Water Environment Federation and Arizona Waters Student Design Competition

Figure 1: WEF Logo [1]

Figure 2: AZ Water Logo [2]

CENE - 486C
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Project Description

Objectives

- Lower the TOC levels less than 2 mg/L
- Reduce chemical usage

Constraints

- Meet water regulations from
  - Environmental Protection Agency (EPA)
  - Arizona Department of Environmental Quality (ADEQ)
  - Maricopa County Environmental Services Department (MCESD)
- Meet expected demand to treat 70MGD by 2050.

Figure 3: Project Location [3]

Current Layout

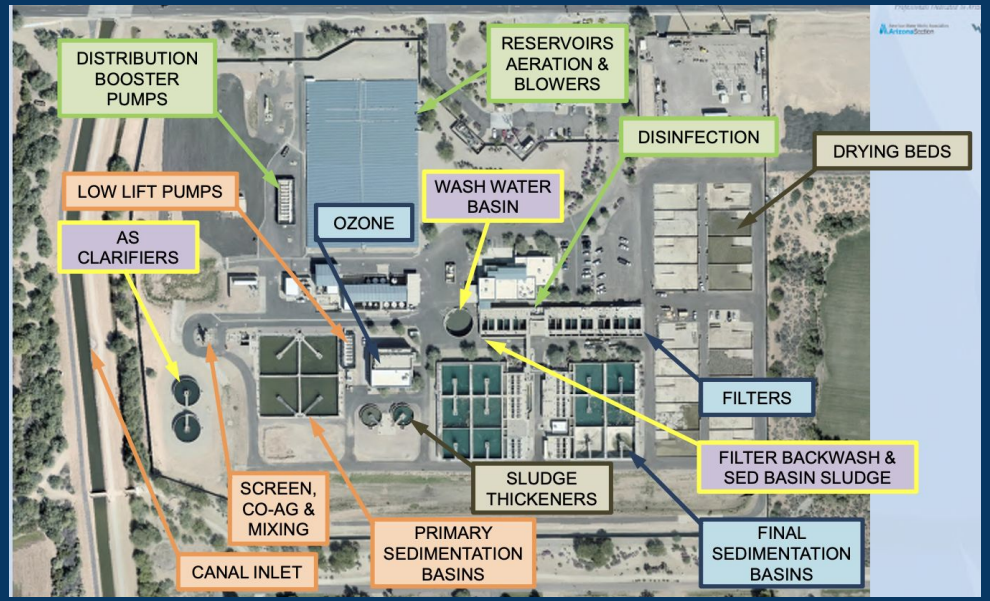


Figure 4: Existing Site Layout [4]

Primary Source	Salt River				Verde River			
	Average[1]	Range[1]	Count[1]	Non-Detect Count	Average[1]	Range[1]	Count[1]	Non-Detect Count
Alkalinity as $CaCO_3$ (mg/L)	156	110-217	503	-	191	111-256	437	-
Arsenic (µg/L)	6.0	3.2-8.9	155	-	8.6	3.6-14.1	155	-
Bromide (mg/L)	0.147	0.054-0.231	142	10	0.106	0.052-0.225	111	35
Conductivity (µS/cm)	1761	630-2288	504	-	833	326-1768	438	-
Nitrate (mg/L as N)	1.14	0.03-5.36	438	66	0.81	0.003-5.07	418	18
pH (SU)	8.23	7.89-8.51	503	-	8.31	7.82-8.74	437	-
Temperature (°C)	25.2	12.7-29.1	503	-	19.5	10.8-29.2	434	-
Total Organic Carbon (mg/L)	3.51	1.08-6.46	282	-	3.67	0.46-6.86	293	4
Turbidity (NTU)	10.2	3.62-157	504	-	15.1	2.83-87.2	438	-

[1]*Non-detect data not included*

Figure 5: Provided Source Water Characteristics [4]

Demand Calculations

Build Out Population:
The maximum population for an area

Table 1: Total Production

Demand per capita (gallons per day per person)	
$\bar{q} = \frac{Q_{2019}}{pop_{2019}}$	274
Total production needed by Build Out Date(mgd)*	
$Q_{build\ out} = \bar{q} * pop_{build\ out}$	90
Total production needed by NGWTP(mgd)**	
$Q_{NGWTP} = Q_{build\ out} - Q_{SVWTP}$	66

* The build out population was used because of its closeness to the 2050 population
** Daily Demand Factors were carried through from present WTP productions

Demand Calculations - Phasing

Design production based on population estimates

Even years & even productions

Table 2: Production Timeline

Production of NGWTP by Year		
	Year	Deisgn Production(MGD)
Phase 0	2021	45
Phase 1	2030	60
Phase 2	2050	70

