DRAFT

MARCO ISLAND RECLAIMED WATER PRODUCTION FACILITY

Advanced Wastewater Treatment Evaluation

BLACK & VEATCH PROJECT NO. 424430

PREPARED FOR

City of Marco Island

27 MARCH 2026

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List of Abbreviations

Abbreviation	Definition
3MADF	Three-Month Average Daily Flow
AADF	Annual Average Daily Flow
ASR	Aquifer Storage Recovery
AWT	Advanced Water Treatment
BOD	Biochemical Oxygen Demand
BNR	Biological Nutrient Removal
CAPEX	Capital Expenditures
CAR	Capacity Analysis Report
$cBOD_5$	Carbonaceous Biochemical Oxygen Demand, 5 day
CCB	Chlorine Contact Basin
COD	Chemical Oxygen Demand
CT	Contact Time
DIW	Deep Injection Well
DO	Dissolved Oxygen
EBPR	Enhanced Biological Phosphorus Removal
EQ	Equalization
FDEP	Florida Department of Environmental Protection
GWMCL	Groundwater maximum contaminant level
HLD	High Level Disinfection
HRT	Hydraulic Retention Time
mg/L	Milligrams per Liter
mgd	Million Gallons per Day
MBR	Membrane Bioreactor
MCL	Maximum Contaminant Limit
MM	Maximum Month
MLE	Modified Ludzack-Ettinger
MLSS	Mixed Liquor Suspended Solids
NPV	Net Present Value
O&M	Operations and Maintenance
OPCC	Opinion of Probable Construction Cost
OPEX	Operational Expenditures (O&M Costs)

Abbreviation	Definition
PAO	Phosphorus Accumulating Organisms
PDF	Peak Daily Flow
PFD	Process Flow Diagram
PHA	Polyhydroxyalkanoates
PdNA	Partial Denitrification–Anammox
RAS	Return Activated Sludge
RWPF	Reclaimed Water Production Facility
S2EBPR	Sidestream Enhanced Biological Phosphorus Removal
SCFM	Standard cubic feet per minute
SRT	Solids Retention Time
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOTEX	Total Expenditures (CAPEX + NPV OPEX)
TP	Total Phosphorus
TRC	Total Residual Chlorine
TSS	Total Suspended Solids
VFA	Volatile Fatty Acids
WAS	Waste Activated Sludge

Definitions

Term	Definition
Influent	Flow into the plant
Effluent	Flow out of the plant, to either reuse or disposal
Bardenpho	Barnard Denitrification and Phosphorus treatment configuration
Anaerobic Zone	A treatment zone in which dissolved oxygen (DO) is essentially absent, creating conditions where microorganisms must obtain energy without using oxygen or nitrate as an electron acceptor. Used in biological phosphorus removal.
Anoxic Zone	A treatment zone in which free dissolved oxygen is absent, but oxidized nitrogen (nitrate or nitrite) is present, allowing microorganisms to use nitrate as an alternative oxygen source. Used in biological nitrogen removal.
Oxic (Aerobic) Zone	A treatment zone in which dissolved oxygen is present at concentrations sufficient to support aerobic microbial activity. Used in both biological nitrogen and phosphorus removal.
Metal Salts	Chemicals used in wastewater treatment with many purposes, one of them being chemical phosphorus (Chem-P) removal.

Term	Definition
Supplemental Carbon	Chemical rich in carbon used in WWTPs to provide proper conditions for nitrogen removal.
RAS	Returned activated sludge, it is a stream of solids that has been removed in a solids separation step and is returned to the biological reactor to retain microorganisms and maintain biological treatment.
Reactor	Tank or vessel where biological treatment processes occur.
WAS	Waste activated sludge is the excess sludge from the biological treatment that has to be removed from the system and ultimately disposed of.

Executive Summary

The City of Marco Island (City) requested Black & Veatch to review the performance of its Reclaimed Water Production Facility (RWPF) and to study options to upgrade the plant to meet **Advanced Water Treatment (AWT)** standards set by the State of Florida. This report explains how the RWPF is currently performing, what challenges exist, and what improvements could be made to meet more stringent water quality requirements in the future.

ES-1 Purpose of the Study

AWT standards are designed to protect public health, groundwater, and the environment, most notably in areas where nutrient impairment has been proven. These standards set lower limits for nutrients such as **nitrogen and phosphorus**, as well as very low limits for solids and bacteria. The goal of this study is to help the City understand:

- How well the RWPF is currently operating
- Whether it can meet future AWT requirements
- What upgrade alternatives are available, and how they compare

ES-2 Existing Facility Overview

The Marco Island RWPF currently treats wastewater from homes and businesses and produces reclaimed water that is reused for irrigation and other approved purposes. When reclaimed water cannot be reused, it is safely disposed through permitted deep injection wells. The facility already uses **advanced treatment processes**, including membrane filtration and disinfection, and it performs very well at removing solids and ammonia. These systems provide a strong foundation for future improvements.

ES-3 Summary of Current Performance

Based on several years of operating data, the following conclusions were drawn:

- **Flows:** The RWPF operates well within its permitted flow capacity. Higher influent flows mainly occur during storm events and seasonal population increases.
- **Solids Removal:** The RWPF consistently produces water with extremely low suspended solids which already meets AWT standards.
- **Ammonia Removal:** Ammonia is consistently reduced to very low levels, indicating that the biological treatment process is working well.
- **Nitrogen (Total Nitrogen):** Total nitrogen is removed to relatively low levels at the RWPF (84% removal on average) which is very good. However, these levels are higher than what would be required under AWT standards.
- **Phosphorus:** Total phosphorus is removed at the RWPF by roughly 63% on average. However, these effluent levels are also higher than AWT limits and would need improvements to meet the lower requirements.
- **Disinfection:** The facility meets reuse disinfection requirements, but upgrades may be needed to fully meet AWT reliability expectations.

Overall, the RWPF performs well and meets its current permit requirements. However, **upgrades will be needed** if the City chooses to meet full AWT standards in the future. As shown in Table ES-1 and summarized in Figure ES-1, the current plant already meets AWT standards for 5-day Carbonaceous

Biochemical Oxygen Demand ($CBOD_5$) and Total Suspended Solids (TSS) but exceeds the Total Nitrogen (TN) and Total Phosphorus (TP) criteria for AWT. Therefore, this evaluation will focus on alternatives to remove these two nutrients.

Table ES-1 Current RWPF Performance Compared to AWT Requirements

Parameter	Criteria	Current Performance	Meets/Exceeds
$CBOD_5$	<5 mg/l	3.51 mg/l	Meets
TSS	<5 mg/l	0.6 mg/l	Meets
Total Nitrogen (TN)	<3 mg/l	7.03 mg/l	Exceeds
Total Phosphorus (TP)	<1 mg/l	3.65 mg/l	Exceeds

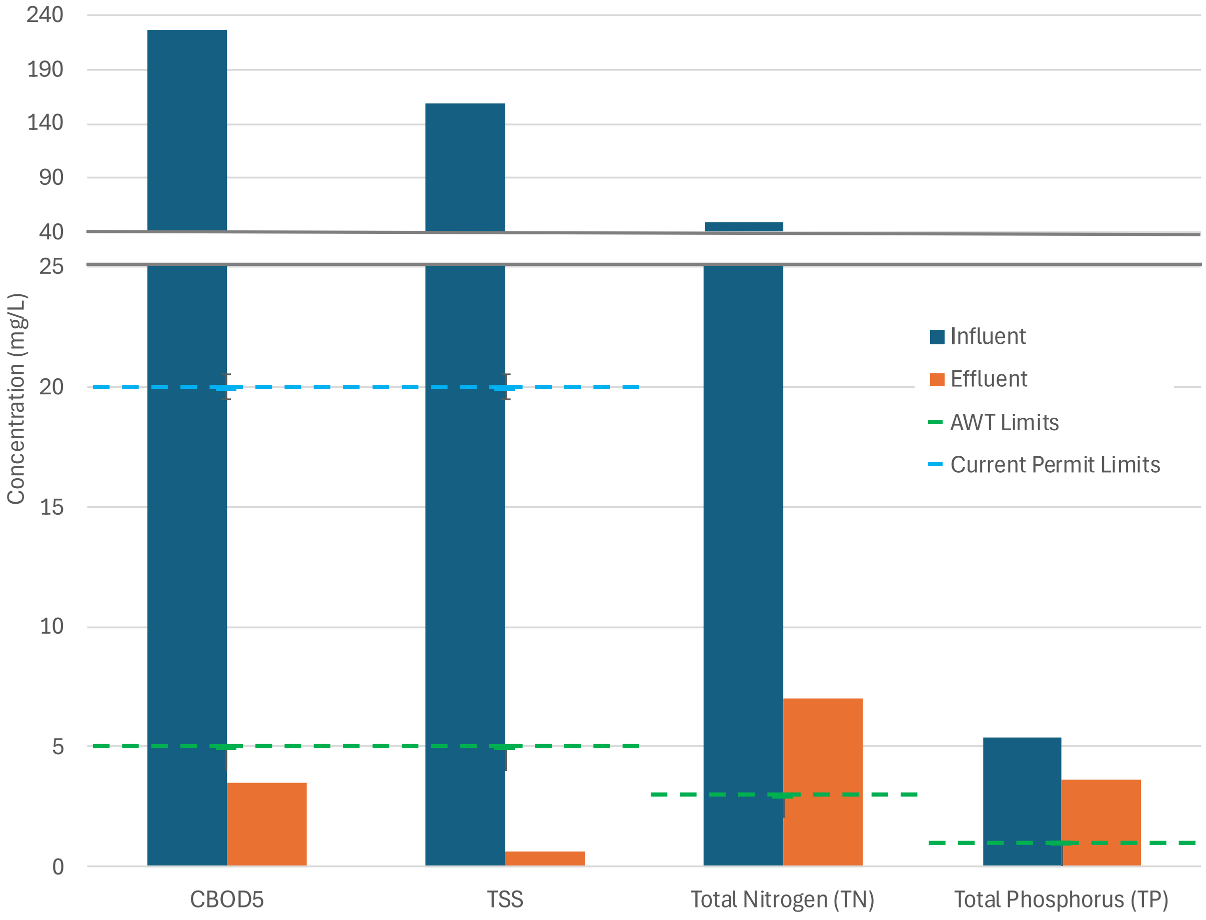


Figure ES-1 Current Average Plant Performance vs AWT Limits

ES-4 Advanced Water Treatment Upgrade Alternatives

Three conventional upgrade alternatives were evaluated in this report. Each alternative would improve nitrogen and phosphorus removal while building on the existing treatment system. The alternatives differ in complexity, cost, and long-term operation requirements. A fourth alternative with an emerging nutrient removal technology was reviewed as part of this study but was not carried forward for detailed evaluation. This technology has not been demonstrated at full-scale wastewater treatment facilities and lacks a proven record of reliable, long-term operation. In addition, sufficient technical information and performance data were not available to allow a meaningful comparison to established treatment methods. Given the City's need for dependable, well-understood solutions, the evaluation focused on proven technologies that have been successfully implemented at similar facilities.

All three viable options would improve removal of nitrogen and phosphorus while using much of the existing treatment system. The main differences are how nutrients are removed, how complex the systems are to operate, and overall cost.

AWT Alternative 1 – Enhanced Biological Treatment (Four-Stage Bardenpho with S2EBPR)
This alternative relies primarily on biological processes to remove nutrients. The existing biological reactors would be modified to a Four-Stage Bardenpho process and operated in a way that allows microorganisms to remove nitrogen and phosphorus more efficiently. A small sidestream process would be added to improve phosphorus removal without heavy chemical use.

This option has lower chemical requirements and generally lower long-term operating costs. It is more sensitive to operating conditions, meaning it requires good process control and operator attention, but it is considered the most cost-effective solution.

AWT Alternative 2 – Biological Treatment with Chemical Phosphorus Removal (Four-Stage Bardenpho + Chemical P Removal)
This alternative also improves biological nitrogen removal similar to Alternative 1, but phosphorus is removed mainly by adding chemicals that bind phosphorus so it can be removed from the water. This approach is commonly used and is reliable for meeting low-level phosphorus limits.

Compared to Alternative 1, this option is simpler to operate and less sensitive to process conditions. However, it requires ongoing chemical use and produces more solids that must be handled and disposed of, which increases long-term operating costs.

AWT Alternative 3 – Advanced Nitrogen Removal with Chemical Phosphorus Removal (PdNA + Chemical P Removal)
This alternative uses a newer biological process configuration to remove nitrogen more efficiently, combined with chemical phosphorus removal. The process can achieve very low nitrogen levels and may reduce the amount of supplemental chemicals needed for nitrogen removal.

While technically effective, this option is more complex and would require additional modifications and operational expertise. It also has higher capital costs compared to the other alternatives, making it less cost-effective for this facility at this time.

In summary:

- All three alternatives evaluated are technically feasible.
- All three alternatives would allow the City to meet AWT nutrient limits.
- Some options rely more on biological treatment, while others use chemicals to remove phosphorus.
- Costs vary depending on construction needs, energy use, and chemical requirements.

- General capital cost for implementing AWT (capital expenditures [CAPEX]) are between US $4 to $11 million of 2026 dollars. Additional operating expenditures (OPEX) for implementing AWT are between US $0.5 to $2.5 million per year.

ES-5 Environmental and Public Health Protection

Groundwater protection is a key concern for Marco Island. Monitoring data shows that **groundwater quality standards for nitrogen have not been exceeded**, **which confirms that the facility is currently protecting local groundwater**. Upgrading to AWT would provide an added level of protection and regulatory certainty for the future.

ES-6 Conclusions

- The Marco Island RWPF is a well-operated facility that meets current permit requirements and performs exceptionally well regarding biochemical oxygen demand (BOD), solids (TSS), and ammonia removal.
- Implementing AWT will require improvements to the biological treatment process to reduce total nitrogen and phosphorus.
- Several viable upgrade alternatives are available to meet AWT standards.
- This study provides the technical basis for the City to select a preferred path forward based on cost, complexity, and long-term goals.
- AWT Alternative 1, S2EPBR + Four-Stage Bardenpho seems to be the most cost-effective alternative considering both CAPEX and OPEX. This alternative will achieve AWT standards reliably.

The findings in this report will help City leaders make informed decisions about future investments in water quality, environmental protection, and sustainable infrastructure for the Marco Island community.

1.0 Introduction

The City of Marco Island's Water and Sewer Department is authorized to operate the City of Marco Island Reclaimed Water Production Facility (RWPF) in accordance with the State of Florida, Department of Environmental Protection (FDEP) Domestic Wastewater Facility Permit No. FLA014167.

This technical memorandum provides an evaluation of treatment alternatives for the City of Marco Island RWPF to meet advanced water treatment (AWT) standards. AWT standards in the state of Florida include criteria for carbonaceous biochemical oxygen demand, 5 day ($cBOD_5$), total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP) as shown in Table 1-1. In addition, high-level disinfection (HLD) requirements must be met for compliance with AWT standards as shown in Table 1-2.

Table 1-1 Advanced Water Treatment Standards

Parameter	Unit	Criteria	Existing Permit
$CBOD_5$	mg/L	< 5	20
TSS	mg/L	< 5	20
TN	mg/L	< 3	Report Only
TP	mg/L	< 1	Report Only
HLD required	NA	Refer to Table 1-2	NA
Notes: All criteria are based on annual averages except for disinfection requirements.			

Table 1-2 High Level Disinfection Criteria

Parameter	Criteria
Minimum Acceptable Contact Time (T) at Peak Hourly Flow[1]	15 minutes
Theoretical Minimum Total Residual Chlorine (TRC) at Outlet	1 mg/L
Theoretical Minimum Concentration x Time (CT)	25 minutes x Chlorine dose (mg/L)
Maximum allowable TRC (at outlet) for Discharge to Injection Wells	FAC 62-600.540
Contact Time requirement > 10,000 Fecal Coliforms per 100 mL	At least 120 mg-minutes/L at peak hourly flow.
Fecal Coliform Values at Outlet	75% of samples < detection limits (over 30-days); any one sample shall not exceed 25 fecal coliform values per 100mL of sample.
TSS Continuous	Any one sample must not exceed 5.0 mg/L.
Redundancy	Maintain operation with largest chlorine contact tanks out of service.
Mixing of Chlorine	Rapid and uniform mixing shall be provided prior to chlorine contact tanks.

Parameter	Criteria

Notes:

1. FAC 62-600-440.
2. All values given above refer to a point prior to disinfection unless otherwise stated (i.e., at outlet).

1.1 Background

The City of Marco Island RWPF is classified as a Category II, Class B domestic wastewater treatment plant (WWTP). The RWPF is located at 807 Elkam Circle, Marco Island, Florida 34145. The RWPF is located adjacent to a channel, the eastern side of the City of Marco Island Water Treatment Plant, Lee County Electric Cooperative substation, and commercial properties. The RWPF is permitted as a 4.92 million gallons per day (mgd) three-month average daily flow (3MADF) municipal WWTP. The most recent upgrades to the RWPF occurred in 2017, which upgraded the headworks and the RWPF began receiving wastewater flows from the Isle of Capri and Marco Shores in February 2020.

1.2 Existing Process Description

Influent wastewater at the RWPF first passes through three parallel influent channels with rotary drum screens and is then stored in four equalization (EQ) storage tanks. The screenings and other debris are collected in a dumpster. The screened sewage is pumped out of the EQ storage tanks and feeds two parallel biological treatment tanks arranged in a configuration that resembles a modified Ludzack-Ettinger (MLE) without an internal mixed liquor recycle. The MLSS is conveyed to five parallel membrane bioreactor (MBR) trains for solids separation. The MBR process with its high return activated sludge (RAS) rate required to keep the MLSS at elevated than normal configurations negates the need for an internal mixed liquor recycle pump as the RAS rates are high enough to return sufficient nitrates back to the anoxic zone to promote denitrification. Permeate from the MBR process is then disinfected using sodium hypochlorite in two chlorine contact basins (CCBs). Treated effluent that meets the current FDEP operating permit requirements (on-spec water) is stored in reclaimed water storage tanks before being sent to the reuse distribution system. Figure 1-1 illustrates a process flow diagram (PFD) depicting the current wastewater treatment process at the RWPF.

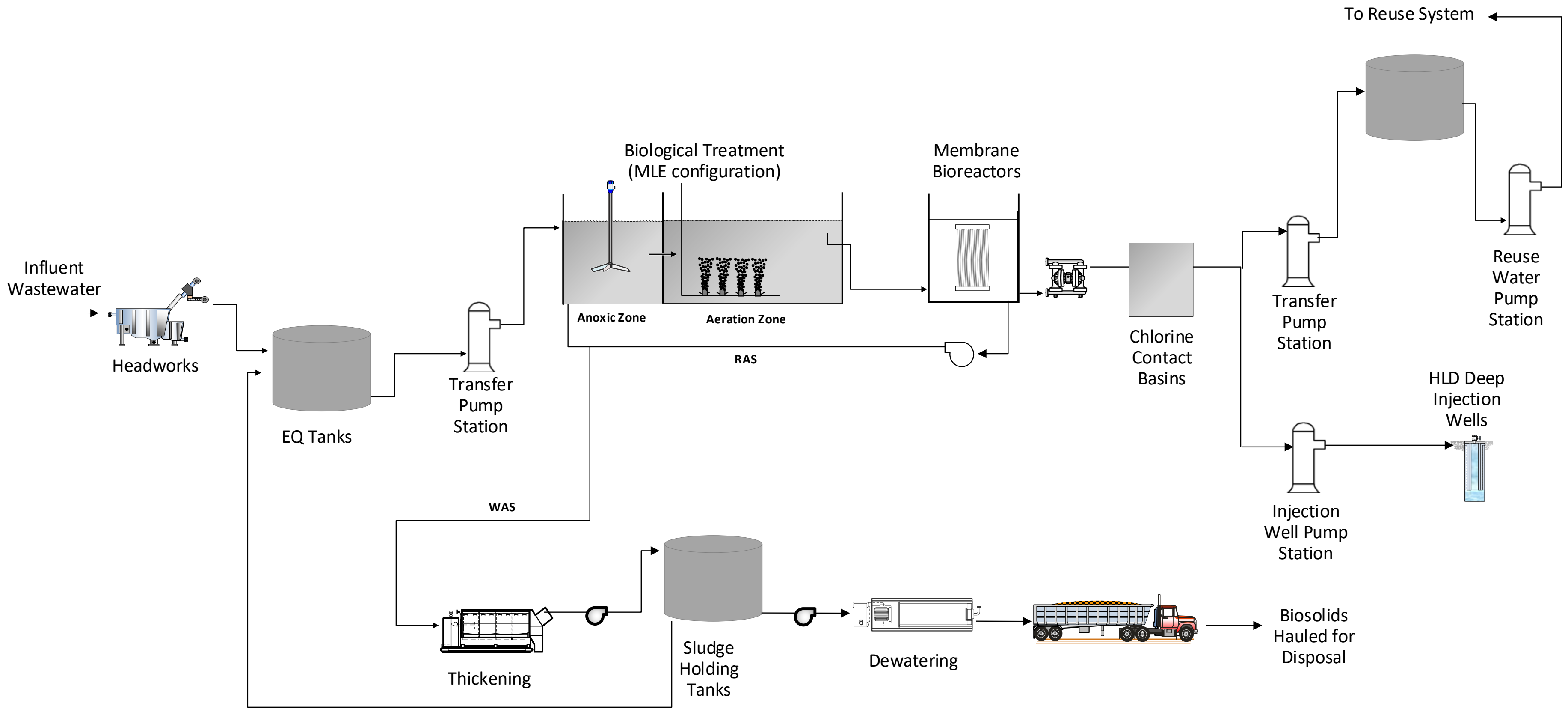


Figure 1-1 City of Marco Island RWPF – Process Flow Diagram

Reuse water is primarily used for public access, such as irrigation of residential and public areas, and is permitted for 2.56 mgd annual average daily flow (AADF). Any off-spec reuse water (water with quality that does not meet the FDEP operating permit requirements) or excess reclaimed water is pumped into two deep injection wells (U-001) on-site which are permitted for 13.14 mgd 3MADF. The sludge from the wastewater treatment process is thickened to about 20% using rotating drum thickeners. Thickened sludge is stored in four sludge holding tanks (SHTs) with a total volume of 737,900 gallons. Biosolids are then dewatered prior to being hauled off site for landfill disposal as Class B biosolids.

The wastewater treatment processes at the RWPF are included in Table 1-3.

Table 1-3 Marco Island RWPF Wastewater Treatment Process Description

Process	Quantity	Description
Headworks	3 channels	Influent channels with rotary drum screens
EQ Tanks	4 x 500,000-gallon tanks	Equalization of influent flows and loads
MLE Tanks	2 x 700,000-gallon MLE tanks	Biological treatment basins. Anoxic zone in middle of circle and aeration zone in the outer portion
Aeration Blowers	4 x 200-HP blowers	Centrifugal blowers used for aeration/biological treatment, 4802 ACFM each, 3550 RPM
MBR Trains	5 MBR trains	TSS removal (MLSS separation)
(CCBs	2 CCBs	Disinfection of secondary effluent. One CCB is 48,000 gallons and one is 69,000 gallons (HRT @ PHF ~ 34 min – Ok for HLD requirements, but does not meet Class I reliability)
Pumping Stations	--	Influent PS, RAS, WAS, DIWs, and reuse water pumps
Public Access Reuse Water Storage Tanks	2 x 500,000-gallon tanks	Storage of treated effluent
Reject Water Pond	0.44-acre pond	Reject water storage, 0.44-acre lined pond
Underground Injection Well System	2 deep injection wells (DIWs)	DIWs permitted for 13.14 mgd 3MADF
Rotating Drum Thickeners	2 thickeners	Biosolids thickening prior to disposal
SHTs	4 tanks (737,900 gallons total)	Four SHTs with a total volume of 737,900 gallons

1.3 Effluent Disposal Permit Limits

There are two approved discharge locations for the RWPF effluent including the underground injection well system and the reuse and land application system.

1.3.1 Underground Injection Control

The underground injection well system consists of two Class I underground injection wells (Department Facility Number WACS 73754) discharging to Class G-IV groundwater. The effluent limits for the underground deep injection wells (DIWs) are summarized in Table 1-4. The DIWs are permitted for a maximum discharge of 13.14 mgd (3MADF).

Table 1-4 Effluent Permit Limits – Underground Deep Injection Wells

Parameter	Unit	Max / Min	Limit	Statistical Basis	Frequency
Flow	mgd	Max Max	Report Report	Monthly Average Quarterly Average	Continuous
$CBOD_5$	mg/L	Max Max Max Max	20.0 30.0 45.0 60.0	Annual Average Monthly Average Weekly Average Single Sample	Weekly
TSS	mg/L	Max Max Max Max	20.0 30.0 45.0 60.0	Annual Average Monthly Average Weekly Average Single Sample	Weekly
pH	S.U.	Min Max	6.0 8.5	Single Sample Single Sample	Continuous

1.4 Reuse and Land Application

The RWPF effluent is permitted for 2.56 mgd for reuse and land application for a slow rate public access reuse system including irrigation of golf courses, landscape areas, highway medians and rights-of-way, businesses, commercial properties, and industrial parks.

An important condition of the permit is that the RWPF effluent for reuse may be augmented (combined) from the Marco Source Water Supply Storage and Recovery Facility (WACS No. 74184), where source water is filtered and disinfected at the Aquifer Storage Recovery (ASR) wells.

The effluent limits for the reuse and land application system are summarized in Table 1-5.

Table 1-5 Effluent Permit Limits – Reclaimed Water

Parameter	Unit	Max / Min	Limit	Statistical Basis	Frequency
Flow	mgd	Max Max	2.56 Report	3-Month Rolling Average Quarterly Average	Continuous
$CBOD_5$	mg/L	Max Max Max Max	20.0 30.0 45.0 60.0	Annual Average Monthly Average Weekly Average Single Sample	Weekly
TSS	mg/L	Max	5.0	Single Sample	Daily, 24 hours
Turbidity	NTU	Max	Report	Single Sample	Continuous
Chlorine, Total Residual (for disinfection)	mg/L	Min	1.0	Single Sample	Continuous

Parameter	Unit	Max / Min	Limit	Statistical Basis	Frequency
Fecal Coliform	#/100 mL	Max	25	Single Sample	Daily, 24 hours
Fecal Coliform, % less than detection	%	Min	75	Monthly Total	Daily, 24 hours
pH	S.U.	Min Max	6.0 8.5	Single Sample Single Sample	Continuous
Giardia	Cysts/100 L	Max	Report	Single Sample	Bi-annually, every 2 years
Cryptosporidium	oocysts/100 L	Max	Report	Single Sample	Bi-annually, every 2 years
Total Nitrogen	mg/L as N	Max Max	Report Report	Monthly Average Single Sample	Weekly
Total Phosphorus	mg/L as P	Max Max	Report Report	Monthly Average Single Sample	Weekly

1.5 Groundwater Protection

In addition to the requirements stated above, the RWPF monitors the groundwater adjacent to the areas that are served by the reuse system to protect the groundwater quality. Specifically, the maximum contaminant limit (MCL) associated with nutrients are 10 mg/L as N for nitrate and 1 mg/L as N for nitrite. The EPA maximum contaminant limits are shown in Table 1-6.

Table 1-6 US EPA Groundwater Protection Criteria

Parameter	Unit	EPA Groundwater Protection Criteria	Regulatory Basis	Protection Purpose
Nitrate (as N)	mg/L	10	SDWA – Primary MCL	Prevents methemoglobinemia (“Blue baby syndrome”)
Nitrite (as N)	mg/L	1	SDWA – Primary MCL	Protects infant health

2.0 Existing Reclaimed Water Production Facility Data Analysis

The following sections describe the RWPF influent and effluent data analysis that was conducted for the evaluation. This data analysis sets the basis for the conversion to AWT alternatives.

2.1 Flow Data

The City of Marco Island RWPF flow data for the period of October 2020 through October 2025 are shown on Figure 2-1. The average flow for the period analyzed was 2.31 mgd. The highest peak daily flow (PDF) observed during this period was 6.51 mgd (associated with storm events). Based on the last 5 years of data provided in the data request, the 2025 maximum month (MM) was 2.79 mgd and 3MADF was 2.62 mgd. The RWPF is permitted for a maximum of 4.92 3MADF. Generally, the highest flow periods are observed during the months of March and April, which coincide with population changes associated with seasonal residents and tourists.

