INTEGRATED MASTER PLAN
FOR THE
MAIN WASTEWATER TREATMENT PLANT

Task Name: MWWTP Existing Performance and Preliminary Capacity Assessment

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FINAL DRAFT

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ACRONYMS

AAF	Annual Average Flow
AB	Assembly Bill
ADC	Alternative Daily Cover
ADWF	Average Dry Weather Flow
ACWMA	Alameda County Waste Management Authority
BAAQMD	Bay Area Air Quality Management District
BACT	Best Available Control Technology
BACWA	Bay Area Clean Water Agencies
Basin Plan	San Francisco Bay (SF Bay) Basin Water Quality Control Plan
BioMAT	Bioenergy Market Adjusting Tariff
CAA	Clean Air Act
CalARP	California Accidental Release Prevention Program
Cal OSHA	California Occupational Safety and Health Administration
CARB	California Air Resources Board
CCR	California Code of Regulations
CECs	Contaminants of Emerging Concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFU	Colony Forming Unit
CWA	Clean Water Act
DDW	Division of Drinking Water
DTSC	Department of Toxic Substances Control
EBMUD	East Bay Municipal Utility District
EBRWP	East Bayshore Recycled Water Plant
ESD	Environmental Services Division
FOG	Fats, Oil, Grease
GHG	Greenhouse Gas
HAB	Harmful Algal Bloom
HFC	Hydrofluorocarbons
HMBP	Hazardous Materials Business Plan
HRSA	Health Risk Screening Analysis
I/I	Inflow and Infiltration
IWC	Instream Waste Concentration
LCFS	Low Carbon Fuel Standard

MF	Minimum Flow
MGD	Million Gallons per Day
MRR	Mandatory Reporting Regulation of Greenhouse Gas Emissions
MPN	Most Probable Number
MWWTP	EBMUD's Main Wastewater Treatment Plant
NAAQS	National Ambient Air Quality Standards
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NMS	Nutrient Management Strategy
NOx	Oxides of Nitrogen
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Administration
PCPPs	Pharmaceuticals and Personal Care Products
PCB	Polychlorinated biphenyl
PDWF	Peak Dry Weather Flow
PEL	Permissible Exposure Limit
PERP	California Portable Equipment Registration Program
PM10	Particulate matter with aerodynamic diameter ≤ 2.5 microns
PM2.5	Particulate matter with aerodynamic diameter ≤ 10 microns
POC	Precursor Organic Compound
POTW	Publicly Owned Treatment Work
PPM	Parts per Million
PS	Prioritization Score
PSRP	Process that Significantly Reduces Pathogens
PWWF	Peak Wet Weather Flow
R2	Resource Recovery
RACT	Reasonably Available Control Technology
REC	Renewable Energy Credit
RIN	Renewable Identification Number
RNG	Renewable Natural Gas
RPS	Renewable Portfolio Standard
SARA	Superfund Amendments and Reauthorization Act
SCCWRP	Southern California Coastal Water Research Project
SCFM	Standard Cubic Feet per Minute
SB	Senate Bill
SFEI	San Francisco Estuary Institute
SFRWQCB	San Francisco Bay Regional Water Quality Control Board
SIP	State Implementation Plan
SOP	Standard Operating Procedure
SO2	Sulfur Dioxide

SOx	Oxides of Sulfur
SPCC	Spill Prevention Control and Countermeasure
STEL	Short Term Exposure Limit
SWRCB	State Water Resources Control Board
TBARCT	Toxics Best Available Retrofit Control Technology
TRE	Toxicity Reduction Evaluation
TSS	Total Suspended Solids
US EPA	United States Environmental Protection Agency
UST	Underground Storage Tank
WDR	Waste Discharge Requirements
WEF MOP	Water Environment Federation Manual of Practice
WWF	Wet Weather Facility
WWTP	Wastewater Treatment Plant

DEFINITIONS

Annual Average	Annual Average Flow by Calendar Year
Max	Maximum value in dataset
Average Max Month	Average of all Max Months
Max Month	Maximum monthly value in a dataset

EXECUTIVE SUMMARY

This Task Report provides an overview of the District's main wastewater treatment plant's (MWWTP's) capacity and performance. This Report is intended to summarize the status of the MWWTP's capacity, in both the hydraulic capacity through the plant as well as the treatment processes, and the performances of each process.

1.1 Hydraulic Profile

The hydraulic profile of the plant has sufficient freeboard at all times during normal and wet weather flows in most areas of the plant. The plant's existing flow restrictions are primarily due to the secondary treatment system and outfall. Specifically, high flows at the Reactors will cause an over-current condition in the Reactor aerators. As such, and for redundancy purposes, the secondary treatment system was derated to 150 mgd to allow for better reliability.

Outfall flows are limited to 278 mgd if we assume a maximum operating level of 139.5-ft in the surge chamber (5.8-ft lower than top of wall to allow for surging) and a 10-year max tide occurrence of 106.87-ft. This is consistent with a 1988 study indicating the maximum design flow through the outfall at 290 mgd at tidal elevation of 105.2-ft. The effluent pumping station originally assumed lower tidal elevation than what is now provided by the National Oceanic and Atmospheric Administration (NOAA). In addition, the original design were based on a design maximum tide of 105.2 ft versus the higher tide elevation used in this report (106.87-ft).

1.2 Overall MWWTP Process

Refer to the figure at the end of this Executive Summary for the overall MWWTP Process and Capacity figure. This figure indicates all processes at the MWWTPP, as well as the design capacity of each major process.

1.3 Overall Treatment Performance

Overall, the MWWTP removes approximately 96, 97, and 89 percent of TSS, cBOD, and COD respectively from the plant influent. See Table 1 and Figure 1. On average, the MWWTP is performing well as a secondary treatment plant. However, the nutrient removal is less than ideal for a WWTP of this type due to the influx of nutrients from the Resource Recovery Program.

The program allows haulers to dump their high strength solids, liquids, and fats/oils/grease into the digesters directly. This high strength material is then digested and mixed with the primary effluent and ultimately into the bay.

Table 1 Overall Treatment Process Performance

Parameter	Primary Treatment	Secondary Treatment	Overall
TSS	67%	89%	96%
CBOD	52%	94%	97%
sCOD	19%	48%	60%
COD	44%	80%	89%
TN	-21%	17%	0%
TP	-11%	58%	54%

1. Values calculated based on historical inlet and outlet averages of each process.

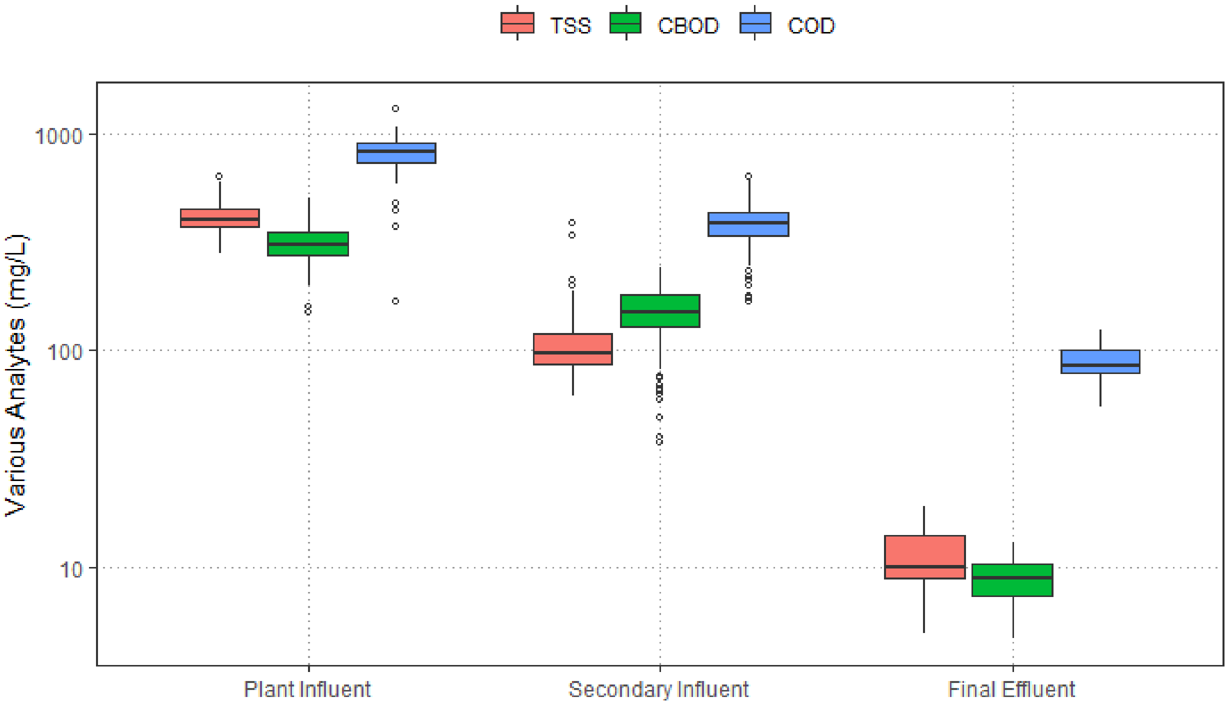


Figure 1 Liquid Treatment Performance

1.4 Liquid Treatment System

The liquid treatment system at the MWWTP consists of the following key elements: Coarse Screens, Influent Pumping Station, Fine Screens, Aerated or Vortex Grit Tanks, Primary Sedimentation Tanks, Midplant Pumping Station, Return Activated Sludge Pumps, Reactor Tanks, Clarifiers, and the Effluent Pumping Station. Other important ancillary facilities or processes are included in this report but not discussed in this section include: Oxygen Generation Plant, Disinfection, and Dechlorination.

1.4.1 Process Capacity

The liquid treatment system process capacity is summarized in Figure 8. This figure indicates the design and current firm and max flows as well as the extent of treatment based on plant influent flows. All liquid treatment processes is performing per their original design intent.

The design flows are based on the design criteria of the original construction of the treatment system while the current flows are the currently rated capacity of the treatment system based on historical information. The firm capacity is the capacity of the treatment process, assuming the standby (or the out-of-service) train is offline. The max capacity assumes all treatment trains are online.

In general, most treatment processes are assumed to be operating at the design capacity due to a lack of historical information regarding the treatment system being hydraulically stressed. This issue applies to the headworks, primary treatment and pumping systems. The hydraulic model indicates the treatment process is able to handle the full design flow with sufficient freeboard.

The treatment processes not meeting design capacity includes the Vortex Grit Tanks, the secondary treatment system, and the effluent pumping station. The Vortex Grit Tanks were derated by 50% to 70 mgd and does not have effective grit removal. This facility is used only in the dry weather when flows and grit loading is low.

The secondary treatment system, reactors and clarifiers, were derated by 11% to 150 mgd (from 168 mgd) due to reactor aerator amperage exceedances caused by high water level in the Reactors and to allow for a standby reactor/clarifier train for reliability purposes. Though the secondary treatment system is derated, Operations will still operate the system at full design flow by operating the aerator motors past their rated amperage of 112 amps and up to 160 amps as well as putting all available trains in service when possible.

1.4.2 Treatment Performance

1.4.2.1 Fine Screens

The fine screens are performing as designed and intended; however, the newer fine screens with 1/4” bar spacing are wearing out fast at the bottom of the screens. The bars have lost 50% of its metal bar depth due to continuous operation from installation in 2014 to 2019. All metal rakes now have teeth, causing further wear (4x of original design).

1.4.2.2 Grit Removal Systems

The AGTs have poor grit removal performance and are not built correctly to achieve helical mixing for maximal grit removal via multiple passes at grit settlement. The system instead uses a one pass grit settlement system where flow enters the tank from one side of the tank and immediately exits on the opposite side. In addition, the aeration going through the AGTs may not be optimized correctly due to a lack of throttling valves. The net result of these short comings is that fine sands will pass through this process. For example, in early 2019, the Operators experienced tons of very fine sand passing through the AGTs and into the primaries—the source was undetermined and the damage to the PSTs chain and flight systems were significant. Again, as another example, when one of the primary tanks were cleaned out in late 2019, a significant portion of grit was accidentally drained into the blend tanks and subsequently removed by the grit removal pilot systems running there at the time. Both events indicate a significant fraction of fine grit is not being removed from the AGTs.

The performances of the VGTs are similar, if not worse, than the AGTs. This is based on the 2009 Computational Fluid Dynamics Analysis for Vortex Grit Removal System TM indicating "the medium and fine grit classes showed no significant removal in the base model" as well as observations made by the District operations staff. This performance deficiency applies to the currently derated flows (70 mgd) and was originally worse if run at design flows (140 mgd).

1.4.2.3 Primary Sedimentation Tanks

The PSTs have a typical average TSS and cBOD removal percentage of: 66.4% and 51.4% respectively. This was within or exceeds the general typical average range of 25-70 for TSS and 25-40 for BOD5.

Interestingly, there is only vague correlation between overflow rate and removal rates. Consistently, the PSTs do not provide maximal removal during the higher overflow (or flow) rates—this is expected--however, the PSTs also do not consistently maximally remove the analytes during the lower overflow (or flow) rates. The rationale behind the lower removal rates at low overflow requires additional analysis outside the scope of this document. Refer to the figures below for the TSS and cBOD removal rates as a function of overflow rate.

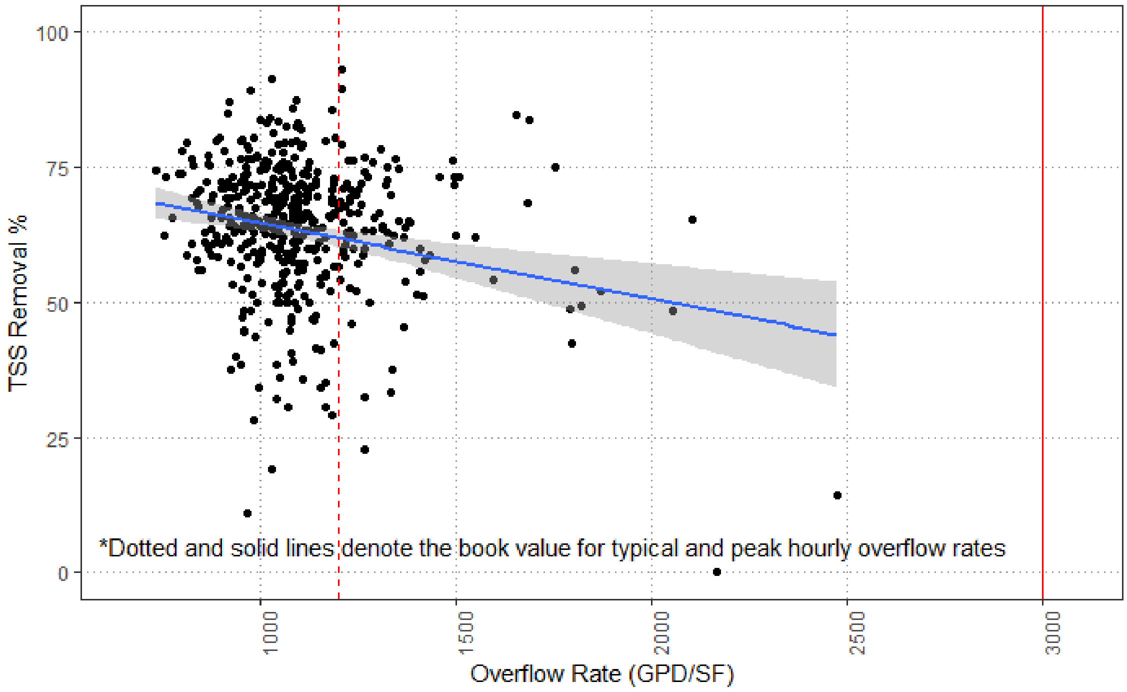


Figure 2 TSS Removal vs Overflow Rate

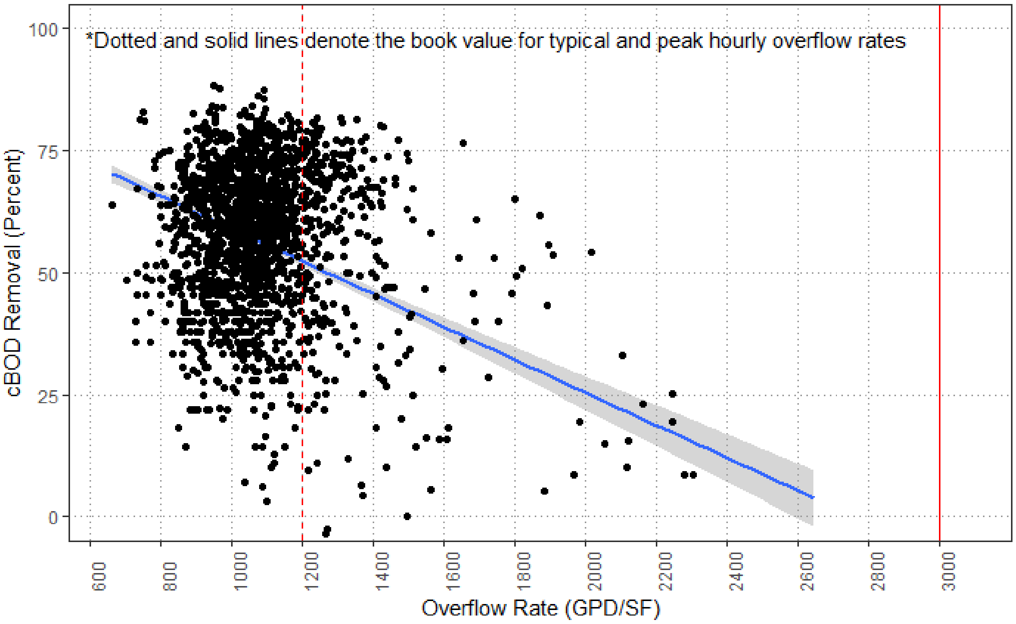
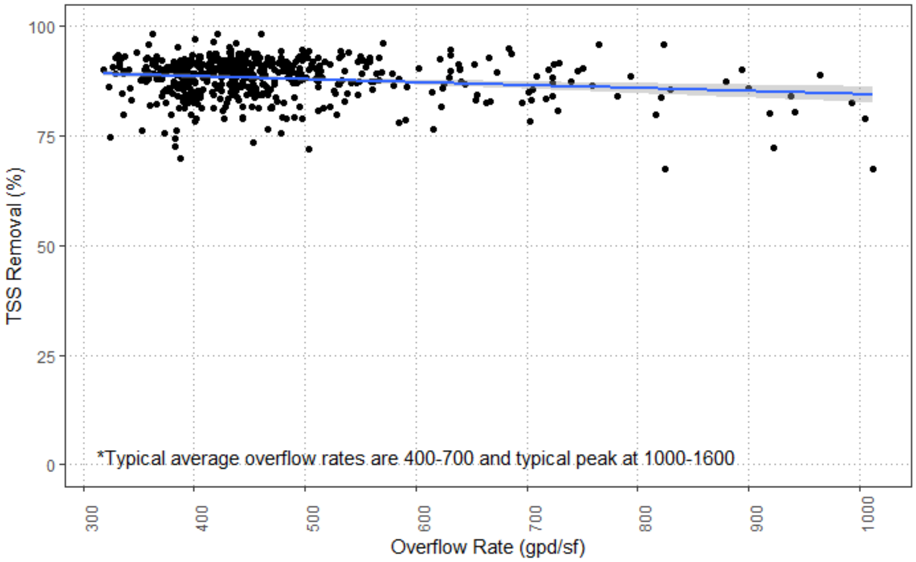


Figure 3 cBOD Removal vs Overflow Rate

1.4.2.4 Secondary Treatment (Reactors and Clarifiers)

The TSS, cBOD percent removal rates through the secondary treatment systems (Reactors and Clarifiers) are 88.5% and 93.5% respectively.

The performance of the secondary treatment system on removing TSS, based on clarifier overflow rate, is provided in the figure below. The performance of the clarifier system are slightly best when overflow rate is low, however, there is no significant reduction in removal efficiency as overflow rate increases.



*Typical average overflow rates are 400-700 and typical peak at 1000-1600

Figure 4 TSS Removal as Overflow Rate Increases

The performance of the reactors, based on cBOD removal as a function of the Reactor’s hydraulic detention time and sludge retention time, are indicated in the figure belowFigure 4-13. Performance does increase, up to a point, with hydraulic retention time and sludge age as shown in the figure below. This indicates that additional hydraulic detention time can only improve the removal rates so much until the effects tapers off.

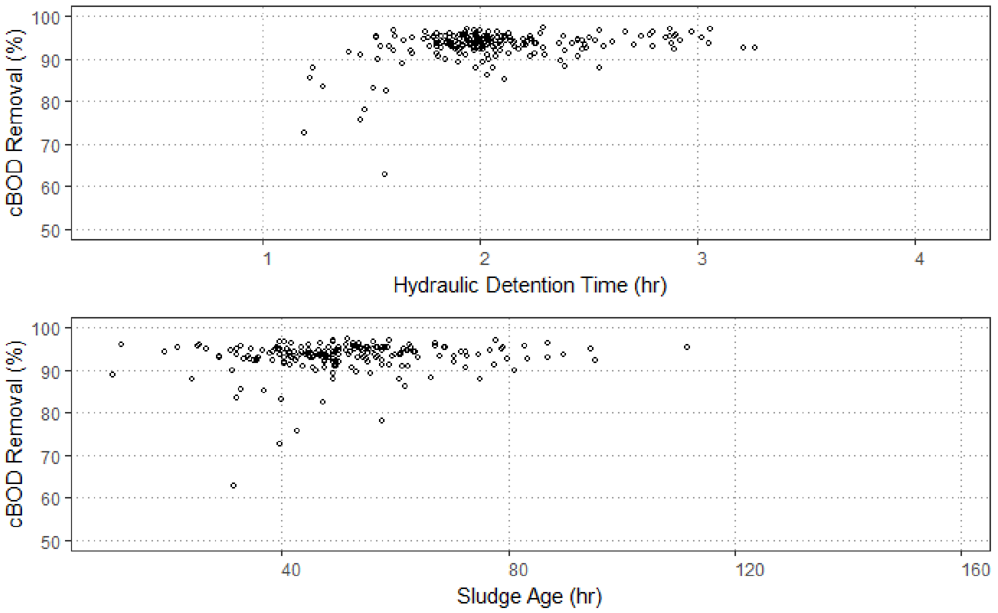


Figure 5 cBOD Removal as HRT and SRT Increases

1.5 Solids Treatment System

The solids treatment system is made up of the blend tanks feeding the first stage digesters, then second stage digesters, followed by centrifuges. It is important to note that unlike the liquid treatment system, the solids treatment system is entirely pumped from one process or tank to another. As such, with the exception of the centrifuges, the capacities are generally limited by the pumping ability of each process area.

1.5.1 Process Capacity

The solids treatment system process capacity is summarized in Figure 9. The Digesters were designed around a 10-day hydraulic retention time (HRT) to provide the District flexibility in digester operation and future flexibility; however, the District aims for a 15-day HRT for EPA regulatory requirements outside of PSRP.

With the exception of the centrifuges, all current firm and flow capacities are based on the historical 99th percentile flow values to best indicate the maximum capacities of the pumping systems given optimal conditions. These values are likely optimistic and does not consider degradation of flow due to severe wear and tear due to grit (the pumps are not designed to handle grit). Operations will regularly replace worn pump parts as the flow becomes unacceptably low.

The centrifuges are severely derated due to high solids loading into the centrifuges, unsteady grit loading, and risks related to the aforementioned items at higher flows potentially causing failures requiring significant downtime to repair. The original design criteria flow was 210 and 300 gpm for the slow and high speed centrifuges, respectively. The current performance of these centrifuges are now 150 (max, if newly rebuilt, but generally 125) and 250 gpm for the slow and high speed centrifuges respectively based on the operator’s experience.

1.5.2 Treatment Performance

Solids process facilities includes only the digesters and dewatering systems.

1.5.2.1 Digesters

The digester performance is quantified in this report by using the VS reduction rate. This rate is plotted as a function of both SRT and the VS loading rate. Both these figures are below.

The trend in the first stage digesters indicates VS is reduced as SRT increases—reasonable—however, after approximately 18 days SRT, the VS reduction is minimal. The second stage digesters is similar; however, potentially little to no VS reduction occurs at times. This can potentially be due to the fact that we would expect less VS reduction in the second stage digesters during times when VS reduction in the first stage digesters is high.

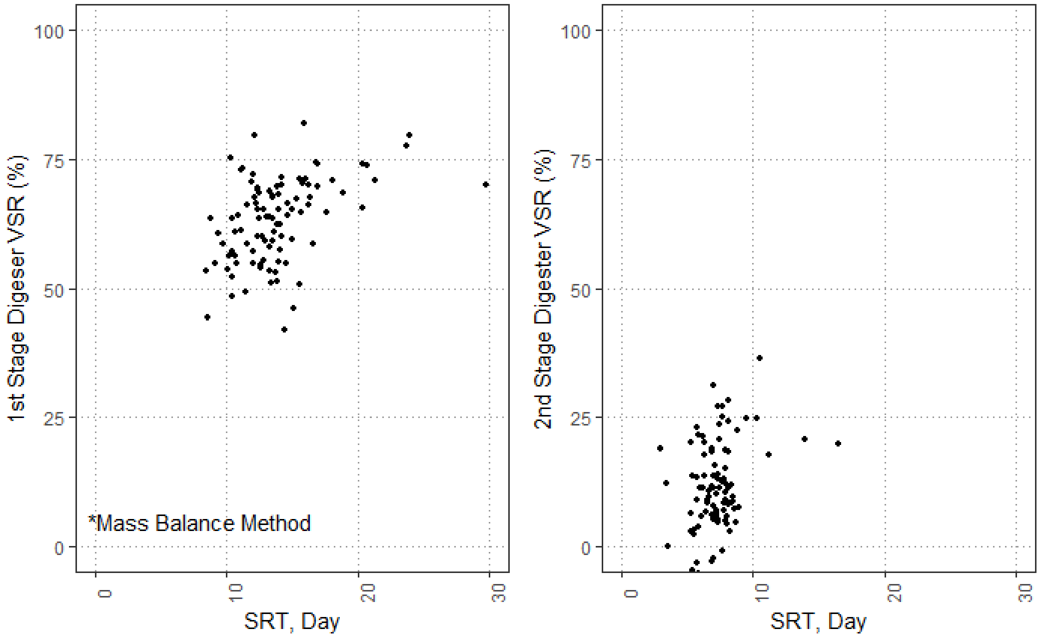


Figure 6. Volatile Solids Reduction as a Function of SRT

The last digester figure, Figure 5-4, indicates the VS reduction as a function of the unit loading rate (in lbs VS per day per 1,000 cubic foot). This figure indicates an interesting trend—as the loading rate increases, the VS reduction increases.

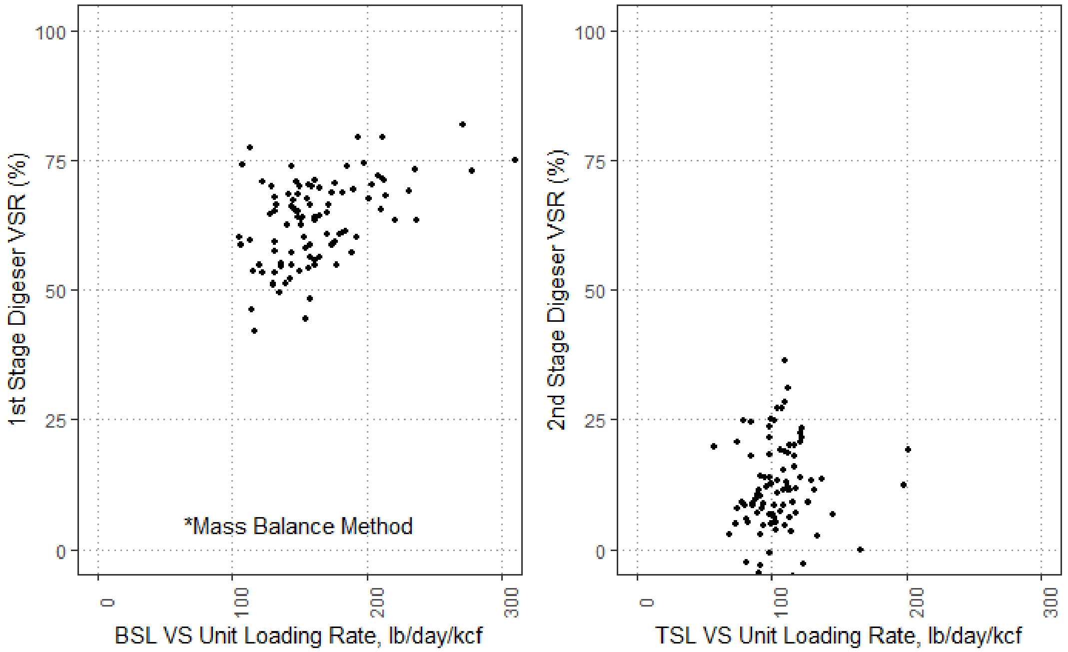
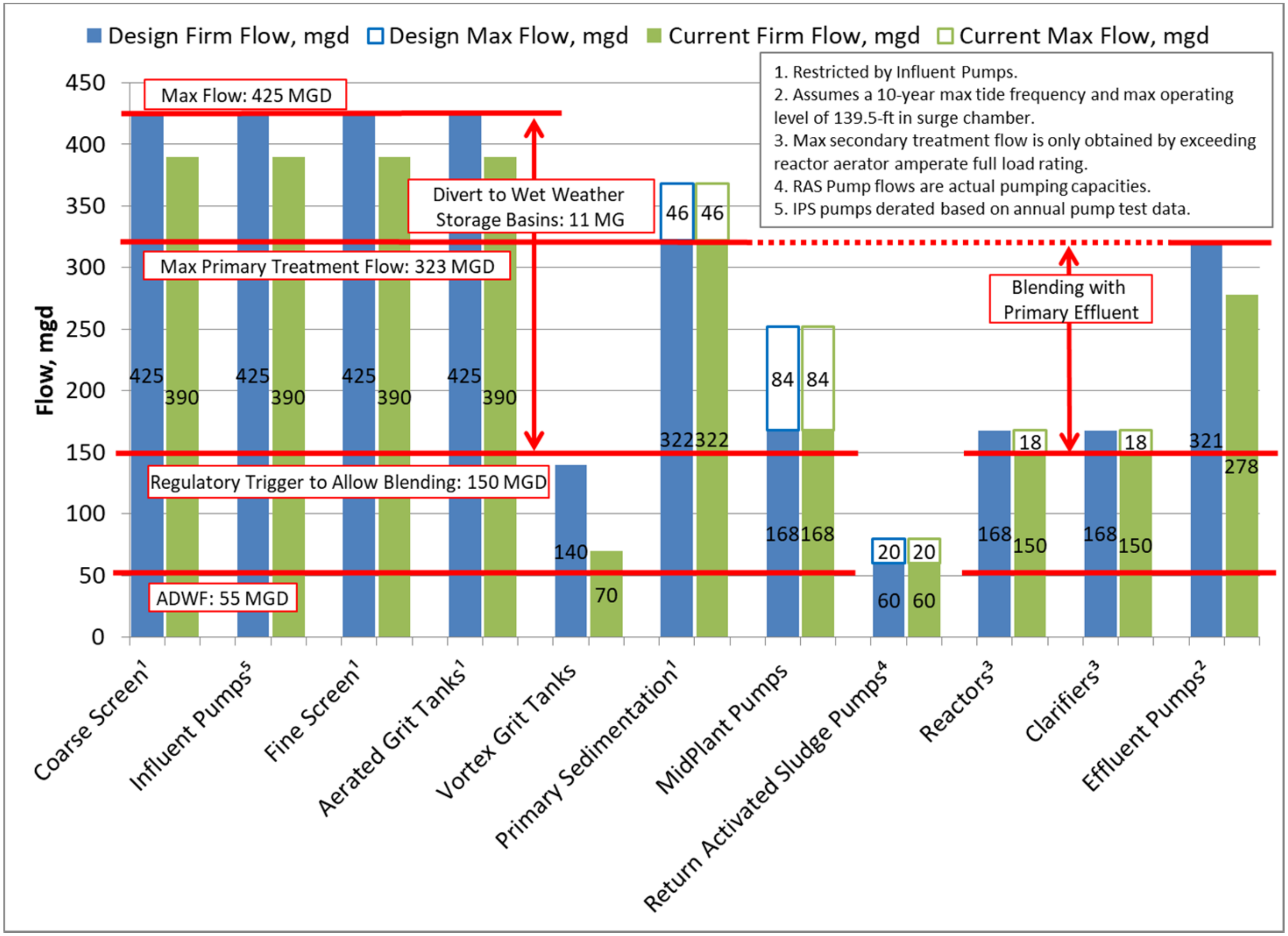


Figure 7. Volatile Solids Reduction as a Function of Loading Rate

1.5.2.2 Dewatering Centrifuges

The dewatering centrifuges to process digested sludge into dewatered sludge (or cake) is set to dewater the solids to 22 to 25% total solids due to piping and equipment limitations. This is done by varying the feed flow, polymer addition, and/or centrifuge speed. However, primary operating limitations for the centrifuges are the high solids limitations and variable grit loading conditions. Operators are most concerned about the centrifuges shutting down or being damaged due to limitation exceedences and related wear and tear.



1. Restricted by Influent Pumps.
2. Assumes a 10-year max tide frequency and max operating level of 139.5-ft in surge chamber.
3. Max secondary treatment flow is only obtained by exceeding reactor aerator amperate full load rating.
4. RAS Pump flows are actual pumping capacities.
5. IPS pumps derated based on annual pump test data.

Figure 8 Liquid Treatment Process Capacities

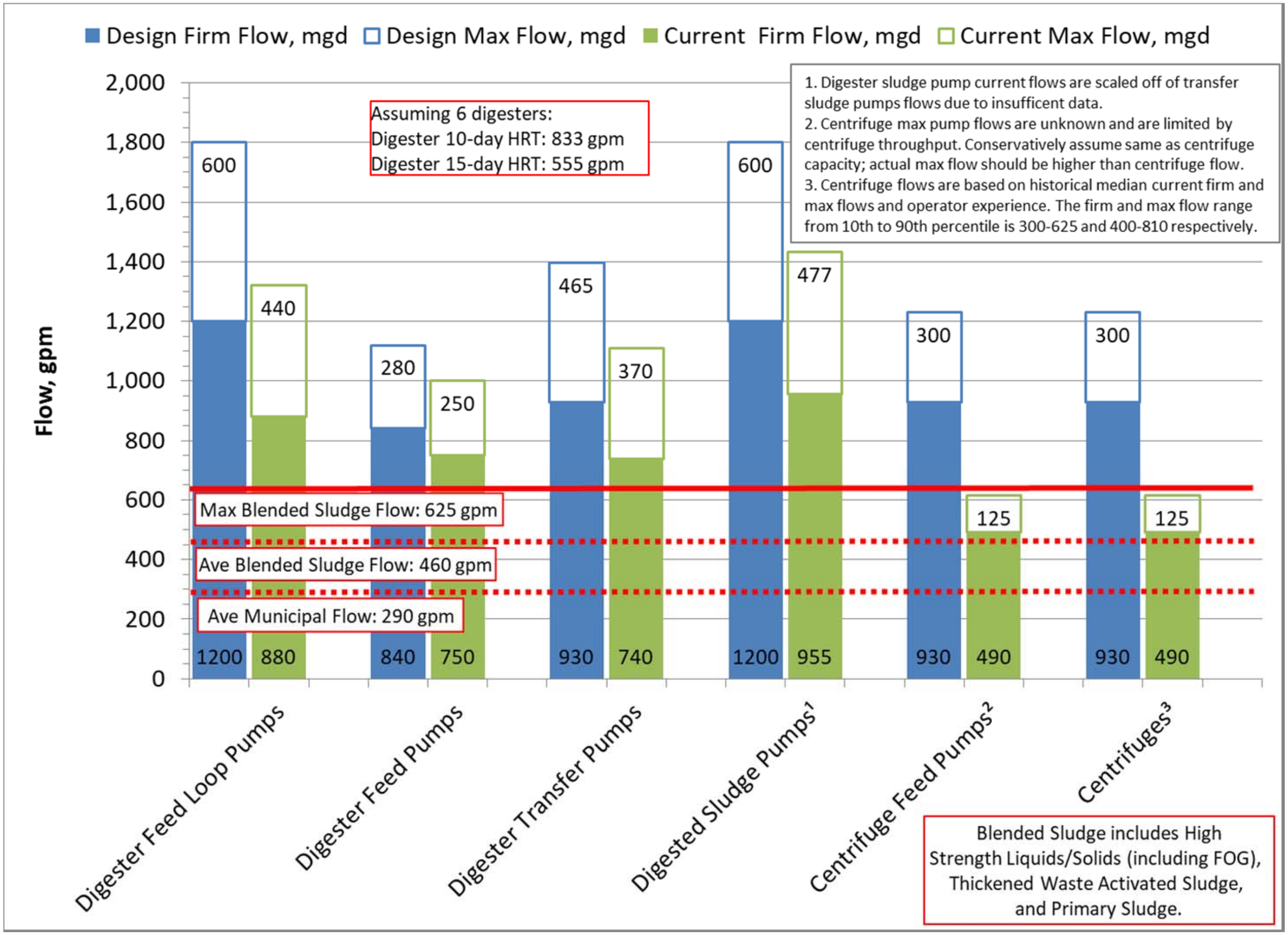
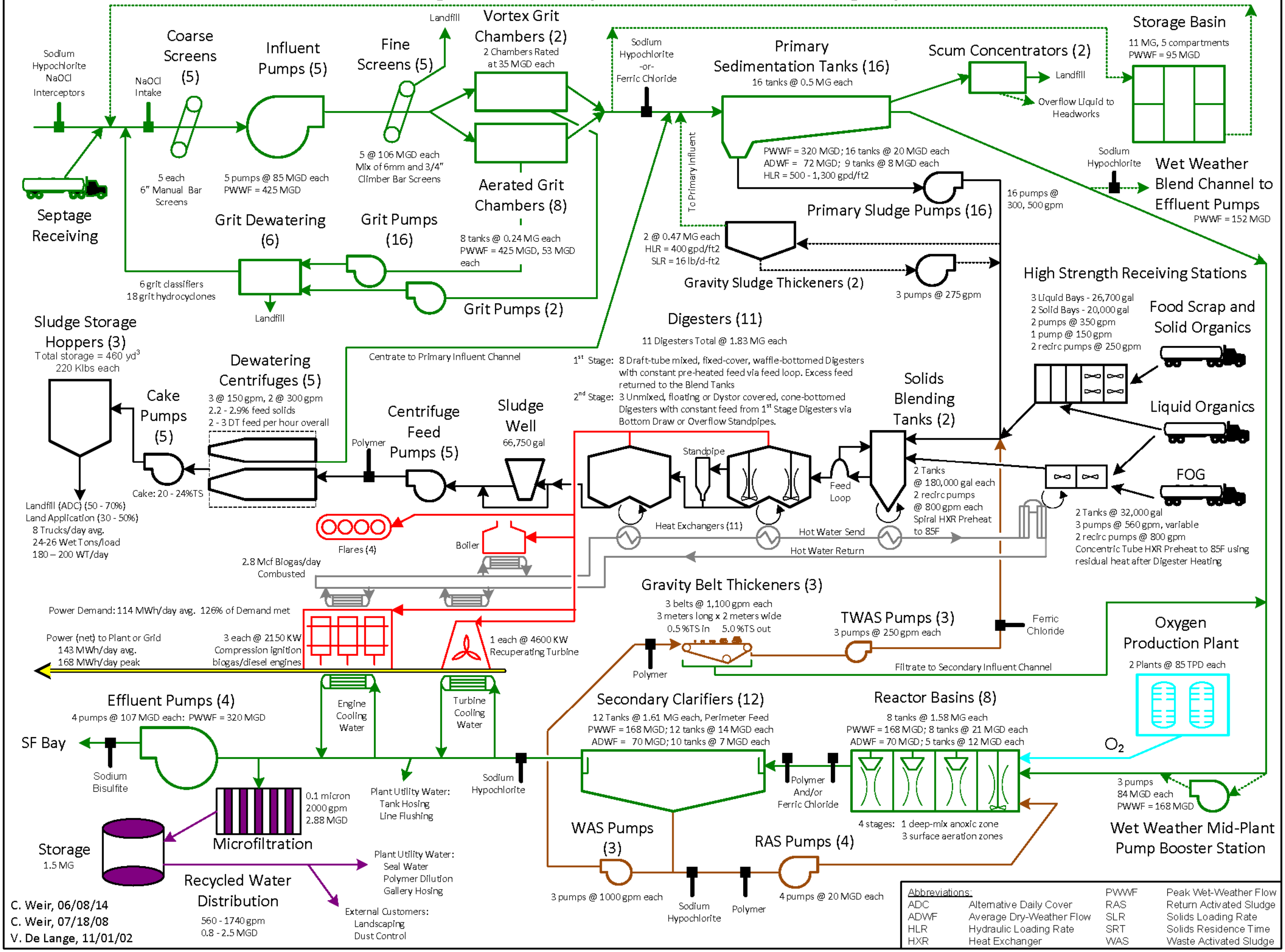


Figure 9 Solids Treatment Process Capacities

Figure 10. Summary of MWWTP Process and Capacity



Abbreviations:

ADC	Alternative Daily Cover	PWWF	Peak Wet-Weather Flow
ADWF	Average Dry-Weather Flow	RAS	Return Activated Sludge
HLR	Hydraulic Loading Rate	SLR	Solids Loading Rate
HXR	Heat Exchanger	SRT	Solids Residence Time
		WAS	Waste Activated Sludge

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V. De Lange, 11/01/02

CHAPTER 1 - INTRODUCTION

1.1 General

This Task Report reviews the overall and individual process performance of the Main Wastewater Treatment Plant (MWWTP). It also includes preliminary assessment of the process capacity using the best currently available information and performance of the individual liquid and solid treatment processes based on operating data compiled from 2010 to 2018.

The preliminary capacity assessment findings in this Task Report will assist the consultants in their work to determine the final capacity rating. The preliminary assessment will determine plant hydraulic profile, the facilities and equipment of interest, original design criteria, reliability, and existing capacity.

The final capacity rating (by Consultants) will be summarized as Maximum Capacity (all units in service) and Reliable Capacity (units OOS, de-rated unit capacity etc.). It'll be determined by considering information provided in this Task Report, industrial standards, and process model findings. Rated capacities of existing facilities will be taken into account when evaluating various treatment process alternatives for our Master Plan.

The existing process performance will be critical in evaluating the MWWTP's ability to meet future capacity and treatment needs and is critical in the planning of new or retrofit of facilities. The process performances information in this task report will be used in the Integrated MWWTP Master Plan in planning for future needs.

1.2 MWWTP Overview

Refer to the Wastewater System Overview Task Report for an overview and description of the MWWTP.

CHAPTER 2 - HYDRAULIC PROFILE

2.1 General

A hydraulic profile covering the liquid treatment systems was developed by District staff in 2019 in Microsoft Excel. The hydraulic profile covers the Influent Pumping Station to the outfall and includes the secondary treatment bypass/blending system. Industry-standard equations were used to calculate theoretical headloss while field measurements and/or DCS level sensor data were used to calibrate it. The hydraulic profile was developed to allow modeling for various operating conditions; for example, the user can vary number of primary tanks in services.

Refer to Appendix A for the hydraulic profile developed, along with assumptions and calculations.

A solids treatment system hydraulic profile is not planned at this time, as all solids conveyance systems are pumped and should be analyzed individually on an as-needed basis. Refer to the solids treatment section of this document for any system deficiencies.

2.2 Assumptions

Assumptions within the hydraulic profile are as follows:

- All pumps are assumed to provide unlimited flow and head. Pumping station performance is not considered in the hydraulic profile.
- All weirs and gates are assumed to be in good condition
- Flow through each treatment system is based on the original design flows, regardless of whether or not it is physically possible due to pumping station limitations

2.3 Theoretical Headloss Calculations

The flow path through the liquid treatment process at the MWWTP was divided into hydraulic flow elements where applicable headlosses could be calculated. For example, long channels were divided into multiple flow elements if there is a defining characteristic change, e.g. cross-sectional area, or maximum water surface elevation, or floor elevation. Gates, weirs, and screens were treated as a single flow element and headloss was calculated based on whether or not they were under a submerged condition. Where possible, simplifications were made; for instance, it was assumed that there was no headloss in large tanks/basins such as the aerated grit tanks, primary sedimentation tanks, or secondary clarifiers.

For each flow element, the total headloss was calculated as the sum of all applicable headlosses. Applicable headloss types include open channel, minor losses, orifice, sharp-crested weir, and V-notch weir. Industry-standard hydraulic equations were used to calculate these various types of headloss, and are listed below in Table 2-1. For minor losses and orifices, loss coefficients (K) and coefficients of discharge (C_d) were taken from the literature when available.

Table 2-1 Types of Headloss Calculations Incorporated into the Hydraulic Profile.

	Open Channel	**Pipe Loss**	**Minor Losses**	**Orifice**	**Sharp Crested Weir**	**V-Notch Weir**
Equation or Method	Chezy-Manning	Darcy-Weisbach	Method of Loss Coefficients	--	--	--
Equation Number[a]	19.12(b)	--	17.41 18.7	17.75 18.7	19.51(b) 19.53	19.55(b)

a. Equation Source: Civil Engineering Reference Manual for the PE Exam, 10th edition.

For each flow element, as-built drawings were used to identify characteristics such as:

- Dimensions (length, width, height, and diameter)
- Floor, top of wall, and pipe invert elevation
- Number of flow elements (e.g. number of v-notch weirs on primary sedimentation tanks and secondary clarifiers)

2.4 Empirical Headloss Calculation for Outfall

An empirical equation was developed for estimating headloss through the Outfall by using the difference between the historical water surface elevation at the Effluent Pumping Station and at the receiving water using tide data from the National Oceanic and Atmospheric Administration. This empirical modeling method was employed for the outfall analysis due to the complex shape, sedimentary condition of the outfall's discharge diffuser, and a complete lack of information regarding the hydraulic grade line within the buried outfall segment.

2.4.1 Outfall Design Flows from Previous Studies

Information from the 1988 Outfall study done by Carollo indicated an outfall design flow of 290 mgd at a tidal elevation of 105.2-ft and a maximum tested head of 50-ft. This concurs with the empirical headloss calculation done by the District under this Task Report as well as the 1986 Wet Weather Facilities Predesign Report indicating maximum outfall flow of 290 mgd.

2.4.2 Tidal Assumptions

The tidal assumptions used in 1941 and other original design documents have since changed in the latest NOAA tidal elevations. Originally, the design tide was the "Extreme high tide" of 105.2-ft based on a San Francisco tide station (Station 9414290)—it is now 106.99-ft. In addition, the Alameda station 9414750 should be used instead of the San Francisco station due to the closer proximity and the more conservative nature of the Alameda station values (high tides are higher at the Alameda station than at the San Francisco station). The differences between these two stations are less than 1-ft.

The other tidal design adjustment is due to the fact that the term "Extreme High Tide" is no longer used and no definition on "extreme high tide" has been found. The new term is likely "Max Tide," which is defined as the highest historically observed tide. This max tide elevation was set at 107.72-ft in 1983 and has an estimated 100 year return frequency. Due to the long frequency, the max tide value is not used. Instead, this Task Report determined that a 10 year frequency is more appropriate, which would be calculated to 106.9-ft based on NOAA's annual exceedence probability chart. This value does not include the impacts of sea level rise.

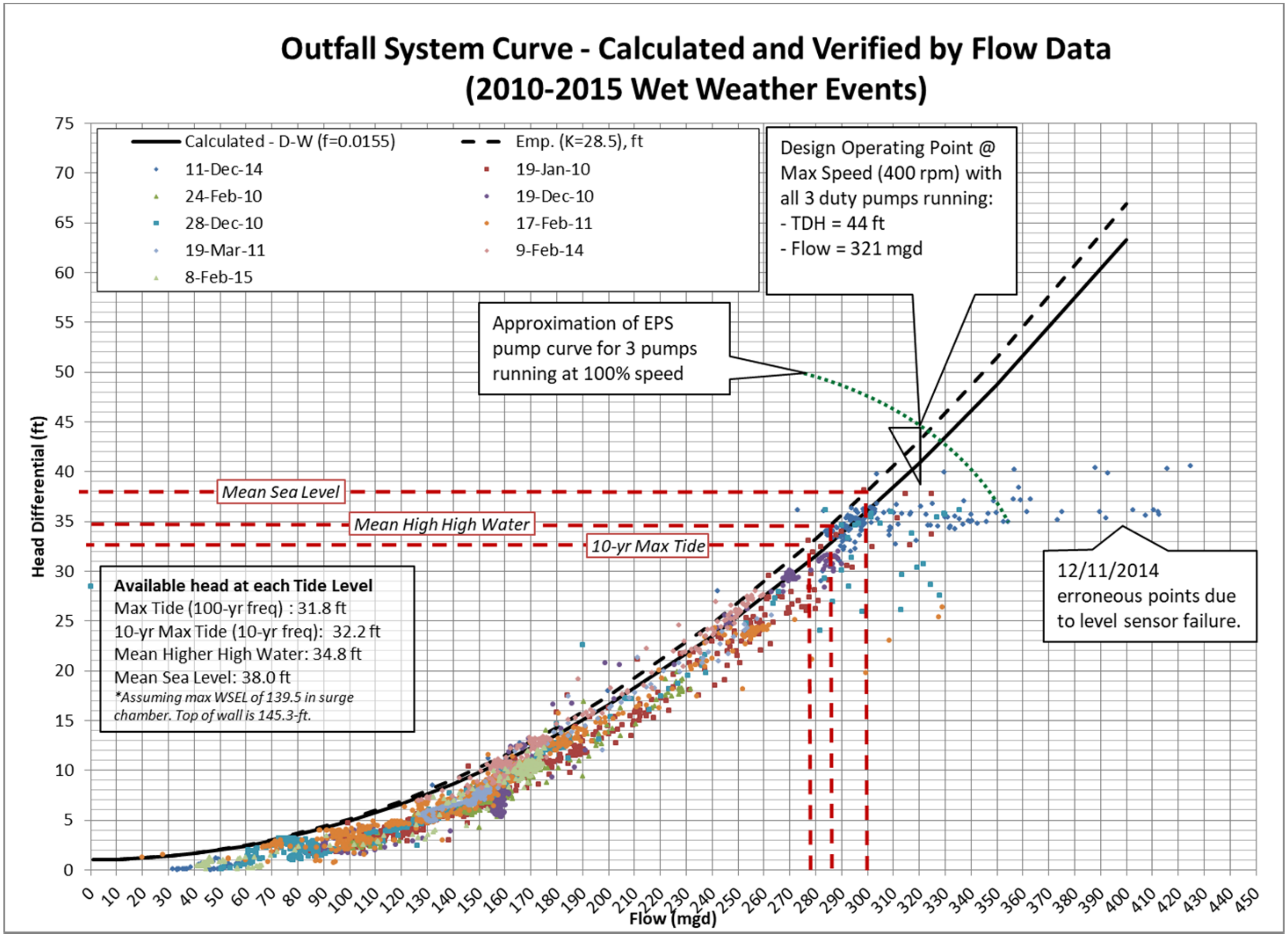
2.4.3 Surge Chamber Freeboard

The top of wall in the surge chamber is 145.33-ft; however, the water surface elevation will vary in the surge chamber due to the pumps ramping up or down. For this reason, the District generally has a normal operating water surface elevation of no more than 135.0-ft and a maximum allowable operable WSEL of 139.50-ft. For the purposes of determining the maximum outfall capacity, the maximum safe operable value of 139.50-ft shall be used.