Matrix Criteria

Lifecycle Costs
- Cost estimation formulas

O&M
- Cost estimation formulas

Social & Environmental Factors
- Available literature
- Process efficiency improvements

Staffing Levels
- Available literature
- Portion of O&M from Staffing

Process Efficiency Improvements
- Process Dependent

Feasibility/Constructability
- Complexity of design
- Resistance to dust storms/heat
- Alternative footprint

Weighting
- Treatment Process Dependent

Preliminary Treatment

Screening

- Bar screen considered enough for preliminary treatment

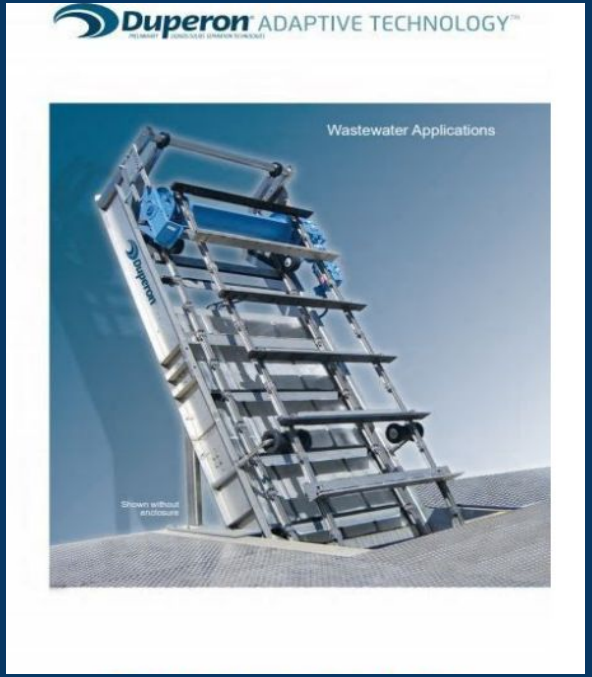


Figure 6 : RakeFlex Bar Screen [11]

Primary Treatment - Decision Matrices

Table 3: Primary Clarifier Decision Matrices

Primary Clarifier

Raw Value

Alternatives	Lifecycle Costs ($)	M&O ($/yr)
Best Value	750,000	103,500
Rectangular	750,000	206,880
Circular	864,600	103,500

Weighted Score

Alternatives	Lifecycle Costs	M&O	Social & Environmental Factors	Staffing Levels	Process Efficiency Improvements	Feasibility/ Constructability	Total Weighted Score
Weight	2	2	1	1	3	3	
Rectangular	2.00	1.00	0.67	1.00	3.00	3.00	7.67
Circular	1.73	2.00	1.00	1.00	1.00	2.00	6.73

Primary Treatment - Design

$$v_s = \frac{g(\rho_s - \rho)d^2}{18\mu}$$

Equation 1: Stokes Equation for Laminar Flow

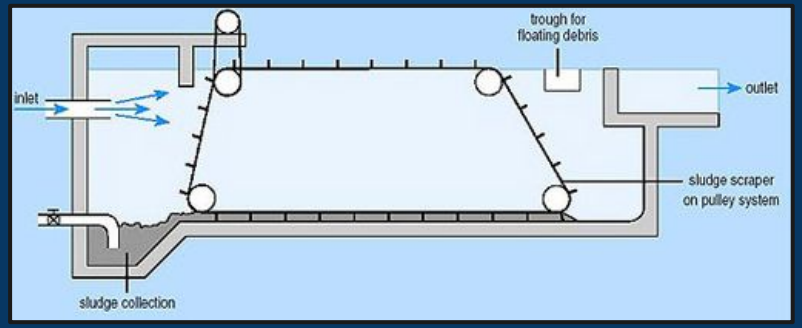


Figure 7: Rectangular Clarifier [5]

Table 4: Rectangular Clarifier Design

Rectangular clarifier	
Dimensions of Clarifier	13.3m wide, 4.3m depth, 37.3m long
Phase 0 (2021) 45 MGD	1 Rectangular Tank Surface area : 496m^2
Phase 1 (2030) 60 MGD	Adding 1 Tank (Total 2 rectangular clarifiers) Total Surface area: 992m^2

Disinfection - Decision Matrices

Table 5: Disinfection Decision Matrices

Disinfection

Raw Value

Alternatives	Lifecycle Costs ($)	M&O ($/yr)
Best Value	1,769,525	77,407
Pre-Ozonation (LOX) and UV (Trojan UV Signa)	24,255,528	2,641,729
UV (Trojan UV Signa)	3,294,000	138,000
Chlorination (Sodium Hypochlorite)	1,769,525	77,407
Ozonation (LOX)	20,961,528	2,503,729
Pre-Ozonation (LOX) and Chlorination (Sodium Hypochlorite)	22,731,053	2,581,135

