FINAL

TM 4.3 - AERATION AND NUTRIENT REMOVAL

NEW Water Facility Plan

B&V PROJECT NO. 402658

PREPARED FOR

NEW Water
The brand of the Green Bay Metropolitan Sewerage District

Green Bay Metropolitan Sewerage District

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DONOHUE

Table of Contents

Executive Summary ES-1
1.0 Introduction 1-1
1.1 Drivers for Aeration Basin Improvements 1-2
1.2 Relationship to Overall Facility Plan 1-2
1.3 Technical Memorandum Approach 1-3
2.0 Infrastructure Gaps and Process Limitations – GBF 2-1
2.1 Infrastructure Limitations 2-1
2.2 Process Limitations 2-1
2.2.1 Effluent Performance 2-1
2.2.2 Settleability 2-4
2.2.3 Aeration 2-10
2.3 Gaps and Process Limitations Summary 2-13
3.0 Preliminary Process Configuration Simulations – GBF 3-1
3.1 Process Configurations 3-1
3.1.1 Nutrient Removal Impacts 3-3
3.1.2 Settleability Impacts 3-5
3.1.3 Aeration Impacts 3-7
3.1.4 Process Configuration for Further Consideration 3-8
3.2 Sidestream Nitrogen Treatment Impacts 3-8
3.3 Recommended Improvements 3-9
4.0 Infrastructure Improvements – GBF Aeration Basins 4-1
4.1 Configuration Modifications 4-1
4.2 Diffuser Modifications 4-1
4.3 Low DO Control 4-3
4.4 Capital Costs 4-4
5.0 Infrastructure Improvements - Sidestream Treatment 5-1
5.1 Sidestream Nitrogen Treatment Technologies 5-1
5.1.1 Traditional Nitrification-Denitrification 5-2
5.1.2 Nitrite Shunt (Nitritation-Denitritation) 5-2
5.1.3 Deammonification 5-3
5.1.4 Design Criteria and Evaluation Approach 5-4
5.1.5 Sidestream Nitrogen Alternatives 5-4
5.1.6 Post-Aerobic Digestion (PAD) 5-4
5.1.7 ANITA Mox 5-5
5.1.8 DEMON 5-7
5.1.9 AnammoPAQ 5-9
5.2 Summary of Sidestream Nitrogen Removal Alternatives 5-10

6.0 Infrastructure Improvements – GBF Blowers 6-1
6.1 Airflow Simulations 6-1
6.2 Blower Sizing 6-4
6.3 Blower System Alternatives 6-5
6.3.1 Alternative 1 6-6
6.3.2 Alternative 2 6-7
6.4 Capital Cost 6-8
6.5 Potential Energy Saving with New Blowers 6-8
6.6 Additional Upgrades 6-9
6.6.1 Air Header 6-9
6.6.2 MCC Replacement 6-9
6.6.3 Electrical Conduit and Conductors 6-9
6.7 GFB Blower Recommendations 6-10
7.0 Future DPF Considerations 7-1
8.0 Applied Research 8-1
8.1 Diffuser Densities and Control 8-1
8.2 A2O Modifications 8-1
8.3 DPF Testing 8-1
9.0 Discussion and Recommendations 9-1
Appendix A. Cost Estimate Support Details A-1

LIST OF TABLES

Table 1-1 Multipliers Used to Determine Total Construction Costs 1-3
Table 2-1 Current GBF Effluent Limitations 2-2
Table 2-2 Percent of Time at Minimum Airflows in 2019 2-12
Table 3-1 Simulated Impacts of Sidestream Flow Treatment on Nutrient Removal 3-9
Table 4-1 North Plant Diffuser Evaluation 4-2
Table 4-2 South Plant Diffuser Evaluation 4-2
Table 4-3 Capital Cost Estimates for Aeration Basin Modifications 4-4
Table 5-1 Comparison of Sidestream Treatment Nitrogen Removal Design and Operating Criteria* 5-3
Table 5-2 Sidestream Treatment Max Month Design Criteria 5-4
Table 5-3 PAD Advantages and Disadvantages 5-5
Table 5-4 ANITA Mox Advantages and Disadvantages 5-7
Table 5-5 DEMON Advantages and Disadvantages 5-8
Table 5-6 AnammoPAQ Advantages and Disadvantages 5-9
Table 5-7 Comparison of Sidestream Treatment Nitrogen Removal Process Design Criteria 5-10

Table 6-1 Scenarios Simulated for Airflow Projections; Each Scenario was Simulated for 2018 Dynamic, 2025 Dynamic, and 2040 Steady State Loadings 6-2
Table 6-2 Airflow Rates in (scfm) for Each Zone in Operation During the Simulations 6-3
Table 6-3 Design Airflow Ranges 6-3
Table 6-4 Design Conditions for the Blowers 6-5
Table 6-5 Summary of Blower Arrangement Alternatives 6-5
Table 6-6 Summary of Blower Arrangement for Alternative 1 6-6
Table 6-7 Summary of Blower Arrangement for Alternative 2 6-7
Table 6-8 Summary of Economic Analysis for the New Blowers 6-8
Table 6-9 Summary of Energy Saving for the Blower Replacement Project (Based on 2020 Loadings) 6-9
Table 6-10 Summary of Economic Analysis for Alternative 1 Phasing 6-10
Table 7-1 Capital Costs for the DPF 7-3
Table 9-1 Infrastructure Packages Developed to Address Aeration and Nutrient Removal Drivers 9-2
Table 9-2 Recommended Infrastructure Packages for the Facility Plan Capital Improvements Plan 9-3

LIST OF FIGURES

Figure 2-1 GBF Effluent Performance Summary for the Past 10 Years 2-3
Figure 2-2 Phosphorus Release Ratio in the NP During Special Sampling in 2019 2-4
Figure 2-3 Historic SVI Summary for GBF 2-5
Figure 2-4 SVI by Month for Each Train in GBF (North and South) for 2009 through 2019 2-5
Figure 2-5 BOD F/M Loading in GBN and GBS First Selector Zones for the Previous Ten Years 2-6
Figure 2-6 COD F/M Loading in GBN and GBS First Selector Zones for the Previous Ten Years 2-6
Figure 2-7 rbCOD F/M Loading in GBN and GBS First Selector Zones for the Previous Ten Years 2-7
Figure 2-8 MLSS in GBN and GBS Aeration Basins for the Previous Ten Years 2-7
Figure 2-9 Selector Zone Effluent Soluble COD (data sown for NP1-SZ2, NP3-SZ2, SP1-SZ2, and NP1-SZ2) 2-8
Figure 2-10 NEW Water Settling Columns and Solids Flux Curve Results 2-9
Figure 2-11 GBF Floc Image 2-9
Figure 2-12 Historic Airflows to the GBF Aeration Basins 2-10
Figure 2-13 Historic Airflows to the GBF Aeration Basins 2-11
Figure 2-14 North Plant Aeration Zones (Image Courtesy of NEW Water) 2-12
Figure 2-15 South Plant Aeration Zones (Image Courtesy of NEW Water) 2-13
Figure 3-1 Process Configurations Considered for the GBF Aeration Basins (Left – South Plant; Right – North Plant) 3-2

Figure 3-2 Nutrient Removal Simulation Results 3-3
Figure 3-3 Simulated PAO Growth in the AO Configuration 3-4
Figure 3-4 rbCOD Profiles for the Three Reactor Configurations 3-5
Figure 3-5 Simulated Growth Profiles 3-6
Figure 3-6 OUR Impacts for the Three Configurations 3-7
Figure 3-7 Simplified Process Flow Diagram for the Addition of a New Sidestream Treatment Unit Process 3-8
Figure 5-1 Nitrogen Removal Biological Transformation Pathways 5-2
Figure 5-2 Depiction of Bacterial Populations Attached to ANITA Mox Media Carriers for MMBR Configurations. Image (Image Courtesy of Veolia) 5-6
Figure 5-3 Images of ANITA Mox Biofilm Carrier Media with Biomass and Media Retention Sieves 5-6
Figure 5-4 Image of the DC Water DEMON System with Inset Anammox Granules (Images Courtesy of DC Water) 5-8
Figure 5-5 AnammoPAQ Anammox Granule Comparison to Anaerobic Granules (Image Courtesy of Ovivo) 5-9
Figure 6-1 Historic BOD Loadings 6-1
Figure 6-2 Summary of Simulated Airflow Ranges in 2025 6-2
Figure 6-3 Comparison of Projected NEW Water Normalized Airflows to Several Facilities and the WEF Benchmark 6-4
Figure 7-1 Potential A2O Layout for the DPF Aeration Basins (preliminary location) 7-1
Figure 7-2 Effluent Nitrogen and Phosphorus for the A2O Configuration at the DPF 7-2
Figure 7-3 Effluent Nitrogen Fractions in the Baseline Model, and with Adjusted Soluble Unbiodegradable COD 7-2

APPENDIX A COST ESTIMATES

Executive Summary

As part of a whole system facility plan for NEW Water, improvements to the aeration basins at both the Green Bay Facility (GBF) and De Pere Facility (DPF) are being considered, as well as improvements to the blower/compressor system at the GBF. There are five key drivers for these improvements for NEW Water:

- Aging equipment: the aeration blowers/compressors at the GBF are over 40 years old, and the air header and electrical systems are in need of significant rehabilitation investment. In addition, previous projects identified the need for future replacement of blowers/compressors at the DPF.
- Energy efficiency: the aging blowers/compressors at the GBF are well maintained and do not cause major maintenance issues, but they are oversized. The result is a significant limitation in terms of operational turndown and energy efficient operation.
- Operational limitations: sludge settleability has been a major issue at the GBF, with average sludge volume index (SVI) values over 200 mL/g. This limits the performance of final clarifiers and hinders efforts to achieve stable, low-level effluent phosphorus concentrations especially during increased hydraulic conditions.
- Future effluent performance: NEW Water already achieves low effluent phosphorus values at both the GBF and DPF related to phosphorus. In addition to identifying operational limitations that impact the stability of phosphorus removal, a path forward to achieve future total nitrogen (TN) limits of 8 mg/L needs to be identified and included in the Facility Plan for both the GBF and the DPF. This value was identified as part of the long-term visioning workshops as a practical target for discharge at an Upper Midwest facility.
- Capacity: the aeration basin capacity at the DPF is a driver for projects, and a third aeration basin was recommended as part of TM 4.4.

Using the flows and loads projections in TM 2.1, the calibrated process model developed in TM 2.3, the regulatory requirements identified in TM 2.4, and the improvements at the De Pere Facility identified in TM 4.4, a series of process improvements were developed and evaluated. These evaluations included:

- Three process configurations for the GBF aeration basins — the existing Anaerobic-Oxic (AO) configuration, modified Ludzag-Ettinger (MLE), and Anaerobic-Anoxic-Oxic (A2O) — for the purposes of achieving better sludge settleability and lower effluent nitrogen levels.
- Reconfiguration of the diffusers in the GBF aeration basins to achieve more efficient aeration.
- An evaluation of several side stream treatment processes for the digester side stream to further reduce effluent nitrogen levels.
- Potential GBF blower reconfigurations using newer blowers to more efficiently deliver air to the aeration basins.
- A new process configuration for the DPF aeration basins to help achieve lower effluent nitrogen levels and improve settleability A third aeration basin is also recommended for the DPF to account for increasing loads, and the new process configuration is recommended to be implemented when the third aeration basin is added.

Key findings of this Technical Memorandum are:

- GBF Process reconfiguration: relatively minor modifications can result in effluent nitrogen below 8 mg/L, effluent total phosphorus below 0.4 mg/L, and improved stability related to sludge settleability and SVI.
- GBF diffuser reconfiguration: should be able to decrease the airflow to the aeration basins by 20 percent to 35 percent from current operation.
- Side stream treatment: will improve stability for both nitrogen and phosphorus removal.
- GBF blower replacement: has the potential to reduce aeration basin energy by up to 58 percent and increase the percentage of produced power from R2E2 from 40 percent to 50 percent of the NEW Water electricity use; this pushes NEW Water closer to their ultimate goal of 75 percent energy production from R2E2 by reducing energy consumption. For capital planning, the full capital cost will be considered. However, a phased implementation approach was developed where two new blowers could be installed in the first phase to realize the majority of the energy savings. The remaining three blowers could be installed when capital is available in the overall capital improvements plan.
- DPF process reconfiguration: achieves effluent nitrogen and phosphorus targets with a modified configuration; the addition of a third aeration basin will provide operational flexibility and increased capacity.

In the process of the evaluations described above, 10 potential infrastructure improvement packages were identified as potential solutions for the NEW Water facilities. Of those ten possible improvement packages, the six packages summarized in Table ES-1 are recommended for incorporation into the NEW Water capital improvement plan. These six packages have the potential to significantly reduce aeration energy while achieving reduced effluent phosphorus concentration and a future effluent total nitrogen limit of 8 mg/L. With an investment in Package 1, 2, and 7, the majority of performance benefits would be realized.

Given the potential impacts of the A2O modifications and the low DO operational strategies, it is recommended that one of the South Plant aeration basins be converted to a demonstration basin to enable testing of the A2O configuration, low DO operation, and stable SRT operation in the near- term to better inform future design and operational strategies. The cost of the demonstration basin construction is estimated as $950,000.

Table ES-1 Recommended Infrastructure Packages for the Facility Plan Capital Improvements Plan

Package	Most Probable Cost	Impacts	Implementation Drivers
Package 1 – A2O Modification	$4.7 M (potential early investment of $950,000 for a single aeration basin)	• Improved settleability stability • Effluent total nitrogen removal • Enables tapered low DO operation and energy savings	• Operational limitations • Effluent performance • Energy efficiency
Package 2 – Low DO instrumentation and control	$0.5M	• Tapered low DO for energy savings • Requires diffuser density modifications with diffuser plugging; potential valving and piping changes	• Operational limitations • Effluent performance • Energy efficiency
Package 4 - AnitaMOX	$15.2M	• Sidestream nitrogen removal provides improved effluent phosphorus stability and future total nitrogen removal improvements • AnitaMOX was the lowest capital and the lowest complexity for operation	• Effluent performance
Package 7 – Five new larger blowers	$26M (potentially for phased blower implementation with early investment of $6.3M)	• Significant energy savings potential, particularly after Package 1 and 2 are implemented • Phased implementation is possible, depending on capital planning	• Agiing infrastructure • Energy efficiency
Package 9 – DPF Aeration Basin Modifications	$1.6M	• Effluent total nitrogen removal • Potential improvements to sludge settling and performance stability	• Operational limitations • Effluent performance • DPF capacity • Likely implemented in conjunction with Package 10
Package 10 – New Aeration Basin	$20M	• Improves DPF capacity and operational stability • Future total nitrogen removal	• Operational limitations • Effluent performance • DPF capacity

1.0 Introduction

The Green Bay Metropolitan Sewerage District, operated under the brand name of NEW Water, collects and treats wastewater from 15 communities in a service area encompassing over 285 square miles with an estimated population of approximately 237,000 in 2019. The NEW Water facility is comprised of the Green Bay Facility (GBF) and the De Pere Facility (DPF). The NEW Water treatment facilities receive domestic, commercial, and industrial wastewater as well as hauled-in waste (HW)/high strength waste (HSW). NEW Water administers an industrial pretreatment program that regulates industrial contributors.

The GBF treated an average of 36.6 million gallons per day (mgd) of total wastewater in 2019 with a liquid treatment train consisting of influent pumping, screening, primary clarification, primary sludge grit removal, activated sludge configured for enhanced biological phosphorus removal (EBPR), secondary clarification, and disinfection with sodium hypochlorite and dechlorinatation with sodium bisulfite. The solids handling treatment train includes sludge thickening with gravity belt thickeners and a thickening centrifuge followed by anaerobic digestion with co-digestion of high strength waste (HSW), centrifuge dewatering, and ending with solids drying and incineration. The GBF receives hauled waste (HW), which is screened and discharged to the plant influent and HSW, which is fed to the digesters. Industrial wastewater flows are separately conveyed to the plant from Green Bay Packaging, Procter & Gamble and Fox River Fiber.

The DPF treated an average of 8.8 mgd in 2019 of wastewater with a treatment train consisting of screening, influent pumping, grit removal, activated sludge configured for enhanced biological phosphorus removal (EBPR), intermediate clarification, final clarification, tertiary sand filters, and UV disinfection. An industrial forcemain pumps waste from the Fox River Fiber industrial customer to downstream of grit removal. Waste activated sludge (WAS) is pumped to the GBF for biosolids processing via a forcemain. In addition, there is an interplant transfer forcemain to the GBF, which provides some flexibility to send DPF influent to the GBF interceptor system for treatment at the GBF. The Fox River Fiber waste can also be transferred to the GBF for treatment via an interplant forcemain.

A full-plant facility plan will identify improvements to the activated sludge system to stabilize performance, plan for future total nitrogen removal, and identify aeration blower/compressor improvements at the GBF. The purpose of Technical Memorandum 4.3 (TM 4.3) is to summarize the historical aeration basin performance at both facilities, evaluate process configurations improvements for the GBF, and identify most feasible alternatives for the Green Bay Metropolitan Sewerage District (NEW Water) Facility Plan. The specific objectives of TM 4.3 are:

1. Summarize infrastructure gaps identified in previous Facility Plan TMs.
2. Evaluate historic performance data to identify the process performance gaps for the GBF.
3. Using the calibrated and validated process model, identify aeration basin configuration improvements that could lead to improved performance at the GBF.
4. Develop infrastructure improvements at both the GBF and DPF for future treatment improvements.
5. Identify potential blower/compressor improvements for the GBF.
6. Provide projected capital and operational costs for each alternative.
7. Recommend which alternative should be implemented going forward.

1.1 Drivers for Aeration Basin Improvements

There are several major drivers for aeration basin improvements at the DPF and GBF over the planning horizon of the Facility Plan:

- Aging equipment: The aeration blowers/compressors at the GBF are over 40 years old, and the air header and electrical systems are in need of significant rehabilitation investment.
- Energy efficiency: The aging blowers/compressors at the GBF are well maintained and do not cause major maintenance issues, but they are oversized. The result is a significant limitation in terms of operational turndown and energy efficient operation.
- Operational limitations: Sludge settleability has been a major issue at the GBF, with average sludge volume index (SVI) values over 200 mL/g. This limits the performance of final clarifiers and hinders efforts to achieve stable, low-level effluent phosphorus concentrations especially during increased hydraulic conditions.
- Future effluent performance: NEW Water already achieves low effluent phosphorus values at both the GBF and DPF related to phosphorus. In addition to identifying operational limitations that impact the stability of phosphorus removal, a path forward to achieve expected future total nitrogen (TN) limits of 8 mg/L needs to be identified and included in the Facility Plan for both the GBF and the DPF.
- Capacity: The aeration basin capacity at the DPF is a driver for projects, and a third aeration basin was recommended as part of TM 4.4.

1.2 Relationship to Overall Facility Plan

This TM has been developed as part of Task 4 of the Facility Plan. Task 1 of the Facility Plan is related to project management at execution. Task 2 of the Facility Plan focused on developing the existing conditions for the NEW Water facilities. In Task 2, the following components are tied to the overall aeration and nutrient removal evaluation:

- TM 2.1 Flows and Loads: The future conditions for both the DPF and GBF are used for performance and aeration projections.
- TM 2.3 Process Model: The process model was used to develop process configurations and airflow requirements.
- TM 2.4 Gap Analysis: Infrastructure gaps identified in the aeration basins will be addressed as part of the thickening improvements.

Task 3 of the Facility Plan identified future drivers for NEW Water, which included the expected 8 mg/L TN limit for planning purposes for the aeration basins. Within Task 4, solutions are being developed to address the gaps identified in Task 2.4 along with the vision developed in Task 3. The recommendations developed as part of this TM and other Task 4 efforts will be combined as part of Task 5 to develop a comprehensive capital improvements plan and infrastructure roadmap for NEW Water.

1.3 Technical Memorandum Approach

The approach taken for this TM was to focus on the GBF process for development of a process configuration, identification of sidestream nitrogen treatment impacts, and the sizing of new aeration blowers/compressors; therefore, Section 2 through 6 will focus on the GBF with the following objectives:

- Section 2: Review historic data and infrastructure gaps to establish process limitations for the GBF.
- Section 3: Identify process configuration modifications that address the needs from Section 2 for the GBF.
- Section 4: Develop process configuration improvements for the GBF aeration basins.
- Section 5: Develop sidestream treatment alternatives for the recycle flows from digestion for the GBF.
- Section 6: Develop blower replacement alternatives for the GBF.

The DPF has already been evaluated in a recent blower project, as well as in TM 4.4. Long-term costs from the previous project will be included in the ultimate CIP as part of the rehabilitation and replacement project list. There is a current recommendation to add a third aeration basin for process stability and capacity. In Section 7, a process configuration will be identified for the existing DPF, as well as the future aeration basin, that achieves future effluent requirements. Section 8 then provides applied research considerations for the GBF and DPF related to aeration and nutrient removal, and Section 9 provides the summary of potential infrastructure improvements.

Total capital costs included in this TM were calculated utilizing construction costs from previous projects completed, similar construction projects completed elsewhere in the past two years, typical installed costs observed from past project experience, and pricing for the main process equipment. Total capital costs were estimated using the percentages listed in Table 1-1. The potential cost ranges presented in the TM represent the range of project costs as defined for a Class 4 cost estimate (AACE International Recommended Practice No. 18R-97), with the range representing 85 percent to 125 percent of that most probable capital cost. Additional cost estimate details are included in **Appendix A**.

Table 1-1 Multipliers Used to Determine Total Construction Costs

Component	Multiplier	Value Multiplied Against
Installation	30%	Equipment
Mechanical	20%	Equipment + Installation
Electrical and I&C	20%	Equipment + Installation
Contractor Overhead and Profit	25%	Installed equipment cost
Contingency	50%	Installed cost + Overhead
Engineering	25%	Installed cost + Overhead + Contingency

2.0 Infrastructure Gaps and Process Limitations – GBF

There are six aeration basins at the GBF: four in the North Plant (NP 1, 2, 3, and 4) and two in the South Plant (SP 1 and 2). Final clarifiers include eight final clarifier for the North Plant and two final clarifiers for the South Plant. Final clarifier capacity and infrastructure gaps have been identified as part of TM 2.3 Process Model Calibration and Validation and 2.4 Infrastructure Gap Analysis for the GBF. The focus of TM 4.3 is identification of the aeration basin gaps and process limitations.

2.1 Infrastructure Limitations

Infrastructure gaps for aeration basins at the GBF were identified in TM 2.4 as:

- Aging infrastructure: The aeration blowers/compressors at the GBF are over 40 years old, and the air header and electrical systems are in need of significant rehabilitation investment.
- Capacity limitations: The aeration basins are not capacity limited through the 2070 expected flows and loads; however, due to the observed settling, the final clarifiers are limiting the overall GBF capacity during increased wastewater flows.
- Operation stability: The biggest constraint is the variable operation of the sludge retention time (SRT) in the aeration basins due to capacity and operational limitations observed in solids processing. The GBF activated sludge process stability is greatly impacted as erratic solids processing operations impacts sidestreams and sludge wasting.

2.2 Process Limitations

Potential process limitations were evaluated based on historic data. The evaluation focused on three key areas:

- Effluent performance
- Settleability
- Aeration

For each of these areas, past performance data will be evaluated. Simulations to understand the cause of the limitations, and potential improvements, are then discussed in Section 3.

2.2.1 Effluent Performance

The current effluent permit limitations are summarized in Table 2-1. Permit changes that are being considered as part of the near-term planning for NEW Water (documented in TM 2.4) that are impacted by aeration basin operation and infrastructure are:

- Low-level phosphorus, with targeted performance of less than 0.35 mg/L as part of the adaptive management program. This target was established as part of the adaptive management program and is based on historic operating data.
- Effluent TSS concentrations below 10 mg/L as part of the adaptive management program.
- Effluent total nitrogen of less than 8 mg/L.

Table 2-1 Current GBF Effluent Limitations

Effluent Parameter	Sampling Frequency	Current GBF Limit	Potential Future Changes
CBOD5	5 times/week	40 mg/L (weekly average) 25 mg/L (monthly average	
Suspended Solids, Total	Daily	45 mg/L (weekly average) 30 mg/L (monthly average)	10 mg/L monthly average
pH	Daily	6 (minimum) 9 (maximum)	
Chlorine, Total Residual	Weekly	38 µg/L (daily maximum, May-Sept)	
Fecal Coliform	Weekly	400#/100 ml (geo mean, May-Sept)	
Nitrogen, Ammonia (NH3-N) Total	GBF: Daily DPF: 5 times/week	Weekly Average: 13 mg/L (May-Sept) 38 mg/L (Oct) Monthly Average: 15 mg/L (Jan-Apr) 4.7 mg/L (May-Sept) 14 mg/L (Oct) 26 mg/L (Nov-Dec)	2 mg/L monthly average
Total Nitrogen (TN)	Daily		8 mg/L
Total Phosphorus	Daily	1.0 mg/L (monthly average)	0.35 mg/L (six-month average)
Mercury, Total Recoverable	Monthly	6.6 ng/L (daily maximum)	

Effluent performance was evaluated for the past 10 years for the GBF effluent. Effluent performance is summarized in Figure 2-1. No permit compliance issues are observed over this time period; however, with respect to effluent phosphorus, three out of the past five full operational years have shown an increased variability in effluent total phosphorus (a larger box is indicative of increased variability for a given year). This may be associated with the variable operation of R2E2 and the introduction of sidestream loadings to the GBF from digestion processes. For total nitrogen removal, nitrate is measured during special sampling campaigns. Typical nitrate is between 8 and 11 mg/L in the combined GBF effluent. This relatively low nitrate concentration is likely driven by the higher return activated sludge (RAS) pumping rate required from the high sludge volume index (SVI) values observed at the GBF.