2.4.4 Outfall Flow Estimation

Using the new 10-yr Max Tide value, in combination with the maximum operating water surface level of 139.50-ft (versus top of wall at 145.33-ft) in the surge chamber, we get a 10-year minimum maximum flow of 278 mgd. That is, every ten years, we will be limited in our outfall to 278 mgd. This is only a problem if flows need to exceed 278 mgd during this 10-yr Max Tide event—it is unknown how often this might occur. The normal maximum flows during the Mean Higher High Water level (defined as the average high high tide, at 104.67-ft) and the Mean Sea Level (101.52-ft) is 285 and 300 mgd respectively. Refer to Figure 2-1 for the Outfall System Curve.

The outfall vents were not analyzed as part of this study; however, incidental information indicates the outfall vents have been known to overflow during high flows.



Outfall System Curve - Calculated and Verified by Flow Data (2010-2015 Wet Weather Events)

Design Operating Point @ Max Speed (400 rpm) with all 3 duty pumps running:
- TDH = 44 ft
- Flow = 321 mgd

Approximation of EPS pump curve for 3 pumps running at 100% speed

12/11/2014 erroneous points due to level sensor failure.

Available head at each Tide Level
Max Tide (100-yr freq) : 31.8 ft
10-yr Max Tide (10-yr freq): 32.2 ft
Mean Higher High Water: 34.8 ft
Mean Sea Level: 38.0 ft
**Assuming max WSEL of 139.5 in surge chamber. Top of wall is 145.3-ft.*

Figure 2-1 Outfall System Curve

2.5 Model Calibration

The hydraulic model was calibrated using field data and/or DCS level sensor data. Field surveys occurred on May 18th, 2017 at 60 MGD and on February 12, 2019 at 285 MGD. Each survey collected water surface elevations (measured off of known structural elevations such as the top of walls) at various and consistent strategic points along the liquid treatment flow path. Furthermore, the operating conditions, e.g. the number of IPS or primary sedimentation tanks in service, during the survey were recorded.

Occasionally during extreme wet weather events when the influent flow exceeded the secondary capacity of 150 MGD, primary effluent bypasses secondary treatment and is blended with secondary effluent (Blending). This is confirmed to have been captured during the February 12, 2019 field calibration event.

In general, the goal of model calibration was to modify the theoretical headloss calculation to be within ± 0.1-ft of the field and/or DCS data. The threshold was increased to ± 0.3 ft for turbulent channels with active aeration (e.g. aerated grit or primary influent) or downstream of pumping (e.g. secondary influent after Mid-Plant Pumping Station).

Since turbulence increases with flow rate, field measurements taken at 60 MGD are likely more accurate; accordingly, the model was calibrated first at 60 MGD. Following this, the calibration was fine tuned to match the higher flow field measurements taken at 285 mgd to obtain a more precise model for higher flow situations.

During the calibration process, several parameters were adjusted to achieve the desired accuracy, including the minor loss coefficient (K), Manning roughness coefficient (n), and the coefficient of discharge for orifices (C_d). In general, the calibration step equally adjusted the coefficients on similar flow elements equally (e.g., all concrete pipe to have the same roughness coefficient) to obtain consistency.

No calibration was required for the outfall empirical calculation as it is based on historical flow and level data.

2.6 Discussion

The freeboard condition of the plant is insufficient at the outfall and limited at the IPS.

The outfall, as discussed in the previous section, is flow limited to 278 due to high tide and freeboard requirements for operational needs in the surge chamber. Other issues regarding outfall vent overflow may occur at the higher flows and/or if the surge chamber is increased to allow higher outfall flows.

All other areas of the plant do not have similar limitations and are flow limited due to freeboard or pumping.

2.7 Results and Conclusions

During typical dry weather flows, the Influent Pump Station sufficiently conveys flow through the treatment process and to the Bay. However, during high flow and high tide conditions, additional freeboard would be needed at the effluent pumping station's surge tower to allow sufficient head for the full design outfall flow.

2.8 Future Improvements

Improvements to this hydraulic profile may be made by obtaining additional field water surface elevations measurements at the maximum plant flow rates through the primary treatment system (320 mgd) and through the influent pumping station (415 mgd). This will improve the precision of the model at the very upper flow limit of what the plant can handle. This would require taking measurements during a rain storm of sufficient size and at the right time.

CHAPTER 3 - DATA SOURCE AND METHODOLOGY

3.1 Introduction

The various sources of wastewater flows, loads, equipment info, and constituent concentrations are provided in this section. Not all data for the full 2010-2018 analysis period was available for certain constituent parameters, what was available will be *presented as needed.* This section does not include the work done as part of the Hydraulic Profile (described in Chapter 2).

3.2 Data Sources and Compilation

This section describes various data sources available and used for this task:

- Low- and High-strength R2 daily data
- Plant flow data (1995-2018)
- Plant Operational Data 2010-2018
    - Liquid MDWs (daily data)
    - Digester Retention Time
    - Biogas and Power generation: Carol compiled the data for Air Permit (where is the file? Does it include biogas CO2 and H2S as well?)
    - Part 503 monthly and annual reports (ready)
    - DataPortal (only flow and pH are QA/QCed, can use PI data for lab results if needed – most data should be already in the MDW)
- California Integrated Water Quality System (CIWQS) data
- Toxicity Investigation Reports (ready, from Chris and Yun)
- Nutrient data for the 2014 Watershed Permit study for additional data for the Master Plan
- Various reports completed by both District and Consultant staff
- Historical project documentation
- Operations and Maintenance Manuals
- Operator’s experience

3.3 Database

All historical regularly recorded data collected were imported into a central database for use. This central database uses the District’s Oracle platform. Access to this database was by use of the data analysis software R.

3.4 Data Analysis Software R Studio

Most of the data was analyzed by the statistical software R Studio, or by Microsoft™ Excel to provide all plots and data analyses. Data was gathered from various sources as mentioned previously. The R Studio software was used to generate plots (such as box and whiskers) that can otherwise not be created by the standard spreadsheet software(s), whereas the spreadsheet was used to generate tabular values where necessary.

3.5 Referenced Book Values

Throughout this Task Report, standard book values for various parameters of the treatment systems were added in tables and texts. These values were primarily from the Metcalf & Eddy, 5th edition, or the WEF Manual of Practice No. 8, 6th Ed.

3.6 Data Gaps

A discrepancy exists regarding one analyte, wherein the District uses cBOD5 in contrast to the BOD5 values given in the book. For the purposes of this Task Report, these two types of BOD5 measurements are assumed to be equal.

In addition, O&M manuals and documentation regarding the rationale behind the design criteria, and in some cases, the design criteria itself, were not were not retrieved for the purposes of this Task Report. This information is not necessarily relevant to the objectives of this Task Report and would require significant effort to retrieve the hardcopy documents from storage and parsing through every page looking for documentation that may or may not exist.

3.7 Performance

The performance information indicated in this document regarding the various processes and equipment does not include issues regarding the equipment controls, wear and tear, or other mechanical issues. That is, this document assumes all equipment and process is working properly per the manufacturer’s or engineer’s design and are available for use. Any issues causing outages is not considered in this document.

CHAPTER 4 - LIQUID TREATMENT

4.1 Introduction

This section describes the liquid treatment efficiency of the MWWTP. Information is provided on both the overall treatment performance and performance of the individual treatment processes which include the following:

- Influent Pumping Station
- Aerated Grit Tanks (wet weather)
- Vortex Grit Tanks (dry weather)
- Primary Sedimentation Tanks
- Mid-Plant Pumping Station
- High purity oxygen reactor
- O2 Generation Plant
- Clarifiers
- Disinfection
- Dechlorination

Preliminary capacity information is also compiled and discussed. This report does NOT describe the treatment process or flow paths; instead, refer to the E00 Task Report for the overview of the MWWTP.

4.2 Liquid Train Overall Performances

The overall treatment system performance is primarily analyzed by comparing the influent and effluent concentrations and percentage removals against the NPDES discharge permit requirements. Table 4-1 Liquids Overview Summary summarizes the influent and effluent flow, loading, and constitutes concentration statistics. In addition to showing the Influent and Effluent locations, data statics performed for the Secondary Influent (including centrate), Return Activated Sludge (RAS), Mixed Liquor, and Secondary Effluent locations are also included in this table.

Table 4-1 Liquids Overview Summary

	Influent		Secondary Influent		RAS		ML		Secondary Effluent		Final Effluent		Overall % Reduction	NPDES Limit	Data Source and Date Range
Flows (mgd)	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**			
Average Annual	62.3	22.7	65.9	20.7	25.2	5.4	91.1	25.4	62.4	19.0	55.4	21.7	--	--	2010-2018 MDW
Max Monthly Average													--	--	2010-2018 MDW
Max Day	259.1	--	171.6	--	53.6	--	220.1	--	179.2	--	256.4	--	--	--	2010-2018 MDW
NPDES Dry Weather Average (Consecutive 3 driest months, assume Jul 1 - Sept 30)	54.4	4.8	58.1	5.6	22.9	2.9	81.1	7.4	54.9	3.3	47.2	19.5	--	>120 mgd	2010-2018 MDW
Watershed's Dry Season Average (May 1 - Se	57.3	26.2	57.3	28.1	22.5	11.1	79.9	39.1	53.9	26.2	46.4	23.7	--	--	2010-2018 MDW
Watershed's Wet Season Average (Oct 1 - Apr	68.0	28.0	71.5	25.0	26.8	6.1	98.3	30.4	67.9	23.1	61.3	34.7	--	--	2010-2018 MDW
													--		
Analytes	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	--		
Temperature, F	70.3	4.3	--	--	--	--	--	--	--	--	--	--	--	--	2010-2018 MDW
pH	6.8	0.2	--	--	--	--	--	--	--	--	6.8	0.1	0.3%	6.0 - 9.0	2010-2018 MDW
Alkalinity	285.8	42.0	352.7	58.2	--	--	--	--	--	--	339.9	54.2	-18.9%	--	2010-2018 MDW
Oil and Grease mg/L	--	--	--	--	--	--	--	--	--	--	0.8	1.4	--	10 ppm, mon avg, 20 ppm, max daily	CIQWS (2011-2018)
													--		
TSS, mg/L	371.9	148.5	124.0	46.4	7005.5	1587.8	2096.9	614.1	--	--	13.7	6.0	96.3%	30 ppm, mo avg, 45 ppm, wk avg, 85% Removal	2010-2018 MDW
TSS, mg/L (Operation's microwave analysis)	--	--	--	--	6962.5	1791.0	2061.9	451.8	--	--	--	--	--	--	--
VSS, mg/L	312.3	81.6	107.6	40.9	5385.6	1259.6	1824.5	536.4	--	--			100.0%	--	
													--		
cBOD5, mg/L	311.4	95.3	151.0	39.4	--	--	--		--	--	9.7	4.1	96.9%	25 ppm, mo avg, 40 ppm, wk avg, 85% Removal	2010-2018 MDW
COD (Soluble), mg/L	176.9	65.6	144.1	48.5	--	--	--	--	--	--	--	--	--	--	LIMS Data Varies
COD, mg/L	774.7	182.5	431.0	104.1	--	--	--	--	--	--	88.1	17.2	88.6%	--	LIMS Data Varies
													--		LIMS Data Varies
NO2 as N, mg/L	0.9	0.4	0.7	0.3	--	--	--	--	--	--	2.0	0.8	-124.9%	--	LIMS Data Varies
NO3 as N, mg/L	2.6	1.5	1.6	1.0	--	--	--	--	--	--	0.9	0.5	65.3%	--	LIMS Data Varies
NH3 as N, mg/L	31.3	7.9	47.1	13.1	--	--	--	--	--	--	40.6	11.7	-29.7%	84 ppm, mo avg, 110 ppm, max day	LIMS Data Varies
TKN as N, mg/L	50.8	11.4	63.3	15.4	--	--	--	--	--	--	51.9	10.4	-2.1%	--	LIMS Data Varies
TN as N, mg/L	54.2	0.0	65.5	0.0	--	--	--	--	--	--	54.4	11.6	-0.3%	--	LIMS Data Varies
													--		
Orthophosphate as P, mg/L	4.1	1.5	6.5	2.5	--	--	--	--	--	--	3.3	2.0	21.3%	--	LIMS Data Varies
Total Phosphorus as P, mg/L	8.4	2.1	9.3	2.9	--	--	--	--	--	--	3.9	1.8	53.8%	--	LIMS Data Varies
													--		
Note: Centrate is returned into the liquid treatment system at the Primary Sedimentation Tanks (upstream of the Secondary Influent															

	Influent		Secondary Influent		RAS		ML		Secondary Effluent		Final Effluent		Overall % Reduction	NPDES Limit	Data Date Range
	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD			
Analytes (Continued)															
Chlorine Total Dose, mg/L	--	--	--	--	--	--	--	--	3.71949	0.50898	--	--	--	--	2010-2018
Chlorine Contact Time, mg/L*min	--	--	--	--	--	--	--	--	78.633	32.2033	--	--	--	--	2010-2018
Chlorine Residual at Dechlor, mg/L	--	--	--	--	--	--	--	--	1.0401	0.30487	--	--	--	--	2010-2018
Sodium Bisulfite Total Dose, mg/L	--	--	--	--	--	--	--	--	10.0238	1.8413	--	--	--	--	2010-2018
Fecal Coliform, MPN/100ml	--	--	--	--	--	--	--	--	--	--	5.43883	59.8445	--	500 at 5-day geometic mean, and 90th percentile of the last ten values not exceed 1,100	CIQWS (2011-2018)
Enterococci, CFU/100 ml	--	--	--	--	--	--	--	--	--	--	2.11676	9.42274	--	35 mo geometic mean	CIQWS (2011-2018)
													--		
													--		
Loading Rates													--		
TSS, lb/day	184.537	75.18	81.019	17.433	--	--	1517.156		--	--	4.779	4.748	97.4%	--	LIMS Data Varies
VSS, lb/day	166.209	36.051	214.259	35.065	--	--	--	--	--	--	--	--		--	LIMS Data Varies
														--	
cBOD, lb/day	153.04	40.191	0.314	0.144	--	--	--		--	--	40.032	5.828	73.8%	--	LIMS Data Varies
COD (Soluble), lb/day	--	--	--	--	--	--	--	--	--	--	--	--	--	--	LIMS Data Varies
COD, lb/day	361.065	59.729	0.768	0.69	--	--	--		--	--	0.911	0.452	99.7%	--	LIMS Data Varies
														--	
NO2 as N, lb/day	0.44	0.212	0.768	0.69	--	--	--		--	--	0.409	0.329	7.0%	--	LIMS Data Varies
NO3 as N, lb/day	1.394	1.086	23.018	2.967	--	--	--		--	--	19.622	3.726	-1307.6%	--	LIMS Data Varies
NH3 as N, lb/day	15.354	1.591	31.693	3.722	--	--	--		--	--	22.516	3.478	-46.6%	--	LIMS Data Varies
TKN as N, lb/day	25.538	2.922	8.233	1.601	--	--	--		--	--	2.174	1.077	91.5%	--	LIMS Data Varies
TN as N, lb/day	27.562	3.268	3.115	0.77	--	--	--		--	--	1.488	0.83	94.6%	--	LIMS Data Varies
														--	
Orthophosphate as P, lb/day	2.01	0.497	4.625	0.853	--	--	--		--	--	1.726	0.761	14.1%	--	LIMS Data Varies
Total Phosphorus as P, lb/day	4.203	0.65	0.097	0.029	--	--	--		--	--	5.901	1.581	-40.4%	--	LIMS Data Varies
													--		
Ratios													--		
cBOD/MLVSS	--	--	0.097	0.029	--	--	--	--	--	--	--	--	--	--	LIMS Data Varies
COD/MLVSS	--	--	0.254	0.069	--	--	--	--	--	--	--	--	--	--	LIMS Data Varies
Alk/TKN	5.901	1.581	5.807	1.161	--	--	--	--	--	--	7.025	0.75	-19.0%	--	LIMS Data Varies
ALK/NH3	9.624	2.989	7.671	1.619	--	--	--	--	--	--	8.644	2.603	10.2%	--	LIMS Data Varies
COD/TN	12.959	2.129	6.504	0.973	--	--	--	--	--	--	1.63	0.177	87.4%	--	LIMS Data Varies
COD/TP	87.824	17.215	46.062	7.455	--	--	--	--	--	--	21.745	6.082	75.2%	--	LIMS Data Varies
sCOD/tTN	3.193	1.056	2.296	0.629	--	--	--	--	--	--	--	--	--	--	LIMS Data Varies
sCOD/tTP	20.979	6.72	16.405	4.097	--	--	--	--	--	--	--	--	--	--	LIMS Data Varies
VSS/TSS							0.871								

Table 4-2 Other NPDES Constituent Concentrations

	Influent		Final Effluent		Overall % Reduction	NPDES Limit
	Average	SD	Average	SD		
Copper ug/L	73.033	18.756	7.151	2.293	90%	47 mo avg, 85 max daily
Cyanide ug/L	1.7	3.2	2.4	2.7	-42%[2]	20 mo avg, 39 max daily
Mercury ug/L	0.174	0.354	0.006	0.003	97%	0.066 mo avg, 0.072 max daily, 1.5 kg/yr annual discharge
Acute Toxicity (% survival)	--	--	98.075	5.742	--	47 mo avg, 85 max daily
Hexachlorobenzene ug/L	0.0000	0.0000	0.0000	0.0000	--	0.0076 mo avg, 0.015 max daily
Dioxin-TEQ ug/L	--	--	--	--	--	1.4E-08 mo avg, 2.8E-08 max daily
PCBs (aroclors) ug/L	--	--	--	--	--	0.012 mo avg, 0.017 max daily

(1) All data in this table is sourced from CIWQS from March 2011 to December 2018.

(2) Cyanide formation may occur due to wastewater disinfection or false positives. Refer to Deeb, et. al. (2004). CYANIDE FORMATION DUE TO WASTEWATER DISINFECTION: LABORATORY ISSUES AND COMPLIANCE STRATEGIES. Proceedings of the Water Environment Federation. 2004. 551-570. 10.2175/193864704784132481.

4.2.1 Flow

The influent and effluent plant flows on an annual and monthly basis are provided in Figure C-1.

To better understand the impact of water year types on the influent flow, historical California water year types for the Sacramento Valley Water Year Hydrologic Classification, and the rainfall totals from for the Oakland International Airport weather station are shown in Figure 4-1. The water year types are provided by the California Department of Water Resources (DWR) via DWR’s California Data Exchange Center and the rainfall data from Weather Underground. The water year is from October to September and is labeled as wet, above normal, below normal, dry, and critical.

It is important to note that the CA water year type and the Oakland rainfall are listed as an indication of the general hydrological conditions in the state affecting water supply and wastewater influent flows. One is a local indication of rainfall and the other a northern California indicator. As such, they are not necessarily always correlated to each.

Of special interest, the state of California had the most severe drought on record from 2011 to 2016 (or 2017, depending on location) and the third more severe drought in 2007 to 2009. These two drought events triggered a statewide proclamation of emergency.

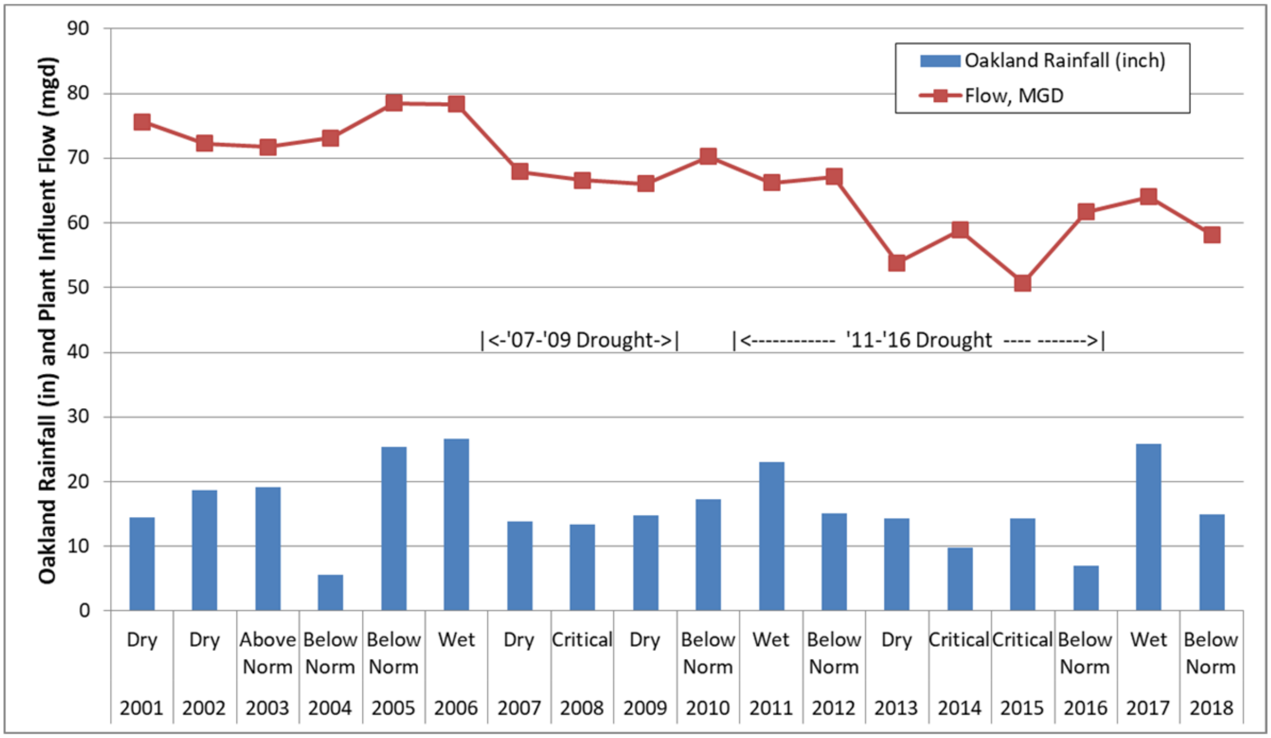
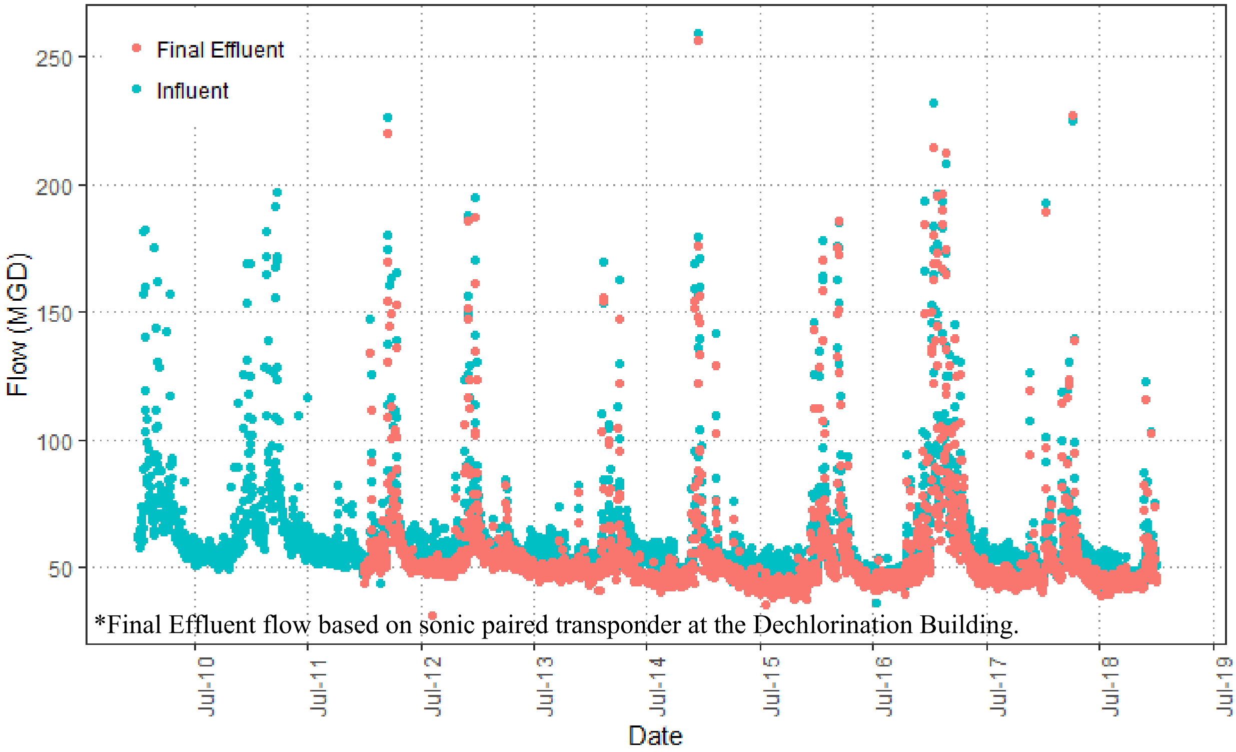


Figure 4-1 Annual Average Influent Flow, Total Rainfall, and Associated Water Year Type

The plant flow is data, in conjunction with the average annual flows, indicates the flow to the MWWTP decreases slightly during multiple year drought periods, as expected due to voluntary and mandatory conservation efforts.

Influent flow through the plant will not necessarily correspond to the effluent flow into the bay. See Figure 4-2 for a graph of the daily (total) average flow in and out of the plant. The discrepancy is due to the following: (1) 11 mg wet weather storage basin being used to store excess flows during high flows to equalize the flows entering the treatment facilities, (2) grit return recycling, (3) scum system return recycling, (4) 3W uses to drain, and (5) East Bayshore Recycle Water Plant secondary effluent usage.



*Final Effluent flow based on sonic paired transponder at the Dechlorination Building.

Figure 4-2 Influent and Effluent Flows (Daily Averages)

4.2.2 Number of Tanks in Service

The monthly and annual average number of Primary Sedimentation, Reactor, and Clarifier tanks in service is provided in Figure C-2. In general, the MWWTP operates as many tanks as possible during wet weather and reduces the number of units in service during dry weather season for inspection, maintenance, rehabilitation, energy conservation, or etc.

4.2.3 Influent and Effluent pH

The monthly and yearly influent and effluent pH is provided in Figure C-3. The influent pH value includes samples taken from both upstream and downstream of the Septage Receiving Stations A and B where septage and trucked low-strength R2 waste is mixed in with the wastewater influent flow; however, there is no perceivable difference between the influent pH values at these two locations, indicating minimal impact on pH due to these wastes addition at the Septage Receiving Station.

The influent pH is generally within the range of 6 to 7.5 with exception of some outliers, while the effluent pH is relatively stable between 6.5 and 7.0. The influent pH appeared slightly lower during dry season months compared to the wet season months. The influent pH also varies with the year. It is worth noting that there was a large variation of influent pH in 2014 for reasons unknown.

4.2.4 Influent Temperature

The plant influent flow temperatures are provided in Figure C-4. As expected, the wastewater temperature is higher in the summer months (up to ~78 degrees F) than in the winter months (~68 degrees F). Interestingly, the temperature has been increasing on an annual average basis as well—potentially due to conservation during the 2011-2016 drought, reduced I&I due to lower groundwater levels during the drought and/or improved infiltration and inflow controls as required by the EPA consent decree. The exact rationale behind the temperature increase is difficult to determine.

4.2.5 Influent and Effluent TSS, cBOD, COD, and sCOD

The influent and effluent TSS, cBOD, COD, and sCOD concentrations on a monthly and annual averages basis are provided in Figure C-5 and Figure C-6 respectively. Influent TSS, cBOD, and sCOD concentrations are generally higher in the dry weather months than in the wet weather ones, likely due to less inflow and infiltration dilution. These concentrations are within range of the book values, based on M&E, for WWTPs in the US. The limited COD data prevents any conclusions at this time.

Table 4-3 shows the typical loading rates for TSS, BOD5, and COD, based on EBMUD's wastewater service population size of 685,000 residents and US average. Total mass loading for TSS, cBOD, COD, and sCOD is provided in Figure C-7. The higher than standard values are potentially due to various industrial waste generators within the service area, water conservation, and the Resource Recovery Program.

Table 4-3. Typical TSS, cBOD, COD, and sCOD Values

Parameter	Actual Values		Typical (Book) Values[1]		
	Concentration, mg/L Average (Range)	**Mass Loading, klb/day Average (Range)**	**Concentration, mg/L[2]**	**Concentration per capita, lb/capita/day (g/capita/day)**	**Mass Loading, klb/day[3]**
TSS	367 (145-2000)	185 (101-1220)	391	0.163 (74)	112
cBOD	310 (94-1300)	153 (88-707)	399	0.168 (76)	115
COD	803 (306-1300)	361 (196-513)	1,013	0.427 (193)	290
sCOD	182 (44-416)	--	--	--	--

1. All typical (book) values based on M&E, 5th Ed., Table 3-16.
2. Assumes 50 gal/capita/day
3. Assumes 685,000 residents in the SD-1 service area.

TSS, cBOD COD, and sCOD concentrations change with the plant daily influent flow, as shown in Figure 4-3. The concentrations are far more variable in the 50–100 MGD flow range and decrease as flow increases due to wet weather events. This is expected as wet weather flow dilutes the concentrations of these constituents. This pattern is not shown clearly on the COD or sCOD graphs due to insufficient data but is expected to be similar. The concentration variability is likely due to the inherit variability in unsettled influent wastewater (e.g., a sample may or may not contain solids of varying shapes and sizes) and due to the Septage Receiving station's acceptance of bulk liquid municipal and industrial wastewater into interceptor directly upstream of the Influent Pumping Station.

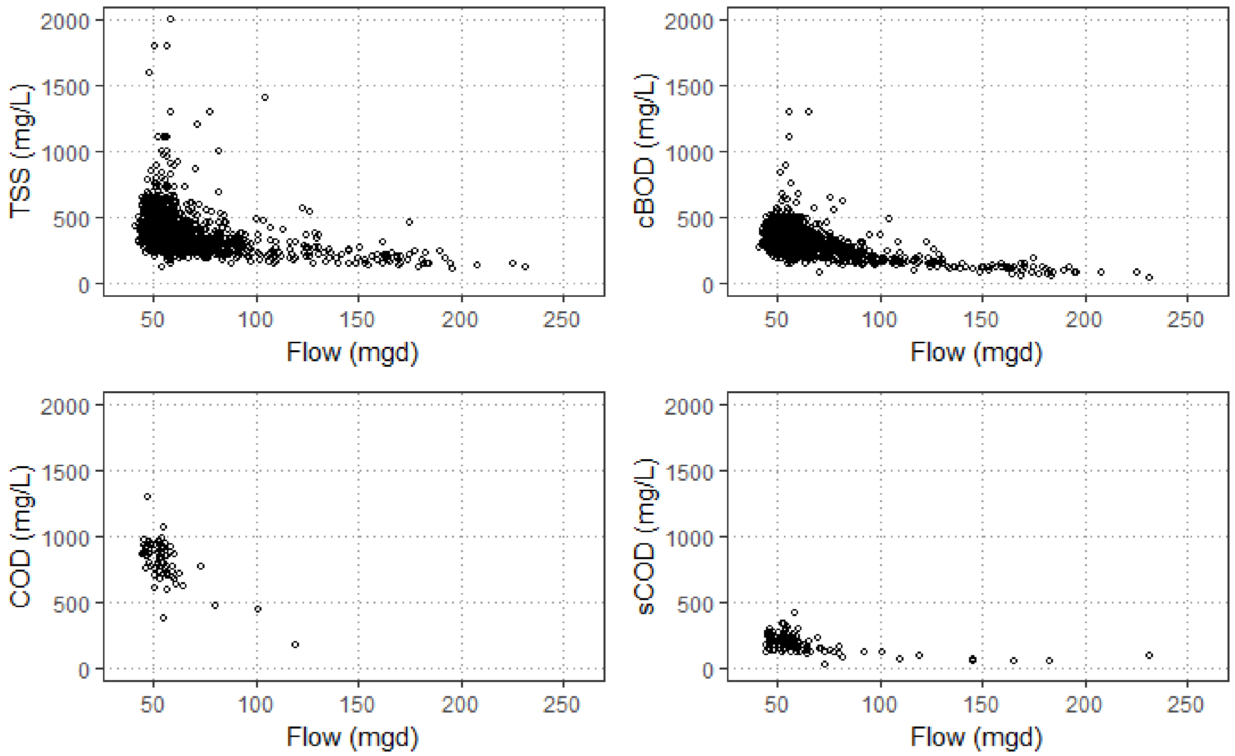


Figure 4-3 TSS, cBOD, COD, and sCOD Influent Concentrations vs Daily Flow

4.2.6 Nutrients (nitrogen and phosphate)

Total Nitrogen (TN), Total Inorganic Nitrogen (TIN), and Organic Nitrogen were calculated using the following:

TN = TKN + NOx-N

TIN = Ammonia-N + NOx-N

Organic N = TKN – Ammonia-N

TN, TIN, and Organic-N concentrations in the Influent (INF), Secondary Influent (SI), and Final Effluent (FE) locations are presented in Figure 4-4. Both TN and TIN increased in the Secondary Influent location compared to the Influent location because this sampling location is downstream of the centrate return. Comparing the concentrations between the SI and FE locations, it clearly indicated some nutrient reductions (an average of 11 mg/L reduction).

It's worth noting that a low concentration of NOx-N is continuously detected at the Influent sampling location, which is not typical for WWTPs. It's very likely that low-strength liquid municipal and industrial wastewater addition to the plant influent (via the Septage Receiving Stations) may be accountable, as some R2 wastes have been found containing high NOx concentrations. Refer to Table 4-4 for actual and typical nutrient values. NOx-N concentrations were also measured at the Secondary Influent and Final Effluent locations at 1.1 and 2.9 mg/L respectively.

Table 4-4. Typical Nutrient Values

Parameter	**Actual Values**		**Typical (Book) Values**[1]		
	Concentration, mg/L Average (Range)	**Mass Loading, klb/day Average (Range)**	**Concentration, mg/L**[2]	**Concentration per capita, lb/capita/day (g/capita/day)**	**Mass Loading, klb/day**[3]
TN	54.5 (21-69.5)	27.6 (21.5-37.7)	Same values as TKN[4]		
TIN	35.7 (11.5-51.4)	17.2 (13.8-32.0)	Same values as NH3-N[4]		
Organic N	20.3 (4.9-33.4)	10.4 (3.0-21.1)	29	0.012 (5.5)	8.2
NH3-N	32.2 (8.2-47.7)	15.4 (11.5-21.3)	40	0.017 (7.7)	11.6
NOx-N	3.5 (0.5-10.0)	1.8 (0.2-9.0)	0[4]	0[4]	0[4]
TKN	50.8 (16.5-64.7)	25.5 (19.8-34.7)	70	0.15 (13.2)	105.5
TP	8.6 (2.8-13.0)	4.2 (3.1-6.3)	11	0.0046 (2.1)	3.2
OrthoP	4.3 (0.8-9.3)	2.0 (1.0-3.9)	--	--	--

1. All typical (book) values based on M&E, 5th Ed., Table 3-16.
2. Assumes 50 gal/capita/day
3. Assumes 685,000 residents in the SD-1 service area.
4. Normal municipal wastewater typically has no nitrite or nitrates.

Figure 4-5 shows nitrogen concentration changes with the influent flow—as influent flow increases, the concentration of the constituent decreases. Additional figures are provided in Appendix C to show the monthly and yearly concentration and loading for TIN, Organic-N, and TN in Figure C-8, Figure C-9, Figure C-10, and Figure C-11 respectively.

Please note, in the figure below and all subsequent figures of similar formatting are box and whisker type plots. The boxes indicates the 1st quartile (or percentile), median, and 3rd quartile and the whiskers indicates the minimum and maximum. If outliers exists, then whiskers extend out by 1.5*IQR from the 1st and 3rd quartile, where IQR is the range between 3rd and 1st quartile. Generally, outliers at the MWWTP do exist and are a result of wet weather flows and not due to erroneous data.

The Total Phosphate (TP) and Ortho-phosphate (as-P) concentrations and loadings are shown in Figure 4-6, Figure C-12, and Figure C-13. Figure 4-7 provides a summary of the phosphate as a function of influent flow. Similar to the nitrogen-based nutrients, as influent flow increases, the concentration decreases due to dilution.

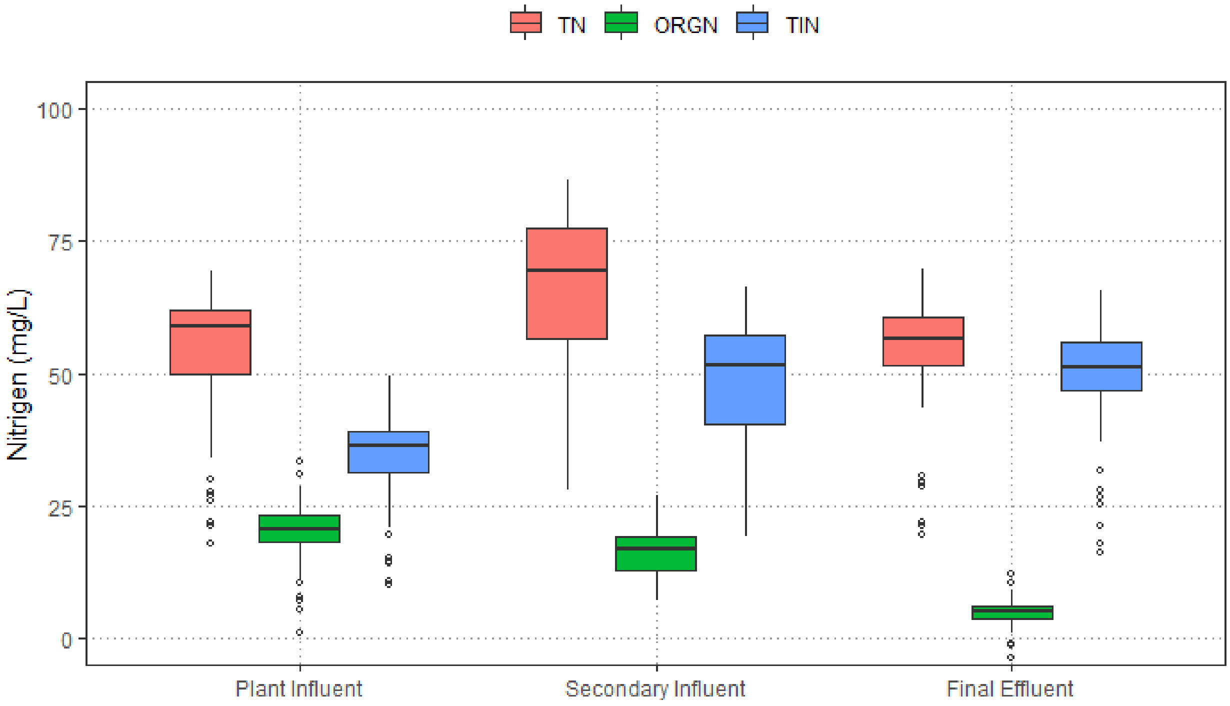


Figure 4-4 Nitrogen Concentrations Through Plant

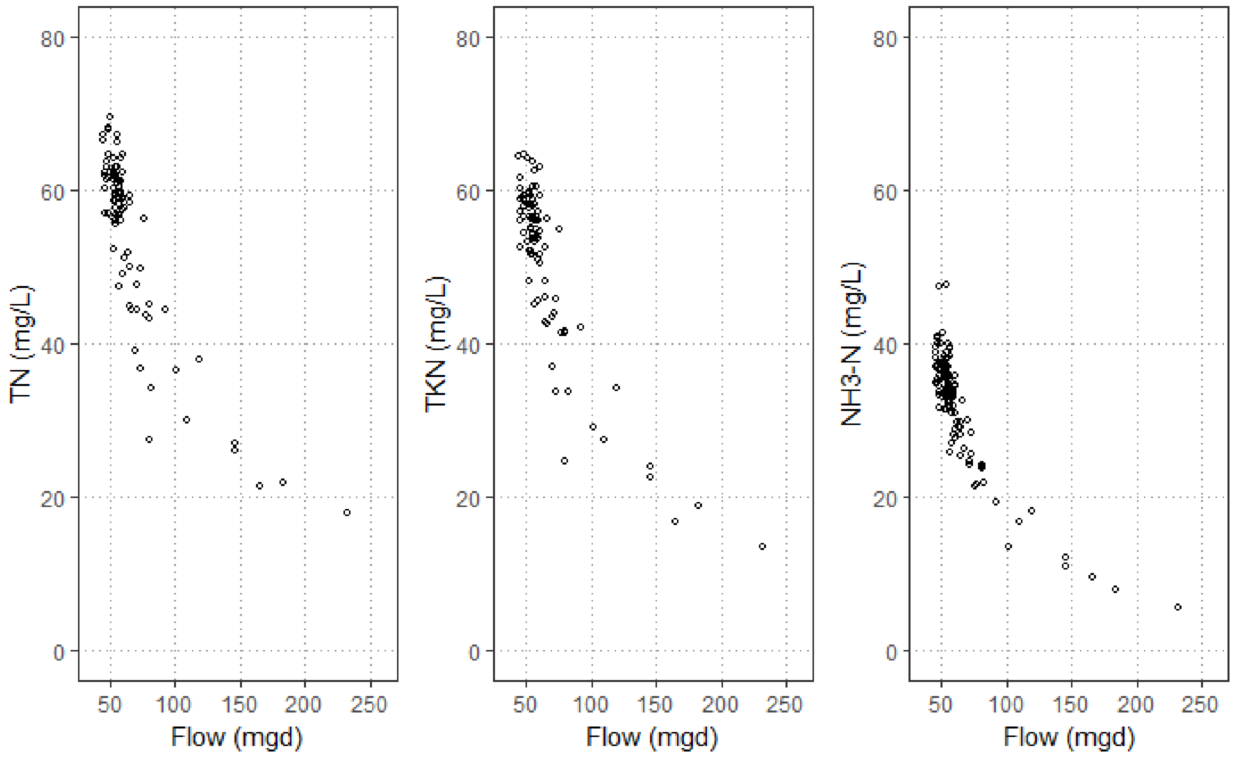
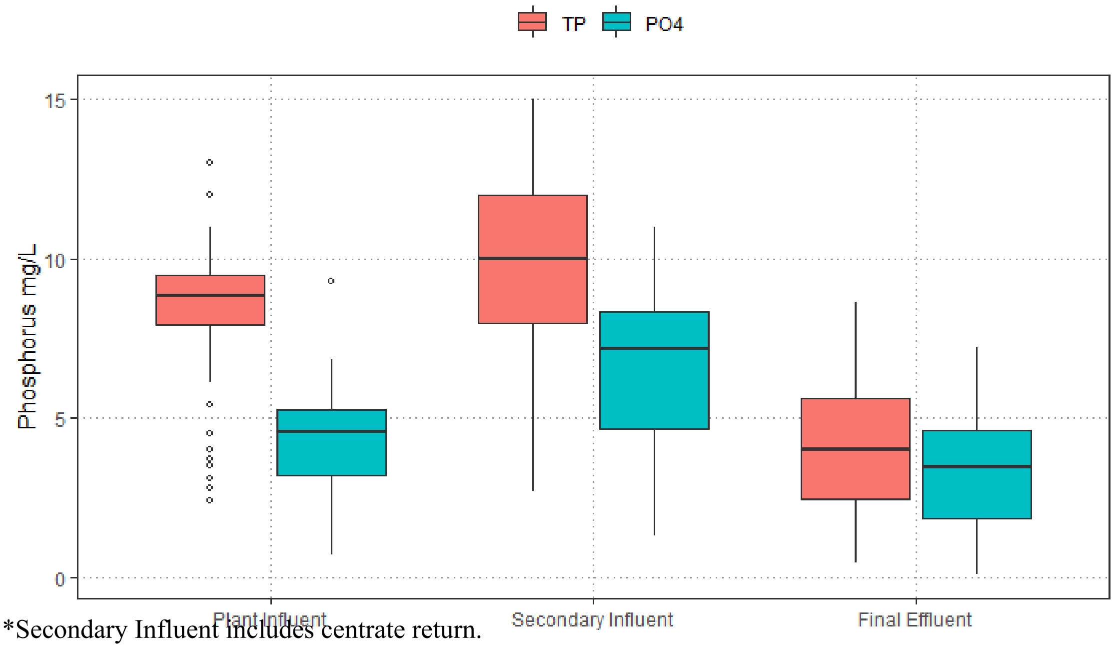


Figure 4-5 Influent Nitrogen (TKN and TN) Concentrations vs Daily Flow



*Secondary Influent includes centrate return.

Figure 4-6 Phosphate Concentrations Through Plant

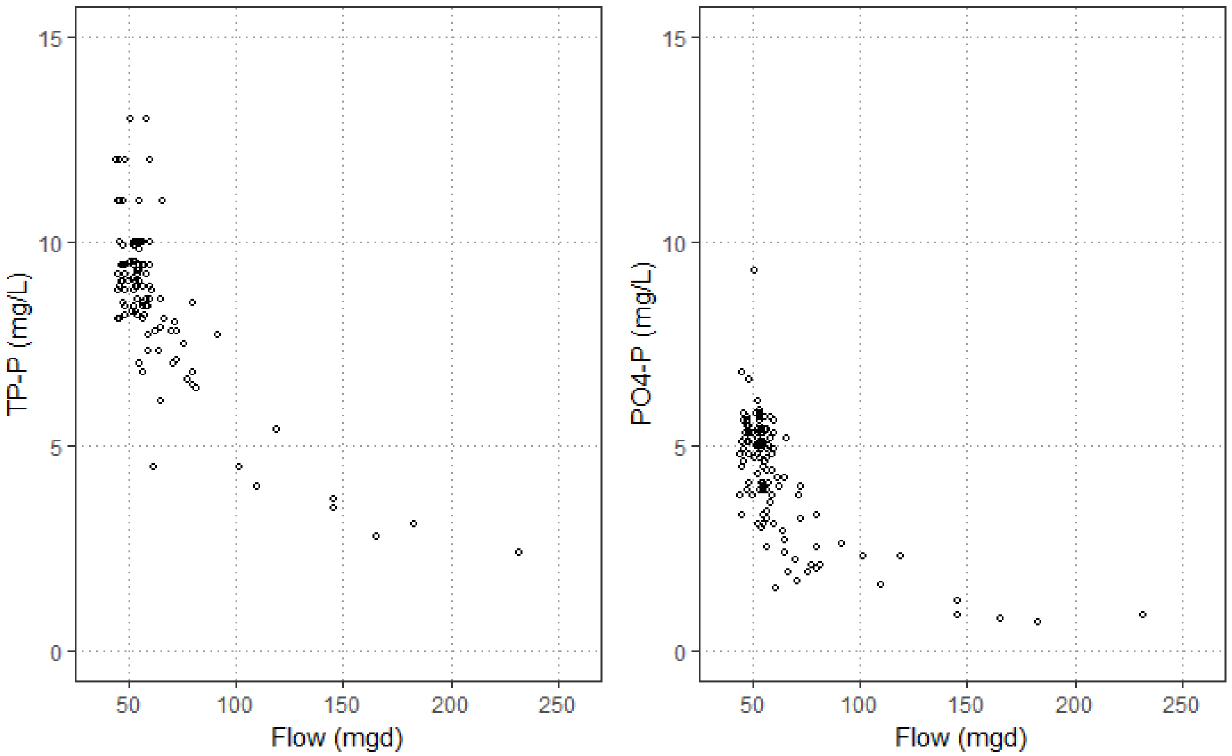


Figure 4-7 Influent Phosphate Concentrations vs Daily Flow

4.3 Influent Pumping Station

The Influent Pumping Station (IPS) consists of 3 sub-structures: the Intake Chamber, the Pump Station Building, and the Fine Screen Building. Wastewater enters the Intake Chamber from the 84-inch diameter North Interceptor, the 60-inch diameter Adeline Interceptor, and the 108-inch diameter South Interceptor. These interceptors flow into the intake structure 35 feet below ground level. At the bottom of the intake chamber there are two pre-chlorination diffusers, the north and the south, which introduce chlorine into the wastewater flow for odor control. Flow is diverted through five inlet sluice gates, into five inlet channels, through five coarse bar screens to the suction side of the Influent Pumps. The wastewater is then lifted approximately 25 feet and passed through the Fine Bar Screens, discharged into Effluent Channel No. 6, and flows on to the next treatment process (grit removal).

With all five Pumps operating, IPS design capacity is 425 mgd (415 mgd plant influent flow and 10 mgd recycle flow) for peak wet weather conditions. No standby Influent Pump is provided; however, there is a standby drive.

4.3.1 Coarse Screens

The purpose of the Coarse Screens is to remove large particles from the plant influent before they reach the Influent Pumps. The screens protect the moving parts (especially the impeller) of the pumps and reduce the chance of them clogging.

The Coarse Screens are located in the Inlet Channels, just before the Influent Pumps. There are five Coarse Screens, one in each Channel. Each Coarse Screen is made of stainless steel tubes welded together with 6-inch clearances between each section. One end of the Coarse Screen sits on the floor of the Inlet Channel and the other end is hinged at the floor of the Coarse Screen Room. These screens are manually cleaned.

4.3.1.1 Design Criteria

The coarse screen design criteria are provided below.

Table 4-5. IPS Coarse Screen Design Criteria

Parameter	Design Criteria
Coarse Screen	
Quantity, #	5
Type	Manual
Channel Width, ft	8.0
Bar Clearance, in	6.0

4.3.1.2 Operational Experience

Operations indicate that the coarse screens work as they were designed and prevent only the very large objects from passing through. Smaller objects, including elongated but narrow objects, less than 6-inches will pass through the bars and cause problems downstream. Rags will also buildup on the screens and force a temporary shutdown to clean each screen manually. There are no differential pressure sensors installed to determine when cleaning is required. There are minimal controls or machinery in use at this process.

4.3.2 Influent Pumps

The purpose of the Influent Pumps is to lift incoming wastewater up to a higher elevation so that the wastewater can flow through the various treatment processes. The Influent Pumps are located in the Main Pump Room of the IPS. There are five Influent Pumps. Each Influent Pump is a vertical, dry-pit, single suction, radial-flow centrifugal wastewater pump rated at 85 mgd. With all five pumps operating, the IPS pumping capacity is 425 mgd. No standby Influent Pump is provided. A 48-in magnetic flow meter is provided downstream of each influent pump.

Each pump has a lubrication system, seal water system, and pump discharge valve, which serves both as the isolation valve and the check valve.

The pumps are operated by six LCI drives and five synchronous motors. Each motor is dedicated to an Influent Pump. Similarly, one drive is dedicated to an Influent Pump and motor. The sixth drive is a standby and can be used to operate any of the Influent Pumps.

The purpose of the Load Commutated Inverter (LCI) Variable Frequency Drive and synchronous Influent Pump motors is to control the operation and speed of the Influent Pumps. The LCI drive and motor provide variable speed control for Pumping. Variable speed is used to accommodate the wide variation in flow rates with fewer Pumps.

4.3.2.1 Design Criteria

The influent pumps design criteria are provided below.

Table 4-6. IPS Pumps Design Criteria

Parameter	Design Criteria	Actual Average	Actual Range
Influent Pumps			
Quantity, # (duty+standby)	5+0	--	--
Type	Vertical Dry Pit Centrifugal	--	--
Capacity, each unit, mgd	85	78[1]	60-94[1]
Total Capacity, mgd	425	390[2]	--
Total Dynamic Head, ft	35	--	--
Discharge velocity, ft/s	4.9-10.5	--	--
Motors		--	--
-Type	Drive Units Load Commutated Inverters (LCI) with Synchronous motors		
-Quantity, #	5		
-Horsepower, HP each unit	700		
-Maximum Speed, rpm	400		
Flow meter Type and Size	42-in magnetic	--	--

1. Pump capacity, actual average and ranges, are based on pump tests done in dry weather flows in 2017-2019 using an inlet WSEL of approximately 90-ft. Additional flow is very likely possible if the inlet WSEL is increased (surcharging the interceptor system). However, for conservative reasons, 390 MGD is used instead in this document.
2. During the 2010-2019 analysis period, the maximum flow occurred at 400 MGD in January 20, 2010. The second highest peak flow was 349 MGD occurring in December 12, 2012.