Weighted Score

Alternatives	Lifecycle Costs	M&O	Social & Environmental Factors	Staffing Levels	Process Efficiency Improvements	Feasibility/ Constructability	Total Weighted Score
Weight	2	1	1	1	4	1	10
Pre-Ozonation (LOX) and UV (Trojan UV Signa)	0.15	0.03	1.00	0.50	4.00	0.80	6.48
UV (Trojan UV Signa)	1.07	0.56	1.00	1.00	1.60	1.00	6.24
Chlorination (Sodium Hypochlorite)	2.00	1.00	0.33	0.50	1.60	0.40	5.83
Ozonation (LOX)	0.17	0.03	1.00	0.50	3.20	0.90	5.80
Pre-Ozonation (LOX) and Chlorination (Sodium Hypochlorite)	0.16	0.03	0.33	0.33	4.00	0.20	5.05

Disinfection (Ozone) - Design

Table 6: Ozone Design

Ozone		
Desired Ozone Dosage		4ppm (4mg/l)
Ozone Concentration in Feed Gas (assumption)		12%
Ozone Diffuser		Ozonia Dome Bubble Diffusers
Required Ozone Generation Rate found for each phase		$O_3GenRate = Q * O_{3\,dos} * 8.34/eff.$
Required Contact Chamber Volume		$V = t_0 * Q$
Ozone Contact Tank Dimensions Designed		6.6m deep X 3.4m wide X 16.5m long
Number of Cells in Contact Chamber		10 (9 contact cells and 1 inlet cell)
Phase 0 (2021) 45MGD	$O_3GenRate$	1668lb/d
	O_3 Generator	2 Ozonia CFV-30 (1 for use, 1 for redundancy)
	Contact Chambers Needed	2 (1 for use, 1 for redundancy)
Phase 1 (2030) 70MGD	$O_3GenRate$	2594.67lb/d
	O3 Generator	3 Ozonia CFV-30 (2 for use, 1 for redundancy)
	Contact Chambers Needed	3 (2 for use, 1 for redundancy)

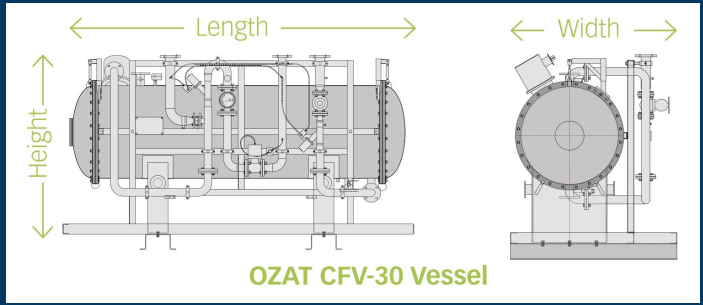


Figure 8: Ozonia CFV-30 Generator [6]

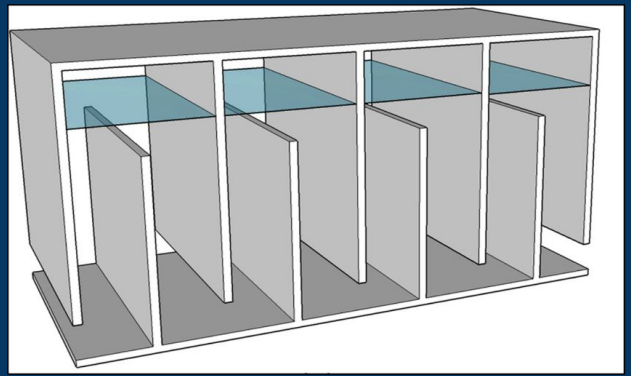


Figure 9: Diagram of Over-Under Contact Chamber [5]

Disinfection (UV) - Design

Figure 10: TrojanUV Signa Diagram [7]

Figure 11: TrojanUV Signa Photo [7]

Table 7: UV Design

UV	
TrojanUV Signa lamps will be used	
Each TrojanUV solo lamp is 1000 Watts	
Phase 0 (2021) 45MGD	144 lamps
	6 Banks-5 for flow, 1 for redundency
Phase 1 (2030) 60MGD	Add 48 lamps (192 total)
	8 Banks-7 for flow, 1 for redundency
Phase 2 (2050) 70MGD	Add 24 lamps (216 total)
	9 Banks-8 for flow, 1 for redundancy