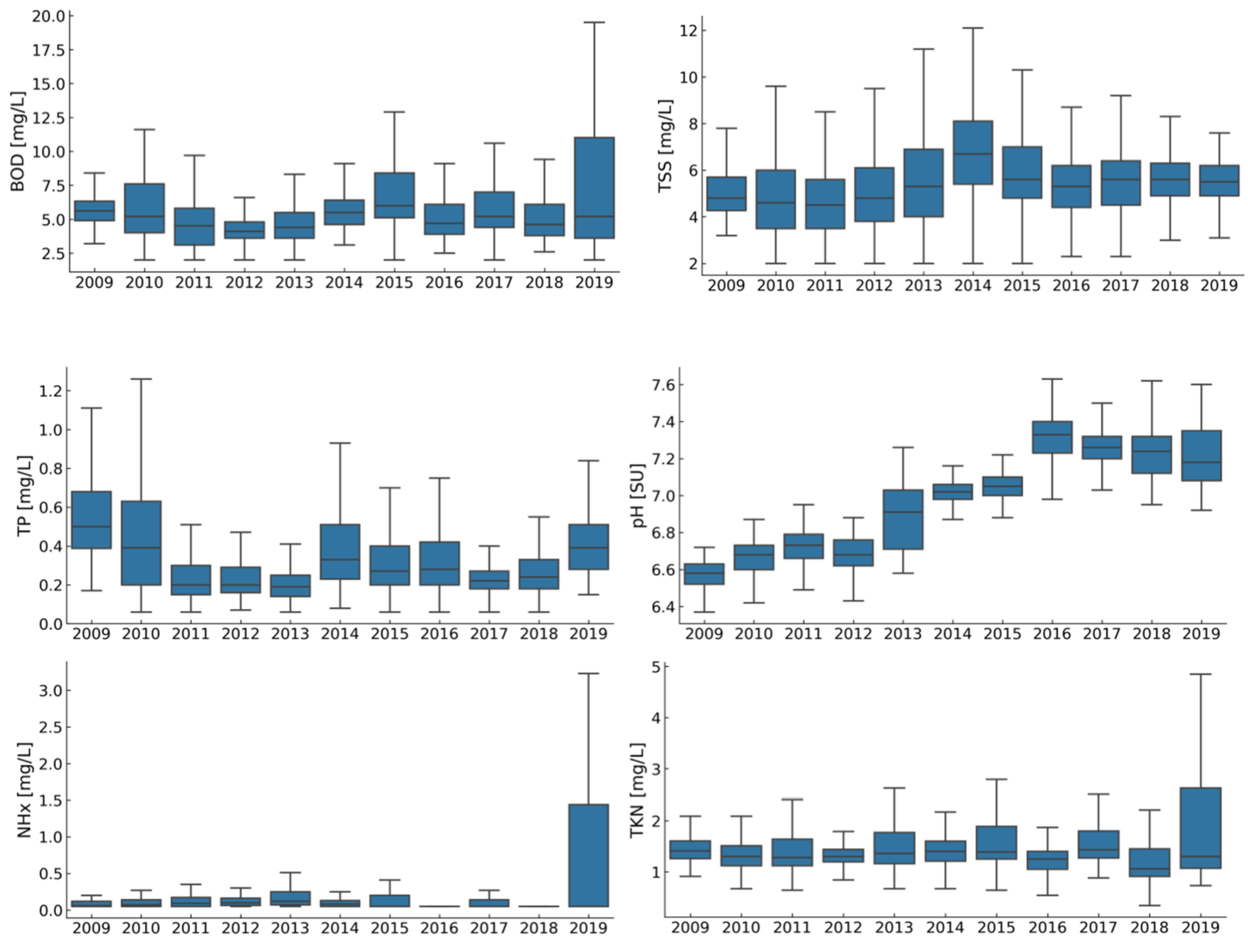

Figure 2-1 GBF Effluent Performance Summary for the Past 10 Years

One significant concern related to effluent phosphorus compliance is the presence and variability of iron and aluminum in the influent wastewater at the GBF. A sampling campaign was completed as part of the R2E2 startup efforts. This previous campaign confirmed the presence of 1 to 3 mg/L of iron and 1 to 3 mg/L of aluminum in the influent. These influent metal concentrations were included as part of the process model calibration and validation (TM 2.3) and a whole plant phosphorus balance was completed after the addition of these metals to the influent. The stability of this influent metal loading and the impact on phosphate accumulating organisms (PAOs) that carry out biological phosphorus removal can be seen by examining the phosphorus release ratio in the selector zones. The phosphorus release ratio is the ratio of selector zone phosphorus to influent phosphorus. When this value is above 1.0, it is indicative of phosphorus release driven by PAO metabolism. When the phosphorus release ratio is less than 1.0, it is indicative of limited PAO activity. As shown in Figure 2-2, the phosphorus release ratio is generally less than 1.0, with periods of high release. This would indicate the PAOs are present in the system, but their metabolism is typically limited by influent metal concentrations. From a process limitation standpoint, the variability in influent metal concentrations drives the need for well-tuned online chemical addition control for phosphorus removal. The GBF already has the instrumentation and control algorithms built in to operation to achieve chemical dosing. In the future, optimization concerning the target concentration and dosing locations will likely be required.

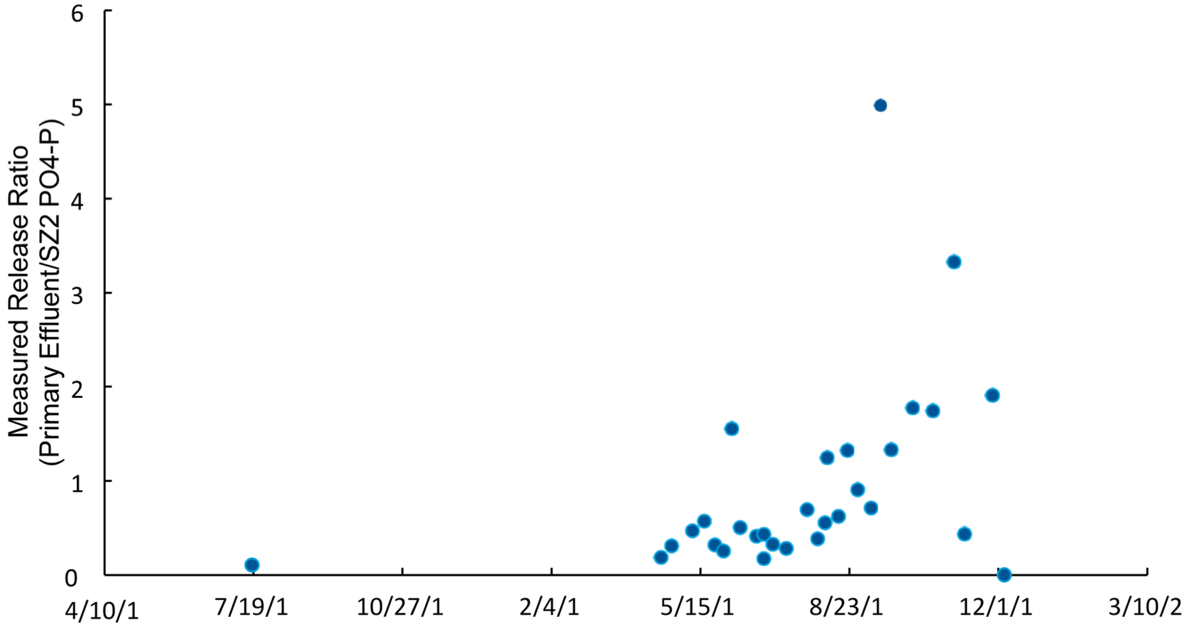

Figure 2-2 **Phosphorus Release Ratio in the NP During Special Sampling in 2019**

2.2.2 Settleability

The ability for activated sludge aggregates to settle in a final clarifier is termed settleability, which is often expressed as a SVI. Settleability of solids in the activated sludge process at the GBF is a major concern for two reasons: particulate phosphorus impacts effluent phosphorus discharge limits, and the ability to meet future TSS limits is tied tightly to the ability to settle solids in the final clarifiers. A lower SVI value is an indicator of better settling sludge, and thus more capacity and better effluent performance. Typically, SVI values below 120 mL/g are considered good settling sludge. GBF SVI data for the past 10 years is summarized in Figure 2-3. There are periods of time where the SVI is less than 100 mL/g, the average SVI each year is typically between 180 and 200 mL/g. SVI performance has decreased after implementation of R2E2 in 2018. This is likely driven by solids processing limitations influencing liquids stream operation. Seasonal SVI trends do indicate improved settling during the majority of summer seasons (Figure 2-4), which can be tied to changes in influent wastewater characteristics and higher bacterial activity during warmer months.

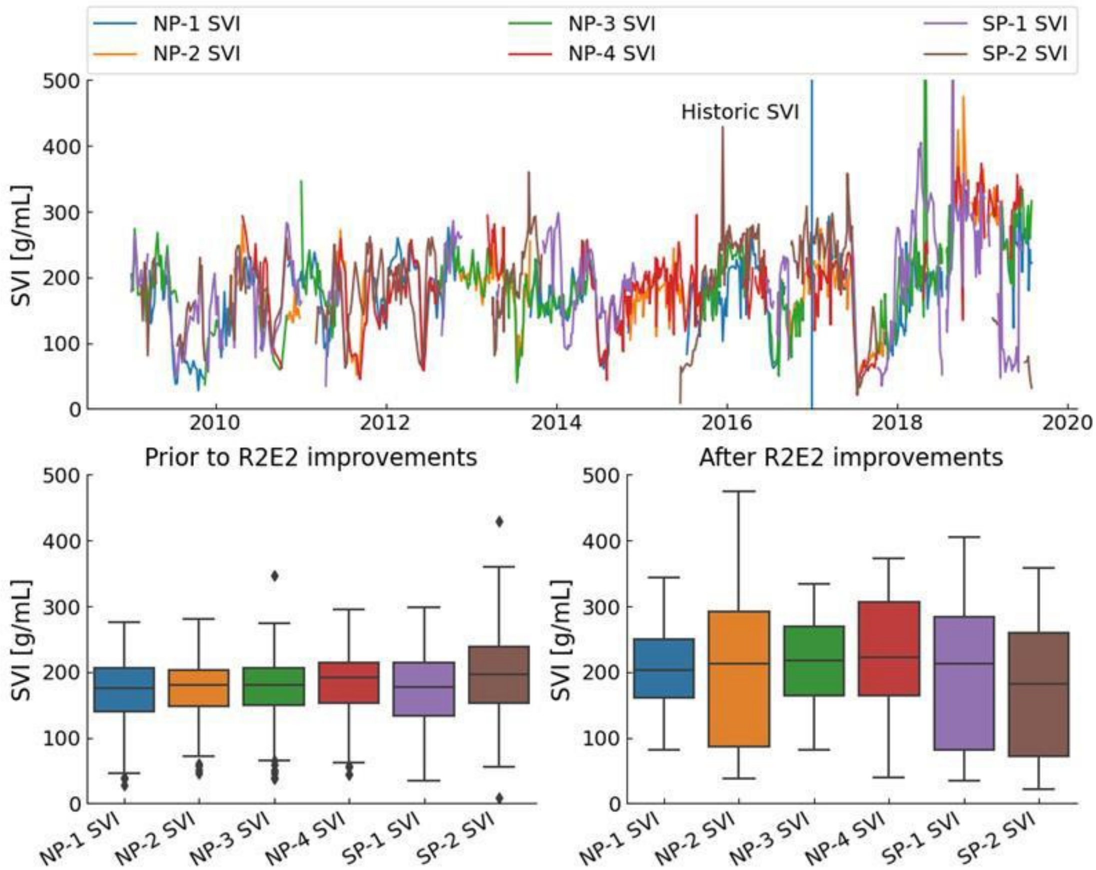

Figure 2-3 Historic SVI Summary for GBF

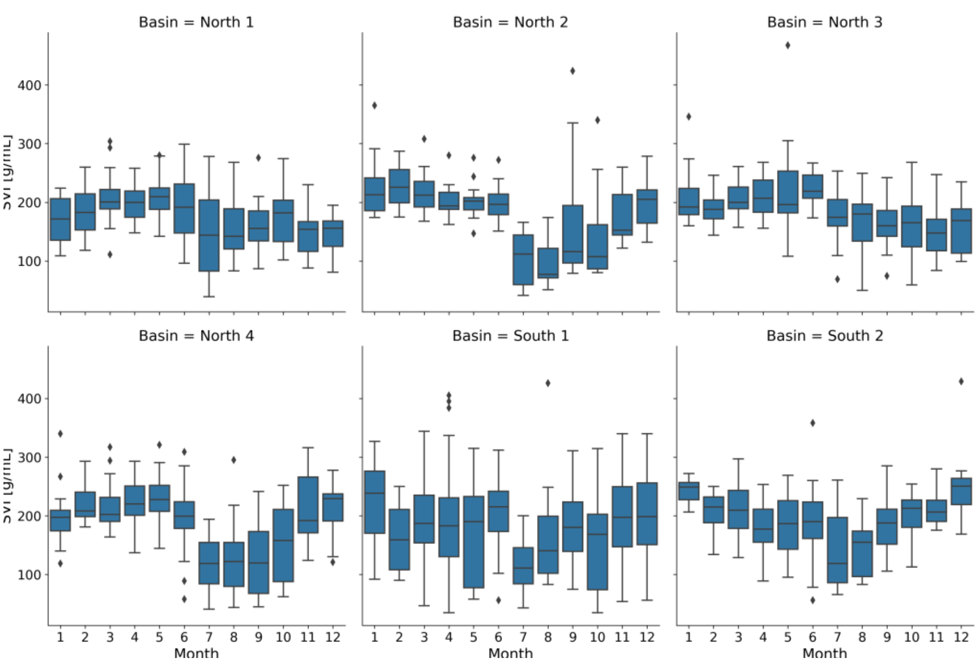

Figure 2-4 SVI by Month for Each Train in GBF (North and South) for 2009 through 2019

One of the key operational parameters that has been tied to good settleability is the food to microorganisms (f/m) ratio in the first selector zone of a process. For good settling sludge, the f/m is important from an average value standpoint, but also from a stability standpoint. A highly variable f/m can result in inconsistent growth pressures in the aeration basin, leading to inconsistent floc formation and filament growth. A recent WRF report summarized past research as well as the most recent activity related to f/m loading rates for BOD, COD, and readily biodegradable COD (rbCOD) (WRF Report 4870, Balancing Flocs and Granules for Activated Sludge Process Intensification in Plug Flow Configurations (2020)). The GBF operating ranges compared to the target values are summarized in Figure 2-5, Figure 2-6, and Figure 2-7 for measured BOD, measured COD, and assumed rbCOD (based on special sampling), respectively. The BOD loading is typically below the target value (1.5 g BOD/gVSS-d), but shows a high level of variability. The COD and rbCOD show periods both above and below the target value (target values are 1.0 g COD/gVSS- d and 0.4 g rbCOD/gVSS-d), but again exhibit a significant amount of variability. Overall, the average f/m loading rates are near the target values, but the high variability would be a key indicator of inconsistent growth pressures that could lead to poor settling conditions.

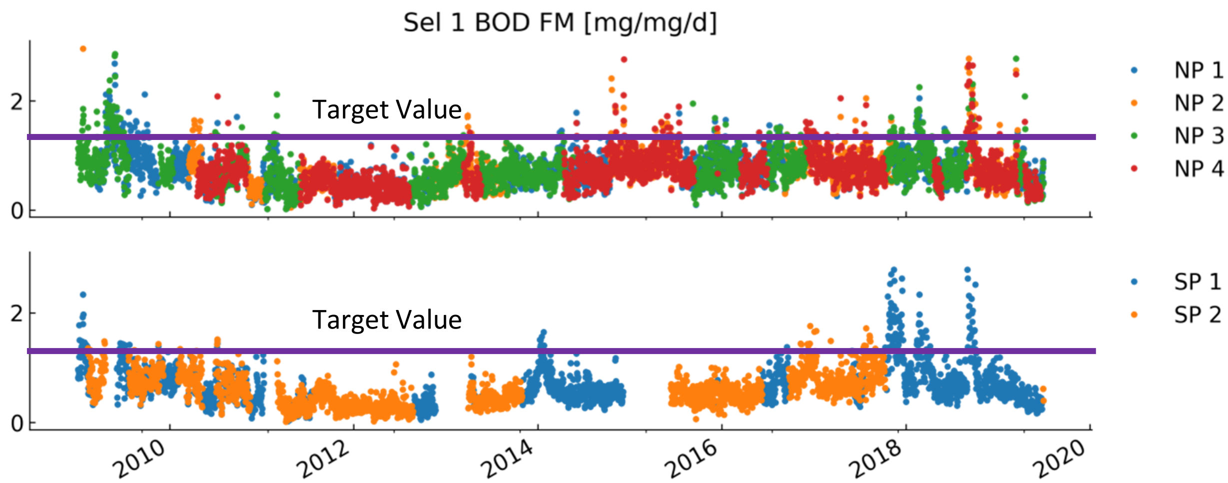

Figure 2-5 BOD F/M Loading in GBN and GBS First Selector Zones for the Previous Ten Years

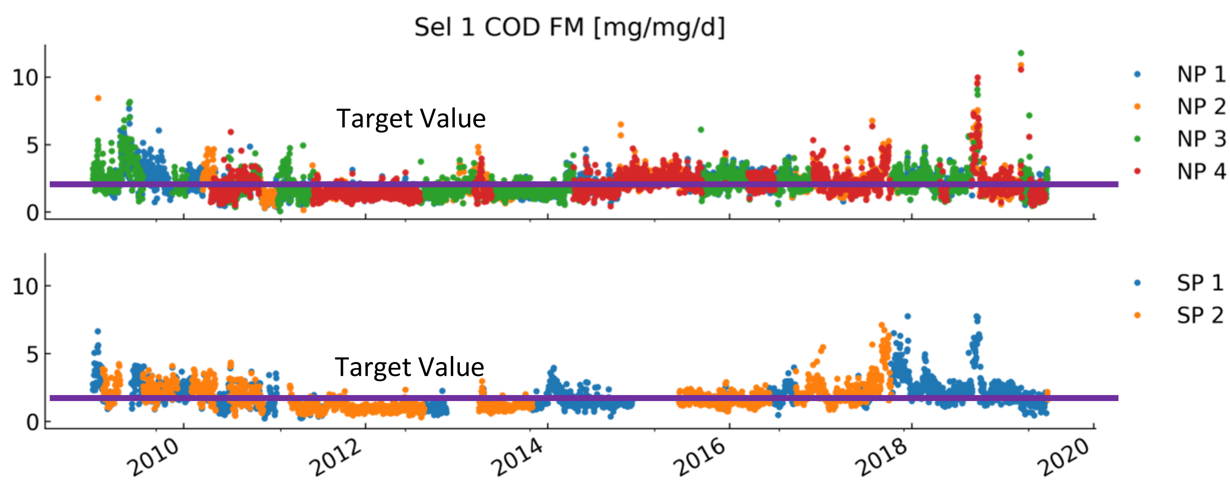

Figure 2-6 COD F/M Loading in GBN and GBS First Selector Zones for the Previous Ten Years

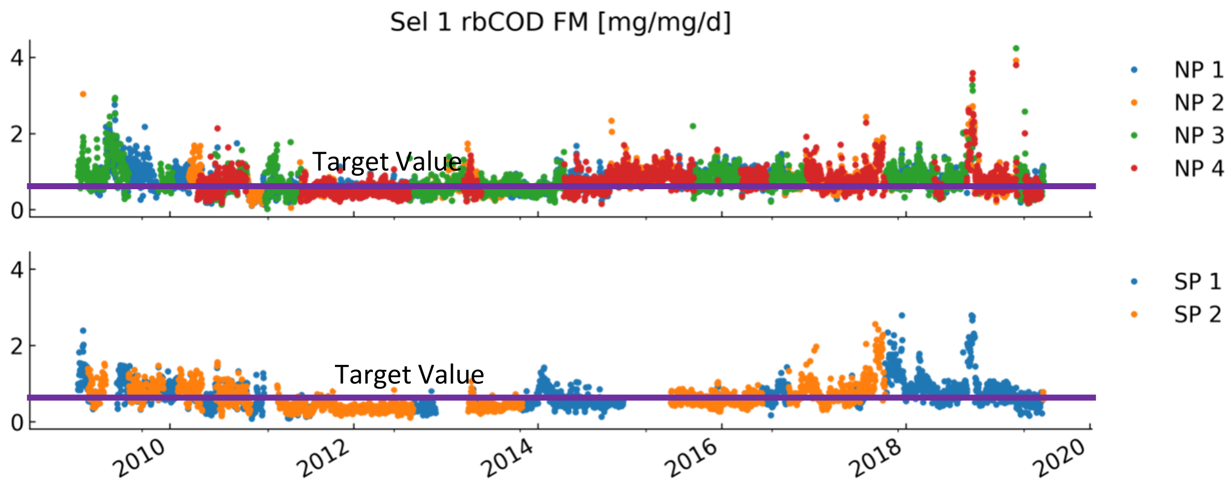

Figure 2-7 rbCOD F/M Loading in GBN and GBS First Selector Zones for the Previous Ten Years

Managing the influent BOD, COD, or rbCOD to meet a taget f/m in the selector zone is not practically achievable. The main operational tool is controlling MLSS and SRT. The variation of MLSS over the past 10 years is shown in Figure 2-8. The MLSS varies significantly over time. The MLSS will shift with varying SRT targets.. Wasting is often driven by the solids handling process, even after the startup of the R2E2 facilities. Operations report the consistent need to build solids in the activated sludge process during solids shutdowns and maintenance operations. This limits the ability to manage the SRT and MLSS to target an f/m, which limits the ability to produce the consistent growth pressures required for good settling sludge.

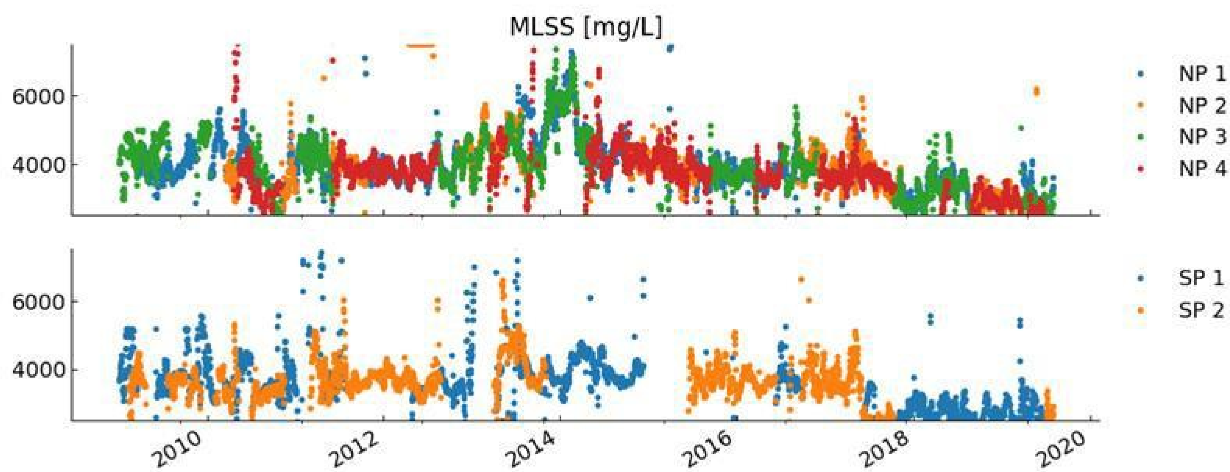

Figure 2-8 MLSS in GBN and GBS Aeration Basins for the Previous Ten Years

There are several reasons that the f/m is a critical parameter for selector zone sizing, but one of the key drivers is that soluble, biodegradable COD is consumed under anaerobic or anoxic conditions. Ideally, a majority of the soluble, biodegradable COD is consumed in the selector to maintain a low biodegradable COD concentration entering aeration thereby limiting the growth conditions for aerobic filaments. Special sampling from 2019 by NEW Water indicated that selector zone effluent soluble COD varied significantly and averaged approximately 80 mg/L over a seven month period (Figure 2-9). Effluent soluble COD averaged 30 mg/L during this same time period, indicating that an average of 50 mg/L of biodegradable COD is leaving the selector zones and entering the aerobic zones. This is a significant driving force for filaments and bulking organisms. Limiting this soluble COD discharge from the selector zone will be important for long-term settling stability, as well as enabling future low DO operation for energy savings.

