FINAL

TECHNICAL MEMORANDUM 2.3 – PROCESS MODEL CALIBRATION AND VALIDATION

NEW Water Facility Plan

B&V PROJECT NO. 402658

PREPARED FOR

NEW Water
The brand of the Green Bay
Metropolitan Sewerage District

13 AUGUST 2021

BLACK & VEATCH

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APPENDICES

Appendix A: **Summary of Historic Data**
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Appendix C: **Calibration Report**
Appendix D: **Validation Report**

Executive Summary

Development of a usable, reliable facility plan is highly dependent on having a firm understanding of existing data to inform the development of predictive tools that can be used to assess infrastructure alternatives. One of the key predictive tools that plays a large role in a planning project is a process model. Development of a calibrated and validated process model will provide key insights when evaluating infrastructure related to activated sludge aeration, biological nutrient removal, and whole plant energy and nutrient balancing.

For development of a calibrated and validated process model for the NEW Water facilities, Good Modeling Practice methodology was implemented as outlined by the International Water Association. Both NEW Water facilities were simulated in the same model, along with all of the Resource Recovery and Energy Efficiency (R2E2) infrastructure components. Five separate wastewater influents were included to represent the various types of influent wastewater observed at the Green Bay Facility and the De Pere Facility. The model was constructed in the Sumo model platform, a product from Dynamita that is commercially available.

Steady-state model calibration, steady-state model validation, and dynamic validation of the model were completed on three separate data sets. For each condition, a month of data was utilized. Special sampling related to influent COD fractionation, influent metal concentration, digester performance, aeration basin performance, and recycle stream nutrients were all included in the model calibration and validation process.

An example of model calibration and validation output is shown in Figure ES-1. Simulated data points were targeted to match the mean monthly values within 10 to 15%; however, the full month of data was visualized in box and whisker plots to understand the fit of the model to the range of the data. For all three conditions (steady-state calibration, steady-state validation, dynamic validation), the model outputs provided a robust predictions of facility performance related to solids balancing, nitrification, digestion, and effluent performance.

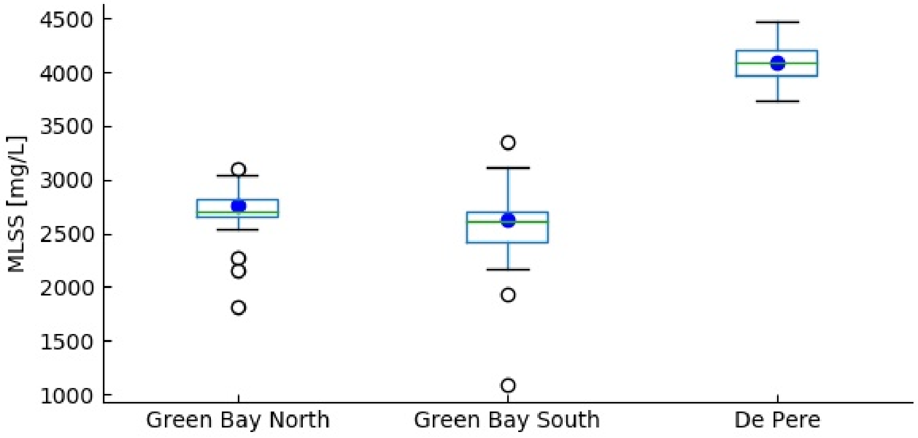
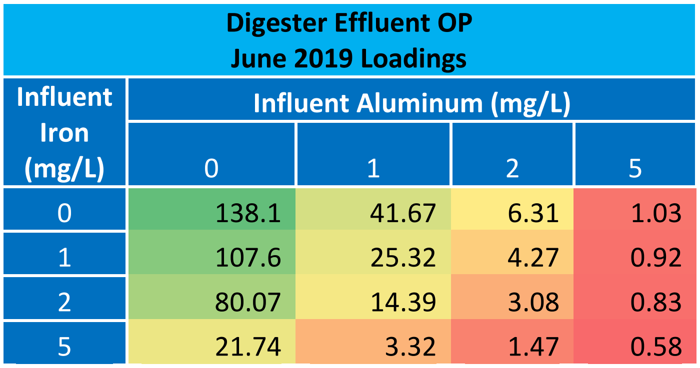


Figure ES-1 Aeration basin MLSS data (box and whisker) versus simulated point (blue dot) for June 2019

The one challenging area for model calibration and validation was related to whole plant phosphorus mass balance. As previously documented by NEW Water, influent iron and aluminum are major contributors to phosphorus removal at both the Green Bay Facility and the De Pere Facility. To understand the impact of iron and aluminum variability on phosphorus removal and cycling, a series of simulations combining various influent iron and aluminum concentrations. An example output is shown in Table ES-1 for the orthophosphorus in the digester as the influent iron and aluminum are varied. The process model was responsive to these variations, and confirmed the importance of this variability on overall phosphorus mass balance at NEW Water. Another important note from the process model development is related to readily biodegradable COD (rbCOD) in the selector zone. At higher influent iron and aluminum concentrations, very limited biological phosphorus removal is occurring. This results in limited rbCOD removal in the selector zones, and high rbCOD loading to the aerobic zones. One of the leading causes of poor settling and filamentous growth is rbCOD feed into aerobic zones.

Table ES-1 Digester orthophosphorus heat map - June 2019 loadings



Digester Effluent OP June 2019 Loadings				
Influent Iron (mg/L)	Influent Aluminum (mg/L)			
	0	1	2	5
0	138.1	41.67	6.31	1.03
1	107.6	25.32	4.27	0.92
2	80.07	14.39	3.08	0.83
5	21.74	3.32	1.47	0.58

The calibrated and validated process model provides a robust representation of the NEW Water facilities under both steady-state and dynamic conditions. It will serve as a key tool for alternatives during the facility planning process and will be a valuable resource for NEW Water both now and in the future.

1 Introduction

Data analytics and modeling tools are key components to the development of an insightful and useful facility plan. The development of models provides a means to evaluate multiple future scenarios that could occur at a facility, and then develop infrastructure to provide the adaptability to continue a high level of service under these future scenarios. Producing a plant model requires good data and therefore another benefit of developing such a model is that there is a detailed assessment of the plant data. An important aspect of the development of calibrated and validated models is to follow good modeling practice to ensure a high level of quality. The International Water Association (IWA) Good Modelling Practice Unified Protocol is used as the framework for this project (**Figure 1-1**). The Unified Protocol consists of 5 major steps:

1. Project Definition
2. Data Collection and Reconciliation
3. Model Setup
4. Calibration and Validation
5. Simulation and Result Interpretation

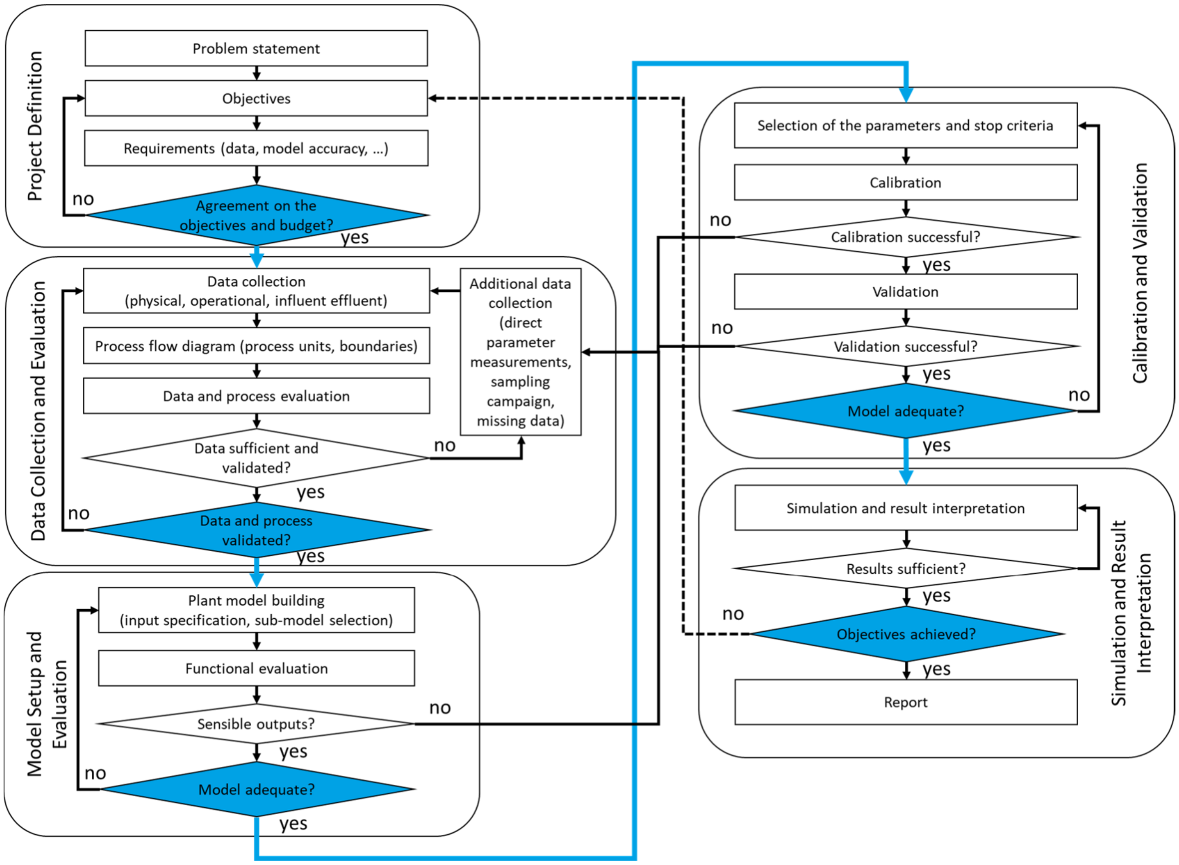


Figure 1-1: Good Modeling Practice Unified Protocol

2 Project Definition

The primary objective of this modeling effort is to develop a model that provides a whole plant liquid stream treatment mass balance of NEW Water's facilities to enable process engineers and NEW Water staff to understand the interaction of unit processes and how the various loads move throughout the plant and affect unit processes. It is expected that the following simulations will be run in the model (simulations run after the calibration and validation are Step 5 of the Unified Protocol):

1. Steady-state calibration simulation based on recent historical data
2. Steady-state validation simulation based on recent historical data
3. Dynamic validation simulation based on recent historical data
4. Simulations to evaluate the existing aeration performance and inefficiencies
5. Simulations of biological nutrient removal alternatives
6. Simulations to understand whole plant energy and nutrient balances for evaluated alternatives

Calibration is the first critical step for process model development. The Water Environment Research Foundation (WERF) report, "Methods for Wastewater Characterization in Activated Sludge Modeling" (2003) describes several levels of model calibration:

- Calibration Level 1 uses default model parameters and assumptions (no calibration for practical use).
- Calibration Level 2 uses historical operating data, specifically data that are routinely collected.
- Calibration Level 3 supplements historical data with data collected during plant-specific sampling campaign(s). Level 3 data collection typically includes composite sampling and grab sampling and may also include diurnal sampling.
- Calibration Level 4 uses direct laboratory measurement of certain bio-kinetic parameters.

For the purposes of this modeling effort, a "Level 3" calibration was considered suitable for a conceptual planning model. Level 3 calibration supplements historical data with data collected during plant-specific sampling campaign. Modeling projects are generally designed to produce data that are accurate to +/- 10-15%. However, different model parameters can be expected to meet different levels of accuracy depending on several factors including the level of detail, measurement method, dynamic nature of the parameter, and the quality of data. Table 2-1 gives the target accuracies that are used as the "stop criteria" for calibration. Stop criteria will be used to adjust influent characteristics and model calibration. If the model calibration does not meet stop criteria, the reasons for not achieving the accuracy targets will be reviewed and documented. Often, the cause for not meeting stop criteria are tied to highly dynamic wastewaters and uncertainty around key influent parameters.

Table 2-1: "Stop Criteria" Target for Calibration Accuracy

PARAMETER	STOP CRITERIA[1] STOP CRITERIA
Primary Effluent TSS, mg/L	+/- 5 mg/L
Primary Effluent BOD5, mg/L	+/- 5 mg/L
Secondary/ Final Effluent CBOD5, mg/L	+/- 2 mg/L or +/-10%, whichever is greater
Secondary/ Final Effluent TSS, mg/L	+/- 1 mg/L or +/- 5%, whichever is greater
Secondary/ Final Effluent Ammonia, mg/L	+/- 1 mg/L or +/- 5%, whichever is greater
Secondary/ Final Effluent Total Nitrogen, mg/L	+/- 2 mg/L or +/-10%, whichever is greater
Secondary/ final Effluent Total Phosphorus, mg/L	+/- 0.7 mg/L or +/- 20%, whichever is greater
MLSS, mg/L	+/-10%
MLVSS, mg/L	+/-10%
Primary sludge quantity, lbs/d	+/-10%
WAS quantity, lbs/d	+/-10%
Digested sludge, lbs/d	+/- 15%
Digester Nutrient Values	+/- 15%
Digester VS Destruction, %	+/-10%
Digester Gas Production, cf/d	+/- 15%

3 Data Collection and Reconciliation

The first step in setting up the computer model for calibration was the analysis of operational and performance data. Ten years of historical data were gathered to assess long-term trends across New Water influents.

3.1 INFLUENT CHARACTERIZATION

Figures 3-1 and 3-2 below show influent flow variability as a function of time for the combined Green Bay and De Pere influents, respectively. Plots for influent concentrations and individual flows (e.g., Green Bay Metro, Fox River Fiber) can be found in Appendix A. For calibration, recent data was chosen as this correlated to influent special sampling at the De Pere facility (DPF) (June 2019). For validation, previous special sampling at the Green Bay facility (GBF) and industrial inputs was identified as the steady-state validation period (August 2017) and recent cold weather, stable loading were identified for the dynamic validation (February 2019).

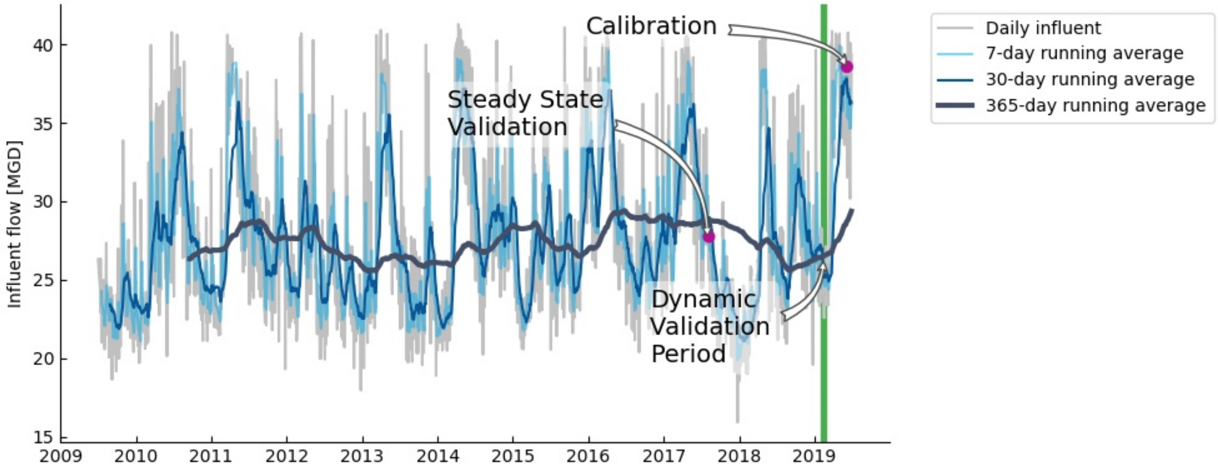


Figure 3-1: Influent flow data for Green Bay combined influent showing 7-day, 30-day, and 365-day running averages. Purple points indicate months used for calibration and state validation. Green bar indicates date range used for dynamic validation.

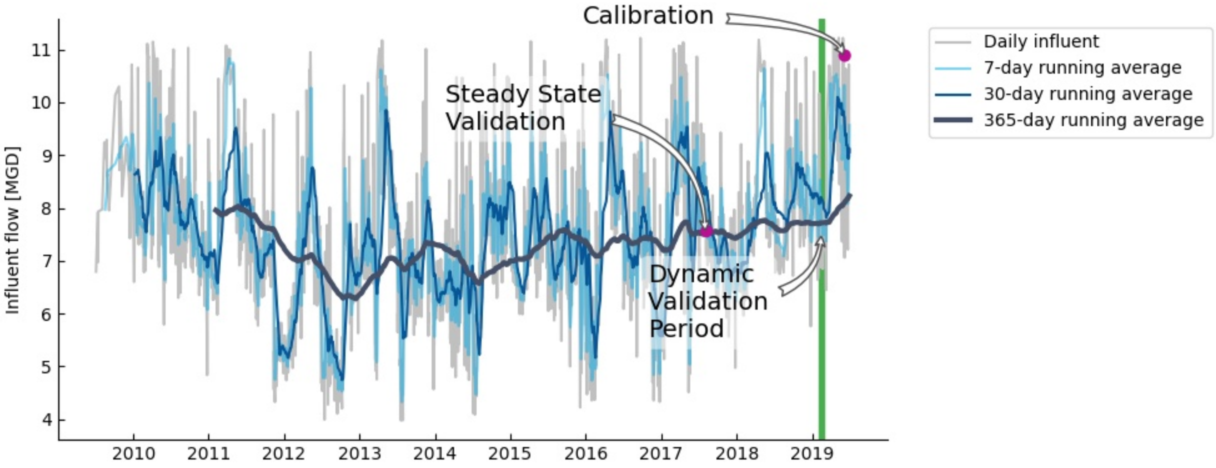


Figure 3-2: **Influent flow data for De Pere combined influent showing 7-day, 30-day, and 365-day running averages. Purple points indicate months used for calibration and state validation. Green bar indicates date range used for dynamic validation.**

Monthly average values from June 2019 were utilized for calibration (Table 3-1).

Table 3-1: June 2019 monthly average values used during calibration

Parameter	GB Metro	Proctor and Gamble	Hauled Waste	DP Metro	Fox River Fiber (included in DPF)
Flow, mgd	31.1	5.03	0.2	8.3	0.69
COD, mg/L	260	217	6727	529	1945
VSS/TSS	0.78	0.55	0.77	0.93	0.99
TKN, mg/L	22.1	14	242.4	26.3	178
TP, mg/L	3.7	2	53.4	4.28	20.3

For the steady state and dynamic validations, only two trains were online in Green Bay North Plant (vs. three trains in calibration), so volumes were reduced by 1/3. Monthly average values from August 2017 were utilized for steady-state validation (Table 3-2).

Table 3-2: August 2017 monthly average values used during steady-state validation

Parameter	GB Metro	Proctor and Gamble	Hauled Waste	DP Metro	Fox River Fiber (included in DPF)
Flow, mgd	22.4	4.05	0.003	7.59	0.69
COD, mg/L	464.54	216	9808	864	1484
VSS/TSS	0.78	0.547	0.765	0.927	0.9978
TKN, mg/L	31.5	3.77	722	39.7	78.4
TP, mg/L	3.86	0.32	90.8	5.3	4.5

In addition to the dynamic data presented below in Figure 3-3 and Tables 7-6 to 7-10 in Appendix D, a dynamic primary clarifier model was utilized to simulate TSS removal performance (see section 4.1 for more information). Temperature was also changed to ~52°F (11°C) to reflect the effects the colder weather would have on performance.

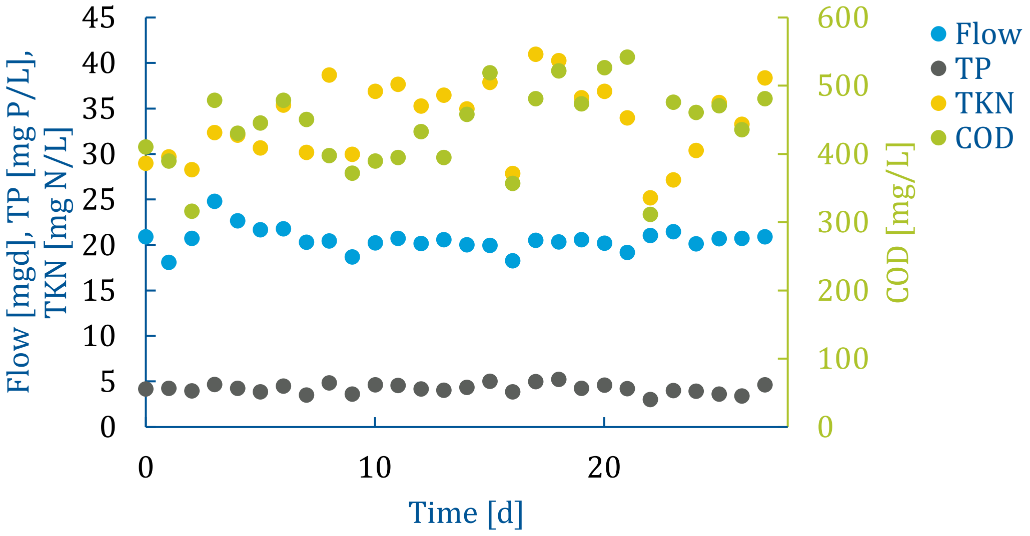


Figure 3-3: Dynamic influent data for Green Bay Metro

3.2 SPECIAL SAMPLING

Fractionation data were gathered during two sampling periods: the week of Aug. 13, 2017 and the week of July 24, 2019 (see Table 7-1 to Table 7-5 in Appendix B for a summary of these results). These data were then input into the Sumo Influent Tool to calibrate the model fractions to most closely match the measured data (see Table 3-1 for the final fractions utilized in SUMO).

Table 3-3: Final fractions utilized in SUMO

Fraction	Green Bay	De Pere	Hauled Waste	Fox River Fiber	Mill	Unit
Fraction of VSS/TSS	86.65	92.74	76.45	99.78	54.75	%
Fraction of filtered COD (SCCOD, 1.5 µm, incl. colloids) in total COD (TCOD)	44.08	45.71	59.02	69.45	60.09	%
Fraction of flocculated filtered (SCOD, wo colloids) COD in total COD (TCOD)	25.83	35.73	51.14	38.33	54.93	%
Fraction of VFA in filtered COD (SCCOD, 1.5 µm, incl. colloids)	8.00	6.06	0.50	2.1	0	%
Fraction of soluble unbiodegradable organics (SU) in filtered COD (SCCOD, 1.5 µm, incl. colloids)	8.76	19.45	3.78	2.44	73.31	%

Fraction	Green Bay	De Pere	Hauled Waste	Fox River Fiber	Mill	Unit
Fraction of particulate unbiodegradable organics (XU) in total COD (TCOD)	27	32	22	15.75	30	%
Fraction of heterotrophs (OHO) in total COD (TCOD)	5	5	5	4	5	%
Fraction of endogenous products (XE) of OHOs	21.25	10	5	17.5	20	%
Fraction of colloidal unbiodegradable organics (CU) in colloidal COD (SCCOD-SCOD)	22.5	20	5	17.5	20	%
Fraction of NHx in total Kjeldahl nitrogen (TKN)	65.88	66.44	45.96	49.57	35.71	%
Fraction of PO4 in total phosphorus (TP)	41.86	47.83	79.40	19.07	50	%
Fraction of N in readily biodegradable substrate (SB)	4	1.1	2	4	0.5	%
Fraction of N in particulate unbiodegradable substrate (XU)	1	0.1	1	1	0.1	%
Fraction of P in readily biodegradable substrate (SB)	1	0.5	0	0.05	0.001	%
Fraction of P in particulate unbiodegradable substrate (XU)	0.1	0.1	0	0.08	0.001	%
COD of biodegradable substrate in volatile solids	2.1	2.1	2.4	1.78	2	g COD/g VSS
COD of particulate unbiodegradable organics in volatile solids	1.3	1.7	1.5	1.42	1	g COD/g VSS

3.2.1 Bio-P Profiling

Profiling was conducted in December 2016, March 2018, and March through July of 2019 to ascertain the extent to which COD and nutrients are able to be consumed within the GBF North and South aeration basins. In 2016, ammonia removal rates were consistently >99%. Orthophosphate removal was typically >70%, but there was no evidence of Bio-P release. 2018 saw high levels of nitrate removal (i.e., >95%) in the aeration basins, but ammonia and nitrite concentrations often increased. PO_4 concentrations increased as well, indicating significant phosphorus release in the aeration basins (i.e., 2-3 orders of magnitude). 2019 sampling typically saw nitrate, COD, and phosphorus removal rates of at least 50%, with no release of orthophosphate in the selector zones (see Figures 3-4 to 3-6). Typically, for a Bio-P facility, a release ratio of greater than 3 is observed in the anaerobic selector zone, meaning the selector zone phosphorus is three times higher than the influent phosphorus. These results indicate that though phosphorus release is possible, as evidenced by the 2018 sampling, more recent samples indicate that no P-release is currently occurring.

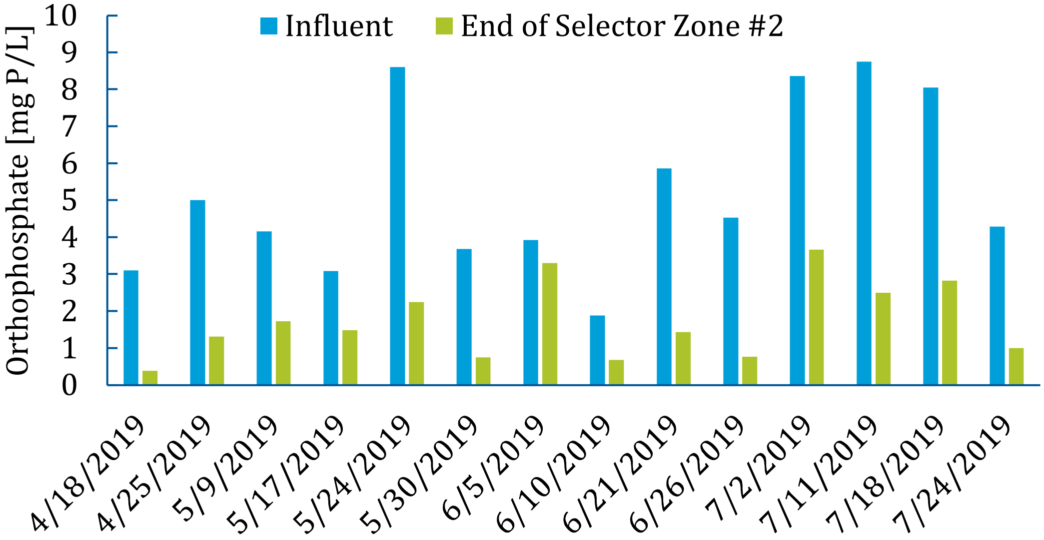


Figure 3-4: North Plant 1 orthophosphate in selector zone influent and end of the selector zone.

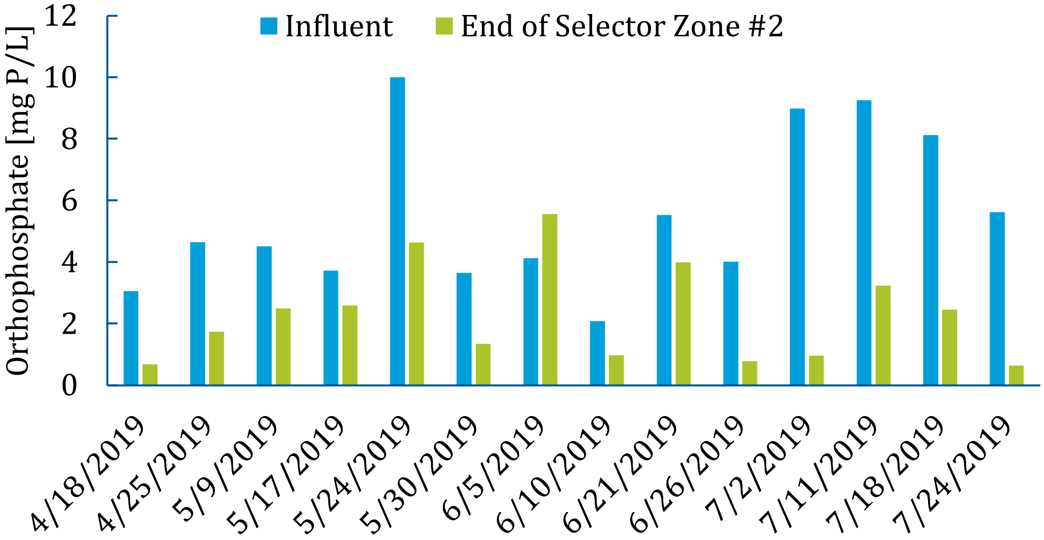


Figure 3-5: North Plant 3 orthophosphate in selector zone influent and end of the selector zone.

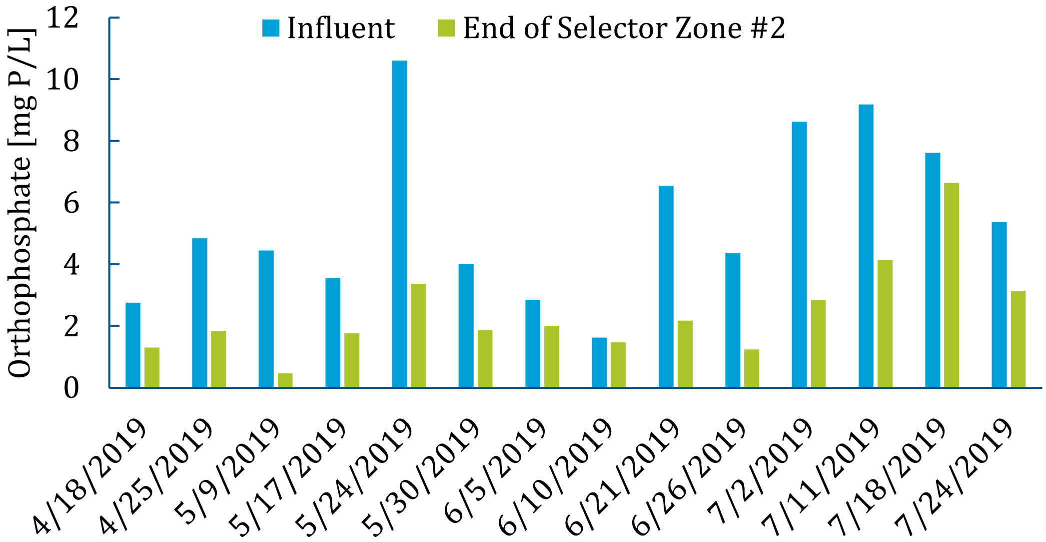


Figure 3-6: South Plant 1 and 2 orthophosphate in selector zone influent and end of the selector zone.

4 Model Development

SUMO19 by Dynamita was utilized for process model construction, calibration, and validation. A summary of major unit process volumes and key operational inputs can be found in Table 4-1 to Table 4-3.