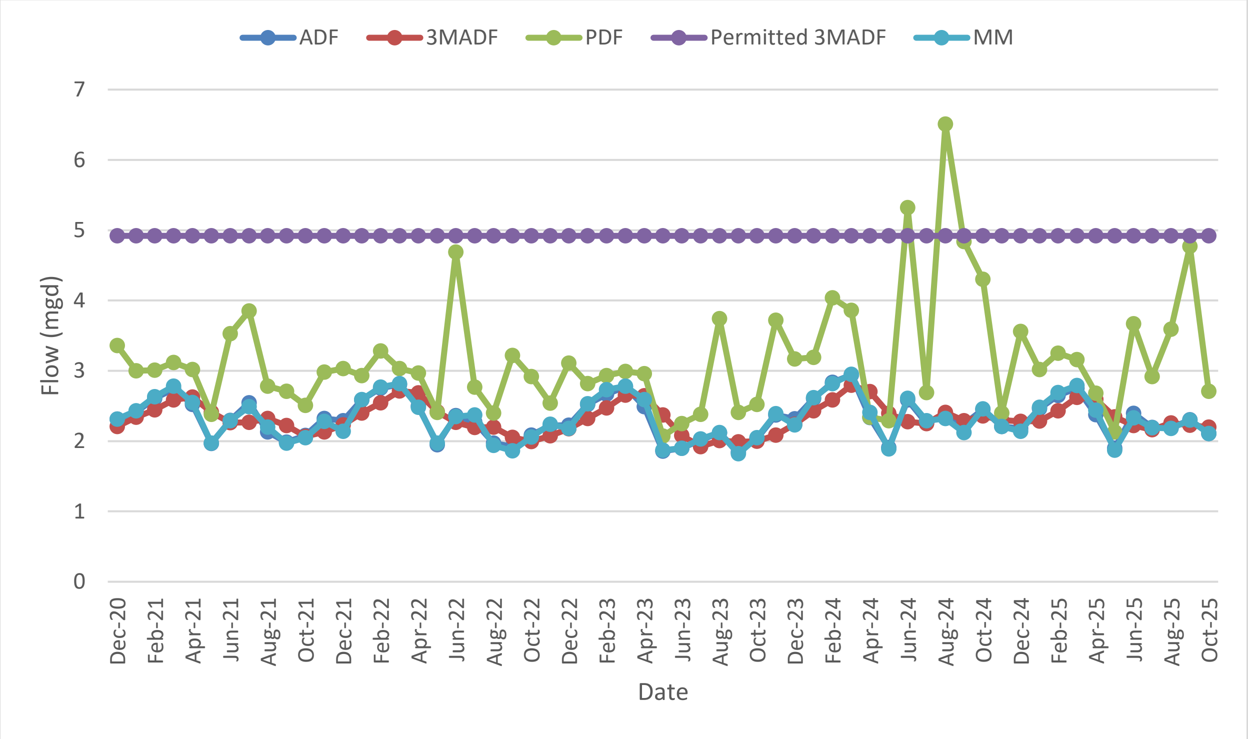


Figure 2-1 RWPF Influent Flow Data (2020 – 2025)

2.2 Influent Water Quality Data

Influent water quality data was reviewed from 2020 to 2025 with data provided by the City. Influent water quality data provided included $CBOD_5$, TSS, total Kjeldahl nitrogen (TKN), ammonia, and TP.

The influent $CBOD_5$ data from 2020 to 2025 is shown on Figure 2-2. The average influent $CBOD_5$ was 227 mg/L with a maximum of 716 mg/L. The average $CBOD_5$ value is within range of typical domestic wastewater (180 to 250 mg/L).

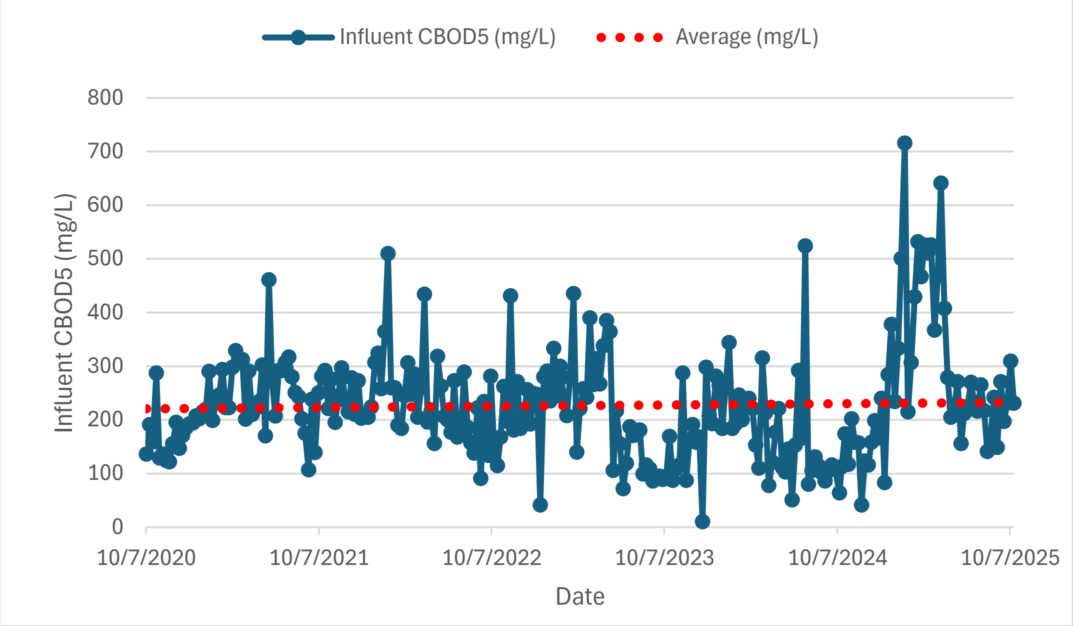


Figure 2-2 **Influent $CBOD_5$ Concentrations (2020 – 2025)**

The influent TSS data from 2020 to 2025 is shown on Figure 2-3. The average influent TSS concentration was 159 mg/L with a maximum of 526 mg/L. The average influent TSS value is within the typical range expected for domestic wastewater (180 to 250 mg/L).

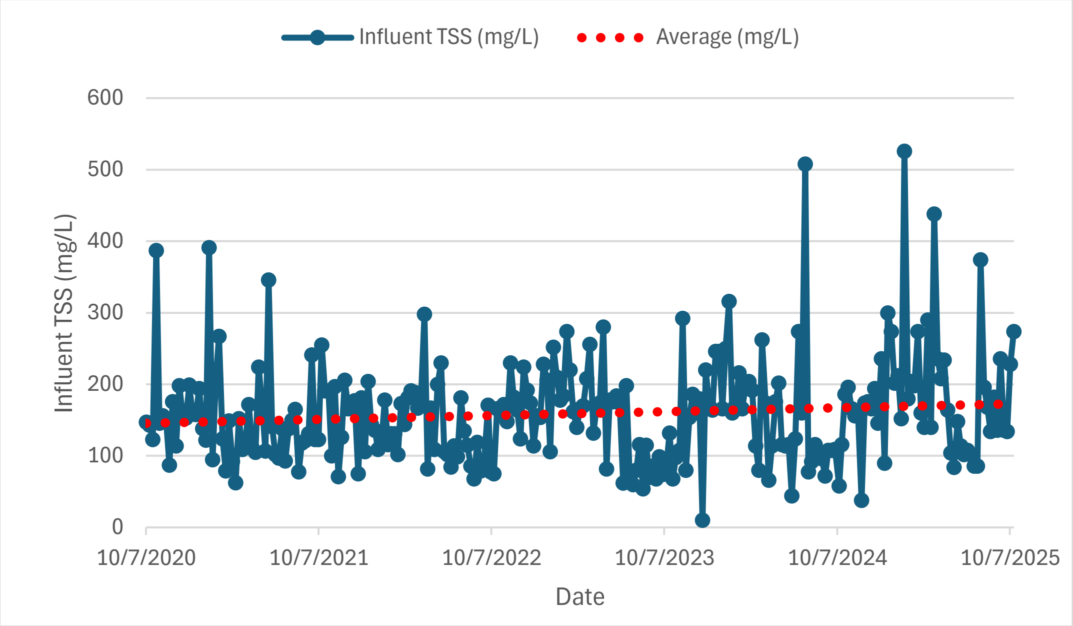


Figure 2-3 **Influent TSS Concentrations (2020 – 2025)**

Influent TKN data from 2020 to 2025 is shown on Figure 2-4. The average influent TKN concentration was 49.7 mg/L with a maximum of 93.5 mg/L. The average influent TKN observed was relatively high compared to the typical range for domestic wastewater (20 to 50 mg/L). The influent TKN also demonstrated seasonal fluctuations with higher levels observed in the summer and lower levels during winter. TKN comprises organic nitrogen (proteins, amino acids, urea, and food waste) and ammonia.

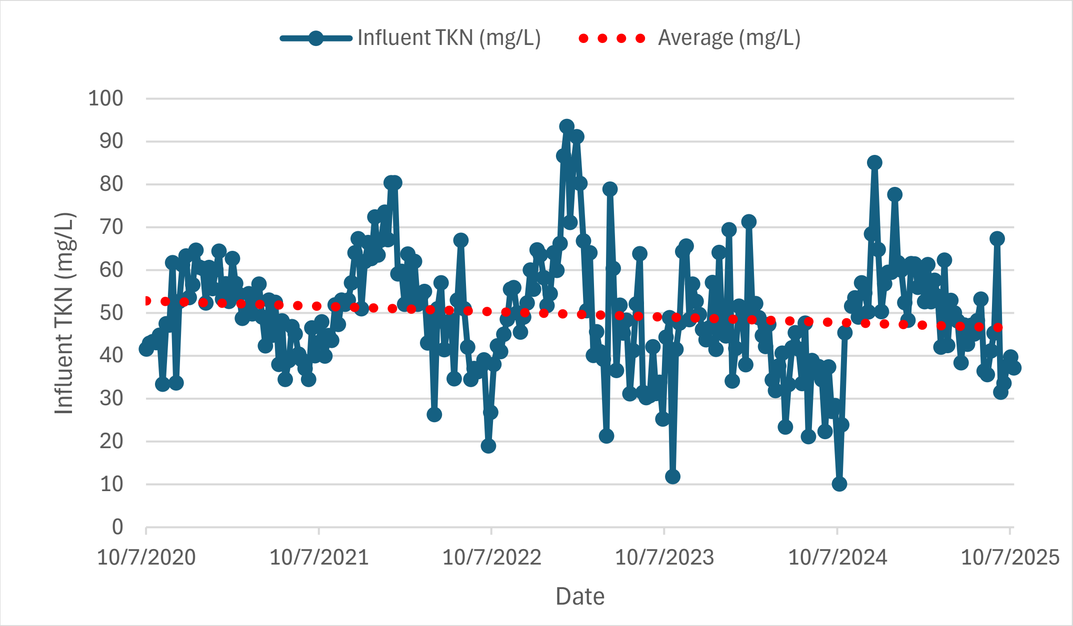


Figure 2-4 **Influent TKN Concentrations (2020 – 2025)**

Influent ammonia data from 2020 to 2025 is shown on Figure 2-5. The average influent ammonia concentration was 38 mg/L with a maximum of 75 mg/L. The average influent ammonia observed is within the typical range expected for domestic wastewater (25 to 40 mg/L). The influent ammonia also demonstrated seasonal variations with lower levels in the winter compared to summer.

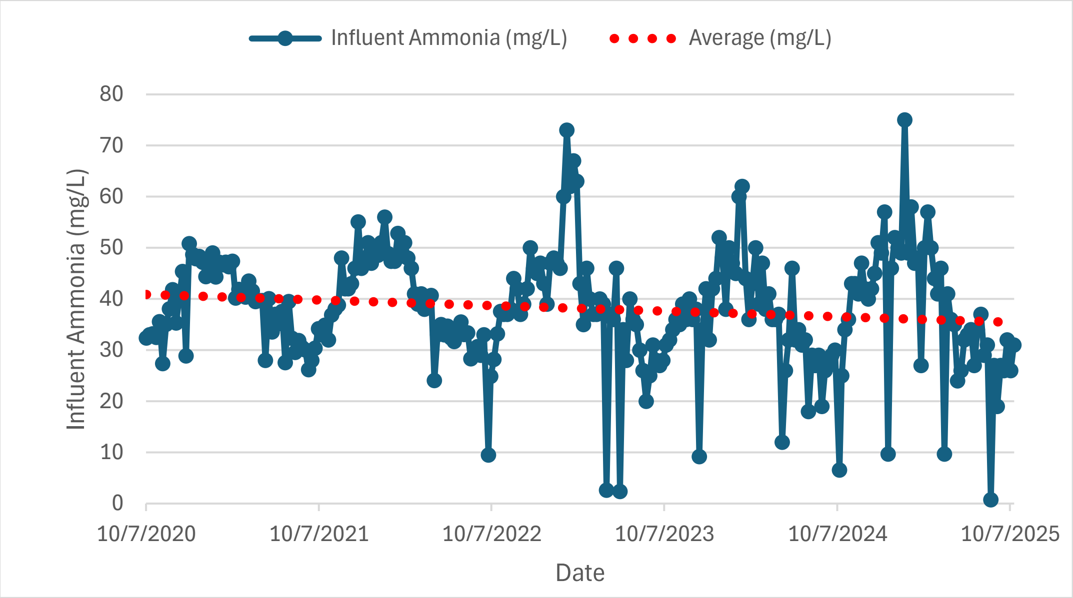


Figure 2-5 **Influent Ammonia Concentrations (2020 – 2025)**

Influent TP data from 2020 to 2025 is shown on Figure 2-6. The average influent TP concentration was 5.42 mg/L with a maximum of 10 mg/L. The average influent TP observed is within the typical range expected for domestic wastewater (4 to 8 mg/L). The influent TP concentration exhibited some season variability with lower levels typically observed during the winter.

Sources of phosphorus in wastewater influent include human waste, detergents and cleaning chemicals, food waste, and industrial discharges. Phosphorus in stormwater runoff or infiltration into the collection system from soil particles, fertilizers, and organic debris can also increase TP loading to WWTPs especially during periods of high rainfall.

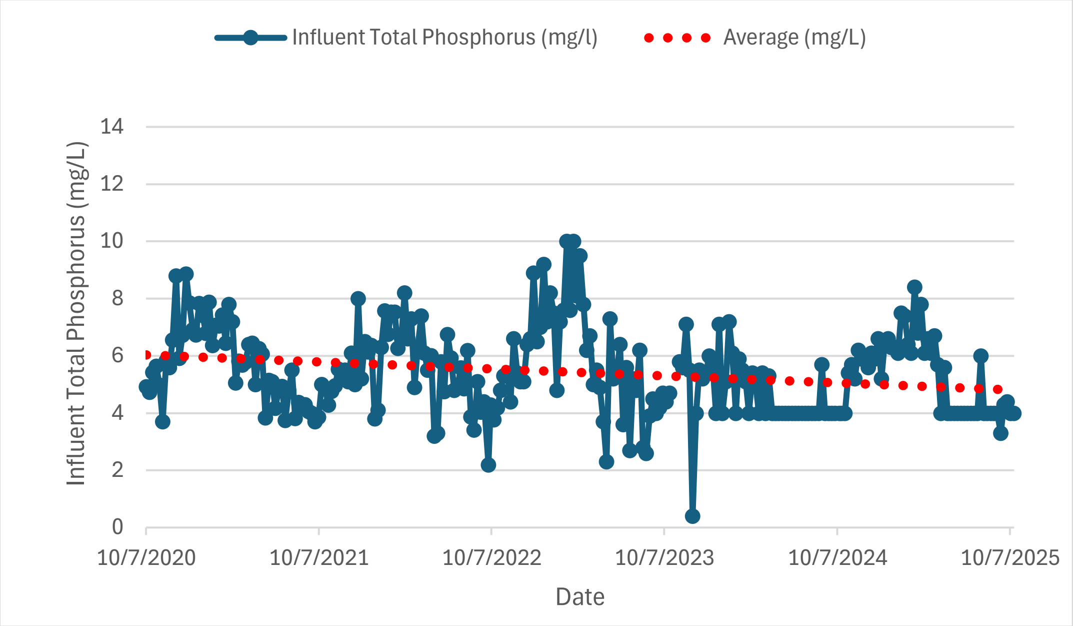


Figure 2-6 **Influent Total Phosphorus Concentrations (2020 – 2025)**

A summary of the RWPF influent wastewater data averages from 2020 to 2025 is included in Table 2-1.

Table 2-1 **RWPF Influent Wastewater Data (2020 – 2025)**

Analyte	Avg (mg/L)
Ammonia	38.2
cBOD5	226.5
TKN	49.7
TSS	159.1
TP	5.4

2.3 Effluent Water Quality

A review of effluent water quality was conducted with data from 2020 to 2025 for the evaluation. Effluent water quality data was provided for $CBOD_5$, TSS, TKN, ammonia, TP, nitrate, and nitrite.

Effluent $CBOD_5$ measurements from 2020 to 2025 are shown on Figure 2-7. From the figure, it is noticeable that the plant has been having challenges with the effluent cBOD5 in the last year. The plant consistently met the effluent reuse permit requirements with the exception of a few days during February through April of 2025. The current treatment process would require modifications and/or improvements to consistently meet AWT limits for $CBOD_5$ (<5 mg/L).

The effluent cBOD5 data in the last year shows a pronounced increase with several points hovering around 20 mg/L. This is inconsistent with all the other effluent data presented. The RWPF's removal of ammonia and TKN is excellent, the plant has adequate levels of nitrate in the effluent, and basically no nitrite indicating complete nitrification. In addition, the TSS effluent data is aligned with a treatment plant with an advanced solids separation process such as MBR membranes with TSS < 2 mg/L. Due to these, the higher cBOD numbers in the effluent cannot be possible (a plant with full nitrification has to remove all of its soluble BOD first). As such, Black & Veatch believes that either a sampling or a laboratory issue must be generating the higher cBOD5 levels reported in the historical data.

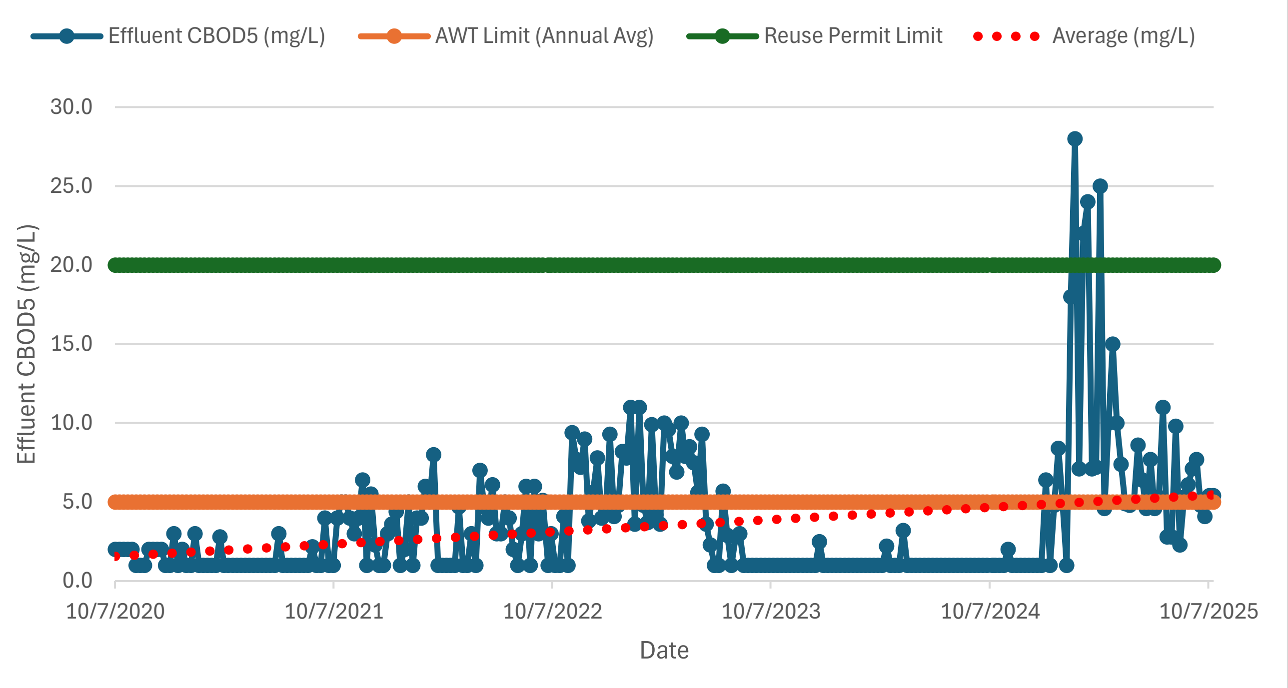


Figure 2-7 **Effluent $CBOD_5$ Concentrations (2020 – 2025)**

Effluent TSS concentrations from 2020 to 2025 are shown on Figure 2-8. The average effluent TSS concentration was 0.60 mg/L with a maximum of 4.20 mg/L. As demonstrated on the figure, the plant consistently removed TSS to below the reuse permit limit and the AWT limit.

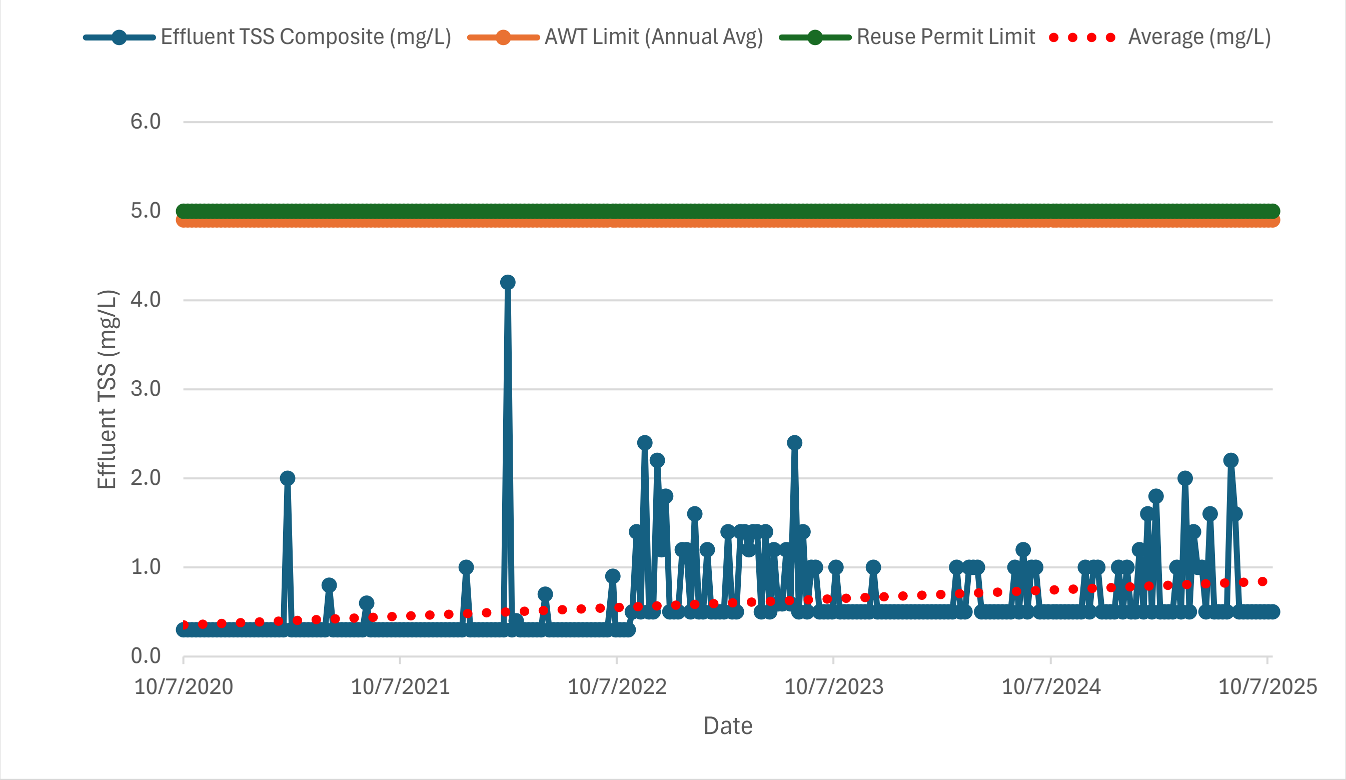


Figure 2-8 **Effluent TSS Concentrations (2020 – 2025)**

Effluent TN concentrations from 2020 to 2025 are shown on Figure 2-9. The average effluent TN concentration was 7.03 mg/L with a maximum of 26.23 mg/L. As demonstrated on the figure, the effluent TN is consistently higher than the AWT limit (<3 mg/L), which would require modifications and improvements to the biological treatment process to support nitrification and denitrification processes to reduce TN below 3 mg/L. The current effluent limit for TN is monitoring only. The groundwater MCL for TN (10 mg/L) is shown for comparison. The effluent from the RWPF is generally below the groundwater MCL approximately 90% of the time (89th percentile = 9.93 mg/L).

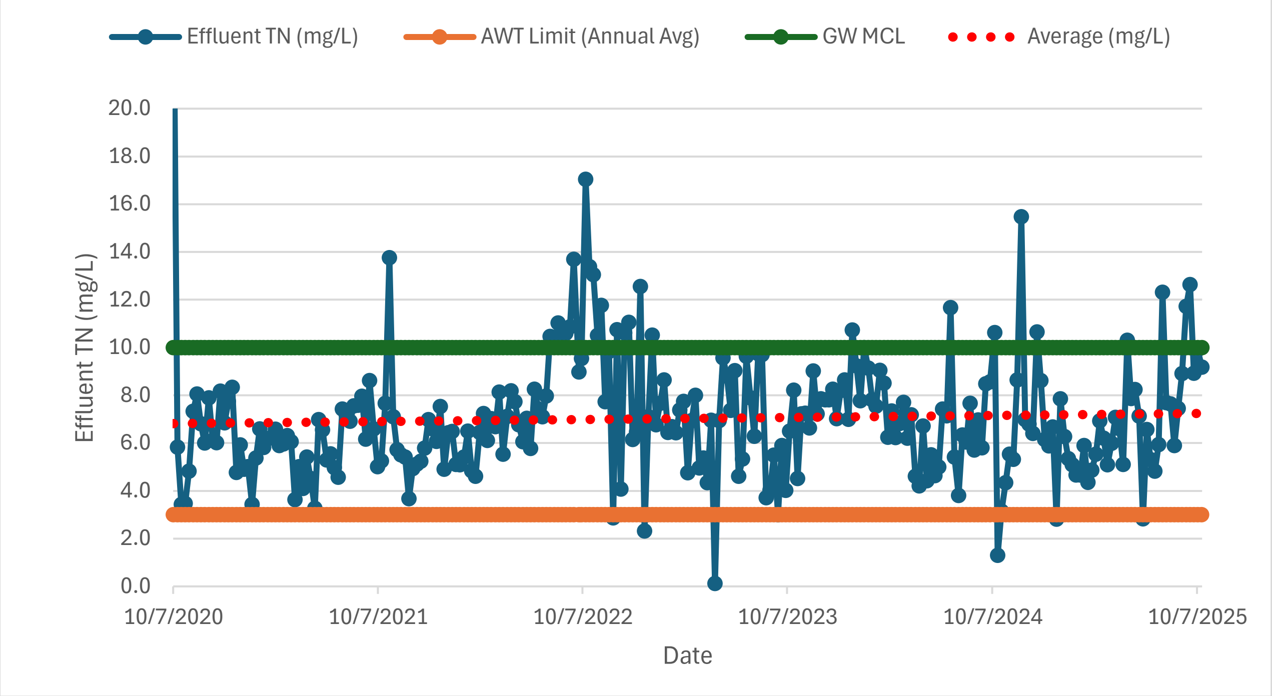


Figure 2-9 Effluent TN Concentrations (2020 – 2025)

Effluent ammonia concentrations from 2020 to 2025 are shown on Figure 2-10. The average effluent ammonia concentration observed was 0.04 mg/L with a maximum of 0.94 mg/L.