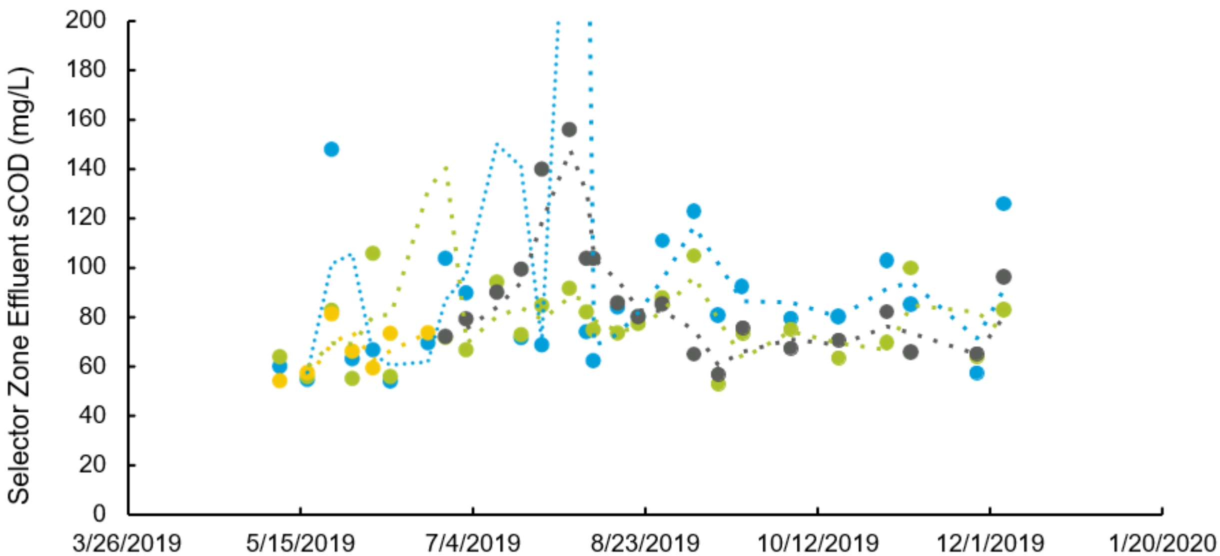

Figure 2-9 **Selector Zone Effluent Soluble COD (data sown for NP1-SZ2, NP3-SZ2, SP1-SZ2, and NP1-SZ2)**

An interesting aspect of the SVI values at the GBF is that effluent TSS does not often exceed 10 mg/L. A major driver for this effluent TSS concentration is the active management of aeration basin volume during wet weather events. Typically, two North Plant aeration basins are in operation. When influent flow to the North Plant exceeds 54 mgd total, additional aeration basins are brought into service. This dilutes the MLSS concentration, and thus lowers the solids loading rate to the final clarifiers. While this contributes to maintaining the effluent TSS during storm events, this shifting of MLSS concentration has a significant impact on growth pressures and may contribute to the overall poor settling of the system.

A second unique aspect of the settling at GBF is the settling characteristics. Settling columns are used by NEW Water to measure the rate of settling and develop site specific solids flux curves (Figure 2-10). When the measured solids flux curves from 2017 are compared to literature values, the GBF flux curves are significantly higher than anticipated (Figure 2-10). Solids flux curves with high peaks are often indicative of good settling activated sludge, not SVIs in the 180 to 200 mL/g range. This may be a result of a unique mixture of aggregates at the GBF. Microscopy indicates a significant number of dense aggregates that would typically characterize a good settling sludge; however, they are interspersed with filaments and *Zooglea* spp. aggregates. It may be possible that the dense aggregates provide a “ballast” for the overall system, helping to settle the filaments and bulking aggregates. This would result in good settling rates, but a large, fluffy blanket. Operational observations confirm a fluffy blanket and a relatively high RAS pumping ratio (100 to 150 percent of the influent flow) is required to manage the size of the blanket. This high RAS pumping manages the final clarifiers, but does impact reactor rates and mixing in the aeration basins.

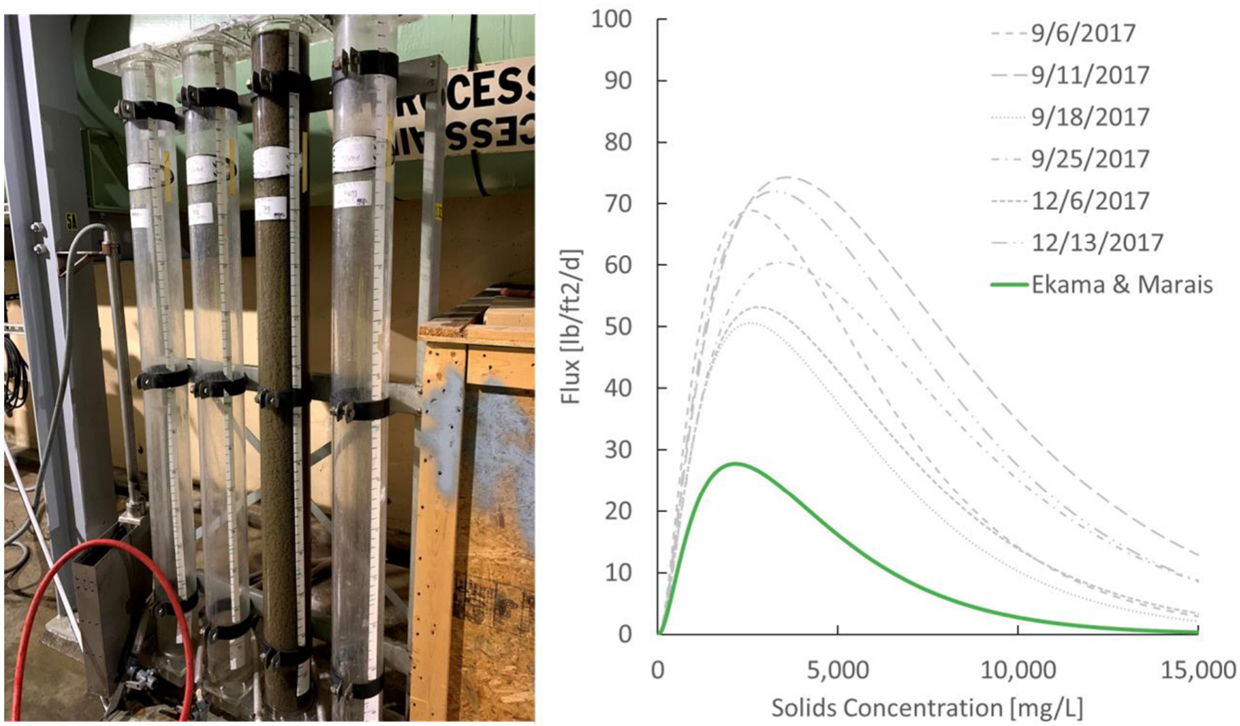

Figure 2-10 NEW Water Settling Columns and Solids Flux Curve Results

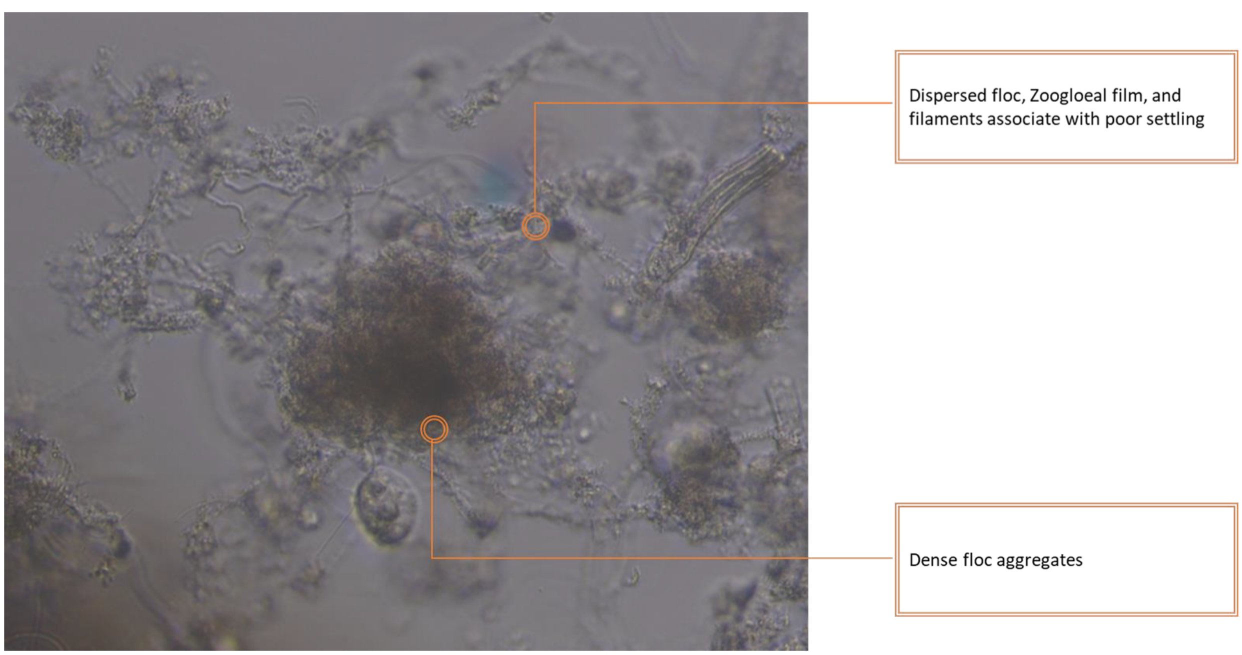

Figure 2-11 GBF Floc Image

NEW Water operations use the existing infrastructure to manage the settling characteristics of the GBF solids. Aeration basin operational changes during wet weather flows, operating at relatively high RAS ratios, and managing MLSS all contribute to the observed performance; however, high selector zone effluent sCOD along with highly variable MLSS operation driven by solids handling limitations limit the performance of the aeration basins by detrimentally impacting settleability.

2.2.3 Aeration

Aeration is supplied to the six GBF aeration basins from a common blower/compressor building. Four existing blowers each have a rated capacity range of 19,500 to 60,000 scfm, depending on operating temperature. Current total airflow provided to the aeration basins is shown in Figure 2-12. New diffusers were installed in 2017, and the total airflow decreased significantly due to the improved efficiency. In 2019, the average airflow to the aeration basins was approximately 13,000 scfm. This is lower than the lowest airflow from the existing blowers. Excess air above what the process requires is discharged away from the aeration basins. This provides the correct airflow to the aeration basins, but is not energy efficient as a significant amount of airflow is discharged.

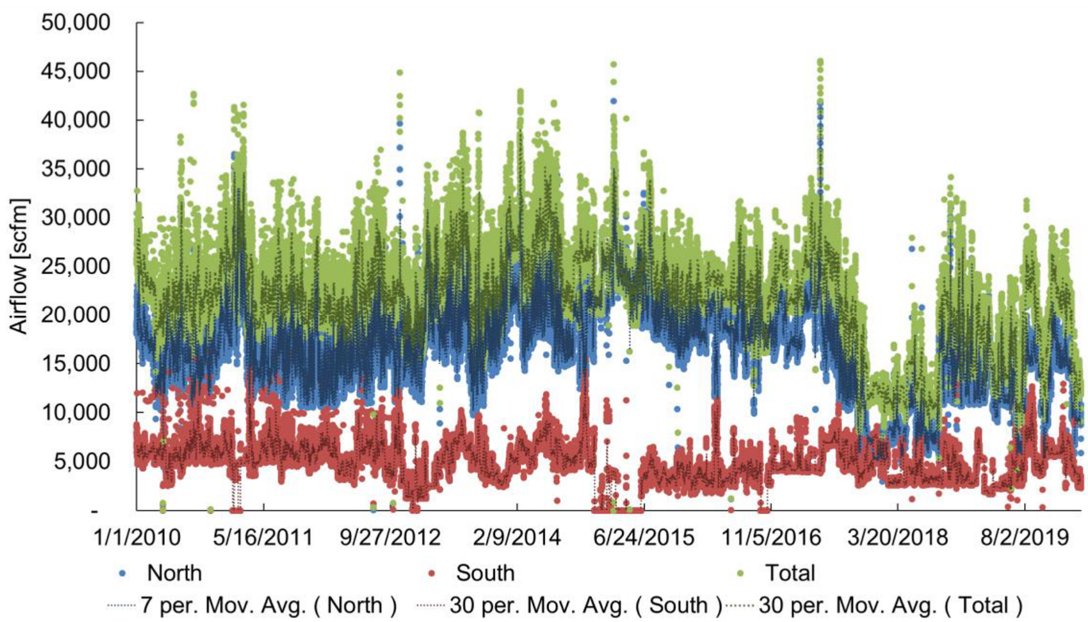

Figure 2-12 Historic Airflows to the GBF Aeration Basins

Loadings drive airflow demand, but the actual airflow is often dictated by DO setpoints and minimum airflow setpoints in aeration basins zones. The GBF has typically operated at DO concentrations above 2 mg/L throughout the aeration basins. When the airflow distributions for 2019 are examined, all zones are operating in the minimum airflow setpoint and not DO control, as evident by the relatively constant airflow in each zone in the distributions (Figure 2-13). Overall, the only zone that was not typically operating at the minimum airflow setpoint in 2019 was Zone 2 of NP 1. All other zones were at the minimum airflow rate at least 65 percent of the year (Table 2-2). The GBF aeration zones are shown graphically, with control notes, in Figure 2-14 and Figure 2-15.

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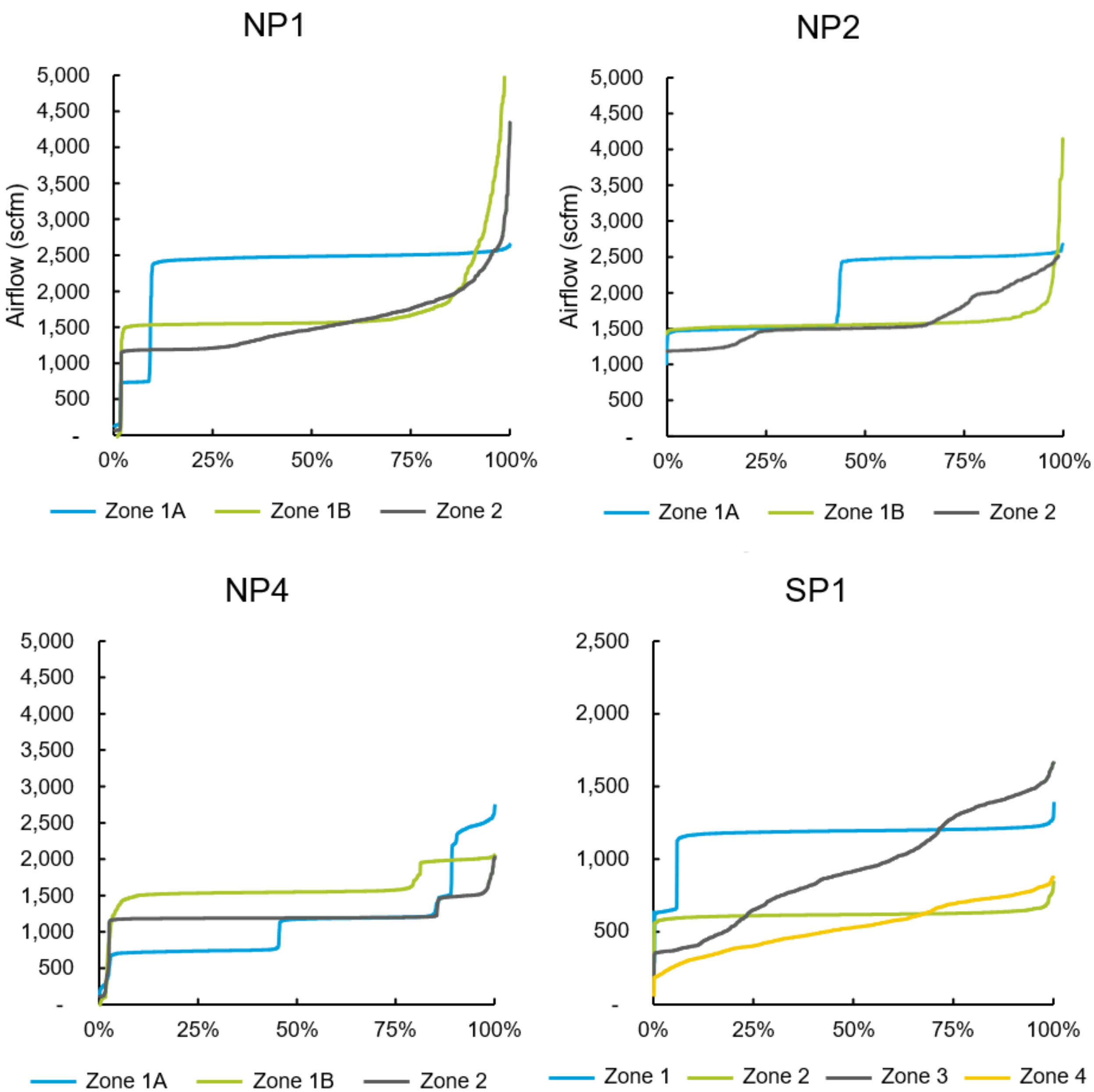

Figure 2-13 Historic Airflows to the GBF Aeration Basins

Table 2-2 Percent of Time at Minimum Airflows in 2019

Zone	Percent of Time at Minimum Airflow
NP1 Zone 1A	97.0%
NP1 Zone 1B	72.0%
NP1 Zone 2	25.0%
NP2 Zone 1A	95.0%
NP2 Zone 1B	74.0%
NP2 Zone 2	65.0%
NP3 Zone 1A	80.0%
NP3 Zone 1B	76.0%
NP3 Zone 2	85.0%

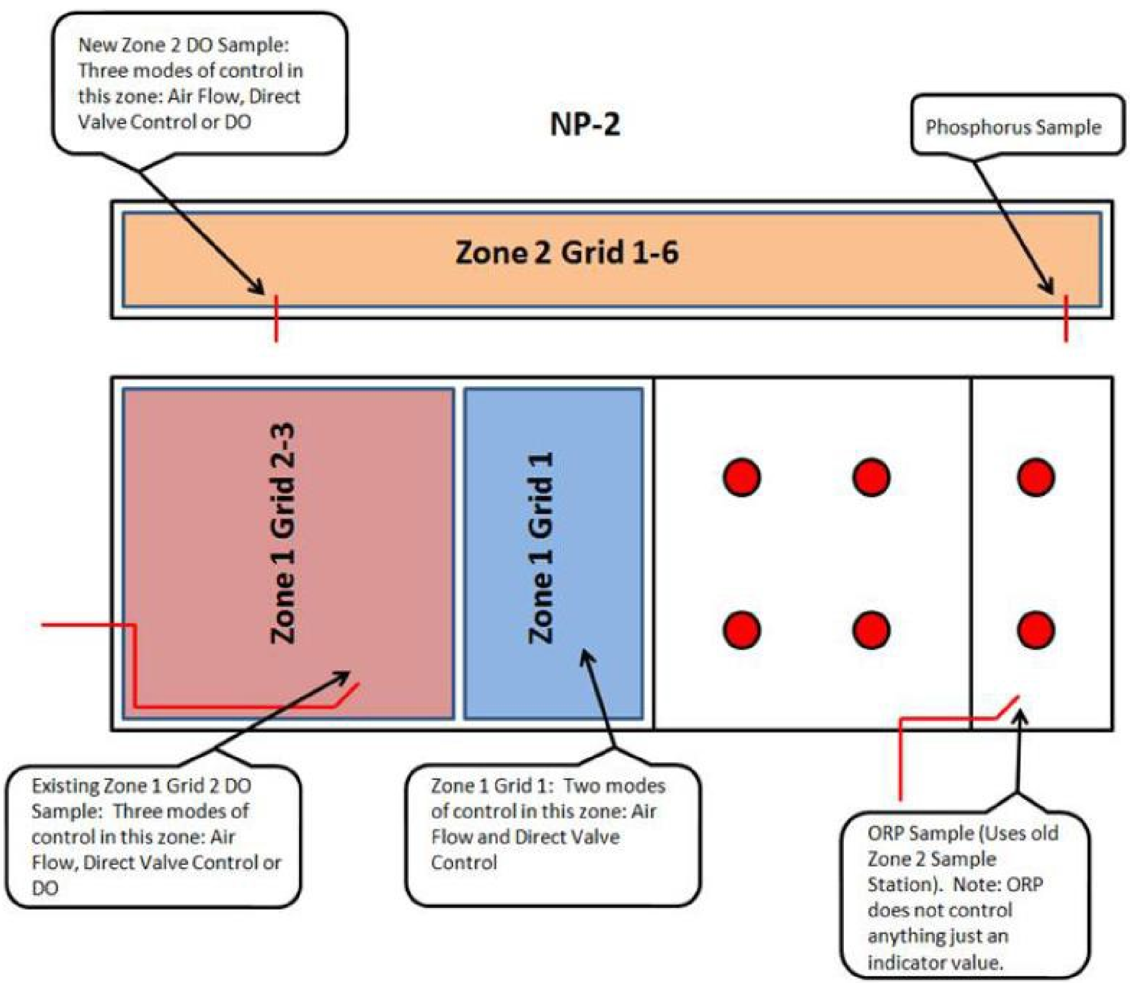

Figure 2-14 North Plant Aeration Zones (Image Courtesy of NEW Water)

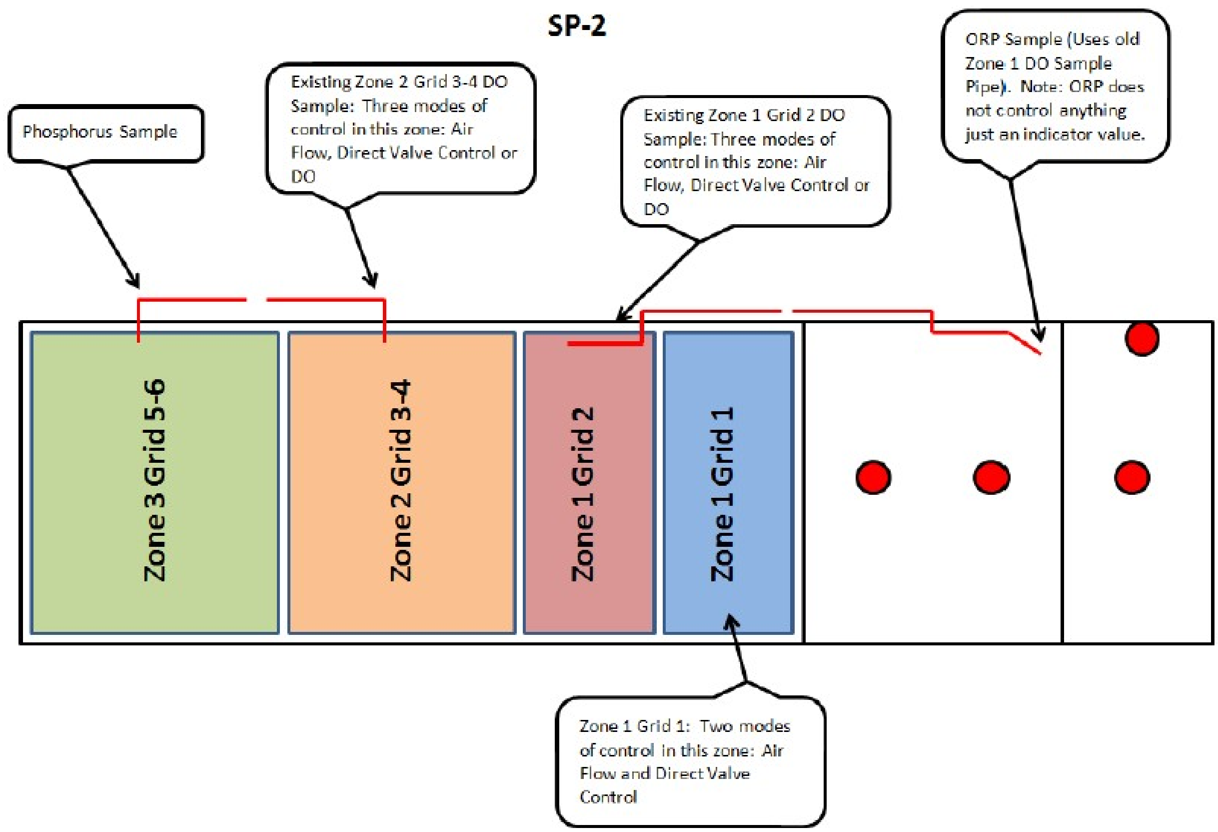

Figure 2-15 South Plant Aeration Zones (Image Courtesy of NEW Water)

Achieving energy efficiency in aeration basins is dependent on aeration basin loading, DO setpoints, the number of diffusers, configuration of air piping and control valves, and having high efficiency blowers. If the in-basin parameters are not well managed, the most efficient blowers will still not provide optimal efficiency because too much air is being utilized. The current GBF blowers are producing more air than the current process is requiring, but the current process is adding significantly more air than needed for the process as evident by the amount of time spent at the minimum airflow rates. Aeration basin modifications that both reduce the process demand by lowering DO setpoints and provide the proper design conditions to not require minimum airflow rates the majority of time are critical considerations before developing airflow ranges for new blowers.

