City of Phoenix
91st Avenue Advanced Water Purification Facility

May 1st, 2026
CENE 486C
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Project Introduction

Purpose:

- Design an Advanced Water Purification Facility (AWPF) that can treat 30 MGD of secondary effluent from the 91st Avenue Wastewater Treatment Plant (91st Ave WWTP)
- Meet drinking water standards from Environmental Protection Agency (EPA), Arizona Department of Environmental Quality (ADEQ), and Maricopa County Environmental Services Department (MCESD)
- Design a pump station to deliver water from Tres Rios Flow Regulating Wetlands (FRW) Outfall 005 to AWPF
- Compete in the Arizona Water Student Design Competition

Clients:

- City of Pheonix
- Dr. Jeffrey Heiderscheidt
- Water Environment Federation (WEF)

Project Location

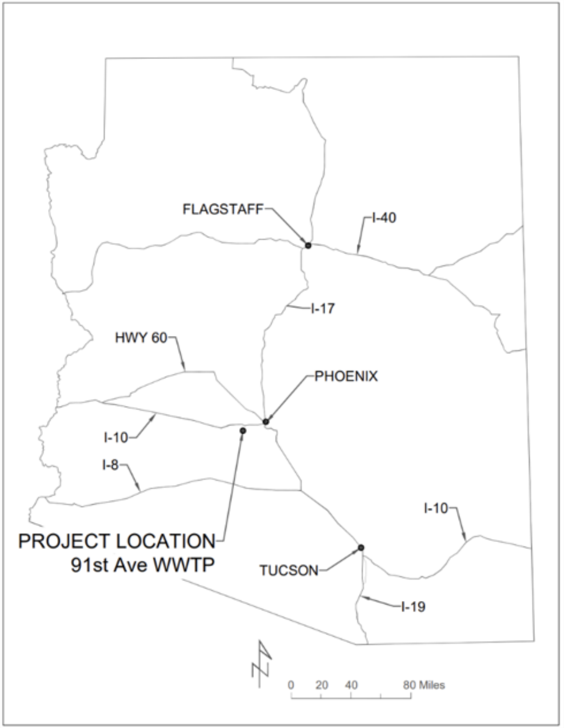


Figure 1: Location Map

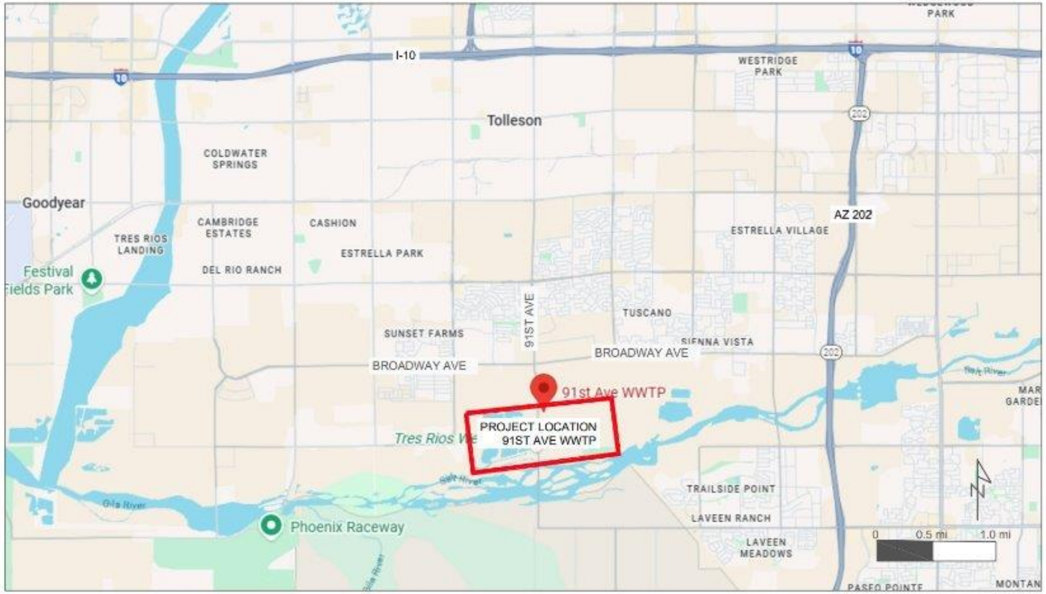


Figure 2: Vicinity Map

Existing Flow Process Diagram

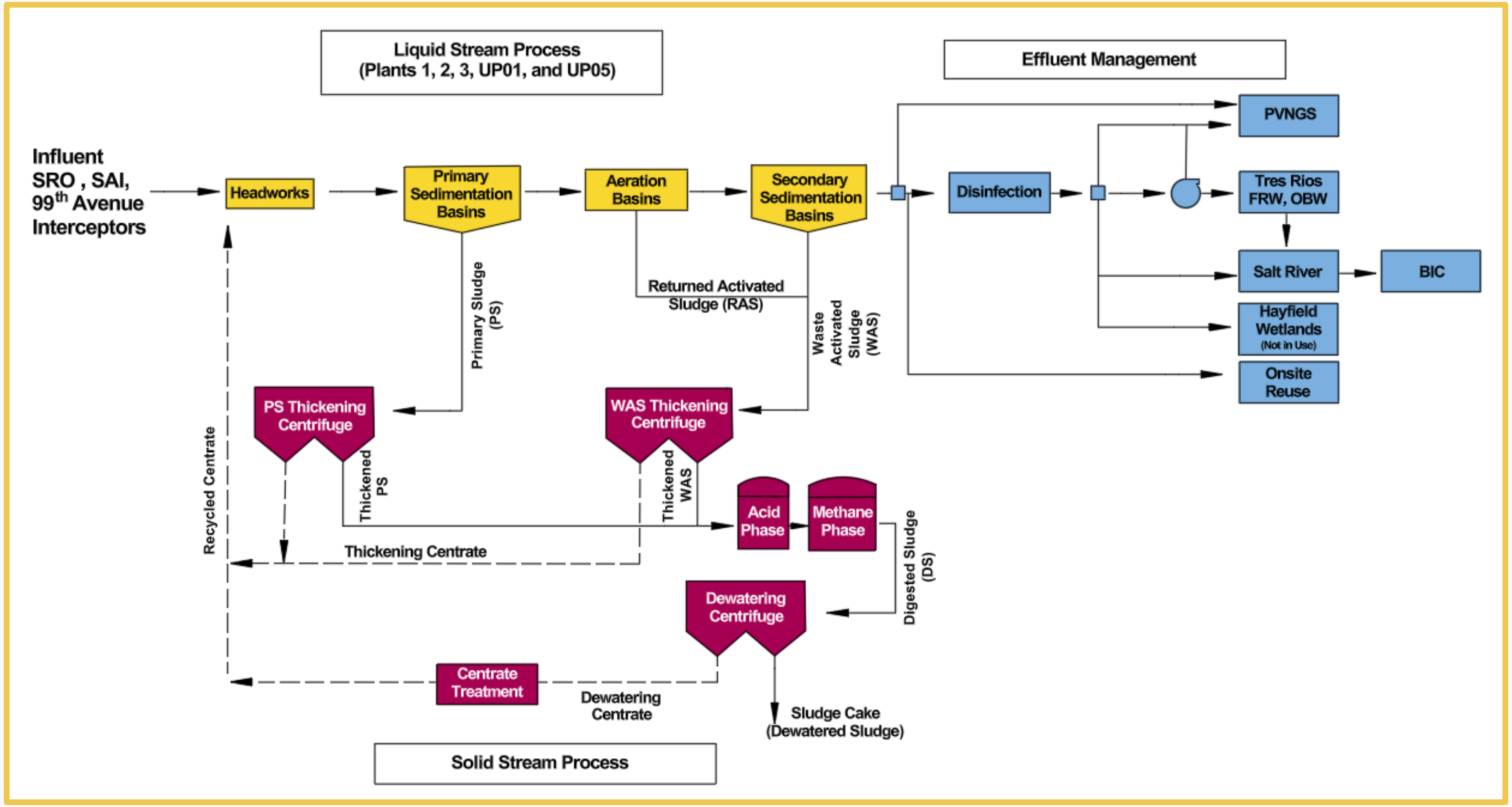


Figure 3: Existing Flow Process Diagram

Parcel Selection

Alternative parcel selection for location of AWPF was determined through a decision matrix

- Parcel 101-33-003 was the selected parcel with an 88-acre lot

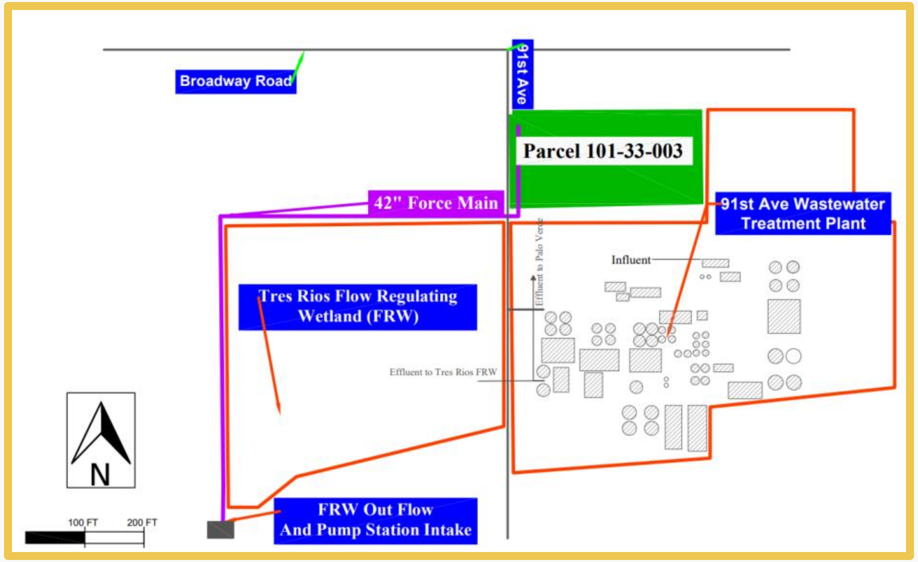


Figure 4: Project Site Map

Table 1: Simplified Parcel Selection Decision Matrix

Parcel	101-33-003	101-33-007
Accessibility (30%)	**3**	1
Size (30%)	**2**	3
Availability (20%)	**3**	2
Potential Hazards (20%)	**3**	3
Total Score	**2.4**	1.9