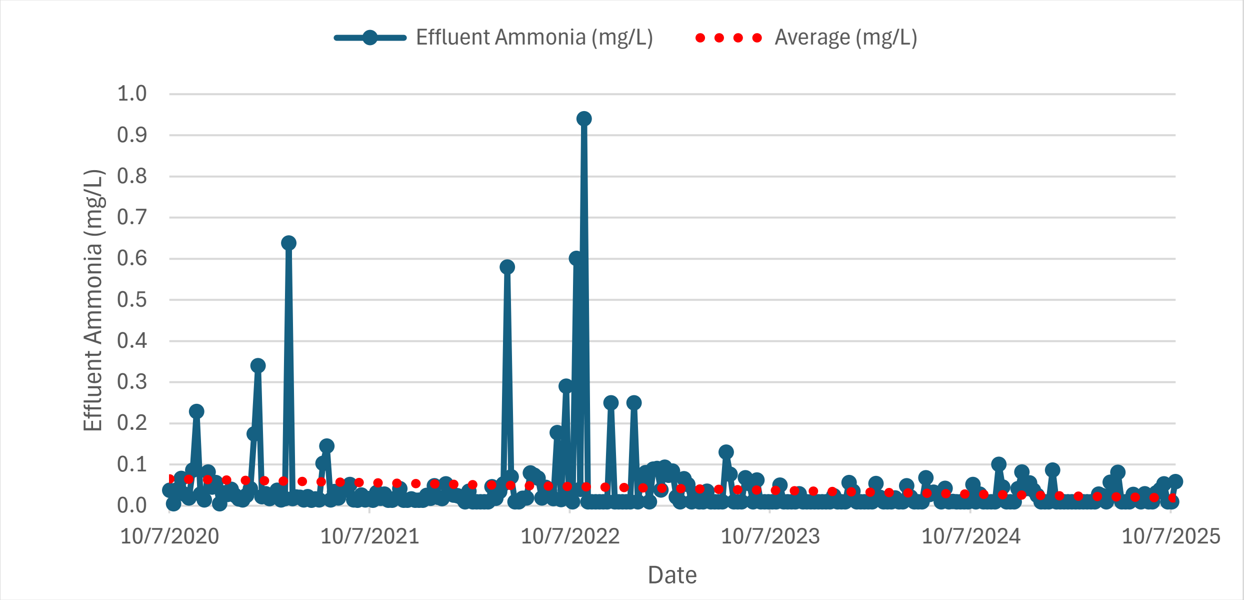


Figure 2-10 Effluent Ammonia Concentrations (2020 – 2025)

Effluent TP concentrations are shown on Figure 2-11. The average effluent TP concentration was 3.65 mg/L with a maximum of 11 mg/L. As demonstrated on the figure, effluent TP concentrations are consistently higher than the AWT limit (<1 mg/L). As such, treatment process modifications would be required to improve TP removal through enhanced biological phosphorus removal or Chem-P removal. The current effluent limit for TP is monitoring only.

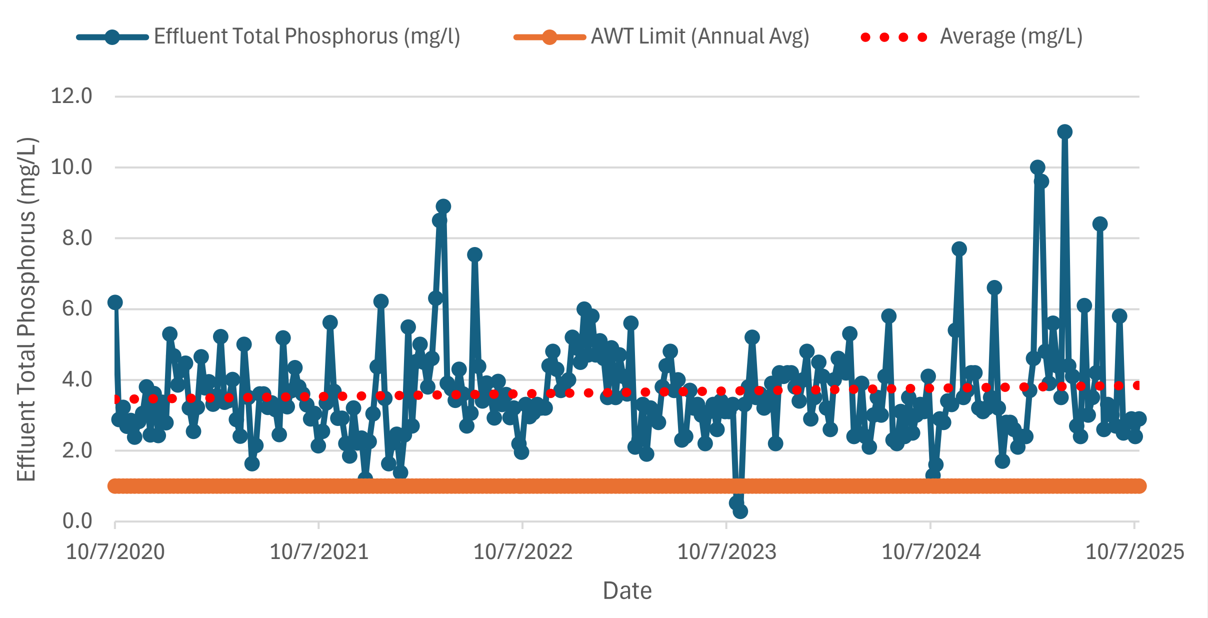


Figure 2-11 **Effluent Total Phosphorus Concentrations (2020 – 2025)**

Effluent nitrate concentrations are shown on Figure 2-12. The average nitrate concentration in the effluent was 6.27 mg/L with a maximum of 24.9 mg/L. The effluent nitrate data indicates that the RWPF is not currently removing the nitrate present in the wastewater. The groundwater MCL for nitrate (10 mg/L) is shown for comparison. The effluent from the RWPF is generally below the groundwater MCL approximately 99.5% of the time (99.5th percentile = 9.93 mg/L).

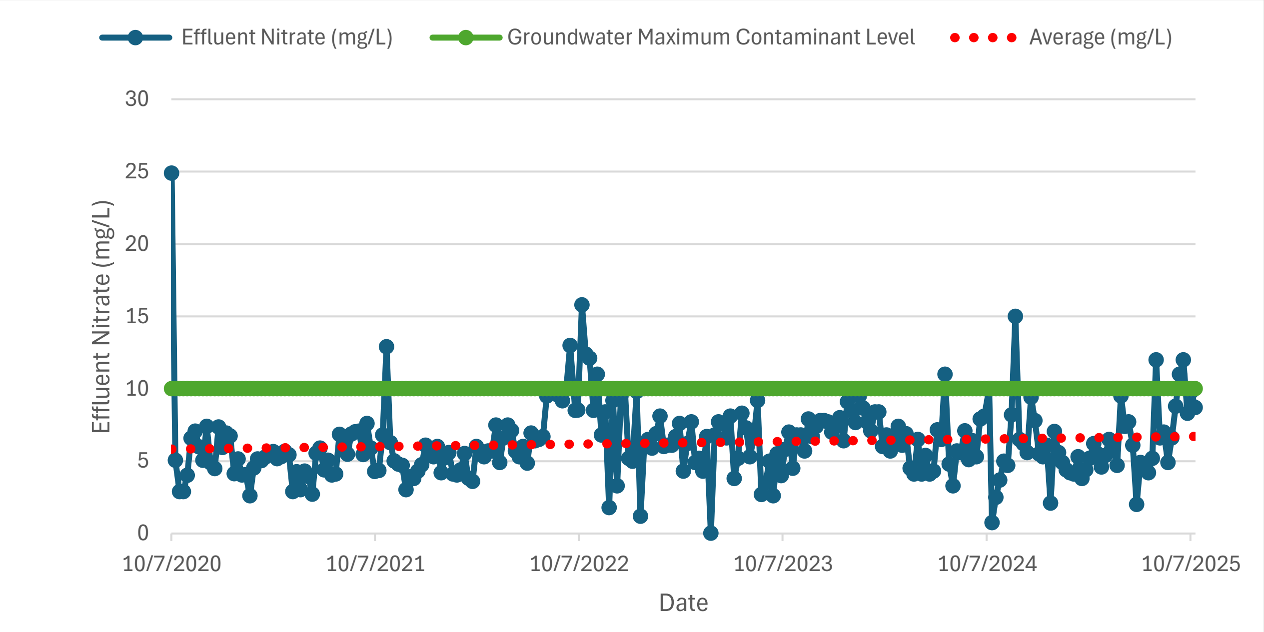


Figure 2-12 **Effluent Nitrate (2020 – 2025)**

Effluent nitrite concentrations are shown on Figure 2-13. The average nitrite concentration in the effluent was 0.01 mg/L with a maximum of 0.09 mg/L. The groundwater MCL for nitrite (1 mg/L) is shown for comparison.

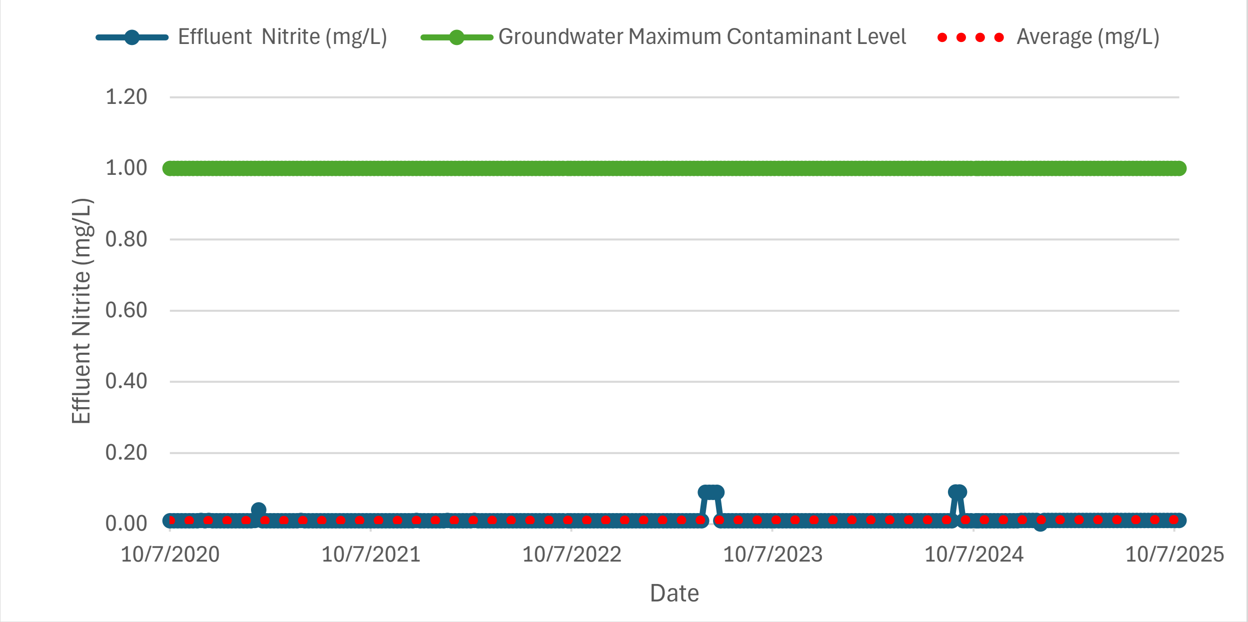


Figure 2-13 Effluent Nitrite (2020 – 2025)

A summary of the RWPF effluent water quality data from 2020 to 2025 is included in Table 2-2.

Table 2-2 RWPF Effluent Wastewater Data (2020 – 2025)

Analyte	Avg (mg/L)
Ammonia	0.04
cBOD5	3.51
Nitrate	6.27
Nitrite	0.01
TKN	0.75
TSS	0.60
TP	3.65

2.4 Groundwater Monitoring

The RWPF monitors the groundwater adjacent to the areas that are served by the reuse system to protect the groundwater quality. Specifically, the MCL associated with nutrients are 10 mg/L as N for nitrate and 1 mg/L as N for nitrite. As such, the RWPF is operated to remove nitrates and nitrites to levels below the MCL to ensure compliance with the primary drinking water standards for groundwater.

2.5 Flow Projections

Flow data was provided by the City from 2020 to 2025. A Capacity Analysis Report (CAR) was completed in 2024 for the RWPF, which included flow and population projections through 2035. Based on the data provided, flow projections for 2040 through 2046 were calculated assuming and average rate of growth in the area of 0.37% and are included in Table 2-3.

In the year 2046, the projected AADF and M3MADF were projected to be 2.624 mgd and 3.113 mgd, respectively.

Table 2-3 RWPF Population and Flow Projections

Year	Population	AADF (mgd)	M3MADF (mgd)	Source	Notes
2020	17,594	2.263	2.684	2024 CAR	0.25% increase in AADF
2022	17,683	2.303	2.733	2024 CAR	0.25% increase in AADF
2024	18,045	2.283	2.708	2024 CAR	1.79% increase in AADF
2026	18,464	2.355	2.793	2024 CAR	0.55% increase in AADF
2028	18,667	2.452	2.909	2024 CAR	0.55% increase in AADF
2030	18,859	2.477	2.939	2024 CAR	0.51% increase in AADF
2035	19,181	2.520	2.989	2024 CAR	0.37% increase in AADF
2040	19,856	2.567	3.045	Projected	0.37% increase in AADF
2045	20,415	2.615	3.101	Projected	0.37% increase in AADF
2046	20,526	2.624	3.113	Projected	0.37% increase in AADF

The projected AADF, M3MADF, and the permitted capacity of 4.92 mgd (M3MADF) are shown on Figure 2-14.

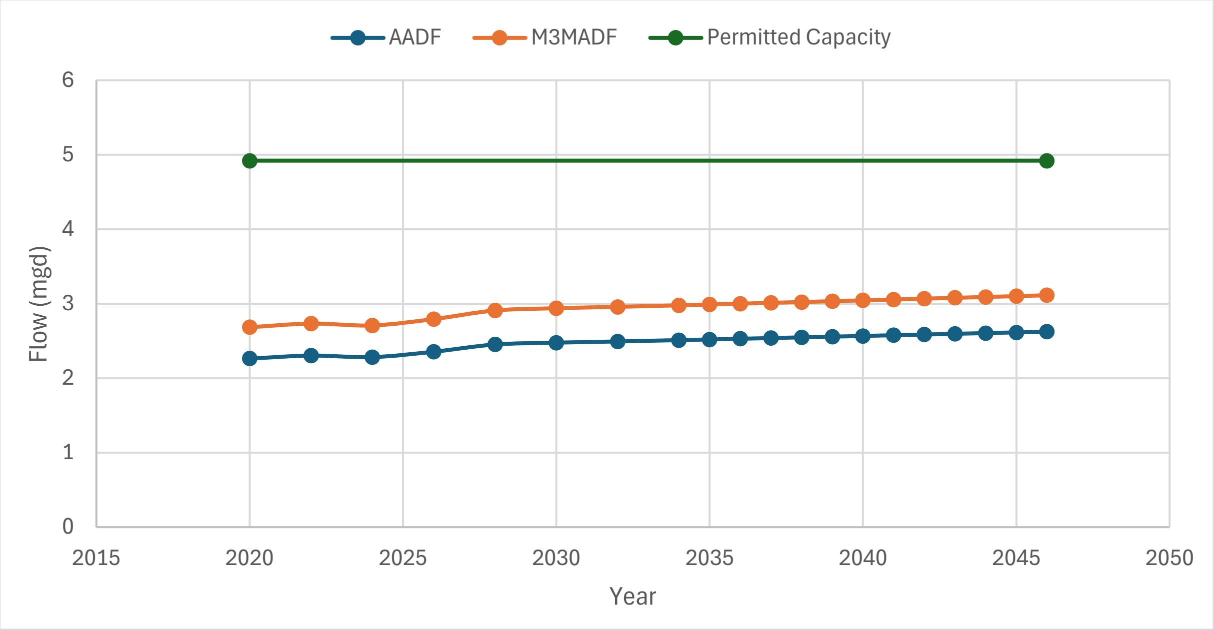


Figure 2-14 Marco Island RWPF Projected Wastewater Flows Through Year 2046

2.6 Analysis of Current Plant Performance

Historical operating data and water quality data were provided by the City. Based on this information, Black & Veatch calculated average wastewater ratios to confirm the validity of the data and the effectiveness of the biological treatment process.

Table 2-4 Influent Wastewater Ratios Comparison

Ratios	Measured	Low Range	High Range	Match
BOD_5/TKN	5.37	4.20	7.10	Good
BOD_5/TP	46.73	20.0	50.0	Good
BOD_5/TSS	1.69	0.82	1.43	Above
Notes: BOD5/cBOD5 was assumed to be 0.84, which is typical for domestic wastewater.				

From the data presented in Sections 2.1 through 2.4, the following conclusions can be made about the current RWPF operation:

1. The data suggests that all the influent wastewater characteristics are within reasonable levels for a domestic wastewater sewershed in this region of the country.
2. The influent wastewater records show relatively balanced wastewater characteristics.
3. The effluent cBOD5 data in the last year shows a pronounced increase with several points hovering around 20 mg/L. This is inconsistent with all the other effluent data presented. The RWPF's removal of ammonia and TKN is excellent, the plant has adequate levels of nitrate in the effluent, and basically no nitrite indicating complete nitrification. In addition, the TSS effluent data is aligned with a treatment plant with an advanced solids separation process such as MBR membranes with TSS <2 mg/L. Due to these factors, Black & Veatch believes that there must be either a sampling or a laboratory issue that is generating the higher cBOD5 levels reported in the historical data.
4. Overall, the RWPF performs very well, and all the effluent measure are typically well below the required limits.

Table 2-5 provides a summary of the existing plant performance with respect to nutrients, solids, and microbiological parameters.

Table 2-5 Summary of Existing Plant Performance

Analyte	Compliance
cBOD5	Over 99% of the time. Exceptional performance.
TSS	Over 99.9% of the time. Exceptional performance.
Turbidity	No permit requirement. MBR treatment provides effluent with exceptionally low turbidity compared to traditional secondary wastewater treatment systems. Turbidity is typically correlated to TSS, and given the exceptional TSS removal performance of the plant then the effluent turbidity must be very low.
Total Coliform	Meets the requirement of the permit. MBR is an effective technology to keep total coliform levels below detection.

Analyte	Compliance
Giardia and Cryptosporidium	There are no specific limits set in the permit, but MBRs provide robust treatment of *Giardia* and *Cryptosporidium*. The removal is so good that it is not possible to measure the effluent concentration of these types of parasitic organisms. Regulatory agencies have developed pathogen crediting frameworks, where they assign log reduction values (LRV) to different treatment systems. For these two organisms, MBRs receive 4 – log credits (which is four times that of a conventional filter).
TN	The plant is operated to meet the groundwater TN, nitrate, and nitrite MCL limits. **Ammonia:** Ammonia nitrogen is completely oxidized in the existing biological nutrient removal (BNR) process at the plant (ammonia removal is not required in the permit). **Nitrite:** The plant has low nitrite in the effluent (<0.1 mg/L as N) and demonstrates enhanced operation of the oxic reactor oxidizing ammonia. Therefore, the plant treats below the levels required to meet the nitrite MCL. **Nitrate:** The plant provides partial removal of nitrate, reducing it by 84% on average (typical effluent levels are between 6 and 7 mg/L nitrate as N). In fact, the RWTP performs to a very high level compared to other Florida plants that practice partial nutrient removal.
TP	The permit has no requirements for TP removal (monitoring only). However, the RWPF does perform partial phosphorus removal in the existing treatment process via assimilation of biomass in the bioreactor. Based on the data, the plant on average removes 63% of the incoming TP, thereby demonstrating that it treats to levels below the requirements of the permit.

In summary, the residents of Marco Island made a significant investment in the RWPF and added a very robust treatment system that more than meets the requirements of the existing permit conditions.

2.7 Plant Loading Conditions

Monthly influent $cBOD_5$ and TSS loads were calculated from October 2020 to October 2025. $cBOD_5$ and TSS loadings in lbs/day were compared to the design loadings. Results shown in Table 2-6 suggest that the RWPF operates within the design loading ranges. Therefore, the current loadings are within the ranges used to establish the design capacity.

Table 2-6 Plant Loading Conditions: BOD and TSS

Year	ADF (mgd)	M3MADF (mgd)	MM (mgd)	Avg $cBOD_5$ Loading (lbs/day)	MM $cBOD_5$ Loading (lbs/day)	Avg TSS Loading (lbs/day)	MM TSS Loading (lbs/day)	Design TSS/ $cBOD_5$ Loading (lbs/day)
2021	2.325	2.759	2.741	4,819	5,679	2,936	3,460	8,207
2022	2.304	2.733	2.803	4,555	5,461	2,814	3,417	8,207
2023	2.242	2.661	2.771	3,711	4,509	2,787	3,371	8,207
2024	2.411	2.708	2.943	3,520	4,234	3,251	3,924	8,207
2025	2.332	2.790	2.755	6,048	7,103	3,823	4,485	8,207

Notes:

1. Design TSS and $cBOD_5$ loading were based on 200 mg/L design concentrations and 4.92 mgd design flow.

Monthly influent TKN and TP loads were also calculated from October 2020 to October 2025. The TKN loading was compared to the design TN loading. Results shown in Table 2-7 suggest that the RWPF operates within the design loading ranges for TN loading.

Table 2-7 Plant Loading Conditions: TKN and TP

Year	ADF (mgd)	M3MADF (mgd)	MM (mgd)	Avg TKN Loading (lbs/day)	MM TKN Loading (lbs/day)	Avg TP Loading (lbs/day)	MM TP Loading (lbs/day)	Design TN Loading (lbs/day)
2021	2.325	2.759	2.741	989	1,157	110	129	1,641
2022	2.304	2.733	2.803	1,010	1,202	107	128	1,641
2023	2.242	2.661	2.771	1,004	1,205	142	171	1,641
2024	2.411	2.708	2.943	934	1,140	97	118	1,641
2025	2.332	2.790	2.755	988	1,154	103	119	1,641

Notes:

1. Design TN loading was based on 40 mg/L design concentration and 4.92 mgd design flow.
2. Design TP loading was not specified in the original design.

3.0 Existing Reclaimed Water Production Facility Treatment Configuration

The biological treatment process at the City of Marco Island RWPF currently consists of two parallel process trains with an anoxic zone followed by an aeration zone. The effluent from the aeration zone is conveyed to the MBR tanks for solids separation. Oxygen delivery for the biological reactors is done through aeration blowers and fine bubble diffusers. Aeration for the MBR tanks is achieved through a different set of blowers. The existing treatment process was designed to remove BOD and TSS to meet effluent permit limits. However, given the operating conditions at the plant, the plants achieve full nitrification, provide partial TN removal given the anoxic zones in each reactor (average TN removal ~84%) and provide partial TP removal through biological assimilation and solids separation (~33% TP removal). As such, it is reiterated that the plant currently performs partial nutrient removal. To meet AWT standards, an average TN removal of 94% and an average TP removal of 82% would be required.

Figure 3-1 Existing MLE Tanks

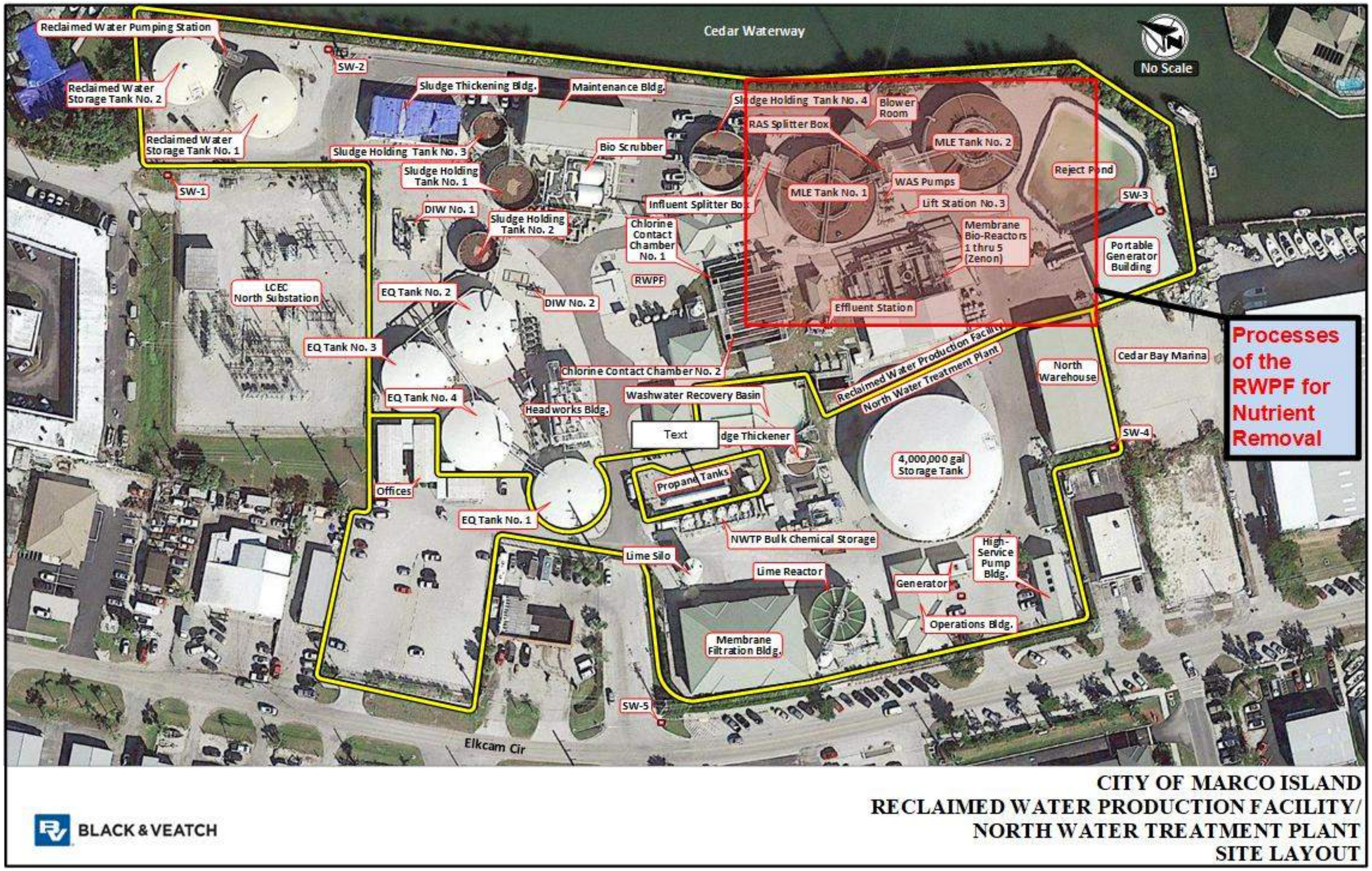


Figure 3-2 RWPF Site Plan

A description of the existing BNR treatment processes are included in Table 3-1.

Table 3-1 Baseline Condition (Existing Treatment Process)

Parameter	Units	Value	Notes
Anoxic Zone			
Number of Basins	Basins	2	Two parallel basins
Total Volume	MG	0.42	Volume at 17 ft total depth
Water Depth	ft	14.82	
Mixing	Mixer	1 mixer, 7.5 hp, 20 rpm	Vertical mixer, 127" diameter
SRT	Days	8 days	At current AADF
HRT	Hours	0.8 hour	At current AADF
Aeration Zone			
Number of Basins	Basins	2	Two parallel basins
Total Volume	MG	1.24	
Water Depth	ft	14.82	
Diffusers	Type	1,500 EPDM fine bubble diffusers	Fine bubble diffusers, 2.0 scfm/diffuser, depth = 14 ft
Blowers	scfm (standard cubic feet per minute)	3,000 scfm each/9,000 scfm firm capacity	PD blowers
MBR			
Number of MBR Trains and Basins	Trains/ basins	5 (4 duty, 1 standby)	Five parallel MBR trains
Volume	MG	0.12	0.03 MG each
Water Depth	ft	9.33	
Total Surface Area	ft2	500,000	100,000 ft^2 per train
Ratio of RAS: Influent Flow		4:1	
RAS Pumps	Pumps	5 (4.9 mgd each)	Five RAS pumps (4 duty, 1 standby). 15.6 mgd firm capacity.
WAS Pumps	Pumps	3	Three WAS pumps located S of MLE No. 1.
MLSS	mg/L	6,000 – 11,000	RAS TSS from MBR
Current Operating Parameters			
Flow	mgd	2.31 Avg Daily Flow 2.79 Max Month Flow > 7 Peak Hourly Flow	

Parameter	Units	Value	Notes
MLSS (MLE)	mg/L	4,000 – 7,000	
SRT - Nominal – Oxic (aSRT)	Days	25 days	Required aSRT for full nitrification at design temperatures (20° C) ~ 6 days
Total SRT - Nominal	days	33 @ current flows, avg. load 13 @ rated plant flow MM	This shows that the plant has excess process capacity.
cBOD5	mg/L	Inf – 227 avg Eff - < 5 Avg	Effluent excludes the listed spikes which are likely due to sampling error.
TSS	mg/L	Inf – 159 avg Eff - < 1 Avg	
TKN/TN	mg/L	Inf – 50 avg (TKN) Eff – 7.03 avg (TN)	
TP	mg/L	Inf – 5.77 avg Eff – 3.65 avg	

This plant was designed to treat up to a 3MADF of 4.92 mgd. As illustrated in Section 2.6, the plant flows and loads currently are significantly lower than the treatment capacity. Furthermore, the plant sewershed is over 90 percent built out, and the projected flows and loads at the 100 percent buildout are roughly 62% of the design conditions. Therefore, there is significant excess plant capacity for the current permit conditions, that can be used to convert the plant to an AWT facility using existing infrastructure with some modifications which significantly minimizes potential capital expenditures, provided that the City accepts the fact that the plant would not be able to process flows in excess of the sewershed buildout capacity. For clarification, the plant's peak hydraulic capacity will not change due to the AWT improvements, and the facility will continue to process the same peak flows it currently manages.