2.3 Gaps and Process Limitations Summary

The GBF consistently achieves effluent concentrations well below permitted values; however, there are several process limitations related to settleability, total nitrogen removal, and increased phosphorus removal stability that should be examined when considering process configuration improvements. Key conclusions related to process limitations are:

- Effluent performance:
  - Effluent is consistently within current permit limits.
  - Increased stability will be required for future effluent phosphorus and TSS requirements.

    - Limited total nitrogen data indicates that the GBF will not meet the targeted 8 mg/L limit without process improvements.
    - Process configuration improvements will focus on achieving total nitrogen removal without impact phosphorus removal.
    - Sidestream loadings from R2E2 may be creating increased instability in phosphorus removal, which would be improved by sidestream nitrogen treatment and/or sidestream equalization.
- Settleability:
    - The GBF generally has poor settling sludge.
    - Major causes of poor settleability are biodegradable COD bleeding through from the selector zone and inconsistent MLSS leading to inconsistent selector zone f/m loading rates.
    - Process configuration improvements in the aeration basins should focus on increased removal of biodegradable COD prior to aeration.
    - Improvements to solids handling should be considered to allow for consistent SRT control in the aeration basins. This should be a priority for the Facility Plan.
    - TSS and phosphorous effluent performance is negatively impacted at increased hydraulic loading rates.
- Aeration:
    - The current diffuser zones operate in minimum airflow mode, indicating too many diffusers for the process air demands.
    - Process configuration improvements will include examining diffuser grid densities as well as DO control setpoints to reduce overall aeration demand.
    - The reduced aeration demand from process configuration improvements will reduce the blower sizing, as well as the overall aeration demand at GBF.

These process configurations can then feed into airflow design ranges, which can be used to optimize the diffuser densities, piping and valve configuration, blower sizing, and DO setpoints in the future.

3.0 Preliminary Process Configuration Simulations – GBF

Before developing design airflow ranges and capital costs for aeration basin and blower modifications, a set of simulations was completed to understand how process configuration modifications and sidestream nitrogen removal would impact effluent performance, sludge settleability, and aeration demand. Process configurations are examined first to understand how the main aeration basin configuration impacts performance, settleability, and aeration.

Simulations were then completed related to sidestream nitrogen removal to understand how that additional treatment step would impact nutrient removal performance.

3.1 Process Configurations

Three process configurations were identified for the GBF aeration basins: the existing Anaerobic- Oxic (AO) configuration, modified Ludzag-Ettinger (MLE), and Anaerobic-Anoxic-Oxic (A2O). The goal of the modified configurations (MLE and A2O) is to recycle nitrate from the effluent of the aeration basin to the head of the aeration basin for denitrification and total nitrogen removal. The MLE and A2O configurations provide a relatively simple reactor configuration modification, as mixed liquor recycle (MLR) is added to bring more nitrate towards the influent of the plant. The general process concept for each description is:

- MLE: nitrate is recycled via MLR from the effluent of the aeration basin to the first selector zone in an aeration basin. The selector zone volume first denitrifies, and then biological phosphorus removal can occur in a second selector zone if sufficient rbCOD is available. MLR rates are typically 250 to 400 percent of the influent flow rate.
- A2O: nitrate is recycled via MLR from the effluent of the aeration basin to the second selector zone in an aeration basin. This preserves an anaerobic zone at the influent of the basin to prioritize rbCOD for biological phosphorus removal. Remaining rbCOD is utilized for denitrification in the second selector zone. MLR rates are typically 200 to 400 percent of the influent flow rate.

No other major changes would occur. These configurations are shown in Figure 3-1. Intensified aeration basin configurations — such as the membrane aerated biofilm reactor (MABR), partial nitrification, or aerobic granular sludge — were not considered given the effluent limits at the GBF and the relative capacity available. Intensified process configurations and technologies often require drivers related to low level nitrogen, capacity limitations, high energy costs, or a combination of these drivers which are not present for NEW Water.

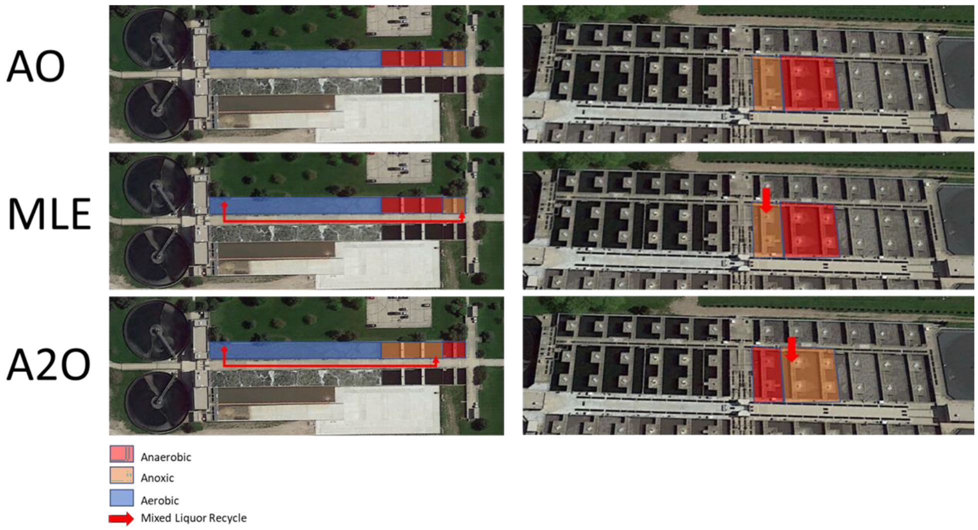

Figure 3-1 Process Configurations Considered for the GBF Aeration Basins (Left – South Plant; Right – North Plant)

To understand the potential impacts of these process conifigurations, a dynamic simulation was completed for all three configurations. The dynamic validation month from TM 2.3 (February 2019) was used for this preliminary evaluation. DO setpoints of 2 mg/L were used throughout the aerobic zones for each configuration as a preliminary setpoint. For the MLE and A2O configurations, a MLR flow of 250 percent of the influent flow rate was utilized. The goal of this MLR flow is to bring more nitrate to the influent side of the basin, which should provide additional soluble, biodegradable COD removal prior to the aerobic zones. For the MLR, the recycle flow was added to the second selector zone for A2O and the first selector zone for MLE. For each configuration, the simulation was completed with measured metals in the influent, and also with no measured metals in the influent.

3.1.1 Nutrient Removal Impacts

The nutrient removal simulation results are summarized in Figure 3-2. For each effluent parameter, the range of effluent concentrations from the dynamic simulation are shown in a box-and-whisker plot. The six key parameters are shown in the left box-and-whisker plot, and then phosphorus is focused on in the right box-and-whisker plot. For each configuration, simulations are shown with background metals included in the influent, and without background metals included. The A2O configuration is the only configuration that achieves simulated effluent concentrations below the targets for both the nitrogen (8 mg/L monthly average) and targeted phosphorus concentrations (0.35 mg/L monthly average) in the effluent, with a 90th percentile nitrogen of 6 mg/L and 90th percentile phosphorus of 0.35 mg/L. The MLR to the first selector zone in the MLE configuration decreases effluent TN, but biological phosphorus removal is limited. This has an effluent phosphorus impact both with and without influent metals present, although effluent phosphorus is higher with no influent metals present. For the AO and A2O configurations, effluent phosphorus is less than 0.3 mg/L both with and without influent metals. All three configurations would continue to meet effluent BOD, TSS, and ammonia requirements.

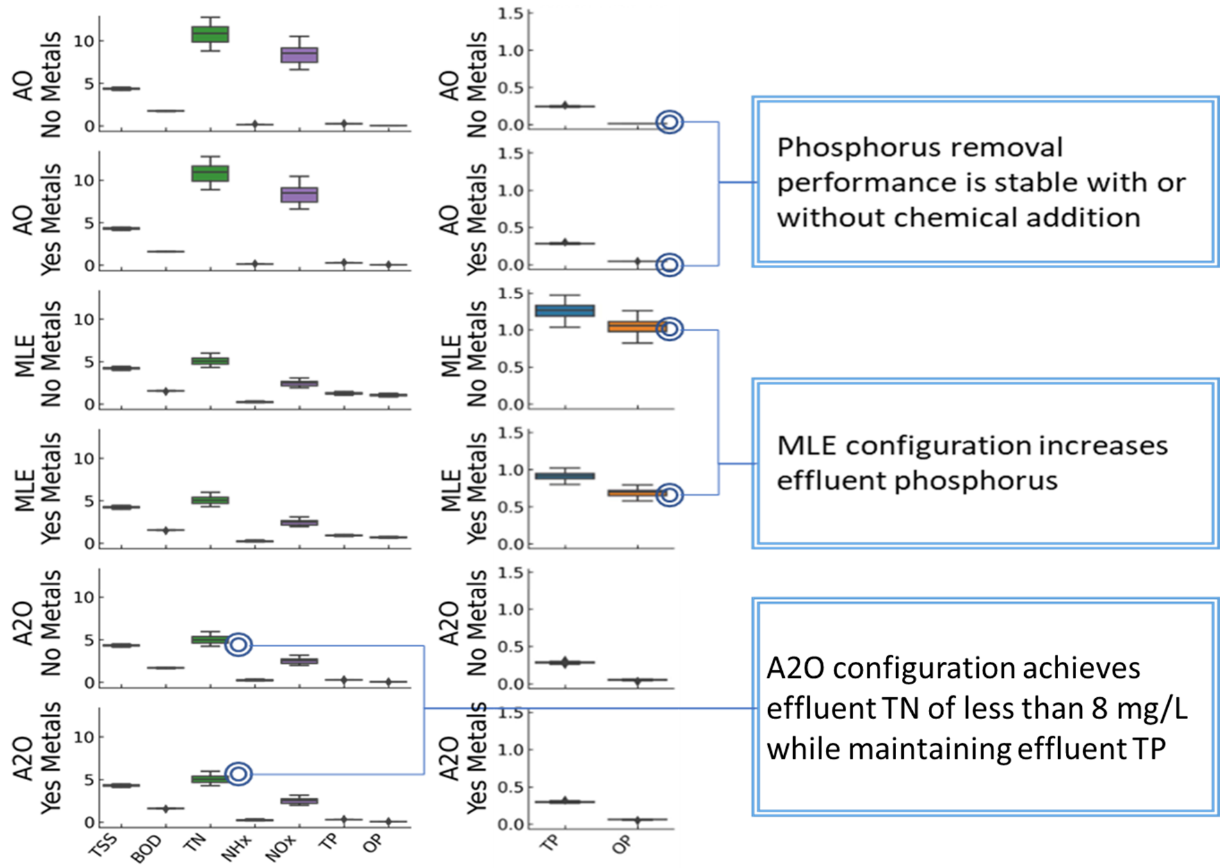

Figure 3-2 Nutrient Removal Simulation Results

These combined results provide insight into the phosphorus removal dynamics at the GBF. While little difference is observed in the AO and A2O configurations for effluent phosphorus with and without influent metals, there is a large difference in the MLE configurations. The influent metals are not sufficient to drive down phosphorus to the concentrations observed at the facility, otherwise the effluent phosphorus in the MLE configuration would have also been near the 0.3 mg/L level. Given the simulation results observed, it would appear that there is a balance between PAO activity and chemical phosphorus removal that is enabling the low effluent phosphorus concentrations observed at the GBF. The simulations indicate that PAO activity with influent metals is approximately 50 percent of the growth rate with no metals, indicating that both the influent metals and PAOs' metabolism are contributing to effluent phosphorus performance for the AO and A2O configurations (all potential PAO activities are shown in Figure 3-3**.** for Selector Zone 1, with PHA storage being the dominate activity during anaerobic conditions).This is an important distinction for operations, as a system with full chemical phosphorus removal will behave differently than a system with a balance of chemical and biological phosphorus removal.

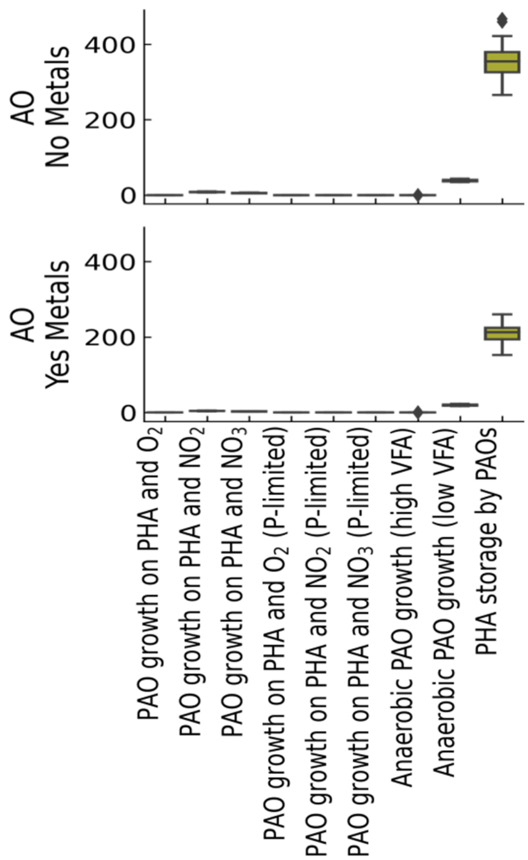

Figure 3-3 Simulated PAO Growth in the AO Configuration

3.1.2 Settleability Impacts

One aspect of settleability is maintaining a more consistent MLSS. Solids handling limitations that are limiting the ability to control the aeration basins for a target SRT and MLSS will be identified in TM 2.6. For these simulations, the SRT was assumed to be controlled at 12 days, resulting in a stable f/m in the selector zone. The process configuration then impacts the biodegradable COD leaving the selector zones and entering the aerobic zones. The rbCOD profiles in the aeration basins is shown in Figure 3-4. The dark green line is the average, and the shaded area around the line is the range of values observed at each location (essentially a box-and-whisker plot profile). The gray areas represent the selector zones, and the profile is shown for the South Plant basin. In the AO configuration, 80 to 90 mg/L of rbCOD is leaving the selector zone, which is similar to the soluble COD observed during the special sampling campaign. In the A2O configuration, the nitrate recycled to Selector 2 consumes additional rbCOD, and the selector zone effluent is reduced to 10 mg/L. This would reduce the available rbCOD to drive filamentous growth in the first aerobic zone. This provides better conditions for settleability, and would also provide the opportunity to operate at lower DO Setpoints in the aerobic zones.

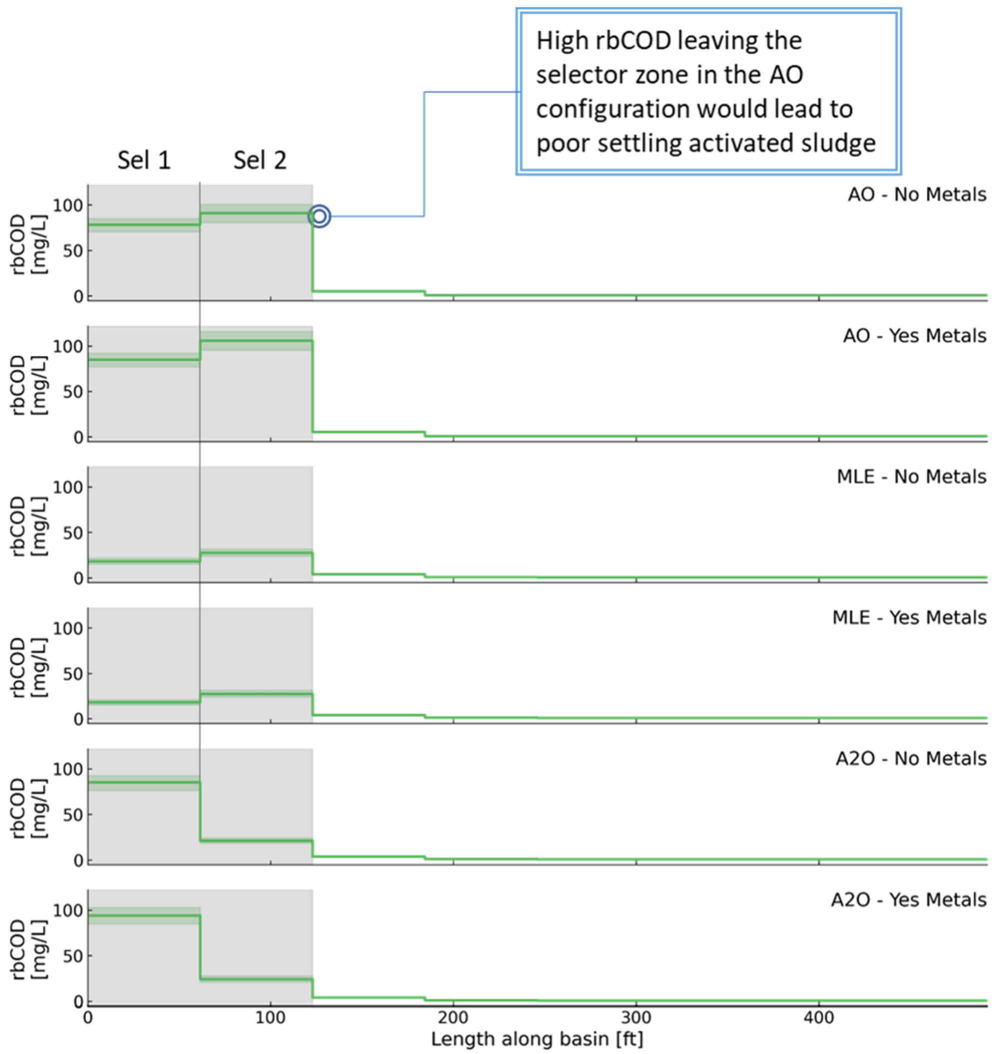

Figure 3-4 rbCOD Profiles for the Three Reactor Configurations

A second important aspect of the configurations is the growth profiles in the basins. It is important to have high growth rates at the influent of the aeration basins to achieve a feast-famine growth profile in the aeration basin. High, consistent growths rate for utilization and uptake of rbCOD need to be accompanied by low growth rate at the effluent of the aeration basin to ensure full utilization of stored carbon. As shown in Figure 3-5, only the A2O configuration maintains high growth rates of both PAOs and ordinary heterotrophic organisms (OHOs) in both selector zones. In Selector 2 for both AO and MLE, there is a relatively stagnant zone where minimal growth activity occurs. This is consistent with having a high rbCOD effluent from the selector zones.

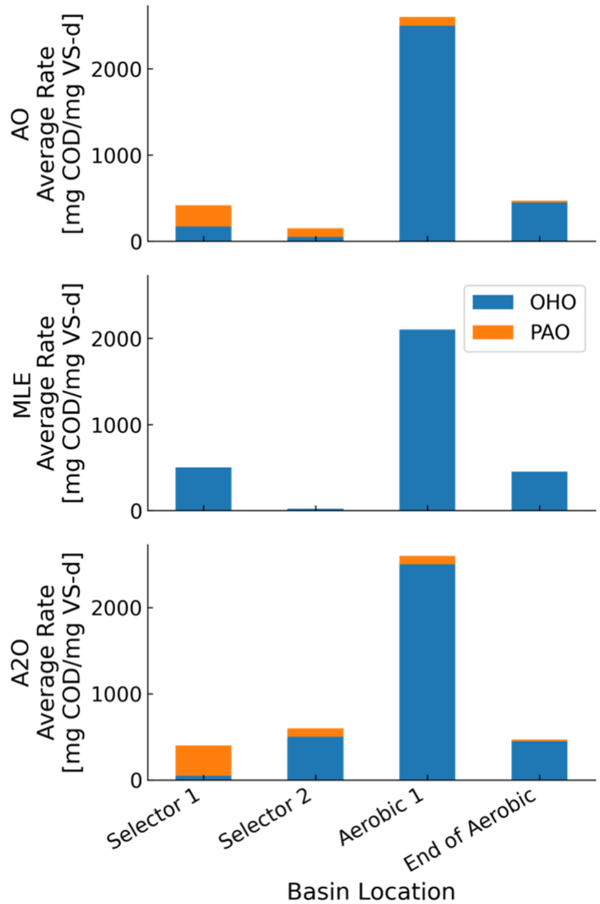

Figure 3-5 Simulated Growth Profiles

3.1.3 Aeration Impacts

Airflows will be examined in more depth in Section 5. For the configuration comparison, the oxygen uptake rate (OUR) profile was compared for AO, MLE, and A2O to understand how the reactor configuration impacts on aeration demands. As shown in Figure 3-6, the OUR profile for the three configurations are similar. The airflow differences between the three configurations will therefore be relatively minor.

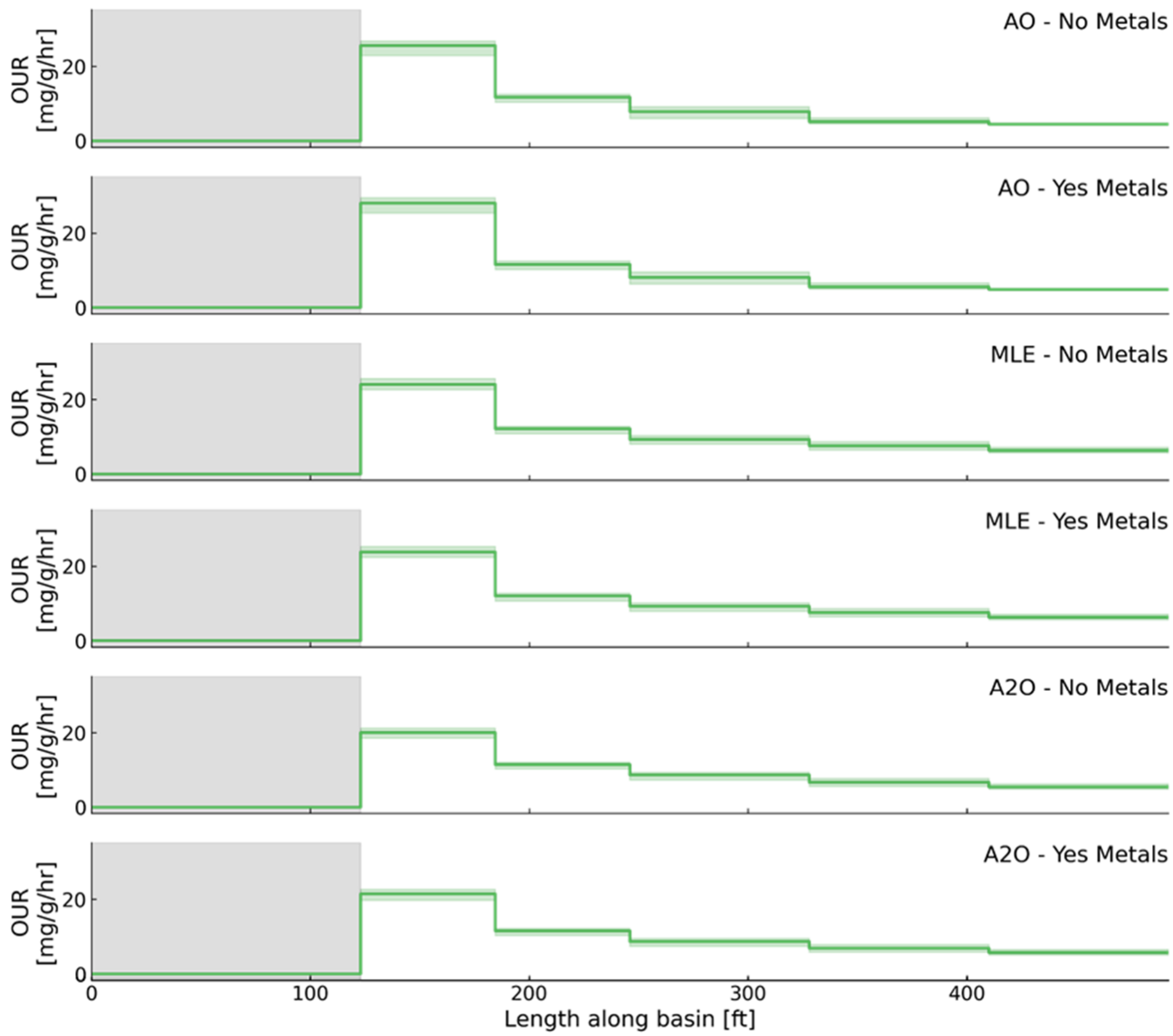

Figure 3-6 OUR Impacts for the Three Configurations

Reducing the operational DO setpoints should also be considered as part of the aeration improvements. Tapered low DO operation, where the DO starts at less than 0.5 mg/L at the influent of an aerobic zone and is increased to 1 to 1.5 mg/L at the effluent of the aerobic zone, can reduce aeration energy by 15 to 25 percent. This savings is driven by energy efficiency improvements at lower DO concentrations. Low DO setpoints can be associated with filament growth if rbCOD leaves the selector zone. Based on simulations of the A2O configuration, the selector zone effluent rbCOD should be limited, thus enabling the potential operation at low DO setpoints.