Physical Screening Alternatives

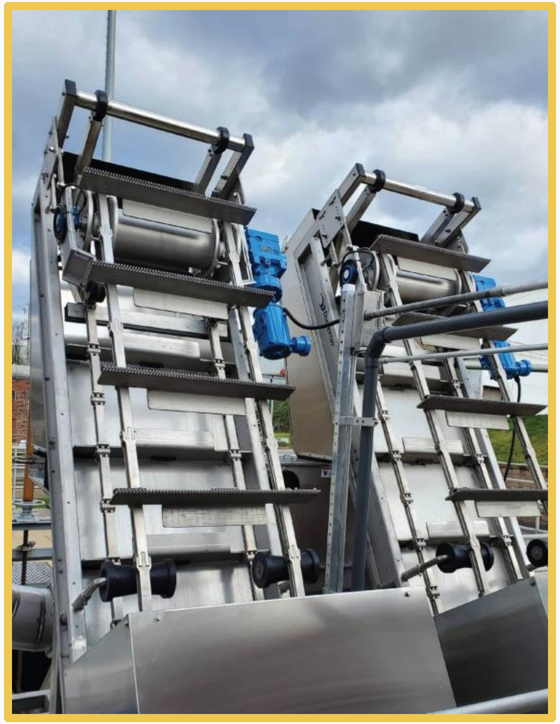


Figure 5: Bar Screen (*FlexRake FPFS Thru-Bar Cleaning Fine Screen*)

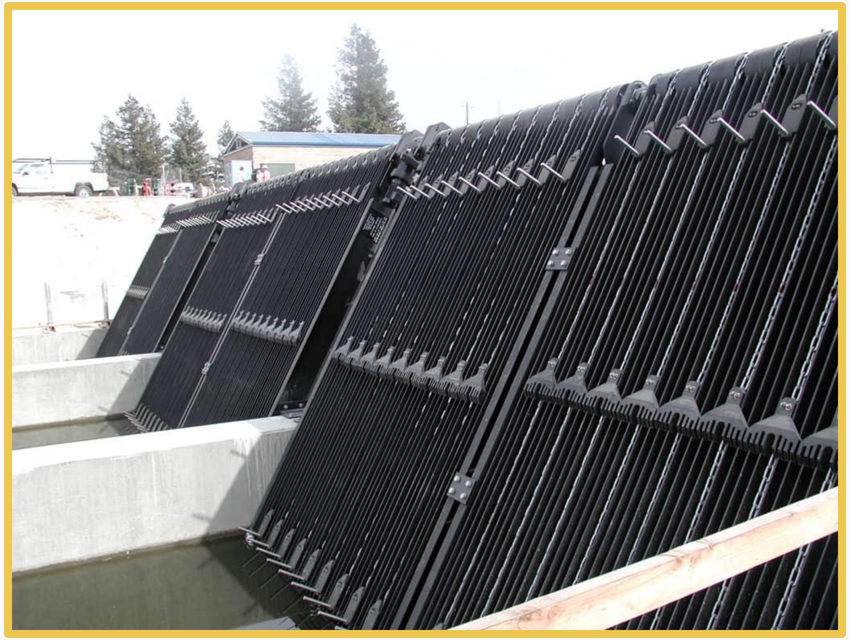


Figure 6: Trash Rack (*Ecosol Trash Rack*)

Fine Screening Alternatives

Figure 7: Step Screen (*HUBER Fine Screen STEP SCREEN SSV*)

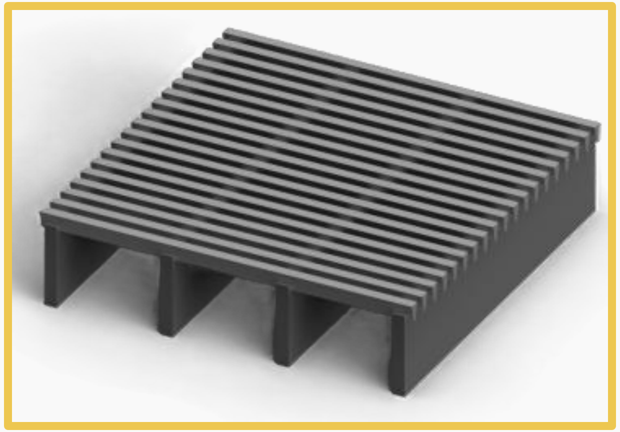


Figure 8: Wedge Wire Screen (*Johnson Vee-Wire Flat Panel Wedge Wire Screen*)

Figure 9: Mesh Screen (*DIG Screen and Disk Filters*)

Screening Decision Matrices

Top scoring alternatives for screening technologies for AWPF were determined through a weighted decision matrix

Table 2: Simplified Physical Screening Decision Matrix

Physical Screening	FlexRake FPFS Thru-Bar Cleaning Fine Screen	Ecosol Trashrack
Cost (15%)	2	1
Effectiveness (25%)	1	2
Durability (20%)	2	1
Maintenance (15%)	2	1
Material (10%)	2	1
Footprint (15%)	2	1
Total Score	1.75	1.25

Physical Screening

Table 3: Simplified Fine Screening Decision Matrix

Fine Screening	HUBER Fine Screen STEP SCREEN SSV	DIG Screen and Disk Filters	Johnson Vee-Wire Flat Panel Wedge Wire Screen
Cost (15%)	2	3	1
Effectiveness (25%)	2	2	3
Durability (20%)	3	1	3
Maintenance (15%)	2	1	3
Material (10%)	1	2	3
Footprint (15%)	1	2	3
Total Score	1.95	1.8	2.7

Fine Screening

Coagulation & Flocculation Alternatives

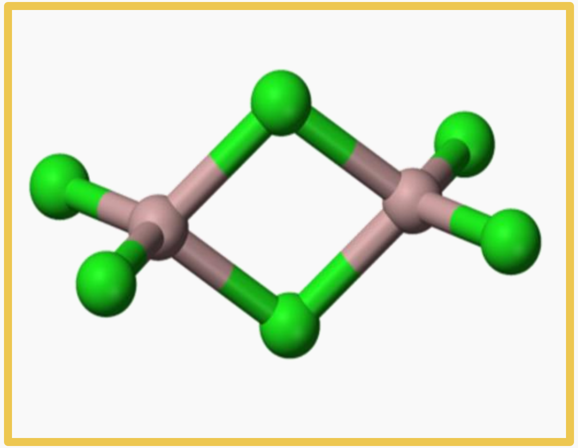


Figure 10: Chemical Structure of Aluminum Chloride

Figure 11: Chemical Structure of Aluminum Sulfate

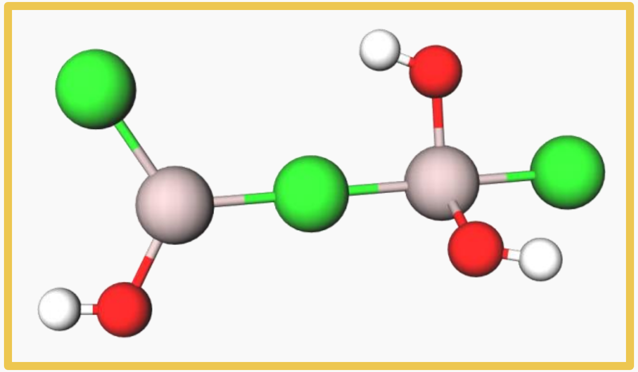


Figure 12: Chemical Structure of Polyaluminum Chloride (PAC)

Coagulation & Flocculation Decision Matrix

Top scoring alternatives for coagulation and flocculation for AWPF were determined through a weighted decision matrix

Table 4: Coagulation and Flocculation Decision Matrix

Coagulation & Flocculation	Aluminum Sulfate	PAC	Aluminum Chloride
Cost (20%)	3	2	1
Effectiveness (30%)	2	3	1
Sludge Production (15%)	1	3	2
Dose Range (15%)	2	3	1
Toxicity (20%)	3	3	2
Total Score	2.25	2.8	1.5

Sedimentation Alternatives

Figure 13: Conventional Settling Tanks (*Ares Tank Clarifier Tank*)

Figure 14: Tube Settlers (*Brentwood Tube Settler System*)

Figure 15: Plate Settlers (*Jim Myer & Sons INC Plate Settler System*)

Sedimentation Decision Matrix

Top scoring alternatives for sedimentation for AWPF were determined through a weighted decision matrix

Table 5: Sedimentation Decision Matrix

Sedimentation	Ares Tank Clarifier Tank	Brentwood Tube Settler System	Jim Myer & Sons, INC. Plate Settler System
Cost (15%)	3	2	1
Effectiveness (25%)	1	2	3
Durability (20%)	3	1	2
Maintenance (15%)	3	1	2
Size (10%)	1	2	3
Versatility Shape (15%)	2	3	3
Total Score	1.88	1.81	2.22

Filtration Alternatives

Figure 16: Rapid Sand Filtration (*Filters ITM Sand Filters*)

Figure 17: Microfiltration (*Gore MF Media Membrane*) and (SPX Flow Membrane Filtration System)

Figure 18: Slow Sand Filtration (*Nalco Ultrasand High Efficient Filter*)

Filtration Decision Matrix

Top scoring alternatives filtration and AF for AWPF were determined through a weighted decision matrix

Table 6: Filtration Decision Matrix

Filtration	Filters ITM Sand Filters	GORE Microfiltration Media	Nalco UltraSand High Efficient Filter
Cost (15%)	2	3	1
Effectiveness (25%)	2	2	3
Durability (20%)	3	1	3
Maintenance (15%)	2	1	3
Size (15%)	1	2	3
Footprint (10%)	1	2	3
Total Score	1.95	1.80	2.70

Advanced Treatment Alternatives

Figure 19: Nanofiltration (*DuPont Filmtec BW30 Pro-400/34 Element*)

Figure 20: Ultrafiltration (*DuPont Ultrafiltration Capabilities*)

Figure 21: Reverse Osmosis (*NF-400 Industrial Systems*)