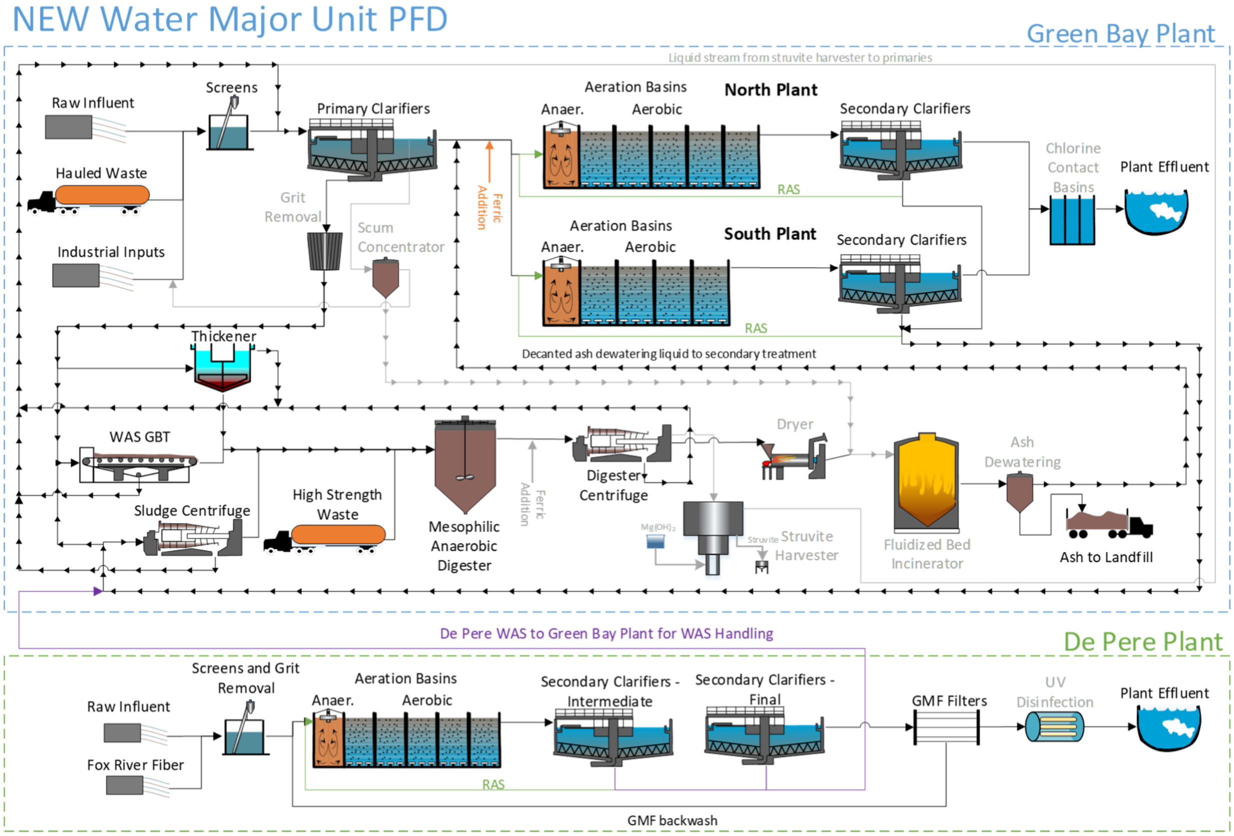


Figure 4-1: Major unit processes and flows in the combined Green Bay/De Pere facility

Table 4-1: Major unit processes in the Green Bay facility

Green Bay					
Unit	**Model**	**Inputs**	**Value**	**Unit**	**Notes**
Primary Clarifier	Volumeless primary with specified primary sludge concentration	Percent removal of solids	63%	%	Adjustable by staff for given simulations
		PS TSS	5630	mg/L	
Primary Sludge Flow Divider to Mechanical Thickening	Flow fraction to pumped	Fraction	25	%	Provides flexibility to send primary sludge to either gravity thickener or mechanical thickening

Green Bay					
Unit	**Model**	**Inputs**	**Value**	**Unit**	**Notes**
South Aeration Basin Flow Divider	Pumped flow	Pumped flow	6.8	MGD	Controls flow split to south aeration basins
North Selector Zones	CSTR with diffused aeration and input DO	Volume Tank depth DO Setpoint	2.84 20 0	MG ft mg O2/L	Two tanks-in-series
North Aeration Basins	CSTR with diffused aeration and input DO	Volume Tank depth DO setpoint	7.35 20 3	MG ft mg O2/L	Five tanks-in-series (3 @ 1.05 MG, 2 @ 2.1 MG); tanks are a model parameter and do not represent baffle walls Higher DO is measured, but will not limit process performance
North Final Clarifier	1D layered clarifier with triple exponential settling velocity model	Surface area Depth Sludge flow	113,440 15 40	ft2 ft MGD	
North WAS Divider	Pumped flow	Pumped flow	0.44	MGD	WAS flow rate from North Plant
South Selector Zones	CSTR with diffused aeration and input DO	Volume Tank depth DO Setpoint	0.4 20 0	MG ft mg O2/L	Two tanks-in-series
South Aeration Basins	CSTR with diffused aeration and input DO	Volume Tank depth DO setpoint	2.52 20 2	MG ft mg O2/L	Six tanks-in-series
South Final Clarifier	1D layered clarifier with triple exponential settling velocity model	Surface area Depth Sludge flow	28,600 15 7.8	ft2 ft MGD	
South WAS Divider	Pumped flow	Pumped flow	0.12	MGD	
Primary Sludge Thickener	Volumeless thickener with specified thickened sludge concentration	Solids percent removal Sludge solids concentration	98 35000	% mg/L	
FeCl Dosing	Flow based	Flow rate	0.000223	MGD	

Green Bay

Unit	Model	Inputs	Value	Unit	Notes
		Soluble Fe	192650	mg Fe/L	40% FeCl3 solution

Table 4-2: Major unit processes in the De Pere facility

De Pere

Unit	Model	Inputs	Value	Unit	Notes
Selector Zone	CSTR with diffused aeration and input DO	Volume	2.7	MG	
		Tank depth	26	ft	
		DO Setpoint	0	mg O2/L	
Aeration Basin	CSTR with diffused aeration and input DO	Volume	5.1	MG	
		Tank depth	26	ft	
		DO setpoint	1.5	mg O2/L	
Intermediate Clarifier	Volumeless clarifier with fixed effluent solids	Sludge flow	8	MGD	
		Effluent solids	30	mg/L	
Final Clarifier	Volumeless clarifier with fixed effluent solids	Sludge flow	0.01	MGD	
		Effluent solids	10	mg/L	
Sand Filter	Sand filter with fixed effluent solids	Effluent solids	2	mg/L	
		Colloidals percent removal	10	%	
WAS Divider	Pumped flow	Pumped flow	0.383	MGD	

Table 4-3: Major unit processes following the combination of Green Bay and De Pere flows

Combined

Unit	Model	Inputs	Value	Unit	Notes
Centrifuge flow divider	Flow fraction to pumped	Fraction	100	%	
Centrifuge	Percent removal volumeless dewatering unit	Solids percent removal	95	%	
		Dewatered cake solids	46500	mg/L	
GBTs	Percent removal volumeless dewatering unit	Solids percent removal	95	%	
		Dewatered cake solids	50000	mg/L	
Digester	Digester with gas phase	Liquid volume	5.35	MG	
		Water temperature	37	°C	
		Gas/volume fraction	10	%	
Dewatering	Percent removal volumeless dewatering unit	Solids percent removal	95	%	
		Dewatered cake solids	340000	mg/L	

4.1 PRIMARY CLARIFIER PERFORMANCE

The Green Bay facility has four square, chamfered primary clarifiers, constructed in 1976, with a combined volume of 5.08 MG and combined surface area of 56,600ft^2. The clarifiers have a sidewater depth of 12 feet. Rather than using a fixed percent removal, Standard primary clarifier models were utilized for calibration and steady state validation. For dynamic validation, a primary clarifier TSS removal equation was included in the model that takes the influent TSS and surface overflow rate into consideration, and more accurately predicts the TSS removal as these parameters change. When estimating TSS removal in a primary clarifier, an understanding of the non-settleable TSS (TSS_{non}) and the solids settling constant is required. While these values are not typically measured, they can be estimated using historic TSS removal as suggested in WEF Clarifier Design Manual (MOP FD-8, 2nd Edition) utilizing the following relationships. The equation included in the model is listed below:

$$E_{TSS,max} = 1 - \left(\frac{TSS_{non}}{TSS_{PI}}\right)$$

$$E_{TSS} = E_{TSS,max} * \left(1 - e^{-\lambda/_{SOR}}\right)$$

Where:
$E_{TSS,max}$ = maximum removal efficiency
E_{TSS} = removal efficiency
TSS_{non} = Non-settable TSS (mgTSS/L)
TSS_{PI} = Primary Influent TSS (mgTSS/L)
SOR = Surface overflow rate (gpd/sqft)
λ = Settling constant (gpd/sqft)

Data from the plant was used to calculate the TSS_{non} and λ factors using the overall removal efficiency of both the circular and square primary clarifiers. TSS_{non} and λ are fitted parameters describing the plant specific TSS under normal operating conditions. TSS_{non} represents TSS that will not will not be settled out by gravity separation alone. This also represents that fraction that can be targeted by CEPT. Utilizing a least squares method of analysis, the TSS_{non} and λ were estimated for the combined primary clarifier data set from 2009 through 2019. The resulting TSS_{non} and λ were estimated to be 56.8 mgTSS/L and 1021.2 gpd/sqft, respectively. The overall equation with those factors is listed below, with a figure describing the fit of the primary clarifier model to the overall data set shown in **Figure 4-2**:

$$E_{TSS} = \left[1 - \frac{56.8}{TSS_{PI}}\right] * \left(1 - e^{-1021.2/_{(Flow\ in\ MGD)}}\right)$$

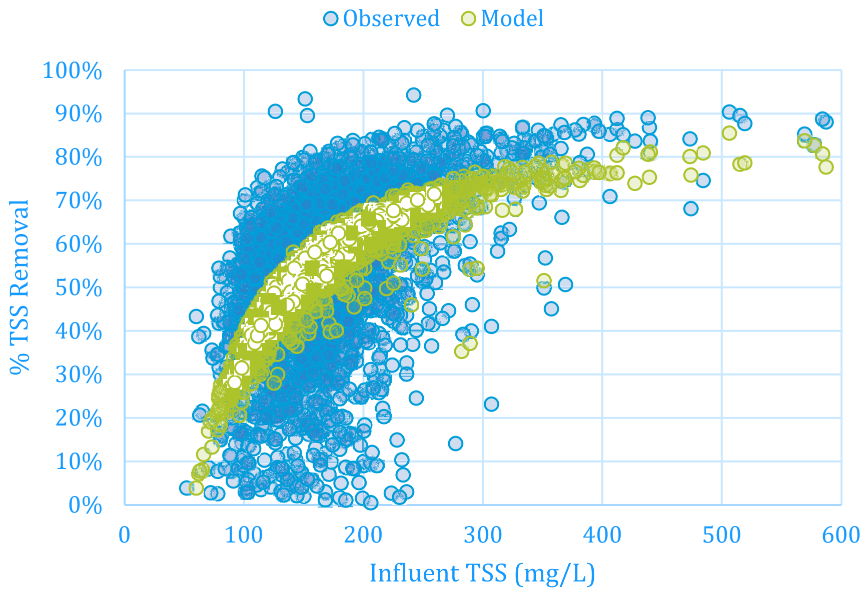


Figure 4-2: Primary clarifier observed performance and modeled performance utilizing the WEF MOP 8 approach

Traditional process modeling has focused on entering in a constant percent removal for a primary clarifier model. This is well suited for steady-state simulations at single design loadings, and will be the approach utilized for steady-state calibration and validation. However, when dynamic loadings are considered, including variable primary clarifier performance has a large impact on the robustness of a process model. For NEW Water, steady-state simulations will utilize a manually entered percent removal based on historical performance. For dynamic simulations, the predictive model based on the WEF MOP 8 guidelines will be utilized.

4.2 AERATION BASIN NUMBER OF TANKS IN SERIES

One of the critical components of an aeration basin process model is simulating the basins with an appropriate number of tanks in series. There are several methods for completing this calculation. For the NEW Water aeration basins, the methodology outlined in the EPA Fine Pore Aeration Systems Design Manual (1989) using the following equation was used for calculating the number of tanks in series for each aeration tank:

$$N = 7.4\, LQ \frac{(1 + Rr)}{WH}$$

Where:
N = number of tanks in series
L = length of tank (m)
Q = influent flow rate (m^3/s)
Rr = ratio of recycle flow rates (RAS percentage)
W = width of tank (m)
H = depth of tank (m)

Table 4-4: Values used to determine minimum number of tanks-in-series needed to simulate actual plant

Location	Green Bay North		Green Bay South		De Pere	
Zone	Selector	Aerated	Selector	Aerated	Selector	Aerated
Length [ft]	123	246	75.33	482.5	70	132.5
Width [ft]	75.33	38.33	35	35	98	98
Sidewater depth [ft]	20	20	20	20	26	26
Flow rate [mgd]	7.23	7.23	4.2	4.2	7	7
Recycle [%]	1.09	1.09	0.92	0.92	0.5	0.5
Number of tanks	**2**	**5**	**1**	**6**	**1**	**1**

The DO setpoint was set to 2 mg/L in all the aerated zones for each train in Green Bay. The DO setpoint was set to 3 mg/L for the De Pere aerated zone. Ceramic disc diffusers were used in the model with default alpha values and fouling constants.

4.3 FINAL CLARIFIERS

The surface area used in the model for the final clarifiers are listed below in Table 4-5 .

Table 4-5: Final clarifier volumes and surface area

Train	Dimensions	Total Area Used In Model
Green Bay North	8 each @ 123 ft x 115 ft	113,440 ft^2
Green Bay South	2 each @ 135 ft diameter	28,600 ft^2
De Pere Intermediate	2 each @ 100 ft diameter	15,800 ft^2
De Pere Final	3 each @ 125 ft diameter	36,900 ft^2

Layered flux models were used for the Green Bay final clarifiers with default values. A target sludge flow of 34 MGD and 5.2 MGD were input for the North and South final clarifiers, respectively. A simple 1-D model was used for the De Pere clarifiers where a target sludge flow of 8.2 and 0.01 MGD were input for the intermediate and final clarifiers, respectively. The effluent solids concentration for the intermediate clarifier was also changed to 30.0 mg/L.

4.4 SOLIDS PROCESSING

After the final clarifiers, Green Bay and De Pere flows combine the solids are pumped to a centrifuge for dewatering. 25% of the primary sludge is dewatered using a gravity belt thickener, and the other 75% is sent to a gravity thickener in the model. All dewatering units achieve 95% solids removal. Thickened sludgeis then combined and pumped to an anaerobic digester for volatile solids reduction and conversion of organics to methane containing biogas. Following anaerobic digestion, effluent from the digester is dewatered (95% solids removal). Sludge is then dried and incinerated for disposal. Water removed from the solids in thickening processes is pumped to the primary influent while water removed from the dewatering process is returned to the GBF influent pump station.

4.5 INFLUENT METAL IMPACTS

A study completed in July 2019 aimed to assess the impacts of influent metals on Bio-P and nutrient recovery. This study determined that influent aluminum loads to NEW Water are significantly higher than typical values for municipal WWTPs due to the contributions from significant industrial users (SIUs). Influent iron loads are also high, with the main contributor being municipal wastewater tributary to the Green Bay and De Pere treatment facilities. Primary treatment PO_4 removal rates are higher than typical values, which is likely due to chelation with the influent metals. Additionally, high Al and Fe interact with PO_4 during digestion, reducing the orthophosphate in the dewatering centrate and potential for struvite formation. The excess of soluble magnesium further signifies that struvite formation in the digesters is insignificant. In order to assess the effects of these metals on Bio-P and nutrient recovery, a sensitivity analysis was conducted on influent metals (see Section 6).

5 Calibration and Validation

Calibration is the process where model parameters are adjusted until model predictions match selected sets of performance data from the plant. The primary objective of calibration is to minimize error between the historical dataset and model prediction. However, it is important to remember that the objective is not to achieve a perfect fit since the model is a simplified version of the real plant. Over-fitting to one dataset might reduce the total error for that particular dataset but will reduce the model's overall predictive power and increase error in other datasets.

When performing a model calibration, it is important to check both sludge quantities and effluent quality to ensure that influent stoichiometry and kinetic parameters are properly assumed. Calibration and validation results are presented in following sections. The goal of the model calibration was to assess the level of agreement between observed plant process characteristics and performance (June 2019) and model predictions. The model calibrations generally exhibited a deviation range between predicted and observed performance that was consistent with a Level 3 calibration. In the cases where significant deviation was observed, explanatory context and potential sources of error are noted (see **Table 5-1**).

Once the model calibration was complete, two independent data sets (August 2017 and February 2019) were used to validate the model to test its predictive power. The following sections also show the validation results from these efforts.

5.1 STEADY-STATE CALIBRATION

Key calibration results are presented in Table 5-1. Model inputs are listed at the beginning of **Table 5-1**, and are highlighted in blue. Key operational setpoints were reviewed with NEW Water for this period and are included in Appendix E. Key operational parameters and setpoints include:

- Three out of the four aeration basin trains in GBF North aeration basins were operating during this time
- One out of the two aeration basin trains at the GBF South aeration basins was in operation
- All WAS flow from GBF and DPF are thickened via the thickening centrifuge
- 75% of primary sludge was thickened via gravity thickening, with the remaining being thickened by gravity belt thickeners (GBTs)
- 100% of Fox River Fiber flow was processed at the DPF

The box and whisker plots in

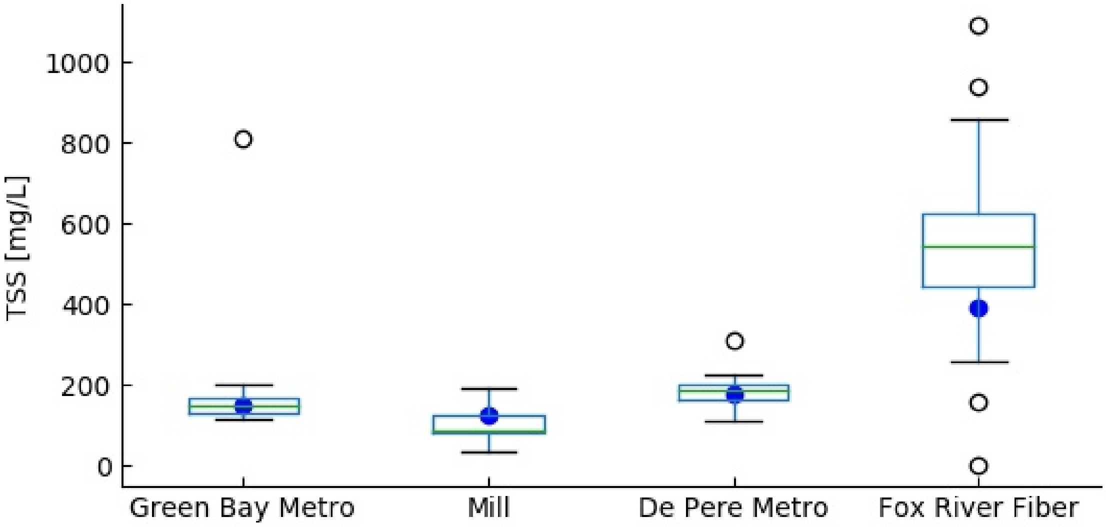


Figure 5-1 through **Figure 5-15: Solids Loadings** give a visual representation of the calibration points compared to the plant data for influent, primary effluent, MLSS, WAS and PS, and effluent parameters. For the box and whisker plots, the box represents the 25th percentile (bottom line), mean value (middle line) and 75th percentile (top line) values from the calibration data set. The whiskers represent the highest and lowest values that are not outliers. Outliers are determined by calculating the "inner fence" (i.e., 1.5 times the range between the 75th and 25th percentiles). Data points that are larger than the 75th percentile + the inner fence or smaller than the 25th percentile – the inner fence are outliers. The visual representation helps to indicate the range of values observed in the data set, and how the simulated value not only represents the average observed performance but the range of values observed. Hollow points are outliers; filled blue points are modeled output values from SUMO.

When reviewing the steady-state calibration results, the following key considerations should be acknowledged:

- Some influent parameters (e.g., GB Metro influent TKN and PG influent TP) had to be adjusted to prevent negative values in the model
- Hauled waste was highly variable, and thus the concentrations chosen represent the best estimate based on special sampling
- The simulated primary effluent BOD for the GBF is higher than measured. An attempt to adjust this value in the model was made to match the measured value, but the adjustments to primary clarifier performance resulted in a large error in simulated TSS concentration and adjustments to wastewater fractions resulted in significant under representation of aeration basin performance.
- Predicted Fox River Fiber BOD concentrations are high, which is likely due to the high influent variability and lack of fractionation data from 2019.

Table 5-1: Green Bay Calibration Results

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
GB Metro Influent					
Flow, mgd	31.1	31.1	0%	-	
COD, mg/L	263	260	1%	-	Assumed COD:BOD = 2.53
BOD, mg/L	104	95.7	-8 mg/L	±5 mg/L	
TSS, mg/L	149	148.5	-1 mg/L	±5 mg/L	One outlier removed (6/10/19)
VSS/TSS	0.66	0.78	-18%	-	
TKN, mg/L	22.1	22.1	0%	-	
NH3-N, mg/L	13	14.6	-12%	-	
TP, mg/L	3.18	3.7	-16%	-	
OP, mg/L	1.06	1.55	-46%	-	
Procter and Gamble Influent					
Flow, mgd	5.07	5.03	1%	-	
COD, mg/L	217	217	0%	-	
BOD, mg/L	26.77	34.4	+8 mg/L	±5 mg/L	
TSS, mg/L	102.2	122.7	+21 mg/L	±5 mg/L	
VSS/TSS	0.55	0.55	0%	-	
TKN, mg/L	1.74	14	-705%	-	
NH3-N, mg/L	0.05	5	-9900%	-	All values below detection limit
TP, mg/L	0.071	2	-2717%	-	All values below detection limit
OP, mg/L	0.03	1	-3233%	-	
Hauled Waste Influent					
Flow, mgd	0.2	0.2	0%	-	
COD, mg/L	6727	6727	0%	-	Assumed COD:BOD = 2.53
VSS/TSS		0.77		-	
TKN, mg/L	293	242.4	17%	-	
NH3-N, mg/L		111.5		-	
TP, mg/L	33.7	53.4	-58%	-	
OP, mg/L		42.4		-	

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
GB Primary Effluent					
BOD, mg/L	41	78	+37 mg/L	±5 mg/L	
TSS, mg/L	55.6	66	+10.4 mg/L	±5 mg/L	
TKN, mg/L	18.9	23.5	+4.6 mg/L	±2 mg/L	
NH3-N, mg/L		18		±2 mg/L	
TP, mg/L	1.39	2.8	+1.4 mg/L	±1 mg/L	
Operation					
Temp, °C	20	20	0%	-	
GB North Train					
Flow, mgd	34.22	28.9	16%	-	
MLSS, mg/L	2,742	2,759	-1%	±10%	
MLVSS, mg/L		1,903		±10%	
RAS, mgd	37.95	38	0%	-	
WAS, ppd	18302	17,861	2%	±10%	
Eff TSS, mg/L		4.5		±1 mg/L	
GB South Train					
Flow, mgd	8.12	8.2	-1%	-	
MLSS, mg/L	2,588	2,631	-2%	±10%	
MLVSS, mg/L		1,828		±10%	
RAS, mgd	8.35	8.3	1%	-	
WAS, ppd	5,774	4,940	14%	±10%	
Eff TSS, mg/L		4.9		±1 mg/L	
GB Final Effluent					
TSS, mg/L	4.3	4.9	+0.6 mg/L	±1 mg/L	
BOD, mg/L	2.8	1.1	-1.7 mg/L	±2 mg/L	
TKN, mg/L	1	2.1	+1.1 mg/L	±2 mg/L	
NH3-N, mg/L	0.059	0.690	+0.6 mg/L	±1 mg/L	Most values below detection limit
NO3-N, mg/L		0.08		±2 mg/L	
TP, mg/L	0.39	1.0	+0.6 mg/L	±0.7 mg/L	
OP, mg/L		0.8		±0.7 mg/L	

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
Solids					
Primary Sludge Flow, mgd	1.06	1.0	-6%	-	Assumes given values are in GPM
Primary Sludge TSS, mg/L		5630			
Primary Sludge TSS, ppd		32204			
GB North WAS, mgd	0.41	0.44	-8%	-	
GB North WAS, mg/L	4952	4864	0%		
GB North WAS, ppd	18302	17,861	2%	±10%	
GB South WAS, mgd	0.13	0.135	-5%	-	
GB South WAS, mg/L	4717	4385	0%		
GB South WAS, ppd	5,774	4,940	14%	±10%	
Digester					
Influent percent TS, %	5%	3.9%	22%	-	Average of four points
Influent percent VS, %	77%	77%	0%		Average of four points
Influent flow, mgd	0.26	0.24	8%		
Biogas production, cfd		196			
Effluent NH3-N, mg/L	796	804	-1%		Average of two points
Effluent OP, mg/L	34.9	1.2	97%	-	Average of two points
Effluent TS, %	3%	2.9%	6%	±10%	Average of four points
Effluent VS, %	65%	70%	-8%	-	Average of four points
VS Destruction Rate, %		34%		±10%	

[1] Values color-coded in blue are inputs to the model

Table 5-2: De Pere Calibration Results

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
DP Metro Influent					
Flow, mgd	8.3	8.3	0%	-	
COD, mg/L	529	529	0%	-	
BOD, mg/L	195	205	+10 mg/L	±5 mg/L	
TSS, mg/L	186	177	-9 mg/L	±5 mg/L	
VSS/TSS	0.93	0.93	0%	-	
TKN, mg/L	26.3	26.3	0%	-	
NH3-N, mg/L	17.6	17.5	1%	-	
TP, mg/L	4.28	4.28	0%	-	

Parameter	Plant data	SUMO^1	± Error^2	Target Accuracy	Notes
OP, mg/L	2	2	0%	-	
Fox River Fiber Influent					
Flow, mgd	0.69	0.69	0%	-	
COD, mg/L	1945	1945	0%	-	
BOD, mg/L	514	1024	+510 mg/L	±5 mg/L	
TSS, mg/L	545	391	-154 mg/L	±5 mg/L	
VSS/TSS	0.99	0.99	0%	-	
TKN, mg/L	178	178	0%	-	
NH3-N, mg/L	97	88.2	9%	-	
TP, mg/L	20.3	20.3	0%	-	
OP, mg/L	0.99	3.87	-291%	-	
Operation					
Temp, °C	20	20	0%	-	
DP Train					
Flow, mgd	8.3	8.3	0%	-	
MLSS, mg/L	4,099	4,092	0%	±10%	
MLVSS, mg/L		3,551		±10%	
RAS, mgd	7.88	8	-2%	-	
WAS, ppd	13215	12,976	2%	±10%	
Eff TSS, mg/L		10		±1 mg/L	
DP Final Effluent					
TSS, mg/L	2.41	2.0	-0.4 mg/L	±1 mg/L	
BOD, mg/L	2.05	1.5	-0.6 mg/L	±2 mg/L	Most values were below detection limit
TKN, mg/L	1.52	3.7	+2.2 mg/L	±2 mg/L	
NH3-N, mg/L	0.05	0.970	+0.9 mg/L	±1 mg/L	Most values were below detection limit
NO3-N, mg/L		0.01		±2 mg/L	
TP, mg/L	0.37	0.4	0 mg/L	±0.7 mg/L	
OP, mg/L		0.3		±0.7 mg/L	

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
Solids					
DP WAS, mgd	0.38	0.39	-3%	-	
DP WAS, mg/L	4099	4092	0%		
DP WAS, ppd	13125	12,976	1%	±10%	