4.3.2.2 Operational Experience

Operations indicates that the influent pumps tend to push more debris and rags through the fine screens if only one pump is in operation. As such, operators generally prefer to operate two pumps instead of one during dry weather flows (40–85 MGD) to reduce the amount of load on the fine screens.

Recent flow testing done in 2017-2019 indicating the individual pumping flow rates are provided in the table above. These pumping tests were done assuming the upstream wetwell elevation was at approximately 90 to 91 feet water surface elevation and done with one pump at a time during dry weather flows. The tests indicate that each pump, on average, provides approximately 78 mgd at any given time during normal operation. It is noted that some pumps perform better than others and the degradation in flow for the pumps are potentially attributed to wear and tear due to low debris removal by the coarse screens or due to the structural modifications done in the influent channels in recent years (bollards installed for fine screen performance improvements); however, these reasons for the pumping degradation are not confirmed. It is likely that the pumps don’t meet the rated capacity consistently due to a multitude of reasons.

The discharge valves and gates also do not seal, here and throughout the IPS building’s wastewater channels and pipelines.

4.3.3 Fine Screens

The Fine Screens remove the smaller debris from the incoming wastewater before treatment. Any particles larger than the bar clear openings are intercepted by the Fine Screens and removed.

The Fine Screens are located in the Fine Screen Room of the IPS. There are five Fine Screens, one in each discharge channel. Fine Screens 3-5 are climber-type mechanical bar screens with 3/4" bar clear openings. Fine Screens 1 and 2 were replaced with Duperon screens (with 1/4-in clear opening) equipped with washer compactors. The fine screenings from both sets of fine screens are dumped onto the Belt Conveyors to the dumpster and eventually hauled away to landfill.

4.3.3.1 Design Criteria

The fine screens design criteria are provided below.

Table 4-7. IPS Fine Screens Design Criteria

Parameter	Design Criteria
Fine Screens (1/4”)	
Quantity, #	2
Type	Duperon Flex rake
Maximum Flow, mgd	106
Channel width, ft	8.0
Channel depth, ft	11.5
Opening between bars, in	0.25
Approach Velocity (40-85 mgd), ft/s	1.3-2.4
Fine Screens (3/4”)	
Quantity, #	3
Type	Climber

Maximum Flow, mgd	106
Channel width, ft	8.0
Channel depth, ft	11.5
Opening between bars, in	0.75
Approach Velocity (40-85 mgd), ft/s	1.3-2.4

4.3.3.2 Operational Experience

Operations indicate the fine screens works as they should after significant manufacturer research and modification after installation on the newer ¼" screens. The fine screens (1/4") bars are wearing out fast at the bottom. Since installation in 2014, the bars have lost 50% of its metal bar depth. All metal rakes now have teeth, causing further wear (4x of original design). The fine screens rakes work on an automated system.

The newer fine screens are also equipped with a washer compactor. The compactor will occasionally fail due to a blockage upstream of compactor inlet (at the hopper) and the trash/rags will then pile up due to the blockage.

4.4 Grit Removal

Grit removal at the MWWTP is done using one of two systems: the Aerated Grit Tanks (AGT) or the Vortex Grit Tanks (VGT). The AGTs are used in the wet weather and/or when flows are high, while the VGTs are used during dry weather.

4.4.1 Aerated Grit Tanks

Aeration is provided to influent and effluent channels for all Grit Chambers, and the Grit Chambers itself, to maintain the grit and organic material in suspension. Aeration also keeps the wastewater from becoming septic.

The aeration system is made up of two 5,000 cfm and two 2,000 cfm Aerated Grit Blowers located in the blower building east of Chamber 5 and 6, and aeration headers located in aerated grit influent and effluent channels and AGTs.

The primary purpose of this configuration is to induce a roll mixing action. Wastewater enters the Chamber just above the aeration headers. The rising air bubbles cause the water to form a roll along the width of the Chamber. Constant roll mixing of the Chamber's content keeps the lighter organic matter suspended while the heavier inorganic or grit material settles to the bottom of the Chamber. However, the AGTs may be improved as the current rolling action is not a helical roll therefore there is only one chance for solids to settle out.

4.4.1.1 Design Criteria

The AGT's original design criteria are provided below.

Table 4-8. AGT Design Criteria

Parameter	Design Criteria	Typical (Book) Value[1] Typical, (Range)
Tanks, #	8	--
Volume (Each), gal	215,000	--
Total capacity, mgd	425	--
Detention Time, at Peak Flow, min	5.8	3 (2-5)
Blowers		
Type	Multistage Centrifugal	--
Quantity, #	4	--
Horsepower, hp	2 @ 250 2 @ 100	--
Discharge pressure, psia	22.2	--
Flow, cfm	2 @ 2,000 2 @ 5,000	--
Grit pumps		
Total Dynamic Head, ft	75	--
Flow, gpm	300	--
Horsepower, hp	30	--
1. M&E, 5th Ed, Table 5-17		

4.4.1.2 Operational Experience

Operations indicate all AGTs tanks are normally in service during wet weather. The AGTs have poor grit removal performance and are not built correctly to achieve helical mixing. In addition, fine sands will pass through this process. In early 2019, the Operators experienced tons of very fine sand passing through the AGTs and into the primaries—source was undetermined and the damage to the PSTs chain and flight systems were significant.

The blowers are in okay condition, however, only three of the four are in operation. Operations indicates that two small blowers or one large blower is needed to operate the AGTs sufficiently.

4.4.2 Vortex Grit Tanks

There are two Vortex Grit Tanks located to the South of the AGT bypass channel; each has a design flow capacity of 30 mgd minimum to 70 mgd. Due to high velocities and headloss, the system was derated by approximately 50% and only run during the dry weather months with both units online. Each VGT has two dedicated grit pumps and a mixer. The VTG pumps send grit to the Grit Dewatering Building for disposal at landfill. Refer to the Appendix H for additional information regarding the VGT performance.

4.4.2.1 Design Criteria

The VGT's original design criteria are provided in table below.

Table 4-9. VGT Design Criteria

Parameter	Design Criteria
Type	Smith and Loveless Model 70A
Units, #	2
Rated Capacity (each), mgd	30-70
Derated Capacity (each), mgd	35
Grit Pumps	
Type	Wemco Model C
Flow, gpm	500
Total Dynamic Head, ft	80
Speed, rpm	830
Mixer	
Horsepower, hp	2
Units, #	2

4.4.2.2 Operational Experience

Operations indicate the VGTs are normally only operated during dry weather, as the wet weather flows exceed the treatment capacity of the VGTs. The VGTs are not efficient in removing grit (worse than the AGTs) and flow cannot be controlled into the two VGT tanks causing uneven flow through each tank.

4.4.3 Grit Dewatering Building

The Grit dewatering building dewaters the grit flow from both the AGTs and the VGTs. The grit is hauled off in a trailer and the wastewater disposed of in the interceptor (directly upstream of the IPS).

4.4.3.1 Design Criteria

The Grit Dewatering Building's original design criteria are provided below.

Table 4-10. Grit Dewatering Building Design Criteria

Parameter	**Design Criteria**
Dewatering Equipment Type	Hydrocyclone + Grit Classifier
Treatment Trains, #	1 New (2 grit separators to one classifier), 5 Original (3 grit separators to one classifier)
Flow per train, gpm	1 @ 1,000, 5 @ 1,600-1,700
New Grit Dewatering Train Performance Requirements	Cyclone underflow of <32 gpm @ 500 inlet flow and >95% removal with particle size 0.1 mm (150-mesh) from the vortex grit tanks. Max 1,500 lbs of grit per hour with screw auger discharge TS concentration at >60% by weight
Old Grit Dewatering Train Performance Requirements	95% of 200 mesh and larger grit at 2.65 S.G. Unit feed assumption of 2% grit slurry or 2% sludge concentration
Grit Separator (New)	
Unit Quantity, #	2
Type	Hydrocyclone
Manufacturer/Model	Wemco Model 1500 Cyclones
Cyclone Diameter	15
Flow, gpm/unit	500
Inlet Pressure, ft	16.5
Maximum Underflow, gpm/unit	32
Grit Separator (Old)	
Unit Quantity, #/train	15
Type	Hydrocyclone with adjustable table apex valve
Manufacturer/Model	Wemco
Flow, gpm/unit	533-567

Grit Classifier (New)	
New Unit Quantity, #	1
Type	Screw
Model	Wemco Model 30 F Classifier
Screw Diameter, in	30
Flow, gpm	140
Grit Classifier (Old)	
New Unit Quantity, #	5
Type	Screw
Model	Wemco
Flow, gpm	1,600-1,700
*Information from construction project (SD-120 and SD-260) specifications and the 1980 O&M Manual.	

4.4.3.2 Operational Experience

Operations indicate all the Grit Dewatering Building's grit separation equipment works fine with plenty of redundancy. However, Operations notes the following issues related to operations:

- The pressure and flow are not measured on the grit separator equipment.
- The grit trailer bay has a low overhead clearance; this prevents the haul-off truck from being able to park the trailer in the optimal location for grit distribution within the trailer.
- There is no way to measure the weight of the trailers. Operators have to dump grit out at the SLW receiving station area when they overfill. The trailers have pressure sensors, but that can't be easily used to convert into pounds.
- Drivers need to reposition the trailer under the hopper with every load so the grit is evenly distributed in the trailer. When driver is not available, staff has to manually move the grit inside the trailer with a rake while standing on a ladder.
- This building is a source of odors—specifically from the grit trailer and trailer's drainage. This building does not have its own odor control system.

4.5 Primary Sedimentation Tanks

There are a total of 16 sedimentation tanks. Each tank is 174-ft long by 36-ft wide and 10.5-ft deep. Each tank holds 492,000 gallons with a maximum flow of 23 million gallons per day. This allows a maximum flow of 322 MGD through the primary sedimentation tanks with 2 out of service.

The PSTs are normally operated with eight or nine in service during dry weather and up to sixteen tanks in service during wet weather for maximum treatment. Number of tanks in service generally depends on the availability and predicted flows. Refer to Figure C-2 regarding the historic average number of tanks in service on a monthly or annual basis.

4.5.1 Design Criteria

The Primary Sedimentation Tank (PST)'s original design criteria and current operating conditions are provided in Table 4-11.

Table 4-11. PST Design Criteria vs Current Operating Conditions

Parameter	Design Criteria	Actual Average, (Range)	Typical (Book) Value[1] Typical, (Range)
Tanks (duty + standby), #	14+2	9.7, (7-16)	--
Volume, gal	492,000	--	--
Surface Area, sqft	6,250	--	--
Unit Capacity, mgd	23	--	--
Overflow Rate (gpd/sf)	1,200 @ 120mgd	1,109, (781 - 2,830)	1,000, (800-1,200)
Peak Hourly Overflow Rate (gpd/sf)	--	See above.	2,500, (2,000-3,000)
Detention Time (hrs)	1.5 @ 120mgd	2, (1-3.3)	2, (1.5-2.5)
Percent TSS Removal (%)	--	63, (0-93)	--, 42-70
Percent BOD Removal (%)	--	50, (0-87)	--, 22-46
Weir Loading (gpd/ft)[2]	--	--	20,000, (10,000-40,000)

1. M&E 5th Ed, Table 5-19.
2. The weir loading rate has little effect on PST efficiency and is therefore not calculated.

4.5.2 Operational Experience

Operations indicate the following operational issues at the PSTs:

- Weirs are not level (currently planned to be fixed in 2023)
- Primary sludge pumps are obsolete and replacement parts are difficult to obtain

- Sludge pumps get overwhelmed and stops pumping if sludge blanket gets too thick; backwashing required to resume operation.
- Pumps will trip on high pressure, occurs when new aftermarket parts are installed causing the system to be overloaded.
- Piping in the West Gallery (west of clarifiers) is inaccessible by vactor truck and cannot be cleaned out without disassembly. In addition, unnecessary elbows are likely causing pumping problems and clogging and there are insufficient clean outs.
- Tanks 1-10's shared scum system occasionally overwhelmed in wet weather rain flows. The excess water from the tanks flow into the scum trough/skimmer system and overwhelms the scum pumps.

4.5.3 Overflow Rate and Hydraulic Detention Time

The overflow rate and detention time of this system is provided in Figure 4-8 and Figure 4-9. Compared to the industry average range, the PST detention time have regularly exceeded the book value's maximum normal overflow rate but are also almost always lower than the peak overflow rate.

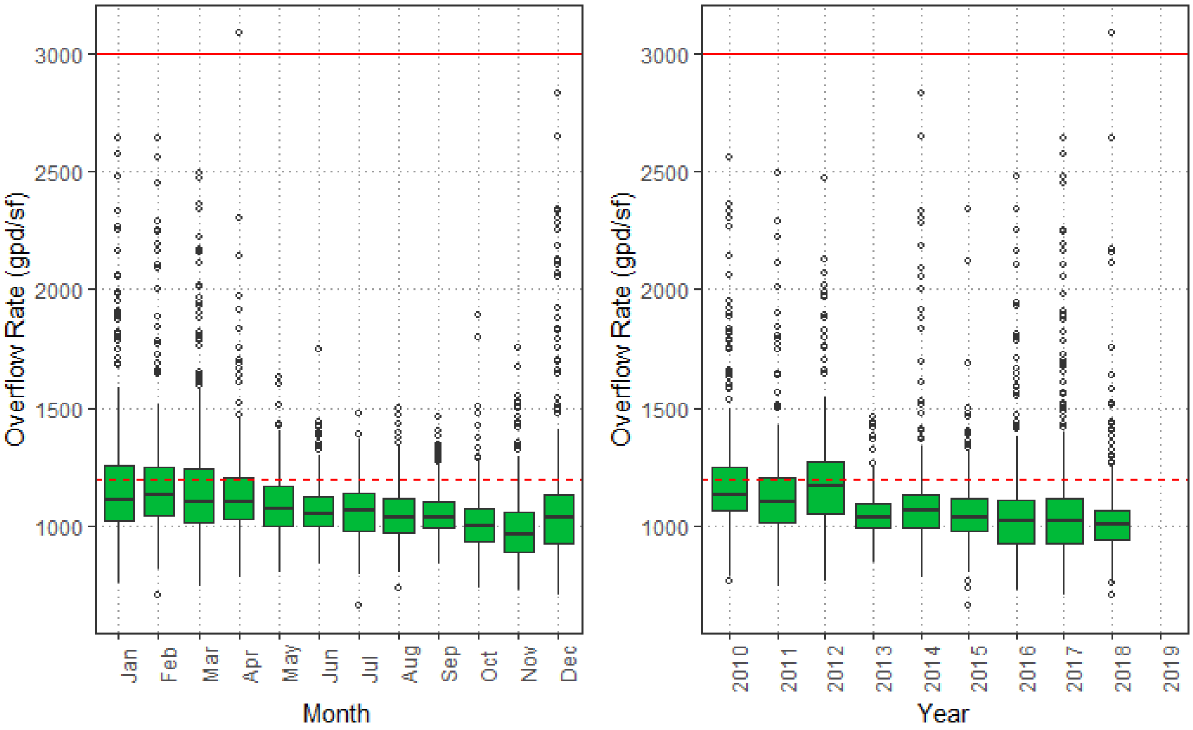


Figure 4-8 PST Overflow Rate (Monthly and Annual Averages)

The average detention time of 2 hours is the same as the typical book value. However, the detention time is frequently lower than 1.5 hr during the wet season and is not uncommon for treatment plants with biological treatment units (M&E, 4th Ed).

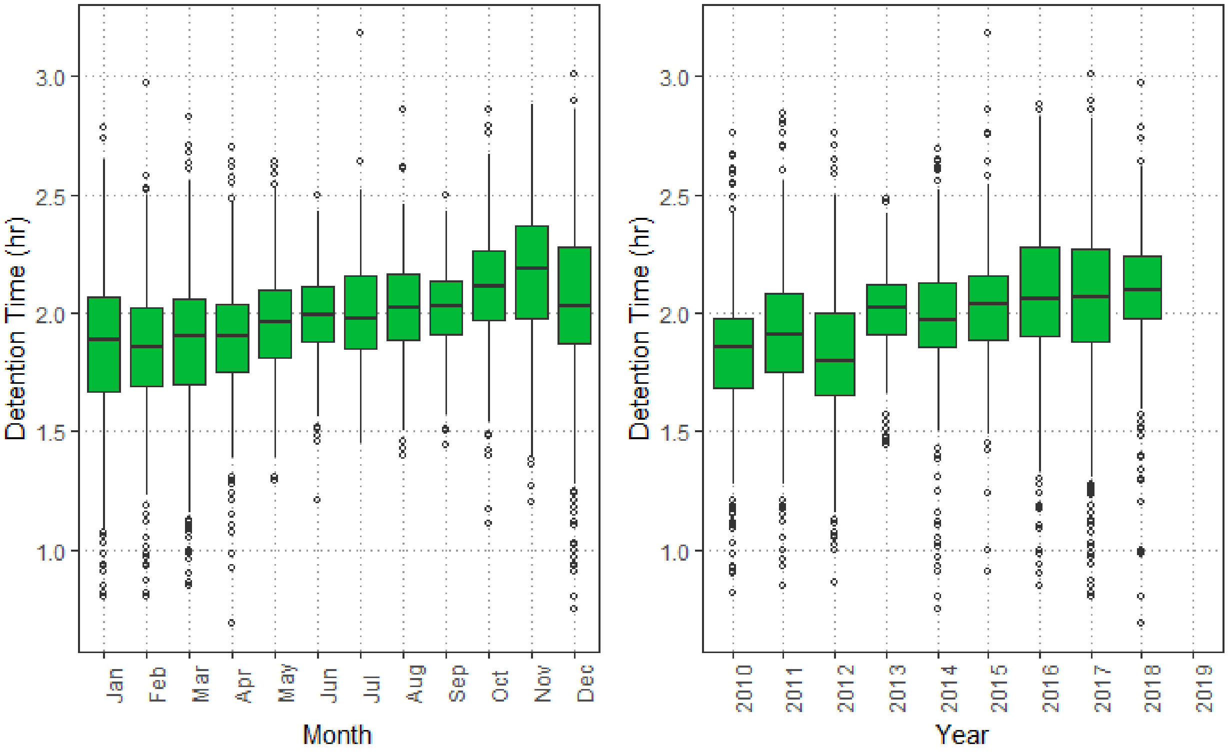


Figure 4-9 PST Detention Time (Monthly and Annual Averages)

4.5.4 Unit Loading Rates

The PST unit loading rates for TSS, cBOD, and COD is provided in Figure D-1.

4.5.5 Treatment Efficiency

The PSTs have a typical median TSS, cBOD, and COD removal percentage as shown monthly and annually in Figure D-2. Please note that the samples for primary influent were taken on a different day than the primary effluent samples. Average percent removal rates are as follows: 66.4%, 51.4%, and 47.1%. This was within or exceeds the general typical average range of 25-70 for TSS and 25-40 for BOD5 and COD (per 2018 WEF MOP No. 8, Table 10.1).

Interestingly, there is only vague correlation between overflow rate and TSS/cBOD/COD removal rates. Consistently, the PSTs do not provide maximal removal during the higher overflow (or flow) rates, however, the PSTs also do not consistently maximally remove the analytes during the lower overflow (or flow) rates. Refer to the figures below for the TSS and cBOD removal rates as a function of overflow rate. Note that COD is not provided due to insufficient data; however, the correlation is expected to be similar.

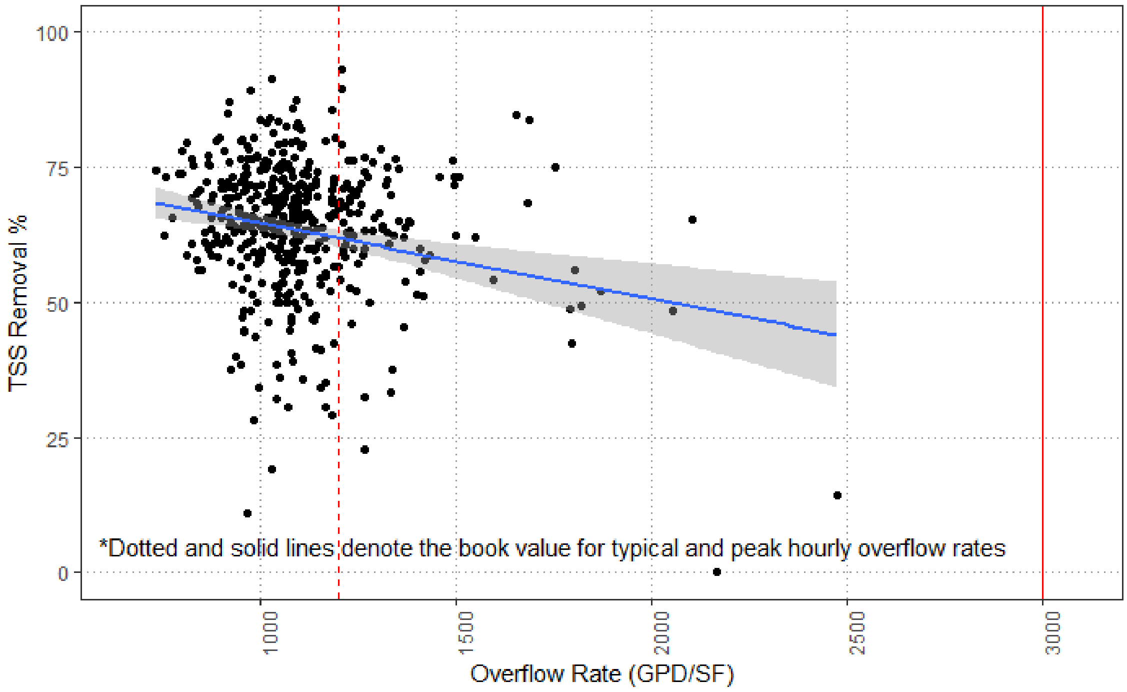


Figure 4-10 TSS Removal vs Overflow Rate

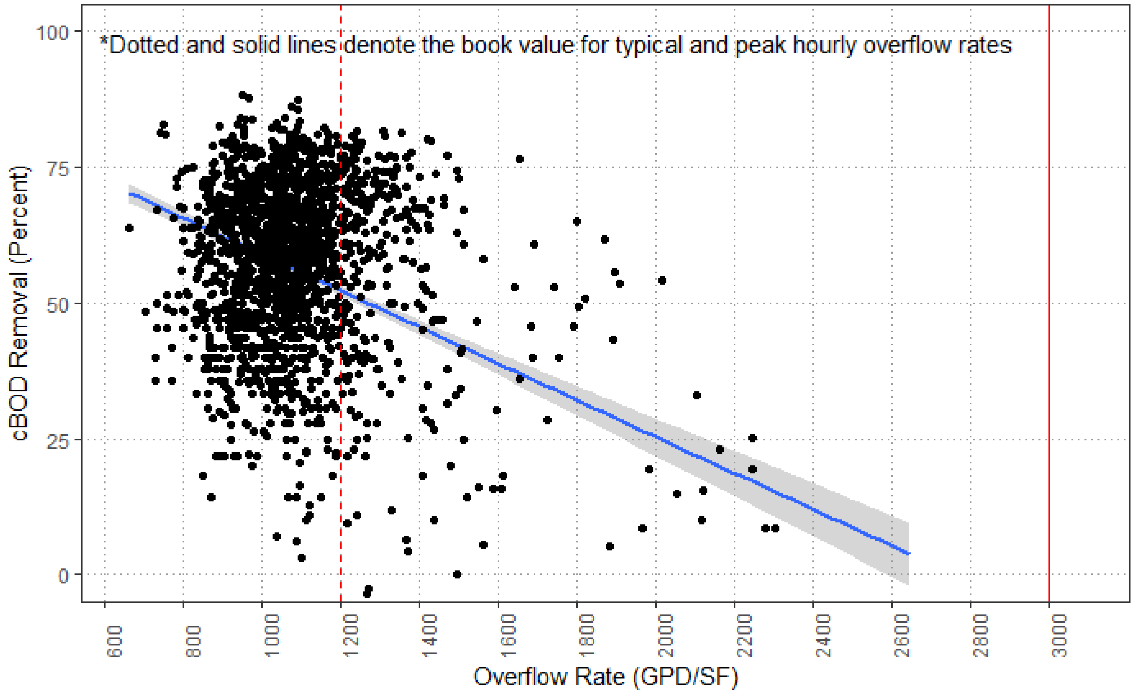


Figure 4-11 cBOD Removal vs Overflow Rate

4.6 Mid-Plant Pumping Station

The Mid-Plant Pump Station is needed to convey a peak wet weather flow of 168 mgd of primary effluent to the Oxygenation Tanks, while preventing submergence of the Primary Sedimentation Tanks' effluent weirs. This pumping station is generally put in service during high flows (around 100 mgd) to provide sufficient water head through the MWTTP. The Mid-Plant Pumping Station's (MPPS) design criteria is provided in Table 4-12.

Table 4-12. MPPS Design Criteria

Parameter	Design Criteria
Pumps (duty + standby), #	2+1
Type	Submersible propeller
Flow, mgd	84
Total Dynamic Head, ft	11.25
Horsepower, HP	250
Motor Speed, rpm	1750

4.6.1 Operational Experience

There are no known operational issues at the Mid Plant Pumping Station.

4.7 Secondary Treatment Overall Treatment

The secondary treatment system is made up of several facilities, as follows:

- Oxygenation Tanks (Reactors)
- Oxygen Production (O2) Plant
- Secondary Clarifiers
- Operations Center (RAS and WAS pumps)

This section describes the overall treatment efficiency of the process related secondary treatment systems (i.e., the Reactors and Clarifiers).

4.7.1 TSS, cBOD, COD

The TSS, cBOD, and COD percent removal rates through the secondary treatment systems (Reactors and Clarifiers) are provided in Figure E-1. The performance of the secondary treatment system on removing TSS, based on clarifier overflow rate, is provided in the figure below. The performance of the clarifier system are slightly best when overflow rate is low, however, there is no significant reduction in removal efficiency as overflow rate increases. An individual clarifier performance and stress testing study was conducted in 2019 and should be referenced if additional clarifier performance details is needed.

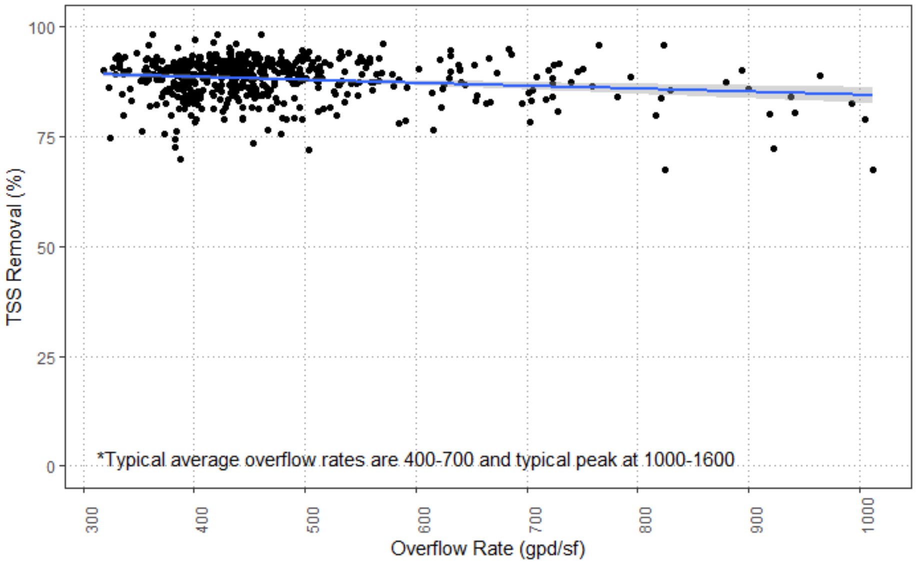


Figure 4-12 TSS Removal as Overflow Rate Increases

The performance of the reactors, based on cBOD removal as a function of the Reactor's hydraulic detention time and sludge retention time, are indicated Figure 4-13. Performance does increase, up to a point, with hydraulic retention time and sludge age as shown in the figure below. Note that COD, while not shown due to a lack of sufficient points, is similar.

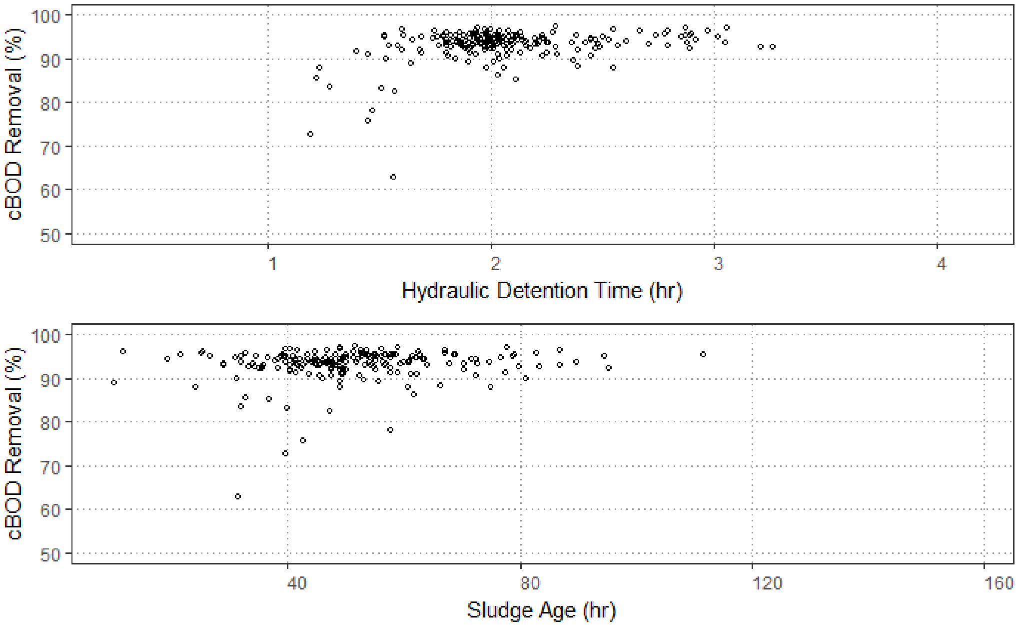


Figure 4-13 cBOD Removal as HRT and SRT Increases

4.7.2 Nutrients

The nutrient removal rates for nitrogen and phosphate based analytes through the secondary treatment systems (Reactors and Clarifiers) are provided in Figure E-3 and Figure E-4. Minimum nitrogen is removed as the secondary treatment system was not designed for nutrient removal. However, the phosphate is removed to a not so insignificant degree, primarily due to metabolic requirements in growing cells in the Rectors. Refer to Figure 4-6 to see the concentrations through the plant.

Much of the nutrient at the plant comes from not only the wastewater influent at the front of the plant but also through the Resource Recovery program through the digesters and centrate. This centrate is deposited from the solids system into the liquid treatment system at the end of the Primary Effluent channel, after the PSTs, and before the Mid-Plant PS.

4.8 Reactors

The eight, four-stage oxygenation reactor trains are the primary bioreactors responsible for removing the contaminants from the wastewater. The number of oxygenation reactors on line can be increased or decreased in response to changing hydraulic loads in order to provide the needed hydraulic detention time. There are eight Reactors which are designed for 21 MGD each but can handle up to 30 MGD at peak flow. Each reactor holds 1.65 million gallons. The first cell in each reactor is used as an anaerobic selector; pure oxygen is introduced into the reactors in the first stage of the reactors.

4.8.1 Design Criteria

The capacity and performance of the Reactors are provided in Table 4-13.

Table 4-13. Reactor Design Criteria

Parameter	Design Criteria	Average	Range (1% to Max)	Book Value
Type	High purity oxygenation	--	--	--
Flow per tank, mgd	21	--	--	--
Tanks (duty + standby), #	8+0	--	--	--
Stages per tank, #	4	--	--	--
Stage Volume, gal	396,000	--	--	--
Reactor headspace Pressure, in	0-10	--	--	--
Detention Time (hrs)	--	2.2	1.4 – 4.2	--
Sludge Retention Time (day)[1]	1.5	2.2	1.0 – 6.6	--

Alpha	.85	--	--	--
Beta	.95	--	--	--
Minimum Dissolved Oxygen at peak load (mg/L)	2	--	--	--
Aerations type	Surface Aerator with draft tubes	--	--	--
Aerator Horsepower, HP	100 in stages 1 and 2; 50 in stages 3 and 4	--	--	--
Aerator Minimum SOTR, lb/hr	255 in stages 1 and 2; 85 in stages 3 and 4	--	--	--
1. Sludge age (days) is calculated as TSS in Reactors (lbs TSS in all cells) divided by the Secondary Influent TSS Loading (lbs/day).				

4.8.2 Operational Experience

Operations indicate the following Reactor operational issues:

- Oxygen sensors do not work and cannot be replaced or accessed.
- Oxygen flow cannot be controlled to individual tanks, Operations significantly over aerates the reactors.
- Tilting weirs tend to lock up in high flows or cold weather. Failure mechanism is unknown.
- Tank drain pumps (also serving the Clarifiers) do not drain the Reactor tanks completely due to insufficient inlet depth. In addition, drain pumping system valves do not seal.

4.8.3 Hydraulic Limitations

The key hydraulic constraint in the secondary treatment system was found to be high water level conditions in the reactors during peak secondary flows, causing amperage exceedances in the Stage 2 aerator motors of greater than the full load amperage (FLA) rating of 112 A. This hydraulic constraint has been observed since the installation of the surface aerators in 1999.

The exact flow rate at which the FLA (112 A) threshold is first reached can vary considerably based on position of the clarifier flow control gates and the number of treatment trains online. For this reason, it is difficult to establish a precise flow rate which accurately represents the hydraulic capacity of the secondary treatment system at all times.

The requirement in EBMUD's NPDES permit to maintain a minimum flow of 150 MGD during blending is achievable. However, it is noted that at flows over 150 MGD, the Stage 2 aerator motors are often in exceedance of the FLA rating (112 A). Operations, if needed, will run the motors beyond the FLA, up to 160 amps, in order to push sufficient flow through the reactors (up to the full design flow of 168 mgd); however, this accelerates wear and tear to the motors. Per the permit, operations is required to maximize secondary treatment whenever possible, as such, the FLA rating is regularly exceeded whenever sufficient treatment trains are available.

Refer to the 2014 MWWTP Secondary Treatment Capacity Evaluation Annual Summary Report 2013-14 for additional information.

4.8.4 Hydraulic and Solids Retention Time

The hydraulic retention time and sludge retention time are shown in Figure 4-14 and Figure 4-15 respectively. Sludge retention time is calculated dividing the TSS in the reactor influent by the total solids in the reactor tanks (all four stages).

The RAS percent return rate are provided in Figure 4-16. This return rate is based on the RAS flow to the Reactors divided by the total secondary influent flow from the PSTs.

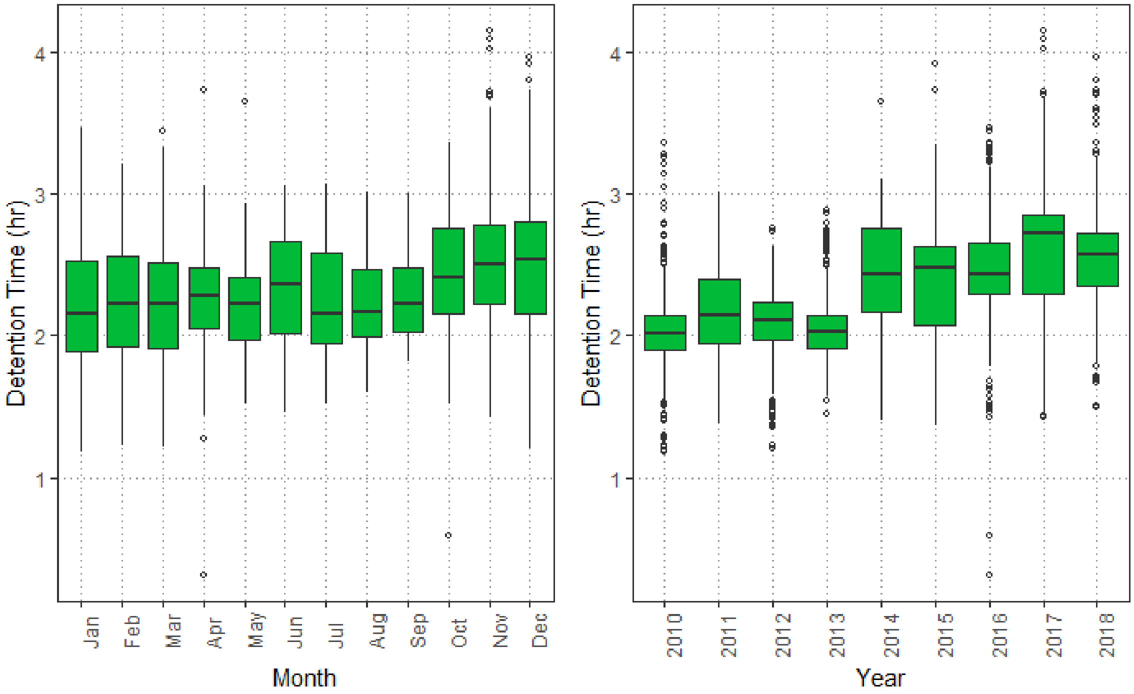


Figure 4-14 Reactor Hydraulic Detention Time (Monthly and Annual Averages)

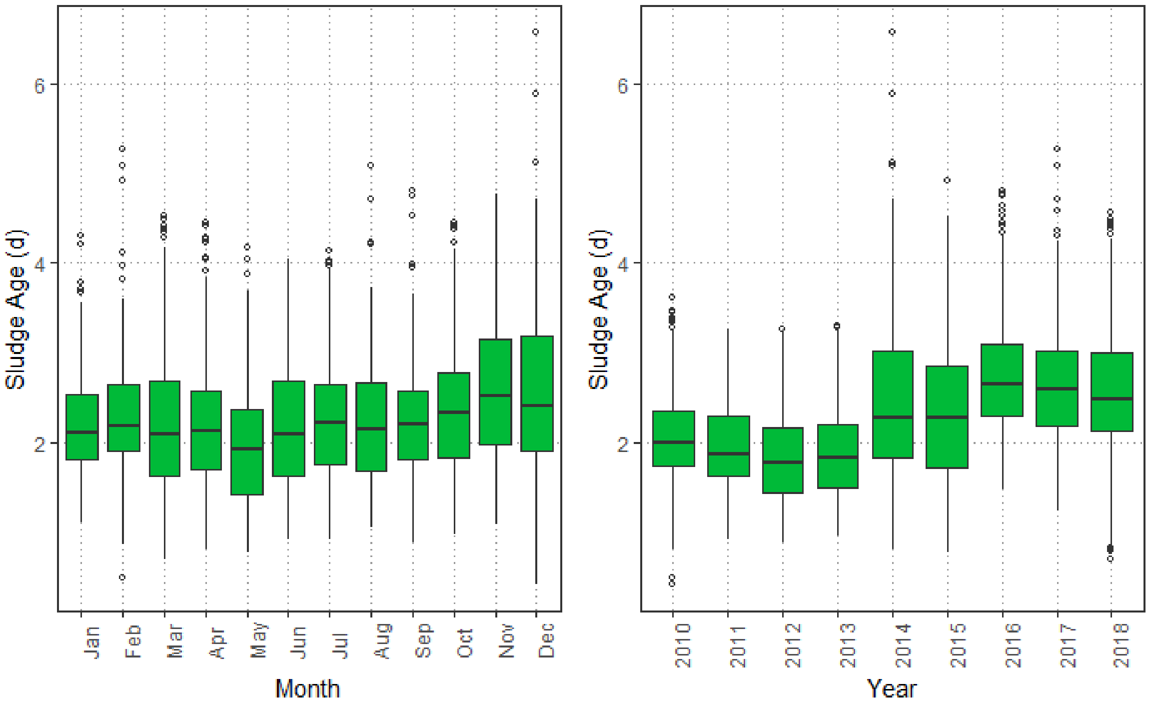


Figure 4-15 Reactor Sludge Age (Monthly and Annual Averages)

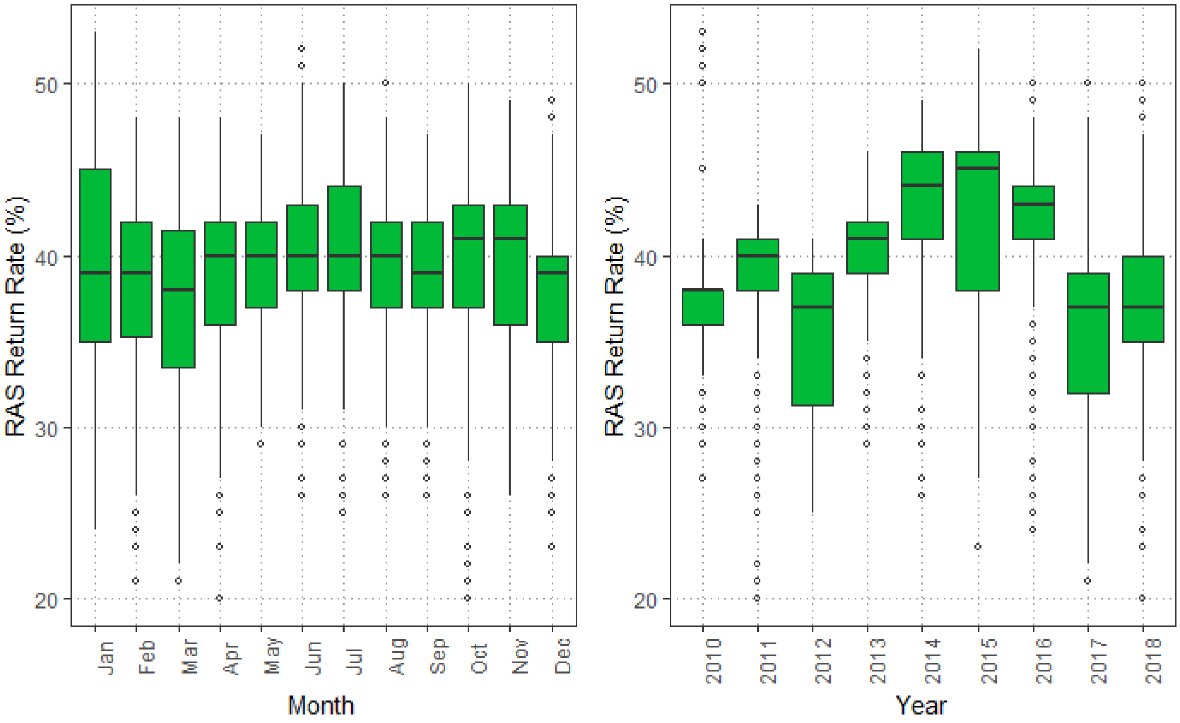


Figure 4-16 RAS Return Rate (Monthly and Annual Averages)

4.8.5 Correlation of TSS, cBOD, and COD with Flow

Generally speaking, the TSS, cBOD, and/or COD concentrations decrease slightly in wet weather flows as shown in Figure 4-17. This is expected due to wet weather flow diluting the concentrations of these constituents. It is interesting to note that the TSS remains fairly consistent as flows increases whereas the COD concentration is reduced. The Reactor unit loading rates are provided in Figure E-2.

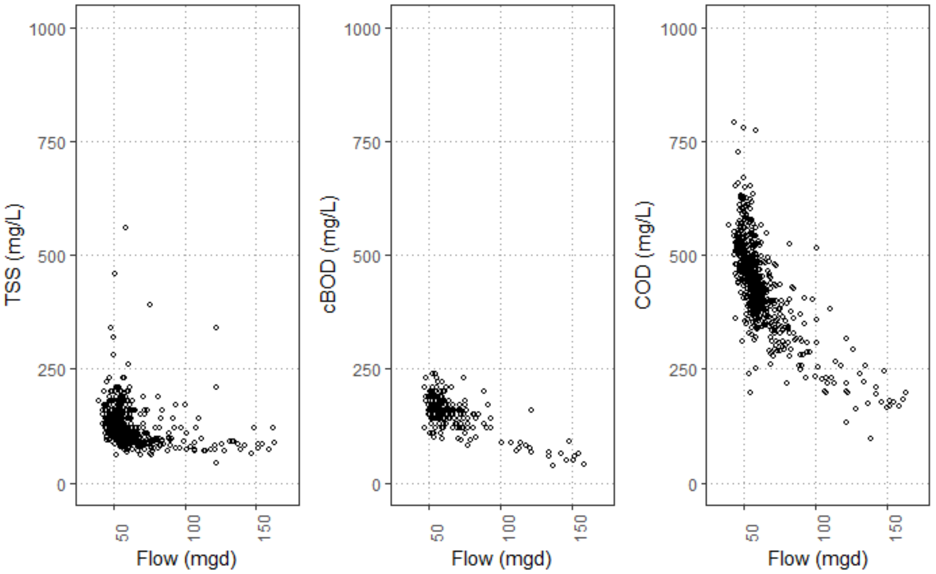


Figure 4-17 TSS, cBOD, COD Secondary Influent Concentrations vs Flow

4.8.6 Treatment Efficiency

The Reactors have a typical TSS, cBOD, and COD removal percentage as shown monthly and annually in Figure E-1. Average percent removal rates (through the secondary treatment process) for TSS, cBOD, and COD are as follows: 88.5%, 93.5%, and 84.5%. This is within the general typical average range of 85-95 for BOD5 per 2018 WEF MOP No. 8.

The monthly average Mixed Liquor Suspended Solids (MLSS) concentration is provided in Figure E-5. The food (cBOD and COD) to microorganism MLVSS ratio is provided in Figure 4-18 and an alternate version using MLSS is provided in Figure E-6. In general, the textbook value for the BOD5 to MLVSS ratio for high-purity oxygen systems is 0.5 to 1.0 (Per M&E, 5th Ed, Table 8-19).

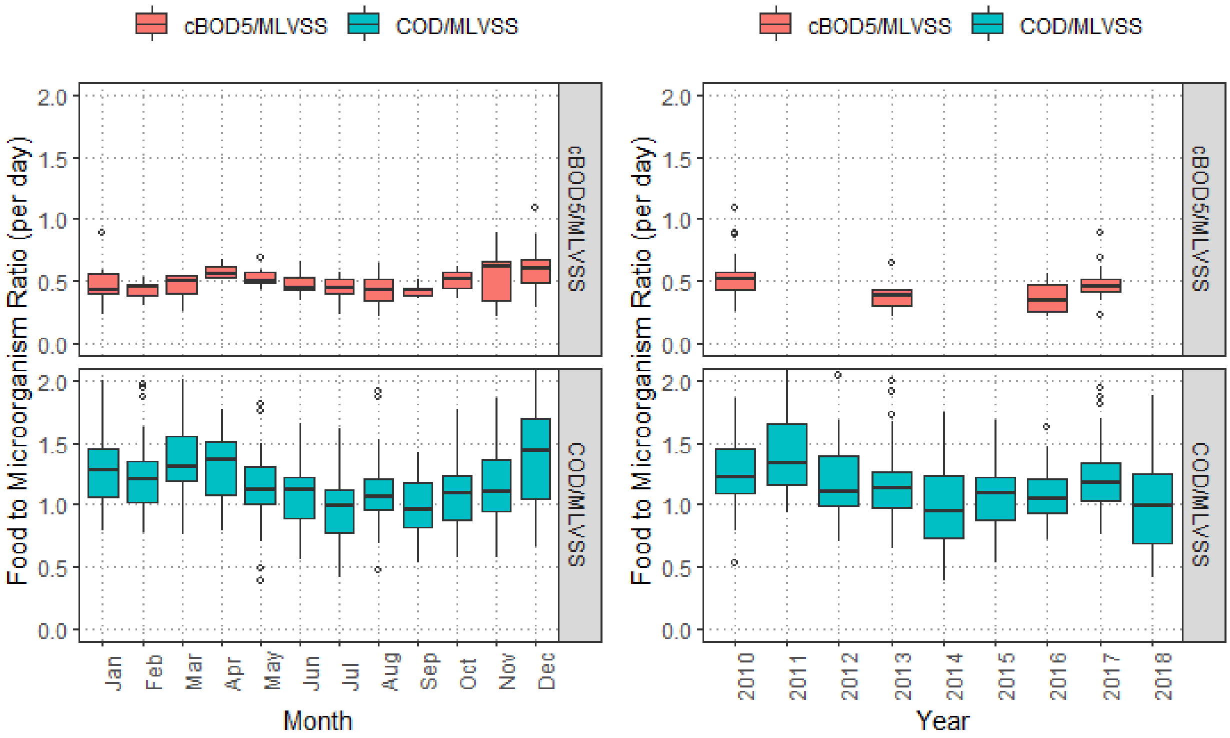


Figure 4-18 cBOD and COD to MLVSS F/M Ratio (Monthly and Annual Averages)

4.9 Oxygenation (O2) Generation Plant

The source of oxygen for our activated sludge process is a cryogenic on-site oxygen generating plant. The facilities consist of two 125 tons per day air separation plants. Each plant is designed to produce oxygen at a minimum purity of 95%. In addition to the oxygen generation facilities, liquid oxygen storage facilities are supplied to store 200 tons. The liquid oxygen storage system is designed to supplement oxygen to the pipeline in the event oxygen demand is more than oxygen production rate, or the oxygen plant is shut down.

4.9.1 Design Criteria

Limited design criteria for the O2 generation plant are provided below. Refer to the 2018 O2 plant assessment study for a detailed and full capacity and performance analysis of the O2 generation plant.

Table 4-14. O2 Production Facility Design Criteria

Parameter	Design Criteria	Actual Operating Range
Type	Cryogenic	
Size, tons/day	125	80-90
Turndown, tons/day @ %	45 @ 35%	
Units, #	2	

Minimum O2 purity, %	95	
Air Compressor, hp	1250	
Number of compressors, #	4	
Number of Liquid O2 Storage Tanks, #	4	
Liquid O2 Storage, gallons per tank	11,000	
Total Liquid O2 Storage, tons	200	

4.9.2 Performance

The monthly averages of the oxygen flow into the Reactors are provided in Figure 4-19. The historical median flow is 85 tons/day ranging from 60 to 127 tons/day. Turndown of the O2 plant to 45 tons/day is possible if needed based on a recent consultant study of the O2 plant (Oxygen System Assessment, 2018); however, turning down the system may causes the system to run unreliably. A 25% reduction in power consumption was demonstrated per the Assessment testing. Refer to the study for a detailed and full capacity and performance analysis of the O2 generation plant.

