV Lamp	Medium Pressure Lamp	

Concentration of Ozone:

$$189250000 \frac{L}{day} \times \frac{3 \text{ mg}}{L} = 567750000 \frac{mg}{day}$$

$$567750000 \frac{mg}{day} \times \frac{0.000002205 \text{ lb}}{1 \text{ mg}} = 1251.9 \frac{lb}{day}$$

Contact Time:

$$\frac{10 \frac{mg \cdot min}{L}}{3 \frac{mg}{L}} = 3.33 \text{ min}$$

Volume:

$$\frac{\text{Flow rate (Q)}}{\text{Contact time}} = \frac{4757 \text{ ft}^3/\text{min}}{3.33 \text{ min}} = 15856 \text{ ft}^3$$

### UV

Volume Calculation:

$$\frac{\text{Flow rate (Q)}}{\text{Contact Time}} = \frac{79.3 \text{ ft}^3/\text{s}}{10 \text{ s}} = 792.82 \text{ ft}^3$$

Area Calculation:

$$\frac{\text{Flow rate (Q)}}{\text{Velocity}} = \frac{79.3 \text{ ft}^3/\text{s}}{0.5 \text{ ft/s}} = 158.56 \text{ ft}^2$$

CST-Aquastore GFS Tank with Dual Laminate FRP Lining	
Area of Tanks (ft <sup>2</sup> )	15000
# of Tanks	3
Max Volume of Tank (MGD)	2.5
Storage Time (hours)	12
Total Land Usage (acres)	1.033058

	MGD	cfs	GPM	Froude Number (Unitless):	$F_D$
Desired Flow to Produce 30 MGD of Potable Water:	40.00	61.94	27777.78	Velocity at Pump Inlet (ft/s):	n
Flow per Pump (Q):	10.00	15.49	6944.44	Flow (GPM):	Q2
				Flow (cfs):	Q1

Sump Dimensions	
$y_1$ , Minimum Approach Length (ft):	11.25
$y_2$ , Floor Clearance (ft):	1.13
B, Back Wall to Pump Centerline (ft):	1.69
$y_3$ , Length Between Divider Walls for Pump Bays (ft):	5.00
S, Minimum Submergence Required (ft):	4.62
$F_D$ :	0.46
$v$ , Velocity (ft/s):	3.89
(3) S Related to Froude's No. :	4.62

Legend	Color
Key Values	

Rejection Rate for Microfiltration and RO:	0.25
Number of Active Pumps:	4.00
D, Suction Bell OD (in):	27.00
D, Suction Bell OD (ft):	2.25
Number of Minutes in a Day:	1440.00
Conversion Factor for GPM to cfs:	0.00223
$\pi$ , Pi:	3.14
x, Divider Wall Thickness Assumption (ft):	0.25
g, Acceleration Due to Gravity (ft/s <sup>2</sup> ):	32.20

Sump Design Equations:	
(1) Equation for Froude No. (FD):	$F_D = V / (g \cdot D)^{0.5}$
(2) S, (USCS Units) Equation for Recommended Minimum Submergence:	$S = (D + 0.574 \cdot Q) / (D^{1.5})$
(3) Recommended Relationship between S and FD:	$S/D = 1.0 + 2.3 \cdot F_D$
(4) B, Length between Pump Centerline and Backwall (ft):	$B = 0.75 \cdot D$
(5) $y_1$ , Minimum Approach Length before break (ft):	$y_1 = 5 \cdot D$
(6) $y_2$ , Floor Clearance (ft):	$y_2 = 0.5 \cdot D$
(7) $y_3$ , Length Between Divider Walls for Pump Bays (ft):	$y_3 = 2 \cdot D + x$
(8) $v$ , Velocity (ft/s):	$v = Q1/A$

#### Example Calculations

Equation	Given Values:
(1) $F_D = \frac{V}{(g \times D)^{0.5}}$	$v$ (ft/s) = 3.89
Calculation	$D$ (ft) = 2.25
$F_D = \frac{3.89}{(32.2 \times 2.25)^{0.5}}$	$g$ (ft/s <sup>2</sup> ) = 32.20
	$F_D = 0.46$

Equation	Given Values:
(2) $S = D + \frac{0.574 \times Q_2}{D^{1.5}}$	Q2 (GPM) = 6944.44
Calculation	$D$ (ft) = 2.25
$S = 2.25 + \frac{0.574 \times 6944.44}{2.25^{1.5}}$	
	$S = 4.62$ ft

Equation	Given Values:
(3) $S = D \times (1.0 + 2.3 \times F_D)$	$D$ (ft) = 2.25
Calculation	$F_D$ = 0.46
$S = 2.25 \times (1.0 + 2.3 \times 0.46)$	
	$S = 4.62$

Equation	Given Values:
(4) $B = 0.75 \times D$	$D$ (ft) = 2.25
Calculation	
(4) $B = 0.75 \times 2.25$	
	$B = 1.69$

Equation	Given Values:
(5) $y_1 = 5 \times D$	$D$ (ft) = 2.25
Calculation	
(5) $y_1 = 5 \times 2.25$	
	$y_1 = 11.25$