A process flow diagram (PFD) for the existing conditions at the RWPF is shown on Figure 3-3.

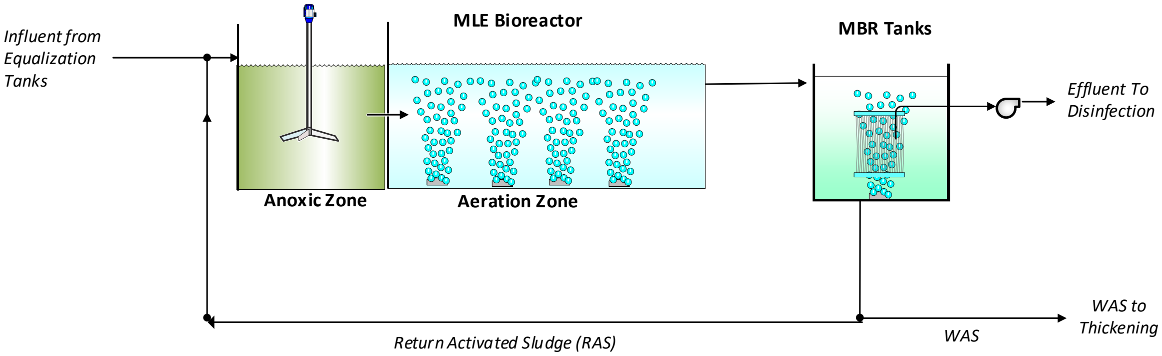


Figure 3-3 RWPF Existing Condition – Process Flow Diagram

4.0 Wastewater Nutrient Removal Fundamentals

WWTPs can remove a wide range of contaminants. All WWTPs target the removal of organic components measured typically by requiring lower BOD and TSS in the plant effluent. In addition to this, WWTPs can also remove common nutrients like nitrogen and phosphorus present in wastewater, if the processes are configured in a way that promotes nutrient removal. This section will provide a generic background of nutrient removal in WWTPs.

4.1 Biological Nutrient Removal

BNR processes remove nutrients such as TN and TP from wastewater using microorganisms under different environmental conditions in the treatment process. BNR has proven to be the most cost-effective and operationally friendly approach to remove nutrients from wastewater for over 50 years. Several BNR process configurations are available. Some BNR systems are designed to remove only TN or TP, while others remove both. The configuration most appropriate for any system depends on the target effluent quality, operator experience, influent quality, and existing treatment processes, if retrofitting an existing facility. BNR configurations vary based on the sequencing of environmental conditions (i.e., aerobic, anaerobic, and anoxic) and timing.

A generic BNR configuration for the removal and TN and TP is presented on Figure 4-1.

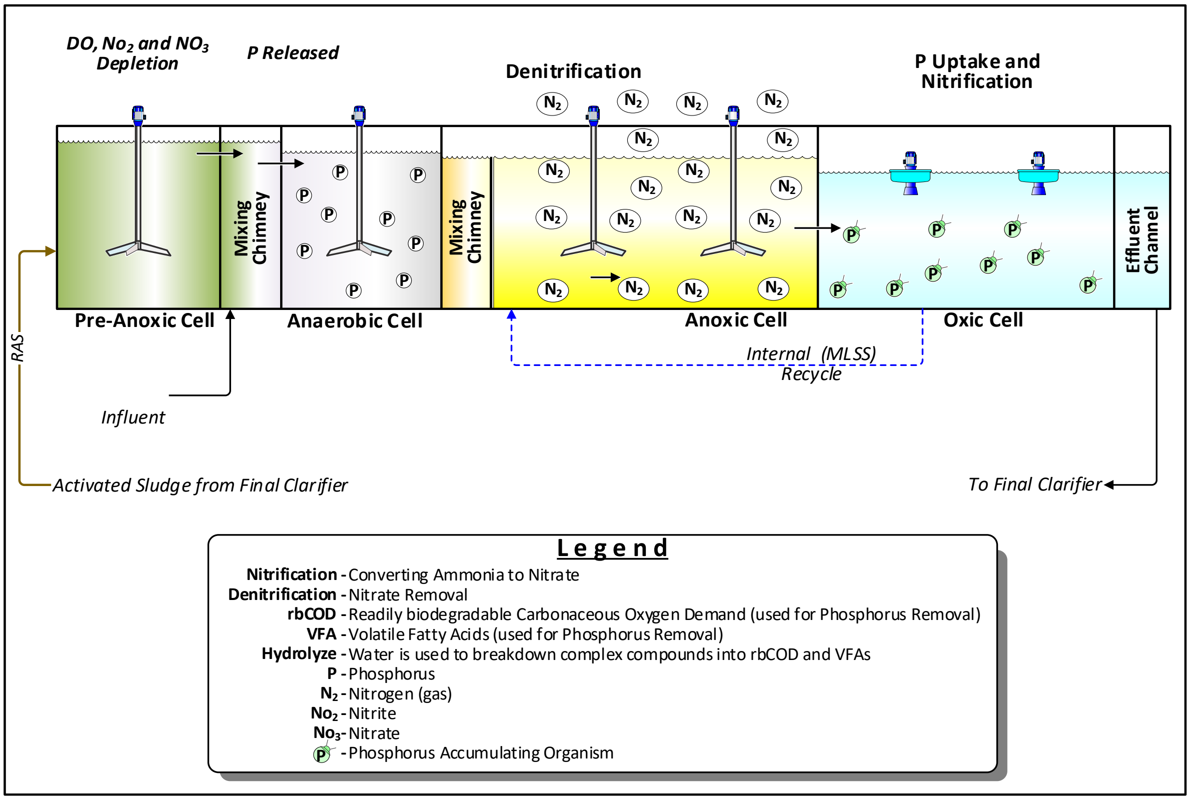


Figure 4-1 General Biological Nutrient Removal Schematic

4.1.1 Nitrogen Removal

TN in wastewater comprises ammonia, nitrate, particulate organic nitrogen, and soluble organic nitrogen. The biological processes that primarily remove nitrogen from wastewater are nitrification and denitrification.

Figure 4-2 illustrates the conventional pathway for achieving TN removal. During nitrification, ammonia is oxidized to nitrite by autotrophic bacteria. Nitrite is then oxidized to nitrate by another autotrophic bacteria group, the most common being *Nitrobacter*. Denitrification involves the biological reduction of nitrate to nitric oxide, nitrous oxide, and nitrogen gas. Nitrification occurs in the presence of oxygen under aerobic conditions, and denitrification occurs in the absence of oxygen under anoxic conditions.

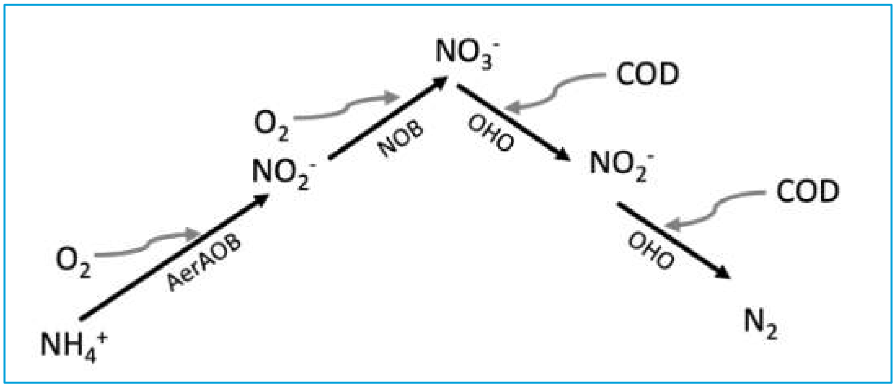


Figure 4-2 Conventional BNR Cycle

As a note, the conventional nitrogen removal cycle is used at the RWPF to reduce nitrate and nitrate levels to the levels below the MCL for groundwater protection (partial nutrient removal).

4.1.1.1 Partial Denitrification-Annamox

The Partial Denitrification–Anammox (PdNA) process is a shortcut BNR configuration that combines controlled partial denitrification with anaerobic ammonium oxidation (anammox) to convert ammonia directly to nitrogen gas with reduced oxygen and external carbon requirements. PdNA is particularly well suited for mainstream wastewater treatment applications where space, energy, and chemical consumption are limiting factors. In the PdNA pathway, a portion of influent ammonia is fully nitrified to nitrate in upstream aerobic zones. This nitrate is subsequently reduced to nitrite in a partial denitrification step using a limited amount of readily biodegradable carbon, intentionally suppressing complete denitrification to nitrogen gas. The generated nitrite, together with residual ammonia, is then removed via the anammox reaction under anoxic or anaerobic conditions, producing nitrogen gas and water. Figure 4-3 shows the nitrogen removal pathway in the PdNA process.

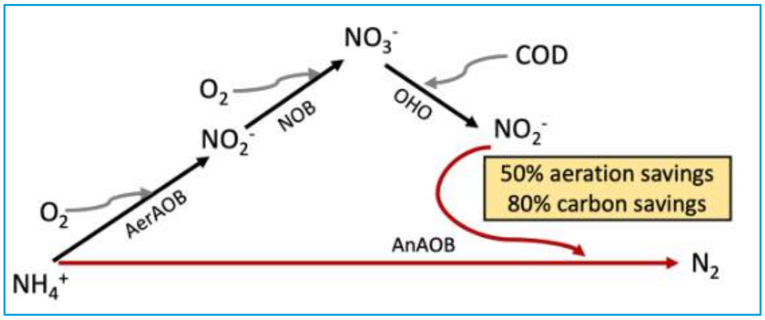


Figure 4-3 PdNA Nitrogen Removal Cycle

Effective PdNA operation relies on selective control of microbial populations, including suppression of nitrite-oxidizing bacteria and retention of anammox organisms. Precise aeration distribution and dissolved oxygen control are required to maintain conditions favorable for partial denitrification and to prevent over-oxidation of nitrite to nitrate.

Compared to conventional nitrification–denitrification, PdNA can significantly reduce oxygen demand, external carbon addition, and alkalinity consumption, while maintaining robust total nitrogen removal performance. Full-scale applications have demonstrated the process to be stable and effective when integrated into existing treatment configurations, particularly as a retrofit to conventional BNR systems or tertiary denitrification filters.

Figure 4-4 illustrates two PdNA configurations (suspended biomass and attached biomass) that are most suited for implementation of PdNA at the RWPF.

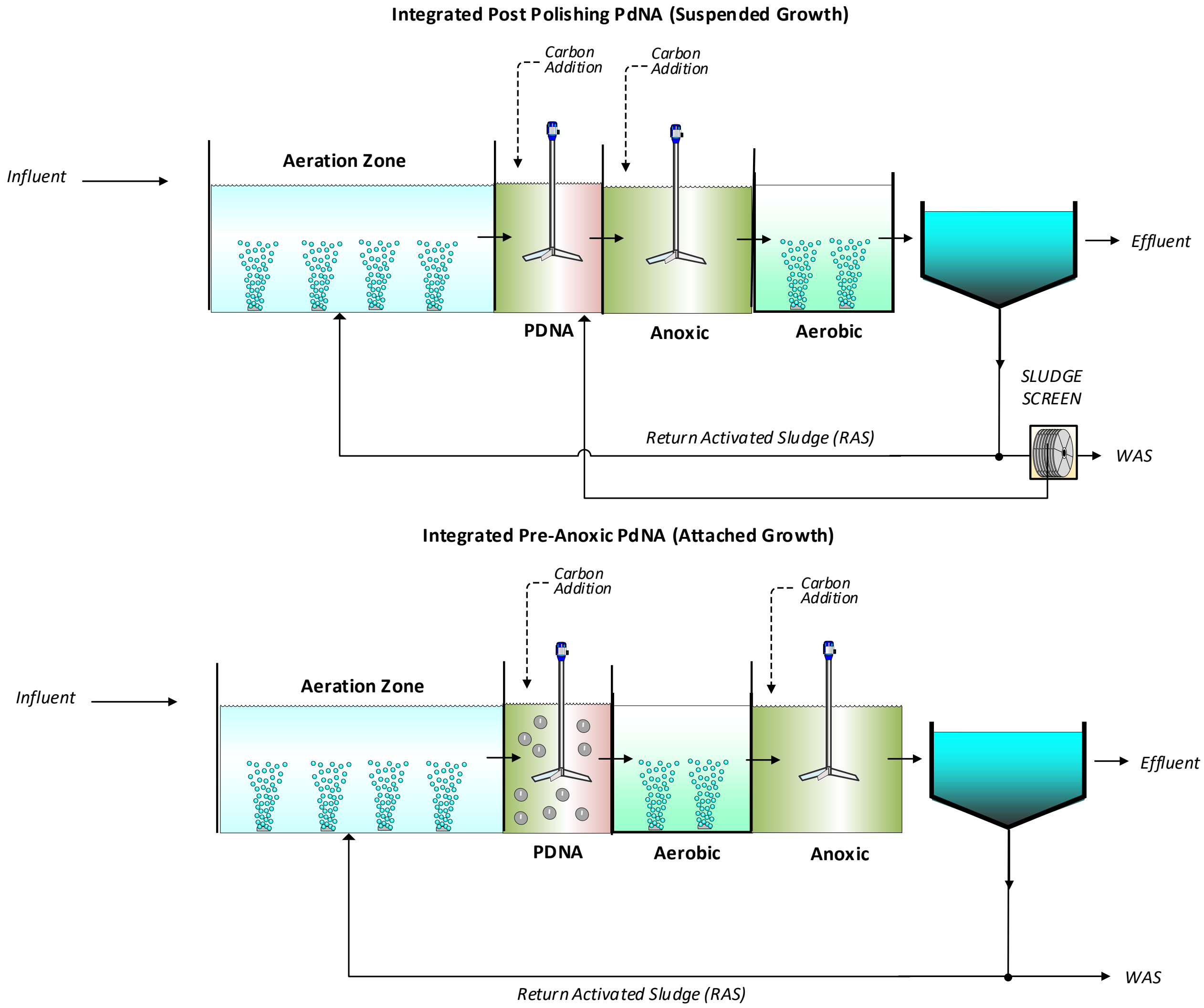


Figure 4-4 **PdNA Configurations**

PdNA processes are great candidates for plants where there is excess capacity or the expansion of new basins is limited, which is the case at the RWPF. However, the control of the process is more complex than traditional BNR processes, and the TN effluent concentration is typically slightly above 3 mg/L, which is the AWT limit. However, this option could potentially provide significant savings for implementing TN removal by reducing supplemental carbon addition and aeration requirements.

4.1.2 Phosphorus Removal

TP comprises soluble and particulate phosphorus. TP can be removed biologically or chemically as explained in the following sections.

4.1.2.1 Enhanced Biological Phosphorus Removal

Enhanced biological phosphorus removal (EBPR) process relies on the activity of naturally occurring microorganisms known as phosphorus accumulating organisms (PAOs). The treatment system is designed to expose wastewater to a sequence of environmental conditions that promotes the growth of these organisms and increases their ability to uptake phosphorus.

In traditional EBPR configurations, influent wastewater is first introduced into an anaerobic zone, where dissolved oxygen and nitrate are absent. Under these conditions, PAOs utilize available organic matter and release a portion of their stored phosphorus. The wastewater then flows to an aerobic zone, where oxygen is present. In this environment, PAOs take up phosphorus from the wastewater in quantities greater than required for normal cell growth and store it internally.

Following biological treatment, the biomass containing the stored phosphorus is separated from the treated water through clarification. Removal of this biomass effectively removes phosphorus from wastewater. The treated effluent, with reduced phosphorus concentrations, is discharged in compliance with applicable permit limits.

EBPR provides a reliable and sustainable method for phosphorus removal by utilizing biological processes rather than chemical addition, contributing to improved effluent water quality and environmental protection.

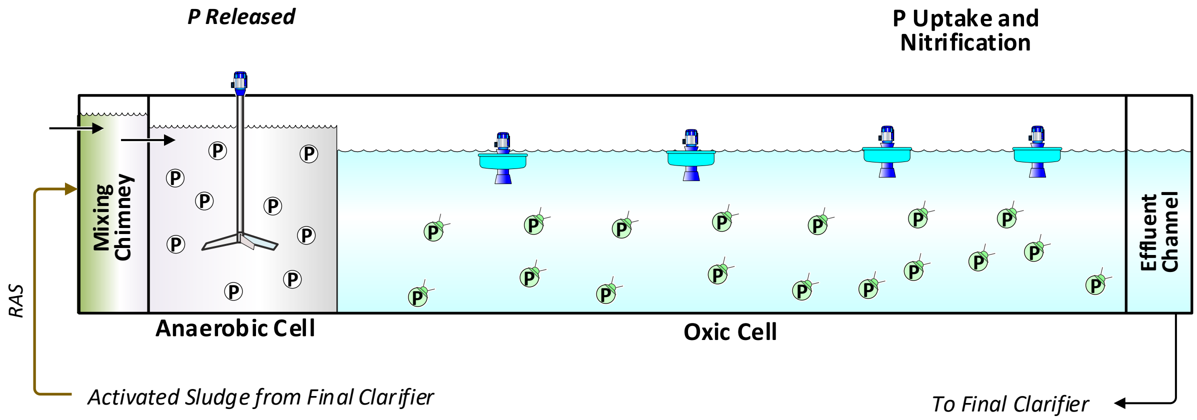
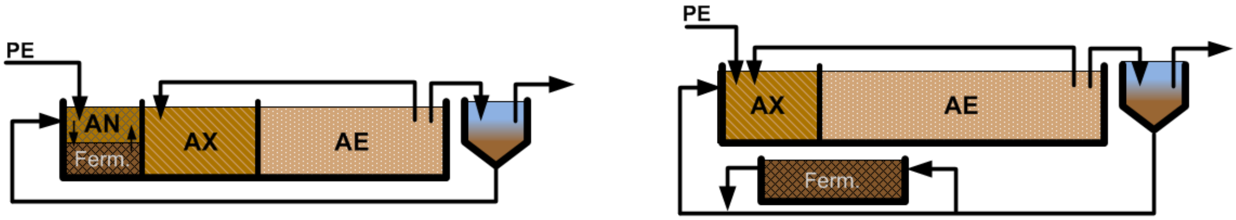


Figure 4-5 Typical EBPR Configuration (Phoredox)

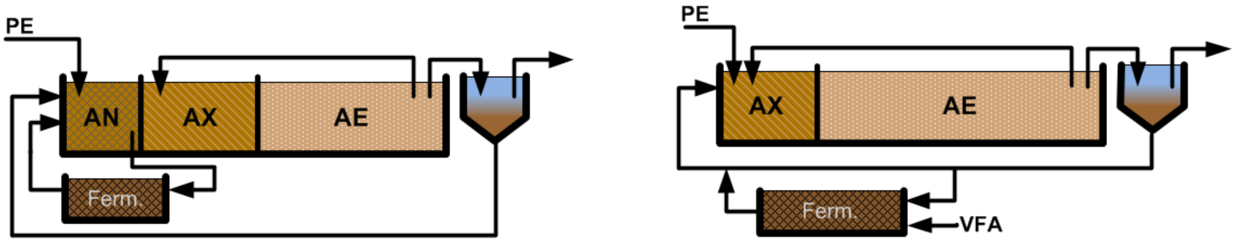
Sidestream EBPR (S2EBPR) is an advanced variation of EBPR designed to improve phosphorus removal stability and efficiency, which uses a fermenter to condition the PAOs under controlled anaerobic conditions. The goal of S2EBPR is to generate VFAs through fermentation which promotes PAO activity without relying on VFAs in the influent wastewater. The fermented RAS is returned to the head end of the BNR process. The S2EBPR process is often used to meet low level nutrient limits and adds operational flexibility to handle variable influent loads.

Figure 4-6 illustrates different configurations commonly used for S2EBPR.



Unmixed In-Line Mixed Liquor Fermentation (UMIF)

Side-Stream RAS Fermentation (SSR)



Side-Stream Mixed Liquor Fermentation (SSM)

Side-Stream RAS Fermentation w/ Additional Carbon (SSRC)

Figure 4-6 S2EBPR Configurations

4.1.2.2 Chemical Phosphorus Removal

Chem-P removal is also common at WWTPs to remove phosphorus. In Chem-P removal, metal salts such as alum or ferric chloride are added to create a reaction that makes the soluble orthophosphate bind with the metal ion, which forms particulate solids that can be removed through solids separation (i.e., filtration, sedimentation). Figure 4-7 shows a conceptual diagram of Chem-P removal illustrating the reaction of dissolved orthophosphate (blue) with metal salts (orange) to form an insoluble metal-phosphate precipitate (green).

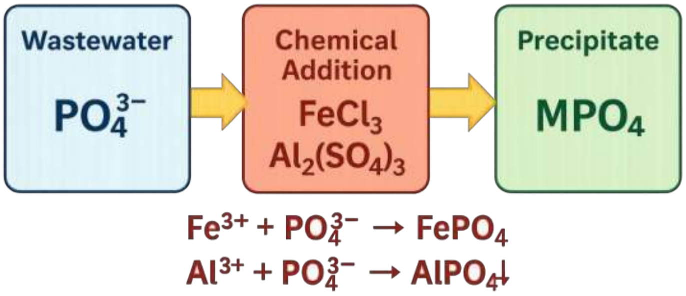


Figure 4-7 Chem-P Removal

4.1.3 Alternative Nutrient Removal Technologies

At the request of the City of Marco Island, an emerging technology for the removal of TN and TP was evaluated.

Nuquatics (formerly known as Phosphorus Free Water Solutions) is a startup company established in 2016. Initially, Nuquatics focused its efforts in developing technologies to deal with removing phosphorus from reservoirs and then tested some of those concepts at a WWTP. Currently, based on public information from its website, Nuquatics is focused on developing technologies for per- and polyfluoroalkyl substances removal. According to discussions with a former Nuquatics employee, Nuquatics left the state of Florida and is now located in Michigan, and while it is not promoting its TN and TP removal technologies actively at this time, there may be interest in licensing its technology to utilities to execute nutrient removal.

Black & Veatch made many attempts to contact Nuquatics, and after a couple of months failing to reach anyone at listed phones or emails, the City provided Black & Veatch with a copy of a proposal that was submitted to respond for RFI No. 2023-001. The proposal dated December 6, 2022, was from Phosphorus Free Water Solutions and contained generic information about the potential use of its technology for removing TN and TP from the RWPF effluent.

Black & Veatch requested to meet with the Nuquatics technical staff to obtain detailed information about its technologies for TN and TP removal; despite repeated attempts for the information, an answer was not obtained.

According to the discussions with the Nuquatics former employee, the technology they would propose for removing TP from the water is based on electrochemical oxidation, where they allow the release of elemental alum to bind with the incoming orthophosphate to precipitate with the metal in an insoluble form (similar to Chem-P removal using metal salts).

Regarding the TN removal, the proposal indicated that the RWPF effluent had 3 to 5 mg/L NH4+, and that they developed a cell to address the NH4+ removal. However, the RWTP effluent does not contain ammonia (NH_4^+< 1 mg/L), as the existing process at the plant oxidizes all ammonia to nitrate in the bioreactors.

The Nuquatics TP removal technologies were tested at a WWTP in Florida for a short period of time. However, Nuquatics has never implemented a permanent system at a WWTP permitted and operated for at least 5 years. Regarding its TN removal system, to Black & Veatch’s knowledge, no TN removal systems have been ever commissioned at any WWTP, so the technology cannot be classified as proven. There is also no substantial information as far as proposed operations and maintenance (O&M) costs to allow comparisons. As such, it appears that the technology proposed is not proven to remove TN at the RWPF and Black & Veatch is not in any position to recommend the Nuquatics technologies at this point.

5.0 Advanced Water Treatment Conversion Alternatives

The following sections describe the AWT alternatives that were considered for this study.

5.1 Operating Parameters Analyzed for Advanced Water Treatment Conversion

Conversion to AWT treatment standards is typically a relatively complex process, requiring significant plant modifications. As such, the following items were evaluated to develop a more sustainable approach to conversion to meeting AWT standards at the RWPF.

5.1.1 Influent Flows

The RWPF has a permitted capacity of 4.92 mgd 3MADF. The reuse system is only permitted for 2.56 mgd, whereas the deep well injection system is permitted for a maximum flow of 13.14 mgd. This suggests that providing AWT capacity for flows beyond 2.56 mgd is not required, as there are no effluent nutrient limits for deep well injection.

Likewise, according to the most recent CAR for the RWPF, the Marco Island sewershed is estimated to be near buildout (92.8% land buildout) plant flows. The CAR reported that the flow projections for the year 2035 have an ADF of 2.52 mgd with a 3MADF of 2.989 mgd. Given that the plant average flow is 2.31 mgd, it is logical to think that conversion to AWT is not required for flows beyond the sewershed buildout. As such, an AADF of 2.60 mgd (3.08 3MADF) is recommended for performing the AWT conversion.

5.1.2 Influent Loads

Regarding loads, the following tables summarize the current plant design and the recommended loads for the AWT conversion.

Table 5-1 Baseline Condition (Existing Treatment Process Design Basis)

Parameter	Design Concentration (mg/L)	Design Loading (lbs/day)
cBOD5	200	8,207
TSS	200	8,207
TKN	40 (TN)	1,641
TP	NA	NA
Notes: Design loading was calculated using the design capacity (4.92 mgd).		

Table 5-2 Recommended AWT Conversion Flows and Loads

	Annual Average Current	Maximum Month Current	Peak Day Current	Annual Average Design	Maximum Month Design	Peak Day Design
Flow	2.33	2.79	4.77	2.58	3.09	6.33
TSS						
ppd	3,113	4,899	8,805	3,481	5,417	11,683
mg/L	162	210	221	162	210	221

	Annual Average Current	Maximum Month Current	Peak Day Current	Annual Average Design	Maximum Month Design	Peak Day Design
$CBOD_5$						
ppd	5,963	10,014	16,510	4,922	11,073	21,906
mg/L	229	430	415	229	430	415
TKN						
ppd	964	1,496	1,496	1,092	1,654	1,985
mg/L	50.9	64.2	37.6	50.9	64.2	37.6
TP						
ppd	102	198	433	124	219	575
mg/L	5.8	8.5	10.9	5.8	8.5	10.9

5.1.3 Other Considerations

The existing MLE process flow patterns are a result of the conversion of the RWPF from contact stabilization around 2005 to an MLE process configuration. The original contact stabilization reactors were utilized to create the MLE process, and this was proven to be effective given the targets of the conversion to an MBR system at the time (TN ~12 mg/L).

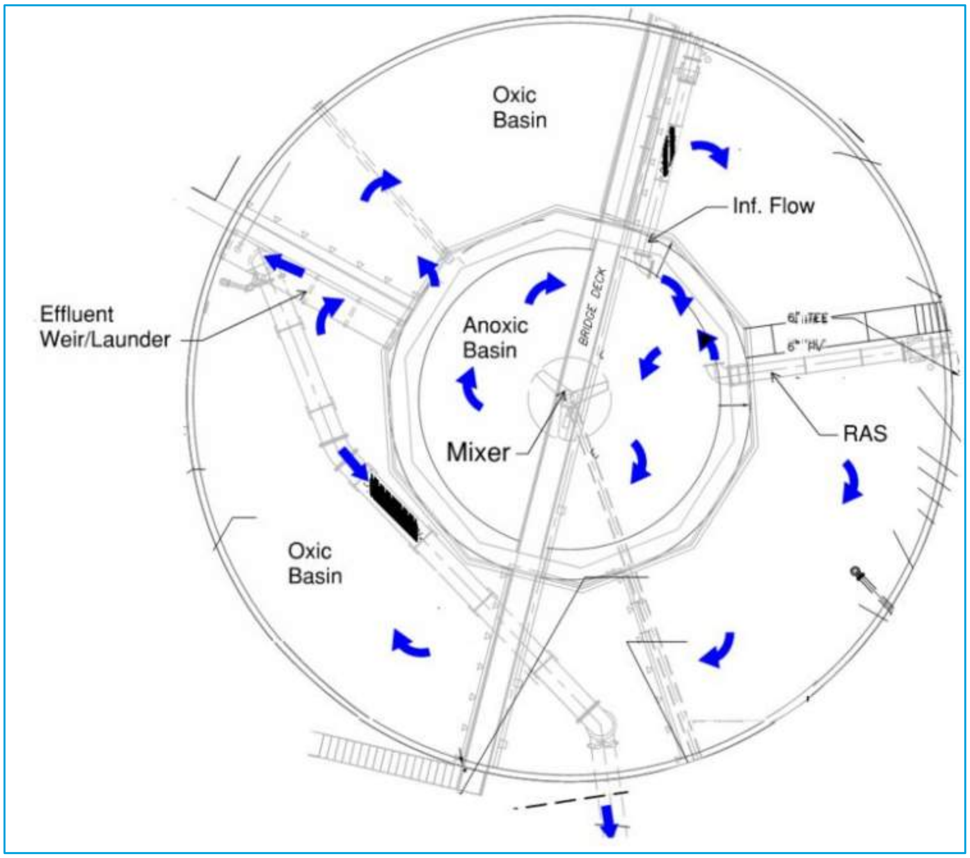


Figure 5-1 Existing MLE Basins Flow Pattern

As illustrated on Figure 5-1, the existing MLE basins flow pattern and configuration likely has short circuiting challenges in the anoxic zone. It is expected that the RAS stream does not adequately mix with the influent flow in an efficient manner which leads to the belief that the denitrification process efficiency is not ideal for meeting AWT standards but is sufficient for the current effluent limitations. As such, either flow pattern improvements or process derating would be advisable in the AWT evaluation to ensure the ability to meet AWT effluent standards.