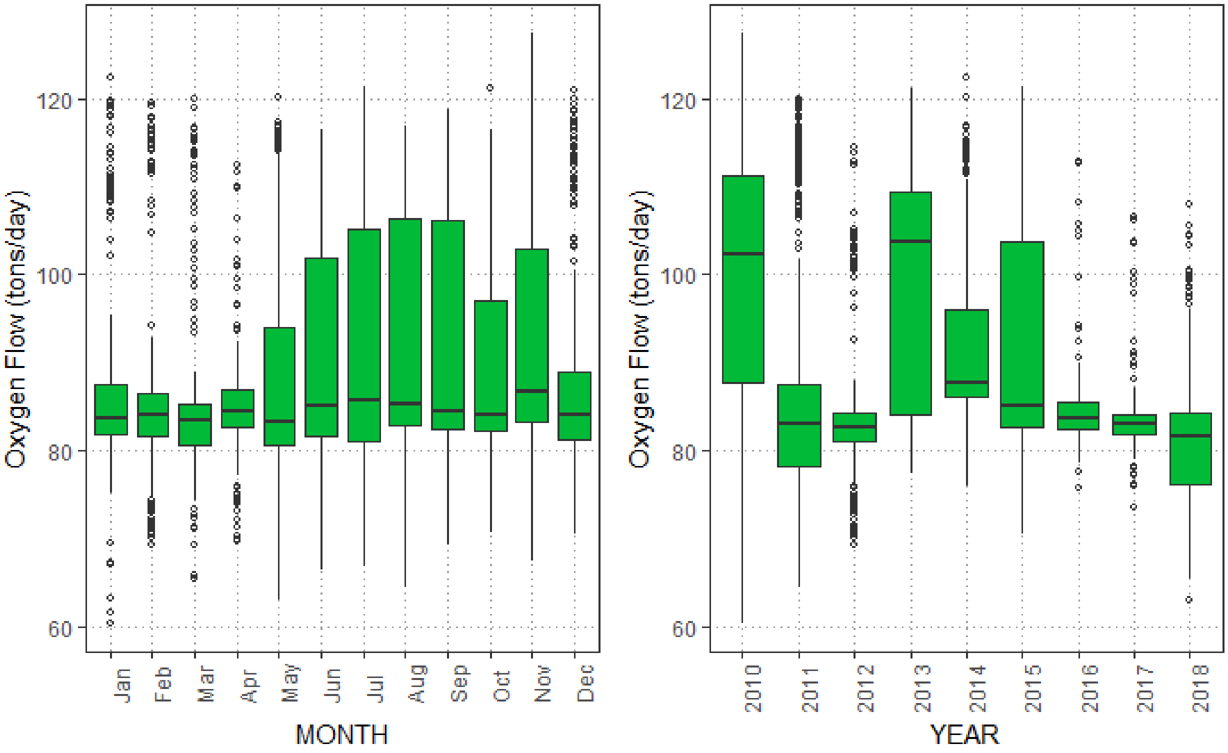


Figure 4-19 Oxygen Flow (Monthly and Yearly Averages)

4.9.3 Operational Experience

Generally, Operations has historically operated the O2 Generation Plant at a target 85 tons/day. However, the 2018 assessment of the system indicated the O2 plant may be operated at a lower flow rate to save energy and improve the treatment process. The actual O2 demand is closer to 50 tons/day based on performance testing in March (at an estimated flow of 65 mgd). As such, the current O2 generation exceeds the daily oxygen requirements of the Reactors and is primarily due to the equipment's turn-down limitations and concerns regarding operational reliability and difficulty at the lower speeds. Refer to the 2018 Solutionwerks Oxygen System Assessment report for additional information.

4.10 Clarifiers

There are a total of 12 clarifiers. Each clarifier is 140 ft in diameter with a maximum water depth of 14 ft and 1.5 in. Each clarifier can hold 1.61 million gallons with a maximum flow of 14 million gallons per day. This allows a maximum flow of 168 MGD through the secondary clarifiers.

4.10.1 Design Criteria

The design criteria for the clarifiers are provided in Table 4-15.

Table 4-15. Secondary Clarifier Design Criteria

Parameter	**Design Criteria**	**Operating Conditions**		
		Average	**Range (1% to Max)**	**Typical (Book) Value[1]**
Number of tanks, #	12+0	--	--	--
Tank radius, ft	140-ft	--	--	--
Tank depth, ft	14-ft	--	--	--
Surface Area, sf	15,394	--	--	--
Volume, cf	215,513	--	--	--
Shaft Rotation Frequency, Min/rotation	45-50	--	--	--
Performance				
Surface Overflow Rate (gpd/sf)	910	470	324 - 1140	Avg: 400-700 Peak: 1000-1600
Detention Time (hrs)	--	4.6	2.4 – 7.1	
Solids Loading (lbs TSS/sf/hr)	--	0.35	0.15-1.28	Avg: 1.0-1.4 Peak: 1.8
SVI, mL/g	--	102	40-516	<150

1. Book values based on M&E, 4th Ed, Table 8-7. Peak is defined as a 2 hr sustained peak.

4.10.2 Performance

The monthly average sludge volume index (SVI) is provided in Figure 4-20. The SVI indicates the settleability of the mixed liquor is generally within a good range during the summer months but increases during wet weather flows. SVI above 150 mL/g is associated with filamentous growth (2018 M&E) and as observed by the MWWTP frequently.

The Secondary Clarifier surface overflow rate is provided in Figure 4-21. The performance of the clarifier, as TSS concentration and removal percentage as a function of the overflow rate, is shown in Figure E-7 and Figure E-8.

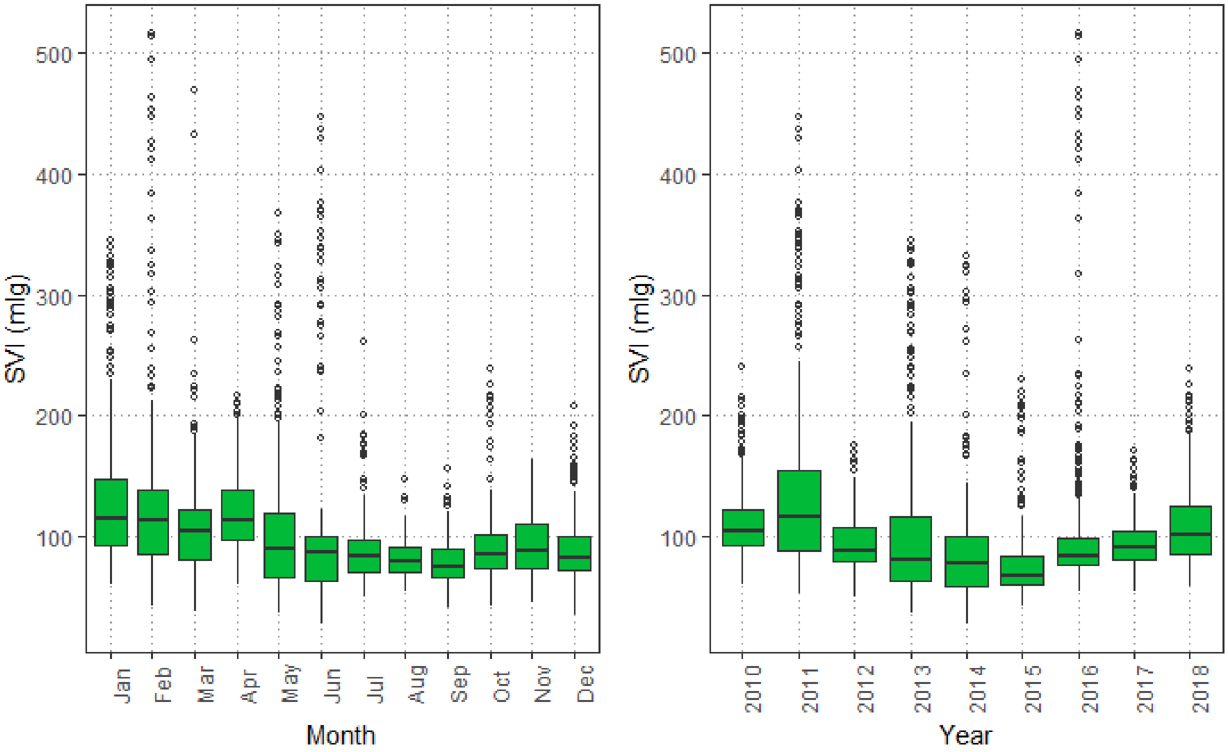


Figure 4-20 Sludge Volume Index (Monthly and Annual Averages)

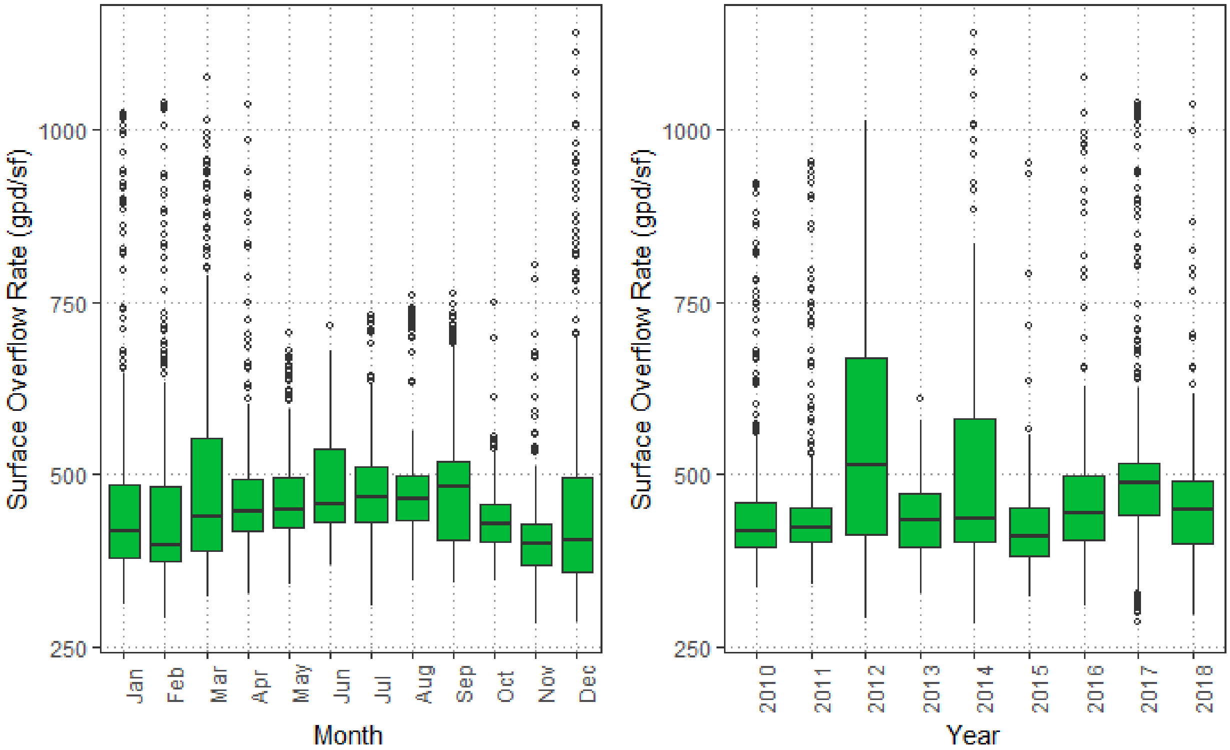


Figure 4-21 Secondary Clarifier Surface Overflow Rate (Monthly and Annual Averages)

4.10.3 Operational Experience

Issues at the clarifiers and associated facilities include the following:

- Foaming will occur in the MLSS channel and associated clarifier influent launders.
    - The foam removal systems in the MLSS channel does not work and needs to be completely rebuilt (to be done in 2024).
    - The clarifier influent launders have scum skimmers that do not effectively remove foam.
- Effluent launder weirs not level, to be fixed in 2023.
- Flow meters on the RAS piping are inaccurate and/or are failing. They will be replaced in a 2022 project.

4.11 Disinfection

The disinfection of the wastewater occurs at the secondary effluent channel (adjacent to the Secondary Clarifiers). When the secondary treatment process is partially bypassed during blending, the bypassed flows are disinfected at the bypass diversion structure. This section does not analyze the use of hypo for odor control or other non-disinfection uses.

4.11.1 Design Criteria

The design criteria the disinfection system is provided in Table 4-16. Much of the disinfection design criteria was based on the old chlorine disinfection system and feed rates.

Table 4-16. Disinfection Design Criteria

Parameter	Design Criteria	Average	Range (1% to Max)	Book Value
Sodium Hypochlorite Demand				
Post-Chlorination Diffuser Dose, (mg/L)	Range: 0 – 9.4 Average: 5.5	3.7	2.6 - 9.4	2 - 8
Secondary Bypass Dose, (mg/L)[2]	Range: 0.3-11 Average: 0	3.8	0.1-51.3	--
Contact Time, mg/L*min[3]		78.6	12.5-243.1	
Storage				
Bulk FRP Hypochlorite Storage Tank Volume, Each (gal)	69,000	--	--	--
Number of storage tanks	3	--	--	--
Chlorinators				
Model	Wallace & Tiernan Water Champ Inductor			
Quantity	2+2			
Size	7.5 HP, 30 gpm	--	--	--
Type	max liquid induction, 23-inMercury maximum vacuum, 3450 rpm			
Feed Pumps (Soon to be demolished in 2020)				
Quantity,	2+2	--	--	--
Pumps, soon to be removed	Max: 18 gpm @ 77ft, 5 HP	--	--	--
Feed Pumps (Constructed 2020)				
Quantity, #	2+2			
Flow, gpm	29			
Head, ft	--			

Notes:

1. Book values based on WEF MOP No. 8, 6th Ed., Table 17.10.
2. Design criteria average value based on the MWWTP Conversion to Sodium Hypochlorite and Permanent Sodium Bisulfite Facilities plan. The design criteria average is likely assumed to be on a daily basis whereas the actual average is instead based only on the times the bypass is used.
3. Contact time is based on the variable volume in the secondary effluent channels bypass tunnel, and outfall. No baffle factor is used. If bypass is used, the minimum contact time is then generally used in the calculation (between the secondary effluent channel versus the bypass channel).

4.11.2 Performance

The monthly and annual average hypochlorite use is indicated in Figure F-1, this figure includes the total amount of hypo applied at the secondary effluent channel, the amount consumed, and the amount remaining before dechlorination. The contact time for disinfection, the correlation between the contact time to the resulting fecal coliform density, and the correlation between dose and resulting fecal coliform density are provided in the figures below. As expected, the fecal coliform density is generally decreased as contact time and/or dose increases. The hydraulic retention time in the final effluent channel/piping is provided in Figure F-2.

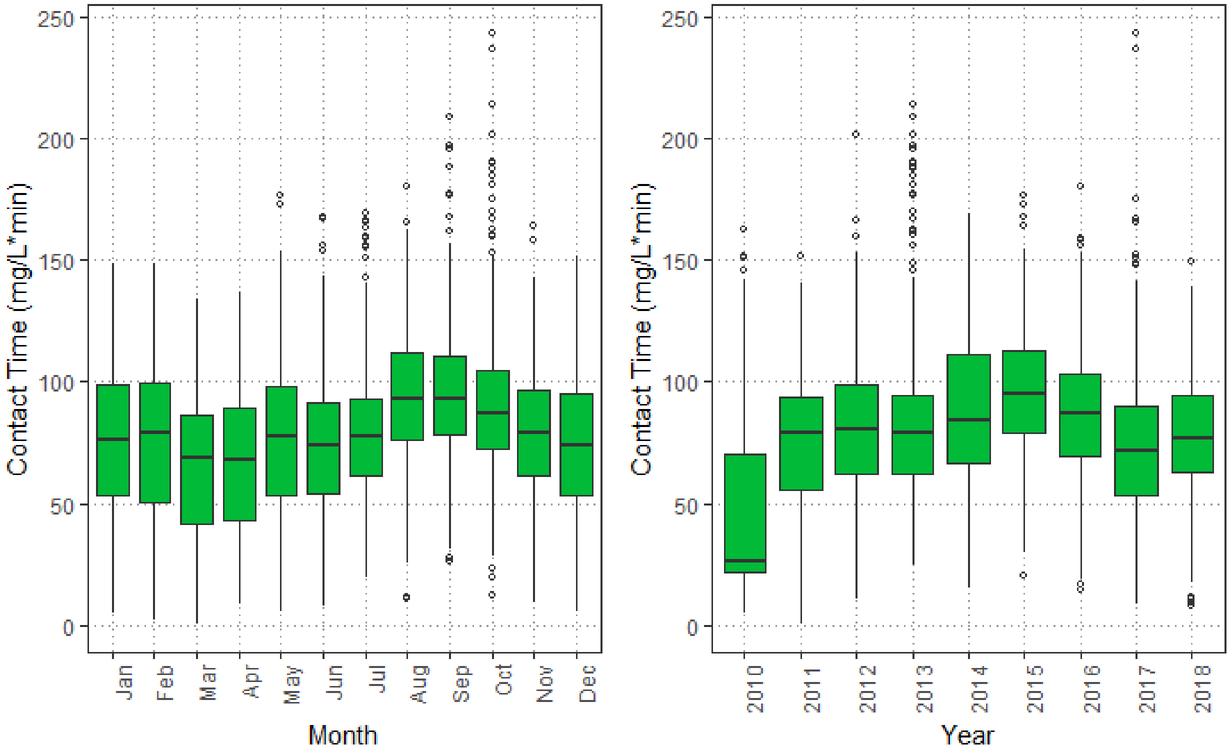


Figure 4-22 Disinfection Contact Time (Monthly and Yearly Averages)

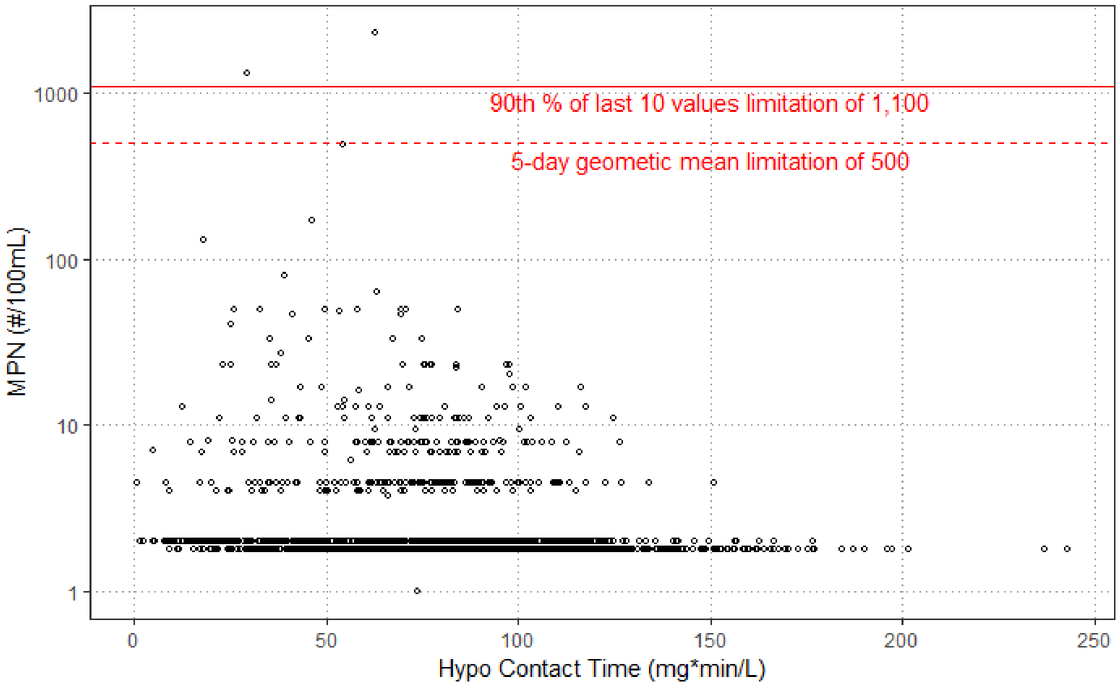


Figure 4-23 MPN to Contact Time

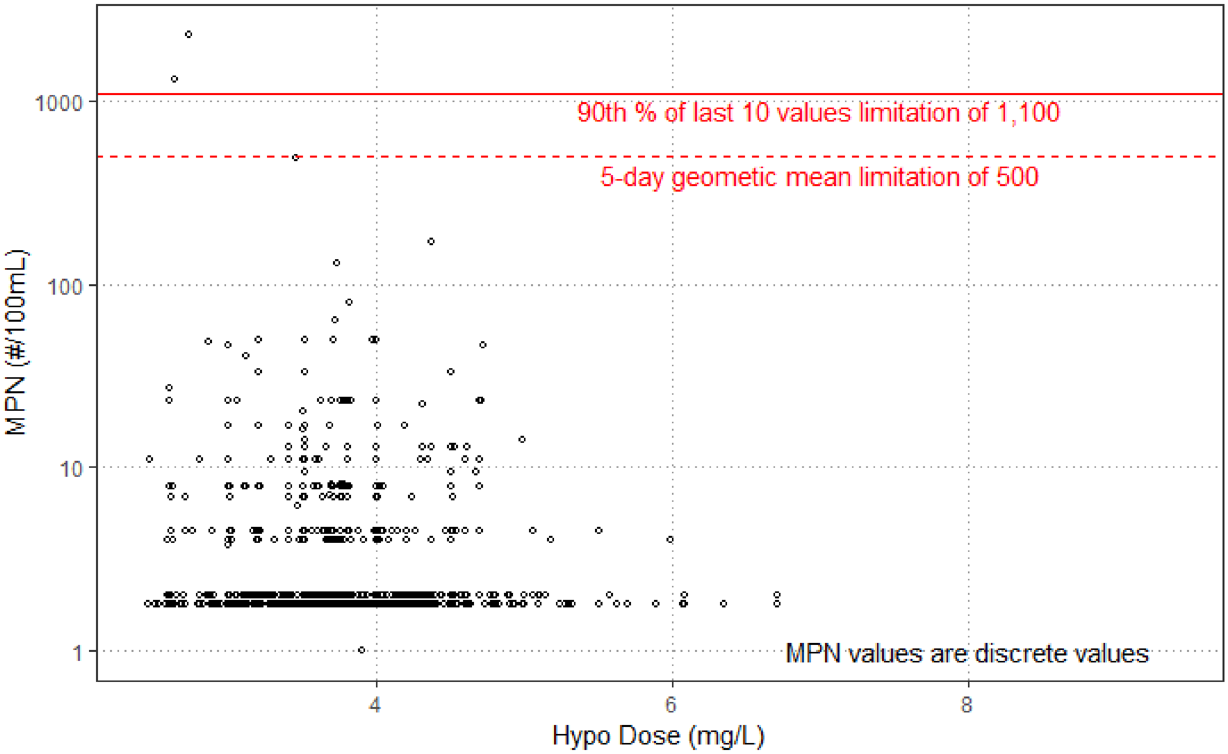


Figure 4-24 MPN to Hypochlorite Dose

4.11.3 Operational Experience

Operations indicate the sodium hypochlorite containment area (formerly Digester 1) drainage systems constantly fail and have in the past caused damage to the equipment due to flooding.

4.12 Effluent Pumping Station

The treated effluent flows into the EPS from either the Secondary Effluent Channel or Secondary Bypass Channel. It flows through the four inlet channels, two north channels and two south channels and into the wet wells for the effluent pumps. Gravity discharge flap gates in the west wall of the wet well allow low flows to flow into the plant outfall by gravity at low tide. Otherwise the 4 effluent pumps are used to lift the effluent into the discharge transition channel. Surge chambers on each discharge transition channel absorb and dissipate energy due to changes in effluent velocity in the plant outfall. The plant outfall discharges into the waters of San Francisco Bay.

With all four pumps operating, pumping station capacity is 428 mgd (107 per pump) at 44-ft of head. However, this is only the total pumping capacity. The Outfall itself cannot handle anything in excess of approximately 300 mgd, depending on the tidal and surge chamber WSEL assumptions. Refer to the hydraulic profile section of this task report for additional information on the Outfall.

There are four LCI Drives and four synchronous motors. Each motor is dedicated to one Effluent Pump. Similarly, each drive is dedicated to one pump and motor.

A Local Control Panel (LCP) is dedicated to each pump-motor set. Its functions include vibration and temperature monitoring and emergency shutdown. The Effluent Pump Control Panel (EPCP) consolidates control and monitoring of all the drives and pump-motor sets at one location. It provides a means for local control of the Pumps or, alternately, accepts control from a remote source.

The LCI Drives use power semi-conductor devices to convert incoming ac power to dc power and additional power semi-conductors to invert the dc power to ac power of variable magnitude and frequency. This semi-conductor technology provides the variable speed operation of the Effluent Pumps. Effluent Pump speed can be varied to match the effluent flow or to control the suction pump levels between preset levels.

4.12.1 Design Criteria

Table 4-17. EPS Pumps Design Criteria

Parameter	Design Criteria
Effluent Pumps	
Quantity, # (duty+standby)	3+1
Type	Vertical Wet Pit, single stage, mixed-flow
Capacity, each unit, mgd	107
Total Capacity, mgd	428
Total Dynamic Head, ft	44
Motors -Type -Quantity, # -Horsepower, HP -Maximum Speed, rpm	 Drive Units Load Commutated Inverters (LCI) with Synchronous motors 5 1,000 1,000
Maximum outfall capacity at 10-yr high tide, mgd	320 (derated to 278)*
*Refer to the hydraulic profile section of this task report for more information regarding outfall limitations	

4.12.2 Operational Experience

The effluent pumps have the following issues:

- Pump motors randomly trip. General Electric came out a few years ago to fix; however, the problem was undetermined. Maintenance suspects the issue is due to corrosion.
- Controls need to be adjusted because the automatic control system causes the pumps to ramp up and down based on inlet level. That is; the pumps ramps up and draws down the inlet channel water level causing the pumps to ramp down and then the water level increases again causing the pumps to ramp back up…and so forth. The pumps will not stabilize without operator intervention to force a steady state condition using manual override.

4.13 Dechlorination

The system consists of two identical feed trains with flow control loops, two liquid injectors, three injector water pumps, and diffusers in the outfall. Sodium bisulfite is supplied by the sodium bisulfite storage tanks.

4.13.1 Design Criteria

Table 4-18. Dechlorination Design Criteria

Parameter	Design Criteria
Storage	
Sodium Bisulfite Storage Tank Volume, Each (gal)	15,200
Number of storage tanks	3
Feed Rates	
Metering Pumps, gph	Up to 1,100 gph @ 95-ft
Turndown	100:1

4.13.2 Performance

The amount of sodium bisulfite remaining, after dechloriation, is indicated in the figure below.

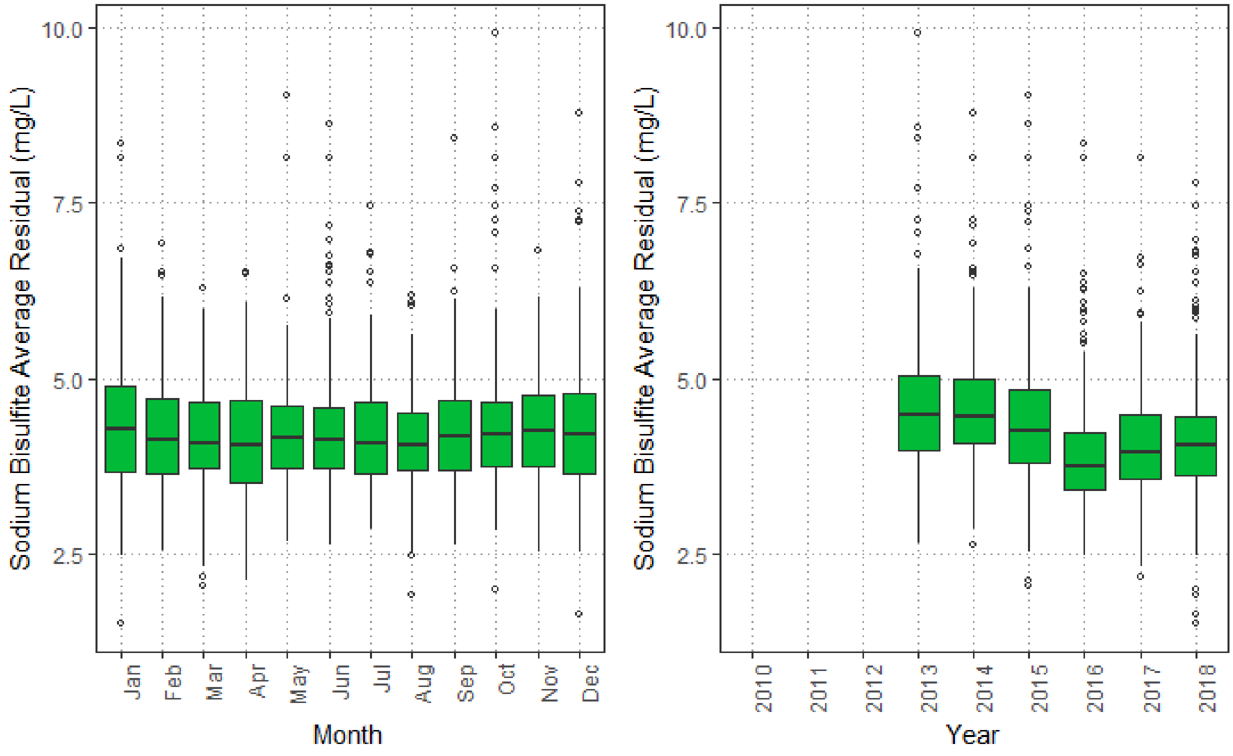


Figure 4-25 Sodium Bisulfite Residual (Monthly and Yearly Averages)

4.13.3 Operational Experience

Generally no issues in the dechlorination systems; however, the sulfur analyzer filters needs frequent cleaning due to solids clogging, on the order of 3 times a week. The solids are likely algae building up in the system and getting sucked into the instrumentation. This issue most frequently occurs after the plant is returned to service after a plant shutdown.

4.14 Miscellaneous Support Systems

Miscellaneous support systems indicated in this section is not comprehensive and only includes systems known to have major issues. As such, this section only describes the operational issues the plant faces on a daily basis and does not delve into the design criteria and such. Operational issues as follows:

- 3W System
  - No redundancy. There are no looped pipelines and the flow to the outer reaches of the plant (such as the FOG/HSL receiving station) is insufficient. Flow to receiving stations needs to be increased to allow for effective washdown and flushing.
  - In general, all valves in the 3W system do not seal.
  - The backup 3W system at the Operations Center Basement has only one pump operable, the standby unit is out of service or abandoned. This Ops center 3W pumping station is also run at a lower pressure.
  - The primary 3W pumping station at the Sedimentation Tanks has 3 pumps, of which 1 is not connected.
  - The Wet Weather Storage Basin washdown monitor pumping station is used as booster pumps to provide additional flow and pressure into the 3W distribution system.
- Plant Drain
  - Plant drain does not work effectively. There are reverse slopes in the system and the main drain line leading up to the interceptor is partially blocked due to a pile penetrating through the pipeline (at the grit building).

CHAPTER 5 - SOLIDS TREATMENT PROCESS PERFORMANCE

5.1 Introduction

This section describes the solids system capacity and process performance. The solids system includes the following facilities

- FOG Receiving Station
- WAS Thickening Station
- Blend Tanks
- 1st Stage Digesters
- 2nd Stage Digesters
- Dewatering Building
- Polymer System

This section describes the solids treatment system capacity and process performance. This report does NOT describe the treatment process or flow paths; instead, refer to the E00 Task Report for the overview of the MWTTP.

5.2 Solids Train Overall Performances

The treatment system performance is based on the parameters provided below and characteristics of other regulated constituents in discharge permit will also be reviewed. The influent and effluent flow statistics are provided in Table 5-1 and Table 5-2. Refer to Task Report E00 MWWTP Wastewater System Overview document for a process flow diagram of the entire treatment plant.

Table 5-1 Solids Overview Summary (Part 1 of 2)

	Primary Sludge (PS)		**Thickened Waste Activated Sludge (TWAS)**		**High Strength Solids (SLW)**		**FOG/High Strength Liquids (FOG/HSL)**		**Blended Sludge (BSL, blend of the left four columns)**		**Transfer Sludge (TSL, after 1st stage digesters)**		**Digested Sludge (DSL, after 2nd stage digesters)**		**Data Source and Date Range**
Flows (kgd)	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	
Annual Averages	221.0	48.5	193.1	44.8	184.4	70.8	66.3	50.8	666.3	105.1	658.4	127.2	682.8	130.4	2010-2018 MDW
Analytes	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	
Temperature, F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Alk	--	--	--	--	--	--	--	--	--	--	8,855	890	8,945	915	2010-2018 MDW
pH	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2010-2018 MDW
TS, %	5.0	1.1	5.0	0.5	--	--	--	--	4.9	0.9	2.7	0.2	2.5	0.2	2010-2018 MDW
TSS, mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2010-2018 MDW
VS, %	3.9	0.7	3.9	0.4	--	--	--	--	3.7	0.8	1.5	0.1	1.3	0.2	2010-2018 MDW
VSS, mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2010-2018 MDW
sCOD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2010-2018 MDW
NH3 as N, mg/L	--	--	--	--	--	--	--	--	--	--	2,069.3	198.5	2,105.4	199.6	LIMS, Data Varies
TKN, mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Orthophosphate (PO4) as P, mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Total Phosphorus as P, mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
VA	--	--	--	--	--	--	--	--	--	--	491.8	207.1	292.1	108.8	2010-2018 MDW
Ratios															
VA / ALK	--	--	--	--	--	--	--	--	--	--	0.06	0.02	0.03	0.01	2010-2018 MDW
VS Added / VS in Digester	--	--	--	--	--	--	--	--	0.06	0.01	0.05	0.01	--	--	2010-2018 MDW

Table 5-2 Solids Overview Summary (Part 2 of 2)

	Biosolids (Cake, DWS)		**Centrate 1***		**Centrate 2***		**Centrate 3***		**Centrate 4***		**Centrate 5***		**Centrate Average**		**Data Source and Date Range**
Flows	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	
Annual Average, mgd	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Mass Flow, klbs/day	402.9	99.4	--	--	--	--	--	--	--	--	--	--	--	--	2010-2018 MDW
Analytes	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	
Temperature, F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
ALK	--	--	4,413	1,909	5,484	1,513	5,447	1,049	6,143	1,311	7,236	749	1,543	424	LIMS, Data Varies
pH	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
TS, mg/L	24.8	1.3	--	--	--	--	--	--	--	--	--	--	--	--	
TSS, mg/L	--	--	1,442	1,062	1,594	735	2,464	1,573	1,077	974	1,117	1,141	1,465	1,194	LIMS, Data Varies
VS, mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
VSS, mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
sCOD	--	--	661.5	259.0	881.6	381.1	675.0	158.4	908.3	468.0	1,018.2	330.4	877.4	388.7	LIMS, Data Varies
NH3 as N, mg/L	--	--	1,249.5	531.4	1,495.2	357.4	1,458.1	301.7	1,588.8	404.3	1,837.2	209.4	1,543.3	424.2	LIMS, Data Varies
TKN, mg/L	--	--	1,142.3	559.8	1,604.2	469.3	1,293.6	339.7	1,742.7	451.6	1,986.4	356.6	1,650.3	522.1	LIMS, Data Varies
Orthophosphate (PO4) as P, mg/L	--	--	88.3	44.4	136.4	51.9	121.7	42.3	153.6	47.8	189.0	55.7	145.9	59.2	LIMS, Data Varies
Total Phosphate as P, mg/L	--	--	148.3	86.8	182.7	59.4	182.9	46.9	186.5	59.1	228.2	63.7	188.8	69.1	LIMS, Data Varies
Biosolids (Cake) Only Analytes															
Fecal Coliform (geometric mean), MPN/g		--													
Volatile Solids Reduction, %		--													
Metals															
Arsenic, mg/kg	1.2	--													LIMS 2010-Mar 2019
Cadmium, mg/kg	0.4	--													LIMS 2010-Mar 2019
Copper, mg/kg	79.9	--													LIMS 2010-Mar 2019
Lead, mg/kg	9.9	--													LIMS 2010-Mar 2019
Mercury, mg/kg	0.2	--													LIMS 2010-Mar 2019
Molybdenum, mg/kg	2.1	--													LIMS 2010-Mar 2019
Nickel, mg/kg	6.8	--													LIMS 2010-Mar 2019
Selenium, mg/kg	0.6	--													LIMS 2010-Mar 2019
Zinc, mg/kg	165.6	--													LIMS 2010-Mar 2019

*Centrate samples are taken from each centrifuge separately and at no point does the centrifuge mix before entering the Primary Influent Channel.

5.3 Blend Tanks

There are two blend tanks where primary sludge, TWAS, and High Strength R2 wastes are blended to provide a relative uniform feed to the digesters. They also provide adequate detention time to reduce peaks. It will allow for equalization over most days, but will not equalize over a week or peak days. Although additional volume would offer better equalization of flows, the resulting increase in detention time could be detrimental. Longer detention times, especially with preheating, can result in acid-phase digestion and complicated odor control. If both are online, the tanks would ideally provide 400,000 gallons total of blend tank volume, which provides 5-hour detention time (9 primary digesters @ max. hydraulic capacity); however, Operations currently operates the two tanks in duty + standby mode for redundancy.

Pre-heating reduces the potential for grease build-up in the feed piping, and it is expected that the material will blend more easily when heated. Heat exchangers are sized and configured so that feed sludge is brought to and maintained at a minimum 85 degrees Fahrenheit. One spiral heat exchanger per blend tank – the same size and model as at the digesters – provides adequate capacity for the calculated heat load of 5.25 million Btu/hr. The spiral heat exchangers will match the spiral heat exchangers in the digester gallery.

The digester heat exchangers are the largest spiral heat exchangers available – sized to maintain 131-degrees- Fahrenheit digester temperature at 15-day SRT. Pre-heating enables digester operation at temperatures greater than 131 °F by reducing the heat load at the digesters (bringing sludge up to digestion temperature accounts for the majority of the digester heat exchanger capacity). Pre-heating also facilitates digester operation at SRT less than 15 days. Operation at 10-day SRT, and/or operation at 140 °F – both require preheating at winter design conditions. The primary constraint on these operating scenarios will be heat production – the amount of heat that the cogeneration systems can provide – not the heat delivery systems.

The pre-heating system is designed as a secondary loop off the hot water system return from the digester heat exchangers. By drawing water from the return side, the pre-heating process uses the hot water system more efficiently.

5.3.1 Design Criteria

Refer to Table 5-3 for additional information on the Blend Tanks' key design criteria.

Table 5-3. Blend Tank Design Criteria

Parameter	Design Criteria	Actual Average	Actual Max Week	Actual Range
Tanks				
Quantity, #	2+0	1+1[3]	--	--
Size, gal (ea)	200,000	--	--	--

Parameter	**Design Criteria**	**Actual Average**	**Actual Max Week**	**Actual Range**
Type	Conical bottom	--	--	--
Diameter, ft	35	--	--	--
Cone bottom EL, ft Wall bottom EL, ft Top Ceiling EL, ft	94.5 110.5 134.5	--	--	--
Feed Sources, gpm (1) Primary Sludge (2) TWAS (3) R2 related	Average/Max 300/500 100/300 250/750			
Hydraulic Retention Time, hours (calculation includes recirculation return flows)	5[2]	5.2	--	2.7-10
Temperature, F	80-85	88[4]	--	--
Heat Exchangers				
Type	Alfa Laval Spiral			
Quantity, #	2			
Size, MBtu/hr	3.4	--	--	--
Hot Water Flow, gpm	400	--	--	--
Sludge Flow, gpm	800	--	--	--
Feed Loop Feed Pumps				
Type	Vogelsang Positive Displacement Rotary Lobe			
Quantity, # (duty+standby)	2+1	--		
Flow, gpm	600	924[1]	--	--
Headloss, ft	115	--	--	--
Horsepower, hp	30	--	--	--

1. Flow from the feed loop pumps include the flow into each of the digesters and return flow to the blend tanks.
2. Equipment sized for 10 day digester HRT, but EPA requires 15 days. Assumes 9 1st stage digesters.
3. Design intent was for both tanks in service; however only one is used at a time.
4. Actual blend tank temperature average is an approximation instead of calculated average. A calculated average will take significant work to retrieve as data does not discriminate between in-service and out-of-service blend tanks.

5.3.2 Performance

The total flow to the blend tanks, not including feed loop return (FOG/HSL, HSW, TWAS, and PS), is summarized in the figure below. In general, the increase in flows through the years is indicative of the increased flows from the Resource Recovery program, which is counted as the FOG/HSL and HSW flows.

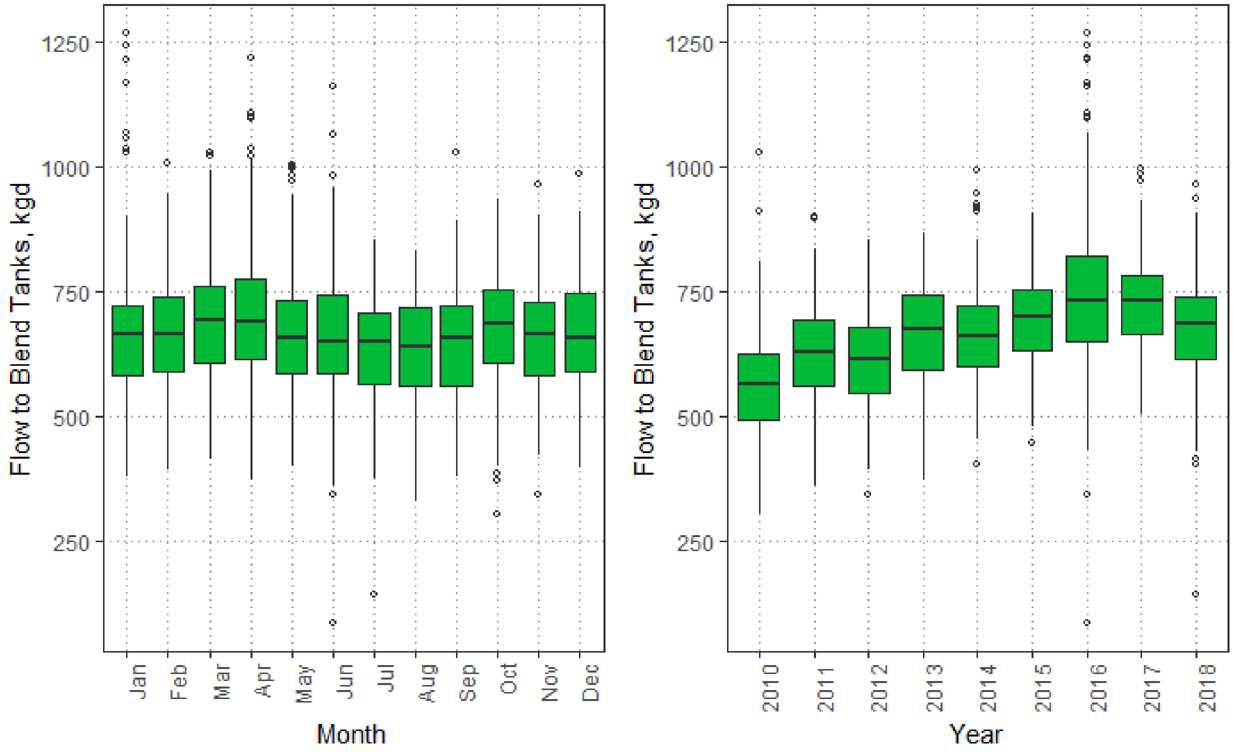


Figure 5-1 Total Flows to Blend Tanks (Monthly and Yearly Averages)

5.3.3 Operational Experience

Due to redundancy and tie in concerns, only one of the two tanks is in service at any given time. This is because the two tanks are tied into the suction side of the digester loop feed pumps without the ability to isolate.

Currently, the blend tank's feed loop pumps have been derated by up to ~40% of the original rated design flow due to the pump's rotary lobe being excessively worn and damaged by grit entering the solids treatment system via the FOG/HSL and the SLW receiving stations. This derated flow will vary based on how damaged the lobes are and when they were last replaced. The derating of the feed pumps, along with higher than designed flows, forces Operations to operate two pumps at a time and revert the digester feed loop into a feed system (with no return flow) to allow the sludge to flow in reverse on the return end of the loop.

In addition, Operations indicate the blend tanks do not have sufficient capacity to handle peak truck unloading times.

5.4 Anaerobic Digesters

Anaerobic digestion of sludge is accomplished by providing a tank in which bacteria reduce the volatile solids (primarily organic matter) in the absence of air. The anaerobic bacteria are commonly maintained in the low thermophilic temperature range. This gas is collected and used to operate the Power Generation Station (PGS) for the production of electricity. The cooling water for the power generators conveys waste heat to the digesters. The digestion process is accelerated if the tank contents are mixed, thus providing a homogeneous mixture of feed sludge and actively digesting sludge within the tank.

Anaerobic digestion is carried out in two stages at the MWWTP, the first and second stages. In the first stage the sludge is heated and mixed continuously. Most of the methane gas production and solids reduction is accomplished in this stage due to the higher energy potential feed, longer detention time, higher heat, and mixed conditions. In the second stage, a relatively quiescent environment is established by reduced gas production and limited heating and mixing. The digested sludge is withdrawn for dewatering and ultimately disposal.

5.4.1 Design Criteria

The first and second stage digesters operate at an average temperature of 123.9 and 110.1 degrees F respectively. Their average detention time is 14.8 and 7.9 days respectively. Refer to Table 5-4 for additional information on the digester's design criteria, overall capacity, and performance. The heat exchangers are the same as those installed for the Blend Tanks.

Table 5-4. Digester Design Criteria

Parameter	Design Criteria	Current Average	Current Range	Typical (Book) Value
General				
Total Quantity of Digesters, #[4]	8+3			
Hydraulic Retention Time, Days	15			
1st Stage Digesters				
Type	Waffle Bottom, fixed dome cover			
Quantity, #	7	--	--	--
Volume, Mgal	2.0 @ Overflow 1.84 @ Average Level	With Grit: 1.97 @ Overflow 1.81 @ Average Level	--	--
Blended Sludge Feed Flow, gpm (ea)	140	113	22-255	--
Detention Time, days	12	14.8	--	--

Parameter	**Design Criteria**	**Current Average**	**Current Range**	**Typical (Book) Value**
Temperature, F	--	124	121-127	122-135
Sludge Density, lb/gal	8.34	--	--	--
Loading Rate, lbs VSS/1,000 CF/day	--	--	--	--
VA/ALK	--	--	--	--
Blended Sludge Feed %TS, %	6	--	--	--
Volatile Solids Reduction, %	55	--	--	--
Total Solids Reduction, %	--	--	--	--
1st Stage Heat Exchangers				
Exchanger Type	Alfa Laval Spiral			
Size, MBtu/hr	3.0			
Pump Type	Wemco non-clog constant speed centrifugal			
Recirculation Pump Flow, gpm	Digester 5, 7 @ 800, all others at 300	--	--	--
Recirculation Pump Headloss, ft	Digester 5, 7 @ 60, all others at 30.5	--	--	--
1st Stage Digester Feed (Blended Sludge) Pumps				
Pump Type	Vogelsang Positive Displacement Rotary Lobe			
Quantity, #	8	--	--	--
Flow, gpm (ea)	140	78	31-128	--
Headloss, psi	50	--	--	--
2nd Stage Digesters				
Type	Conical Bottom, floating and/or dual membrane covers[3]			
Quantity, #	2	--	--	--
Volume, Mgal	2.07 @ Overflow 1.94 @ Average Level	With Grit: 2.03 @ Overflow 1.90 @ Average Level	--	--
Transfer Sludge Feed Flow, gpm (ea)	465 rated, 600 max			
Digested Sludge Flow, gpm	600 rated, 750 max			
Detention Time, days	--	7.9		
Temperature, F	--	110	95-120	

Parameter	**Design Criteria**	**Current Average**	**Current Range**	**Typical (Book) Value**
Loading Rate, lbs VSS/kcf/day[5]	--			120-160 or 100-300
VA/ALK	--			
Blended Sludge Feed %TS, %	--			
Volatile Solids Reduction, %	--			
Total Solids Reduction, %	--			
2nd Stage Heat Exchangers				
Exchanger Type	Alfa Laval Spiral			
Size, MBtu/hr	3.0			
Pump Type	Wemco non-clog constant speed centrifugal			
Recirculation Pump Flow, gpm	300	--	--	--
Recirculation Pump Headloss, ft	30.5	--	--	--
2nd Stage Digester Feed (Transfer Sludge) Pumps				
Pump Type	Vogelsang Positive Displacement Rotary Lobe			
Quantity, #	3	--	--	--
Flow, gpm (ea)	465	162	61-372	--
Headloss, ft	115	--	--	--
2nd Stage Digested Sludge (Digested Sludge) Pumps				
Pump Type	Vogelsang Positive Displacement Rotary Lobe			
Quantity, #	3	--	--	--
Flow, gpm (ea)	600	--	--	--
Headloss, ft	115	--	--	--
Digester Mixing Pumps (To be Installed in 2020-2022)				
Pump Type	Centrifugal			
Quantity, #	3+0	--	--	--
Flow, gpm	5,000	--	--	--
Headloss, ft	42.7	--	--	--
Digester Gas Storage				
Digester 2 Dual Membrane				
Type	Evoqua Dystor, top draw off			
Gas Dome Pressure, in	6-12			
Size (not including the volume below the top of wall), CF	160,000			
Digester 3 and 4 Dual Membrane[3]				
Type	Manufacturer TBD, side drawoff[3]			

Parameter	**Design Criteria**	**Current Average**	**Current Range**	**Typical (Book) Value**
Gas Dome Pressure, in	6-12			
Size (not including the volume below the top of wall), CF	~188,000			
Dual Membrane Air Blowers (To be installed in 2020-2022)				
Flow, cfm	600			
Digester Gas Production				
Gas Production Rate, cf/lb of VS destroyed	15			
Gas Production (per digester), cfm	400			

1. All data is based on 2014-2018 data.
2. District's standard minimum combined (1st and 2nd stage digesters) detention time is 15-days.
3. SD-356 MWWTP Digester Upgrades Phase 3 project will replace the Digester 3 and 4 floating covers with dual membrane covers with side draw-offs. Estimated completion is 2021.
4. Any two (from first or second stage) digesters may be out of service or on standby. This table assumes one from first and one from second.
5. The WEF MOP #8 indicates typical high rate VSS loading of 0.12-0.16 lbs/cf/d versus the 100-300 lbs/kcf/d given in M&E 5th Ed.

5.4.2 Performance

The historic number of digesters, generally online, is provided in Figure G-1. However, it is important to know that the Digester Phase 2, Digesters 6 and 9 Recoatings, and Digesters 10 and 11 Recoatings projects occurred during this timeframe. Operations would generally prefer to keep as many digesters online where feasible; with no more than 2 digesters offline. At most, 3 digesters may be taken out of service for a short duration, but this would require redirecting High Strength Liquids (R2) flows and other migratory steps.

The volatile solids reduction in the sludge is indicated in the figure below for both the first and second stage digesters. The VSR is generally consistent overtime for the first stage digesters and varies in the second stage digesters. Both the mass balance (MB) and the Van Kleeck (VK) formulas are used; however, the Van Kleeck formula indicates VSR values below zero at times (more so than the mass balance formula). The difference between the two is generally that the Van Kleeck formula assumes there is no accumulation of grit in the digester (which is widely known to occur in these digesters). As such, the mass balance method is likely the better method to use moving forward in this report.

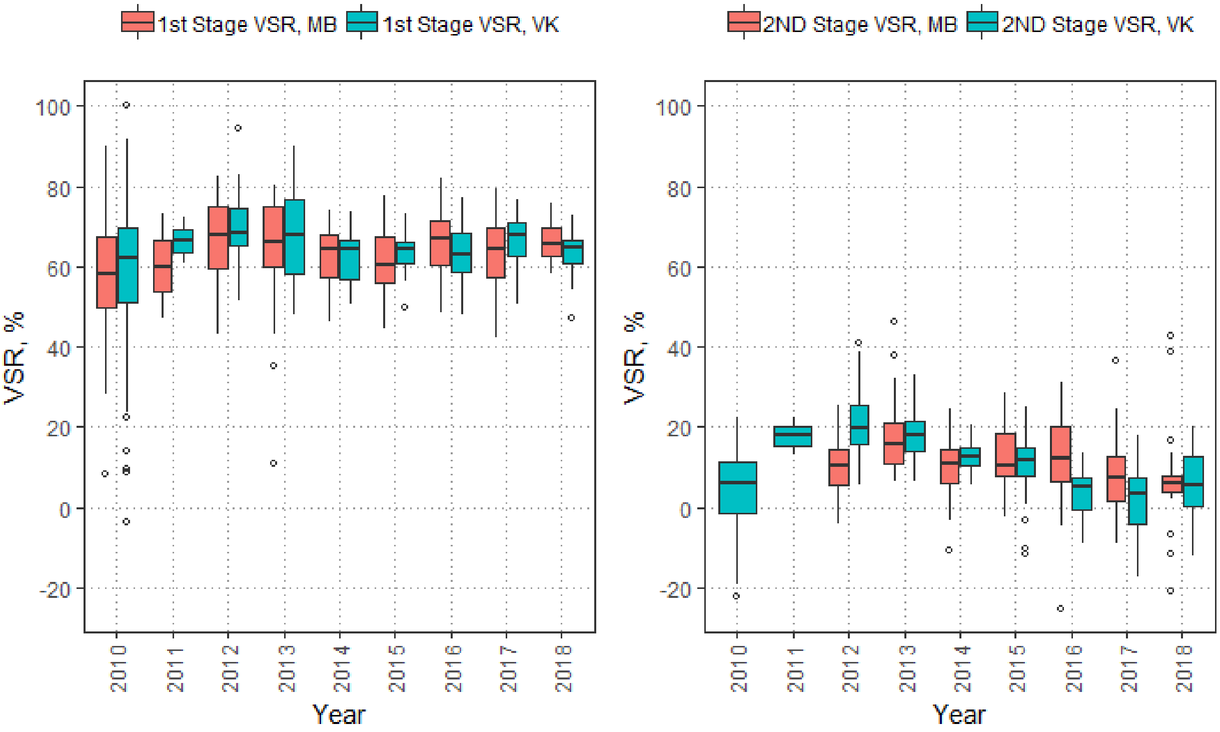


Figure 5-2. Volatile Solids Reduction using Mass Balance and Van Kleek Methods (Yearly Averages)

The digester VS removal efficiency, as a function of solids retention time, is provided in Figure 5-3. The trend in the first stage digesters indicates VS is reduced as SRT increases—reasonable—however, after approximately 18 days SRT, the VS reduction is minimal. The second stage digesters is similar; however, potentially little to no VS reduction occurs at times. This can potentially be due to the fact that we would expect less VS reduction in the second stage digesters during times when VS reduction in the first stage digesters is high.