Equation	Given Values:
(6) $y_2 = 0.5 \times D$	$D$ (ft) = 2.25
Calculation	
(6) $y_2 = 0.5 \times 2.25$	
	$y_2 = 1.13$

Equation	Given Values:
(7) $y_3 = 2 \times D + x$	$D$ (ft) = 2.25
Calculation	$x$ (ft) = 0.25
(7) $y_3 = 2 \times (2.25) + 0.25$	

Equation	Given Values:
(8) $v = \frac{Q_1}{A}$	Q1 (cfs) = 15.49
Calculation	$A$ (ft <sup>2</sup> ) = 3.98
	$\pi$ , Pi: 3.14
(8) $v = \frac{Q_1}{(\pi \times 2.25^2) \div 4}$	
	$v = 3.89$

Static Headloss (ft):	58.00
Minor Headloss (ft):	5.00

Elev. Gain from Pump Station to Headworks (ft)	43.00
Lower Water Level Depth in Sump (ft):	15.00

Treatment Step	Headloss (ft)
Bar Screen	0.008
Wedge-Wire Screen	0.003
Coagulation w/ PAC	2.00
Flocculation	0.30
Plate Settlers	1.53
Microfiltration	22.50
Reverse Osmosis	34.80
GAC	9.04
AOP	
Connecting Basins/Pipes	3.00

L, Pipe Length (ft):	9900.00
Hazen-Williams Constant PVC (C):	140.00
D, diameter of pipe (ft):	4.00
D, diameter of pipe (ft):	3.50
D, diameter of pipe (ft):	3.00
Minor Headloss Nominal Value (C) from FE Handbook 10-5	0.04

$\pi$ , Pi	3.14
Number of Minutes in a Day	1440.00
Conversion Factor for GPM to cfs	0.00223
Water Rejection Rate:	0.25
Acceleration due to Gravity (ft/s <sup>2</sup> )	32.17
Friction Headloss (ft):	$h_f$
Flow (unit varies):	Q
Diameter of Pipe (ft):	D
Hydraulic Radius (ft):	$R_H$
Velocity (ft/sec):	V
Cross-sectional Area of Flow (ft <sup>2</sup> ):	A
Flow (cfs):	$Q_1$

NPSHa (ft):	35.6
NPSHr (ft):	24
Atmospheric Pressure (ft):	33
Submergence Height of Pump intake(ft):	5
Vapor Pressure @ 86 degree F (ft):	1.4
Intake Friction (ft):	1
NPSHa > NPSHr?	Yes

Color Legend	
Operating Point:	
Final Calculation:	
Assumption:	

Q, Flow (MGD)	Q, Flow (GPM)	Q, Flow (cfs)	$h_f$ Friction Headloss 48 inch PVC (ft):	S (ft/ft):	Static Headloss (ft):	Minor Headloss (ft)	TDH (ft)	Velocity (ft/s):
0.00	0.00	0.00	0.00	0.000000	58.00	0.00	58.00	0.00
15.00	10416.67	23.23	1.97	0.000199	58.00	5.00	64.97	1.85
30.00	20833.33	46.46	7.10	0.000717	58.00	5.00	70.10	3.70
37.20	25833.33	57.61	10.57	0.001068	58.00	5.00	73.57	4.58
40.00	27777.78	61.94	12.10	0.001222	58.00	5.00	75.10	4.93
50.00	34722.22	77.43	18.29	0.001847	58.00	5.00	81.29	6.16

Q, Flow (MGD)	Q, Flow (GPM)	Q, Flow (cfs)	$h_f$ Friction Headloss 42 inch PVC (ft):	S (ft/ft):	Static Headloss (ft):	Minor Headloss (ft)	TDH (ft)	Velocity (ft/s):
0.00	0.00	0.00	0.00	0.000000	58.00	0.00	58.00	0.00
15.00	10416.67	23.23	3.77	0.000381	58.00	5.00	66.77	2.41
30.00	20833.33	46.46	13.60	0.001374	58.00	5.00	76.60	4.83
37.20	25833.33	57.61	20.26	0.002047	58.00	5.00	83.26	5.99
40.00	27777.78	61.94	23.18	0.002341	58.00	5.00	86.18	6.44
50.00	34722.22	77.43	35.04	0.003539	58.00	5.00	98.04	8.05

Q, Flow (MGD)	Q, Flow (GPM)	Q, Flow (cfs)	$h_f$ Friction Headloss 36 inch PVC (ft):	S (ft/ft):	Static Headloss (ft):	Minor Headloss (ft)	TDH (ft)	Velocity (ft/s):
0.00	0.00	0.00	0.00	0.000000	58.00	0.00	58.00	0.00
15.00	10416.67	23.23	7.98	0.000806	58.00	5.00	70.98	3.29
30.00	20833.33	46.46	28.82	0.002911	58.00	5.00	91.82	6.57
37.20	25833.33	57.61	42.92	0.004336	58.00	5.00	105.92	8.15
40.00	27777.78	61.94	49.10	0.004960	58.00	5.00	112.10	8.76
50.00	34722.22	77.43	74.23	0.007498	58.00	5.00	137.23	10.95