[1]Values color-coded in blue are inputs to the model

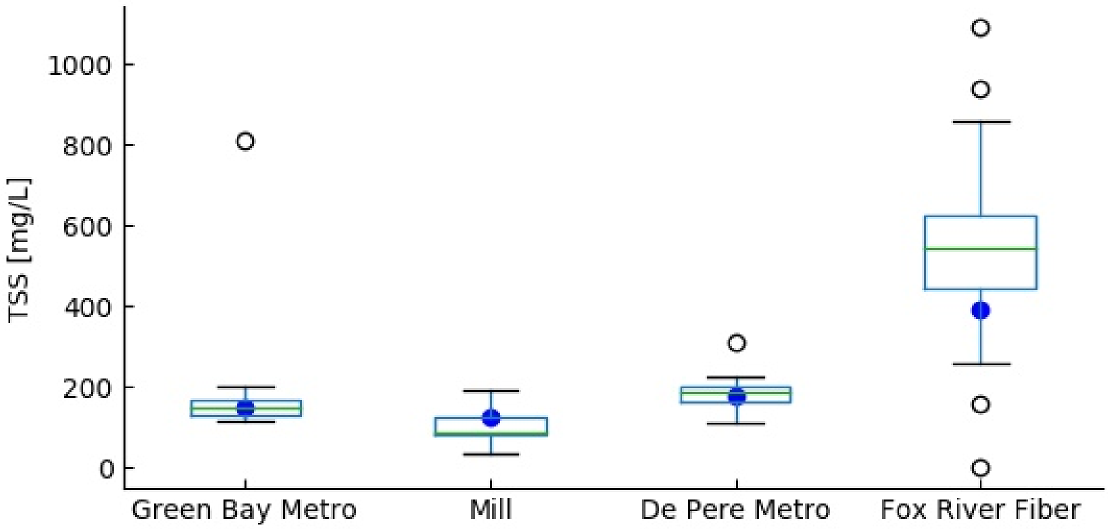


Figure 5-1: Influent TSS

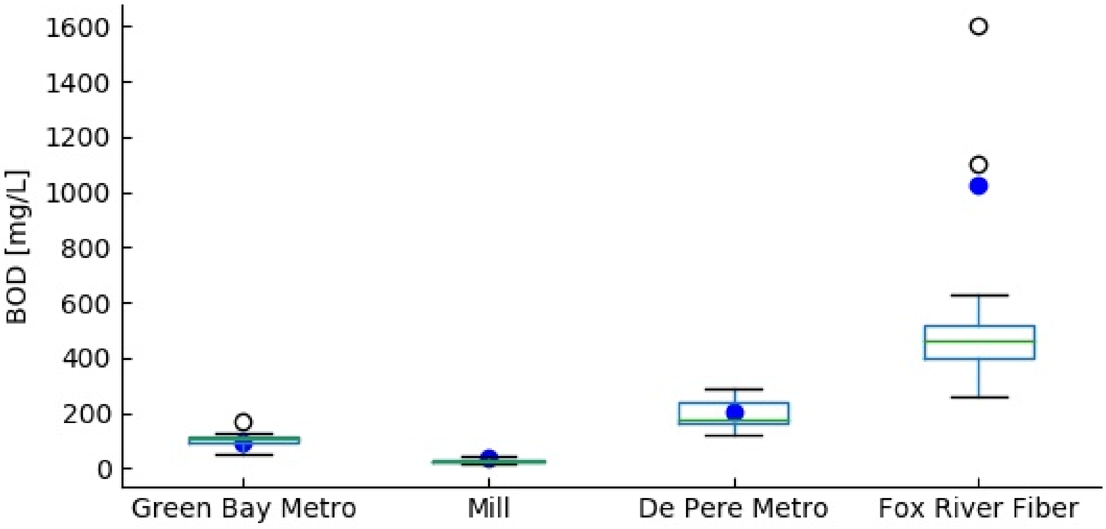


Figure 5-2: Influent BOD

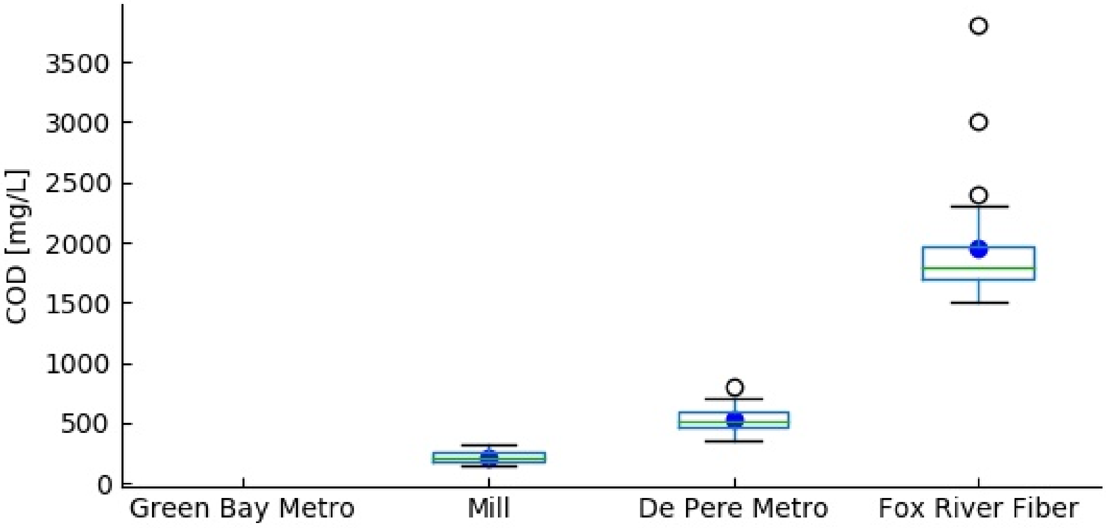


Figure 5-3: Influent COD

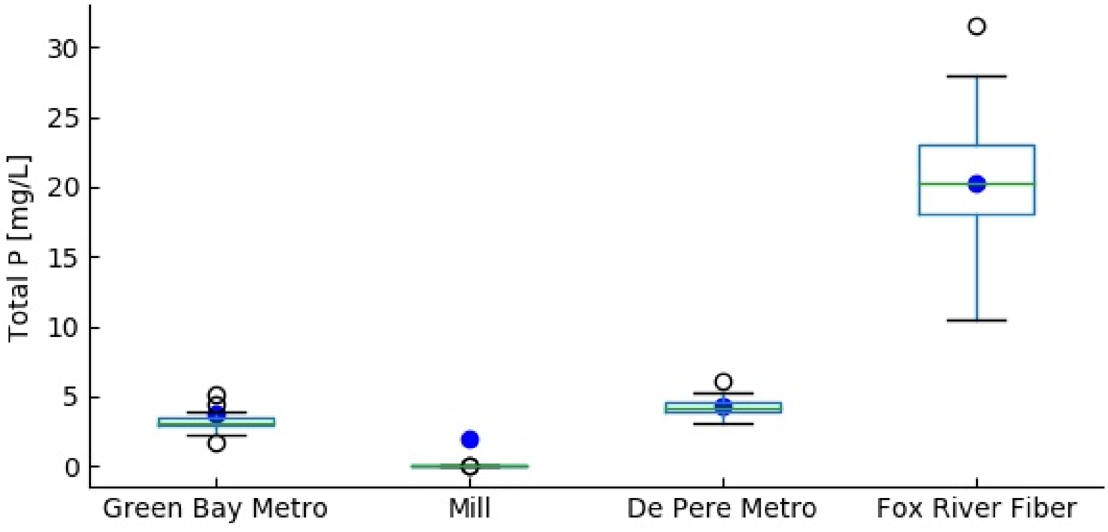


Figure 5-4: Influent TP

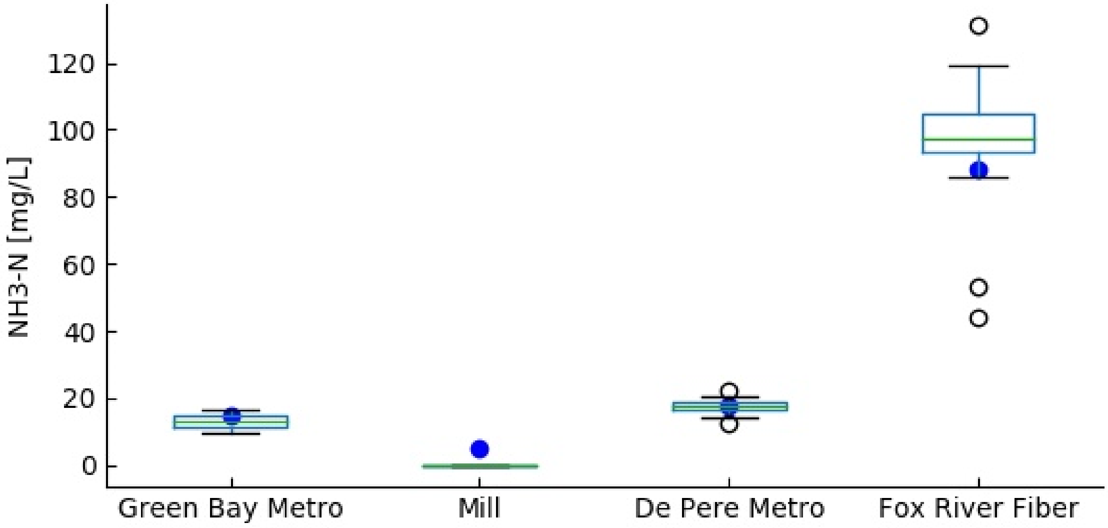


Figure 5-5: Influent Ammonia

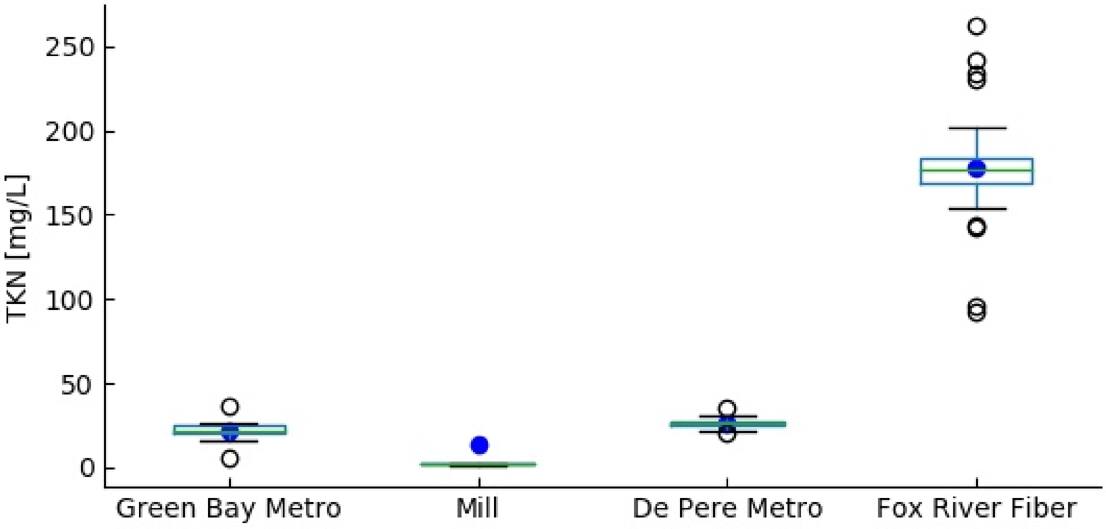


Figure 5-6: Influent TKN

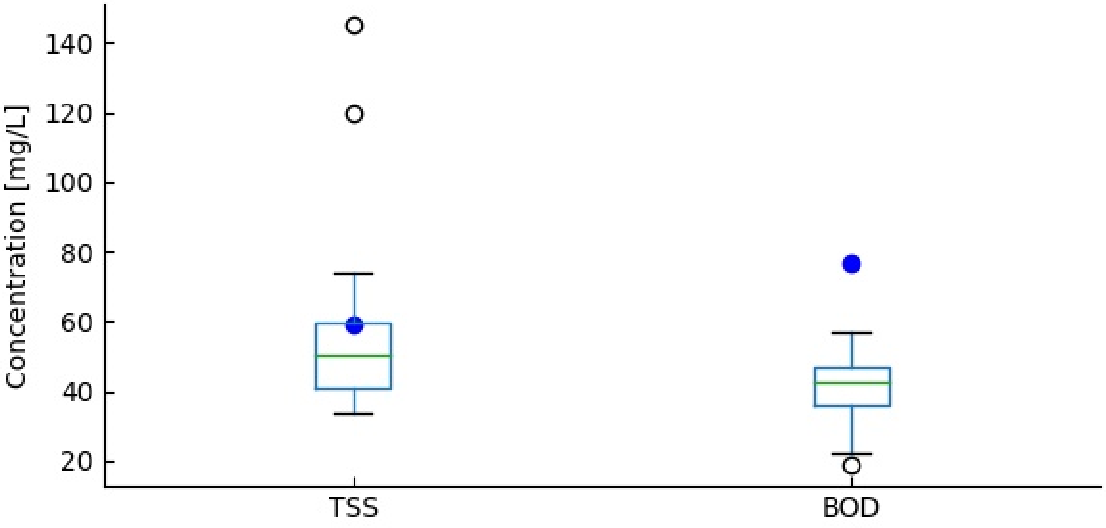


Figure 5-7: Primary Effluent TSS, and BOD

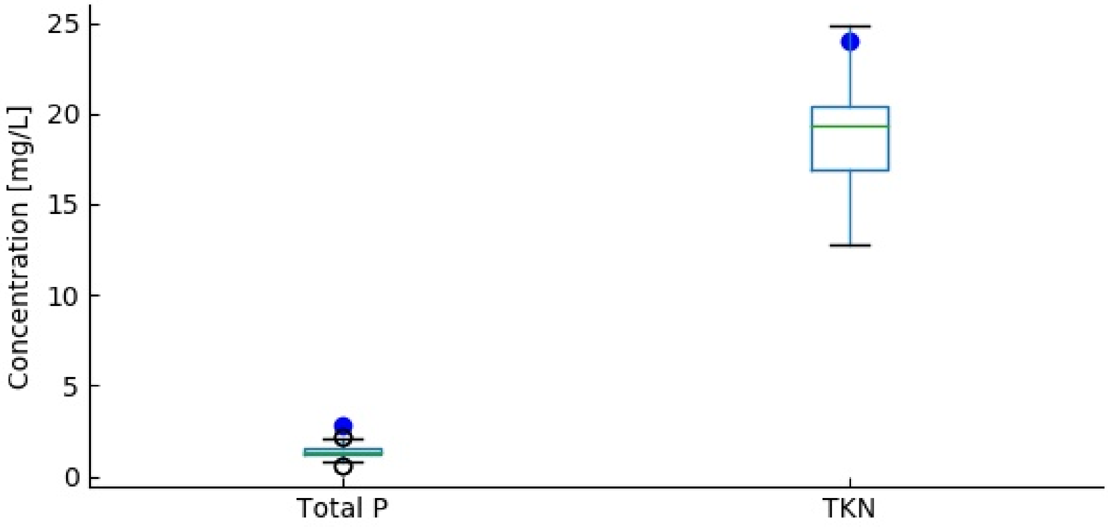


Figure 5-8: Primary Effluent TP and TKN

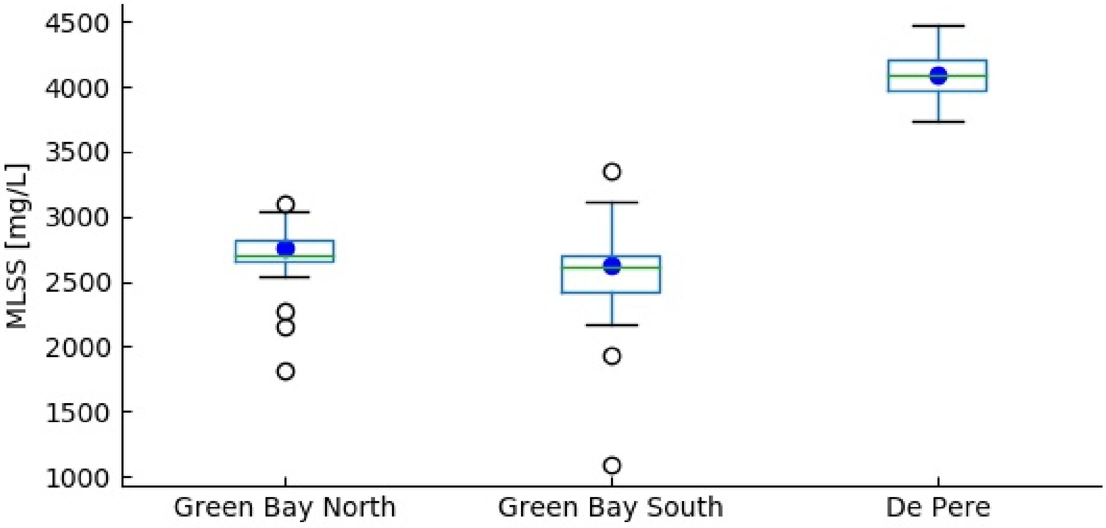


Figure 5-9: AB MLSS

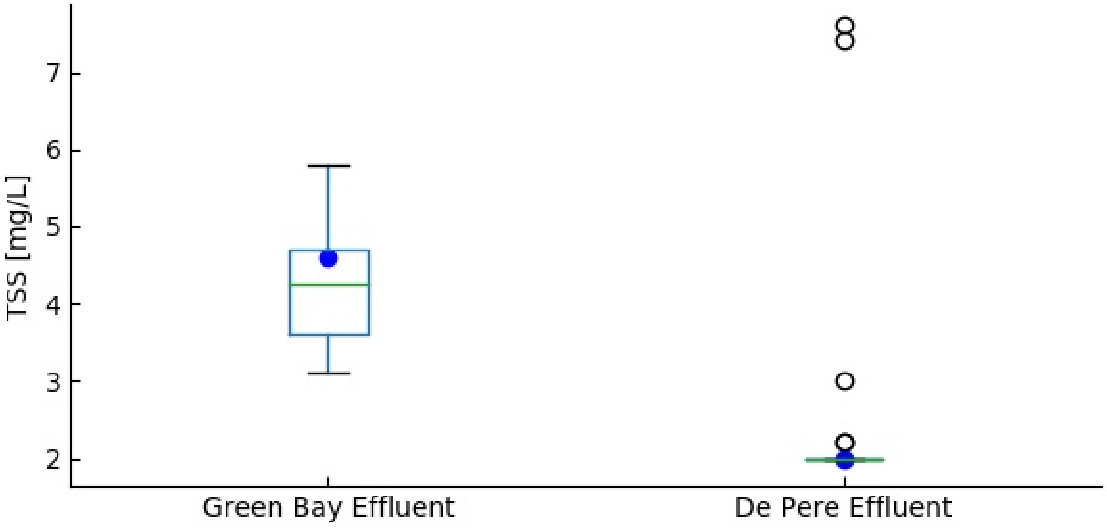


Figure 5-10: Effluent TSS

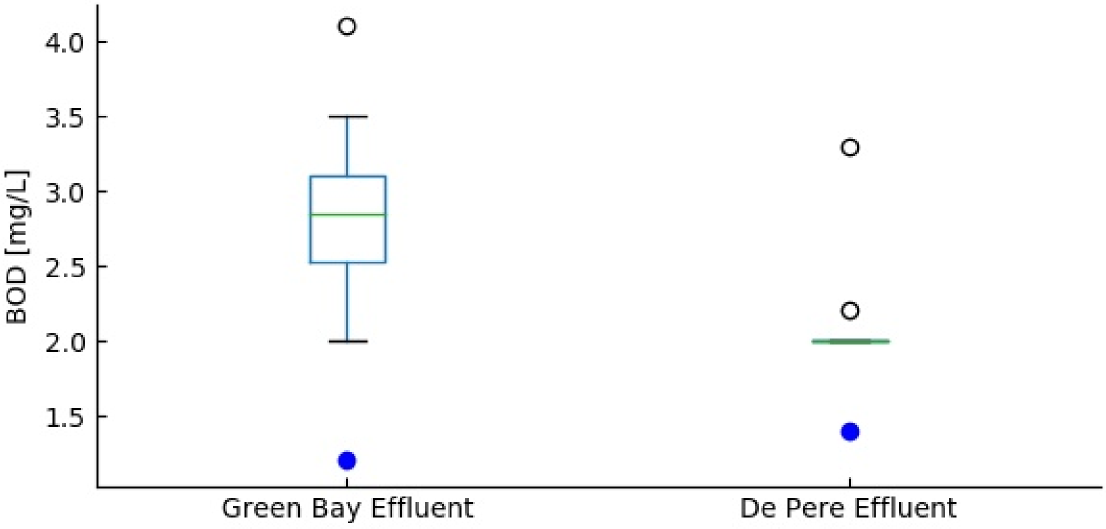


Figure 5-11: Effluent BOD

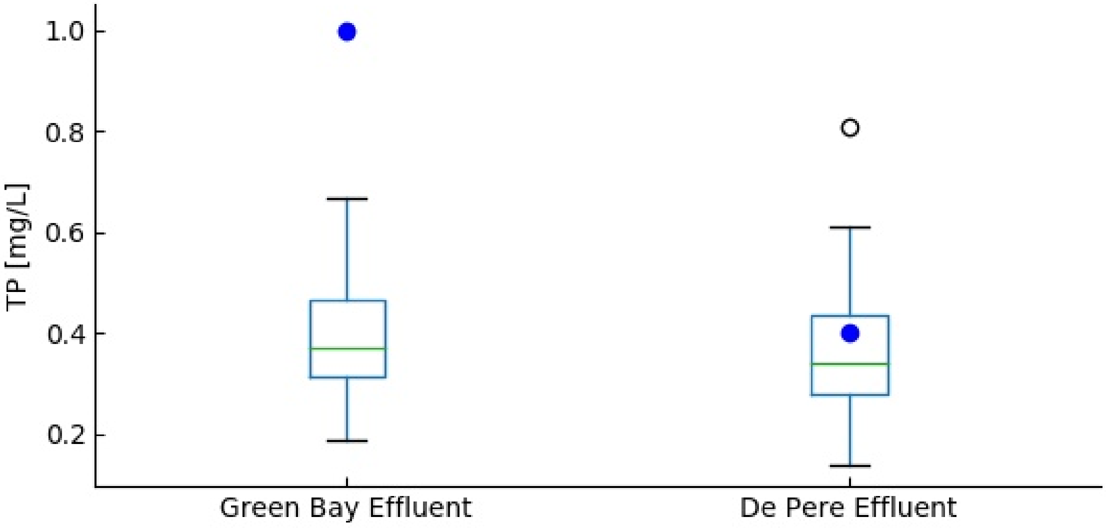


Figure 5-12: Effluent TP

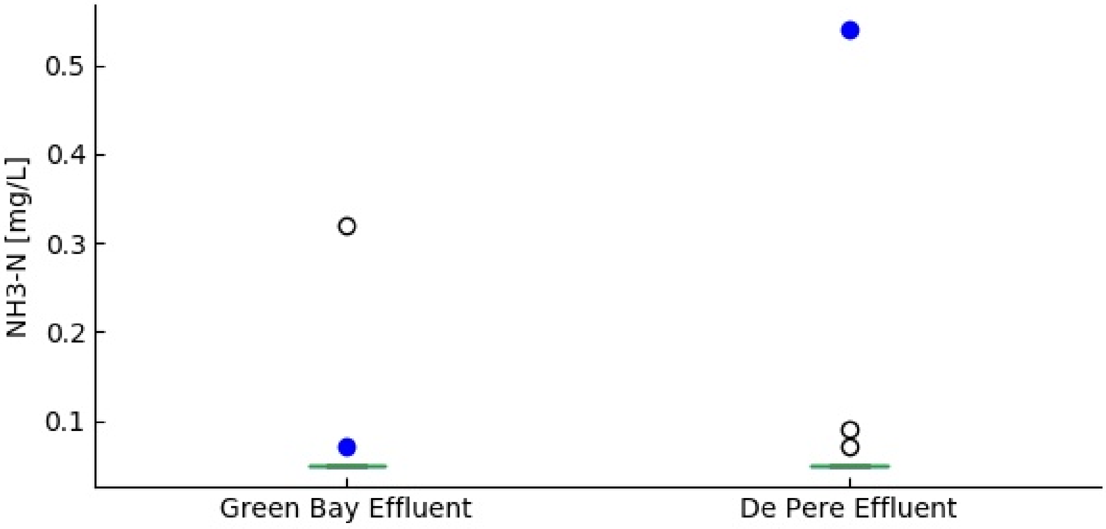


Figure 5-13: Effluent Ammonia

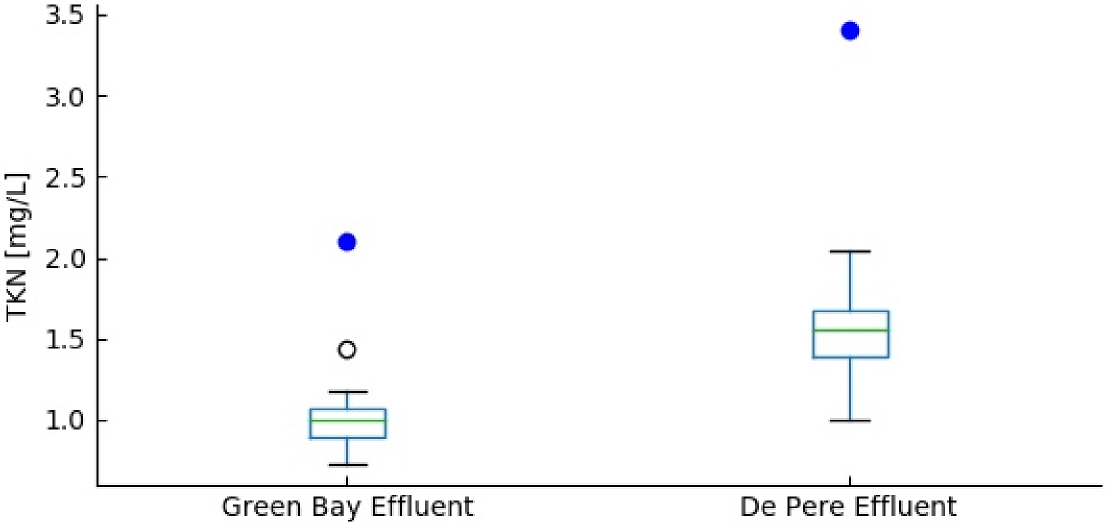


Figure 5-14: Effluent TKN

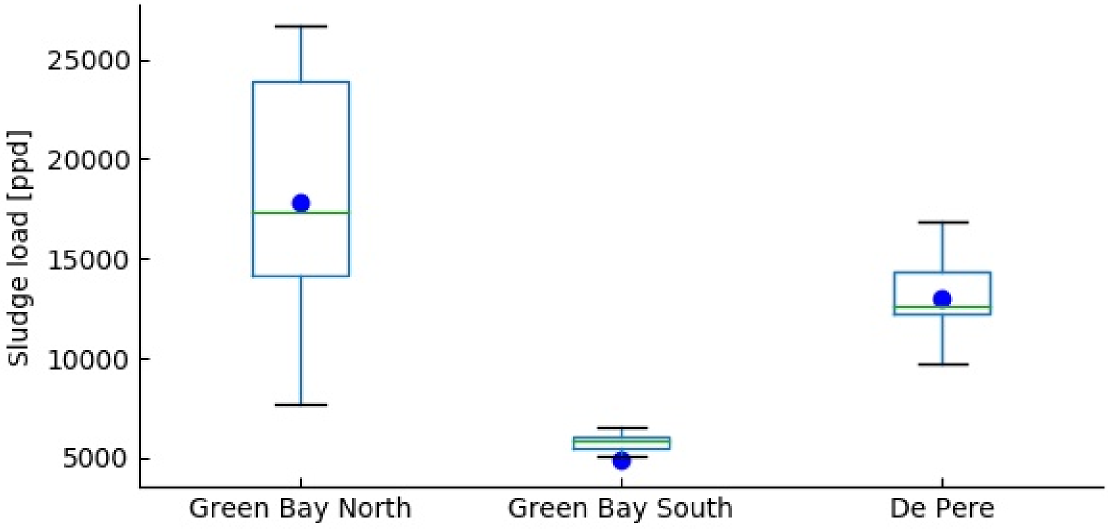


Figure 5-15: Solids Loadings

The majority of calibration involved the influent fractions, and developing the influent specific fractions required for the various NEW Water influents. Outside of the five influent fractionations, the following parameter adjustments were made:

- Global parameters:
  - Rate of Aluminum Hydroxide precipitation was adjusted to 0.5 day^{-1} in an attempt to balance liquid stream phosphorus removal performance with observed digester soluble phosphorus
- Digester specific parameters:
  - Vivianite precipitation kinetics were adjusted in the digester specific unit process for the same reason as aluminum kinetics were adjusted. The Rate of vivianite precipitation was reduced to 0.001 g/m^3-day and the rate of dissolution was increased to 0.1 g/m^3-day.
  - Given the unique nature of the NEW Water influents, particularly the industrial influents, the decay of endogenous decay products becomes more critical. The rate of decay for endogenous decay products was increased to 0.07 g/m^3-day to match the volatile solids destruction in the anaerobic digester.

5.2 STEADY STATE VALIDATION

Key steady-state validation results are presented in Table 5-3 and Figure 5-4for August 2017. Model inputs are listed at the beginning of **Table 5-3** and **Error! Reference source not found.**, and are highlighted in blue. Box and Whisker plots that give a more visual representation of the model fit for the Aug 2017 validation are given below Figure 5-16 through Figure 5-30.

Key operational parameters and setpoints include:

- Two out of the four aeration basin trains in GBF North aeration basins were operating during this time
- One out of the two aeration basin trains at the GBF South aeration basins was in operation
- All WAS flow from GBF and DPF are thickened via the thickening centrifuge
- 75% of primary sludge was thickened via gravity thickening, with the remaining being thickened by GBTs, which was indicative of this operating period
- 100% of Fox River Fiber flow was processed at the DPF

Similar to the steady-state calibration, the steady-state validation results indicate good agreement for the liquid treatment parameters, but variation between modeled and measured values for the solids flow streams did exist. As discussed above, it is not unusual for actual solids data to vary from modeled data, since solids monitoring is suited for permit compliance and is often less robust for process model calibration. It should be noted that the data from 2017 was simulated in the whole plant model, which included the Resource Recovery and Energy Efficiency (R2E2) improvements. This would not have a significant impact on overall aeration basin solids balance but would have impacts on nutrients and the hauled solids values. This approach was chosen as it is important to understand how the R2E2 facilities will have an impact at past loading conditions.

When reviewing the calibration results, the following key considerations should be acknowledged:

- The model input is in terms of COD, TKN, and TP, and the fractions determine the TSS and VSS. The model fractions were not adjusted to best fit the TSS values in the influent to help understand how representative the fractions are across different time periods. The baseline fractions produce a slightly higher TSS than observed in 2017, however the overall model results still provide a robust prediction of overall process performance.
- Hauled waste was highly variable, and thus the concentrations chosen represents the best estimate based on special sampling
- Primary effluent prediction was strong

Table 5-3: Green Bay Model Validation Results Aug 2017

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
GB Metro Influent					
Flow, mgd	22.4	22.4	0%	-	
COD, mg/L	464.54	464.54	0%	-	Assumed COD:BOD = 2.53
BOD, mg/L	183	170.94	-12 mg/L		
TSS, mg/L	212	262.8	+51 mg/L		
VSS/TSS		0.78		-	
TKN, mg/L	31.5	31.5	0%	-	
NH3-N, mg/L	20.1	20.8	-3%	-	

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
TP, mg/L	3.86	3.86	0%	-	
OP, mg/L		1.6		-	
Proctor and Gamble Influent					
Flow, mgd	4.05	4.05	0%	-	
COD, mg/L	216	216	0%	-	
BOD, mg/L	31.8	34.285	+2 mg/L	±5 mg/L	
TSS, mg/L	139	122.17	-17 mg/L	±5 mg/L	
VSS/TSS	0.55	0.547	1%	-	
TKN, mg/L	3.77	3.77	0%	-	
NH3-N, mg/L	0.028	1.3459	-4707%	-	About half are below detection limit
TP, mg/L	0.32	0.32	0%	-	
OP, mg/L		0.16		-	
Hauled Waste Influent					
Flow, mgd	0.003	0.003	9%	-	
COD, mg/L	9808.81	9808	0%	-	Assumed COD:BOD = 2.53
BOD, mg/L	3877	5390.3	+1513 mg/L	±5 mg/L	
TSS, mg/L	8323	3355.8	-4967 mg/L	±5 mg/L	
VSS/TSS		0.765		-	
TKN, mg/L	722	722	0%	-	
NH3-N, mg/L		332.12		-	
TP, mg/L	90.8	90.8	0%	-	
OP, mg/L		72.095		-	
GB Primary Effluent					
BOD, mg/L	99.5	107	+8 mg/L	±5 mg/L	
TSS, mg/L	115	115	0 mg/L	±5 mg/L	
TKN, mg/L	22.172	29.9	+7.7 mg/L	±2 mg/L	
NH3-N, mg/L		23	+23 mg/L	±2 mg/L	
TP, mg/L	3.003	2.7	-0.3 mg/L	±1 mg/L	
Operation					
Temp, °C	20	20	0%	-	

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
GB North Train					
Flow, mgd	25	25	0%	-	
MLSS, mg/L	3,587	3,485	3%	±10%	
MLVSS, mg/L		2,518		±10%	
RAS, mgd	33.7	34	-1%	-	
WAS, ppd	22333	20,888	6%	±10%	
Eff TSS, mg/L		4.5		±1 mg/L	
GB South Train					
Flow, mgd	6.8	6.8	0%	-	
MLSS, mg/L	2,504	2,733	-9%	±10%	
MLVSS, mg/L		1,980		±10%	
RAS, mgd	5.25	5.25	0%	-	
WAS, ppd	7,155	6,914	3%	±10%	
Eff TSS, mg/L		4.9		±1 mg/L	
GB Final Effluent					
TSS, mg/L	5.19	4.6	-0.6 mg/L	±1 mg/L	
BOD, mg/L	4.42	1.1	-3.3 mg/L	±2 mg/L	
TKN, mg/L	1.45	2.4	+1 mg/L	±2 mg/L	
NH3-N, mg/L	0.05	0.080	0 mg/L	±1 mg/L	All values below detection limit
NO3-N, mg/L		0.020		±2 mg/L	
TP, mg/L	0.34	0.55	+0.2 mg/L	±0.7 mg/L	
OP, mg/L		0.39		±0.7 mg/L	
Solids					
Primary Sludge Flow, mgd	0.56	0.69	-23%	-	
Primary Sludge TSS, mg/L		5630			
Primary Sludge TSS, ppd		32402			
GB North WAS, mgd	0.42	0.45	-7%	-	
GB North WAS, mg/L	6712	5561	17%		
GB North WAS, ppd	22333	20,885	6%	±10%	
GB South WAS, mgd	0.12	0.12	0%	-	
GB South WAS, mg/L	7162	6325	12%		
GB South WAS, ppd	7155	6,862	4%	±10%	

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
Digester					
Influent percent TS, %		3.9%	0%		
Influent percent VS, %		3.1%	0%		
Flow, mgd		0.27	0%		
Biogas production, cfm		221	0%		
Effluent NH3-N, mg/L		629	0%		
Effluent OP, mg/L		1.2	0%		
Effluent TS, %		3.0%	0%		
Effluent VS, %		2%	0%		
VS Destruction Rate, %		31%	0		

[1]Values color-coded in blue are inputs to the model

Table 5-4: De Pere Model Validation Results Aug 2017

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
DP Metro Influent					
Flow, mgd	7.59	7.59	0%	-	
COD, mg/L	864	864	0%	-	
BOD, mg/L	339	334.97	-4 mg/L	±5 mg/L	
TSS, mg/L	304	287.12	-17 mg/L	±5 mg/L	
VSS/TSS		0.927		-	
TKN, mg/L	39.7	39.7	0%	-	
NH3-N, mg/L	24	26.361	-10%	-	
TP, mg/L	5.3	5.3	0%	-	
OP, mg/L		2.5334		-	
Fox River Fiber Influent					
Flow, mgd	0.69	0.69	0%	-	No flow data given, using calibration value
COD, mg/L	1484	1484	0%	-	
TSS, mg/L	306	298.71	-7 mg/L	±5 mg/L	
VSS/TSS		0.9978		-	
TKN, mg/L	78.4	78.4	0%	-	

Parameter	Plant data	SUMO[1]	± Error[2]	Target Accuracy	Notes
NH3-N, mg/L	39.6	38.863	2%	-	
TP, mg/L	4.5	4.5	0%	-	
OP, mg/L		0.8582		-	
Operation					
Temp, °C	20	20	0%	-	
DP Train					
Flow, mgd	7.59	8.3	-9%	-	
MLSS, mg/L	4,469	4,575	-2%	±10%	
MLVSS, mg/L		3,992		±10%	
RAS, mgd	8.18	7.6	7%	-	
WAS, ppd	18569	19,090	-3%	±10%	
Eff TSS, mg/L		10		±1 mg/L	
DP Final Effluent					
TSS, mg/L	2.22	2.0	-0.2 mg/L	±1 mg/L	Most are below detection limit
BOD, mg/L	2.13	1.5	-0.6 mg/L	±2 mg/L	Most are below detection limit
TKN, mg/L	1.59	4.3	+2.7 mg/L	±2 mg/L	
NH3-N, mg/L	0.025	0.630	+0.6 mg/L	±1 mg/L	Most are below detection limit
NO3-N, mg/L		0.01		±2 mg/L	
TP, mg/L	0.29	0.2	-0.1 mg/L	±0.7 mg/L	
OP, mg/L		0.0		±0.7 mg/L	
Solids					
DP WAS, mgd	0.5	0.50	0%	-	
DP WAS, mg/L	4469	4575	-2%		
DP WAS, ppd	18569	19,090	-3%	±10%	

