Rochester Water Reclamation Plant

2019 Facilities Plan

Technical Memorandum 2: Wastewater Characterization and BioWin Calibration

TM 2 of 13 | J4325

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Technical Memorandum

Prepared for: City of Rochester

Project Title: Water Reclamation Plant Facilities Plan

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Technical Memorandum No. 2

Subject: Wastewater Characterization and BioWin Calibration

Date: September 8, 2018

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Limitations:

This document was prepared solely for the City of Rochester in accordance with professional standards at the time the services were performed and in accordance with the contract between City of Rochester and Brown and Caldwell dated May 15, 2017. This document is governed by the specific scope of work authorized by the city of Rochester; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by the City of Rochester and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Executive Summary

This section provides a summary of the key outcomes from the wastewater characterization and BioWin™ simulator calibration. The simulator was calibrated to daily plant operating data reported from April 1 through August 31, 2017 and specialized wastewater characterization sampling data from August 20 through 31, 2017. A summary of key findings and conclusions are presented below. Additional testing and evaluations recommended below should be completed prior to, or during, the next project phase.

- Wastewater characterization sampling in August 2017 showed the plant influent contains a high fraction of soluble readily biodegradable organic material and high organic nitrogen content. The influent organic nitrogen includes a higher than normal fraction of soluble non-biodegradable nitrogen (4 percent versus a typical 2 percent) which results in an effluent soluble non-biodegradable nitrogen content of roughly 2 to 3 mg/L. The high soluble non-biodegradable nitrogen will be critical if trying to reduce effluent total nitrogen discharges to low levels. It is recommended the City begin monitoring industrial users for total Kjeldahl nitrogen (TKN), filtered TKN (1.5 um filter) and ammonia.
- Water Reclamation Plant (WRP) lab reported chemical oxygen demand (COD) concentrations during the August 2017 wastewater characterization testing were consistently 35 percent or higher than measured by Minnesota Valley Testing Laboratories. WRP lab reported COD data is not used in this analysis and the City should continue to investigate its COD analytical procedures to ensure accurate readings.
- BioWin calibration using the reported plant influent and primary effluent data underestimated primary sludge and waste sludge production and mixed liquor suspended solids (MLSS) concentrations. Plant reported data and the August 2017 wastewater characterization data showed high overall sludge production rates and activated sludge yields 25 to 35 percent higher than typically observed. The high solids production means either the influent/secondary influent loadings are higher than reported or the mass of primary wand waste sludge solids generated are less than reported.

The plant staff investigated several factors which could influence the sludge production values such as return sludge meter accuracy and whether representative plant influent and primary effluent samples are collected. Drawdown tests showed the Intermediate Clarifier and Secondary Clarifier 5 return sludge flow (RAS) rates to be within 10 percent of reported values while Secondary Clarifiers 1-4 reported RAS flows were roughly 15 percent higher than reported. Increasing the Secondary Clarifier RAS flow by 15 percent in the BioWin calibration model decreases the 2nd Stage high purity oxygen activated sludge (HPOAS) sludge production but does not close the solids discrepancy. The City conducted 5-day sampling campaigns in November/December 2017 and January 2018 to determine if the plant influent, Primary Clarifier 1/2 and Primary Clarifier 3 effluent loadings are higher than reported. Data collected showed the reported sample concentrations from the existing samplers to be lower than samples collected with an ISCO samplers. Table ES-1 provides a comparison of the ISCO sampler: Existing Sampler measured concentrations. For example, the ISCO sampler COD concentrations were 15 percent higher than the existing plant influent sampler.

Table ES-1. Summary of Plant Influent and Primary Effluent Sample Comparison

	ISCO Sampler: Existing Sampler		
	November 28-December 7, 2017/January 2018/April 2018		
Item	Plant Influent	Primary Clarifier 1/2	Primary Clarifier 3
COD	--/1.15/1.2	--/1.2/1.2	1.55/--/--
cBOD5	--	--	1.65/--/--
TSS	--/1.4/1.2	--/1.2/1.2	1.55/--/--
TP	--/1.0/1.07	--/1.1/1.1	1.2/--/--
TKN	--/--/1.05		

Primary clarifier stress testing and volatile fatty acid (VFA) sampling supports the increase COD and 5-day carbonaceous biochemical oxygen demand (cBOD5) is particulate matter and not soluble organic matter. BioWin (and HiPure) simulations which increased the plant influent and primary effluent particulate concentrations to achieve the multiplication factors below, matched the plant reported primary sludge and waste sludge production and provided a very good correlation to the plant reported operating data including MLSS, airflow, and effluent quality.

- Plant Influent COD, cBOD5, and total suspended solids (TSS) multiplication factors of 1.15, 1.15, and 1,2 respectively.
- Primary Clarifier 1/2 effluent COD, cBOD5, and TSS multiplication factors of 1.2 and total phosphorus (TP) by 1.1.
- Primary Clarifier 3 effluent COD, cBOD5, and TSS multiplication factors of 1.55 and TP by 1.2.

Based upon the subsequent BioWin model calibration and desire to evaluate seasonal changes in influent characteristics during cold weather, the City conducted another 10-day sampling event on the plant influent in April 2018. This sampling data also supports the higher influent concentration/multiplication factors in Table ES-1 but did see an increase in relative soluble concentrations as measured by the filtered COD:total COD ratio. It is recommended the City continue to investigate the sample anomalies to refine the plant loadings and wastewater characteristics.

- Nitrification rate kinetics presented in Technical Memorandum Nitrification Rate Testing (BC, 2017a) were used in the BioWin calibration. Process modeling shows several periods of Secondary Clarifier 1-4 high effluent ammonia not associated with the modeled nitrification rates, but rather something else occurring at the plant. The City should continue to investigate potential causes of the periodic reduced nitrification rates such as influent toxic loadings.
- Primary Clarifier 3 TSS removal is roughly 45 percent. The City should try to reduce the clarifier sludge blanket depths (SBDs) to the minimum level which can achieve the target primary sludge concentrations as the influent volatile fatty acid (VFA) concentrations are sufficient to maintain the Aeration Basin Complex (ABC) phosphorus removal performance. The reduced SBD should help improve primary clarifier TSS removal performance and reduce ABC organic loadings.
- The August 2017 and April 2018 influent wastewater characterization sampling campaigns showed two notably different influent wastewater characteristics. The cold weather sampling (April 2018) had influent nitrate+nitrite concentrations of roughly 2 mg-N/L compared to negligible concentrations in August and April had a higher fraction of ortho-phosphate:TP in the

influent. The plant should continue monitoring influent nitrate+nitrite twice per month to confirm influent loadings and begin measuring the influent phosphate concentration a minimum of twice per week as HPOAS chemical dosing will be directly related to the influent phosphate concentration.

Section 1: Objective

This technical memorandum (TM) summarizes the September 2017 wastewater characterization and subsequent BioWin™ wastewater treatment whole-plant calibration for the City of Rochester (City) Water Reclamation Plant (WRP). The TM is organized into the following sections

- Executive Summary
- Section 1: Objective
- Section 2: Background
- Section 3: Influent Wastewater Characterization
- Section 4: BioWin Calibration Influent Itinerary
- Section 5: BioWin Calibration
- Section 6: References

Section 2: Background

The WRP liquid stream processes consists of common influent pumping, screening, grit removal, and flow equalization systems. After grit removal, the plant has two liquid stream trains: high purity oxygen activated sludge (HPOAS) and conventional air activated sludge commonly referred to as Aeration Basin Complex (ABC). The HPOAS train consist of rectangular primary clarifiers followed by a two-stage HPOAS system. The first stage HPOAS operates at low solids retention time (SRT) to remove carbonaceous compounds. The second stage HPOAS operates at a SRT greater than 10 days to nitrify ammonia to nitrate. The two stages are fed HPO gas from a cryogenic oxygen generation system. Phosphorus removal in the HPOAS train is primarily accomplished via ferric chloride addition to the primary clarifiers with some trimming using alum in the HPOAS trains if needed. The ABC train has one circular primary clarifier followed by an enhanced biological phosphorus removal (EBPR) nitrifying activated sludge system. The ABC plant operates independently of the HPOAS train except that primary influent flow can be split between the two treatment trains as a way of load balancing. Effluent from each secondary treatment train is blended and then routed to the chlorine contact tanks for disinfection.

Primary solids are thickened in the primary clarifiers. Waste activated sludge (WAS) from each activated sludge system is blended and thickened using gravity belt thickeners (GBTs). Thickened sludges are pumped to mesophilic anaerobic digesters (MAD). Digested biosolids are fed to a sludge holding tank and then thickened using GBTs. Thickened biosolids are then pumped to sludge storage tanks for land application. Recycle streams from the GBTs are routed to the head of the plant influent/equalization. Figure 2-1 provides a simplified plant flow schematic and Figure 2-2 shows a plant layout drawing.

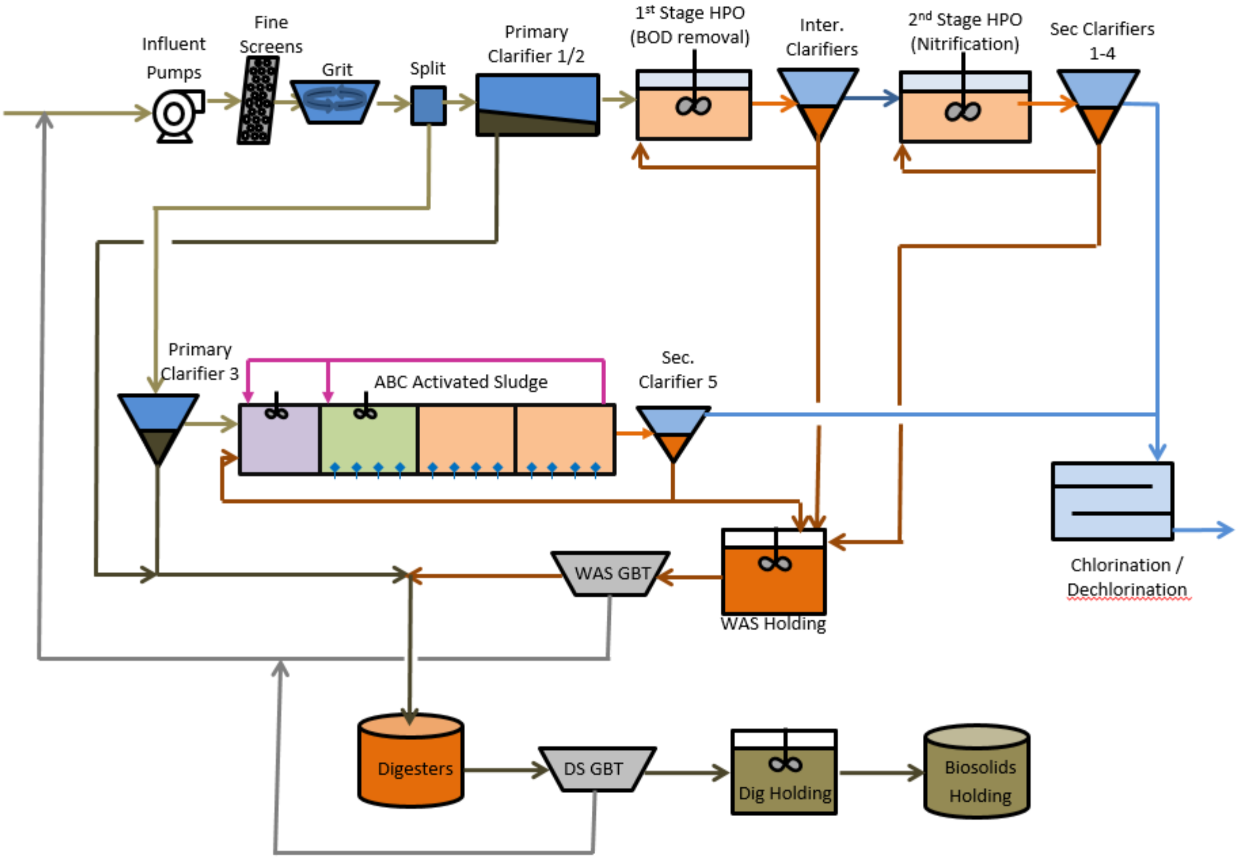

Figure 2-1. Rochester WRP Flow Schematic.

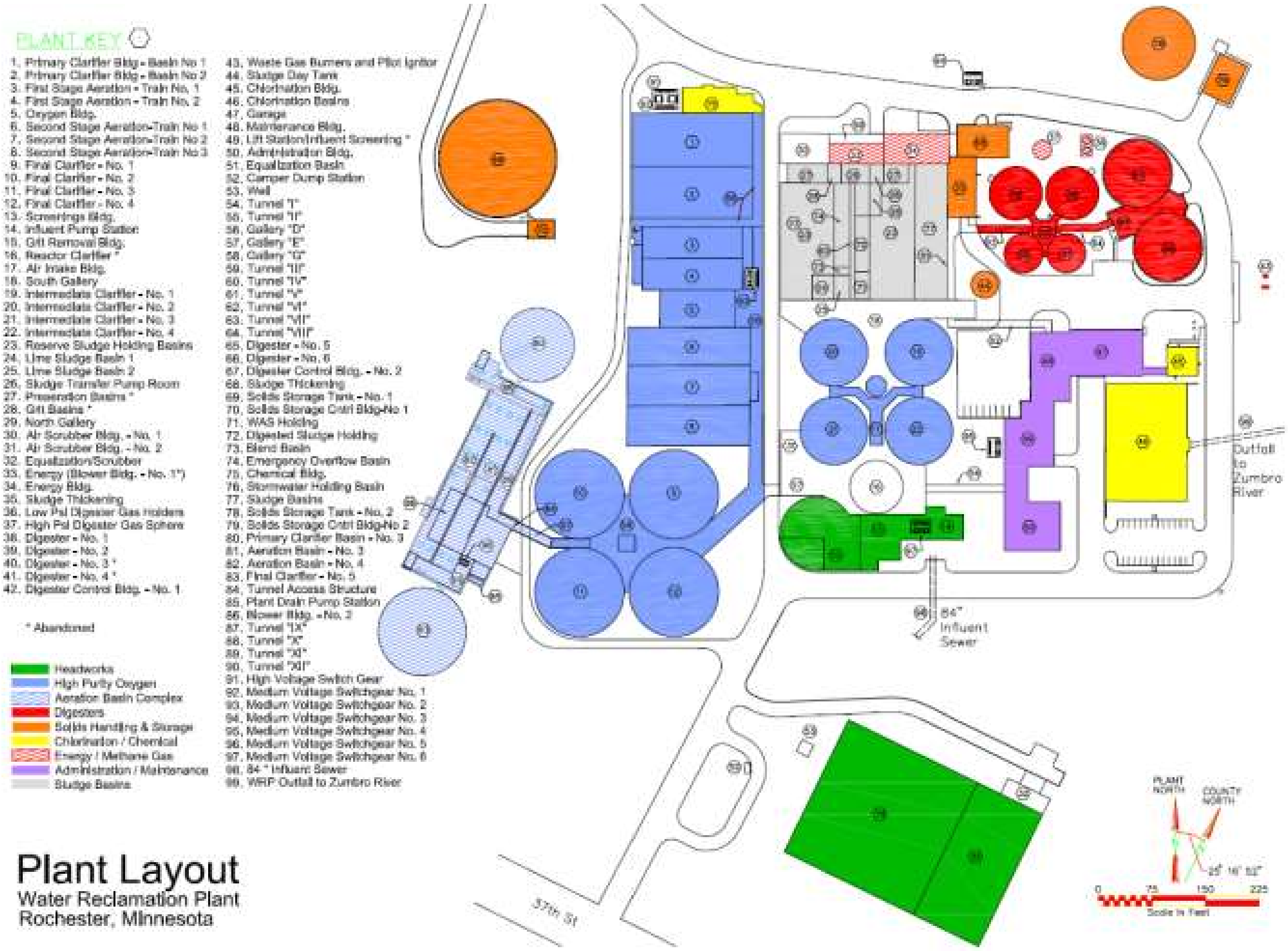

Figure 2-2. Rochester WRP Plant Layout.

2.1 BioWin Calibration Configuration

BioWin™ Version 5.3 (EnviroSim Associates Limited, Hamilton, Ontario, Canada) was used for the wastewater treatment plant model calibration. Figure 2-3 shows the WRP whole-plant BioWin simulator calibration configuration. The BioWin configuration and calibration are based on plant operating data and wastewater characterization data collected from April 1 through August 31, 2017. During this period all process units and tankage were in service except for 1 of 2 1st stage HPOAS reactor trains were in service (outside of 11 days in May/June).

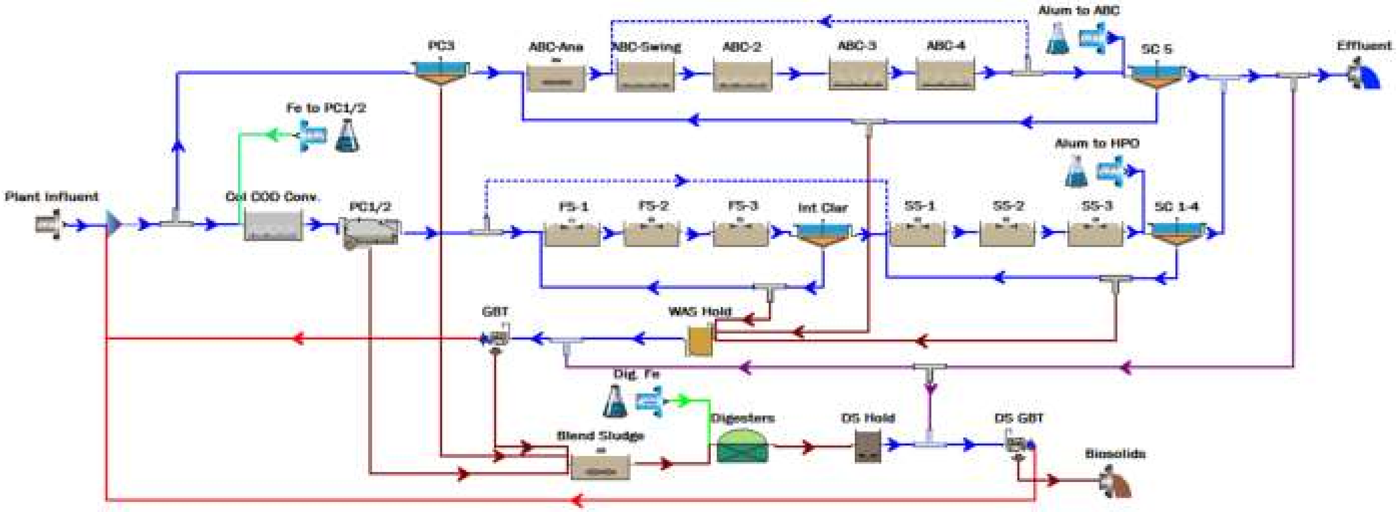

Figure 2-3. Rochester WRP BioWin Calibration Flow Schematic.

The plant calibration configuration includes all key liquid and solids stream processes as follows:

- HPO train primary clarifier (PC) operations consist of three model units. The two PCs are combined into one PC (PC1/2) with an equivalent total surface area and solids pumping rate. To account for colloidal/soluble chemical oxygen demand (COD) removal from ferric chloride addition which cannot be modeled in a clarifier module, the HPO train PCs include a model builder unit (Col. COD Conv) for capturing colloidal COD and a ferric chloride addition module (Fe to PC1/2). The ABC PC (PC3) is configured as a single PC unit.
- The one first stage HPOAS train consists of three staged bioreactors (FS-1 through FS-3) followed by a single model clarifier (Int. Clar) representing Intermediate Clarifier 1-4 total surface area and return sludge pumping rate.
- The second stage HPOAS train consists of three staged bioreactors (SS-1 through SS-3) followed by a single model clarifier (SC 1-4) which represent the total second stage bioreactor volume and Secondary Clarifier 1-4 surface area/return sludge pumping rate. A primary effluent bypass to the second stage HPOAS is also provided to simulate PE flows routed directly to second stage.
- The two ABC basins are combined into one BNR train (ABC-Ana through ABC-4). Anaerobic, anoxic and aerobic zone volumes are based upon the total volume of each zone type when in operation. The ABC basins were operated in an anaerobic/oxic (A/O) configuration for all the calibration period except the first 11 days. The ABC aeration oxygen transfer modeling parameters were updated based upon the off-gas testing results presented

in TM Aeration Basin Off-Gas Testing (BC, 2017b). The ABC secondary clarifier (SC5) is modeled as a single unit.

- The HPOAS and ABC train alum feeds (HPO alum and ABC alum) are also included in the model. BioWin only allows the chemistry of one metal salt (Fe or Al) to be modeled at a time. As such, the model ferric chloride feed rate was adjusted to match the same quantity of chemical sludge produced from alum addition. The metal:P ratio of alum and ferric differ, so TP reduction will not be fully accurate.
- The chlorine contact tanks downstream of the secondary clarifiers are not incorporated into the model.

Section 3: Influent Wastewater Characterization

Process simulation modeling requires accurate characterization of the influent carbon, nitrogen and phosphorus fractions shown in Figure 3-1

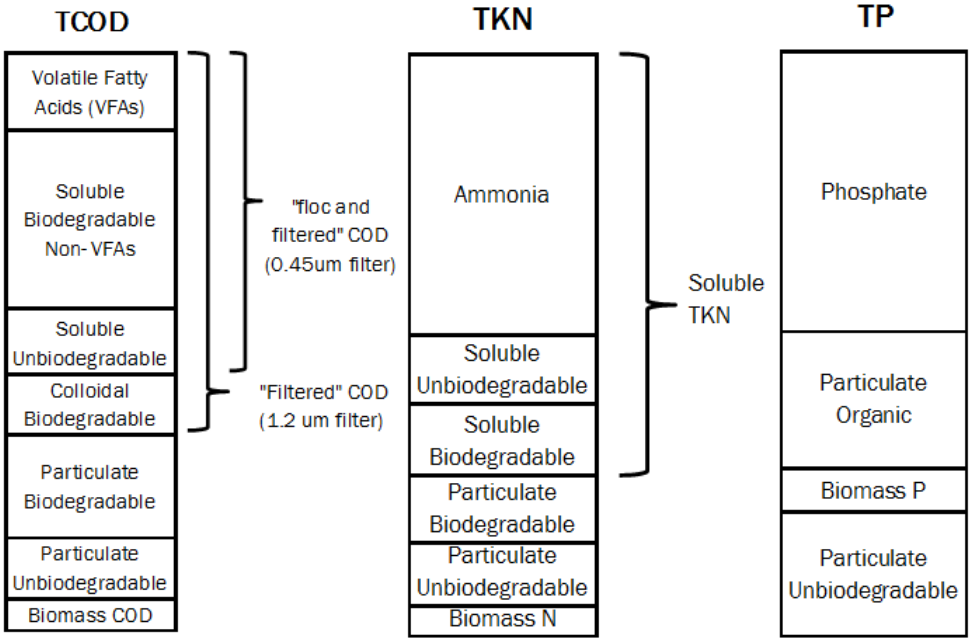

Figure 3-1. Graphical Representation of BioWin™ Influent COD, TKN and TP fractions.

The City conducted several sampling campaigns to define the influent wastewater characteristics. The first sampling campaign was conducted in August 2017 to characterize the plant influent along with liquid and solid stream process operations. Table 3-1 summarizes the influent wastewater characteristics measured during the sampling period. Appendix A contains the wastewater characterization sampling plan.

Subsequent data analysis and BioWin model calibration, suggested the plant influent organic loadings (COD, cBOD5, TSS,..) are higher than measured/reported. As such the City conducted two 5-day sampling events in November/December 2017 in which samples were collected from the plant influent, Primary Clarifier 1/2 effluent and Primary Clarifier 3 effluent using the plants existing samplers and portable ISCO type samplers. Samples from each sampler were tested for TSS, COD, and TP. Testing results consistently showed the ISCO TSS samples to be 20 to 45 percent greater than reported values (existing Sonford sampler) and ISCO COD samples to be 10 to 20 percent greater than reported values as summarized in Table ES-1. No quantifiable differences in influent TP were observed.

Comparison of the influent soluble COD:total COD ratios from the VFA grab sampling conducted during the August 2017 special sampling and HPO train primary clarifier testing suggests the increase in influent COD is associated with particulate material and soluble COD is not impacted. Based upon these results and BioWin calibration, the reported plant influent COD and cBOD5 particulate concentrations were increased to increase the overall COD concentration by 15 percent and the reported TSS and volatile suspended solids (VSS) increased by 35 and 31 percent respectively as shown in Table 3-1.

The last sampling campaign was completed in April 2018. Additional information on this sampling campaign and its results are provided in Section 3.2.

Table 3-1. Rochester WRP Influent Wastewater Characteristics

Item	Units	August 2017 Reported Data		Aug 2017 Adjusted Data[1]	BioWin Calibration	April 2018		Typical Fractions[2]
		Average	Range			Average	Range	
Flow	mgd	14.2	13.2 - 14.8			12.5	11.6 - 13.2	
Temperature	C	18.8	18.2 - 19.4			12.9	12.0 - 13.0	
5-Day Carb.Biochemical oxygen demand (CBOD5)	mg/L	343	264 - 428	394		452	374 - 537	
Soluble CBOD5 (1.5 um)	mg/L	148	101 - 229			243	213 - 283	
Total suspended soids (TSS)	mg/L	229	156 - 354	308		298	210 - 592	
Volatile suspended solids (VSS)	mg/L	206	135 - 318	268		262	184 - 546	
Alkalinity (as CaCO3)	mg/L	414	389 - 431			380	358 - 389	
Chemical Oxygen Demand								
Chemical Oyxgen Demand (COD)	mg/L	648	474 - 833	745		783	634 - 928	
Soluble COD (1.5um filter)	mg/L	309	257 - 430			407	348 - 463	
Flocculated and Filtered COD	mg/L	200	148 - 295			285	258 - 350	
Volatile Fatty Acids (as COD)	mg/L	27	25 - 32			40	24 - 66	
Nitrogen								
Total kjeldahl nitrogen (TKN)	mg N/L	40	36 - 53			44	41 - 47	
Soluble TKN (1.5 um)	mg N/L	30	28 - 32			38	37 - 40	
Ammonia (NH3-N)	mg N/L	21	17 - 22			25	24 - 26	
Nitrate+Nitrite (NOX-N)	mg N/L	0.1	0.1 - 0.4			1.8	1.5 - 2.7	
Phosphorus								
Total phosphorus (TP)	mg P/L	7.5	6.2 - 9.4			7.7	6.6 - 8.7	
Soluble phosphorus (1.5 um)	mg P/L	4.2	3.7 - 4.9			5.0	4.4 - 5.7	
Ortho-phosphate (PO4-P)	mg P/L	4.2	3.4 - 4.9			5.2	4.5 - 6.2	
COD fractions								
Readily biodegradable (Fbs)	g/g TCOD	0.29/(0.28)[3]	0.17 - 0.30	0.25	0.262	0.34/(0.27)[3]	0.28 - 0.39	0.11 - 0.27
Unbiodegradable soluble (Fus)	g/g TCOD	0.042	0.02 - 0.07	0.037	0.037	0.024	0.02 - 0.03	0.03 - 0.09
Unbiodegradable particulate (Fup - estimated)	g/g TCOD				0.13			0.11 - 0.24
Acetate:Readily biodegradable COD (Fac)	g/g RBCOD	0.20	0.12 - 0.26		0.21	0.18	0.12 - 0.30	0.08 - 0.47
Particulate slowly biodegradable (Fxscp - estimated)	g/g TCOD	–			0.57	–		0.68 - 0.85
Nitrogen Fractions								
Ammonia-N:TKN (Fna)	g/g TKN	0.53	0.42 - 0.60		0.53	0.57	0.54 - 0.61	0.5 - 0.73
Soluble TKN:TKN	g/g TKN	0.75	0.59 - 0.83		–	0.85	0.80 - 0.89	
Particulate organic nitrogen (Fnox)	g/g OrgN	0.52	0.40 - 0.70		0.40	0.34	0.26 - 0.45	0.41 - 0.71
Phosphorus Fractions								
Phosphate-P:TP (Fpo4)	g/g TP	0.56	0.46 - 0.60		0.55	0.67	0.61 - 0.73	0.4 - 0.68
Other								
COD:BOD5	g/g	1.9	1.7 - 2.1			1.74	1.6 - 2.2	1.8 - 2.7
COD:TKN	g/g	16	13 - 21	18		18	15 - 22	10 - 18
COD:TP	g/g	87	75 - 109	100		102	83 - 122	65 - 110
Solube COD:COD	g/g	0.50/(0.49)[3]	0.37 - 0.56	0.44		0.52/(0.54)[3]	0.46 0.62	
ffCOD:COD	g/g	0.33/(0.32)[3]	0.2 - 0.4	0.29		0.37/(0.30)[3]	0.30 - 0.41	0.19 - 0.34
VSS:TSS	g/g	0.90	0.8 - 0.9	0.87		0.88	0.68 - 0.01	0.8 - 0.9
Particulate COD:VSS	g/g	1.59	1.3 - 2.3	1.58	1.55	1.53	0.92 - 1.82	1.35 - 2.1

1. Only adjusted values shown
2. Based upon Brown and Caldwell wastewater sampling database.
3. Fraction based upon composite samples/VFA grab samples

3.1 Wastewater Characteristics – August 2017

The adjusted COD data shows that 25 percent of the influent COD is readily biodegradable (Fbs) and matches well with the VFA/COD grab sample Fbs of 0.28. In addition, the adjusted flocculated and filtered COD(ffCOD):COD ratio of 0.29 matches well (within 10 percent) with the VFA sampling fraction of 0.32 and the adjusted soluble COD:COD ratio of 0.44 is also within 10 percent of the VFA sampling fraction. These correlations along the primary clarifier testing data support the assumption that the increase in COD is associated particulate COD.

The final BioWin calibration uses an Fbs of 0.263 as a blend of these two Fbs values. The influent soluble unbiodegradable COD (Fus) of 0.037 is on the lower side but within the range of typical municipal wastewaters. The influent VFA concentration averaged 20 mg/L as COD representing a VFA:readily biodegradable COD fraction (Fac) of 0.2 which is also typical

The influent ammonia to total Kjeldahl nitrogen (TKN) fraction (Fna) of 0.53 is low for municipal wastewater and most likely due to organic nitrogen from local industries. The ortho-phosphate (PO4-P):TP (F_{PO4}) ratio of 0.56 is typical of municipal influents.

It is often useful to evaluate several additional wastewater characteristics in assessing data validity, seasonal variations, and general wastewater characteristics. These data are useful to consider as there is usually considerable day-to-day variation in concentration values; however, the ratio of COD:TKN, for example should not show large fluctuations. Table 3-1 shows several "other" parameter ratios measured during the August 2017 sampling event are typical of municipal wastewater

Attachment B contains the August 2017 daily wastewater characterization data and two 5-day comparative sampling program results.

3.2 Wastewater Characteristics – April 2018

Based the BioWin model calibration need to include influent "adjustment factors" and recommendation to evaluate seasonal changes in influent characteristics during cold weather, the City conducted a 10-day sampling event on the plant influent in April 2018. Table 3-1 summarizes the influent sampling data which was collected with an ISCO sampler and Table ES-1 compares the ISCO and existing sampler data.

April 2018 sampling data shows the ISCO COD and TSS sample concentration to be 20 percent greater than measured with the existing sampler. Based upon this data, the previous two comparative sampling campaigns, and BioWin calibration no change to the influent COD, cBOD5, and TSS adjustment factors used in the BioWin calibration were recommended. The plant also sampled for TKN and TP and found the ISCO and existing sampler concentrations to be within 10 percent and the difference is considered negligible.

Table 3-1 summarizes the results of the April 2018 influent wastewater characterization results. The Fus of 0.024 was slightly less than measured in August 2017 (0.037). This difference is considered negligible. Similar to the August sampling, the Fbs measured using the composite samples (0.34) was higher than measured during VFA grab sampling (0.27). This analysis will continue to use the Fbs of 0.263 based upon the VFA sampling event Fbs.

The influent Fna of 0.57 is slightly higher than measured in August 2017 (0.53). At an average influent TKN of 40 mg/L, the increase in Fna would increase the ammonia concentration from 21.2 to 22.8 mg-N/L. This increase in ammonia is less than 10 percent and considered negligible. It should be noted that nitrate+nitrite measured during the April sampling event averaged 1.8 mg-N/L (180 lb-

N/d). Figure 3-2 shows the influent nitrate+nitrite concentration measured since January 2017. The influent nitrate+nitrite comes from industrial sources and appears to be seasonal with highest concentrations in late Winter/early Spring when wastewater temperatures are cold. This BioWin calibration maintains the influent nitrate at zero, however the alternative analysis will include nitrate in the influent when simulating colder weather periods. The plant should continue to measure the influent nitrate+nitrite concentration twice per month to influent nitrate+nitrite loadings.

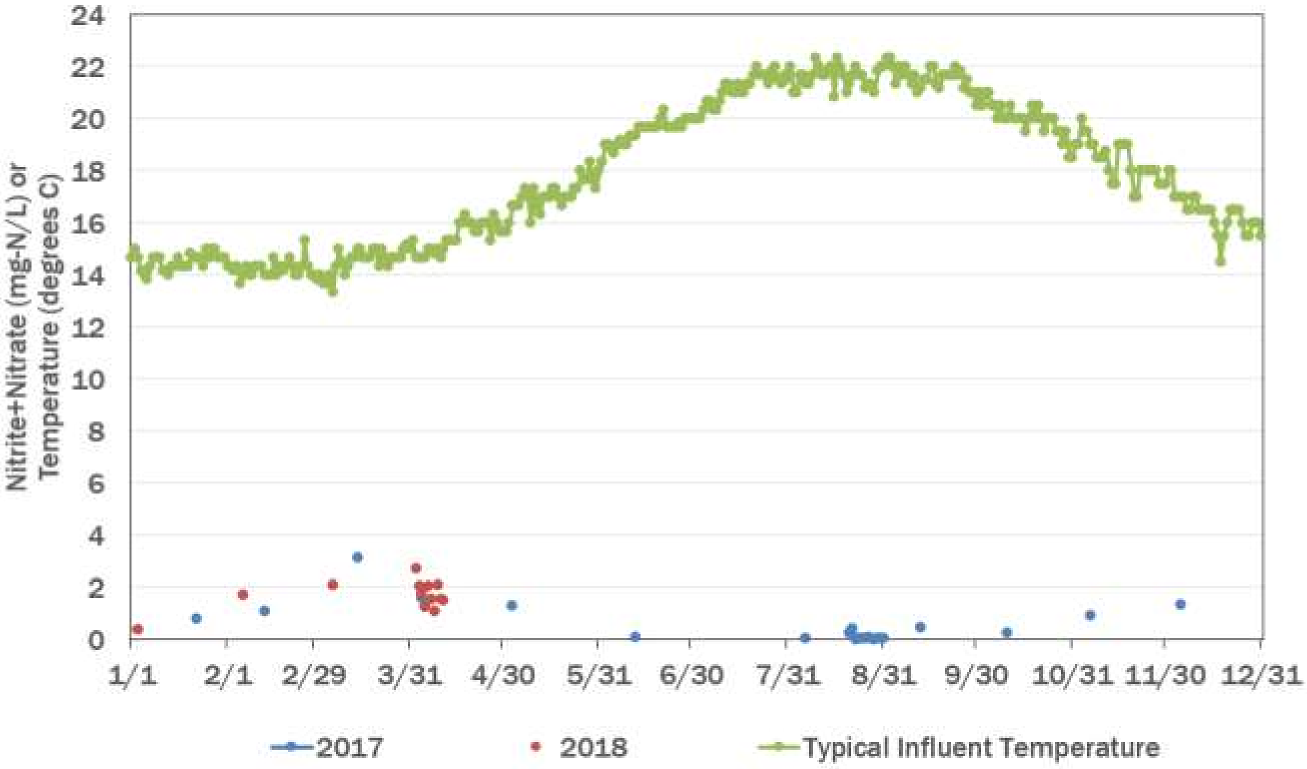

Figure 3-2. Rochester WRP Influent Nitrate+Nitrite Concentrations.

The April 2017 influent F_{PO4} ratio of 0.67 is 17 percent higher than measured in August 2018. A BioWin calibration simulation using the April Fna of 0.57 and F_{PO4} of 0.67 showed changing the fractions did not impact predicted effluent quality, diurnal profiles, airflows or solids generation. The final calibration uses an F_{PO4} ratio of 0.62. The plant should begin measuring the influent phosphate concentration once or twice per week as HPOAS chemical dosing will be directly related to the influent phosphate concentration.

Attachment C contains the April 2018 daily wastewater characterization data results.

Section 4: BioWin Calibration Influent Itinerary

As presented in Section 3, BioWin™ uses COD, TKN, and TP as the basis for process simulations. The model allows the user to input influent flow, COD, TKN, TP, alkalinity, inert suspended solids (ISS), nitrate, pH, alkalinity, and temperature. Using the wastewater fractions in Table 3-1, BioWin will calculate additional influent parameters such as filtered COD, cBOD5, TSS, VSS, ammonia, and PO4-P. The plant influent calibration itinerary was developed using plant operating data and wastewater characterization data from April 1 through August 31, 2017. Where influent concentration data was not available (i.e. the plant did not sample that day) the 30-day moving average loading was calculated and used as a basis for the influent load/concentration.

Figures 4-1 through 4-5 show the key plant influent itinerary inputs for the BioWin calibration. Plant reported values are shown using square icons and BioWin predicted values are shown in lines. Calculated influent COD is based upon the reported influent cBOD5 concentration (adjusted) and the COD:cBOD5 ratio measured during the August 2017 wastewater characterization sampling period. The influent TSS and VSS itinerary are calculated in BioWin based upon the influent COD characteristics and inert suspended solids concentrations. The plant reported TSS and VSS were adjusted by a factor of 1.35 and 1.31, respectively as noted above. Calculated influent TKN and phosphate concentrations assume an Fna and F_{PO4} of 0.53 and 0.62 respectively.

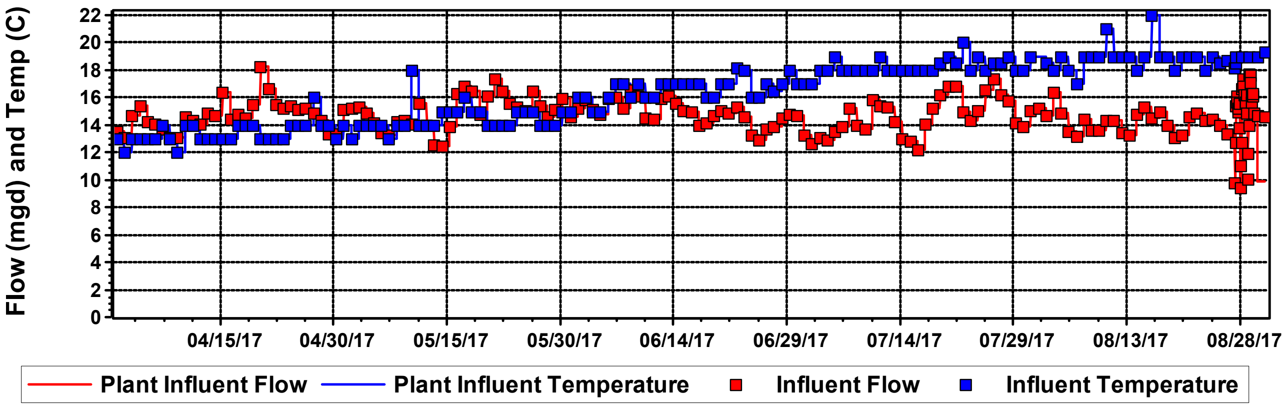

Figure 4-1. BioWin Calibration Plant Influent Flow and Temperature Itinerary.

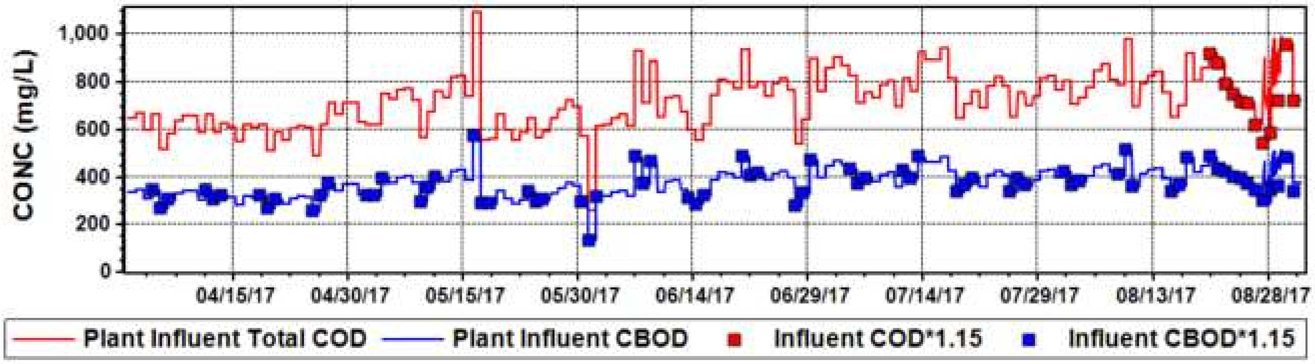

Figure 4-2. BioWin Calibration Plant Influent COD and cBOD5 Itinerary.

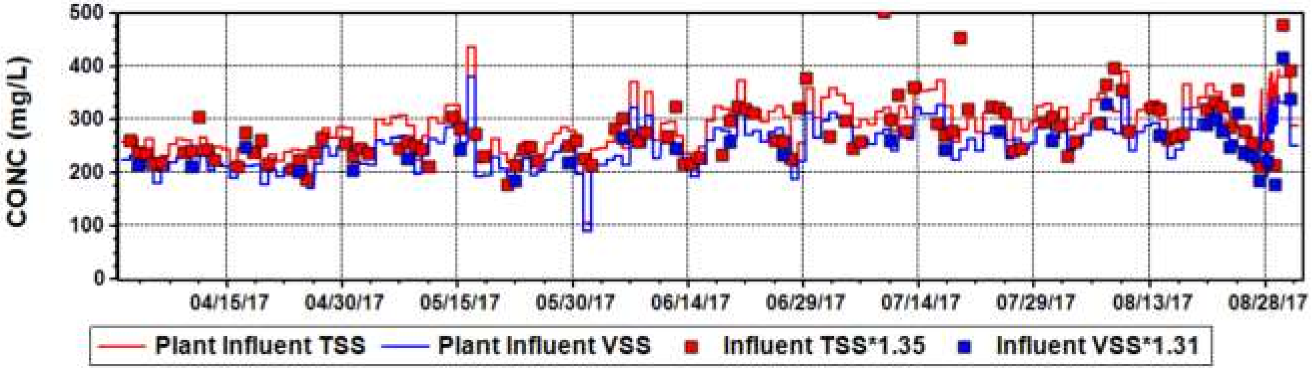

Figure 4-3. BioWin Calibration Plant Influent TSS and VSS Itinerary.

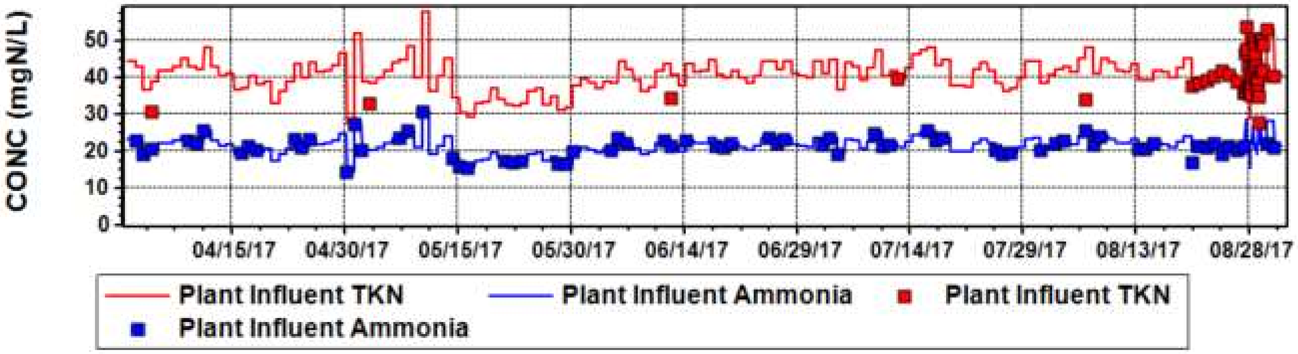

Figure 4-4. BioWin Calibration Plant Influent TKN and Ammonia Itinerary.

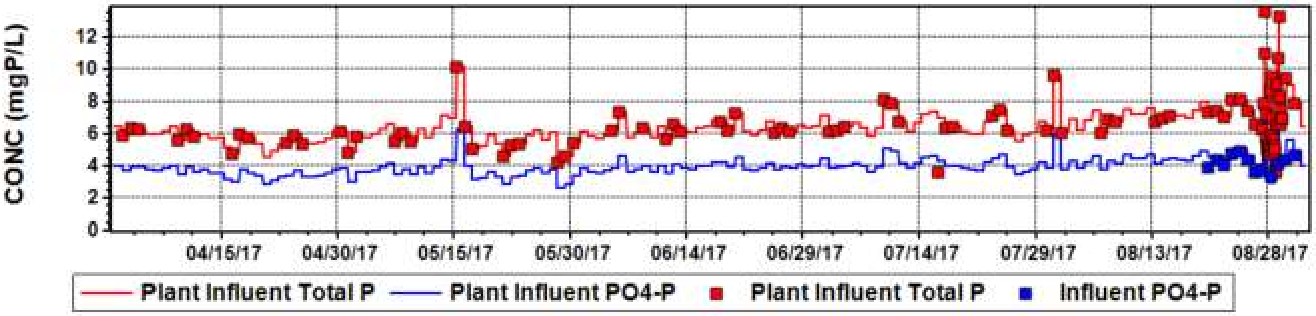

Figure 4-5. BioWin Calibration Plant Influent TP and Phosphate Itinerary.

Section 5: BioWin Calibration

The BioWin simulator calibration consists of a two-step process. Step 1 calibrates the simulator to steady- state conditions using the average plant reported value from April 1 through August 31,2017. Step 2 further validates the model liquid stream process output and key solids stream outputs under a dynamic simulation using the daily measurements observed during this same period.

Simulator calibration generally involves combining the “operational” or “controllable” aspects of the treatment plant with the input wastewater characteristics and adjusting selected parameters to fit a set of plant performance data. It should be noted that often it is not possible to adjust simulator parameters such that an exact match between predicted and observed values is achieved. Rather, the goal in calibrating a simulator is to achieve a good correlation between the overall trend of predicted and observed values while minimizing the error between datasets and simulator predictions. It also is crucial to observe the simulator fit to all important variables. It is preferable to fit to most of the measured variables reasonably, rather than fit perfectly to one selected (albeit perhaps important) component concentration and poorly to others.

5.1 Step 1 - Steady State Calibration

Tables 5-1 compares the measured and simulated constituent concentrations for the liquid and solids stream flows respectively. The BioWin™ predicted values correlate very well with the reported values on a steady-state basis. Several noteworthy items are discussed further below:

- Reported Primary Clarifier 1/2 effluent COD, cBOD5, TSS, and TP concentrations equal 1.2*, 1,2*, 1.2* and 1.1*measured value respectively based upon January 2018 testing (see Attachment A) The predicted cBOD5 is slightly higher than reported (adjusted) as the effluent TSS is 8 percent higher and the cBOD5 adjustment factor of 1.2 was assumed based upon the COD adjustment factor.
- Predicted Primary Clarifier 1/2 effluent TP is higher than reported because the BioWin Fe:P molar ratio for chemical phosphorus removal was increased from 1.6 to 2.5 to prevent phosphorus limited conditions in the second stage HPOAS. As such, chemical phosphorus removal in the primary clarifiers, activated sludge systems, and digesters is less than observed in the field.
- Reported Primary Clarifier 3 effluent COD, cBOD5, TSS, and TP concentrations equal 1.55*, 1,55*, 1.55* and 1.2*measured value respectively based upon January 2018 testing (see Attachment A) The Primary Clarifier 3 adjustment factors are believed to be higher than Primary Clarifier 1/2 as a result of the non-representative sampling location from the primary effluent piping and lower TSS removal in Primary Clarifier 3.
- Predicted First Stage HPOAS effluent cBOD5 and TSS are higher than reported as the reported data are sampled only once per week which skews the average value lower.
- Solids production and digester VSS destruction are within 10 percent of reported values.
- WRP lab reported influent and Primary Clarifier 3 effluent COD is not compared to the predicted values as the WRP lab data was 35 to 50 percent higher than measured by Minnesota Valley Testing Laboratories (MVTL) during the wastewater characterization testing and use of the WRP lab COD data results in nutrient limitations in both the HPOAS systems and excessively higher airflows in the ABC train.

Table 5-1. Steady State BioWin Calibration

Item	Units	Reported	Predicted	Difference
Plant Influent[a]				
Flow	mgd	14.7	14.7	0%
COD	mg/L	--	718	NA
cBOD5	mg/L	370	372	1%
TSS	mg/L	278	285	2%
Ammonia	mgN/L	21.5	21.5	0%
TP	mg/L	6.4	6.3	-2%
Primary Clarifier 1/2 Effluent[b]				
Flow	mgd	11.8	11.6	-1%
COD	mg/L	NA	394	NA
cBOD5	mg/L	188	222	18%
TSS	mg/L	92	100	8%
Ammonia	mgN/L	29.8	30.3	2%
TP	mg/L	4.5	5.7	26%
Primary Clarifier 3 Effluent[c]				
Flow	mgd	3.7	3.7	-1%
COD	mg/L	--	545	NA
cBOD5	mg/L	317	296	-7%
TSS	mg/L	173	170	-1%
Ammonia	mgN/L	31.5	30.3	-4%
TP	mg/L	7.7	7.6	-1%
First Stage HPOAS				
MLSS	mg/L	2169	2047	-6%
MLVSS	mg/L	1906	1777	-7%
Effluent TSS	mg/L	21	34	13 mg/L
Effluent cBOD5	mg/L	16	25	9 mg/L
Effluent Ammonia	mgN/L	25.2	26.7	1.5 mg-N/L
Effluent TP	mg/L	1.3	2.0	0.7 mg-P/L
Second Stage HPOAS				
MLSS	mg/L	3108	3125	1%
MLVSS	mg/L	2657	2590	-2%
Effluent TSS	mg/L	13	10	-3 mg/L
Effluent cBOD5	mg/L		2.9	
Effluent Ammonia	mgN/L	1.3	0.1	-1.2 mg-N/L
Effluent TP	mg/L	1.1	2.1	1.0 mg-P/L
ABC Complex				
MLSS	mg/L	2759	2800	1%
MLVSS	mg/L	2262	2110	-7%
Effluent TSS	mg/L	8	10	2 mg/L
Effluent cBOD5	mg/L	3.8	3.7	-0.1 mg/L
Effluent Ammonia	mgN/L	0.16	0.2	--
Effluent Nitrate	mgN/L		14.8	NA
Effluent TP	mg/L	0.5	0.5	0. mg/L

Table 5-1. Steady State BioWin Calibration

Item	Units	Reported	Predicted	Difference
Primary Sludge				
PC 1 /2 TSS	mg/L	3.2	3.4	8%
PC 1 /2 TSS	lb/d	23,226	25,325	9%
PC1/2 VSS:TSS		80%	83%	3.5%
PC 3 TSS	mg/L	3.05	3.1	2%
PC 3 TSS	lb/d	4,204	4,285	2%
PC3 VSS:TSS		83%	86%	4%
Waste Activated Sludge				
First Stage HPOAS TSS	mg/L	6108	5660	-7%
First Stage HPOAS TSS	lb/d	14,561	13,390	-8%
Second Stage HPOAS TSS	mg/L	8,392	8,285	-1%
Second Stage HPOAS TSS	lb/d	1,823	1,665	-8%
ABC Complex TSS	mg/L	6,469	6,285	-3%
ABC Complex TSS	lb/d	5,593	5,345	-4%
Blended Sludge				
Flow	mgd		0.14	NA
TSS	% TS	4.04	4.1	1%
TSS	lb/d	46,264	47,810	3%
VSS	% VS	3.22	3.4	6%
Digester 5/6				
TSS	% TS	2.06	1.8	-13%
VSS	% VS	1.26	1.1	-13%
VSS Destruction	Percent	67	68	1%
Digested Sludge GBT				
Feed rate	mgd		0.14	
Feed TS	% TS	1.64	1.8	10%
Thickened TS	% TS	6.5	6.1	-6%
Thickened TS	lb/d	18,445	18,815	2%

a. Reported Plant Influent COD, cBOD5, and TSS concentrations = 1.15, 1.15, 1.351* reported value respectively based upon January 2018 testing.

b. Reported Primary Clarifier 1/2 effluent COD, cBOD5, TSS, and TP concentrations = 1.2, 1.2, 1.2 and 1.1* reported value respectively based upon January 2018 testing.

c. Reported Primary Clarifier 3 effluent COD, cBOD5, TSS, and TP concentrations = 1.55, 1.55, 1.55 and 1.2* reported value respectively based upon January 2018 testing.

