**Water Treatment System Cost**

Each prototype filter will be scaled up to handle a flowrate of 20 million gallons per day (MGD). The effluent water must have an average turbidity of less than 2 NTU. To handle back-washing and cleaning of the treatment system, the overall size of the treatment system should be increased by 20% or a factor of safety of 1.2

The full-scale treatment system may be constructed with any combination of the following three processes: coagulation and flocculation basins (5 MGD); sedimentation tanks (each tank is 75,000 gallons); and gravity granular-media filters (1,000 ft.$^2$ per filter).

***Coagulation and Flocculation System***

Operation and maintenance costs for the coagulation and flocculation system are dependent on the system flowrate. A single full-scale coagulation and flocculation unit capable of treating 5 MGD costs $25,000 per year. Ferric chloride and associated chemicals cost $1/*kg*. The weight of coagulant, $wt_c$ (kg/gallon), required per gallon of treated water is estimated as

$$wt_c = D\left(\frac{3.785\,\text{L}}{\text{gallon}}\right)\left(\frac{\text{kg}}{10^6\ \text{mg}}\right) \tag{1}$$

where $D$ is the dosage (mg/L) of ferric chloride used in the treatment system. The number of coagulation and flocculation units $NCF$ required is:

$$NCF = Roundup\left[\left(\frac{20(MGD)}{5\ (MGD)}\right)\times 1.2\right] \tag{2}$$

The cost of coagulation and flocculation $Cost_{CF}$ is:

$$Cost_{CF} = NCF\left(\frac{\$25{,}000}{\text{year}}\right) + wt_c\left(2\times 10^7\,(\text{gpd})\right)\left(\frac{365\ \text{days}}{\text{year}}\right)\left(\frac{\$1}{\text{kg}}\right) \tag{3}$$

***Sedimentation System***

The size of the prototype sedimentation tank can be varied - each sedimentation basin contains four individual tanks. Each prototype tank is approximately 3 in. wide, 10 in. deep, and 12 in. long (volume = 5,905 mL). Each full-scale sedimentation tank has a volume of 75,000 gallons.

To estimate the cost of sedimentation: first, compute the prototype sediment tank retention time $t_p$ (minutes) as

$$t_P = \frac{n_t\,(5{,}905\ \text{mL})}{Q} \tag{4}$$

where $n_t$ is the number of prototype tanks and $Q$ (mL/min) is the prototype water treatment system flowrate. The full-scale treatment flowrate $Q_{ST}$ (gpm) per sedimentation tank is:

$$Q_{ST} = \frac{75{,}000 \text{ gallons}}{t_P} \tag{5}$$

Then, compute the effective flowrate $Q_{SE}$ (gpm) in a sedimentation tank as:

$$Q_{SE} = \frac{Q_{ST} \times \text{filter run time}}{60 \text{ minutes}} \tag{6}$$

Next, estimate the number of full-scale sedimentation tanks $NS$ required to handle the daily volume as:

$$NS = Roundup\left[\left(\frac{20 \times 10^6 \text{ (gpd)}}{Q_{SE}\text{(gpm)}}\right)\left(\frac{\text{day}}{1{,}440 \text{ min}}\right) \times 1.2\right] \tag{7}$$

The operation and maintenance cost per full-scale sedimentation tank is $35,000/tank. The cost of the sedimentation system $Cost_S$ is:

$$Cost_S = NS\left(\frac{\$35{,}000}{\text{tank}}\right) \tag{8}$$

***Filtration System***

The full-scale filters will have the following characteristics: each filter is about 32 ft. by 32 ft. in area (1,000 ft.$^2$), a 20% factor of safety (this will accommodate the backwashing time), and the filter media will be replaced every five years. The operation and maintenance cost per year for a full-scale filter is $75,000. The unit cost for anthracite and filter sand are $9.50/ft.$^3$ and $5.90/ft.$^3$, respectively.

To estimate the cost of filtration: first, convert the average flowrate through the prototype filter (the 3.5 in. diameter prototype filter has an area of 0.0668 ft.$^2$) into a prototype filter loading rate $Q_F$ (gpm/ft.$^2$) as:

$$Q_F = Q\left(\frac{\text{gallon}}{3{,}785 \text{ mL}}\right)\left(\frac{1}{0.0668 \text{ ft.}^2}\right) \tag{9}$$

Then, compute the full-scale treatment flowrate $Q_{FT}$ (gpm) as:

$$Q_{FT} = Q_F \times 1{,}000 \text{ ft.}^2 \tag{10}$$

Next, the effective flowrate $Q_{FE}$ (gpm) is:

$$Q_{FE} = \frac{Q_F \times \text{filter run time}}{60 \text{ minutes}} \tag{11}$$

Then, compute the number of full-scaled filters, *NF*, required for the daily volume as:

$$NF = Roundup\left[\left(\frac{20 \times 10^6 \text{ (gpd)}}{Q_{FE} \text{ (gpm)}}\right)\left(\frac{\text{day}}{1{,}440 \text{ min}}\right) \times 1.2\right] \tag{12}$$

The cost of filtration $Cost_F$ is:

$$Cost_F = NF\left(\frac{\$45{,}000}{\text{filter}}\right) \tag{13}$$

The yearly cost for anthracite $Cost_{FMa}$ is

$$Cost_{FMa} = t_a\left(\frac{\$9.50}{\text{ft.}^3}\right)\left(\frac{\text{ft.}}{12 \text{ in.}}\right)\left(1{,}000 \text{ ft.}^2\right)\left(\frac{NF}{R}\right) \tag{14}$$

where $t_a$ is the thickness (in.) of the anthracite in the prototype filters, and *R* is the number of years until the next replacement cycle of the media. The yearly cost for the filter sand $Cost_{FMs}$ is

$$Cost_{FMs} = t_s\left(\frac{\$5.90}{\text{ft.}^3}\right)\left(\frac{\text{ft.}}{12 \text{ in.}}\right)\left(1{,}000 \text{ ft.}^2\right)\left(\frac{NF}{R}\right) \tag{15}$$

where $t_s$ is the thickness (in.) of the filter sand in the prototype filters.

The total yearly capital, operation, and maintenance cost for a 20 MGD water treatment system is estimated as follows:

$$Cost = Cost_{CF} + Cost_S + Cost_F + Cost_{FMa} + Cost_{FMs} \tag{16}$$