[1] Values color-coded in blue are inputs to the model

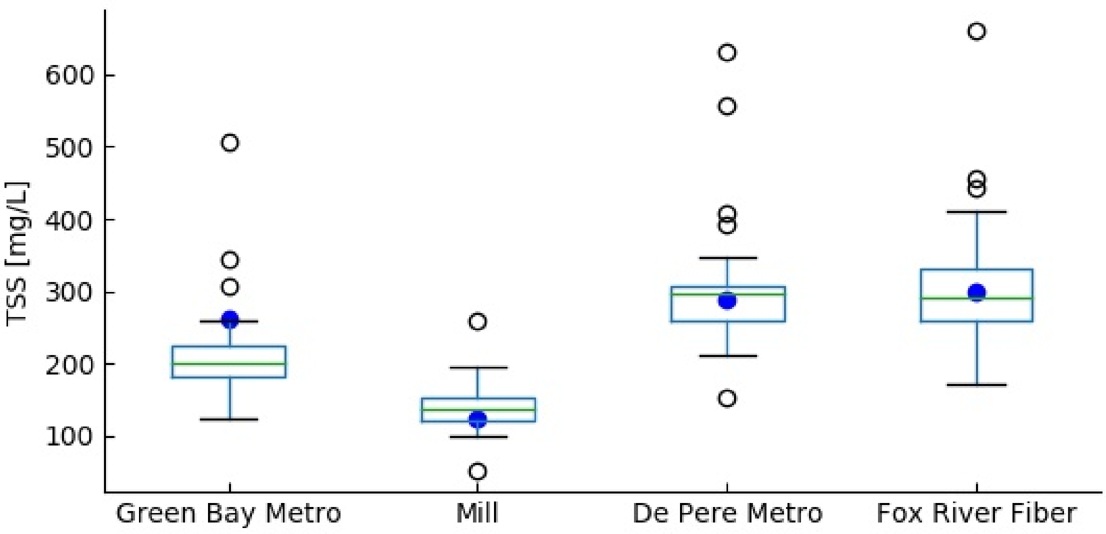


Figure 5-16: Influent TSS

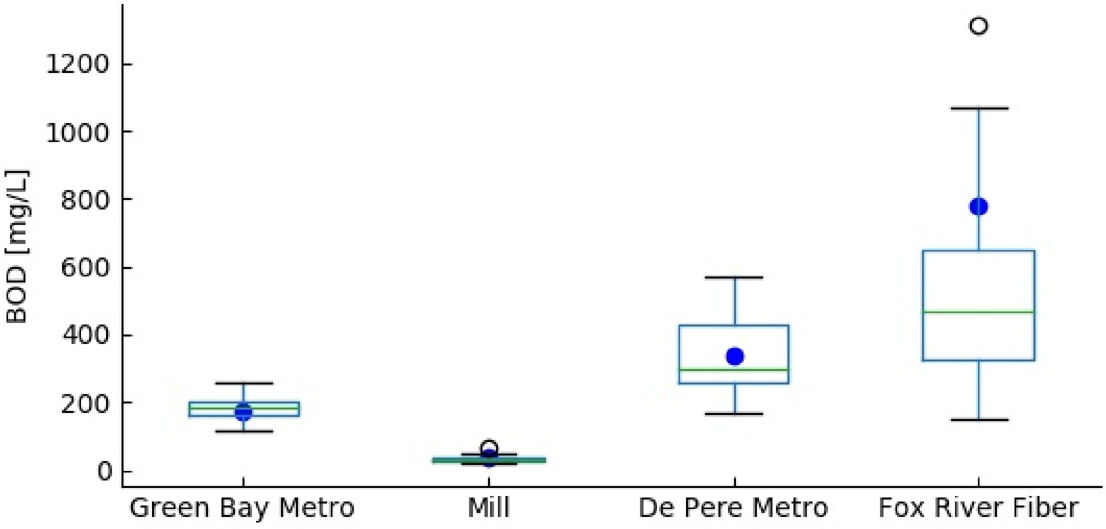


Figure 5-17: Influent BOD

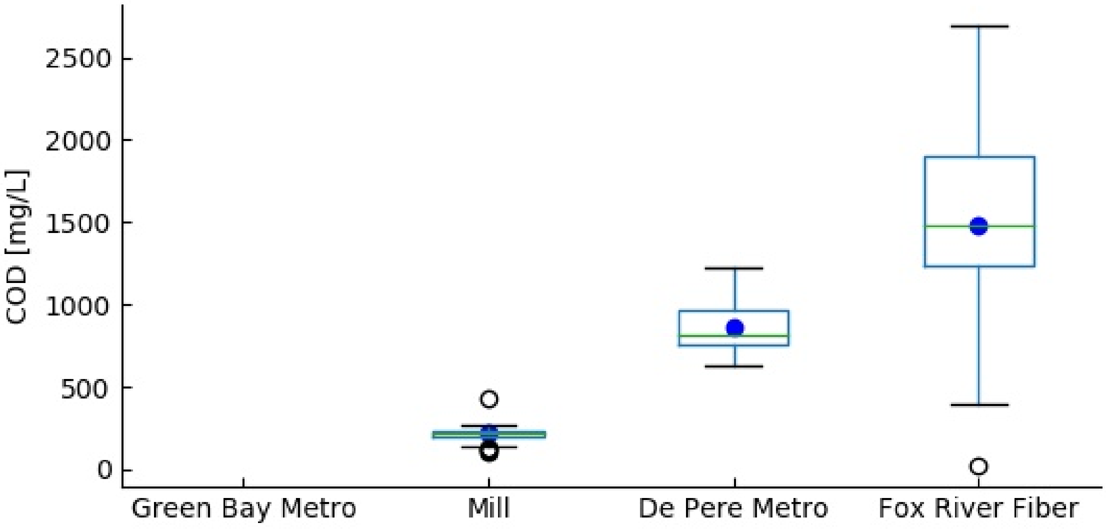


Figure 5-18: Influent COD

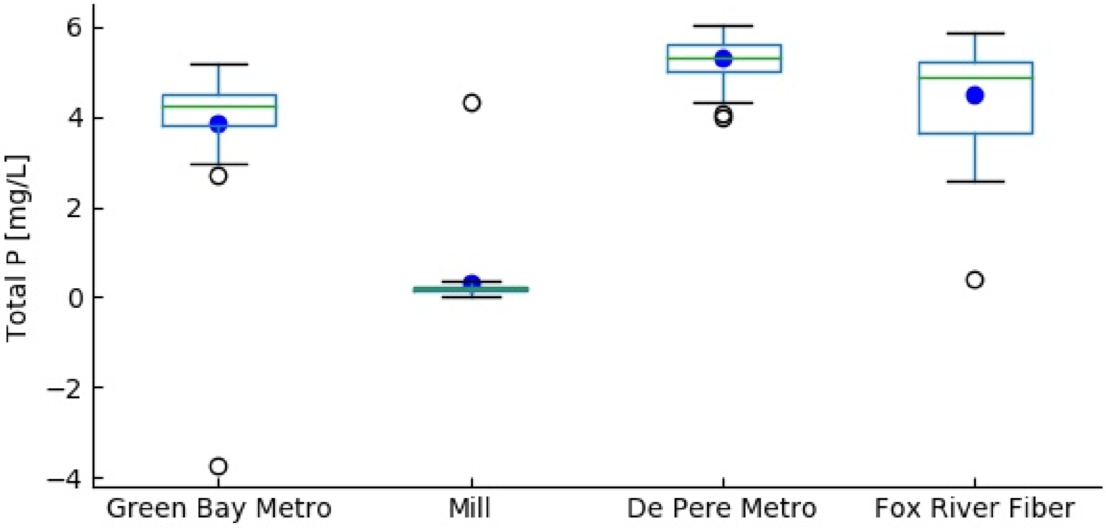


Figure 5-19: Influent TP

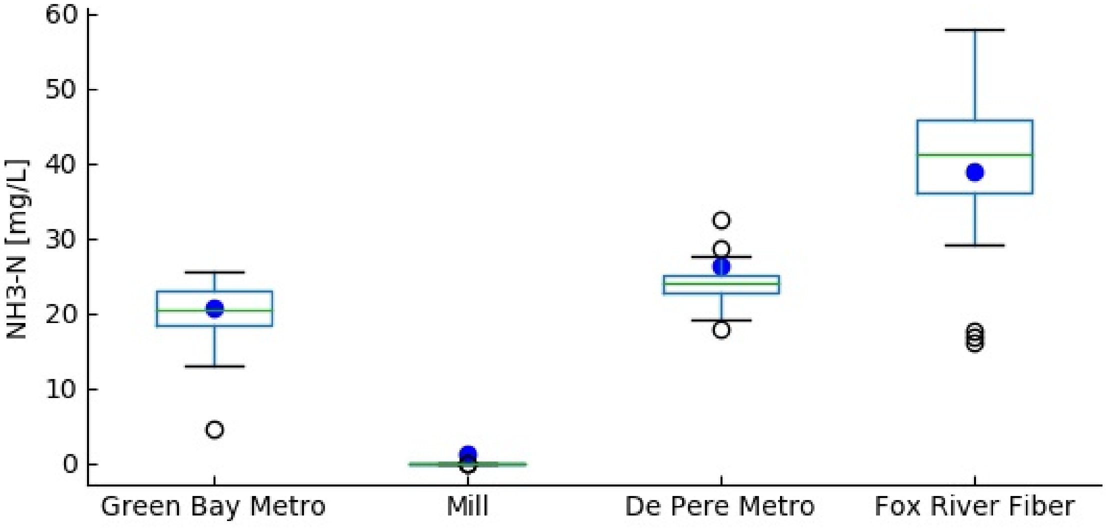


Figure 5-20: Influent Ammonia

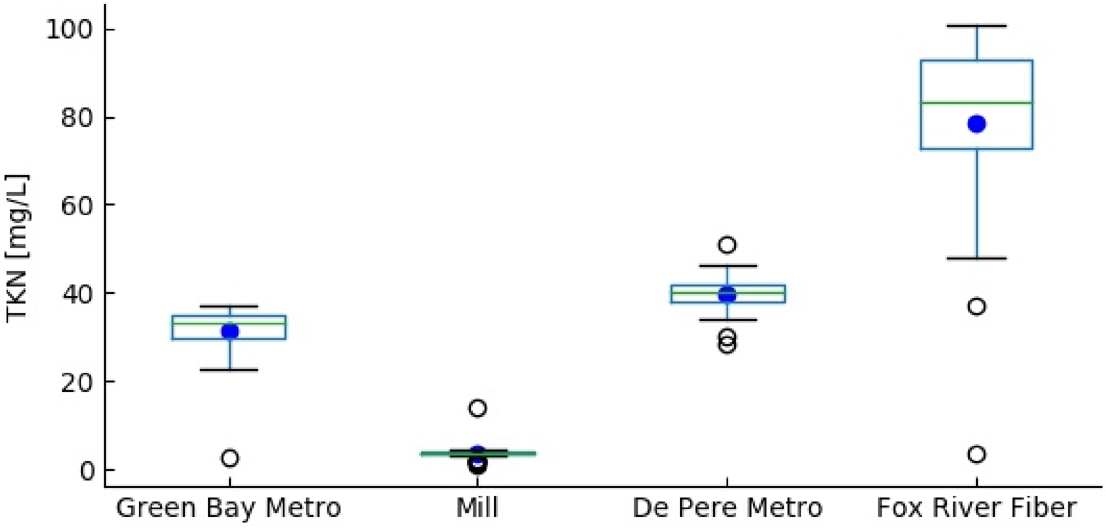


Figure 5-21: Influent TKN

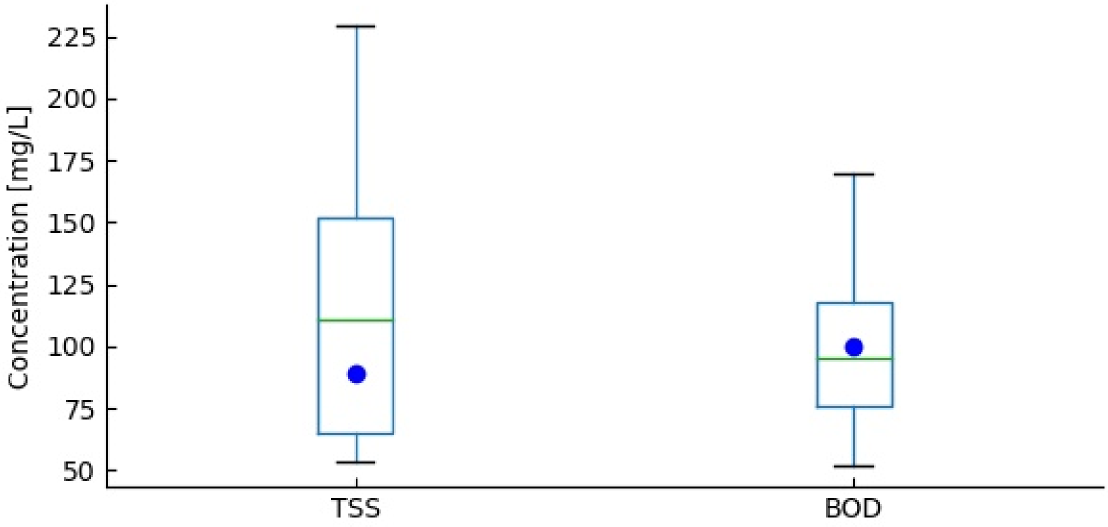


Figure 5-22: Primary Effluent TSS, and BOD

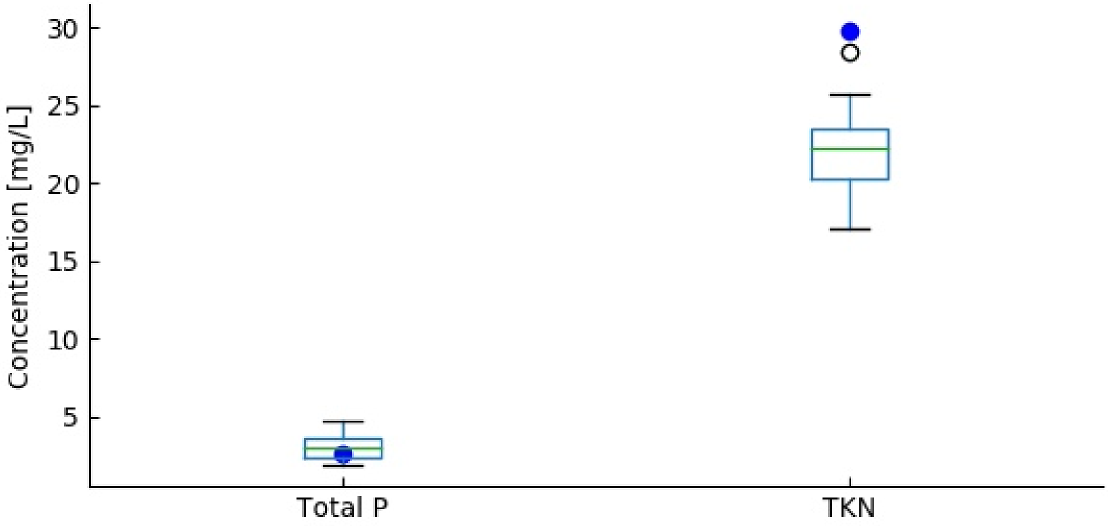


Figure 5-23: Primary Effluent TP and TKN

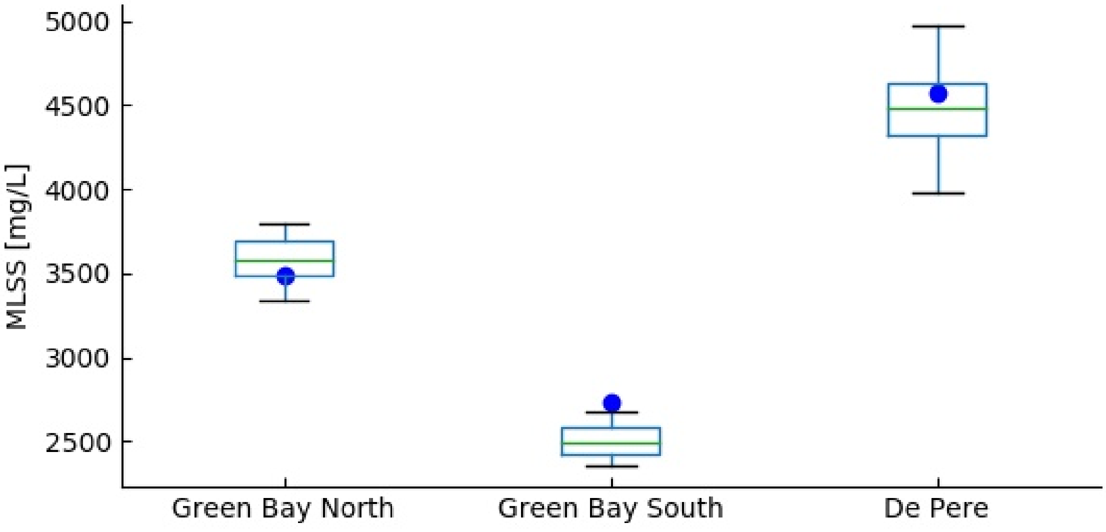


Figure 5-24: AB MLSS

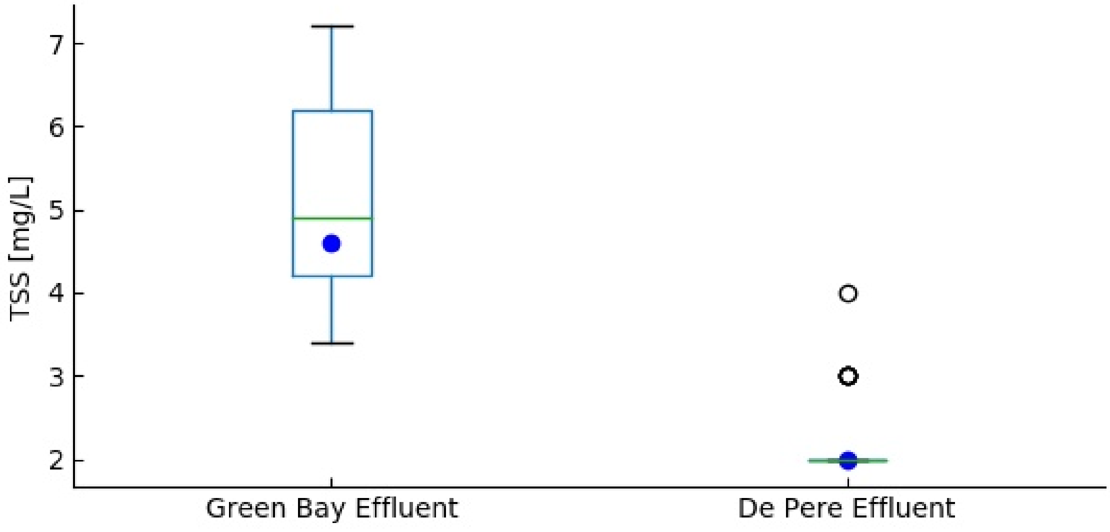


Figure 5-25: Effluent TSS

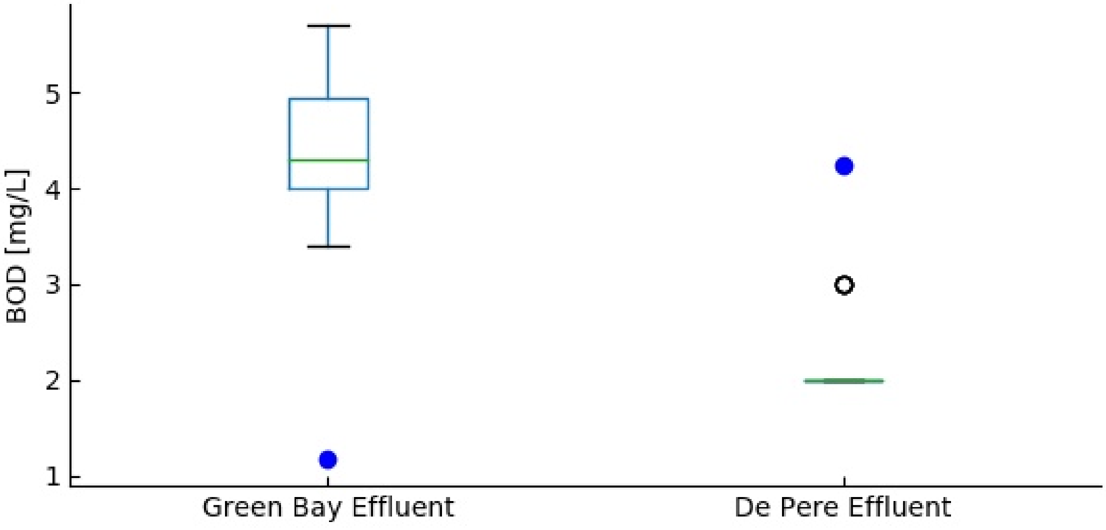


Figure 5-26: Effluent BOD

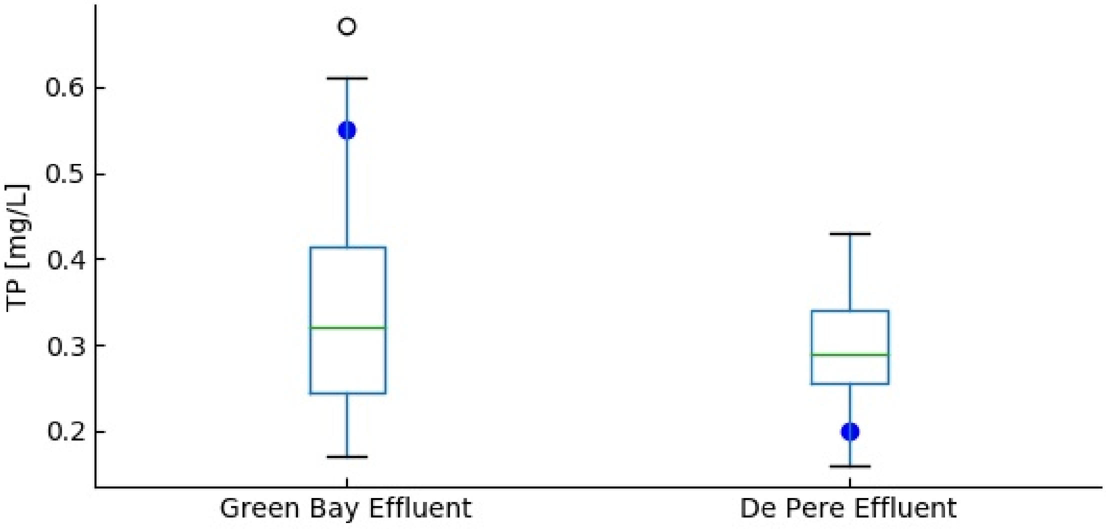


Figure 5-27: Effluent TP

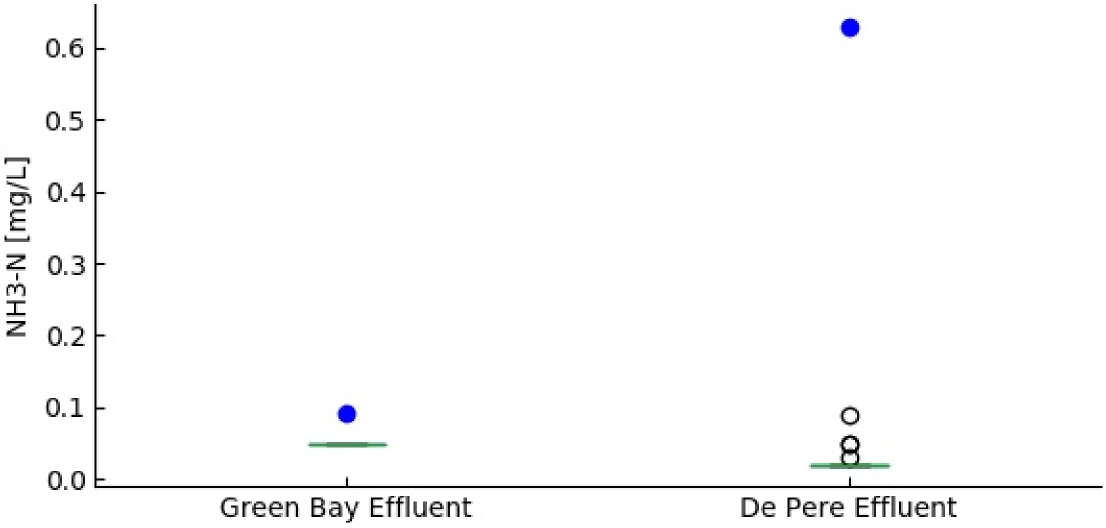


Figure 5-28: Effluent Ammonia

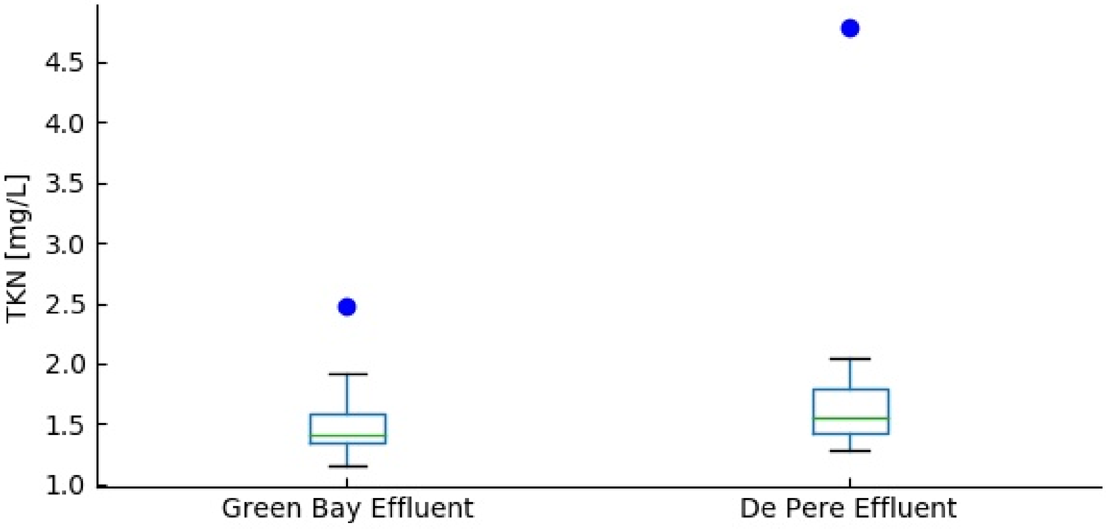


Figure 5-29: Effluent TKN

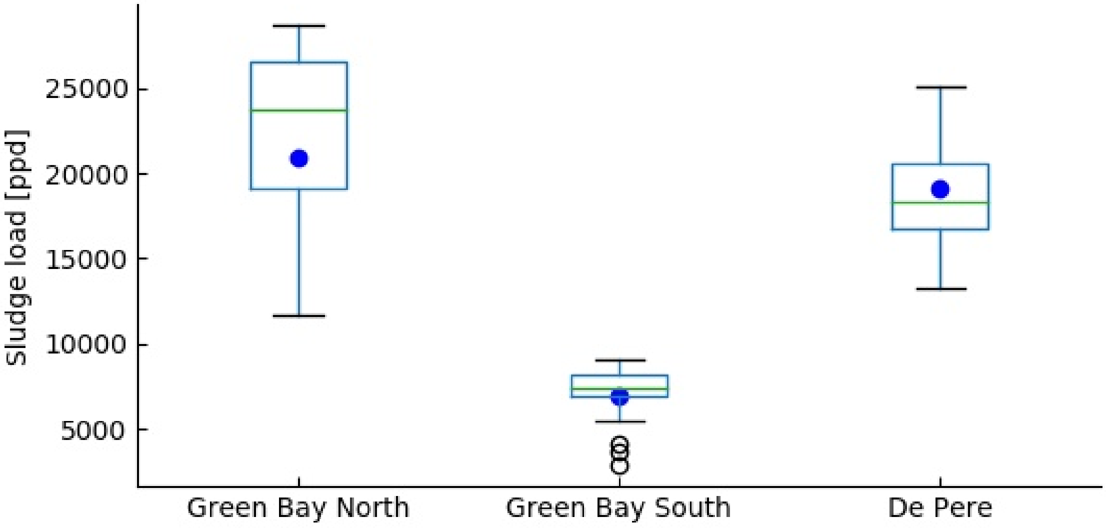


Figure 5-30: Solids Loadings

5.3 DYNAMIC VALIDATION

Understanding dynamic responses of processes are a critical aspect when evaluating potential aeration and nutrient removal improvements. This is particularly important for system like NEW Water, where high variability in influent conditions from industrial sources can have significant dynamic impacts on performance. For dynamic simulations, the daily influent flow, BOD, TKN, and TP values from February 2019 were entered into the model. Key dynamic operational parameters like WAS pumping rates and RAS rates, were also added on a daily basis to the process model. Key operational parameters and setpoints include:

- Three out of the four aeration basin trains in GBF North aeration basins were operating during this time
- One out of the two aeration basin trains at the GBF South aeration basins was in operation
- All WAS flow from GBF and DPF are thickened via the thickening centrifuge
- 75% of primary sludge was thickened via gravity thickening, with the remaining being thickened by GBTs
- Fox River Fiber flow was adjusted to match the reduced flows noted at the DPF in February 2019
- Based on the monthly ferric chloride added in February 2019, and average ferric chloride flow rate of 533 gpd was included at the GBF downstream of primary clarification

Time series scatter plots are included in **Figure 5-31** through **Figure 5-44** to give a visual representation of the model fit to plant data for the February 2019 validation. Points are measured values, lines are simulated SUMO values. Overall, the dynamic simulation provides a meaningful indication of performance trends and variation. The major challenge with Dynamic simulation is that rarely is every fractionation change captured, nor every operational change. The value of dynamic simulation is to provide insight into general trends and variability of the existing process, and any potential alternatives. One important note for the dynamic simulation is that the predictive model developed based on the WEF MOP 8 guidelines was utilized for dynamic prediction of TSS removal performance.