Secondary Treatment - Decision Matrices

Table 8: Secondary Clarifier Decision Matrices

Secondary Clarifier							
	Raw Value						
Alternatives	Lifecycle Costs ($)	M&O ($/yr)					
Best Value	336,854	5,053					
Circular	2,419,055	27,665					
Floc Blanket	336,854	5,053					
Rectangular	6,030,664	219,597					
Lamella/Plate	109,433,114	1,549,923					
			Weighted Score				
Alternatives	Lifecycle Costs	M&O	Social & Environmental Factors	Staffing Levels	Process Efficiency Improvements	Feasibility/ Constructability	Total Weighted Score
Weight	1.5	1.5	1	1	3	2	
Circular	0.209	0.274	0.500	1.000	3.000	1.800	6.783
Floc Blanket	1.500	1.500	0.214	0.200	1.800	1.000	6.214
Rectangular	0.084	0.035	0.429	0.800	1.800	2.000	5.147
Lamella/Plate	0.005	0.005	1.000	0.200	3.000	1.400	5.610

Secondary Treatment - Design

$$v_s = \frac{g(\rho_s - \rho)d^2}{18\mu}$$

Equation 1 : Stokes Equation for Laminar Flow

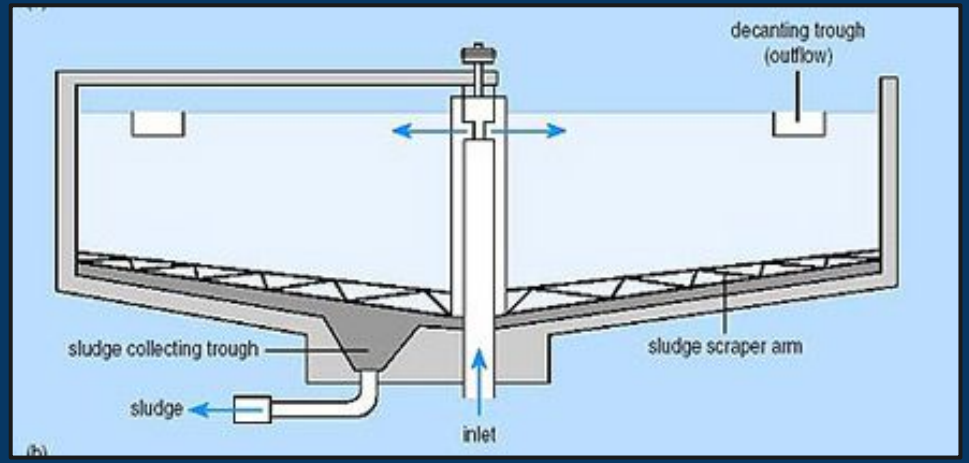


Figure 12: Circular Clarifier [5]

Final Design (14 m diameter)			
	Count	Total Surface Area (m^2)	Overdesign Percentage
Phase 0	4	616	18%
Phase 1	6	924	32%
Phase 2	6	924	14%

Table 9 : Secondary Clarifier Design Phasing Information

Tank diameter, m (ft*)	Side water depth, m (ft)	
	Minimum	Suggested
Up to 12 (40)	3 (10)	3.7 (12)
12 – 21 (40 – 70)	3.3 (11)	3.7 (12)
21 – 30 (70 – 100)	3.7 (12)	4 (13)
30 – 43 (100 – 140)	4 (13)	4.3 (14)
>43 (140)	4.3 (14)	4.6 (15)

Table 10: Recommended Clarifier Tank Depths [5]

Filtration - Decision Matrices

Table 11: Filtration Decision Matrices

Filtration

Raw Value

Alternatives	Lifecycle Costs ($)	M&O ($/yr)
Best Value	8,854,154	200,000
Rapid Sand Filter (Anthracite/Sand)	8,854,154	554,889
Cloth Media Filter	10,000,000	200,000
Slow Bio-Sand Filter	14,412,231	720,611
Ultrafiltration	98,139,691	8,247,032
Reverse Osmosis w/ Pre-Treatment	196,279,382	17,729,152

Weighted Score

Alternatives	Lifecycle Costs	M&O	Social & Environmental Factors	Staffing Levels	Process Efficiency Improvements	Feasibility/ Constructability	Total Weighted Score
Weight	2	2	1	1	3	1	
Rapid Sand Filter (Anthracite/Sand)	2.00	0.72	1.00	0.50	2.40	1.00	7.62
Cloth Media Filter	1.77	2.00	1.00	1.00	0.60	1.00	7.37
Slow Bio-Sand Filter	1.23	0.56	1.00	0.33	2.70	0.67	6.48
Ultrafiltration	1.00	0.02	0.33	0.33	3.00	0.33	5.02
Reverse Osmosis w/ Pre-Treatment	0.18	0.05	0.50	0.50	2.70	0.67	4.60