Another key consideration is the number of diffusers per zone. Based on the airflow distributions in Figure 2-13, the zones are constantly operating at minimum airflow rates. These rates are driven by the number of diffusers in the basins. Further evaluation of diffuser densities should be incorporated into process configuration improvements.

3.1.4 Process Configuration for Further Consideration

The MLE configuration does not achieve effluent phosphorus performance and would likely result in decreased settleability due to the lack of activity in Selector 2. The AO configuration provides phosphorus removal but does not achieve the future targeted total nitrogen target. The A2O configuration achieves effluent compliance and should also improve settleability. For aeration basin configurations moving forward, the current AO configuration will be considered, along with the A2O configuration. For both configurations, low DO setpoints and modifications of the diffuser densities to limit the minimum airflow operation shown previously in Figure 2-13 should be considered. The DO setpoints and diffuser modifications are driven by energy efficiency in the aeration basins.

3.2 Sidestream Nitrogen Treatment Impacts

An additional process consideration is the addition of a sidestream unit process for nitrogen removal. The digestion process creates a sidestream that is high in ammonium and potential phosphorus. Future sidestream phosphorus loads were considered with R2E2, and a struvite harvesting facility was included to mitigate the impacts of sidestream phosphorus loading. Influent metals currently limit the sidestream phosphorus concentrations; however, sidestream ammonium concentrations are typically in the 600 to 1,000 mg/L range. This represents approximately 15 to 20 percent of the influent nitrogen load to the facility. This additional nitrogen load will impact the ability to achieve future effluent TN requirements. The additional nitrogen also has the potential to impact phosphorus removal, as the additional nitrate generated from nitrification of this sidestream load in the aeration basins will impact biological phosphorus removal. Sidestream treatment would be a new unit process installed on the filtrate water generated from the dewatering of digested sludge (simple process flow diagram shown in Figure 3-7), and it would remove the nitrogen present in this sidestream. This is a supplement to any modifications to the aeration basins, and would target reducing the load to the aeration basins. The driver to include sidestream treatment would be to stabilize nutrient removal in the activated sludge process.

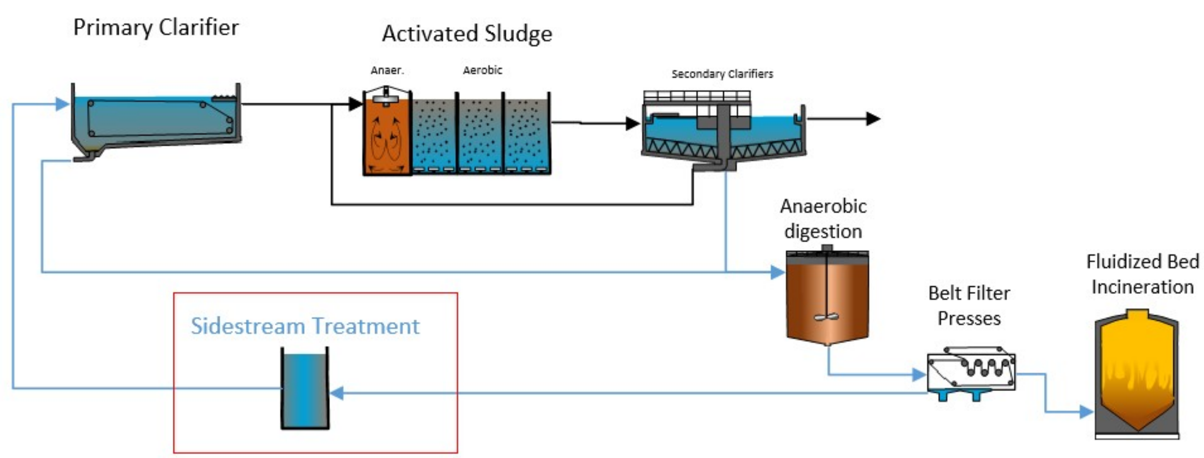

Figure 3-7 Simplified Process Flow Diagram for the Addition of a New Sidestream Treatment Unit Process

The calibrated whole-plant model was simulated at the 2025 average day loading condition under four scenarios to understand the impacts of sidestream loadings. These four scenarios examined the impact of influent metals and the impact of recycle streams on effluent phosphorus and effluent total nitrogen. Simulation results are summarized in Table 3-1. Treating the sidestream flow positively impacts both effluent phosphorus and effluent total nitrogen, and alternatives for sidestream treatment should be considered to achieve effluent nutrient targets.

Table 3-1 Simulated Impacts of Sidestream Flow Treatment on Nutrient Removal

Influent Metals	Sidestream Flow	Effluent P (mg/L)	Effluent TN (mg/L)
Present	Recycled to influent	0.4	9
Present	Treated prior to influent	0.32	7.2
Not present	Recycled to influent	1.3	9
Not present	Treated prior to influent	0.8	6.5

3.3 Recommended Improvements

Preliminary simulations identified potential Improvements to the aeration basins that should be considered as part of the NEW Water Facility Plan. There are three major categories of improvements:

- Aeration basins improvements:
  - Modifications to convert the aeration basins to the A2O configuration.
  - Evaluation and recommendations for improved diffuser densities to limit minimum airflow operation.
  - Control valve and instrumentation modifications to enable low DO operation to reduce energy requirements for aeration.
  - Infrastructure changes and capital costs will be presented in Section 4.
- Sidestream treatment improvements:
  - Removing the sidestream nitrogen loading provides improved process stability for effluent phosphorus and nitrogen
  - Sidestream nitrogen removal technologies will be considered as a possible improvement. Infrastructure changes and capital costs will be presented in Section 5. Based on simulated results, sidestream treatment would be triggered by either a future nitrogen limit, or a reduction in influent metals that would impact biological phosphorus removal stability.
- Blower/compressor improvements:
  - Blower/compressor improvements should be developed for both the AO and A2O configuration, along with a range of DO setpoints and diffuser density modifications developed for the aeration basin improvements.
  - Infrastructure changes and capital costs will be presented in Section 6.

Each improvement area will be developed individually. Applied research opportunities will be identified in Section 8, and overall recommendations will be discussed in Section 9.

4.0 Infrastructure Improvements – GBF Aeration Basins

Aeration basin infrastructure improvements are tied to three components at the GBF: addition of MLR to convert the process configuration from AO to A2O, evaluation and potential modification of diffuser densities, and control considerations to achieve low DO setpoints.

4.1 Configuration Modifications

Conversion to an A2O configuration will require the addition of a MLR pump. These low head pumps would be sized to pump 250 percent of the influent average day flow into the second selector zone for each aeration basin. The South Plant has existing wall penetrations for an MLR pump at the effluent end of the aeration basin. New pumps and piping would be required to provide flow transfer of 25 mgd per basin, and would be located within the tunnel system.

The addition of MLR pumping in the North Plant would require an MLR pump that transfers flow from the end of the aeration basin into Selector Zone 2. This would require minimum piping due to the two pass configuration of the North Plant. It would require a submersed recycle pump, which is essentially a large-blade mixer that would push flow through a wall penetration between the second pass and Selector 2.

4.2 Diffuser Modifications

A key aspect of diffuser densities is developing a design and setpoints that enables the airflow to operate above the minimum airflow setpoints. If the oxygen demand is less than the minimum airflow setpoint, the zone operates with the minimum airflow setpoint and is over-aerated. The number of diffusers, as compared to the mixing limitation and simulated minimum airflow, is shown in Table 4-1 and Table 4-2 for the North Plant and South Plant, respectively. The minimum simulated airflow is at or above mixing limited condition, but significantly lower than the airflows shown previously in Figure 2-12. With a target minimum diffuser airflow of 0.5 scfm/diffuser, several of the zones would require a significant reduction in diffusers via plugging to ensure that the minimum airflow is lower than the typical airflow demand. Even with the plugged diffusers, there would still be a high maximum airflow for each zone based on a 4.0 scfm/diffuser maximum.

Table 4-1 North Plant Diffuser Evaluation

Aeration Zone	Number of Diffusers	Mixing Limitation (scfm)	Minimum Simulated Airflow (scfm)	Airflow Per Diffuser At Minimum (scfm/Diff)	Number of Diffusers to Plug	Zone Min. Airflow (scfm)	Maximum Airflow with Plugged Diffusers
1A	1,482	249	720	0.49	41	720	5,763
1B	2,964	506	624	0.21	1717	624	4,988
2	994	755	754	0.76	0	497	3,976

Table 4-2 South Plant Diffuser Evaluation

Aeration Zone	Number of Diffusers	Mixing Limitation (scfm)	Minimum Simulated Airflow (scfm)	Airflow Per Diffuser At Minimum (scfm/Diff)	Number of Diffusers to Plug	Zone Min. Airflow (scfm)	Maximum Airflow with Plugged Diffusers
1	1,292	165	419	0.32	455	419	3,348
2	1,230	165	245	0.20	740	245	1,959
3	736	330	384	0.52	0	368	2,944
4	376	330	348	0.93	0	188	1,504

Diffuser modifications would not require a significant capital investment, but would require NEW Water to purchase diffuser orifice plugs from SSI and plug several hundred diffusers in each aeration basin. Plugging diffusers would allow for the process airflow requirements to drive airflow rates rather than minimum airflow requirements to keep the diffusers operational. This would significantly reduce the overall aeration demand for the GBF aeration basins.

4.3 Low DO Control

Moving to low DO setpoints can significantly reduce energy requirements, as well as reduce effluent nitrogen and phosphorus. The majority of infrastructure is in place for low DO operation at the GBF. In the past, the limitation has been the need for a higher DO concentration after the selector zone due to selector zone effluent biodegradable COD. In the A2O configuration, this condition is eliminated, which will allow for operation at low DO setpoints. A tapered low DO approach would be recommended, with the following DO setpoints:

- North Plant
  - Zone 1A: 0.4 mg/L
  - Zone 1B: 0.75 mg/L
  - Zone 2: 2.0 mg/L
- South Plant
  - Zone 1: 0.4 mg/L
  - Zone 2: 0.4 mg/L
  - Zone 3: 0.75 mg/L
  - Zone 4: 2.0 mg/L

The infrastructure required to enable these reduced DO setpoints would be relatively minor, and consists of an ammonium sensor for monitoring in the aeration basins. This ammonium sensor could be incorporated into an ammonium based aeration control (ABAC) strategy, but this would likely require demonstration testing before full-scale implementation. One potential area that needs to be evaluated further is the existing control valves. If the air supply control valves are two large to facilitate the low airflow rates achievable by the tapered low DO Setpoints, they would need to be replaced with valves that allow efficient operation at the full airflow range.

4.4 Capital Costs

The only major capital cost associated with modification of the aeration basins to A2O would be the MLR pumps in all aeration basins. Capital costs were developed with details included in **Appendix A.**

Table 4-3 Capital Cost Estimates for Aeration Basin Modifications

Package	Major Infrastructure	Capital Cost Range	Most Probable Cost
Package 1 – A2O Modification	Six MLR recycle pumps, one for each aeration basin Associated piping and controls	$4.0M to $5.9M	$4.7M
Package 2 – Low DO Instrumentation and Control	Ammonium sensors	$0.3M to $0.7M	$0.5M

5.0 Infrastructure Improvements - Sidestream Treatment

The characteristics of low volume, high concentration recycle streams from anaerobic digestion create opportunities for alternative means of treatment for nutrient management. Specifically, the recycle wastewater from anaerobic digestion differs from typical municipal influent wastewater in the following ways:

- Ammonia-nitrogen and orthophosphate concentrations are higher by an order of magnitude or more. The projected ammonia-nitrogen concentrations are over 1,000 mg N/L.
- The temperature is 25 to 35 C after dewatering due to mesophilic anaerobic digestion solids treatment processes.
- Alkalinity is typically 50 percent of the requirement for full nitrification.

The benefit of the high nutrient concentrations and warm temperatures is that sidestreams are amenable to a high-rate biological and chemical treatment process. As a result, nutrient removal can be achieved in a relatively small footprint and at a lower energy intensity than in the main stream. On the other hand, relatively low alkalinity and potential for inhibition requires external inputs and process control to maintain stable treatment.

The advantages of sidestream processes for NEW Water include:

- Stabilizes mainstream treatment by mitigating a high-strength recycle stream.
- Reduces mainstream aeration energy.

5.1 Sidestream Nitrogen Treatment Technologies

Sidestream nitrogen technologies evaluated in this section focus on biological transformations involving a variety of bacteria able to utilize a diversity of pathways for ultimate removal from the liquids stream. Figure 5-1 illustrates three biological pathways for nitrogen removal that can be utilized in sidestream treatment. The first step of nitrogen removal entails aerating wastewater to support growth of nitrifying bacteria that oxidize ammonia to nitrite and nitrate. In shortcut processes (i.e. nitrite shunt and deammonification), ammonia oxidation is stopped at nitrite reducing oxygen demand. All processes require aerated phases with oxygen and unaerated or low dissolved oxygen (DO) phases deprived of oxygen. After nitrite or nitrate is formed, nitrogen can be removed by denitrification. This can be driven by either COD based denitrification, or by anaerobic ammonium oxidation (Anammox) where ammonium serves as the electron donor for nitrate-based denitrification.

Several proprietary technologies with multiple instances of full-scale operational installations are available.

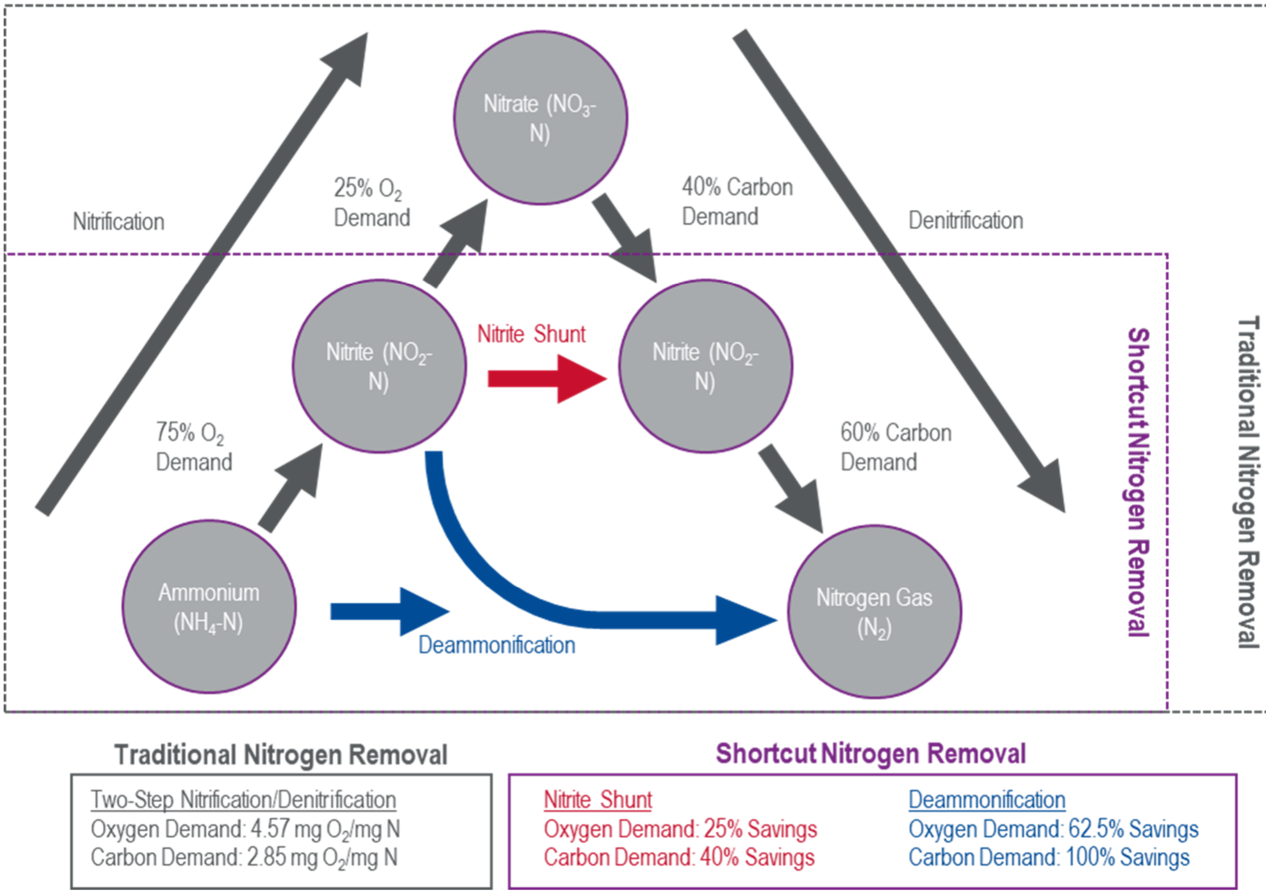

Figure 5-1 Nitrogen Removal Biological Transformation Pathways

5.1.1 Traditional Nitrification-Denitrification

Nitrifying bacteria oxidize ammonia to nitrate (typically a two-step process) with oxygen (nitrification). Nitrate is then reduced to N2 gas by facultative heterotrophic denitrifying bacteria (denitrification) using COD. Because of the unique characteristics of anaerobic digestion sidestreams (high nutrients, low biodegradable COD), substantial supplemental alkalinity is required to achieve complete nitrification and supplemental external carbon is required for denitrification. The need for external chemical inputs can, however, be greatly reduced if denitrification, and thus nitrogen removal, is not a requirement. The potential benefits include bioaugmentation from recirculation of nitrifiers in waste sludge to the main-stream activated sludge process and odor control from recycle of effluent nitrates to the headworks.

Focus has recently shifted towards shortcut nitrogen removal processes. Nitrification-denitrification has been implemented at multiple facilities but the perceived benefits are not well-documented.

Meanwhile, advancement in the understanding of the microbiology and process control of shortcut nitrogen removal has led to reliable operation and realization of energy and resource savings.

5.1.2 Nitrite Shunt (Nitritation-Denitritation)

Nitrifying bacteria oxidize ammonia to nitrite with oxygen (nitritation). Incomplete nitrification (to nitrate) is prevented due to the sidestream characteristics (primarily temperature, ammonia concentration, and SRT). Nitrite is then reduced to N2 gas by facultative heterotrophic denitrifying bacteria (denitritation) using COD. Supplemental alkalinity and an external carbon source are typically required for full nitritation-denitritation. The Digestivore™ PAD (Ovivo) technology utilizes a nitritation-denitritation pathway.

5.1.3 Deammonification

Nitrifying bacteria partially oxidize ammonia to nitrite with oxygen (nitritation). Anammox bacteria oxidize the remainder of the ammonia to N2 gas using nitrite as the electron acceptor (deammonification). Alkalinity demand is reduced by half and the carbon requirement is eliminated. Retaining anammox bacteria is a critical aspect due to their slow growth, which can be on the order of less than 20-30 times that of traditional nitrifying bacteria (Jin et al., 2008 and Peng et al., 2006). Due to the slow growth rate, a need to separate the SRT of anammox versus traditional nitrifiers is required.

Two methods can be used to achieve this separation: 1) selective retention through physical means; this can be settling characteristics (granules), hydrocyclones, or sieving, and 2) use of attached growth (biofilm) media to retain anammox. The deammonification technologies each have unique designs for anammox retention. ANITA Mox™ (Veolia/Kruger), DEMON® (World Water Works), and Anammox (AnammoPAQ®) (Ovivo) technologies utilize a deammonification pathway.

A comparison of the operational and design characteristics of the nitrogen removal pathways is provided in Table 5-1. Deammonification has the highest allowable loading rate (smallest reactor) and lowest demand for external inputs. It requires a high SRT for the slow-growing bacteria that drive the anammox reaction. Therefore, a key aspect of various deammonification technologies is how the anammox bacteria are selectively retained.

Table 5-1 Comparison of Sidestream Treatment Nitrogen Removal Design and Operating Criteria*

Sidestream Treatment N Removal Technology	Loading Rate (Kg NH_3-N/M^3-D)	SRT (Days)	HRT (Days)	Energy Demand (kWh/Kg N)	Carbon Demand (Kg Cod/ Kg N)	Alkalinity Consumed (Kg $CaCo_3$/Kg N)
Nitrification / denitritrification	0.3 to 0.4	5 to10	1.5 (Nit) 3 (TN)	4 to 6.5	3 to 4	7.14
Nitritation / denitritation	0.6 to 1.0	2 to10	2 ¼ to 3	1.8 to 2.9	1.8 to 2.5	7.14
Deammonification	0.7 to 2.0	20 to 30	1 to 3	1.0 to 1.6	0.1	3.6
* Based on published data						

5.1.4 Design Criteria and Evaluation Approach

The max month design loading criteria for the sidestream treatment alternatives is shown in Table 5-2.

Table 5-2 Sidestream Treatment Max Month Design Criteria

Parameter	Value
Digested sludge flow, gpd	300,000
Centrate flow, gpd	260,000
Ammonia concentration	1,200 mg/L

The design and costs for each alternative are based on a similar evaluation that Black & Veatch is preparing for the Cedar Rapids, IA Wastewater Treatment Plant. The loadings for Cedar Rapids are similar to the projected loadings for NEW Water. Sizing and pricing from vendor budget proposals from that project are scaled for the projected NEW water conditions.

A specific energy requirement for the major process equipment components is in kWh/lbs. N is provided for each alternative based on annual average loading conditions assuming a max month factor of 1.3.

5.1.5 Sidestream Nitrogen Alternatives

The following sidestream nitrogen technologies were selected for evaluation:

1. Digestivore PAD
2. ANITA Mox
3. DEMON
4. AnammoPAQ

The first alternative is a nitritation-denitritation technology. The other three technologies are deammonification technologies. Each will be evaluated and summarized in detail within subsequent sections.

5.1.6 Post-Aerobic Digestion (PAD)

The post-aerobic digestion (PAD) technology is unique from the other alternatives because it treats the solids matrix rather than the filtrate. All other technologies are applied downstream from dewatering. The PAD technology provides nitritation of digested sludge followed by denitritation, achieving nitrogen removal via the nitrite shunt pathway. As of 2020, the PAD technology has three installations worldwide.

Anaerobic digestion effluent would be transferred to the reactor with a minimum solids retention time (SRT) of six days to maintain a nitrifying population. Through either low dissolved oxygen (DO) control or intermittent timed aeration, the reactor provides environmental conditions for both nitritation and denitritation using the available alkalinity and carbon available in the biosolids matrix. Table 5-3 summarizes the key advantages and disadvantages of the technology.

Table 5-3 PAD Advantages and Disadvantages

Advantages	Disadvantages
Limited washout risk, reseeding not required	High capital costs due to large tank volume
Familiarity with process (nitrification)	Higher aeration energy requirement
Odor control – ammonia and sulfide removal	Proprietary (single manufacturer)
Phosphorus removal with chemical addition	Potentially reduces solids dewaterability
Potential to incorporate biosolids storage in the alternative	

PAD advantages are related to the simplicity of the approach and potential for odor reduction of the processed biosolids downstream.

One of the major limitations is the required tank volume to achieve the target HRT. Additionally, the nitrification pathway used and nature of the solids matrix increases aeration requirements compared to other alternatives. Alkalinity addition can be a requirement to increase ammonia removal.

5.1.6.1 Process Impacts

The PAD vendor claims up to 98 percent ammonia removal and up to 90 percent total inorganic nitrogen (TIN) removal can be achieved. This is higher removal than deammonification technologies and would minimize the nitrogen recycled to main-stream treatment. These results have been observed at the Northern Treatment Plant (NTP) in Denver over a four-year operating period.

Reduced dewaterability of digested PAD solids has been observed. This could result in lower dewatering loading rates, longer processing times, and increased sludge volume. Sidestream phosphorus removal is a potential in PAD, and reducing mainstream loading can be achieved with alkalinity addition (salts of calcium or magnesium).