5.2 CAPEX, OPEX, and TOTEX Development

As part of this evaluation, a rough order of magnitude opinion of probable construction cost (OPCC) was developed consistent with a Class 5 OPCC according to the American Association of Cost Engineers International (AACE). Class 5 is suitable for this evaluation as these are only concept level alternatives, and no detailed engineering drawings will be developed under this study.

To account for the preliminary nature of the OPCCs presented, Black & Veatch used a probabilistic approach for developing the possible OPCCs by coupling the main elements in the alternatives to probability distributions to account for variability. As such CAPEX, OPEX, and total expenditures (TOTEX) were developed as envelopes that include the possible ranges of costs coupled with the probability of occurrence of each of the costs to allow for better decision making. The envelopes for this project included 5,000 simulations randomly selected based on the probability functions assigned to each main variable. Figure 5-2 illustrates the main concepts/elements of OPCC envelopes graphs.

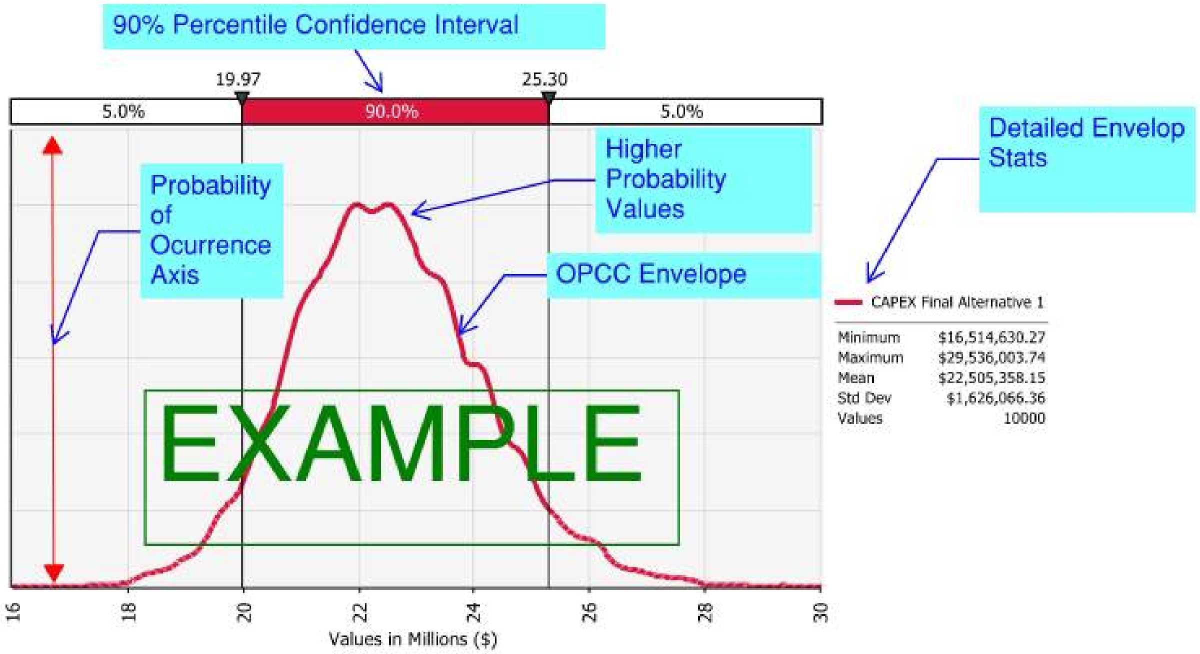


Figure 5-2 **Example Cost Envelope Concepts**

5.3 AWT Alternative 1 – Four-Stage Bardenpho + S2EBPR

This alternative consists of converting the existing MLE biological treatment system into a S2EBPR + four-stage Bardenpho configuration. Under this alternative, TP will be removed by conditioning a portion of the RAS stream to promote biological phosphorus removal, while the existing MLE process will be converted to a four-stage Bardenpho (first anoxic, aerobic/oxic, post anoxic, and reaeration using the existing MBR to remove total nitrogen to less than 3 mg/L as N. Supplemental carbon will be added to the second anoxic reactors to improve nitrogen removal and compliance with the TN limit. A PFD for Alternative 1 is included on Figure 5-3.

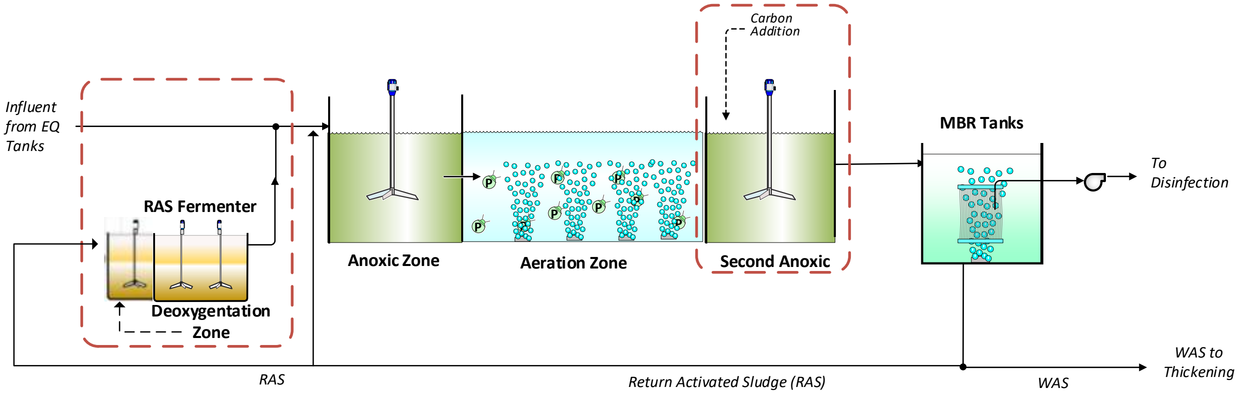


Figure 5-3 AWT Alternative 1 – Four-Stage Bardenpho + S2EBPR PFD

The process shown above could be further optimized by returning the RAS to the aeration basin and adding an internal recycle pump from the tail end of the aeration zone to the head end of the first anoxic zone. This will improve denitrification in the first anoxic zone and minimize the carbon requirements in the second anoxic zone. However, for simplicity and commonality with the current process, this alternative was evaluated as shown on Figure 5-3, as the cost difference is negligible.

To convert the existing MLE process into a four-stage Bardenpho + S2EBPR, a portion of the aeration zone will be converted to a second anoxic zone to allow for denitrification of nitrate and compliance with the TN limit. TP removal will be accomplished through the S2EBPR process and the addition of a RAS fermenter (0.3 MG) to anaerobically condition the sludge to promote phosphorus uptake and removal. Design criteria and sizing for each of the zones in the four-stage Bardenpho configuration for this alternative are included in Table 5-3.

Table 5-3 AWT Alternative 1 – Process Criteria

Parameter	Units	Value
First Anoxic Zone (Existing)		
Total Volume	MG	0.42
Depth	feet	17
SRT - Nominal	days	5 days at MM Load 6 days at AADF Load
HRT	hours	0.6 hour at AADF (w/ recycle)

Parameter	Units	Value
Oxic Zone (Modified)		
Total Volume	MG	0.83
Depth	ft	17
Target Dissolved Oxygen (DO)	mg/L	Varies – Multiple zones 1.0 - 2.0 mg/L
Aerobic SRT - Nominal (aSRT)	days	11 days at MM Load 13 days at AADF Load
HRT	hours	1.4
Second Anoxic (new)		
Total Volume	MG	0.41
Depth	feet	17
SRT - Nominal	days	5.5 days at MM Load 6.6 days at AADF Load
HRT	hours	0.7 hour at AADF (w/ recycle)

An RAS fermenter will be used to enhance EBPR to generate VFAs for PAOs to accumulate phosphorus. PAOs require VFAs under anaerobic conditions to release phosphorus and store internal carbon as PHAs, which enables subsequent phosphorus uptake in aerobic zones. Fermenting a portion of the RAS can supply the carbon needed internally. RAS piping modifications would be required to convey RAS (typically 10-30% of overall RAS quantity) to the fermenter for sidestream treatment. Design criteria for the RAS fermenter is included in Table 5-4.

Table 5-4 RAS Fermenter – Design Criteria

Parameter	Units	Value
RAS Fermenter		
Volume	MG	0.30
Depth	feet	17
Nominal Diameter	feet	50
Flow (at AADF)	mgd	1.2
HRT	hours	0.6

Supplemental carbon addition (e.g., methanol, Micro-C) will be required to provide a carbon source for microorganisms to perform the denitrification process and reliably meet AWT requirements. Design criteria for the supplemental carbon chemical feed system is included in Table 5-5.

Table 5-5 AWT Alternative 1 – Supplemental Carbon – Design Criteria

Parameter	Units	Value
Chemical Type	Type	Micro-C
Concentration	mg/L COD	1,100,000
Nominal Usage	gal/day	220
Nominal Storage Required (15-day capacity) at avg. conditions	gal	4,000

The proposed site layout for this alternative is shown on Figure 5-4.

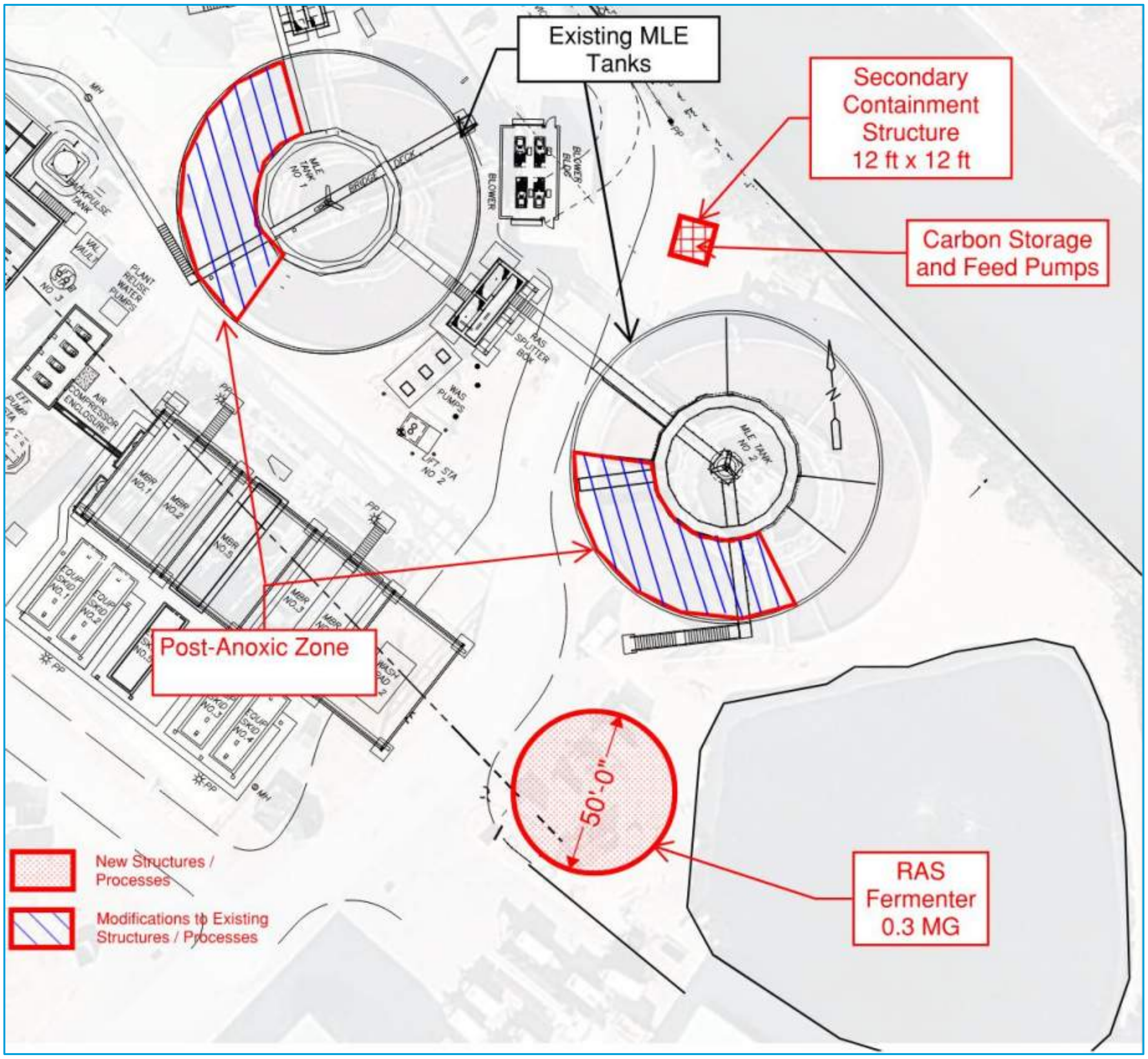


Figure 5-4 Alternative 1 – Four-Stage Bardenpho + S2EBPR – Proposed Site Layout (proposed shown in red)

One note from the layout above is that for this alternative the pond to the west of the proposed fermenter location may have to be modified to accommodate the fermenter and allow access for pond maintenance. Improvements to the pond are outside the scope of this study and may require additional costs and permits for construction.

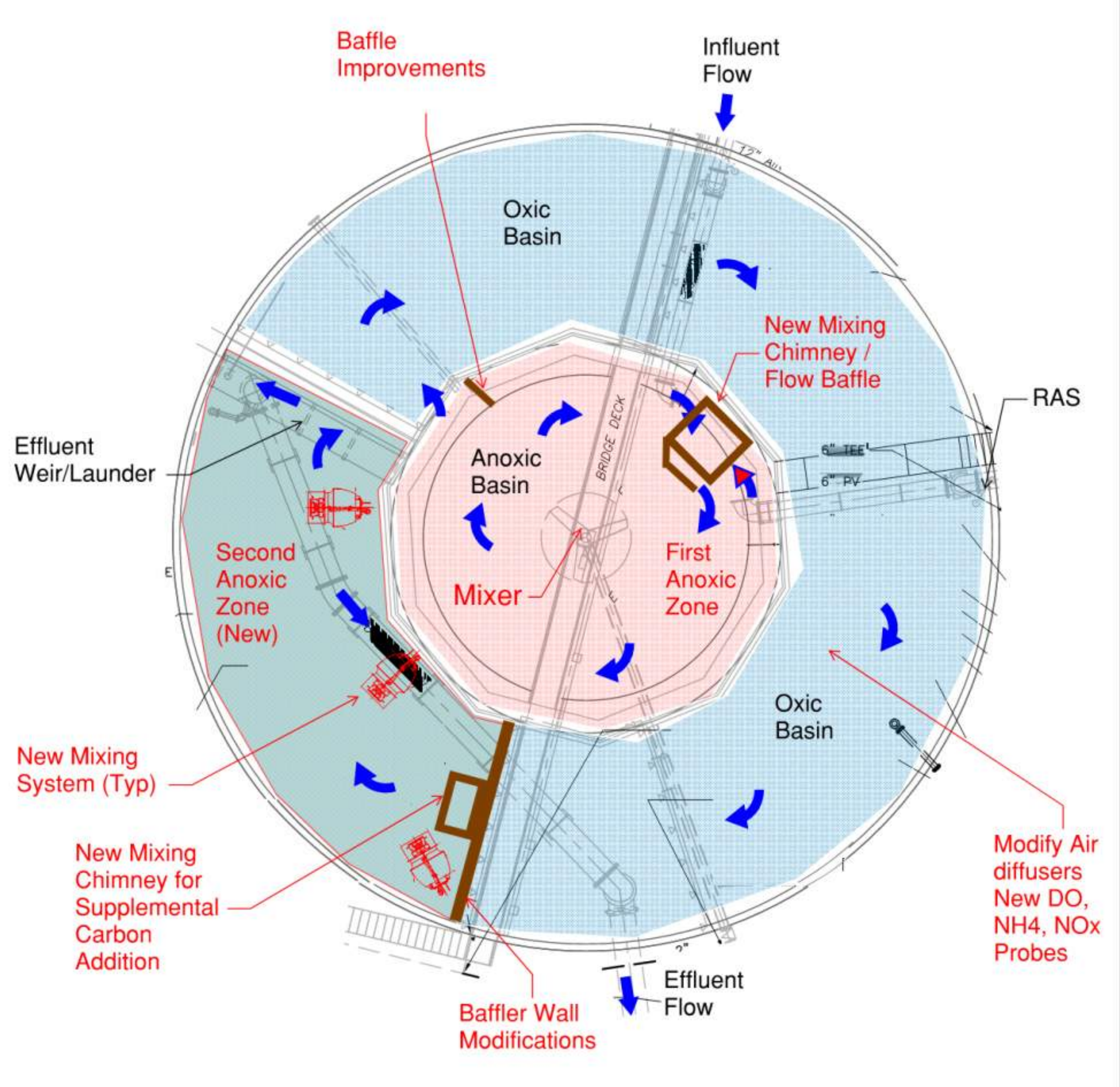


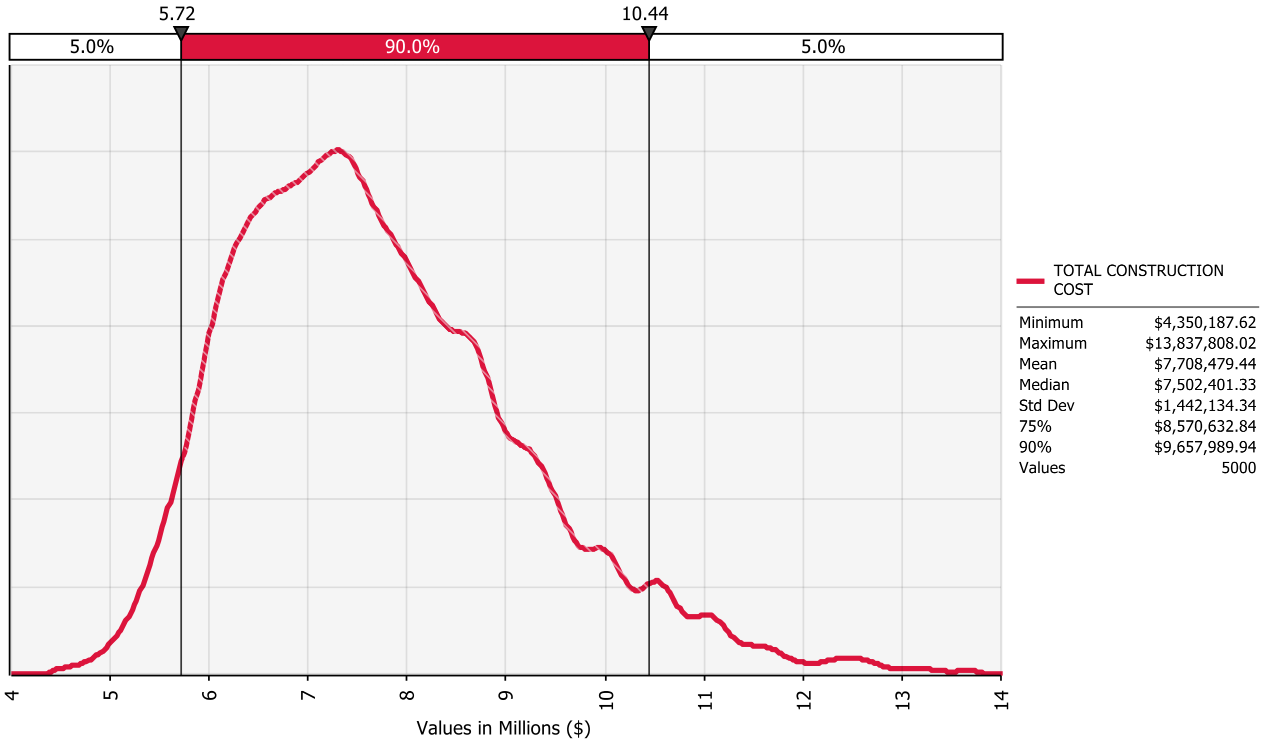
Figure 5-5 **AWT Alternative 1 – Four-Stage Bardenpho + S2EBRP / Required Bioreactor Modifications (labeled in red)**

Table 5-6 AWT Alternative 1 – Summary of Improvements

Improvements	Benefit	Elements Required
Construction of new RAS Fermenter	Promote S2EBPR to reduce TP in the effluent biologically	New concrete tank, mixers, pumps, piping, controls
Modify MLE Tank Anoxic Zone (existing anoxic zone)	Improve mixing and flow pattern by adding mixing chimney and baffles to optimize denitrification to achieve lower TN in the effluent	Baffles
Modify MLE Tank Oxic Zone	Reconfigure oxic zone to allow the addition of the second anoxic zone	Baffle walls, reconfigure air diffusers, automate air delivery with automated valves, flowmeters, and probes
Add new second anoxic zone in MLE Tank	Repurpose part of the oxic zone into a second anoxic zone to complete denitrification to the required AWT limits	Baffles, mixing chimney for carbon addition, mixing equipment for the new anoxic zone, removal of diffusers
New Supplemental Carbon Storage and Metering System	Provide supplemental carbon for the second anoxic zone to promote denitrification to the AWT limits	Storage tanks, containment area, canopy structure, chemical metering skid

5.3.1 AWT Alternative 1 – Four-Stage Bardenpho + S2EBPR CAPEX

The CAPEX for this alternative consists of several capital upgrades to modify the existing treatment configuration to a four-stage Bardenpho process, the addition of chemical feed equipment and storage, and upgraded controls and instrumentation. This alternative requires repurposing a portion of the existing MLE tanks into a new post-anoxic zone. Baffling would be required to control the hydraulics and create a new post-anoxic zone. Mixers would be required in the new post-anoxic zone and the existing aeration headers and diffusers would be removed in that area. For the S2EBPR process, capital improvements include installation of a new sidestream RAS fermenter, RAS piping modifications, mixers, and aeration system improvements. Chemical feed equipment and storage would be required for external carbon (Micro-C). A detailed OPCC including the CAPEX for Alternative 1 is included in Appendix A and the CAPEX OPCC envelope is shown on Figure 5-6.



Minimum	$4,350,187.62
Maximum	$13,837,808.02
Mean	$7,708,479.44
Median	$7,502,401.33
Std Dev	$1,442,134.34
75%	$8,570,632.84
90%	$9,657,989.94
Values	5000

Figure 5-6 AWT Alternative 1 Four-Stage Bardenpho + S2EBPR OPCC CAPEX Envelope

5.3.2 AWT Alternative 1 – Four-Stage Bardenpho + S2EBPR OPEX

OPEX for a four-stage Bardenpho + S2EBPR process are driven primarily by energy, chemicals, labor/monitoring, and routine maintenance of equipment and facilities. Chemical costs include external carbon required (Micro-C). S2EBPR can shift some OPEX from chemicals to biological processes by using sidestream fermentation to generate VFAs but adds process control, operations, and maintenance requirements. Routine mechanical and electrical maintenance includes DO sensors, water quality sensors (TP, PO_4, NH_3, NO_3), blowers, mixers, pumps, valves, and diffusers.

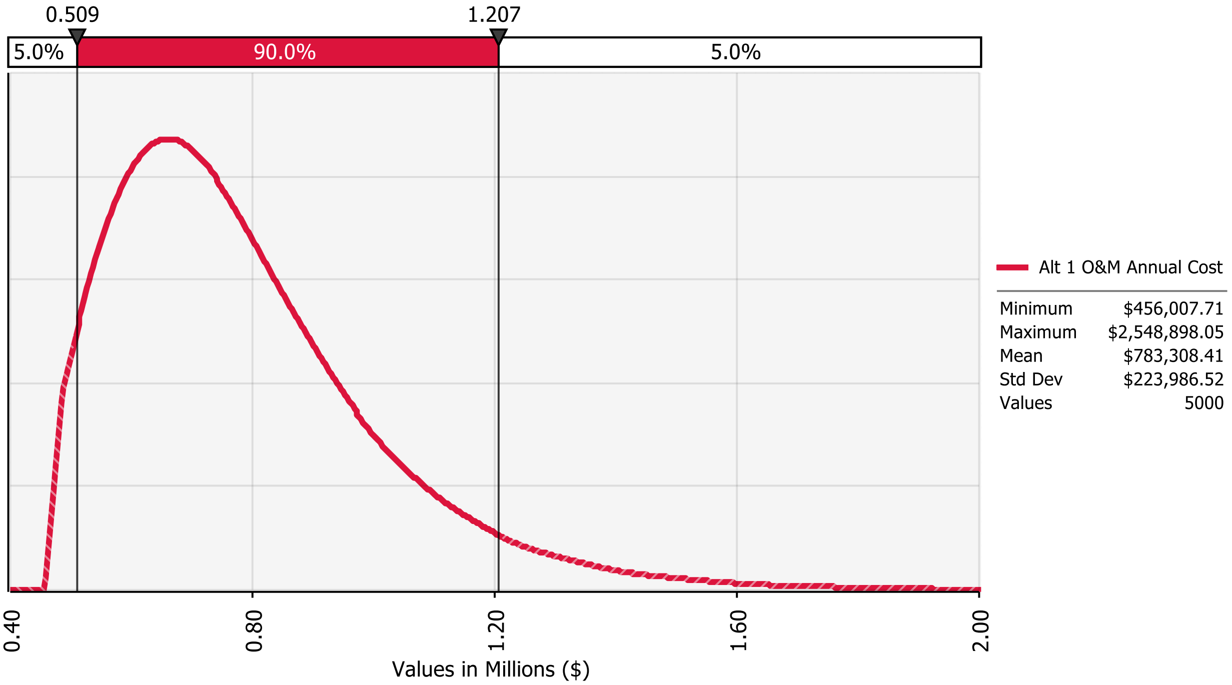


Figure 5-7 **AWT Alternative 1 – Annual OPEX Envelope**

5.4 AWT Alternative 2 – Four-Stage Bardenpho + Chem-P Removal

Similar to Alternative 1, this alternative consists of converting the existing MLE process to a four-stage Bardenpho configuration to address TN removal. Phosphorus removal is addressed by the addition of metal salts (i.e., alum) prior to the MBR to precipitate soluble phosphate and facilitate TP removal.

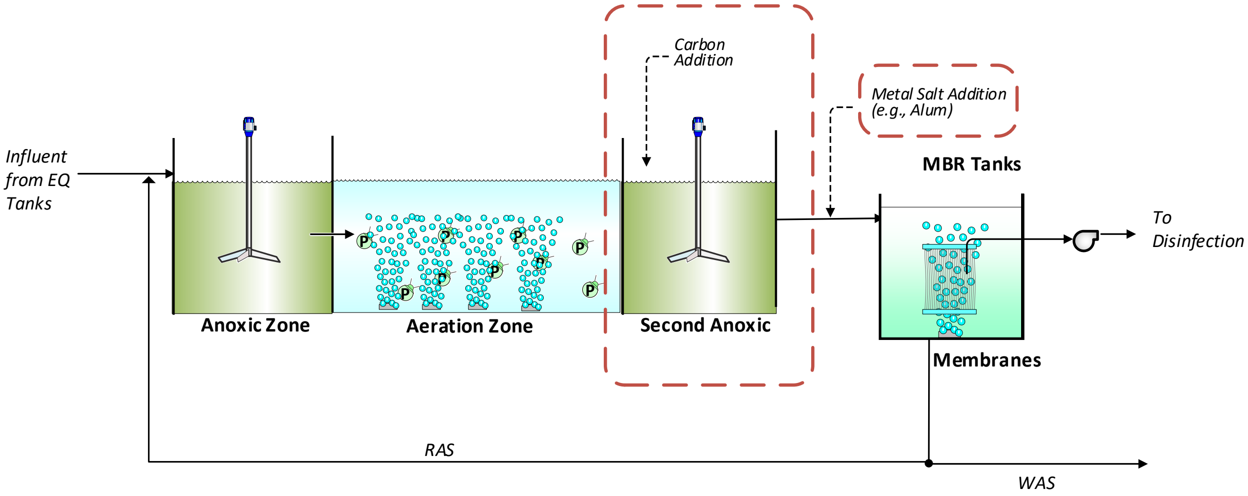


Figure 5-8 AWT Alternative 2 – Four-Stage Bardenpho + Chem-P PFD

The above process could be further optimized by returning the RAS to the aeration basin and adding an internal recycle pump from the tail end of the aeration zone to the head end of the first anoxic zone. This will improve denitrification in the first anoxic zone and minimize the carbon requirements in the second anoxic zone. However, for simplicity and commonality with the current process, this alternative was evaluated as shown on Figure 5-8, as the cost difference is negligible.