Filtration- Design

Table 12: Filtration Design

Rapid Sand Filtration-Veolia Filtraflo TGV			
	Phase 0 (2025) 45MGD	Phase 1 (2030) 60MGD	Phase 2 (2050) 70MGD
Desired Velocity (m/hr)	16	16	16
Total Required Filter Area, $A_T(\mathrm{m}^2) = Q/V$	443.6	591.5	739.3
Minimum Filters Needed with filter size of 50m² $\#Filters = A_T/50m^2$	9	12	15
Number of Filters Total	10 (9 for treatment, 1 for redundancy)	14 (12 for treatment, 2 for redundancy)	16 (15 for treatment, 1 for redundancy)
Dimensions of Each Individual Filter	8m X 6m	8m X 6m	8m X 6m
Area of All Filters (m²)	480	672	768
Total Depth of Media (m)	1.5	1.5	1.5
Height of Filtration Unit (including 1m for underdrain system, media, water level, 0.6m freeboard)	4.5m	4.5m	4.5m
Width of Unit (m)	18	18	18
Length of Unit (m)	38	50	56

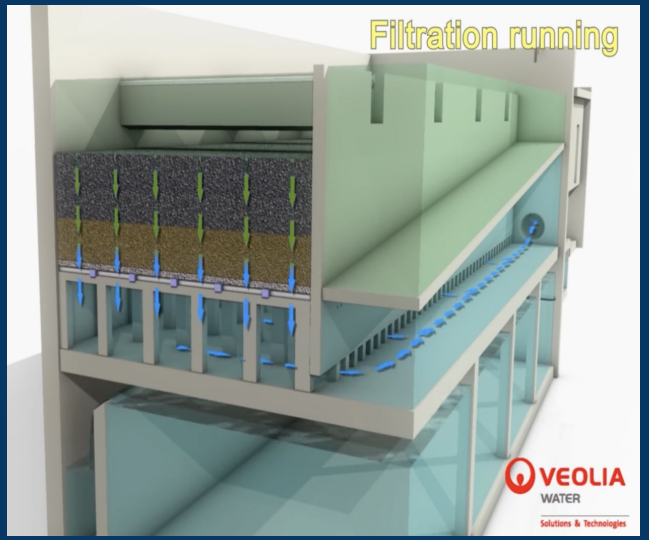


Figure 13: Veolia FiltraFlo TGV Media View [8]

Solid Treatment

Table 13: Solids Decision Matrices

Biosolids				
Raw Value				
Alternatives	Initial Investment($)			
Best Value	120,000			
Belt Filter Press	120,000			
Heat Drying	300,000			
Centrifuge Thickening	650,000			
Gravity Thickening	3,200,000			
Weighted Score				
Alternatives	Initial Investment	Total Lifecycle Cost	Social & Environmental Factors	Total Weighted Score
Weight	5	3	2	10
Belt Filter Press	5.00	3.00	2.00	10.00
Heat Drying	2.00	2.40	1.33	5.73
Centrifuge Thickening	0.92	2.70	1.78	5.40
Gravity Thickening	0.19	2.40	1.56	4.14

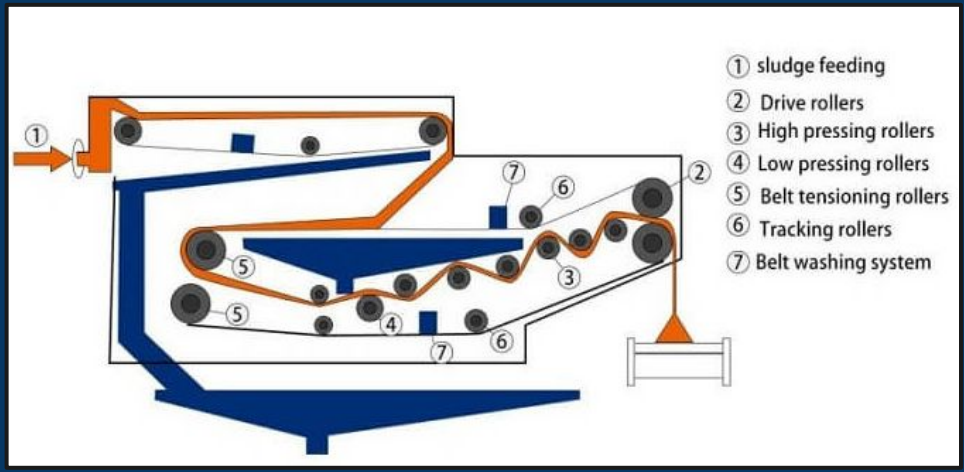


Figure 14: Belt Filter Press Diagram [9]