5.2 Step 2 – Dynamic Calibration

This section presents the dynamic calibration results for both the liquid and solids stream processes. Similar to Section 3, plant reported values are shown using square icons and BioWin predicted values are shown in lines.

5.2.1 Primary Influent

Figures 5-1 through 5-5 show the primary influent predicted and reported values. The plant reported primary influent COD, cBOD5, TSS, and VSS use the same adjustment factors as applied to the plant influent. The predicted values match very well with the reported data. Primary influent TP/phosphate concentrations are higher than reported values due to the high Fe:P molar ratio allows more phosphate to be recycled back in the digested sludge GBT filtrate.

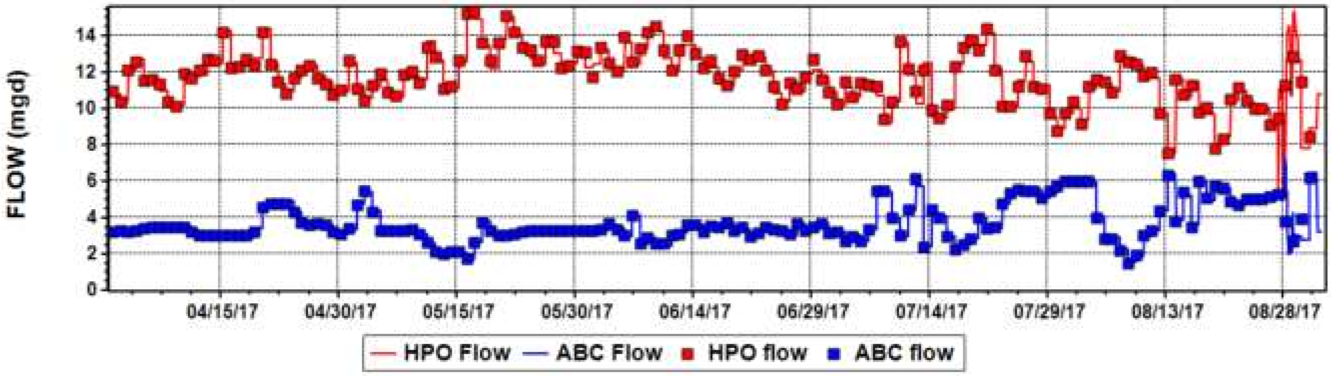

Figure 5-1. BioWin Calibration Primary Influent Flows.

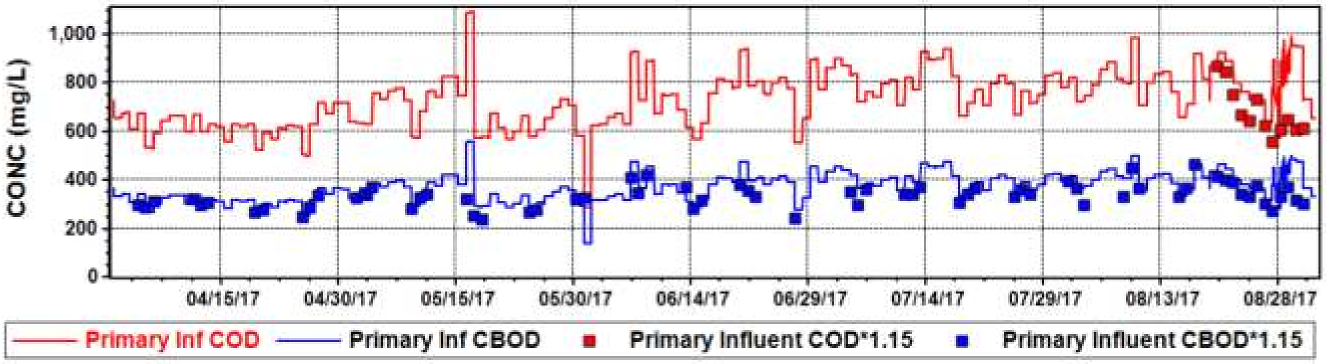

Figure 5-2. BioWin Calibration Primary Influent COD and cBOD5.

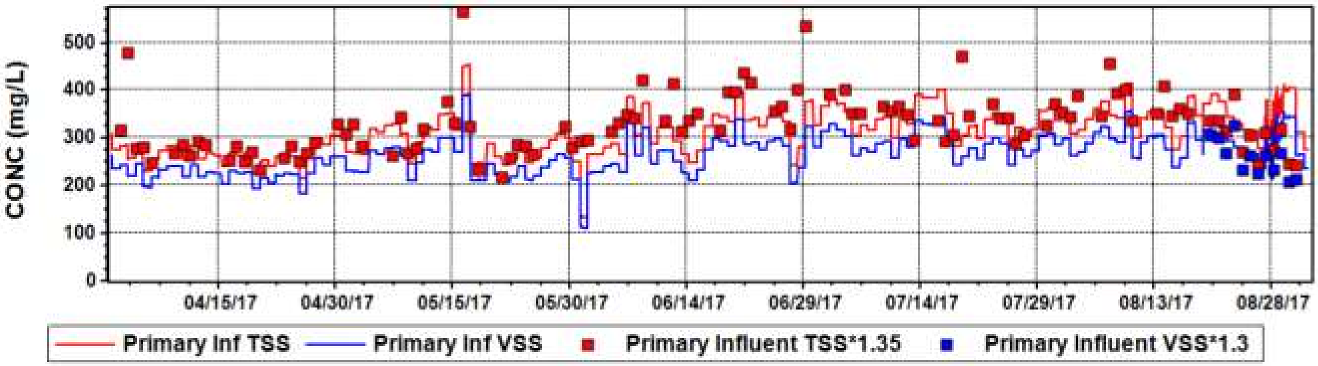

Figure 5-3. BioWin Calibration Primary Influent TSS and VSS.

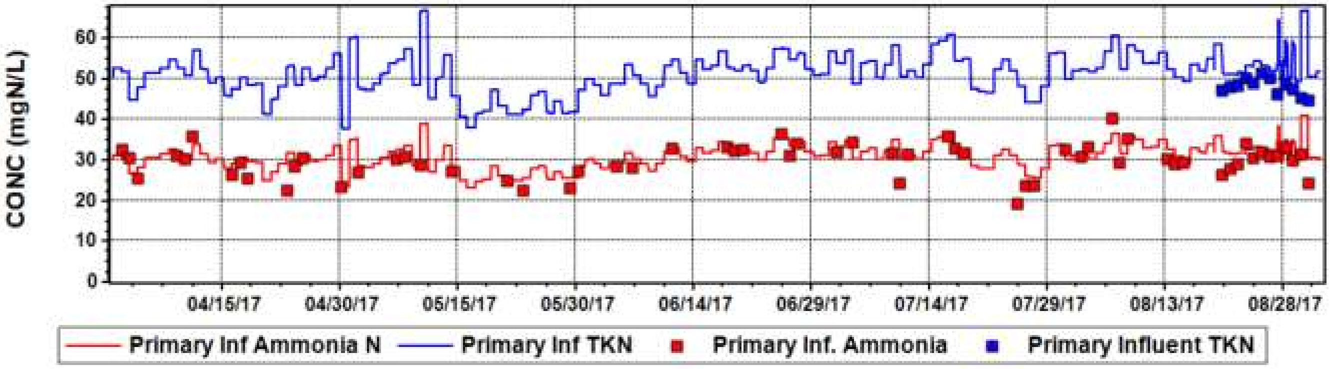

Figure 5-4. BioWin Calibration Primary Influent TKN and Ammonia.

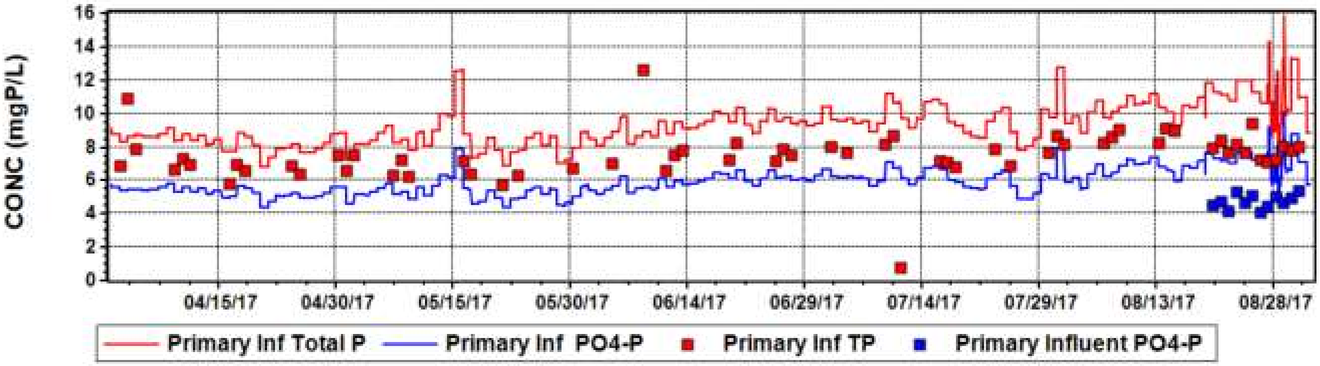

Figure 5-5. BioWin Calibration Primary Influent TP and Phosphate.

5.2.2 Primary Clarifier 1/2

Primary Clarifier 1/2 performance was modeled in a two-step process. The first step uses a model builder to convert colloidal/soluble COD to particulate COD. The second step is an ideal primary clarifier with 72.5 percent TSS removal (based upon TSS after the Step 1 model builder) and reported primary sludge flow rates. The BioWin ideal primary clarifier TSS removal rate is slightly higher than the plant reported average TSS removal of 68 percent since FeCl3 and colloidal solids are not accounted for the WRP calculations. The primary clarifier was configured with a 1-foot sludge blanket to match the average sludge blanket recorded during the calibration period. The colloidal COD conversion step (Step 1) is necessary to match the reported cBOD5 removal rates of roughly 40 to 45 percent, soluble cBOD5 removal rates of roughly 15 percent, and effluent filtered (soluble) COD as shown in Figure 5-7. Primary Clarifier 1/2 COD removal rates average 40 percent. Figure 5-8 shows the BioWin predicted plant influent and primary effluent VFA concentrations as mg COD/L. The BioWin input matches well the reported plant influent VFA concentrations. On two occasions, the VFA concentration in the primary effluent was much higher than the influent concentration. The higher VFAs could be the result of fermentation reactions in the primary clarifiers or changes in the influent VFA concentration not captured by the VFA grab samples (time offset). Simulations with the primary clarifier biological reactions in “ON” could not duplicate the increase in VFA concentration. This calibration conservatively assumes the change in VFA concentration is due to difference in plant influent VFAs rather than sludge fermentation.

Figures 5-9 and 5-10 shows the predicted effluent TSS, VSS, TKN, and ammonia match very well with reported data. Figure 5-11 shows the predicted primary effluent phosphate and TP are higher than reported for the reasons previously provided above.

Figure 5-12 shows the predicted primary sludge solids concentration and trend match very well with the plant data. This observation, along with the January 2018 plant influent and primary clarifier 1/2 effluent sampling support the use of the influent and primary effluent "adjustment factors".

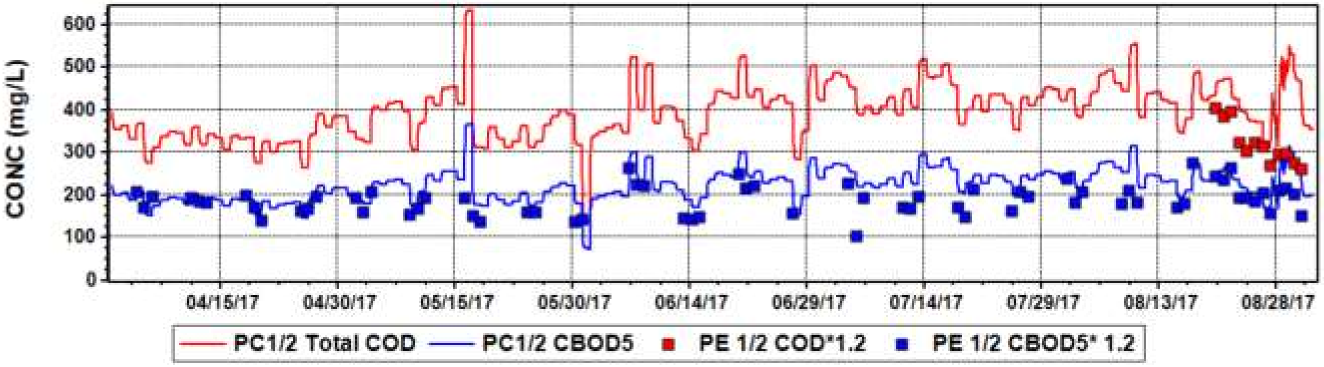

Figure 5-6. BioWin Calibration Primary Clarifier 1/2 Effluent COD and cBOD5.

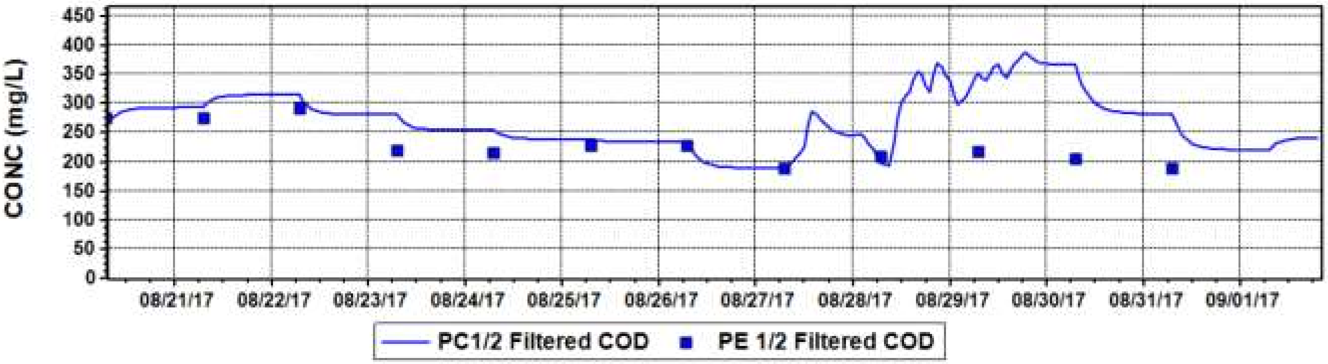

Figure 5-7. BioWin Calibration Primary Clarifier 1/2 Effluent Filtered (Soluble) COD.

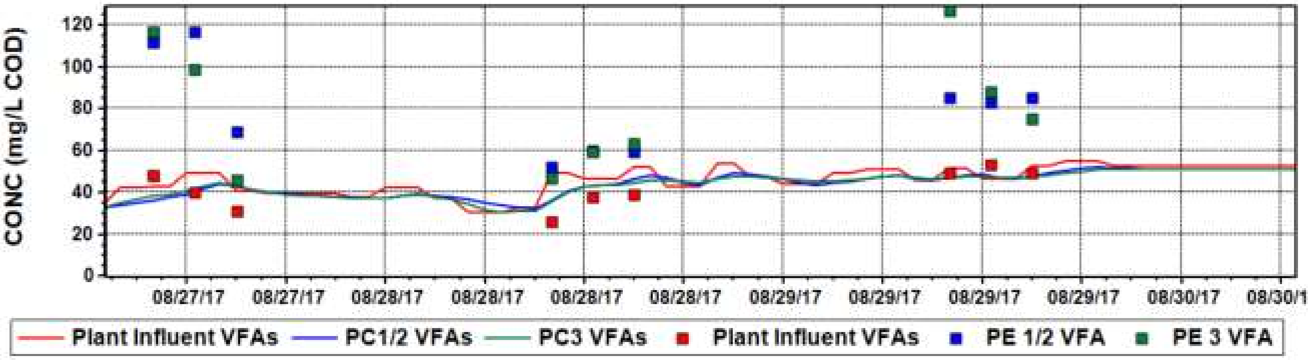

Figure 5-8. BioWin Calibration Influent and Primary Effluent Volatile Fatty Acids.

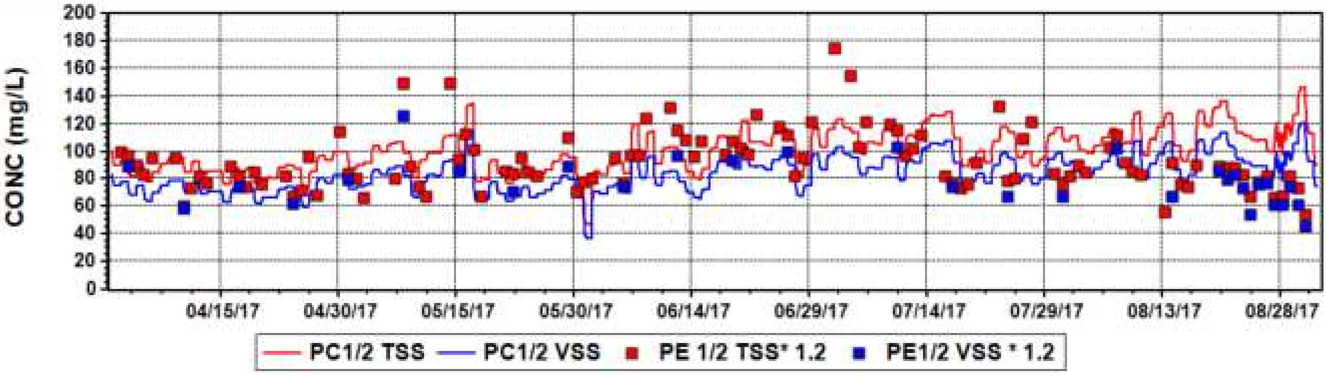

Figure 5-9. BioWin Calibration Primary Clarifier 1/2 Effluent TSS and VSS.

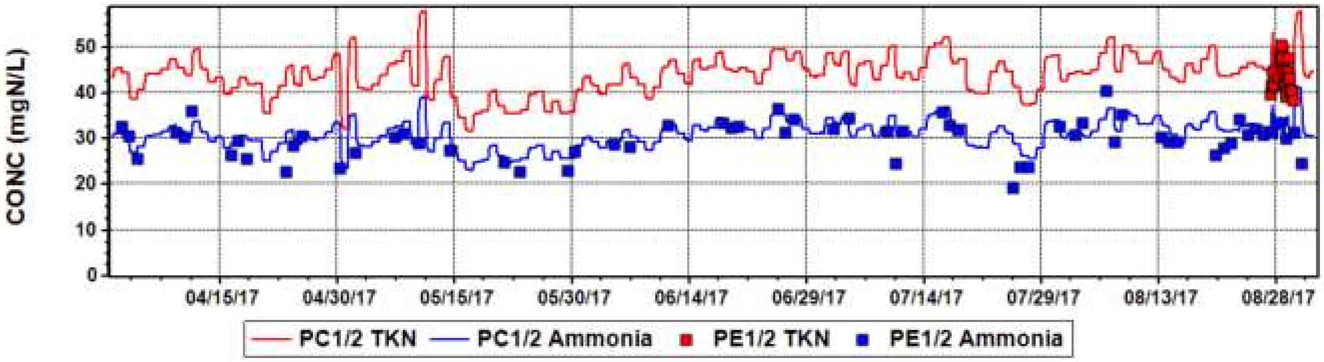

Figure 5-10. BioWin Calibration Primary Clarifier 1/2 Effluent TKN and Ammonia.

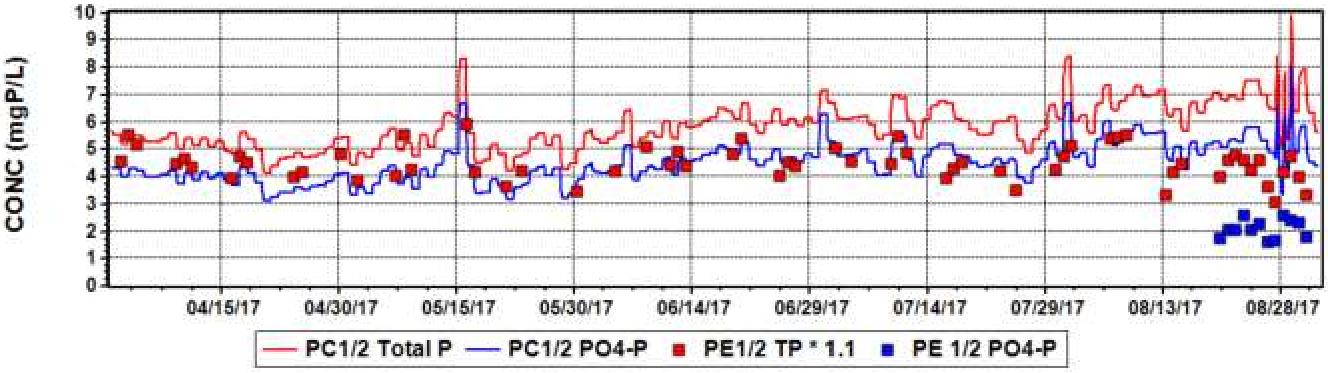

Figure 5-11. BioWin Calibration Primary Clarifier 1/2 Effluent TP and Phosphate.

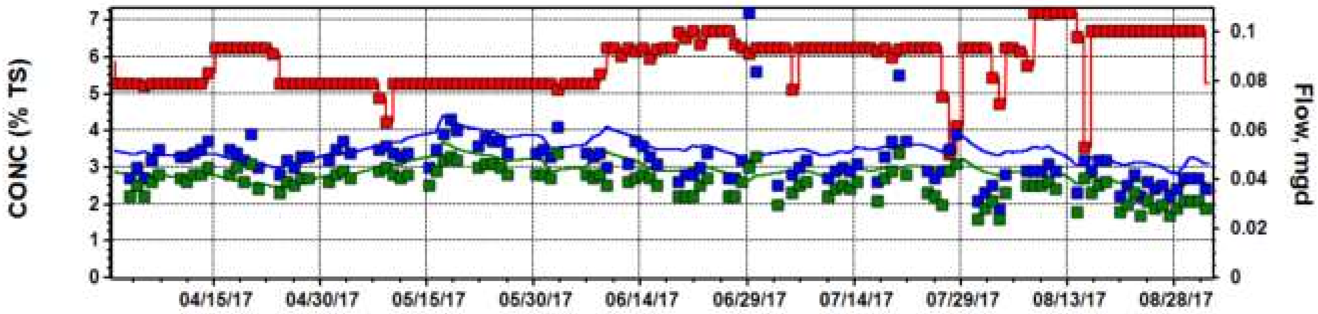

Figure 5-12. BioWin Calibration Primary Clarifier 1/2 Sludge Flows and Concentrations.

5.2.3 Primary Clarifier 3

Primary Clarifier 3 is modeled as ideal primary clarifier with 45 percent TSS removal and reported primary sludge flow rates. Predicted cBOD5 and COD removal rates averaged 25 and 20 percent respectively. The primary clarifier was configured with a 4-foot sludge blanket to match the average sludge blanket recorded during the calibration period. Figures 5-13 through 5-17 show the predicted Primary Clarifier 3 performance matched well with the reported nutrient data and adjusted TSS and cBOD5 data. The predicted Primary Clarifier 3 effluent TSS and COD were higher during the end of the calibration period because of high influent COD/TSS concentration, but overall provides a good fit.

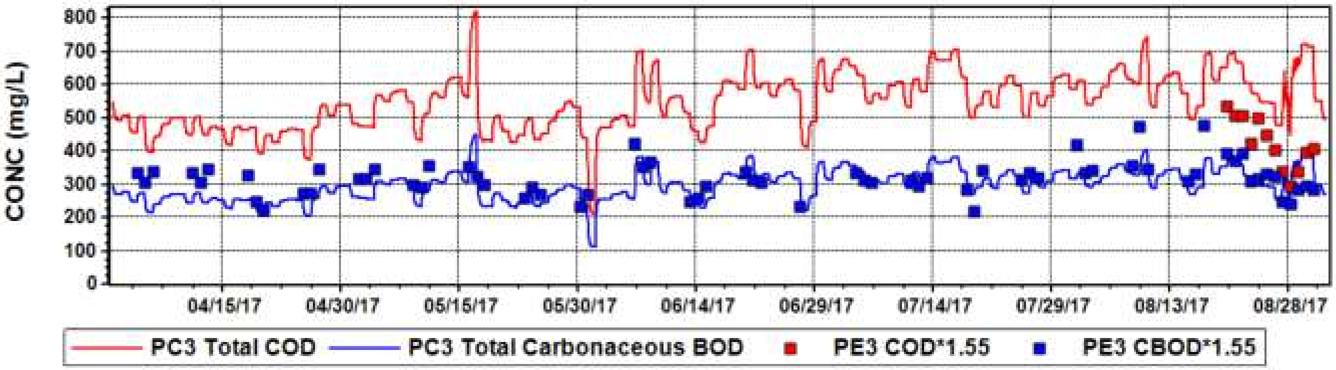

Figure 5-13. BioWin Calibration Primary Clarifier 3 Effluent COD and cBOD5.

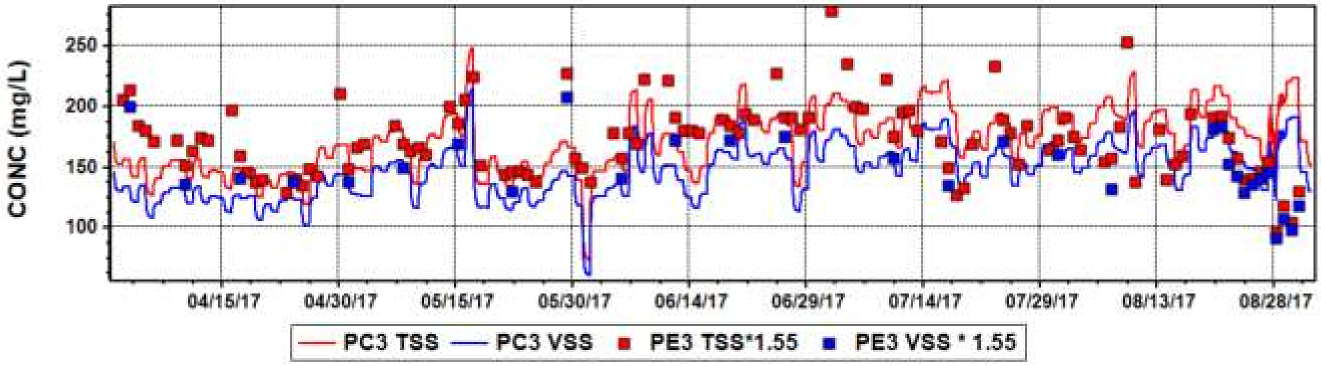

Figure 5-14. BioWin Calibration Primary Clarifier 3 Effluent TSS and VSS.

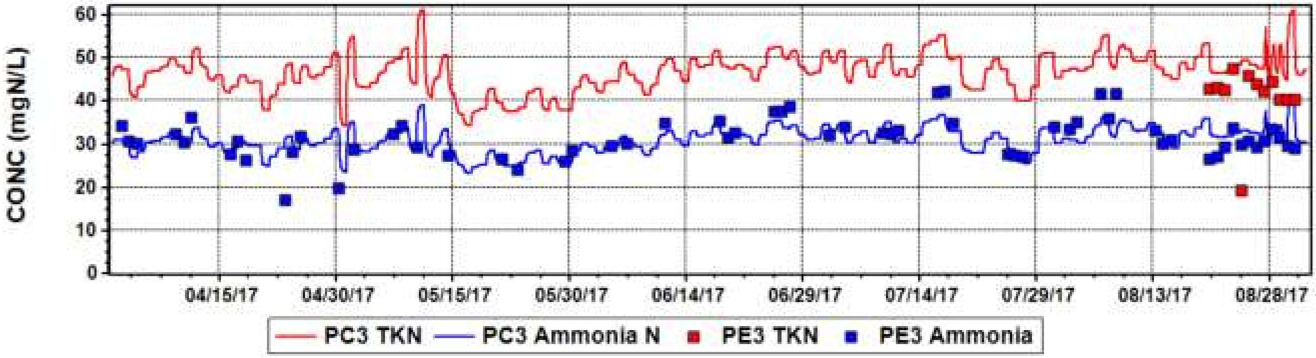

Figure 5-15. BioWin Calibration Primary Clarifier 3 Effluent TKN and Ammonia.

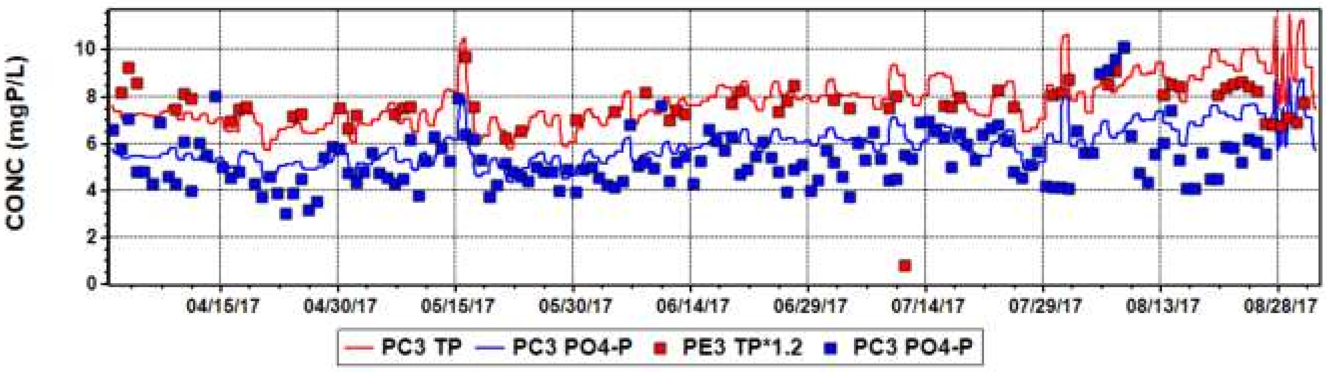

Figure 5-16. BioWin Calibration Primary Clarifier 3 Effluent TP and Phosphate.

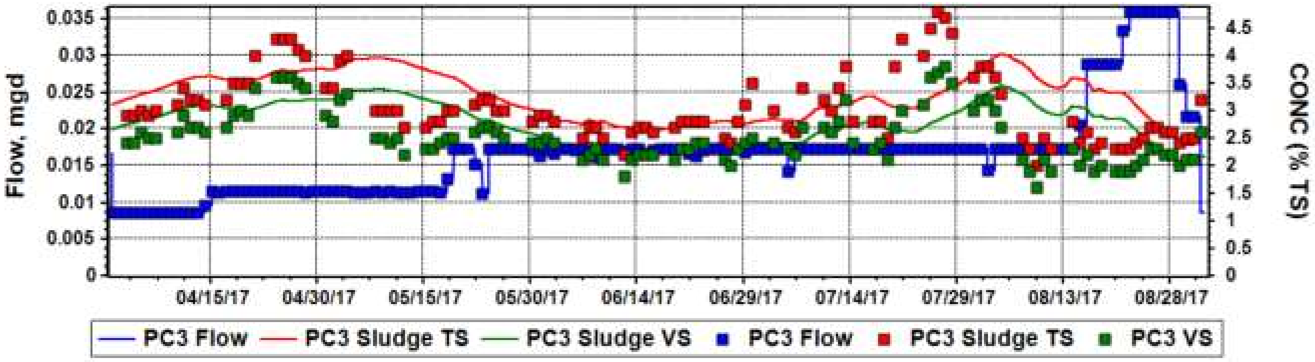

Figure 5-17. BioWin Calibration Primary Clarifier 3 Sludge Flows and Concentrations.

5.2.4 ABC Aeration Basins

The ABC activated sludge calibration focused on matching the mixed liquor suspended solids (MLSS), MLVSS, total airflow, and nutrient profiles. Figure 5-18 shows the predicted MLSS matches very well with the reported average MLSS and the predicted MLVSS:MLSS is slightly lower than reported for ABC Basin 3. The predicted total airflow in Figure 5-19 also matches the reported values very well using the oxygen transfer coefficients presented in Technical Memorandum Aeration Basin Off Gas Testing (BC, 2017b). Figures 5-20 show six phosphate profiles over a three-day period. Nutrient profiles were collected in the morning and afternoon of each test day. In general, the model predicted phosphate (P) release is higher than measured with slower P uptake in the aerated zones. The difference in profile can be associated with several factors including slightly higher phosphate levels in the Primary Clarifier 3 effluent, alum addition to ABC during this period, and sampling location differing from modeled location. In general, the model shows a good release and uptake by the end of the aerated zones and is considered calibrated for facility evaluation.

Predicted ammonia and nitrate/nitrite profiles in Figures 5-21 and 5-22 match well with reported data with some slight differences depending upon the downstream aerated sampling locations. It should be noted the nitrification rate kinetics measured in the nitrification rate tests (BC, 2017a) are used in the BioWin simulations. Plant staff have noted that inhibition observed during the sampling event does not always occur at the plant. The City should continue to investigate potential causes of the periodic reduced nitrification rates such as influent toxic loadings.

Parameter	Units	Model Default	BioWin Calibration
AOB maximum specific growth rate	1/d	0.9	0.7
NOB Maximum specific growth rate	1/d	0.7	0.65

Figure 5-18. BioWin Calibration ABC MLSS and MLVSS:MLSS.

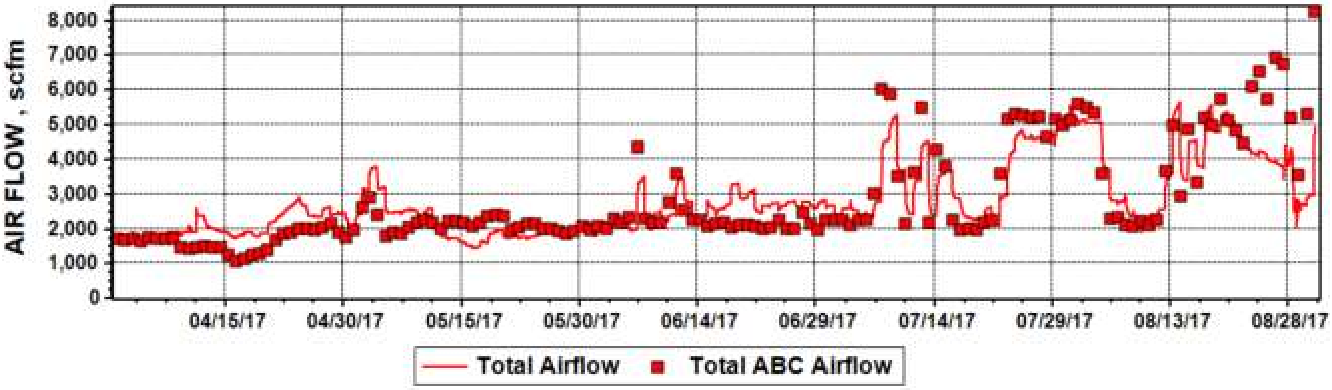

Figure 5-19. BioWin Calibration ABC Total Airflow.

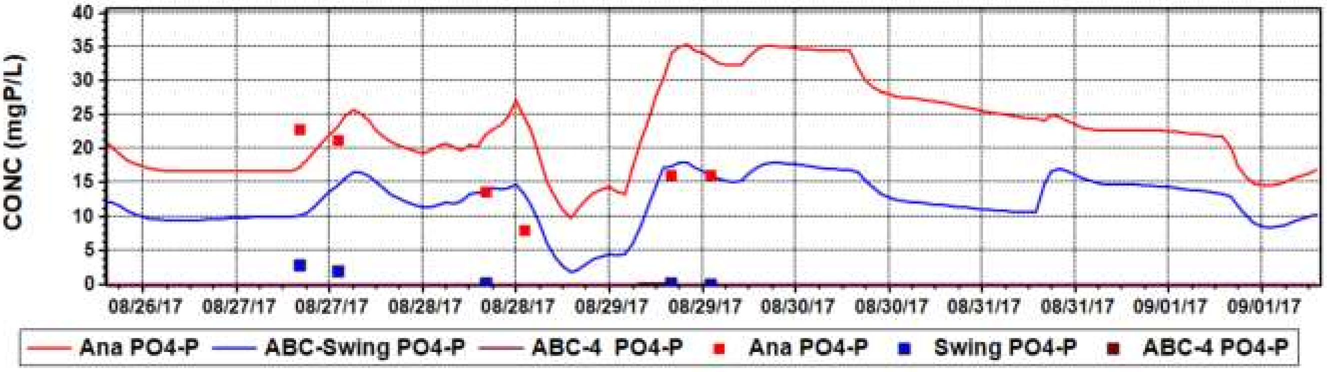

Figure 5-20. BioWin Calibration ABC Phosphate Profile.

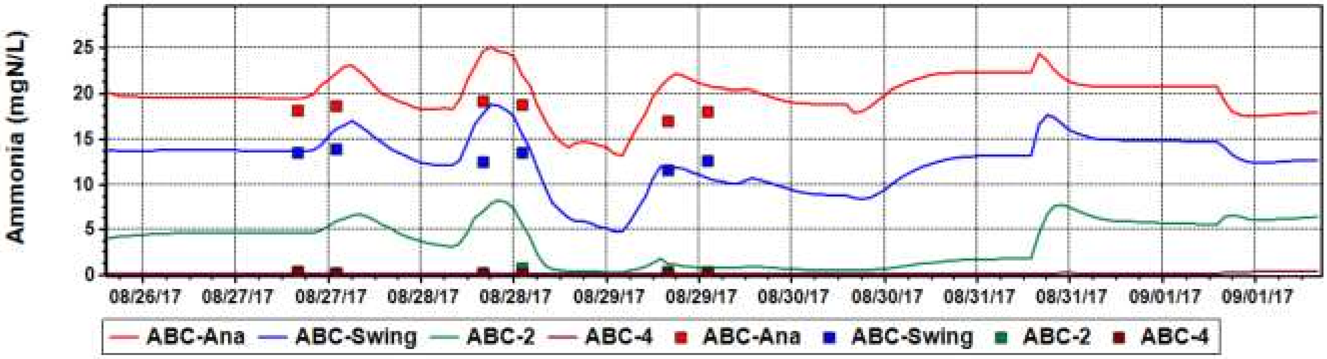

Figure 5-21. BioWin Calibration ABC Ammonia Profile.

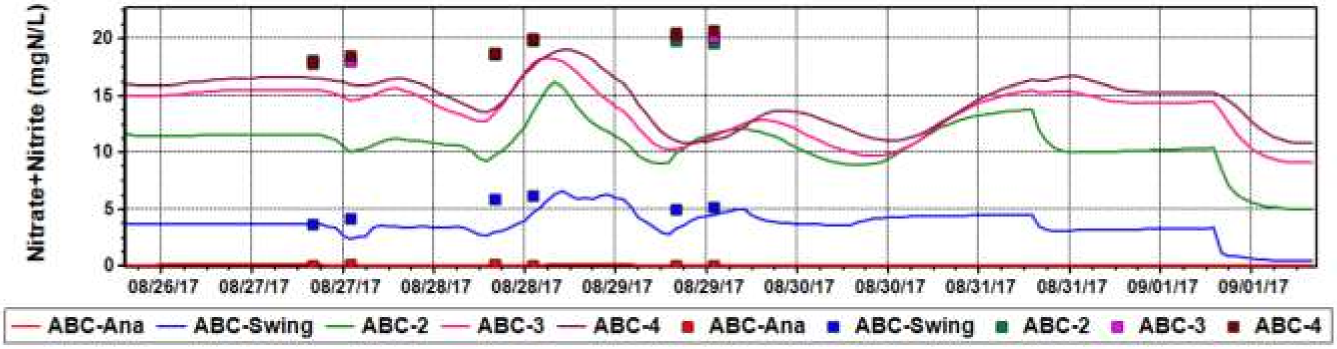

Figure 5-22. BioWin Calibration ABC Nitrate+Nitrite Profile.

5.2.5 ABC Secondary Clarifier 5

Figure 5-23 shows predicted effluent TSS concentrations match well with measured values using a TSS removal efficiency of 99.8 percent. Figure 5-24 shows the predicted cBOD5 also match well with the measured values. Figure 5-25 shows the predicted effluent ammonia matches well with reported data except for a 3-day period in mid-April when high flows were observed at cold temperatures. During this period the influent TKN loadings were estimated. To match the measured effluent TKN concentration in August, the influent soluble non-biodegradable TKN ratio was increased from 0.02 to 0.04. The predicted effluent nitrate+nitrite (NOx) trends with the calibration period data from ABC Basin 3 effluent with slightly lower NOX predicted during the August 2017 sampling period. Figure 5-28 shows the predicted TP and phosphate match the reported values very well except for the 3-week period the plant observed high phosphate concentrations which could have been associated with a sludge bulking event immediately prior to the high effluent phosphorus period. Figure 5-29 shows the predicted RAS concentrations matches very well with the reported data.

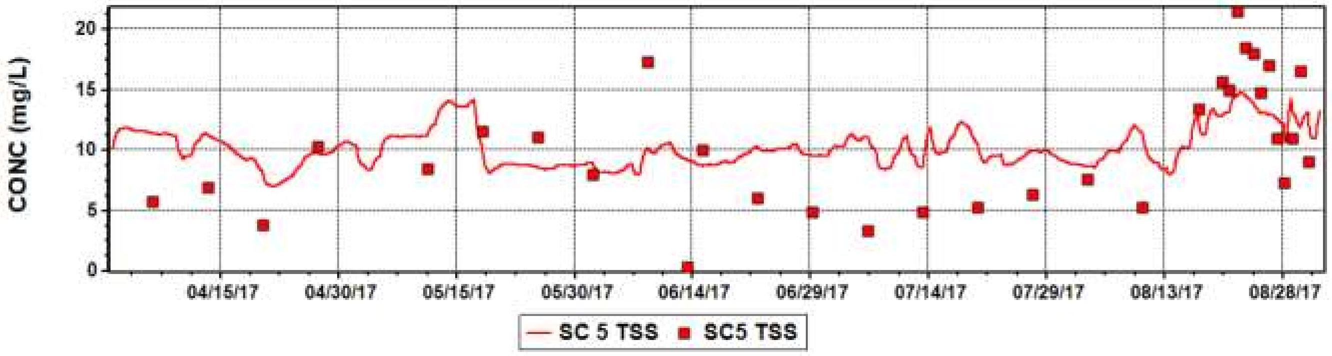

Figure 5-23. BioWin Calibration Secondary Clarifier 5 Effluent TSS.

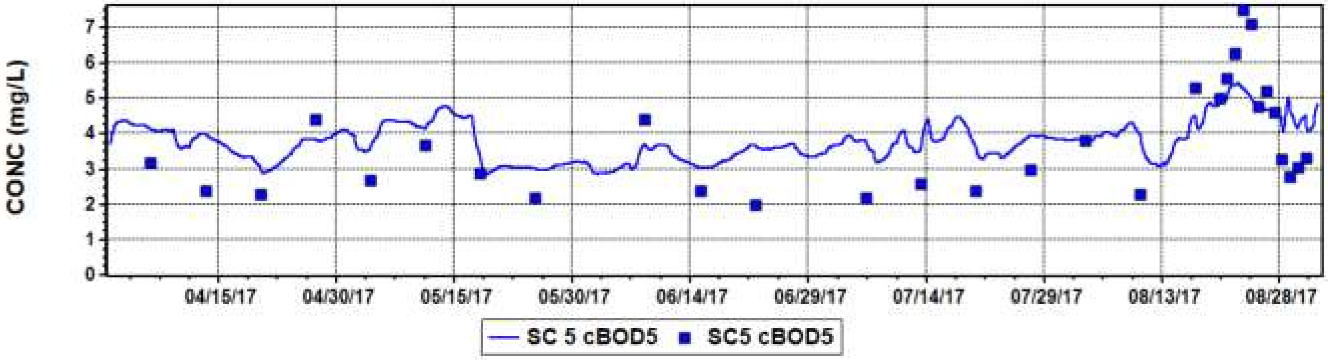

Figure 5-24. BioWin Calibration Secondary Clarifier 5 Effluent cBOD5.

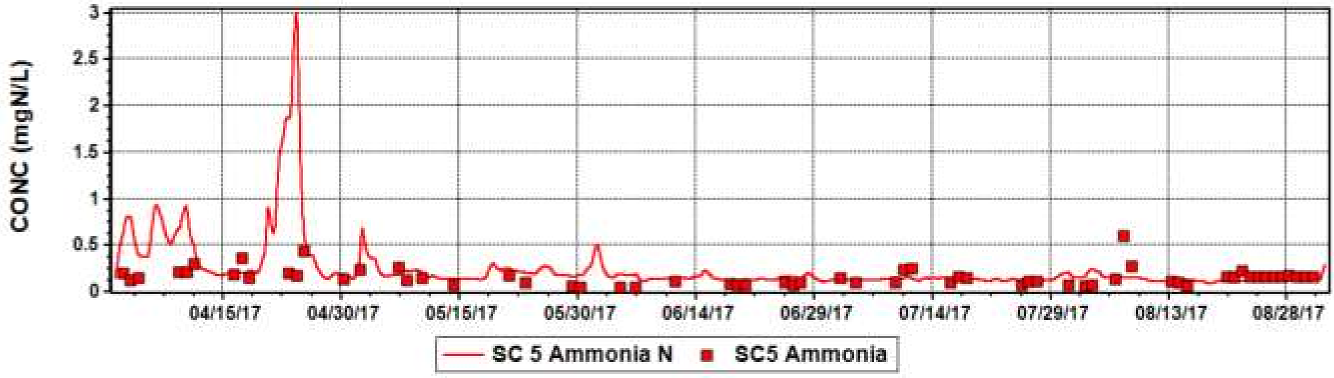

Figure 5-25. BioWin Calibration Secondary Clarifier 5 Ammonia.

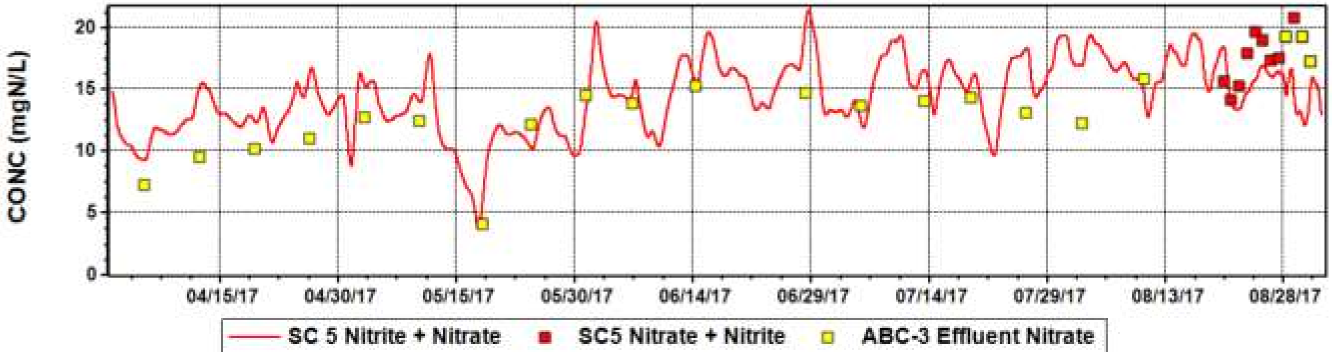

Figure 5-26. BioWin Calibration Secondary Clarifier 5 Nitrate + Nitrite.

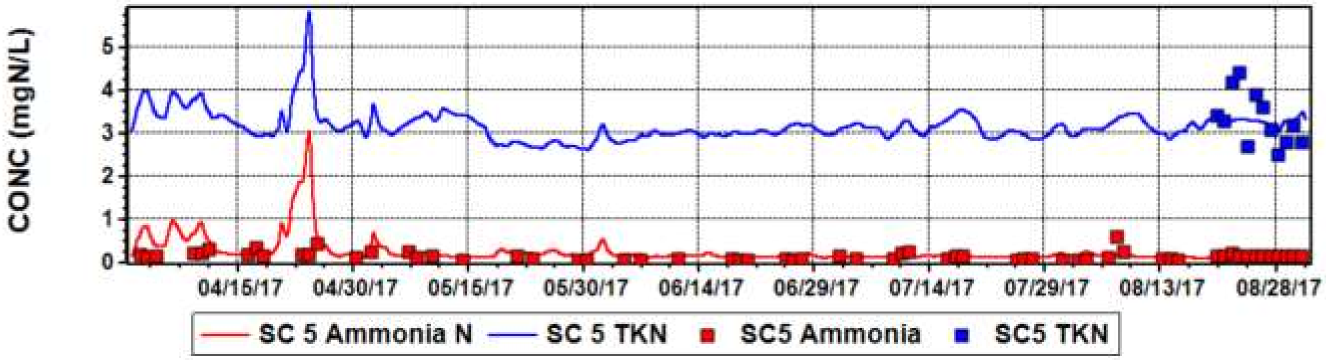

Figure 5-27. BioWin Calibration Secondary Clarifier 5 TKN.

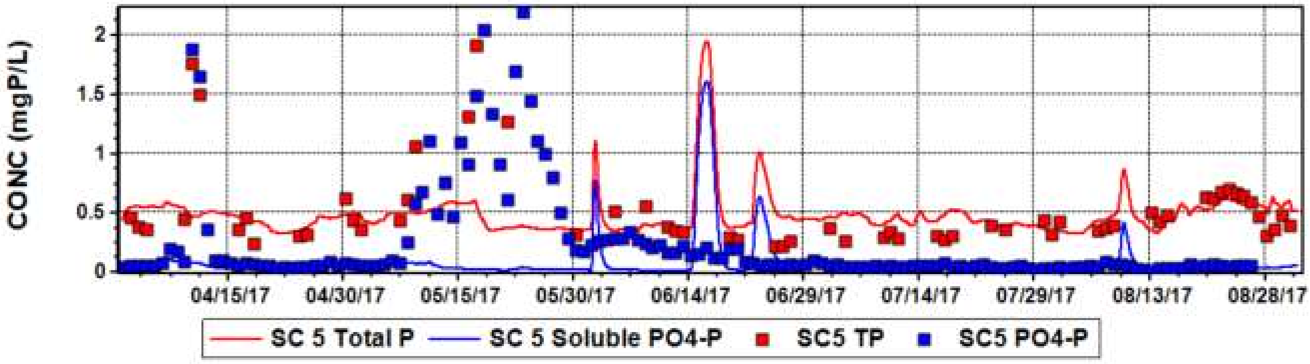

Figure 5-28. BioWin Calibration Secondary Clarifier 5 Phosphorus.

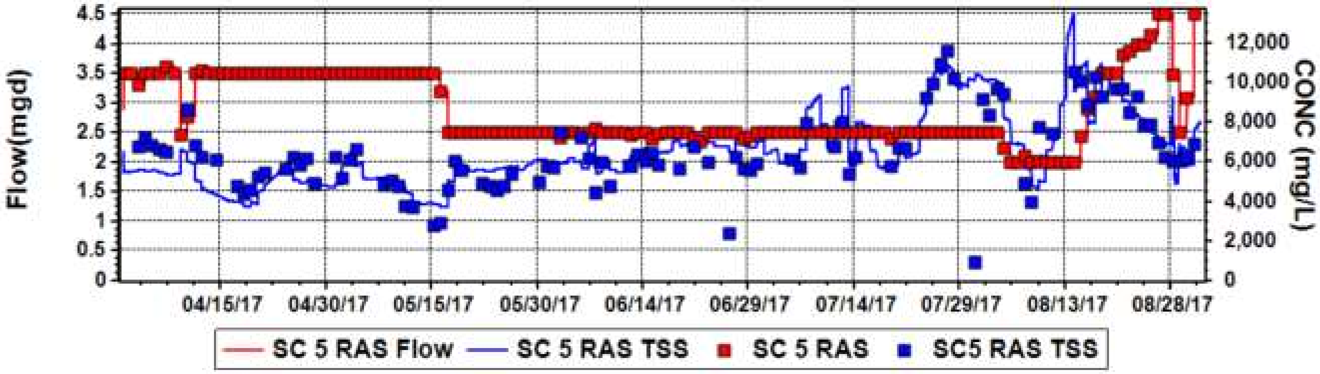

Figure 5-29. BioWin Calibration Secondary Clarifier 5 Return Sludge Flow and TSS.