To convert the existing MLE process into a four-stage Bardenpho, a portion of the aeration zone will be converted to a post-anoxic zone to allow for denitrification of nitrate and compliance with the design TN limit (<3 mg/L). Design criteria and sizing for each of the zones in the four-stage Bardenpho configuration for this alternative are included in Table 5-7. Mixers would be required for the second anoxic zone to provide mixing. Aeration grids and diffusers in the post-anoxic reactor would need to be removed. Improvements to the aeration system including valves and aeration controls would be required to more accurately control and monitor aeration and DO levels in the aerobic zone (0.8 to 2.0 mg/L).

Table 5-7 AWT Alternative 2 – Four-Stage Bardenpho + Chem-P Design Criteria

Parameter	Units	Value
First Anoxic Zone (Existing)		
Total Volume	MG	0.42
Depth	feet	17
SRT - Nominal	days	4.5 days at MM Load 5.5 days at AADF Load
HRT	hours	0.9 hour at AADF (w/ recycle)

Parameter	Units	Value
Oxic Zone (Modified)		
Total Volume	MG	0.83
Depth	feet	17
Target DO	mg/L	Varies – Multiple zones 1.0 - 2.0 mg/L
Aerobic SRT - Nominal (aSRT)	Days	10 days at MM Load 12 days at AADF Load
Second Anoxic (new)		
Total Volume	MG	0.41
Depth	ft	17
SRT - Nominal	days	5 days at MM Load 6 days at AADF Load
HRT	hours	1 hour at AADF (w/ recycle)

For this alternative, alum ($Al_2(SO_4)_3*14\ H_2O$) will be used for chemical TP removal. Alum is one of the most widely used chemical coagulants at WWTPs. Implementing alum for TP removal would require chemical dosing equipment, chemical storage, process control, and monitoring to ensure compliance with AWT standards. Alum would be added after the post-anoxic basin and prior the MBRs and re-aeration process.

Table 5-8 AWT Alternative 2 – Chem-P Removal – Design Criteria

Parameter	Units	Value
Chemical	Type	Alum ($Al_2(SO_4)_3*14\ H_2O$)
Dose	mg/L	70
Nominal Usage (ADF)	gal/day	125
Nominal Storage Tank Required (15-day capacity)	gal	2,000

Supplemental carbon addition (e.g., methanol, Micro-C) will be required to provide a carbon source for microorganisms to perform the denitrification process and reliably meet AWT requirements. Design criteria for the supplemental carbon chemical feed system is included in Table 5-9.

Table 5-9 AWT Alternative 2 – Supplemental Carbon – Design Criteria

Parameter	Units	Value
Chemical Type		Micro-C
Concentration	mg/L COD	1,100,000
Nominal Usage	gal/day	200
Nominal Storage Tank Required (15-day capacity) at average load conditions	gal	4,000

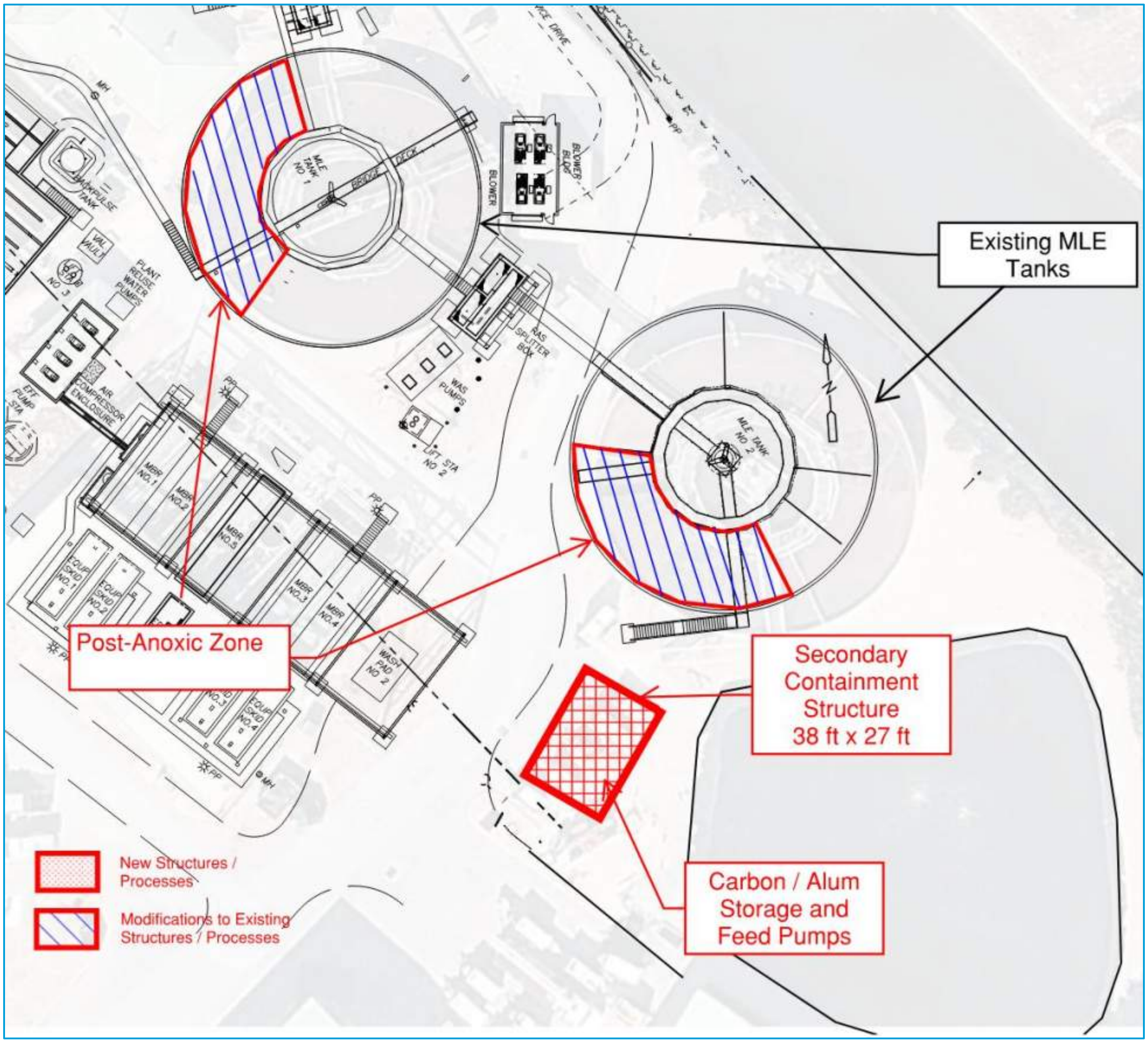


Figure 5-9 AWT Alternative 2 – Four-Stage Bardenpho + Chem-P Removal Site Layout

AWT Alternative 2 bioreactors modifications are very similar to the modifications required in AWT Alternative 1. The only difference is the addition of an alum dosing point.

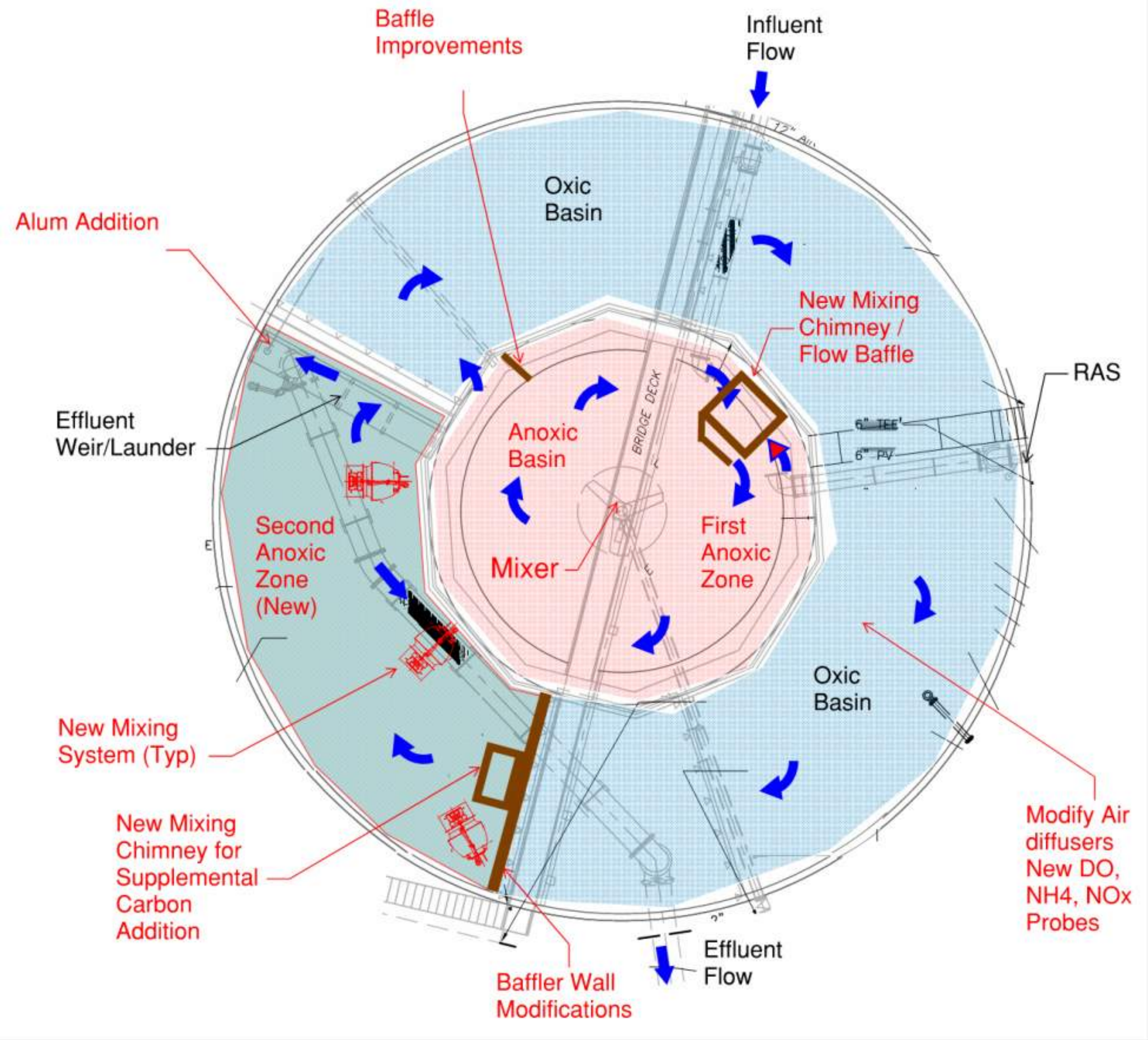


Figure 5-10 **AWT Alternative 2 – Four-Stage Bardenpho + Chem-P Required Bioreactor Modifications (shown in red)**

Table 5-10 AWT Alternative 2 – Four-Stage Bardenpho + Chem-P Summary of Improvements

Improvements	Benefit	Elements Required
Modify MLE Tank Anoxic Zone (existing anoxic zone)	Improve mixing and flow pattern by adding mixing chimney and baffles to optimize denitrification to achieve lower TN in the effluent	Baffles
Modify MLE Tank Oxic Zone	Reconfigure oxic zone to allow the addition of the second anoxic zone	Baffle walls, reconfigure air diffusers, automate air delivery with automated valves, flowmeters, and probes
Add new second anoxic zone in MLE Tank	Repurpose part of the oxic zone into a second anoxic zone to complete denitrification to the required AWT limits	Baffles, mixing chimney for carbon addition, mixing equipment for the new anoxic zone, removal of diffusers
New supplemental carbon storage and metering system	Provide supplemental carbon for the second anoxic zone to promote denitrification to the AWT limits	Storage tanks, containment area, canopy structure, chemical metering skid
New Alum storage and metering system	Provide metal salt (alum) for the TP removal to meet the AWT limits	Storage tanks, containment area, canopy structure, chemical metering skid

5.4.1 AWT Alternative 2 – Four-Stage Bardenpho + Chem-P CAPEX

The CAPEX for this alternative consists of several capital upgrades to modify the existing treatment configuration to a four-stage Bardenpho process, the addition of chemical feed equipment and storage, and upgraded controls and instrumentation. This alternative requires repurposing a portion of the existing aerobic zone into a new post-anoxic zone. Baffling would be required to control the hydraulics and create a new post-anoxic zone. Mixers would be required for mixing and the existing aeration headers and diffusers would be removed. Chemical feed equipment and storage required for this alternative included external carbon (Micro-C) for TN removal and alum for TP removal.

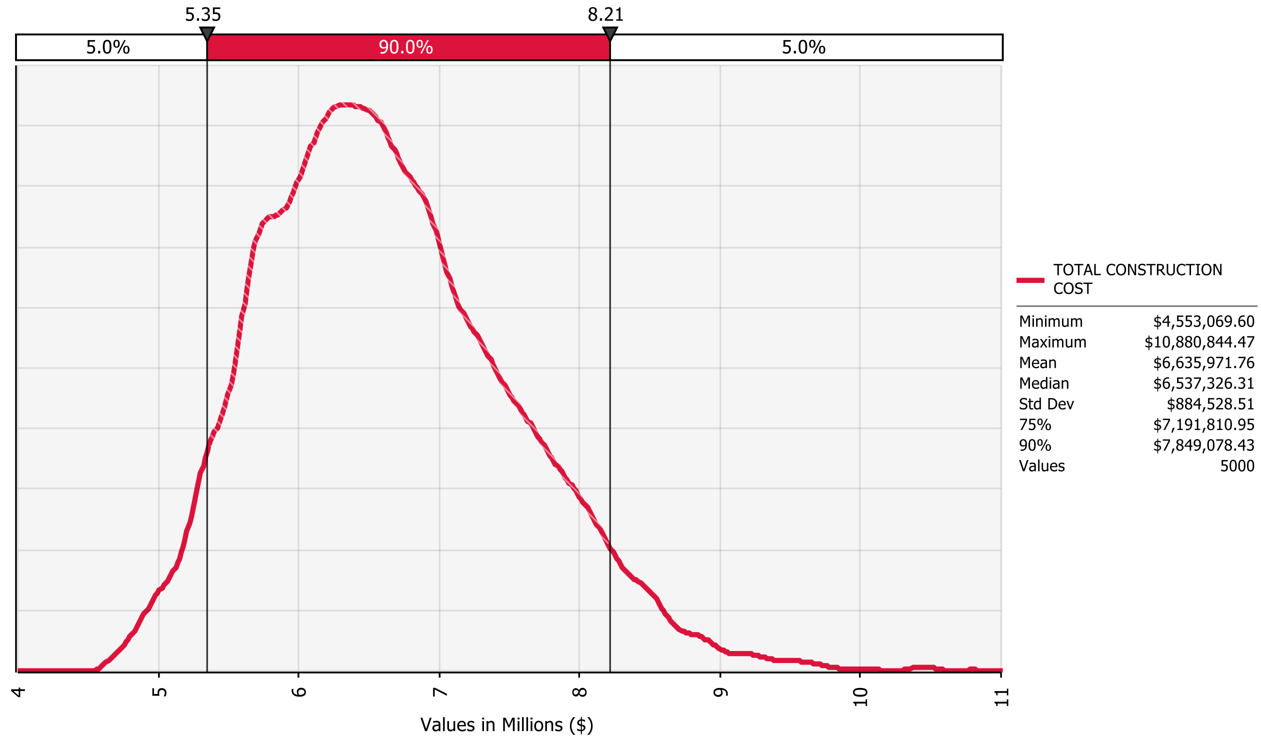


Figure 5-11 **AWT Alternative 2 – CAPEX OPCC Envelope**

5.4.2 AWT Alternative 2 – Four-Stage Bardenpho + Chem-P OPEX

OPEX for a four-stage Bardenpho process + chemical TP removal is driven primarily by energy, chemicals, labor/monitoring, and routine maintenance of equipment and facilities. Additional sludge production due to the chemical addition will increase the overall plant biosolids disposal costs. Chemical costs include Micro-C and alum. Routine mechanical and electrical maintenance includes blowers, mixers, pumps, valves, diffusers, chemical feed equipment, and associated equipment.

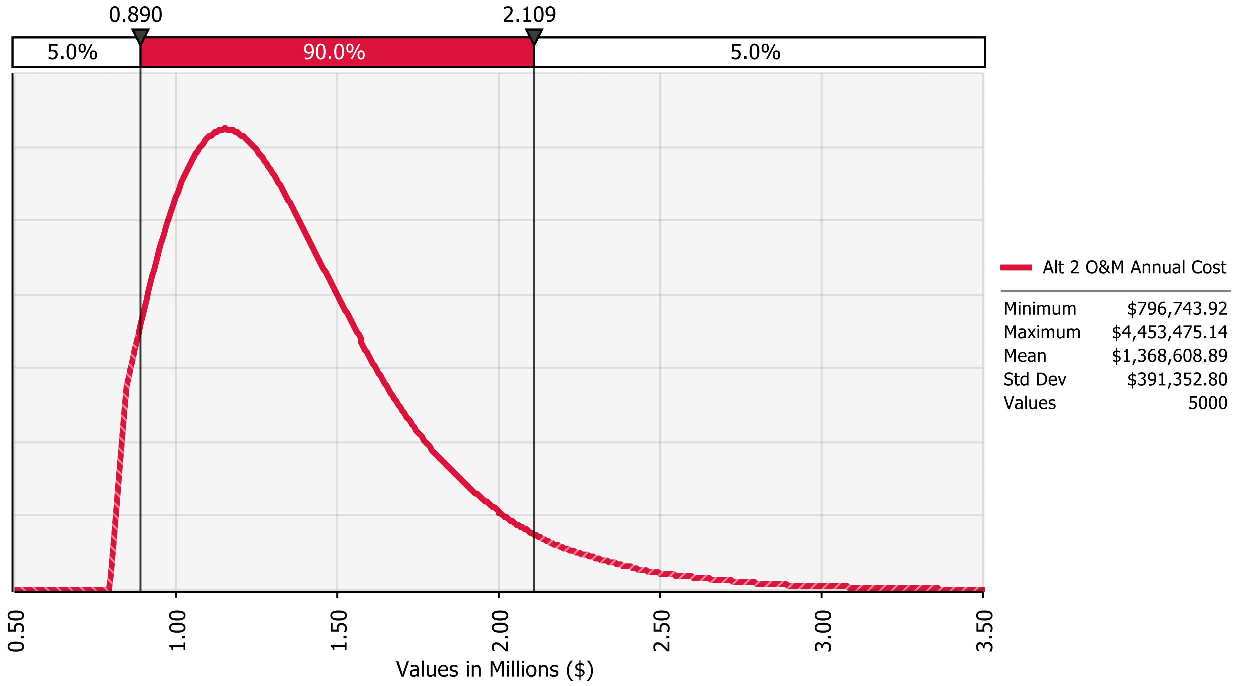


Figure 5-12 AWT Alternative 2 – OPEX OPCC Envelope

5.5 AWT Alternative 3 – PdNA + Chem-P Removal

This alternative consists of converting the existing MLE biological treatment system into PdNA configuration. Under this alternative, TP will be removed chemically using metal salts (similar to Alternative 2). Supplemental carbon will be added to the PdNA and post-anoxic reactors to improve nitrogen removal and compliance with the design TN limit.

To convert the existing MLE process into a PdNA configuration, a portion of the oxic zone will be converted as follows: Oxic (aeration) with and ammonia over Nitrate control, a PdNA zone where carbon will be dosed to promote the PdNA pathway, and a second-anoxic zone to complete the PdNA cycle. Implementation of a PdNA process would "short-cut" the conventional nitrogen removal pathway, and instead of fully nitrifying ammonia to nitrate and reducing it to nitrogen gas, the PdNA process intentionally stops denitrification at nitrite, which then feeds the anammox reaction in the PdNA reactor. The anammox reaction is the key microbial pathway for implementing this alternative, which converts nitrite and ammonium ions directly into nitrogen gas and water. Anammox bacteria convert ammonia to nitrite then to nitrogen gas, using minimal carbon and requiring minimal aeration. Annamox bacteria typically grow slowly and would require the retention of the biomass to maintaining a viable PdNA reactor.

New mixers would be required for the PdNA and second anoxic zones to keep the mixed liquor suspended and properly mixed. Aeration grids and diffusers in the PdNA reactor and the second anoxic zones would need to be removed. Improvements to the aeration system, including valves and aeration controls, would be required to more accurately control and monitor aeration and DO levels in the aerobic zone. A new sludge screen would be required to retain the annamox biomass in the reactor.

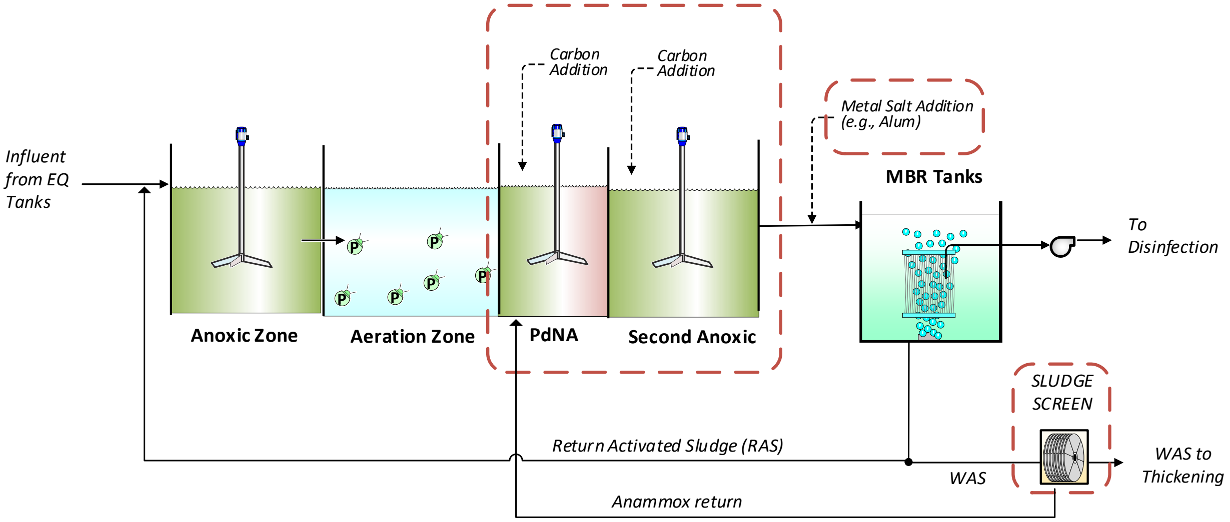


Figure 5-13 AWT Alternative 3 – PdNA + Chem-P PFD

Likewise, as AWT Alternatives 1 and 2, the above process could be further optimized by returning the RAS to the aeration basin and adding an internal recycle pump from the tail end of the aeration zone to the head end of the first anoxic zone. This will improve denitrification in the first anoxic zone and minimize the carbon requirements in the second anoxic zone. However, for simplicity and commonality with the current process, this Alternative will be evaluated as shown on Figure 5-13, as the cost difference is negligible.

The design criteria for Alternative 3 are included in Table 5-11.

Table 5-11 AWT Alternative 3 – PdNA + Chem-P Design Criteria

Parameter	Units	Value
First Anoxic Zone (Existing)		
Total Volume	MG	0.42
Depth	feet	17
SRT - Nominal	days	3.6 days at MM Load 4.5 days at AADF Load
HRT	hours	0.8 hours at AADF (w/ recycle)
Oxic Zone (Modified)		
Total Volume	MG	0.66
Depth	ft	17

Parameter	Units	Value
Target DO	mg/L	Varies – Multiple zones 1.0 - 2.0 mg/L
Aerobic SRT - Nominal (aSRT)	days	8.8 @ MM Load 10.4 @ ADF Load
PdNA Zone (New)		
Total Volume	MG	0.205
Depth	feet	17
SRT – Nominal (anammox retention)	days	40+ days at MM Load 40+ days at AADF Load
Second Anoxic (new)		
Total Volume	MG	0.205
Depth	ft	17
SRT - Nominal	days	5.5 days at MM Load 6.6 days at AADF Load
HRT	hours	0.7 hour at AADF (w/ recycle)

For this alternative, similar to AWT Alternative 2, alum ($Al_2(SO_4)_3$*14 H_2O) will be used for chemical TP removal. Alum would be added after the post-anoxic basin and prior the MBRs and re-aeration process.

Table 5-12 AWT Alternative 3 – Chem-P Removal – Design Criteria

Parameter	Units	Value
Chemical	Type	Alum ($Al_2(SO_4)_3$*14 H_2O)
Dose	mg/L	70
Nominal Usage (ADF)	gal/day	125
Nominal Storage Tank Required (15-day capacity)	gal	2,000

Supplemental carbon addition (e.g., methanol, Micro-C) will be required to provide a carbon source for microorganisms to perform the partial denitrification/anammox process. Carbon addition would be required in the PdNA reactor and the post-anoxic reactor. Design criteria for the supplemental carbon system for this alternative is included in Table 5-13.

Table 5-13 AWT Alternative 3 – Supplemental Carbon – Design Criteria

Parameter	Units	Value
Chemical Type	Type	Micro-C
Concentration	mg/L COD	1,100,000
Nominal Usage	gal/day	50
Nominal Storage Tank Required (15-day capacity)	gal	1,000

The proposed site layout for this alternative is shown on Figure 5-14.