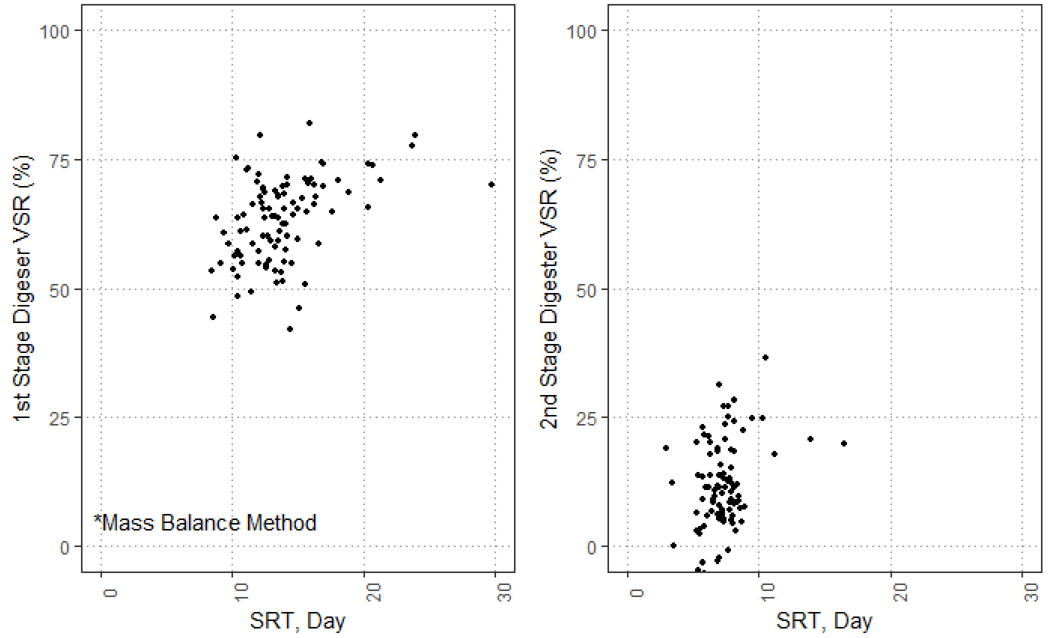


Figure 5-3. Volatile Solids Reduction as a Function of SRT

The last digester figure, Figure 5-4, indicates the VS reduction as a function of the unit loading rate (in lbs VS per day per 1,000 cubic foot). This figure indicates an interesting trend—as the loading rate increases, the VS reduction increases.

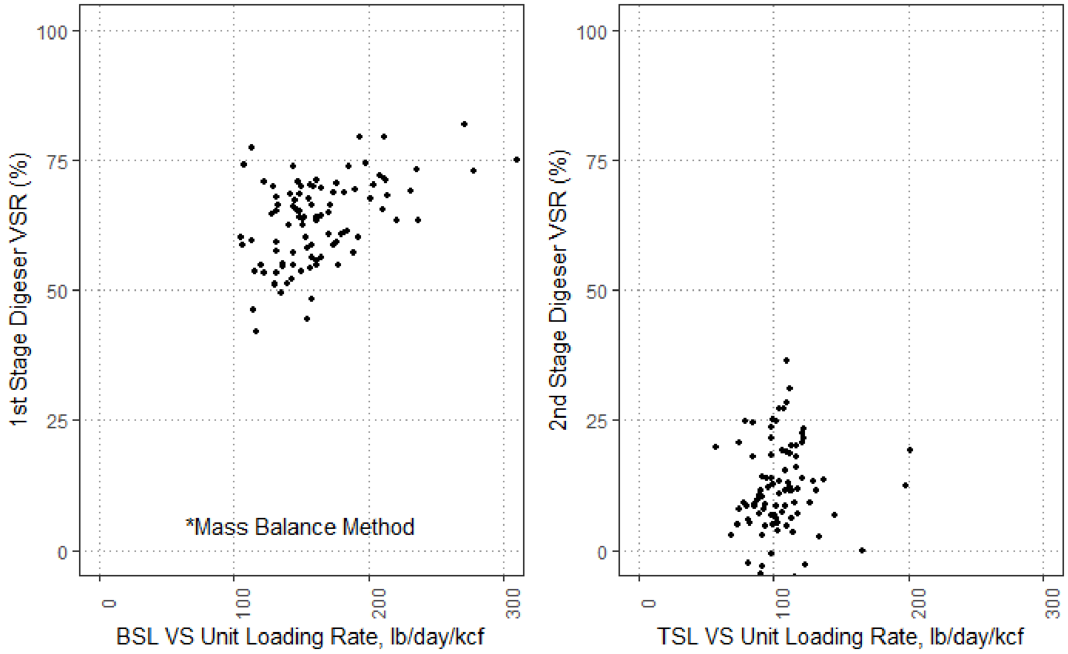


Figure 5-4. Volatile Solids Reduction as a Function of Loading Rate

Historic energy production, as a function of volatile solids loading rate, is provided in the figure below. As expected, gas production increases as organic material is introduced into the digester, primarily from the Resource Recovery Program (trucked high strength wastes). Only the first stage digester gas production values are provided as the vast majority of treatment occurs in that stage. The second stage digesters are not currently mixed as of the writing of this document.

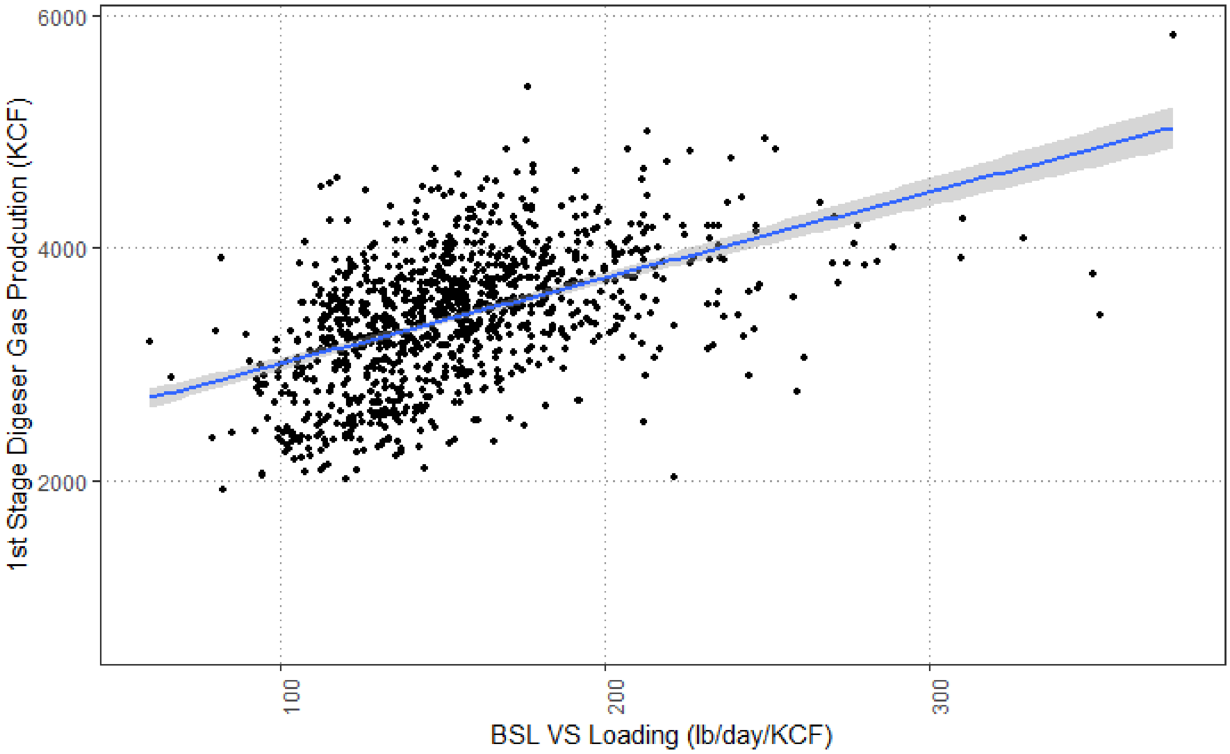


Figure 5-5. 1st Stage Digester Gas Production

5.4.3 Operational Experience

Generally, the digesters operate optimally until struvite plugs up a pipeline and operators then have to clean out the plug or reroute the flow via an alternative piping system or penetration into the digester. Digesters themselves are on a, targeted, 5-yr cleaning schedule where the digester and associated valves are taken out of service for cleaning. All work is done in house by MWWTP operations and maintenance staff.

Currently the solids treatment system works as designed process-wise only. There are several issues in the digester solids treatment system as follows:

- **Pumping.** Blended Sludge is not pumped sufficiently through the digester feed loop. The pumps are Vogelsang rotary lobe pumps and have been significantly derated (up to 50%) due to the low flow output from each pump. It is suspected that the grit within the blended sludge causes premature wear and tear in the rotary lobes and that the grit may be building up in the feed loop itself causing additional headloss.

- **Standpipes.** The standpipes, for top withdrawal on each pair of digesters, are not currently being used. This is because the standpipes will get clogged due to rags and other contamination in the digester itself when started up. This may be solved by starting the standpipes after cleaning the digesters; however, the standpipes were not designed to operate independently as all standpipes need to be in service (or none at all) due to the control system setup. As such, the District cannot put the standpipes in service without cleaning out all the digesters at the same time, yet cannot shut all digesters down for cleaning due to process limitations.
- **Severe grit issues.** The solids treatment system was not designed to handle grit as, historically speaking; all sludge came from the liquid treatment systems, downstream of the degritting and screening (headworks) facilities. However, the District, has embarked on a mission to accept solid wastes from non-traditional sources such as Fats, Oils, and Grease (FOG), food waste, industrial process waste and other high strength liquids and solids. These high strength solids and liquids are received at the solids treatment systems and pumped straight into the digesters with minimal grit or contamination removal systems. As such, the District's digesters contain rags and grit of all sizes that buildup in the digesters and are only removed via the dewatering building in the downstream processes or by digester cleaning.
- **Struvite.** Struvite builds up in the pipelines and digester mixers. This struvite causes clogging and reduced pumping performance and requires manual labor to remove via hydrojetting or hammer and chisel.

An anticipated grit removal construction project in 2020 is expected to remove the largest of the grit approximately 1/8" or greater. This will improve solids treatment systems by reducing wear and tear on the pumps and reduce grit buildup in the digesters. The Digester Upgrades Phase 4 (est. 2030) will address the standpipes by increasing the standpipe piping size and revising the controls.

5.5 Dewatering

Currently, digested sludge (DSL or DS) flows by gravity (pumping is optional for thicker sludge or higher flows) through a 10 inch pipe into the sludge holding tank. The tank level is controlled automatically by a level sensor and a motorized inlet control valve. The five centrifuges are fed digested sludge from the digested sludge holding tank by respective centrifuge feed pumps and grinders. The sludge holding tank can be bypassed using a common 8 inch header—this is normally done due to excessive struvite, inaccessibility to clean, and odor formation in the sludge holding tank.

Once in the dewatering building, the digested sludge is piped to a centrifuge train containing an in-line grinder, progressive cavity pump, and centrifuge.

The three Humboldt solid bowl, medium speed dewatering centrifuges operate with a co-current flow path. Digested sludge enters the bowl through an inlet tube, and centrifugal forces cause sedimentation of the solids on the wall of the bowl. A screw conveyor (scroll) rotates at differential speed in the opposite direction as the bowl. Increasing the differential speed raises the rate of sludge cake removed, while lowering the differential speed allows larger cake inventories to build up within the bowl which results in higher cake dryness. However, high solids capture is often adversely impacted by reduction in clarification depth and available volume.

The two Flottweg, high speed dewatering centrifuges operate with a Simp Drive to automatically control scroll differential speed according to the torque load the feed stream generates. Digested sludge enters the bowl through an inlet tube, and centrifugal forces cause sedimentation of the solids on the wall of the bowl. A screw conveyor (scroll) rotates at differential speed in the opposite direction as the bowl. Increasing the differential speed raises the rate of sludge cake removed, while lowering the differential speed allows larger cake inventories to build up within the bowl which results in higher cake dryness. However, high solids capture is often adversely impacted by reduction in clarification depth and available volume.

Dewatered cake discharges from the centrifuge into a respective cake pump feed hopper and is pumped to the hoppers.

During times when cake quality is poor, usually during start up, sludge is allowed to build up above the feed pumps and overflow, draining to the building sumps. The cake pump feed hoppers were designed with diverter valves, but these are not in use.

A ferric chloride storage and feed system is provided to reduce sulfide odors in the sludge holding tank and to condition the sludge prior to dewatering. However, the ferric system is not normally used due to high chemical costs.

There are three main 12-inch diameter centrate lines that receive centrate from the Dewatering centrifuges and discharge to the end of the Primary Influent Channel (west end). The lower speed centrifuges discharge into Centrate Line 3, while the higher speed centrifuges discharge into its own dedicated centrate line (Lines 1 and 2). For emergencies or bypassing, each line has a bypass into the Primary Effluent channel and there is an interconnect between Line 1 and 3.

5.5.1 Design Criteria

Table 5-5. Dewatering Design Criteria

Parameter	Design Criteria	Average	Range
Feed Pumps			
Type	Moyno Progressive Cavity	--	--
Quantity, #	5	--	--
Flow, gpm C1-C3: C4: C5:	 350 300 300	--	--
Head, psi		--	--

Parameter	Design Criteria	Average	Range
C1-C3: C4: C5:	65 24 24		
Horsepower, HP C1-C3: C4: C5:	 -- 25 20	--	--
Total Solids, % C1-C3: C4: C5:	 5 -- --	--	--
In-line Grinder			
Type	Franklin Millter Super Shredder	--	--
Quantity, #	5	--	--
Horsepower, HP	5	--	--
Flow, gpm	350	--	--
Centrifuges (Low Speed)			
Type	Humboldt Model S4-1	--	--
Quantity, #	3	--	--
Total Solids, %TS**	3-5	2.5	2-3.2
Dewatered Sludge (Cake), %TS	22	25	22-28
Speed, rpm	1400		
Flow (ea), gpm (2010-2018)	210***	C1 @ 113 C2 @ 114 C3 @ 103	5-170
Flow (ea), gpm (2015-2018, current R2 Program years only))	210***	C1 @ 98 C2 @ 107 C3 @ 91	5-135
Centrifuges (High Speed)			
Type	Flottweg Z73-4/454	--	--
Quantity, #	2	--	--
Digested Sludge Feed TS, %	Ave: 2.3 Range: 2.1-2.6	2.5	2-3.2
Dewatered Sludge (Cake) TS, %	24	25	22-28

Parameter	Design Criteria	Average	Range
Speed, rpm	2750		
Flow (ea), gpm (2010-2018)	300	C4 @ 215 C5 @ 235	13-330
Flow (ea), gpm (2015-2018, current R2 Program years only))	300	C4 @ 209 C5 @ 203	13-272
Hoppers			
Bins, #	3	--	--
Load Cells per Bin, #	4	--	--
Total Storage, CY	460	--	--
Total Storage, days	2-3	--	--
*All data is based on 2014-2018 data., ranges uses the 1st to 99th percentile values. **Design criteria not well documented. ***Original centrifuge design flows were 210 per the SD-130 documents; however, this value seems to have been derated in subsequent documents to 150 gpm in the 1980s. Subsequently, both these two numbers float around in various documents as the "design" capacity of these low speed centrifuges.			

5.5.2 Performance

The centrifuge performances does not meet the manufacturer's rated flow capacity. Figure G-2 indicates the average sludge flow into each centrifuge on an annual basis. Similarly, Figure G-3 indicates the solids loading rate into each centrifuge. In general, the biosolids production from the dewatering building is consistent across most months and years as shown in the figure below. However, the flows from each dewatering train will vary significantly from time to time.

The current capacity of the centrifuges is difficult to pin down as the centrifuges may trip out/overload due to high solids, equipment problems, controls issues, or grit slugging events. It is suspected that the varying levels of dewatering train capacities are dependent on the severity of the equipment's wear and tear as well as the characteristics of the digested solids.

However, in very general terms, the current capacity can be estimated to be 125 gpm and 250 gpm for the low speed and high speed centrifuges respectively, based on operator's experience. This is reasonable for the high speed centrifuges since the high end range of the digested sludge at the time was 2.6 and is now 3.1. If normalized for solids loading, the current max flow rate would then be approximately 244 gpm—close to the accepted current maximum flow value of 250. Regarding the low speed centrifuge, there is insufficient data to make such conclusions.

Figure G-4 indicates the total annual biosolids (or cake) produced from each centrifuge individually.

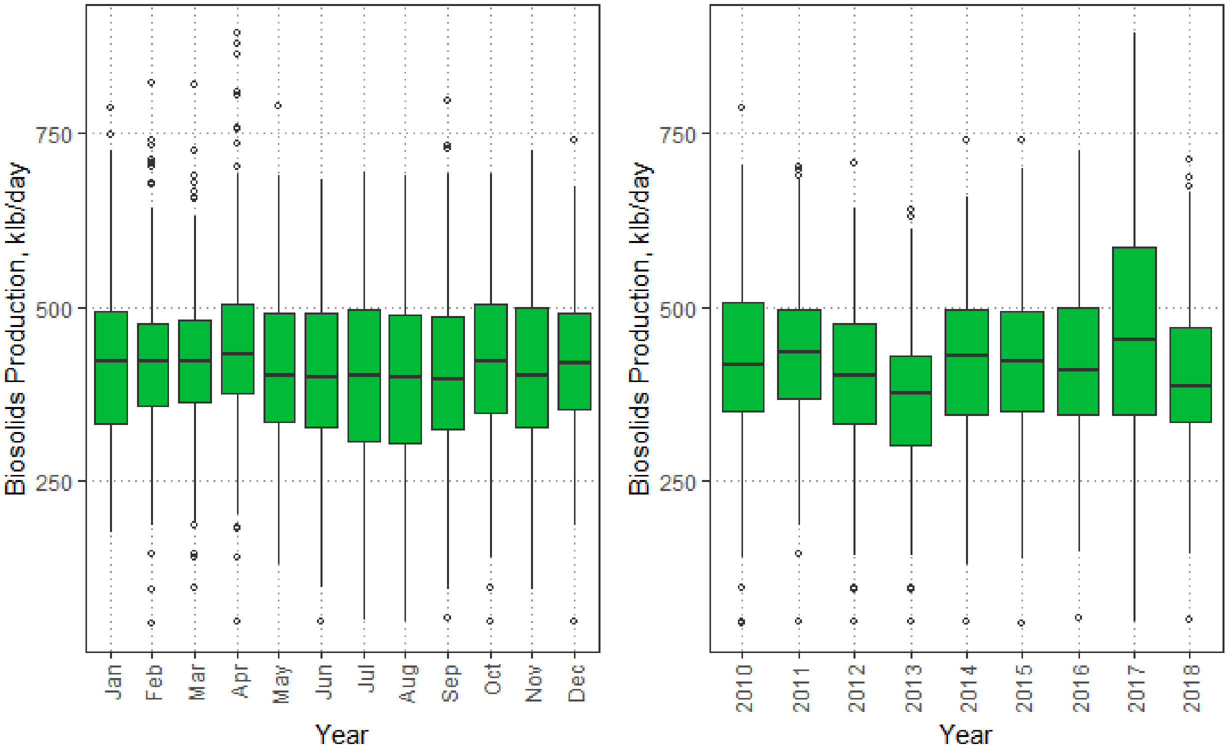


Figure 5-6. Biosolid Production (Monthly and Yearly Averages)

5.5.3 Operational Experience

There are many operational issues at the dewatering building, as follows:

- Centrifuges
    - The centrifuges are typically at lower than rated flow and one centrifuge is usually out of service for maintenance. The new centrifuges are derated due to non-steady state grit issues (wherein the grit comes in slugs due to buildup within the digesters) and high solids loading. When the flow or loading is exceeded, the centrifuge may torque out and/or vibrations may occur. Generally the solids loading limit is reached before the flow limit. The grit slugs are expected to reduce in frequency, duration, and severity once the 2nd Stage Digesters receive a pumped mixing system in the Digester Upgrades Phase 3 project (Est. Completion in 2022).
    - The design flow for the old centrifuges (Humboldt model No. S4-1) is 210 gpm, but centrifuges are commonly operated between 125 gpm to 145 gpm for optimal performance and to prevent shutdowns.
    - The design flow for the newer high speed Flottweg centrifuges is 300 gpm, but centrifuges are derated to 250 gpm to prevent damage from grit slugs (which will shutdown or damage the centrifuge when operated at full speed).

  - Both the estimated derated flow rates for the centrifuges are subjective, and are based on the operator's experience as well as how recently it was rebuilt.
  - C4/C5 centrifuges have many interlocks preventing operations from freely operating them. They are also not designed to handle struvite sand.
- Sludge well
  - Normally bypassed because it fills up with grit too quickly and is difficult to clean out. In addition, struvite will buildup on the suction piping.
- Cake Pumping
  - Always fail (level sensors, pistons, electrical, etc), see DWB report.
  - Piping leaking/failing due to high pressure/stress/wear
- Cake Hoppers
  - Truck loading has insufficient overhead clearance. There are only 1.5 days of storage (much less than the recommended)

5.5.4 Centrate Ammonia

Centrate ammonia concentrations, as a function of each centrifuge, are provided in the figure below. Note that the District collects samples from each centrifuge individually and centrifuges do not operate on a continuous flow or time basis; as such, an overall average centrifuge ammonia concentration cannot be easily calculated.

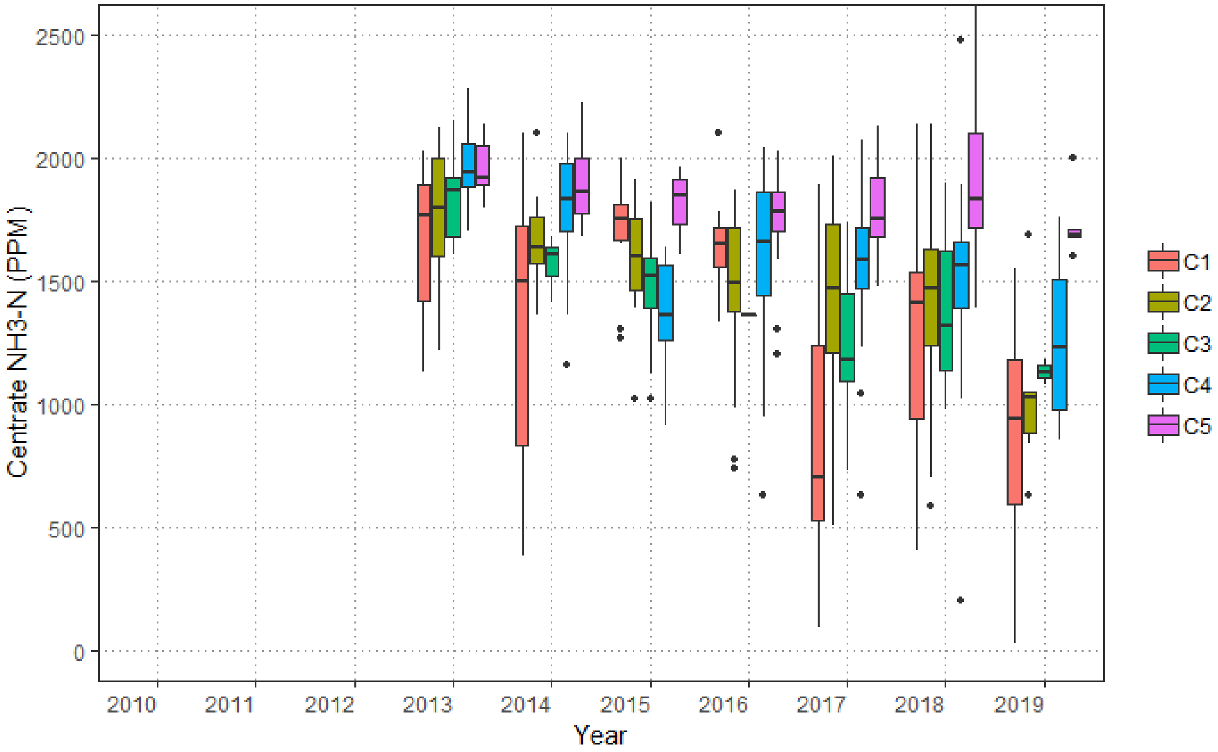


Figure 5-7. Ammonia-N Concentrations (Yearly Averages)

5.6 Waste Activated Sludge Thickeners

The WAS uses gravity belt thickeners (GBTs) to concentrate the WAS.

5.6.1 Design Criteria

The design criteria are provided in Table 5-6.

Table 5-6. WAS Thickening Design Criteria

Parameter	Typical Design Criteria	Average	Range
Gravity Belt Thickeners			
Type	Ashbrook Simon-Hartley Aquabelt 3.0M	--	--
Quantity, #	2+1	--	--
Flow, gpm	--		
Horsepower, HP	--		
Length, ft	6.6		
Total Solids, %	5		
Filtrate Pumps			
Type	--		
Quantity, #	3		
Flow, gpm	--	1.6	0.7-2.8
Horsepower, HP	--		
TWAS Pumps			
Type	Progressive Cavity, Moyno 2JOKAI (Pumps No. 11 and 12 are different from 13)		
Quantity, #	2+1	--	--
Flow, gpm	240 gpm	193	102-444
TDH, psi	No. 11/12: 65-550 gpm @ 35-65 psi No. 13: 30-300 gpm @ 50-125 psi		
Horsepower, HP	--	--	--
Total Solids, %	No. 11/12: 6 No. 13: 10		

5.6.2 Operational Experience

The issues at the WAS Thickener facility is as follows:

- Belt Filters
  - No DCS monitoring
  - No feed forward control
  - Requires frequent monitoring to adjust polymer based on WAS wasting rates at reactors
  - May shut off for no reason and stop the belt filter.
  - Out of service for months at a time due to electrical issues. PLC is out of date and the parts difficult to get (from salvage)
- TWAS pump/piping
  - Pumps may shut off for non-discernible reasons
- Flow meter
  - WAS pump meter is inaccurate or there's a potential leak back in the other pumps causing a mis-read in actual WAS pumps. This makes the control strategy difficult in controlling WAS wasting rate.

5.7 Polymer System, Sludge Dewatering

The dewatering process currently uses emulsion polymer which is delivered to bulk storage tank at the Bulk Chemical Storage Area (also known as the Tank Farm). From the storage tanks, the "neat" polymer is pumped to the Polymer Blend Units 5 and 6 and aged at the mixing/aging (M/A) tank 3. Alternatively, the polymer may be pumped to a Day Tank in the Dewatering Building Basement, which feeds DWB Polymer Blend Units 1, 2, 3, and 4 followed by DWB M/A tanks 1 and 2.

At the Polymer Blend Units, the neat polymer is diluted with water (typically 2W or RW) and the polymer solution is sent to mix/age tanks. Mix/Age Tanks 1 and 2 are located in the Dewatering Building Basement. Mix/Age Tank 3 is located in the Tank Farm. There are two polymer solution feed pumps for each centrifuge train (one serving as back up), which draw from the Mix/Age Tanks and feed the centrifuge train either upstream of the sludge feed pump or upstream of the centrifuges.

5.7.1 Design Criteria

Refer to Table 5-7 for additional information on the Blend Tanks' key equipment information.

Table 5-7. Polymer (DWB) System Design Criteria

Parameter	Design Criteria	Parameter	Design Criteria
Storage Tanks		Mixing/Aging Tanks	
Quantity, #	3	Quantity, #	1
Type	Polyethylene	Type	Fiberglass
Volume, gals	6,300	Volume, gal	5,000
Recirculation/Transfer Pump		Transfer Pump*	
Quantity, #	2	Quantity, #	2
Flow, gpm	--	Flow, gpm	5
TDH, ft	--	TDH, psi	50
Speed, rpm	--	Speed, rpm	300
Horsepower, hp	--	Horsepower, hp	1
Polymer Blending Units			
Type	Hydro-Mechanical		
Quantity, #	2		
Flow, gph	300-6000		
TDH, psi	40-70		
Speed, rpm	--		
Mixer Power, hp	1.5		
Pump Motor, hp	0.5		
Dilution Water, type	2W/RW		
*Needs verification. Please note that the information regarding these systems are sparse and not easily available in any known documentation.			

5.7.2 Performance

Polymer performance is quantified here as both a ratio of total flow and total polymer use. For each centrifuge, the historic annual ratio is provided in Figure G-6 and the total polymer use in Figure G-7.

5.7.3 Operational Experience

No known issues regarding the polymer storage or feed systems.

5.8 Polymer System, WAS Thickening

At the Polymer Blend Units, the neat polymer is diluted with water (typically 2W or RW) and the polymer solution is sent to mix/age tanks. Mix/Age Tanks 1 and 2 are located in the Dewatering Building Basement. Mix/Age Tank 3 is located in the Tank Farm. There are two polymer solution feed pumps for each centrifuge train (one serving as back up), which draw from the Mix/Age Tanks and feed the centrifuge train either upstream of the sludge feed pump or upstream of the centrifuges.

5.8.1 Design Criteria

Refer to Table 5-8 for additional information on the Blend Tanks' key design criteria. Note that much of the information is blank due to a lack of importance in these systems—as such, minimal effort was allotted for this section.

Table 5-8. Polymer (WAS Thickening) System Design Criteria

Parameter	Design Criteria	Parameter	Design Criteria
Storage Tanks		Mixing/Aging Tanks*	
Quantity, #	2	Quantity, #	2
Type	Poly	Type	--
Volume, gals	16,000	Volume, gal	--
		Transfer Pump*	
Polymer Blending Units		Quantity, #	2
Type	Hydro-Mechanical	Flow, gpm	--
Quantity, #	2	TDH, ft	--
Flow, gph	300-6000	Speed, rpm	--
TDH, psi	40-70	Horsepower, hp	--
Speed, rpm			
Mixer Power, hp	1.5		
Pump Motor, hp	0.5		
Dilution Water, type	2W/RW		
*Needs verification.			

5.8.2 Operational Experience

No known issues regarding the polymer storage or feed systems.

5.9 Biosolids

On average, the MWWTP produces approximately 75,000 wet tons per year of biosolids at about 24 percent Total Solids (approximately 10 truckloads per day), which are treated to Class B standards through anaerobic digestion process per the U.S. EPA 40 CFR Part 503. Biosolids are hauled off-site by an outside contractor for beneficial reuse.

During the dry weather season the majority is used as a soil amendment at land application sites in Merced County; during the wet weather season the majority is used as alternative daily cover (ADC) at nearby landfills. A smaller portion may be used as a compost feedstock or wet weather storage and land application. The average quantity of biosolids disposed of at each location is indicated in Figure G-5.

CHAPTER 6 - ODOR CONTROL

6.1 Introduction

The MWWTP has several odor control systems (OCS) throughout the liquid and solids treatment and conveyance processes. These OCSs are listed below:

- Influent Pumping Station (IPS) – Coarse Screen Room and Intake Structure
- IPS – Fine Screen and Off-Haul Bin Room
- Septage Receiving Station A
- Blend Tanks
- Fats, Oils, and Grease/High Strength Liquids (FOG/HSL) Receiving Station
- Solids/Liquids Waste (SLW) Receiving Station
- Dewatering/Thickening Building

6.2 Odor Control Goals

The District has a key performance indicator that each fiscal year we receive 30 or fewer odor complaints from the neighbors surrounding the WWTP. For fiscal year 2019 and 2018, the District received 15 and 17 complaints respectively. While the key performance indicator was met, the District aims to have no odor impacts off-site and no odor complaints.

6.3 Influent Pumping Station – Coarse Screen Room and Intake Structure

A two stage OCS for the IPS Coarse Screen Room and Intake Structure is used to treat odors from the coarse screen room and intake structure. The new OCS includes two fiberglass reinforced plastic (FRP) centrifugal exhaust fans (with one in standby), two stages of treatment, and a grease/mist eliminator.

The FRP fan exhausts 18,000 CFM of ventilation and foul air from the coarse screen room/channels and intake structure; 13,000 CFM and 5,000 CFM, respectively. The first stage of treatment is comprised of two, 12’ diameter by 35’-2” high biotrickling filters (BTF). The BTFs have three media beds of non-proprietary polyurethane foam media at a depth of 6’-8” for each bed. Each BTF has a dedicated irrigation recirculation pump, but are configured to use either recirculation or once-through irrigation modes. The second stage of treatment is comprised of two, 11’ diameter by 16’-8” high dual bed carbon adsorbers. Table 6-1 provides treatment performance design criteria for each stage and the overall OCS.

Table 6-1 IPS Coarse Screen and Intake Structure OCS Design Criteria

Parameter	Criteria	Actual
Biotrickling Filters		
Inlet H_2S Loading	5 PPM Avg, 50 PPM Peak	--
H_2S Removal Performance	99.0% or 0.5 PPMV, whichever is greater	--
Inlet Odor Loading	9,300 D/T Avg, 17,000 D/T Peak	--
Odor Removal Performance	90% or 300 DT, whichever is greater	--
# Units (duty + standby)	2+0	--
Size, diameter x height	12' x 35'2"	--
Flow Capacity, cfm (ea)	9,000	--
Empty Bed Residence Time, s (ea)	15	--
Media Type	Polyurethane foam	--
Carbon Adsorbers		
Inlet H_2S Loading	5 PPM Avg, 50 PPM Peak	--
H_2S Removal Performance	99.5% or 0.1 PPMV, whichever is greater	--
# Units (duty + standby)	2+0	--
Flow Capacity, cfm (ea)	9,000	--
		--
Overall OCS		
Inlet H_2S Loading	5 PPM Avg, 50 PPM Peak	0 or 5 ppm Avg (0 occurs due to submerged interceptor conditions)
H_2S Removal Performance	99.5% or 0.1 PPMV, whichever is greater	--
Inlet Odor Loading	9,300 D/T Avg, 17,000 D/T Peak	--
Odor Removal Performance	95% or 200 DT, whichever is greater	--
Exhaust Fan, cfm	18,000	--

The new system uses Sensidyne H_2S analyzers to monitor the OCS inlet, midpoint (between BTF and Carbon Adsorbers), and outlet H_2S concentrations. The data is monitored and archived on the District's DCS.

6.3.1 Operational Experience

This is a new OCS and is operating within normal parameters. There are no historical operational data related to this facility.

6.4 Influent Pump Station – Fine Screen and Off-Haul Bin Room OCS

The OCS includes two roof mounted FRP centrifugal exhaust fans (with one in standby), a grease/mist eliminator, and a Calgon Carbon Phoenix carbon adsorber OCU.

The FRP fan exhausts foul air from the fine screen room, channels, and off-haul bin room. The OCU utilizes a proprietary activated carbon installed in removable radial flow removable canisters. The canisters are arranged into vertical chambers to allow for water regeneration. Once the carbon is spent the canisters can be removed and replaced individually. Table 6-2 provides treatment performance design criteria for each stage and the overall OCS.

Table 6-2 IPS Fine Screen Area OCS Design Criteria

Parameter	Value
Overall OCS	
Inlet H_2S Loading, ppm	5 PPM Avg, 50 PPM Peak @ 18,000 CFM
H_2S Removal Performance, %	99%
Exhaust Fan, cfm	22,000

The existing system uses Sensidyne H_2S analyzers to monitor the OCS inlet and outlet H_2S concentrations. The data is monitored and archived on the District's DCS.

Replacement of the OCU was removed from SD-361 scope due to air sampling and odor characterization efforts showing the Fine Screen H_2S loading has traditionally been close to zero. Our current air permit requires treatment of the Fine Screen Area ventilation, but future options could include an in-kind replacement with a newer carbon adsorber or removing the air permit requirement for treatment. Replacement of the OCU is required in the near term due to the OCS being at the end of its useful life.

6.4.1 Operational Experience

The odor loading on this OCS is minimal compared to the size and capacity of this OCS and is not regularly changed out.

6.5 Septage Receiving Station A

The OCS includes a FRP centrifugal exhaust fan, a two stage radial flow carbon adsorption treatment, and a grease/mist eliminator. The FRP fan exhausts captured foul air from the headspace and ambient area around near the catch basin with a duct hood. Each FRP carbon adsorber vessel is 5' diameter by 7'-8" high. There is also an 8' diameter by 10' high FRP contact vessel that was used previously with a VAPEX hydroxyl ion OCU that was trialed. The VAPEX unit was later removed when the second stage of carbon adsorption was added under

SD-340. Table 6-3 provides treatment performance design criteria for each stage and the overall OCS.

Table 6-3 Septage Receiving Station A OCS Design Criteria

Parameter	Value
Overall OCS	
Inlet H_2S Loading	125 PPM Peak
H_2S Removal Performance	<1.0 PPM
Exhaust Fan	1,800 CFM

6.5.1 Operational Experience

Annual change out of media is required to maintain effectiveness.

6.6 Blend Tanks and FOG/HSL

The Blend Tanks OCU and FOG/HSL are both currently undersized and will soon be replaced in 2020 with a combined system. This new system is currently in the planning/design phase (as of May 2019) and the design odor and foul air flow is not yet finalized. Please refer to project SD-409 for additional information.

6.7 SLW Receiving Station

The SLW Receiving Station's OCS is comprised of a two stage bioscrubber and carbon adsorber polishing unit. The OCS is currently undersized and the bioscrubber has been abandoned due to a broken 2W pipeline. In the same project to upgrade the Blend Tanks and FOG/HSL OCSs, the old Blend Tanks carbon scrubber may be relocated for the SLW Receiving Station. This relocated Blend Tank carbon scrubber is sized at 600 CFM and is meant to provide minimal odor control at the SLW Receiving Station. Alternatively, a new properly sized OCS may be built at this receiving station; however, the District has not yet decided upon which path to take. One outstanding issue is that the SLW Receiving Station's future odor potential is expected to be reduced from current levels when high strength trucked waste will be diverted to the FOG/HSL tanks; however, it is unknown to what extent the SLW Receiving Station's odor potential will be reduced.

6.8 Solids Dewatering and Thickening Buildings

The Solids Dewatering and Thickening Buildings are ventilated by separate supply and exhaust push-pull ventilation systems. This includes five wall mounted propeller fans, one ground level centrifugal fan, and two roof mounted vaneaxial inline fans. Exhaust is provided by two large axial flow inline exhaust fans. The potential odor impact of this untreated exhaust was evaluated using dispersion modeling and found to be minor. In 2019, a planning and design project will provide improvements for both ventilation systems, but will not include the odor control systems.

Point source odors are collected and treated by two separate OCS's; one for Dewatering and the other for Thickening. Both include an FRP centrifugal exhaust fan, a Calvert Atomizing Mist Chemical Scrubber; and a common air compressor. Table 6-4 provides treatment performance design criteria for each OCS, but the airflow to each vessel was increased in 2007 (SD-266). The original system was designed for 3,000 CFM, each, of odorous air with 3,000 CFM of make-up air to be introduced at the exhaust fan inlet to eliminate the vapor exhaust plume. Due to odors causing workplace environment issues and low inlet average H_2S of 5 PPM, additional point sources were exhausted to the OCS as an interim measure.

The Dewatering Building area fan captures foul air from the centrifuges, digested sludge well headspace, and the ambient area above the solids storage hoppers while the Thickening Building area fan captures foul air from the gravity belt thickeners (GBT), the GBT drain chutes, and the thickened waste activated sludge sumps.

Each FRP chemical scrubber contact vessel is 6'-6" diameter by 23' high. The chemical scrubbers are connected to the MWWTP's sodium hypochlorite bulk storage feed. A common air blower provides 100 SCFM of air to each, 200 SCFM total, scrubber atomizing nozzles to generate finely divided chemical solution droplets to absorb and oxidize the concurrent foul air flow.

Table 6-4 Solids Dewatering and Thickening Building OCS Design Criteria

Parameter	Value
Overall OCS, Each	
Inlet H_2S Loading	20 PPM Peak @ 3,000 CFM
H_2S Removal Performance	<0.20 PPM
Quantity, # (duty+standby)	2+0
Fan Exhaust Fan, cfm (ea)	6,000
Type	Chemical Scrubber
Scrubber Air Supply, cfm (ea)	100

Atomized mist scrubbing is considered older technology with an industry track record of problems including clogging atomization nozzles and poor performance for variable odor loading. The structures are also aging and they are not performing well.

6.8.1 Operational Experience

Operations must recalibrate the chemical flows for effective odor control daily as the flows tend to drift. In addition, the odor control system does not capture ambient odors during biosolids loading due to open truck trailer and an open bay nor does it capture odors from the biosolids hoppers and air louvers.

CHAPTER 7 - POWER GENERATING STATION

7.1 Introduction

Digester biogas, containing methane, carbon dioxide, and other compounds, is used to generate power at the Power Generation Station (PGS) 1 and 2.

Power generation is dependent on the amount of biogas produced in the Digesters, which in turn is dependent largely on the amount of high strength wastes received at the R2 receiving stations (either at the FOG/HSL or the SLW receiving stations). This biogas production is variable and will fluctuate hourly, daily, and/or weekly based on the quantity and energy density of the truck hauled high strength wastes.

7.2 Historical Energy Production

The plant has in recent years produced approximately 140% of the annual plant energy needs. On a daily basis, the MWWTP turbine produces an average of 82,300 kWh/day and the engines 53,700 kWh/day. In normal operating conditions, the turbine is running 24/7 with 1-3 engines running and acting as peak load units.

7.3 Engines

PGS 1 contains 3 internal piston/reciprocating combustion (IC) engines rated to take in 600 cfm of biogas and produce 2.15 MW per engine. PGS 2 encompasses the turbine engine which uses approximately 1,300 cfm to generate 4.6 MW.

It is reasonable to assume 1 turbine and 2 engines will be online under normal conditions due to the installation of additional dual membrane digester covers on Digester 3 and 4 in 2020-2020 for equalization. This assumption, however, will only hold as long as biogas is only used for generating electricity.

7.4 Flares

Excess biogas not used by the generators are flared off at the low and high capacity flares. There are 2 high capacity flares and 4 low capacity flares. The high capacity flares are sized at 1,500 scfm with a turndown of 300 scfm each while the low capacity flares are sized at 0-900 scfm each.

7.5 Gas Conditioning System

The gas condition system removes the siloxane from the biogas so that the silicone dioxide does not build up and cause damage or increased O&M costs on the turbine engines. As well, the system will reduce O&M costs on the IC engines and boilers as well. The current gas conditioning system was built in the PGS 2 expansion project and was sized for 3,000 scfm on the intake size. This flow rate translates to 2,700 scfm on the outlet side of the conditioning system.

As the PGS 1 and PGS 2 engines are sized for a total approximate flow of 3,100 scfm. As such, all four engines cannot be operated simultaneously. A project in 2020 will determine the feasibility of upsizing the gas conditioning system in order to operate all engines simultaneously.

7.6 Boilers

Though not strictly required for generating power, a boiler are onsite to provide supplemental heat for the digesters when there are not at least two engines online. The boiler is sized for 175 to 500 scfm with a 3,148 gallon tank.

CHAPTER 8 - POWER DEMANDS

8.1 Introduction

The MWWTP uses, on average, 4.6 MWs of energy. Much of this power is used for pumping and running the secondary treatment systems. The following is a list of major power demands at the plant:

- Influent Pumping Station
- Reactors
- Operations Center
- O2 Plant
- Dewatering Building

8.2 Power Use Overview

The power information is split up into the various substations, or groups of substations, throughout the plant. Each substation may serve part of a facility, the entire facility, or multiple facilities. Refer to Table 8-1 for an overview of each substation, their size, connected loads, and power demands. Refer to Figure 8-1 and Figure 8-2.

8.3 Substation Size and Connected Loads

The substation size and connected loads is not provided in this document. Information regarding the topic is currently being consolidated in the 2019 Load Study and provided in Task Report *E10 Previous and Ongoing Studies Summary*.

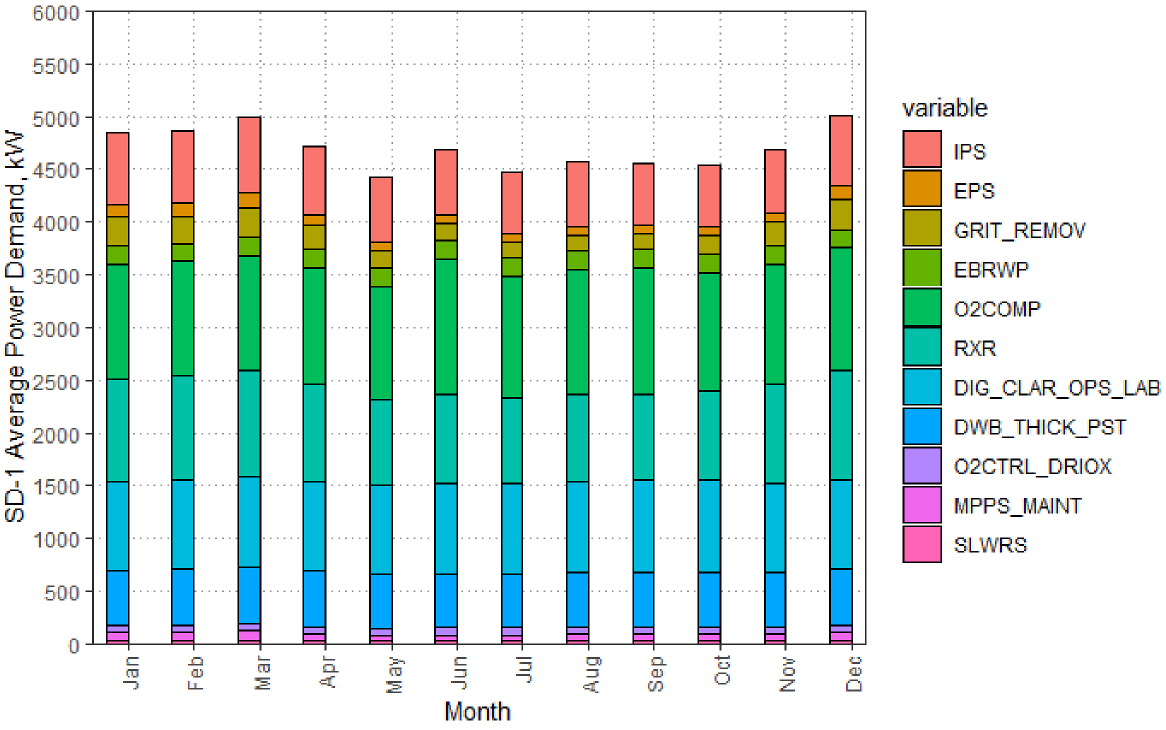


Figure 8-1. SD-1 Power Demand, Average Monthly

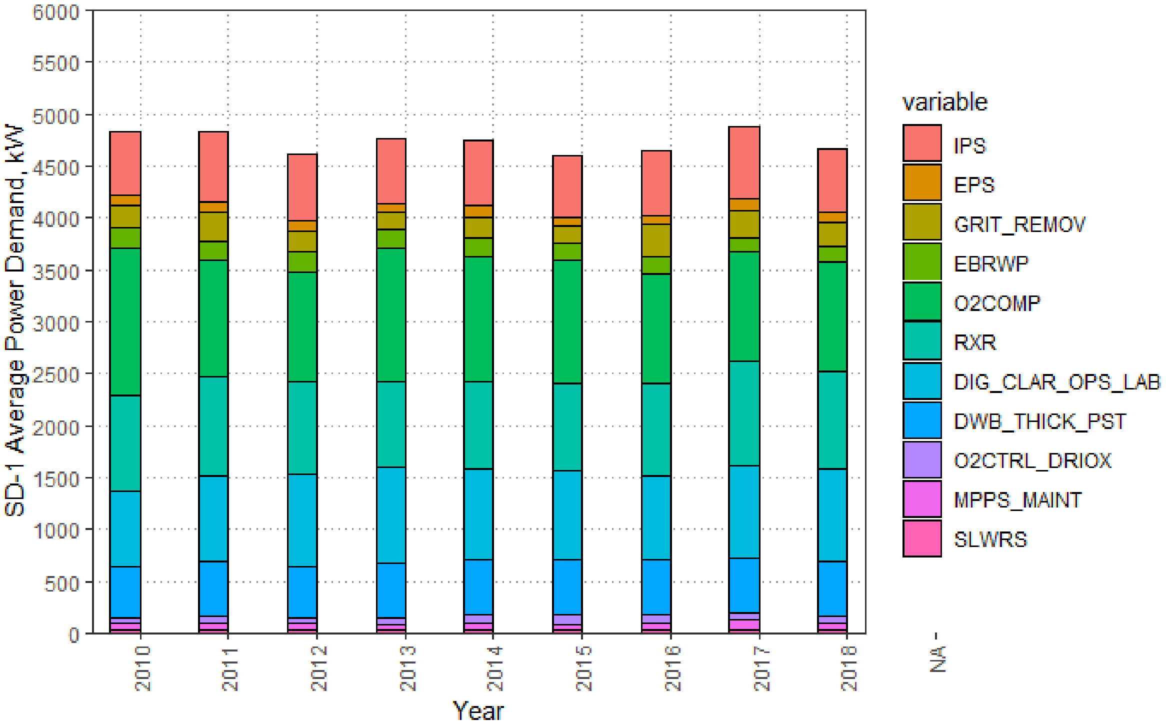


Figure 8-2. SD-1 Power Demand, Average Yearly

Table 8-1 Substation Summary

		Annual and Dry Weather Averages and Standard Deviation				**Percentiles**						**Days with Data Count**
Substation	**Facility/Process Area**	**AA Mean**	**AA STDEV**	**DW (NPDES) Mean**	**DW (NPDES) Stdev**	**0%**	**25%**	**50%**	**75%**	**90%**	**Max**	
Plant Influent Pumpng Flows (in MGD)												
N/A	IPS Flow, MGD	61	22	53	5	11	52	56	61	77	226	3,090
Power Generation/Substation Demands (in KW)												
N/A	PGE Feed	3,992	1,615	3,609	1,710	0	4,148	4,414	4,739	5,091	8,250	3,082
N/A	PGS 1 Generation	3,330	1,346	3,525	1,415	0	2,438	3,737	4,217	4,369	6,480	3,088
N/A	PGS 2 Generation	3,528	1,311	3,304	1,454	0	3,557	4,062	4,268	4,399	4,507	2,636
S1/U20/U21	IPS, Primary Sludge Thickeners, Prechlor, Grit Dewatering	631	141	600	62	0	562	605	656	716	1,722	3,088
S2	EPS, Effluent Sampling Building, Field Services	97	96	81	17	0	64	73	92	115	1,404	3,088
U1	Aerated Grit Tanks	146	128	58	61	(0)	16	150	219	360	455	3,088
U3	Recycle Water Plant, 3W PS, Old Maintenance Building	174	29	179	29	(0)	158	175	192	210	270	3,088
S3	O2 PLT Compressors	1,139	252	1,183	239	0	1,005	1,034	1,313	1,465	2,459	3,090
U6/U7/U8/U9	Reactors	895	167	808	94	(0)	795	867	953	1,150	1,442	3,090
U4/U5/U12/U16	Operations, Clarifiers, Admin, Lab, Digesters, Blend Tanks	861	73	866	70	(0)	819	868	908	940	1,051	3,088
U14/U15	Dewatering, Thickeners, Primary Sedimentation	521	65	516	51	(0)	491	528	558	588	696	3,088
U10/U11	O2 Plant Ctrl, Driox Vap Pit	70	23	76	28	(0)	55	65	75	102	233	3,088
U22	MidPlant PS	70	59	59	18	(0)	44	62	70	84	431	3,088
U13	SLW Receiving Station	22	9	22	9	(0)	17	21	26	32	106	3,088
MSB	Maintenance Building	No Data										0
	Total Power Use	4,628	598	4,447	316	(0)	4,285	4,501	4,828	5,265	8,254	3,088
*Data produced from the District's DCS and is based on average daily data from 2010 to 2018.												