5.2.6 1st Stage HPOAS

The 1st Stage HPOAS system was evaluated using two biological process simulators: BioWin whole plant simulator and HiPure. BioWin is used to model the whole plant including the reactor biological reactions (carbonaceous BOD removal, nitrification, and fate of nutrients) and solids generation (mixed liquor, return sludge, and waste sludge). BioWin is limited in modeling High Purity Oxygen (HPO) systems as reactor element limits the maximum reactor DO to 14 mg/L and does not model the gas and liquid phase transfer in the tank headspace. HiPure, developed by Dr. Michael Stenstrom of the University of California in Los Angeles, models the oxygen transfer by simulating the kinetics of gas transfer in the reactor headspace, both for oxygen into solution and for carbon dioxide and water vapor that are stripped from solution in concert with the reaction kinetics of the biomass in the mixed liquor. Unlike BioWin, HiPure can predict the gas partial pressure in each stage, enabling the user to predict plant capacity limits that might result from oxygen transfer limitations and evaluate how the load may be distributed within the plant to maximize the utilization of the transfer devices. Consequently, the simulators are complementary with respect to the information that may be gained from them.

5.2.6.1 BioWin 1st Stage HPOAS Analysis.

Figures 5-30 and 5-31 show the measured and predicted MLSS, MLVSS, and intermediate clarifier effluent TSS concentrations match very well with reported values. To match the intermediate clarifier effluent TSS, the clarifier TSS removal performance had to be adjusted on a daily basis to best match the effluent TSS, especially in August when a combination of poor sludge quality and a clarifier collector leaking seal resulted in effluent TSS concentrations of 100 mg/L or higher. The high effluent TSS also caused high effluent cBOD5 concentrations observed in Figure 5-32. The plant cBOD5 values shown for August 21-23, and 25th were identified to be "greater than reported" and not considered representative. Figure 5-33 compares the predicted intermediate clarifier effluent COD concentrations with reported values from the August 2017 wastewater sampling period. The model predicted COD follows the general trend of the overall COD data, is slightly conservative to the overall data set, and is considered more representative than the cBOD5 data. Figure 5-34 and 5-35 show the predicted nitrogen discharges match the reported data very well since no nitrification is occurring and effluent phosphorus concentrations are slightly greater than reported due to the high Primary clarifier 1/2 effluent phosphorus concentrations (Fe:P molar ratio assumption used). Figure 5-36 shows the predicted intermediate clarifier return sludge TSS concentration matches well with the reported values, even with concerns of a leaking collector seal.

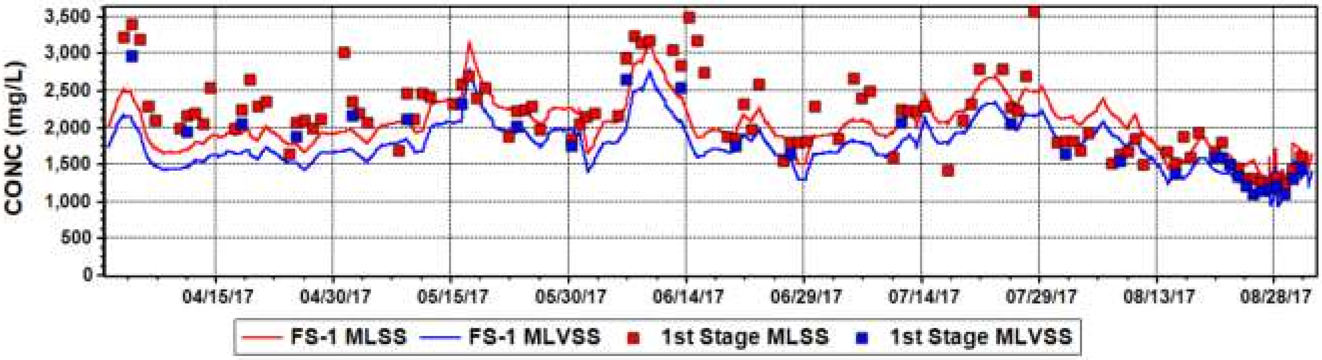

Figure 5-30. BioWin Calibration 1st Stage HPOAS MLSS and MLVSS.

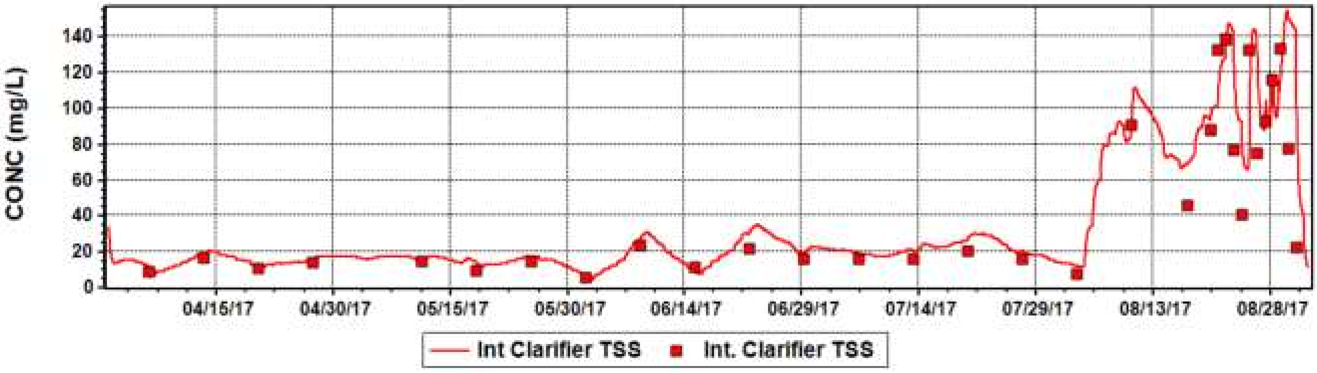

Figure 5-31. BioWin Calibration 1st Stage HPOAS Effluent TSS.

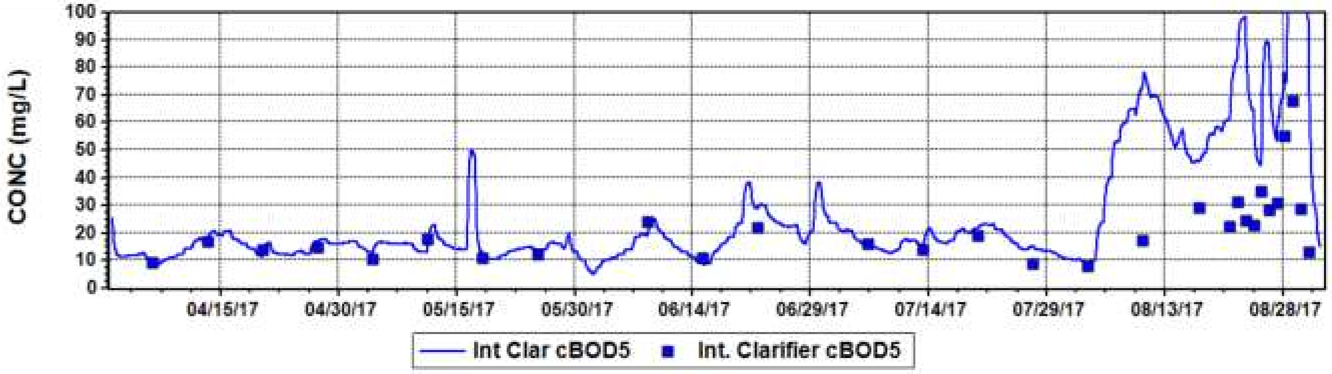

Figure 5-32. BioWin Calibration 1st Stage HPOAS Effluent cBOD5.

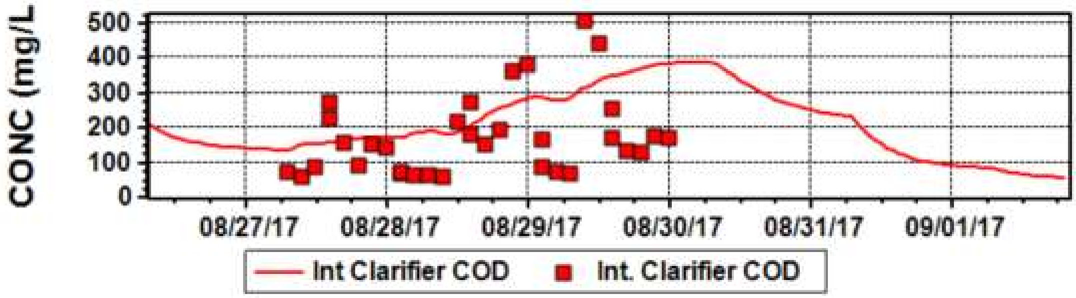

Figure 5-33. BioWin Calibration 1st Stage HPOAS Effluent COD.

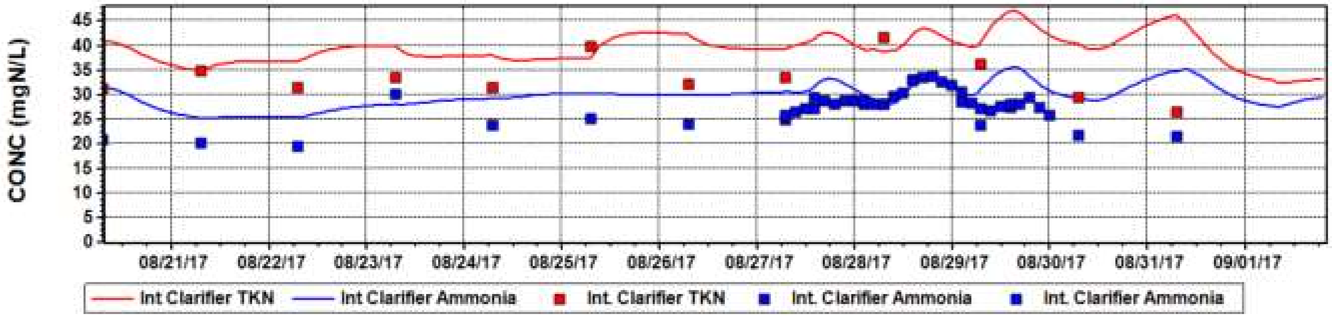

Figure 5-34. BioWin Calibration 1st Stage HPOAS Effluent Nitrogen.

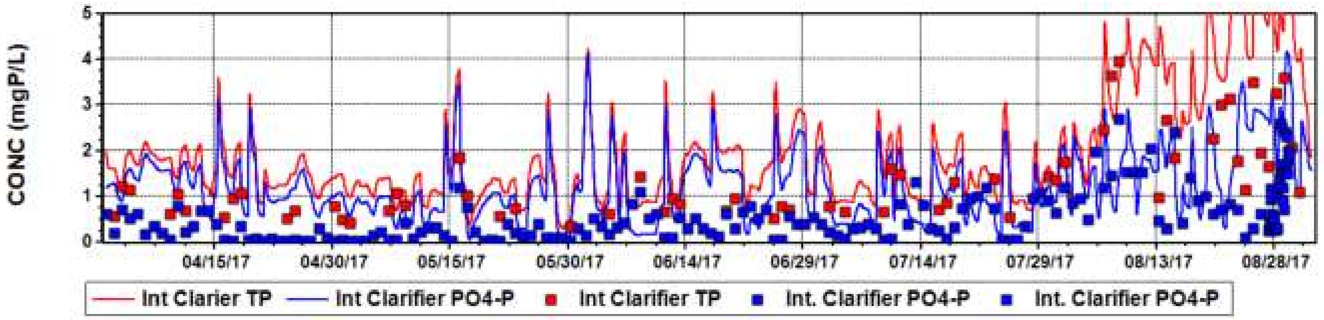

Figure 5-35. BioWin Calibration 1st Stage HPOAS Effluent Phosphorus.

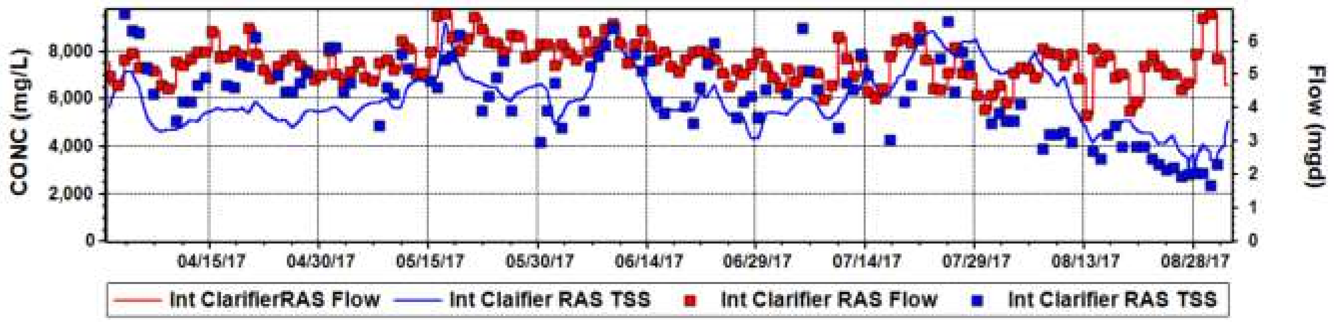

Figure 5-36. BioWin Calibration 1st Stage HPOAS Clarifier Return Sludge Flow and TSS.

5.2.6.2 HiPure Oxygen Transfer Analysis.

The HiPure activated sludge model can predict HPOAS system oxygen, nitrogen and carbon dioxide head space gas purities and dissolved liquid stream concentrations making it ideal for determining the aeration capacity of the 1st Stage reactors. To calibrate the HiPure model, oxygen transfer field testing on the 1st Stage reactors was conducted starting on August 28 and ending on August 30, 2017. Field measurements were made every four to eight hours on parameters specific to the calibration of the HiPure simulator including the Train 1 mixed liquor DO concentrations and head space oxygen purity for all three stages and vent gas flow. In addition, daily and discrete samples of the 1st Stage influent, MLSS, RAS, and TSS, and effluent were collected at 2-hour intervals to define the reactor loadings. Table 5-2 summarizes the 1st Stage reactor average DO and head space oxygen purity measured during testing. Attachment D contains the 1st Stage field testing data.

Table 5-2. 1st Stage HPOAS field testing average dissolved oxygen and head space oxygen purity.

	Day 1 – Average (Range)		Day 2 Average (Range)	
	DO	Head Space Oxygen	DO	Head Space Oxygen
Reactor Stage	mg/L	Percent O_2	mg/L	Percent O_2
1	15 (11-19)	69 (63 to 77)	11.5 (9.7–12.8)	55 (48 – 58)
2	>17 (12.7to >20)	62 (52 to 72)	11.3 (8.9 – 14.2)	41 (37 – 48)
3	>16 (12.4 to >20)	58 (41 to 70)	10.5 (7.4 – 15.1)	33 (25-44)

Day 1 sampling occurred on August 28 10:30 am through 8:30 am on August 29, 2018.
Day 2 sampling occurred on August 29 11:45 am through 8:45 am on August 30, 2018.

When performing HPO oxygen transfer evaluations, the vent gas purity and vent gas flow rate are routinely measured. Vent gas oxygen purity should equal the Stage 3 oxygen purity which was generally true during testing. Gas flow though the vent gas control system occurs because the reactor stages are under slight positive pressure, usually two to three inches of water column. During evening measurements there were occasions when the Stage 3 pressure would drop below atmospheric meaning that no gas sample could be collected. This is typical of systems with leaky tanks or operation without pressure control. When the HPO oxygen generation system is set at constant flow rate, it means that oxygen flow is usually too low during high loading periods and too high during low loading periods. Based upon measured diurnal loadings, the periods in which vent gas could not be measured occurred at both high and low loadings suggesting excessive leakage of HPO gas from the reactor. Excessive reactor gas leakage makes it very difficult if not impossible to obtain a pressure feedback signal for control. Hence, the cryogenic oxygen plant is operated at high rate to provide a margin of safety.

To understand the reasons for low reactor gas pressure, several observations were made. A Teledyne 320 oxygen probe was used detect leakage at cracks as the meter responds quickly to oxygen content. By holding the probe next to a suspected leak, the probe's meter will quickly indicate more than 21% oxygen where leaks occur. The probe was used in numerous points around Stages 1 and 2 reactors. Several leaking joints were found. The joints that had been patched previous by the plant staff were tested and generally found to be not leaking. A leakage inspection of the Stage 1 reactor near the end of HPO testing was conducted. There is a lot of piping around this part of the reactor, which includes piping for HPO gas entry, a pressure sampling port, the ventilators to exhaust the reactors in the case of hydrocarbon detection, and a pressure relief valve. A leak caused by corrosion was found on a ¾-inch galvanized pipe cap with gas flowing from the cap/line. The cap was replaced and the leak plugged. The large lines connecting the ventilation blowers to the tank were not leaking.

During the first day of testing, the 1st Stage reactors operated at high DO concentrations and elevated headspace oxygen purity. Typical HPO plants operate with approximately 40% oxygen purity in the last reactor stage. However, during field testing, the Stage 3 oxygen purities were more than 60% on the first day. The high operating DOs and Stage 3 oxygen purity means that the oxygen utilization is low and the HPO gas flow rate could be decreased. Typical HPO oxygen utilizations are 85 to 90 percent of the supplied HPO oxygen mass. It is estimated only 44 percent of the supplied oxygen mass was being utilized during the first day of testing. As a result, the HPOAS train loading on the second day was increased reducing the average DO and head space levels to more typical values. Unfortunately, headspace purity could not be consistently measured during this period, so the HiPure calibration focused on the DO and oxygen purity field data collected on the first day of testing.

The HiPure model was calibrated to the average value of the August 2017 wastewater characterization data as shown in Table 5-3. The average influent COD, cBOD5, TSS, and VSS concentrations represent the "adjusted" values as used in the BioWin calibration. It should be noted that during this time the plant was experiencing filamentous bulking. To calibrate the HiPure simulator, alpha factors of 0.8 and 0.70 were used for Stage 1 and the subsequent two stages, respectively, where alpha is the ratio of oxygen transfer in process water to that in clean water. Alpha values are affected by the nature of the wastewater as well as the device used to transfer oxygen. These values are a little lower than typical (0.8 to 0.9) which was attributed to the lower power density in the reactor stages. For example, the WRP power densities of 2.3, 1.5 and 1.5 hp/1000ft^3 in stages 1, 2 and 3 are much less than other plants having power densities as high as 3.0 hp/1000ft^3.

Table 5-3 summarizes HiPure simulator results that are pertinent to the 1st Stage HPOAS reactor calibration. The agreement between measured and predicted values of the parameters in Table 5-3 is very close. Given the difficulties in obtaining accurate stage purity and vent gas flow rates due to leakage, this is good closure for the HiPure model calibration.

Table 5-3. HiPure Steady State Calibration Results

Item	Units	Reported	Predicted
1st Stage HPOAS Influent			
Flow	mgd	9.4	9.4
COD	mg/L	388	input
cBOD5	mg/L	205	input
TSS	mg/L	76	input
VSS	mg/L	69	input
1st Stage HPOAS			
MLSS	mg/L	1,435	1,518
MLVSS	mg/L	1,316	1,373
pH	S.U.	6.5	6.3
SRT	days	0.6	input
RAS TSS	mg/L	3,142	3,331
WAS	mgd	0.22	0.2
WAS[1]	lb VSS/d	11,825	11.813
Oxygen Transfer Components			
O2 Flow	SCFM	156	154
HPO Gas Feed Rate	Tons/d	8.4	8.3
Reactor 1 DO	mg/L	13.5	12.1
Reactor 2 DO	mg/L	15.6	10.9
Reactor 3 DO	mg/L	12.9	10.3
Reactor 1 O2 Purity	%	65	68
Reactor 2 O2 Purity	%	57	59
Reactor 3 O2 Purity	%	54	50
Utilization	%	--	74
Effluent			
COD	mg/L	67	54

[1] Includes effluent TSS

All the mixer motors during testing were operating at reduced power draw. The aerators horse powers, if reduced by the ratio of amperage draw to name plate amperage were 48, 29 and 29 compared to 60, 40 and 40 name plate horsepower. Motor amperage was measured at both low and high flow rates to determine if water level might change power draw. There was no significant difference between power draw at low and high flow rates. The types of impellers used at the WRP are called "Pitch Bladed Turbines" or PBT. Lightnin's model number for this type of propeller is A200 and it is the most common type of impeller used in HPOAS plants. It has a nominal Standard Aeration Efficiency (SAE) of 2.8 lbsO2/hp-hr and the benefit of being relatively insensitive to liquid level. It is also inexpensive to manufacture. If oxygen transfer becomes an issue at the plant, the propeller submergence can be adjusted to increase power draw or a different, new model impeller with a higher SAE, such as Lightnin's R335, could be used.

5.2.7 2nd Stage HPOAS

Figures 5-37 and 5-38 show the measured and predicted MLSS, MLVSS, and Secondary Clarifier 1-4 effluent TSS concentrations. The predicted MLSS and MLVSS follow the general trend of the reported data but do not match it directly. The 2nd Stage MLSS is very sensitive to the influent organic load and effluent TSS. Small differences in loadings or effluent TSS can greatly impact the predicted MLSS/MLVSS value. Given the Primary Effluent 1/2 flow routed directly to the 2nd Stage system was estimated for the first 100 days of the 152-day itinerary, the focus of the 2nd stage MLSS calibration was to match the general trend of the data during the last 52 days (starting July 7th) which it does well. The increase in MLSS at the end of the simulation can be attributed to the predicted low effluent TSS concentration which resulted in less solids being wasted from the system.

Figure 5-39 shows the predicted ammonia matches the reported values well using the updated nitrification kinetics except during periods of plant upset in July and late August. Figure 5-40 shows some response in effluent nitrate due to less nitrification/nitrogen loadings but does not match the inhibitory effect observed at the plant. As noted above, the City should continue to work with industry to define whether something is being added to the system which inhibits nitrification and whether low phosphate levels could be limiting nitrification.

Figure 5-41 shows the predicted effluent phosphorus concentrations are greater than reported due to high phosphate concentrations resulting from the Fe:P molar ratio assumption used (and less effective Me dose per BW). Figure 5-42 shows the predicted Secondary Clarifier 1-4 return sludge TSS concentration and flow. The BioWin RAS flow was increased by 15 percent based upon clarifier draw-down testing.

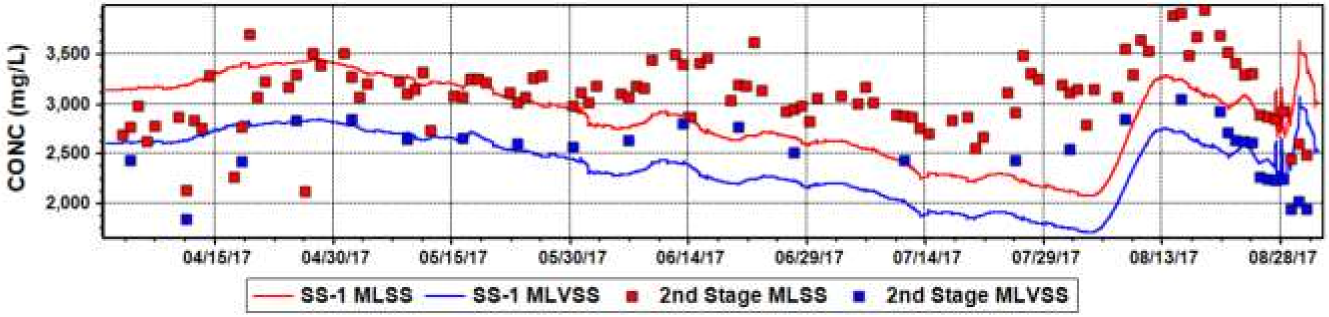

Figure 5-37. BioWin Calibration 2nd Stage HPOAS MLSS and MLVSS.

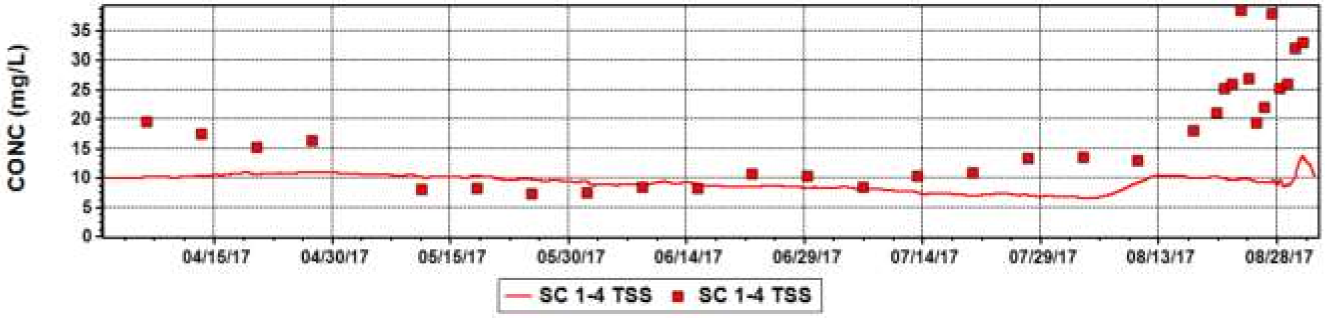

Figure 5-38. BioWin Calibration Secondary Clarifier 1-4 Effluent TSS.

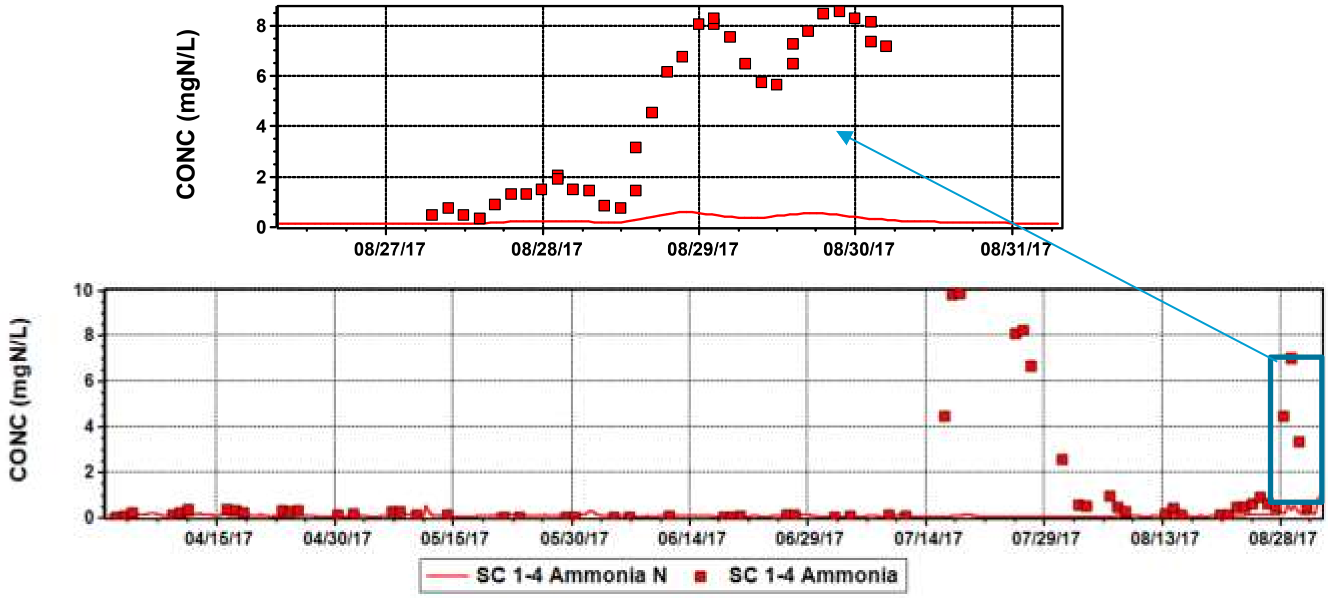

Figure 5-39 BioWin Calibration Secondary Clarifier 1-4 Effluent Ammonia.

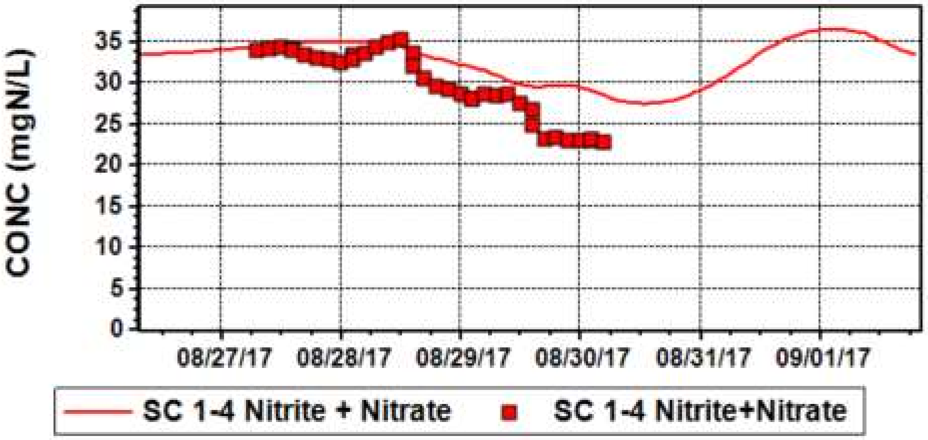

Figure 5-40 BioWin Calibration Secondary Clarifier 1-4 Effluent Nitrate+Nitrite (NOx).

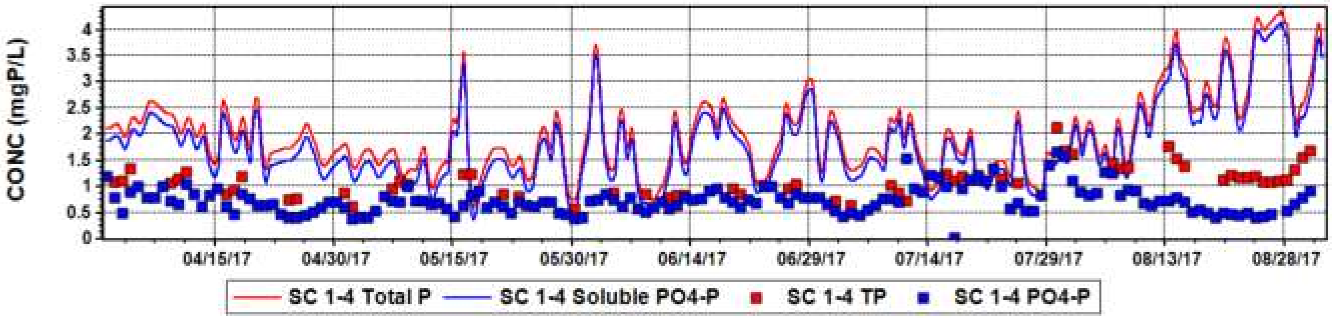

Figure 5-41. BioWin Calibration Secondary Clarifier 1-4 Effluent Phosphorus.

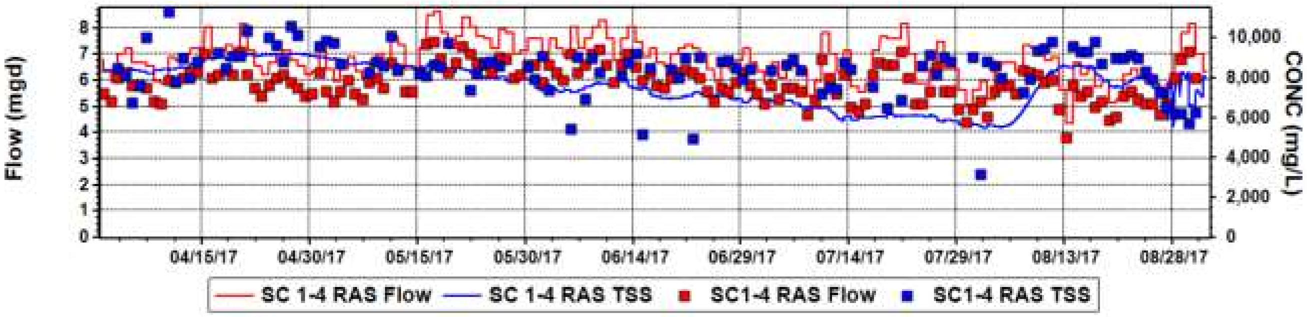

Figure 5-42. BioWin Calibration 2nd Stage HPOAS Clarifier Return Sludge Flow and TSS.

5.2.8 Plant Effluent

The chlorine contact tanks were not modeled in the calibration. Data shows the combined effluent TSS can decrease by 1 to 4 mg/L depending upon the effluent quality from the secondary clarifiers.

5.2.9 Waste Activated Sludge (WAS) Gravity Belt Thickeners

Figures 5-43 and 5-44 show the predicted and measured WAS GBT feed flows and solids after combining all waste sludge in the Sludge Holding Tank match very well. Thickened sludge flow rate and TS (TWAS) matches well using a solids capture of 89 percent and underflow rate of 7 percent of the influent feed rate as shown in Figure 5-45. The influent feed rate includes 70 gpm of belt wash water. Figures 5-46 through 5-49 show the measured and predicted GBT filtrate parameter correlate very well. Figure 5-49 shows there is some phosphate release occurring in the WAS Holding Tank (1 to 2 hour detention time) as phosphate is increasing across the GBT.

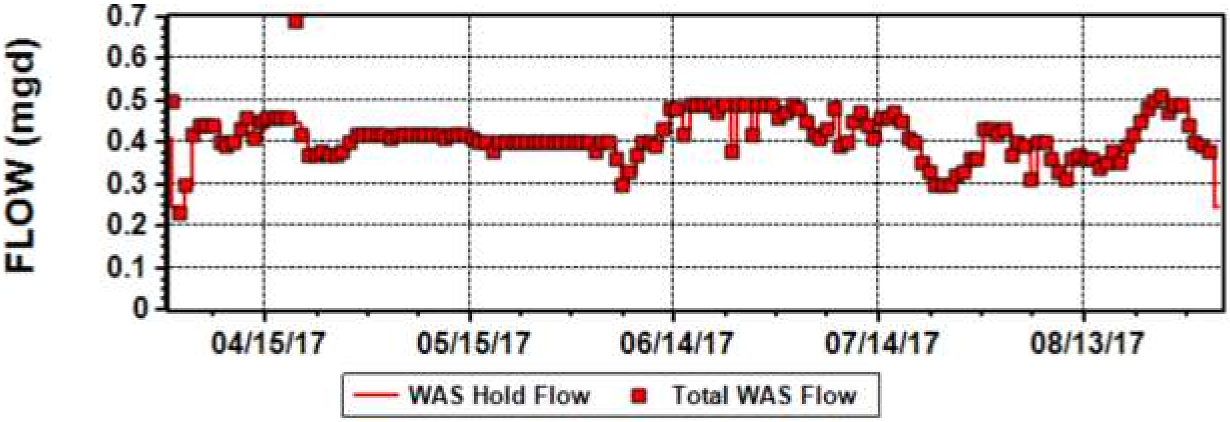

Figure 5-43. BioWin Calibration WAS Gravity Belt Thickener Feed Flow.

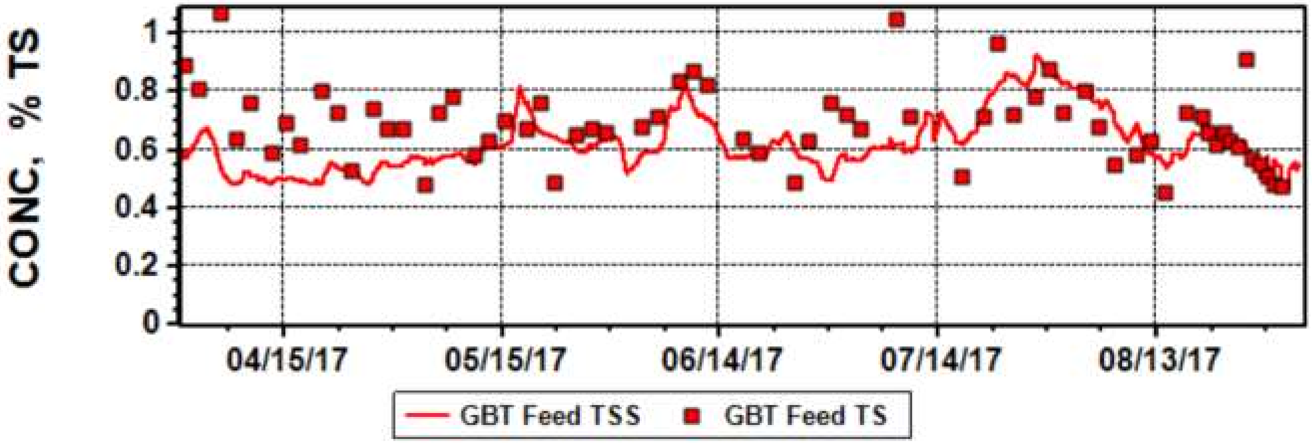

Figure 5-44. BioWin Calibration WAS Gravity Belt Thickener Feed TSS.

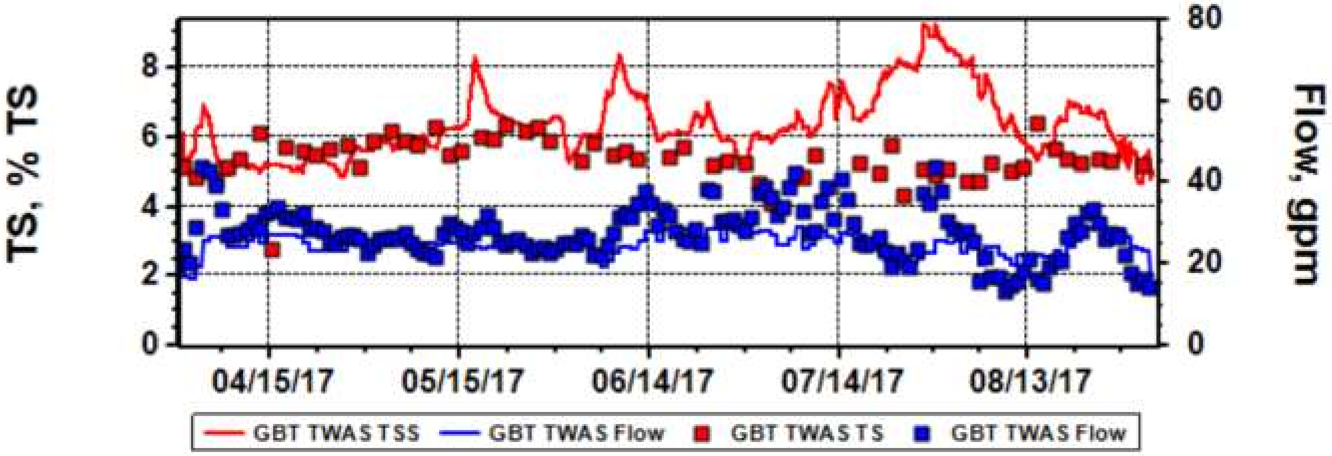

Figure 5-45. BioWin Calibration WAS Gravity Belt Thickener Thickened Sludge Flow and TSS.

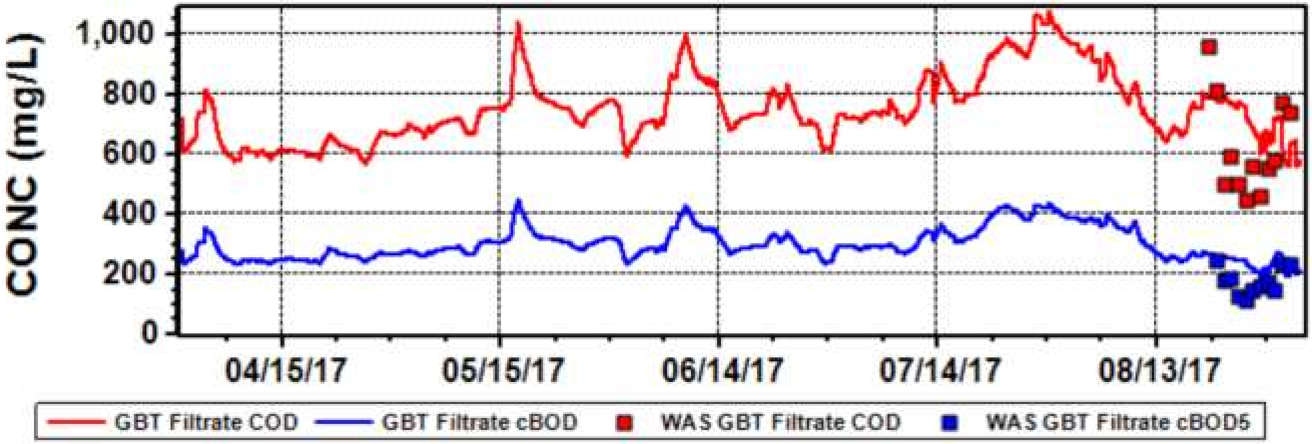

Figure 5-46. BioWin Calibration WAS Gravity Belt Thickener Filtrate Solids.

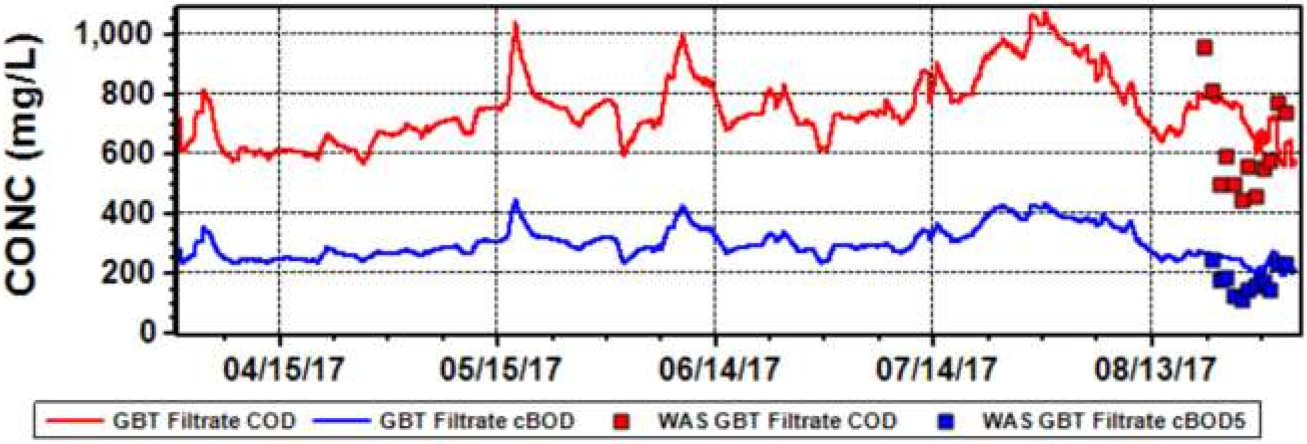

Figure 5-47. BioWin Calibration WAS Gravity Belt Thickener Filtrate COD and cBOD5.

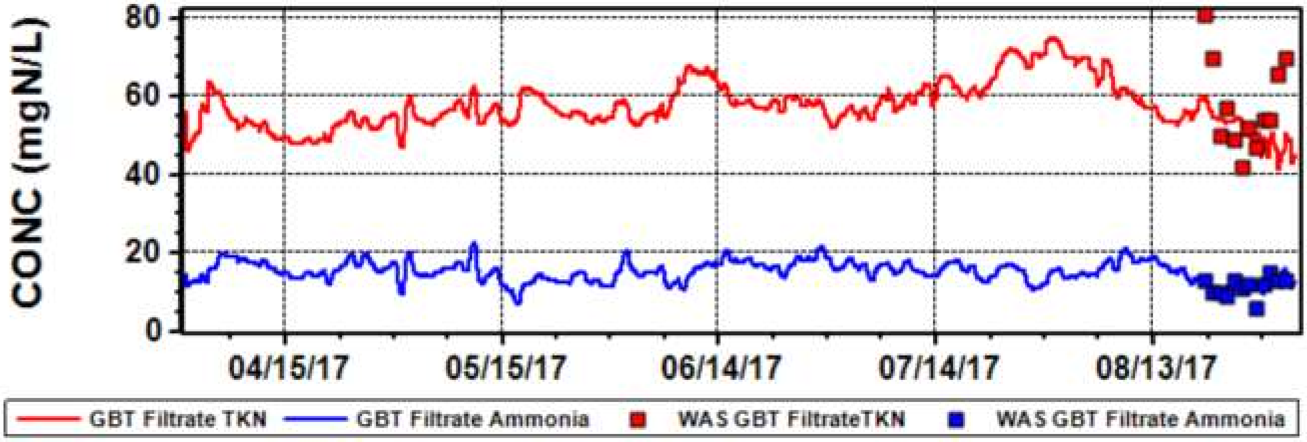

Figure 5-48. BioWin Calibration WAS Gravity Belt Thickener Filtrate Nitrogen.

Figure 5-49. BioWin Calibration WAS Gravity Belt Thickener Filtrate Phosphorus.

5.2.10 Digester Feed

Primary sludge and TWAS is blended together prior to feeding the digesters. Figures 5-50 through 5-52 show predicted digester feed solids and total phosphorus match very well with the reported plant data.

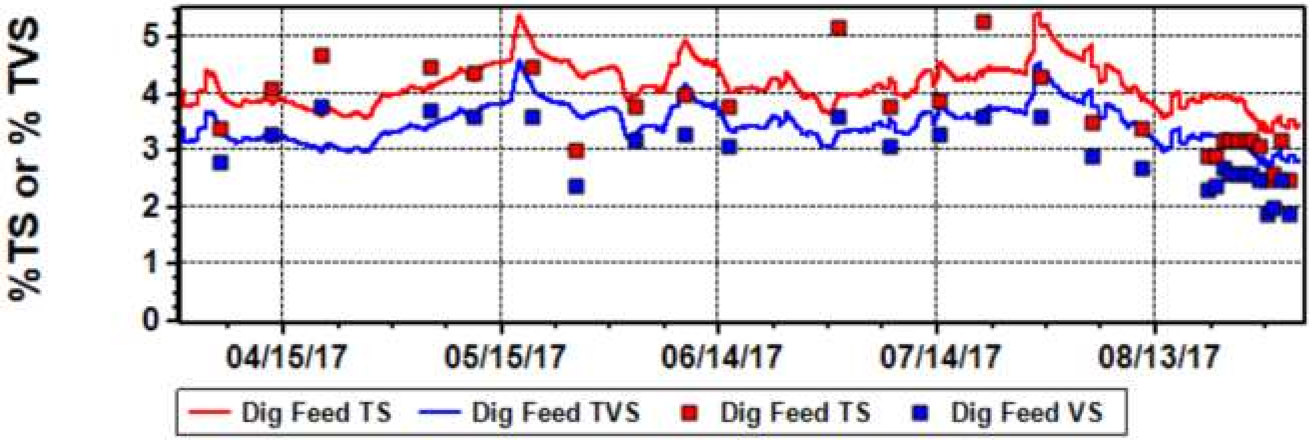

Figure 5-50. BioWin Calibration Digester Feed Solids.

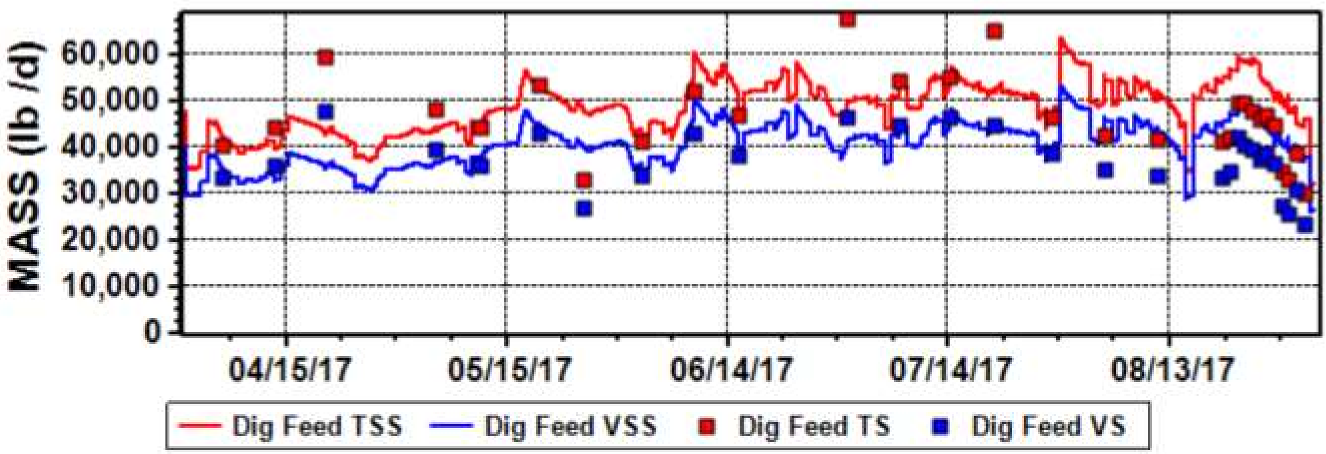

Figure 5-51. BioWin Calibration Digester Feed Mass Loadings.

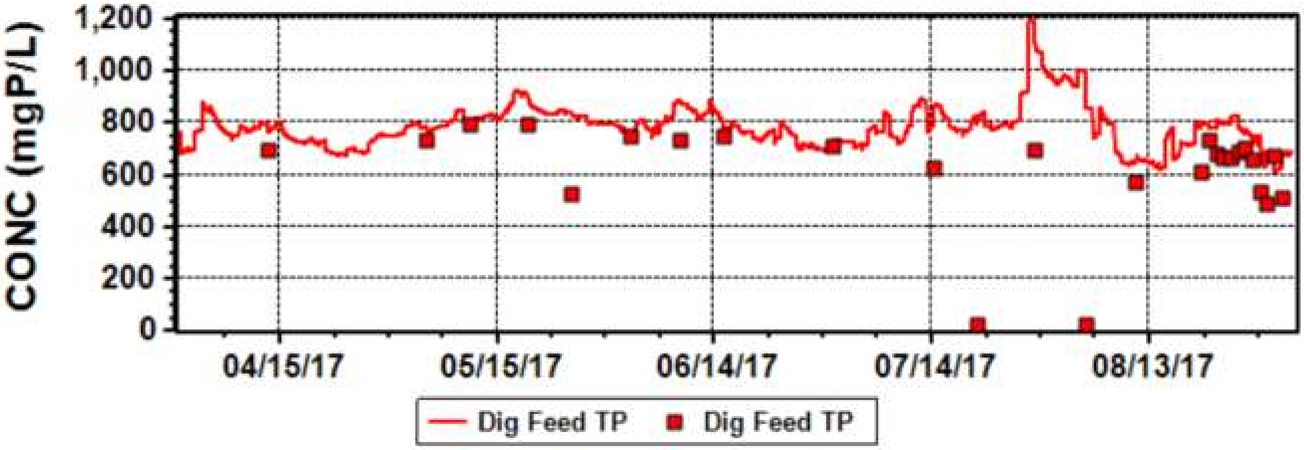

Figure 5-52. BioWin Calibration Digester Feed Phosphorus.

5.2.11 Digesters

Anaerobic digesters performance is defined by volatile solids (VS) destruction and resulting solids concentrations. BioWin predicted VS destruction and solids matches very well with the plant reported data shown in Figures 5-53 and 5-54.

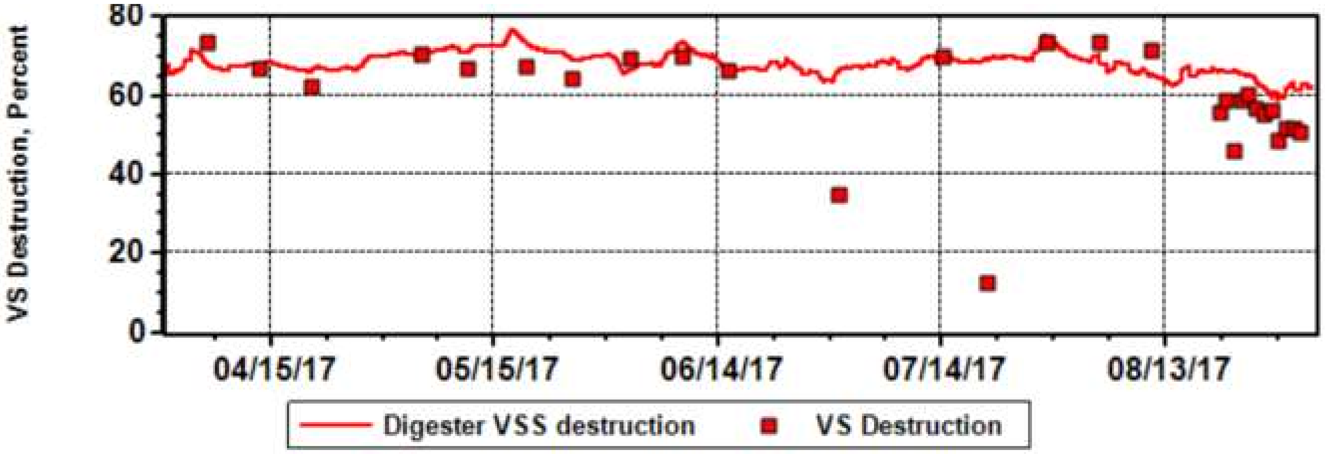

Figure 5-53. BioWin Calibration Digester Volatile Solids Destruction.