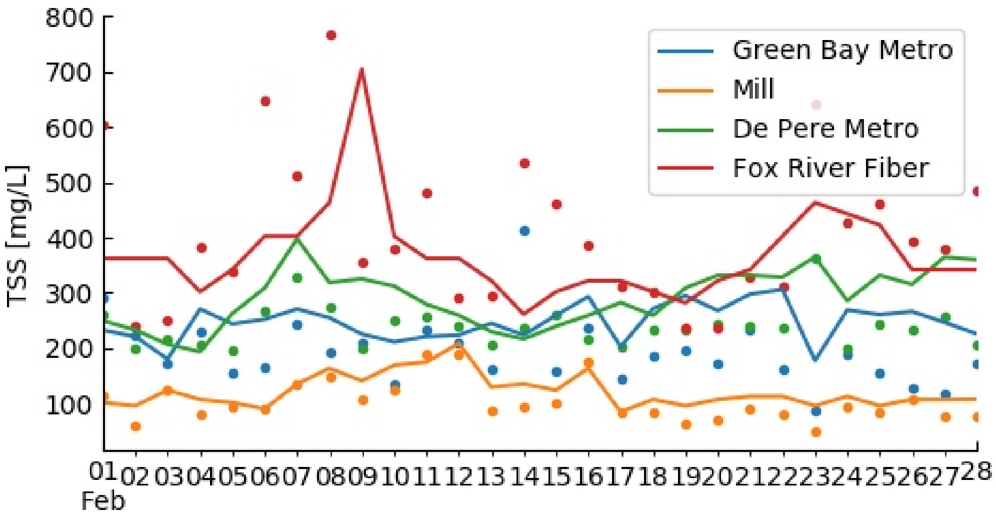


Figure 5-31: Influent TSS

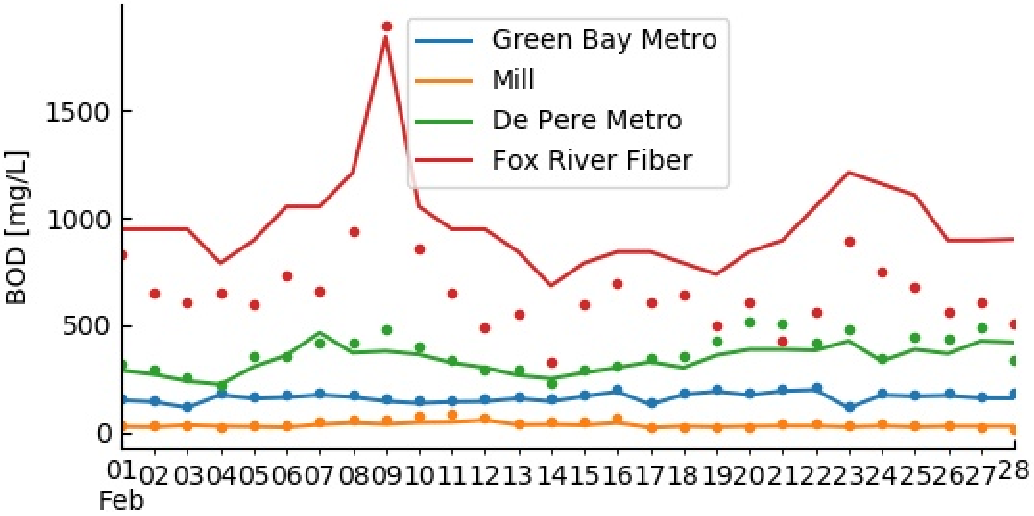


Figure 5-32: Influent BOD

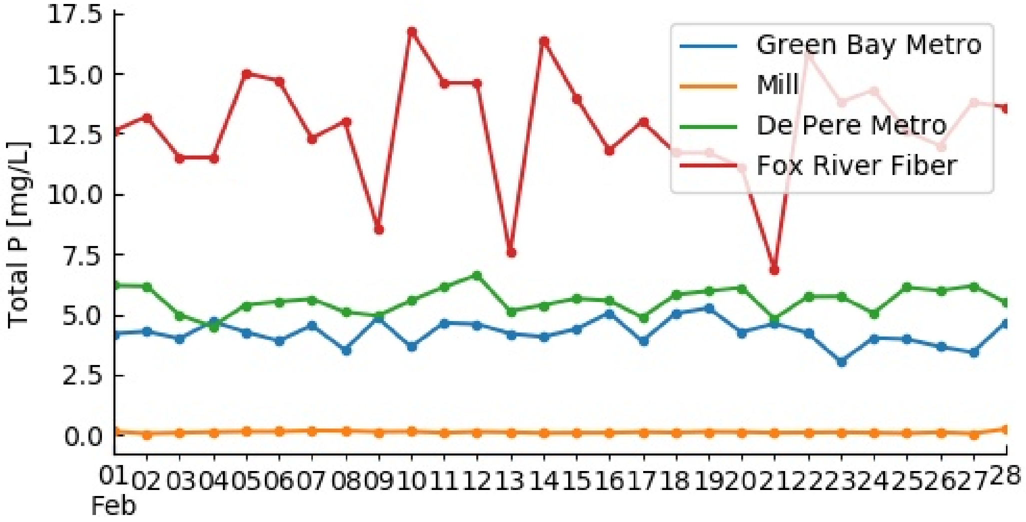


Figure 5-33: Influent TP

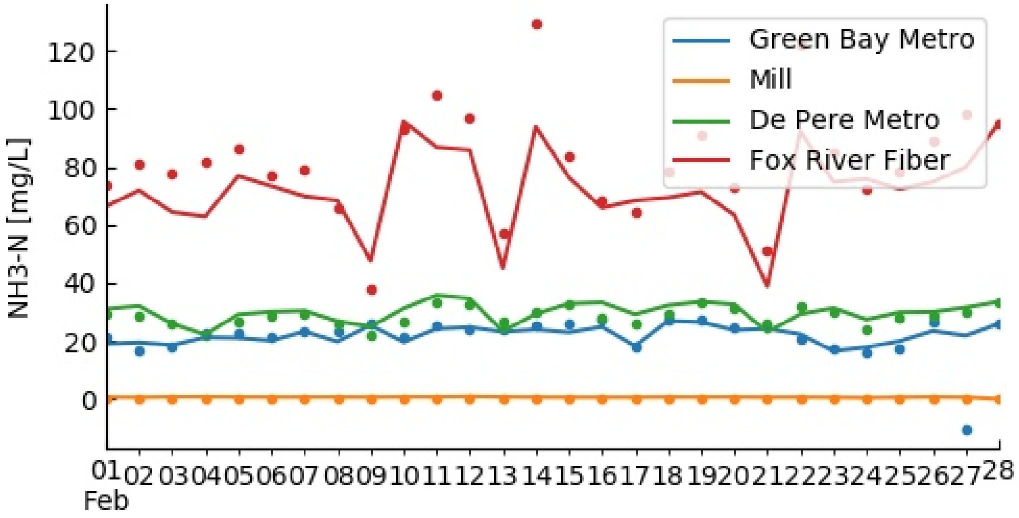


Figure 5-34: Influent Ammonia

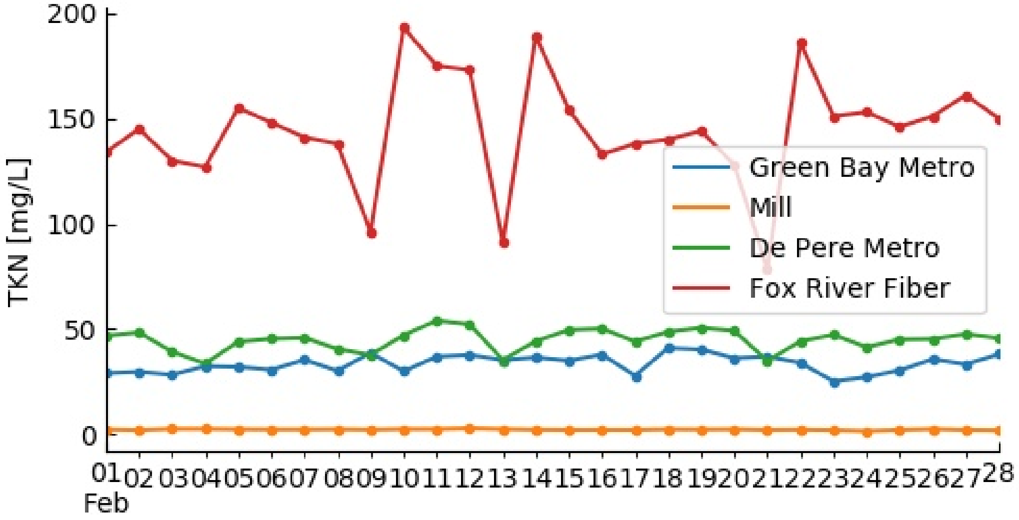


Figure 5-35: Influent TKN

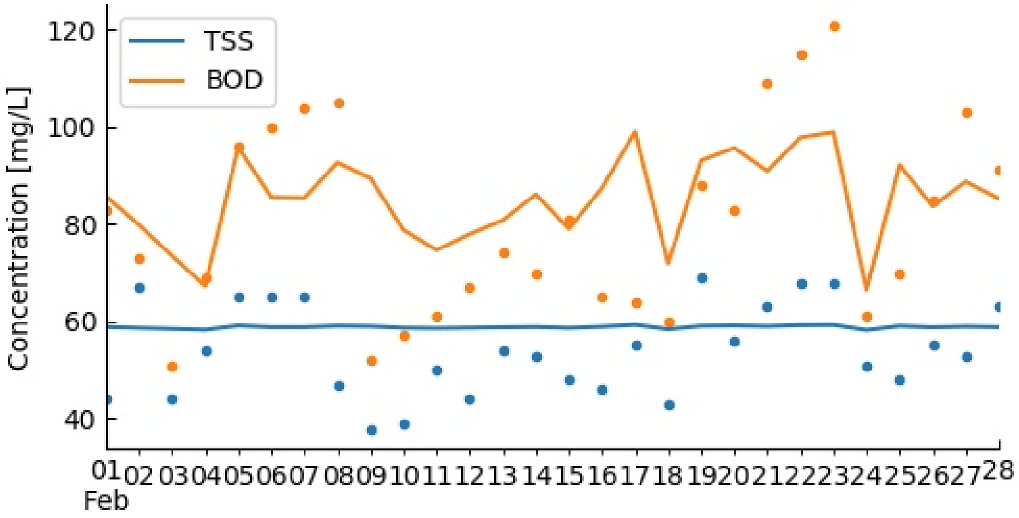


Figure 5-36: Primary Effluent TSS, and BOD

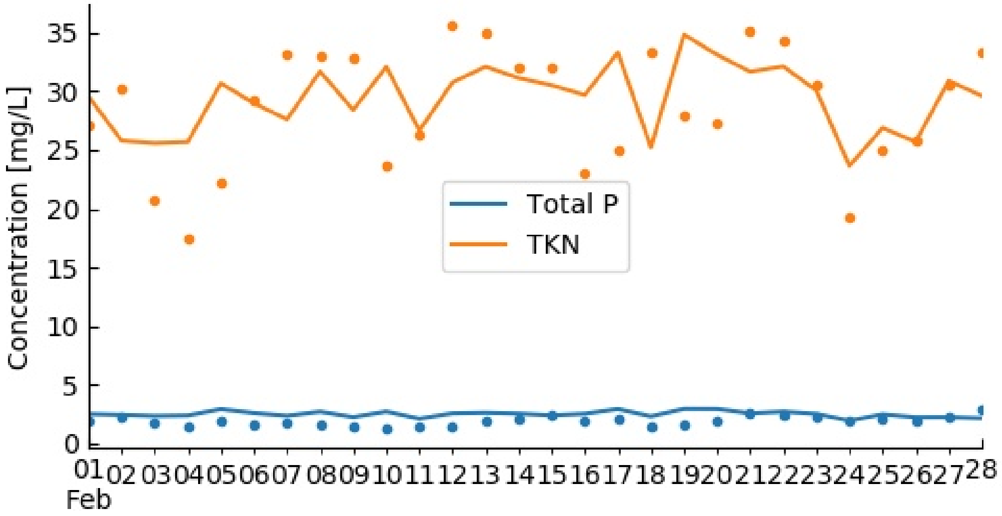


Figure 5-37: 0Primary Effluent TP and TKN

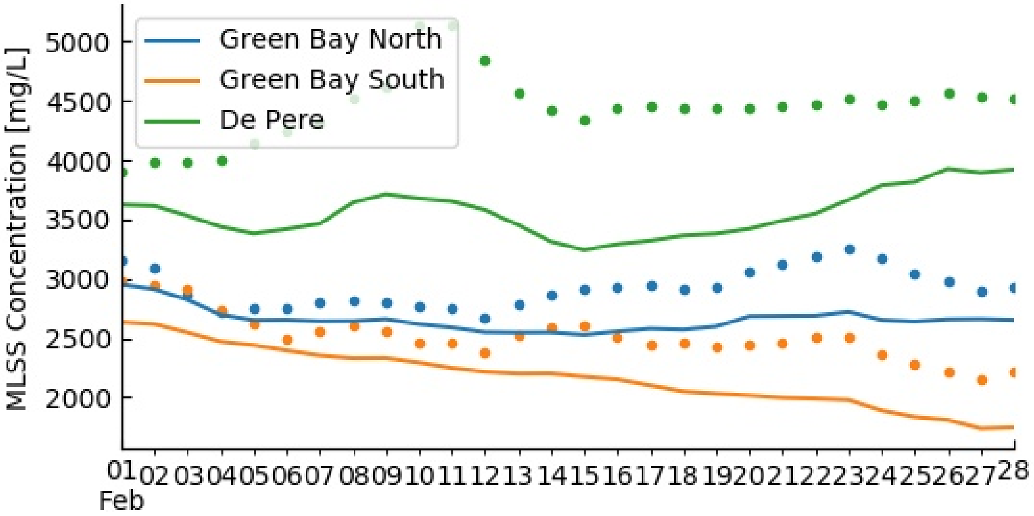


Figure 5-38: AB MLSS

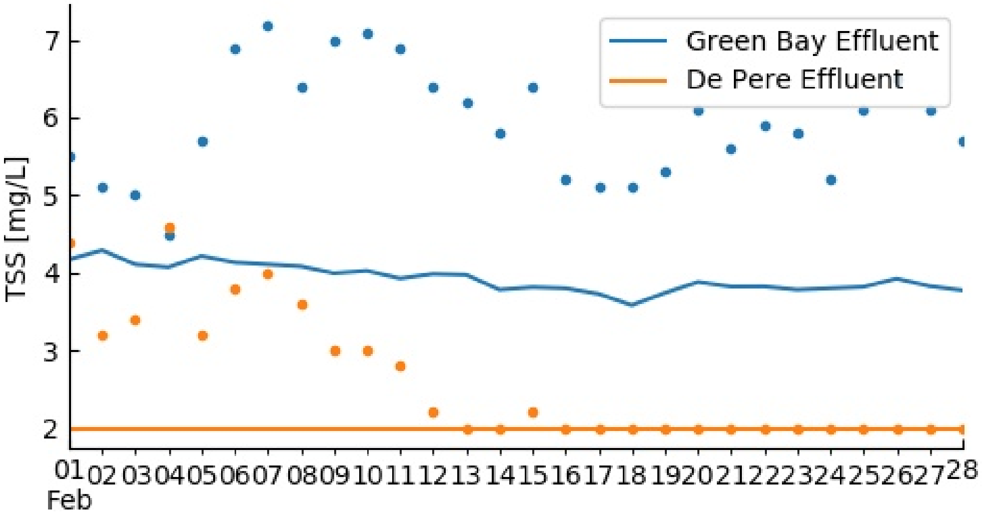


Figure 5-39: Effluent TSS

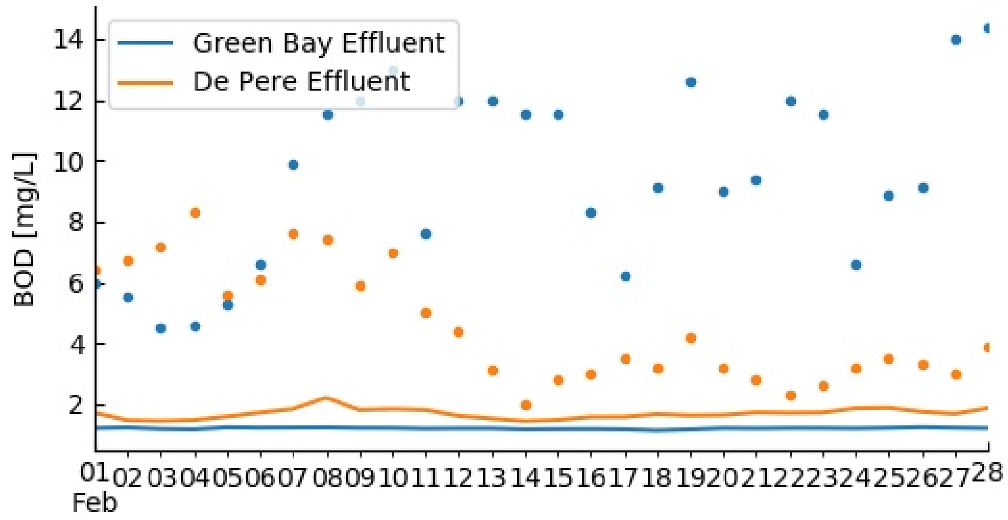


Figure 5-40: Effluent BOD

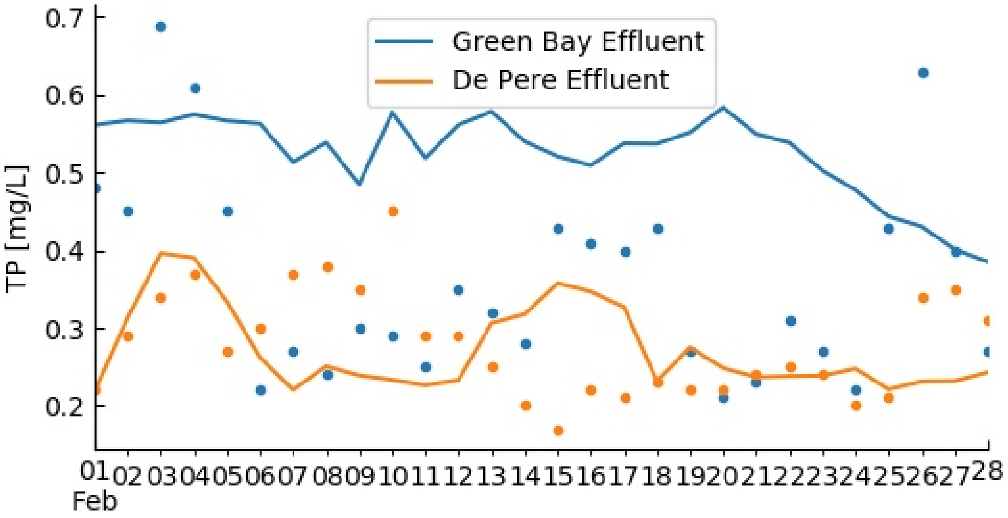


Figure 5-41: Effluent TP

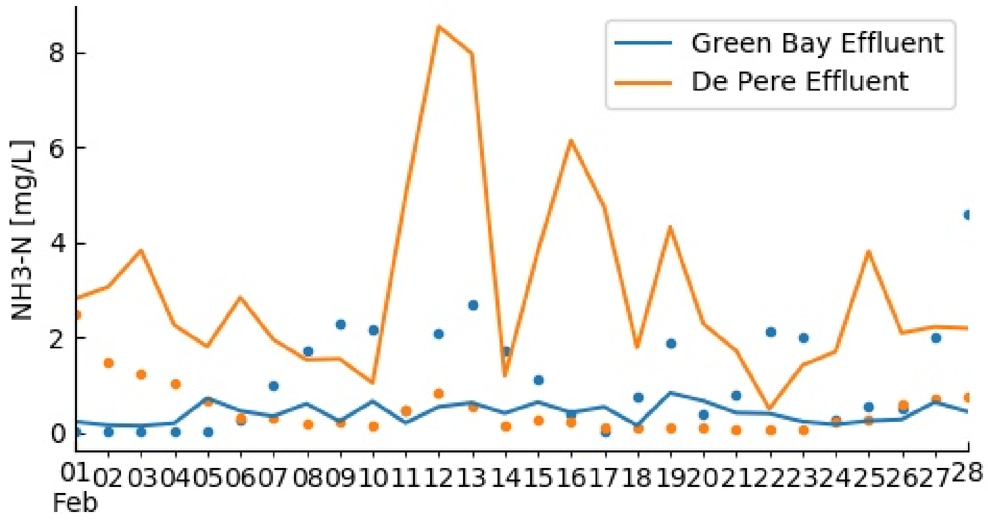


Figure 5-42: Effluent Ammonia

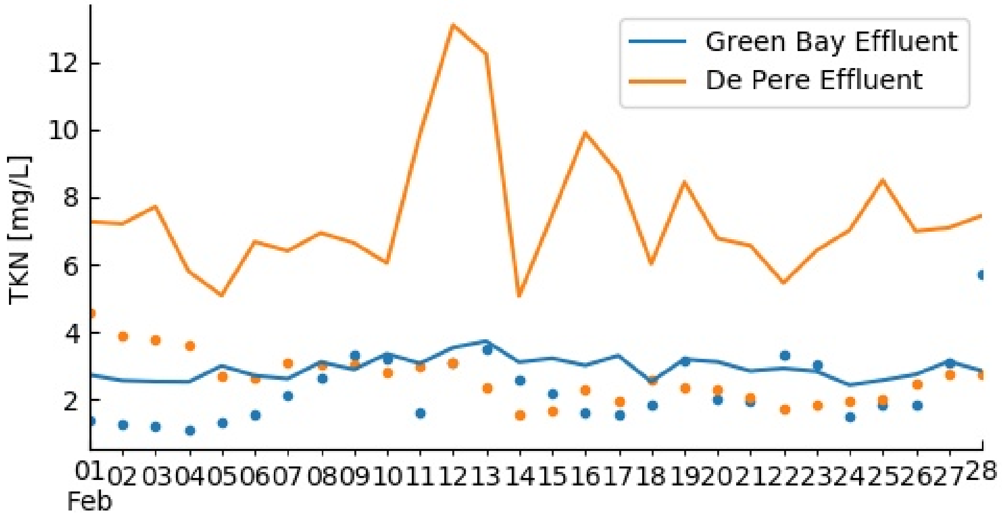


Figure 5-43: Effluent TKN

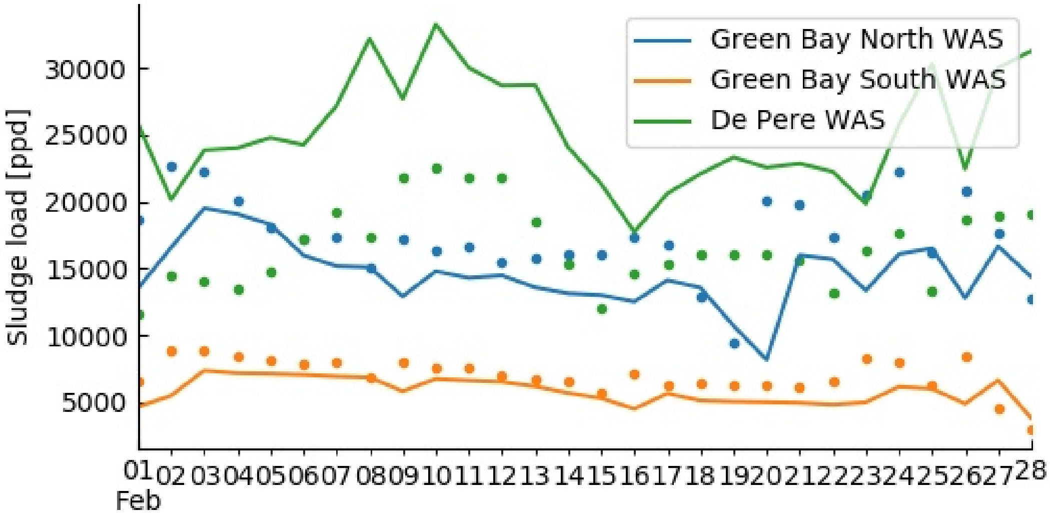


Figure 5-44: Solids Loadings

5.4 CALIBRATION AND VALIDATION CONCLUSIONS

Calibration was performed in a steady-state simulation based on influent fractions developed for all five influent sources at the NEW Water facilities. Adjustment of influent fractions and three key chemical precipitation related parameters resulted in a model that met the established stop criteria for every major process performance indicator. When this calibrated model was then used to simulate a separate steady-state condition and a dynamic condition, the model provided a robust indicator of process performance. The one area of note is that the liquid stream phosphorus removal and digester phosphorus release resulted in some variation between simulated and measured data. Based on previous special sampling by NEW Water, this is likely due to the impact of influent metal concentrations. In the next section, the sensitivity of the model predications related to phosphorus will be explored relative to the influent concentrations of aluminum and iron.

6 Discussion on Impacts of Influent Metal Concentrations

In order to assess the impacts of influent Fe and Al on Bio-P and nutrient removal, a sensitivity analysis was conducted using the calibrated SUMO model by concurrently varying the influent Fe and Al for Green Bay and De Pere municipal influents. Influent Fe and Al were separately varied across four concentrations (0, 1, 2, and 5 mg/L) while maintaining all other model inputs constant for the June 2019 (i.e., calibration data set) and August 2017 (i.e., validation data set) monthly averages. The steady state results of each of these 32 simulations were analyzed to determine the potential performance of the New Water facility.

As was mentioned in Section 3.2, phosphorus removal has been successfully performed at New Water in the past, but recent special sampling results indicate that Bio-P is not currently occurring. Apart from variability in influent phosphorus, New Water's unique circumstances regarding influent metals lowers the likelihood for successful Bio-P performance. During the sensitivity simulations, a range of Fe and Al concentrations were combined to determine the impact of influent metals on phosphorus removal performance.

The main driver for initially examining the influent metal concentrations was the limited phosphorus release observed in the digesters. Influent metal concentrations were shown to have an impact on phosphorus cycling in the aeration basins, and the relative impact on digester soluble phosphorus was even more pronounced. As shown in **Table 6-1** and **Table 6-2**, the model provides sensitive prediction of the digester phosphorus cycling. Although a significant amount of phosphorus is entering the digester, no P-release is occurring at high influent metal concentrations because the metals chelate the phosphorus out of solution. At low metal concentrations, however, P-release is significant, which would enable harvesting of precipitates such as struvite or vivianite.

Table 6-1: Digester orthophosphorus heat map - June 2019 loadings

Digester Effluent OP June 2019 Loadings				
Fe	Al			
	0	1	2	5
0	138.1	41.67	6.31	1.03
1	107.6	25.32	4.27	0.92
2	80.07	14.39	3.08	0.83
5	21.74	3.32	1.47	0.58

Table 6-2: Digester orthophosphorus heat map – August 2017 loadings

Digester Effluent OP August 2017 Loadings				
Fe	Al			
	0	1	2	5
0	82.24	21.13	3.76	0.84
1	63.84	13.01	2.95	0.76

2	48.18	8.05	2.29	0.69
5	12.13	2.37	1.18	0.49

While high metals concentrations can allow for lower effluent TP and orthophosphorus due to chelation, a lack of sufficient Bio-P performance can have impacts across the entire facility. Selector zones are designed to remove rbCOD prior to aeration in order to prevent filamentous growth. However, if there is insufficient phosphorus, the anaerobic organisms cannot consume all of the rbCOD, allowing a portion of it to enter the aerated zones. This then creates conditions that readily allow filamentous organisms to grow. As shown in **Table 6-3** and **Table 6-4**, under all influent metal conditions, a significant amount of rbCOD is anticipated to be leaving the selector zone and entering aeration. This rbCOD dynamic may be a significant driver for the settleability issues at NEW Water.

Table 6-3: Selector zone effluent rbCOD – June 2019 loadings

Green Bay North Selector Zone Effluent rbCOD June 2019 Loadings				
Fe	**Al**			
	0	1	2	5
0	21.61	21.44	21.23	21.21
1	21.58	21.37	21.22	21.22
2	21.53	21.30	21.21	21.22
5	21.35	21.22	21.21	21.23

Table 6-4: Selector zone effluent rbCOD – August 2017 loadings

Green Bay North Selector Zone Effluent rbCOD August 2017 Loadings				
Fe	**Al**			
	0	1	2	5
0	16.34	16.16	16.08	16.10
1	16.30	16.13	16.08	16.10
2	16.26	16.11	16.08	16.11
5	16.14	16.09	16.10	16.14

7 Conclusions

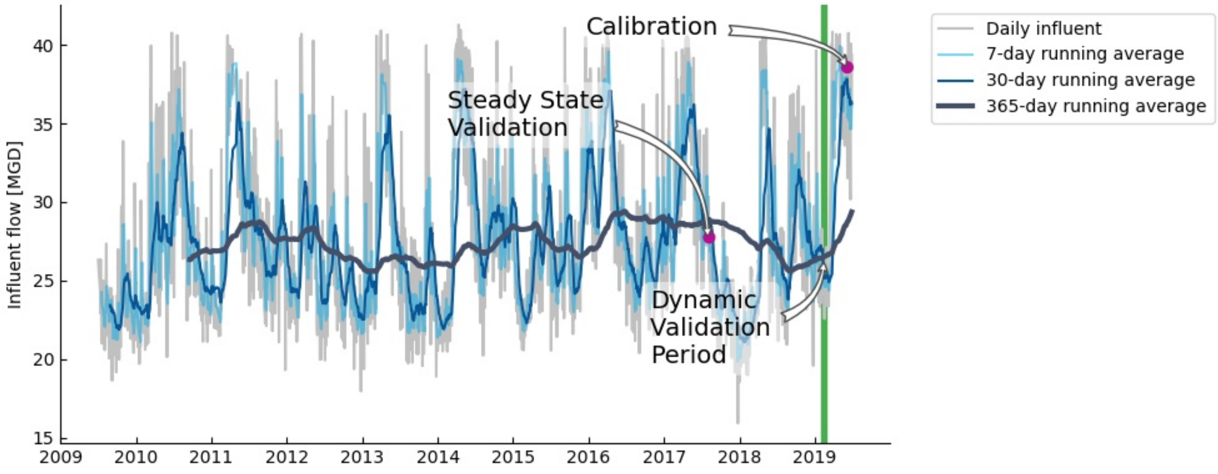
Once a calibrated plant-wide mass balance model is established, it can be effectively used to project plant performance, identify process bottlenecks, generate profiles of nutrients and other pollutants throughout the facility, and to investigate operational adjustments to optimize performance and variable influent and process conditions, making the model a powerful tool to help identify design or operational factors that may be limiting the facility. The developed process model will be a key tool for evaluations during the current facility plan, and for future projects for NEW Water.

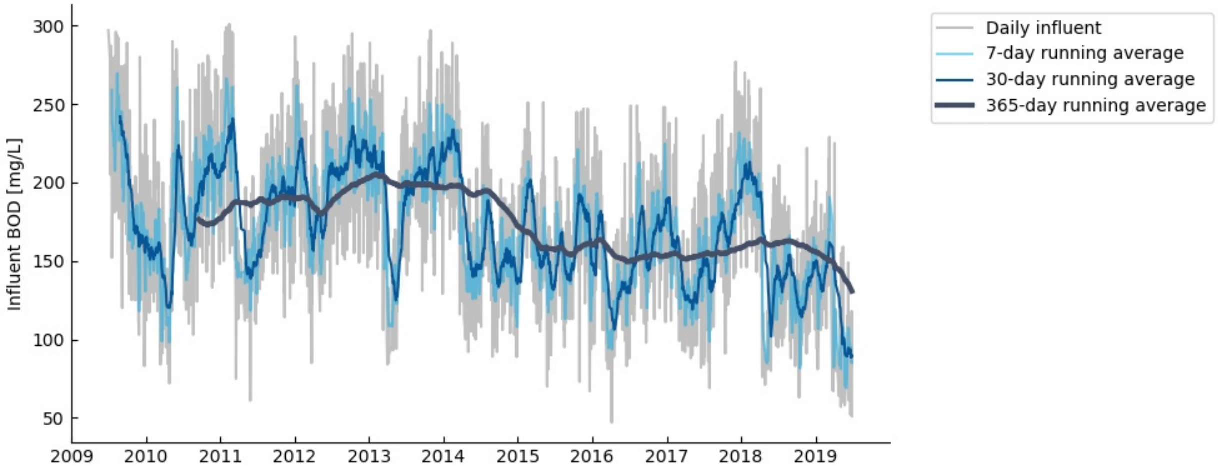
Appendix A

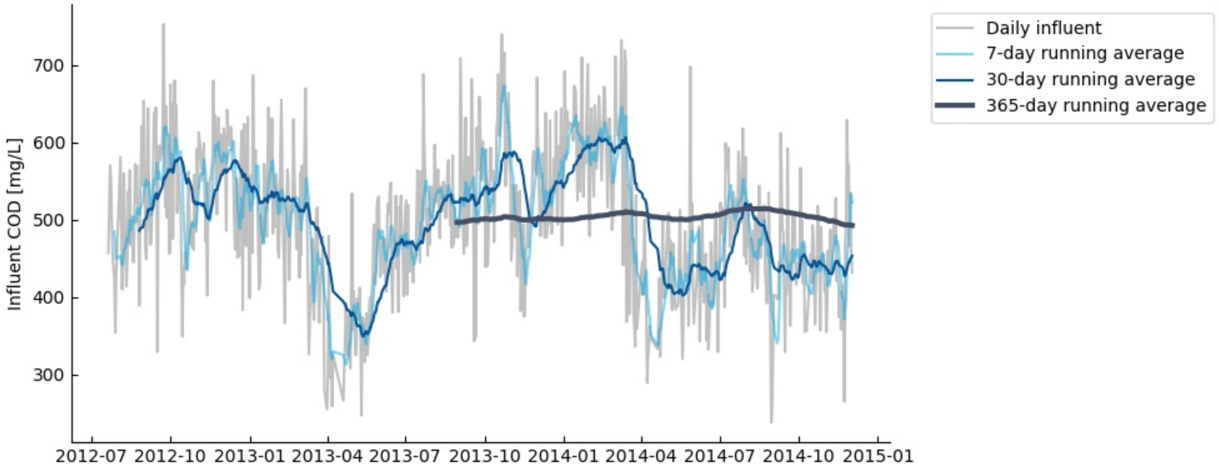
Summary of Historic Data

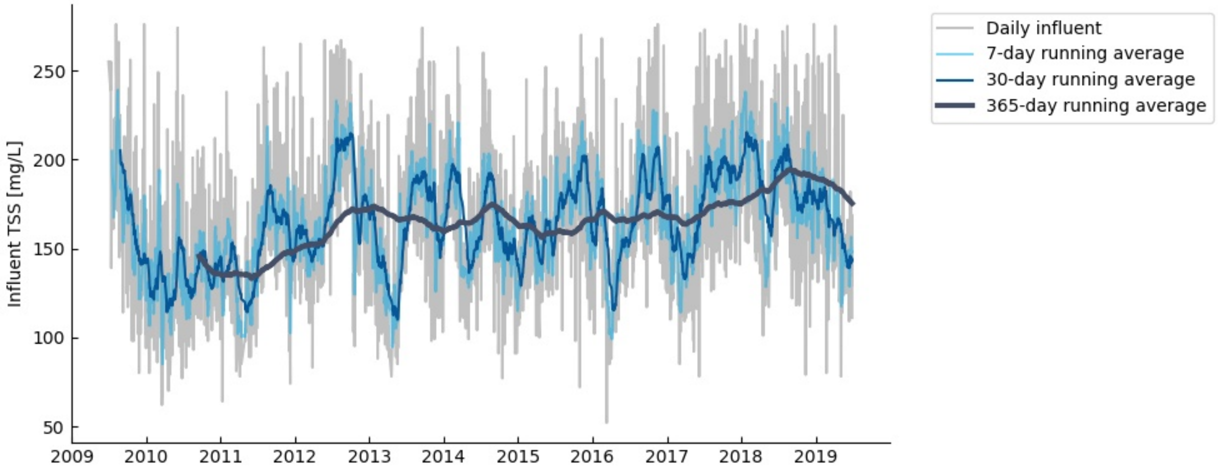
7.1 GREEN BAY HISTORIC DATA

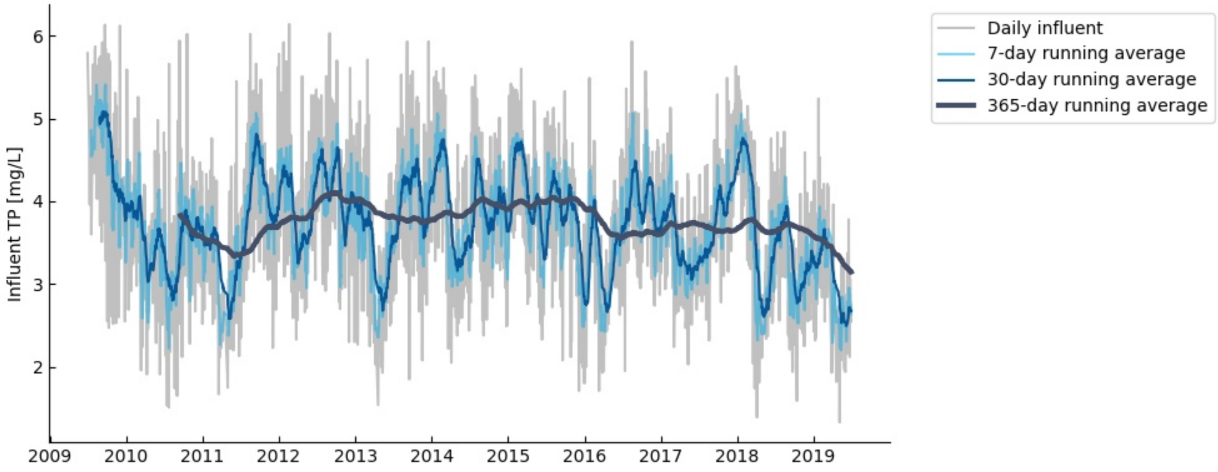
7.1.1 Green Bay Combined

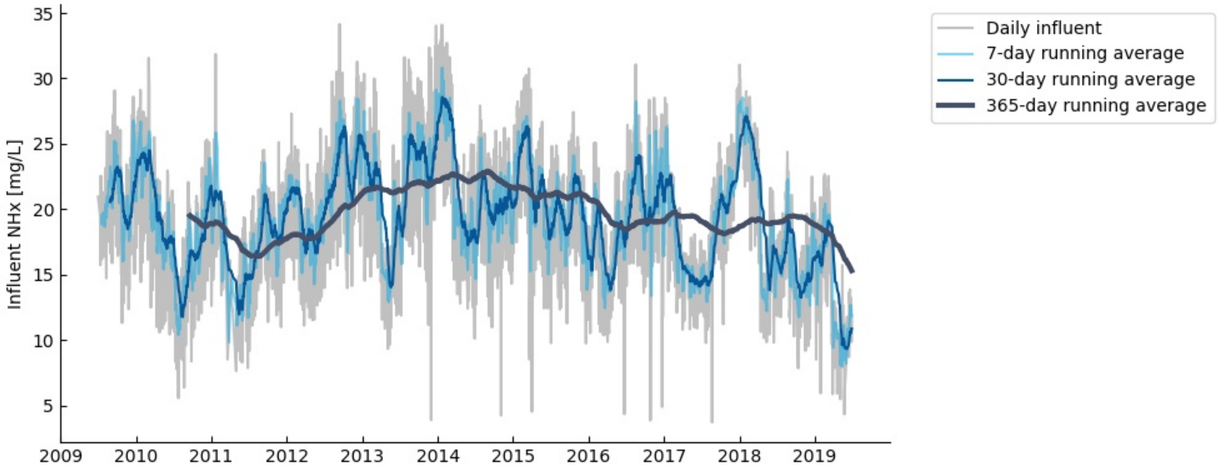


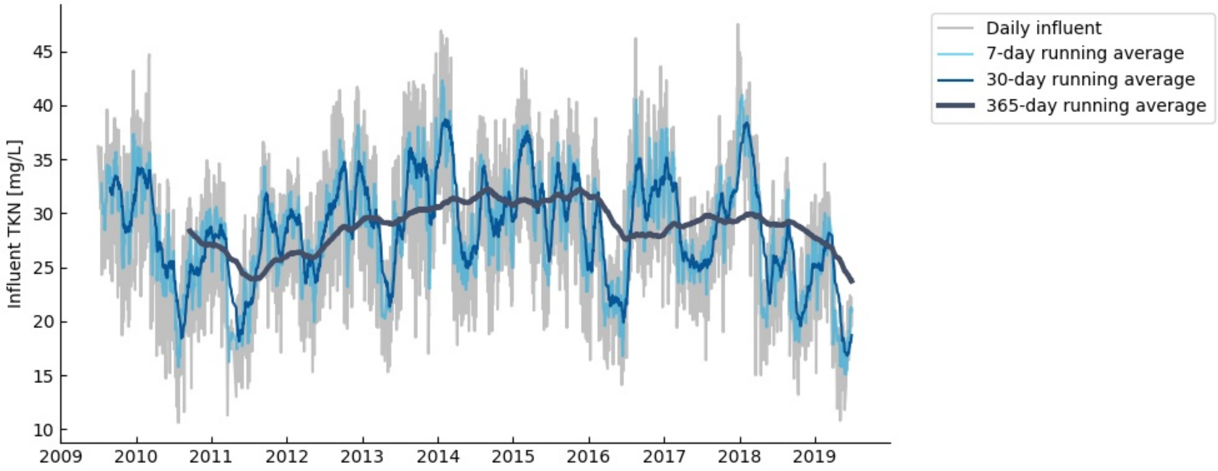




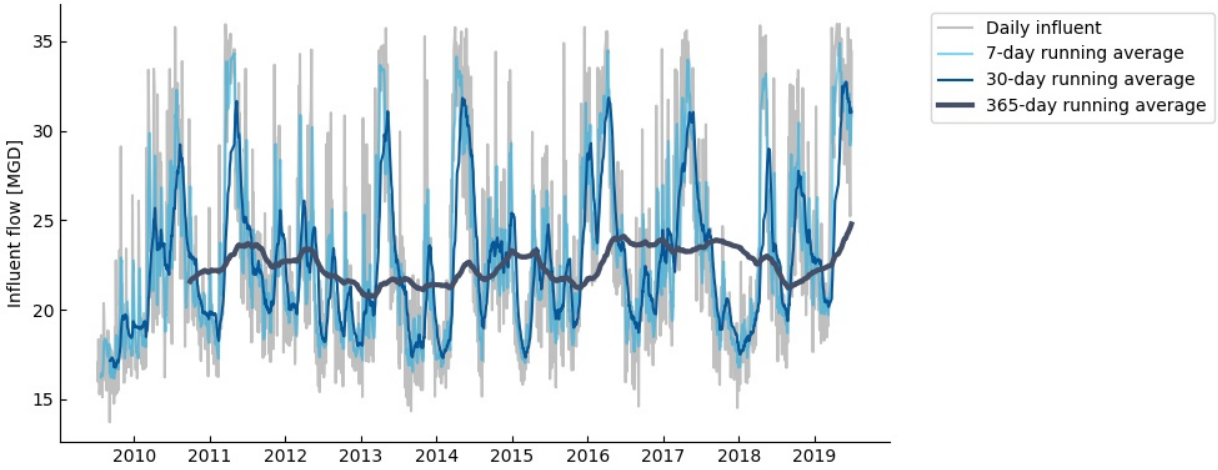

Influent TSS [mg/L]
250
200
150
100
50
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

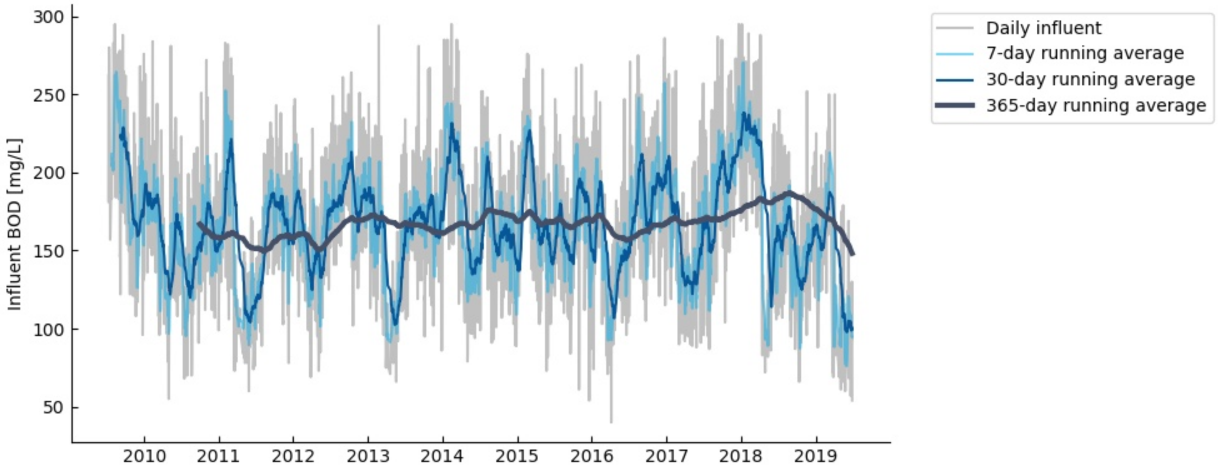

Influent TP [mg/L]
6
5
4
3
2
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

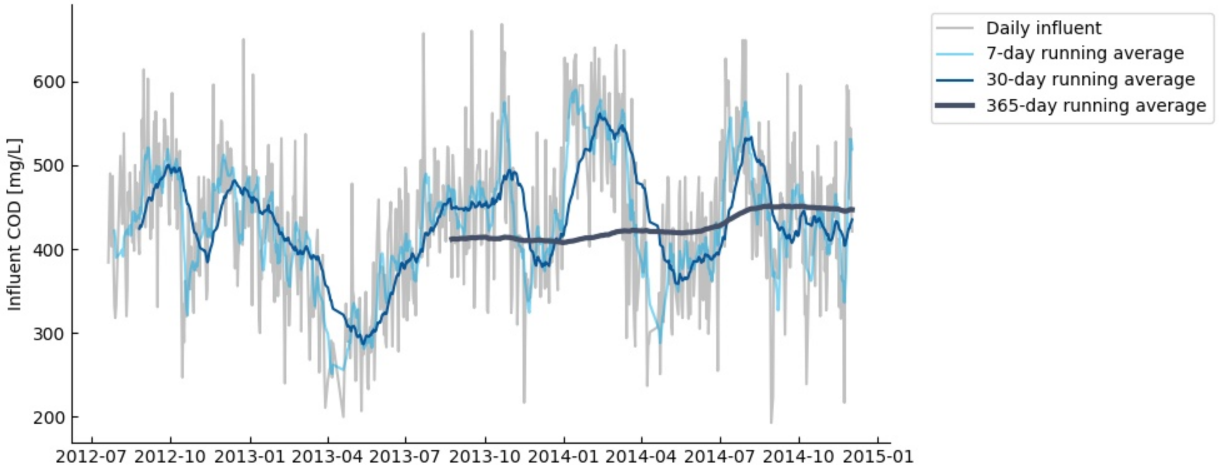

Influent NHx [mg/L]
35
30
25
20
15
10
5
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