CHAPTER 9 - CHEMICAL USES

9.1 Introduction

The WWTP uses various chemicals during normal and expected operations. The chemicals currently in use during the 2017 year consists of: Sodium Hypochlorite (NaOCl), Sodium Bisulfite (NaHSO3), Polymer, and Ferric Chloride (FeCl). Chemical use information is provided in those sections requiring chemicals for treatment elsewhere in this document. This section is intended to provide a high level overview on the cost and use of each chemical.

9.2 Sodium Hypochlorite

Sodium hypochlorite (12.5%) is used for odor control in the interceptor (coming into the plant upstream of the influent pumping station), grit, diversion flows, and disinfection. The quantity, concentration, and use location are summarized in Table 8-1. Cost of sodium hypochlorite at the MWWTP was $0.525/gal in 2019.

Table 9-1. Sodium Hypochlorite Historic Use

Location	Daily Average Quantity, gal	Daily Average Dose, mg/L
Interceptor	7,900	20.4
Grit	740	2.4
Diversion	550	12.4
Disinfection	1,600	3.7
Note: Daily average quantity is based on total and average daily information from 2010 to 2017.		

9.3 Sodium Bisulfite

Sodium Bisulfite (25%) is used by the WWTP to neutralize excess hypochlorite (dechlorination) before the final effluent is discharged into the receiving water. The historic 2010 to 2018 average dose was 10 mg/L and the average sodium hypochlorite neutralization demand was 5.8 mg/L. Cost of chemical was $0.3745/lb in 2019 (or $1.08/gal).

9.4 Ferric Chloride

Ferric chloride (40%) is used for sulfur emission control at the Power Generation Station. The injection point for ferric chloride is primarily into the Blend Tanks, either via the TWAS line or directly into the tank from the tank's roof. Ferric chloride may also be injected into the Primary Influent Channel; though this was found to be an inefficient way of controlling sulfur emissions.

Total ferric chloride use in 2017 was 3.18 million pounds with an average dose of 1,585 gpd from 2010-2018. Cost of chemical was $0.4375/lb in 2019.

9.5 Polymer

The WAS thickening and centrifuge dewatering systems both use the same kind of polymer (inverse emulsion), Zetag 8818 from BASF. In 2017, the centrifuges used an average of 3,343 lbs of polymer per day at the dewatering centrifuges and 550 lbs/day at the thickeners.

Cost of chemical was $0.8760/lb and $0.9310/lb for dewatering and thickening polymer respectively in 2018. The different costs are due to the two facilities using separate contracts and future polymer providers may not be the same for each facility.

CHAPTER 10 - REGULATORY COMPLIANCE

10.1 Introduction

This section provides a high-level summary of plant compliance with existing regulatory requirements for the MWWTP. Refer to Task Report *E20: Regulations* for information regarding the regulatory requirements.

10.2 NPDES Permit Compliance

The MWWTP operates under NPDES Permit No. CA0037702. Order No. R2-2015-0018 is the current version of this permit and it expires on June 30, 2020. The Current and Potential Future Regulations Task Report contains additional information on this permit, current effluent limits, and other provisions in the permit.

The MWWTP has not experienced an effluent limit violation for 20 years. In 2017, the MWWTP received the NACWA Platinum 18 Award commemorating 18 years of compliance.

In spite of maintaining 18 years of compliance with effluent limitations, some compliance issues have arisen during this time. Two instances where effluent limit were exceeded are briefly described below, along with the resolution.

- TSS weekly and monthly average exceedances occurred in 2006-2007 during three separate months. No violations occurred after these exceedances since they were caused by a plant upset.
- Acute toxicity exceedances occurred between June 2010 and September 2010. No violations occurred from these exceedances since the cause was demonstrated to be dissolved carbon dioxide which is rendered harmless once discharged to San Francisco Bay.

The MWWTP has also experienced three unauthorized discharges since 2010 where partially treated wastewater has been released outside of the facility boundary into areas impacting surface water. Appropriate corrective actions have occurred after each of these incidents and no long-term master plan level actions are required.

A few cases of deficient monitoring have occurred at the MWWTP in the last several years. In these cases, the MWWTP did not submit all required monitoring data to the RWQCB due laboratory issues, equipment issues, or operational issues. Monitoring deficiencies have been investigated and measures to prevent reoccurrence have been implemented when possible.

The NPDES Permit also contains provisions that must be met for blending during high flows experienced during storms. One important provision that must be met is increased effluent monitoring. The MWWTP has conducted this increased monitoring and has not noted any effluent limit violations during blend events. Another provision of that must be met while blending is that flow through the secondary system must be at least 150 MGD. On a few occasions, flow has slipped below 150 MGD during blending events, primarily due to power fluctuations at the plant during storms. These incidents have been reported to the RWQCB and no enforcement action has resulted.

10.3 Watershed Permit (2014)

10.3.1 MWWTP Nutrient Discharge to San Francisco Bay

Like most of the Wastewater Treatment Plants (WWTPs) in the Bay Area, the MWWTP was not designed to remove nutrients from wastewater, although some removal is achieved through the existing wastewater treatment processes. As a result, the current effluent contains a significant amount of nutrients (refer to Table 1) and contributes approximately 19 percent of the total nutrient discharges to San Francisco Bay from all 37 Bay WWTPs combined.

Municipal WWTPs account for about 63 percent of the total nitrogen load to the SF Bay based on past regional evaluations. On April 9, 2014, the SFRWQCB issued Order No. R2-2014-0014, Waste Discharge Requirements for Nutrients from Municipal Wastewater Discharges to San Francisco Bay (Watershed Permit). The Permit is effective from July 1, 2014 to June 30, 2019, and is expected to be renewed upon expiration.

The existing nutrient Watershed Permit requires routine nutrient effluent monitoring and reporting, completion of a study to evaluate Potential Nutrient Discharge Reductions, and the submittal of an annual Nutrients Report. The MWWTP has complied with the major provisions of this Permit. Refer to the BACWA Group Annual Report for more information (https://bacwa.org/wp-content/uploads/2017/10/Group-Annual-Report-2017-Combined.pdf).

Table 10-1. MWWTP Nutrient Discharge Summary

	Dry Weather Season (May 1 to September 30)	**Annual Average (January 1 to December 31)**
Effluent to the San Francisco Bay	~48 MGD	~58 MGD
Ammonia (as N)	~8,400	~8,600
Total Kjeldahl Nitrogen (TKN) (as N)	~9,500	~9,700
NOx (Nitrite + Nitrate) (as N)	~700	~850
Total Nitrogen (as N)	~10,200	~10,600
Ortho-P (as P)	~520	~620
Total Phosphate (TP) (as P)	~700	~760
*All units in kg/day, based on data from 07/01/2012–06/30/2017		

10.4 Biosolids Regulations

Consistent with our 17 years of perfect compliance with our NPDES permit, EBMUD has an excellent track record of complying with all regulations related to biosolids. The regulations EBMUD reliably meets or exceeds include but are not limited to:

- 40 CFR Part 503 – Standards for the Use or Disposal of Sewage Sludge
- 40 CFR Part 258 – Criteria for Municipal Solid Waste Landfills
- CA Code, Title 27, Division 2, Subdivision 1 "Consolidated Regulations for Treatment, Storage, Processing and Disposal of Solid Waste"
- Merced County Code, "Regulations of Sewage Sludge," Chapter 9.52
- San Joaquin Valley Unified Air Pollution Control District Rule 8081 – Agricultural Sources

EBMUD has produced approximately 200 wet tons per day of Class B biosolids for the last five years and prior with no violations. EBMUD complies with all pathogen reduction requirements of the EPA 503 rule by exceeding time and temperature requirements for anaerobic digestion, a Process to Significantly Reduce Pathogens (PSRP). In addition, EBMUD voluntarily tests its biosolids for fecal coliforms twice per week as an added factor of safety. We meet the vector reduction requirements of the EPA 503 rule by reducing volatile solids by a minimum of 38% in the anaerobic digesters (typically EBMUD's VSR is 65%). We meet pollutant limits by complying with Cumulative Pollutant Loading Rates. Under these rules, biosolids may contain pollutant concentrations up to the Ceiling Concentration Limits for land application yet, out of an abundance of caution, EBMUD sets data alarms at the lower Pollutant Concentration Limits for Class A EQ biosolids.

As shown in the table below, EBMUD exceeded all regulatory requirements for biosolids for calendar year 2016 by wide margins.

Table 10-2 2016 Biosolids Regulatory Requirements

Constituent	EBMUD Data (Min or Max Month in 2016)	EPA Requirement
Fecal Coliform (geometric mean)	25 MPN/gram (April 2016, max)	2 million MPN/gram
Volatile Solids Reduction	58% (Aug, Oct, min)	38% minimum
Metals		
Arsenic	34 mg/kg (Mar, max)	75 mg/kg max
Cadmium	8.7 mg/kg (Jul, Sep, max)	85 mg/kg max

Constituent	EBMUD Data (Min or Max Month in 2016)	EPA Requirement
Copper	390 mg/kg (Nov, max)	4,300 mg/kg max
Lead	49 mg/kg (Feb, max)	840 mg/kg max
Mercury	0.91 mg/kg (Dec, max)	57 mg/kg max
Molybdenum	17 mg/kg (Sep, max)	75 mg/kg max
Nickel	36 mg/kg (Mar, max)	420 mg/kg max
Selenium	6.4 mg/kg (Mar, max)	100 mg/kg max
Zinc	1,100 mg/kg (Mar, max)	7,500 mg/kg max

MPN – most probable number

EBMUD conducts additional testing to support the waste characterization needs of the various landfills where the biosolids are applied as ADC. This helps the landfills comply with CFR 258. The parameters in the semi-annual tests include cyanide and total sulfides, for which the biosolids regularly test low. The semi-annual tests also include volatile organics (EPA 8260B), semi-volatile organics (EPA 8270C), and silver.

For more than ten years, EBMUD biosolids have been land applied in the dry weather season to farms in Merced County. To comply with General Order requirements that biosolids not be land applied to water-saturated or frozen ground, EBMUD does not land apply during the wet weather season. Our contractor ensures that the biosolids are applied at a rate that does not exceed the agronomic rate for the crops being grown. To assist with the bulk biosolids notification requirements, EBMUD prepares monthly reports called Notice and Necessary Information reports, or NANIs. These reports, signed by the Wastewater Treatment Superintendent, include metals and nitrogen concentrations to enable the land applier to use correct loading rates.

10.4.1 Biosolids Management Program:

In addition to meeting regulatory requirements, EBMUD imposes further controls with its longstanding Biosolids Management Program. The program includes monthly audits of destination landfills during the wet weather season, monthly audits of the land application practice during the dry weather season, and monthly audits of the trucks upon loading. The audits are conducted by EBMUD Wastewater Control Inspectors and extend beyond regulatory requirements to capture best management practices. For example, the land application audit requires checks for good housekeeping at the site and confirmation that field staff is wearing appropriate safety gear. The truck audit requires measures beyond the Merced County 9.52.035 regulations, such as checks that the drivers have a basic knowledge of biosolids and carry communication materials in both English and Spanish.

10.5 Air Permit Compliance

The MWWTP operates under two air permits. The BAAQMD has issued a Permit to Operate to the MWWTP that includes approximately 30 permitted sources. The BAAQMD has also issued a Major Facility Review (Title V) Permit to the MWWTP which includes slightly less permitted sourced but additional reporting requirements.

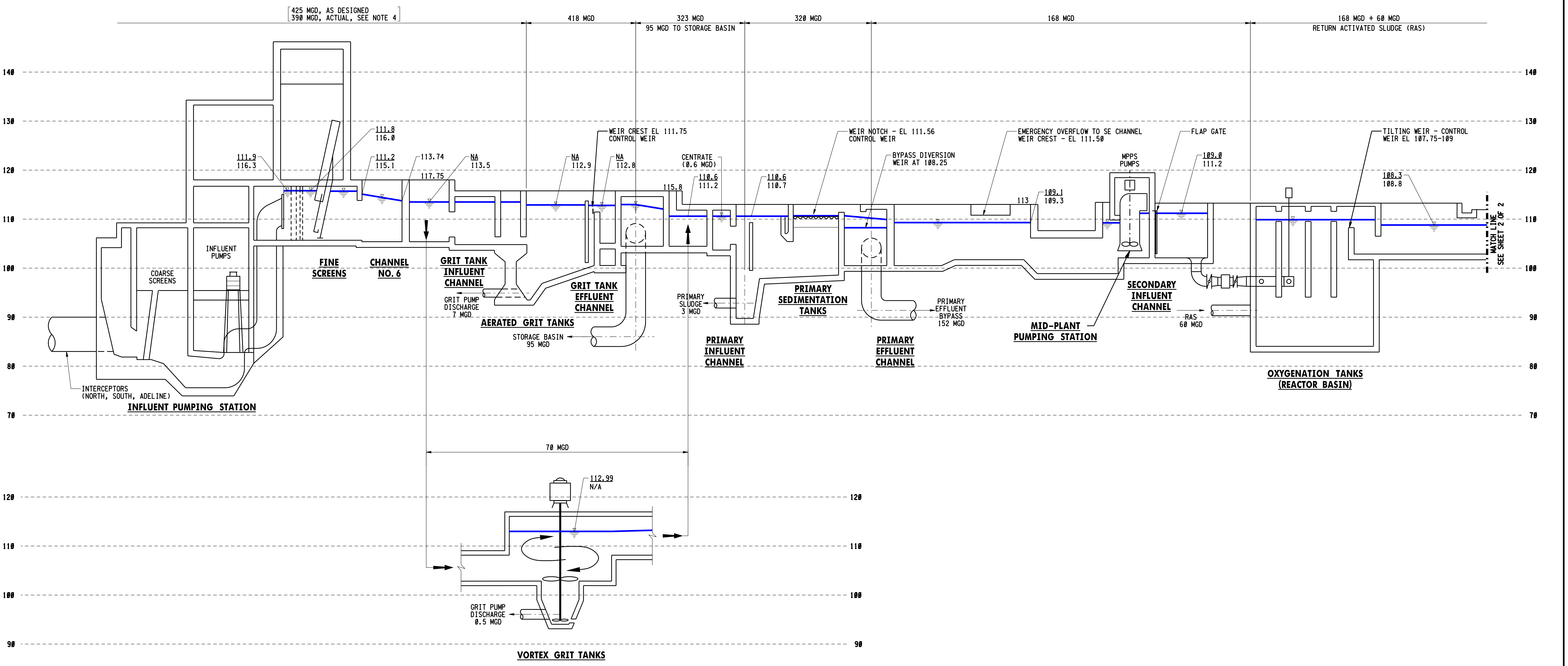
About ten notices of violation have been issued to the MWWTP for exceeding the allowable total sulfur content in digester gas between 2010 and 2017. At the time of the violations, the total sulfur limit for digester gas was 340ppm (instantaneous limit). The MWWTP put several corrective actions into place during this time to better control total sulfur levels in digester gas including several upgrades and refinements to the ferric chloride system used to reduce digester gas hydrogen sulfide formation. In 2017, the BAAQMD granted a new total sulfur limit of 200ppm (annual average). The MWWTP has been in compliance with this new limit since 2017.

The MWWTP has also received about ten notices of violation for the release of unabated digester gas to the atmosphere between 2010 and 2017. The air permit prohibits the release of digester gas to the atmosphere except under prescribed exceptions for certain safety and maintenance activities. The violations had various causes and each individual event was investigated and appropriate corrective actions put in place.

APPENDIX A - Hydraulic Profile

Appendix A contains the following information:

- Drawings indicating the hydraulic profile elevations
- Field data used to calibrate the hydraulic profile



HYDRAULIC PROFILE

VERT SCALE : 1"=10'-0"

TABLE 1. CALCULATED HYDRAULIC GRADE LINES

A = Average Dry Weather Flow (ADWF)

B = Peak Wet Weather Flow (PWWF)

TABLE 2. HYDRAULIC GRADE LINE ASSUMPTIONS	A	B	MAX
FLOW	ADWF	PWWF	UNITS
Flow, MGD	50	425	n/a
UNITS ONLINE			
Fine Screens	2	5	5
Vortex Grit Tank	2	0	2
Aerated Grit Tanks	0	8	8
Primary Sedimenation Tanks	9	16	16
Oxygenation Reactors	5	8	8
Clarifiers	9	12	12

NOTES

1. REFER TO TABLE 1 AND 2 FOR HYDRAULIC GRADE LINE LEGEND AND ASSUMPTIONS.
2. VGT'S HAS LESS HEADLOSS THAN AGT'S.
3. MAXIMUM FLOWS THROUGH EACH SYSTEM VARIES DEPENDING ON THE SYSTEM AND IS SHOWN AT THE TOP OF PAGE.
4. IPS PUMPS' ACTUAL MAXIMUM FLOW CLOSER TO 78 MGD (390 MGD TOTAL) BASED ON PUMP TESTS FROM 2017-2019. HYDRAULIC PROFILE ASSUMES DESIGN FLOWS.

3" ON ORIGINAL DOCUMENT
0 1 2 3

NO.	DATE	REVISION	BY	REC.	APP.

DESIGN
DESIGN BY: G. LIN
DRAWN BY:

REVIEW
DESIGN CHECKED BY: Jenny H Tran
R.P.E. No. C83148 JENNY H TRAN
CONSTRUCTABILITY CHECKED BY:
ELECTRICAL CHECKED BY:
R.P.E. No.

PROJECT ENGINEER
R.P.E. No.
PROJECT MANAGER
R.P.E. No.
RECOMMENDED:
SR. ENGINEER
R.P.E. No.

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND. CALIFORNIA

MAIN WASTEWATER TREATMENT PLANT

GENERAL
HYDRAULIC PROFILE
1 OF 2

SCALE AS SHOWN
DATE 04MAR2020

HYDRAULIC PROFILE 1
DRAWING NUMBER

1
REV.

REF 7:
REF 8:
REF 9:

REF 4:
REF 5:
REF 6:

REF 1: J:\WWP\ref\wbdr.mst
REF 2: J:\wwp\wwp.plant.process.dgn
REF 3:

PLOT SCALE: 20:1

USER: supsorns
DATE: 05-MAR-2020 08:37
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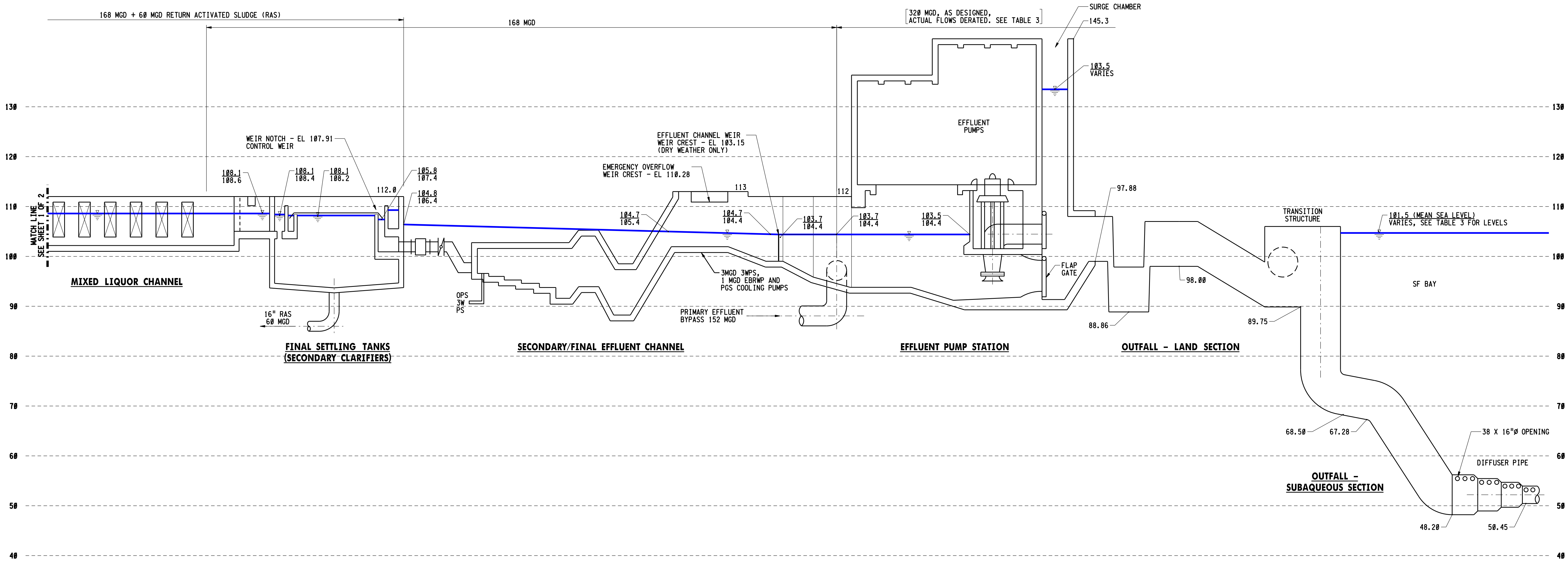

HYDRAULIC PROFILE

VERT SCALE : 1"=10'-0"

TABLE 3. OUTFALL FLOWS AS A FUNCTION OF TIDE AND SURGE CHAMBER WATER SURFACE ELEVATIONS

Tide Elevations	Alameda Station Tide Elvations, MLLW Datum, FT	Alameda Station Tide Elevations, SD-1 Datum, FT[1]	Maximum Surge Chamber Operating WSEL, FT[4]	Outfall Flow, MGD[2]
Max Tide[3]	9.65	**107.72**	139.5	273
10-yr Max Tide[3]	8.8	**106.87**	139.5	278
Mean Higher High Water	6.6	**104.67**	139.5	286
Mean High Water	5.98	**104.05**	139.5	290
Mean Sea Level	3.45	**101.52**	139.5	300
Mean Low Water	1.14	**99.21**	139.5	309
Mean Lower-Low Water	0	**98.07**	139.5	313

Notes:

1. Equivalent Tide elevations are actual elevations +1.0' (1.0' = Diff. in head due to diff. of water density between effluent in sub-aqueous portion (depth = 50') and bay water). A conversion of +97.069 is used to convert between Mean Lower-Low Water (MLLW) to SD-1 datum using Alameda Tidal Station.
2. Outfall flows based on tidal and surge chamber elevations. Historical data is used to determine the system curve and thus flow rates.
3. Max tide shown, but not used to determine maximum flow due to infrequent occurance (100 year return frequency). Profile instead uses the tide level matching a 10 year return frequency.
4. Surge chamber WSEL is capped the maximum normal operating level of 139.5' (physical top of wall is EL. 143.3')

3" ON ORIGINAL DOCUMENT
0 1 2 3

NO.	DATE	REVISION	BY	REC.	APP.

DESIGN
DESIGN BY: G. LIN
DRAWN BY:

REVIEW
DESIGN CHECKED BY: Jenny H Tran
R.P.E. No. C83148 JENNY H TRAN
CONSTRUCTABILITY CHECKED BY:
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R.P.E. No.
RECOMMENDED:
SR. ENGINEER
R.P.E. No.

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
OAKLAND. CALIFORNIA

MAIN WASTEWATER TREATMENT PLANT

GENERAL
HYDRAULIC PROFILE
2 OF 2

SCALE AS SHOWN
DATE 04MAR2020

HYDRAULIC PROFILE 2
DRAWING NUMBER

1
REV.

REF 7:
REF 8:
REF 9:
REF 4:
REF 5:
REF 6:
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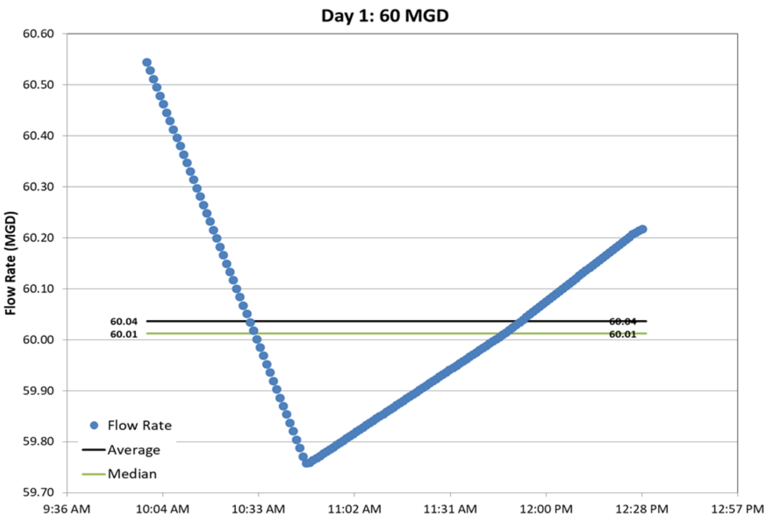
REF 2: J:\wwp\wwp_plant_process.dgn
REF 3:
PLOT SCALE: 20:1
USER: supsorns
DATE: 04-MAR-2020 17:01
FILE: J:\wwp\Hydraulic_Profile 2 of 2.r01

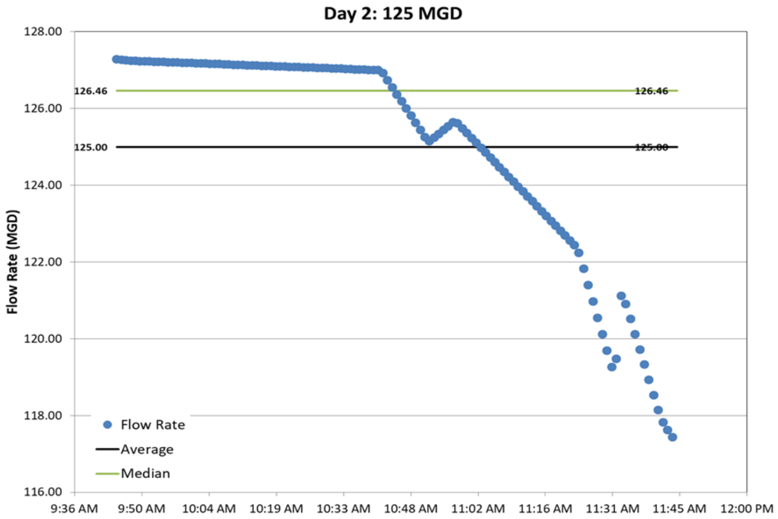
Hydraulic Calibration Field Data

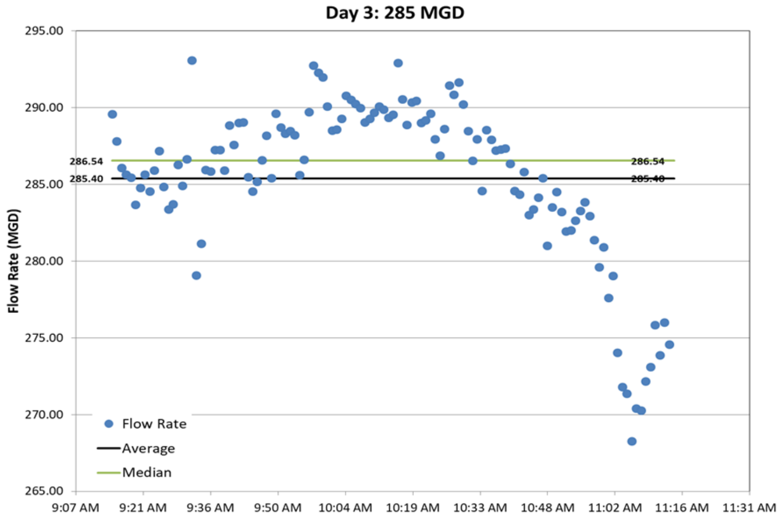
Date	**5/18/2017**	**1/7/2019**	**2/13/2019**
Time	**10:15 AM - 12:15 PM**	**10-11:30 AM**	**9:30-11 AM**
Average Flow Rate (MGD) (*see plots below*)	**60**	**125**	**285**

#	**Location**	**Reading, in**	**Reading, in**	**Reading, in**	**Reference**	**Ref EL, FT**	**60 MGD WSEL, FT**	**125 MGD WSEL, FT**	**285 MGD WSEL, FT**	**Notes**
0	INF Channel u/s	68	62.5	40.5	Top of Wall	117.75	112.08	112.54	114.38	
1	INF channel d/s (u/s of BFVs)	69	65	43	Top of Deck	117.75	112.00	112.33	114.17	
2	AGT Main INF channel, @ tank 8 (d/s of BFV)	44.5	42.5	30.75	Top of Deck	115.8	112.09	112.26	113.24	2/13/19 - flow was turbulent
3	AGT Main INF channel, @ tank 1	45	44.25	32	Top of Deck	115.8	112.05	112.11	113.13	
4	AGT 1 Lateral INF channel, d/s	45	44	32	Top of Deck	115.8	112.05	112.13	113.13	
5	Grit Tank 1	45	44.5	33	Top of Deck	115.8	112.05	112.09	113.05	
6	AGT 1 Lateral EFF Channel, u/s	58.5	52	33.5	Top of Deck	115.8	110.93	111.47	113.01	
7	AGT EFF Channel @ 1	60.25	55	35.75	Top of Deck	115.8	110.78	111.22	112.82	
7A	AGT EFF Channel @ 6 (u/s of gates)	--	55.75	38.25	Top of Deck	115.8	--	111.15	112.61	
7B	AGT EFF Channel @ 7 (d/s of gates)	--	56.75	40.75	Top of Deck	115.8	--	111.07	112.40	
8	AGT EFF Channel ! 8 u/s of BFV	61	56.25	41	Top of Deck	115.8	110.72	111.11	112.38	
8A	AGT EFF Channel ! 8 d/s of BFV	61.25	57.25	43.75	Top of Deck	115.8	110.70	111.03	112.15	2/13/19 - flow was turbulent, suspect BFV was partially closed?
9	PI Channel, @ PST 1	27.75	28.25	25.75	Top of Deck	113	110.69	110.65	110.85	<--highly turbulent area
10	PI Channel, @ PST14	28	26.5	24	Top of Deck	113	110.67	110.79	111.00	
11	PST 1	28.25	29	28.75	Top of Deck	113	110.65	110.58	110.60	
12	PST 13	28.5	28.5	28	Top of Deck	113	110.63	110.63	110.67	
13	PE Channel, u/s @ PST 1	47	61.75	40.5	Top of Deck	113	109.08	107.85	109.63	
14	PE Channel, @ PST 16	48	66	43	Top of Deck	113	109.00	107.50	109.42	
15	PE Channel @ PST Control Building	58	65.25	43.5	Top of Channel (ne	113.875	109.04	107.56	109.38	<---Bubbler measured 109.05-ft
16A	PE Channel, @ MPPS (u/s of flap gate, PS online)	--	68	49.75	Top of Wall	113	--	107.33	108.85	
16B	PE Channel, @ MPPS (PS Wetwell, PS online)	--	74.5	60.75	Top of Wall	113	--	106.79	107.94	
16	PE Channel, @ MPPS (d/s of flap gate)	48.2	36.5	23.75	Top of Wall	113	108.98	109.96	111.02	<--Online instrument off by 1/2 ft?
17	SI Channel at O2 Tank 1	48	35.75	23.875	Top of Wall	113	109.00	110.02	111.01	
18	SI Channel, @ O2 Tank 8	48	35.5	23	Top of Wall	113	109.00	110.04	111.08	Reading for highest WSE (from traces of prev water line: 8.75")
19	MLSS Channel @ O2 Tank 8	Too much foa	52.5	Foamed	Top of Wall	113	--	108.63	--	
20	MLSS Channel @ Secondary Clarifier 08	43.5	43.25	41	Top of Wall	112	108.38	108.40	108.58	
21	MLSS Channel @ Secondary Clarifier 11	43.75	42.5	40.75	Top of Wall	112	108.35	108.46	108.60	
22	Clarifier INF Launder	46	45.25	Foamed	Top of Wall	112	108.17	108.23	--	
23	Clarifier Eff Launder d/s	42	34.5	28.25	Top of Launder Wa	109.5	106.00	106.63	107.15	
24	SE Channel @ PST Control Building	95	47.75	92.75	Top of wall (next to	113	105.08	109.02	105.27	
25	SE Channel @ 90 degree turn	95.5	104	109.5	Top of Deck	113	105.04	104.33	103.88	
26	SE Channel u/s of weir (north side)	85.25	98.5	98	Top of Wall	112	104.90	103.79	103.83	
27	SE Channel d/s of weir (@ EPS, north side)	103	98.25	97.5	Top of Wall	112	103.42	103.81	103.88	
	Bypass Inlet DS of weir			64	Top of Deck	113			107.67	2/13/19 - flow was turbulent
	Bypass Outlet US of Gates			96	Top of Wall	113			105.00	
	*MPPS Test indicated 0.4 ft drop (@ 80mgd) between PE channel bubbler (at Pri Sed Building) to u/s of MPPS									

Process	**Online Equipment**			**Number Online**		
	60 MGD	**125 MGD**	**285 MGD**	**60 MGD**	**125 MGD**	**285 MGD**
IPS Pumps	1, 2	1,2,5	1-5	2	3	5
AGTs	1,2,5,6	1,2,3,4,7,8	1-8	4	6	8
VGTs	N/A	N/A	N/A	0	0	0
PSTs	1,2,7,8,9,11,1	1-10, 13, 14, 1	1-12,15,16	9	13	14
Mid-Plant Pumps	N/A	2, 3	1,3	0	2	2
Reactors	1,3,5,7,8	1-8	1-8	5	8	8
Secondary Clarifiers	2,3,4,6,7,8,9,1	1-12	1-12	9	12	12
EPS Pumps	N/A	3,4	1,3,4	0	2	3


Day 1: 60 MGD


Day 2: 125 MGD


Day 3: 285 MGD

APPENDIX B - Existing Treatment Process Capacity

This appendix contains a table indicating the equipment size, dimensions, equipment number, design condition, values, and quantity where

Summary of Existing Capacity MWWTP Liquid Treatment Processes

			In Field			Original Design Criteria										Existing Performance			
Process	**Facility**	**Equipment/Tanks**	**Total # Units**	**Physical Parameters or Type**	**Equipment Number**	**Design Conditions (flow, load, etc)**	**Design Parameters**	**Design Parameter Values**		**Duty Units**	**Standby Units (OOS)**	**Unit Capacity (/ea)**	**Units**	**Firm Capacity**	**Max Capacity**	**Firm capacity per unit (/ea)**	**Units Used (Duty)**	**Performance Value Average**	**Performance Value Range**
Receiving Stations	Septage A Receiving Station	Receiving Bays	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Septage B Receiving Station	Receiving Bays	1	--	--	--	--	--	--	1	0	--	--	--	--	--	--	--	--
	K2 Brine Receiving Station	Receiving Bay	1	--	--	--	--	--	--	1	0	--	--	--	--	--	--	--	--
Preliminary Treatment (Headworks)	Coarse Screen Room	Coarse Bar Screens	5	8" channel width, 6" clearance btwn bars	W-12-BSC-001(2,3,4,5)-00	Peak Influent Flow (Wet Weather) - 415 Recycled Flow - 10 Total Design Flow - 425	--	--	--	5	0	85	mgd	425	425	--	5	--	--
	Influent Pumping Station Pumps	IPS Pumps	5	Vertical dry-pit mixed-flow centrifugal, 85mgd, 35 TDH, 700 HP,	W-12-PMP-001(2,3,4,5)-00	same as above	--	--	--	5	0	85	mgd	425	425	78	5	78	60-94
	Fine Screens	3/4-in Screens	3	Climber Type, 106 mgd/ea, 3/4" opening btwn bars, 0.5" headloss @ 85mgd, 90 sec cycle time	W-12-SCG-BSC-003(4,5)-00	PHWWF? 425mgd?	Velocity (85 mgd), headloss	2.4	ft/s	3	0	85	mgd	255	255	--	3	--	--
		1/4-in Screens	2	1/4" opening btwn bars, 5.46-in headloss at 25% screen binding at 60 MGD, or 7.42 at 85 MGD in Summer, or 5.01 at 106 mgd	W-12-SCG-BSC-001(2)	Average dry weather - 60 mgd Peak Design Flow - 85 mgd Hydraulic peak flow (bypass one screen) - 106 mgd Velocity: 3 fps	Velocity	3	ft/s	2	0	85	mgd	170	170	--	2	--	--
	Aerated Grit Removal	Grit Tanks	8	123'x18'x13' (LxWxD), 215,000 gal	W-13-TKS-001(2,3,4,5,6,7,8)-00	425 mgd all 8 tanks, 40 mgd minimum flow per tank Design flow of 37.5 MGD per tank at 8 min detention time requiring max air of 10 cfm/ft per original O&M Manual	--	--	--	8	0	37.5	mgd	300	300	--	8	--	--
		Aerated Grit Blowers	2	Hoffman Model 75105A1, multistage centrifugal, constant speed,2 at 250 HP, 5000 cfm @ 22.2 psia, #1 is out of service (abandoned in place).	W-13-BLW-001(2)-01	Air requirement based on mixing (flow per linear length of grit tank)	Air requirement WW Flows	10 5000	cfm/ft cfm	1	1	5000	cfm	5000	10000	--	1	--	--
		Aerated Grit Blowers	2	Hoffman Model 74106A, multistage centrifugal, constant speed,100 HP, 2000 cfm @ 22.2 psia	W-13-BLW-004(5)-01	Air requirement based on mixing (flow per linear length of grit tank)	Air requirement DW Flows	10 2000	cfm/ft cfm	1	1	2000	cfm	2000	4000	--	1	--	--
		Grit tank conveyors	16	54'x1.5', constant speed one motor per two conveyors, 30 HP, 1300 CF/day	W-13-AGC-001(2,3,4,5,6,7,8)-01(02)	--	--	--	--	16	--	1300	cf/day	20800	20800	--	16	--	--
		Grit Pumps	16	Wemco Model C non-clog vortex constant speed, 300 gpm @ 75 TDH, 30 HP (or 85 TDH per 1980 O&M Manual)	W-13-PMP-01E(1W,2E,2W,3E,3W,4E,4W,5E,5W,6E,6W,7E,7W,8E,8W)-01	--	--	--	--	16	--	300	gpm	4800	4800	--	16	--	--
	Vortex Grit Removal	VGT Pumps	4	Wemco Model C 8x6, 500 gpm @80 TDH, 830 rpm	W-13A-GR-PMP-101(102,201,202)	--	--	--	--	4	--	500	gpm	--	2000	--	--	--	--
		VGT Mixer	2	2 HP Mixer	W-13A-GR-MIX-101(102)	--	--	--	--	2	0	--	--	--	--	--	--	--	--
		Vortex Tank	2	--	--	WW Max of 140mgd through two tanks, remaining (to 425mgd) to aerated grit tanks DW Max of 95 MGD, DW Average of 80 mgd	--	--	--	2	0	70	mgd	140	140	70 mgd for both VGTs together in service	2	--	--
	Grit Dewatering	New Hydrocyclones	2	Wemco Model 1500 cyclones, 500 gpm inlet @ 77.5 inlet pressure	--	--	--	--	--	2	--	500	gpm	--	1000	--	--	--	--
		New Grit Classifier	1	Wemco Hydrogritter Model 30 F Classifier, 420-840 gpm, operating at 500 gpm (3 HP), screw conveyor	W-16-GCL-001	--	Flow	420-840	gpm	1	--	500	gpm	--	500	--	--	--	--
		Old Hydrocyclones	15	Wemco 5 units (3 cyclones per 1 classifer)	--	1600-1700 gpm hydraulic cyclone grit separator with adj. table apex valve (per 1980 O&M)	Sludge Concentration	2% grit slurry or 2% sludge concentration	%TS	15	--	n/a	n/a	--	--	--	--	--	--
		Old Grit Classifier	5	Unit efficiency: 95% of 200 mesh and larger grit at 2.65 SG, screw conveyor	W-16-GCL-002(3,4,5,6)-01	1600-1700 gpm				5	--	1700	gpm	--	8500	--	--	--	--

Process	Facility	Equipment/Tanks	Total # Units	Physical Parameters or Type	Equipment Number	Design Conditions (flow, load, etc)	Design Parameters	Design Parameter Values		Duty Units	Standby Units (OOS)	Unit Capacity (/ea)	Units	Firm Capacity	Max Capacity	Firm capacity per unit (/ea)	Units Used (Duty)	Performance Value Average	Performance Value Range
WW Storage	Wet Weather Storage	WW Storage Tanks	5	4x 2.2 MG tanks, 1x 2.4MG, for a total volume of 11.0 MG. Sidewall depth at 30-ft, 208x259 ft overall dimensions.	--	Peak diversion to storage basin. Flow based on max capacity of AGTs (323 MGD) and on design storm.	Flow	95	mgd	5	--	11	mg	--	55	--	--	--	--
		WW Return Pumps	2	Submersible, nonclog basin drain pumps at 40 mgd@27 TDH each, 316 HP, 710 RPM	W-10-PMP-DP1(2)-00	Maximum basin drainage, 80 mgd	--	--	--	2	--	80	mgd	--	160	--	--	--	--
Primary	Primary Sedimentation Tanks	Primary Sedimentation Tanks	16	174'x36'x10.5', 492,000 gal/tank, 6250 sqft surface area, total volume is 7872000 gal with a total surface area of 100,000 sqft, detention time is 1.5 hours at 120mgd, surface settlign rate at 120mgd is 1,200 gpd/sqft	W-24-TKS-001(02,03,04,05,06,07,08,09,10,11,12,13,14,15,16)-01	Average flow, dry season (130mgd), wet season (130mgd), PWWF (290mgd)	Surface settling rate at 120 mgd	1200	gpd/sqft	14	2	23	mgd	322	368	--	14	--	--
		Raw Sludge Pump (Primary Sludge)	16	Two Speeds: 300 gpm @ 46 TDH and 500 gpm @ 48TDH (20 and 30 HP)	W-24-PMP-001(02,03,04,05,06,07,08,09,10,11,12,13,14,15,16)-01	n/a	--	--	--	14	--	500	gpm	7000	8000	No Data	14	--	--
		Scum Grinder	2	Muffin Monster	W-24-SGR-001(2)-01	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Scum Pump	2	Moyno 300 gpm @ 25psig (for PST 11-16)	W-24-PMP-001(2)-02	n/a	--	--	--	1	--	300	gpm	300	600	--	--	--	--
		Scum Pump	2	Moyno 80 gpm@25psig (for PST 1-10)	W-24-PMP-003(4)-02	n/a	--	--	--	1	--	80	gpm	80	160	--	--	--	--
	Scum Dewatering Station	Scum Separator	2	150 gpm feed rate, 1.7 gpm/SF overflow rate, 20min detention time, 0.5 HP skimming drive, 50% dewatered scum solids concentration	W-15-SCM-001(2)-00	n/a	Overflow rate	1.7	gpm/sqft	2	--	150	gpm	--	300	--	--	--	--
	WW Primary Sludge Thickener	PS Thickener Tanks	2	Diameter: 75', sidewater depth: 14', Influent flow rate (Initial Storage mode and Average thicking modes): 4800 and 2400 gpm	W-23-SCP-001(2)-00	PWWF (425 MGD)	Flow	2400 or 4800	gpm	2	--	2400 or 4800	gpm	--	4800 or 9600	--	--	--	--
		Thickened Sludge Pumps	3	Progressive Cavity Pump, 275gpm@160TDH, 30 HP	W-23-PMP-001(2,3)-00	PWWF (425 MGD)	--	--	--	3	--	275	gpm	--	825	--	--	--	--
Secondary	Mid-plant Pump Station	MPS Pumps	3	ABS Pumps, VFD Submersible propeller, 84mgd@11.25' TDH (or 95mgd@4' TDH), 250HP, 1750 rpm	W-46-PMP-001(2,3)-00	Design PWWF through secondary treatment - 168	--	--	--	2	1	84	mgd	168	252	84	2	--	--
	Secondary Reactors	Reactor Tanks	8	Dimensions: enclosed 46x46x25; 52,900 cf per stage, for a total of 1.7M CF. Each stage uses one surface aerator, 4 stages per unit	W-45-TKS-RX1(2,3,4,5,6,7,8)-01	See SI characteristics	--	--	--	8	0	21	mgd	168	168	21	7	--	--
	O2 Plant	O2 Plants	2	Union Carbide Corporation, 125 tons O2/day at 95% purity, at 2 psig	--	--	--	--	--	1	1	125	tons O2/day	125	250	--	--	--	--
		LOX Storage	2	Union Carbide Corporation, 2 tanks per unit (4 total), 11,000 gallons (50 tons LOX) per tank at 25 psig operating pressure. Total storage is 200 tons.	W-44-TKS-1(2)-1(2)-01	--	--	--	--	0	2	11000	gal	0	22000	--	--	--	--
		LOX Vaporizor	2	Union Carbide Corporation, 2 units, 250 tons/day	--	--	--	--	--	1	1	250	tons O2/day	250	500	--	--	--	--
		Air Compressors	4	Joy Manufacturing Company, 4 units, 3 stage centrifugal, 1250 HP, 3 at 5850 ICFM, 1 at 7020 ICFM, Discharging to 88.8 and 94 psia respectively	W-44-ACP-1-1-01	--	--	--	--	4	--	5850-7020	ICFM	--	24570	--	--	--	--
	Operations Building	RAS Pumps	4	Centrifugal, mixed flow, variable speed, 20 mgd@15TDH, 125 HP	W-54-PMP-001(2,3,4)-01	--	--	--	--	3	1	20	mgd	60	80	--	--	--	--
		WAS Pumps	3	centrifugal, non-clog, variable speed, 1000 gpm @ 70 TDH, 30 HP	W-54-PMP-001(2,3)-02	--	--	--	--	3	--	1000	gpm	--	3000	--	--	--	--
	Secondary Clarifiers	Secondary Clarifiers Tanks	12	140-ft diameter, 14-ft deep, volume: 215,513 cf, surface area is: 15,394 sqft	W-55-CLF-001(2,3,4,5,6,7,8,9,10,11,12)-01	See SI characteristics	surface overflow rate	910	gpd/sqft	12	--	14	mgd	--	168	--	11	--	--

Process	Facility	Equipment/Tanks	Total # Units	Physical Parameters or Type	Equipment Number	Design Conditions (flow, load, etc)	Design Parameters	Design Parameter Values		Duty Units	Standby Units (OOS)	Unit Capacity (/ea)	Units	Firm Capacity	Max Capacity	Firm capacity per unit (/ea)	Units Used (Duty)	Performance Value Average	Performance Value Range
Disinfection/ Effluent PS	Disinfection	Hypochlorite Bulk Storage Tanks	3	69,000 gals/Tank, 14' diameter, 60' straight shell length horizontal tanks, containing 12.5-15% NaOCl	W-85-TKS-101-01(02,03)	Minimum storage based on 5-day max pre-chlor demand during wet weather season and a 4-day max post-chlor demand during wet weather	--	--	--	3	0	69000	gal	207000	207000	--	--	--	--
		Hypochlorite day tank (prechlor)	1	15,900 gal, 13' diameter verticle tank, 17.5' high	W-14-TKS-111-01	--	dosage Flow Sized for 8-hrs of max chlorine demand	5 70	mg/L mgd	1	--	15900	gal	--	15900	--	--	--	--
		SHC Feed Pumps (Post Chlor) Old/Abandoned	2	Vaton, Chem-gard Horizontal drive centrifugal, 60 gpm@25' TDH, 5 HP	W-85-PMP-120-01(04)	SE Post Chlorination: 5.5 gpm ave, 9.4 gpm max Secondary Bypass: 0.3 gpm min, 11 gpm max Prechlor: 2.1 gpm min, 6.9 gpm ave, 33 gpm max	--	--	--	2	--	60	gpm	--	120	--	--	Post-Chlorination feed rate of 6.7 gpm maximum demand with an average of 2.6 gpm	--
		SHC Feed Pumps (Post Chlor)	4	Sundyne Ansimag, Magnetic drive centrifugal, 18gpm @ 77'TDH, 5 HP	W-85-PMP-120-02(03)		--	--	--	2	--	18	gpm	--	72	--	--	--	--
		SHC Feed Pumps (Post Chlor) Future (~2021 onwards)	3	Feed pump, 29 gpm	TBD	Max flow demand of 45 gpm	--	--	--	2	1	--	--	--	--	--	--	--	--
		SHC Transfer Pumps (to Prechlor Day Tank)	2	Vanton horizontal centrifugal (x1) and sundyne ansimag magnetic drive centrifugal (x1), 350 gpm @ 35' TDH, 10 HP	W-85-PMP-106-01(02)	--	--	--	--	1	1	350	gpm	--	700	--	--	--	--
		Disinfection Chlorinators (post chlor)	4	Wallace & Tiernan Water Champ Inductor, 7.5 HP, 30 gpm max liquid induction, 23-inMercury maximum vacuum, 3450 rpm	W-83-CRN-001(2,3,4)-00	--	NaOCl dose Hypo (12.5%) Max Flow Ave Flow	20 9.4 5.5	mg/L Max GPM (12.5% Hypo) Ave GPM	2	2	--	mg/L Max GPM (12.5% Hypo) Ave GPM	--	--	--	--	--	--
	EPS	EPS Pumps	4	Vertical Turbine, wet-pit, 107mgd@44TDH, 1000 HP	W-74-PMP-001(2,3,4)-00	PWWF (425 MGD)	Flow	425	mgd	3	1	107	mgd	--	428	278 MGD Total based on new tidal information	3	--	--
	Dechloration Station	Sodium Bisulfite Injector (Carry) Water Metering Pump	3	in-line centrifugal pump, 600 gpm, 50 HP	W-94-PMP-110-01(02,03)	Based on Flow conditions: 1) DW Diurnal Low (30mgd, Cl residual of 3 mg/L): 480 gpd at 95 day storage 2) DW Ave Month (70 mgd, Cl residual of 5 mg/L): 1,900 gpd at 24 day storage 3) PWWF 4 day average (200 mgd, Cl residual 12 mg/L): 12,800 gpd at 3.6 day storage 4) PWWF Max Hour (340 mgd, Cl residual 12 mg/L): 21,800 gpd at 2.1 day storage	--	--	--	--	--	600	gpm	--	1800	--	--	--	--
		Sodium Bisulfite Transfer Pump	1	1,100 gph, 100:1 turndown, accurate to 0.5% of turndown, 95 TDH, 162 strokes/min, 2HP, with pulsation dampener	W-94-PMP-106-01		--	--	--	1	0	1100	gph	1100	1100	--	--	--	--
		Sodium Bisulfite Injector	2	2 at 100% capacity, 1 online normally, size is 2/3/3 inch (inlet/outlet/suction), 180 gpm water flow, at 180 psi, suction capacity at 20 gpm minimum	W-94-MSL-INJ-01(02)		--	--	--	1	1	20	gpm	--	40	--	--	--	--
		Sodium Bisulfite Vent Injector	2	--	W-94-MSL-INJ-03(04)		--	--	--	--	--	--	--	--	--	--	--	--	--
		Sodium Bisulfite Storage Tanks	3	25% sodium bisulfate in 15,200 gal/tank, 13.5 to 14-ft diameter, 13.3 to 14-ft straight side height, HDXLPE	W-94-TKS-101-01(02,03)		--	--	--	3	0	15200	gal	45600	45600	--	--	--	--
	Outfall	Outfall	1	--	--	--	--	--	--	1	0	--	--	420	420	--	--	--	--

Process	Facility	Equipment/Tanks	Total # Units	Physical Parameters or Type	Equipment Number	Design Conditions (flow, load, etc)	Design Parameters	Design Parameter Values	Duty Units	Standby Units (OOS)	Unit Capacity (/ea)	Units	Firm Capacity	Max Capacity	Firm capacity per unit (/ea)	Units Used (Duty)	Performance Value Average	Performance Value Range

*Highlighted cells denote unconfirmed infromation.