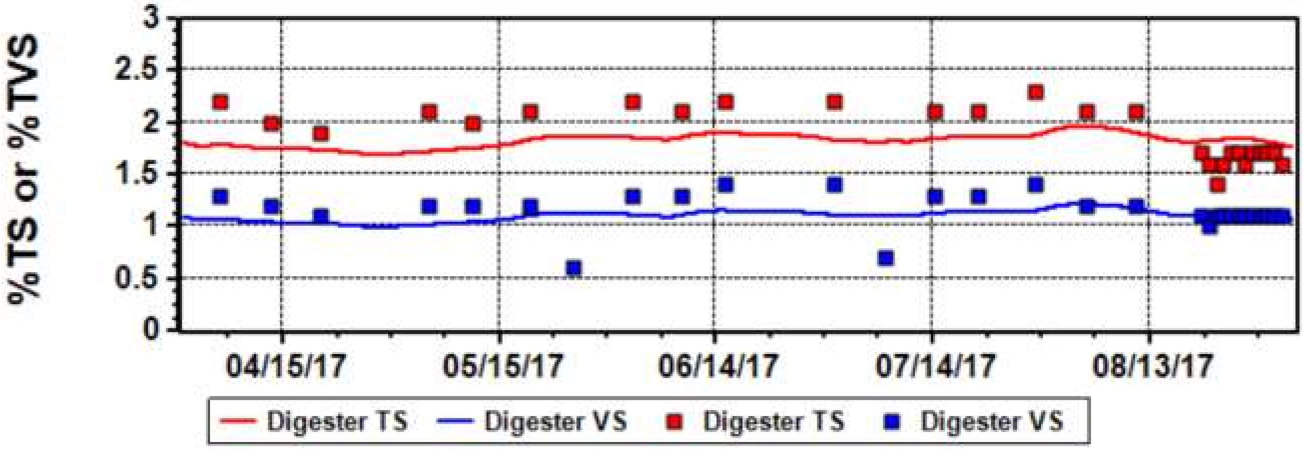

Figure 5-54. BioWin Calibration Digester Solids.

5.2.12 Digested Sludge Holding

During the August 2017 wastewater characterization sampling event, the Digested Sludge Holding (DSH) tank TS and VS matched the digester effluent as shown in Figures 5-54 and 5-55. Plant operating data prior to the August sampling event shows additional VS destruction is occurring in the DSH tank as the TS concentration decreased from roughly 2.1% TS to 1.8% TS. Given the HRT in the DSH tank is typically less than 1 day, the model was calibrated to the August 2017 VS destruction (limited to no VS destruction).

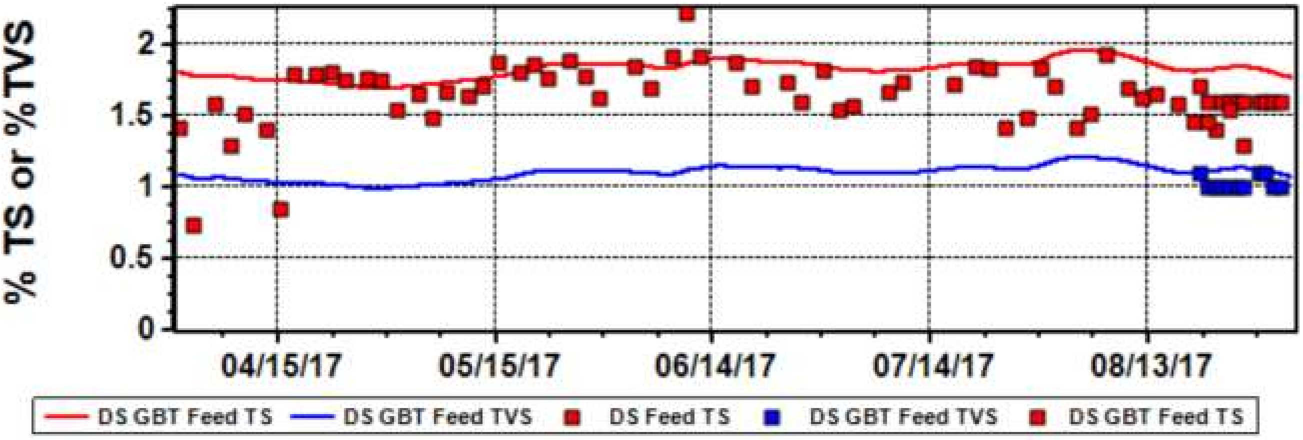

Figure 5-55. BioWin Calibration Digested Sludge Holding Tank Solids.

5.2.13 Digested Sludge (DS) GBTs

Figure 5-56 shows the predicted and measured thickened sludge flow rate and TS matches well using a solids capture of 89 percent and underflow rate of 15 percent of the influent feed rate. The influent feed rate includes 85 gpm of belt wash water. Figures 5-57 and 5-58 show the measured and predicted GBT filtrate solids and COD match the measured values very well. Figures 5-59 and 5-60 show the measured and predicted GBT filtrate TKN and phosphorus are lower than measured values. Predicted filtrate phosphorus concentrations are higher than measured due to the high Fe:P molar ratio used in the calibration.

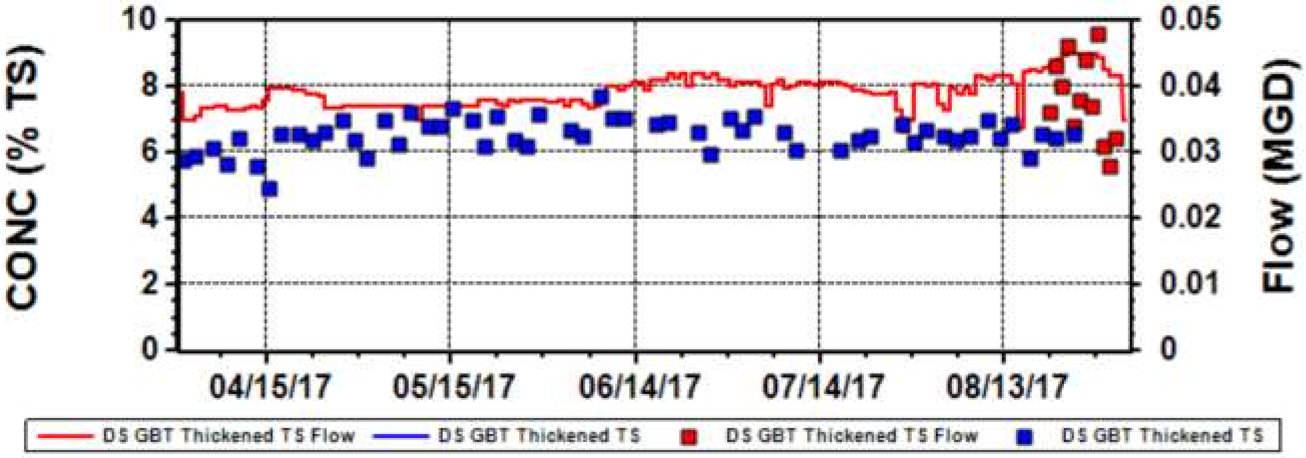

Figure 5-56. BioWin Calibration Digested Sludge GBT Thickened Sludge Flow and Solids.

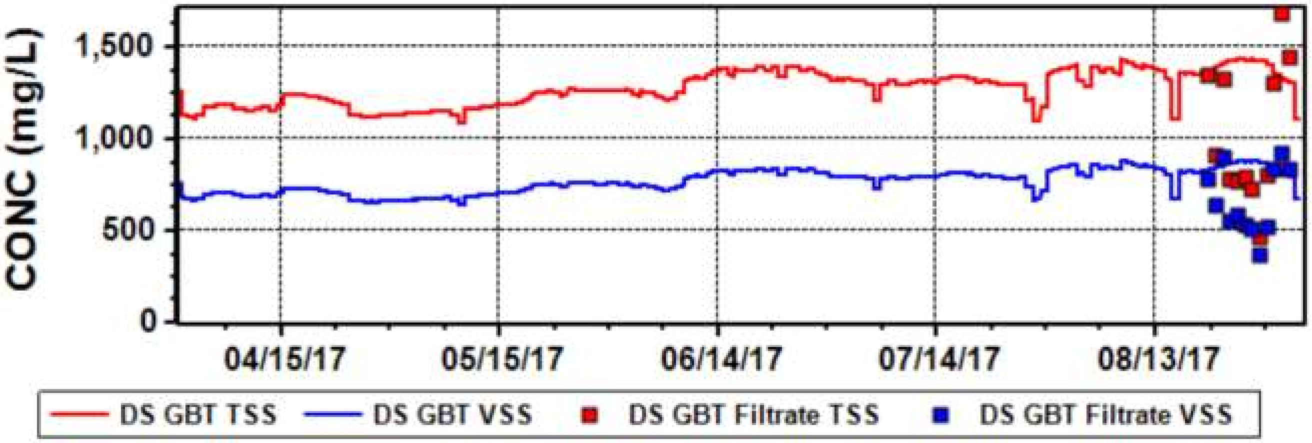

Figure 5-57. BioWin Calibration DS Gravity Belt Thickener Filtrate Solids.

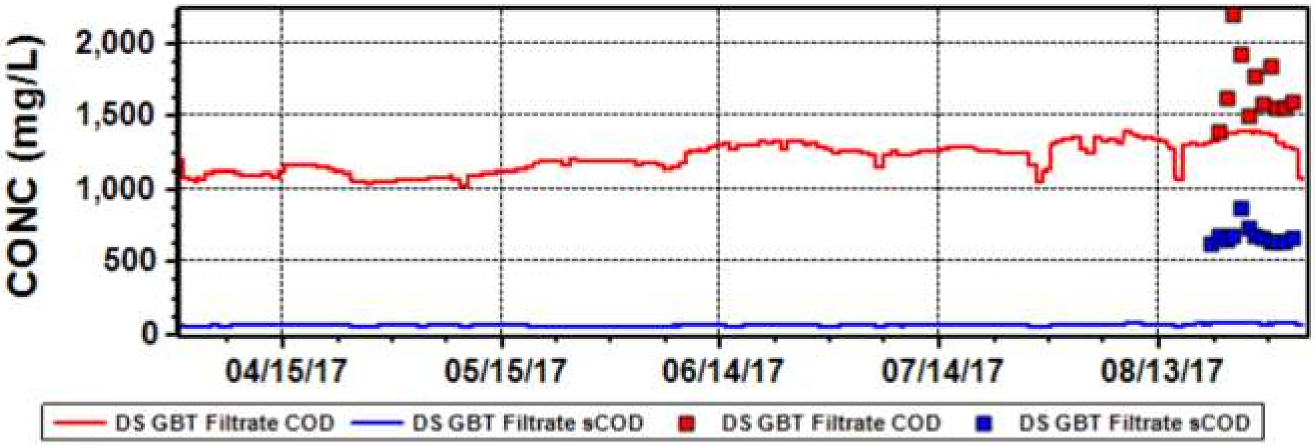

Figure 5-58. BioWin Calibration DS Gravity Belt Thickener Filtrate COD and Filtered COD.

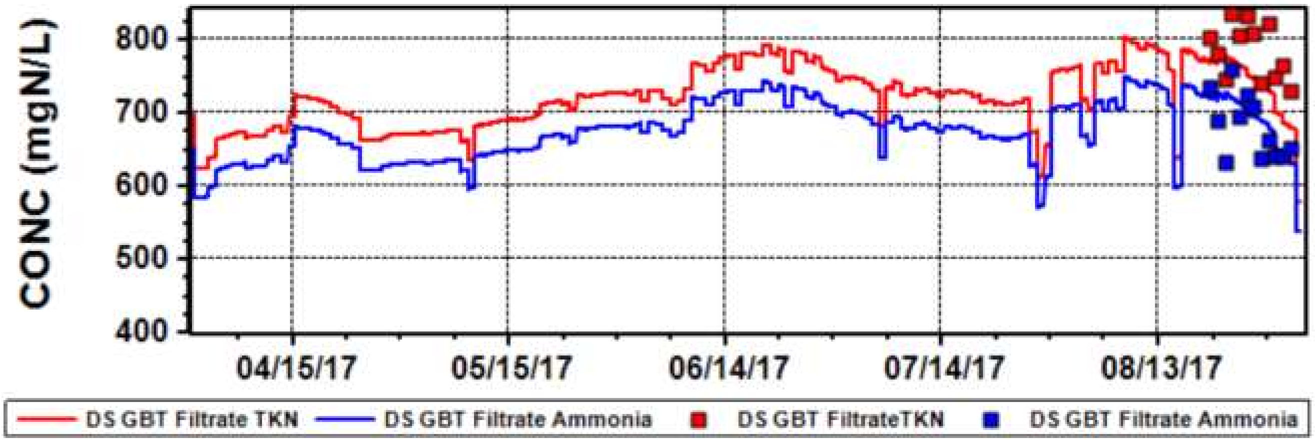

Figure 5-59. BioWin Calibration DS Gravity Belt Thickener Filtrate Nitrogen.

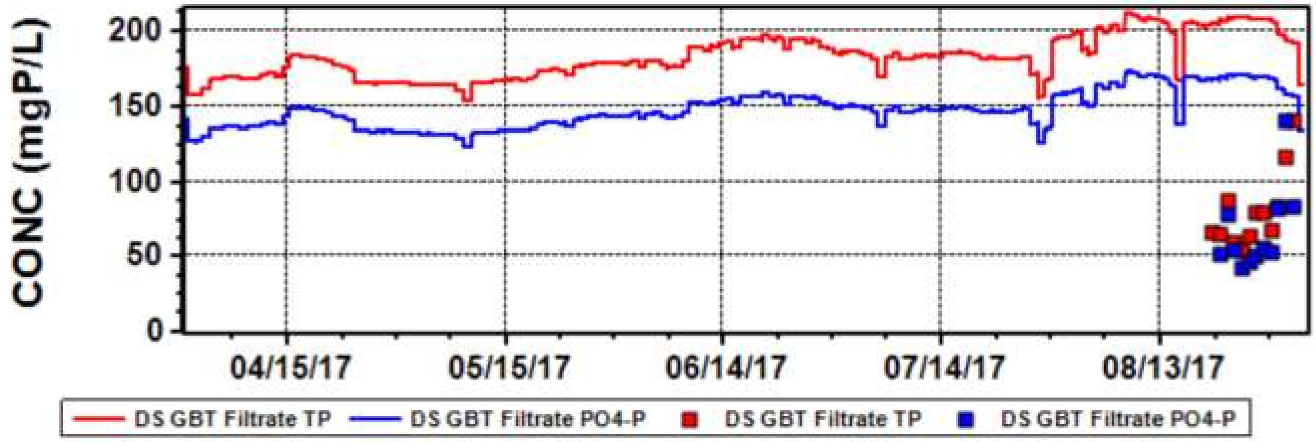

Figure 5-60. BioWin Calibration DS Gravity Belt Thickener Filtrate Phosphorus.

Section 6: References

Brown and Caldwell (BC). 2017a. Rochester Water Reclamation Plant Facilities Plan. Technical Memorandum Nitrification Rate Testing, September.

BC. 2017b. Rochester Water Reclamation Plant Facilities Plan. Technical Memorandum Aeration Basin Off Gas Testing, November.

Attachment A: Wastewater Characterization Sampling Plan

Wastewater Characterization Sampling Plan

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St. Paul, Minnesota 55101
T: 651.298.0710

Prepared for:	City of Rochester Water Reclamation Plant
Project Title:	WRP Facilities Plan
Project No.:	150811
Subject:	Wastewater Characterization Sampling Plan
Date:	August 4, 2017
To:	Matt Baker, P.E. Project Manager
From:	Harold Voth, P.E. Project Manager
Prepared by:	Lloyd Winchell, P.E. Process Engineer Don Esping, P.E., Senior Process Engineer Dr. Michael Stenstrom, Ph.D, Consulting Engineer
Reviewed by:	Jose Jimenez, Ph.D, Senior Process Engineer

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Section 1: Introduction

This document summarizes the wastewater characterization sampling program for the City of Rochester (City) Water Reclamation Plant (WRP) BioWin™ and HiPure process simulator calibrations. Data from the sampling program will be used, in conjunction with historical plant data, by Brown and Caldwell (BC) to calibrate a whole-plant BioWin™ simulator and the first stage high purity oxygen activated sludge process (HPOAS1) process model which will then be used for identifying treatment capacity and evaluate alternatives. The sampling program is designed to provide information on the following:

1. Influent wastewater chemical oxygen demand (COD), total kjeldahl nitrogen (TKN), and total phosphorus (TP) characteristics. Figure 1 shows a graphical representation of BioWin™ influent COD, TKN, and TP partitioning. Use of a 1.5 um glass fiber filter for “filtered” COD is acceptable in lieu of a 1.2 um filter.
2. Daily diurnal flow and concentration/loading patterns (Flow, COD, TKN, TP).
3. Characterize plant performance and individual unit process performance.

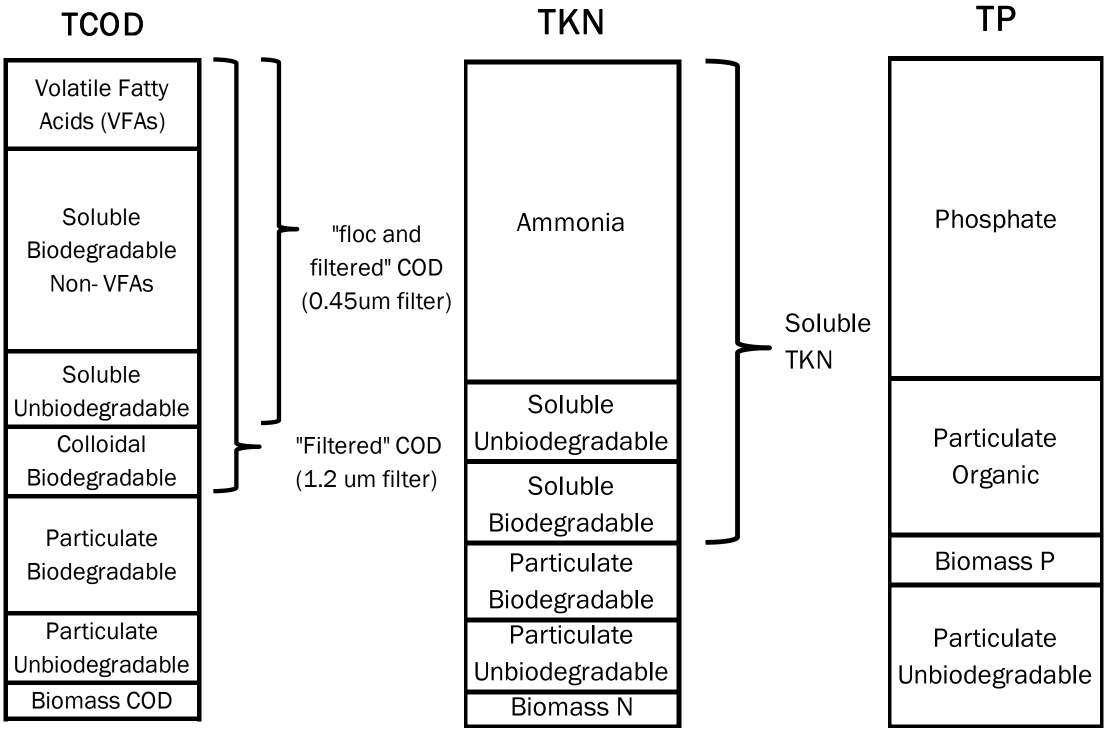


Figure 1-1. Graphical Representation of BioWin™ COD, TKN, and TP fractions in wastewater.

This document summarizes the sampling, sample analysis methods, data management, and recommended additional sampling.

Section 2: Sampling

The sampling program will be conducted over 12 consecutive days starting August 20 and ending August 31, 2017. The sampling program is designed to supplement the City's current sampling and analysis regime as required for BioWin™ and HiPure calibrations. Three types of samples are required and described below. Also, two special sampling efforts, diurnal and aeration basin profiles, supplement the sampling program as described below.

2.1 General

The following list summarizes some general requirements for the sampling program. Several others will likely arise as the details for the sampling program are worked through.

- Collect samples at a point representative of the total flow.
- All samples shall be collected and analyzed by City staff.
- Grab samples should be taken at the same time each sampling day and shall be within the same period as automated samplers. **Record sample collection time.**
- Sampling and analysis shall be in accordance with *Standard Methods*.
- Sampler/samples must be refrigerated or packed in ice for sample preservation during the sampling period and transport to the lab.
- Record the sample collection time.
- All filtered and floc-filtered samples shall be filtered prior to preservation.

Figure 2-1, WRP Process Flow Schematic shows the sampling locations referenced in Table 2-1 below.

2.2 Flow Weighted Composite Samples

Flow weighted composite samples using the existing WRP influent, primary effluent, and effluent samplers will be collected and analyzed for parameters identified in list below. Additional composite samplers may be needed to complete the program. Contact BC for compositing volumes if samplers do not have flow weighting capability.

Table 2-1 lists all the parameters analyzed from the composite sample with the few exceptions noted below.

- WRP Influent – all samples except flow, pH, and temperature from WRP instrumentation
- Primary influent– all samples except flow and pH from WRP instrumentation.
- Primary Clarifier 1/2 Effluent – all samples except flow and pH from WRP instrumentation - and sludge blanket depth (SBD) measured by WRP staff.
- Primary Clarifier 3 Effluent – all samples except flow and pH from WRP and SBD measured by WRP staff.
- Intermediate Effluent - all samples except flow and pH from WRP instrumentation and sludge blanket depths for one clarifier measured by WRP staff
- Final 1-4 Effluent – all samples except flow and pH from WRP instrumentation and sludge blanket depths for one clarifier measured by WRP staff
- Final 5 Effluent – all samples except flow and pH from WRP instrumentation and sludge blanket depth measured by WRP staff
- Plant Effluent – temperature and pH from WRP instrumentation
- WAS Gravity Belt Thickener (GBT) Washwater - flow from WRP instrumentation
- Digested GBT Washwater - flow from WRP instrumentation

2.3 Composite Grab Samples

Flow streams requiring composite grab samples are listed below and in Table 2-1. Composite grab samples consist of 3 individual grab samples taken over the course of a day, or shift, and evenly spaced over that period (from day to day individual grab samples shall be taken at the same time). Upon collection of the third grab sample, equal volumes of the three grab samples will be combined into one singe composite sample for analysis. Note, that grab sample taken earlier in the period shall be stored per *Standard Methods* before compositing.

- HPO Intermediate RAS – all except flow from WRP instrumentation (note WAS flow required as well)
- HPO Final RAS - all except flow from WRP instrumentation (note WAS flow required as well)
- ABC RAS - all except flow from WRP instrumentation (note WAS flow required as well)
- Primary 1/2 Sludge - all except flow from WRP instrumentation
- Primary 3 Sludge - all except flow from WRP instrumentation
- WAS GBT Feed - all except flow from WRP instrumentation
- WAS GBT Cake - all except flow

2.4 Grab Samples

Grab samples are used for liquid stream and solid stream flows and diurnal sampling. City staff will collect the grab samples from the flow streams identified in the list below once per day. For processes in which there is more than 1 process unit or reactor (i.e. HPOAS or ABC basins, digesters, etc.) a grab sample from each reactor/process unit shall be collected and equal volumes of each reactor sample shall be combined to form one sample for analysis.

In Table 2-1, if a process unit/flow stream is out of service, samples will not be collected. For samples where a solids blanket level is required (e.g. primary clarifiers), estimate the solids blanket depth using a sludge judge and reading the solids/liquid interface in one of the clarifiers.

Grab samples are listed below and in Table 2-1.

- 1st Stage Mixed Liquor – all except DO and airflow provided from WRP instrumentation
- 2nd Stage Mixed Liquor – all except DO and airflow provided from WRP instrumentation
- Basin ¾ Mixed Liquor – all except DO and airflow provided from WRP instrumentation
- WAS GBT Cake - flow
- WAS GBT Filtrate – all except flow from WRP instrumentation
- Digester Feed - all except flow from WRP instrumentation
- Digester Overflow - all except flow from WRP instrumentation
- Digested GBT Feed - all except flow from WRP instrumentation
- Digested GBT Cake- all except flow from WRP instrumentation
- Digested GBT Filtrate – all

Both WAS and Digested GBT Filtrate samples can include wash water provided the daily wash water flow is measured.

2.5 Diurnal and Aeration Basin Profile Sampling

On days of diurnal/aeration basin profile sampling, the WRP shall process influent flow as it is received during the day and not use the influent equalization basin. Table 2-2 summarizes the diurnal and aeration basin profile sampling. Diurnal samples shall be collected with automated ISCO type samplers provided by the City capable of taking discrete samples. Aeration basin profile and COD/VFA samples shall be grab samples except oxygen flow or airflow shall be recorded by the WRP existing instrumentation.

- Three days diurnal sampling and aeration basin profiling on August 27, 28, and 29th are recommended. These diurnal and tank profile events will be conducted on the same day. The diurnal sampling start time shall match the same start time as the plant influent composite sampler.
- Samples will be taken every hour using a discrete sampler (24 bottle variety). The contents of two hourly sample bottles will be combined to form a single two-hour composite sample (i.e. the 7 and 8 a.m. sample combine to form the 7/8 a.m. sample). Sample volumes combined from each hourly sample will be flow weighted and BC will provide a spreadsheet to calculate composite volumes. Analyze streams for the parameters identified in Table 2-2.
- For estimating COD fractions in the plant influent, an influent grab sample will be collected at 9 am, 12 pm and 3pm on each diurnal sampling day and analyzed for total, filtered, flocculted and filtered COD (ffCOD), volatile fatty acids (VFAs), and volatile acids. For VFA samples, collect a sub-sample and immediately filter solids by using a syringe filter as described in the section below. Fill the 40 ml VFA sample vial, by overfilling the vial to form a reverse meniscus, so when the cap is screwed on, there are no air bubbles (turn sample vial over to observe if air bubble is present). See below for additional instructions. Be sure to note sample time for comparison to composite sampler data.
- Primary effluent VFA grab samples are also collected at the same time as the influent VFA sample to define if VFA generation is occurring across the primary clarifiers.
- During each diurnal sampling day aeration basin profiles shall be completed. Select one train each from the ABC, HPOAS 1, and HPOAS 2 systems for profiling and analyze for parameters identified in Table 2-2. During each day of diurnal testing, each aeration basin system shall have two profiles completed – one in the morning and one in the afternoon. Samples shall be collected at the locations shown in Figure 2-2. Also, during each profile collect a RAS sample representative of the RAS delivered to the profiled basin.
- For aeration basin nutrient profile samples (NH3-N, NOX-N, NO3-N, NO2-N, PO4-P, filtered COD) separate solids immediately after sampling by settling MLSS sample for 5 minutes, pour supernatant through coffee filter collecting filtrate and then preserve sample for filtering with 0.45 um filter/analysis by lab or filter sample with 0.45 um filter within 5 minutes and send filtered sample to lab for analysis.

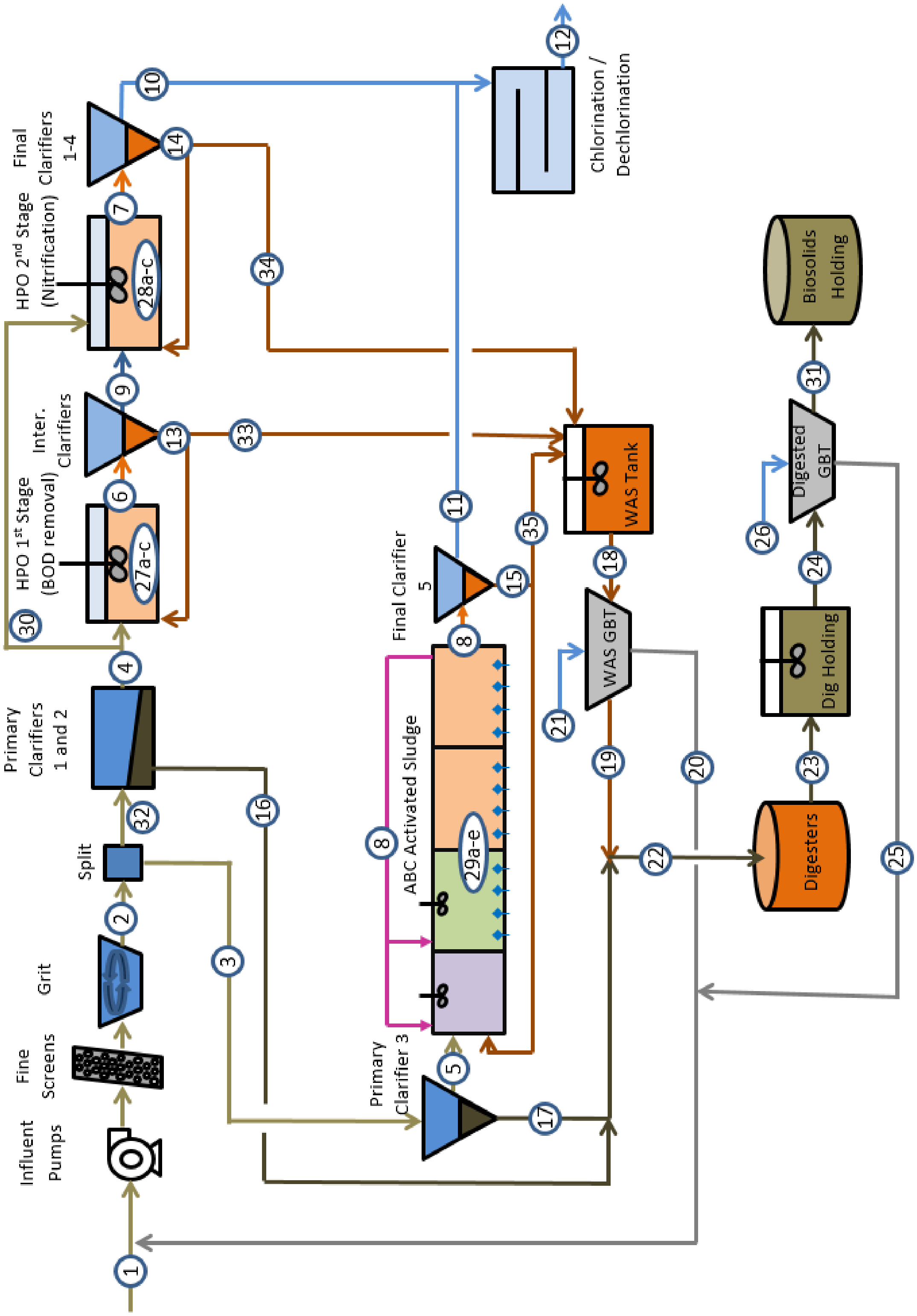


Figure 2-1. Rochester WRP Wastewater Sampling Flow Diagram (Tables 2-1 and 2-2 Contain Sample Keys).

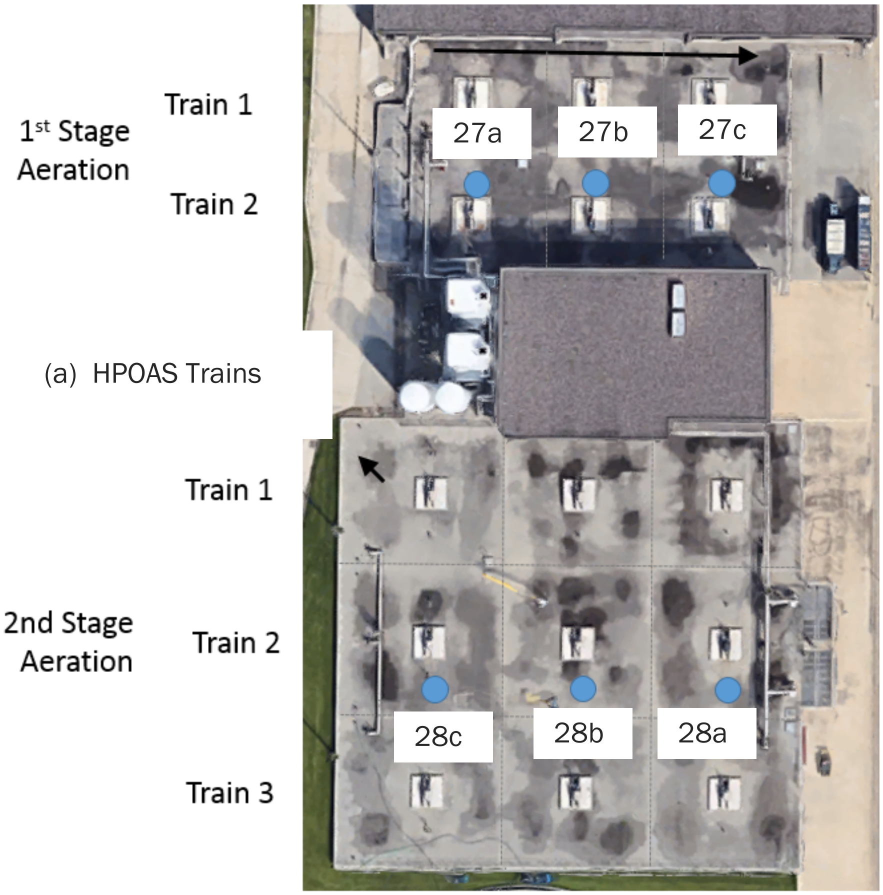
Table 2-1. Rochester WRP Wastewater Characterization Sampling Plan.

Parameter	12 Days of Composite and Grab Samples																														
	WRP Influent	Primary Influent	Primary Clarifier 1/2 Influent	Primary Clarifier 3 Influent	Primary 1/2 Effluent	Primary 3 Effluent	Primary 1/2 Effluent to Stage 2	1st Stage Mixed Liquor	2nd Stage Mixed Liquor	Basin 3/4 Mixed Liquor	Intermediate Effluent	Final 1-4 Effluent	Final 5 Effluent	Plant Effluent	HPO Intermediate RAS	HPO Intermediate WAS	HPO Final RAS	HPO Final WAS	ABC RAS	ABC WAS	Primary 1/2 Sludge	Primary 3 Sludge	WAS GBT Feed	WAS GBT Cake	WAS GBT Filtrate	WAS GBT Washwater	Digester Feed	Digester Overflow	Digested GBT Feed	Digested GBT Filtrate	Digested GBT Washwater	Digested GBT Cake
Sample Key	1	2	32	3	4	5	30	6	7	8	9	10	11	12	13	33	14	34	15	35	16	17	18	19	20	21	22	23	24	25	26	31
Flow	1/d	1/d	1/d	1/d	1/d	1/d	1/d			1/d (IMLR)	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d	1/d
Ferric Chloride Flow					1/d																						1/d					
TSS	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d		🟥 1/d	🟥 1/d	🟥 1/d	🟩 1/d	🟩 1/d	🟩 1/d	🟩 1/d	🟦 1/d		🟦 1/d		🟦 1/d						🟥 1/d					🟥 1/d		
VSS	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d		🟥 1/d	🟥 1/d	🟥 1/d	🟩 1/d	🟩 1/d	🟩 1/d												🟥 1/d					🟥 1/d		
TS																					🟦 1/d	🟦 1/d	🟦 1/d	🟦 1/d			🟥 1/d	🟥 1/d	🟥 1/d			🟥 1/d
VS																					🟦 1/d	🟦 1/d	🟦 1/d	🟦 1/d			🟥 1/d	🟥 1/d	🟥 1/d			🟥 1/d
CBOD5	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d					🟩 1/d	🟩 1/d	🟩 1/d	🟩 1/d											🟥 1/d							
filtered CBOD5	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d																										
COD	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d		🟥 1/d	🟥 1/d	🟥 1/d															🟥 1/d			🟥 1/d	🟥 1/d	🟥 1/d		
Filtered COD	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d					🟩 1/d	🟩 1/d	🟩 1/d												🟥 1/d					🟥 1/d		
floc/filtered COD	🟩 1/d	🟩 1/d									🟩 1/d	🟩 1/d	🟩 1/d																			
TKN	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d		🟥 1/d	🟥 1/d	🟥 1/d	🟩 1/d	🟩 1/d	🟩 1/d	🟩 1/d											🟥 1/d					🟥 1/d		
Filtered TKN	🟩 1/d	🟩 1/d																														
NH3-N	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d					🟩 1/d	🟩 1/d	🟩 1/d	🟩 1/d											🟥 1/d					🟥 1/d		
NOX-N, NO3-N	🟩 1/d	🟩 1/d										🟩 1/d	🟩 1/d	🟩 1/d																		
TP	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d		🟥 1/d	🟥 1/d	🟥 1/d	🟩 1/d	🟩 1/d	🟩 1/d	🟩 1/d											🟥 1/d		🟥 1/d	🟥 1/d	🟥 1/d	🟥 1/d		
Filtered TP	🟩 1/d	🟩 1/d																														
PO4-P	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d				🟥 1/d	🟩 1/d	🟩 1/d	🟩 1/d												🟥 1/d		🟥 1/d			🟥 1/d		
Temperature	🟥 1/d													🟥 1/d														🟥 1/d				
pH	🟥 1/d	🟥 1/d			🟥 1/d	🟥 1/d		🟥 1/d	🟥 1/d	🟥 1/d	🟥 1/d	🟥 1/d	🟥 1/d	🟥 1/d														🟥 1/d				
Alkalinity	🟩 1/d	🟩 1/d			🟩 1/d	🟩 1/d					🟩 1/d	🟩 1/d	🟩 1/d															🟥 1/d				
Soluble Mg, Ca	🟩 1/d																											🟥 1/d (Mg Only)				
DO								1/d	1/d	1/d																						
Airflow								1/d	1/d	1/d																						
Digester Methane																												🟥 1/d				
Sludge Blanket Depth											🟥 1/d	🟥 1/d	🟥 1/d								🟥 1/d	🟥 1/d										

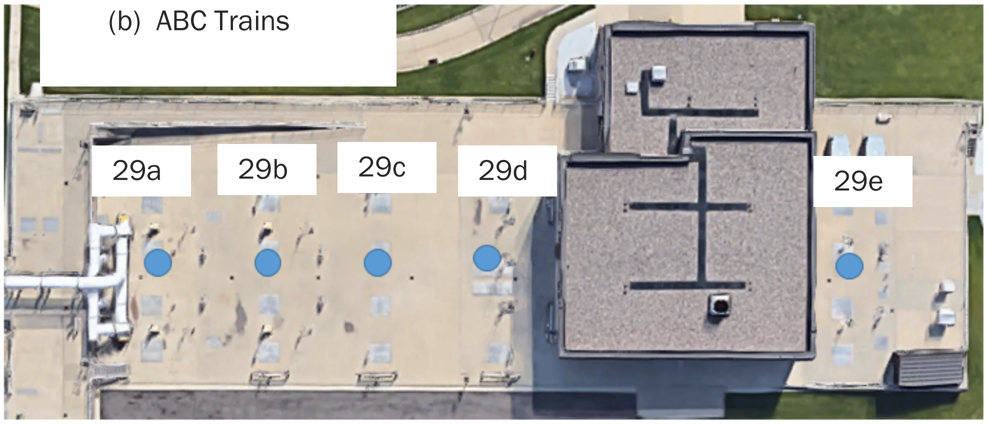
1/d = parameter existing instrument recorded data or currently sampled and analyzed - daily average value
🟩 = flow weighted composite
🟦 = composite grab sample (three grabs composited to form single sample)
🟥 = grab sample
IMLR = internal mixed liquor return

Table 2-2. Rochester WRP Wastewater Characterization Diurnal and Aeration Basin Profile Sampling Plan.

Parameter	Diurnal (3 Days) and Aeration Basin Profile (3 events) Grab Samples								
	WRP Influent	Primary 1/2 Effluent	Primary 3 Effluent	Intermediate Effluent	Final 1-4 Effluent	Final 5 Effluent	HPO 1st Stage Profile	HPO 2nd Stage Profile	ABC Profile
Sample Key	1	4	5	9	10	11	27a-c	28a-c	29a-e
Flow	12/event	12/event	12/event	12/event	12/event	12/event	2/event	2/event	2/event
TSS	12/event	12/event	12/event	12/event	12/event	12/event	6/event	6/event	10/event
VSS	12/event	12/event	12/event	12/event	12/event	12/event			
COD	12/event	12/event	12/event	12/event	12/event	12/event			
COD	3/event								
Filtered COD	3/event						6/event	6/event	10/event
floc/filtered COD	3/event								
Volatile fatty acids	3/event	3/event	3/event						
Volatile acids	3/event	3/event	3/event						
TKN	12/event	12/event	12/event						
NH3-N				12/event	12/event	12/event	6/event	6/event	10/event
NOX-N, NO3-N				12/event	12/event	12/event	6/event	6/event	10/event
NO2-N							6/event	6/event	10/event
TP	12/event	12/event	12/event						
PO4-P				12/event	12/event	12/event	6/event	6/event	10/event
DO							6/event	6/event	10/event
Airflow							6/event	6/event	10/event



(a) HPOAS Trains



(b) ABC Trains

● Sample location

Figure 2-2. Aeration Basin Profile Sample Locations.

Section 3: Sampling Analysis Methods

This section summarizes key analytical methods and requirements of the sampling program.

3.1 Total COD/TKN/TP Sample Preparation

COD (total), TKN (total) and TP (total) samples should be thoroughly homogenized (blended) prior to analysis. This applies to samples of (a) raw influent, (b) mixed liquor, and (c) effluent. It is recommended the City run three or four comparison split samples of plant influent COD with and without blending these samples prior to starting the sampling program to define any differences in analytical results.

3.2 "Filtered" COD/TKN/TP Samples

Several samples will be analyzed for "filtered" COD, TKN, and TP. For collection of these samples, the filtrate from 1.5µm glass fiber TSS filtration is collected in a test tube during the sample filtration process. Triple rinse glass fiber filters with de-ionized water and thoroughly dry filters prior to filter samples when collecting soluble filtrate sample. Do not include rinse water in sample volume. Care must be exercised not to dilute the sample (filtrate) volume with filter rinse water.

3.3 Flocculated and Filtered COD (ffCOD)

Influent readily biodegradable COD concentration (RBCOD) will be measured using the ffCOD (flocculated and filtered COD) method of Mamais *et al.* (1993). The method is based on a physical separation, which involves pre-flocculation of the sample followed by filtration (referred to as the flocCODsol test or "ffCOD"). It is assumed that the flocculation step removes the colloidal material, resulting in a filtrate that contains only "truly soluble" material. The procedure is outlined briefly below:

1. 1 mL of 100 g/L zinc sulfate solution is added to 100 mL of wastewater;
2. the sample is then mixed vigorously for approximately 1 minute;
3. the sample pH is adjusted to approximately 10.5 using 6 M sodium hydroxide solution;
4. the sample is then allowed to settle, and a sample of the supernatant is withdrawn;
5. the supernatant sample is filtered using a 0.45 µm membrane filter, and the filtrate COD is analyzed.

Mamais, D., D. Jenkins and P. Pitt (1993) A Rapid Physical-chemical Method for the Determination of Readily Biodegradable Soluble COD in Municipal Wastewater. *Water Res.*, 27(1):195-197.

3.4 Volatile Fatty Acid (VFA) Sampling

The following sampling procedures should be used for VFA sample collection. Sample collection time shall be at same time for every sample.

1. VFA sample procedure:
    a. Collect sample- do not stir or agitate the sample further.
    b. Prepare the VFA sample in the field using a syringe filter as follows:
        (1) Take the required volume (usually 50 ml) in a syringe;
        (2) Attach a syringe filter. Whatman GD/X filters are suitable. They have a coarse layer, followed by a finer layer, ending with a membrane to 0.20 µm. 25mm filters are recommended to allow membrane filtration of raw wastewater;
        (3) Fill a 40 ml VOA vial containing the recommended HCl acid preservative. Tubing could be used out of the syringe filter to avoid splashing into the vial;

(4) There should be no headspace in the filled vial to avoid contamination and oxygen intrusion: (VOA vials are tall cylindrical sample vials with a Teflon septum and special cap typically used for volatile organics sampling. The vial is filled so that the meniscus is above the top of the vial. The septum is slid over the top, displacing some of the meniscus, so the vial has no headspace or bubbles. The cap has a hole in the middle so that a portion of the sample can be obtained through the exposed septum with a syringe for injection into the GC in the laboratory. The vials are usually purchased with acid preservative).

(5) Store the samples in a refrigerator at 4^0C then deliver to the laboratory as soon as possible with a cold pack/ice to maintain the low temperature. Using the syringe filter, volatilization should have been minimized, the sample should be bacteria-free, and further reactions or loss of VFAs should be minimized. Inform the lab that samples have already been filtered to 0.20 µm. Further filtration in the lab is not required – this will minimize a possible volatilization and loss of VFAs in the lab.

2. The lab doing the VFA analyses should be equipped for detection limits down to reporting limits of 5 mg/l and method detection limits down to 1 mg/l. Typically this will be achieved with gas chromatography with flame ionization detection (GC/FID). Typically, the method involves direct aqueous injection onto a specialized capillary column to separate the low molecular weight fatty acids with a selective stationary phase designed for acidic compounds. The following labs are available to conduct VFA analysis.

    a. EMA, EnviroMatrix Analytical, Inc. 4340 Viewridge Ave., San Diego, CA 92123: 858-560-7717
    b. Minnesota Valley, 1126 North Front Street, New Ulm, MN 56073: 800-782-3557
    c. Specialty Analytical, 11711 SE Capps Rd., Clackamas, OR 97015: 503-607-1331
    d. LWH Laboratories, Royal Oaks Drive #100, Monrovia, CA 91016: 800-566-LABS

3.5 Hach COD

Presumably COD analyses will be conducted using the Hach Test-in-tube spectrophotometric method. High range tubes (0 – 1,500 mg/L) will be appropriate for the raw influent and primary effluent samples. In the case of mixed liquor CODs, it may be necessary to dilute samples. For example, if the MLVSS concentration is say 2,000 mg/L, the expected COD will be approximately 1.5X MLVSS or 3,000 mgCOD/L. In that case it would be necessary to dilute samples 3:1 (i.e. two parts water, one part sample).

Section 4: Data Management

Laboratory results shall be input into an excel spreadsheet provided by Brown and Caldwell. As soon as data is available, please e-mail results to Don Esping and Lloyd Winchell.

Section 5: Additional Testing

Readily biodegradable COD (RBCOD) and volatile fatty acids (VFA) levels in municipal wastewater can have a significant impact on biological nutrient removal performance. In general, the higher the RBCOD/VFA levels, the BNR performance improves. RBCOD /VFA levels normally vary based upon two primary factors: temperature and collection system detention time. Typically, warmer temperatures promote hydrolysis and fermentation of wastewater components in collection systems. RBCOD/VFAs are commonly higher in summer/fall and lower in winter/spring. Similarly, RBCOD/VFAs typically decrease during peak flow events when wastewater detention times in the collection system are minimized. Therefore, it is recommended to repeat the plant influent COD/TKN/TP wastewater characterization during winter when RBCOD/VFA generation is lowest.