Struvite potential in downstream dewatering is reduced from the removal of ammonia.

5.1.7 ANITA Mox

With the ANITA Mox process, nitrogen removal is achieved using the deammonification pathway. ANITA Mox is a proprietary process owned by Veolia (Cary, NC). A diverse consortium of bacteria are cultivated in layers surrounding synthetic biofilm carrier media as shown in Figure 5-2**.**. Continuous aeration creates dissolved oxygen (DO) in the bulk liquid which supports ammonia oxidizing bacteria (AOB) in outer layers. Nitrite and ammonia diffuse into the inside layer containing anammox bacteria. The media and biomass are held in the reactor using cylindrical sieves. An image of the biomass and sieves is shown in Figure 5-3. There are seven full-scale and one pilot-scale ANITA Mox installations in the US. Globally, ANITA Mox is four percent of the installed deammonification capacity and ten percent of the installed installations.

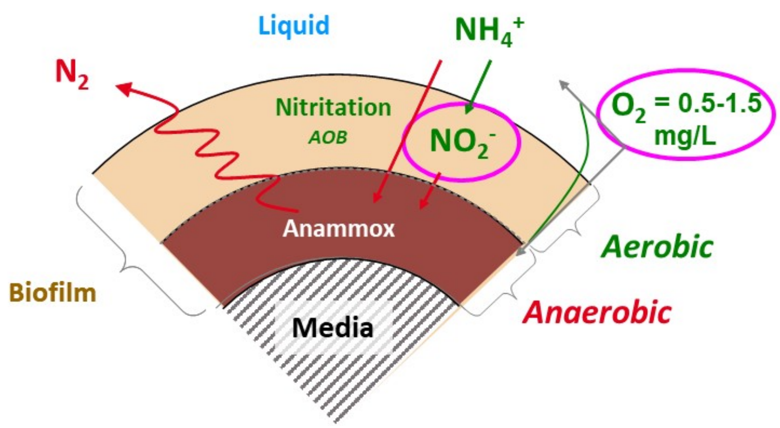

Figure 5-2 Depiction of Bacterial Populations Attached to ANITA Mox Media Carriers for MMBR Configurations. Image (Image Courtesy of Veolia)

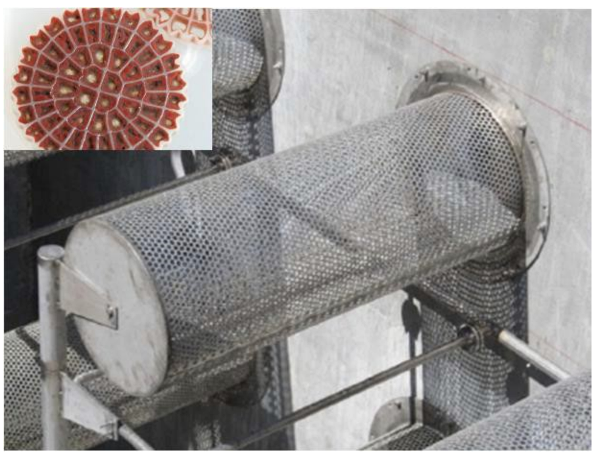

Figure 5-3 Images of ANITA Mox Biofilm Carrier Media with Biomass and Media Retention Sieves

A moving bed biofilm reactor (MBBR) is used for treatment post anerobic digestion. An MBBR is an attached growth process relying on the plastic media carriers only to contain biomass. Biomass slowly sloughs from the media and leaves with the liquid effluent; no external clarification or recycle flows are required. The major treatment component is an aerated and mixed reactor containing plastic biofilm carrier media.

Advantages and disadvantages for the ANITA Mox alternative are shown in Table 5-4. The main advantage of ANITA Mox for the Cedar Rapids application is process stability. A biofilm application reduces the risk of anammox washout and biofilms are more resilient to shock load events.

The disadvantages are a higher energy requirement relative to the other deammonification technologies and a larger footprint. Energy input is required to maintain media in suspension.

Table 5-4 ANITA Mox Advantages and Disadvantages

Advantages	Disadvantages
Attached growth limits anammox washout	Higher energy requirement to suspend media (aeration and mixing)
Stability of biofilm process	Proprietary (single manufacturer)
Less impact from TSS spikes	
Simple capacity expansion with more media	
No external biomass retention equipment or clarifiers	

5.1.7.1 Process Impacts

The vendor claims 85 percent to 90 percent ammonia removal and 80 percent to 85 percent TIN removal. The treated recycle stream ammonia load would be 260 to 390 lbs. N/day.

No sludge stream is generated. Waste solids sloughed from the biomass flow out with liquid effluent and would be recycled to main-stream treatment.

5.1.8 DEMON

The DEMON process implements nitrogen removal via the deammonification pathway. DEMON is a proprietary process licensed in the US by World Water Works (Oklahoma City, OK). It is a suspended growth system that utilizes aeration-nitritation and mixing-deammonification stages in sequence as controlled by pH to support growth of ammonia-oxidizing bacteria (AOB) and anammox bacteria, respectively. Biomass populations are managed by settling and straining through the combination of an external sieve and an internal settler. Intermittently, as needed, sludge is pumped to a separation device (static or rotating screen). Anammox granules are physically retained on the screen and returned to the DEMON reactor. Smaller flocs containing nitrifiers pass through the screen and are wasted from the system.

The DEMON technology is the most widespread of the deammonification technologies. It represents 29 percent of the installed capacity and 47 percent of the installations (Blue Tech Research). US installations include DC Water; Hampton Roads Sanitation District (HRSD) in Virginia; and Greeley, CO. An image of the installation at DC Water is shown in Figure 5-4 along with DEMON anammox granules.

Figure 5-4 Image of the DC Water DEMON System with Inset Anammox Granules (Images Courtesy of DC Water)

The major treatment components include an intermittently aerated reactor and an external screening sieve to retain anammox granules. Recycle and waste streams would be pumped to pre- treatment. Submersible mixers suspend biomass during the mixing phase. Waste sludge would be pumped to the sidestream pre-treatment system.

Advantages and disadvantages for the AnammoPAQ alternative are summarized in Table 5-5.

Table 5-5 DEMON Advantages and Disadvantages

Advantages	Disadvantages
Most US installations	Potential for anammox washout
Lowest aeration energy requirement	Proprietary (single manufacturer)

5.1.8.1 Process Impacts

The vendor claims 90 percent ammonia removal and 80 percent TIN removal. The treated recycle stream ammonia load would be 260 lbs. N/day.

An intermittent sludge stream would be generated. The waste sludge could be pumped to secondary treatment for a bioaugmentation effect.

5.1.9 AnammoPAQ

With AnnamoPAQ, nitrogen removal is achieved using the deammonification pathway. AnammoPAQ is a proprietary process owned by Ovivo USA (Round Rock, TX). It is a suspended growth granular sludge system that utilizes continuous aeration and granules consisting of segregated AOB and anammox populations. Biomass populations are managed by settling with large, dense granules retained by an internal settler. Granules are wasted, as needed (infrequently on a monthly basis), through a valve at the bottom of the tank. The AnammoPAQ deammonification system is most similar to DEMON; however, the granules within the system are significantly larger and host both nitrifying populations (AOB and anammox). See Figure 5-5 for reference to granule size. The AnammoPAQ system does not rely on external anammox retention devices or flocculant SRTs to maintain biomass population; the granules are the primary mechanism for retention.

AnammoPAQ has the fewest US installations of the deammonification technology alternatives. The only municipal US installation is at Fond du Lac, WI. The technology is established globally with 65 percent of total installed capacity and 38 percent of the total number of installations. AnammoPAQ granules were the first global installation of deammonification.

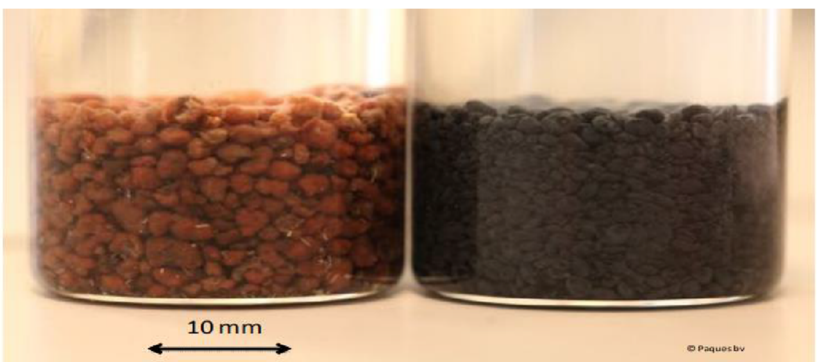

Figure 5-5 AnammoPAQ Anammox Granule Comparison to Anaerobic Granules (Image Courtesy of Ovivo)

The major treatment component consists of an aerated AnammoPAQ.

Advantages and disadvantages for the AnammoPAQ alternative are summarized in Table 5-6.

Table 5-6 AnammoPAQ Advantages and Disadvantages

Advantages	Disadvantages
Highest loading rate / smallest footprint	Potential for anammox washout
Lower aeration energy requirement	Proprietary (single manufacturer)
No external biomass retention equipment or clarifiers	

Sizing and loading criteria of sidestreams ranges from 2.0 to 2.5 kg N/m3 per day. Furthermore, there is evidence of meeting target removals at peak loading factors of 2:1, demonstrating an ability to maintain stable performance during and after increased loading events. The relatively high loading rates are possible because of the vendor-supplied pre-treatment and the granular sludge configuration, which protects against inhibition. In addition, the density of granular sludge results in very high retention of the anammox bacteria with gravity separation.

5.1.9.1 Process Impacts

The vendor claims effluent ammonia from the Sidestream system would be 60 mg N/L (95 percent removal). The treated recycle stream ammonia load would be 130 lbs. N/day.

An intermittent sludge stream would be generated. The waste sludge could be pumped to secondary treatment for a bioaugmentation effect.

5.2 Summary of Sidestream Nitrogen Removal Alternatives

A comparison of sidestream nitrogen removal alternatives is shown in Table 5-7. Capital costs were developed for each potential package, with capital cost details included in **Appendix A**. A recommendation concerning implementation timeline is included in Section 9.

Table 5-7 Comparison of Sidestream Treatment Nitrogen Removal Process Design Criteria

Package	Major Infrastructure	Capital Cost Range	Most Probable Cost
Package 3 – PAD	• Nitritation-denitritation • Large tank, potential to incorporate with digested sludge storage • 90% TIN removal • 3.0 kwh/lb N	\$21.8M to \$32.0M	\$25.6M
Package 4 - AnitaMOX	• Biofilm based deammonification • Filtrate treatment • 75 to 85% TIN removal • 1.2 kwh/lbs N	\$12.9M to \$19.0M	\$15.2M
Package 5 - Demon	• Granule retention • Filtrate treatment • 80% TIN removal • 0.77 kwh/lbs N	\$13.5M to \$19.9M	\$15.9M
Package 6 - AnammoPAQ	• Granule retention • Filtrate treatment • 80% TIN • 0.85 kwh/lbs N	\$15.7M to \$23.1M	\$18.5M

6.0 Infrastructure Improvements – GBF Blowers

GBF has four existing radial compressor blowers that are over 40 years old. These blowers each have a capacity of 60,000 scfm and can be throttled down to approximately 19,500 cfm. A single blower is typically run around 25,000 cfm and air is vented to the off-line basins to reach the minimum air compressor flow rates. In an event of power failure, the GBF backup power system is not able to support the existing blowers and no air is supplied to the aeration basins for treatment.

Blower No. 1 is currently out of service since it does not have a breaker or updated controls. The remaining blowers (Nos. 2-4) are in operable condition. However, the reliability of the blowers for future planning is in question as their useful life has been exceeded. The treated cooling water system and oil system for the blowers have high maintenance demand and would require refurbishment.

The blower improvements at the GBF need to consider current conditions, future loadings, and potential changes to process configurations in the future. Simulations can help to bracket the impacts of the process changes discussed in Section 4 and 5 and provide a blower sizing that can meet the range of design conditions. Appropriately sized blower units, can increase energy efficiency for GBF and ensure proper air supply for treatment even during power outages.

6.1 Airflow Simulations

A series of simulations were completed to establish the potential design ranges for the GBF blowers. The first set of simulations represented a dynamic year at current loadings. The 2018 year was simulated as this was the year that contained the most special sampling and provided a representative range of BOD loadings (BOD loadings shown in Figure 6-1). This dynamic year simulation provides an indication of the range of airflows that are required for design at current loadings. A second dynamic simulation was completed at the scaled 2025 loading condition, which includes the new industrial flows. The maximum sizing criteria were developed based on steady- state simulations of the 2040 minimum week, average, and maximum month conditions. Maximum day airflow requirements were then based on calculations completed as part of TM 2.5.

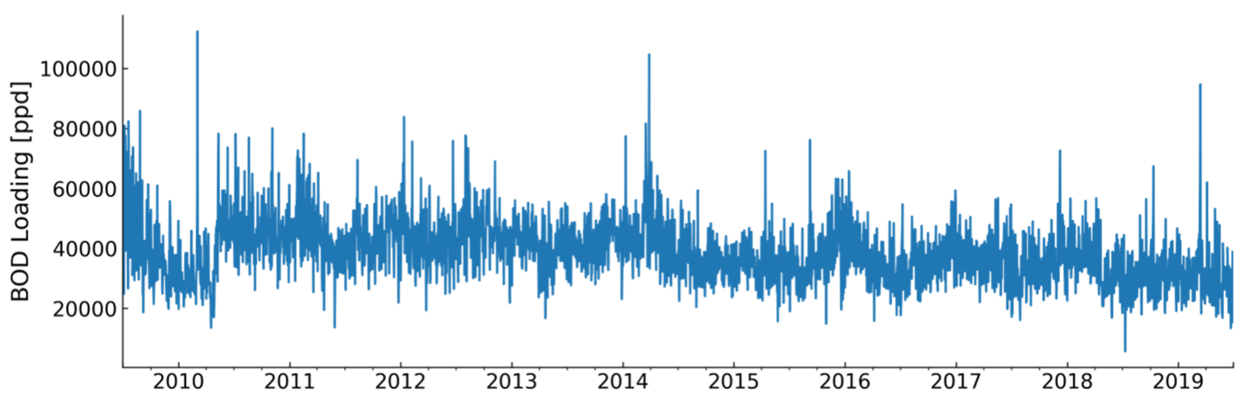

Figure 6-1 **Historic BOD Loadings**

A matrix of simulations were completed to develop airflow ranges. A total of 12 scenario were developed (Table 6-1), and these scenarios were simulated at the three conditions presented above (2018 dynamic year, 2025 dynamic year, 2040 steady-state loadings). For the base simulations, it was assumed that two North Plant aeration basins and one South Plant aeration basin were in operation. An additional simulation at the 2040 steady-state loadings was completed with three North Plant aeration basins in operation, one North Plant aeration basin in idle operation, one South Plant aeration basin in operation, and one South Plant aeration basin in idle operation.

Table 6-1 Scenarios Simulated for Airflow Projections; Each Scenario was Simulated for 2018 Dynamic, 2025 Dynamic, and 2040 Steady State Loadings

Configuration	Metals On/Off	DO	Sidestream Treatment	Scenario
A2O	N	Current	N	1
		Tapered Low DO	N	2
			Y	3
	Y	Current	N	4
		Tapered Low DO	N	5
			Y	6
AO	N	Current	N	7
		Tapered Low DO	N	8
			Y	9
	Y	Current	N	10
		Tapered Low DO	N	11
			Y	12

A summary of the simulated airflow ranges comparing current DO setpoints, tapered low DO setpoints, and tapered low DO setpoints with sidestream treatment is provided in Figure 6-2 for the 2025 dynamic year simulation. Operating in tapered low DO has the potential to reduce airflow requirements by 20 percent, and sidestream treatment has the potential to reduce that aeration energy by an additional 5 percent.

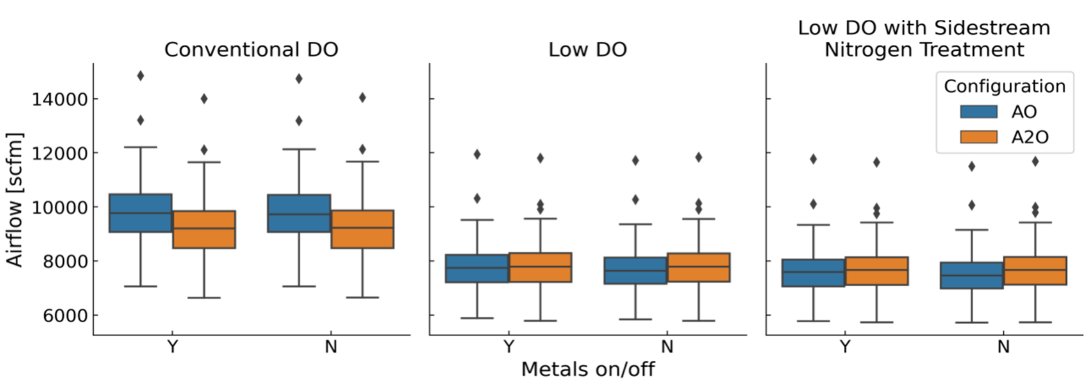

Figure 6-2 Summary of Simulated Airflow Ranges in 2025

The resulting airflow per zone for each simulation is summarized Table 6-2. This provides the range of airflow simulated from the minimum values (tapered DO with sidestream treatment) up to the maximum values (conventional DO setpoints with no sidestream treatment). The total simulated airflow ranges are summarized in Table 6-3. For reference, these simulated airflows are normalized to influent flow rate and compared to other facilities and the WEF benchmark in Figure 6-3. These airflow ranges can be used to develop sizing criteria for blower evaluation, and will provide the flexibility to operate at tapered low DO setpoints or conventional DO setpoints in either the AO or A2O process configuration.

Table 6-2 Airflow Rates in (scfm) for Each Zone in Operation During the Simulations

	Number of Basins	Design Value	NP 1A	NP 1B	NP 2	SP 1	SP 2	SP 3-4	SP 5-6
2018	2 NP	7-d Min	720	624	754	419	245	384	348
	1 SP	Average	1170	887	915	864	410	599	445
		30-d Max	1948	1309	1205	1594	763	921	674
2025	2 NP	7-d Min	1041	876	926	561	298	451	361
	1 SP	Average	1550	1286	1277	1033	472	728	572
		30-d Max	2461	1837	1598	1801	853	1101	768
2040	2 NP	7-d Min	1452	1245	1099	551	293	471	348
	1 SP	Average	1905	1608	1683	696	352	538	419
		30-d Max	2832	2120	2230	968	467	663	514
2040	3 NP	7-d Min	968	830	733	551	292	461	348
	1 SP	Average	1358	1154	1189	681	292	461	412
		30-d Max	2127	1720	1557	968	347	534	514

Table 6-3 Design Airflow Ranges

Design Year	Condition	Basin Operation	Design Air Temperature (C)	North Basins (scfm)	South Basins (scfm	Total (scfm)
2018	Minimum Week	2 NP, 1 SP	-4	4,200	1,400	5,600
2025	Annual Average	2 NP, 1 SP	8	8,300	2,900	11,200
2040	Maximum North	3 NP, 1 SP	27	16,300	4,600	20,900
2040	Maximum North	4 NP (1 idle), 2 SP (1 idle)	27	17,300	5,100	22,400

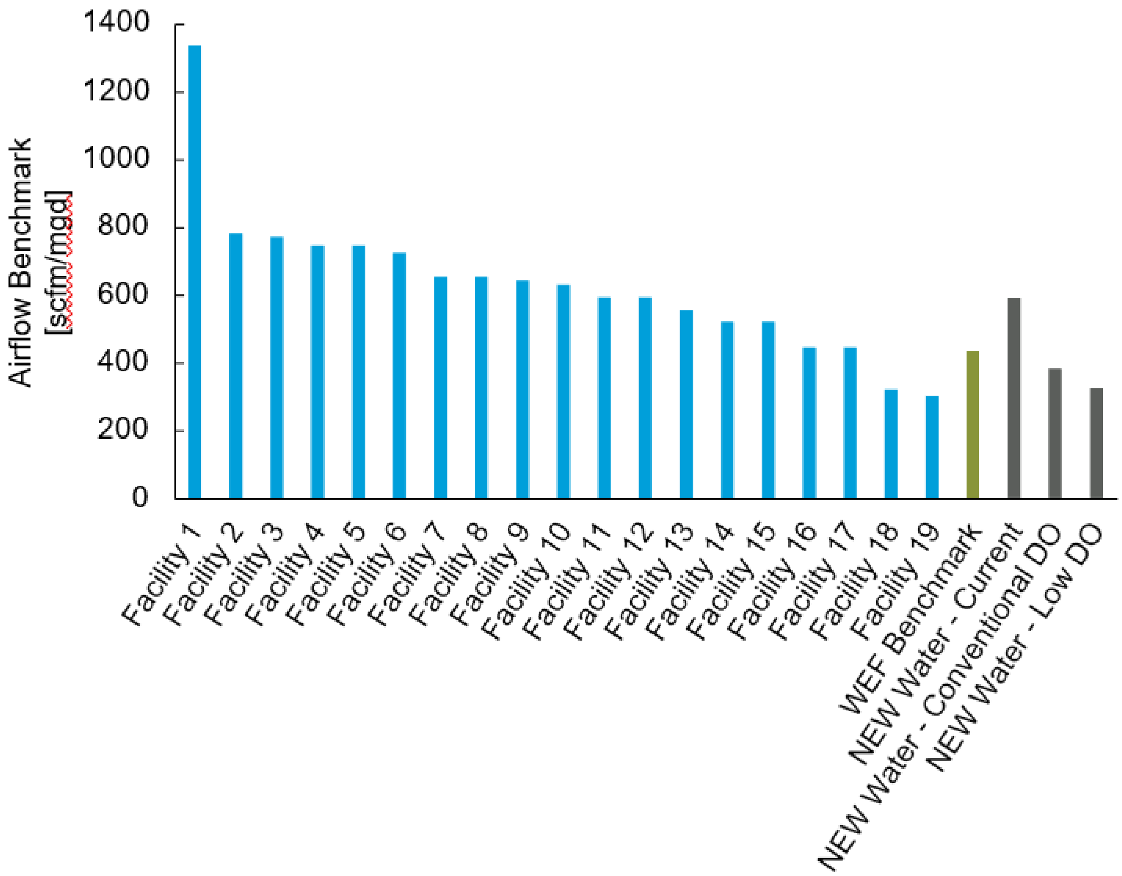

Figure 6-3 **Comparison of Projected NEW Water Normalized Airflows to Several Facilities and the WEF Benchmark**

6.2 Blower Sizing

In order for the aeration and blower systems to be more efficient, replacement of a portion of the existing blowers with new high speed turbo (HST) blower technology is likely the most cost efficient approach. HST blowers offer a significant increase in energy efficiency compared to the existing radial compressors and can be sized to provide greater flexibility and turn-down to match process needs. Two HST blower technologies were evaluated. One type is manufactured by Turblex and Next Turbo, and is an integrally geared unit using a standard speed motor to operate the blower shaft at speeds up to 20,000 RPM. This blower technology will subsequently be referred to as a "geared turbo" blower. The second type is a direct-drive high speed turbo blower. The direct- drive blowers implement a motor and blower impeller on a single, integral shaft that is supported by high speed airfoil or magnetic bearings. They are oil free and have relatively low mechanical noise. The design conditions for the blower sizing for the evaluation are shown in Table 6-4.

Table 6-4 Design Conditions for the Blowers

Parameter	Value
Discharge Pressure (psig)	10
Desired Voltage (V)	480 or 4160
Minimum Air Demand (scfm)	5,600
Average Air Demand (scfm)	13,000
Maximum Month Air Demand (scfm)	22,400
Peak Day Air Demand (scfm)	44,000

6.3 Blower System Alternatives

Two blower alternatives are proposed for the NEW Water blower replacement evaluation:

Alternative 1 involves the selection of all new blowers. The four existing units would be completely removed and five new units would be provided, each sized for 11,000 scfm. This sizing would provide a firm capacity of 44,000 scfm to handle the identified peak day air demand and capability to turn down to the minimum identified air demand of 5,600 scfm with one unit operating.

Alternative 2 utilizes one existing blower for peak events and four new blowers, each sized for 5,500 scfm. This sizing would provide 22,000 scfm firm capacity, which would meet the identified maximum month condition. Under this alternative, the new blowers would operate a majority of the year with the larger existing blower only needed for peak loading events. The total firm capacity is smaller with this alternative; however, the risk of a peak event occurring at the same time the larger existing blower is out of service for maintenance is assumed to be minimal.

The details of each blower alternative are presented in the next subsections. Table 6-5 summarizes the blower arrangement alternative.