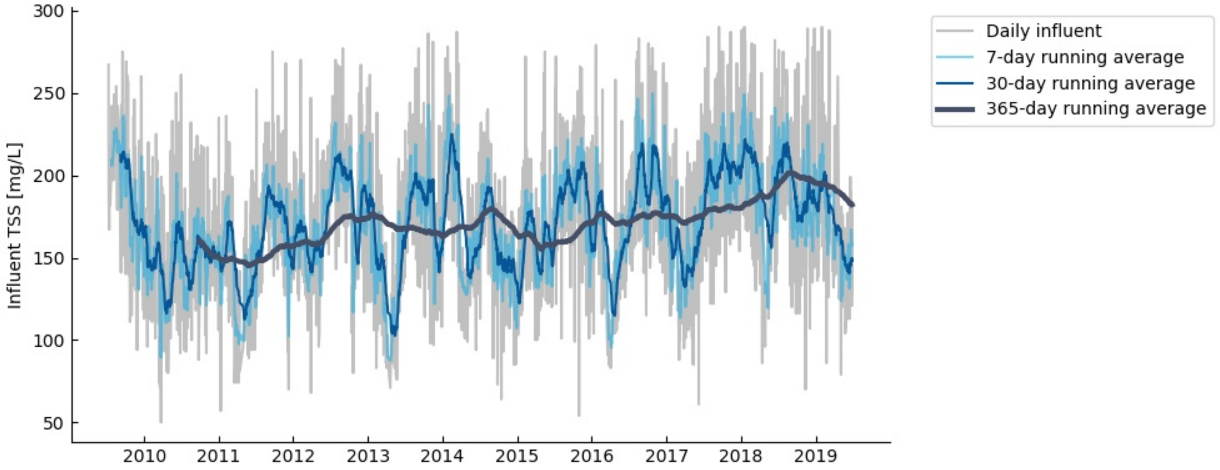


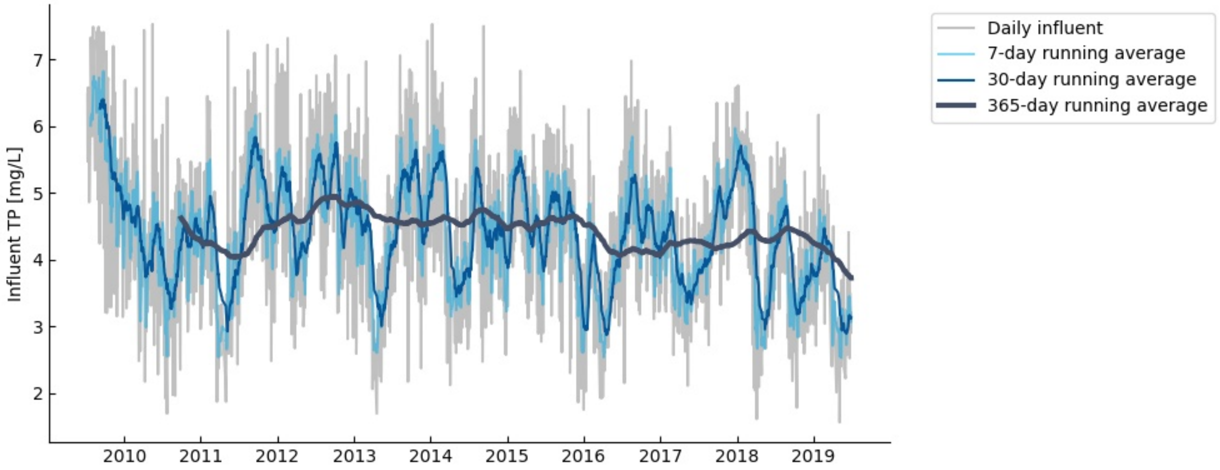
7.1.2 Green Bay Metro

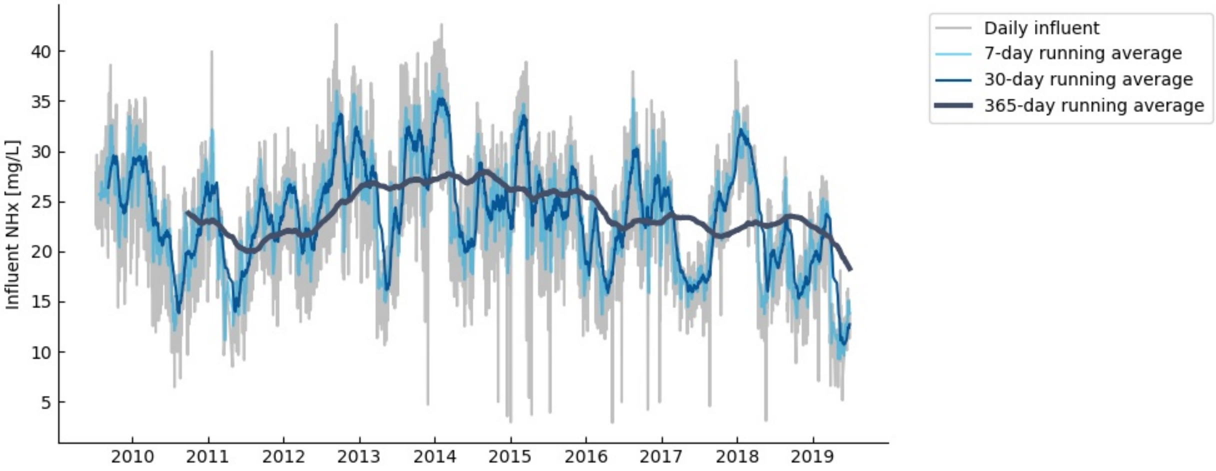


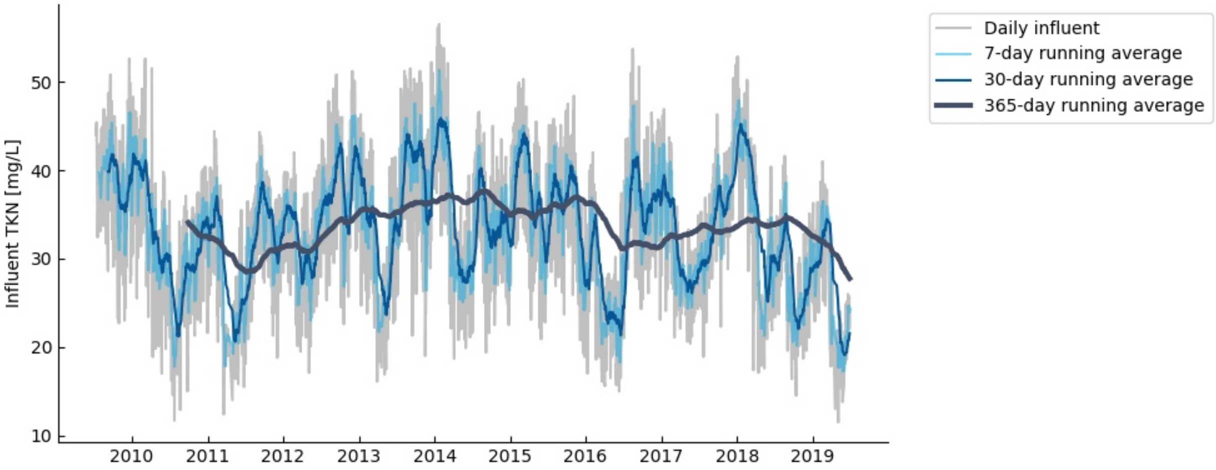



Influent COD [mg/L]
200
300
400
500
600
2012-07
2012-10
2013-01
2013-04
2013-07
2013-10
2014-01
2014-04
2014-07
2014-10
2015-01
Daily influent
7-day running average
30-day running average
365-day running average

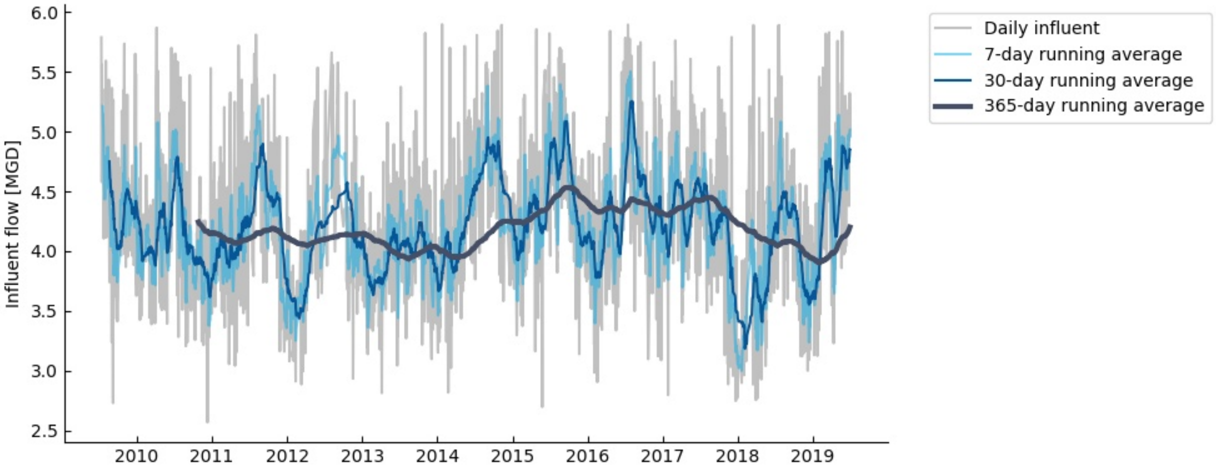

Influent TSS [mg/L]
50
100
150
200
250
300
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

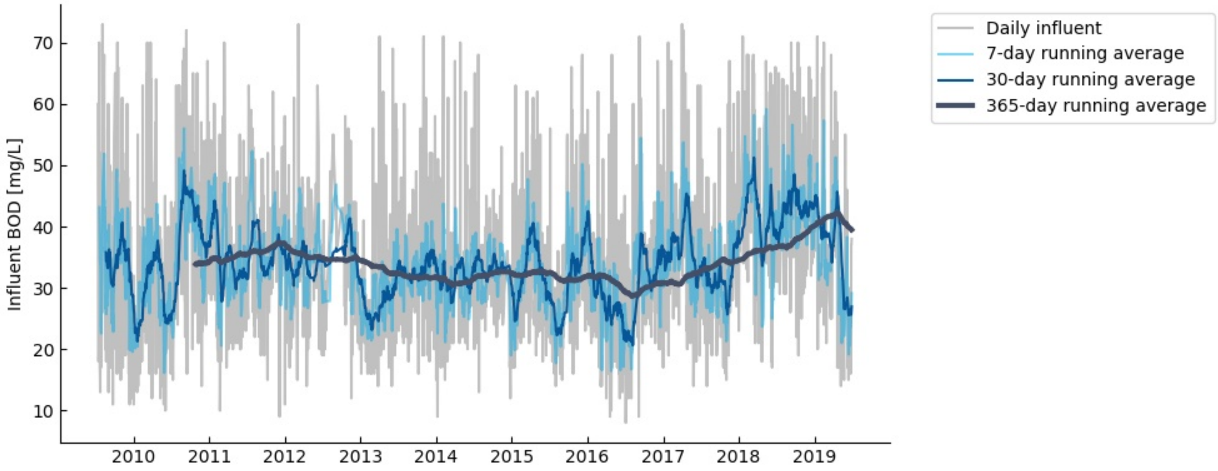

Influent TP [mg/L]
2
3
4
5
6
7
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

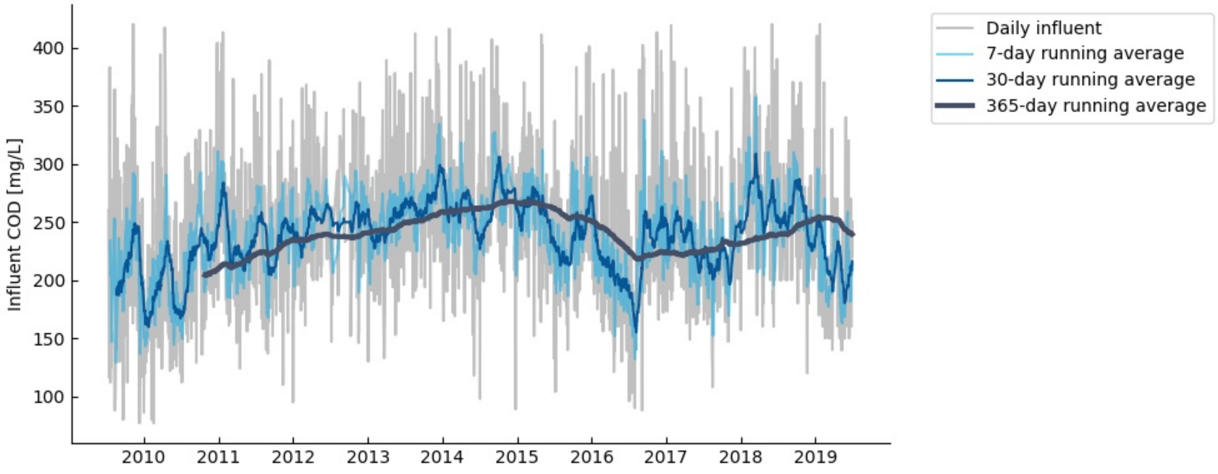


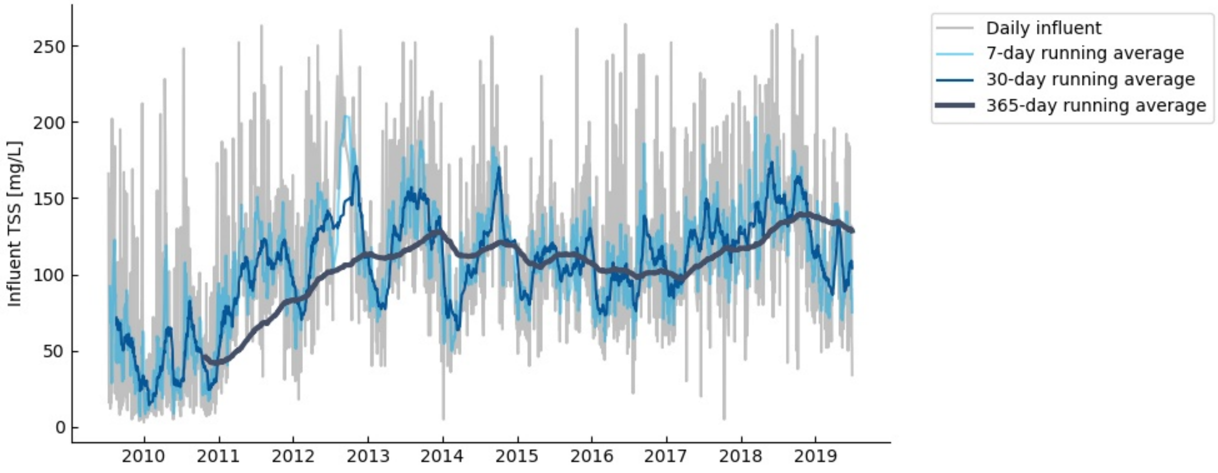


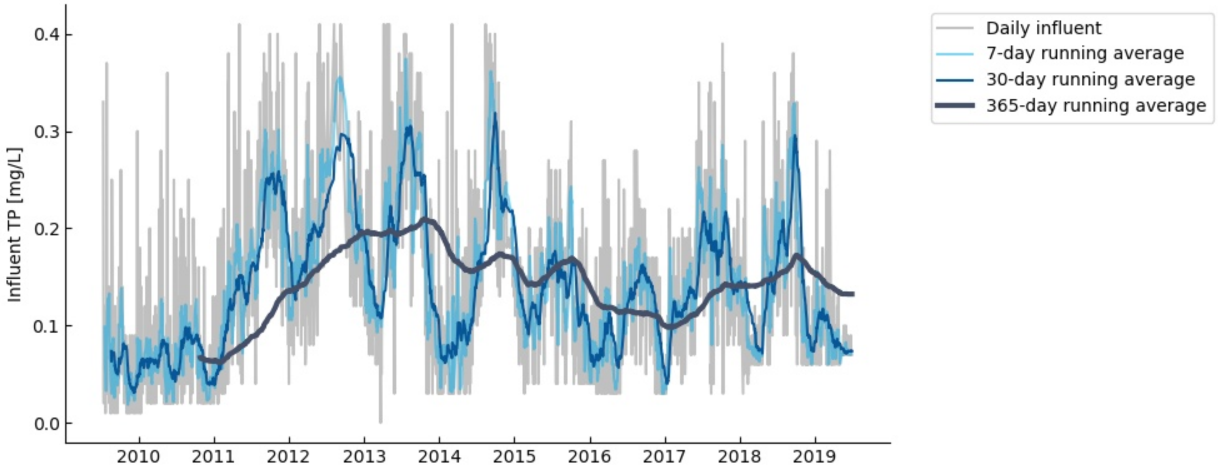
7.1.3 Proctor and Gamble (Mill)

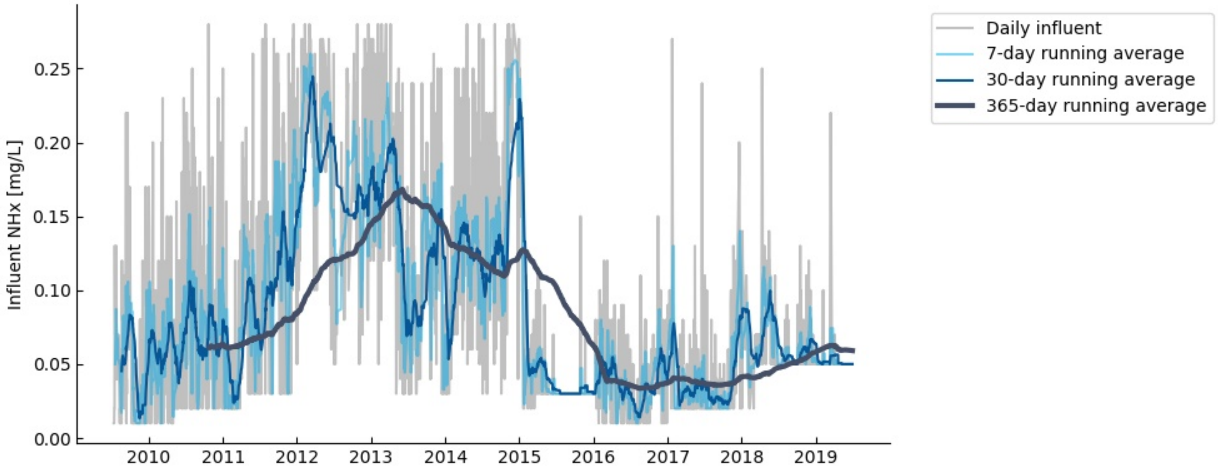


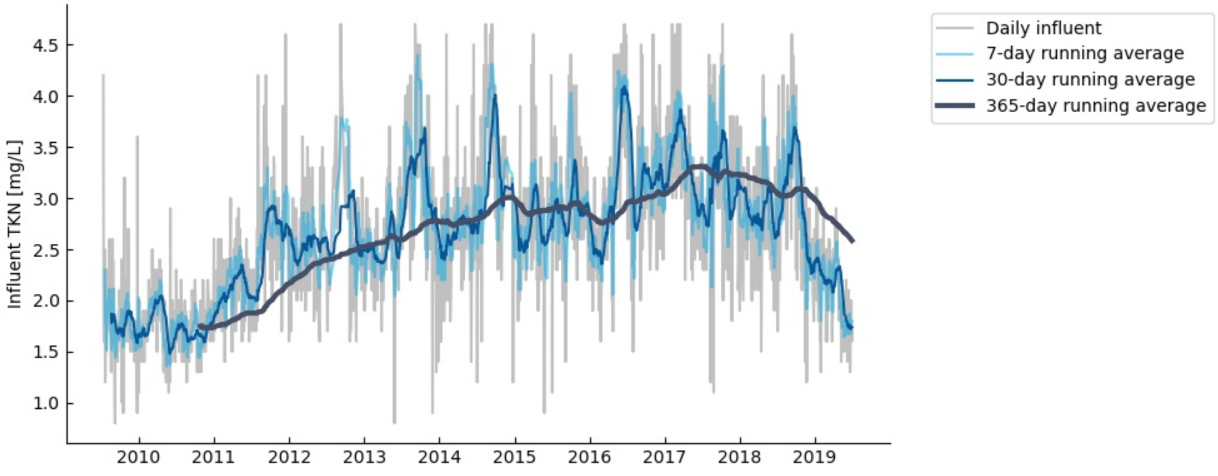

Influent BOD [mg/L]
10
20
30
40
50
60
70
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average


Influent COD [mg/L]
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

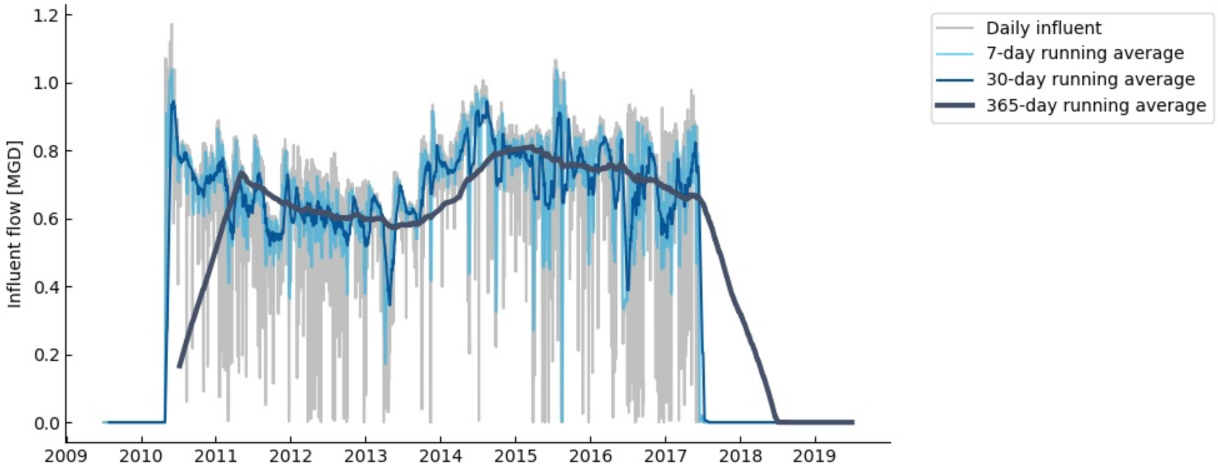

Influent TSS [mg/L]
0
50
100
150
200
250
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

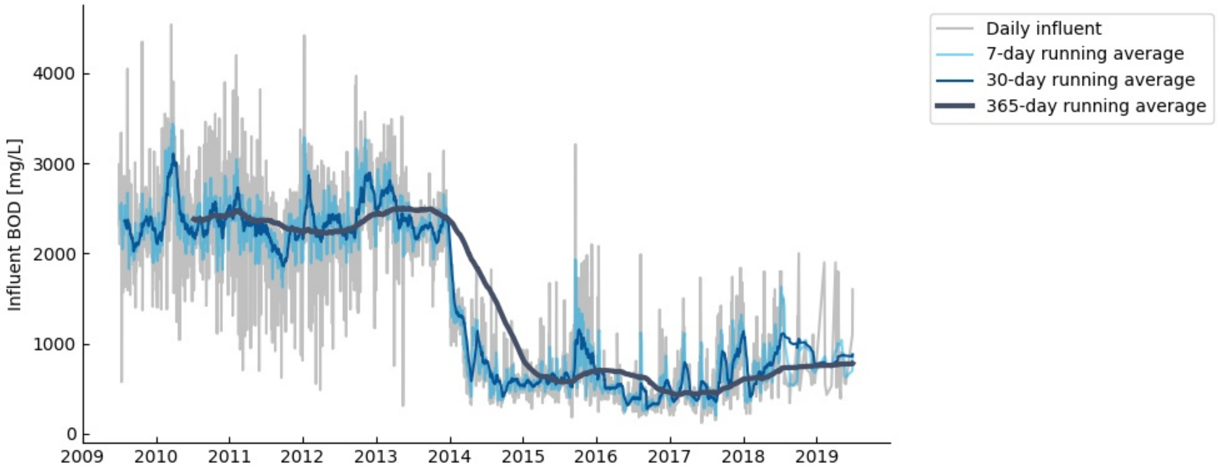

Influent TP [mg/L]
0.0
0.1
0.2
0.3
0.4
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

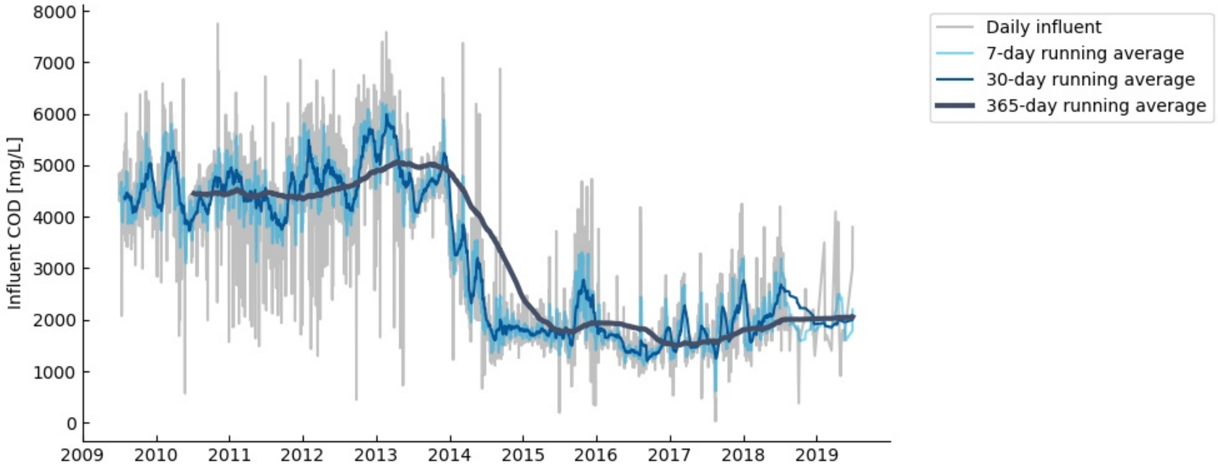

Influent NHx [mg/L]
0.00
0.05
0.10
0.15
0.20
0.25
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

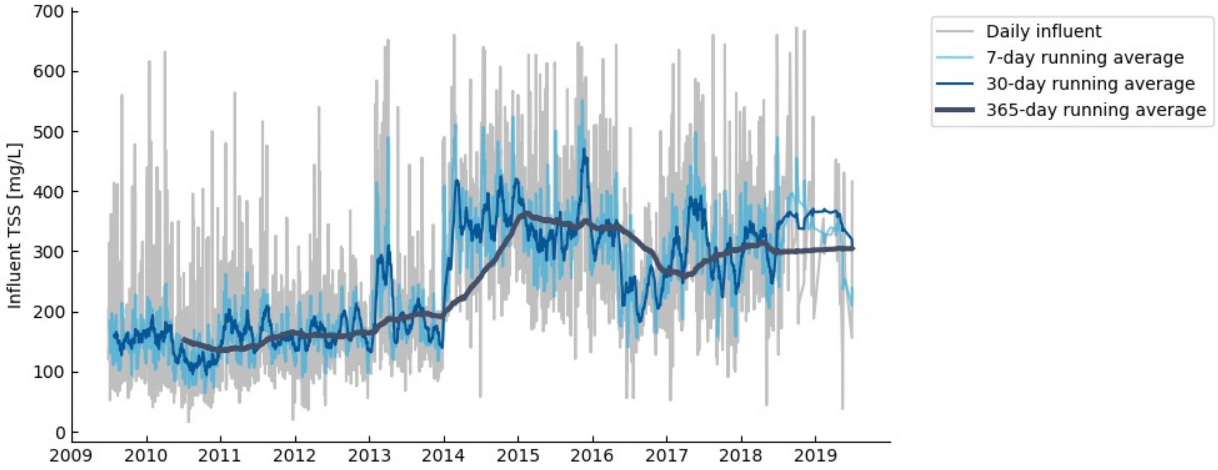

Influent TKN [mg/L]
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

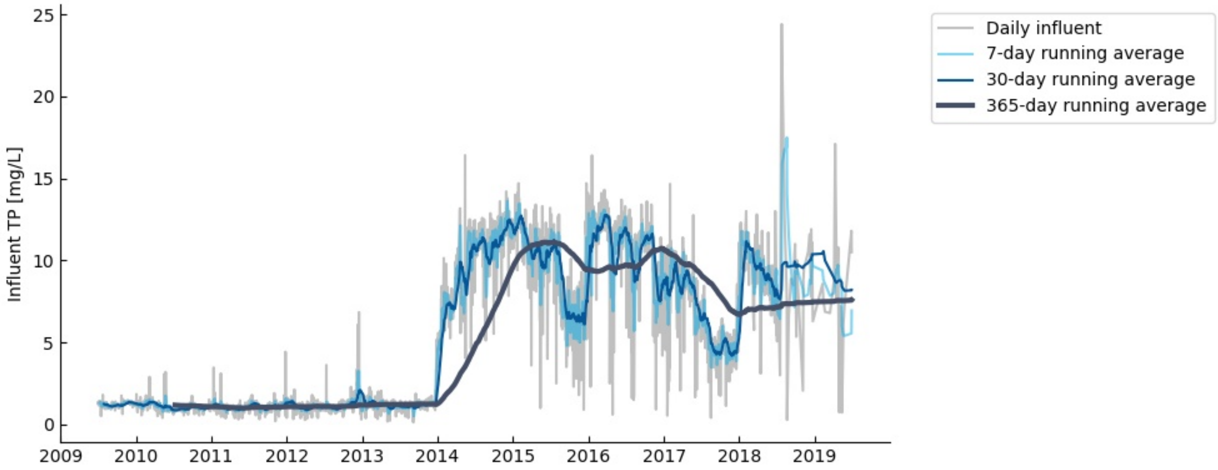
7.1.4 Fox River Fiber

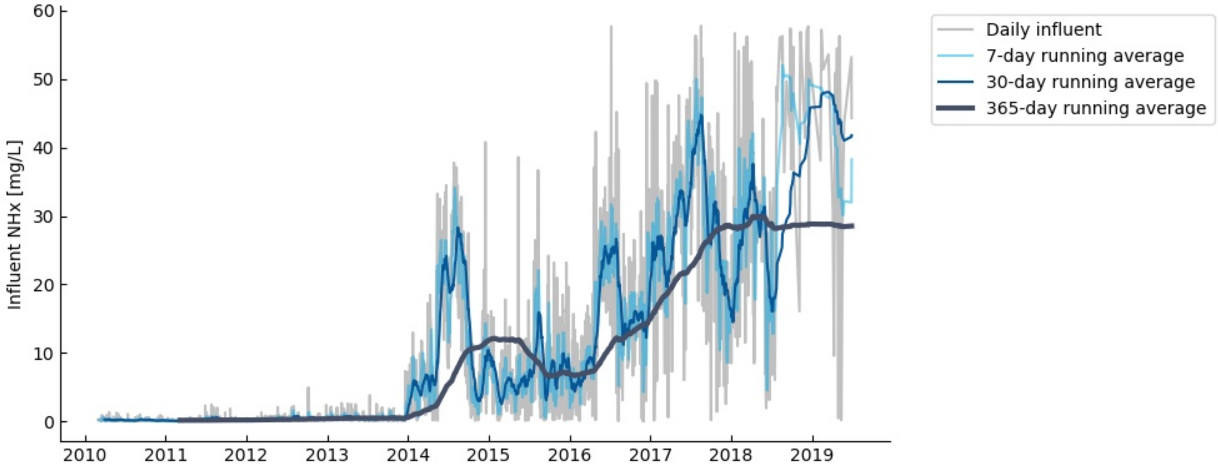


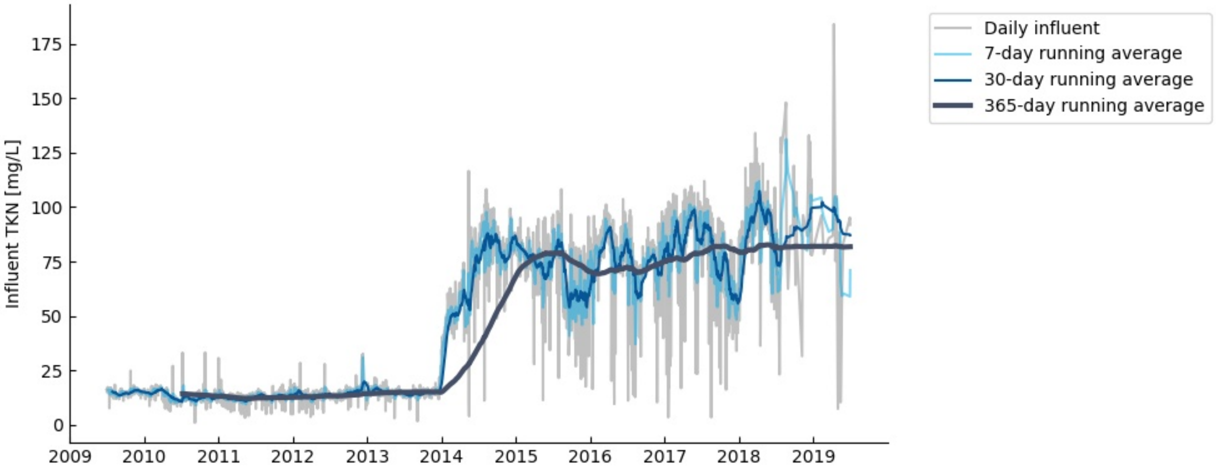





Influent TSS [mg/L]
0
100
200
300
400
500
600
700
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

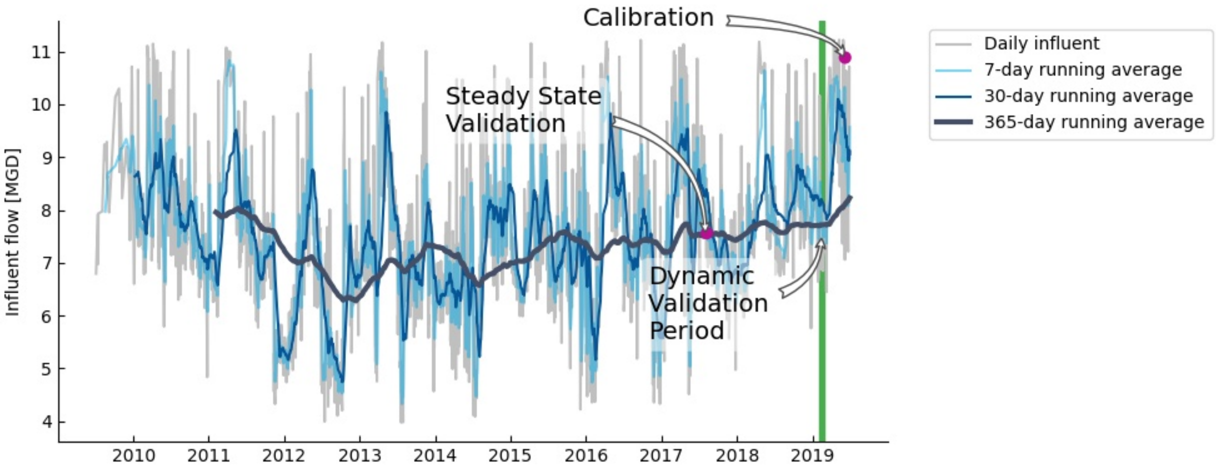

Influent TP [mg/L]
0
5
10
15
20
25
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