Attachment B: Wastewater Characterization Data

This spreadsheet tab reflects the results of the January 2018 testing which showed by influent COD is 15% higher than reported and influent TSS is 35% higher than reported
Assume CBOD5 increases by 15% -same as CBOD
Assume VSS increases by COD increase/1.6 or roughly 1.31x

Don Esping:
Assumes Additional VSS = Additional COD/1.58 mg COD/mg VSS

WRP Influent - Adjusted

Day	Date	Flow mgd	COD mg/L	COD (WRP) mg/L	Filtered COD mg/L	ffCOD mg/L	Filtered Mg mg/L	CBOD5 mg/L	Filtered CBOD5 mg/L	TKN mg/L as N	Filtered TKN mg/L as N	NH3 mg/L as N	Nitrate/Nox as N, mg/L	Total P mg/L as P	Filtered P mg/L as P	PO4-P mg/L as P	Total Alk mg/L as CaCO	TSS mg/L	VSS mg/L	pH	Temp F	Filtered Ca mg/L
	Adjustment Factor		1.15					1.15										1.35	1.58			
1	**8/20/2017**	13.3	921	1090	430	295	28	492	229	38	28.2	17.1	0.24	7.4	4.0	4.0	389	319	297	6.76	19.4	91
2	**8/21/2017**	14.6	884	940	389	261	27	438	208	39	28.2	18.5	0.42	7.4	4.3	4.4	389	335	302	6.86	19.1	87
3	**8/22/2017**	14.8	794	970	368	269	25	426	203	39	28.7	20.7	< 0.05	7.1	4.2	4.1	410	325	279	6.69	18.6	91
4	**8/23/2017**	14.3	752	940	312	203	27	401	133	40	30.6	22.2	0.07	8.2	4.86	4.8	421	286	253	7.23	18.9	89
5	**8/24/2017**	14.4	718	800	297	190	27	399	131	42	30.6	19.1	0.05	8.2	4.4	4.9	431	356	298	7.19	18.4	91
6	**8/25/2017**	14.0	715	820	348	225	27	376	156	41	30.3	21.3	0.06	7.4	4.6	4.4	415	277	240	7.13	18.4	93
7	**8/26/2017**	13.4	622	710	293	195	27	351	144	39	30.6	20.5	0.09	6.6	3.9	3.6	414	257	227	6.75	18.7	95
8	**8/27/2017**	13.2	545	730	257	148	32	304	112	36	29.1	21.6	0.06	6.2	3.7	3.7	415	211	187	6.9	18.2	82
9	**8/28/2017**	14.2	588	770	274	167	27	350	101	40	30.5	21.4	< 0.05	6.8	3.9	3.4	424	252	218	7.13	18.7	92
10	**8/29/2017**	14.8	725	850	321	203	28	366	122	38	31.8	21.8	0.05	6.9	4.3	4.2	423	215	195	7.15	19.3	93
11	**8/30/2017**	14.7	958	980	306	195	26	484	126	53	31.2	22.1	< 0.05	9.4	4.4	4.4	423	478	397	7.48	19.0	88
12	**8/31/2017**	14.7	725	850	295	197	27	344	108	41	29.3	21.2	0.05	7.9	4.1	4.7	418	392	319	7.14	19.3	90
	Average	**14.2**	**745**	**871**	**324**	**212**	**27**	**394**	**148**	**40.4**	**29.9**	**20.6**	**0.12**	**7.5**	**4.2**	**4.2**	**414**	**308**	**268**	**7.03**	**18.8**	**90**
	Median	**14.4**	**725**	**850**	**309**	**200**	**27**	**388**	**132**	**39.7**	**30.4**	**21.3**	**0.06**	**7.4**	**4.2**	**4.3**	**417**	**302**	**266**	**7.13**	**18.8**	**91**
	Minimum	**13.2**	**545**	**710**	**257**	**148**	**25**	**304**	**101**	**36.1**	**28.2**	**17.1**	**0.1**	**6.2**	**3.7**	**3.4**	**389**	**211**	**187**	**6.69**	**18.2**	**82**
	Maximum	**14.8**	**958**	**1090**	**430**	**295**	**32**	**492**	**229**	**52.8**	**31.8**	**22.2**	**0.4**	**9.4**	**4.9**	**4.9**	**431**	**478**	**397**	**7.48**	**19.4**	**95**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**9**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

🟨 **= Data Screened from dataset**

🟩 **Adjusted influent data**

CALCULATIONS

		GENERAL					SOLIDS CHARACTERIZATION								COD FRACTIONS							
Day	**Date**	**COD:TKN**	**TP:TKN**	**COD(WRP): COD**	**COD:TP**	**cBOD5: TSS**	**VSS:TSS**	**ISS**	**Fcvxi/s pCOD:VSS**	**pN:VSS**	**pP:VSS**	**FupN pN/pCOD**	**FupP pP:pCOD**	**Fna NH3:TKN**	**COD:BOD5**	**SCOD:COD**	**RBCOD**	**colCOD**	**Fbs**	**Fus**	**Fpo4 PO4-P:TP**	**COD:TSS**
1	8/20/2017	24.4	0.195	1.18	125	1.54	0.93	22	1.65	0.032	0.011	0.019	0.007	0.45	1.9	0.47	275	135	0.30	0.022	0.54	2.9
2	8/21/2017	23.0	0.194	1.06	119	1.31	0.90	33	1.64	0.034	0.011	0.021	0.006	0.48	2.0	0.44	248	128	0.28	0.015	0.59	2.6
3	8/22/2017	20.3	0.180	1.22	113	1.31	0.86	47	1.53	0.037	0.010	0.024	0.007	0.53	1.9	0.46	239	99	0.30	0.038	0.58	2.4
4	8/23/2017	18.6	0.202	1.25	92	1.40	0.88	33	1.74	0.039	0.013	0.022	0.008	0.55	1.9	0.41	177	109	0.24	0.035	0.58	2.6
5	8/24/2017	17.2	0.196	1.11	88	1.12	0.84	58	1.41	0.037	0.013	0.026	0.009	0.46	1.8	0.41	162	107	0.23	0.039	0.60	2.0
6	8/25/2017	17.6	0.183	1.15	96	1.36	0.87	37	1.53	0.043	0.012	0.028	0.008	0.52	1.9	0.49	201	123	0.28	0.034	0.59	2.6
7	8/26/2017	16.0	0.169	1.14	94	1.37	0.89	29	1.45	0.037	0.012	0.026	0.008	0.53	1.8	0.47	173	98	0.28	0.035	0.54	2.4
8	8/27/2017	15.1	0.173	1.34	87	1.44	0.89	24	1.54	0.037	0.014	0.024	0.009	0.60	1.8	0.47	120	109	0.22	0.051	0.59	2.6
9	8/28/2017	14.6	0.168	1.31	87	1.38	0.86	35	1.44	0.045	0.013	0.031	0.009	0.53	1.7	0.47	141	107	0.24	0.044	0.50	2.3
10	8/29/2017	18.9	0.181	1.17	104	1.70	0.91	20	2.07	0.034	0.014	0.016	0.007	0.57	2.0	0.44	171	118	0.24	0.044	0.60	3.4
11	8/30/2017	18.1	0.178	1.02	102	1.01	0.83	81	1.64	0.054	0.013	0.033	0.008	0.42	2.0	0.32	167	111	0.17	0.029	0.46	2.0
12	8/31/2017	17.9	0.196	1.17	91	0.88	0.81	73	1.35	0.035	0.012	0.026	0.009	0.52	2.1	0.41	171	98	0.24	0.057	0.59	1.9
	Average	**18.5**	**0.185**	**1.18**	**100**	**1.32**	**0.87**	**41**	**1.58**	**0.039**	**0.012**	**0.025**	**0.008**	**0.51**	**1.89**	**0.44**	**187**	**112**	**0.25**	**0.037**	**0.56**	**2.48**
	Median	**18.0**	**0.182**	**1.17**	**95**	**1.36**	**0.88**	**34**	**1.54**	**0.037**	**0.012**	**0.025**	**0.008**	**0.53**	**1.87**	**0.45**	**172**	**109**	**0.24**	**0.037**	**0.59**	**2.51**
	Minimum	**14.6**	**0.168**	**1.02**	**87**	**0.88**	**0.81**	**20**	**1.35**	**0.032**	**0.010**	**0.016**	**0.006**	**0.42**	**1.68**	**0.32**	**120**	**98.0**	**0.17**	**0.015**	**0.46**	**1.85**
	Maximum	**24.4**	**0.202**	**1.34**	**125**	**1.70**	**0.93**	**81**	**2.07**	**0.054**	**0.014**	**0.033**	**0.009**	**0.60**	**2.11**	**0.49**	**275**	**135.0**	**0.30**	**0.057**	**0.60**	**3.38**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

This spreadsheet tab reflects the results of the January 2018 testing which showed by influent COD is 15% higher than reported and influent TSS is 35% higher than reported
Assume CBOD5 increases by 15% -same as CBOD
Assume VSS increases by COD increase/1.6 or roughly 1.3x

Don Esping:
Assumes Additional VSS = Additional COD/1.58 mg COD/mg VSS

Primary Influent - Adjusted

Day	Date	Flow to HPO mgd	Flow to ABC mgd	COD mg/L	Filtered COD mg/L	ffCOD mg/L	CBOD5 mg/L	Filtered CBOD5 mg/L	TKN mg/L as N	Filtered TKN mg/L as N	NH3 mg/L as N	Nitrate/Nox as N, mg/L	Total P mg/L as P	Filtered P mg/L as P	PO4-P mg/L as P	Total Alk mg/L as CaCO	TSS mg/L	VSS mg/L	pH	Notes
	Adjustment Factor			1.15			1.15										1.35	1.58		
1	**8/20/2017**	8.3	5.6	869	368	244	415	190	47.2	35.3	26.7	1.33	8.0	4.2	4.5	418	335	305	6.82	
2	**8/21/2017**	10.5	4.9	845	342	220	400	172	48.2	36.2	27.9	1.50	8.4	5.5	4.8	418	335	301	6.87	
3	**8/22/2017**	11.1	4.7	750	312	240	391	166	48.3	34.3	28.6	0.78	7.7	4.5	4.1	430	313	269	6.74	
4	**8/23/2017**	10.5	5.0	668	276	188	340	110	50.2	40.4	32.7	1.27	8.2	4.76	5.3	460	392	326	7.05	
5	**8/24/2017**	10.0	5.0	644	274	171	331	110	48.9	39.0	28.9	1.63	7.7	4.4	4.7	450	271	232	7.11	
6	**8/25/2017**	10.0	5.0	730	316	203	376	150	51.4	40.4	30.2	1.46	9.4	5.0	5.1	455	305	262	7.06	
7	**8/26/2017**	9.1	5.1	622	263	167	302	131	50.2	37.6	28.7	1.86	7.3	4.3	4.1	435	246	225	6.87	
8	**8/27/2017**	9.5	5.3	558	229	131	274	88	46.3	37.5	30.6	1.85	7.1	3.6	4.5	425	311	263	7.01	
9	**8/28/2017**	11.3	3.8	607	250	148	331	94.4	48.7	40.3	32.3	1.41	7.2	3.8	5.0	454	275	234	7.1	
10	**8/29/2017**	12.9	2.7	649	286	205	371	103	47.5	37.0	28.3	1.36	8.0	4.1	4.7	433	319	269	7.15	
11	**8/30/2017**	11.5	4.0	607	269	184	317	112	45.4	36.6	27.8	1.11	7.8	4.4	4.9	433	246	208	7.12	
12	**8/31/2017**	8.4	6.2	612	272	169	304	106	44.8	39.1	28.6	1.38	8.0	4.5	5.4	448	243	214	7.13	
	Average	**10.3**	**4.8**	**680**	**288**	**189**	**346**	**128**	**48.1**	**37.8**	**29.3**	**1.41**	**7.9**	**4.4**	**4.8**	**438**	**299**	**259**	**7.00**	
	Median	**10.2**	**5.0**	**646**	**275**	**186**	**336**	**111**	**48.3**	**37.6**	**28.7**	**1.40**	**7.9**	**4.4**	**4.7**	**434**	**308**	**263**	**7.06**	
	Minimum	**8.3**	**2.7**	**558**	**229**	**131**	**274**	**88**	**44.8**	**34.3**	**26.7**	**1.4**	**7.1**	**3.6**	**4.1**	**418**	**243**	**208**	**6.74**	
	Maximum	**12.9**	**6.2**	**869**	**368**	**244**	**415**	**190**	**51.4**	**40.4**	**32.7**	**1.9**	**9.4**	**5.5**	**5.4**	**460**	**392**	**326**	**7.15**	
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12.00**	

🟨 **= Data Screened from dataset**

🟩 **Adjusted influent data**

CALCULATIONS

Day	Date	GENERAL				SOLIDS CHARACTERIZATION								COD FRACTIONS							
		COD:TKN	**TP:TKN**	**COD:TP**	**BOD5:TSS**	**VSS:TSS**	**ISS**	**Fcvxi/s pCOD:VSS**	**pN:VSS**	**pP:VSS**	**FupN pN/pCOD**	**FupP pP:pCOD**	**Fna NH3:TKN**	**COD:BOD5**	**SCOD:COD**	**RBCOD**	**colCOD**	**Fbs**	**Fus**	**Fpo4 PO4-P:TP**	**COD:TSS**
1	8/20/2017	18.4	0.169	109	1.24	0.91	30	1.64	0.039	0.01	0.024	0.008	0.57	2.1	0.42	224	124	0.26	0.023	0.57	2.6
2	8/21/2017	17.5	0.174	101	1.20	0.90	34	1.67	0.040	0.01	0.024	0.006	0.58	2.1	0.40	207	122	0.24	0.015	0.57	2.5
3	8/22/2017	15.5	0.159	98	1.25	0.86	44	1.63	0.052	0.01	0.032	0.007	0.59	1.9	0.42	210	72	0.28	0.040	0.54	2.4
4	8/23/2017	13.3	0.163	81	0.87	0.83	65	1.20	0.030	0.01	0.025	0.009	0.65	2.0	0.41	162	88	0.24	0.039	0.65	1.7
5	8/24/2017	13.2	0.157	84	1.22	0.85	40	1.60	0.043	0.01	0.027	0.009	0.59	1.9	0.43	143	103	0.22	0.043	0.61	2.4
6	8/25/2017	14.2	0.183	78	1.23	0.86	44	1.58	0.042	0.02	0.027	0.011	0.59	1.9	0.43	179	113	0.25	0.033	0.54	2.4
7	8/26/2017	12.4	0.145	86	1.23	0.91	21	1.60	0.056	0.01	0.035	0.008	0.57	2.1	0.42	145	96	0.23	0.035	0.56	2.5
8	8/27/2017	12.0	0.153	79	0.88	0.85	47	1.25	0.033	0.01	0.027	0.011	0.66	2.0	0.41	103	98	0.18	0.050	0.63	1.8
9	8/28/2017	12.5	0.149	84	1.20	0.85	42	1.53	0.036	0.01	0.024	0.010	0.66	1.8	0.41	122	102	0.20	0.043	0.69	2.2
10	8/29/2017	13.7	0.169	81	1.17	0.84	50	1.35	0.039	0.01	0.029	0.011	0.60	1.7	0.44	173	81	0.27	0.049	0.58	2.0
11	8/30/2017	13.4	0.172	78	1.29	0.84	38	1.63	0.042	0.02	0.026	0.010	0.61	1.9	0.44	156	85	0.26	0.046	0.63	2.5
12	8/31/2017	13.7	0.179	76	1.25	0.88	29	1.59	0.027	0.02	0.017	0.010	0.64	2.0	0.44	143	103	0.23	0.067	0.67	2.5
	Average	**14.1**	**0.164**	**86**	**1.17**	**0.87**	**40**	**1.52**	**0.040**	**0.014**	**0.026**	**0.009**	**0.61**	**1.96**	**0.42**	**164**	**99**	**0.24**	**0.040**	**0.60**	**2.30**
	Median	**13.5**	**0.166**	**83**	**1.23**	**0.86**	**41**	**1.59**	**0.039**	**0.014**	**0.026**	**0.009**	**0.59**	**1.95**	**0.42**	**159**	**100**	**0.24**	**0.041**	**0.60**	**2.39**
	Minimum	**12.0**	**0.145**	**76**	**0.87**	**0.83**	**21**	**1.20**	**0.027**	**0.009**	**0.017**	**0.006**	**0.57**	**1.75**	**0.40**	**103**	**72.0**	**0.18**	**0.015**	**0.54**	**1.71**
	Maximum	**18.4**	**0.183**	**109**	**1.29**	**0.91**	**65**	**1.67**	**0.056**	**0.017**	**0.035**	**0.011**	**0.66**	**2.11**	**0.44**	**224**	**124.0**	**0.28**	**0.067**	**0.69**	**2.60**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

This spreadsheet tab reflects the results of the January 2018 testing which showed by Primary effluent values higher than reported values
Analysis assumes the soluble/filtered concentrations are not impacted

Don Esping:
Assume same as TSS due to Fe solids added

Primary 1/2 Effluent-Adjusted

Day	Date	Reported Flow mgd	Pri. Effluent to HPOAS Stage 2 mgd	COD mg/L	Filtered COD mg/L	ffCOD mg/L	CBOD5 mg/L	Filtered CBOD5 mg/L	TKN mg/L as N	Filtered TKN mg/L as N	NH3 mg/L as N	(Grab) Nitrate as N, mg/L	Total P mg/L as P	Filtered P mg/L as P	PO4-P mg/L as P	Total Alk mg/L as CaCO3	TSS mg/L	VSS mg/L	pH	FeCl3 gpd	Notes
	Adjustment Factor			1.2			1.2						1.1				1.2	1.2			
1	**8/20/2017**	8.3	0.8	487	276	[redacted]	244	147	39	[redacted]	26.5	[redacted]	4.0	[redacted]	1.76	389	89	85	6.54	685	
2	**8/21/2017**	10.5	0.8	462	276	[redacted]	236	145	40.2	[redacted]	28	[redacted]	4.6	[redacted]	2.06	399	88	79	6.5	674	
3	**8/22/2017**	11.1	0.8	478	293	[redacted]	264	153	39.9	[redacted]	29	[redacted]	4.8	[redacted]	2.07	420	88	83	6.52	603	
4	**8/23/2017**	10.5	0.8	388	220	[redacted]	193	92	46.1	[redacted]	34.1	[redacted]	4.6	[redacted]	2.59	431	83	73	6.71	614	
5	**8/24/2017**	10.0	0.8	365	216	[redacted]	193	91.9	43.2	[redacted]	30.7	[redacted]	4.3	[redacted]	2.06	431	67	54	6.7	600	
6	**8/25/2017**	10.0	0.9	388	227	[redacted]	186	103	44.6	[redacted]	32.2	[redacted]	4.6	[redacted]	2.28	425	78	76	6.8	606	
7	**8/26/2017**	9.1	0.8	379	229	[redacted]	205	111	41.2	[redacted]	30.8	[redacted]	3.7	[redacted]	1.63	414	82	77	6.7	608	
8	**8/27/2017**	9.5	0.8	323	188	[redacted]	157	69	41.5	[redacted]	31.3	[redacted]	3.1	[redacted]	1.65	425	66	61	6.77	611	
9	**8/28/2017**	11.3	0.8	356	210	[redacted]	210	80	44.5	[redacted]	33.3	[redacted]	4.2	[redacted]	2.58	434	67	61	6.88	600	
10	**8/29/2017**	12.9	0.8	359	218	[redacted]	216	94	40.7	[redacted]	30.1	[redacted]	4.7	[redacted]	2.42	423	82	74	6.8	606	
11	**8/30/2017**	11.5	0.9	331	205	[redacted]	204	125	42	[redacted]	31.4	[redacted]	4.0	[redacted]	2.33	413	73	61	6.7	738	
12	**8/31/2017**	8.4	0.8	313	188	[redacted]	152	78	39.1	[redacted]	24.5	[redacted]	3.3	[redacted]	1.80	418	54	46	6.64	680	
	Average	**10.3**	**0.8**	**386**	**229**	**#DIV/0!**	**205**	**107**	**42**	**#DIV/0!**	**30**	**#DIV/0!**	**4.2**	**#DIV/0!**	**2.1**	**419**	**76**	**69**	**7**	**635**	
	Median	**10.2**	**0.8**	**372**	**219**	**#NUM!**	**205**	**99**	**41**	**#NUM!**	**31**	**#NUM!**	**4.2**	**#NUM!**	**2.1**	**422**	**80**	**74**	**7**	**610**	
	Minimum	**8.3**	**0.8**	**313**	**188**	**0**	**152**	**69**	**39**	**0**	**25**	**0**	**3.1**	**0**	**1.6**	**389**	**54**	**46**	**7**	**600**	
	Maximum	**12.9**	**0.9**	**487**	**293**	**0**	**264**	**153**	**46**	**0**	**34**	**0**	**4.8**	**0**	**2.6**	**434**	**89**	**85**	**7**	**738**	
	Count	**12**	**12**	**12**	**12**	**0**	**12**	**12**	**12**	**0**	**12**	**0**	**12**	**0**	**12**	**12**	**12**	**12**	**12**	**12**	

🟨 **= Data Screened from dataset**

🟩 **Adjusted data**

CALCULATIONS

		GENERAL				SOLIDS CHARACTERIZATION								COD FRACTIONS							
Day	**Date**	**COD:TKN**	**TP:TKN**	**COD:TP**	**BOD5:TSS**	**VSS:TSS**	**ISS**	**Fcvxi/s pCOD:VSS**	**pN:VSS**	**pP:VSS**	**TSS:TP**	**FupP pP:pCOD**	**Fna NH3:TKN**	**COD:BOD**	**SCOD:COD**	**RBCOD**	**colCOD removed**	**Est Coll COD**	**Fus**	**Alkalinity, mmoles/L**	**Fpo4 PO4-P:TP**
1	8/20/2017	12.5	0.102	122	2.74	0.96	4	2.48	0.46	0.047	18		0.68	2.0	0.57		92	32		7.78	0.44
2	8/21/2017	11.5	0.115	100	2.70	0.90	8	2.35	0.51	0.058	16		0.70	2.0	0.60		66	56		7.98	0.45
3	8/22/2017	12.0	0.120	100	3.01	0.95	5	2.23	0.48	0.058	17		0.73	1.8	0.61		19	53		8.40	0.43
4	8/23/2017	8.4	0.100	84	2.33	0.88	10	2.29	0.63	0.063	22		0.74	2.0	0.57		56	32		8.62	0.56
5	8/24/2017	8.4	0.099	85	2.88	0.80	13	2.76	0.80	0.079	21		0.71	1.9	0.59		58	45		8.62	0.48
6	8/25/2017	8.7	0.103	84	2.38	0.97	2	2.12	0.59	0.061	16		0.72	2.1	0.59		89	24		8.50	0.49
7	8/26/2017	9.2	0.089	103	2.51	0.94	5	1.96	0.54	0.048	17		0.75	1.8	0.60		34	62		8.28	0.44
8	8/27/2017	7.8	0.074	105	2.38	0.93	5	2.20	0.68	0.050	18		0.75	2.1	0.58		41	57		8.50	0.54
9	8/28/2017	8.0	0.093	86	3.13	0.91	6	2.39	0.73	0.068	16		0.75	1.7	0.59		40	62		8.68	0.62
10	8/29/2017	8.8	0.116	76	2.65	0.91	7	1.89	0.55	0.064	18		0.74	1.7	0.61		68	13		8.46	0.51
11	8/30/2017	7.9	0.095	83	2.79	0.84	12	2.06	0.69	0.065	19		0.75	1.6	0.62		64	21		8.26	0.59
12	8/31/2017	8.0	0.085	94	2.82	0.84	8	2.75	0.86	0.073	18		0.63	2.1	0.60		84	19		8.36	0.54
	Average	9.3	0.099	94	2.69	0.90	7	2.29	0.625	0.061	18		0.72	1.89	0.59		59	40		8.37	0.51
	Median	8.6	0.099	90	2.72	0.91	7	2.26	0.610	0.062	18		0.73	1.92	0.59		61	39		8.43	0.503
	Minimum	7.8	0.074	76	2.33	0.80	2	1.89	0.458	0.047	15.745		0.63	1.62	0.57		19	13		7.78	0.432
	Maximum	12.5	0.120	122	3.13	0.97	13	2.76	0.857	0.079	22.210		0.75	2.08	0.62		92	62		8.68	0.620
	Count	12	12	12	12	12	12	12	12	12	12		12	12	12		12	12		12	12

This spreadsheet tab reflects the results of the January 2018 testing which showed by Primary effluent values higher than reported values
Analysis assumes the soluble/filtered concentrations are not impacted

Primary 3 Effluent - Adjusted

Day	Date	Reported Flow mgd	COD mg/L	COD (WRP) mg/L	Filtered COD mg/L	ffCOD mg/L	CBOD5 mg/L	Filtered CBOD5 mg/L	TKN mg/L as N	Filtered TKN mg/L as N	NH3 mg/L as N	(Grab) Nitrate as N, mg/L	Total P mg/L as P	Filtered P mg/L as P	PO4-P mg/L as P	Total Alk mg/L as CaCO3	TSS mg/L	VSS mg/L	pH	Temp F	Notes
	Adjustment Factor		1.55				1.55						1.2				1.55	1.55			
1	**8/20/2017**	5.6	828	650	340		392	167	43		26.5		8.1		4.77	428	191	181	6.75		
2	**8/21/2017**	4.9	786	890	306		372	161	43.3		27		8.4		4.64	418	192	183	6.67		
3	**8/22/2017**	4.7	781	800	310		394	156	42.7		29.3		8.5		4.45	440	174	153	6.6		
4	**8/23/2017**	5.0	653	920	267		310	108	47.5		33.7		8.6		5.19	470	158	143	6.77		
5	**8/24/2017**	5.0	775	655	267		316	112	19.3		30		8.4		4.65	460	140	129	6.7		
6	**8/25/2017**	5.0	693	590	274		332	122	46		30.8		8.2		4.55	455	141	136	6.8		
7	**8/26/2017**	5.1	626	600	276		322	134	44		29.4		6.9		4.07	445	147	141	6.7		
8	**8/27/2017**	5.3	524	500	220		248	84	42.4		30.6		6.8		3.96	446	155	146	6.87		
9	**8/28/2017**	3.8	457	660	197		239	62	44.5		33.4		6.7		4.40	454	96	91	7.04		
10	**8/29/2017**	2.7	524	450	242		285	93	40.5		31.5		7.1		4.17	443	118	107	6.8		
11	**8/30/2017**	4.0	617	520	267		295	121	40.3		29.5		6.9		4.08	443	104	98	6.9		
12	**8/31/2017**	6.2	629	650	272		285	113	40.5		29.2		7.7		4.51	438	130	118	6.97		
	Average	**4.8**	**658**	**657**	**270**		**316**	**119**	**41**		**30**		**7.7**		**4.5**	**445**	**145**	**135**	**7**		
	Median	**5.0**	**641**	**650**	**270**		**313**	**117**	**43**		**30**		**7.9**		**4.5**	**444**	**144**	**139**	**7**		
	Minimum	**2.7**	**457**	**450**	**197**		**239**	**62**	**19**		**27**		**6.7**		**4.0**	**418**	**96**	**91**	**7**		
	Maximum	**6.2**	**828**	**920**	**340**		**394**	**167**	**48**		**34**		**8.6**		**5.2**	**470**	**192**	**183**	**7**		
	Count	**12**	**12**	**12**	**12**	**0**	**12**	**12**	**12**	**0**	**12**	**0**	**12**	**0**	**12**	**12**	**12**	**12**	**12**	**0**	

🟨 **= Data Screened from dataset** 🟩 **Adjusted data**

CALCULATIONS

Day	Date	GENERAL					SOLIDS CHARACTERIZATION							Fna NH3:TKN	COD FRACTIONS						Alkalinity, mmoles/L	Fpo4 PO4-P:TP
		COD:TKN	TP:TKN	COD(WRP): COD	COD:TP	BOD5:TSS	VSS:TSS	ISS	Fcvxi/s pCOD:VSS	pN:VSS	pP:VSS	FupN pN/pCOD	FupP pP:pCOD		COD:BOD	SCOD:COD	RBCOD	colCOD removed	Fbs	Fus		
1	8/20/2017	19.2	0.188	0.79	102	2.06	0.95	9	2.69	0.24	0.045	0.088	0.017	0.62	2.1	0.41		28.00			8.56	0.59
2	8/21/2017	18.1	0.193	1.13	94	1.94	0.95	9	2.62	0.24	0.046	0.090	0.017	0.62	2.1	0.39		36.00			8.36	0.55
3	8/22/2017	18.3	0.200	1.02	92	2.27	0.88	20	3.07	0.28	0.056	0.091	0.018	0.69	2.0	0.40		2.00			8.80	0.52
4	8/23/2017	13.7	0.182	1.41	76	1.96	0.90	16	2.70	0.33	0.061	0.123	0.022	0.71	2.1	0.41		9.00			9.40	0.60
5	8/24/2017	40.2	0.437	0.85	92	2.27	0.92	11	3.95	0.15	0.066	0.038	0.017	1.55	2.5	0.34		7.00			9.20	0.55
6	8/25/2017	15.1	0.179	0.85	84	2.35	0.97	5	3.07	0.34	0.060	0.110	0.020	0.67	2.1	0.40		42.00			9.10	0.55
7	8/26/2017	14.2	0.156	0.96	91	2.19	0.96	6	2.48	0.31	0.049	0.126	0.020	0.67	1.9	0.44		-13.00			8.90	0.59
8	8/27/2017	12.4	0.160	0.95	77	1.60	0.94	9	2.09	0.29	0.047	0.140	0.022	0.72	2.1	0.42		9.00			8.92	0.58
9	8/28/2017	10.3	0.152	1.44	68	2.48	0.95	5	2.85	0.49	0.074	0.171	0.026	0.75	1.9	0.43		53.00			9.08	0.65
10	8/29/2017	12.9	0.176	0.86	74	2.42	0.91	11	2.64	0.38	0.067	0.144	0.025	0.78	1.8	0.46		44.00			8.86	0.59
11	8/30/2017	15.3	0.171	0.84	89	2.84	0.94	6	3.58	0.41	0.071	0.115	0.020	0.73	2.1	0.43		2.00			8.86	0.59
12	8/31/2017	15.5	0.191	1.03	82	2.19	0.90	12	3.03	0.34	0.066	0.113	0.022	0.72	2.2	0.43		0.00			8.76	0.58
	Average	17.1	0.199	1.01	85	2.21	0.93	10	2.90	0.316	0.059	0.112	0.020	0.77	2.08	0.41		18.25			8.90	0.58
	Median	15.2	0.180	0.96	87	2.23	0.94	9	2.77	0.323	0.060	0.114	0.020	0.72	2.10	0.42		9.00			8.88	0.585
	Minimum	10.3	0.152	0.79	68	1.60	0.88	5	2.09	0.150	0.045	0.038	0.017	0.62	1.84	0.34		-13.00			8.36	0.522
	Maximum	40.2	0.437	1.44	102	2.84	0.97	20	3.95	0.487	0.074	0.171	0.026	1.55	2.45	0.46		53.00			9.40	0.652
	Count	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12		12			12	12

HPO Aeration Basins

		1st Stage Mixed Liquor (BOD HPOAS)												2nd Stage Mixed Liquor (Nitrifying HPOAS)											
Day	Date	Flow mgd	MLSS mg/L	MLVSS mg/L	COD mg/L	NH3-N mg/L	TKN mg/L as N	Total P mg/L as P	RAS flow mgd	RAS TSS mg/L	WAS mgd	Oxygen Flow cfm	pH	Flow mgd	MLSS mg/L	MLVSS mg/L	COD mg/L	NH3-N mg/L	TKN mg/L as N	Total P mg/L as P	RAS flow mgd	RAS TSS mg/L	WAS mgd	Oxygen Flow cfm	pH
1	8/20/2017	7.52	1,675	1,600	1,630	25	148	36	4.18	4,000	0.238	126	6.35	8.1	3,690	2,930	3,910	6.74	241	130	4.58	9,000	0.067	247	5.83
2	8/21/2017	9.68	1,800	1,600	4,640	22	167	30	5.26	4,000	0.238	125	6.40	10.3	3,520	2,720	4,420	4.00	231	121	5.44	9,000	0.076	248	5.93
3	8/22/2017	10.31	1,500	1,350	3,230	21	156	27	5.57	3,500	0.233	145	6.49	10.9	3,410	2,640	3,850	3.89	242	120	5.58	9,150	0.090	228	5.97
4	8/23/2017	9.64	1,460	1,350	3,740	24	160	28	5.24	3,250	0.238	142	6.41	10.2	3,300	2,630	3,510	3.43	227	106	5.33	8,950	0.094	232	5.97
5	8/24/2017	9.17	1,320	1,220	3,040	28	168	27	5.01	3,000	0.231	177	6.58	9.8	3,310	2,610	3,680	3.03	221	110	5.11	8,300	0.100	253	5.92
6	8/25/2017	9.13	1,310	1,110	2,760	31	158	30	5.00	3,100	0.204	194	6.53	9.8	2,890	2,270	2,860	3.31	196	103	5.10	7,900	0.091	211	5.95
7	8/26/2017	8.27	1,260	1,150	2,200	29	144	29	4.56	2,750	0.216	165	6.61	8.9	2,870	2,240	3,510	3.31	207	99	4.70	7,250	0.089	209	5.98
8	8/27/2017	8.64	1,270	1,180	1,860	29	162	27	4.75	2,800	0.216	174	6.51	9.3	2,850	2,230	8720	3.60	201	100	5.08	6,550	0.090	203	5.90
9	8/28/2017	10.47	1,330	1,220	2,400	32	165	30	5.62	2,850	0.216	183	6.53	11.1	2,930	2,240	3,290	5.29	198	101	6.13	6,200	0.090	192	5.83
10	8/29/2017	12.01	1,250	1,100	2,050	24	140	25	6.70	2,850	0.216	166	6.56	12.6	2,450	1,940	2,460	6.71	168	79	6.77	6,200	0.090	199	6.00
11	8/30/2017	10.61	1,440	1,310	1,950	21	151	29	6.82	2,350	0.216	131	6.48	11.2	2,600	2,020	2,760	6.43	182	89	7.11	5,700	0.079	212	6.03
12	8/31/2017	7.60	1,610	1,450	2,120	26	193	33	5.49	3,250	0.216	143	6.42	8.2	2,490	1,940	2,460	4.89	162	89	6.11	6,250	0.075	257	5.95
	Average	**9.4**	**1435**	**1303**	**2635**	**26**	**159**	**29**	**5.35**	**3142**	**0.22**	**156**	**6.5**	**10.0**	**3026**	**2368**	**3337**	**4.6**	**206**	**104**	**5.59**	**7538**	**0.09**	**224**	**5.9**
	Median	**9.4**	**1385**	**1265**	**2300**	**25**	**159**	**29**	**5.25**	**3050**	**0.22**	**155**	**6.5**	**10.0**	**2910**	**2255**	**3510**	**3.9**	**204**	**102**	**5.39**	**7575**	**0.09**	**220**	**6.0**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**11**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

🟨 **= Data Screened from dataset**

		HPO Activated Sludge Plant 1							Calc. RAS		HPO 1st Stage DO				HPO Activated Sludge Plant 2							Calc. RAS		HPO 2nd Stage DO		
Day	Date	COD: VSS	TP:VSS	TKN: VSS	MLVSS :MLSS	RAS VSS		SRT days	Theory	Theory:Reported	Train 1 Cell 3 mg/L	Train 2 Cell 3 mg/L	mg/L		COD: VSS	TP:VSS	TKN: VSS	RAS VSS	MLVSS: MLSS	Hyd SRT days	SRT days	Theory	Theory:reported	Train 1 Cell 3 mg/L	Train 2 Cell 3 mg/L	Train 3 Cell 3 mg/L
1	8/20/2017	1.02	2.3%	9.3%	96%	3821		0.6	4532	1.13	8.1	10.5			1.33	4.4%	8.2%	7146	79%	[redacted]	13.2	10185	1.13	8.9	6.7	13.0
2	8/21/2017	2.90	1.9%	10.4%	89%	3556		0.5	4869	1.22	6.5	8.7			1.63	4.4%	8.5%	6955	77%	[redacted]	10.4	10111	1.12	9.9	7.6	12.9
3	8/22/2017	2.39	2.0%	11.6%	90%	3150		0.4	4017	1.15	3.6	6.2			1.46	4.6%	9.2%	7084	77%	[redacted]	8.6	10017	1.09	7.4	5.6	10.8
4	8/23/2017	2.77	2.1%	11.9%	92%	3005		0.6	4005	1.23	1.4	3.9			1.33	4.0%	8.6%	7133	80%	[redacted]	7.4	9557	1.07	5.8	2.2	7.7
5	8/24/2017	2.49	2.2%	13.8%	92%	2773		0.7	3662	1.22	10.4	12.6			1.41	4.2%	8.5%	6545	79%	[redacted]	8.5	9582	1.15	6.0	1.9	8.0
6	8/25/2017	2.49	2.7%	14.2%	85%	2627		0.4	3458	1.12	19.4	20.4			1.26	4.5%	8.6%	6205	79%	[redacted]	8.9	8393	1.06	8.6	4.6	10.8
7	8/26/2017	1.91	2.5%	12.5%	91%	2510		0.6	3408	1.24	18.0	19.8			1.57	4.4%	9.2%	5659	78%	[redacted]	9.5	8257	1.14	7.0	2.2	8.9
8	8/27/2017	1.58	2.3%	13.7%	93%	2602		0.5	3412	1.22	16.9	19.2			3.91	4.5%	9.0%	5125	78%	[redacted]	8.5	7982	1.22	8.1	2.8	9.3
9	8/28/2017	1.97	2.4%	13.5%	92%	2614		0.4	3592	1.26	19.8	20.5			1.47	4.5%	8.8%	4740	76%	[redacted]	9.7	8188	1.32	8.7	3.3	9.7
10	8/29/2017	1.86	2.3%	12.7%	88%	2508		0.3	3251	1.14	18.3	19.7			1.27	4.1%	8.7%	4909	79%	[redacted]	7.7	6974	1.12	7.6	4.6	11.5
11	8/30/2017	1.49	2.2%	11.5%	91%	2138		0.6	3561	1.52	8.8	11.6			1.37	4.4%	9.0%	4428	78%	[redacted]	9.0	6665	1.17	2.4	2.5	8.7
12	8/31/2017	1.46	2.3%	13.3%	90%	2927		1.1	3808	1.17	6.2	8.6			1.27	4.6%	8.4%	4869	78%	[redacted]	9.4	5800	0.93	4.5	3.0	9.0
	Average	**2.03**	**2.3%**	**12.4%**	**91%**	**2852**	**#DIV/0!**	**0.58**	**3798**	**1.22**	**11.45**	**13.47**	**#DIV/0!**	**#DIV/0!**	**1.40**	**4.4%**	**8.7%**	**5900**	**78%**	[redacted]	**9.2**	**8476**	**1.13**	**7.09**	**3.92**	**10.02**
	Median	**1.94**	**2.3%**	**12.6%**	**91%**	**2700**	**#NUM!**	**0.56**	**3627**	**1.22**	**9.58**	**12.09**	**#NUM!**	**#NUM!**	**1.37**	**4.4%**	**8.6%**	**5932**	**78%**	[redacted]	**8.9**	**8325**	**1.13**	**7.53**	**3.14**	**9.48**
	Count	**12**	**12**	**12**	**12**	**12**	**0**	**12**	**12**	**12**	**12**	**12**	**0**	**0**	**11**	**12**	**12**	**12**	**12**	[redacted]	**12**	**12**	**12**	**12**	**12**	**12**

Brown AND Caldwell

Intermediate Effluent

Date	Flow mgd	Filtered COD mg/L	ffCOD mg/L	Colloidal COD mg/L	CBOD5 mg/L	TKN mg/L as N	NH3 mg/L as N	Total P mg/L as P	PO4-P mg/L as P	Total Alk mg/L as CaCO3	TSS mg/L	VSS mg/L	pH	Blanket depth feet
8/20/2017	7.3	54	43	11		31.3	20.8	2.25	0.63	379	88	80	6.42	
8/21/2017	9.4	58	28	30	>22.5	34.9	20.2	3.02	0.58	379	133	125	6.5	
8/22/2017	10.1	92	39	53	>31.5	31.5	19.5	3.13	0.62	400	139	120	6.47	
8/23/2017	9.4	90	47	43	>24.4	33.5	30.1	1.77	0.33	401	77	71	6.51	
8/24/2017	8.9	66	45	21	23	31.4	23.8	1.15	0.25	411	41	39	6.6	
8/25/2017	8.9	56	32	24	>35	39.8	25.2	3.49	0.81	405	133	121	6.6	
8/26/2017	8.1	56	32	24	29	32.1	24.1	1.94	0.63	394	75	74	6.6	
8/27/2017	8.4	64	43	21	31	33.5	24.9	1.66	0.17	385	93	87	6.59	
8/28/2017	10.3	75	41	34	55	41.7	28.2	3.26	1.30	404	116	107	6.6	
8/29/2017	11.8	75	37	38	68	36.3	23.8	3.60	1.52	403	134	119	6.6	
8/30/2017	10.4	60	32	28	29	29.4	21.8	2.07	0.88	383	78	72	6.6	
8/31/2017	7.4	60	69		13	26.6	21.5	1.09	0.57	397	23	21	6.6	
Average	**9.2**	**67**	**38**	**30**	**35**	**33.5**	**23.7**	**2.4**	**0.7**	**395**	**94**	**86**	**6.5**	**#DIV/0!**
Median	**9.2**	**62**	**39**	**28**	**29**	**32.8**	**23.8**	**2.2**	**0.6**	**399**	**91**	**84**	**6.6**	**#NUM!**
Minimum	**7.3**	**54**	**28**	**11**	**13**	**26.6**	**19.5**	**1.1**	**0.2**	**379**	**23**	**21**	**6.4**	**0.0**
Maximum	**11.8**	**92**	**47**	**53**	**68**	**41.7**	**30.1**	**3.6**	**1.5**	**411**	**139**	**125**	**6.6**	**0.0**
Count	**12**	**12**	**11**	**11**	**7**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12.0**	**0.0**

Final 1-4 Effluent

Day	Date	Flow mgd	Filtered COD mg/L	ffCOD mg/L	CBOD5 mg/L	TKN mg/L as N	NH3 mg/L as N	Nitrate/NOx as N, mg/L	Total P mg/L as P	PO4-P mg/L as P	TSS mg/L	VSS mg/L	pH	Alkalinity mgCaCO3/L	Alum Feed gpd	Blanket Depth ft
1	8/20/2017	8.0	34	20	3.4	2.2	<0.16	29.8	1.14	0.65	21	17	5.8	185	318	1.8
2	8/21/2017	10.2	30	13	4.8	3.7	<0.16	27.8	1.21	0.61	25	22	5.8	195	318	1.9
3	8/22/2017	10.8	49	30	6.3	4.9	0.51	27.0	1.18	0.56	26	24	5.9	220	344	1.5
4	8/23/2017	10.1	49	26	6.9	4.6	0.51	26.6	1.18	0.61	39	30	5.9	215	399	2.0
5	8/24/2017	9.7	47	28	4.9	4.4	0.66	33.0	1.19	0.60	27	22	5.9	196	398	1.9
6	8/25/2017	9.7	45	24	3.9	5.5	0.94	33.9	1.09	0.54	20	17	5.9	198	389	1.5
7	8/26/2017	8.8	37	22	4.2	4.0	0.66	34.1	1.08	0.55	22	19	5.9	192	380	1.4
8	8/27/2017	9.2	49	28	4.6	4.1	0.51	33.6	1.11	0.62	38	36	5.9	187	378	1.4
9	8/28/2017	11.0	52	26	5.3	7.9	4.49	31.9	1.13	0.70	25	20	5.8	202	384	1.3
10	8/29/2017	12.5	52	32	7.4	10.9	7.05	25.6	1.32	0.75	26	20	6.0	237	445	1.5
11	8/30/2017	11.2	54	28	5.7	8.5	3.36	26.6	1.55	0.85	32	25	6.0	222	507	1.4
12	8/31/2017	8.2	45	41	5.9	5.2	0.51	31.4	1.69	0.96	33	24	6.0	194	508	0.5
	Average	**9.9**	**45**	**27**	**5.3**	**5.5**	**1.9**	**30.1**	**1.2**	**0.67**	**28**	**23**	**5.9**	**204**		**1.5**
	Median	**9.9**	**48**	**27**	**5.1**	**4.8**	**0.7**	**30.6**	**1.2**	**0.62**	**26**	**22**	**5.9**	**197**		**1.5**
	Minimum	**8.0**	**30**	**13**	**3.4**	**2.2**	**0.5**	**25.6**	**1.1**	**0.54**	**20**	**17**	**5.8**	**185**		**0.5**
	Maximum	**12.5**	**54**	**41**	**7.4**	**10.9**	**7.1**	**34.1**	**1.7**	**0.96**	**39**	**36**	**6.0**	**237**		**2.0**
	Count	**12**	**12**	**12**	**12**	**12**	**10**	**12**	**12**	**12**	**12.0**	**12**	**12**	**12**		**12**

🟨 **= Data Screened from dataset**

Basin 3/4 Mixed Liquor (ABC)

Day	Date	Flow mgd	MLSS mg/L	MLVSS mg/L	COD mg/L	TKN mg/L as N	NH3-N mg/L as N	Total P mg/L as P	RAS flow mgd	RAS TSS mg/L	WAS mgd	Airflow cfm	pH	MLR mgd	PO4-P mg/L
1	**8/20/2017**	5.6	3,807	3,210	3800	275	1.71	127.2	3.50	9,700	0.115	5,744	6.98	0	5.1
2	**8/21/2017**	4.9	3,760	3,170	4080	268	2.86	123.6	3.82	9,700	0.133	5,140	6.97	0	11.4
3	**8/22/2017**	4.7	3,600	3,000	4060	296	3.60	112.6	3.88	8,500	0.157	4,840	6.98	0	7.6
4	**8/23/2017**	5.0	3500	2970	3610	272	2.86	114.0	4.00	9300	0.170	4,480	6.89	0	6.7
5	**8/24/2017**	5.0	3340	2610	3570	269	4.74	108	4.00	7800	0.179	6,112	6.90	0	8.3
6	**8/25/2017**	5.0	3210	2650	3310	239	5.60	112	4.15	7900	0.174	6,523	6.83	0	8.4
7	**8/26/2017**	5.1	3020	2450	3210	240	3.31	109	4.50	6950	0.180	5,741	6.90	0	8.3
8	**8/27/2017**	5.3	2,970	2,530	3340	277	4.17	96.8	4.50	6,250	0.182	6,940	6.81	0	9.7
9	**8/28/2017**	3.8	2,860	2,390	2610	232	4.89	92.8	3.49	6,050	0.137	6,750	6.75	0	9.3
10	**8/29/2017**	2.7	2,900	2,450	2740	218	4.44	94.8	2.50	6,050	0.094	5,217	6.81	0	9.8
11	**8/30/2017**	4.0	2760	2300	2930	190	4.55	91.8	3.08	6200	0.094	3,582	7.00	0	9.8
12	**8/31/2017**	6.2	2600	2134	2840	162	4.72	93.8	4.50	6900	0.094	5,326	7.01	0	10.1
	Average	**4.8**	**3194**	**2655**	**3342**	**245**	**4.0**	**106**	**3.83**	**7608**	**0.14**	**5533**	**7**	**0**	**9**
	Median	**5.0**	**3115**	**2570**	**3325**	**254**	**4.3**	**109**	**3.94**	**7375**	**0.15**	**5533**	**7**	**0**	**9**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

🟨 **= Data Screened from dataset**

		ABC Basins							Calc. RAS		DO		
Day	Date	COD: VSS	TP:VSS	TKN: VSS	MLVSS:MLSS	Hyd SRT days	Aerobic SRT days	Total SRT days	Theory RAS	Theory:Reported Ras	Location 1 mg/L	Location 2 mg/L	RAS VSS
1	8/20/2017	1.18	4.0%	8.6%	84%	9.4	7.6	8.9	9895	1.02			8179
2	8/21/2017	1.29	3.9%	8.5%	84%	9.2	6.6	7.7	8612	0.89			8178
3	8/22/2017	1.35	3.8%	9.9%	83%	8.1	6.0	7.1	7968	0.94			7083
4	8/23/2017	1.22	3.8%	9.2%	85%	7.3	5.0	5.9	7878	0.85			7892
5	8/24/2017	1.37	4.1%	10.3%	78%	7.0	5.4	6.3	7518	0.96			6095
6	8/25/2017	1.25	4.2%	9.0%	83%	7.3	5.3	6.2	7079	0.90			6522
7	8/26/2017	1.31	4.4%	9.8%	81%	7.3	5.4	6.3	6465	0.93			5638
8	8/27/2017	1.32	3.8%	10.9%	85%	7.1	6.0	7.0	6466	1.03			5324
9	8/28/2017	1.09	3.9%	9.7%	84%	9.8	8.0	9.4	5977	0.99			5056
10	8/29/2017	1.12	3.9%	8.9%	84%	14.4	11.7	13.6	6035	1.00			5111
11	8/30/2017	1.27	4.0%	8.3%	83%	13.0	10.2	11.9	6309	1.02			5167
12	8/31/2017	1.33	4.4%	7.6%	82%	12.6	8.9	10.4	6184	0.90			5663
	Average	**1.26**	**4.0%**	**9.2%**	**83%**	**9.36**	**7.2**	**8.4**	**7199**	**0.95**	**#DIV/0!**	**#DIV/0!**	
	Median	**1.28**	**3.9%**	**9.1%**	**83%**	**8.65**	**6.3**	**7.4**	**6772**	**0.95**	**#NUM!**	**#NUM!**	
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**0**	**0**	

Final 5 Effluent (ABC Effluent)

Day	Date	Flow mgd	Filtered COD mg/L	ffCOD mg/L	CBOD5 mg/L	TKN mg/L as N	NH3 mg/L as N	Nitrate/NOx as N, mg/L	Total P mg/L as P	PO4-P mg/L as P	TSS mg/L	VSS mg/L	pH	Alkalinity mg/L CaCO3	Alum Feed gpm	Blanket Depth ft	Notes
1	**8/20/2017**	5.5	37	20	5.0	3.4	< 0.16	15.70	0.63	0.07	16	14.7	7.2	282	0.0	2.5	
2	**8/21/2017**	4.8	37	15	5.6	3.3	< 0.16	14.20	0.63	0.04	15	13.6	7.2	292	46	2.0	
3	**8/22/2017**	4.6	43	30	6.3	4.2	0.23	15.30	0.68	0.09	22	18.8	7.1	285	161	2.0	
4	**8/23/2017**	4.8	47	30	7.5	4.4	< 0.16	18.00	0.70	0.08	19	16.3	7.2	274	160	3.0	
5	**8/24/2017**	4.8	45	39	7.1	2.7	< 0.16	19.70	0.67	0.07	18	14.8	7.1	274	159	3.0	
6	**8/25/2017**	4.8	41	41	4.8	3.9	< 0.16	19.00	0.64	0.06	15	13.4	7.1	267	161	4.0	
7	**8/26/2017**	5.0	43	26	5.2	3.6	< 0.16	17.40	0.59	0.06	17	15.8	6.9	283	162	1.0	
8	**8/27/2017**	5.1	41	32	4.6	3.1	< 0.16	17.60	0.47	0.05	11	10.3	7.1	278	161	3.5	
9	**8/28/2017**	3.7	43	22	3.3	2.5	0.17	19.30	0.31	<.033	7	7.25	7.0	257	164	2.0	
10	**8/29/2017**	2.6	66	28	2.8	2.8	< 0.16	20.80	0.36	0.06	11	10	6.9	252	130	2.0	
11	**8/30/2017**	3.9	41	28	3.1	3.2	< 0.16	19.30	0.48	0.05	17	15.5	7.0	272	79	0.5	
12	**8/31/2017**	6.1	39	26	3.3	2.8	< 0.16	17.30	0.40	0.03	9	8	7.2	285	79	3.0	
	Average	**4.6**	**44**	**28**	**4.9**	**3.3**	**0.2**	**17.80**	**0.55**	**0.06**	**14.6**	**13.2**	**7.1**	**275**	**121.9**	**2.4**	
	Median	**4.8**	**42**	**28**	**4.9**	**3.3**	**0.2**	**17.80**	**0.61**	**0.06**	**15.3**	**14.2**	**7.1**	**276**	**159.8**	**2.3**	
	Minimum	**2.6**	**37**	**15**	**2.8**	**2.5**	**0.2**	**14.2**	**0.31**	**0.03**	**7.3**	**7.3**	**6.9**	**252**	**0.0**	**0.5**	
	Maximum	**6.1**	**66**	**41**	**7.5**	**4.4**	**0.2**	**20.8**	**0.70**	**0.09**	**21.5**	**18.8**	**7.2**	**292**	**164.4**	**4.0**	
	Count	**12**	**12**	**12**	**12**	**12**	**2**	**12**	**12**	**11**	**12.0**	**12**	**12**	**12**	**12**	**12**	

🟨 **= Data Screened from dataset**

Plant Effluent

Day	Date	Flow mgd	CBOD5 mg/L	TKN mg/L as N	NH3 mg/L as N	Nitrate/NOX as N, mg/L	Total P mg/L as P	TSS mg/L	Temp	pH	Notes
1	**8/20/2017**		4.37	2.3	<.056	23.7	0.88	16	21.5	6.5	
2	**8/21/2017**		4.41	2.9	0.15	23.7	0.96	16	21.0	6.5	
3	**8/22/2017**		5.55	3.8	0.19	23.0	0.95	19	21.0	6.4	
4	**8/23/2017**		6.12	3.9	<0.16	23.2	0.96	21	21.0	6.5	
5	**8/24/2017**		5.30	3.4	0.23	28.5	0.98	19	21.0	6.5	
6	**8/25/2017**		4.82	3.7	0.37	28.2	0.88	18	20.9	6.5	
7	**8/26/2017**		4.80	3.4	0.37	28.2	0.84	16	20.6	6.4	
8	**8/27/2017**		4.60	3.4	0.29	27.1	0.84	16	21.0	6.4	
9	**8/28/2017**		5.75	5.9	2.50	29.5	0.93	21	21.8	6.6	
10	**8/29/2017**		4.90	8.4	4.92	25.5	1.01	19	21.0	6.4	
11	**8/30/2017**		4.56	5.6	1.93	24.7	1.09	20	21.5	6.6	
12	**8/31/2017**		5.14	3.7	<0.16	24.4	1.04	19	21.4	6.7	
	Average	**#DIV/0!**	**5.0**	**4.2**	**1.2**	**25.8**	**0.9**	**18**	**21.1**	**6.5**	
	Median	**#NUM!**	**4.9**	**3.7**	**0.4**	**25.1**	**1.0**	**19**	**21.0**	**6.5**	
	Minimum	**0.0**	**4.4**	**2.3**	**0.2**	**23.0**	**0.8**	**16**	**20.6**	**6.4**	
	Maximum	**0.0**	**6.1**	**8.4**	**4.9**	**29.5**	**1.1**	**21**	**21.8**	**6.7**	
	Count	**0**	**12**	**12**	**9**	**12**	**12**	**12.0**	**12**	**12**	

Primary Clarifer Sludge

		Primary 1/2 Sludge (HPO)				Primary 3 Sludge (ABC)			
	Date	Flow	Sludge Blanket	TS	TVS	Flow	Sludge Blanket	TS	TVS
Day		mgd	feet	mg/L or %TS	mg/L or %TS	mgd	feet	mg/L or %TS	mg/L or %TS
1	**8/20/2017**	0.101	1.0	2.20	82	0.029	6.0	2.31	83
2	**8/21/2017**	0.101	2.3	2.49	82	0.029	4.0	2.28	84
3	**8/22/2017**	0.101	1.3	2.76	82	0.033	5.0	2.25	83
4	**8/23/2017**	0.101	1.5	2.18	80	0.036	5.0	2.42	84
5	**8/24/2017**	0.101	1.3	2.58	81	0.036	3.0	2.53	84
6	**8/25/2017**	0.101	1.5	2.38	80	0.036	4.5	2.68	85
7	**8/26/2017**	0.101	2.0	2.46	82	0.036	2.5	2.65	85
8	**8/27/2017**	0.101	0.5	2.16	78	0.036	2.5	2.64	84
9	**8/28/2017**	0.101	1.8	2.44	79	0.036	4.0	2.63	85
10	**8/29/2017**	0.101	2.8	2.65	81	0.036	1.0	2.36	84
11	**8/30/2017**	0.101	1.5	2.67	80	0.026	0.5	2.49	83
12	**8/31/2017**	0.101	1.8	2.67	80	0.022	2.5	2.49	83
	Average	**0.1008**	**1.6**	**2.470**	**80**	**0.0326**	**3.4**	**2.478**	**84**
	Median	**0.1008**	**1.5**	**2.475**	**80**	**0.0360**	**3.5**	**2.490**	**84**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

Waste Sludge Gravity Belt Thickeners

		WAS GBT Feed			WAS GBT Cake			WAS GBT Filtrate											
Day	Date	Flow gpm	TS %	TVS %	Flow gpm	TS %	TVS %	COD mg/L	TKN mg/L as N	NH3 mg/L as N	Total P mg/L as P	PO4-P mg/L as P	cBOD5 mg/L	TSS mg/L	VSS mg/L	Filtered COD mg/L	Polymer Flow gpm	Dilution Water gpm	WAS GBT Washwater gpm
1	8/20/2017	301	0.66	75.87	29.7	4.6	82	957	81	13	24	6		810	700	103	1.4	4.5	58.8
2	8/21/2017	318	0.62	74.84	28.1	4.8	82	814	70	10	23	7	245	735	645	69	1.5	4.5	58.8
3	8/22/2017	352	0.66	73.97	32.6	3.9	82	498	50	10	16	4	181	490	430	58	1.7	4.5	58.9
4	8/23/2017	369	0.63	75.00	33.4	4.6	81	594	57	9	17	3	189	550	470	66	1.8	9.8	59.0
5	8/24/2017	380	0.61	72.82	30.0	5.6	81	498	49	13	12	4	126	480	425	58	1.8	11.1	59.0
6	8/25/2017	345	0.91	74.50	25.9	5.2	80	449	42	11	12	3	113	360	325	64	1.4	11.0	59.4
7	8/26/2017	367	0.57	71.62	27.4	5	81	562	52	12	16	4	146	470	405	77	1.5	12.0	59.5
8	8/27/2017	375	0.55	71.10	26.4	5.5	80	462	47	6	13	4	160	510	450	54	1.5	11.9	59.5
9	8/28/2017	346	0.51	70.41	21.9	5.3	80	554	54	12	16	5	176	480	400	49	1.2	12.0	59.4
10	8/29/2017	311	0.48	70.91	17.6	5.2	80	579	54	15	15	5	146	655	500	54	1.0	10.7	59.5
11	8/30/2017	298	0.47	69.66	15.2	5.4	81	776	66	13	19	7	234	705	645	56	0.9	10.6	59.5
12	8/31/2017	296	0.50	69.37	16.0	5.2	80	739	70	13	22	7	236	725	640	52	1.0	10.6	59.5
	Average	**338**	**0.597**	**72.506**	**25.345**	**5.0**	**80.917**	**624**	**57.5**	**11.3**	**17**	**5**	**177**	**581**	**503**	**63**	**1.382**	**9.439**	**59.237**
	Median	**345**	**0.588**	**72.220**	**26.873**	**5.2**	**81.110**	**571**	**53.7**	**12.2**	**16**	**4**	**176**	**530**	**460**	**58**	**1.442**	**10.656**	**59.408**
	Count	**12**	**12**	**12**	**12**	**12**	**12.000**	**12**	**12**	**12**	**12**	**12**	**11**	**12**	**12**	**12**	**12**	**12**	**12**