Table 6-5 Summary of Blower Arrangement Alternatives

Blower Arrangement Alternative	1	2
Number of New Blowers	5	4
Duty Units	4	4
Standby Units	1	0
Number of Existing Blowers (standby unit)	0	1
Target Capacity per Blower (scfm)	11,000	5,500
Total Firm Blower Capacity (largest unit out of service)	44,000	22,000
Total Blower Capacity	55,000	67,000

6.3.1 Alternative 1

This alternative involves the selection of five turbo blowers, each at approximately 11,000 scfm for a target firm capacity of 44,000 scfm. Four manufacturers provided sizing and budgetary cost information for this alternative:

- Next Turbo
- Turblex
- APG Neuros
- Sulzer

Table 6-6 summarizes the proposed blower systems provided by the vendors to NEW Water for Alternative 2.

Table 6-6 Summary of Blower Arrangement for Alternative 1

Blower Information	Next Turbo	Turblex	APG Neuros	Sulzer
		No. of New Blowers		
Total Installed	5	5	5	6
Duty	4	4	4	5
Standby	1	1	1	1
Blower Type	Geared turbo	Geared turbo	Direct-drive	Direct-drive
Motor Size (HP)	600	600	490	500
Voltage (V)	480 or 4160	480 or 4160	480	480
Turndown	60%	60%	50%	40%
Turndown Method	Inlet guide vanes and variable diffuser vanes	Inlet guide vanes and variable diffuser vanes	Variable frequency drive	Variable frequency drive
Design Air Flow per Blower (scfm)	11,000	11,000	11,000	8,800
Minimum Air Flow per Blower (scfm)	4,400	4,400	5,500	5,280
Inlet Pipe Size (inches)	30	30	30	30
Discharge Pipe Size (inches)	24	24	24	24
Cooling Method	Water or air	Water or air	Water or air	Air
Winter Building Heat Utilization	Yes	Yes	No	Yes
Footprint per Blower (inches)	135” by 65”	100” by 54”	85” by 83”	98” by 70”

6.3.2 Alternative 2

This alternative involves the selection of four smaller blowers, each at approximately 5,500 scfm for a target capacity of 22,000 scfm. One of the existing radial compressor blowers will remain for peak events. Blowers provided by the same manufacturers, as listed in Section 6.2.1, provided information for this alternative. Table 6-7 summarizes the proposed blower systems provided by the vendors for Alternative 2.

Table 6-7 Summary of Blower Arrangement for Alternative 2

Blower Information	Next Turbo	Turblex	APG Neuros	Sulzer
No. of New Blowers				
Total Installed	4	4	4	4
Duty	4	4	4	4
Standby	0	0	0	0
No. of Existing Blowers				
Total Installed	1	1	1	1
Duty	0	0	0	0
Standby	1	1	1	1
Blower Type	Geared turbo	Geared turbo	Direct-drive	Direct-drive
Motor Size (HP)	300	300	300	300
Voltage (V)	480 or 4160	480 or 4160	480	480
Turndown	60%	60%	58%	42%
Turndown Method	Inlet guide vanes and variable diffuser vanes	Inlet guide vanes and variable diffuser vanes	Variable frequency drive	Variable frequency drive
Design Air Flow per Blower (scfm)	5,500	5,500	5,500	5,500
Minimum Air Flow per Blower (scfm)	2,200	2,200	2,310	3,190
Inlet Pipe Size (inches)	20	20	20	20
Discharge Pipe Size (inches)	16	16	16	16
Cooling Method	Water or air	Water or air	Water or air	Air
Winter Building Heat Utilization	Yes	Yes	No	Yes
Footprint per Blower (inches)	89” by 43”	60” by 30”	83” by 55”	91” by 69”

6.4 Capital Cost

A comparison of the blower alternatives is shown in Table 6-8. Capital costs were developed for each potential package, with capital cost details included in **Appendix A**.

Table 6-8 Summary of Economic Analysis for the New Blowers

Package	Major Infrastructure	Capital Cost Range	Most Probable Cost
Package 7 – Five New Larger Blowers	• 5 New 11,000 scfm blowers • Removal of all 4 existing blowers and appurtenances • Replacement of inlet and discharge piping • Replacement of electrical and I&C equipment • Structural modifications for new blowers • Additional upgrades described in Section 6.6	$22.4M to $33.0M	$26.4M
Package 8 – Four New Smaller Blowers	• 4 New 5,500 scfm blowers • Removal of 3 existing blowers and appurtenances • Replacement of inlet and discharge piping • Replacement of electrical and I&C equipment • Structural modifications for new blowers • Additional upgrades described in Section 6.6	$18.5M to $27.3M	$21.8M

6.5 Potential Energy Saving with New Blowers

Energy savings obtained by replacement of the existing blowers with new turbo blowers are estimated in this section. Table 6-9 compares the existing electrical cost with the upgraded conditions involving new blowers at 2020 loadings. Both the conventional DO setpoints and tapered low DO setpoints are compared, with the assumption that offline basins are operating with mixing airflow in an idle mode. It should be noted that the energy usage estimation is based on the theoretical air demand and is the same for both Alternative 1 and Alternative 2. The savings is realized via using a more efficient blower system, which is reflected in the air supply efficiency (scfm/kw) in addition to an overall reduction in air supply due to improved turn-down of the equipment and right sizing of the blowers for demand. Based on the data presented in Table 6-9, an approximately 48 percent energy savings can be realized by replacing the existing blowers with new turbo blowers and operating at conventional DO setpoints. If tapered, low DO Setpoints are implemented, an energy savings of 58 percent can be realized. These energy savings have a major economic benefit, but they also provide a significant advancement towards net energy use goals for NEW Water. The tapered, low DO operation with new blowers would result in NEW Water, producing 50 percent of their net electricity use based on 2019 energy use. Currently, NEW Water is producing approximately 40 percent of the whole system electricity used.

Table 6-9 Summary of Energy Saving for the Blower Replacement Project (Based on 2020 Loadings)

	Existing	Upgraded – Conventional DO	Upgraded – Tapered Low DO
Estimated Average Aeration Supply, scfm	17,750	11,000	9,000
Estimated Annual Energy Usage, MWh	6,219	3,212	2,628
Estimated Annual Energy Savings, MWh		3,006	3,519
Estimated Average Energy, kW	710	366	300
Estimated Air Supply Efficiency, scfm/kW	25	25	21
Average Electrical Cost, $/kWh	0.08	0.08	0
Annual Electrical Cost, $	$ 497,568	256,960	210,240
Estimated Annual Electrical Savings, $		240,608	287,328
Estimated Energy Savings, %		48%	58%

6.6 Additional Upgrades

6.6.1 Air Header

The condition of the buried 48-inch air pipes to both the North Plant and South Plant is a concern based on known leaking. A long-term solution for the refurbishment of the buried air piping is necessary to provide reliable service through the planning period.

The cost opinion considers the full length of the 48-inch buried air piping to both the North Plant and South Plant aeration tanks, approximately 950 ft. Potential alternatives for long term resolution include: carbon fiber-reinforced polymer lining (CFRP), geopolymer spray-in-place lining (SIPP), replacement of the piping, exterior repair and recoating, and exterior carbon fiber wrap.

At this point, limited information is available regarding the condition of the buried air header. In order to effectively evaluate alternatives to rehabilitate or replace the air piping. It is recommended to conduct inspections of the piping. In order to account for the refurbishment work, replacement of the existing piping has been included in the estimated project cost. The preliminary pricing information received for lining systems was found to be similar in cost to replacement.

6.6.2 MCC Replacement

The motor control center (MCC) for the existing blowers is beyond its useful life and needs to be replaced. MCC replacement has been included in the estimated project cost.

6.6.3 Electrical Conduit and Conductors

NEW Water staff have noted that the electrical conduits containing the high voltage (4160V) feeders from the primary switchgear to the Compressor Building have significant water leaks. The staff is also concerned about the age and condition of the conductors in the conduits. The estimated project cost includes replacement of the full length of the conduit, conductors, and duct bank.

6.7 GFB Blower Recommendations

One key consideration between the two alternatives is the fact that Alternative 2 requires one of the old blowers to be reliable for the planning period. During discussions with NEW Water, a variation of Alternative 1 was considered where the project could be phased to offer an initial upgrade with a lower capital cost and a future second phase to install the remaining blowers required to fully replace the existing system. Based on this phasing concept, Alternative 1 is recommended for implementation for the following reasons:

1. All blowers are replaced over the planning period to provide renewed, reliable service.
2. The first phase of the project can be identified to minimize initial capital cost.
3. The first phase of the project will provide significant energy savings that can be achieved with smaller, more efficient blowers along with improved process control.
4. The second phase of the project can be pushed into the later portion of the planning period to provide more funding flexibility.

Given the large capital required for asset renewal, the payback of the full blower projects is long. However, the majority of the energy savings is realized with two new blowers. It is possible to implement in two phases, where three of the existing blowers would be maintained for redundancy until the capital plan provides the driver for asset renewal of the blowers as well as the additional upgrades. Phase 1 would involve removal of Blower Nos. 1 and 2 and the installation of two new blowers. Phase 2 would remove Blowers Nos. 3 and 4 for the installation of the remaining three new blowers. Upon completion of Phase 1, NEW Water would experience immediate energy savings with the new Turbo blowers. In addition, the backup generator system would be able to support this size blower and supply air to the aeration tanks for treatment during a power outage. Table 6-10 provides a summary of economic analysis for the Alternative 1 phasing approach. Capital costs were developed for each phase, with capital cost details included in Appendix A. The phasing of the blower improvements will be discussed in detail during the capital planning process.

Table 6-10 Summary of Economic Analysis for Alternative 1 Phasing

Phase	Major Infrastructure	Capital Cost Range	Most Probable Cost
1	• 2 New 11,000 scfm blowers • Removal 2 existing blowers and appurtenances • Replacement of inlet and discharge piping • Structural modifications for new blowers • Modifications to electrical and I&C equipment • Modifications to MCC	$5.3M to $7.8M	$6.3M
2	• 3 New 11,000 scfm blowers • Removal of 2 existing blowers and appurtenances • Replacement of inlet and discharge piping • Structural modifications for new blowers • Replacement of electrical and I&C equipment • Electrical feeder replacement • Buried air header replacement	$17.1M to $25.2M	$20.1M

7.0 Future DPF Considerations

As discussed in TM 4.4, the major aeration basin capital cost for the DPF will be the addition of a third aeration basin in the future. The driver for this future aeration basin is loading, and this loading is projected to be exceeded in two to seven years. Based on simulations at the GBF, a modification to the selector zones to include anoxic volume in an A2O configuration would be beneficial in the existing aeration basins, as well as the future aeration basin. A potential layout of A2O for the DPF is shown in Figure 7-1. The anaerobic selector could be split in half in a serpentine pattern to achieve the anaerobic and anoxic volumes. The aeration volume could also be divided with a new baffle wall to create two tanks-in-series, which would improve operational control. MLR could be transferred from the second aeration basin to the anoxic selector zone volume. MLR would be 250% of influent average day flow, resulting in a MLR pump with 6.5 mgd capacity in each basin.

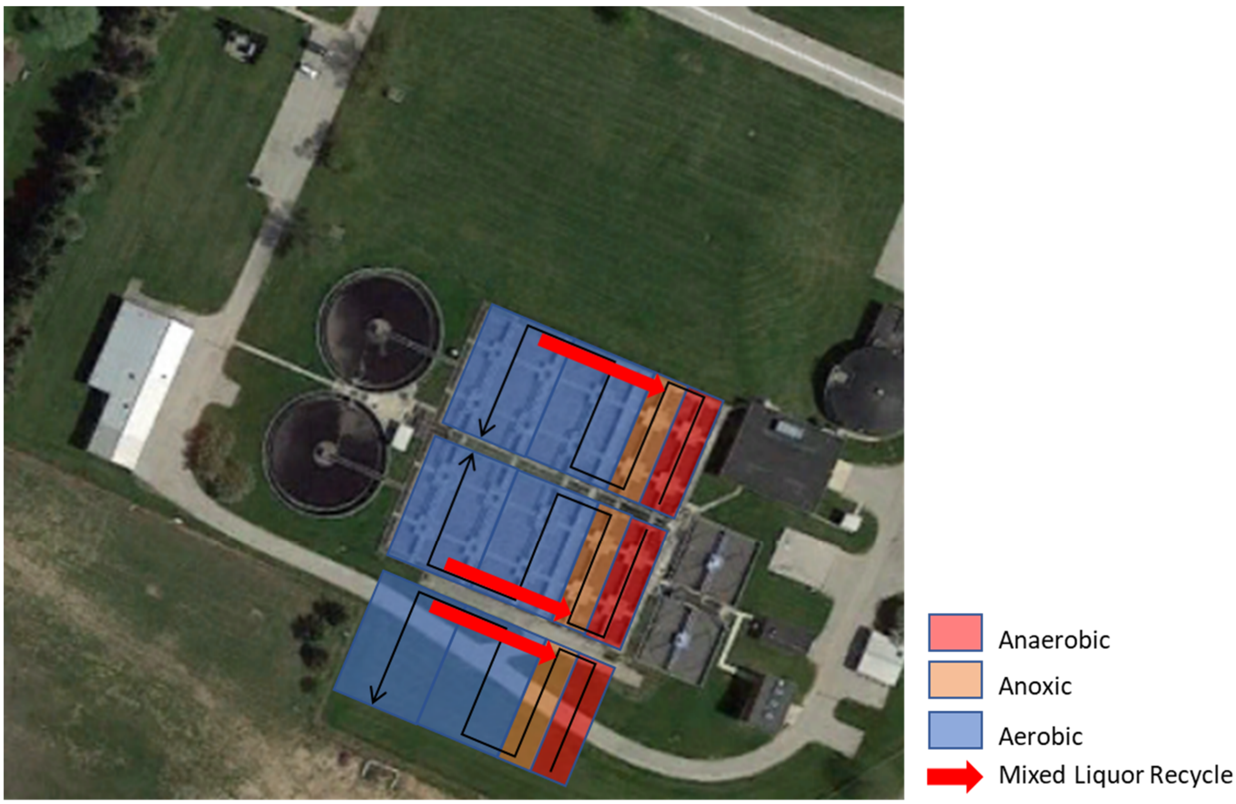

Figure 7-1 Potential A2O Layout for the DPF Aeration Basins (preliminary location)

Similar to the configuration evaluation for the GBF, a dynamic month simulation was completed for the DPF at the validation month (February 2019). Effluent total nitrogen and total phosphorus for the baseline model from the model validation are shown in Figure 7-2. Effluent phosphorus averaged just below 0.3 mg/L, but this was with an assumed effluent TSS of 3 mg/L. The total nitrogen was typically higher than the target concentration of 8 mg/L. When the fractionation of this effluent total nitrogen is examined, the majority of effluent total nitrogen is associated with recalcitrant dissolved organic nitrogen (rDON) (Figure 7-3). This is not typical, and is driven by the high effluent soluble COD observed at the DPF during special sampling. If the fraction of effluent soluble COD is reduced in the model space, effluent nitrogen of less than 8 mg/L is achieved. The rDON fraction in the influent is currently based on assumptions, and not measured effluent rDON currently observed at the DPF. Regardless of the configuration, this rDON fraction is difficult to remove without advanced oxidation processes. As NEW Water prepares for a future total nitrogen limit, further exploration of the rDON fraction in the effluent should be explored. This can be measured now, even without the A2O configuration, as the effluent rDON is not impacted by the bioloigical processes.

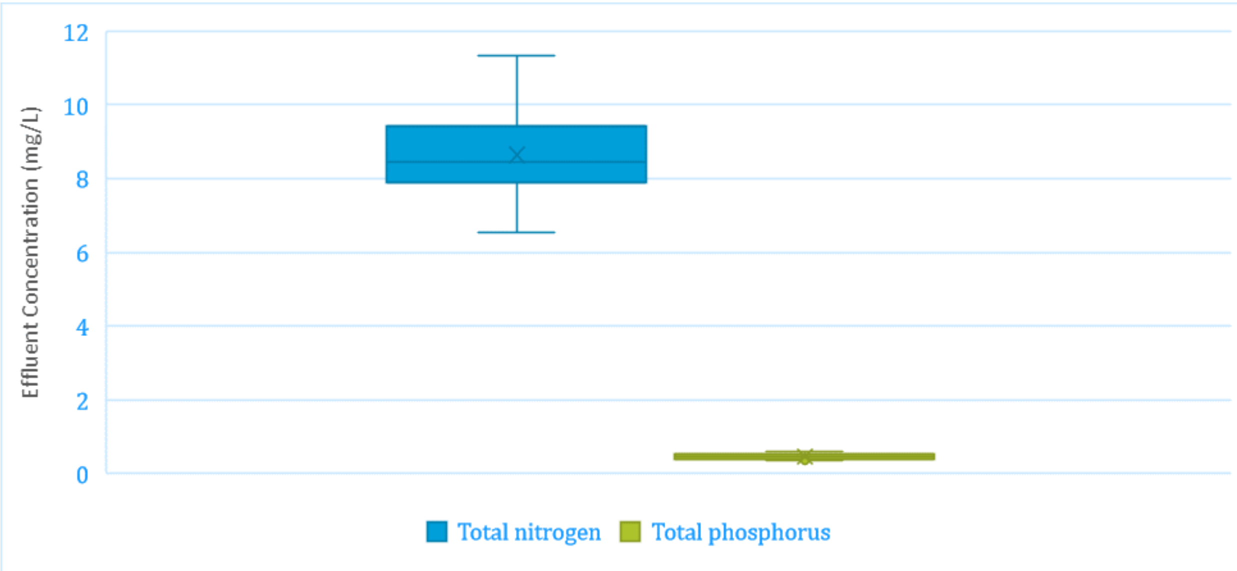

Figure 7-2 Effluent Nitrogen and Phosphorus for the A2O Configuration at the DPF

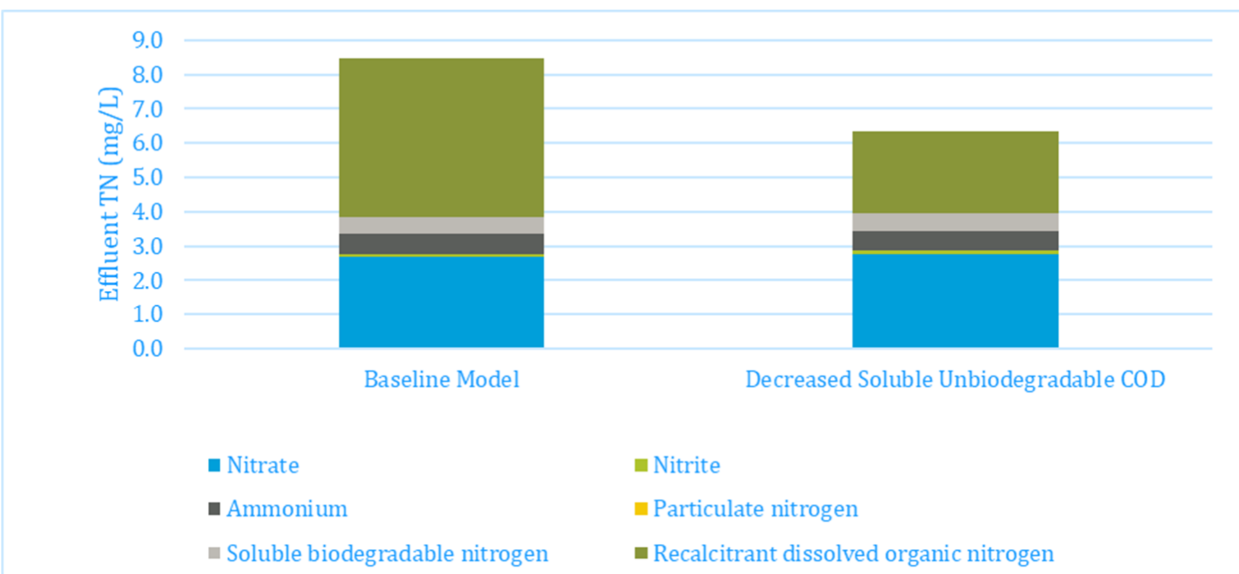

Figure 7-3 Effluent Nitrogen Fractions in the Baseline Model, and with Adjusted Soluble Unbiodegradable COD

The major capital cost for the DPF aeration basins is the addition of a third aeration basin, as identified in TM 4.4. The blowers have sufficient aeration capacity through the 2040 loading conditions, which limits the required blower investment. For the Facility Plan, two infrastructure packages were developed: modification of the existing aeration basins to A2O and addition of a third aeration basin. For application, this would likely be one large project, but the packages could be implemented separately. The capital cost requirements are provided in Table 7-1, and capital cost details are included in **Appendix A**. Overall operating costs would not be significantly impacted with these improvements.

Table 7-1 Capital Costs for the DPF

Package	Major Infrastructure	Capital Cost Range	Most Probable Cost
Package 9 – Aeration Basin Modifications	• New baffling in aeration basins • Modifications to existing diffuser grids and control	$1.4 to $2.0M	$1.6M
Package 10 – New Aeration Basin	• New aeration basin (from TM 4.4)	$14 to $30M	$20 M

8.0 Applied Research

Improvements to the aeration basins for energy savings and nutrient removal provide unique opportunities for applied research at both the GBF and the DPF. Testing releated to diffuser densities, aeration control, A2O modifications, and DPF nitrogen testing can be completed to inform future design decisions.

8.1 Diffuser Densities and Control

As noted, there appear to be too many diffusers in several of the aeration grids to allow for DO control based on current loadings. Decreasing the diffuser count would enable testing of different DO control strategies. The tapered, low DO control strategy should not be tested until the A2O configuration is implemented, as the rbCOD leaving the selector zones would have a negative impact on settleability.

The cost to plug diffusers to modify the diffuser grid densities would be tied to NEW Water labor and the procurement of diffuser plugs. The diffuser plugs cost $2 to $5 per plug, and 4,270 diffusers need to be plugged. Budgeting $50,000 for the plugs should provide the required plugs for modifications. Location of the plugs should be examined in more detail. This diffuser plugging would be beneficial in all six aeration basins, but could be implemented in a single basin as a trial. Oxygen transfer efficiency testing could be completed as part of the diffuser evaluation. Offgas testing and diffuser evaluations can be completed by several independent contractors, including Redmon Engineering, and can be used to refine the location of plugged diffusers.

8.2 A2O Modifications

Testing the A2O configuration would be relatively easy to accomplish in the South Plant aeration basins. The majority of infrastructure is already in place. Major improvements would require a MLR pump and modification of existing piping. The diffuser plugging should also be completed before demonstration testing. Testing could take place in one basin, and the goal of this demonstration testing would be to verify the impact of MLR on effluent nitrogen, settleability, and effluent phosphorus. Conversion to A2O would also enable testing of tapered low DO setpoints. After observing operation in A2O, this South Plant would also present an opportunity

Investment in conversion of one South Plant aeration basin to a demonstration basin in 2021 would provide NEW Water with significant flexibility over the coming years to test MLR pumping rates, DO setpoints, and potentially the impacts of more stable SRT operation before investment in the North Plant aeration basins. Total capital cost to add MLR pumping in one South Plant Aeration basin is $950,000. This is the partial capital cost for the A2O modifications developedin in Section 4.

8.3 DPF Testing

Applied research efforts at DPF would be more limited, but critical for future nitrogen removal requirements. As noted, the DPF has a relatively high effluent soluble COD, likely due to the high fraction of industrial loading. Understanding the rDON fraction in this effluent COD will influence the ability to achieve an 8 mg/L effluent nitrogen limit at the DPF. Measurement of effluent soluble COD and rDON would need to be considered in future aeration basin planning projects.

9.0 Discussion and Recommendations

A series of infrastructure package improvements were developed to address five main drivers related to the aeration basins and nutrient removal at the NEW Water facilities:

- Aging equipment at the GBF
- Energy efficiency in the GBF aeration system
- Operational limitations related to sludge settleability at the GBF
- Future effluent performance related to total nitrogen removal and stable phosphorus removal at the GBF and DPF
- Capacity limitations at the DPF require a third aeration basin, and the process configuration at the DPF should be designed to achieve future nutrient removal requirements

To address these drivers, a total of 10 infrastructure packages were identified as potential solutions for NEW Water. The full list of infrastructure packages is provided in Table 9-1. Based on the drivers and available technologies, the following packages are recommended for inclusion in the capital improvements plan, with drivers for each discussed in Table 9-2:

- Package 1 A2O Modifications
- Package 2 Low DO instrumentation and controls
- Package 4 AnitaMOX
- Package 7 Five new blowers
- Package 9 DPF aeration basin modifications
- Package 10 DPF new aeration basin

The impacts and implementation drivers for each of these packages is presented in Table 9-2. These impacts and drivers will be considered as part of Task 5 when developing the overall capital improvements plan. Given the potential impacts of the A2O modifications and the low DO operational strategies, it is recommended that one of the South Plant aeration basins be converted to a demonstration basin to enable testing of the A2O configuration, low DO operation, and stable SRT operation in the near-term to better inform future design and operational strategies. The cost of the demonstration basin construction is estimated as $950,000.