Advanced Treatment Decision Matrix

Top scoring alternatives advanced treatment for AWPF were determined through a weighted decision matrix

Table 7: Advanced Treatment Decision Matrix

Advanced Treatment	FilmTec BW30 PRO-400/34 Element	DuPont Ultrafiltration Capabilities	NF-400 Industrial Nanofiltration Systems
Cost (15%)	1	3	2
Effectiveness (25%)	3	1	2
Durability (20%)	2	3	3
Maintenance (15%)	1	2	2
Footprint (10%)	1	3	2
Total Score	1.70	2.35	2.20

Advanced Oxidation Process Alternatives

Figure 22: Ozone and UV (MiPRO AOP)

Figure 23: Ozone and Hydrogen Peroxide (Capital Control Ozone Generation System)

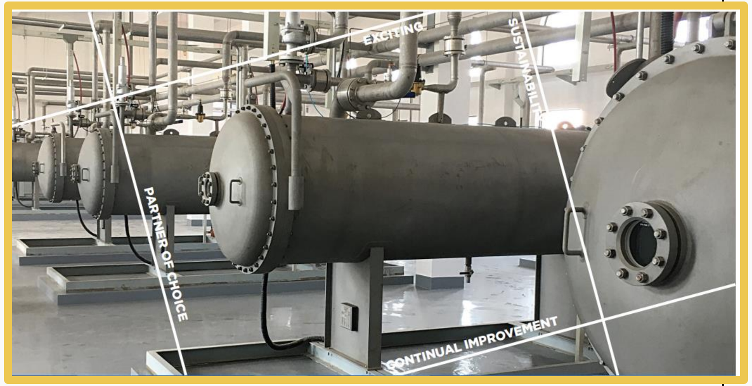


Figure 24: Hydrogen Peroxide and UV (Advanox AOP)

AOP Decision Matrix

Top scoring alternatives AOP for AWPF were determined through a weighted decision matrix

Table 8: AOP Decision Matrix

AOP	MiPRO AOP Ozone/UV	Capital Control Ozone Generation System Ozone/Hydrogen Peroxide	ADVANOX AOP Hydrogen Peroxide/UV
Cost (15%)	2	1	3
Effectiveness (25%)	3	2	1
Dose (20%)	2	3	1
Maintenance (15%)	3	3	3
Footprint (10%)	1	3	2
Total Score	2.20	2.35	1.90

Brine Management Alternatives

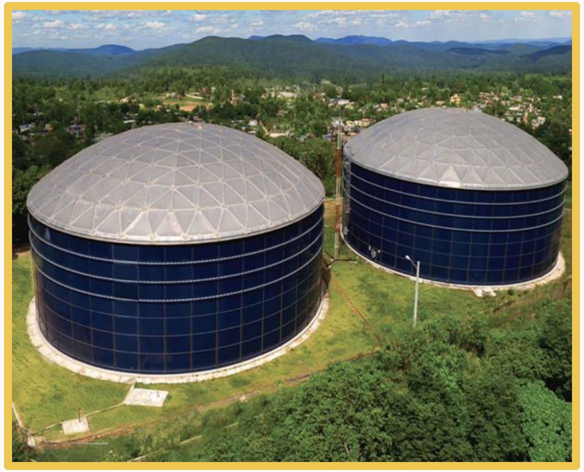


Figure 25: Brine Storage Tanks (*CST Aquastore Tanks*)

Figure 26: Evaporation Ponds (*Lenntech Water Treatment*)

Figure 27: Membrane Distillation (memsys Vacuum Multi-Effect Membrane Distillation)

Brine Management Decision Matrix

Top scoring alternatives brine management for AWPF were determined through a weighted decision matrix

Table 9: Brine Management Decision Matrix

Brine Management	CST Aquastore Tanks	Lenntech Water Treatment Solutions Evaporation Ponds	MEMSYS Vacuum Multi Effective Membrane Distillation
Cost (20%)	2	3	1
Effectiveness (25%)	3	2	3
Durability (20%)	2	2	2
Maintenance (15%)	3	1	2
Footprint (20%)	3	1	3
Total Score	2.25	1.85	1.90

Designing Three Alternative Treatment Trains

Three treatment trains were designed to meet different goals, each created using different treatment alternatives to meet each goal

- **Treatment Train #1**: Focused on reusing the most brine while providing quality effluent water
- **Treatment Train #2**: Focused on the most cost-effective treatment processes that could still meet standards for drinking water
- **Treatment Train #3**: Focused on treatment performance and providing excellent quality drinking water

Treatment trains had core aspects for all three designs

- In-Line Coagulant Mechanical Mixer
- Flocculation Basins
- Remineralization
- Granular Activated Carbon (GAC)
- UV and Cl_2 gas

Treatment Train Alternative #1

Treatment Train #1 was design with alternatives that would reuse the most brine.

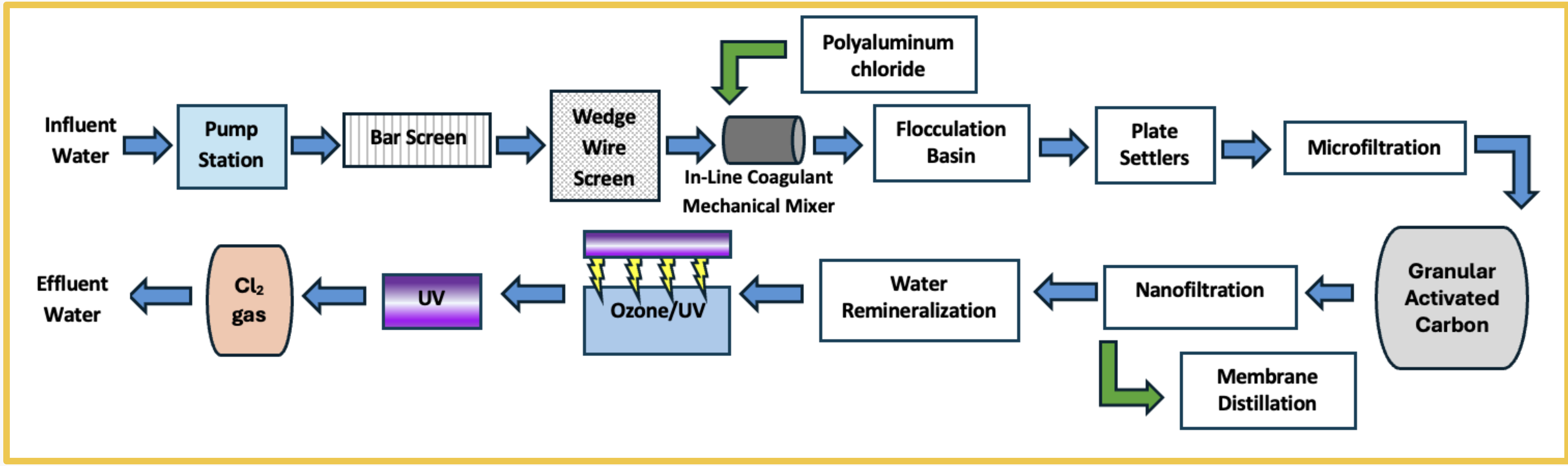


Figure 28: Treatment Train Alternative #1 Process

Treatment Train Alternative #2

Treatment Train #2 was design with alternatives that were the most cost effective.

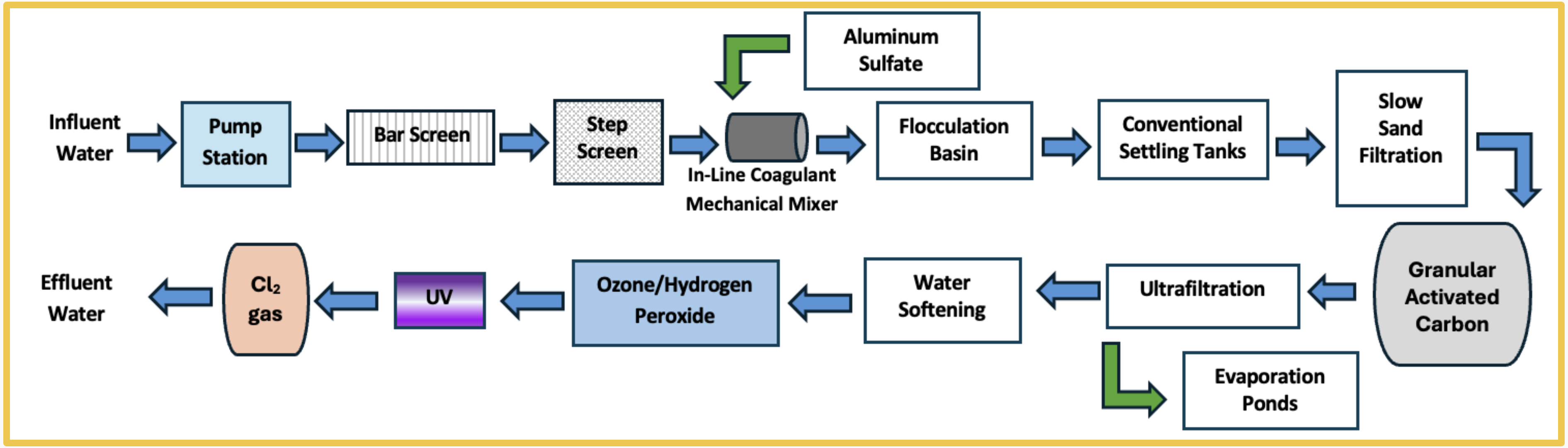


Figure 29: Treatment Train Alternative #2 Process

Treatment Train Alternative #3

Treatment Train #3 was design with alternatives that would have the best treatment performance and water reuse.