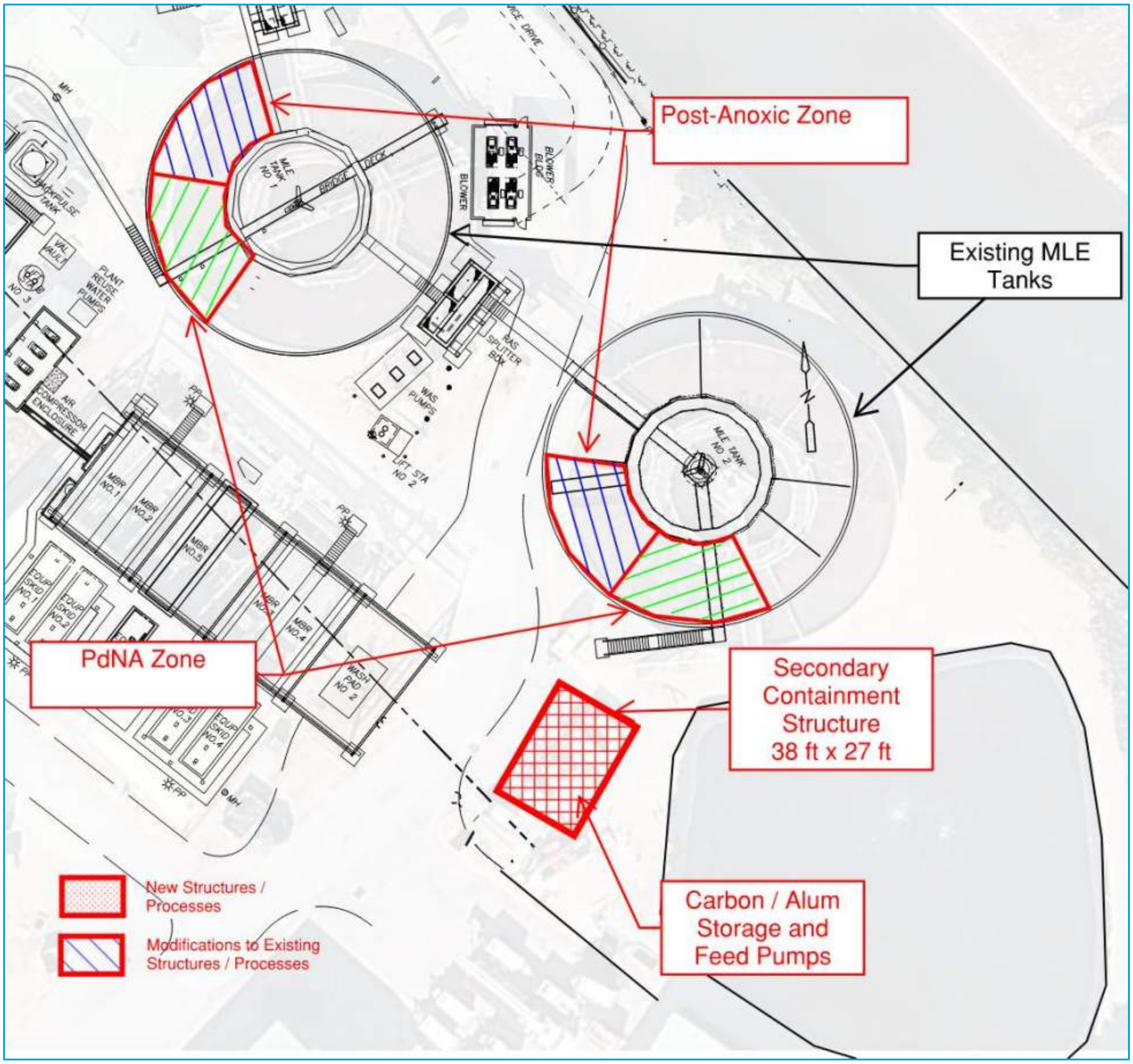


Figure 5-14 **Alternative 3 – PdNA + Chem-P Site Layout**

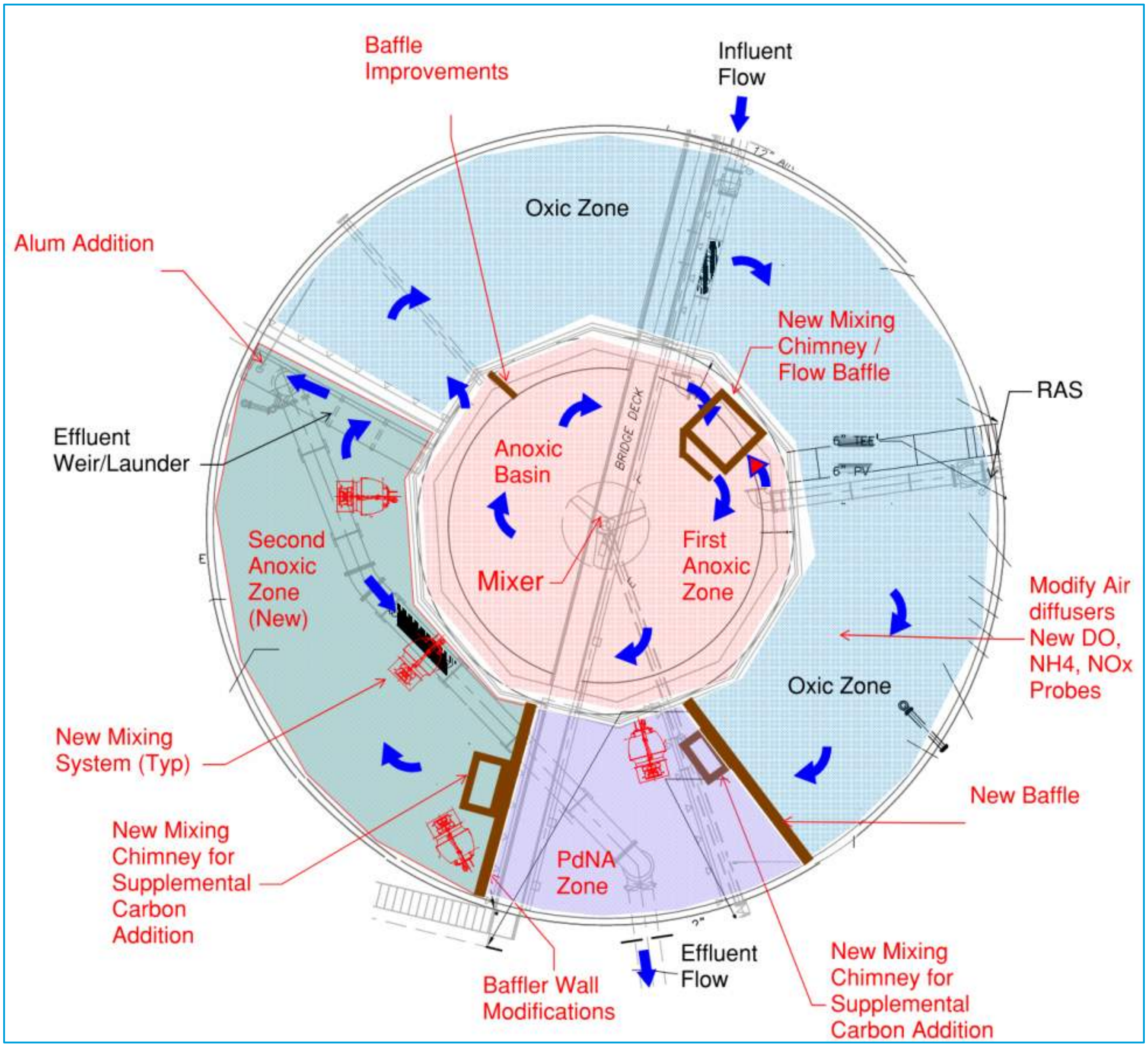


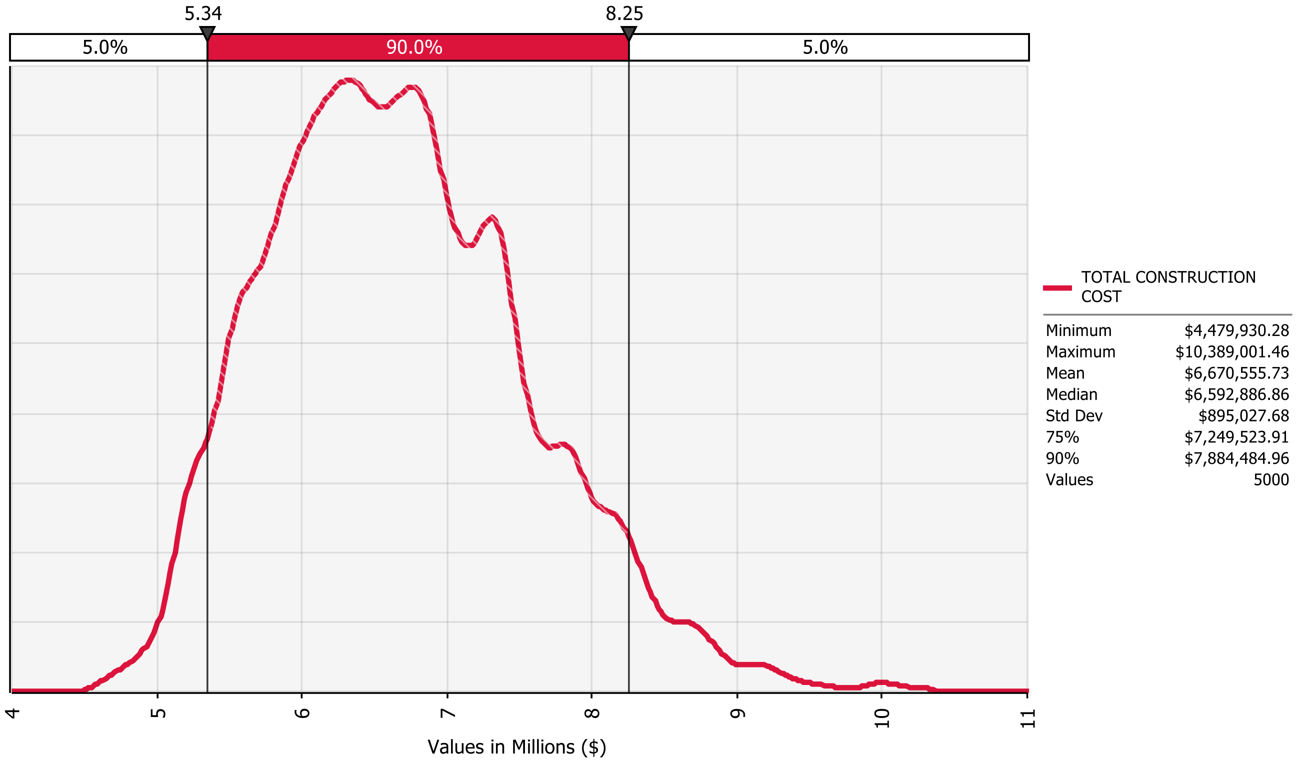
Figure 5-15 AWT Alternative 3 – PdNA + Chem-P Required Bioreactor Modifications

Table 5-14 AWT Alternative 3 – PdNA + Chem-P Summary of Improvements

Improvements	Benefit	Elements Required
Modify MLE Tank Anoxic Zone (existing anoxic zone)	Improve mixing and flow pattern by adding mixing chimney and baffles to optimize denitrification to achieve lower TN in the effluent	Baffles
Modify MLE Tank Oxic Zone	Reconfigure oxic zone to allow the addition of the PdNA and second anoxic zone	Baffle walls, reconfigure air diffusers, automate air delivery with automated valves, flowmeters, and probes
Add new PdNA zone in MLE Tank	Repurpose part of the oxic zone into a PdNA zone to complete denitrification to the required AWT limits	Baffles, mixing chimney for carbon addition, mixing equipment for the new PdNA zone, removal of diffusers
Add new second anoxic zone in MLE Tank	Repurpose part of the oxic zone into a second anoxic zone to complete denitrification to the required AWT limits	Baffles, mixing chimney for carbon addition, mixing equipment for the new anoxic zone, removal of diffusers
New supplemental carbon storage and metering system	Provide supplemental carbon for the second anoxic zone to promote denitrification to the AWT limits	Storage tanks, containment area, canopy structure, chemical metering skid
New Alum storage and metering system	Provide metal salt (alum) for the TP removal to meet the AWT limits	Storage tanks, containment area, canopy structure, chemical metering skid
New Sludge Screening	Retention of anammox bacteria to make PdNA viable	Sludge screen and associated sludge pump, return pipe to PdNA reactor

5.5.1 AWT Alternative 3 – PdNA + Chem-P/CAPEX

The CAPEX for this alternative consists of several capital upgrades to modify the existing treatment configuration, add sidestream treatment capacity, and upgrade controls for the PdNA + Chem-P removal. This alternative requires repurposing a portion of the existing aerobic zone to allow a new PdNA and second anoxic zones to be added. For the PdNA process, a sludge screen would be required to retain annamox microorganisms in the reactor and ensure the viability of PdNA. Baffling would be required to control the hydraulics/mixing and create the new PdNA zone. Mixers would be required to keep the solids suspended. New chemical feed system for carbon and alum would be required.



Minimum	$4,479,930.28
Maximum	$10,389,001.46
Mean	$6,670,555.73
Median	$6,592,886.86
Std Dev	$895,027.68
75%	$7,249,523.91
90%	$7,884,484.96
Values	5000

Figure 5-16 AWT Alternative 3 – CAPEX Envelope

5.5.2 AWT Alternative 3 – PdNA + Chem-P/OPEX

OPEX for a PdNA + chemical TP alternatives are driven primarily by energy, chemicals, labor/monitoring, and routine maintenance of equipment and facilities. Additional sludge production due to the chemical addition will increase the overall plant biosolids disposal cost. The PdNA process can reduce blower power requirements versus full nitrification-denitrification by throttling aerobic loading and targeting nitrite, but it does increase mixing requirements and internal recycling pumping required. Supplemental carbon costs with PdNA are substantially reduced. One important item of the PdNA alternative is that it requires more operator attention and highly skilled process control to reduce TN to low levels. As such, additional labor was considered in the estimate to account for this. Sludge reduction compared to AWT Alternatives 1 and 2 could be achieved given that less supplemental carbon is required, but it is considered negligible compared to the overall BOD load to the plant.

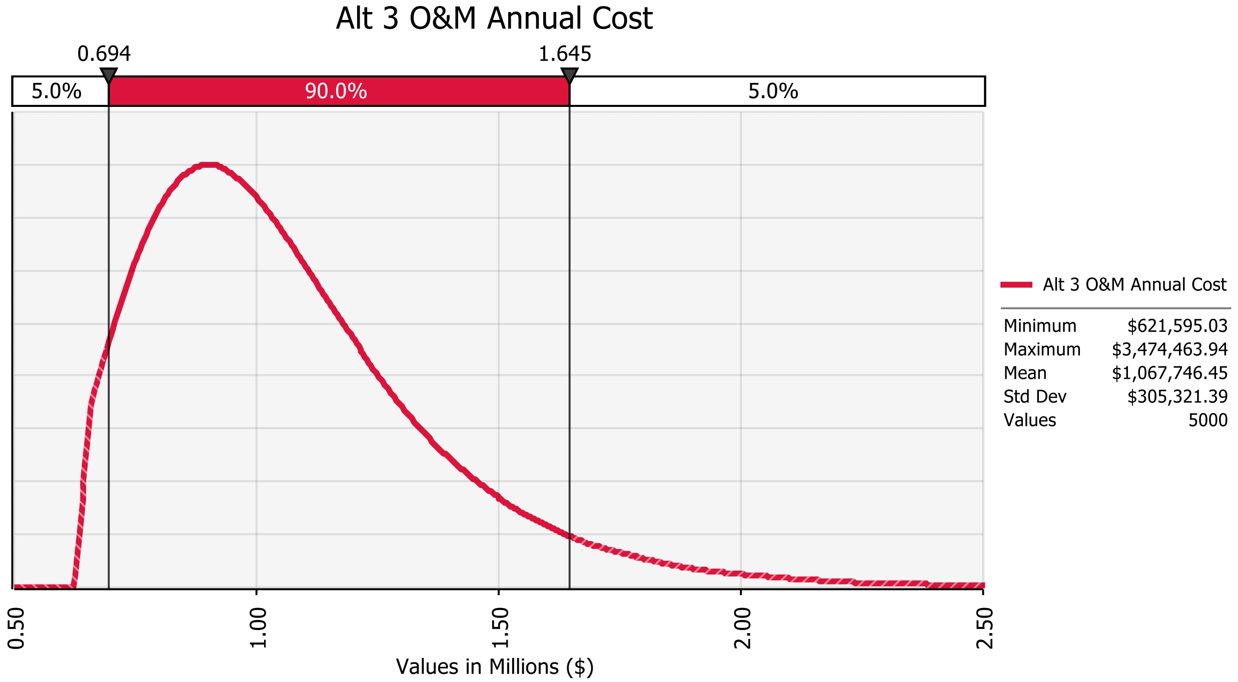


Figure 5-17 **AWT Alternative 3 – OPEX Envelope**

5.6 Alternatives Evaluation

5.6.1 Alternatives Evaluation Criteria

This section describes the criteria used for evaluating the different alternatives.

5.6.1.1 CAPEX

The four selected alternatives were evaluated based on a Class 5 Opinion of Probable Construction Cost (OPCC) (expected accuracy range: Low -20 percent to 50 percent and High: +30 percent to +100 percent), as defined by the AACE. OPCC for each of the four alternatives are included in **Appendix A.** CAPEX of the alternatives was estimated using parametric estimation based on major equipment cost and markups factors for all other components including installation, balance of plant items, electrical, I&C, etc.

A probability analysis was also developed for the CAPEX to generate envelopes of costs associated with probabilities of the main variables, given the preliminary nature of the alternatives being evaluated. The total cost of each project was calculated by adding the construction and construction contingency costs together. Additional information on the CAPEX envelopes is included in **Appendix A**.

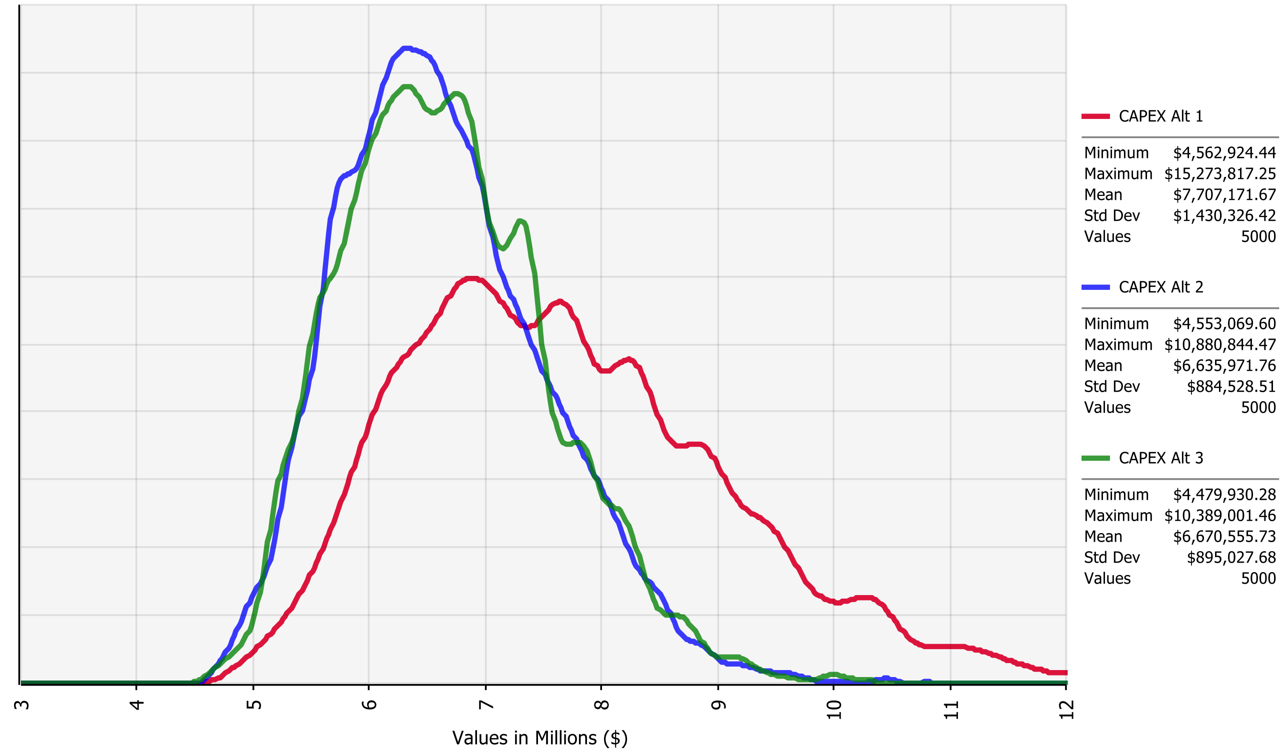


Figure 5-18 **AWT Alternatives Combined CAPEX Envelopes**

5.6.1.2 OPEX

OPEX costs associated with the alternatives were estimated based on reference designs developed for each of the alternatives. OPEX included the following components:

- **O&M Labor**: Labor hours for treatment plant operations and equipment maintenance.
- **Materials**: Costs of equipment replacement, replacement parts, etc.
- **Chemicals**: Costs for chemical aids for processes that require them, such as supplemental carbon or coagulant addition.
- **Power**: Costs of power use for all treatment processes.

Similar to CAPEX, a probability evaluation of OPEX was also performed to account for possible variability of the main O&M variables. Additional information on the OPEX envelopes is included in **Appendix A**.

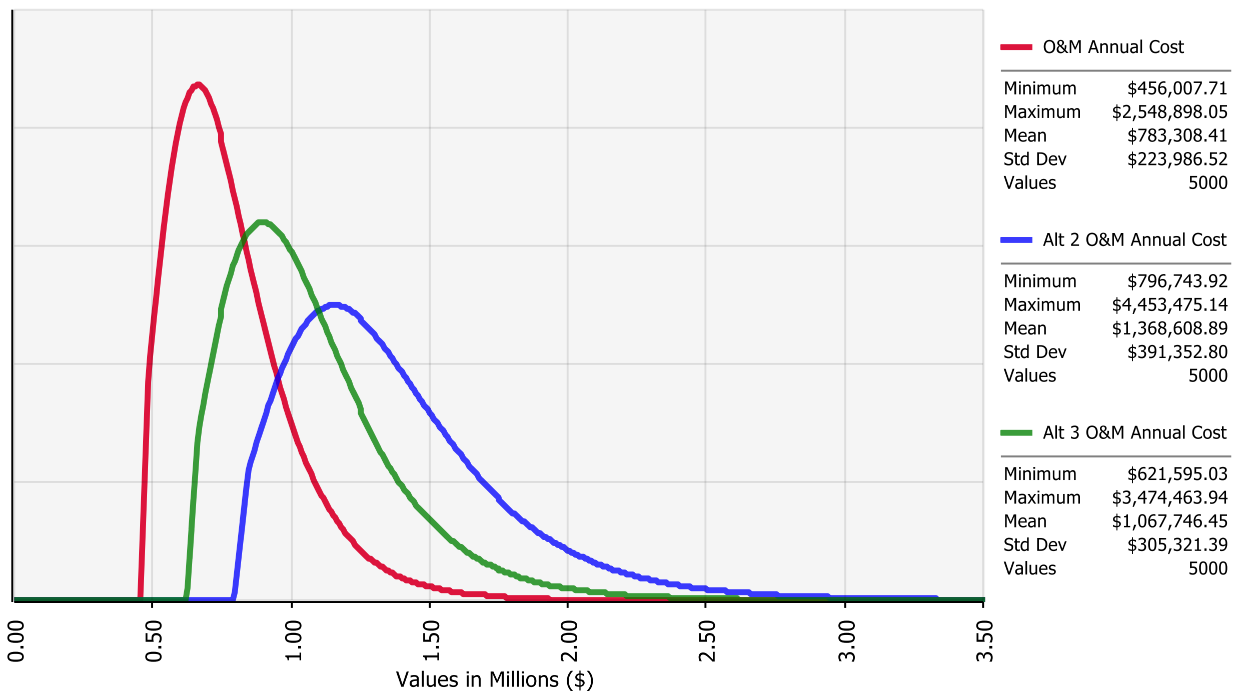


Figure 5-19 **AWT Alternatives Combined OPEX Envelopes**

5.6.1.3 TOTEX

The present worth costs consider the timeline of capital improvements and the estimated annual OPEX over a **20-year period**. These costs are brought back to the present year and combined into the present worth cost. The present worth is equivalent to the amount of money that the City would need to have currently available to cover for capital improvements and annual OPEX in future years. It considers the interest rate of loans and the time value of money.

For capital projects, the costs from planning and design were assumed to be encumbered in the first planned design year. The construction cost, contingency, and engineering costs for construction administration were assumed to be encumbered in the first year of construction.

O&M costs were calculated at a fixed point in time: the design year at average flow. To provide a fair comparison between system-wide alternatives, annual costs were estimated for each year over the 20-year planning period.

An inflation factor was applied to future year's costs. The discount rate was applied to the future year cash flow to determine the net present worth. The assumed inflation and discount rates are shown in Table 5-15.

Table 5-15 **Present Worth Assumptions**

Criteria	Description
Interest Rate	5 percent
Period	20 years

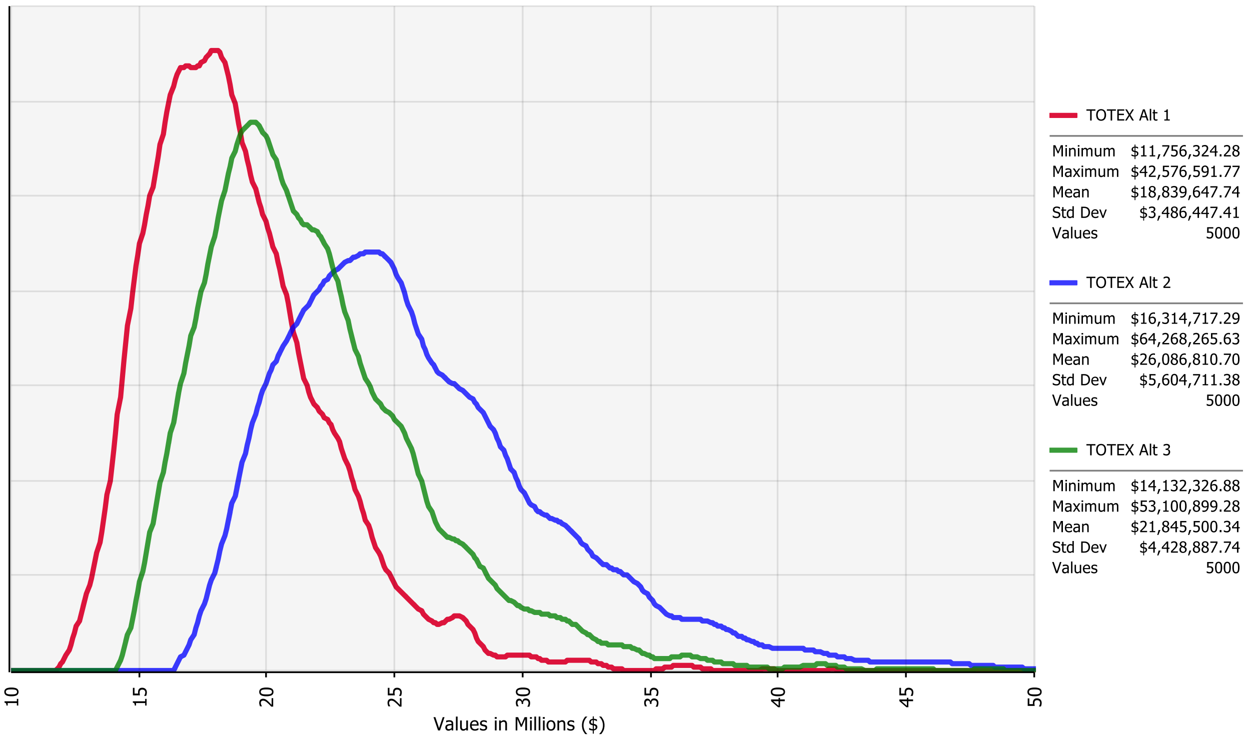


Figure 5-20 AWT Alternatives Combined TOTEX Envelopes – Over a 20 Year Period

5.6.1.4 Reliability

The reliability and experience criterion assesses the ability of the proposed alternative to consistently meet performance requirements under a range of operating conditions. This includes consideration of process redundancy, operational stability, sensitivity to influent variability, and resilience to equipment failures. In addition, this criterion evaluates the level of industry experience with the technology, including the number of full-scale installations, length of operational history, and demonstrated performance at comparable facilities.

5.6.1.5 Regulatory Risks

The regulatory risks criterion evaluates the likelihood that the alternative will receive timely regulatory approval and remain compliant with current and anticipated future regulations. This includes consideration of permitting complexity, regulatory acceptance of the proposed technology, potential schedule impacts due to regulatory review, and uncertainty associated with evolving treatment standards. Alternatives with higher regulatory risk may face increased permitting challenges or future compliance constraints.

5.6.1.6 Treatment Performance

The treatment performance criterion assesses the ability of the alternative to reliably achieve the required effluent quality objectives across the full range of design flows and loading conditions. This includes compliance with applicable effluent limits for parameters such as biochemical oxygen demand, total suspended solids, nutrients, and other regulated constituents. The evaluation considers both average and peak conditions, as well as process robustness and performance consistency.

5.6.1.7 Expandability

The expandability criterion evaluates the flexibility of the alternative to accommodate future changes, such as increased flows, more stringent regulatory requirements, or additional treatment objectives. This includes the ability to incrementally expand capacity, integrate new process components, or modify existing systems without significant disruption to ongoing operations. Alternatives with greater expandability are better positioned to address long-term planning uncertainties.

5.6.1.8 Operability

The operability criterion considers the level of operational complexity associated with the alternative, including process control requirements, operator skill level, automation needs, and day-to-day operational burden. This evaluation reflects the ease with which plant staff can operate, monitor, and maintain the system while consistently achieving performance objectives. Simpler and more intuitive processes generally result in lower operational risk and training requirements.

5.6.1.9 Time to Implement Alternatives

This criterion evaluates the anticipated duration and complexity required to implement the alternative, including design, permitting, procurement, construction, and commissioning. Factors considered may include equipment fabrication lead times, constructability, integration with existing facilities, and potential impacts to ongoing plant operations. Alternatives that can be implemented more quickly and with fewer disruptions are generally considered more favorable.

5.6.1.10 Environmental Impacts

The environmental impacts criterion assesses the potential effects of the alternative on the natural and built environment. This includes impacts related to energy consumption, greenhouse gas emissions, chemical usage, residuals generation, land use, noise, odors, and overall sustainability. The evaluation considers both short-term construction-related impacts and long-term operational impacts associated with the alternative.