Hydraulics

Table 14:Pump Information

Maximum Flow Capacity (MGD)	70
Pipe Material	Ductile Iron
Pipe Diameter (ft)	3
Number of Pumps	3 (1 for redundancy)
Type of Pumps	Goulds 3420 centrifugal pump
Capacity(GPM)	65,000

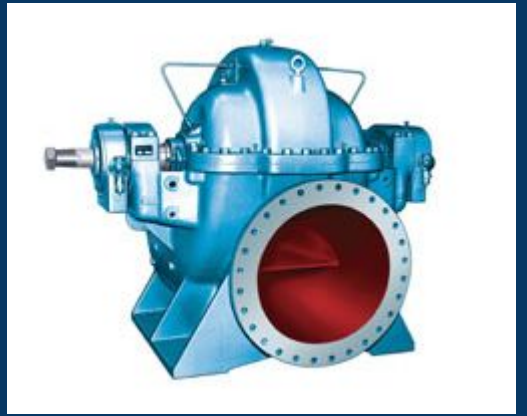


Figure 16 : Centrifugal Pump [10]

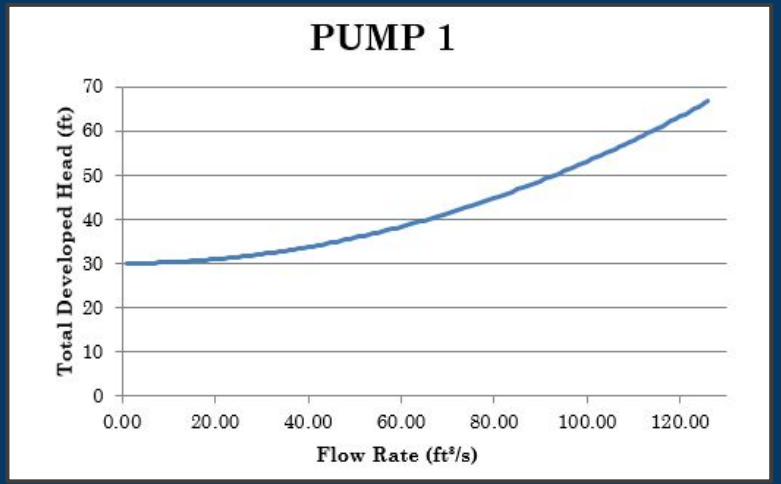
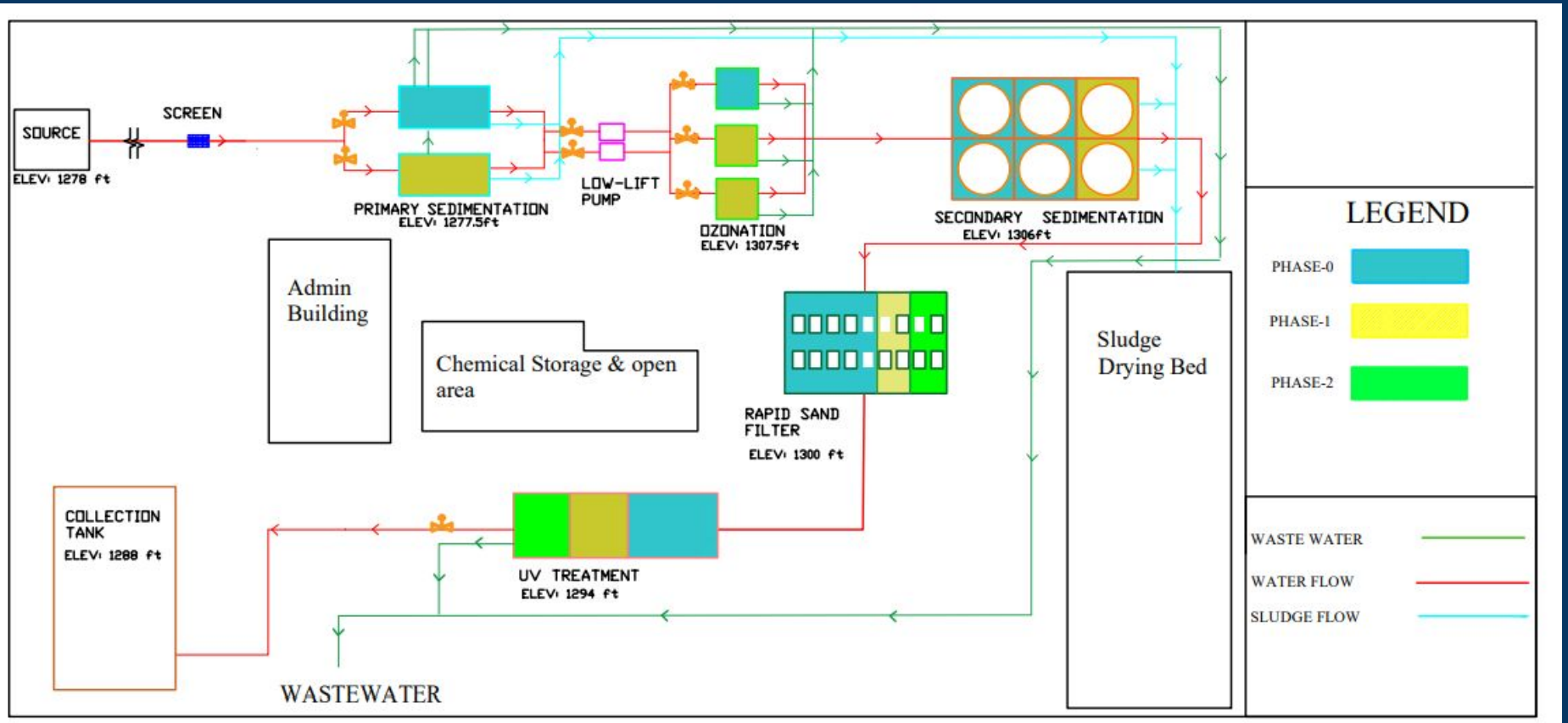
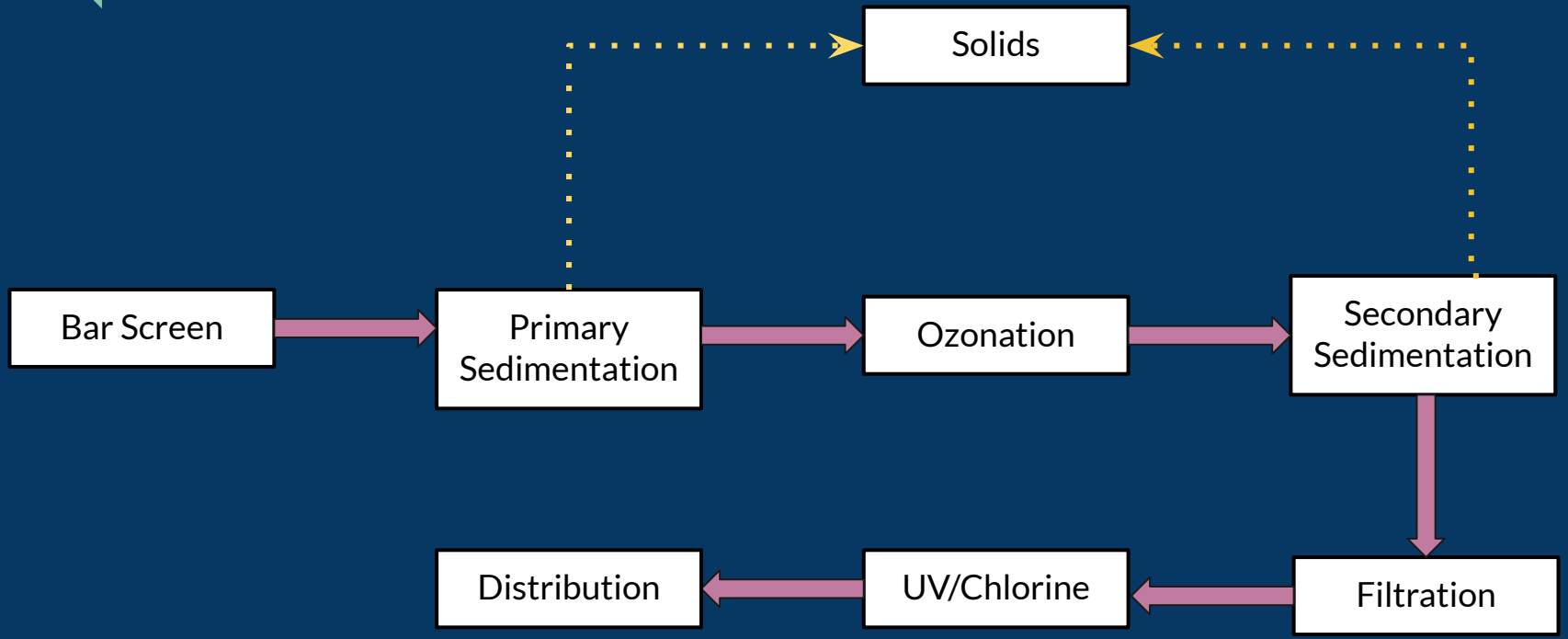