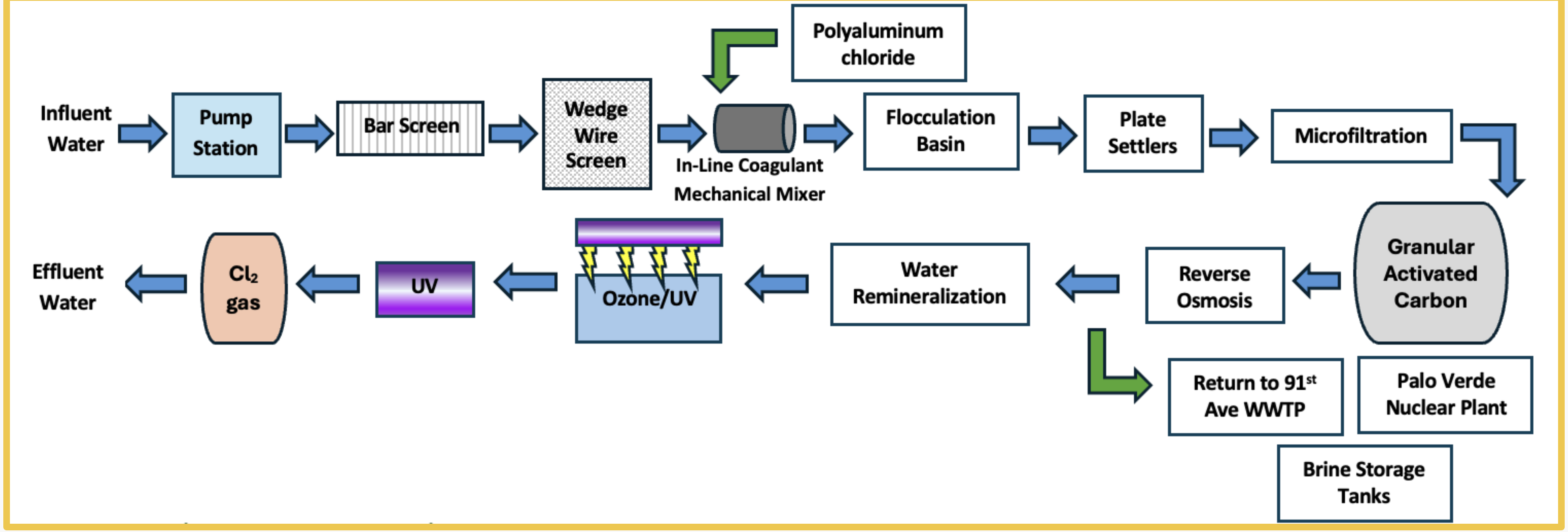


Figure 30: Treatment Train Alternative #3 Process

Treatment Train Decision Matrix

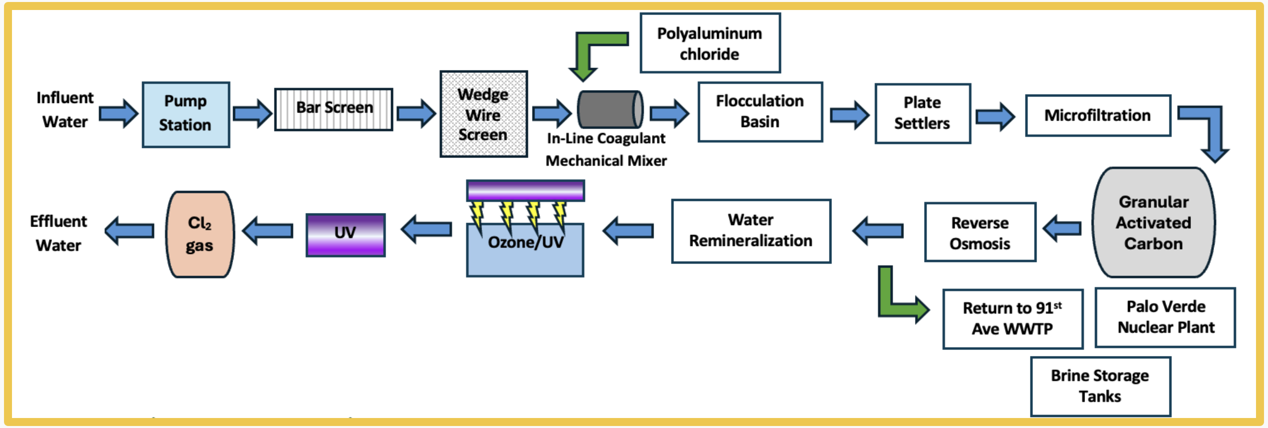
Treatment Train alternatives were scored using criteria deemed the most important for the final treatment train design.

Table 10: Treatment Trains Decision Matrix

Treatment Train	Treatment Train #1	Treatment Train #2	Treatment Train #3
Cost (20%)	2	3	**1**
Operational Flexibility (25%)	2	1	**3**
Footprint (20%)	2	3	**1**
Construction Time (5%)	2	1	**2**
Land Usage (15%)	2	1	**2**
Treatment Performance (10%)	2	1	**3**
Total Score	2.00	1.67	**2.17**

Why Treatment Train #3 is the Optimal Choice

- Membrane-based train creates a compact and low land usage alternative, provides space for possible future expansions
- Reverse osmosis (RO) has highest removal rates for dissolved solids, salts, pathogens, pharmaceuticals and organics; outperforming nano and ultrafiltration
- Ensures upmost public health, trust, and transparency
- Long-term investment to the metropolitan Phoenix area for water security and resilience
- Serves as a mitigation effort for the Phoenix water scarcity problem



Influent Water
Pump Station
Bar Screen
Wedge Wire Screen
Polyaluminum chloride
In-Line Coagulant Mechanical Mixer
Flocculation Basin
Plate Settlers
Microfiltration
Granular Activated Carbon
Reverse Osmosis
Return to 91st Ave WWTP
Palo Verde Nuclear Plant
Brine Storage Tanks
Water Remineralization
Ozone/UV
UV
Cl_2 gas
Effluent Water

Figure 30: Treatment Train Alternative #3 Process

Treatment Train Design Calculation: Physical Screening

Equation 1: Headloss through Bar Screen

$$H_L = \frac{k\left[(v_{thru})^2 - \left(v_{approach}\right)^2\right]}{2g}$$

Where:

H_L= Headloss, ft

k= empirical discharge coefficient

v_{thru}= velocity through the bar screen, ft/s

$v_{approach}$=approach velocity ft/s

g= gravitational acceleration= 32.2 ft/s

Equation 2: Area

$$A = L * W$$

Where:

A= Area ft2

L= Length, ft

W= Width, ft

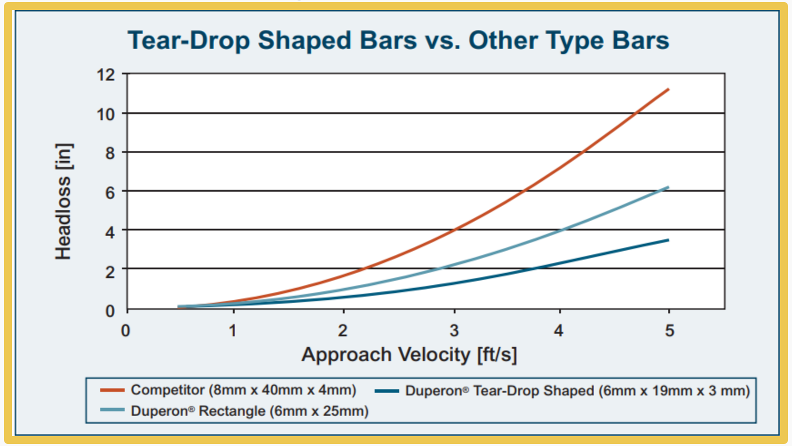


Figure 31 : Bar Screen Headloss vs Approach Velocity Graph

Equation 3: Approach Velocity

$$v_{approach} = \frac{Q}{A}$$

Where:

$v_{approach}$= Approach Velocity, ft/s

Q= Flow, ft3/s

A= Area, ft2

Table 11: Bar Screening Values

Variables	Results
Flow Rate, Q	61.574 ft^3/s
Area, A	21 ft^2
Units	6 Screens
Velocity of Approach, $V_{approach}$	0.4887 ft/s
Headloss, H	0.0083 ft

Treatment Train Design Calculation: Coagulation

Equation 4: Hydraulic Retention Time

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

where

$t = theoretical\ detention\ time, s$

$\forall = volume\ of\ fluid\ in\ reactor, m^3$

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

Equation 5: Hydraulic Power

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

where

$h_f = Headloss, ft$

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

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

Equation 6: Volume of Cylinder

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

where

$r = radius, ft$

$h = height, ft$

Equation 7: Velocity Gradient Equation

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

where

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

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

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

$\forall = Volume\ of\ liquid, m^3$

Table 12: Design Criteria and Given/Known Values

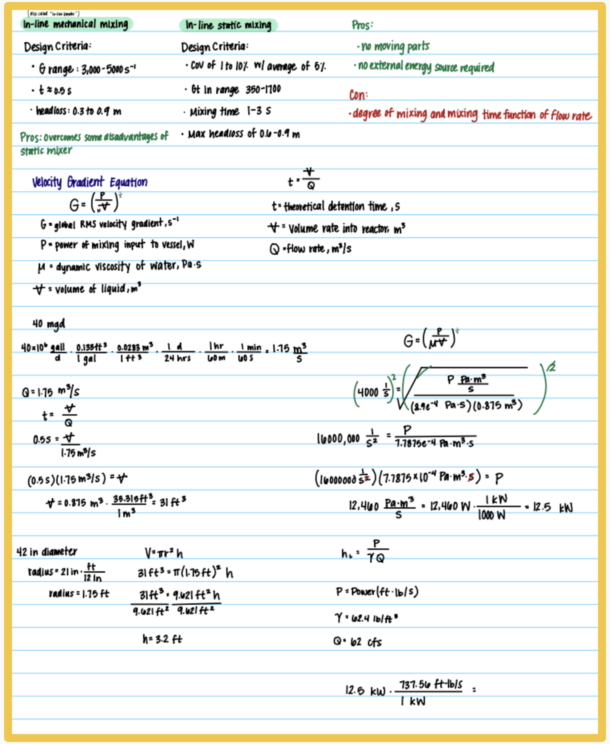
Design Criteria	**Values**	**Units**
Global RMS Velocity Gradient, G	3,000-5,000	s^{-1}
Detention Time	0.5	s^{-1}
Head Loss	1.0-3.0	ft
Given Values		**Units**
Dynamic Viscosity of Water, μ	8.9E-4	Pa*s
Flow Rate, Q	50,000,000	gall/d
Radius of Pipe	1.75	ft
Specific Weight of Water, γ	62.4	lb/ft^3

Treatment Train Design Calculation: Coagulation Cont.