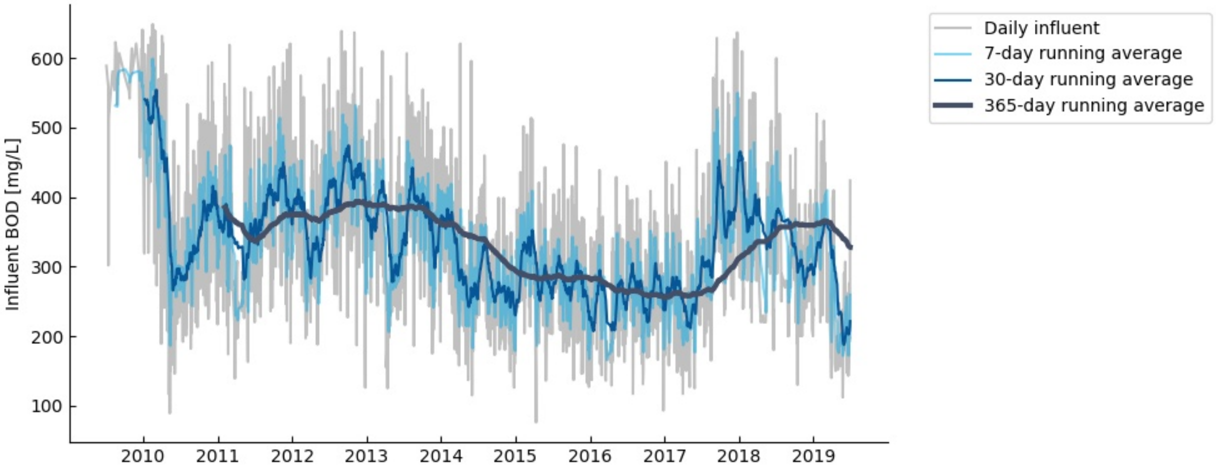

Influent NHx [mg/L]
0
10
20
30
40
50
60
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

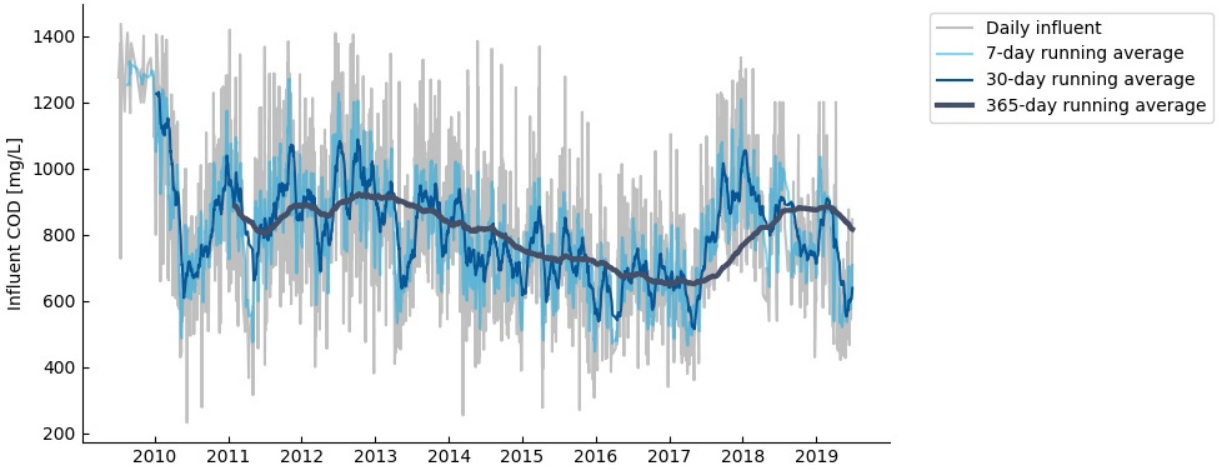


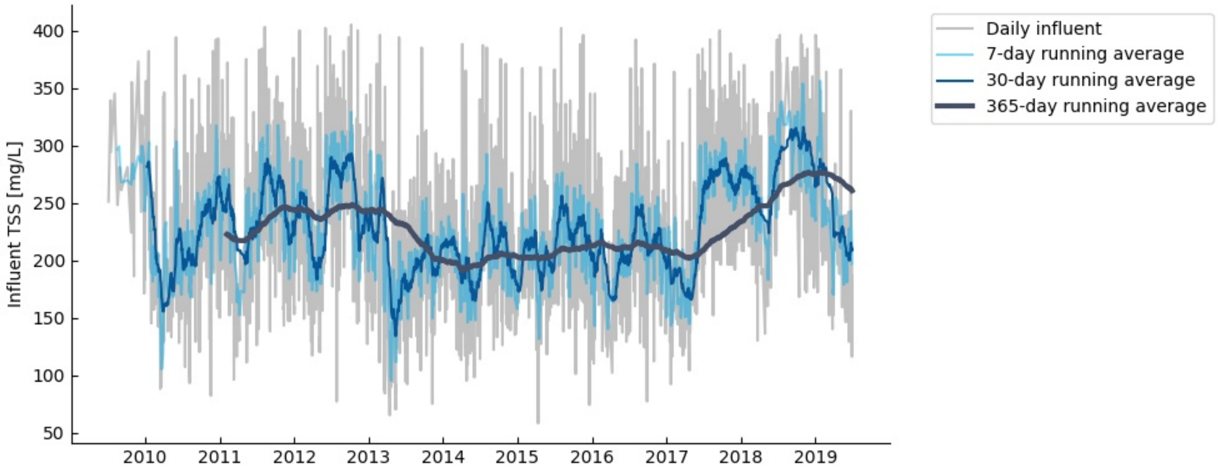
7.2 DE PERE HISTORIC DATA

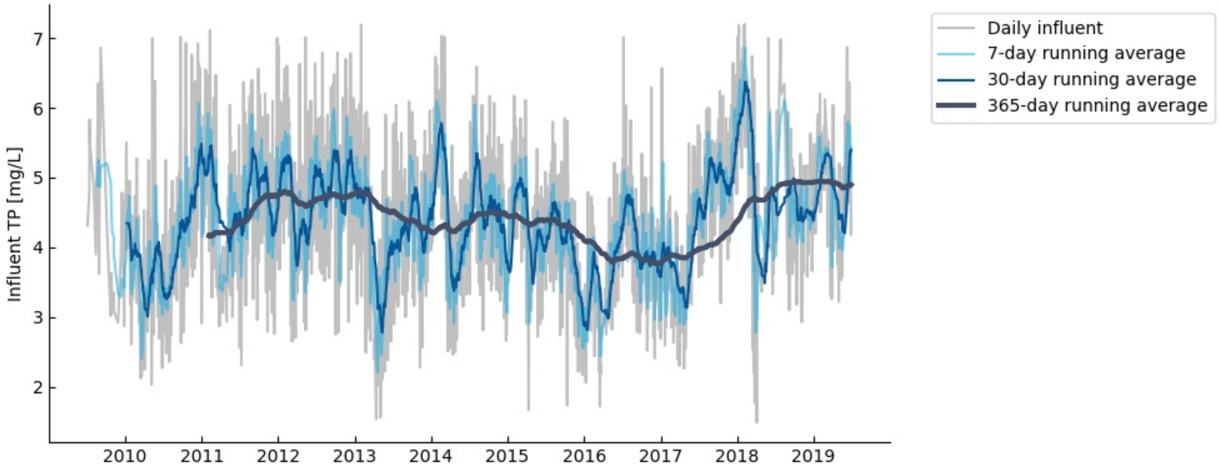
7.2.1 De Pere Combined

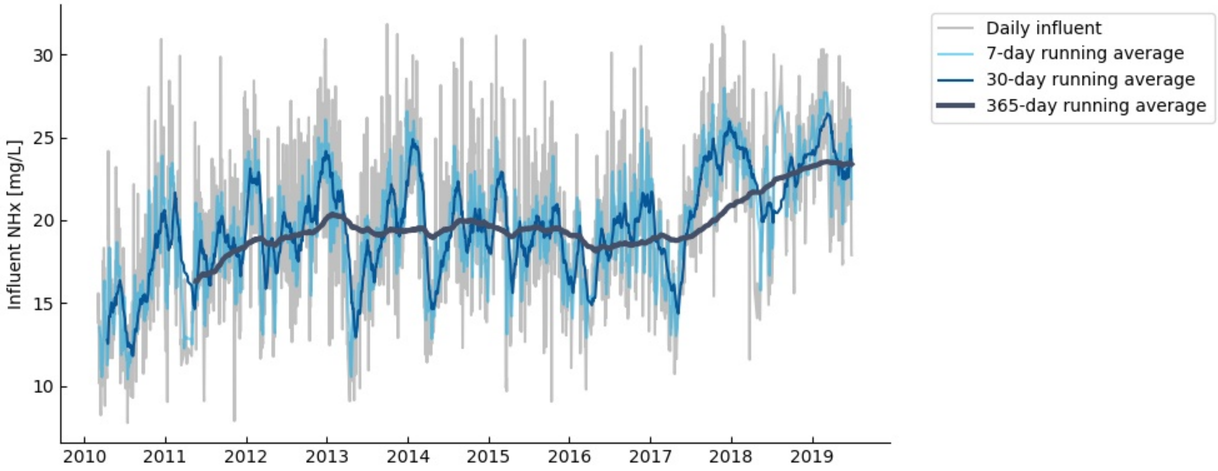


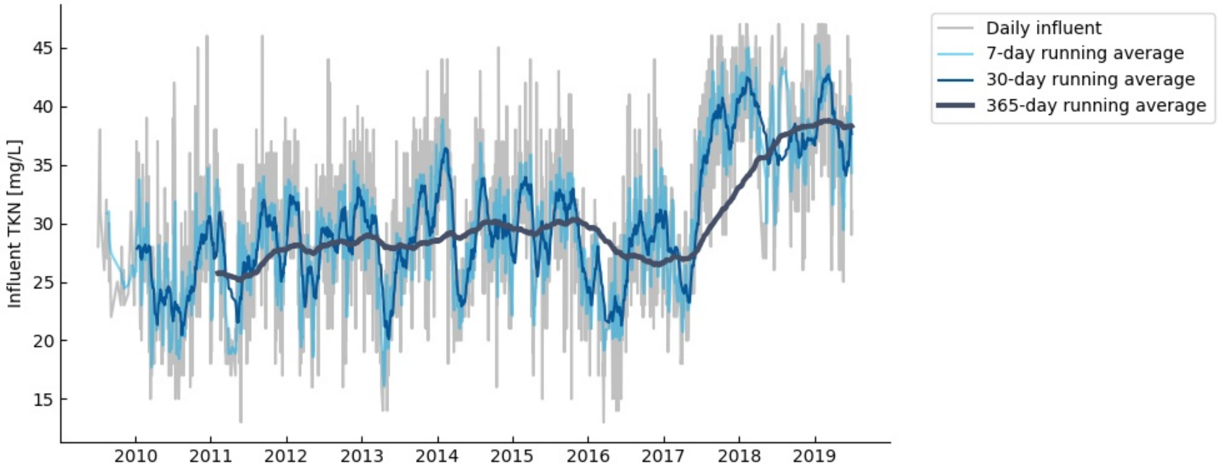



Influent COD [mg/L]
1400
1200
1000
800
600
400
200
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

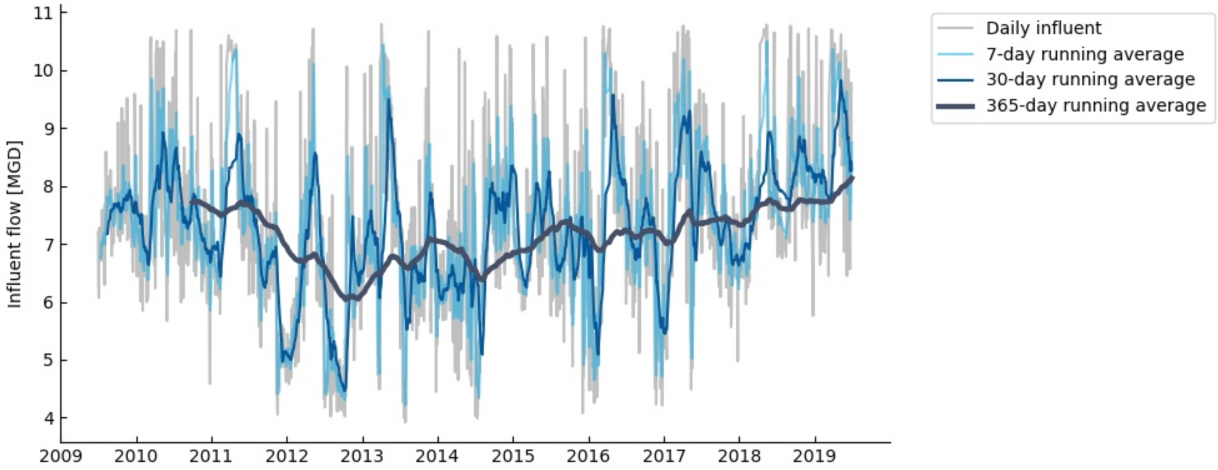

Influent TSS [mg/L]
400
350
300
250
200
150
100
50
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

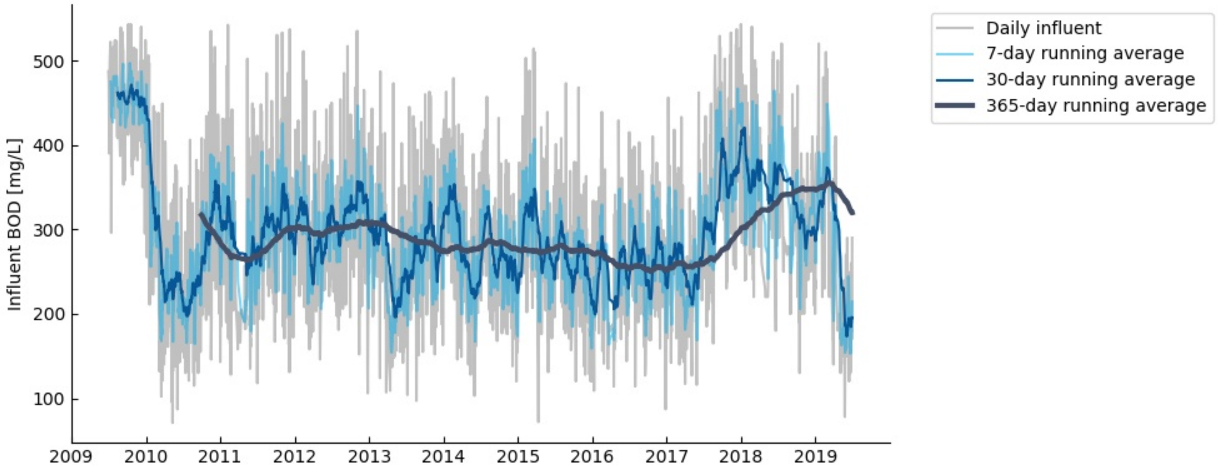

Influent TP [mg/L]
7
6
5
4
3
2
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

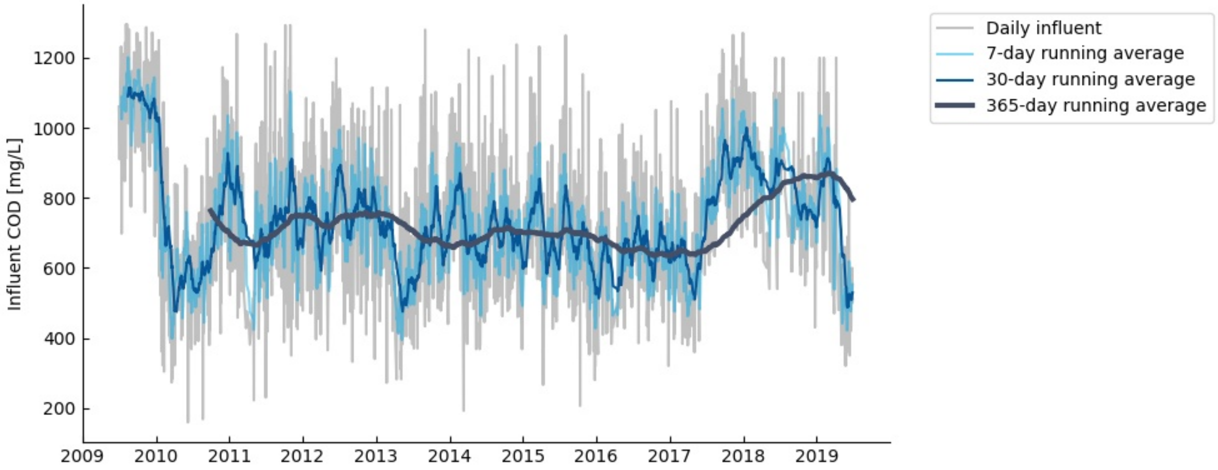


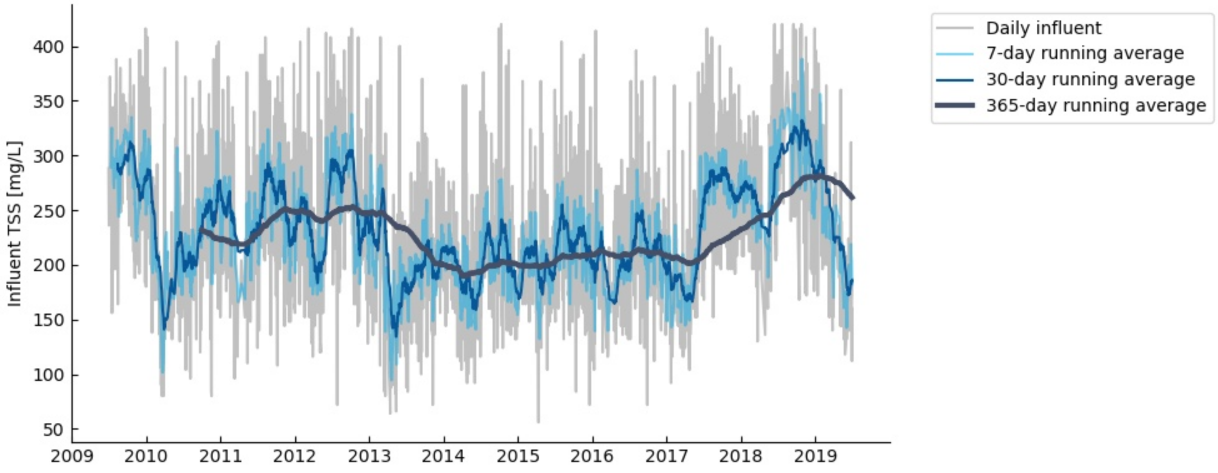


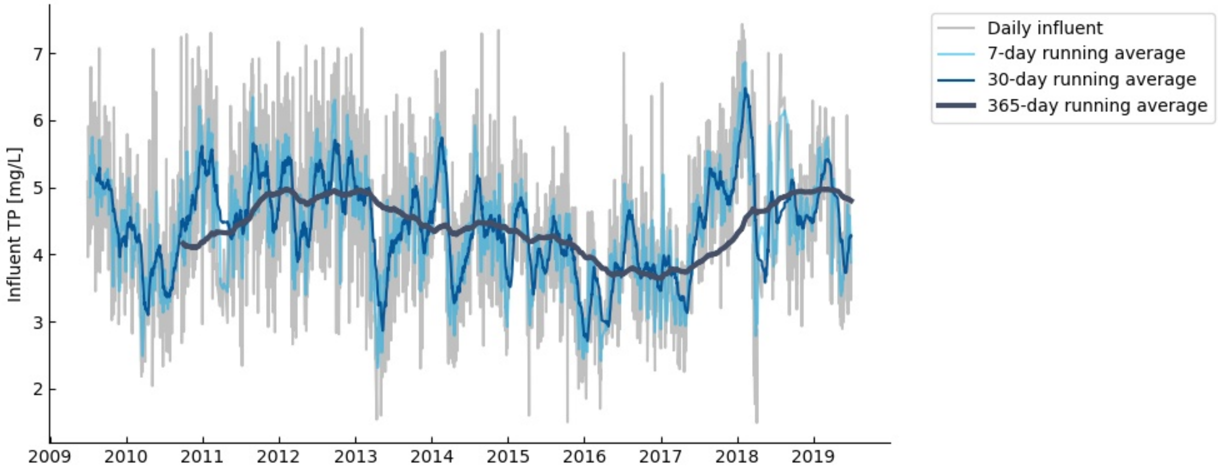
7.2.2 De Pere Metro

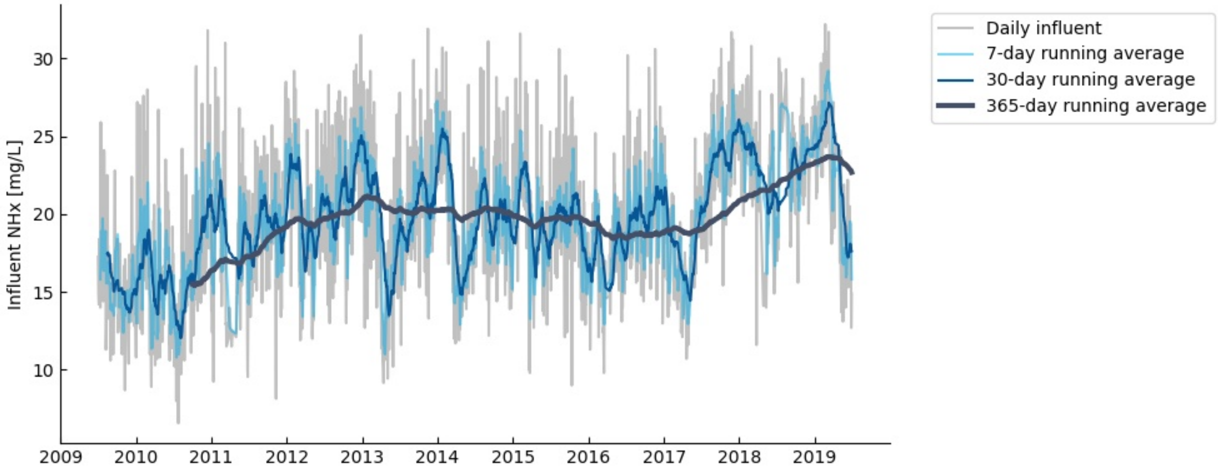


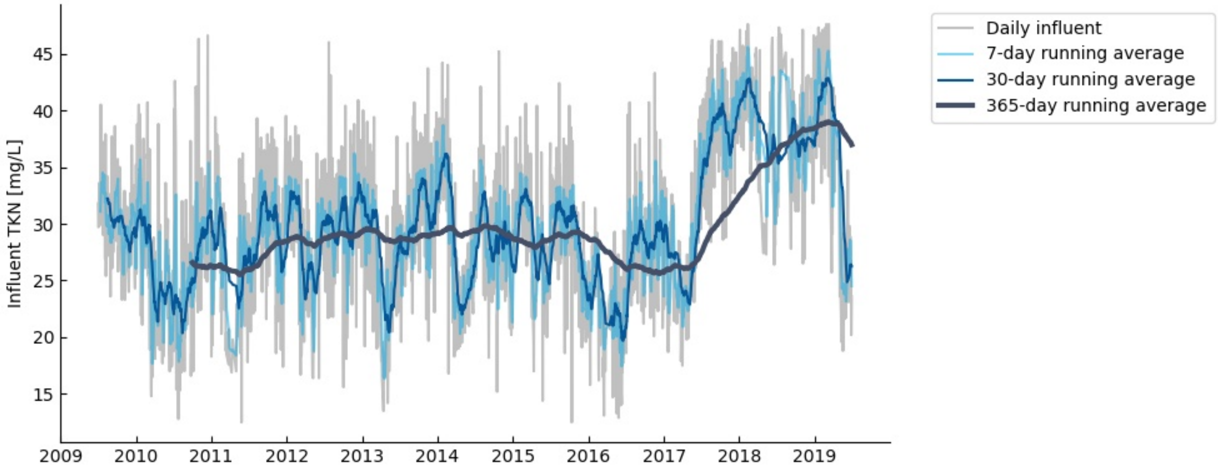

Influent BOD [mg/L]
100
200
300
400
500
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average


Influent COD [mg/L]
200
400
600
800
1000
1200
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

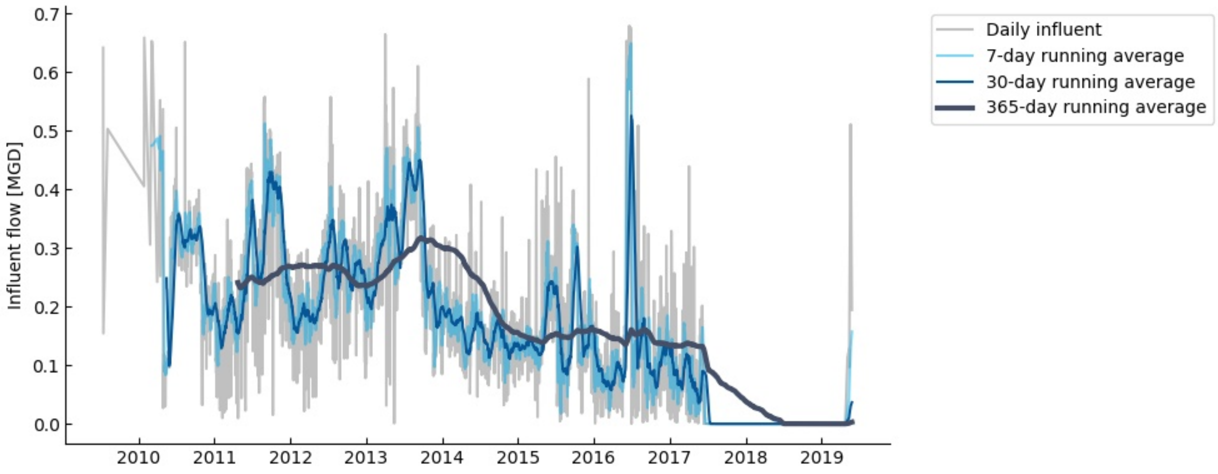

Influent TSS [mg/L]
50
100
150
200
250
300
350
400
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

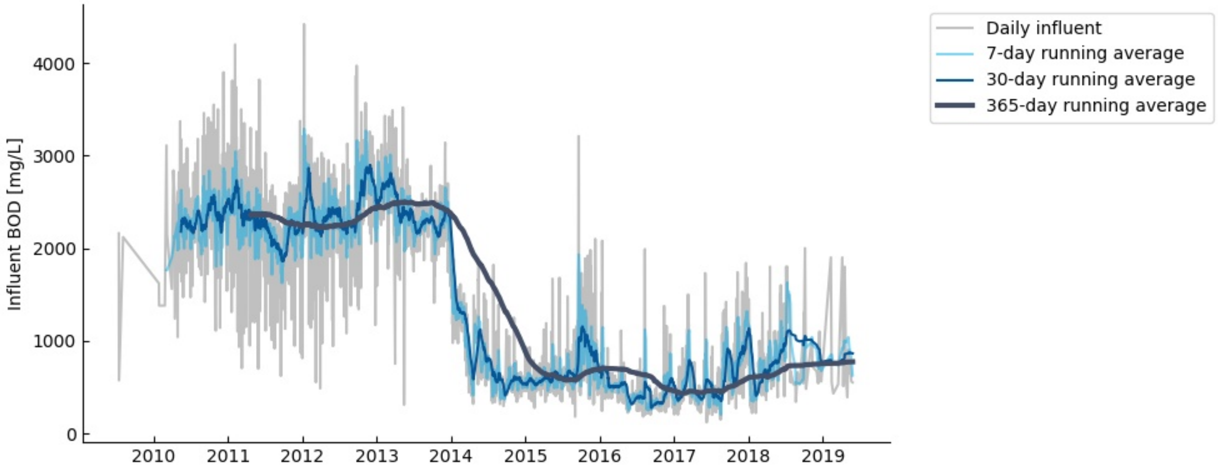

Influent TP [mg/L]
7
6
5
4
3
2
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

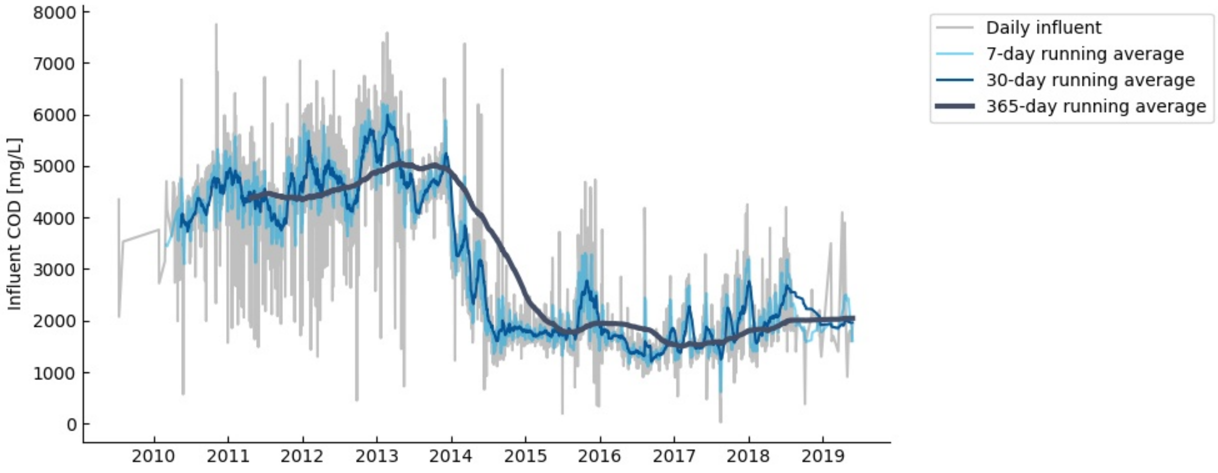

Influent NHx [mg/L]
30
25
20
15
10
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

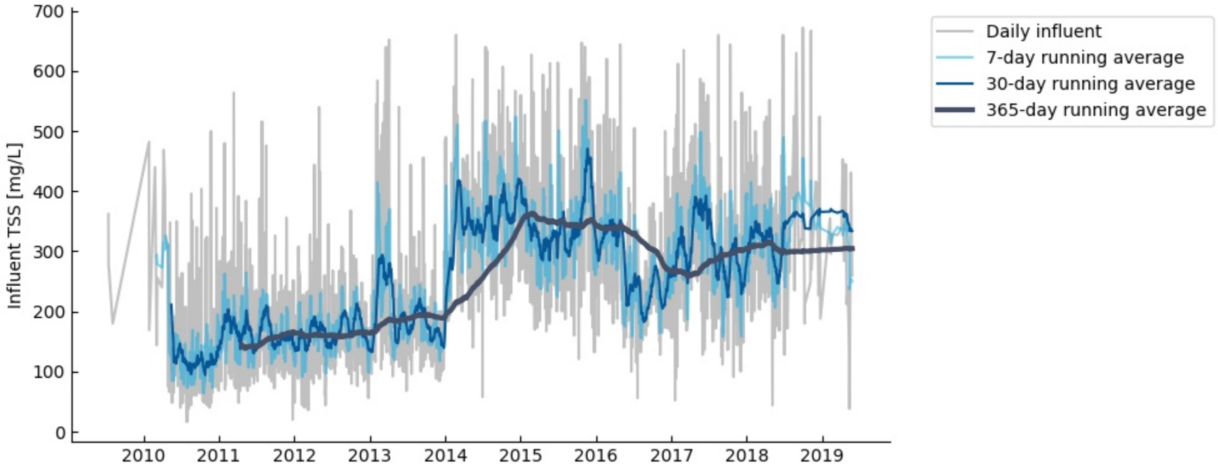

Influent TKN [mg/L]
45
40
35
30
25
20
15
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