Figure 15: System Curve


SOURCE
ELEV: 1278 ft
SCREEN
PRIMARY SEDIMENTATION
ELEV: 1277.5ft
LOW-LIFT PUMP
OZONATION
ELEV: 1307.5ft
SECONDARY SEDIMENTATION
ELEV: 1306ft
Admin Building
Chemical Storage & open area
RAPID SAND FILTER
ELEV: 1300 ft
Sludge Drying Bed
COLLECTION TANK
ELEV: 1288 ft
UV TREATMENT
ELEV: 1294 ft
WASTEWATER
LEGEND
PHASE-0
PHASE-1
PHASE-2
WASTE WATER
WATER FLOW
SLUDGE FLOW

Final Design Summary - Plant Flow Chart



Final Design Summary - Treatment Phasing

Table 15: Design Summary

	Ozone	Rapid Sand Filter (Anthracite/Sand)	UV Lights	Primary Clarifier	Secondary Clarifier
Phase 0 (2021) 45 MGD	2 Ozonia CFV- 30 generators [1 for treatment, 1 for redundancy] 2 Contact Chambers [1 for treatment, 1 for redundancy]	10 filters 480 m^2	144 lamps 6 banks	1 Rectangular Tank Surface area: 496m^2	4 (14 m circular clarifiers) Surface area: 615m^2
Phase 1 (2030) 60 MGD	+1 Ozonia CFV-30 generator [2 for treatment, 1 for redundancy] +1 Contact Chamber [2 for treatment, 1 for redundancy]	+4 filters (14 total) 672 m^2 size	+48 lamps and 2 banks (Total 192 lamps, 8 banks)	+1 (Total 2 rectangular tanks) Total Surface area: 992 m^2	+2 (14m circular clarifiers) Surface area: 307m2 Total Surface area: 922 m^2
Phase 2 (2050) 70 MGD	-	+2 filters (16 total) 768 m^2 size	+24 lamps and 1 bank (Total 216 lamps, 9 banks)	-	-

Cost Analysis - Example Calculation

1 Calculating interest rate
2 Initial year values
3 Converted to present day money
4 Grand Total

Principal & O&M Yearly Cost (Simple interest)

$$P = F(1+i)^{n}$$

Equation 2 : Simple Interest

O&M Total Cost (Uniform Series)

$$P = A\left(\frac{(1+i)^{n}-1}{i(1+i)^{n}}\right)$$

Equation 3 : Uniform Series

Table 16 : Example Cost Analysis Table

Ozone					
			Name	Value	Unit
			Initial year	2009	Year
			Common Year	2021	Year
			Year Difference	12	Year
		Constants 1	Annual of Initial year CPI	214.537	
			January of 2021 CPI	261.582	
			Percentage increase between Years	22%	%
			Per year Inflation	2%	%
			Projected Present Inflation Rate	2%	%
	Phase 0	2 Initial year Money	Principal Cost	$ 7,525,674	$
			O&M Yearly Cost	$ 1,380,248	$/yr
		3 2021 Money	Principal Cost	$ 9,352,344	$
			O&M Yearly Cost	$ 1,715,268	$/yr
			O&M Total Cost	$44,599,186	$
	Phase 1	Initial year Money	Principal Cost	$ 9,665,965	$
			O&M Yearly Cost	$ 673,190	$/yr
		2021 Money	Principal Cost	$12,012,138	$
			O&M Yearly Cost	$ 836,591	$/yr
			O&M Total Cost	$18,231,483	$
	Phase 2	Initial year Money	Principal Cost		$
			O&M Yearly Cost		$/yr
		2021 Money	Principal Cost	$ -	$
			O&M Yearly Cost	$ -	$/yr
			O&M Total Cost	$ -	$
4	Completion	2021 Money	Total Cost	$84,195,151	$

Cost Analysis - Totals

By Phase

Phase Completion Costs		
Phase 0	$	83,476,642
Phase 1	$	43,979,156
Phase 2	$	7,633,875
Grand Total	$	135,089,673

Table 17: Cost by Phase

By Process

Process Completion Costs	
Ozone	$ 84,195,151
Rapid Sand Filter (Anthracite/Sand)	$ 22,129,395
UV Lights	$ 8,628,595
Primary Clarifier	$ 19,138,194
Secondary Clarifier	$ 998,338
Grand Total	$ 135,089,673

Table 18: Cost by Process

Impacts

Table 19: Impacts

Social	Economic	Environmental
Positive		
•Potable water is provided •Reduced chlorine usage •Quality potable water	•Low cost treatment options •Low upkeep treatment options •Future proof	•Reduced chemical usage •Solids applications
Negative		
•Odor •Noise	•Expensive disinfection	•Disinfection byproducts (DBPs)

References

[1] Water Environment Federation - WEF Home, "WEF Home." [Online]. Available: https://www.wef.org/.

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Questions?