Using the equations, shown in the previous slide these results were found for the coagulation in-line mechanical mixer design.

Table 13: Coagulation Design Values

Variables	Calculated Values	Units
Volume of Pipe, $\forall$	155	ft^3
Power of mixing input to vessel, *P*	62,501. 1	Watts
Length of Mixing in Pipe, *L*	16.1	ft
Head loss, H_f	10	ft



(also called "in-line blender")

In-line mechanical mixing

Design Criteria:

- G range : 3,000-5000 s^{-1}
- $t \approx 0.5$ s
- headloss: 0.3 to 0.9 m

Pros: overcomes some disadvantages of static mixer

In-line static mixing

Design Criteria:

- COV of 1 to 10% w/ average of 5%
- Gt in range 350-1700
- Mixing time 1-3 s
- Max headloss of 0.6-0.9 m

Pros:

- no moving parts
- no external energy source required

Con:

- degree of mixing and mixing time function of flow rate

Velocity Gradient Equation

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

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

P = power of mixing input to vessel, W

μ = dynamic viscosity of water, Pa·s

$\forall$ = volume of liquid, m^3

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

t = theoretical detention time, s

$\forall$ = Volume rate into reactor, m^3

Q = flow rate, m^3/s

40 mgd

$$40\times10^6 \frac{gall}{d} \cdot \frac{0.135 ft^3}{1 gal} \cdot \frac{0.0283 m^3}{1 ft^3} \cdot \frac{1 d}{24 hrs} \cdot \frac{1 hr}{60 m} \cdot \frac{1 min}{60 s} = 1.75 \frac{m^3}{s}$$

$Q = 1.75\ m^3/s$

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

$$0.5 s = \frac{\forall}{1.75 m^3/s}$$

$$(0.5 s)(1.75 m^3/s) = \forall$$

$$\forall = 0.875\ m^3 \cdot \frac{35.315 ft^3}{1 m^3} = 31 ft^3$$

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

$$\left(4000 \frac{1}{s}\right)^2 = \left(\sqrt{\frac{P \frac{Pa\cdot m^3}{s}}{(8.9e^{-4}\ Pa\cdot s)(0.875\ m^3)}}\right)^2$$

$$16000,000 \frac{1}{s^2} = \frac{P}{7.7875e^{-4}\ Pa\cdot m^3\cdot s}$$

$$\left(16000000 \frac{1}{\cancel{s^2}}\right)\left(7.7875\times10^{-4}\ Pa\cdot m^3\cdot \cancel{s}\right) = P$$

$$12,460 \frac{Pa\cdot m^3}{s} = 12,460 W \cdot \frac{1 kW}{1000 W} = 12.5\ kW$$

42 in diameter

$$radius = 21 in \cdot \frac{ft}{12 in}$$

radius = 1.75 ft

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

$$31 ft^3 = \pi(1.75 ft)^2\ h$$

$$\frac{31 ft^3}{9.621 ft^2} = \frac{9.621 ft^2 h}{9.621 ft^2}$$

h = 3.2 ft

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

P = Power (ft·lb/s)

γ = 62.4 lb/ft^3

Q = 62 cfs

$$12.5\ kW \cdot \frac{737.56\ ft\cdot lb/s}{1\ kW} =$$

Figure 32: Hand Calculations for the In-Line Mechanical Mixer Design

Treatment Train Design Calculation: Sedimentation Tanks Design

Equation 8: Total 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 9: Individual Tank Area

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

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 10: Velocity in Settler

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

Where:

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

A = Area per tank (m^2)

θ = Plate Angle (°)

Equation 11: Reynold's Number

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

Where:

R_e = Reynold's Number (unitless)

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

R_H = Reynold's Multiplier (m)

ν = Viscosity (Pa • s)

Table 14: Assumed Sedimentation Calculations Values

Variables	Values
Flow Rate, Q	40 MGD
# of Tanks, n	6 Tanks
Plate Diameter, D_H	60 mm
Plate Angel, θ	59°
Width, W	5 m
Side Water Depth, SWD	4.90 m
Freeboard	5.50 m

Equation 12: Froude's Number

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

Where:

F_R = Froude's Number (unitless)

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

g = gravity (m/s^2)

R_H = Reynold's Multiplier (m)

Equation 13: Loading Rate

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

Where:

WL = Loading Rate ($m^3/d \cdot m^2$)

Q = Flow Rate (m^3/s)

n = # of tanks

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

Treatment Train Design Calculation: Sedimentation Tank Design Cont.

Using the equations, these results are found for the sedimentation tank design.

Table 15: Sedimentation Calculation Results

Variables	Results
A_S	3,312 ft^2
A_{Tank}	1,811 ft^2/tank
$L_{Settler}$	110 ft
L_{Basin}	147 ft
Total Tank Depth	18 ft
# of Tanks	6 tanks

Plate settlers calculations

*GRUMB guidance was used to check if values were to standards

$Q = 40\,MGD = 1.753\,m^3/s = 151417.728\,m^3/d$

$T = 25°C$ $D_H = 60\,mm$ $\theta = 59°$ $V_0 = 150\,m^3/d\cdot m^2$

$A_s = \frac{Q}{V_0} = \frac{(151417.728\,m^3/d)}{(150\,m^3/d\cdot m^2)} = \boxed{1{,}009.453\,m^2}$

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

$L_{settler} \times w = A_{tank} \rightarrow L_{settler} = \frac{A_{tank}}{w} = \frac{168.242\,m^2}{5m} = \boxed{33.648\,m}$

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

settler depth = 0.6 m
Launder depth = 1.3 m
sludge zone = 3.0 m

$+ = SWD = \boxed{4.90\,m \rightarrow 3m \leq 4.90\,m \leq 5m ✓}$ ↑ approach depth

Freeboard = 0.6 m

Total tank depth = $\boxed{5.5m}$

$A_{approach} = w \times SWD = (5m) \times (4.90m) = \boxed{24.5\,m^2}$

$V_A = \frac{Q}{(n)(A_{approach})} = \frac{(1.753\,m^3/s)}{(6\,tanks)(24.5\,m^2)} = \boxed{0.01\,m/s \rightarrow 0.01\frac{m}{s} \geq 0.01\frac{m}{s} ✓}$

velocity in settler, $\bar{V}_{FC} = \frac{Q}{A\sin\theta} = \frac{1.753\,m^3/s}{(6\,tanks)(168.242\,m^2)(\sin(59°))} = \boxed{0.00273\,m/s}$

$\boxed{\bar{V}_{FC} = 0.0025\,m/s \leq 0.00273\,m/s \leq 0.0033\,m/s ✓}$

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

$R_e = \frac{\bar{V}_{FC} R_H}{\nu} = \frac{(0.00273\,m/s)(0.015m)}{(8.927 \times 10^{-7}\,m^2/s)} = \boxed{45.814 \rightarrow 46 \rightarrow R_e = 46 < 50 ✓}$

$F_R = \frac{(\bar{V}_{FC})^2}{g R_H} = \frac{(0.00273\,m/s)^2}{(9.81\,m/s^2)(0.015m)} = \boxed{5.052 \times 10^{-5} \rightarrow F_R = 5.052 \times 10^{-5} > 1 \times 10^{-5} ✓}$

$L_W = 3\,launders \times \frac{2\,sides}{launder} \times 34m = \boxed{201.890\,m}$

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

$W_L = \frac{Q}{L_W} = \frac{(151417.728\,m^3/d)}{(6\,tanks)(168.242\,m/tank)} = \boxed{125\,m^3/d\cdot m^2}$

$\boxed{W_L = 125\,m^3/d\cdot m^2 < 300\,m^3/d\,m^2 ✓}$

$A_{tank} = 1{,}811\,ft^2/tank$
$L_{settler} = 110\,ft$
$L_{basin} = 147\,ft$
Total tank depth = 18 ft
# of tanks = 6 tanks
Total Area = 3312 ft^2

Figure 33 : Hand Calculations for Sedimentation Design

Treatment Train Design Calculation: Sedimentation Headloss

Equation 14: Number of Orifices

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

Where:

LW = Launder Width (m)

D_o = Diameter of Orifices (m)

Equation 15: Flow Rate per Tank

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

Where:

Q_{Tank} = Flow Rate per Tank (m^3/s)

Q = Total Flow Rate (m^3/s)

n = # of Tanks

Equation 16: Flow Rate of Orifice

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

Where:

$Q_{Orifices}$ = Flow Rate per Orifice (m^3/s)

Q_{Tank} = Flow Rate per Tank (m^3/s)

N = # of Orifices

Equation 17: Area of Orifice

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

Where:

A = Area per Orifice (m^2)

D = Diameter of Orifice (m)

Table 16: Sedimentation Headloss Variables

Variables	Values
Flow Rate, Q	40 MGD
Number of Tanks, n	6 Tanks
Diameter of Orifices, $D_{Orifices}$	5 cm
Placement	1 m
Length of settler, L	34 m

Equation 18: Headloss for Orifices

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

Where:

h = Headloss (m)

g = Gravity (m/s^2)

$Q_{Orifices}$ = Flow Rate per Orifice (m^3/s)

K = Coefficient (unitless)

A = Area per Orifice (m^2)

Equation 19: Minor Loss

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

Where:

K = Coefficient (unitless)

ν = Viscosity (Pa • s)

g = Gravity (m/s^2)

Treatment Train Design Calculation: Sedimentation Headloss Cont.

Using the equations, these results are found for the sedimentation total headloss.