Acronyms:

PHWWF: Peak Hour Wet Weather Flow	**AD: Average Day**	**Reliable Units: Defined as number of units expected to be available at all times.**
PWWF: Peak Wet Weather Flow	**DW: Dry Weather**	**Standby Units: Defined as maximum number of units expected to be out of service at any given time due to failures, maintenance, or etc.**
ADMM: Average Day, Max Month	**WW: Wet Weather**	
	F: Flow	

Summary of Existing Capacity MWWTP Solids Treatment Processes

			In Field			Original Design Criteria										Existing Performance			
Process	**Facility**	**Equipment/Tank**	**Total # Units**	**Physical Parameters or Type**	**Eq Number**	**Design Conditions (flow or load)**	**Design Parameters**	**Design Parameter Values**		**Duty Units**	**Standby Units (OOS)**	**Unit Capacity (/ea)**	**Units**	**Firm Capacity**	**Max Capacity**	**Firm capacity per unit (/ea)**	**Units Used (Duty)**	**Performance Value Average**	**Performance Value Range**
Pre-Digester Solids Thickening	**TWAS Thickening Station**	TWAS Gravity Belt Thicker	3	Ashbrook Simon-Hartley Aquabelt 3.0M 6.6-ft (2-m) long each	W-30-GBT-011(12,13)-00	~5% TS ~12,870 gal/yr neat polymer (Ashland Praestol® K275 FLX, Anionic polymer, emulsion form)	5% TS	--	--	--	--	--	--	--	--	--	--	--	--
		Filtrate Pump	2?	?	W-30-PMP-C11(12)-04	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		TWAS Transfer Pump	3	Moyno 2JOKAI - Pumps #11 and 12, 240 gpm, 65-550 gpm (150-350 rpm), 35-65 psi, 6% TS; Moyno 2JOKAI - Pumps #13, 240 gpm, 30-300 gpm (75-300 rpm), 125 psi at 300 gpm, 50 psi at 30 gpm, 10% TS	w-30-PMP-B11-01, w-30-PMP-C12-01, w-30-PMP-B13-01	6% TS or 10% TS depending on pump	Flow	--	--	--	--	550	gpm	--	1650	--	--	--	--
	WW Primary Sludge Thickener	PS Thickener Tanks	2	75-ft diameter, 14-ft sidewater depth, 463,000 gallons, 0.5% TS	n/a	2400 gpm total PS to thickeners at 0.5% TS, 145,000 lbs/d Hydraulic overflow rate of 390 average and 780 peak, Solids loading rate of 16 Thickened sludge flow of 240 gpm	0.5% TS	--	--	--	--	1200	gpm	--	2400	--	--	--	--
		Thickened Sludge Pumps	3	275 gpm	W-23-PMP-001(2,3)-00	--	--	--	--	--	--	275	gpm	--	825	--	--	--	--
Pre-Digester HSW Receiving Stations	**SLW Receiving Station**	Liquid Tanks (1, 2, 3)	3	20,000 gal/tank	W-33-SLW-TNK-01(02,03)	--	--	--	--	2	1	20000	gal	--	60000	--	--	--	--
		Solids Tanks (4, 5)	2	16,000 gal/tank	W-33-SLW-TNK-04(05)	--	--	--	--	1	1	16000	gal	--	32000	--	--	--	--
		Grinder	2	n/a	W-33-SLW-GRD-04(05)	--	--	--	--	1	1	--	--	--	--	--	--	--	--
		PC Pumps	2	Moyno progressive cavity, 250 gpm at 379.5 ft, 60 HP	W-33-PMP-121(122)-01	--	--	--	--	1	1	250	gpm	--	500	--	--	--	--
		Polishers (Paddle Finisher	2	n/a	W-33-SLW-PF-001(002)	--	--	--	--	1	1	--	--	--	--	--	--	--	--
		Hose Pumps	2	Watson Marlow/Bredel SPX100, 63-250 gpm at 379.5-ft, 60-HP	W-33-PMP-123(124)-01	--	--	--	--	1	1	250	gpm	--	500	--	--	--	--
		In-line Grinder	1	n/a	W-33-GRN-111-01	--	--	--	--	1	--	--	--	--	--	--	--	--	--
	FOG/HSL Receiving Station	Receiving Tanks	2	22,000 gal	n/a	West tank takes FOG, East tank takes high strength liquids	--	--	--	2	0	22000	gal	--	44000	--	--	--	--
		Coarse Bars	4	0.75 inch bar spacing	n/a	--	--	--	--	4	0	--	--	--	--	--	--	--	--
		Recirculation Pumps	2	Vaughan Vertical chopper pumps, 250 gpm at 55-ft TDH, 1750 rpm, 15 HP	W36-FOG-PMP-P04(05)	Maintain 85F, fluid btwn 40-95 F, pH at 5-8, and up to 12% solids containing grit, organic material, rags, plastics, hair, paper, and petroleum and fats and greases. And run dry for 15 minutes.	--	--	--	2	0	250	--	--	500	--	--	--	--
		Heat Exchangers	2	Concentric tube	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Hot Water Pump	2	Horizontal, constant speed, end suction, centrifugal pumps, 185gpm at 37 TDH, 3HP, 1800rpm	W36-FOG-PMP-P06(07)	--	--	--	--	2	0	185	gpm	--	370	--	--	--	--
		In-line Grinder	3	RotaCut, 600gpm at 10 TDH, 10 HP, 22-in cutting champer height, 0.75 max particle passing size	W36-FOG-GRD-G01(02,03)	--	--	--	--	3	0	600	gpm	--	1800	--	--	--	--
		Transfer Pumps (to BTs)	3	Vogelsang positive displacment rotary lobe pumps, 333gpm at 115 TDH, 30HP	W36-FOG-PMP-P01(02,03)	Fluid to be pumped is assumed to be FOG, between 40-95F, pH 4-9, up to 10% solids containing grit, organic material, rags, plastics, hair, paper products, and small quantities of solvents and petroleum products.	--	--	--	2	1	333	gpm	666	999	--	--	--	--

Process	Facility	Equipment/Tank	Total # Units	Physical Parameters or Type	Eq Number	Design Conditions (flow or load)	Design Parameters	Design Parameter Values		Duty Units	Standby Units (OOS)	Unit Capacity (/ea)	Units	Firm Capacity	Max Capacity	Firm capacity per unit (/ea)	Units Used (Duty)	Performance Value Average	Performance Value Range
Blend Tanks	**Blend Tanks**	Blend Tanks	2	200,000 gallon tanks each, conical bottoms, 35-ft internal diameter, Bottom at EL 94.5-ft, Bottom wall at EL 110.5-ft, Top (ceiling) at 134.5-ft. Feed source: PS - 300 typ, 500 max TWAS - 100 typ, 300 max R2 - 250 typ, 750 max	--	5-hour detention time, based on 400,000 gal volume at 9 primary digesters at 10-day SRT with 2 digesters out of service	--	--	--	2	1	200000	gal	--	400000	--	--	--	--
		Heat Exchangers	2	Alfa Laval Spiral Sludge Heat Exchangers, 3,400,000 btu/hr, 400 gpm hot water flow, 800 gpm sludge flow, pressure loss at 21.5-ft for sludge and 10.2-ft for hot water, plate spacing is 1-in for hot water and sludge, entering hot water temp at 165F, entering sludge temp at 165F	W36-BT1(2)-HEX-H01	Maintain blend tank contents at 80-85 F, sludge at 2-5% solids at 115-ft pressure, and temp up to 200F,	--	--	--	2	1	3,400,000	btu/hr	--	6800000	--	--	--	--
		Blend Tank Hot Water Pu	2	Horizontal, constant speed, end suction, centrifugal pumps, 400 gpm at 39 TDH, 7.5 HP, 1800 rpm	W36-BT1(2)-PMP-P02	--	--	--	--	2	1	400	gpm	--	800	--	--	--	--
		Recirculation Pumps	2	Horizontal End Suction Chopper Pumps, 800 gpm at 60 ft TDH, 25 HP	W36-BT1(2)-PMP-P01	--	--	--	--	2	1	800	gpm	--	1600	--	--	--	--
		Digester Feed Loop Pump	3	Vogelsang positive displacment rotary lobe pumps, 600gpm at 115 ft tdh, 30HP	W36-DFL-PMP-P01(02,03)	Fluid to be pumped is assumed to be FOG, between 40-95F, pH 4-9, up to 10% solids containing grit, organic material, rags, plastics, hair, paper products, and small quantities of solvents and petroleum products.	--	--	--	2	1	600	gpm	1200	1800	440	2	--	--
Digesters	**Digesters, 1st stage**	Feed Pumps	8	Vogelsang positive displacment rotary lobe Pumps, 140gpm at 115 TDH, 10 hp	W36-D05(06,07,08)-PMP-P01, W37-D09(10,11,12)-PMP-P01	Fluid to be pumped is assumed to be FOG, between 40-95F, pH 4-9, up to 10% solids containing grit, organic material, rags, plastics, hair, paper products, and small quantities of solvents and petroleum products.	--	--	--	8	0	140	gpm	--	1120	125	6	--	--
		Digesters	8	95' tank diameter, waffle bottom	--	10 day HRT	--	--	--	6	2	2	Mgal	--	16	--	--	--	--
		Digester Dome Covers	8	18 inH2O internal gas pressure, Life and vacuum load of 50 psf, 95-131F operating temp, 10-120F ambient air temp, Seismic Design code CBC 2007, Seixmic Zone 4, I Factor 1.25, C_a coefficient 0.51, Fluid convective wave effect standard AWWA D110, R_w 2.5, S at 1.0, Wind velocity, 90 mph, I-factor 1.15	--	--	--	--	--	6	2	--	--	--	--	--	--	--	--
		Heat Exchangers (Old)	6	Spiral sludge heat exchangers, 75 psig working pressure, design temp of 650F, 3,000,000 BTU/hr, 300gpm sludge flow, 300 gpm heating water flow, Water temp in/out is 190/170 F, sludge in/out is 85/105 F with 246 sqft of heating surface area, with Digester operating at 95F Alfa Laval Model 36 by 61, 550 SF?	W-36-DIG-HTR-06(08), W-37-DIG-HTR-09(10,11,12),	--	--	--	--	6	0	3000000	btu/hr	--	18000000	--	--	--	--
		Heat Exchangers (New for	2	Spiral Sludge Heat Exchangers, 3,400,000 btu/hr, 400 gpm hot water flow, 800 gpm sludge flow, pressure loss at 21.5-ft for sludge and 10.2-ft for hot water, plate spacing is 1-in for hot water and sludge, entering hot water temp at 165F, entering sludge temp at 165F	W36-D05(07)-HEX-H01	2-5% solids by weight	--	--	--	2	0	3400000	btu/hr	--	6800000	--	--	--	--
		Recirculation Pumps (Old)	6	Wemco, non-clog constant speed centrifugal, 10 HP, 300 GPM (or 310gpm?) at 30.5 TDH, 1150 RPM	W-36-PMP-006(008)-01, W-37-PMP-009(010,011,012)-01	--	--	--	--	6	0	300	gpm	--	1800	--	--	--	--
		Recirculation Pumps (New	2	Horizontal End Suction Chopper Pumps, 800 gpm at 60 ft TDH, 25 HP	W36-D05(07)-PMP-P02	--	--	--	--	2	0	800	gpm	--	1600	--	--	--	--
		Mixers (4/digester)	32	Westech SMI1 Extreme Duty, Draft Tube Type Mechanical Mixers, 36-in impeller diameter, 39-in draft tube diameter, 1200rpm, 17,500 gpm at high speed, 13,000 gpm at low speed, 15 HP, 4 per digester	W36-D05(06,07,08)-MIX-M01(02,03,04), W37-D09(10,11,12)-MIX-M01(02,03,04)	30 min turnover rate, 90% active volume, less than 10% short circui9ting, mixer outlet velocity of 4 fps or less in tube	--	--	--	4	0	17000	gpm	--	544000	--	--	--	--

Process	Facility	Equipment/Tank	Total # Units	Physical Parameters or Type	Eq Number	Design Conditions (flow or load)	Design Parameters	Design Parameter Values		Duty Units	Standby Units (OOS)	Unit Capacity (/ea)	Units	Firm Capacity	Max Capacity	Firm capacity per unit (/ea)	Units Used (Duty)	Performance Value Average	Performance Value Range
	Digesters, 2nd stage	Feed (Transfer) Pumps	3	Vogelsang positive displacment rotary lobe Pumps, 465gpm at 115 ft TDH, 20 HP	W35-D02(03,04)-PMP-P01	Fluid to be pumped is assumed to be FOG, between 40-95F, pH 4-9, up to 10% solids containing grit, organic material, rags, plastics, hair, paper products, and small quantities of solvents and petroleum products.	--	--	--	2	1	465	gpm	930	1395	370	2	--	--
		Digesters	3	95' tank diameter, conical bottom	--	3 day HRT	--	--	--	2	1	2.07	Mgal	--	6.21	--	--	--	--
		Heat Exchangers	3	Spiral sludge heat exchangers, 75 psig working pressure, design temp of 650F, 3,000,000 BTU/hr, 300gpm sludge flow, 300 gpm heating water flow, Water temp in/out is 190/170 F, sludge in/out is 85/105 F with 246 sqft of heating surface area, with Digester operating at 95F	W-35-DIG-HTR-02(03,04)	--	--	--	--	2	1	3000000	btu/hr	--	9000000	--	--	--	--
		Recirculation Pumps	3	Wemco, non-clog constant speed centrifugal, 10 HP, 300 GPM (or 310gpm?) at 30.5 TDH, 1150 RPM (or is it 25 hp?)	W-35-PMP-002(003,004)-01	--	--	--	--	2	1	300	gpm	--	900	--	--	--	--
		Digested Sludge Pumps	3	Vogelsang positive displacment rotary lobe Pumps, 600 gpm at 115 ft TDH, 30 HP	W35-DSL-PMP-P01(02,03)	Fluid to be pumped is assumed to be FOG, between 40-95F, pH 4-9, up to 10% solids containing grit, organic material, rags, plastics, hair, paper products, and small quantities of solvents and petroleum products.	--	--	--	2	1	600	gpm	1200	1800	477	0	--	--
Post-Digester Dewatering	**Sludge Dewatering**	Sludge Well	1	--	--	--	--	--	--	1	0	--	--	--	--	--	--	--	--
		Sludge Feed pumps (1-3)	3	0-350 gpm, 65 psi, 0-230 rpm at 5% digested sludge total solids percent	W-25-PMP-0C1(OC2,OC3)-14	--	--	--	--	4	0	350	gpm	1400	1050	--	--	--	--
		Sludge Feed pumps (4)	1	Operating condition is 300 gpm at 181.55 rpm, minimum flow is 100 gpm at 64.08 rpm, discharge prz is 24 psi. Can run at 600 gpm at 360 rpm with lightly abrasive sludge. 25 HP Motor	W-25-DSL-PMP-401	--	--	--	--	1	0	300	gpm	300	300	--	--	--	--
		Sludge Feed pumps (5)	1	Operating condition is 300 gpm at 225 rpm, minimum flow is 100 gpm, discharge prz is 24 psi. Can run at 600 gpm at 367 rpm with lightly abrasive sludge. 20 HP motor	W-25-PMP-0C5-14	--	--	--	--	1	0	300	gpm	300	300	--	--	--	--
		Sludge Line Grinder (old)	3	Franklin Millter Super Shredder, in-line 350 gpm, 5 HP	W-25-SGR-0C1(OC2,OC3)-14	--	--	--	--	3	0	350	gpm	1050	1050	--	--	--	--
		Sludge Line Grinder (New	2	Franklin Millter Super Shredder, in-line 350 gpm, 5 HP	W-25-DSL-GRD-401, W-25-DSL-SGR-OC5-01	--	--	--	--	2	0	350	gpm	700	700	--	--	--	--
		Digested Sludge Line Grin	1	--	W-25-SGR-001-01	--	--	--	--	1	0	--	--	--	--	--	--	--	--
		Centrifuges, Old (Lo Spd)	3	(Humboldt Model S4-1) 150 gpm flow per centrifuge (derated from 180)	W-25-CTF-0C1(2,3)-01	Hydrulic Loading: 210 GPM Solids Loading: 5250 lbs/hr (@ 3-5%) Operating Characteristics: (180 gpm, 20% TS, Centrate TSS of 3000 mg/L) per SD130, cake solids at 22%	--	--	--	3	1	210	gpm	630	630	125	2	--	--
		Centrifuges, New (Hi Spd)	2	High speed, Flottweg (Model Z73-4/454), inlet solids 2-3%, cake solids 25-37%, minimum solids removal, 95%, capacity at 300/3900 lbs/hr, motor HP at 250, main, and 50 back. Flow is 300 derated to 250 gpm or less	W-25-DSL-CTF-401, W-25-DSL-CTF-0C5-01	300 gpm, cake solids at 24%	--	--	--	2	0	300	gpm	600	600	250	1	--	--
		Cake Pumps	5	Schwing bioset KSP25 H(HD)L, max 60 gpm, 70% fill efficiency, 13 strokes/min, continuous gpm is half the max (gpm and spm), minimum is 2 strokes/min, max discharge at 950 psig with a max 1970 psi piston pressure	W-25-PMP-OC1(2,3)-13, W-25-DWS-PMP-401, W-25-DWT-PMP-OC5-13	--	--	--	--	5	0	60	gpm	300	300	--	--	--	--

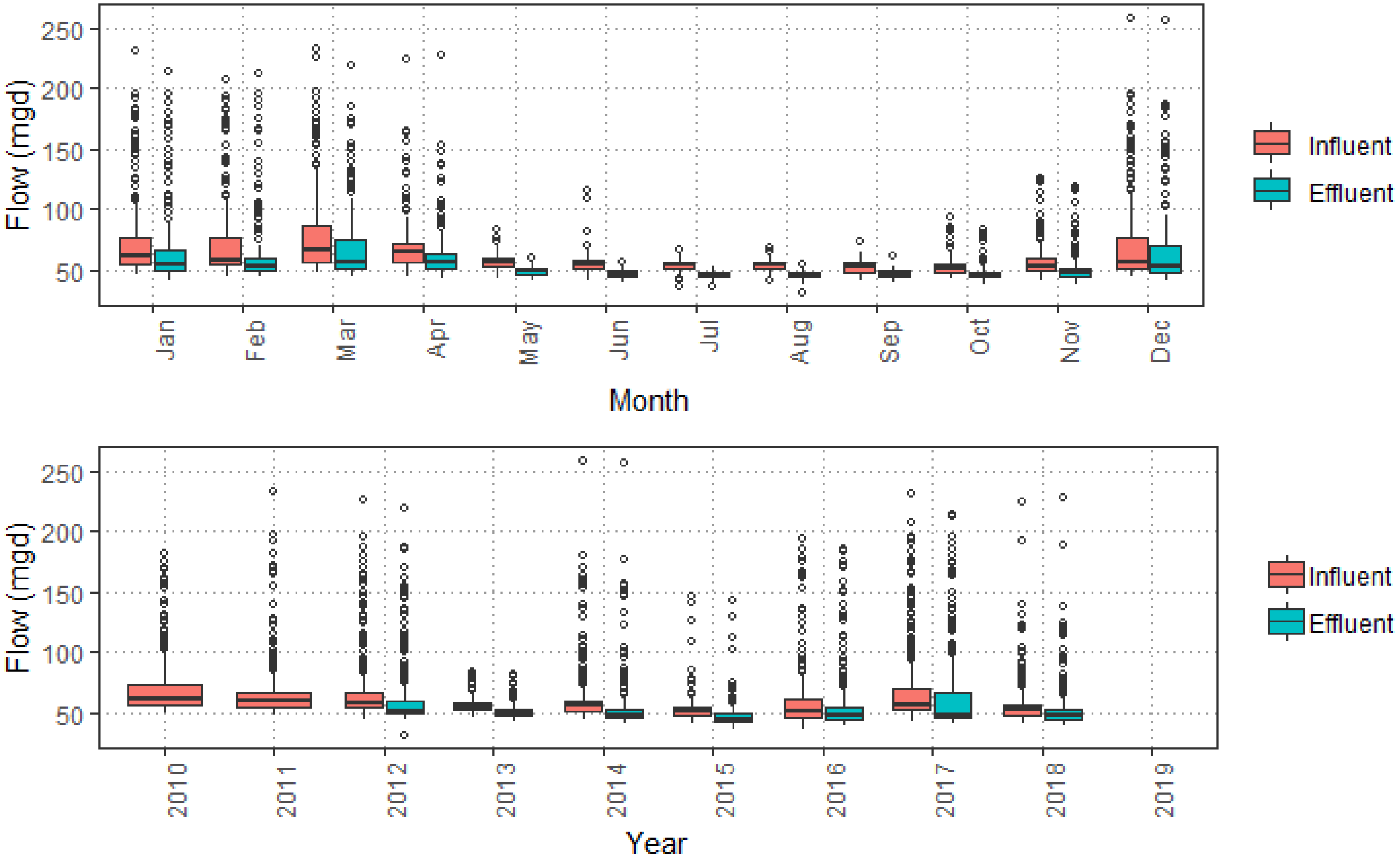
Process	Facility	Equipment/Tank	Total # Units	Physical Parameters or Type	Eq Number	Design Conditions (flow or load)	Design Parameters	Design Parameter Values		Duty Units	Standby Units (OOS)	Unit Capacity (/ea)	Units	Firm Capacity	Max Capacity	Firm capacity per unit (/ea)	Units Used (Duty)	Performance Value Average	Performance Value Range
Tank Farm	**TWAS Polymer System**	Tanks	2	16,000 gal/tank, high density crosslinked Polyethylene tanks; 14-ft diameter	W-32-TKS-531-01, W-32-TKS-532-01	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Polymer Blend Units	2	Thickening polymer blend unit No 1 and 2; hydro-mechanical, 300-6000 gph, 40-70 psi, 0.5 HP pump, 1.5 HP mixer, VFD, 480/3/60 power, Siemens/Stranco Polyblend M 6000-G400-BB-V	w32-POL-CFR-101-WAS, w32-POL-CFR-201-WAS	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Polymer Mixing Tank	2	Polymer Mixing Tanks No 1 and 2 in the Thickening building basement.	w30-PLYM-T1, w30-PLYM-T2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Polymer Transfer Pumps	2	No 11 and 12	--	--	--	--	--	--	--	15	gpm	--	30	--	--	--	--
		Polymer Feed Pump	3	No 11, 12, and 13	w-30-PMP-B11-02, w-30-PMP-C12-02, w-30-PMP-B13-02	--	--	--	--	--	--	30	gpm	--	90	--	--	--	--
	DWB Polymer System	Tanks	3	6,300 gal/tank, high density crosslinked Polyethylene tanks; 10-ft diameter	W-32-TKS-701-01, W-32-TKS-702-01, w-32-TKS-501-01	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Polymer Blend Units	2	Dewatering Polymer Blend Units No 5 and 6; hydro-mechanical, 300-6000 gph, 40-70 psi, 0.5 HP pump, 1.5 HP mixer, VFD, 480/3/60 power, Siemens/Stranco Polyblend M 6000-P60BC-V with C controls	w32-POL-CFR-501-DSL, w32-POL-CFR-601-DSL	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Polymer Recirculation Pumps		--	w32PMP50301, w32PMP50401,	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Polymer Transfer Pumps	2	Progresive Cavity Pump, 5 gpm, 50 psi, 300 max rpm, 1 HP	w32PMP51101, w32PMP51201,	emulsion polymer assumed	--	--	--	--	--	--	--	--	--	--	--	--	--
		Mixing/Aging Tank No.3	1	5,000 gal, 10-ft diameter, fiberglass tank with low shear mixer (45 rpm)	w32-POL-TKS-301-DWMA	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Polymer Feed Pump	2?	C-4 polymer solution feed pump No 1 and 2; progressive cavity type, 15-91 gpm, 65 psi, 7.5 HP on VFD, 480/3/60, Moyno 2000 series	w25-POL-PMP-301, w25-POL-PMP-401	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Ferric Chloride Tanks	Tanks	3	6,300 gal/tank, high density crosslinked Polyethylene tanks; 10-ft diameter; Note. The FCL tank (603-01) replaced an original polymer tank of the same size under SD-341.	w-32-TKS-601-01, w-32-TKS-602-01, w-32-FCL-TNK-603-01	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Feed Pumps	2	ProMinent Fluid Controls Model Meta HM101-530P Metering pumps; 167 gph, 50 psi, 1750 rpm, 6.875-in diaphragm, 0.5 HP	w32PMP61101, w32PMP61201	Ferric Chloride at 39 to 44%, 100 degree max temp, pH <1, 12.2 lbs/gal density	--	--	--	--	--	--	--	--	--	--	--	--	--

*Highlighted cells indicate unconfirmed information.

**Empty cells indicate no analysis done, or insufficient data.

APPENDIX C - Influent and Overall Figures

This appendix provides additional figures for informational purposes only regarding the plant influent and overall status.



Note: Final effluent flows based on ultrasonic flow meter at the Dechlorination Building installed in 2012.

Figure C-1 Influent and Effluent Flows (Monthly and Annual Averages)

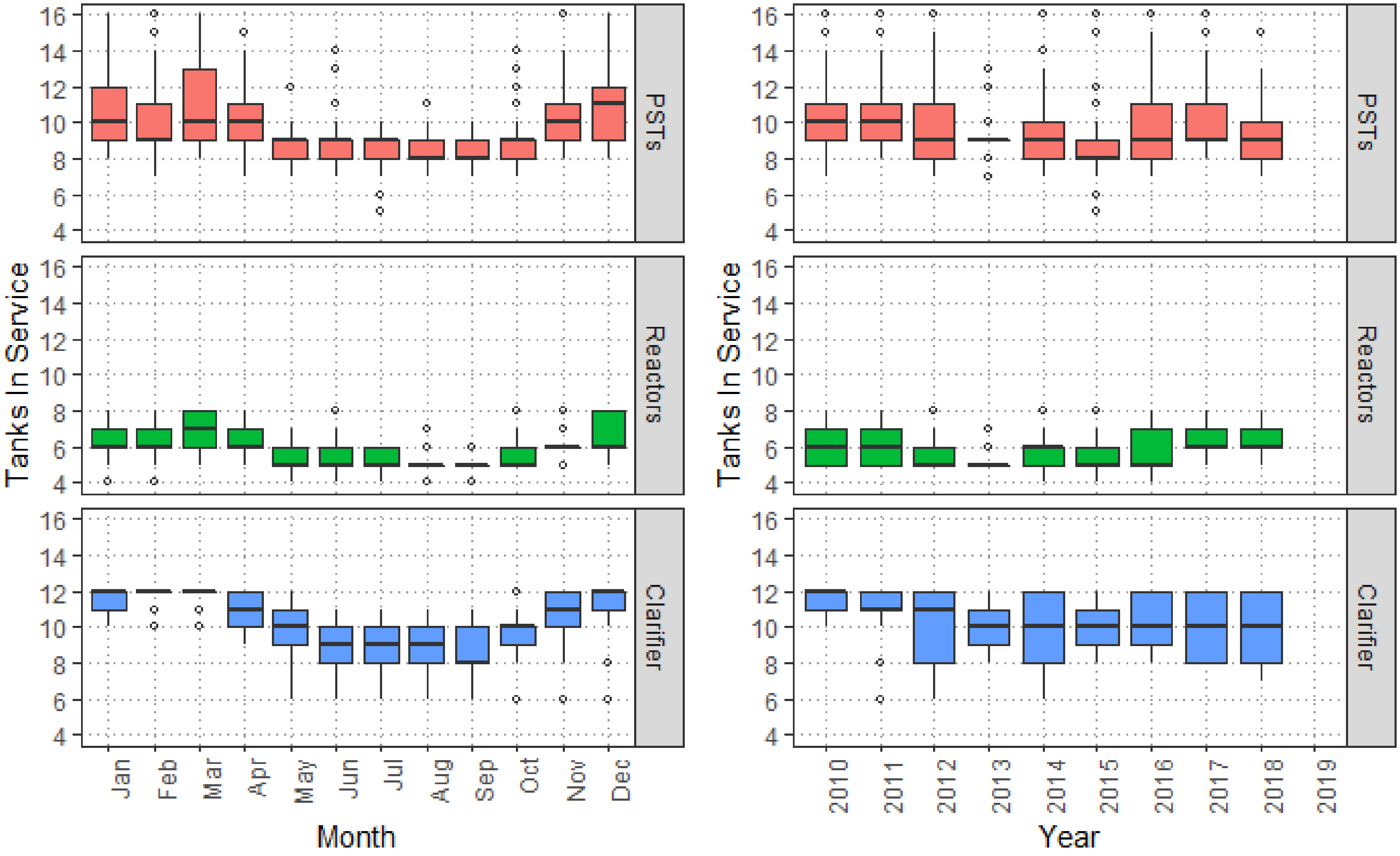
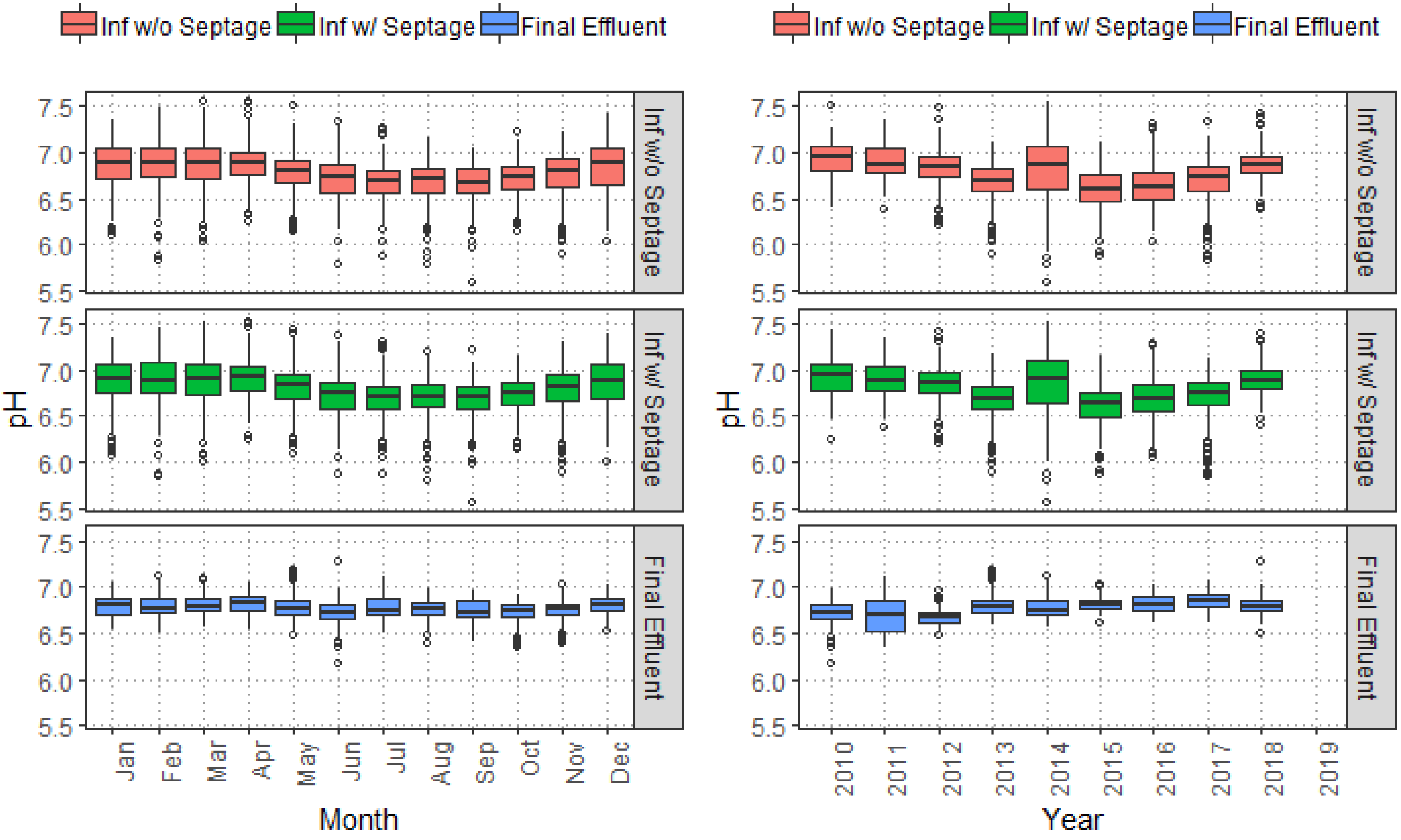


Figure C-2 Number of Tanks in Service (Monthly and Annual Averages)



Note: Influent flow (Inf) samples were taken prior to and after Septage and Low-strength R2 waste addition into the interceptor.

Figure C-3 Influent and Effluent pH (Monthly and Annual Averages)

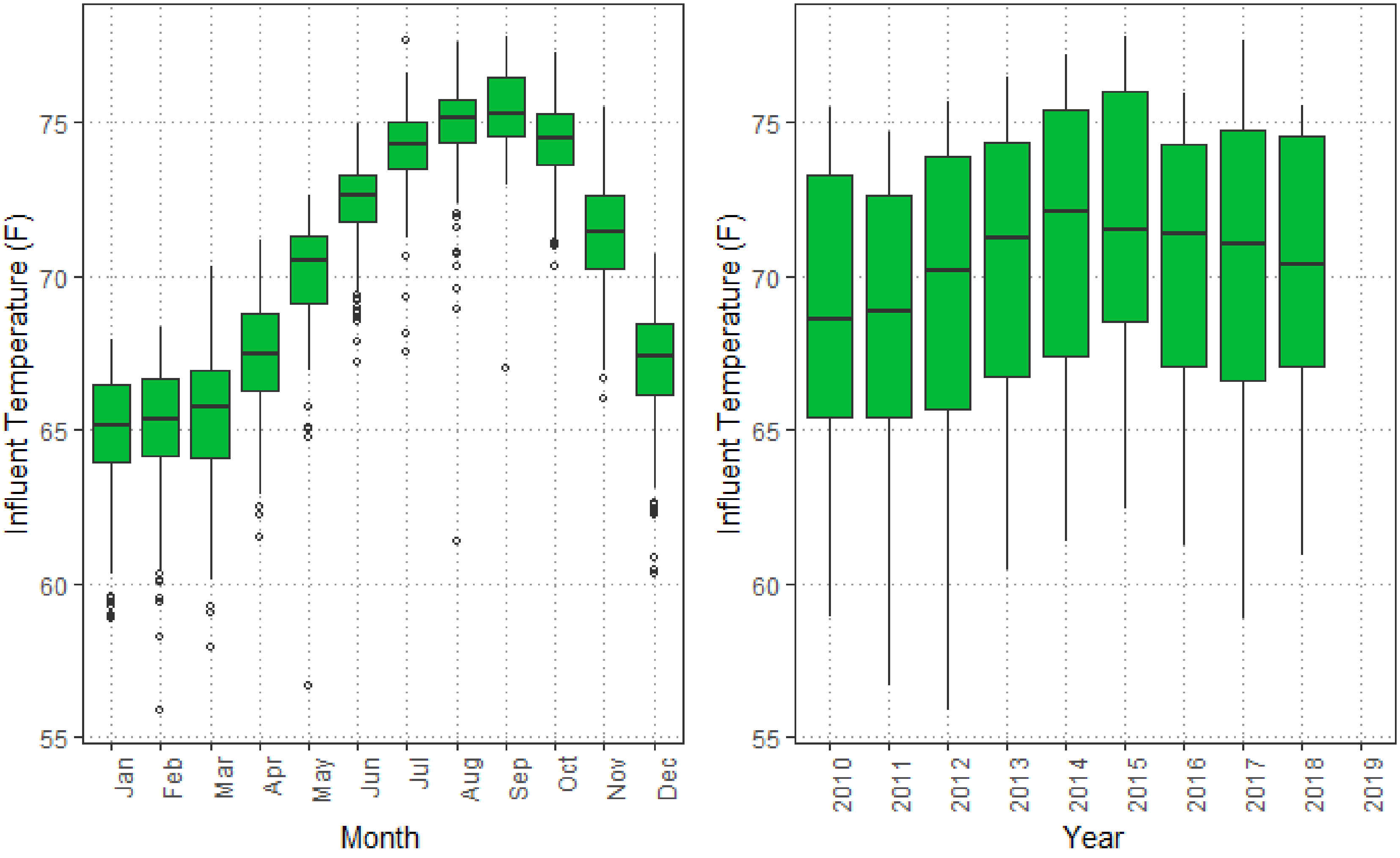


Figure C-4 Influent Temperature (Monthly and Annual Averages)

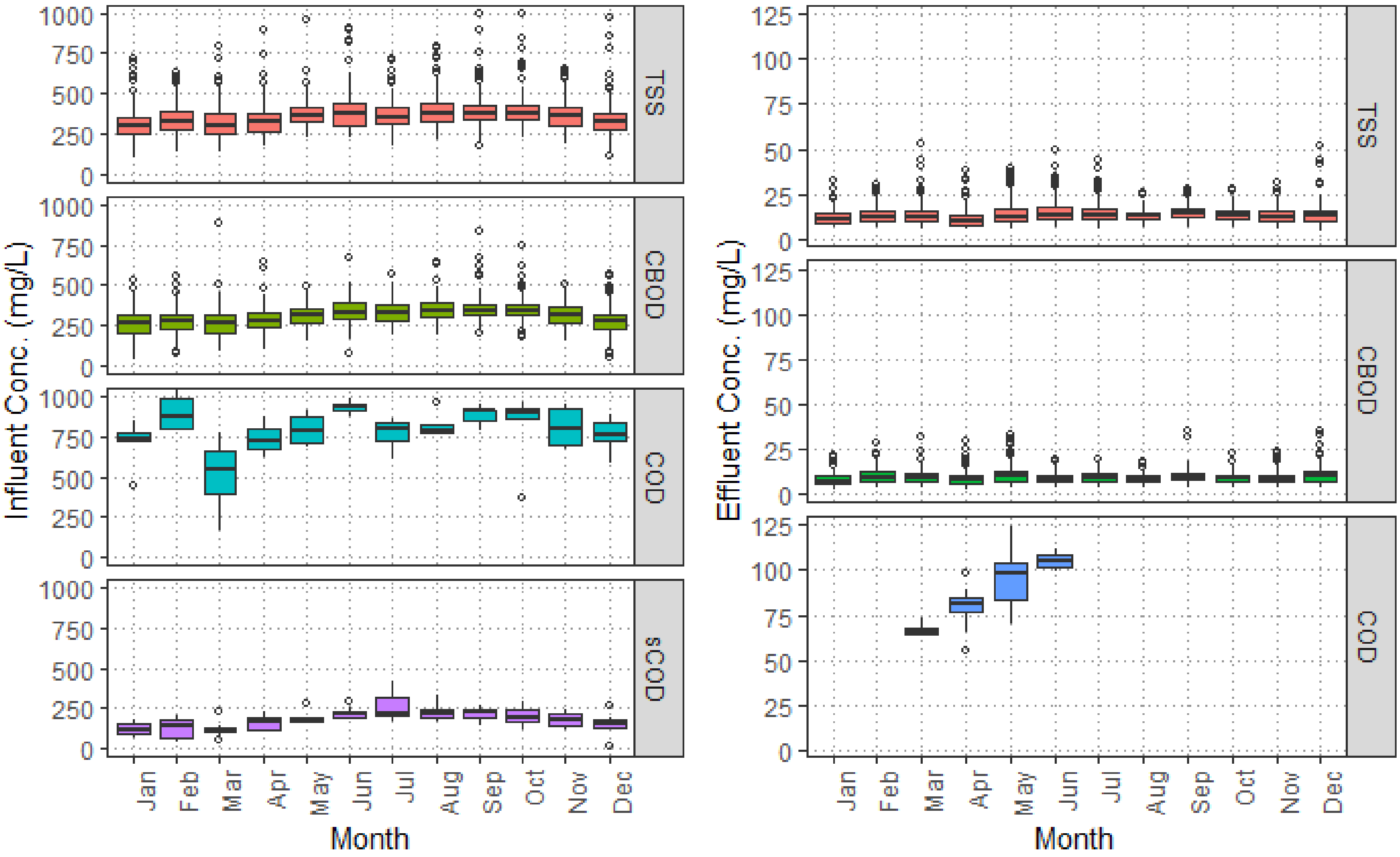


Figure C-5. Influent and Effluent TSS, cBOD, COD, and sCOD Concentrations (Monthly Averages)

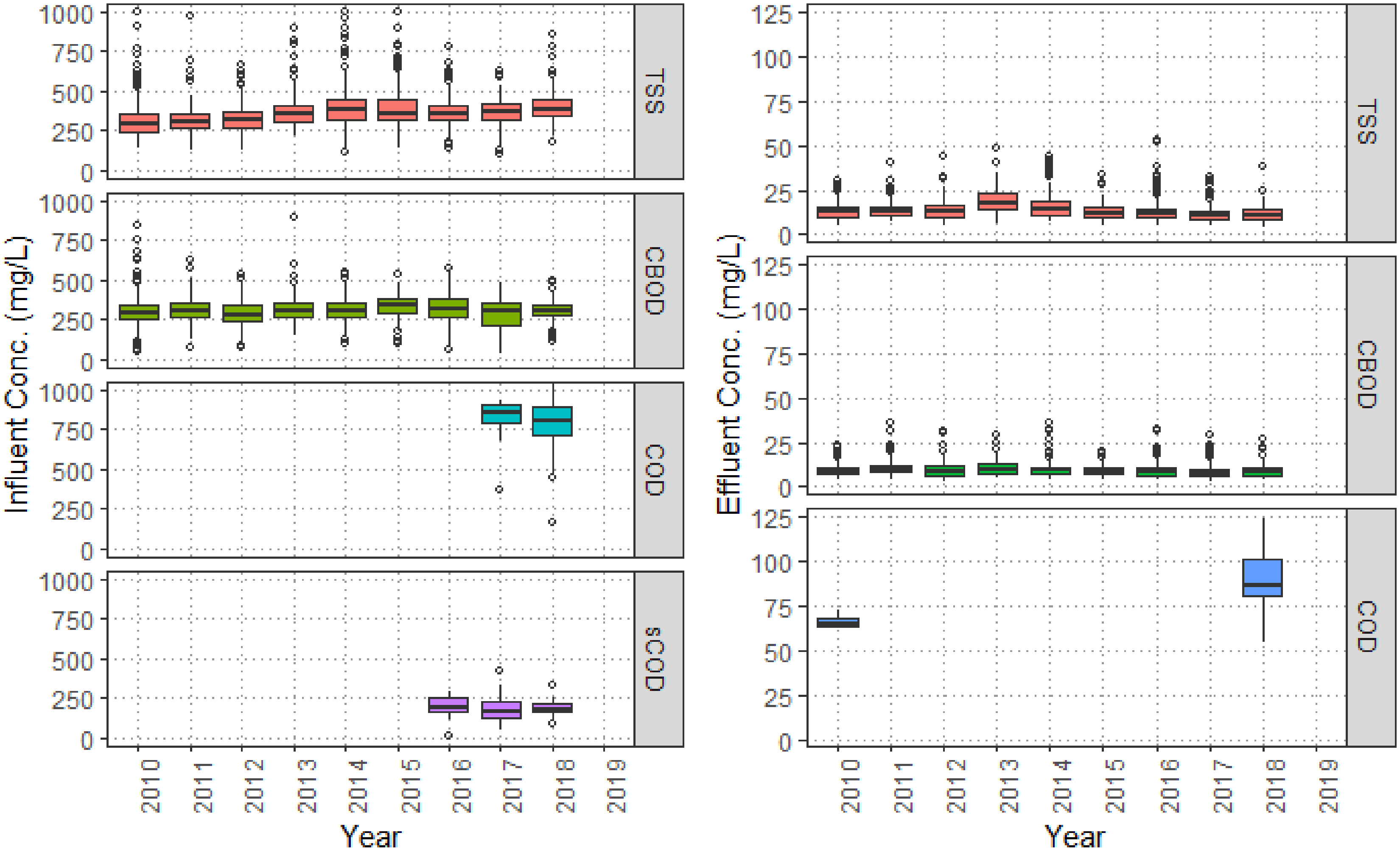


Figure C-6. Influent and Effluent TSS, cBOD, COD, and sCOD Concentrations (Annual Averages)

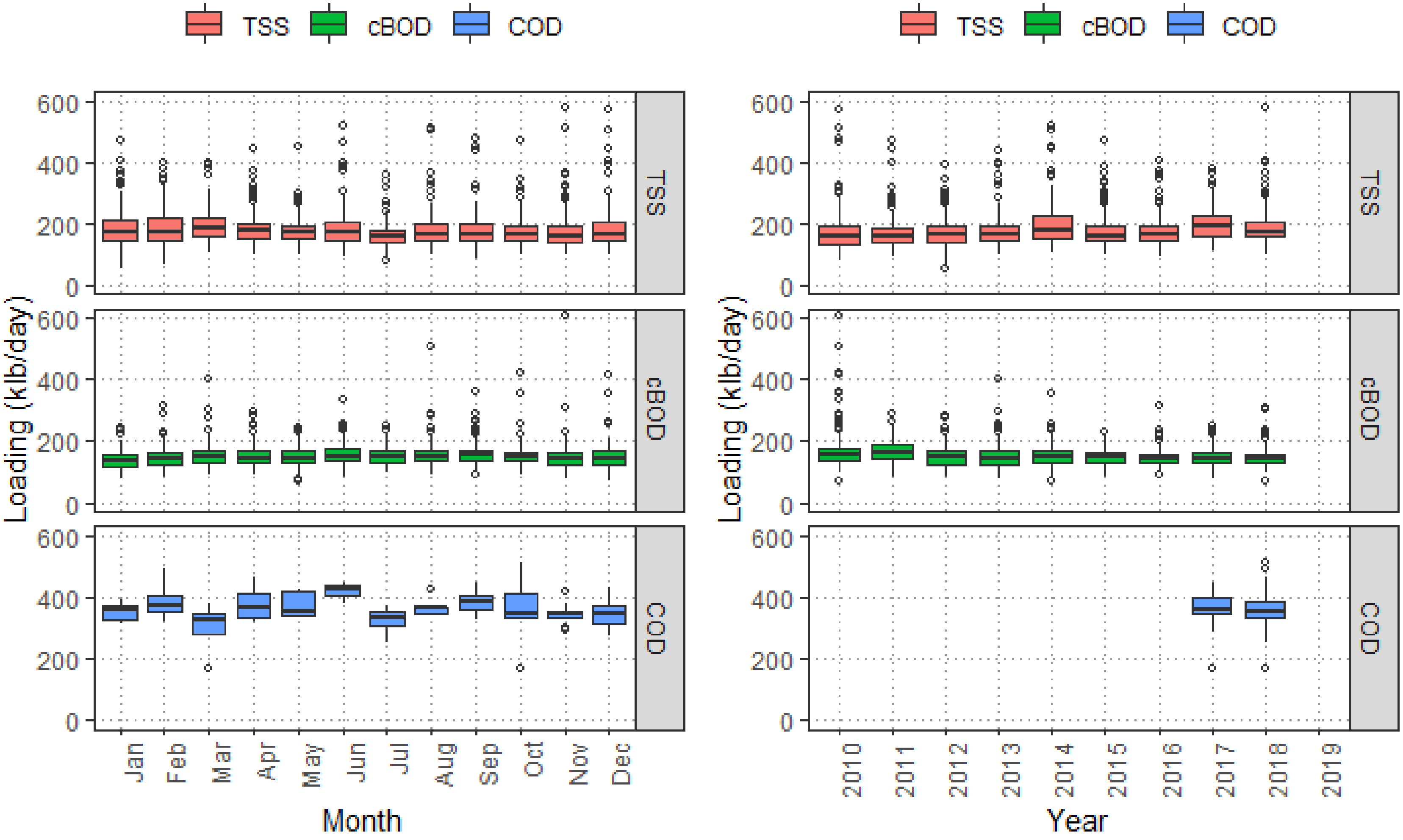
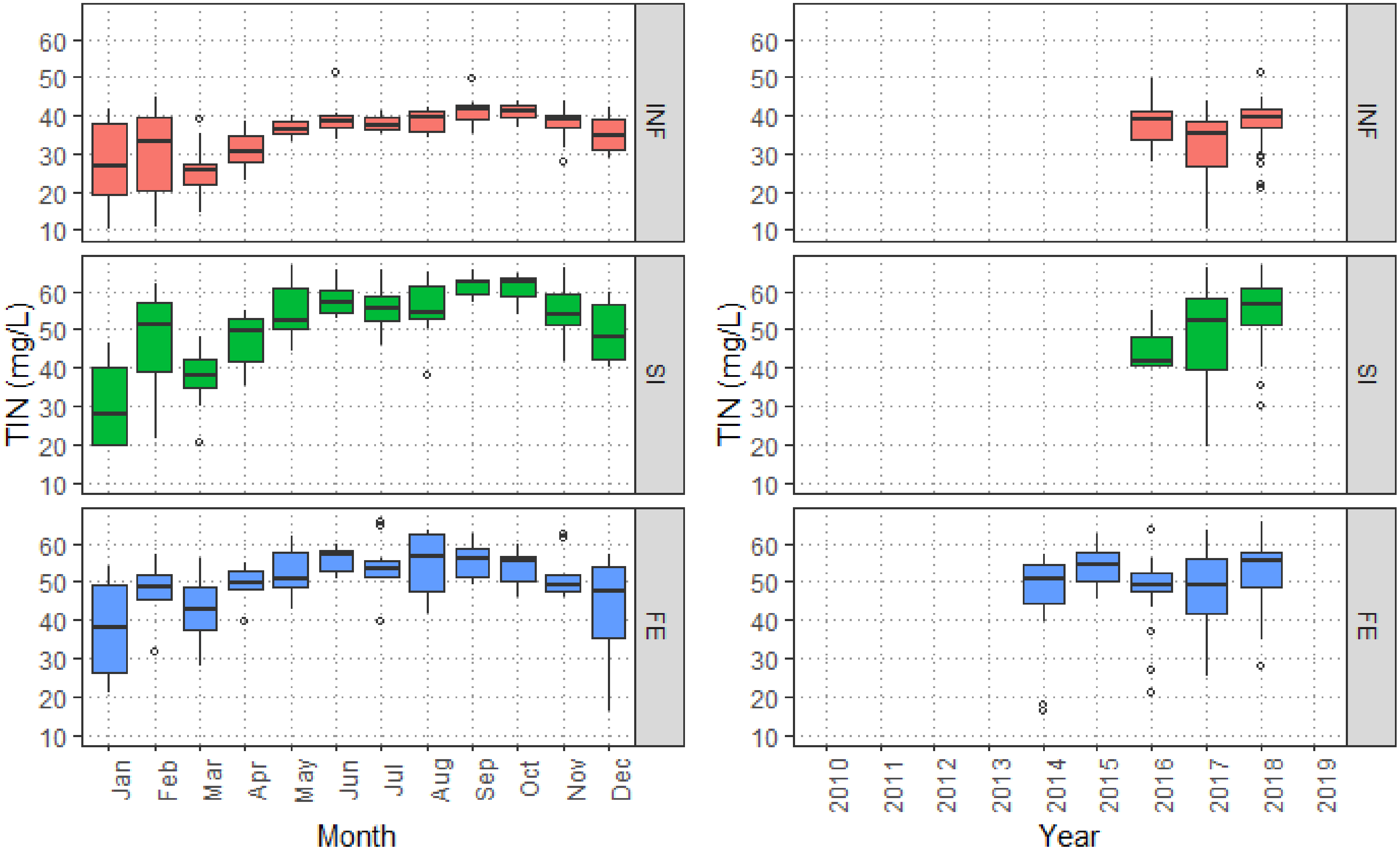
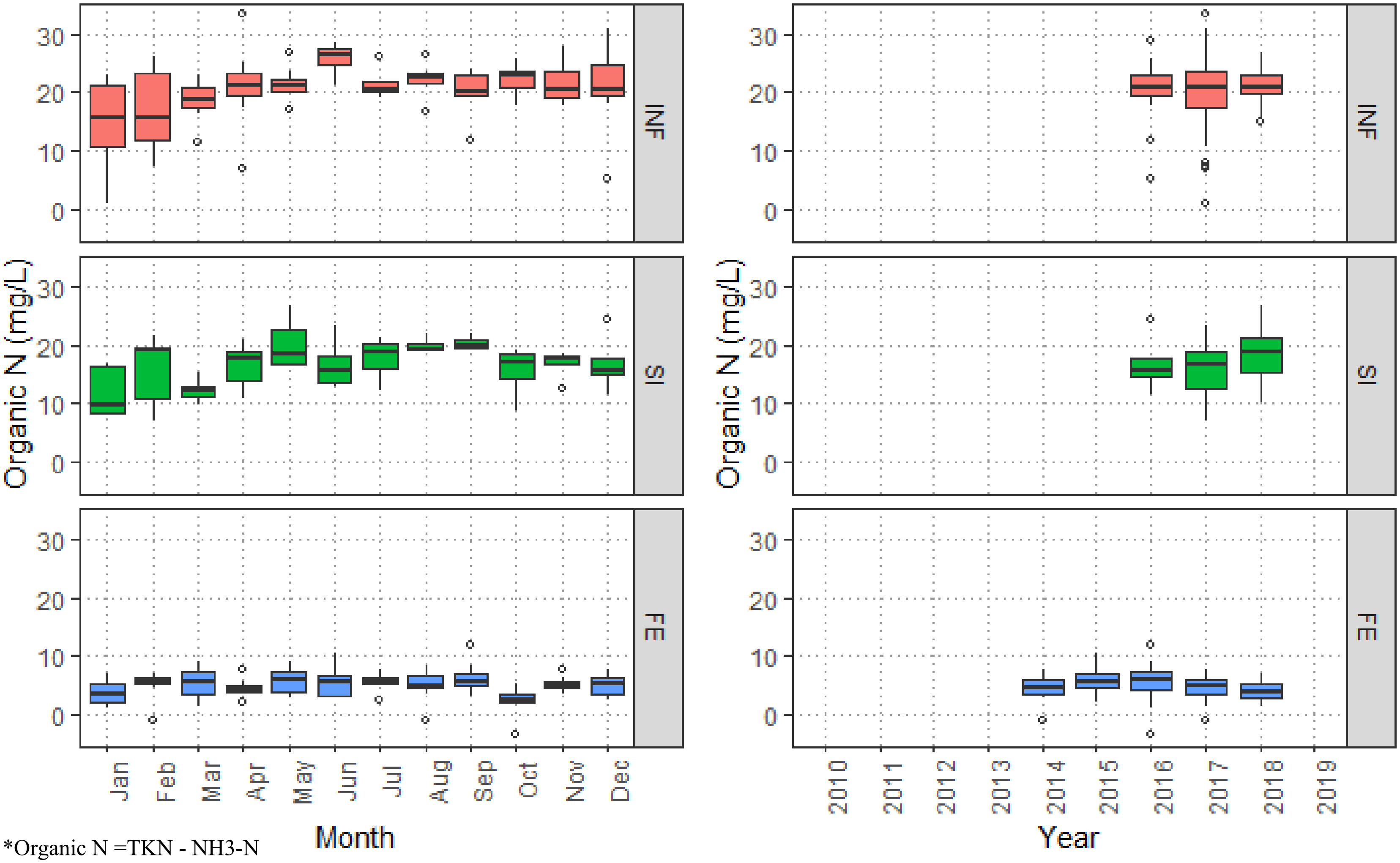