🟨 = Data Screened from dataset

CALCULATIONS

		TSS Capture	Filtrate										
Day	Date	Percent	TKN:COD	TP:TKN	COD:VSS	COD:TSS	SCOD:COD	VSS:TSS	ISS	TP:VSS	TKN:VSS	PO4-P:TP	NH3:TKN
1	8/20/2017	88.0	0.084	0.293	1.37	1.18	0.11	0.86	110	0.034	0.115	0.24	0.16
2	8/21/2017	88.3	0.086	0.325	1.26	1.11	0.08	0.88	90	0.035	0.108	0.31	0.14
3	8/22/2017	93.2	0.100	0.314	1.16	1.02	0.12	0.88	60	0.036	0.116	0.25	0.20
4	8/23/2017	91.6	0.095	0.301	1.26	1.08	0.11	0.85	80	0.036	0.120	0.18	0.16
5	8/24/2017	92.1	0.098	0.245	1.17	1.04	0.12	0.89	55	0.028	0.115	0.29	0.26
6	8/25/2017	96.3	0.093	0.294	1.38	1.25	0.14	0.90	35	0.038	0.129	0.23	0.27
7	8/26/2017	91.7	0.092	0.318	1.39	1.20	0.14	0.86	65	0.040	0.127	0.24	0.23
8	8/27/2017	90.5	0.102	0.271	1.03	0.91	0.12	0.88	60	0.028	0.105	0.29	0.12
9	8/28/2017	90.1	0.097	0.292	1.39	1.15	0.09	0.83	80	0.039	0.134	0.32	0.23
10	8/29/2017	85.3	0.093	0.282	1.16	0.88	0.09	0.76	155	0.030	0.107	0.36	0.28
11	8/30/2017	83.5	0.085	0.293	1.20	1.10	0.07	0.91	60	0.030	0.102	0.34	0.20
12	8/31/2017	84.2	0.095	0.313	1.15	1.02	0.07	0.88	85	0.034	0.109	0.30	0.18
	Average	**89.6**	**0.093**	**0.295**	**1.24**	**1.08**	**0.10**	**0.87**	**78**	**0.034**	**0.116**	**0.28**	**0.201**
	Median	**90.3**	**0.094**	**0.293**	**1.23**	**1.09**	**0.11**	**0.88**	**73**	**0.035**	**0.115**	**0.29**	**0.198**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

		Digesters																	
		Digester Feed						Digester	Digester Overflow										
Day	Date	Flow mgd	TS %	TVS %	TP mg/L	PO4-P mg/L	Ferric Added gpd	Methane SCFH	Flow mgd	NH3 mg/L as N	COD mg/L	TS %	TVS %	Total P mg/L as P	PO4-P mg/L as P	pH	Filtered Mg mg/L	Temp C	Total Alk mg/L as CaCO3
1	8/20/2017	0.20	2.87	81	610	321	255	16270			12400	1.68	65.4	800	570	7.5	31	32	5039
2	8/21/2017	0.20	2.90	82	734	341	255	16756			12000	1.61	64.9	650	491	7.57	30	32	5098
3	8/22/2017	0.21	3.24	85	678	305	255	17994			13300	1.41	74.9	588	467	7.5	30	34	4920
4	8/23/2017	0.21	3.21	82	662	324	255	17656			13100	1.63	64.6	507	458	7.5	29	31	4820
5	8/24/2017	0.21	3.19	82	663	305	255	17191			13500	1.68	64.7	596	561	7.49	32	33	4750
6	8/25/2017	0.20	3.16	82	687	294	255	17350			13700	1.66	65.6	632	458	7.45	27	34	4650
7	8/26/2017	0.20	3.20	82	707	302	255	17230			13300	1.63	66.9	614	488	7.43	33	35	4470
8	8/27/2017	0.20	3.06	81	656	347	255	16214			14300	1.68	65.6	569	491	7.54	27	34	4550
9	8/28/2017	0.19	2.48	78	537	278	255	15133			13300	1.67	64.7	611	528	7.47	31	35	4560
10	8/29/2017	0.18	2.59	78	492	279	255	15481			12600	1.69	63.8	623	511	7.47	30	32	4600
11	8/30/2017	0.16	3.22	79	675	350	255	15029			13700	1.68	64.7	669	391	7.49	34	28	4550
12	8/31/2017	0.16	2.47	79	516	278	255	15154			12400	1.63	64.7	606	485	7.53	33	30	4490
	Average	**0.193**	**2.966**	**80.9**	**634.7**	**310.3**	**255**	**16454.719**	**#DIV/0!**	**#DIV/0!**	**13133**	**1.64**	**66**	**622**	**492**	**7**	**30**	**32**	**4708**
	Median	**0.199**	**3.110**	**81.5**	**662.5**	**305.0**	**255**	**16512.938**	**#NUM!**	**#NUM!**	**13300**	**1.66**	**65**	**613**	**490**	**7**	**30**	**33**	**4625**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**0**	**0**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

Digested Sludge Gravity Belt Thickeners

		Digested GBT Feed					Digested GBT Cake			Digested GBT Filtrate											
Day	Date	Flow gpm	COD mg/L	Total P mg/L as P	TS %	TVS %	Flow gpm	TS %	TVS %	COD mg/L	Filtered COD mg/L	TKN mg/L as N	NH3 mg/L as N	Total P mg/L as P	PO4-P mg/L as P	TSS mg/L	VSS mg/L	Polymer Flow gpm	Dilution Water gpm	Digested GBT Washwater gpm
1	**8/20/2017**	**109**	16000	593	1.68	64	25.1	7.1	64	6670	626	802	734	66		1345	775	3.800	5.052	46.617
2	**8/21/2017**	**111**	11100	619	1.57	64	29.9	6.9	65	1390	684	781	689	65	52	910	640	3.997	5.011	46.647
3	**8/22/2017**	**108**	12400	575	1.44	70	28.0	7.4	64	1630	658	744	633	88	78	1325	900	3.318	5.113	46.671
4	**8/23/2017**	**138**	12200	611	1.58	65	32.0	7.3	65	2200	686	834	758	60	55	780	550	5.581	4.849	46.665
5	**8/24/2017**	**105**	13500	653	1.60	65	23.7	7.6	65	1920	878	805	695	54	43	770	590	4.282	4.416	46.669
6	**8/25/2017**	**110**	12000	625	1.61	65	26.6	7.7	65	1500	739	831	723	64	47	790	530	4.023	4.626	46.900
7	**8/26/2017**	**116**	13100	628	1.59	65	30.3	7	67	1780	684	806	707	79	51	730	510	3.818	4.964	47.670
8	**8/27/2017**	**101**	14100	606	3.05	81.44	25.8	6.9	65	1580	675	739	637	79	56	470	365	3.012	5.009	47.589
9	**8/28/2017**	**129**	11800	647	1.65	65	33.1	6.8	65	1840	639	820	661	68	53	800	520	4.384	4.867	47.464
10	**8/29/2017**	**95**	13100	569	1.61	66	21.8	7.4	67	1560	643	748	639	84	82	1300	830	3.101	4.978	47.571
11	**8/30/2017**	**89**	11800	613	1.61	64	19.7	7.9	66	1560	641	763	640	116	141	1680	920	2.701	4.998	47.672
12	**8/31/2017**	**96**	12600	554	1.58	65	22.3	8.1	68	1600	673	729	651	140	84	1440	830	2.842	4.946	47.759
	Average	**109**	**12808**	**608**	**1.593**	**65**	**26.541**	**7.4**	**65**	**1687**	**686**	**783.5**	**680.6**	**80**	**67**	**1028**	**663**	**3.738**	**4.902**	**47.158**
	Median	**108**	**12500**	**612**	**1.600**	**65**	**26.199**	**7.4**	**65**	**1600**	**674**	**791.5**	**675.0**	**73**	**55**	**855**	**615**	**3.809**	**4.971**	**47.182**
	Count	**12**	**12**	**12**	**11**	**11**	**12**	**12**	**12.000**	**11**	**12**	**12**	**12**	**12**	**11**	**12**	**12**	**12**	**12**	**12**

🟨 = Data Screened from dataset

CALCULATIONS

		TSS Capture	Filtrate										
Day	Date	Percent	TKN:COD	TP:TKN	COD:VSS	COD:TSS	SCOD:COD	VSS:TSS	ISS	TP:VSS	TKN:VSS	PO4-P:TP	NH3:TKN
1	8/20/2017	93.8	0.120	0.082	8.61	4.96	0.09	0.58	570	0.085	1.035		0.92
2	8/21/2017	93.4	0.562	0.083	2.17	1.53	0.49	0.70	270	0.102	1.220	0.81	0.88
3	8/22/2017	92.8	0.456	0.118	1.81	1.23	0.40	0.68	425	0.098	0.827	0.89	0.85
4	8/23/2017	93.5	0.379	0.071	4.00	2.82	0.31	0.71	230	0.108	1.516	0.92	0.91
5	8/24/2017	93.2	0.419	0.067	3.25	2.49	0.46	0.77	180	0.092	1.364	0.80	0.86
6	8/25/2017	93.1	0.554	0.076	2.83	1.90	0.49	0.67	260	0.120	1.568	0.74	0.87
7	8/26/2017	93.3	0.453	0.097	3.49	2.44	0.38	0.70	220	0.154	1.580	0.65	0.88
8	8/27/2017	97.6	0.468	0.106	4.33	3.36	0.43	0.78	105	0.215	2.025	0.72	0.86
9	8/28/2017	93.9	0.446	0.082	3.54	2.30	0.35	0.65	280	0.130	1.577	0.78	0.81
10	8/29/2017	93.5	0.479	0.112	1.88	1.20	0.41	0.64	470	0.101	0.901	0.98	0.85
11	8/30/2017	93.1	0.489	0.152	1.70	0.93	0.41	0.55	760	0.126	0.829	1.22	0.84
12	8/31/2017	93.4	0.456	0.192	1.93	1.11	0.42	0.58	610	0.169	0.878	0.60	0.89
	Average	**93.7**	**0.440**	**0.103**	**3.3**	**2.2**	**0.39**	**0.67**	**365**	**0.125**	**1.277**	**0.83**	**0.868**
	Median	**93.4**	**0.456**	**0.090**	**3.0**	**2.1**	**0.41**	**0.68**	**275**	**0.114**	**1.292**	**0.80**	**0.867**
	Count	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**11**	**12**

HPO 1st Stage Aeration Basin Profiles

Date	Time	Item	Flow	TSS	Filtered COD	NH3-N	NOx-N	PO4-P	NO3-N	NO2-N	Oxygen Flow
8/27/2017	8:00 AM	**Profile # 1**	**MGD**								MCFH
		Cell 1	**5.2**	**1180**	**64**	27.10	0.20	<.033	0.16	0.04	10.92
		Cell 2	**5.2**	**1160**	**54**	25.80	0.20	<.033	0.16	0.04	
		Cell 3	**5.2**	**1180**	**52**	26.80	0.12	<.033	0.09	0.03	
8/27/2017	1:00 PM	**Profile # 2**									
		Cell 1	**11.55**	**1080**	**71**	30.10	1.55	0.37	1.00	0.55	11.39
		Cell 2	**11.55**	**1140**	**60**	29.70	1.34	0.19	0.92	0.42	
		Cell 3	**11.55**	**1100**	**52**	28.70	1.02	0.09	0.72	0.30	
8/28/2017	8:00 AM	**Profile # 3**									
		Cell 1	**5.23**	**1220**	**52**	29.40	0.07	<.033	0.03	0.04	10.74
		Cell 2	**5.23**	**1300**	**52**	28.70	0.11	<.033	0.07	0.04	
		Cell 3	**5.23**	**1320**	**52**	29.40	0.08	<.033	0.03	0.05	
8/28/2017	1:00 PM	**Profile # 4**									
		Cell 1	**14.65**	**900**	**68**	33.30	1.62	1.24	0.92	0.70	9.63
		Cell 2	**14.65**	**820**	**60**	33.10	1.43	0.92	0.81	0.62	
		Cell 3	**14.65**	**920**	**54**	32.20	1.04	0.67	0.53	0.51	
8/29/2017	8:00 AM	**Profile # 5**									
		Cell 1	**9.04**	**1000**	**54**	28.00	0.18	0.19	0.05	0.13	8.06
		Cell 2	**9.04**	**1100**	**45**	25.90	0.37	0.04	0.12	0.25	
		Cell 3	**9.04**	**1100**	**45**	25.90	0.28	<.033	0.06	0.22	
8/29/2017	1:00 PM	**Profile # 6**									
		Cell 1	**15.46**	**760**	**75**	30.80	0.31	1.45	0.06	0.25	6.95
		Cell 2	**15.46**	**740**	**60**	29.90	1.12	1.05	0.59	0.53	
		Cell 3	**15.46**	**740**	**56**	29.50	1.13	0.96	0.54	0.59	
		Median Values									
		Cell 1	10.30	1040.00	66.00	29.75	0.26	0.81	0.11	0.19	10.19
		Cell 2	10.30	1120.00	57.00	29.20	0.75	0.56	0.38	0.34	
		Cell 3	10.30	1100.00	52.00	29.05	0.65	0.67	0.31	0.26	

HPO 2nd Stage Aeration Basin Profiles

Date	Time		Flow	TSS	Filtered COD	NH3-N	NOx-N	PO4-P	NO3-N	NO2-N	Oxygen Flow
8/27/2017	8:00 AM	**Profile # 1**	**MGD**								**MCFH**
		Cell 1	**5.2**	**4100**	**56**	1.37	31.40	0.13	31.40	0.00	11.6
		Cell 2	**5.2**	**4140**	**47**	0.16	34.90	0.14	35.10	-0.20	
		Cell 3	**5.2**	**4160**	**49**	0.23	36.30	0.27	36.40	-0.10	
8/27/2017	1:00 PM	**Profile # 2**									
		Cell 1	**11.55**	**3540**	**45**	7.37	24.70	0.23	24.60	0.10	11.4
		Cell 2	**11.55**	**3600**	**47**	1.23	32.20	0.15	32.10	0.10	
		Cell 3	**11.55**	**3580**	**45**	0.23	28.50	0.19	28.50	0.00	
8/28/2017	8:00 AM	**Profile # 3**									
		Cell 1	**5.23**	**3880**	**41**	2.09	33.10	0.09	33.00	0.10	11.6
		Cell 2	**5.23**	**3900**	**41**	0.16	37.00	0.12	37.00	0.00	
		Cell 3	**5.23**	**4060**	**45**	0.16	38.60	0.16	38.60	0.00	
8/28/2017	1:00 PM	**Profile # 4**									
		Cell 1	**14.65**	**3380**	**56**	10.30	22.70	0.15	22.60	0.10	12.3
		Cell 2	**14.65**	**3260**	**39**	5.06	29.30	0.12	29.20	0.10	
		Cell 3	**14.65**	**3400**	**37**	1.42	34.40	0.14	34.30	0.10	
8/29/2017	8:00 AM	**Profile # 5**									
		Cell 1	**9.04**	**3660**	**39**	9.33	23.30	0.26	23.20	0.10	12.1
		Cell 2	**9.04**	**3820**	**45**	4.15	31.10	0.34	31.00	0.10	
		Cell 3	**9.04**	**3880**	**45**	0.65	36.60	0.32	36.50	0.10	
8/29/2017	1:00 PM	**Profile # 6**									
		Cell 1	**15.46**	**3320**	**49**	13.20	18.60	0.35	18.50	0.10	13.5
		Cell 2	**15.46**	**3320**	**45**	8.33	22.50	0.31	22.40	0.10	
		Cell 3	**15.46**	**3180**	**47**	4.92	27.00	0.32	26.90	0.1	
		Median Values									
		Cell 1	10.30	3600.00	47.00	8.35	24.00	0.19	23.90	0.10	11.88
		Cell 2	10.30	3710.00	45.00	2.69	31.65	0.15	31.55	0.10	
		Cell 3	10.30	3730.00	45.00	0.44	35.35	0.23	35.35	0.05	

ABC Aeration Basin Profiles

Date	Time		Flow	TSS	Filtered COD	NH3-N	NOx-N	PO4-P	NO3-N	NO2-N	Airflow	DO
8/27/2017	8:00 AM	**Profile # 1**	**MGD**									
		Anaerobic	**5.26**	2760	79	18.2	0.05	22.9	0.05	0.00	NA	NA
		Swing	**5.26**	2700	49	13.5	3.67	2.85	3.17	0.50	1506	NA
		Grid 2	**5.26**	2820	45	0.37	18.10	<.033	16.90	1.20	1021	2.5
		Grid 3	**5.26**	2720	43	0.23	18.00	<.033	16.70	1.30	625	1.7
		Grid 4	**5.26**	2800	41	0.37	17.80	<.033	16.80	1.00	476	1.7
8/27/2017	1:00 PM	**Profile # 2**										
		Anaerobic	**5.38**	2840	88	18.7	0.1	21.3	0.07	0.03	NA	NA
		Anoxic	**5.38**	2900	52	13.9	4.11	1.92	3.78	0.33	1426	NA
		Grid 2	**5.38**	2740	47	0.23	18.20	<.033	18.00	0.20	957	2.2
		Grid 3	**5.38**	2660	47	0.23	18.00	<.033	17.80	0.20	585	1.4
		Grid 4	**5.38**	2660	45	0.16	18.50	<.033	18.50	0.00	451	1.7
8/28/2017	8:00 AM	**Profile # 3**										
		Anaerobic	**5.31**	2700	64	19.2	0.11	13.6	0.07	0.04	NA	NA
		Anoxic	**5.31**	2580	52	12.5	5.88	0.19	5.31	0.57	1359	NA
		Grid 2	**5.31**	2680	47	0.28	18.60	<.033	18.40	0.20	899	2.5
		Grid 3	**5.31**	2780	47	0.37	18.70	<.033	18.50	0.20	547	1.8
		Grid 4	**5.31**	2760	39	0.16	18.70	<.033	18.70	0.00	415	2.0
8/28/2017	1:00 PM	**Profile # 4**										
		Anaerobic	**2.73**	3120	60	18.9	0.05	7.95	0.05	0.00	NA	NA
		Anoxic	**2.73**	2740	39	13.5	6.13	<.033	5.75	0.38	915	NA
		Grid 2	**2.73**	2700	30	0.74	19.80	<.033	19.50	0.30	596	2.4
		Grid 3	**2.73**	2700	32	0.37	19.90	<.033	13.90	6.00	458	0.4
		Grid 4	**2.73**	2780	34	0.17	20.00	<.033	20.00	0.00	360	1.6
8/29/2017	8:00 AM	**Profile # 5**										
		Anaerobic	**2.5**	2800	77	17	0.05	16.2	0.05	0.00	NA	NA
		Anoxic	**2.5**	2800	54	11.6	5.01	0.093	4.71	0.30	780	NA
		Grid 2	**2.5**	2880	43	0.45	19.80	<.033	19.50	0.30	506	1.4
		Grid 3	**2.5**	2880	41	0.16	20.30	<.033	20.20	0.10	328	0.5
		Grid 4	**2.5**	2840	34	0.16	20.60	<.033	20.60	0.00	245	0.5
8/29/2017	1:00 PM	**Profile # 6**										
		Anaerobic	**2.54**	2700	56	18.1	0.05	16.2	0.05	0.00	NA	NA
		Anoxic	**2.54**	2620	39	12.6	5.17	0.08	5.02	0.15	647	NA
		Grid 2	**2.54**	2560	43	0.37	19.60	<.033	19.40	0.20	437	1.4
		Grid 3	**2.54**	2740	34	0.23	20.10	<.033	20.00	0.10	403	1.0
		Grid 4	**2.54**	2660	30	0.16	20.80	<.033	20.80	0.00	384	2.1
		Median Values										
		Anaerobic	4.00	2780.00	70.50	18.45	0.05	16.20	0.05		#NUM!	#NU
		Swing - Aerated	4.00	2720.00	50.50	13.05	5.09	0.19	4.87		1137.01	#NU
		Grid 2	4.00	2720.00	44.00	0.37	19.10	0.03	18.90	0.25	747.36	2.3
		Grid 3	4.00	2730.00	42.00	0.23	19.30	0.03	18.15	0.20	502.23	1.2
		Grid 4	4.00	2770.00	36.50	0.16	19.35	0.03	19.35	0.00	399.82	1.7

WRP Influent - VFAs

Date	Time	Sample	Flow, mgd	COD, mg/L	Filtered COD, mg/L	ffCOD, mg/l	Acetic Acid ppm	Propionic Acid ppm	Isobutyric Acid ppm	Butyric Acid ppm	2-Methylbutyric Acid ppm	Isovaleric Acid ppm	Valeric Acid ppm	VFAs as mg COD/L	Volatile Acids, mg/L	Proprionic VFA as COD	Effluent ffCOD	Fbs	Fac
		Event 1		474	257	148													
8/27/2017	10:00 AM	Sample 1	13.1	823	547	413	34.6	7.4	< 1	< 1	< 1	< 1	< 1	48	109	11	28	0.47	0.12
8/27/2017	12:30 PM	Sample 2	16.6	682	293	180	31.4	4	< 1	< 1	< 1	< 1	< 1	40	103	6	28	0.22	0.26
8/27/2017	3:00 PM	Sample 3	16.2	665	284	163	24.6	3.1	< 1	< 1	< 1	< 1	< 1	31	116	5	28	0.20	0.23
		Event 2		511	274	167													
8/28/2017	10:00 AM	Sample 1	16.5	586	248	152	20.4	2.5	< 1	< 1	< 1	< 1	< 1	26	77	4	26	0.22	0.20
8/28/2017	12:30 PM	Sample 2	17.1	844	380	261	30.7	3.6	< 1	< 1	< 1	< 1	< 1	38	124	5	26	0.28	0.16
8/28/2017	3:00 PM	Sample 3	16.2	688	366	222	31.1	3.8	< 1	< 1	< 1	< 1	< 1	39	115	6	26	0.28	0.20
		Event 3		630	306	195													
8/29/2017	10:00 AM	Sample 1	17.9	930	430	304	37.3	6.2	< 1	< 1	< 1	< 1	< 1	49	134	9	32	0.29	0.18
8/29/2017	12:30 PM	Sample 2	17.5	906	429	280	38.8	7.8	< 1	< 1	< 1	< 1	< 1	53	131	12	32	0.27	0.21
8/29/2017	3:00 PM	Sample 3	17.2	793	408	274	37.2	6.1	< 1	< 1	< 1	< 1	< 1	49	119	9	32	0.31	0.20
		Average	**16.5**	**711**	**352**	**230**	**31.8**	**4.9**						**41**	**114**	**7**		**0.28**	**0.20**
		Median	**16.6**	**685**	**336**	**208.5**	**31.4**	**4**						**40**	**116**	**6**		**0.28**	**0.20**
		Minimum	**13.1**	**474**	**248**	**148**	**20.4**	**2.5**						**26**	**77**	**4**		**0.20**	**0.12**
		Maximum	**17.9**	**930**	**547**	**413**	**38.8**	**7.8**						**53**	**134**	**12**		**0.47**	**0.26**

Primary 1/2 Effluent - VFAs

Date	Time	Sample	Flow, mgd	COD,mg/L	sCOD, mg/L	ffCOD, mg/l	Acetic acid, mg/L	Propionic Acid, mg/L	N Buteric Acid, mg/L	Iso Buteric Acid, mg/L	N Valeric Acid, mg/L	Iso Valeric Acid, mg/L	Sec Valeric Acid, mg/L	VFAs as mg COD/L	VFA Increase	Proprionic VFA as COD	Effluent ffCOD	Fbs	Fac
		Event 1		[redacted]	[redacted]	[redacted]												[redacted]	[redacted]
8/28/2017	10:00 AM	Sample 1	8.5	[redacted]	[redacted]	[redacted]	73.1	20.6	< 1	1.5	< 1	< 1	< 1	112	64	31		[redacted]	[redacted]
8/28/2017	12:30 PM	Sample 2	12.0	[redacted]	[redacted]	[redacted]	73.1	22.8	< 1	1.5	< 1	1.1	< 1	117	78	34		[redacted]	[redacted]
8/28/2017	3:00 PM	Sample 3	11.8	[redacted]	[redacted]	[redacted]	49	10.9	< 1	< 1	< 1	< 1	< 1	69	38	16		[redacted]	[redacted]
		Event 2		[redacted]	[redacted]	[redacted]												[redacted]	[redacted]
8/28/2017	10:00 AM	Sample 1	12.2	[redacted]	[redacted]	[redacted]	38.8	7.1	< 1	< 1	< 1	< 1	< 1	52	27	11		[redacted]	[redacted]
8/28/2017	12:30 PM	Sample 2	15.5	[redacted]	[redacted]	[redacted]	45.2	8	< 1	< 1	< 1	< 1	< 1	60	22	12		[redacted]	[redacted]
8/28/2017	3:00 PM	Sample 3	14.5	[redacted]	[redacted]	[redacted]	45.1	7.1	< 1	< 1	< 1	< 1	< 1	59	20	11		[redacted]	[redacted]
		Event 3		[redacted]	[redacted]	[redacted]												[redacted]	[redacted]
8/28/2017	10:00 AM	Sample 1	16.2	[redacted]	[redacted]	[redacted]	57.3	14.7	< 1	1.1	< 1	< 1	< 1	85	36	22		[redacted]	[redacted]
8/28/2017	12:30 PM	Sample 2	15.8	[redacted]	[redacted]	[redacted]	59.9	12.8	< 1	< 1	< 1	< 1	< 1	83	30	19		[redacted]	[redacted]
8/28/2017	3:00 PM	Sample 3	15.3	[redacted]	[redacted]	[redacted]	61.4	12.6	< 1	< 1	< 1	< 1	< 1	85	36	19		[redacted]	[redacted]
		Average	**13.5**	[redacted]	[redacted]	[redacted]	**55.9**	**13.0**	**< 1**	**1.37**	**< 1**	**< 1**	**< 1**	**80**	**39**	**20**	**#DIV/0!**	[redacted]	[redacted]
		Median	**14.5**	[redacted]	[redacted]	[redacted]	**57.3**	**12.6**	**< 1**	**1.5**	**< 1**	**< 1**	**< 1**	**83**	**36**	**19**	**#NUM!**	[redacted]	[redacted]
		Minimum	**8.5**	[redacted]	[redacted]	[redacted]	**38.8**	**7.1**	**< 1**	**1.1**	**< 1**	**< 1**	**< 1**	**52**	**20**	**11**	**0**	[redacted]	[redacted]
		Maximum	**16.2**	[redacted]	[redacted]	[redacted]	**73.1**	**22.8**	**< 1**	**1.5**	**< 1**	**< 1**	**< 1**	**117**	**78**	**34**	**0**	[redacted]	[redacted]

Primary 3 Effluent - VFAs

Date	Time	Sample	Flow, mgd	COD,mg/L	sCOD, mg/L	ffCOD, mg/l	Acetic acid, mg/L	Propionic Acid, mg/L	N Buteric Acid, mg/L	Iso Buteric Acid, mg/L	N Valeric Acid, mg/L	Iso Valeric Acid, mg/L	Sec Valeric Acid, mg/L	VFAs as mg COD/L	VFA Increase	Proprionic VFA as COD	Effluent ffCOD	Fbs	Fac
		Event 1		[redacted]	[redacted]	[redacted]												[redacted]	[redacted]
8/29/2017	10:00 AM	Sample 1	5.5	[redacted]	[redacted]	[redacted]	74.6	21.3	< 1	2.8	< 1	< 1	< 1	117	69	32		[redacted]	[redacted]
8/29/2017	12:30 PM	Sample 2	5.4	[redacted]	[redacted]	[redacted]	69.5	14.7	< 1	1.3	< 1	< 1	< 1	99	59	22		[redacted]	[redacted]
8/29/2017	3:00 PM	Sample 3	5.2	[redacted]	[redacted]	[redacted]	36.1	5	< 1	< 1	< 1	< 1	< 1	46	15	8		[redacted]	[redacted]
		Event 2		[redacted]	[redacted]	[redacted]												[redacted]	[redacted]
8/29/2017	10:00 AM	Sample 1	5.2	[redacted]	[redacted]	[redacted]	36	5.7	< 1	< 1	< 1	< 1	< 1	47	21	9		[redacted]	[redacted]
8/29/2017	12:30 PM	Sample 2	2.4	[redacted]	[redacted]	[redacted]	44.8	7.3	< 1	< 1	< 1	< 1	< 1	59	21	11		[redacted]	[redacted]
8/29/2017	3:00 PM	Sample 3	2.5	[redacted]	[redacted]	[redacted]	49.3	6.6	< 1	< 1	< 1	< 1	< 1	63	24	10		[redacted]	[redacted]
		Event 3		[redacted]	[redacted]	[redacted]												[redacted]	[redacted]
8/29/2017	10:00 AM	Sample 1	2.5	[redacted]	[redacted]	[redacted]	76.2	20.2	1.2	4.3	< 1	1.3	1.2	127	78	31		[redacted]	[redacted]
8/29/2017	12:30 PM	Sample 2	2.4	[redacted]	[redacted]	[redacted]	64.7	11.7	< 1	1	< 1	< 1	< 1	88	35	18		[redacted]	[redacted]
8/29/2017	3:00 PM	Sample 3	2.6	[redacted]	[redacted]	[redacted]	57.1	9.2	< 1	< 1	< 1	< 1	< 1	75	26	14		[redacted]	[redacted]
		Average	**3.7**	[redacted]	[redacted]	[redacted]	**56.5**	**11.3**	**1.2**	**2.35**	**#DIV/0!**	**1.3**	**1.2**	**80**	**39**	**17**	**#DIV/0!**	[redacted]	[redacted]
		Median	**2.6**	[redacted]	[redacted]	[redacted]	**57.1**	**9.2**	**1.2**	**2.05**	**#NUM!**	**1.3**	**1.2**	**75**	**26**	**14**	**#NUM!**	[redacted]	[redacted]
		Minimum	**2.4**	[redacted]	[redacted]	[redacted]	**36.0**	**5**	**1.2**	**1**	**0**	**1.3**	**1.2**	**46**	**15**	**8**	**0**	[redacted]	[redacted]
		Maximum	**5.5**	[redacted]	[redacted]	[redacted]	**76.2**	**21.3**	**1.2**	**4.3**	**0**	**1.3**	**1.2**	**127**	**78**	**32**	**0**	[redacted]	[redacted]

Diurnal Event 1

Date 8/27/17 to 8/28/17

		WRP Influent						Primary 1/2 Effluent						Primary 3 Effluent					
Sample	Time	Flow mgd	COD mg/L	TKN mg/L as N	TP mg/L	TSS mg/L	VSS mg/L	Flow mgd	COD mg/L	TKN mg/L as N	TP mg/L	TSS mg/L	VSS mg/L	Flow mgd	COD mg/L	TKN mg/L as N	TP mg/L	TSS mg/L	VSS mg/L
1	**7:00**	9.84	667	36.1	6.27	158	150	5.83	338	39.8		30	28	5.29	440	44.7	6.15	62	60
2	**9:00**	12.76	678	46.6	7.93	226	204	8.28	344	41.2	2.72	22	22	5.29	481	44.7	6.1	80	80
3	**11:00**	15.42	780	53.7	11.03	312	282	11.03	366	41.9	3.53	20	20	5.31	524	51.7	7.27	94	86
4	**13:00**	16.14	618	47.8	13.63	324	270	11.69	338	44.7	4.69	48	40	5.28	432	50.3	7.96	106	96
5	**15:00**	15.66	643	43.1	7.22	220	200	11.25	291	44.7	4.49	34	30	5.29	391	47.5	7.95	96	82
6	**17:00**	14.92	620	37.5	5.8	216	196	10.49	304	41.9	3.5	28	26	5.29	417	44.7	6.4	68	58
7	**19:00**	15.21	620	37.5	5.17	210	204	10.77	316	41.9	3.1	32	24	5.30	434	44.7	5.58	72	64
8	**21:00**	15.57	601	36.1	5.06	206	196	11.14						5.31	421	41.9	5.16	66	62
9	**23:00**	13.85	673	36.7	5.2	208	196	9.44						5.29	428	41.9	5.15	64	60
10	**1:00**	11.07	543	35	5.0	118	114	6.66						5.29	440	45	5.2	58	56
11	**3:00**	9.42	588	29.1	5.0	194	174	5.05						5.26	391	43.3	5.27	50	48
12	**5:00**	9.05	595	29.4	5.09	196	176	4.69			1.84			5.33	359	44.7	6.01	50	48
Average		**13.2**	**636**	**39.1**	**6.9**	**216**	**197**	**8.9**	**328**	**42.3**	**3.4**	**30.6**	**27.1**	**5.3**	**430**	**45.4**	**6.2**	**72.2**	**66.7**
Median		**14.4**	**620**	**37.1**	**5.5**	**209**	**196**	**10.0**	**338**	**41.9**	**3.5**	**30.0**	**26.0**	**5.3**	**430**	**44.7**	**6.1**	**67.0**	**61.0**
Count		**12**	**12**	**12**	**12**	**12**	**12**	**12**	**7**	**7**	**7**	**7**	**7**	**12**	**12**	**12**	**12**	**12**	**12**
Flow weight average			**639**	**40**	**7.1**	**222**	**203**								**430**	**45.4**	**6.2**	**72**	**67**
MVTL Composite Data		**13.2**	**474**	**36**	**6.2**	**156**	**142**	**9.5**						**5.3**	**338**	**42**	**5.7**	**100**	**94**
Difference		**0%**	**35%**	**11%**	**14%**	**43%**	**43%**	**-7%**						**0%**	**27%**	**7%**	**9%**	**-28%**	**-29%**

🟨 Values estimated based upon composite influent ratios for the day of testing

		WRP Influent						Primary 1/2 Effluent						Primary 3 Effluent					
Sample	Time	COD:TSS	TKN:COD	TP:TKN	COD:TP	VSS:TSS	TP:TSS	COD:TSS	TKN:COD	TP:TKN	COD:TP	VSS:TSS		COD:TSS	TKN:COD	TP:TKN	COD:TP	VSS:TSS	
1	7:00	4.22	0.05	0.17	106	0.95	0.040	12.07	0.12	0.00	#DIV/0!	0.93		7.33	0.10	0.14	72	0.97	
2	9:00	3.00	0.07	0.17	85	0.90	0.035	15.64	0.12	0.07	126	1.00		6.01	0.09	0.14	79	1.00	
3	11:00	2.50	0.07	0.21	71	0.90	0.035	18.30	0.11	0.08	104	1.00		6.09	0.10	0.14	72	0.91	
4	13:00	1.91	0.08	0.29	45	0.83	0.042	8.45	0.13	0.10	72	0.83		4.50	0.12	0.16	54	0.91	
5	15:00	2.92	0.07	0.17	89	0.91	0.033	9.70	0.15	0.10	65	0.88		4.77	0.12	0.17	49	0.85	
6	17:00	2.87	0.06	0.15	107	0.91	0.027	11.69	0.14	0.08	87	0.93		7.19	0.11	0.14	65	0.85	
7	19:00	2.95	0.06	0.14	120	0.97	0.025	13.17	0.13	0.07	102	0.75		6.78	0.10	0.12	78	0.89	
8	21:00	2.92	0.06	0.14	119	0.95	0.025							6.79	0.10	0.12	82	0.94	
9	23:00	3.24	0.05	0.14	129	0.94	0.025							7.13	0.10	0.12	83	0.94	
10	1:00	4.60	0.07	0.14	109	0.97	0.042							7.86	0.10	0.12	85	0.97	
11	3:00													8.15	0.11	0.12	74	0.96	
12	5:00													7.48	0.12	0.13	60	0.96	
Average		**3.1**	**0.06**	**0.17**	**98**	**0.92**	**0.033**	**12.7**	**0.13**	**0.07**	**#DIV/0!**	**0.9**		**6.7**	**0.11**	**0.14**	**71**	**0.9**	
Median		**2.9**	**0.06**	**0.16**	**107**	**0.93**	**0.034**	**12.1**	**0.13**	**0.08**	**#DIV/0!**	**0.9**		**7.0**	**0.10**	**0.14**	**73**	**0.9**	
Count		**10**	**10**	**10**	**10**	**10**	**10**	**7**	**7**	**7**	**6**	**7**		**12**	**12**	**12**	**12**	**12**	
stdev		**0.78**	**0.01**	**0.05**	**26**	**0.04**	**0.01**												

Intermediate Effluent								Final 1-4 Effluent								Final 5 (ABC) Effluent							
Flow mgd	COD mg/L	NH3-N mg/L as N	NOx-N mg/L as N	NO3-N mg/L as N	PO4-P mg/L	TSS mg/L	VSS mg/L	Flow mgd	COD mg/L	NH3-N mg/L as N	NOx-N mg/L as N	NO3-N mg/L as N	PO4-P mg/L	TSS mg/L	VSS mg/L	Flow mgd	COD mg/L	NH3-N mg/L as N	NOx-N mg/L as N	NO3-N mg/L as N	PO4-P mg/L	TSS mg/L	VSS mg/L
	75	25.9	< 0.05		0.265	22	22		69	0.51	34.1		0.66	26	20		54	< 0.16	15.8		0.034	12	11
	60	26.6	< 0.05		0.253	8	7		64	0.8	34.2		0.608	23	17		54	< 0.16	15.9		0.034	12	10
	90	27.3	< 0.05		0.415	44	42		66	0.51	34.5		0.635	22	17		58	0.23	16.2		<.033	10	10
	274	27.3	< 0.05		1.17	124	114		62	0.37	34.2		0.607	21	16		56	0.37	16.2		0.033	11	10
	229	29.4	0.2		0.93	126	114		81	0.37	34.1		0.658	28	23		49	< 0.16	16.3		0.035	12	10
	158	28.7	1.1		0.6	80	74		64	0.9	33.5		0.7	25	16		49	< 0.16	16.7		0.035	14	9
	94	28	1.32		0.35	42	38		58	1.36	33.1		0.63	24	14		56	< 0.16	18.2		0.037	14	13
	156	28.7	0.6		0.555	80	62		56	1.36	32.9		0.603	21	12		66	< 0.16	18.3		0.035	14	12
	143	28.7	0.26		0.453	68	40		60	1.51	32.5		0.64	29	18		49	< 0.16	18.2		0.034	13	11
	69	28	0		0.3	22			64	2	33		0.6	26	15		49	< 0.16	18		0.038	15	13
	75	28.7	0.12		0.27	14			62	1.93	33		0.692	26	16		47	< 0.16	17.9		0.035	14	12
	66	28	0.09		0.27	16			62	1.51	33.6		0.652	29	16		47	0.23	17.8		0.033	17	14
	124	**27.9**	**0.5**		**0.5**	**53.8**	**57.0**		**64**	**1.1**	**33.6**	**#DIV/0!**	**0.6**	**24.9**	**16.4**	**#DIV/0!**	**53**	**0.3**	**17.1**	**#DIV/0!**	**0.0**	**13.0**	**11.2**
	92	**28.0**	**0.2**		**0.4**	**43.0**	**42.0**		**63**	**1.2**	**33.6**	**#NUM!**	**0.6**	**25.4**	**15.8**	**#NUM!**	**52**	**0.2**	**17.3**	**#NUM!**	**0.0**	**13.2**	**11.0**
	12	**12**	**8**		**12**	**12**	**9**		**12**	**12**	**12**	**0**	**12**	**12**	**12**	**0**	**12**	**3**	**12**	**0**	**11**	**12**	**12**
	0	**0**	**0**		**0.0**	**0**	**0**		**0**	**0**	**0**	**0**	**0**	**0**	**0**		**0**	**0**	**0**	**0**	**0**	**0**	**0**

Diurnal Event 2

Date 8/28/17 to 8/29/17

		WRP Influent						Primary 1/2 Effluent						Primary 3 Effluent					
Sample	Time	Flow mgd	COD mg/L	TKN mg/L as N	TP mg/L	TSS mg/L	VSS mg/L	Flow mgd	COD mg/L	TKN mg/L as N	TP mg/L	TSS mg/L	VSS mg/L	Flow mgd	COD mg/L	TKN mg/L as N	TP mg/L	TSS mg/L	VSS mg/L
1	**7:00**	12.78	485	41.7	4.65	178	164	8.36	235	43.3	1.59	32	32	5.31	282	44.2	5.43	42	36
2	**9:00**	16.66	513	43.1	5.87	300	266	12.27	240	43.3	2.02	36	36	5.28	323	45.1	4.96	52	48
3	**11:00**	17.35	776	50.1	8.68	108	100	14.74	306	47.5	3.55	48	46	3.47	372	47.1	5.87	70	64
4	**13:00**	16.87	729	48.7	9.48	330	284	15.19	351	47.5	5.6	68	64	2.49	507	49.4	7.89	72	64
5	**15:00**	16.21	748	46.1	7.04	282	252	14.83	338	48.9	5.68	60	52	2.20	406	49.1	8.6	74	66
6	**17:00**	15.61	821	43.3	5.7	282	252	14.44	410	50.3	5.2	62	54	2.00	428	48.8	7.5	74	66
7	**19:00**	15.72	682	39.1	4.77	224	204	14.11	425	47.5	4.84	52	44	2.41	474	51.4	6.76	72	70
8	**21:00**	16.21	850	39.1	5.27	254	230	14.52	404	44.7	4.15	52	52	2.48	451	47.4	6.23	68	60
9	**23:00**	14.83	746	39.1	5.1	278	250	13.17	402	41.9	4.25	60	56	2.50	460	44.7	5.95	72	70
10	**1:00**	11.97	692	36	3.8	84	80	10.27	387	42	3.6	46	42	2.50	485	45	5.6	82	76
11	**3:00**	10.10	571	34.9	3.61	186	170	8.41	366	41.4	3.04	46	46	2.51	419	44.5	5.06	66	64
12	**5:00**	9.83	466	27.9	3.73	120	106	8.15	344	40.3	2.79	46	46	2.49	408	49.9	5.26	52	52
Average		**14.5**	**673**	**40.8**	**5.6**	**218.8**	**196.5**	**12.4**	**351**	**44.9**	**3.9**	**50.7**	**47.5**	**3.0**	**418**	**47.2**	**6.3**	**66.3**	**61.3**
Median		**15.7**	**711**	**40.4**	**5.2**	**239.0**	**217.0**	**13.6**	**359**	**44.0**	**3.9**	**50.0**	**46.0**	**2.5**	**424**	**47.3**	**5.9**	**71.0**	**64.0**
Count		**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**
Flow weight average			**687**	**42**	**5.9**	**227**	**203**		**355**	**45**	**4.1**	**52**	**49**		**398**	**47**	**6.0**	**63**	**58**
MVTL Composite Data		**14.2**	**511**	**40**	**6.8**	**187**	**169**	**11.3**	**299**	**45**	**3.8**	**56**	**51**	**3.8**	**295**	**45**	**5.6**	**62**	**59**
Difference		**2%**	**34%**	**3%**	**-13%**	**21%**	**20%**	**9%**	**19%**	**2%**	**8%**	**-7%**	**-5%**	**-22%**	**35%**	**5%**	**7%**	**2%**	**-1%**

		WRP Influent					Primary 1/2 Effluent					Primary 3 Effluent				
Sample	Time	COD:TSS	TKN:COD	TP:TKN	COD:TP	VSS:TSS	COD:TSS	TKN:COD	TP:TKN	COD:TP	VSS:TSS	COD:TSS	TKN:COD	TP:TKN	COD:TP	VSS:TSS
1	7:00	2.72	0.09	0.11	104	0.92	7.34	0.18	0.04	148	1.00	7.83	0.16	0.12	52	0.86
2	9:00	1.71	0.08	0.14	87	0.89	6.67	0.18	0.05	119	1.00	6.73	0.14	0.11	65	0.92
3	11:00	7.19	0.06	0.17	89	0.93	6.65	0.16	0.07	86	0.96	5.81	0.13	0.12	63	0.91
4	13:00	2.21	0.07	0.19	77	0.86	5.48	0.14	0.12	63	0.94	7.92	0.10	0.16	64	0.89
5	15:00	2.65	0.06	0.15	106	0.89	6.50	0.14	0.12	60	0.87	6.15	0.12	0.18	47	0.89
6	17:00	2.91	0.05	0.13	145	0.89	7.59	0.12	0.10	79	0.87	6.48	0.11	0.15	57	0.89
7	19:00	3.04	0.06	0.12	143	0.91	9.66	0.11	0.10	88	0.85	6.77	0.11	0.13	70	0.97
8	21:00	3.35	0.05	0.13	161	0.91	7.77	0.11	0.09	97	1.00	7.52	0.11	0.13	72	0.88
9	23:00	2.68	0.05	0.13	146	0.90	7.18	0.10	0.10	95	0.93	6.57	0.10	0.13	77	0.97
10	1:00	8.24	0.05	0.10	184	0.95	9.21	0.11	0.09	108	0.91	6.38	0.09	0.12	87	0.93
11	3:00	3.07	0.06	0.10	158	0.91	7.96	0.11	0.07	120	1.00	6.55	0.11	0.11	83	0.97
12	5:00	3.88	0.06	0.13	125	0.88	7.48	0.12	0.07	123	1.00	7.85	0.12	0.11	78	1.00
Average		**3.6**	**0.06**	**0.14**	**127**	**0.90**	**7.5**	**0.13**	**0.08**	**99**	**0.9**	**6.9**	**0.12**	**0.13**	**68**	**0.9**
Median		**3.0**	**0.06**	**0.13**	**134**	**0.90**	**7.4**	**0.12**	**0.09**	**96**	**0.9**	**6.7**	**0.11**	**0.13**	**68**	**0.9**
Count		**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

Intermediate Effluent								Final 1-4 Effluent								Final 5 (ABC) Effluent							
Flow	COD	NH3-N	NOx-N	NO3-N	PO4-P	TSS	VSS	Flow	COD	NH3-N	NOx-N	NO3-N	PO4-P	TSS	VSS	Flow	COD	NH3-N	NOx-N	NO3-N	PO4-P	TSS	VSS
mgd	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L	mg/L	mgd	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L	mg/L	mgd	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L	mg/L
8.06	64	28.1	0.07		0.3	30	30	8.14	64	1.51	34.4		0.667	25	21	5.22	56	< 0.16	17		<.033	10	9
11.98	62	29.7	0.08		0.26	24	24	12.06	62	0.94	35		0.633	27	21	5.19	49	< 0.16	17.2		<.033	10	9
14.44	220	30.4	< 0.05		0.99	156	144	14.52	122	0.8	35.4		0.668	26	19	3.37	56	< 0.16	17.5		<.033	7	7
14.89	276	33.1	0.09		1.22	170	160	14.97	64	1.51	33.6		0.676	27	19	2.40	58	< 0.16	18		<.033	7	7
14.54	184	32.9	0.49		1.16	112	104	14.62	64	3.21	32.2		0.671	25	19	2.11	49	< 0.16	18.6		<.033	6	6
14.14	152	33.5	1.2		1.4	76	72	14.22	62	4.6	30.6		0.7	28	21	1.91	45	< 0.16	19.3		<.033	5	5
13.82	195	33.7	0.56		1.7	114	104	13.90	69	6.2	29.7		0.693	25	19	2.32	54	< 0.16	19.7		<.033	4	4
14.22	363	32.6	< 0.05		2.57	162	144	14.30	66	6.77	29.3		0.72	25	19	2.39	43	< 0.16	19.7		<.033	4	4
12.88	385	32	< 0.05		2.45	200	180	12.96	71	8.05	28.8		0.757	23	18	2.41	41	< 0.16	20.2		<.033	4	4
9.98	169	31	< 0.05		1.5	88	74	10.06	73	8	28		0.8	23	18	2.40	45	< 0.16	21		<.033	3	3
8.12	88	28.6	< 0.05		1.17	26	26	8.20	73	8.33	28.1		0.788	26	21	2.41	43	< 0.16	20.8		<.033	4	4
7.86	77	28.3	< 0.05		0.94	16	14	7.94	77	7.62	28.8		0.731	26	23	2.40	45	< 0.16	20.6		<.033	4	4
12.1	**186**	**31.1**	**0.4**		**1.3**	**97.8**	**89.7**	**12.2**	**72**	**4.8**	**31.2**		**0.70**	**25.6**	**19.7**	**2.9**	**49**	< 0.16	**19.1**		<.033	**5.7**	**5.6**
13.3	**177**	**31.3**	**0.3**		**1.2**	**100.0**	**89.0**	**13.4**	**68**	**5.4**	**30.2**		**0.68**	**25.7**	**19.3**	**2.4**	**47**	< 0.16	**19.5**		<.033	**4.6**	**4.6**
12	**12**	**12**	**6**	**0**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**0**	**12**	**12**	**12**	**12**	**12**	**0**	**12**	**0**	**0**	**12**	**12**
	168	**26**	**0**	**0**	**1.1**	**90**	**83**		**61**	**4**	**26**	**0**	**0.6**	**21**	**16**		**41**	**0**	**16**	**0**	**0**	**5**	**5**
10.3		**28**			**1.3**	**116**	**107**	**11.0**		**4.5**			**0.7**	**25**	**20**	**3.7**						**7**	**7**
18%		**-7%**			**-12%**	**-22%**	**-23%**			**-15%**			**-17%**	**-15%**	**-18%**							**-34%**	**-35%**

Influent Sampling Location Comparison

Sample No.	Sample Loc:	Date:	TSS	TP	COD	TSS:TP	COD:TSS	COD:TP
#15	Influent ISCO Sampler Trough	1/10/2018	332	8.14	797	41	2.40	98
#20	Influent ISCO Sampler Trough	1/11/2018	271	7.15	864	38	3.19	121
#25	Influent ISCO Sampler Trough	1/12/2018	339	8.34	862	41	2.54	103
#30	Influent ISCO Sampler Trough	1/22/2018	325	7.76	782	42	2.41	101
#35	Influent ISCO Sampler Trough	1/23/2018	292	7.64	776	38	2.66	102
	Influent ISCO Sampler Trough	Average	**312**	**7.81**	**816**	**40**	**2.64**	**105**
	Influent ISCO Sampler Trough	Median	**325**	**7.76**	**797**	**41**	**2.54**	**102**
#14	Influent Sonford Sampler Station	1/10/2018	239	7.37	696	32	2.91	94
#19	Influent Sonford Sampler Station	1/11/2018	229	7.18	715	32	3.12	100
#24	Influent Sonford Sampler Station	1/12/2018	232	7.82	868	30	3.74	111
#29	Influent Sonford Sampler Station	1/22/2018	220	7.97	655	28	2.98	82
#34	Influent Sonford Sampler Station	1/23/2018	225	7.61	722	30	3.21	95
	Influent Sonford Sampler Station	**Average**	**229**	**7.59**	**731**	**30**	**3.2**	**96**
	Influent Sonford Sampler Station	**Median**	**229**	**7.61**	**715**	**30**	**3.1**	**95**
	Wastewater Characterization	**Average**				**30**	**2.9**	**86.8**
		Median				**30**	**2.9**	**82.8**

Influent Isco Trough : Sonford Sampler

Date	TSS	TP	COD
1/10/2018	1.39	1.10	1.15
1/11/2018	1.18	1.00	1.21
1/12/2018	1.46	1.07	0.99
1/22/2018	1.48	0.97	1.19
1/23/2018	1.30	1.00	1.07
Average	**1.36**	**1.03**	**1.12**
Median	**1.39**	**1.00**	**1.15**