Table 17: Headloss for Plate Settlers

Variables	Values
Headloss, h	2.5 inch
Minor Headloss	0.8412 inch
Total Headloss	3.35 inch

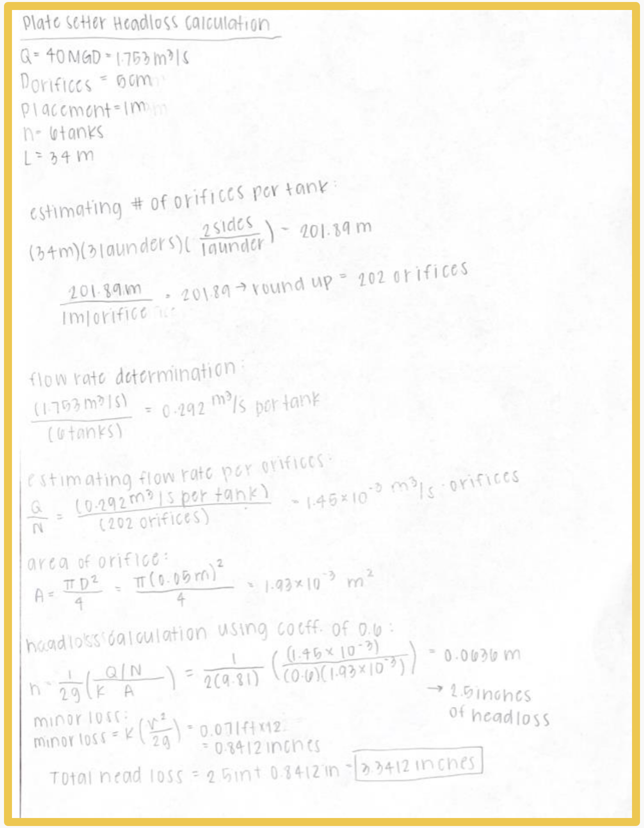


Plate Setter Headloss Calculation

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

$D_{orifices} = 5cm$

$placement = 1m$

$n = 6\ tanks$

$L = 34\ m$

estimating # of orifices per tank:

$(34m)(3\ launders)\left(\frac{2\ sides}{launder}\right) = 201.89\ m$

$\frac{201.89m}{1m/orifice} = 201.89 \rightarrow$ round up = 202 orifices

flow rate determination:

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

estimating flow rate per orifices:

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

area of orifice:

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

headloss calculation using coeff. of 0.6:

$h = \frac{1}{2g}\left(\frac{Q/N}{K\ A}\right) = \frac{1}{2(9.81)}\left(\frac{(1.45 \times 10^{-3})}{(0.6)(1.93 \times 10^{-3})}\right) = 0.0636\ m$

→ 2.5 inches of headloss

minor loss:

$minor\ loss = K\left(\frac{v^2}{2g}\right) = 0.071 ft \times 12$

$= 0.8412$ inches

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

Figure 34: Headloss for Plate Settlers Hand Calculation

Proposed Flow Process Diagram

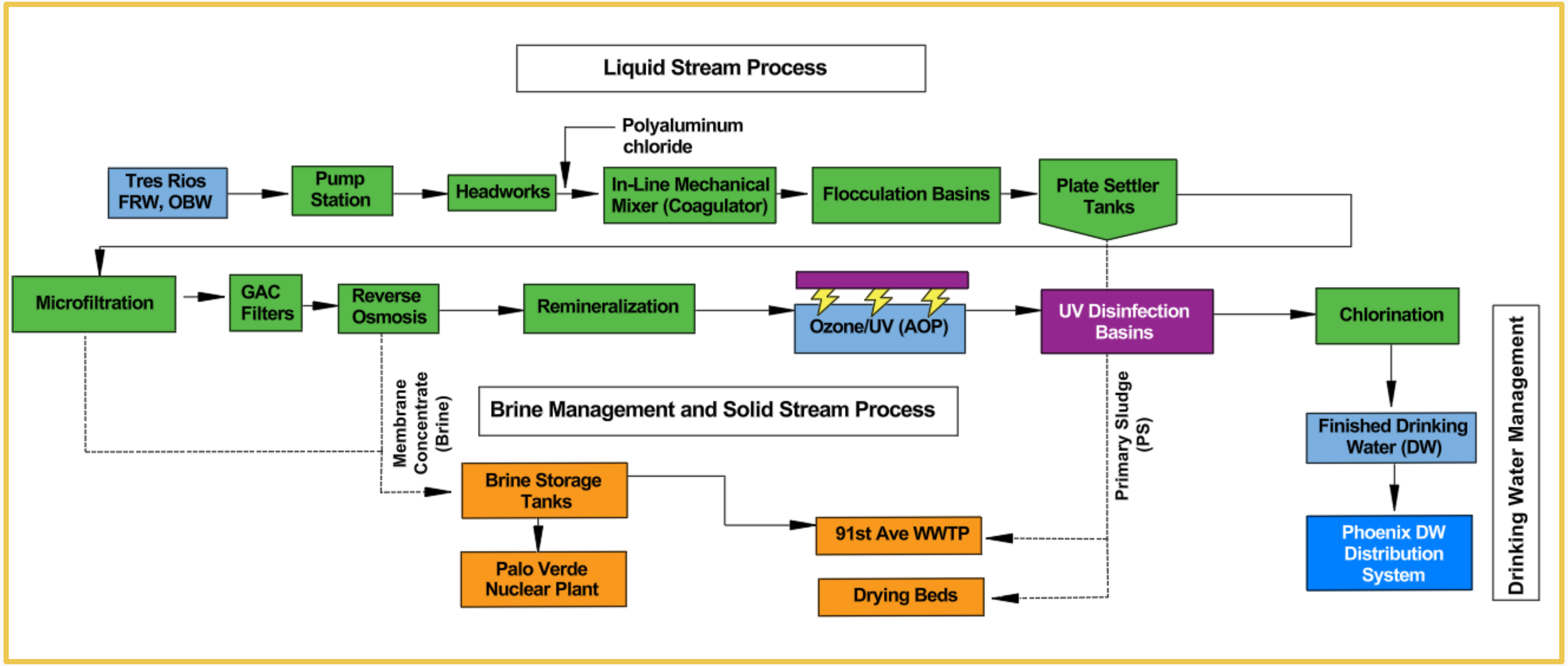


Figure 35: Final Design Proposed Flow Diagram

Final Design Water Quality

Assumptions were used to calculate the water quality throughout treatment

Final Effluent Quality is up to standards with the:
- EPA
- ADEQ
- MCESD

Table 18: Simplified Water Quality Table

Parameters	Units	Influent	Effluent
Alkalinity	mg/L as $CaCO_3$	181.0	60.0
Calcium	mg/L as $CaCO_3$	194.6	70.0
Chloride	mg/L	367.0	0.4
Magnesium	mg/L as $CaCO_3$	131.6	30.0
pH	Unitless	7.4	7.4
Orthophosphate	mg/L as P	3.2	0.0
Potassium	mg/L	23.0	0.2
Silica	mg/L as SiO_2	16.0	0.2
Sodium	mg/L	256.0	2.7
Sulfate	mg/L	181.0	1.9
TDS	mg/L	1142.0	0.2
Temperature	C	25.0	25.0
TKN	mg/L as N	3.3	0.0
TSS	mg/L	8.6	0.0

Sizing for AWPF Treatment Processes

Table 19: AWPF Preliminary Sizing

Process Equipment	Physical Sizing
Coarse Static Bar Screens	6 Units (Total Area: 126 Sq. Ft)
Mechanical Bar & Wedge-Wire Screens	10 Units (Total Area: 320 Sq. Ft)
Coagulation In-Line Mechanical Mixer	Length: 16.1 ft, Radius: 1.75 ft
Flocculation Basins	4 Basins (809 ft L x 42 ft W x 3.5 ft D)
Plate Settler Tanks	6 Tanks (130 ft L x 14 ft W)
Microfiltration Filters	Total Land Acreage: 0.5
GAC Tank	7 Filters, dimensions per filter (81 ft L x 20 ft W x 15 ft D)
RO System	Total Land Acreage: 0.5
Brine Storage Tanks	3 x 9-foot Diameter
Remineralization	Length: 16.1 ft, Radius: 1.75 ft
Ozone Contact & Medium Pressure UV	Total Area: 159 Sq. Ft
Chlorine Gas	Total Area: 159 Sq. Ft
Total Land Area	**4.5 acres**

Pump Alternatives

The three primary pump configurations analyzed to meet the facility's conveyance requirements.

Figure 36: Fairbanks NIJHUIS Vertical Turbine Pump

Figure 37: Submersible Pump

Figure 38: Dry Pit Centrifugal Pump

Pump Decision Matrix

The table below prioritizes the accessibility of the pump types and the structural footprint.

Table 20: Pump Decision Matrix

Pump	Vertical Turbine	Dry Pit Centrifugal	Submersible Pump
Maintenance Accessibility (60%)	**3**	2	1
Structural Footprint (40%)	**3**	1	3
Total Score	**3.00**	1.60	1.80

Pipe Material Alternatives

The three primary material types for the force main.

Figure 39: AWWA C905 PVC Pipe Material Example

Figure 40: Ductile Iron Pipe Material Example

Figure 41: High-Density Polyethylene Pipe Example

Pipe Sizing Alternatives

Hydraulic modeling results used to balance total dynamic head (TDH) and fluid velocity across our pipe diameter alternatives.

Table 21: Pipe Diameter Alternatives

Diameter	Q, Flow (cfs)	TDH (ft)	Velocity (ft/s):
48 Inch	23.23	64.97	1.85
	46.46	70.10	3.70
	57.91	73.57	4.58
	61.94	75.10	4.93
42 Inch	23.23	66.77	2.41
	46.46	76.60	4.83
	57.91	83.26	5.99
	61.94	86.18	6.44
36 Inch	23.23	70.98	3.29
	46.46	91.82	6.57
	57.91	105.92	8.15
	61.94	112.10	10.95

Pipe Material and Sizing Matrices

Decision matrices weighing the different criteria for the most optimal force main.