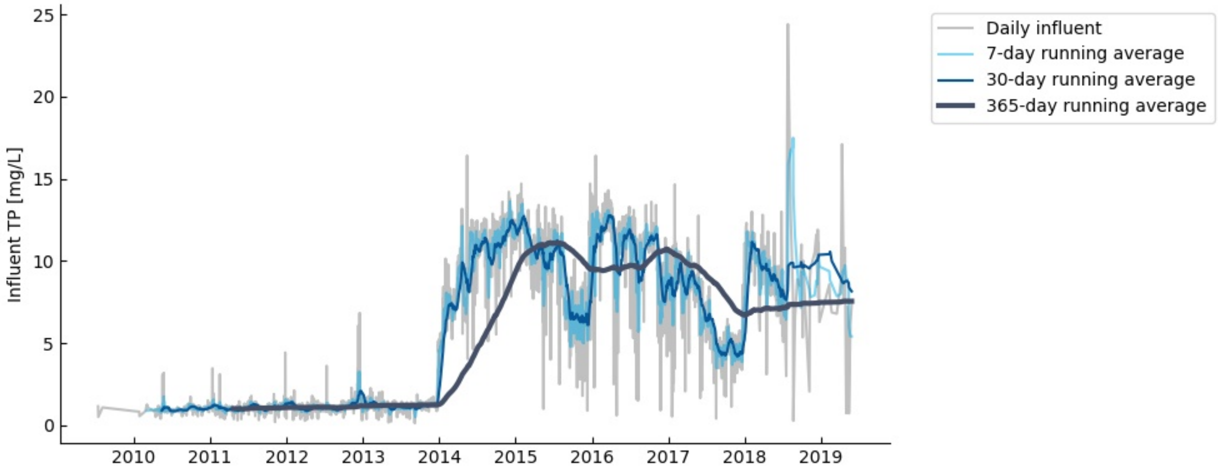
7.2.3 Fox River Fiber

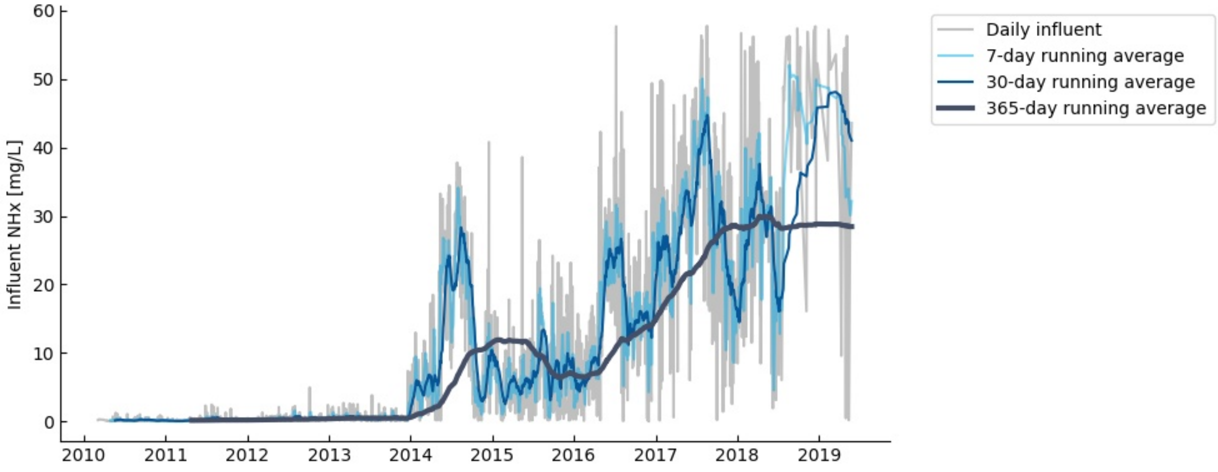


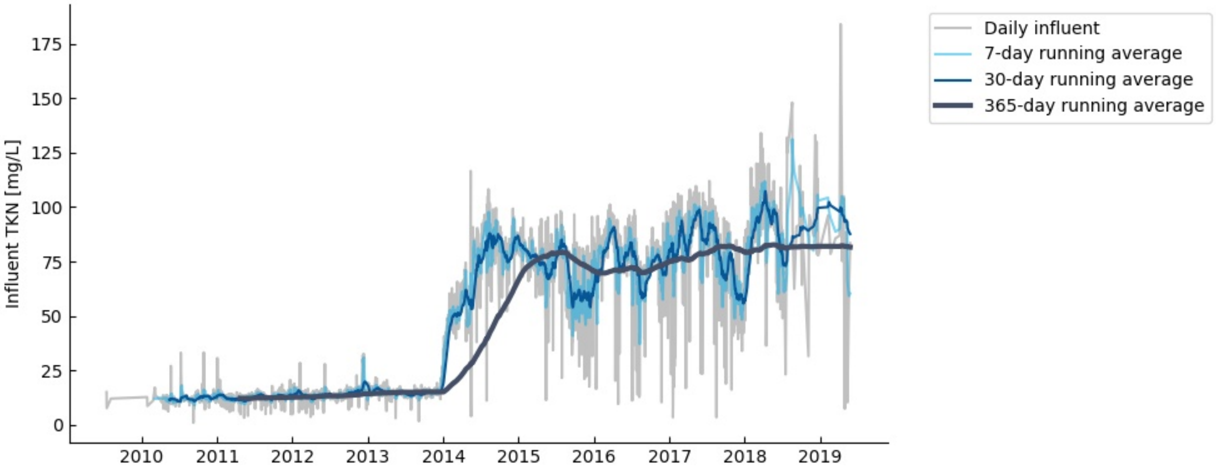





Influent TSS [mg/L]
0
100
200
300
400
500
600
700
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average


Influent TP [mg/L]
0
5
10
15
20
25
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average


Influent NHx [mg/L]
0
10
20
30
40
50
60
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average


Influent TKN [mg/L]
0
25
50
75
100
125
150
175
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Daily influent
7-day running average
30-day running average
365-day running average

Appendix B

Special Sampling Data

Table 7-1: Green Bay Metro fractionation data

Green Bay Influent						
Analyte	8/13/2017	8/14/2017	8/15/2017	8/16/2017	8/17/2017	7/30/2019
BOD	158	176	238	206	215	150
COD	418.3	468	644.1	520.8	487.7	420
NH3	20.233	25.366	21.379	24.23	23.713	25.5
Orthophosphate	1.9174	2.1392	1.5935	1.9114	1.6884	1.06
Phosphorus	3.976	4.498	4.05	4.277	3.905	5.38
TKN	29.628	37.3	35.151	36.758	34.657	37.8
TSS	190	174	194	208	202	318
VSS	174	152	176	170	168	210
Filtered BOD	54.9	70	106	93.9	99.6	37
fCOD	168.2	222.3	257.9	253.6	232.9	150
Filtered Phosphorus	2.243	2.396	1.838	2.241	2.261	-
Filtered TKN	22.923		24.289	26.738	27.295	-
ffCOD	71.3	137.8	172.8	157.2	133.5	85
Ag	-	-	-	-	-	0
Al	-	-	-	-	-	1390
Alkalinity	-	-	-	-	-	370
As	-	-	-	-	-	0
Ba	-	-	-	-	-	51.7
Be	-	-	-	-	-	0
Ca	-	-	-	-	-	68400
Cd	-	-	-	-	-	0
Cr	-	-	-	-	-	6.02
Cu	-	-	-	-	-	100
Fe	-	-	-	-	-	2190
K	-	-	-	-	-	16800
Mg	-	-	-	-	-	27200
Mn	-	-	-	-	-	105
Mo	-	-	-	-	-	7.09
Na	-	-	-	-	-	256000
Ni	-	-	-	-	-	15.7
Pb	-	-	-	-	-	0
pH	-	-	-	-	7.6	14.9
Sb	-	-	-	-	-	0
Se	-	-	-	-	-	0
Tl	-	-	-	-	-	0
XSS	-	-	-	-	-	33.1
Zn	-	-	-	-	-	106

Table 7-2: De Pere fractionation data

De Pere Influent							
Analyte	**7/24/2019**	**7/25/2019**	**7/26/2019**	**7/27/2019**	**7/28/2019**	**7/29/2019**	**7/30/2019**
Ag	0	0	0	0	0	0	0
Al	3,730	2,620	4,230	4,680	1,690	2,040	3,870
Alkalinity	310	290	280	300	280	300	280
As	0	0	0	0	0	0	0
Ba	42	45.5	43.1	41.2	39.8	40.5	41.7
Be	0.068	0.047	0	0	0	0.038	0
BOD	300	370	320	180	270	200	260
Ca	67,700	66,400	60,500	61,300	64,800	61,800	59,500
CBOD	450	510	180	71	120	77	100
Cd	0	0	0	0	0	0.51	0
COD	1,330	1,410	1,310	970	1230	980	1270
Cr	15.4	13.1	16.6	16.7	7.28	8.65	22
Cu	105	102	106	94.7	117	178	147
Fe	3270	3270	3320	2020	842	976	3200
K	12,300	11,500	11,900	10,500	10,500	10,500	11,000
Mg	27,800	26,800	24,600	25,900	26,200	25,800	23,500
Mn	83.5	85.6	85.8	77.7	68.7	55.3	89.4
Mo	10.9	12.9	12	7.1	7.68	8.43	18
Na	146,000	143,000	144,000	134,000	135,000	139,000	132,000
NH3	20.3	19.7	19.8	19	18	43.4	20
Ni	57.9	38.1	63.8	85	24.3	65.5	51.6
Nitrate	2.3	0.643	0	0	0.077	2.5	0.77
Nitrite	0	0	0	0	0	0	0
Orthophosphate	-	-	-	-	-	-	1.03
Pb	0	0	7.26	0	0	0	0
pH	14.5	14.5	14.2	14.3	14	14.4	14.5
Phosphorus	7.54	5.07	4.99	4.29	4.31	8.96	5.37
Sb	0	0	0	0	0	0	0
Se	0	0	0	0	0	0	0
TKN	32.6	29.6	29.7	27	26.5	51.3	29.3
Tl	0	3.56	0	0	0	0	0
TSS	208	240	260	208	204	180	260
VSS	184	264	236	180	176	180	228
XSS	88.5	110	90.8	86.5	86.3	100	87.7
Zn	110	113	122	96.8	98.3	117	126

Table 7-3: Hauled waste fractionation data

Hauled Waste Influent					
Analyte	**8/13/2017**	**8/14/2017**	**8/15/2017**	**8/16/2017**	**8/17/2017**
BOD	5600	2200	2590	3800	1920
COD	9752	5568	6884	8720	4706
NH3	74.773	68.639	129.245	257.412	172.757
Orthophosphate	80.906	32.1765	34.3773	48.5428	21.793
Phosphorus	105.81	8.443	52.332	117.02	47.082
TKN	274.35	120.54	300.56	478.94	274.14
TSS	2213.333	2880	1930	4580	1980
VSS	1753.33	2220	1440	3620	1470
Filtered BOD	4030	1350	1840	1750	1370
fCOD	6572	2194	3621	3087	3495
Filtered Phosphorus	89.008	5.198	37.796	51.514	25.012
Filtered TKN	201.732	89.104	234.648	300.352	214.084
ffCOD	5860	2399	2950	2666	2554

Table 7-4: Fox River Fiber fractionation data

Fox River Fiber Influent					
Analyte	**8/13/2017**	**8/14/2017**	**8/15/2017**	**8/16/2017**	**8/17/2017**
BOD	330	268	254	323	182
COD	1266.2	1225.8	1093.4	1155.2	517.2
NH3	39.951	41.199	44.556	45.373	0.699
Orthophosphate	1.0592	1.1234	1.1044	0.6598	0.1955
Phosphorus	5.037	5.199	5.36	5.053	5.846
TKN	85.79	84.584	87.492	87.135	56.69
TSS	280	304	228	188	660
VSS	272	296	224	200	596
Filtered BOD	179	180	156	214	150
fCOD	885.2	800.9	747.8	856.8	63.8
Filtered Phosphorus	3.357	3.411	3.31	3.397	0.412
Filtered TKN	72.304	69.064	73.5	70.602	3.476
ffCOD	478.4	468.7	394.2	476.6	26.4

Table 7-5: PG fractionation data

PG Influent					
Analyte	**8/13/2017**	**8/14/2017**	**8/15/2017**	**8/16/2017**	**8/17/2017**
BOD	34	33.9	35.6	30.3	33.2
COD	223.6	213.7	253	234.6	209.9
NH3	0	0	0.046	0	0
Orthophosphate	0	0	0	0	0
Phosphorus	0.211	0.213	0.33	0.221	0.268
TKN	3.945	3.672	4.373	3.592	3.812
TSS	144	100	196	136	140
VSS	84	64	108	56	80
Filtered BOD	23	27.2	21.8	24.1	25.5
fCOD	150.2	144.7	126.5	127.7	133
Filtered Phosphorus	0.064	0.049	0	0.088	0.041
Filtered TKN	2.261	1.99	1.919	1.936	1.819
ffCOD	142.9	127.8	126	107.8	119

Appendix C

Influent Metal Sensitivity

7.2.4 June 2019 Data Set

7.2.4.1 Biological Phosphorus Removal Insights

Green Bay North Selector Zone Effluent OP				
Fe	Al			
	0	1	2	5
0	2.52	1.79	1.44	1.07
1	2.24	1.59	1.34	0.99
2	1.97	1.43	1.24	0.91
5	1.32	1.08	0.95	0.68

Green Bay South Selector Zone Effluent OP				
Fe	Al			
	0	1	2	5
0	2.37	1.67	1.36	1.06
1	2.09	1.48	1.26	0.98
2	1.83	1.33	1.16	0.90
5	1.20	0.98	0.88	0.67

De Pere Selector Zone Effluent OP				
Fe	Al			
	0	1	2	5
0	8.35	4.90	2.91	1.03
1	6.95	3.85	2.25	0.83
2	5.56	2.89	1.68	0.66
5	1.65	1.00	0.73	0.42

Green Bay Effluent TP				
Fe	Al			
	0	1	2	5
0	2.54	1.79	1.43	1.06
1	2.26	1.60	1.33	0.98
2	2.01	1.45	1.23	0.91
5	1.37	1.09	0.95	0.70

Green Bay Effluent OP				
Fe	Al			
	0	1	2	5
0	2.40	1.64	1.28	0.88
1	2.12	1.45	1.17	0.80
2	1.86	1.29	1.07	0.72
5	1.21	0.92	0.77	0.51

De Pere Effluent TP				
Fe	Al			
	0	1	2	5
0	0.39	0.39	0.38	0.34
1	0.39	0.38	0.37	0.32
2	0.38	0.37	0.35	0.28
5	0.31	0.20	0.17	0.17

De Pere Effluent OP				
Fe	Al			
	0	1	2	5
0	0.25	0.25	0.24	0.21
1	0.25	0.24	0.23	0.18
2	0.25	0.23	0.22	0.14
5	0.17	0.06	0.03	0.03

7.2.4.2 Sidestream Phosphorus Impacts

Digester Influent TP				
Fe	Al			
	0	1	2	5
0	514.7	536.3	554.1	597.7
1	527.1	547.7	566.2	608.1
2	539.5	559.6	578.7	618.7
5	578.9	603.2	620.2	646.8

Digester Influent OP				
Fe	Al			
	0	1	2	5
0	2.66	2.19	1.99	1.84
1	2.50	2.09	1.95	1.81
2	2.35	2.01	1.91	1.77
5	1.99	1.83	1.77	1.68

Digester Effluent TP				
Fe	Al			
	0	1	2	5
0	518.1	539.7	557.1	600.1
1	530.4	551.0	568.8	610.3
2	542.8	562.6	581.2	620.6
5	581.6	605.1	621.9	648.4

Digester Effluent OP				
Fe	Al			
	0	1	2	5
0	138.1	41.67	6.31	1.03
1	107.6	25.32	4.27	0.92
2	80.07	14.39	3.08	0.83
5	21.74	3.32	1.47	0.58

7.2.4.3 Selector zone performance impacts on settleability

Green Bay North Selector Zone Influent rbCOD				
Fe	Al			
	0	1	2	5
0	27.58	27.59	27.59	27.60
1	27.58	27.59	27.59	27.60
2	27.59	27.59	27.59	27.60
5	27.59	27.60	27.60	27.61

Green Bay North Selector Zone Effluent rbCOD

Fe	Al			
	0	1	2	5
0	21.61	21.44	21.23	21.21
1	21.58	21.37	21.22	21.22
2	21.53	21.30	21.21	21.22
5	21.35	21.22	21.21	21.23

Green Bay South Selector Zone Influent rbCOD

Fe	Al			
	0	1	2	5
0	30.10	30.10	30.11	30.12
1	30.10	30.10	30.11	30.12
2	30.10	30.11	30.11	30.12
5	30.11	30.11	30.12	30.13

Green Bay South Selector Zone Effluent rbCOD

Fe	Al			
	0	1	2	5
0	16.81	16.62	16.40	16.38
1	16.77	16.54	16.38	16.38
2	16.72	16.47	16.38	16.39
5	16.52	16.38	16.38	16.40

De Pere Selector Zone Influent rbCOD

Fe	Al			
	0	1	2	5
0	116.7	116.7	116.7	116.7
1	116.7	116.7	116.7	116.7
2	116.7	116.7	116.7	116.7
5	116.7	116.7	116.7	116.7

De Pere Selector Zone Effluent rbCOD				
Fe	Al			
	0	1	2	5
0	114.2	114.2	114.2	114.2
1	114.2	114.2	114.2	114.3
2	114.2	114.2	114.2	114.3
5	114.2	114.3	114.4	114.5

7.2.5 August 2017 Data Set

7.2.5.1 Biological Phosphorus Removal Insights

Green Bay North Selector Zone Effluent OP				
Fe	Al			
	0	1	2	5
0	1.79	1.11	0.87	0.63
1	1.52	0.95	0.77	0.56
2	1.28	0.82	0.68	0.50
5	0.68	0.51	0.44	0.33

Green Bay South Selector Zone Effluent OP				
Fe	Al			
	0	1	2	5
0	1.94	1.28	1.03	0.80
1	1.68	1.12	0.94	0.72
2	1.44	0.98	0.84	0.64
5	0.84	0.67	0.59	0.45

De Pere Selector Zone Effluent OP				
Fe	Al			
	0	1	2	5
0	4.14	1.98	1.15	0.56
1	2.80	1.32	0.94	0.51
2	1.69	1.14	0.84	0.47
5	1.17	0.80	0.60	0.35

Green Bay Effluent TP

Fe	Al			
	0	1	2	5
0	1.84	1.15	0.89	0.65
1	1.57	0.99	0.80	0.59
2	1.34	0.85	0.70	0.52
5	0.73	0.54	0.47	0.38

Green Bay Effluent OP

Fe	Al			
	0	1	2	5
0	1.70	1.01	0.75	0.50
1	1.43	0.84	0.65	0.43
2	1.19	0.71	0.55	0.36
5	0.57	0.38	0.31	0.22

De Pere Effluent TP

Fe	Al			
	0	1	2	5
0	0.38	0.36	0.31	0.19
1	0.36	0.28	0.19	0.18
2	0.26	0.19	0.19	0.18
5	0.19	0.19	0.18	0.18

De Pere Effluent OP

Fe	Al			
	0	1	2	5
0	0.22	0.19	0.14	0.02
1	0.20	0.11	0.03	0.02
2	0.10	0.03	0.02	0.02
5	0.02	0.02	0.02	0.02

7.2.5.2 Sidestream Phosphorus Impacts

Digester Influent TP

Fe	Al			
	0	1	2	5
0	385.1	396.4	405.8	426.2
1	394.1	406.2	416.8	432.0
2	405.3	416.5	424.5	437.2
5	431.7	439.3	443.7	448.6

Digester Influent OP

Fe	Al			
	0	1	2	5
0	2.24	1.78	1.62	1.50
1	2.08	1.68	1.56	1.48
2	1.93	1.60	1.53	1.46
5	1.57	1.47	1.44	1.40

Digester Effluent TP

Fe	Al			
	0	1	2	5
0	386.4	397.7	406.9	427.1
1	395.4	407.3	417.7	432.9
2	406.3	417.5	425.3	438.0
5	432.6	440.0	444.4	449.4

Digester Effluent OP

Fe	Al			
	0	1	2	5
0	82.24	21.13	3.76	0.84
1	63.84	13.01	2.95	0.76
2	48.18	8.05	2.29	0.69
5	12.13	2.37	1.18	0.49

7.2.5.3 Selector zone performance impacts on settleability

Green Bay North Selector Zone Influent rbCOD

Fe	Al			
	0	1	2	5
0	25.22	25.23	25.23	25.24
1	25.23	25.23	25.23	25.24
2	25.23	25.23	25.24	25.24
5	25.23	25.24	25.24	25.25

Green Bay North Selector Zone Effluent rbCOD

Fe	Al			
	0	1	2	5
0	16.34	16.16	16.08	16.10
1	16.30	16.13	16.08	16.10
2	16.26	16.11	16.08	16.11
5	16.14	16.09	16.10	16.14

Green Bay South Selector Zone Influent rbCOD

Fe	Al			
	0	1	2	5
0	41.12	41.12	41.13	41.14
1	41.12	41.12	41.13	41.14
2	41.12	41.13	41.13	41.15
5	41.13	41.14	41.14	41.15

Green Bay South Selector Zone Effluent rbCOD

Fe	Al			
	0	1	2	5
0	34.25	34.07	33.98	34.01
1	34.21	34.03	33.99	34.02
2	34.17	34.02	34.00	34.03
5	34.05	34.01	34.02	34.08

De Pere Selector Zone Influent rbCOD

Fe	Al			
	0	1	2	5
0	137.7	137.7	137.7	137.8
1	137.7	137.7	137.8	137.8
2	137.7	137.8	137.8	137.8
5	137.8	137.8	137.8	137.8

De Pere Selector Zone Effluent rbCOD

Fe	Al			
	0	1	2	5
0	126.2	126.3	126.3	126.5
1	126.2	126.3	126.4	126.6
2	126.3	126.4	126.5	126.6
5	126.4	126.5	126.5	126.7

Appendix D

Dynamic Validation Data (February 2019)

Table 7-6: Green Bay Metro dynamic data

Green Bay Metro				
time	Q	TCOD	TP	TKN
d	mgd	mg/L	mg/L	mg/L
0	20.913	410.51	4.2	29
1	18.136	390.24	4.29	29.7
2	20.752	316.75	4	28.3
3	24.817	478.93	4.7	32.4
4	22.68	430.78	4.27	32.1
5	21.687	445.99	3.9	30.7
6	21.811	478.93	4.54	35.4
7	20.317	451.06	3.53	30.2
8	20.472	397.84	4.86	38.7
9	18.727	372.50	3.65	30
10	20.273	390.24	4.65	36.9
11	20.768	395.31	4.6	37.7
12	20.203	433.32	4.2	35.3
13	20.622	395.31	4.07	36.5
14	20.066	458.66	4.39	35
15	19.969	519.47	5.06	37.9
16	18.284	357.30	3.89	27.9
17	20.531	481.46	5.03	41
18	20.356	522.01	5.26	40.3
19	20.612	473.86	4.26	36.2
20	20.213	527.08	4.62	36.9
21	19.212	542.28	4.23	34
22	21.075	311.68	3.04	25.2
23	21.489	476.40	4.02	27.2
24	20.142	461.19	3.97	30.4
25	20.711	471.33	3.66	35.7
26	20.771	435.85	3.42	33.3
27	20.931	481.46	4.67	38.4

Table 7-7: PG dynamic data

Procter and Gamble				
time	Q	TCOD	TP	TKN
d	mgd	mg/L	mg/L	mg/L
0	5.458	180	0.14	2.3
1	5.985	170	0.06	2
2	4.447	220	0.09	2.6
3	3.471	190	0.12	2.6
4	4.311	180	0.14	2.4
5	5.085	160	0.14	2.3
6	4.569	240	0.18	2.3
7	4.224	290	0.17	2.4
8	5.239	250	0.13	2.2
9	5.641	300	0.14	2.5
10	5.77	310	0.09	2.5
11	5.127	370	0.13	2.9
12	3.912	230	0.11	2.5
13	4.984	240	0.08	2.2
14	5.372	220	0.09	2.1
15	4.513	290	0.09	2.1
16	4.269	150	0.12	2.1
17	4.114	190	0.1	2.4
18	5.534	170	0.13	2.3
19	4.486	190	0.12	2.4
20	4.921	200	0.09	2.1
21	5.189	200	0.1	2.2
22	4.237	170	0.11	2
23	4.264	200	0.09	1.6
24	6.986	170	0.07	2.1
25	5.175	190	0.11	2.5
26	4.561	190	0.06	2.1
27	4.541	180	0.24	1.9

Table 7-8: De Pere Metro dynamic data

De Pere Metro				
time	Q	TCOD	TP	TKN
d	mgd	mg/L	mg/L	mg/L
0	7.526	750	6.2	46.8
1	7.563	700	6.17	48.4
2	8.472	620	4.97	39.2
3	10.165	580	4.5	33.6
4	8.412	790	5.39	44
5	8.207	930	5.53	45.4
6	8.267	1200	5.64	45.9
7	8.187	960	5.1	40.5
8	8.019	980	4.94	37.7
9	7.486	940	5.57	47.1
10	7.713	840	6.13	54
11	7.353	780	6.63	52.3
12	6.872	690	5.14	35.3
13	7.749	650	5.38	44.3
14	7.938	720	5.66	49.6
15	7.406	780	5.57	50.2
16	7.760	850	4.88	44.1
17	7.539	780	5.81	48.7
18	7.164	930	5.96	50.6
19	7.108	1000	6.11	49.2
20	6.848	1000	4.82	34.9
21	7.157	990	5.73	44.2
22	7.624	1100	5.74	47.3
23	8.062	860	5.05	41.4
24	7.847	1000	6.12	45.1
25	7.604	950	5.98	45.3
26	7.704	1100	6.18	47.6
27	7.656	830	5.5	45.7

Table 7-9: Fox River Fiber dynamic data

Fox River Fiber			
time	TCOD	TP	TKN
d	mg/L	mg/L	mg/L
0	1800	12.6	134
1	1800	13.2	145
2	1800	11.5	130
3	1500	11.5	127
4	1700	15	155
5	2000	14.7	148
6	2000	12.3	141
7	2300	13	138
8	3500	8.57	96.2
9	2000	16.8	193
10	1800	14.6	175
11	1800	14.6	173
12	1600	7.58	91.3
13	1300	16.4	189
14	1500	14	154
15	1600	11.8	133
16	1600	13	138
17	1500	11.7	140
18	1400	11.7	144
19	1600	11.1	128
20	1700	6.87	78.5
21	2000	15.8	186
22	2300	13.8	151
23	2200	14.3	153
24	2100	12.6	146
25	1700	12	151
26	1700	13.8	161
27	1600	13.6	150

Table 7-10: Dynamic pumping rates used during the Feb dynamic month simulation

	GBN RAS	GBS RAS	GBN WAS	GBS WAS	GB N/S Divider	DP RAS	DP WAS
time	Flow	Flow	Flow	Flow	Flow	Flow	Flow
d	mgd	mgd	mgd	mgd	Mgd	mgd	mgd
0	35.29	10.88	0.44	0.15	8.00	8.10	0.36
1	35.40	10.86	0.56	0.20	8.00	8.13	0.43
2	35.34	10.86	0.56	0.20	8.00	8.16	0.42
3	37.54	10.65	0.53	0.20	8.00	8.19	0.40
4	39.42	10.47	0.48	0.20	8.00	8.14	0.42
5	39.40	10.47	0.46	0.20	8.00	8.14	0.48
6	39.40	10.48	0.46	0.20	7.99	8.14	0.54
7	39.34	10.48	0.40	0.17	8.00	8.12	0.46
8	39.33	10.48	0.46	0.20	8.00	8.10	0.57
9	39.32	10.47	0.46	0.20	8.00	8.11	0.52
10	39.31	10.47	0.46	0.20	8.00	8.06	0.51
11	39.23	10.48	0.43	0.19	8.00	8.08	0.54
12	36.99	10.48	0.42	0.19	6.99	8.11	0.49
13	34.68	10.48	0.39	0.19	6.00	8.10	0.42
14	32.49	9.82	0.36	0.16	6.00	8.11	0.33
15	30.02	8.14	0.40	0.19	6.00	8.09	0.40
16	30.02	8.15	0.40	0.17	6.00	8.08	0.41
17	30.02	8.15	0.30	0.17	6.00	8.11	0.43
18	30.02	8.14	0.22	0.17	6.00	8.10	0.43
19	30.02	8.14	0.43	0.17	5.99	8.12	0.43
20	30.02	8.14	0.42	0.17	6.00	8.13	0.42
21	29.98	8.14	0.36	0.18	6.00	8.13	0.35
22	29.95	8.15	0.43	0.23	6.00	8.05	0.43
23	29.95	8.15	0.45	0.23	6.00	8.02	0.48
24	29.95	8.13	0.33	0.19	6.00	8.04	0.36
25	29.95	8.14	0.44	0.27	6.00	7.98	0.49
26	27.60	8.14	0.38	0.15	6.00	7.85	0.50
27	25.12	8.15	0.29	0.09	6.00	7.93	0.50

Appendix E

Key Operational Setpoints

Reviewed by NEW Water

Green Bay

Metro Influent	Current Model Set point	General Comment	NEW Water Comment	Unit
Flow rate	31.29	Calibration month data		MGD
Total BOD$_5$	103.93	Calibration month data		mg BOD/L
Total Kjeldahl nitrogen (TKN)	22.12	Calibration month data		mg N/L
Total phosphorus	3.18	Calibration month data		mg P/L

Proctor and Gamble Influent				
Flow rate	5.07	Calibration month data	This flow seems a little high to me. We usually average a 4.2 mgd from P&G. Just a quick spot check shows an average flow from Jan 1st 2018 to present. Some of the older data shows higher flows but I don't consider that normal operation for them as of late. Just something to discuss. Also, as Bruce mentioned in the last meeting we want to be sure to take into account the potential load from Green Bay Packaging.	MGD
Total COD	217.00	Calibration month data		mg COD/L
Total Kjeldahl nitrogen (TKN)	1.74	Calibration month data		mg N/L
Total phosphorus	0.07	Calibration month data		mg P/L

Screen				
Solids percent removal	1%	Typical input for screening performance		-

Primary Clarifier				
Primary sludge flow	380.00	Average value from data set	We normally run with a total primary sludge flow of 380gpm per side or 760gpm primary sludge pumping total. As stated previously, we have been running 1/2 of that load to the two gravity thickeners and the remaining 1/2 load over one or two GBT's.	gpm
Sludge solids concentration	7,500	Target value; model calculates the flow rate. Reported range is 0.5 to 1.5%	Reported ranges sound correct. We have drastic fluctuations of PS concentration at this facility mainly driven by industry. P&G for example can take us from .4% PS concentration to 1.5% in a matter of hours if they bypass pretreatment processes. Drastic effects of this are felt throughout the entire solids handling process. The paper pulp like solids make dryer and incinerator operation more variable and it makes it way though the system quicker than one would expect - it's almost like the material settles in the digesters quickly and is transferred out within a day though the bottom wasting option.	mg/L

Grit Chamber				
Percent increase in VSS/TSS ratio	2%	Typical input value for grit removal performance	Sounds appropriate. Just want to note we have noted less grit removal since startup of the new primary sludge tanks and pumping scheme post R2E2. This info can be found in the hauled waste data provided - dumpster weights are screenings and grit combined. We have no way of quantifying them separately short of visual observation.	-

PC Effluent flow split				
Percent to PS Gravity Thickener	50%	Remaining flow to gravity belt thickener	Correct.	-
PS Gravity Thickener				
Thickened solids concentration	46,500	Thickened primary solids assumption; based on 5% average into digestion	We have run a 3.1% concentration since restarting the gravity thickeners this spring. I would say we should be able to run about 4-5% this winter but we tend to run 3-4% in the summer months.	mg/L
Solids percent removal	90%	Assumed value	Fair assumption. We do have issues at times where solids will flow over weirs but only during abnormal conditions.	-
Ferric Addition				
Flow rate	0	Assuming no dosing for initial models runs; to be calibrated with actual ferric feed rates from June 2019	Would you like me to comb though the June plant log and try to provide actual ferric feed rates/location for that month?	gpd
Flow divide between North and South				
Flow fraction to North	80%	Is flow fixed to South Plant in mgd, or paced as a percentage of influent?	We run south plant at a constant flow rate (usually 8mgd with one basin online). North plant handles the remaining flow diurnally.	-
Anoxic zone of North AS basins (2 tanks-in-series)				
DO	0	Selector zones		mg O_2/L

Aerobic zone of North AS basins (9 tanks-in-series)				
DO	2	Assumed full basin target of 2 mg/L; is the most recent profile data representative of current operations?	We have been running a basin wide average of 3.0mg/L. Not sure why we are running so high it would be nice to be closer to the 2.0mg/L.	mg O_2/L
North Final Clarifier				
RAS flow (total)	31.6		Usually run a 4.5-5.0 mgd set point out of each final.	MGD
WAS flow (total)	0.41		Correct.	MGD
Effluent solids	5	Targeting average for initial calibration; layered clarifier with SVI considered for future evaluations	Correct.	mg/L
Anoxic zone of South AS basins (2 tanks-in-series)				
DO	0	Selector zones		mg O_2/L
Aerobic zone of South AS basins (6 tanks-in-series)				
DO	2	Assumed full basin target of 2 mg/L; is the most recent profile data representative of current operations?	We have been running a basin wide average of 3.0mg/L. Not sure why we are running so high it would be nice to be closer to the 2.0mg/L.	mg O_2/L
South Final Clarifier				
RAS flow (total)	7.8		Correct. We run a RAS pump out of each final near 100% output.	MGD

WAS flow (total)	0.4		This is too high of a wasting rate for south plant. We need to revisit this.	MGD
Effluent solids	5	Targeting average for initial calibration; layered clarifier with SVI considered for future evaluations	Correct.	mg/L
WAS to GBT				
Flow split percent	50%	Percent of WAS to GBT; remaining to centrifuge	We try to run 100% of the WAS through the thickening centrifuge. Only during unique wasting conditions (trying to catch up after an equipment failure) do we need to run a GBT to take the remaining WAS load. In addition, when the thickening centrifuge is down for maintenance we run all WAS over the GBT's. I would run the model with 100% of the WAS going though the thickening centrifuge.	-
WAS GBT				
WAS solids content	46,500	GBT solids concentration (when operated with primary sludge) based on 5% into digestion	Correct.	mg/L
Solids percent removal	90%	GBT solids capture (when operated with primary sludge)	Sounds good.	-

WAS Centrifuge				
WAS solids content	46,500	Centrifuge solids concentration, based on 5% into digestion	Correct.	mg/L
Solids percent removal	90%	Centrifuge solids capture	Sounds good. We can get as high as 95% but normal operation is closer to 88-90%	-
Feed to Digester				
Solids concentration	46,500	Based on 5.1% into digestion	Sounds good.	mg/L
Solids flow rate	265,000	Digester 1 + Digester 2; confirm fed in parallel	Yes we are running them in parallel.	gpd
Mesophilic Anaerobic Digester				
Solids concentration	30,000	Average digester effluent TSS	Correct.	mg/L
Water temperature	95.00		98 degrees.	°F
Digester Centrifuge				
Cake solids	31	Centrifuge solids concentration	19-21%	%cake
Solids percent removal	90%	Centrifuge solids capture	Correct.	-
Dryer				
Solids percent removal	95%	Assumed percent solids capture	We lose very little capture efficiency in this process. Would say 98% plus. We usually discharge the dryer at 39-41% solids.	-
Fluidized Bed Incinerator				
Solids percent removal	95%	Assumed percent solids capture		-

Ash Dewatering				
Solids percent removal	95%	Assumed percent solids capture		-
$Mg(OH)_2$ dosing				
Flow rate	0	Confirm that struvite harvesting is not in operation	Not currently running system.	MGD
Struvite removal				
Struvite fraction to underflow	60%	Confirm that struvite harvesting is not in operation	Not currently running system.	-

De Pere

Metro Influent	**Current Model Set point**	**General Comment**	**NEW Water Comment**	**Unit**
Flow rate	8.28			MGD
Total chemical oxygen demand	529.33			mg COD/L
Total Kjeldahl nitrogen (TKN)	26.25			mg N/L
Total phosphorus	4.28			mg P/L
Fox River Fiber Influent				
Flow rate	0.69			MGD
Total chemical oxygen demand	1945.07			mg COD/L
Total Kjeldahl nitrogen (TKN)	178.49			mg N/L
Total phosphorus	20.38			mg P/L
Anoxic zone of AS basins (1 tank-in-series)				
DO	0	Selector zones		mg O_2/L

Aerobic zone of AS basins (1 tank-in-series)				
DO	3	Assumed high DO given control and configuration	We try to control a 2.5mg/L but we tend to run closer to the 3.0 mg/L. Note - we have been playing with potential ammonia control but programming tweaks are still being made.	mg O_2/L
Intermediate Secondary Clarifier				
RAS flow	8.10	Based on historic operation		MGD
WAS to Green Bay				
Flow Rate	0.3600	Based on historic operation; assuming RAS wasting	Sounds like an appropriate flow rate. Note - we can waste either MLSS or RAS and it is dependent on plant loadings.	MGD
Final Secondary Clarifier				
RAS flow	0			MGD
GMF Filter				
Solids percent removal	80%		80-90% removal. Note - an upgrade to disc filters in planned in the near future. Engineering can provide more info.	-