Influent and PC1&2 Effluent Sampling Location Comparison

Sample No.	Sample Loc:	Date:	TSS	TP	COD	TSS:TP	COD:TSS	COD:TP
#11	PC1&2 ISCO Effluent Channel	1/10/2018	89	4.67	453	19.1	5.09	97
#16	PC1&2 ISCO Effluent Channel	1/11/2018	93	5.27	489	17.6	5.26	93
#21	PC1&2 ISCO Effluent Channel	1/12/2018	89	5.67	489	15.7	5.49	86
#26	PC1&2 ISCO Effluent Channel	1/22/2018	107	5	472	21.4	4.41	94
#31	PC1&2 ISCO Effluent Channel	1/23/2018	102	5.65	481	18.1	4.72	85
	PC1&2 ISCO Effluent Channel	Average	**96**	**5.25**	**477**	**18.4**	**4.99**	**91**
	PC1&2 ISCO Effluent Channel	Median	**93**	**5.27**	**481**	**18.1**	**5.09**	**93**
#12	PC1&2 ISCO Sampler Trough	1/10/2018	80	4.65	446	17.2	5.58	96
#17	PC1&2 ISCO Sampler Trough	1/11/2018	85	5.45	474	15.6	5.58	87
#22	PC1&2 ISCO Sampler Trough	1/12/2018	81	5.69	485	14.2	5.99	85
#27	PC1&2 ISCO Sampler Trough	1/22/2018	91	5.2	446	17.5	4.90	86
#32	PC1&2 ISCO Sampler Trough	1/23/2018	84	5.58	479	15.1	5.70	86
	PC1&2 ISCO Sampler Trough	Average	**84**	**5.31**	**466**	**15.9**	**5.55**	**88**
	PC1&2 ISCO Sampler Trough	Median	**84**	**5.45**	**474**	**15.6**	**5.58**	**86**
#13	PC1&2 Sonford Sampler Station	1/10/2018	77	3.94	388	19.5	5.04	98
#18	PC1&2 Sonford Sampler Station	1/11/2018	78	4.9	397	15.9	5.09	81
#23	PC1&2 Sonford Sampler Station	1/12/2018	77	5.06	416	15.2	5.40	82
#28	PC1&2 Sonford Sampler Station	1/22/2018	79	4.51	386	17.5	4.89	86
#33	PC1&2 Sonford Sampler Station	1/23/2018	84	5.14	392	16.3	4.67	76
	PC1&2 Sonford Sampler Station	Average	**79**	**4.71**	**396**	**16.9**	**5.02**	**85**
	PC1&2 Sonford Sampler Station	Median	**78**	**4.90**	**392**	**16.3**	**5.04**	**82**
	Wastewater Characterization	**Average**				**16.6**	**5.07**	**86**
		Median				**16.3**	**5.12**	**82**

HPO Primary 1/2 Isco Channel:Isco Trough

Date	TSS	TP	COD
1/10/2018	1.11	1.00	1.02
1/11/2018	1.09	0.97	1.03
1/12/2018	1.10	1.00	1.01
1/22/2018	1.18	0.96	1.06
1/23/2018	1.21	1.01	1.00
Average	**1.14**	**0.99**	**1.02**
Median	**1.11**	**1.00**	**1.02**

HPO Primary 1/2 Isco Trough:Sonford Sampler

1/10/2018	1.04	1.18	1.15
1/11/2018	1.09	1.11	1.19
1/12/2018	1.05	1.12	1.17
1/22/2018	1.15	1.15	1.16
1/23/2018	1.00	1.09	1.22
Average	**1.07**	**1.13**	**1.18**
Median	**1.05**	**1.12**	**1.17**

HPO Primary 1/2 Isco Channel:Sonford Sampler

Date	TSS	TP	COD
1/10/2018	1.16	1.19	1.17
1/11/2018	1.19	1.08	1.23
1/12/2018	1.16	1.12	1.18
1/22/2018	1.35	1.11	1.22
1/23/2018	1.21	1.10	1.23
Average	**1.21**	**1.12**	**1.20**
Median	**1.19**	**1.11**	**1.22**

Primary Clarifier 3 Sampling Location Comparison

Sample No.	Sample Loc:	Date:	TSS	TP	COD	CBOD5	TSS:TP	COD:TSS	COD:TP	COD:BOD	CBOD:TSS	CBOD:TP
#1	PC3 ISCO Effluent Channel	11/28/2017	121	7.28	485	239	16.6	4.01	67	2.03	1.98	32.8
#4	PC3 ISCO Effluent Channel	11/29/2017	108	7.96	464	200	13.6	4.30	58	2.32	1.85	25.1
#7	PC3 ISCO Effluent Channel	11/30/2017	111	7.8	511	248	14.2	4.60	66	2.06	2.23	31.8
#10	PC3 ISCO Effluent Channel	12/6/2017	100	7.48	548	305	13.4	5.48	73	1.80	3.05	40.8
#13	PC3 ISCO Effluent Channel	12/7/2017	96	7.63	517	264	12.6	5.39	68	1.96	2.75	34.6
	PC3 ISCO Effluent Channel	**Average**	**107**	**7.63**	**505**	**251**	**14.1**	**4.75**	**66**	**2.03**	**2.37**	**33**
	PC3 ISCO Effluent Channel	**Median**	**108**	**7.63**	**511**	**248**	**13.6**	**4.60**	**67**	**2.03**	**2.23**	**33**
#2	PC3 ISCO Sampler Trough	11/28/2017	89	6.57	403	189	TSS:TP	COD:TSS	COD:TP	COD:BOD	CBOD:TSS	CBOD:TP
#5	PC3 ISCO Sampler Trough	11/29/2017	99	6.65	375	187	14.9	3.79	56	2.01	1.89	28.1
#8	PC3 ISCO Sampler Trough	11/30/2017	98	6.95	483	200	14.1	4.93	69	2.42	2.04	28.8
#11	PC3 ISCO Sampler Trough	12/6/2017	105	6.81	455	250	15.4	4.33	67	1.82	2.38	36.7
#14	PC3 ISCO Sampler Trough	12/7/2017	87	6.83	420	201	12.7	4.83	61	2.09	2.31	29.4
	PC3 ISCO Sampler Trough	**Average**	**96**	**6.76**	**427**	**205**	**14.3**	**4.47**	**64**	**2.08**	**2.16**	**31**
	PC3 ISCO Sampler Trough	**Median**	**98**	**6.81**	**420**	**200**	**14.5**	**4.58**	**64**	**2.05**	**2.18**	**29**
#3	PC3 Sampler Station	11/28/2017	72	6.12	313	137	TSS:TP	COD:TSS	COD:TP	COD:BOD	CBOD:TSS	CBOD:TP
#6	PC3 Sampler Station	11/29/2017	67	6.4	304	134	10.5	4.54	48	2.27	2.00	20.9
#9	PC3 Sampler Station	11/30/2017	80	6.26	334	157	12.8	4.18	53	2.13	1.96	25.1
#12	PC3 Sampler Station	12/6/2017	65	6.29	358	164	10.3	5.51	57	2.18	2.52	26.1
#15	PC3 Sampler Station	12/7/2017	64	6.29	337	160	10.2	5.27	54	2.11	2.50	25.4
	PC3 Sampler Station	**Average**	**70**	**6.27**	**329**	**150**	**10.9**	**4.87**	**53**	**2.17**	**2.25**	**24**
	PC3 Sampler Station	**Median**	**67**	**6.29**	**334**	**157**	**10.4**	**4.90**	**53**	**2.16**	**2.25**	**25**
	Wastewater Characterization	**Average**					**14.6**	**4.59**	**66**	**2.08**	**2.21**	**31.7**
		Median					**13.7**	**4.47**	**67**	**2.10**	**2.23**	**31.1**

HPO Primary 3 Isco Channel:Isco Trough

Date	TSS	TP	COD	CBOD5
11/28/2017	1.36	1.11	1.20	1.26
11/29/2017	1.09	1.20	1.24	1.07
11/30/2017	1.13	1.12	1.06	1.24
12/6/2017	0.95	1.10	1.20	1.22
12/7/2017	1.10	1.12	1.23	1.31
Average	**1.13**	**1.13**	**1.19**	**1.22**
Median	**1.10**	**1.12**	**1.20**	**1.24**

HPO Primary 1/2 Isco Trough:Sonford Sampler

Date	TSS	TP	COD	CBOD5
11/28/2017	1.24	1.07	1.29	1.38
11/29/2017	1.48	1.04	1.23	1.40
11/30/2017	1.23	1.11	1.45	1.27
12/6/2017	1.62	1.08	1.27	1.52
12/7/2017	1.36	1.09	1.25	1.26
Average	**1.38**	**1.08**	**1.30**	**1.37**
Median	**1.36**	**1.08**	**1.27**	**1.38**

HPO Primary 1/2 Isco Channel:Sonford Sampler

Date	TSS	TP	COD	CBOD5
11/28/2017	1.68	1.19	1.55	1.74
11/29/2017	1.61	1.24	1.53	1.49
11/30/2017	1.39	1.25	1.53	1.58
12/6/2017	1.54	1.19	1.53	1.86
12/7/2017	1.50	1.21	1.53	1.65
Average	**1.54**	**1.22**	**1.53**	**1.67**
Median	**1.54**	**1.21**	**1.53**	**1.65**

Attachment C: April 2018 Wastewater Characterization Data

WRP Influent

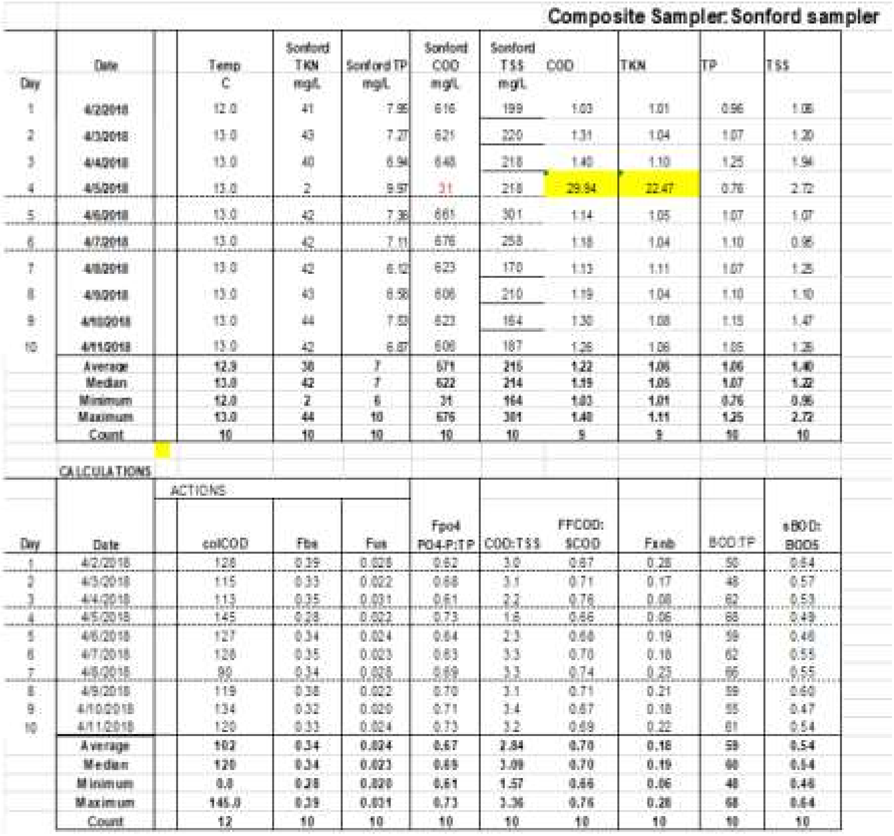
Day	Date	Flow mgd	COD mg/L	Filtered COD mg/L	ffCOD mg/L	CBOD5 mg/L	Filtered CBOD5 mg/L	TKN mg/L as N	Filtered TKN mg/L as N	NH3 mg/L as N	Nitrate/Nox as N, mg/L	Total P mg/L as P	Filtered P mg/L as P	PO4-P mg/L as P	Total Alk mg/L as CaCO3	TSS mg/L	VSS mg/L
1	**4/2/2018**	11.6	634	391	263	378	242	41.3	36.9	25.2	2.70	7.6	5.7	4.7	389	210	184
2	**4/3/2018**	12.5	812	397	282	374	213	44.8	37.2	25.2	2.07	7.8	4.4	5.3	389	264	228
3	**4/4/2018**	12.4	910	463	350	537	283	43.6	38.6	24.6	1.76	8.7	5.0	5.3	365	423	387
4	**4/5/2018**	12.5	928	427	282	514	253	42.7	37.2	24.9	1.27	7.6	4.89	5.6	358	592	546
5	**4/6/2018**	12.8	751	403	276	467	217	44.0	36.9	24.4	2.07	7.9	5.1	5.0	384	322	218
6	**4/7/2018**	12.7	798	427	299	483	265	44.3	38.3	25.8	1.56	7.8	5.1	4.9	386	244	222
7	**4/8/2018**	12.0	706	348	258	434	240	46.3	36.9	25.5	1.10	6.6	4.6	4.5	388	212	198
8	**4/9/2018**	12.1	721	412	293	423	255	44.6	37.2	24.6	2.09	7.2	4.7	5.0	376	232	202
9	**4/10/2018**	12.8	810	410	276	474	225	46.9	39.5	25.5	1.54	8.7	5.4	6.2	375	241	222
10	**4/11/2018**	13.2	763	393	273	438	236	44.9	38.9	26.4	1.49	7.2	5.0	5.3	386	236	216
	Average	**12.5**	**783**	**407**	**285**	**452**	**243**	**44.3**	**37.8**	**25.2**	**1.77**	**7.7**	**5.0**	**5.2**	**380**	**298**	**262**
	Median	**12.5**	**781**	**407**	**279**	**453**	**241**	**44.5**	**37.2**	**25.2**	**1.66**	**7.7**	**5.0**	**5.1**	**385**	**243**	**220**
	Minimum	**11.6**	**634**	**348**	**258**	**374**	**213**	**41.3**	**36.9**	**24.4**	**1.5**	**6.6**	**4.4**	**4.5**	**358**	**210**	**184**
	Maximum	**13.2**	**928**	**463**	**350**	**537**	**283**	**46.9**	**39.5**	**26.4**	**2.7**	**8.7**	**5.7**	**6.2**	**389**	**592**	**546**
	Count	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**9**	**10**	**10**	**10**	**10**

🟨 **= Data Screened from dataset**

April 2nd sample represents 7:30am on 4/1 to 7:30am on 4/2

CALCULATIONS

		GENERAL					SOLIDS CHARACTERIZATION										
Day	**Date**	**COD:TKN**	**TP:TKN**	**COD(WRP): COD**	**COD:TP**	**cBOD5: TSS**	**VSS:TSS**	**ISS**	**Fcvxi/s pCOD:VSS**	**Fcvxi/s pCOD:VSS**	**pN:VSS**	**pP:VSS**	**FupN pN/pCOD**	**FupP pP:pCOD**	**Fna NH3:TKN**	**COD:BOD5**	**SCOD:COD**
1	4/2/2018	15.4	0.185	0.97	83	1.80	0.88	26	1.32	1.32	0.024	0.011	0.018	0.008	0.61	1.7	0.62
2	4/3/2018	18.1	0.174	0.76	104	1.42	0.86	36	1.82	1.82	0.033	0.015	0.018	0.008	0.56	2.2	0.49
3	4/4/2018	20.9	0.199	0.71	105	1.27	0.91	36	1.16	1.16	0.013	0.009	0.011	0.008	0.56	1.7	0.51
4	4/5/2018	21.7	0.178	0.03	122	0.87	0.92	46	0.92	0.92	0.010	0.005	0.011	🟨	0.58	1.8	0.46
5	4/6/2018	17.1	0.179	0.88	95	1.45	0.68	104	1.60	1.60	0.033	0.013	0.020	0.008	0.55	1.6	0.54
6	4/7/2018	18.0	0.176	0.85	102	1.98	0.91	22	1.67	1.67	0.027	0.012	0.016	0.007	0.58	1.7	0.54
7	4/8/2018	15.2	0.142	0.88	108	2.05	0.93	14	1.81	1.81	0.047	0.010	0.026	0.006	0.55	1.6	0.49
8	4/9/2018	16.2	0.162	0.84	100	1.82	0.87	30	1.53	1.53	0.037	0.012	0.024	0.008	0.55	1.7	0.57
9	4/10/2018	17.3	0.185	0.77	93	1.97	0.92	19	1.80	1.80	0.033	0.015	0.019	0.008	0.54	1.7	0.51
10	4/11/2018	17.0	0.161	0.79	106	1.86	0.92	20	1.71	1.71	0.028	0.010	0.016	0.006	0.59	1.7	0.52
	Average	**17.7**	**0.174**	**0.75**	**102**	**1.65**	**0.88**	**35**	**1.53**	**1.53**	**0.029**	**0.011**	**0.018**	**0.007**	**0.57**	**1.74**	**0.52**
	Median	**17.2**	**0.177**	**0.82**	**103**	**1.81**	**0.91**	**28**	**1.63**	**1.63**	**0.030**	**0.011**	**0.018**	**0.008**	**0.56**	**1.70**	**0.51**
	Minimum	**15.2**	**0.142**	**0.03**	**83**	**0.87**	**0.68**	**14**	**0.92**	**0.92**	**0.010**	**0.005**	**0.011**	**0.006**	**0.54**	**1.61**	**0.46**
	Maximum	**21.7**	**0.199**	**0.97**	**122**	**2.05**	**0.01**	**104**	**1.82**	**1.82**	**0.047**	**0.015**	**0.026**	**0.008**	**0.61**	**2.17**	**0.62**
	Count	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**9**	**10**	**10**	**10**



Composite Sampler: Sonford sampler

Day	Date		Temp C	Sonford TKN mg/L	Sonford TP mg/L	Sonford COD mg/L	Sonford TSS mg/L	COD	TKN	TP	TSS
1	4/2/2018		12.0	41	7.95	616	199	1.03	1.01	0.96	1.06
2	4/3/2018		13.0	43	7.27	621	220	1.31	1.04	1.07	1.20
3	4/4/2018		13.0	40	6.94	648	218	1.40	1.10	1.25	1.94
4	4/5/2018		13.0	2	9.97	31	218	29.94	22.47	0.76	2.72
5	4/6/2018		13.0	42	7.36	661	301	1.14	1.05	1.07	1.07
6	4/7/2018		13.0	42	7.11	676	258	1.18	1.04	1.10	0.96
7	4/8/2018		13.0	42	6.12	623	170	1.13	1.11	1.07	1.25
8	4/9/2018		13.0	43	6.58	606	210	1.19	1.04	1.10	1.10
9	4/10/2018		13.0	44	7.53	623	164	1.30	1.08	1.15	1.47
10	4/11/2018		13.0	42	6.87	606	187	1.26	1.06	1.05	1.26
	Average		12.9	38	7	571	216	1.22	1.06	1.06	1.40
	Median		13.0	42	7	622	214	1.19	1.05	1.07	1.22
	Minimum		12.0	2	6	31	164	1.03	1.01	0.76	0.96
	Maximum		13.0	44	10	676	301	1.40	1.11	1.25	2.72
	Count		10	10	10	10	10	9	9	10	10

CALCULATIONS

		ACTIONS									
Day	Date		colCOD	Fbs	Fus	Fpo4 PO4-P:TP	COD:TSS	FFCOD: SCOD	Fxnb	BOD:TP	sBOD: BOD5
1	4/2/2018		128	0.39	0.028	0.62	3.0	0.67	0.28	50	0.64
2	4/3/2018		115	0.33	0.022	0.68	3.1	0.71	0.17	48	0.57
3	4/4/2018		113	0.35	0.031	0.61	2.2	0.76	0.08	62	0.53
4	4/5/2018		145	0.28	0.022	0.73	1.6	0.66	0.06	68	0.49
5	4/6/2018		127	0.34	0.024	0.64	2.3	0.68	0.19	59	0.46
6	4/7/2018		128	0.35	0.023	0.63	3.3	0.70	0.18	62	0.55
7	4/8/2018		90	0.34	0.028	0.69	3.3	0.74	0.25	66	0.55
8	4/9/2018		119	0.38	0.022	0.70	3.1	0.71	0.21	59	0.60
9	4/10/2018		134	0.32	0.020	0.71	3.4	0.67	0.18	55	0.47
10	4/11/2018		120	0.33	0.024	0.73	3.2	0.69	0.22	61	0.54
	Average		**102**	**0.34**	**0.024**	**0.67**	**2.84**	**0.70**	**0.18**	**59**	**0.54**
	Median		**120**	**0.34**	**0.023**	**0.69**	**3.09**	**0.70**	**0.19**	**60**	**0.54**
	Minimum		**0.0**	**0.28**	**0.020**	**0.61**	**1.57**	**0.66**	**0.06**	**48**	**0.46**
	Maximum		**145.0**	**0.39**	**0.031**	**0.73**	**3.36**	**0.76**	**0.28**	**68**	**0.64**
	Count		**12**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**

WRP Influent - VFAs

Date	Time	Sample	COD, mg/L	Filtered COD, mg/L	ffCOD, mg/l	Acetic Acid ppm	Propionic Acid ppm	Isobutyric Acid ppm	Butyric Acid ppm	2-Methylbutyric Acid ppm	Isovaleric Acid ppm	Valeric Acid ppm	VFAs as mg COD/L	Effluent ffCOD	Fbs	Fac	sCOD: COD	ffCOD: COD
4/2/2018	12:59 PM	Sample 1	772	340	199	17.9	2.3	<1	1	<1	<1	<1	24	18	0.23	0.13	0.44	0.26
4/3/2018	12:30 PM	Sample 2	755	395	269	26.9	9.5	<1	1.3	<1	<1	<1	45	18	0.33	0.18	0.52	0.36
4/4/2018	9:00 AM	Sample 3	716	659	229	16.8	3.8	<1	<1	<1	<1	<1	24	28	0.28	0.12	0.92	0.32
4/5/2018	8:42 AM	Sample 4	923	520	242	28.8	23.2	<1	<1	<1	<1	<1	66	20	0.24	0.30	0.56	0.26
		Average	**792**	**479**	**235**	**22.6**	**9.7**	**#DIV/0!**	**1.2**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**40**		**0.27**	**0.18**	**0.61**	**0.30**
		Median	**764**	**458**	**235.5**	**22.4**	**6.65**	**#NUM!**	**1.15**	**#NUM!**	**#NUM!**	**#NUM!**	**35**		**0.26**	**0.16**	**0.54**	**0.29**
		Minimum	**716**	**340**	**199**	**16.8**	**2.3**	**0**	**1**	**0**	**0**	**0**	**24**		**0.23**	**0.12**	**0.44**	**0.26**
		Maximum	**923**	**659**	**269**	**28.8**	**23.2**	**0**	**1.3**	**0**	**0**	**0**	**66**		**0.33**	**0.30**	**0.92**	**0.36**

Final 5 Effluent (ABC Effluent)

	Date	ffCOD
Day		**mg/L**
1	**4/2/2018**	18
2	**4/3/2018**	18
3	**4/4/2018**	28
4	**4/5/2018**	20
5	**4/6/2018**	18
6	**4/7/2018**	18
7	**4/8/2018**	20
8	**4/9/2018**	16
9	**4/10/2018**	16
10	**4/11/2018**	18

Attachment D: HPOAS Off Gas Testing Data

Rochester Diurnal Data									
		1st Stage (Carbon) HPOAS Train							
Date	Time	DO 1	DO 2	DO 3	Pur 1	Pur 2	Pur 3	Vent	Vent Vel
8/28/2017	10:30	19	>20	>20	76	72	70	72	6.7
8/28/2017	13:25	17.8	>20	>20	77	72	70	68	3.6
8/28/2017	16:00	18.8	19	19	70	64	62	64	4.75
8/28/2017	20:20	8.2	12.7	15.2	68	58	54	54	1.5
8/29/2017	0:45	11	12.8	12.4	62	52	41	45	
8/29/2017	8:30	16.8	16.9	17.1	63	53	48	48	1.53
8/29/2017	11:45	12.3	14.2	15.1	58	48		44	1.5
8/29/2017	16:30	10.2	9.8	9.4	48	37	30		
8/29/2017	20:00	9.7	8.9	7.9					
8/30/2017	0:30	12.5	10	7.4	58	38	25		
8/29/2017	8:45	12.8	13.5	12.8					
		2nd Stage Nitrificatin Train							
		DO 1	DO 2	DO 3	Pur 1	Pur 2	Pur 3	Vent	Vent Vel
8/28/2017	10:30	8.1	9	10.2	70	60	52		
8/28/2017	13:25	9	8.1	8.6	68	60	51		
8/28/2017	16:00	6.4	7.4	6.4	72	59	49		
8/28/2017	20:20	6.5	6.4	4.7	69		46		
8/29/2017	0:45	3.8	4.8	3.7	68				
8/29/2017	8:30	7.56	7.56	5.88	65		38		
8/29/2017	11:45	5	5.7	3.8	64	54	40		
8/29/2017	16:30	4.2	5.7	3.8	72	59	43		
8/29/2017	20:00	4.5	5.3	3.5	72	52	42		
8/30/2017	0:30	3.2	3.7	2.7	70	50	41		
8/29/2017	8:45	5.1	3.7	6.9	73	61	42		

Attachment E: Nitrification Rate Testing

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Technical Memorandum

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Prepared for: City of Rochester

Project Title: Rochester WRP Facilities Plan

Project No.: 150811

Technical Memorandum

Subject: Nitrification Rate Testing

Date: September 2017

To: Matt Baker, P.E. Project Manager

From: Harold Voth, P.E. Project Manager

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Reviewed by: Don Esping, P.E. Senior Process Engineer

Limitations:

This document was prepared solely for the City of Rochester in accordance with professional standards at the time the services were performed and in accordance with the contract between City of Rochester and Brown and Caldwell dated May 15, 2017. This document is governed by the specific scope of work authorized by the city of Rochester; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by the City of Rochester and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 1: Introduction

- The greatest uncertainty in biological nutrient removal plant design and/or process optimization is nitrification performance. Nitrification performance essentially is quantified by the maximum specific growth rate of the autotrophic nitrifiers (μ_{AUT}) in the system. Experience has shown that in many instances there is consistency in the magnitude of the μ_{AUT} parameter from plant to plant, particularly if there is limited industrial input to the wastewater. However, significantly lower than typical values are encountered on occasion due to inhibitory components in the influent. The implication of a low nitrifier growth rate is that the system must be operated at a longer aerobic SRT to avoid washout of nitrifiers and maintain nitrification. This in turn translates into an increased sludge mass in the system, resulting in either increased reactor tankage and clarifier area for new plant designs or reduced treatment capacity for existing plants. Typically, if pilot testing is not conducted to measure the plant-specific μ_{AUT} value, engineering analysis necessarily should be based on a conservative (low) estimate of the value. This in turn can have a substantial capital cost implication.

The nitrification testing conducted in this investigation was used to determine whether nitrifier growth is being inhibited at the Rochester Water Reclamation Plant (WRP). The plant treats an average of 13 million gallons per day (mgd) and is comprised of two parallel treatment processes: A High Purity Oxygen (HPO) plant and an Aeration Basin Complex (ABC) capable of biological nutrient removal. The HPO plant is rated at 19.1 mgd and the ABC is rated at 4.75 mgd. The raw influent is screened, degritted and then split between the HPO plant and ABC. The split ratio between the two processes can be varied to a degree to optimize the overall plant performance.

In recent years, nitrification has been modelled as a two-step process whereby ammonia oxidizing bacteria (AOB) convert ammonia to nitrite and nitrite oxidizing bacteria (NOB) convert nitrite to nitrate. Each type of bacteria has a unique set of kinetic and stoichiometric parameters, including a maximum specific growth rate, μ_{AOB} and μ_{NOB}. The maximum specific growth rate of nitrifiers (μ_{AUT}) in the traditional one-step nitrification model essentially is equivalent to the maximum specific growth rate of AOB (μ_{AOB}) in the two-step nitrification model. The proviso here is that there is not significant nitrite accumulation, and the ammonia converted to nitrite is in turn converted to nitrate.

Two types of nitrification tests were carried out:

- ***Washout Test:*** A batch test method with duration of approximately five days was conducted to estimate the maximum specific nitrifier growth rate (μ_{AUT}) for the ABC plant at the Rochester WRP. This μ_{AUT} value will indicate whether there are components of the influent that are causing inhibition of nitrification. This parameter is of paramount importance for a nitrifying plant in that it essentially determines the aerobic solids retention time (SRT) that the plant must be operated at to achieve stable nitrification.
- ***Specific Nitrification Rate Tests:*** Four specific nitrification rate (SNR) batch tests each lasting several hours were conducted to determine whether:
    - The ABC plant is fully nitrifying and therefore has a typical ratio of NOB to AOB.
    - There are inhibitory compounds present in the HPO primary effluent and whether those are biologically degraded in the HPO plant.
    - The nitrification rate increases as the pH of the HPO mixed liquor is increased to 7.

Further background on the testing that was conducted is provided in Section 2. Results and discussion are presented in Section 3.

Section 2: Background on Testing

This section provides further information on the tests that were conducted at the Rochester WRP.

2.1 Washout Test

The Washout Test method for estimating the maximum specific nitrifier growth rate (μ_{AUT}) is based on monitoring the effluent nitrite and nitrate responses over a period of several days in a flow-through reactor initially filled with nitrifying mixed liquor from the full-scale plant (WERF, 2003). Influent to the reactor typically is plant raw influent or primary effluent. At the start of the test the mixed liquor in the test reactor is supplemented with ammonia, and ammonia is added to the influent each day to ensure that the ammonia concentration in the reactor is not limiting to ensure that AOB are operating at their maximum rate. Additional alkalinity is added as required to ensure that nitrifier growth is not limited by non-optimal pH. The influent flow rate (Q) is selected such that the hydraulic retention time [HRT = Volume/Q (equivalent to SRT for a flow-through reactor)] will result in nitrifier washout. EnviroSim has found this test to be a very robust method for determination of μ_{AUT}.

A typical test response is shown in Figure 1. The test influent flow rate was set such that the SRT was 0.75 days. Effluent samples from the Washout Test were collected throughout the day, filtered immediately, and analyzed for nitrate, nitrite, and ammonia concentrations. The test was completed within 5 days. Features to note are:

- Initially, the nitrite+nitrate response shows an increase to a maximum. During this phase, the mass of nitrifiers in the system is large and a substantial amount of the influent ammonia is oxidized.
- A maximum nitrite+nitrate concentration is followed by a semi-exponential decrease with time. The nitrifiers are being washed out of the system, and the remaining mass oxidizes a lesser and lesser amount of the influent ammonia.
- The large change in nitrite+nitrate response over the test duration is particularly suitable for parameter estimation and lowers the influence of “outlier” data points.
- Test duration typically is 4 to 6 days.

Nitrification at WWTPs may be adversely impacted due to nitrifying organisms’ sensitivity to a variety of compounds in the influent (*e.g.* certain metals and organic compounds). Problems of nitrification inhibition at WWTPs usually are manifested by a reduced nitrifier maximum specific growth rate (μ_{AUT}). Knowledge of μ_{AUT} is therefore very important in diagnosing nitrification performance. For example, it determines the appropriate aerobic SRT that the plant should be operated at to achieve and maintain stable nitrification performance. The implication of a low nitrifier growth rate is that the system must be operated at a long SRT to avoid washout of nitrifiers and/or effluent ammonia breakthrough. Also, the value of μ_{AUT} can be compared to conventionally accepted values for this parameter to help determine whether the plant is experiencing acute or chronic nitrification inhibition.

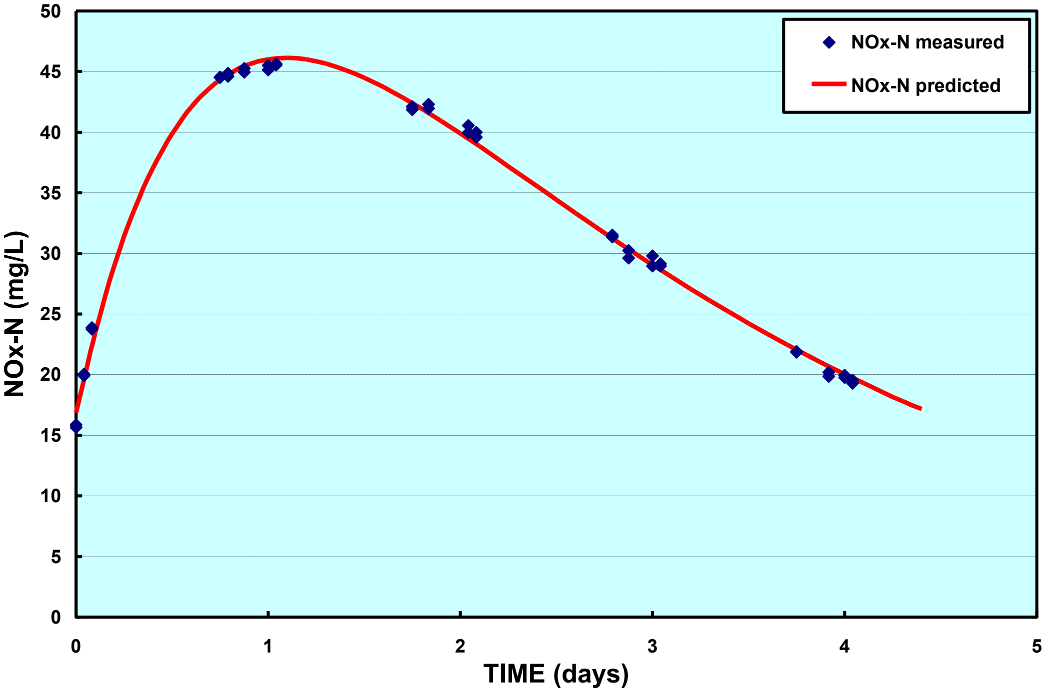


Figure 1. Typical Washout Test Response

2.2 Specific Nitrification Rate Test

In an specific nitrification rate (SNR) test, a volume of mixed liquor or return activated sludge (RAS) is collected from a nitrifying plant and mixed with a diluent (*e.g.* treatment plant influent wastewater, primary effluent, *etc.*). Ammonia typically is added to the batch test at the start to set a target initial concentration in the range of 25 to 35 mgN/L. The batch test is then fully aerated and the production of nitrite and nitrate (NO_X) is monitored over time (*e.g.* 3-6 hours). Dissolved oxygen (DO) concentration is maintained above say 3 mg/L to ensure that DO does not limit nitrifying organisms (AOB or NOB). Because the relative change in nitrifier population is small over the duration of the test, there usually is a linear response in the nitrogen species.

Figure 2 shows an example of the response of ammonia-, nitrite-, and nitrate-nitrogen in a fully-aerated SNR test. Total inorganic nitrogen (TIN) is also plotted as this provides an approximate mass balance check and an indication of whether factors such as ammonia stripping or denitrification are interfering in test results. In tests where influent wastewater is added the initial ammonia response may not be initially linear primarily as a result of conversion of organic nitrogen to ammonia offsetting ammonia removal by AOB.

Linear regression analysis is used to estimate the ammonia removal rate (NH_3RR), observed nitrite accumulation rate (NO_2AR), nitrate production rate (NO_3PR) and NO_X production rate (NO_XPR). Dividing the NH_3RR and NO_XPR by the batch volatile suspended solids (VSS) concentration yields the specific ammonia removal rate (SNH_3RR) and the specific NO_X production rate (SNO_xPR), as shown in Table 1. It should be noted that the SNH_3RR and SNO_xPR are different and hence the TIN concentration changes slightly throughout the test. This is expected, since nitrification is not the only process impacting the ammonia concentration in these tests. For example, ammonia also is produced in the test *via* the ammonification of organic nitrogen from the influent wastewater or that released through heterotrophic bacteria decay; it is consumed as a cellular synthesis requirement during heterotrophic bacteria growth, *etc.* Because of the multiple processes impacting ammonia concentration, it is important that ***only*** NO_X production be used to assess nitrification kinetics.

In Table 1 the specific rates were corrected to 20°C using the following equation where θ is the Arrhenius value. An Arrhenius value of 1.072 was used for the SNH_3RR, SNO_3PR and SNO_XPR.

$$SNPR_{20} = SNPR_{T}\theta^{(20-t)}$$

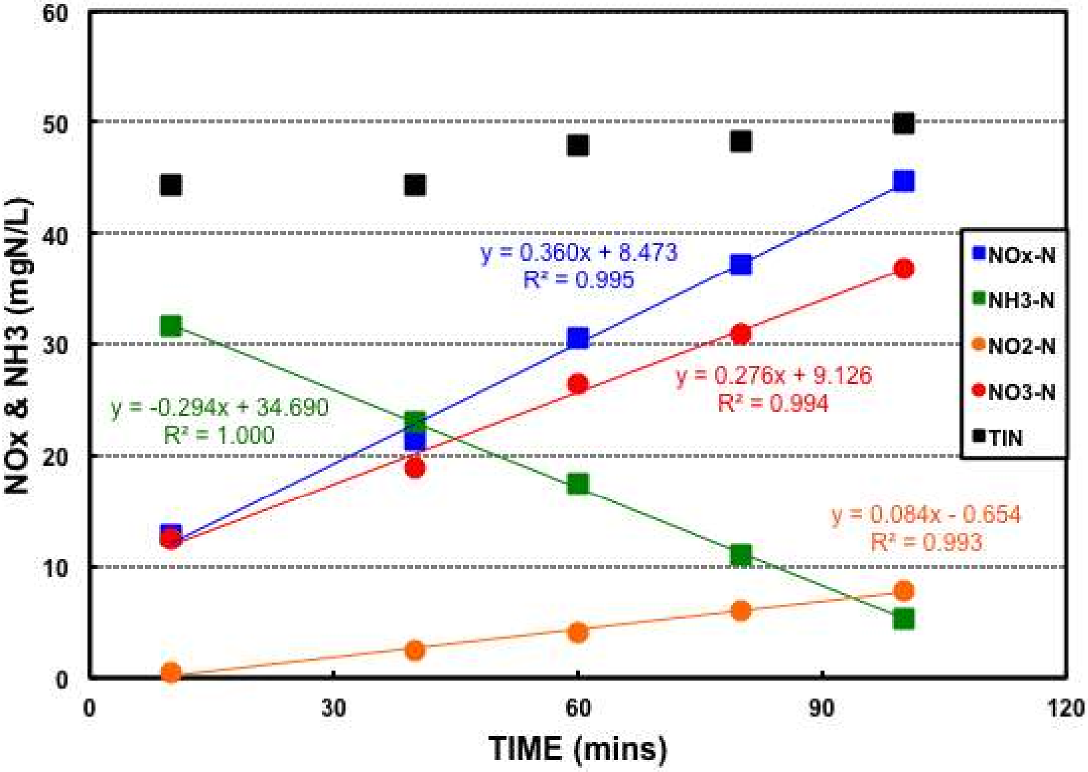


Figure 2. Ammonia Removal and Oxidized Nitrogen Production vs. Time in an Example SNR Test.

Table 1. Summary of Results for Example SNR Test	
VSS (mg/L)	3116
Average Test Temperature (°C)	21.9
NH_3RR (mgN/L/min)	0.294
SNH_3RR (mgN/gVSS/hr)	5.65
SNH_3RR corrected to 20°C (mgN/gVSS/hr)	4.96
NO_xPR (mgN/L/min)	0.360
SNO_xPR (mgN/gVSS/hr)	6.92
SNO_xPR corrected to 20°C (mgN/gVSS/hr)	6.07
NO_3PR (mgN/L/min)	0.276
NO_2AR (mgN/L/min)	0.084

Although these tests do not yield an estimate of the AOB and NOB maximum specific growth rate required for process modelling input, they do provide very useful quantitative information and also help to identify inhibition problems. Comments on problems with estimating nitrifier maximum specific growth rates from SNR test data are provided in WERF, 2003. In a *fully nitrifying* system, if all of the nitrite generated from AOB oxidation is in turn converted to nitrate by NOB (*i.e.* no nitrite-shunt is occurring and the same amount of nitrogen is processed in each step) then the ratio of NOB/AOB should equal the ratio of the respective yield coefficients. For example, if Y_{NOB} = 0.09 and Y_{AOB} = 0.15, then NOB/AOB = 0.6 (Dold *et al.*, 2015).

In the fully-aerated SNR test, nitrite is generated from ammonia and converted to nitrate simultaneously, so the overall nitrite production rate (NO_2PR) equals the observed nitrite accumulation (NO_2AR) rate plus the nitrate production rate (NO_3PR):

$$NO_3PR \ = \ \Delta NO_3/\Delta \mathrm{t}$$

$$NO_2PR \ = \frac{\Delta NO_2}{\Delta t} + \frac{NO_3}{\Delta t} = \frac{\Delta NO_X}{\Delta t} = NO_XPR$$

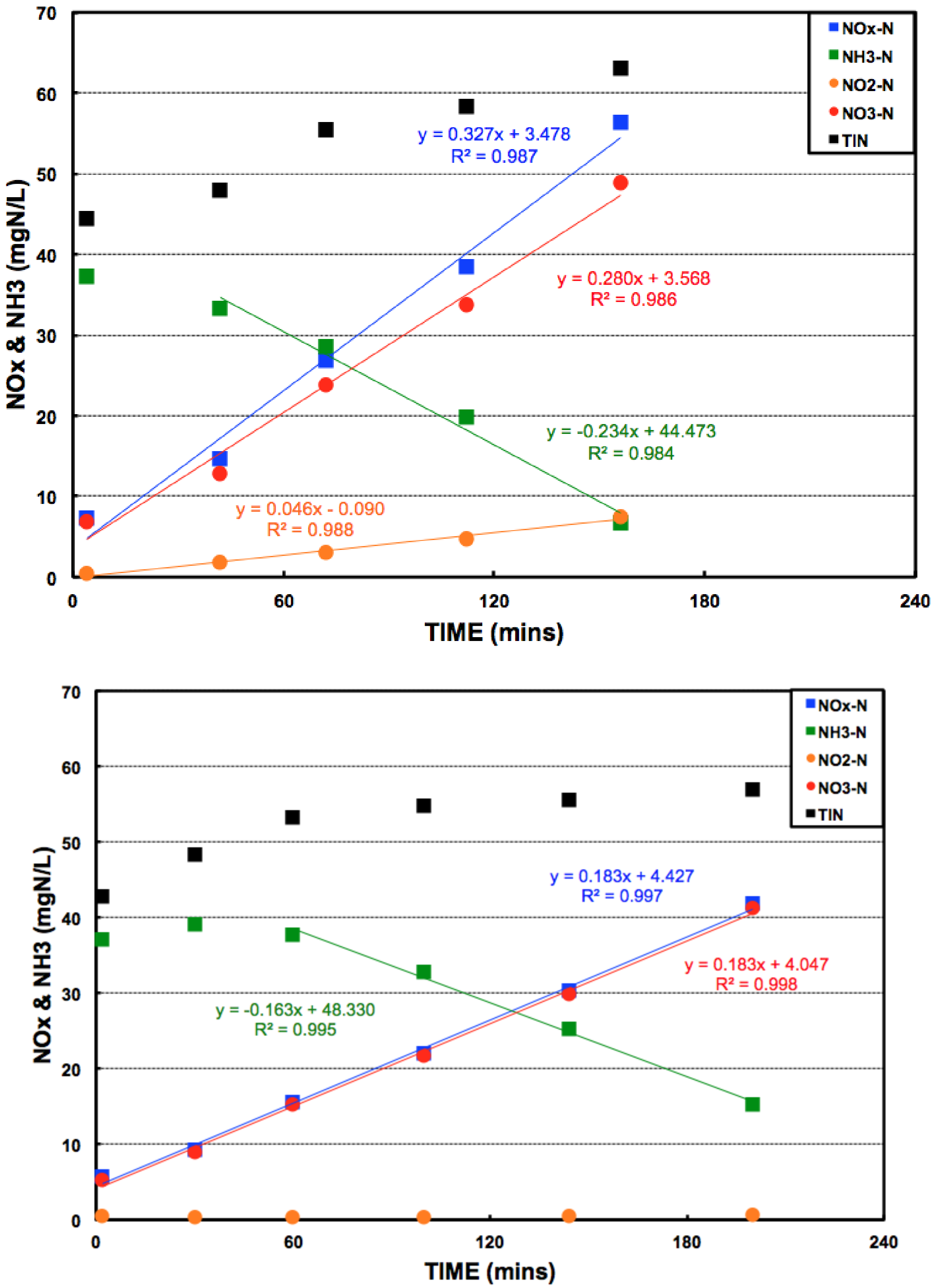
The ratio NO_3PR/NO_XPR [i.e. ($\Delta NO_3/\Delta t$) / ($\Delta NO_X/\Delta t$)] is linked directly to the NOB/AOB organism ratio (but not equal to NOB/AOB because NO_3PR/NO_XPR incorporates the maximum growth rates of AOBs and NOBs). The NO_3PR / NO_XPR should equal the ratio of the NOB and AOB and maximum specific growth rates (μ_{NOB} /μ_{AOB}) (Dold *et al.*, 2015). For 20°C values of μ_{NOB} = 0.7 /d and μ_{AOB} = 0.9 /d, the ratio is μ_{NOB} /μ_{AOB} = 0.78. However, if a lower value is measured in a fully-aerated SNR test on plant mixed liquor, then it is likely that the NOB population is suppressed and nitrite shunt is occurring in the plant.

In the fully-aerated example SNR test in Figure 2, the NO_3PR is 0.276 mgN/L/min and the NO_XPR is 0.360 mgN/L/min, hence the NO_3PR/NO_XPR is 0.77. This indicates that NOB are not repressed and that nitrite-shunt is not occurring at the plant.

The main utility of the SNR test is that, by varying a single factor (*e.g.* influent sample) between two tests, the two results can be compared to see if that factor impacts nitrification rate. When investigating potential inhibition of nitrification, a pair of SNR tests would be conducted where one test is performed in the absence of the suspected inhibitor (the control), and the other test is performed in the presence of the suspected inhibitor. The mixed liquor used in both tests should be from a fully nitrifying plant where there is no apparent inhibition (preferably with minimal industrial input). Comparing the relative results can provide useful qualitative and quantitative information about the potential inhibition. Figure 3 below shows an example from such an approach from a wastewater treatment plant that was accepting significant inputs from an industrial source.

In the pair of SNR tests shown in Figure 3, the control test (upper chart) was conducted in the absence of the industrial input and the test in the lower chart was conducted with the industrial input present at the anticipated concentration levels (based on flows and loads), which in this case was 4% of the influent by volume. The SNO_XPR in the control test was 3.26 mgN/gVSS/hr whereas it was 1.92 mgN/gVSS/hr in the test containing industrial influent. Thus, the presence of the industrial influent reduced the SNO_XPR by 41.2%, which clearly demonstrates nitrification inhibition. It should be noted that in both tests, at the start the net ammonia removal rate appeared to be low for a period before it was removed at a steady rate. This occurred because the ammonification of organic nitrogen in the influent wastewater was generating ammonia at the same time nitrification was removing ammonia. The example SNR tests shown in Figure 3 were part of a project where several pairs of

SNR tests were run to investigate the impact of different dilution ratios on nitrification. For example, when the industrial input comprised 1% of the influent by volume, the SNO$_X$PR was reduced by 20.5%.



1. **Figure 3. Results from Parallel SNR Tests Conducted to Identify and Quantify Inhibition from an Industrial Source.**

It is important to know how much lower an SNO$_X$PR value from a test with a suspected inhibitor must be compared to the SNO$_X$PR value of the control SNR test to confidently state that the test demonstrates nitrification inhibition compared to the control test. Each SNR test is subject to various sources of error such as mixing gradients, measurement of solids and nitrogen species, *etc.* It is therefore expected that even carefully controlled replicate tests conducted in parallel under seemingly identical conditions likely will yield slightly differing SNO$_X$PR values. EnviroSim has conducted past in-house investigations to asses this variability. To determine the absolute percent difference in SNO$_X$PR values above which a test demonstrates nitrification inhibition compared to the control test, EnviroSim ran a series of 7 identical control SNR tests on reactors containing mixed liquor and raw influent from a well-nitrifying activated sludge plant. These tests were run over several days while the influent loading and operation (including SRT) of the plant were relatively constant. The average percent difference in SNO$_X$PR values among the control tests was found to be 4.9% with an upper bound of 8.5% at a 95% confidence interval. Therefore, a reasonable basis for assessing data is to assume that nitrification inhibition is occurring if the SNO$_X$PR value is *more than* 8.5% lower than the control test.

Section 3: Results and Discussion

3.1 Washout Test

A Washout Test using mixed liquor obtained from the sampling port at the end of the ABC plant aeration tanks at the Rochester WRP was completed over a period of 5 days. The general procedure for the tests followed the published Washout Test protocol (WERF, 2003) discussed in the previous section. Prior to commencing the test, the ABC mixed liquor was allowed to settle in a bucket. Some of the supernatant was decanted from the bucket to thicken the mixed liquor by a factor of about 1.33. This was done to increase the ABC mixed liquor concentration to approximately 4,000 mg/L. Fresh primary effluent from the ABC plant was collected each day to serve as feed to the test reactor. Feed batches were grab samples generally collected around 9:30 am from the ABC primary effluent sample pump. The sample pump was turned on and the primary effluent was allowed to flow into the drain for approximately one minute before it was collected in a sample container. This was done to flush the sampling pipe of any sediment that may have been present to ensure the collected sample was representative of primary effluent. The ABC primary effluent sample had a black color every day it was collected. The test reactor was aerated using aquarium air pumps and air stones, and a stand mixer provided mixing. The nominal reactor volume was 8 L and the influent flow rate was set at a target of 11.43 L/d, resulting in an SRT of 0.70 day. Effluent samples from the Washout Test were collected and filtered immediately several times per day and analyzed for nitrate-, nitrite-, and ammonia-nitrogen using the following Hach spectrophotometric methods: TNTplus 832 HR Ammonia; TNTplus 836 HR Nitrate; TNTplus 840 HR Nitrite. The collection time and volume of each sample was recorded and the volume of effluent collected was measured each day to allow calculation of the exact flow through the reactor, thereby accounting for any small errors in the set pump flow rate. Table 2 summarizes the target conditions for the Washout Tests. Figure 4 shows the testing apparatus set up at the Rochester WRP laboratory facility by EnviroSim.

Table 2. Summary of Washout Test Target Conditions for Rochester WRP ABC Plant Mixed Liquor, Aug. 31 – Sept. 1, 2017

Parameter	Value/Detail
Nominal Test Volume (L)	8
Target feed rate (L/d)	11.43
Target HRT (days)	0.70
Mixed Liquor Source	End of ABC aeration tank
Feed Source	ABC primary effluent

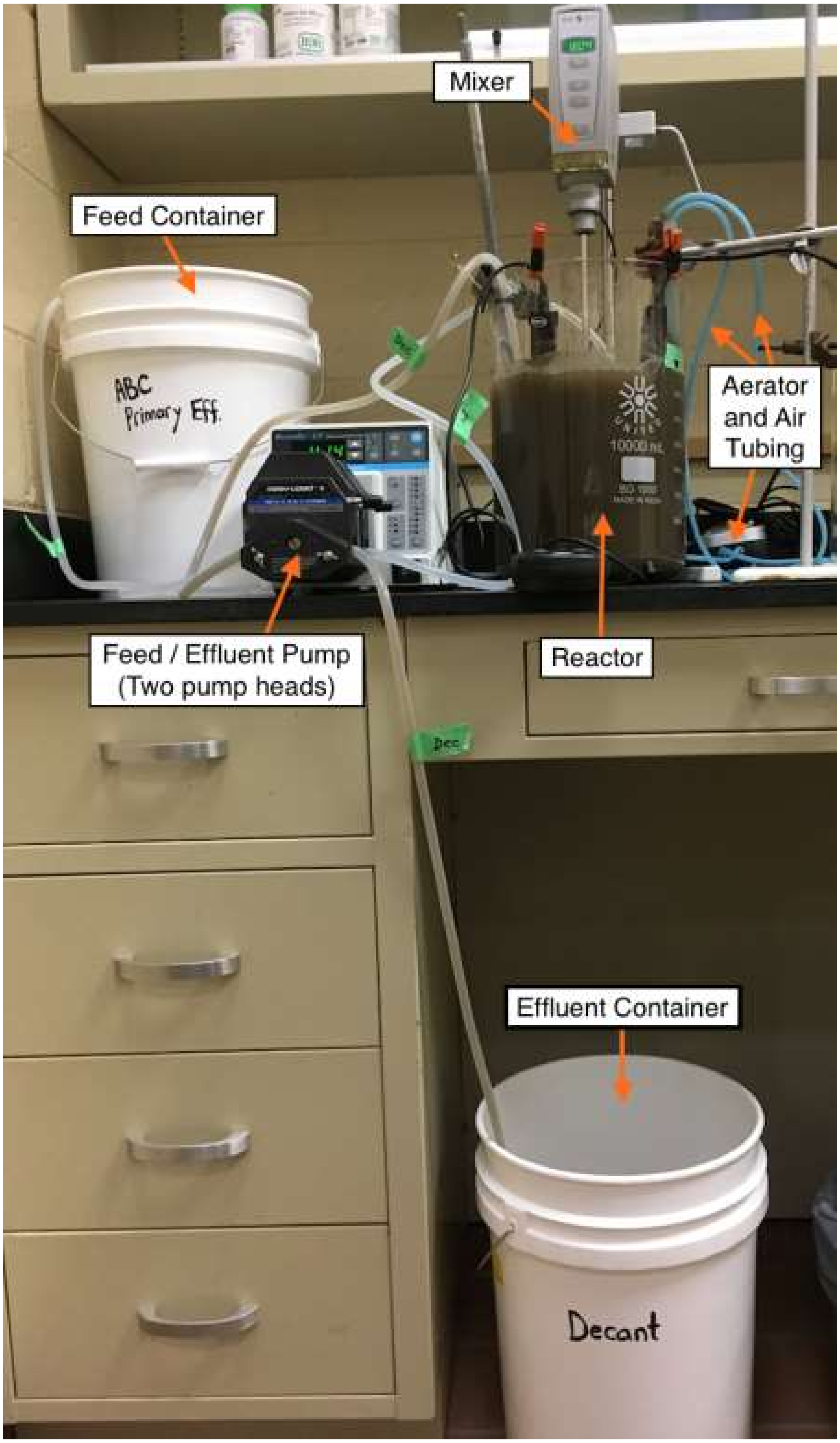


Figure 4. Washout Test Apparatus for Rochester WRP ABC Plant Mixed Liquor

Although the Washout Test methodology is quite robust and environmental conditions in the test usually remain stable, test conditions are checked several times daily through measurement of temperature, pH and DO concentration. The test was set up in a room with reasonable temperature control, and the temperature fluctuated about ±2°C around 25°C. The average temperature was used to adjust the μ_{AUT} estimate to the standard reference temperature of 20°C using the following Arrhenius relationship:

$$\mu_{AUT,T} = \mu_{AUT,20} \cdot 1.072^{(T-20)} \qquad [1]$$

Temperature measurements for the test are shown in Figure 5. The average temperature in the test was 25.0°C with a standard deviation of 1.3°C.