Table 22: Pipe Material Decision Matrix

Pipe Material	C905 PVC	Ductile Iron	HDPE
C Factor (20%)	**3**	2	3
Life Cycle Cost (40%)	**3**	2	2
Durability (40%)	**2**	2	2
Total Score	**2.60**	2.00	2.00

Table 23: Pipe Diameter Decision Matrix

Pipe Sizing	Diameter 36"	Diameter 42"	Diameter 48"
Velocity (40%)	2	**3**	1
Energy Efficiency (30%)	2	**3**	3
Lifecycle Cost (10%)	3	**2**	1
Future Capacity (20%)	1	**2**	3
Total Score	1.90	**2.70**	2.40

Proposed Site Layout

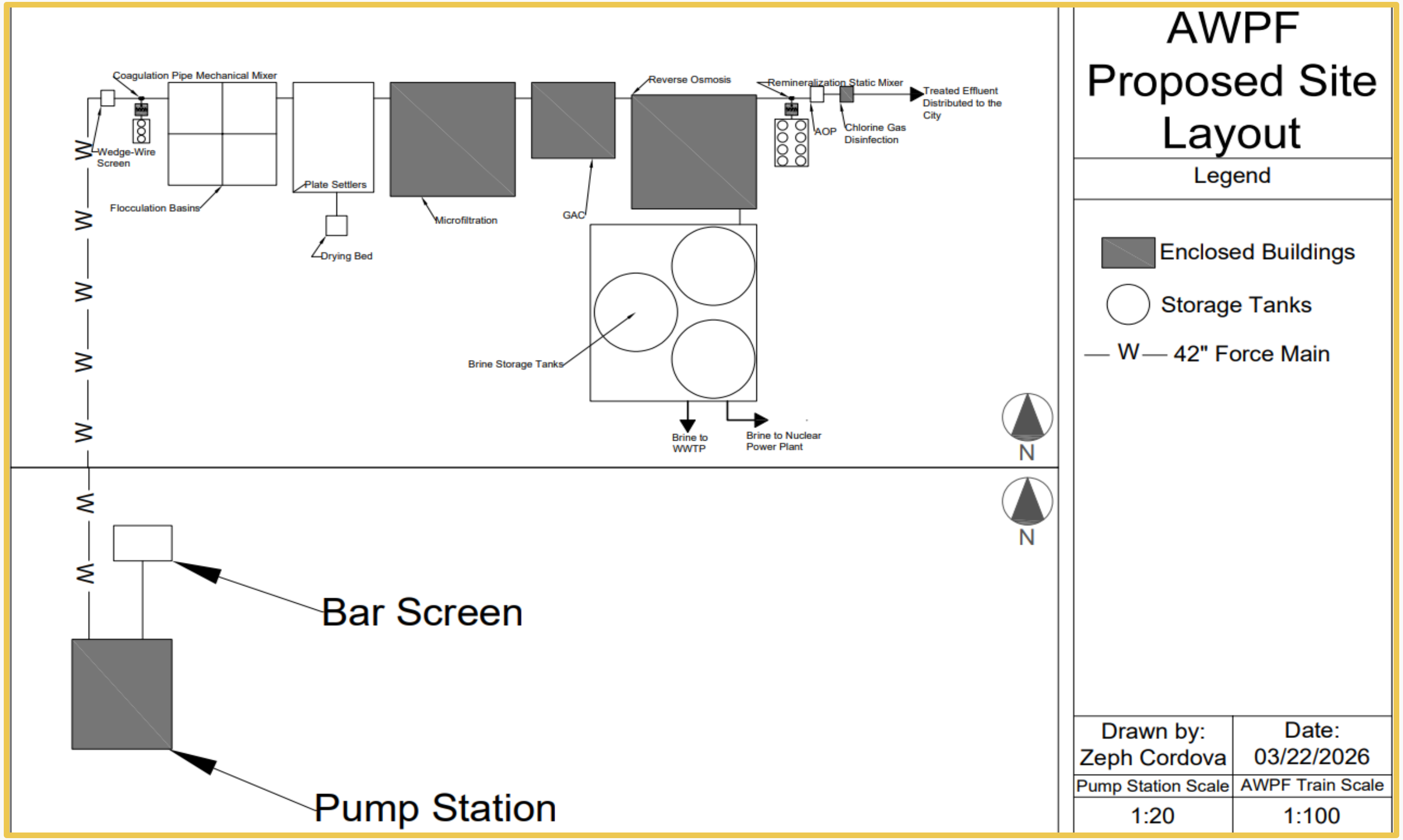


Figure 42: AWPF Proposed Detailed Site Layout

Final Hydraulic Design

- **5 Pumps (1 Standby)**: 27ML-BRZ Pentair Fairbanks Nijhuis Mixed Flow Vertical Turbine
- 9920 LF Piping of AWWA C905 PVC – 42' Diameter
- **Pump Operating Point**: 86.18 ft TDH, 6944.5 GPM, 80% Efficiency with Variable Frequency Drives (VFD)
- **Design Flow Rate of 40 MGD**

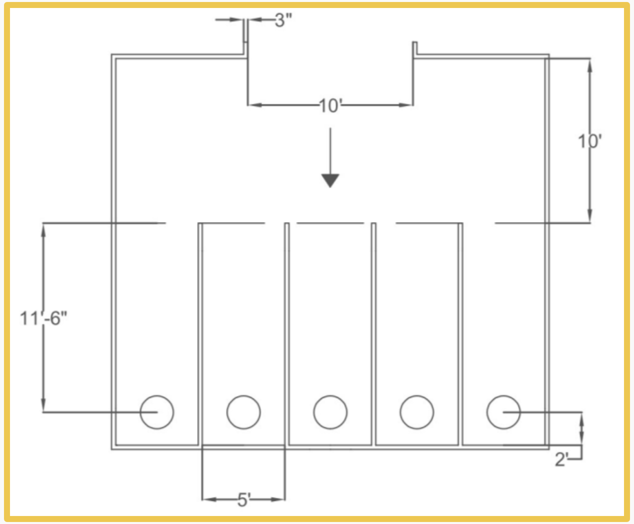


Figure 43: Plan View Detailed Sump Station Layout

Scale:
1"=8'

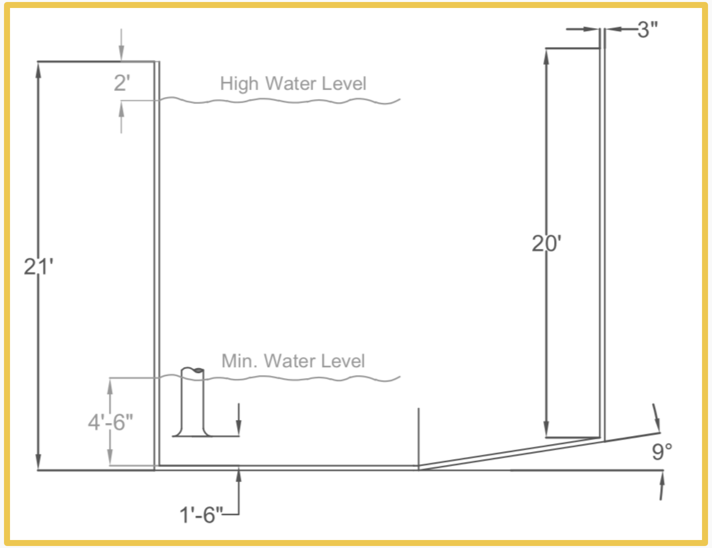
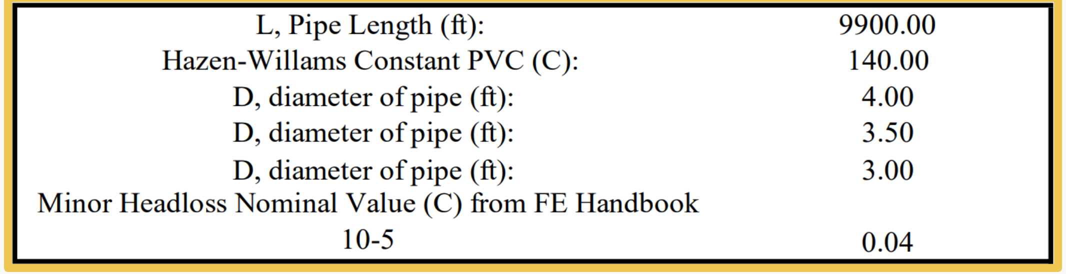


Figure 44: Profile View Detailed Sump Station Layout

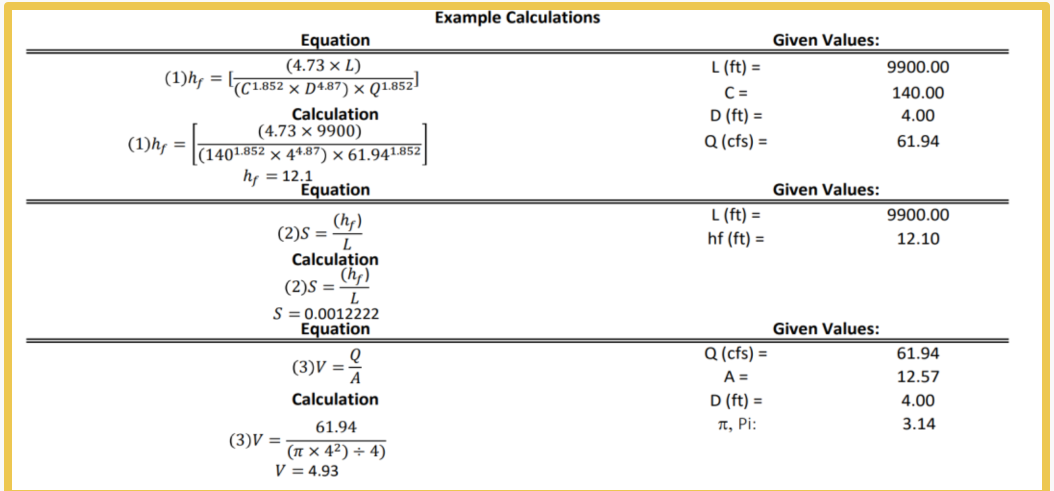
Hydraulic Final Design Calculations

Table 24: Defined Variables and Constants

Defined Variables and Units	Value
π, Pi	3.14
Minutes in a Day	1440.00
Conversion Rate for GPM to cfs	0.00223
Water Rejection Rate:	0.25
Acceleration due to Gravity (ft/s^2)	32.17
Friction Headloss (ft):	h_f
Diameter of Pipe (ft):	D
Hydraulic Radius (ft):	R_H
Velocity (ft/sec):	V
Cross-sectional Area of Flow (ft^2):	A
Flow (cfs):	Q_1



L, Pipe Length (ft):	9900.00
Hazen-Willams 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



Example Calculations

Equation

$$(1)h_f = [\frac{(4.73 \times L)}{(C^{1.852} \times D^{4.87}) \times Q^{1.852}}]$$