Table 9-1 Infrastructure Packages Developed to Address Aeration and Nutrient Removal Drivers

Package	Major Infrastructure	Capital Cost Range	Most Probable Cost
GBF Improvements			
Package 1 – A2O Modification	• Six MLR recycle pumps, one for each aeration basin • Associated piping and controls	$4.0M to $5.9M	$4.7M
Package 2 – Low DO Instrumentation and Control	• Ammonium sensors • Improvements to several control valves and air piping in first drop legs	$0.3M to $0.7M	$0.5M
Package 3 – PAD	• Large tank, potential to incorporate with digested sludge storage • 90% TIN removal • 3.0 kwh/lb N	$21.8M to $32.0M	$25.6M
Package 4 - AnitaMOX	• Filtrate treatment • 75 to 85% TIN removal • 1.2 kwh/lbs N	$12.9M to $19.0M	$15.2M
Package 5 - Demon	• Filtrate treatment • 80% TIN removal • 0.77 kwh/lbs N	$13.5M to $19.9M	$15.9M
Package 6 - AnammoPAQ	• Filtrate treatment • 80% TIN • 0.85 kwh/lbs N	$15.7M to $23.1M	$18.5M
Package 7 – Five New Larger Blowers	• 5 New 11,000 scfm blowers • Removal of all 4 existing blowers and appurtenances	$22.4M to $33.0M	$26.4M
Package 8 – Four New Smaller Blowers	• 4 New 5,500 scfm blowers • Removal of 3 existing blowers and appurtenances • Structural modifications for new blowers	$18.5M to $27.3M	$21.8M
DPF Improvements			
Package 9 – DPF Aeration Basin Modifications	• New baffling in aeration basins and MLR pumps	$1.4 to $2.0M	$1.6M
Package 10 – DPF New Aeration Basin	• New aeration basin (from TM 4.4)	$14 to $30M	$20M

Table 9-2 Recommended Infrastructure Packages for the Facility Plan Capital Improvements Plan

Package	Most Probable Cost	Impacts	Implementation Drivers
Package 1 – A2O Modification	$4.7 M (potential early investment of $950,000 for a single aeration basin)	• Improved settleability stability • Effluent total nitrogen removal • Enables tapered low DO operation and energy savings	• Operational limitations • Effluent performance • Energy efficiency
Package 2 – Low DO Instrumentation and Control	$0.5M	• Tapered low DO for energy savings • Requires diffuser density modifications with diffuser plugging; aeration valving and piping changes	• Operational illimitations • Effluent performance • Energy efficiency
Package 4 - AnitaMOX	$15.2M	• Sidestream nitrogen removal provides improved effluent phosphorus stability and future total nitrogen removal improvements • AnitaMOX was the lowest capital, and the lowest complexity for operation	• Effluent nitrogen regulatory driver • Changes to influent metal concentrations impacts biological phosphorus removal performance
Package 7 – Five New Larger Blowers	$26.4M	• Significant energy savings potential, particularly after Package 1 and 2 are implemented	• Aging infrastructure • Energy efficiency
Package 9 – DPF Aeration Basin Modifications	$1.6M	• Effluent total nitrogen removal • Potential improvements to sludge settling and performance stability	• Operational limitations • Effluent performance • DPF capacity • Likely implemented in conjunction with Package 10
Package 10 – New Aeration Basin	$20M	• Improves DPF capacity and operational stability • Future total nitrogen removal	• Operational limitations • Effluent performance • DPF capacity

Appendix A. Cost Estimate Support Details

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

OPCC

Process	Total Cost	Total Cost -15%	Total Cost +25%
Aeration - South Plant	$ 1,910,000	$ 1,620,000	$ 2,390,000
Aeration - North Plant	$ 2,790,000	$ 2,370,000	$ 3,490,000
	$ 4,700,000	$ 4,000,000	$ 5,880,000
Aeration - De Pere	$ 1,610,000	$ 1,370,000	$ 2,010,000
Applied Research	$ 954,000	$ 810,000	$ 1,190,000
Post-Aerobic Digestion in New Tank	$ 25,600,000	$ 21,800,000	$ 32,000,000
AnitaMOX	$ 15,200,000	$ 12,900,000	$ 19,000,000
Demon	$ 15,900,000	$ 13,500,000	$ 19,900,000
AnnammoPAQ	$ 18,500,000	$ 15,700,000	$ 23,100,000
Blowers - Alt 1	$ 26,400,000	$ 22,400,000	$ 33,000,000
Blowers - Alt 2	$ 21,800,000	$ 18,500,000	$ 27,300,000

Contractor Overhead and Profit	25%
Contingency	50%
Engineering	25%

Quantity Estimate	Units	Rate	Notes
Sitework			
Sitework for buildings	SF	$ -	
Excavation	CY	$ -	
Backfill	CY	$ -	
	CY	$ -	
	SF	$ -	
Steel and Concrete			
Building Cost "large"	SF	$ -	
Building Cost "small"	SF	$ -	
Total 4000 psi Concrete - Walls	CY	$ 1,600	From O'Brien OPCC
	SF	$ -	
Mechanical			
36" DI Pipe	LF	$ 725	From O'Brien OPCC
42" DI Pipe	LF	$ 825	From O'Brien OPCC
Equipment			
Mixed Liquor Recycle Pump - 6.5MGD	EA	$ 20,000	Xylem quote from O'Brien (scaled)
Mixed Liquor Recycle Pump - 25MGD	EA	$ 75,000	Xylem quote from O'Brien
Mixed Liquor Recycle Pump - 60MGD	EA	$ 180,000	Xylem quote from O'Brien (scaled)
	EA	$ -	
	EA	$ -	

Xylem Quote from 2-19-19 for O'Brien
Wall Mounted Horizontal Propeller Pump

23,000	gpm
33,120,000	gpd
$ 75,000	ea including cranes (22 pumps and 4 cranes)

Methodology

Construction costs were calculated utilizing construction costs from previous projects completed, similar construction projects completed elsewhere in the past two years, typical installed costs observed from past project experience, pricing for the main process equipment and previous estimates completed for NEW Water.

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

Aeration - South Plant
OPCC

	Qtny	Units	Rate	Cost
Demolition				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Sitework				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Concrete & Metals				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Mechanical				
36" DI Pipe	800	LF	$ 725	$ 580,000
			$ -	$ -
Total				**$ 580,000**
Equipment				
Mixed Liquor Recycle Pump - 25MGD	2	EA	$ 75,000	$ 150,000
			$ -	$ -
Install			30%	$ 45,000
Subtotal				$ 195,000
Mechanical			0%	$ -
Electrical & I&C			20%	$ 39,000
Total				**$ 234,000**
Subtotal				**$ 814,000**
Contractor Overhead and Profit			25%	$ 203,500
Subtotal				$ 1,017,500
Contingency			50%	$ 508,800
Total Construction Cost				**$ 1,526,000**
Engineering			25%	$ 381,500
Total Cost				**$ 1,908,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

Aeration - North Plant
OPCC

	Qtny	Units	Rate	Cost
Demolition				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Sitework				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Concrete & Metals				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Mechanical				
42" DI Pipe	80	LF	$ 825	$ 66,000
			$ -	$ -
Total				**$ 66,000**
Equipment				
Mixed Liquor Recycle Pump - 60MGD	4	EA	$ 180,000	$ 720,000
			$ -	$ -
Install			30%	$ 216,000
Subtotal				$ 936,000
Mechanical			0%	$ -
Electrical & I&C			20%	$ 187,200
Total				**$ 1,123,200**
Subtotal				**$ 1,189,200**
Contractor Overhead and Profit			25%	$ 297,300
Subtotal				$ 1,486,500
Contingency			50%	$ 743,300
Total Construction Cost				**$ 2,230,000**
Engineering			25%	$ 557,500
Total Cost				**$ 2,788,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

Aeration - De Pere
OPCC

	Qtny	Units	Rate		Cost
Demolition					
			$ -	$	-
			$ -	$	-
Total				**$**	**-**
Sitework					
			$ -	$	-
			$ -	$	-
Total				**$**	**-**
Concrete & Metals					
Baffle Walls	300	CY	$ 1,600	$	480,000
			$ -	$	-
Total				**$**	**480,000**
Mechanical					
36" DI Pipe	200	LF	$ 725	$	145,000
			$ -	$	-
Total				**$**	**145,000**
Equipment					
Mixed Liquor Recycle Pump - 6.5MGD	2	EA	$ 20,000	$	40,000
			$ -	$	-
Install			30%	$	12,000
Subtotal				$	52,000
Mechanical			0%	$	-
Electrical & I&C			20%	$	10,400
Total				**$**	**62,400**
Subtotal				**$**	**687,400**
Contractor Overhead and Profit			25%	$	171,900
Subtotal				$	859,300
Contingency			50%	$	429,700
Total Construction Cost				**$**	**1,289,000**
Engineering			25%	$	322,300
Total Cost				**$**	**1,611,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

Applied Research
OPCC

	Qtny	Units	Rate	Cost
Demolition				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Sitework				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Concrete & Metals				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Mechanical				
36" DI Pipe	400	LF	$ 725	$ 290,000
			$ -	$ -
Total				**$ 290,000**
Equipment				
Mixed Liquor Recycle Pump - 25MGD	1	EA	$ 75,000	$ 75,000
			$ -	$ -
Install			30%	$ 22,500
Subtotal				$ 97,500
Mechanical			0%	$ -
Electrical & I&C			20%	$ 19,500
Total				**$ 117,000**
Subtotal				**$ 407,000**
Contractor Overhead and Profit			25%	$ 101,800
Subtotal				$ 508,800
Contingency			50%	$ 254,400
Total Construction Cost				**$ 763,000**
Engineering			25%	$ 190,800
Total Cost				**$ 954,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

Post-Aerobic Digestion in New Tank
OPCC

	Qtny	Units	Rate	Cost
Demolition				
			$ -	$ -
			$ -	$ -
			$ -	$ -
Total				**$ -**
Sitework				
Excavation	3,900	CY	$ 25	$ 97,500
Backfill	2,000	CY	$ 25	$ 50,000
Total				**$ 147,500**
Concrete & Metals				
2.4 MG Glass-Lined Circular Tank	1	EA	$ 1,560,000	$ 1,560,000
Sidestream Treatment Building	6,600	SF	$ 400	$ 2,640,000
Total				**$ 4,200,000**
Mechanical				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Equipment				
PAD Equipment Package	1	LS	$ 1,962,000	$ 1,962,000
Blowers	5	EA	$ 300,000	$ 1,500,000
Dewatering Feed Pumps	5	EA	$ 17,500	$ 87,500
Head Exchangers	2	EA	$ 33,000	$ 66,000
Install			30%	$ 1,084,650
Subtotal				$ 4,700,150
Mechanical			20%	$ 940,030
Electrical & I&C			20%	$ 940,030
Total				**$ 6,580,210**
Subtotal				**$ 10,927,700**
Contractor Overhead and Profit			25%	$ 2,731,900
Subtotal				$ 13,659,600
Contingency			50%	$ 6,829,800
Total Construction Cost				**$ 20,489,000**
Engineering			25%	$ 5,122,300
Total Cost				**$ 25,611,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

AnitaMOX
OPCC

	Qtny	Units	Rate	Cost
Demolition				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Sitework				
Excavation	650	CY	$ 25	$ 16,000
Backfill	150	CY	$ 25	$ 4,000
Total				**$ 20,000**
Concrete & Metals				
Slab on Grade	130	CY	$ 625	$ 81,000
Walls	500	CY	$ 1,600	$ 800,000
Accessories	1	LS	$ 10,000	$ 10,000
Sidestream Treatment Building	2,650	SF	$ 400	$ 1,060,000
Total				**$ 1,951,000**
Mechanical				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Equipment				
AnitaMOX Equipment	1	LS	$ 2,347,000	$ 2,347,000
Heat Exchangers	2	EA	$ 20,000	$ 40,000
Centrate Effluent Pumps	2	EA	$ 9,500	$ 19,000
Chemical Feed Equipment	1	LS	$ 80,000	$ 80,000
Install			30%	$ 745,800
Subtotal				$ 3,231,800
Mechanical			20%	$ 646,360
Electrical & I&C			20%	$ 646,360
Total				**$ 4,524,520**
Subtotal				**$ 6,495,500**
Contractor Overhead and Profit			25%	$ 1,623,900
Subtotal				$ 8,119,400
Contingency			50%	$ 4,059,700
Total Construction Cost				**$ 12,179,000**
Engineering			25%	$ 3,044,800
Total Cost				**$ 15,224,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

Demon
OPCC

	Qtny	Units	Rate	Cost
Demolition				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Sitework				
Excavation	2,100	CY	$ 25	$ 53,000
Backfill	200	CY	$ 25	$ 5,000
Total				**$ 58,000**
Concrete & Metals				
Aluminum Cover for New Tanks	2,850	SF	$ 50	$ 143,000
Slab on Grade	160	CY	$ 625	$ 100,000
Walls	510	CY	$ 1,600	$ 816,000
Accessories	1	LS	$ 10,000	$ 10,000
Sidestream Treatment Building	3,725	SF	$ 400	$ 1,490,000
Total				**$ 2,559,000**
Mechanical				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Equipment				
Demon Equipment	1	LS	$ 2,112,000	$ 2,112,000
Heat Exchangers	2	EA	$ 20,000	$ 40,000
Centrate Effluent Pumps	2	EA	$ 9,500	$ 19,000
WAS Pumps	2	EA	$ 14,000	$ 28,000
Chemical Feed Equipment	1	LS	$ 80,000	$ 80,000
Install			30%	$ 683,700
Subtotal				$ 2,962,700
Mechanical			20%	$ 592,540
Electrical & I&C			20%	$ 592,540
Total				**$ 4,147,780**
Subtotal				**$ 6,764,800**
Contractor Overhead and Profit			25%	$ 1,691,200
Subtotal				$ 8,456,000
Contingency			50%	$ 4,228,000
Total Construction Cost				**$ 12,684,000**
Engineering			25%	$ 3,171,000
Total Cost				**$ 15,855,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

AnnammoPAQ
OPCC

	Qtny	Units	Rate	Cost
Demolition				
Demo of Existing Decant Tanks	2	EA	$ 50,000	$ 100,000
			$ -	$ -
Total				**$ 100,000**
Sitework				
Excavation	600	CY	$ 25	$ 15,000
Backfill	200	CY	$ 25	$ 5,000
Total				**$ 20,000**
Concrete & Metals				
Slab on Grade	60	CY	$ 625	$ 38,000
Walls	140	CY	$ 1,600	$ 224,000
Accessories	1	LS	$ 10,000	$ 10,000
Sidestream Treatment Building	7,650	SF	$ 400	$ 3,060,000
Total				**$ 3,332,000**
Mechanical				
			$ -	$ -
			$ -	$ -
Total				**$ -**
Equipment				
AnnammoPAQ Equipment	1	LS	$ 2,288,000	$ 2,288,000
Heat Exchangers	2	EA	$ 20,000	$ 40,000
Effluent Pumps	3	EA	$ 11,000	$ 33,000
Chemical Feed Equipment	1	LS	$ 80,000	$ 80,000
Install			30%	$ 732,300
Subtotal				$ 3,173,300
Mechanical			20%	$ 634,660
Electrical & I&C			20%	$ 634,660
Total				**$ 4,442,620**
Subtotal				**$ 7,894,600**
Contractor Overhead and Profit			25%	$ 1,973,700
Subtotal				$ 9,868,300
Contingency			50%	$ 4,934,200
Total Construction Cost				**$ 14,803,000**
Engineering			25%	$ 3,700,800
Total Cost				**$ 18,504,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

Five New Larger Blowers

General Description

This alternative involves removal of all 4 existing blowers and related appurtenances and the installation of 5 new turbo blowers sized at 11,000 scfm each. Four of the new blowers would provide a firm capacity of 44,000 scfm to meet future peak day air demand while the fifth unit would be a backup. The inlet and discharge piping in the building would be removed and replaced to accomidate the five blower units. The electrical and I&C equipment in the building would be replaced to provide a new system. Structural modifications would occur for the new blower locations.In order to fix air leaks, the 48" air piping headers to the North Plant and South Plant would be replaced or a liner would be installed. The electrical conduit and cables feeding the Compressor Building from the Switchgear would be replaced due to age and condition. Some refurbishment work related to Compressor No. 3 and 4 oil and liquid cooling systems is included in the mechanical and plumbing multipliers below.

	Qtny	Units	Rate		Cost
Demolition					
Piping	1	ls	$ 30,000	$	30,000
Blowers and Equipment Pads	4	ea	$ 25,000	$	100,000
Electrical and I&C Equipment	1	ls	$ 15,000	$	15,000
Total				**$**	**145,000**
Equipment and Piping					
11,000 scfm Turbo Blower	5	ea	$ 320,000	$	1,600,000
Intake and Discharge Piping, Valves, Accessories	5	ea	$ 150,000	$	750,000
Master Control Panel	1	ea	$ 100,000	$	100,000
Electrical MCC Circuit Breakers	5	ea	$ 50,000	$	250,000
VFD / Soft Starters	5	ea	$ 50,000	$	250,000
Roof Intake Modifications	5	ea	$ 5,000	$	25,000
Air Header Replacement or Lining- 48"	950	lf	$ 2,000	$	1,900,000
Elec. Conduit and Cable Replace from Switchgear	1	ls	$ 470,000	$	470,000
Install			30%	$	1,603,500
Subtotal				$	6,948,500
Mechanical			20%	$	1,389,700
Electrical & I&C			20%	$	1,389,700
HVAC and Plumbing			10%	$	694,850
Structural Rehabilitation			10%	$	694,850
Total				**$**	**11,117,600**
Subtotal				**$**	**11,262,600**
Contractor Overhead and Profit			25%	$	2,815,700
Subtotal				$	14,078,300
Contingency			50%	$	7,039,200
Total Construction Cost				**$**	**21,118,000**
Engineering			25%	$	5,279,500
Total Cost				**$**	**26,398,000**

NEW Water Blower Evaluation
Green Bay Facility

Alternative 1 - Five New Larger Blowers
Phase 1 - Two Blowers

General Description

The first phase of this project involves removal of 2 existing blowers (Compressor No. 1 and 2) and related appurtenances and the installation of two new turbo blowers sized at 11,000 scfm each. The two new blowers would provide 22,000 scfm, which would cover up to maximum month conditions. The two remaining existing blowers would provide backup and peak flow capacity. The inlet and discharge piping would be modified to connect the two new turbo blowers. The electrical and I&C equipment in the building would be modified to accomidate the two new turbo blowers. Structural modifications would occur for the new blower locations. Some refurbishment work related to Compressor No. 3 and 4 oil and liquid cooling systems is included in the mechanical and plumbing multipliers below.

	Qtny	Units	Rate	Cost
Demolition				
Piping	1	ls	$ 15,000	$ 15,000
Blowers and Equipment Pads	2	ea	$ 25,000	$ 50,000
Electrical and I&C Equipment	1	ls	$ 7,500	$ 8,000
Total				**$ 73,000**
Equipment and Piping				
11,000 scfm Turbo Blower	2	ea	$ 320,000	$ 640,000
Intake and Discharge Piping, Valves, Accessories	2	ea	$ 150,000	$ 300,000
Master Control Panel	1	ea	$ 100,000	$ 100,000
MCC Replacement	2	ea	$ 50,000	$ 100,000
VFD / Soft Starters	2	ea	$ 50,000	$ 100,000
Roof Intake Modifications	2	ea	$ 5,000	$ 10,000
Install			30%	$ 375,000
Subtotal				$ 1,625,000
Mechanical			20%	$ 325,000
Electrical & I&C			20%	$ 325,000
HVAC and Plumbing			10%	$ 162,500
Structural Rehabilitation			10%	$ 162,500
Total				**$ 2,600,000**
Subtotal				**$ 2,673,000**
Contractor Overhead and Profit			25%	$ 668,300
Subtotal				$ 3,341,300
Contingency			50%	$ 1,670,700
Total Construction Cost				**$ 5,012,000**
Engineering			25%	$ 1,253,000
Total Cost				**$ 6,265,000**

NEW Water Blower Evaluation
Green Bay Facility

Alternative 1 - Five New Larger Blowers
Phase 2 - Three More Blowers

General Description

The second phase of this project involves removal of the remaining 2 existing blowers (Compressor No. 3 and 4) and related appurtenances and the installation of three additional turbo blowers sized at 11,000 scfm each. The completed system of five blowers would provide 44,000 scfm of firm capacity with one redundant unit. This sizing would cover up to peak day conditions. The inlet and discharge piping would be modified to connect the three additional turbo blowers. The electrical and I&C equipment in the building would be modified to accomidate the three additional turbo blowers. Structural modifications would occur for the new blower locations. In order to fix air leaks, the 48" air piping headers to the North Plant and South Plant would be replaced or a liner would be installed. The electrical conduit and cables feeding the Compressor Building from the Switchgear would be replaced due to age and condition.

	Qtny	Units	Rate	Cost
Demolition				
Piping	1	ls	$ 15,000	$ 15,000
Blowers and Equipment Pads	2	ea	$ 25,000	$ 50,000
Electrical and I&C Equipment	1	ls	$ 7,500	$ 8,000
Total				**$ 73,000**
Equipment and Piping				
11,000 scfm Turbo Blower	3	ea	$ 320,000	$ 960,000
Intake and Discharge Piping, Valves, Accessories	3	ea	$ 150,000	$ 450,000
MCC Replacement	3	ea	$ 50,000	$ 150,000
VFD / Soft Starters	3	ea	$ 50,000	$ 150,000
Roof Intake Modifications	3	ea	$ 5,000	$ 15,000
Air Header Replacement or Lining- 48"	950	lf	$ 2,000	$ 1,900,000
Elec. Conduit and Cable Replace from Switchgear	1	ls	$ 470,000	$ 470,000
Install			30%	$ 1,228,500
Subtotal				$ 5,323,500
Mechanical			20%	$ 1,064,700
Electrical & I&C			20%	$ 1,064,700
HVAC and Plumbing			10%	$ 532,350
Structural Rehabilitation			10%	$ 532,350
Total				**$ 8,517,600**
Subtotal				**$ 8,590,600**
Contractor Overhead and Profit			25%	$ 2,147,700
Subtotal				$ 10,738,300
Contingency			50%	$ 5,369,200
Total Construction Cost				**$ 16,108,000**
Engineering			25%	$ 4,027,000
Total Cost				**$ 20,135,000**

NEW Water
Green Bay Facility and De Pere Facility
Facility Plan

Four New Smaller Blowers

General Description

This alternative involves removal of 3 existing blowers and related appurtenances and the installation of 4 new turbo blowers sized at 5,500 scfm each. All 4 new blowers would provide a firm capacity of 22,000 scfm to meet future maximum month air demand while one of the existing blowers would be maintained as a backup for peak demand conditions. The inlet and discharge piping in the building would be modified to accomidate the 4 new blower units. The electrical and I&C equipment in the building would be replaced to provide a new system. Structural modifications would occur for the new blower locations. In order to fix air leaks, the 48" air piping headers to the North Plant and South Plant would be replaced or a liner would be installed. The electrical conduit and cables feeding the Compressor Building from the Switchgear would be replaced due to age and condition. Some refurbishment work related to Compressor No. 4 oil and liquid cooling system is included in the mechanical and plumbing multipliers below.

	Qtny	Units	Rate		Cost
Demolition					
Piping	1	ls	$ 25,000	$	25,000
Blowers and Equipment Pads	3	ea	$ 25,000	$	75,000
Electrical and I&C Equipment	1	ls	$ 15,000	$	15,000
Total				**$**	**115,000**
Equipment and Piping					
5,500 scfm Turbo Blower	4	ea	$ 250,000	$	1,000,000
Intake and Discharge Piping, Valves, Accessories	4	ea	$ 130,000	$	520,000
Master Control Panel	1	ea	$ 100,000	$	100,000
Electrical MCC Circuit Breakers	4	ea	$ 50,000	$	200,000
VFD / Soft Starters	4	ea	$ 50,000	$	200,000
Roof Intake Modifications	4	ea	$ 5,000	$	20,000
Air Header Replacement or Lining- 48"	950	lf	$ 2,000	$	1,900,000
Elec. Conduit and Cable Replace from Switchgear	1	ls	$ 470,000	$	470,000
Install			30%	$	1,323,000
Subtotal				$	5,733,000
Mechanical			20%	$	1,146,600
Electrical & I&C			20%	$	1,146,600
HVAC and Plumbing			10%	$	573,300
Structural Rehabilitation			10%	$	573,300
Total				**$**	**9,172,800**
Subtotal				**$**	**9,287,800**
Contractor Overhead and Profit			25%	$	2,322,000
Subtotal				$	11,609,800
Contingency			50%	$	5,804,900
Total Construction Cost				**$**	**17,415,000**
Engineering			25%	$	4,353,800
Total Cost				**$**	**21,769,000**