In this project, pH control was achieved through addition of sodium bicarbonate to the influent feed batches and test reactor as required. Figure 6 shows the observed pH during the test. The test was aerated with an aquarium air pump and air stones. The dissolved oxygen was maintained between 2 and 5 mg/L to provide adequate aeration so that oxygen would not limit the nitrification rate.

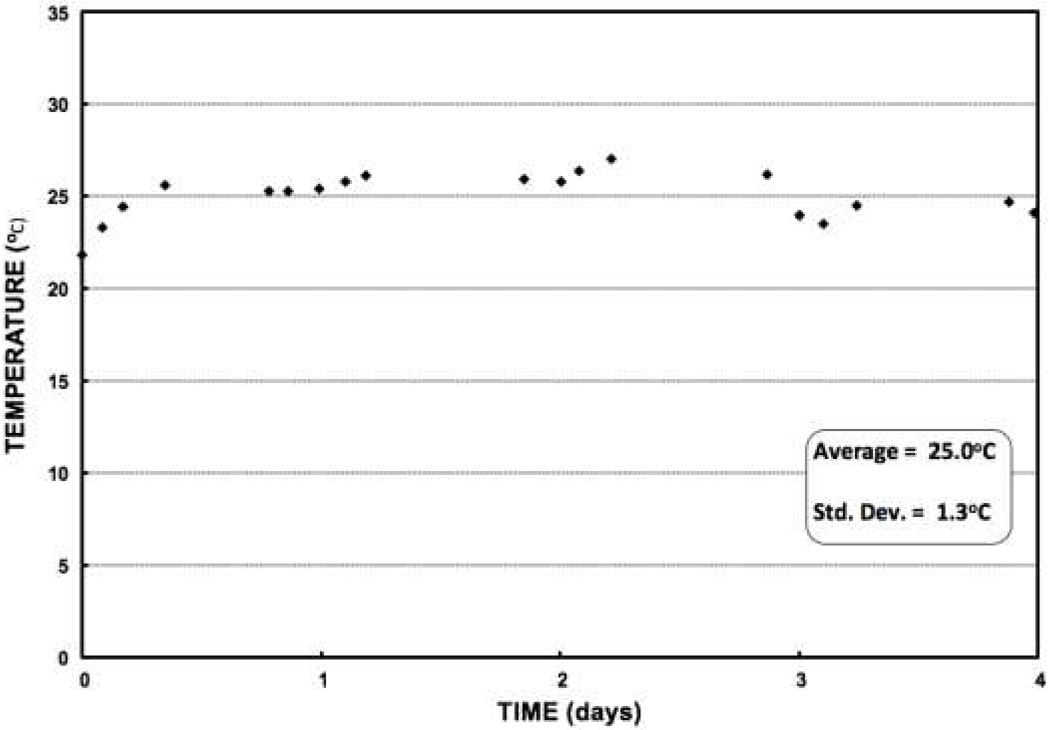


Figure 5. Measured Temperature in Washout Test.

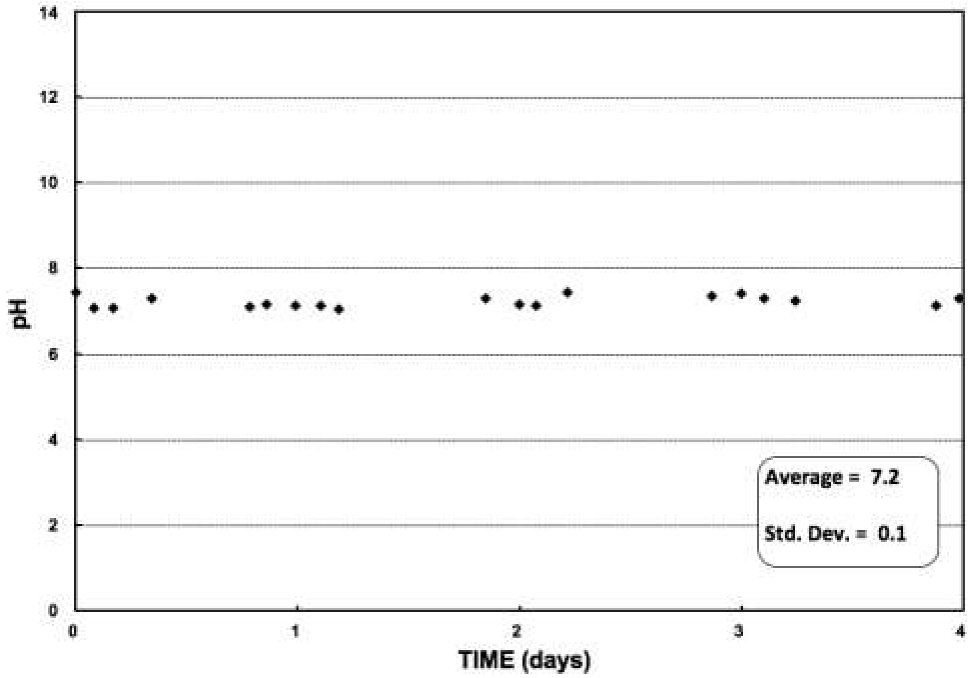


Figure 6. Observed pH in Washout Test

Phosphorous in the form of potassium dihydrogen phosphate was dosed periodically into the reactor to maintain a soluble phosphate concentration of at least 1 mgPO4-P/L throughout the Washout Test. At the time of testing the ABC plant was biologically removing phosphorous. Phosphorous uptake was observed during the fully-aerated Washout Test because the ABC mixed liquor contained a substantial population of PAOs.

The NO_X-N response for the Washout Test is shown in Figure 7. The continuous line shown in Figure 7 results from the non-linear regression fit of the equation that describes the expected theoretical response (WERF, 2003). This regression yielded a μ_{AUT} estimate of 0.63 d^{-1} (corrected to 20°C using Equation [1]). Some adjustment of the Washout μ_{AUT} estimate is necessary to account for the kinetic model switches that simulators such as BioWin™ apply to μ_{AUT}. The most significant correction will be for the DO concentration in the test. The average measured DO was 3.8 mg/L. Using a typical DO switching function half-saturation value of 0.25 mg/L, the corrected μ_{AUT} value suitable for direct input to BioWin will be:

$$\mu_{AUT,CORR} = 0.63d^{-1}.\frac{(0.25\frac{mg}{L} + 3.8\frac{mg}{L})}{3.8\frac{mg}{L}} = 0.68d^{-1} \qquad [2]$$

The μ_{AUT} estimate of 0.68 d^{-1} (with a 95% confidence interval of <0.65 d^{-1}, 0.70 d^{-1}>) is lower than the typical range of 0.8 – 1.0 d^{-1} observed at many other wastewater treatment plants (WERF, 2003). This suggests that there is some degree of nitrification inhibition at the Rochester WRP.

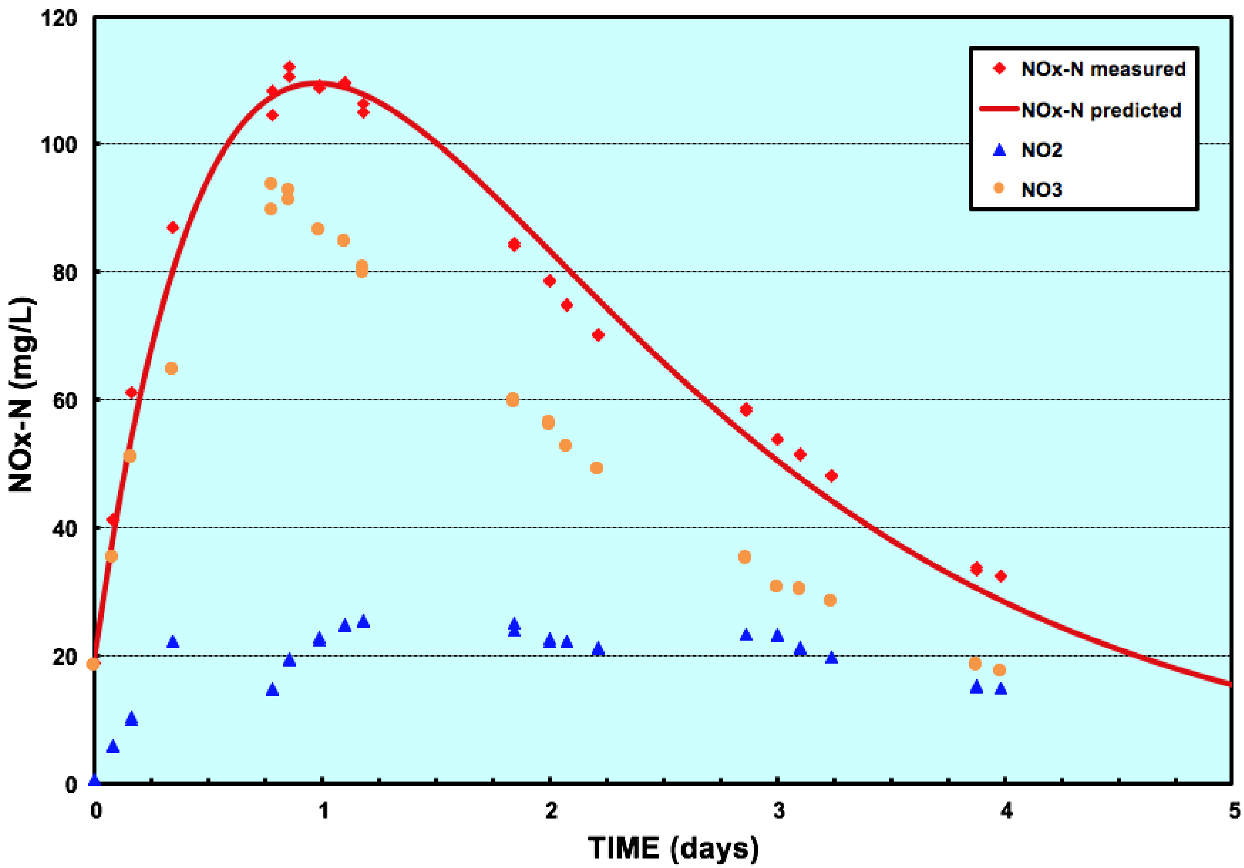


Figure 7. Washout Test Showing Observed (Points) and Predicted (Line) Response.

Figure 8 below shows the Washout Test reactor on Day 3. The mixed liquor in the reactor is noticeably more dilute than its starting concentration on Day 0 shown previously in Figure 4.

Figure 8. Washout Test Reactor on Day 3.

The Washout Test was simulated using BioWin which employs a two-step nitrification model. The model was calibrated by adjusting the maximum specific growth rate of AOB (μ_{AOB}) and NOB (μ_{NOB}). The purpose of simulating the Washout Test was to: (1) verify μ_{AUT} (*i.e.* μ_{AOB}) estimated from the non-linear regression described above; and (2) estimate μ_{NOB}.

The ABC plant was simulated at steady-state at an aerobic SRT of 9 days to estimate the AOB and NOB concentrations in the ABC mixed liquor. The NOB/AOB ratio was 0.6 in the mixed liquor, which is expected for a fully nitrifying system. The Washout Test was simulated similar to the operation of the actual test:

- A batch reactor was filled with ABC mixed liquor supplemented with ammonia and alkalinity.
- The batch reactor was fed with an influent stream representing ABC primary effluent supplemented with ammonia and alkalinity.
- The Washout Test was simulated dynamically for 5 days at the same temperature and dissolved oxygen concentration as in the actual test.

The simulated and measured concentrations of nitrate- and nitrite-nitrogen in the Washout Test are shown in Figure 9. The purpose here was not to conduct an exhaustive simulation study. Rather, the objective was mainly to provide confirmation of the experimental results. It is evident that the simulation shows good agreement in terms of nitrite, nitrate and NO_X-N concentrations.

The maximum specific growth rate of AOB and NOB in the calibrated model are:

$$\mu_{AOB} = 0.70\ d^{-1}$$

$$\mu_{NOB} = 0.65\ d^{-1}$$

The μ_{AOB} value of 0.70 d^{-1} estimated using the BioWin model closely agrees with the μ_{AUT} (*i.e.* μ_{AOB}) value of 0.68 d^{-1} (with a 95% confidence interval of <0.65 d^{-1}, 0.70 d^{-1}>) estimated by nonlinear regression. The μ_{NOB} value of 0.65 d^{-1} estimated from the simulation is close to the typical μ_{NOB} value of 0.70 d^{-1}.

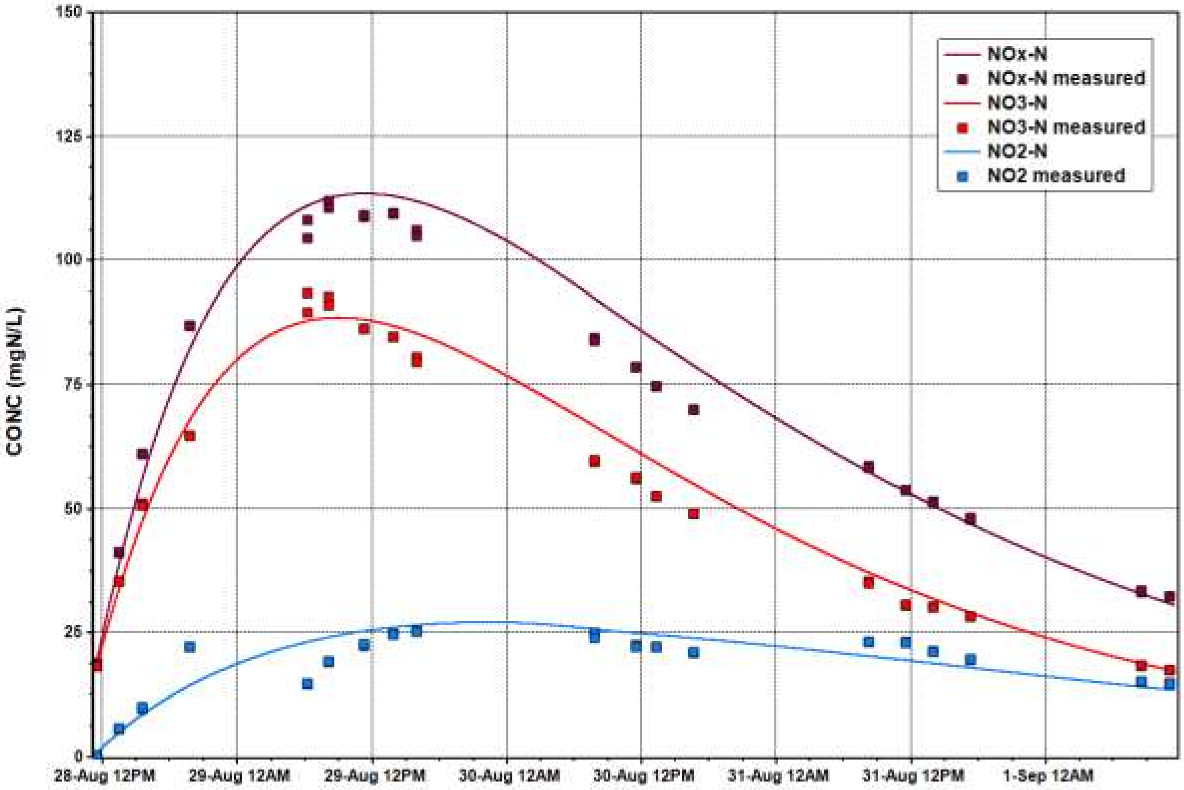


Figure 9. Washout Test Showing Observed (Points) and BioWin-Simulated (Line) Response.

3.2 SNR Testing

Four SNR tests were conducted alongside the Washout Test on August 29th, 30th and 31st, 2017. These SNR tests were used to determine whether:

- The ABC plant is fully nitrifying and therefore has a typical ratio of NOB to AOB.
- There are inhibitory compounds present in the HPO primary effluent and whether those are biologically degraded in the HPO plant.
- The nitrification rate increases as the pH of the HPO mixed liquor is increased from the value in the HPO reactor (5.85) to 7.

Table 3. Summary of SNR Tests Conducted at Rochester WRP, Aug. 29-31, 2017

SNR Test	Test Date(s)	Test Objective	Activated Sludge Source & Volume	Diluent Source & Volume	Target Test Starting NH_3 (mg/L)	Summary of Result
1	August 29, 2017	Determine SNO3PR / SNOXPR ratio to verify whether ABC plant is fully nitrifying	ABC RAS (4 L)	ABC Primary Effluent (4 L)	30	SNO3PR / SNOXPR = 0.78 which suggests typical biomass ratio of NOB/AOB for fully nitrifying plant
2	August 30, 2017	Determine whether there are inhibitory compounds present in the HPO primary effluent and whether they are biologically degraded in the HPO plant	HPO 2^{nd} Stage RAS (4 L)	HPO Primary Effluent (4 L)	30	The SNOXPR values between SNR 2 and SNR 3 are equivalent indicating that the HPO reactors do not remove the inhibitory components in the plant influent
3			HPO 2^{nd} Stage RAS (4 L)	HPO Secondary Effluent (4 L)	30	
4	August 31, 2017	Determine whether the nitrification rate increases as the pH is allowed to increase from 5.85 to 7 in the SNR test	HPO 2^{nd} Stage Mixed Liquor (4 L)	N/A	30	The nitrification rate remained constant as the pH increased from 5.85 to 7 in the SNR test

The following points provide further experimental details for the various SNR tests:

- The first SNR test was seeded with a grab sample of RAS from the ABC plant. A grab sample of ABC primary effluent was added to the activated sludge seed.
- The second and third SNR tests were seeded with grab samples of RAS from the HPO 2nd Stage clarifiers.
    - In SNR Test 2 a grab sample of HPO primary effluent was added to the activated sludge seed.
    - In SNR Test 3 a grab sample of HPO second stage effluent was added to the activated sludge seed.
- The fourth SNR test was seeded with mixed liquor from the HPO 2nd Stage activated sludge basin.
- Ammonium chloride was added to each of the four SNR tests such that the initial ammonia concentration was approximately 30 mgN/L.
- A small amount of supplemental phosphorus (in the form of potassium dihydrogen phosphate) was added to each SNR test to ensure nutrient limitations would not impact the test.
- Each SNR test was aerated using aquarium air pumps and air stones, and a stand mixer provided mixing.
- In SNR tests 1, 2 and 3, additional alkalinity in the form of sodium bicarbonate was added to ensure stable pH throughout the test.
- In SNR test 4, the pH was allowed to slowly increase order to assess the impact of pH on the nitrification rate. The mixed liquor sample for this test was obtained by inserting tubing connected to a portable peristaltic pump into a sampling port at the end of the HPO 2nd Stage reactor and pumping out approximately 6 L of mixed liquor into a sample container. A pH meter was inserted into the sample container to measure the pH of the sample as it was pumped out of the basin. The sample container was sealed with no headspace and immediately transported to the on-site lab. SNR test 4 was commenced within 20 minutes of withdrawing the sample and the test was carried out in the sample container rather being poured into a glass beaker. These steps were taken to minimize the release of CO_2 gas from the mixed liquor sample to allow SNR test 4 to begin at a similar pH (5.85) as that in the HPO 2nd Stage reactor. The DO concentration in the mixed liquor sample was initially above 5 mg/L and decreased to 2 mg/L during the first 20 minutes of the test. An air stone connected to an aquarium air pump was then inserted into the sample container to maintain the DO concentration at around 2 mg/L for the remainder of the test.

Figure 10 shows the testing apparatus set up at the Rochester WRP laboratory facility by EnviroSim for SNR 2 (left) and SNR 3 (right). SNR 1 was carried out using the same apparatus. Figure 11 shows the testing apparatus set up for SNR 4 at the beginning of the test. The results from each SNR test are summarized in the following sections.

Figure 10. SNR Test 2 (Left) and SNR Test 3 (Right), August 30, 2017

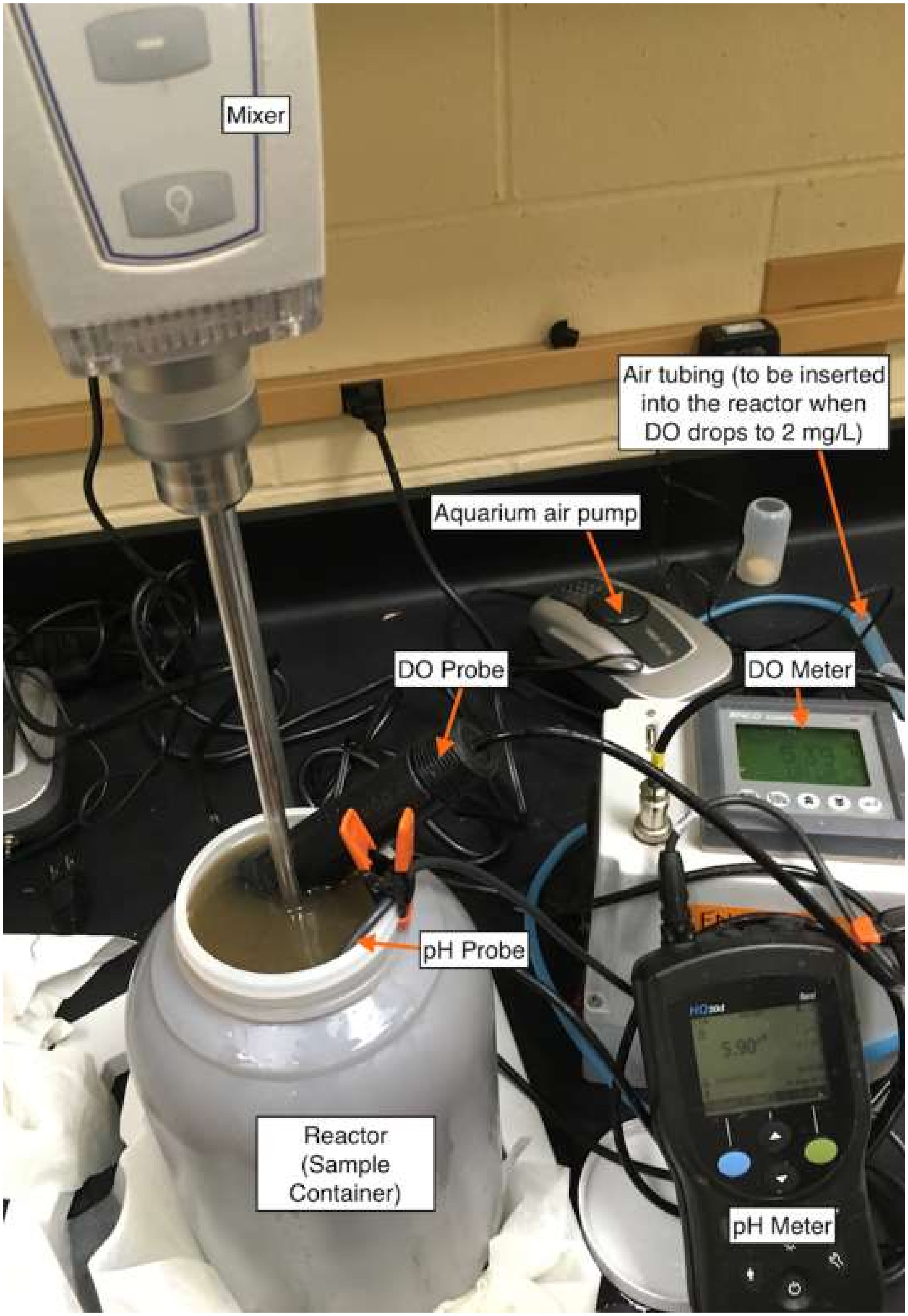


Figure 11. SNR Test 4, August 31, 2017

3.2.1 SNR Test 1

The first SNR was performed on August 29th, 2017, using RAS and primary effluent from the ABC plant. At the start of the test, three 20 mL aliquots were removed, separately filtered, and analyzed for ammonia-, nitrite-, and nitrite-nitrogen. In addition, a VSS analysis was carried out on the solids retained on each filter paper. Every 20 to 60 minutes over the duration of the test, a 20 mL aliquot was removed, filtered and analyzed for ammonia-, nitrite-, and nitrite-nitrogen.

Plotting the ammonia-, nitrate-, and nitrite-nitrogen data versus time shows linear responses for ammonia removal and oxidized nitrogen (consisting of both nitrite and nitrate) production, as evident in Figure 12.

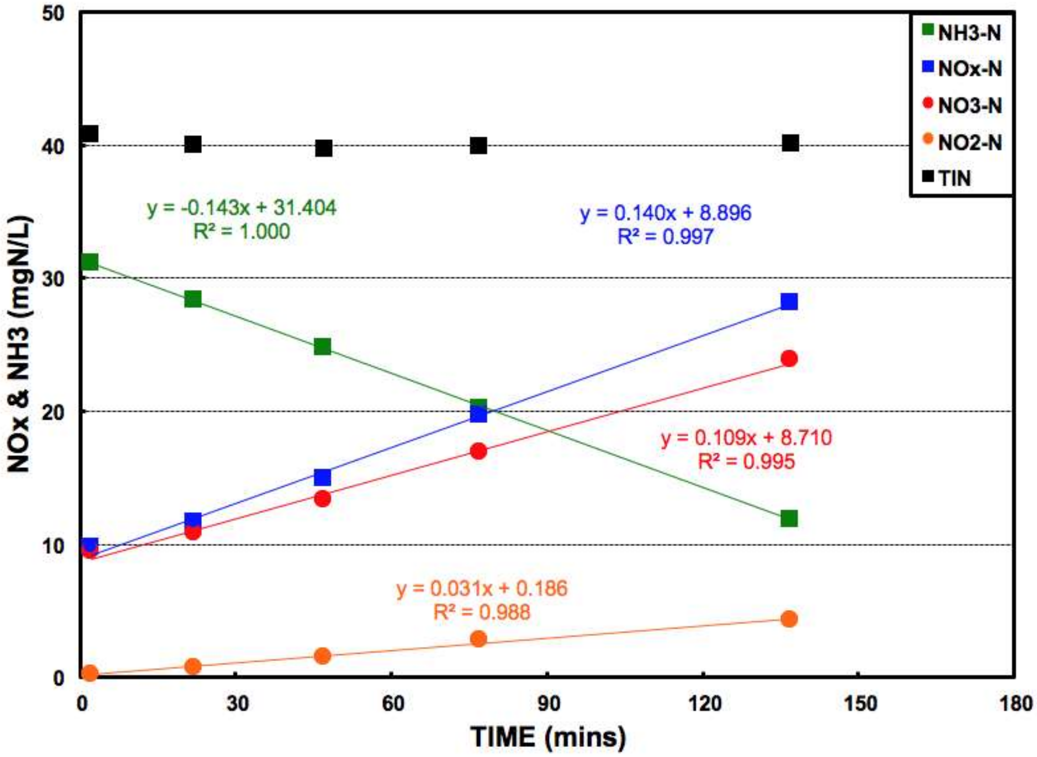


Figure 12. Ammonia Removal and NOx Production vs. Time for SNR Test 1.

Linear regression analysis is used to estimate the ammonia removal rate and the nitrite, nitrate and NOx production rates. Dividing these rates by the batch VSS concentration yields the specific rates, as shown in Table 4.

Table 4. Summary of Results for SNR Test 1

Activated sludge source	ABC RAS
Diluent source	ABC primary effluent
VSS (mg/L)	1928
NO_3 Production Rate (mgN/L/min)	0.109
Ammonia Removal Rate (mgN/L/min)	0.143
Specific Ammonia Removal Rate (mgN/gVSS/hr)	4.45
Average Test Temperature (°C)	21.9
SNH3RR corrected to 20°C (mgN/gVSS/hr)	3.90
NO_X Production Rate (mgN/L/min)	0.140
Specific NO_X Production Rate (mgN/gVSS/hr)	4.36
SNOxPR corrected to 20°C (mgN/gVSS/hr)	3.82

The specific rates were corrected to 20 °C using Equation [3]. The adjustment was achieved using the same Arrhenius coefficient as used to adjust the μ_{AUT}. That is,

$$SNPR_{20} = SNPR_T \cdot 1.072^{\cdot(20-T)} \qquad [3]$$

- As previously mentioned, the ratio NO_3PR/NO_XPR is linked directly to the ratio NOB/AOB (but not equal to NOB/AOB). For example, in a fully nitrifying plant with balanced AOB and NOB populations the ratio typically should be close to 0.8. In SNR Test #1, the NO_3PR is 0.109 mgN/L/min and the NO_XPR is 0.140 mgN/L/min, hence the NO_3PR/NO_XPR is 0.78. This confirms that the ABC plant has a typical NOB/AOB biomass ratio of a fully-nitrifying plant. The TIN concentration remained relatively constant throughout the test.

3.2.2 SNR Test 2 and SNR Test 3

The second and third SNR tests were performed in parallel on August 30th, 2017 using grab samples of RAS from the HPO 2nd Stage clarifiers as seed. In SNR Test 2 a grab sample of HPO primary effluent was added to the seed. In SNR Test 3 a grab sample of HPO second stage effluent was added to the seed. At the start of each test, three 20 mL aliquots were removed, separately filtered, and analyzed for ammonia-, nitrite-, and nitrite-nitrogen. In addition, a suspended solids analysis was carried out on the solids retained on each filter paper. Every 20 to 75 minutes over the duration of the test, a 20 mL aliquot was removed, filtered and analyzed for ammonia-, nitrite-, and nitrite-nitrogen.

Plotting the ammonia-, nitrate-, and nitrite-nitrogen data versus time shows linear responses for ammonia removal and oxidized nitrogen (consisting of both nitrite and nitrate) production. The results for SNR Test 2 are shown in Figure 13.

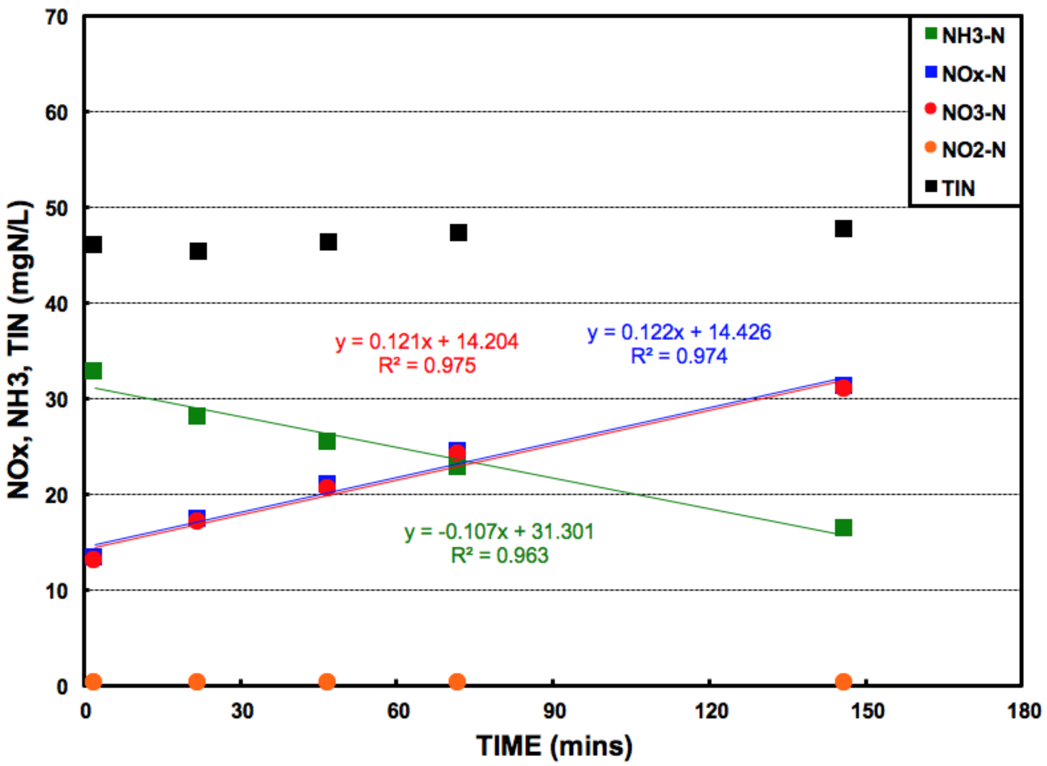


Figure 13. Ammonia Removal and NO_X Production vs. Time for SNR Test 2.

Linear regression analysis is used to estimate the ammonia removal rate and nitrate and NO_X production rates. Dividing these rates by the batch VSS concentration yields the specific rates, as shown in Table 5.

The results for SNR Test 3 are shown in Figure 14.

Table 5. Summary of Results for SNR Tests 2 and 3

Item	SNR Test 2	SNR Test 3
Activated sludge source	HPO 2nd Stage RAS	HPO 2nd Stage RAS
Diluent source	HPO Primary Effluent	HPO 2nd Stage Effluent
VSS (mg/L)	1962	1933
NO_3 Production Rate (mgN/L/min)	0.121	0.129
Ammonia Removal Rate (mgN/L/min)	0.107	0.108
Specific Ammonia Removal Rate (mgN/gVSS/hr)	3.27	3.35
Average Test Temperature (°C)	22.4	22.4
SNH3RR corrected to 20°C (mgN/gVSS/hr)	2.77	2.85
NO_X Production Rate (mgN/L/min)	0.122	0.125
Specific NO_X Production Rate (mgN/gVSS/hr)	3.73	3.88
SNOxPR corrected to 20°C (mgN/gVSS/hr)	3.15	3.29

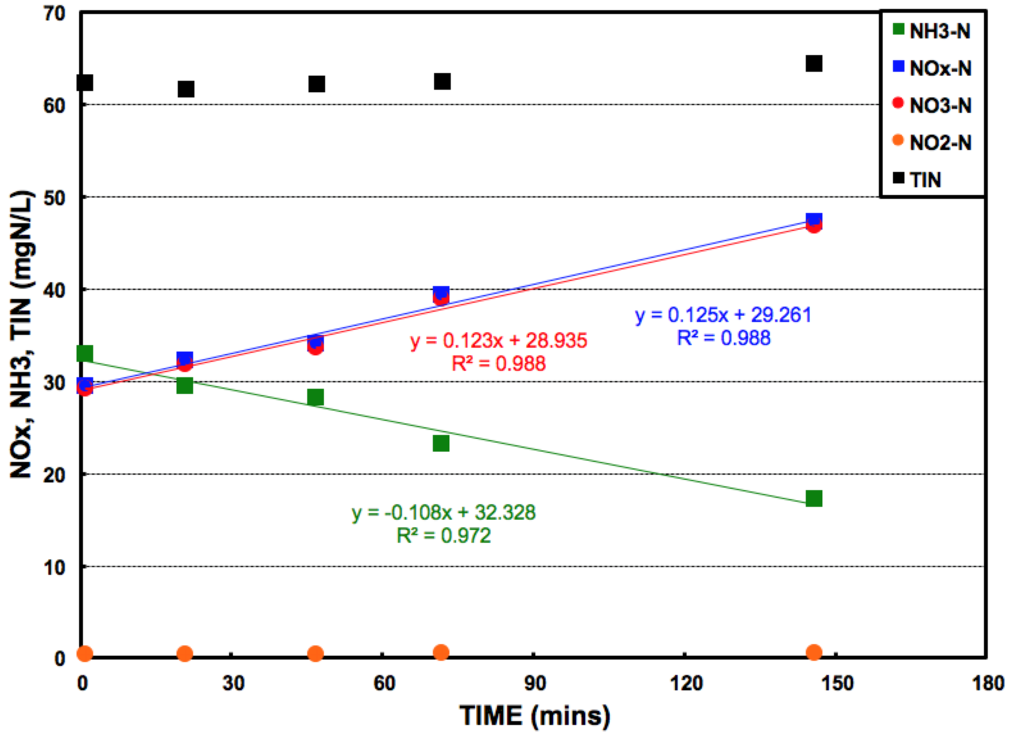


Figure 14. Ammonia Removal and NO_X Production vs. Time for SNR Test 3

The TIN concentration remained essentially constant throughout SNR Test 2 and SNR Test 3. In both tests there was no accumulation of nitrite, and the NO_3PR closely matched the NO_XPR. This likely is a consequence of at least a degree of inhibition of the first step in nitrification; that is, inhibition of AOBs.

The SNO_XPR measured in SNR Test 3 was very close to that measured in SNR Test 2 (*i.e.* difference in values corrected to 20 °C was less than 5%). This indicates that if the lower than typical nitrification rate observed in the ABC plant is due to an influent inhibitory substance, it is not being removed across both stages of the HPO reactors. If an inhibitory substance was being removed across the HPO reactors, the SNO_XPR for SNR Test 3 with secondary effluent should have been significantly higher than the SNO_XPR for SNR Test 2 with primary effluent.

3.2.3 SNR Test 4

The fourth SNR test was performed on August 31st, 2017, using HPO 2nd Stage mixed liquor supplemented with ammonia. As mentioned previously, the pH of the mixed liquor in SNR Test 4 was allowed to increase from the low value (5.85) at which it was obtained to around 7. The pH in the test increased as the reactor was mixed and aerated, resulting in stripping of dissolved CO2. When the pH reached approximately 7, sodium bicarbonate was added to prevent the pH from decreasing due to the consumption of alkalinity by nitrification.

At the start of the test, three 20 mL aliquots were removed, separately filtered, and analyzed for ammonia-, nitrite-, and nitrite-nitrogen. In addition, a VSS analysis was carried out on the solids retained on each filter paper. While the pH increased from 5.85 to approximately 6.7, samples were taken from the reactor every 4 to 10 minutes to provide better data resolution to assess whether the nitrification rate increased with pH. As the pH increased from 6.7 to 7 and was maintained at around 7, samples were taken every 30 to 100 minutes as it was assumed that the nitrification rate would remain the same at a neutral pH. For each sample, a 20 mL aliquot was removed, filtered and analyzed for ammonia-, nitrite-, and nitrite-nitrogen.

The ammonia-, nitrate-, and nitrite-nitrogen data in SNR Test 4 were plotted versus time in Figure 15 along with the pH. The upper chart shows the data over the entire test and the bottom chart shows the data over the first 108 minutes of the test when the pH increased from 5.85 to 6.9. The pH rapidly increased from 5.85 to 6.9 over the first 108 minutes of the test and then remained around 7 for the last 4 hours of the test. The ammonia-, nitrate-, and nitrite-nitrogen data are linear over the duration of the test. Linear regression was performed on the full dataset for each of these parameters and the R-squared value for each linear regression is very close to 1. Had the nitrification rate increased with pH, the ammonia-, nitrate-, and nitrite-nitrogen data would have been nonlinear.

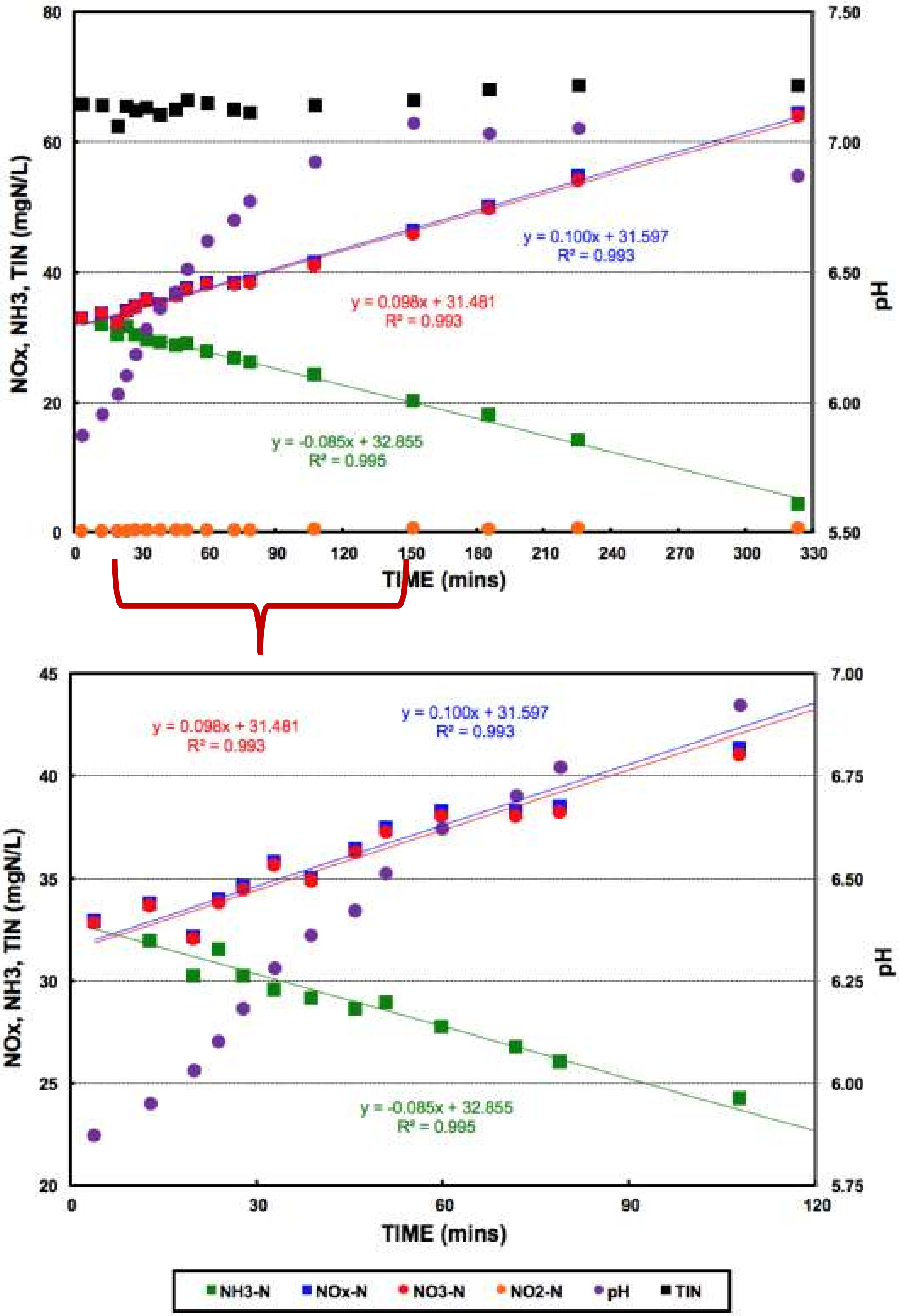


Figure 15. Ammonia Removal and NOx Production vs. Time for SNR Test 4.

The ammonia removal rate and nitrate and NO_X production rates were estimated from the linear regression analysis. Dividing these rates by the batch VSS concentration yields the specific rates, as shown in Table 6.

Table 6. Summary of Results for SNR Test 4

VSS (mg/L)	1900
NO_3 Production Rate (mgN/L/min)	0.098
Ammonia Removal Rate (mgN/L/min)	0.085
Specific Ammonia Removal Rate (mgN/gVSS/hr)	2.68
Average Test Temperature (°C)	21.5
SNH3RR corrected to 20°C (mgN/gVSS/hr)	2.42
NO_X Production Rate (mgN/L/min)	0.100
Specific NO_X Production Rate (mgN/gVSS/hr)	3.16
SNOxPR corrected to 20°C (mgN/gVSS/hr)	2.85

The TIN concentration remained relatively constant throughout SNR Test 4. As with SNR Test 2 and Test 3, there was no accumulation of nitrite, and the NO_3PR closely matched the NO_XPR. Again, this likely is a consequence of at least a degree of inhibition of the first step in nitrification; that is, inhibition of AOBs.

The measured SNO_XPR at 20°C in SNR Test 4 was 2.85 mgN/gVSS/hr. This is approximately 11% lower than the corresponding SNO_XPR values observed in SNR Test 2 and SNR Test 3. In SNR Test 4 the pH increased from 5.85 to 7 whereas it was maintained at close to 7 throughout SNR tests Test 2 and Test 3. [As mentioned in Section 2.2, a reasonable basis for assessing data is to assume that nitrification inhibition is occurring if the SNO_XPR value is *more than* 8.5% lower than the control test]. Thus it would appear that the lower pH in SNR Test 4 further reduced nitrification rate as expected.

Section 4: Conclusions

The nitrification testing conducted in this investigation was used to determine whether nitrifier growth is being inhibited at the Rochester WRP. Two main goals were addressed:

- Measurement of μ_{AUT} for the ABC train of the Rochester WRP based on the Washout Test protocol.
- Conducting SNR tests to determine:
  - Whether the ABC plant is fully nitrifying and has a typical ratio of NOB to AOB.
  - Whether there are inhibitory compounds present in the HPO primary effluent, and if so, whether those are biologically degraded in the HPO plant.
  - Whether the nitrification rate increases as the pH of the HPO mixed liquor is increased to 7.

The first goal was achieved using the Washout Test protocol as outlined above. A Washout Test was conducted over a period of 5 days with mixed liquor from the ABC plant at the Rochester WRP used as the nitrifier seed source. Influent to the reactor was ABC primary effluent. This test yielded a μ_{AUT} estimate of 0.68 d^{-1} for the plant at the time of the testing. The μ_{AUT} estimate of 0.68 d^{-1} (with a 95% confidence interval of <0.65 d^{-1}, 0.70 d^{-1}>) is lower than the typical range of 0.8 – 1.0 d^{-1} observed at many other wastewater treatment plants (WERF, 2003). This suggests that there is some degree of nitrification inhibition at the Rochester WRP.

The overall outcome of the study suggests that simulations on the Rochester WRP should apply the following maximum specific growth rates for AOB and NOB (referenced to 20°C).

$\mu_{AOB} = 0.70\ d^{-1}$

$\mu_{NOB} = 0.65\ d^{-1}$

The second goal of this study was addressed by performing four SNR batch tests. Table 7 summarizes the results and conclusions from the SNR batch tests.

Table 7. Summary of SNR Tests Conducted at Rochester WRP, Aug. 29-31, 2017

SNR Test	Test Date(s)	SNO$_X$PR	SNO$_3$PR/SNO$_X$PR	Activated Sludge Source & Volume	Diluent Source & Volume	Summary of Result
1	August 29, 2017	3.82	0.78	ABC RAS (4 L)	ABC Primary Effluent (4 L)	Result indicates typical NOB/AOB biomass ratio for fully nitrifying plant
2	August 30, 2017	3.15	0.99	HPO 2nd Stage RAS (4 L)	HPO Primary Effluent (4 L)	The SNO$_X$PR values between SNR Test 2 and SNR Test 3 are equivalent indicating that HPO reactors do not remove the inhibitory components in the plant influent; that is, whatever is causing the lower than typical nitrification rate estimated using the Washout method is persistent. In both tests, the NO$_3$PR closely matched the NO$_X$PR. This likely is a consequence of at least a degree of inhibition of the first step in nitrification; that is, inhibition of AOBs
3		3.29	1.03	HPO 2nd Stage RAS (4 L)	HPO Secondary Effluent (4 L)	
4	August 31, 2017	2.85	0.98	HPO 2nd Stage Mixed Liquor (4 L)	N/A	The nitrification rate remained constant as the pH increased from 5.85 to 7 in the SNR test. However, the overall nitrification rate is statistically lower than that in SNR Test 2 and Test 3, indicating that the lower pH in SNR Test 4 further reduced the nitrification rate. As with SNR Test 2 and Test 3, the NO$_3$PR closely matched the NO$_X$PR. This likely is a consequence of at least a degree of inhibition of the first step in nitrification; that is, inhibition of AOBs.

Section 5: Recommendations

It is important to note that the Washout Test is considered a spot check of the μ_{AUT} (μ_{AOB}) at the time the samples are taken. The inhibition observed here may occur sporadically due to 'spike' inputs of inhibitory compounds. To assess whether these rates are a true reflection of the average rate at the plant would require a more comprehensive sampling study similar to those discussed in Bye *et al.* (2012). For BioWin Version 5.2, an μ_{AOB} value of 0.70 d^{-1} and μ_{NOB} value of 0.65 d^{-1} are recommended and should be confirmed in the planned dynamic BioWin calibration.

The main effect of a low μ_{AOB} value of 0.70 d^{-1} for the Rochester WRP is that a longer aerobic SRT is required to ensure complete nitrification. Consider Figure 16, which shows the predicted effluent ammonia *versus* SRT for typical and low μ_{AOB} and μ_{NOB} values at a design temperature of 12 °C. There is an increase in the minimum aerobic SRT for a μ_{AOB} value of 0.70 d^{-1} when compared to a typical value of 0.9 d^{-1}.

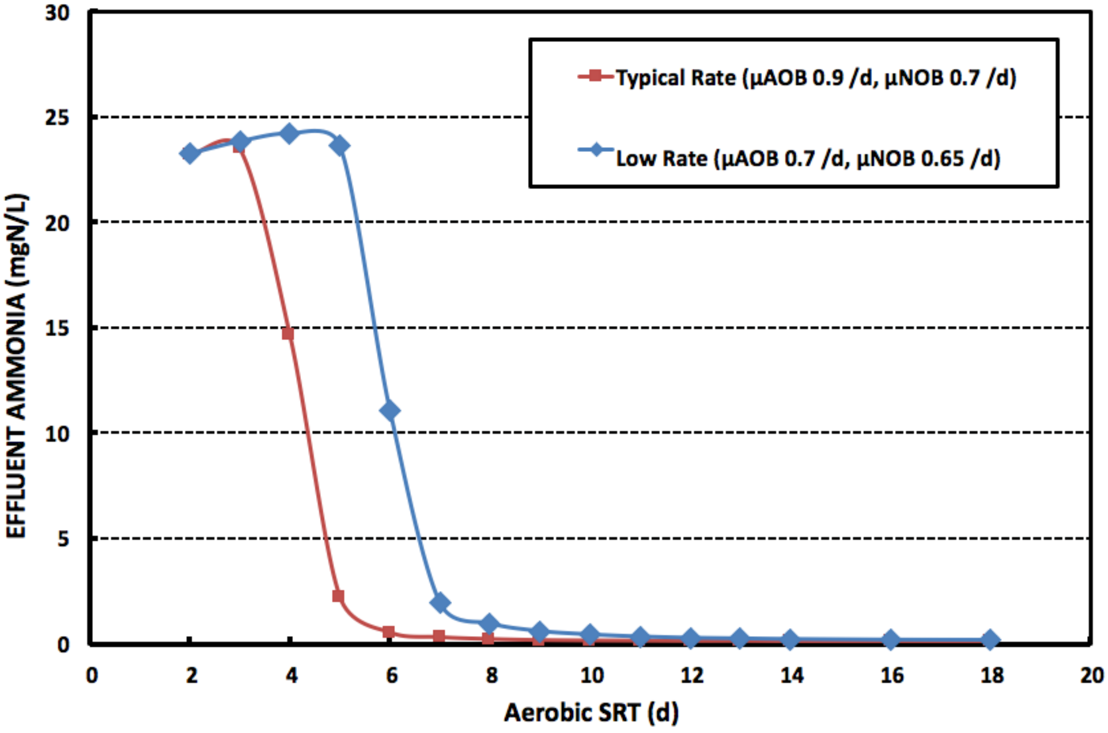


Figure 16. Effluent Ammonia vs. Aerobic SRT for Different μ_{AOB} and μ_{AOB} Values (12 °C).

Section 6: References

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