Calculation

$$(1)h_f = \left[\frac{(4.73 \times 9900)}{(140^{1.852} \times 4^{4.87}) \times 61.94^{1.852}}\right]$$

$$h_f = 12.1$$

Given Values:

L (ft) =	9900.00
C =	140.00
D (ft) =	4.00
Q (cfs) =	61.94

Equation

$$(2)S = \frac{(h_f)}{L}$$

Calculation

$$(2)S = \frac{(h_f)}{L}$$

$$S = 0.0012222$$

Given Values:

L (ft) =	9900.00
hf (ft) =	12.10

Equation

$$(3)V = \frac{Q}{A}$$

Calculation

$$(3)V = \frac{61.94}{(\pi \times 4^2) \div 4)}$$

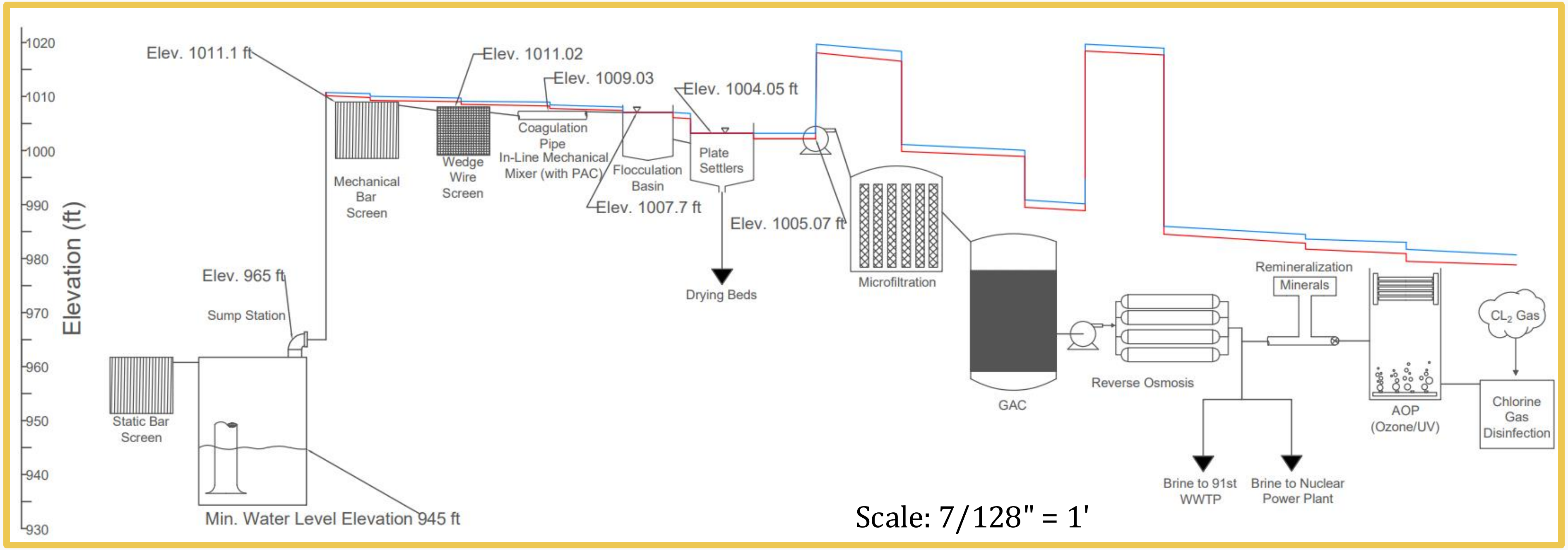
$$V = 4.93$$

Given Values:

Q (cfs) =	61.94
A =	12.57
D (ft) =	4.00
π, Pi:	3.14

Hydraulic Profile

The facility's water elevations prior to the intermediate pumps can be seen in the profile, demonstrating how the site is graded to maximize gravity flow and minimize energy inefficiencies.



Scale: 7/128" = 1'

Figure 45: AWPF Hydraulic Profile

Capital Cost

Capital cost for the AWPF in include:

- Construction
- Material
- Construction Labor

Table 25: AWPF Capital Cost

AWPF Capital Cost	
Hydraulic Design	$3,354,964
Bar Screen	$550,000
Fine Screen	$750,000
Coagulation & Flocculation	$250,000
Sedimentation	$930,000
GAC	$4,360,000
Microfiltration	$151,100,000
Reverse Osmosis	$201,800,000
Remineralization	$360,000
AOP	$4,300,000
UV & Chlorine	$3,600,000
Brine Management	$4,500,000
Labor	$680,323,848
Grand Total	**$1,056,178,812**

Operation & Maintenance Cost

Operations & Maintenance (O&M) costs included:

- Energy
- Chemicals
- Labor for maintenance
- Replacements of materials

Table 26: O&M Cost per Year for the AWPF Table

Category	O&M Cost per year
Energy	$16,734,556
Chemicals	$30,980,475
Systems	$4,375,930
Maintenance	$2,250,835
Labor	$2,046,500
Total Cost	**$59,951,720**

Construction Sequencing

Construction sequencing will be in 8 phases and will total around 32 months

Table 27: Construction Phasing Table

Phase	Process	Time
1	Site Preparation	Month 1-4
2	Excavation	Month 3-9
3	Structural Building	Month 5-10
4	Treatment Train Construction	Month 6-20
5	Pipe Construction	Month 10-22
6	Education Center	Month 12-24
7	Mechanical/Electrical Construction	Month 16-26
8	Testing and Full Operation	Month 26-32

Construction Sequencing Cont.

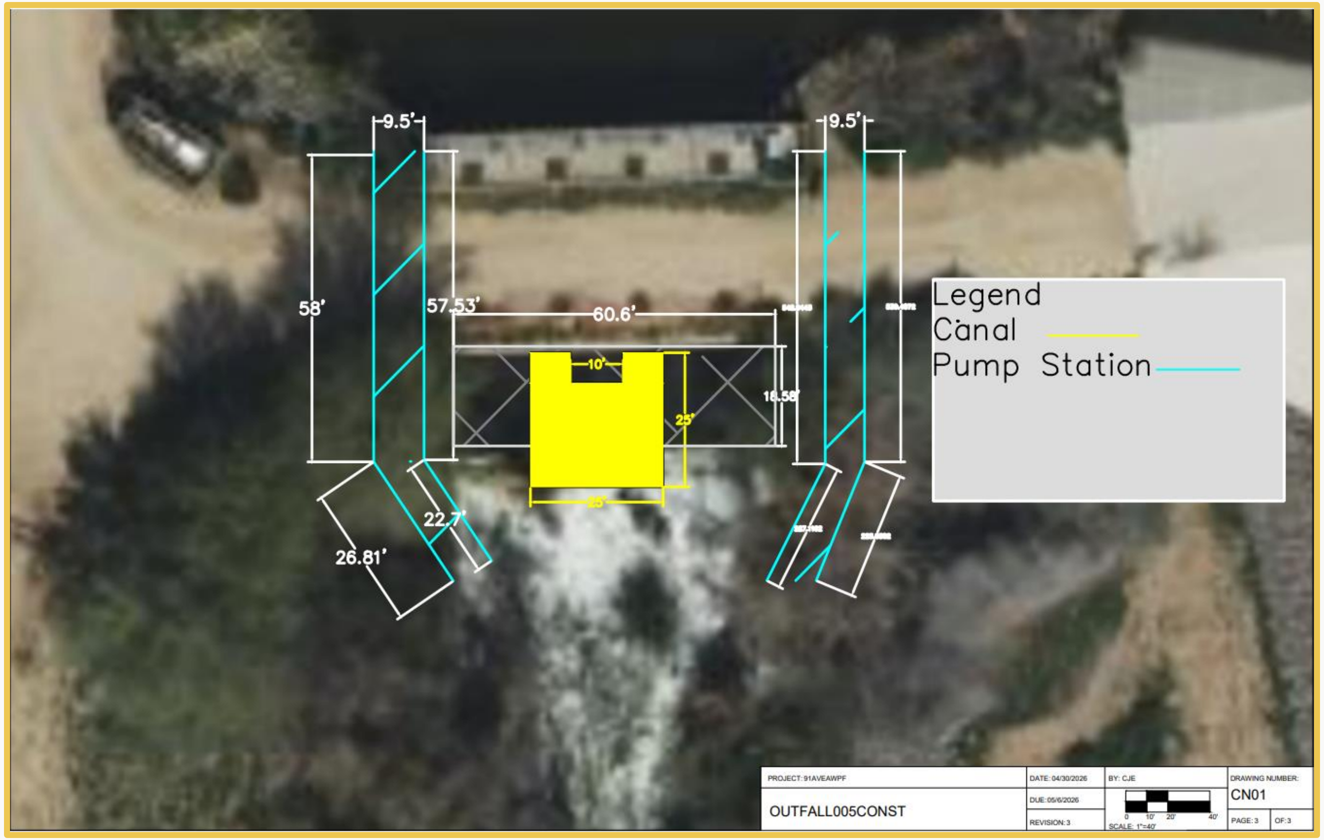


Figure 46: Outfall 005 Canal Plan

Public Outreach Plan

Figure 47: Proposed Educational Center Location

- Public Engagement and Educational meetings
- Education Center for the public
- Tour guide around FRW and 91st Ave WWTP
- Discuss and educate public on AWPF and processes/results

Conclusion

Treatment Train Design:

- Successfully created a train that can treat water to EPA, ADEQ, and MCESD drinking water standards
- Treatment train prioritizes public health, and is adaptable for Phoenix area growth
- Creates a new, safe source of drinking water for the Phoenix area
- Helps combat the water crisis within the Phoenix area

Hydraulic Design:

- Successfully designed a pump station that can deliver 40 MGD
- Pump Station houses five vertical turbine pumps with one on standby
- The pump overcomes 86.3 ft of TDH and motors are rated for 250 HP.
- 9920 LF of 42-inch Diameter AWWA C905 PVC Force Main
- Headworks of AWPF is 40 feet above grade (Elev: 1011.1 ft) for gravity pushes the flow through the treatment train up to the intermediate pumps

Thank you!

Figure 48: CJE at the FRW

Figure 49: CJE at AZ Water Student Design Competition

Any Questions?

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