5.6.1.11 Public Perception

The public perception criterion evaluates how the alternative is likely to be viewed by the surrounding community and other stakeholders. This may include considerations related to visual impacts, odors, noise, traffic, perceived environmental benefits, and overall compatibility with community values and development goals. Alternatives that are more easily understood, less intrusive, and aligned with public expectations generally present lower stakeholder risk.

5.6.2 Alternatives Evaluations

Black & Veatch evaluated four alternatives to treat wastewater to meet AWT standards at the RWPF. The proposed wastewater resource recovery facility alternatives are designed to comply with the recommended water quality targets in Table 1-1.

In this subsection, the screening of all the presented alternatives to achieve AWT standards is performed with the goal of selecting the most suitable alternative for meeting the goals of this project. Each of the alternatives was evaluated according to the criteria in Section 4.1. A summary of the evaluation of each of the alternatives is included in Table 5-16.

Table 5-16 Summary of AWT Alternatives Evaluations

Criteria	Alternative 1 Bardenpho + S2EBPR	Alternative 2 Bardenpho + Chemical TP Removal	Alternative 3 PdNA + Chemical TP Removal
Description of Process	Biological TN and TP removal	Biological TN removal, chemical TP removal	Biological TN removal, chemical TP removal
CAPEX	Highest	Lowest	Low, similar to Alternative 2
OPEX	Moderate. Removes TN & TP biologically. Increased operational complexity with S2EBPR.	Highest. High chemical costs due to alum and external carbon required.	Lowest. Lower aeration power required. Additional chemicals required (alum and external carbon).
TOTEX	Lowest, less influence from chemical cost but requires additional infrastructure.	High. While the CAPEX is low, high Chemical costs are impactful.	Moderate to low. Savings from chemicals and energy use drives this alternative TOTEX down.
Reliability/ Experience	Reliable treatment process. Implemented at many WWTPs across the US.	Reliable treatment process. Implemented at many WWTPs across the US.	Emerging treatment process. Few full-scale installations.
Regulatory Risk	Solid alternative for possible future tighter effluent limits.	Solid alternative for possible future tighter effluent limits.	Solid alternative for possible future tighter effluent limits but not as good as Alternatives No. 1 and 2.
Treatment Performance (TN, P Removal)	High TN and TP removal. Could meet AWT effluent standards reliably.	High TN and TP removal. Could meet AWT effluent standards reliably.	Meeting AWT TN limits will not be as easy compared to Alternatives 1 and 2.
Expandability	Less able to be expanded.	TN Removal: Less ability to be expanded. TP removal: Easily expanded for future capacity.	TN Removal: Not easily expandable. TP removal: Easily expanded for future capacity.
Operability	Increased complexity of operation with RAS fermenter. Increased process controls, equipment, labor, and O&M required. Requires more operator and lab work attention.	Requires more operator and lab work attention. Relatively simple operation (chemical feed systems). Overfeeding alum could induce bioreactor upsets due to TP limitations.	More complex operation requirements and controls. Requires advanced operations and sophisticated control loops. Requires more operator and lab work attention.
Time and Ease to Implement Alternative	Additional infrastructure required. Longer time to implement.	Moderate infrastructure required. Easiest to implement.	Moderate infrastructure required. Easiest to implement.

Criteria	Alternative 1 Bardenpho + S2EBPR	Alternative 2 Bardenpho + Chemical TP Removal	Alternative 3 PdNA + Chemical TP Removal
Environmental Impact	Reduces TN and TP to AWT levels. Smaller chemical feed usage and footprint for TP removal. Larger biological removal footprint with RAS fermenter. More site impacts compared to other alternatives.	Reduces TN and TP to AWT levels. Higher chemical feed footprint and chemical usage. Higher emissions due to chemical manufacturing. Limited site impacts.	Reduces to TN and TP to limits close to AWT limits. Reduced aeration, alum, and supplemental carbon footprint. Lower emissions due to reduced energy and chemical use. Limited site impacts.
Public Perception	Likely positive, removes TN and TP biologically.	Likely positive, removes TN biologically and TP chemically.	Moderate, as effluent limits are higher than Alternatives 1 & 2. Emerging treatment process configuration with less track record of implementation.

From Table 5-16, the most advantageous AWT Alternative from the TOTEX standpoint is Alternative 1. Alternative 3 is relatively close and can also be implemented with S2EBPR instead of chemical TP removal, which would yield the lowest TOTEX of all. Below are some other considerations for all alternatives:

- Alternative 3 is an emerging treatment technique with few WWTPs practicing PdNA.
- For Alternative 3, achieving AWT-level total nitrogen (TN) limits would be challenging. However, the anticipated performance difference is relatively small — approximately 1 to 1.5 mg/L higher effluent TN compared to AWT Alternatives 1 and 2. The key consideration then becomes whether achieving this additional 1 to 1.5 mg/L of TN removal justifies an estimated 50 to 100 percent increase in CAPEX.
- Operating AWT Alternative 3 would be clearly more challenging, as high level of process control would be required. As such, we included additional O&M labor for this, and more plant staff attention would be required.
- AWT Alternative 2 is the simplest to implement, but the TOTEX is the highest of all.
- AWT Alternative 1 has more CAPEX compared to AWT Alternative 2, but over the life cycle of the project, the savings in chemicals reduce the overall TOTEX.

5.7 Recommendations

Based on the information provided below, Black & Veatch recommends the AWT Alternative 1 / four-stage Bardenpho / S2EBPR for the possible implementation of AWT at the RWPF, due to the following reasons:

- AWT Alternative 1 has the lowest TOTEX of all alternatives.
- AWT Alternative 1 has similar operational characteristics to the existing MLE process, making it relatively easy for the current operation staff to implement.
- AWT Alternative 1 does not rely on chemical addition for TP removal which hedges against future price escalation of chemicals used for TP removal.

- AWT Alternative 1 is a very well-established process showing excellent performance for meeting AWT limits reliably.
- Unlike Alternative 3, Alternative 1 does not require a lot more operational input from the plant staff compared to the existing treatment process.

5.8 Limitations of the Opinion Probable Construction Costs

The OPCC estimate was based on 2026 prices and on a conceptual level of design detail and information as required to develop a Class 5 OPCC in accordance with AACE. As such, this estimate is preliminary and has a range of uncertainty, and this should always be communicated to the OPCC recipient. Each OPCC estimate is prepared for guidance in project evaluation and implementation from the information available at the time the estimate was developed. The final costs of a project will depend on actual labor and material cost, competitive market conditions, final project scope, implementation schedule, and other variable conditions such as market events beyond the control of Black & Veatch and its client, and political events. As a result, the OPCC does not represent a certainty, and construction costs may vary from the OPCC range presented.

The estimate is based on the project being advertised on a competitive bid basis. All contractors are equal, with a reasonable project schedule, non-restricted subcontractor pool, no overtime, and constructed as under a single contract with no liquidated damages. If a project is bid with a limited number of bidders, affecting the competitive process, the result could increase the estimated project cost considerably.

Appendix A. Supporting Materials OPCC

Project:	**City of Marco Island**
Client:	**Marco Island**
Descripti	**AWT Alternative 1 - Rough Order of Magnitude - Four-Stage Bardenpho + S2EBPR**

Opinion of Probable Construction Cost (Class 5)

	Cost Item	%		Cost	Cost Totals	S/C	Probability Distribution
	DIRECT COSTS					S/C	
	Key Process Equipment						
	Second Anoxic Mixing			$ 404,520.13			Ext Min Val
	Removal of diffuser headers in post-anoxic zone			$ 100,000.00			Logistic
	Replace diffusers in aeration zones (fine bubble)			$ 117,808.34			Weibull
	DO sensors			$ 21,438.04			Normal
	Other sensors and probes (ORP, NH4, NO3, PO4)			$ 53,595.11			Normal
	Valves for Aeration Header			$ 196,347.23			Weibull
	RAS Recycle pumps for RAS Fermenter			$ 53,595.11			Normal
	Submersible Mixers - RAS fermenter			$ 53,595.11			Normal
	Micro C Tanks			$ 53,595.11			Normal
	Micro C Dosing System			$ 75,033.15			Normal
				$ -			
				$ -			
				$ -			
				$ -			
				$ -			
A	***Subtotal - Key Process Equipment***				**$ 1,129,527**		
	BOP Mechanical Equipment						
	Base Mechanical BOP Equipment	20%	of Key Process Eqpt	$ 242,148.56		X	Normal
	Additional Adjustment for project specific scope						
	1						
	2						
B	***Subtotal BOP Mechanical Equipment***				**$ 242,149**		
	Mechanical Equipment Install						
	Base Mechanical Install Cost	30%	of Key Process & BOP Eqpt	$ 441,090.72		X	Normal
	Additional Adjustment for project specific Scope						
	1					X	
	2					X	
	3					X	
C	***Subtotal Mech Install***				**$ 441,091**		
	Mechanical Piping, valves, etc.						
	Base Mechanical Piping Cost (incl. install)	15%	of Key Process & BOP Eqpt	$ 220,545.36		X	Normal
	Additional Adjustment for project specific Scope						
	1						
	2						
D	***Subtotal Mech Piping***				**$ 220,545**		
	Site Civil Work						
	Base Civil Site Scope	4%	of all above items	$ 87,180.46		X	Normal
	Additional adjustment for project specific scope						
	1						
	2						
E	***Subtotal Site Civil Work***				**$ 87,180**		
	Buildings & Building Mechanical						
	1 Canopy			$ 107,190.22		X	Normal
	2						
F	***Subtotal Building & Building Mech***				**$ 107,190**		
	Concrete & Structural						
	FRP Baffle Walls / Mixing Chimneys			$ 52,523.21		X	Normal
	New 0.3 Mgal Tank			$ 643,141.31			Normal
	Walkways/Stairs			$ 42,876.09			Normal
	Containment Area	51.11	1,500.00	$ 82,536.47			Normal
G	***Subtotal Concrete & Structural***				**$ 821,077**		
	Electrical and I&C						
	Base Electrical Cost (incl. install)	12%	of Key process, BOP Mech & bldg	$ 178,796.72		X	Normal
	Base I&C Cost (incl. install)	10%	of Key process, BOP Mech & bldg	$ 148,997.27		X	Normal
	Additional Adjustment for project specific Scope						
	1 DO sensors						
	2 Other sensors and probes (ORP, NH4, NO3, PO4)						
H	***Subtotal EI&C***				**$ 327,794**		
I	**Subcontract Markup**	15%	of all costs marked "X" above		**$ 221,771**		

J	**TOTAL DIRECT COSTS**				**$ 3,598,325**		
	INDIRECT COSTS						
	GENERAL CONDITIONS (CMCI)						
K	All work subcontracted out	12%	of Direct Costs	--------------->	**$ 431,799**	X	
	Mix of subcontract and self-perform	15%	of Direct Costs	--------------->	**$ -**		
	All work self-performed	18%	of Direct Costs	--------------->	**$ -**		
	Other adjustments(extended startup, fragmenetd schedule, etc.)						
	DESIGN & HO MGMT (Burdened Cost)						
	Management (incl. Procurement, Estimating, etc.)	4%	of all Direct Costs & CMCI	**$ 161,205**			
	Initial Study (to 15%)	2%	of all Direct Costs & CMCI	**$ 80,602**		X	
	Engineering to GMP (15 to 60%)	3%	of all Direct Costs & CMCI	**$ 120,904**		X	
	Detailed Engineering (60% to 100% IFC)	4%	of all Direct Costs & CMCI	**$ 161,205**		X	
	Construction Phase Support (RFI's, Submittals, etc.)	3%	of all Direct Costs & CMCI	**$ 120,904**		X	
	Enginering adjustment - to account for project specific scope (Burdened Salary)						
	Other engineering Costs (subs, etc.) Permits	0.5%		$ 20,151			
L	***Subtotal - Engineering & HO Mgmt***				**$ 664,970**		
M	**BONDING & INSURANCES**	2.0%	of all costs above	--------------->	**$ 93,902**		
	SALES TAX - applied to materials & equipment	0.0%	of 50% of Direct Costs	--------------->	**$ -**		
	CONTINGENCY (sum of J + K+ L + M)	35.0%	of all costs above	--------------->	**$ 2,102,893**		Lognorm
	TOTAL INDIRECT COSTS				**$ 3,293,564**		
	OVERHEAD & PROFIT	12%	of all costs above		**$ 827,027**		
	TOTAL CONSTRUCTION PRICE				**$ 7,718,916**		

Values above represent one static run only.

Project: City of Marco Island
Client: Marco Island
Descripti AWT Alternative 2 - Rough Order of Magnitude - Four-Stage Bardenpho + Chemical Phosphorus Removal

Opinion of Probable Construction Cost (Class 5)

	Cost Item	%		Cost	Cost Totals		Probability Distribution
	DIRECT COSTS					S/C	
	Key Process Equipment						
	Second Anoxic Mixing			$404,520.13			Ext Min Val
	Removal of diffuser headers in post-anoxic zone			$100,000.00			Logistic
	Replace diffusers in aeration zones (fine bubble)			$117,808.34			Weibull
	DO sensors			$21,438.04			Normal
	Other sensors and probes (ORP, NH4, NO3, PO4)			$53,595.11			Normal
	Valves for Aeration Header			$196,347.23			Weibull
	Alum Tanks			$53,595.11			Normal
	Alum Dosing System			$75,033.15			Normal
	Micro C Tanks			$53,595.11			Normal
	Micro C Dosing System			$75,033.15			Normal
				$0.00			
				$0.00			
				$0.00			
				$0.00			
				$0.00			
A	***Subtotal - Key Process Equipment***				**$ 1,150,965**		
	BOP Mechanical Equipment						
	Base Mechanical BOP Equipment	20%	of Key Process Eqpt	$ 241,606.75		X	Normal
	Additional Adjustment for project specific scope						
	1						
	2						
B	***Subtotal BOP Mechanical Equipment***				**$ 241,607**		
	Mechanical Equipment Install						
	Base Mechanical Install Cost	30%	of Key Process & BOP Eqpt	$ 434,892.15		X	Normal
	Additional Adjustment for project specific Scope						
	1					X	
	2					X	
	3					X	
C	***Subtotal Mech Install***				**$ 434,892**		
	Mechanical Piping, valves, etc.						
	Base Mechanical Piping Cost (incl. install)	15%	of Key Process & BOP Eqpt	$ 217,446.08		X	Normal
	Additional Adjustment for project specific Scope						
	1						
	2						
D	***Subtotal Mech Piping***				**$ 217,446**		
	Site Civil Work						
	Base Civil Site Scope	4%	of all above items	$ 84,079.15		X	Normal
	Additional adjustment for project specific scope						
	1						
	2						
E	***Subtotal Site Civil Work***				**$ 84,079**		
	Buildings & Building Mechanical						
	1 Canopy			$ 160,785.33		X	Normal
	2						
F	***Subtotal Building & Building Mech***				**$ 160,785**		
	Concrete & Structural						
	FRP Baffle Walls / Mixing Chimneys			$ 52,523.21		X	Normal
				$ -			Normal
	Walkways/Stairs			$ 42,876.09			Normal
	Containment Area	102.22	1,500	$ 164,001.03			Normal
G	***Subtotal Concrete & Structural***				**$ 259,400**		
	Electrical and I&C						
	Base Electrical Cost (incl. install)	12%	of Key process, BOP Mech & bldg	$ 181,641.99		X	Normal
	Base I&C Cost (incl. install)	10%	of Key process, BOP Mech & bldg	$ 151,368.33		X	Normal
	Additional Adjustment for project specific Scope						
	1 DO sensors						
	2 Other sensors and probes (ORP, NH4, NO3, PO4)						
H	***Subtotal EI&C***				**$ 333,010**		
I	**Subcontract Markup**	15%	of all costs marked "X" above		**$ 228,651**		
J	**TOTAL DIRECT COSTS**				**$ 3,110,837**		

	INDIRECT COSTS									
	GENERAL CONDITIONS (CMCI)									
K	All work subcontracted out	12%	of Direct Costs			--------------->	**$**	**373,300**	X	
	Mix of subcontract and self-perform	15%	of Direct Costs			--------------->	**$**	**-**		
	All work self-performed	18%	of Direct Costs			--------------->	**$**	**-**		
	Other adjustments(extended startup, fragmenetd schedule, etc.)									
	DESIGN & HO MGMT (Burdened Cost)									
	Management (incl. Procurement, Estimating, etc.)	4%	of all Direct Costs & CMCI	**$**	**139,365**					
	Initial Study (to 15%)	2%	of all Direct Costs & CMCI	**$**	**69,683**				X	
	Engineering to GMP (15 to 60%)	3%	of all Direct Costs & CMCI	**$**	**104,524**				X	
	Detailed Engineering (60% to 100% IFC)	4%	of all Direct Costs & CMCI	**$**	**139,365**				X	
	Construction Phase Support (RFI's, Submittals, etc.)	3%	of all Direct Costs & CMCI	**$**	**104,524**				X	
	Enginering adjustment - to account for project specific scope (Burdened Salary)									
	Other engineering Costs (subs, etc.)	0.5%		$	17,421					
L	***Subtotal - Engineering & HO Mgmt***						**$**	**574,883**		
M	**BONDING & INSURANCES**	2%	of all costs above			--------------->	**$**	**81,180**		
	SALES TAX - applied to materials & equipment	0%	of 50% of Direct Costs			--------------->	**$**	-		
	CONTINGENCY (sum of J + K+ L + M)	35%	of all costs above			--------------->	**$**	**1,818,001**		Lognorm
	TOTAL INDIRECT COSTS						**$**	**2,847,364**		
	OVERHEAD & PROFIT	12%	of all costs above				**$**	**714,984**		
	TOTAL CONSTRUCTION PRICE						**$**	**6,673,186**		

Values above represent one static run only.

Project: City of Marco Island
Client: Marco Island
Descripti AWT Alternative 3 - Rough Order of Magnitude - PdNA + Chemical Phosphorus Removal

Opinion of Probable Construction Cost (Class 5)

		Cost Item	%			Cost	Cost Totals		Probability Distribution
		DIRECT COSTS						S/C	
		Key Process Equipment							
		Second Anoxic / PdNA Mixing				$ 404,520.13			Ext Min Val
		Removal of diffuser headers in post-anoxic zone				$ 100,000.00			Logistic
		Replace diffusers in aeration zones (fine bubble)				$ 117,808.34			Weibull
		DO sensors				$ 21,438.04			Normal
		Other sensors and probes (ORP, NH4, NO3, PO4)				$ 53,595.11			Normal
		Valves for Aeration Header				$ 196,347.23			Weibull
		Alum Tanks				$ 37,516.58			Normal
		Alum Dosing System				$ 75,033.15			Normal
		Micro C Tanks				$ 37,516.58			Normal
		Micro C Dosing System				$ 75,033.15			Normal
						$ -			
						$ -			
						$ -			
						$ -			
						$ -			
A		***Subtotal - Key Process Equipment***					**$ 1,118,808**		
		BOP Mechanical Equipment							
		Base Mechanical BOP Equipment	20%	of Key Process Eqpt		$ 235,175.34		X	Normal
		Additional Adjustment for project specific scope							
	1								
	2								
B		***Subtotal BOP Mechanical Equipment***					**$ 235,175**		
		Mechanical Equipment Install							
		Base Mechanical Install Cost	30%	of Key Process & BOP Eqpt		$ 423,315.61		X	Normal
		Additional Adjustment for project specific Scope							
	1							X	
	2							X	
	3							X	
C		***Subtotal Mech Install***					**$ 423,316**		
		Mechanical Piping, valves, etc.							
		Base Mechanical Piping Cost (incl. install)	15%	of Key Process & BOP Eqpt		$ 211,657.81		X	Normal
		Additional Adjustment for project specific Scope							
	1								
	2								
D		***Subtotal Mech Piping***					**$ 211,658**		
		Site Civil Work							
		Base Civil Site Scope	4%	of all above items		$ 81,841.02		X	Normal
		Additional adjustment for project specific scope							
	1								
	2								
E		***Subtotal Site Civil Work***					**$ 81,841**		
		Buildings & Building Mechanical							
	1	Canopy				$ 160,785.33		X	Normal
	2								
F		***Subtotal Building & Building Mech***					**$ 160,785**		
		Concrete & Structural							
		FRP Baffle Walls / Mixing Chimneys				$ 128,628.26		X	Normal
						$ -			Normal
		Walkways/Stairs				$ 42,876.09			Normal
		Containment Area	102.22		1,500	$ 164,001.03			Normal
G		***Subtotal Concrete & Structural***					**$ 335,505**		
		Electrical and I&C							
		Base Electrical Cost (incl. install)	12%	of Key process, BOP Mech & bldg		$ 177,289.55		X	Normal
		Base I&C Cost (incl. install)	10%	of Key process, BOP Mech & bldg		$ 147,741.29		X	Normal
		Additional Adjustment for project specific Scope							
	1	**DO sensors**							
	2	**Other sensors and probes (ORP, NH4, NO3, PO4)**							
H		***Subtotal EI&C***					**$ 325,031**		
I		**Subcontract Markup**	15%	of all costs marked "X" above			**$ 234,965**		
J		**TOTAL DIRECT COSTS**					**$ 3,127,085**		

	INDIRECT COSTS									
	GENERAL CONDITIONS (CMCI)									
K	All work subcontracted out	12%	of Direct Costs			--------------->	$	375,250	X	
	Mix of subcontract and self-perform	15%	of Direct Costs			--------------->	$	-		
	All work self-performed	18%	of Direct Costs			--------------->	$	-		
	Other adjustments(extended startup, fragmenetd schedule, etc.)									
	DESIGN & HO MGMT (Burdened Cost)									
	Management (incl. Procurement, Estimating, etc.)	4%	of all Direct Costs & CMCI	$	140,093					
	Initial Study (to 15%)	2%	of all Direct Costs & CMCI	$	70,047				X	
	Engineering to GMP (15 to 60%)	3%	of all Direct Costs & CMCI	$	105,070				X	
	Detailed Engineering (60% to 100% IFC)	4%	of all Direct Costs & CMCI	$	140,093				X	
	Construction Phase Support (RFI's, Submittals, etc.)	3%	of all Direct Costs & CMCI	$	105,070				X	
	Enginering adjustment - to account for project specific scope (Burdened Salary)									
	Other engineering Costs (subs, etc.)	0.5%		$	17,512					
L	***Subtotal - Engineering & HO Mgmt***						$	577,885		
M	**BONDING & INSURANCES**	2%	of all costs above			--------------->	$	81,604		
	SALES TAX - applied to materials & equipment	0%	of 50% of Direct Costs			--------------->	$	-		
	CONTINGENCY (sum of J + K+ L + M)	35%	of all costs above			--------------->	$	1,827,496		Lognorm
	TOTAL INDIRECT COSTS						$	2,862,236		
	OVERHEAD & PROFIT	12%	of all costs above				$	718,719		
	TOTAL CONSTRUCTION PRICE						**$**	**6,708,039**		

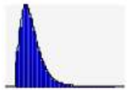
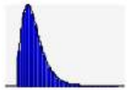
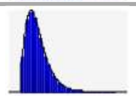
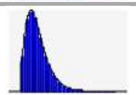
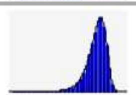
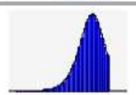
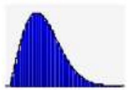
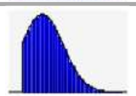
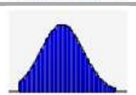
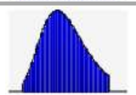
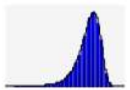
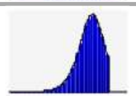
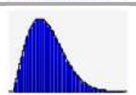
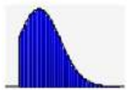
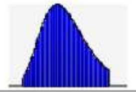
Values above represent one static run only.

$5M to $10M

Inputs

Report: Summary Statistics Report
Performed By: bot32745
Date: Friday, February 20, 2026

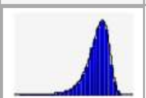
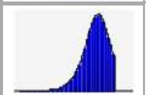
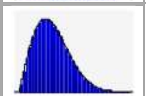
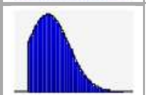
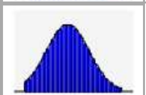
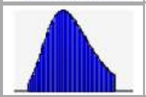
Summary Statistics

Input	Cell	Graphs	Function	Minimum	Maximum	Mean	Std Dev	5%	95%
$/kwh	'CAPEX and OPEX...		RiskLognorm (1.2,0.5,RiskShift(0.5),...	1.0003	5.5915	1.7183	0.4914	1.1175	2.6475
$/gal	'CAPEX and OPEX...		RiskLognorm (1.2,0.5,RiskShift(0.5),...	1.0003	5.3009	1.7183	0.4909	1.1177	2.6479
$/d / $100/ft	'CAPEX and OPEX...		RiskLognorm (1.2,0.5,RiskShift(0.5),...	1.0004	5.1051	1.7183	0.4910	1.1176	2.6487
$/hr / $/yr / $100/ft	'CAPEX and OPEX...		RiskLognorm (1.2,0.5,RiskShift(0.5),...	1.0004	5.0946	1.7183	0.4907	1.1175	2.6473
Second Anoxic Mixing...	'A.1 CAPEX Varia...		RiskExtvalueMin (0.9,0.09)	-0.15664	1.09610	0.84801	0.11574	0.63260	0.99866
Removal of diffus...	'A.1 CAPEX Varia...		RiskLogistic (1,0.1,RiskTruncate2(,1...	0.08934	1.19992	0.95853	0.14652	0.69203	1.16330
Replace diffusers in aer...	'A.1 CAPEX Varia...		RiskWeibull (2,0.8,RiskShift(0.6),Ris...	0.6107	2.9537	1.3090	0.3706	0.7812	1.9839
DO sensors / Distr...	'A.1 CAPEX Varia...		RiskNormal (1,0.25,RiskTruncate2(0...	0.75008	1.96726	1.07190	0.19840	0.79009	1.43158
X / Distribution	'A.1 CAPEX Varia...		RiskNormal (1,0.2,RiskTruncate2(0....	0.60001	1.49803	1.00751	0.18357	0.70654	1.31974
of all costs above	'A.1 CAPEX Varia...		RiskLognorm (1,0.3,RiskShift(0.3),Ris...	0.75050	1.79964	1.25460	0.23427	0.89340	1.67319
Second Anoxic Mixing...	'A.2 CAPEX Varia...		RiskExtvalueMin (0.9,0.09)	0.09165	1.10016	0.84805	0.11542	0.63267	0.99871
Removal of diffus...	'A.2 CAPEX Varia...		RiskLogistic (1,0.1,RiskTruncate2(,1...	0.02263	1.19997	0.95851	0.14664	0.69214	1.16342
Replace diffusers in aer...	'A.2 CAPEX Varia...		RiskWeibull (2,0.8,RiskShift(0.6),Ris...	0.6074	2.9705	1.3090	0.3706	0.7811	1.9841
DO sensors / Distr...	'A.2 CAPEX Varia...		RiskNormal (1,0.25,RiskTruncate2(0...	0.75014	1.95714	1.07190	0.19840	0.79011	1.43174
X / Distribution	'A.2 CAPEX Varia...		RiskNormal (1,0.2,RiskTruncate2(0....	0.60060	1.49990	1.00751	0.18356	0.70668	1.31986
of all costs above	'A.2 CAPEX Varia...		RiskLognorm (1,0.3,RiskShift(0.3),Ris...	0.75071	1.79974	1.25460	0.23427	0.89345	1.67290

Inputs

Report: Summary Statistics Report
Performed By: bot32745
Date: Friday, February 20, 2026

Summary Statistics

Input	Cell	Graphs	Function	Minimum	Maximum	Mean	Std Dev	5%	95%
Second Anoxic / PdNA...	'A.3 CAPEX Varia...		RiskExtvalueMin(0.9,0.09)	0.04473	1.10241	0.84805	0.11543	0.63259	0.99875
Removal of diffus...	'A.3 CAPEX Varia...		RiskLogistic(1,0.1,RiskTruncate2(,1...	0.06689	1.19991	0.95852	0.14658	0.69198	1.16331
Replace diffusers in aer...	'A.3 CAPEX Varia...		RiskWeibull(2,0.8,RiskShift(0.6),Ris...	0.6016	2.9599	1.3090	0.3705	0.7809	1.9840
DO sensors / Distr...	'A.3 CAPEX Varia...		RiskNormal(1,0.25,RiskTruncate2(0...	0.75014	1.89826	1.07189	0.19835	0.79023	1.43146
X / Distribution	'A.3 CAPEX Varia...		RiskNormal(1,0.2,RiskTruncate2(0....	0.60017	1.49912	1.00751	0.18357	0.70665	1.31975
of all costs above	'A.3 CAPEX Varia...		RiskLognorm(1,0.3,RiskShift(0.3),Ris...	0.75065	1.79998	1.25460	0.23427	0.89347	1.67326