(1) Hazen-Williams Friction Head Loss Equation (ft) :	$h_f = [(4.73 * L) / (C^{1.852} * D^{4.87})] * Q_1^{1.852}$
(2) Slope of Energy Gradeline Equation (ft/ft):	$S = (h_f) / L$
(3) Velocity Equation (fps):	$V = Q / A$

Example Calculations

Equation	Given Values:
$(1) h_f = \frac{(4.73 * L)}{(C^{1.852} * D^{4.87}) * Q_1^{1.852}}$	L (ft) = 9900.00
Calculation	C = 140.00
$(1) h_f = \frac{(4.73 * 9900)}{(140^{1.852} * 4^{4.87}) * 61.94^{1.852}}$	D (ft) = 4.00
$h_f = 12.1$	Q (cfs) = 61.94

Equation	Given Values:
$(2) S = \frac{(h_f)}{L}$	L (ft) = 9900.00
Calculation	$h_f$ (ft) = 12.10
$(2) S = \frac{(h_f)}{L}$	
$S = 0.0012222$	

Equation	Given Values:
$(3) V = \frac{Q}{A}$	Q (cfs) = 61.94
Calculation	A = 12.57
$(3) V = \frac{61.94}{(\pi * 4^2) * 4}$	D (ft) = 4.00
$V = 4.93$	$\pi$ , Pi: 3.14

K-Values	
$K_1$ , Flush Entrance:	0.50
$K_2$ , Pipe Exit:	1.00
Design Flow (MGD):	$Q_1$
$g$ , acceleration due to gravity (ft/s <sup>2</sup> ):	32.17
$\gamma$ , Specific Weight of Water (lb/ft <sup>3</sup> ):	62.4
Pipe Length between Processes (ft):	L
Hazen-Williams Constant PVC (C):	140.00
Fluid Pressure (lb/ft <sup>2</sup> ):	P
Elevation head (ft):	z
$\pi$ , Pi	3.14
d, Pipe Diameter between Processes (ft):	3.5
Equations:	
(1) $Q_2$ , Flow (cfs):	$Q_2 = Q_1 * 1.5472$
(2) $V$ , Velocity (ft/s):	$V = (Q_2) / ((\pi * d^2) / 4)$
(3) $V_m$ , Velocity Head (ft):	$V^2 / (2 * g)$
(4) Hazen-Williams Friction Head Loss Equation (ft) :	$h_f = [(4.73 * L) / (C^{1.852} * d^{4.87})]^2 * Q_2^{1.852}$
(5) $h_m$ , Minor Loss (ft):	$h_m = (K_1 + K_2) * V_m$
(6) $Y_2$ , Total Headloss (ft):	$Y_2 = h_f + h_m$

Color Legend	
Final Calculation:	
Assumption:	

Segment Description	Flow (MGD)	Flow (CFS)	Pipe Dia. (ft)	L, Length (ft)	Velocity inside stage (ft/s)	Velocity Head (ft)	Friction Loss $h_f$ (ft)	Minor Loss $h_m$ (ft)	Total Segment Headloss (ft)
Bar Screen	40.00	61.89	3.50	30.00	0.00	0.00	0.0701128	0.00	0.07
Wedge-Wire to Coagulation	40.00	61.89	3.50	30.00	0.00	0.00	0.0701128	0.00	0.07
Coagulation to Flocculation	40.00	61.89	3.50	30.00	6.43	0.64	0.0701128	0.96	1.03
Flocculation to Plate Settlers	40.00	61.89	3.50	20.00	0.00	0.00	0.0467418	0.00	0.05
Plate Settlers to MF Sump	40.00	61.89	3.50	20.00	0.00	0.00	0.0467418	0.00	0.05

Process Step	Physical Configuration	EGL (ft)	HGL (ft)	Starting WSE (ft)	Connecting Pipe Loss (ft)	Process Equip. Loss (ft)	Free-Fall Drop (ft)	Final Basin WSE (ft)
1. Bar Screen	Open to Air	1011.10	1011.10	1011.10		0.00		1011.10
2. Wedge-Wire Screen	Open to Air	1011.02	1011.02	1011.10	0.07	0.01	-	1011.02
3. PAC Coagulation	Pressurized Pipe	1009.03	1008.39	1011.10	0.07	2.00	-	1009.03
4. Flocculation Basin	Open to Air	1007.70	1007.70	1009.03	1.03	0.30	-	1007.70
5. Plate Settlers	Open to Air	1006.12	1006.12	1007.70	0.05	1.53	-	1006.12
6. Microfiltration Sump	Open to Air	1005.07	1005.07	1006.12	0.05	-	1.00	1005.07

Example Calculations

Equation	Given Values:
(1) $Q_2 = Q_1 \times 1.5472$	$Q_1$ (MGD) = 40.00

Equation	Given Values:
(1) $Q_2 = 40.00 \times 1.5472$	$Q_2 = 61.89$
(2) $V = \frac{Q_2}{(\pi \times D)^2 \div 4}$	D (ft) = 3.50 $\pi$ , Pi = 3.14