Figure C-7. Influent TSS, cBOD, and COD Loading



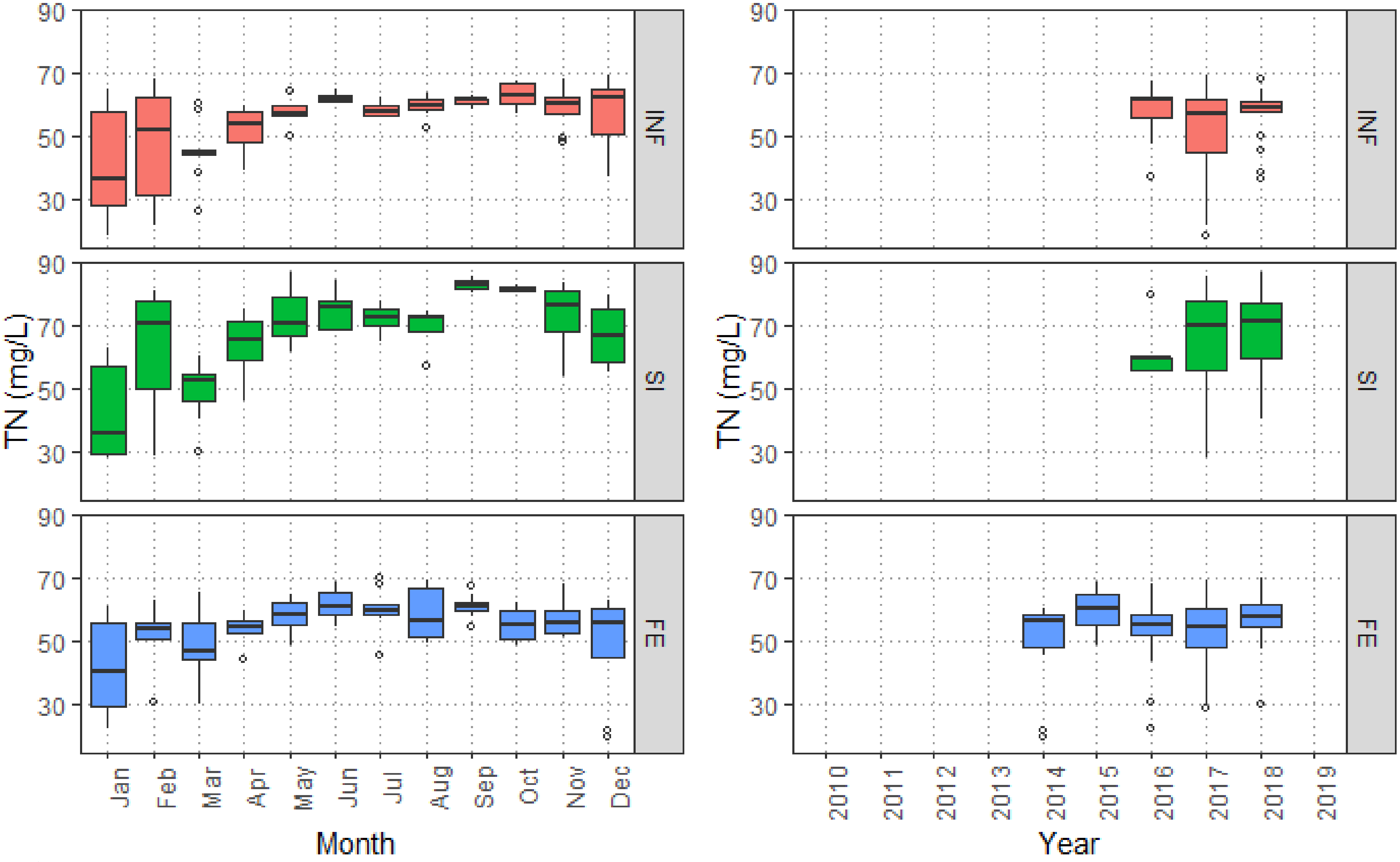
*TIN =NH3-N + NO2-N + NO3-N

Figure C-8 Total Inorganic Nitrogen Concentrations Through Plant (Monthly and Annual Averages)



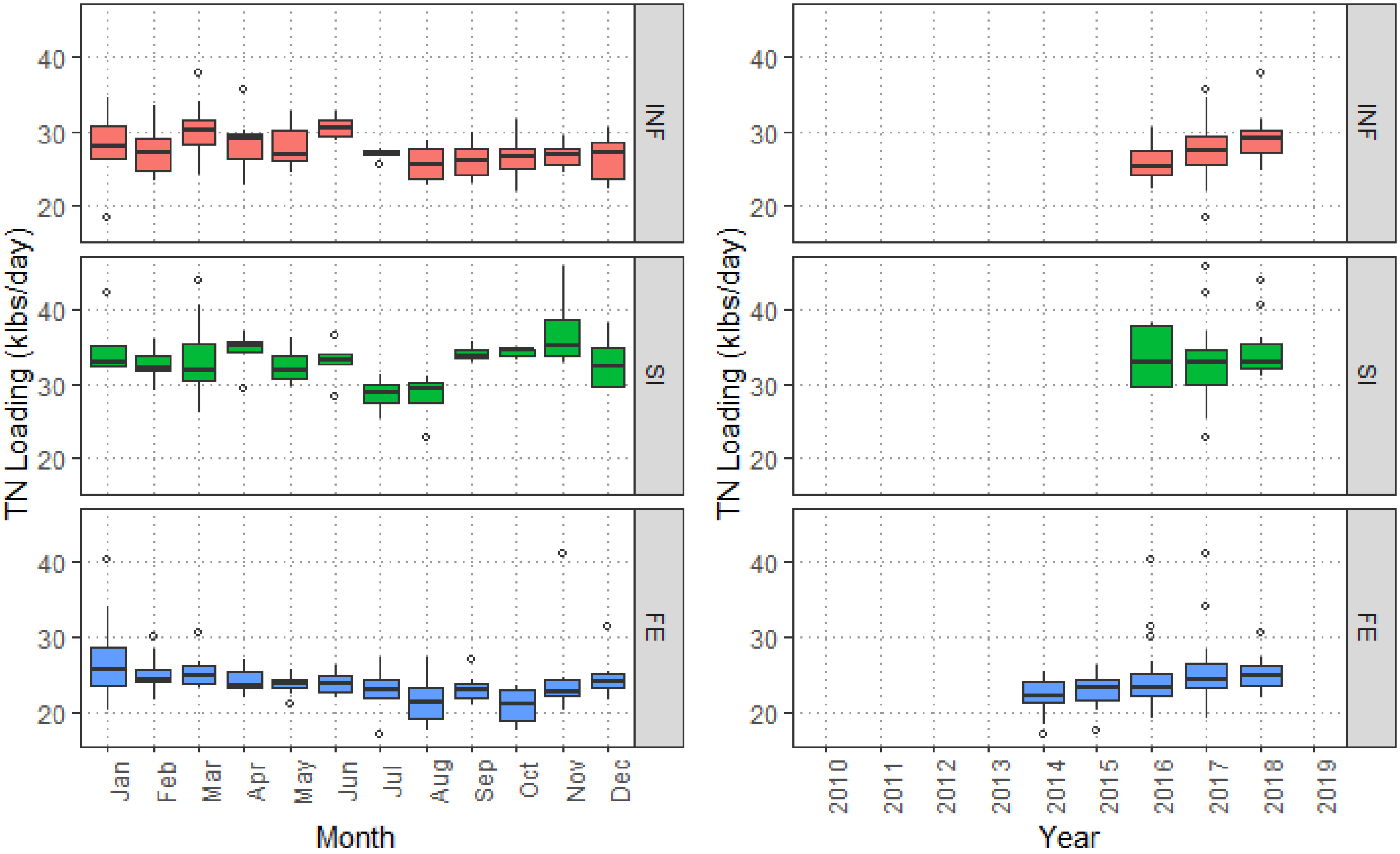
*Organic N =TKN - NH3-N

Figure C-9 Organic Nitrogen Concentrations Through Plant (Monthly and Annual Averages)



*TN =TKN + NO2-N + NO3-N

Figure C-10 Total Nitrogen Concentrations Through Plant (Monthly and Annual Averages)



*TN =TKN + NO2-N + NO3-N

Figure C-11 Total Nitrogen Loading Rate Through Plant (Monthly and Annual Averages)

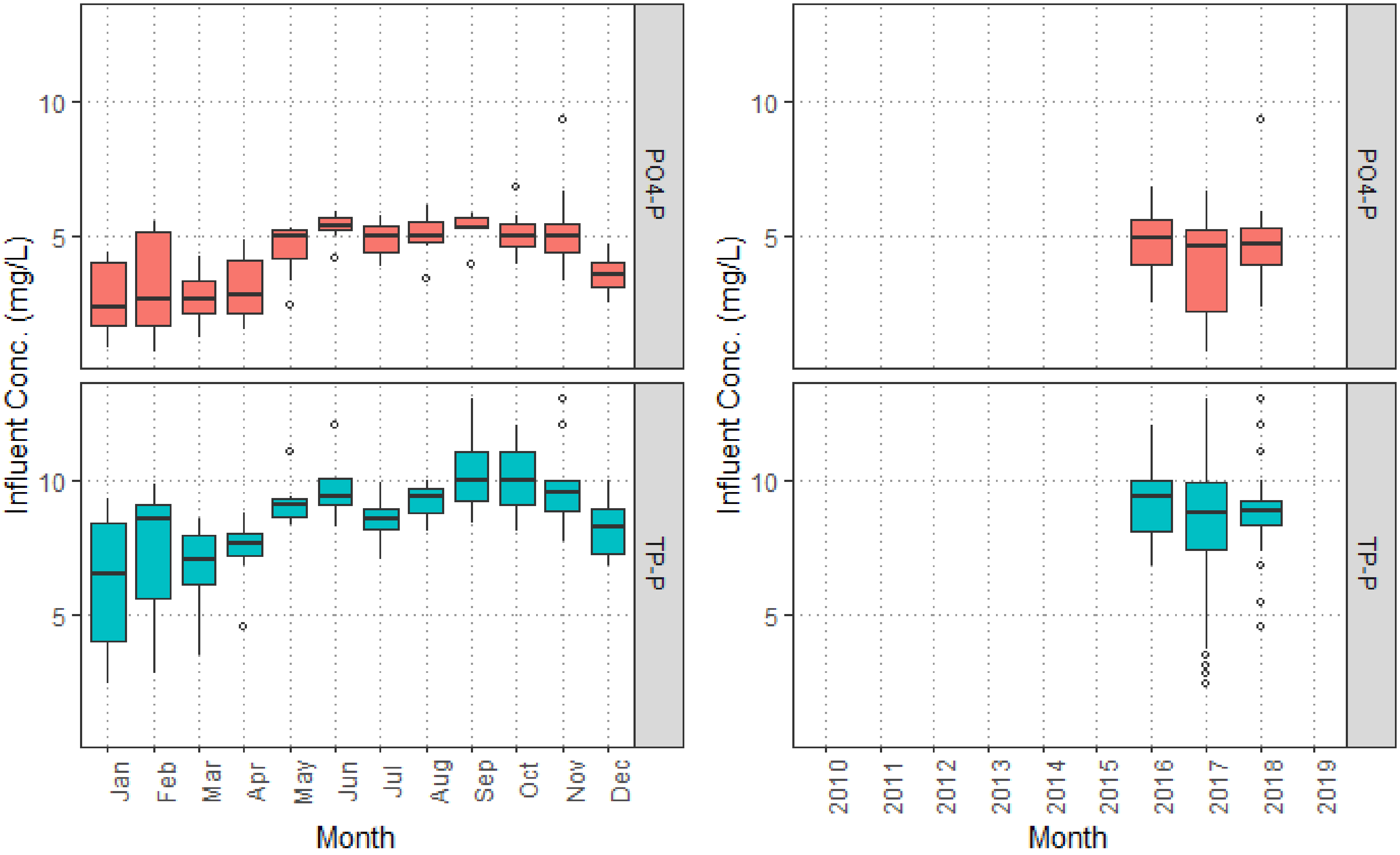
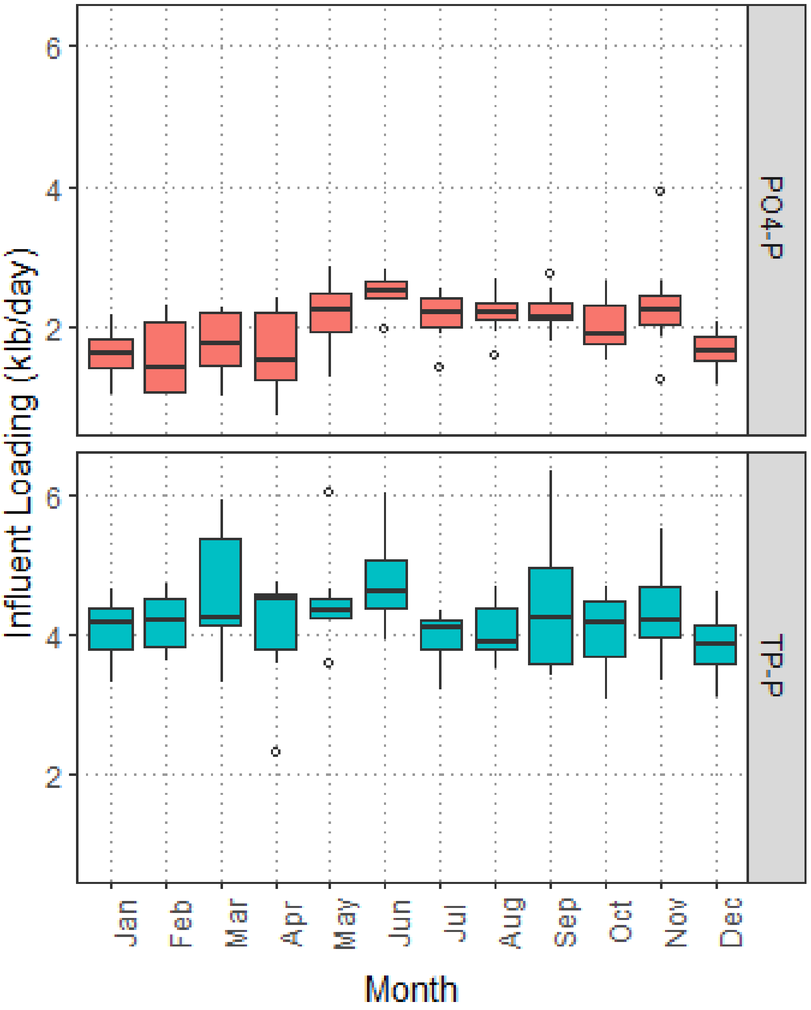


Figure C-12 Influent Orthophosphate and Total Phosphate Concentrations (Monthly and Annual Averages)



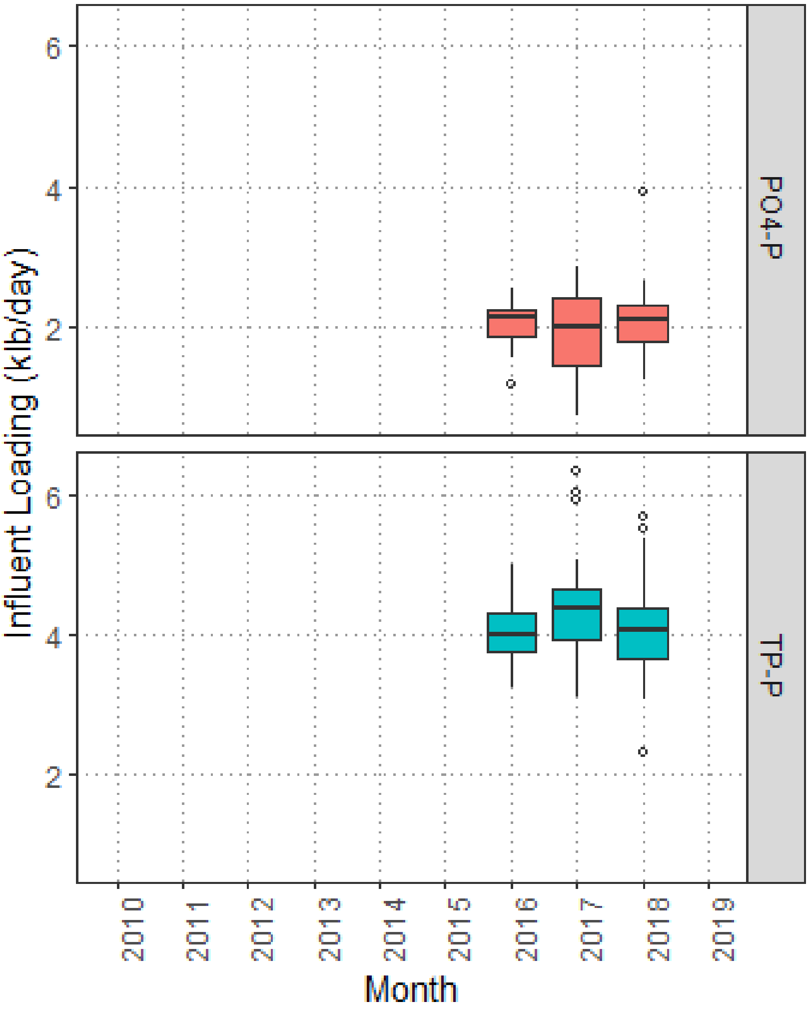


Figure C-13 Influent Total Phosphate and Orthophosphate Loading (Monthly and Annual Averages)

APPENDIX D - Primary Sedimentation Figures

This appendix provides additional figures for informational purposes only regarding the plant's primary treatment system.

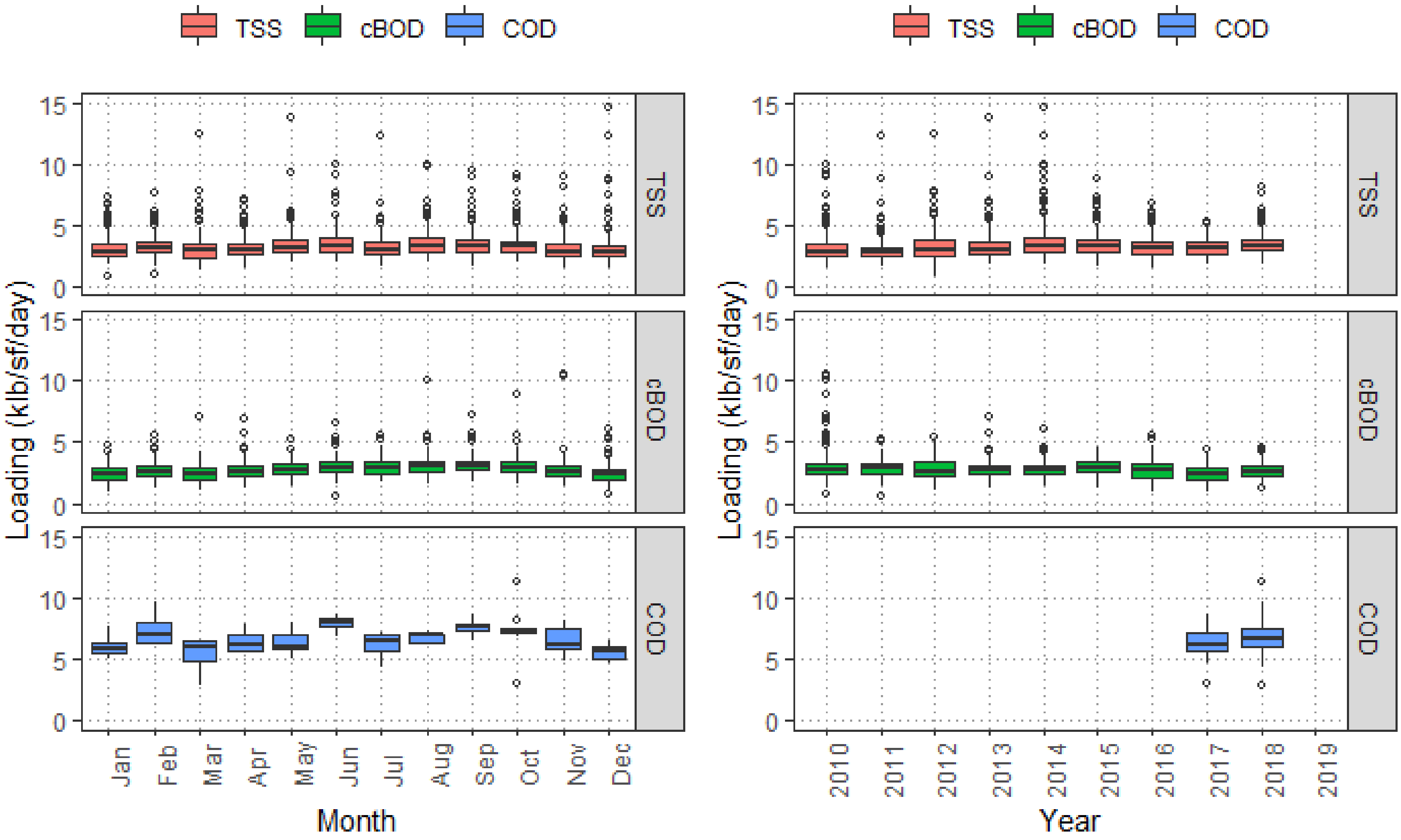


Figure D-1 PST Loading Rates (Monthly and Annual Averages)

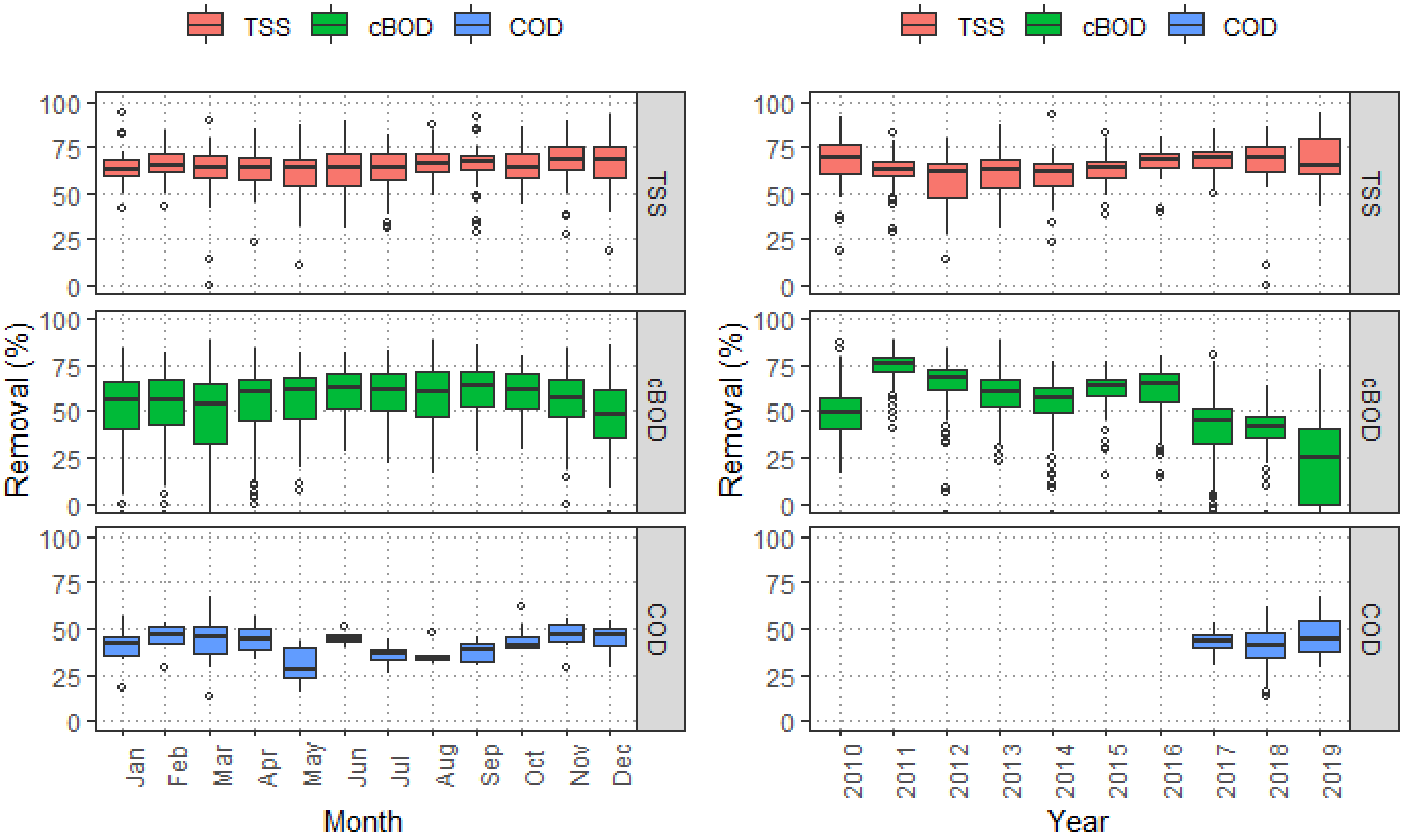


Figure D-2 PST TSS and COD Removal Efficiency (Monthly and Yearly)

Note: Removal percentages based on sample results taken on separate days.

APPENDIX E - Secondary Treatment Figures

This appendix provides additional figures for informational purposes only regarding the plant’s secondary treatment system.

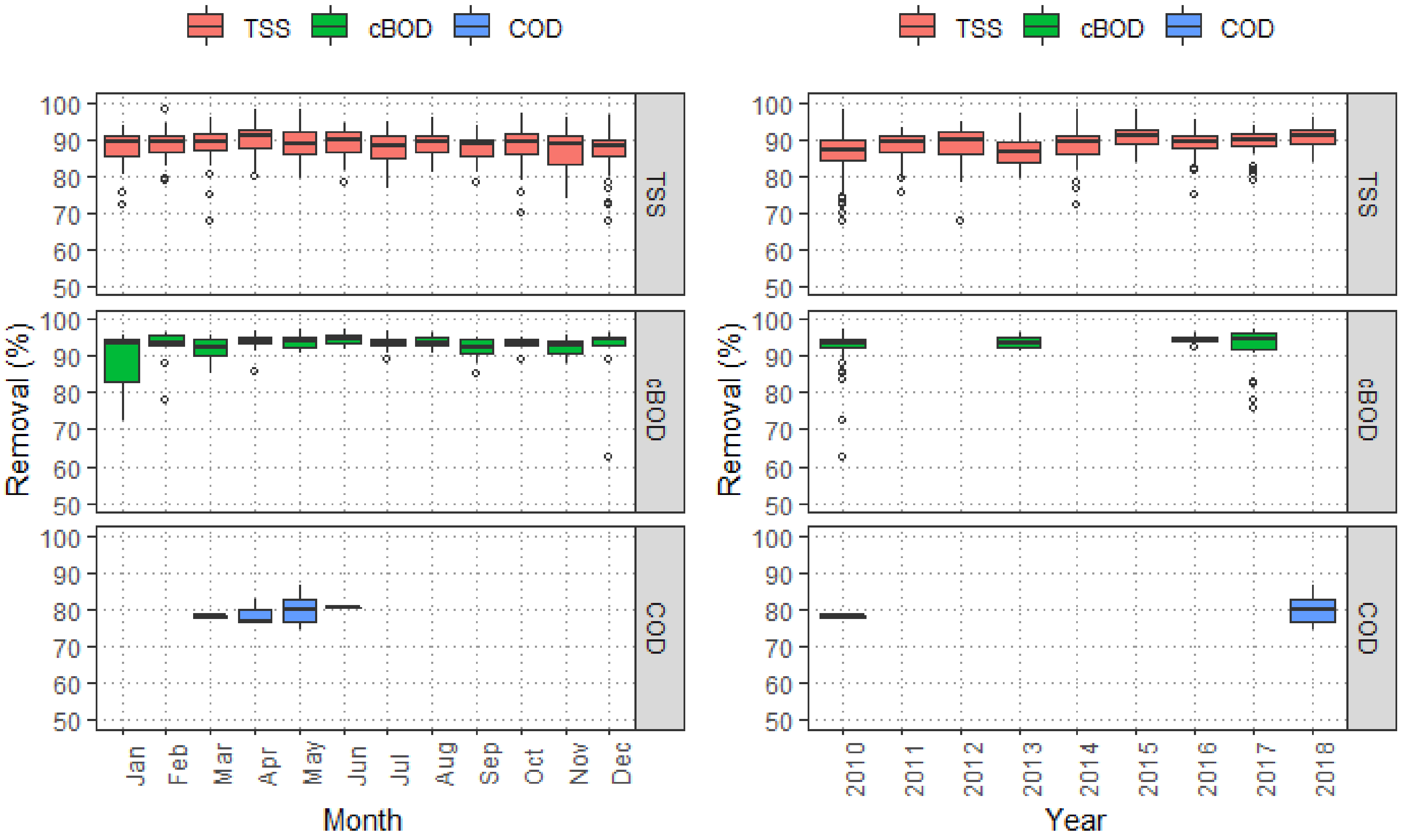


Figure E-1 Secondary Treatment TSS, cBOD, and COD Removal Percentages (Monthly and Annual Averages)

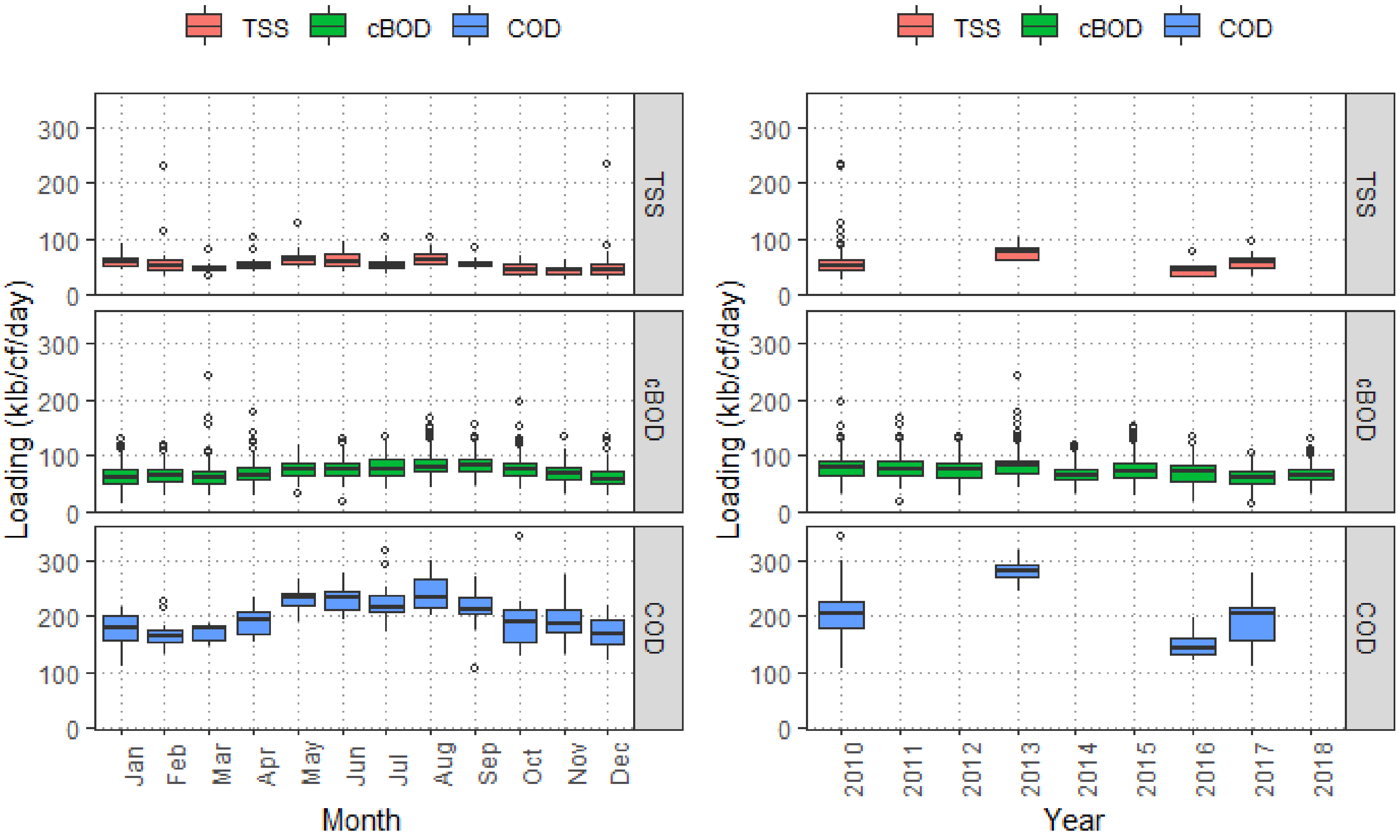


Figure E-2 Secondary Treatment TSS, cBOD, and COD Loading Rates (Monthly and Annual Averages)

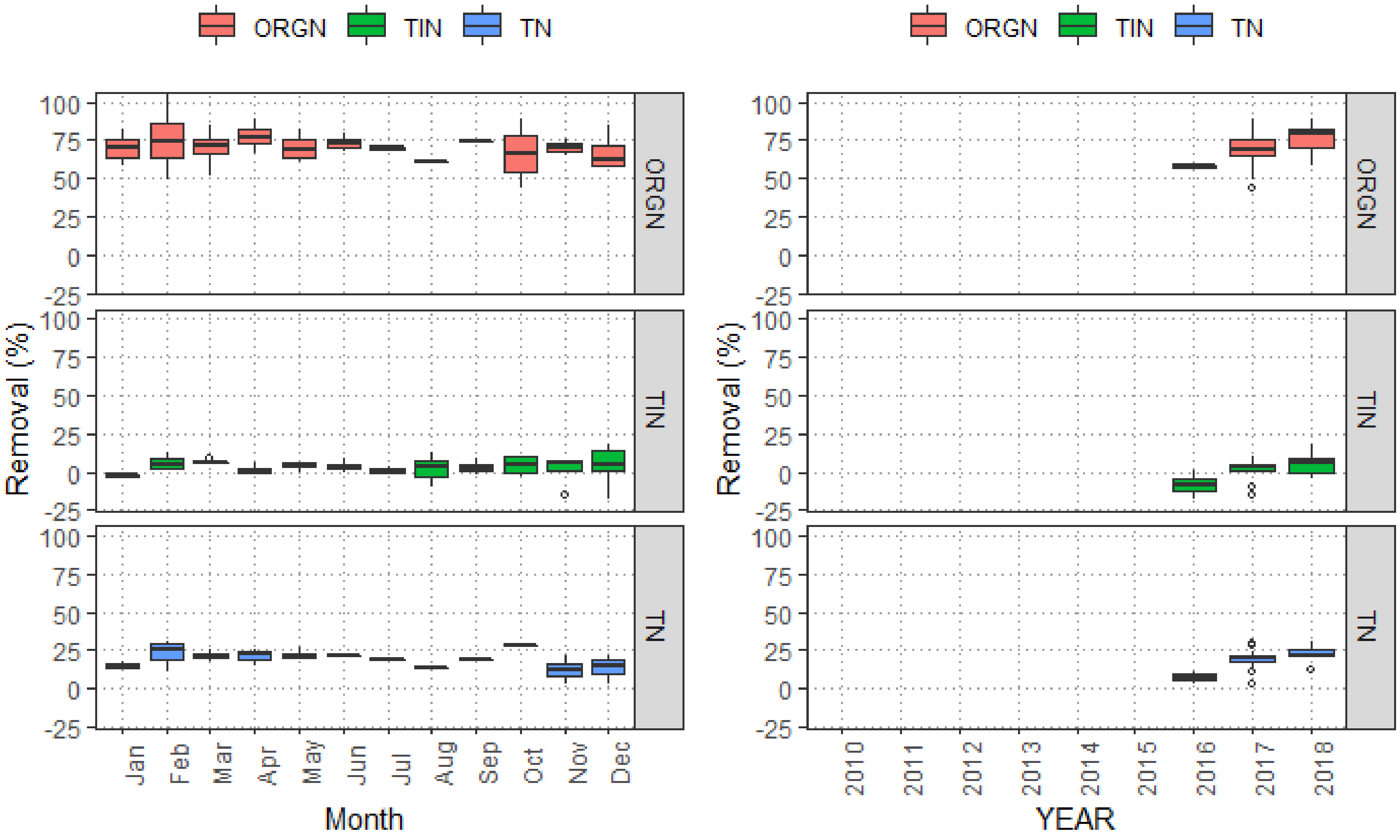


Figure E-3 Secondary Treatment Nitrogen Removal Rates (Monthly and Annual Averages)

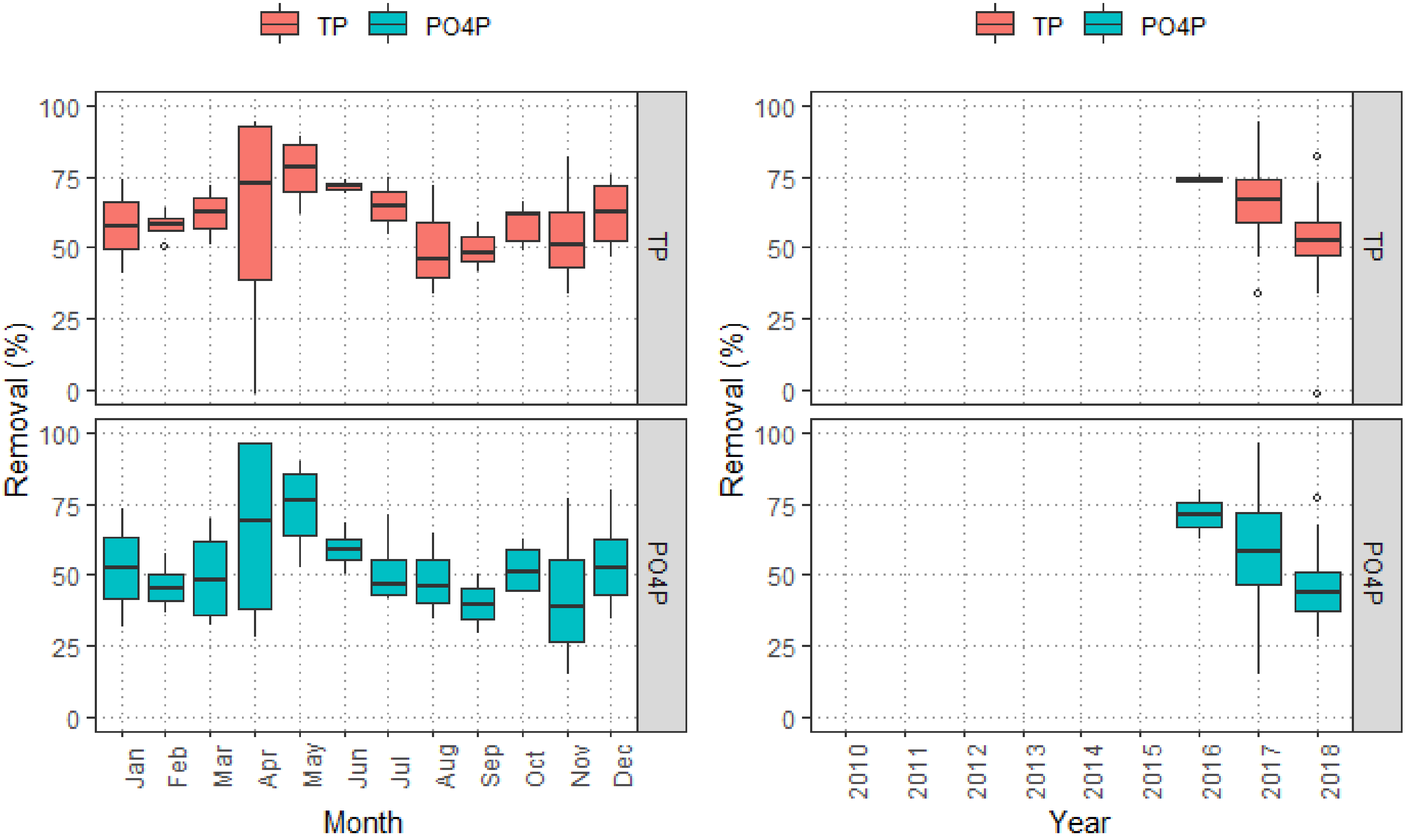


Figure E-4 Secondary Treatment Phosphate Removal Rates (Monthly and Annual Averages)

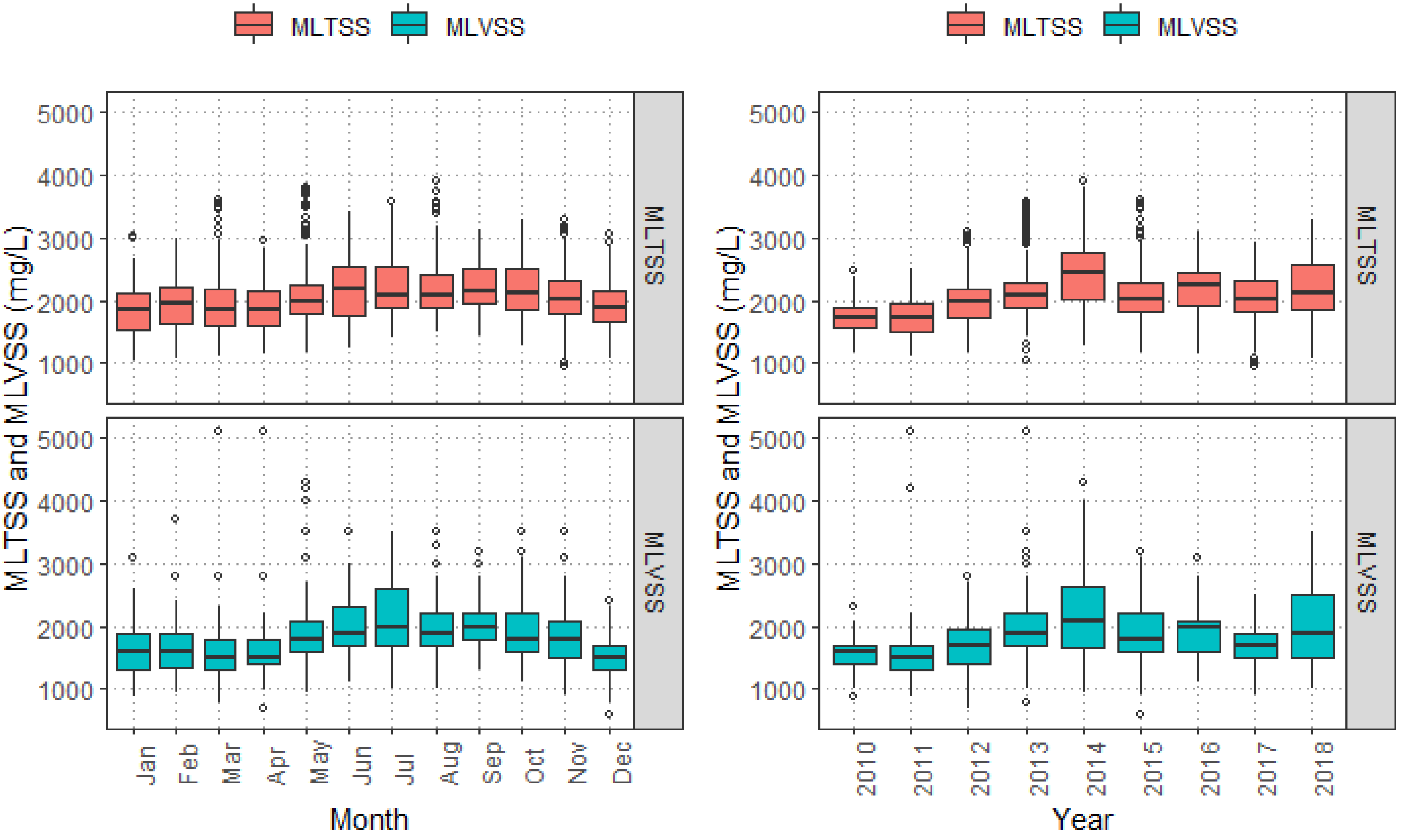


Figure E-5 MLSS and MLVSS Concentrations (Monthly and Annual Averages)

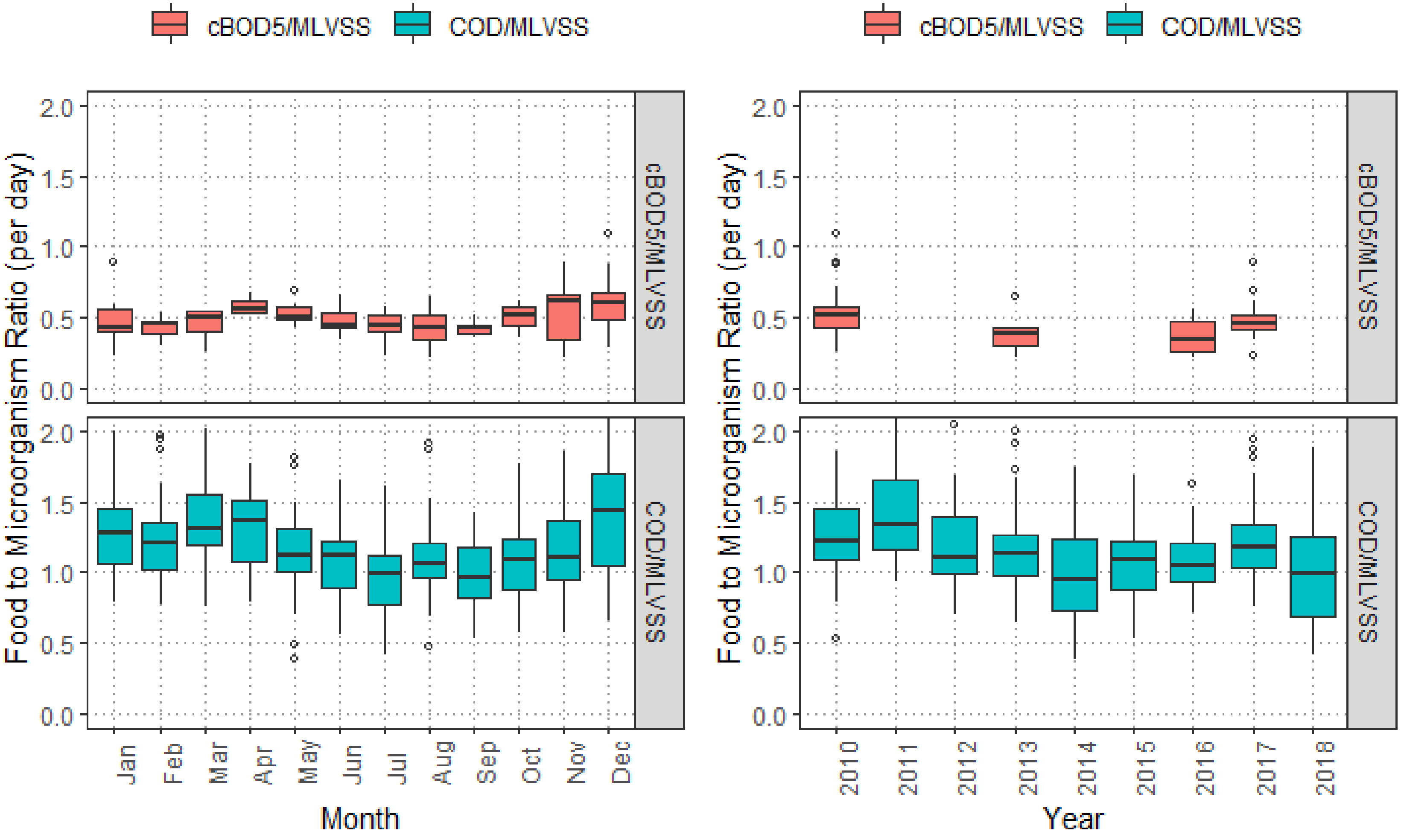


Figure E-6 Secondary Influent cBOD and COD to MLTSS F/M Ratio (Monthly and Annual Averages)

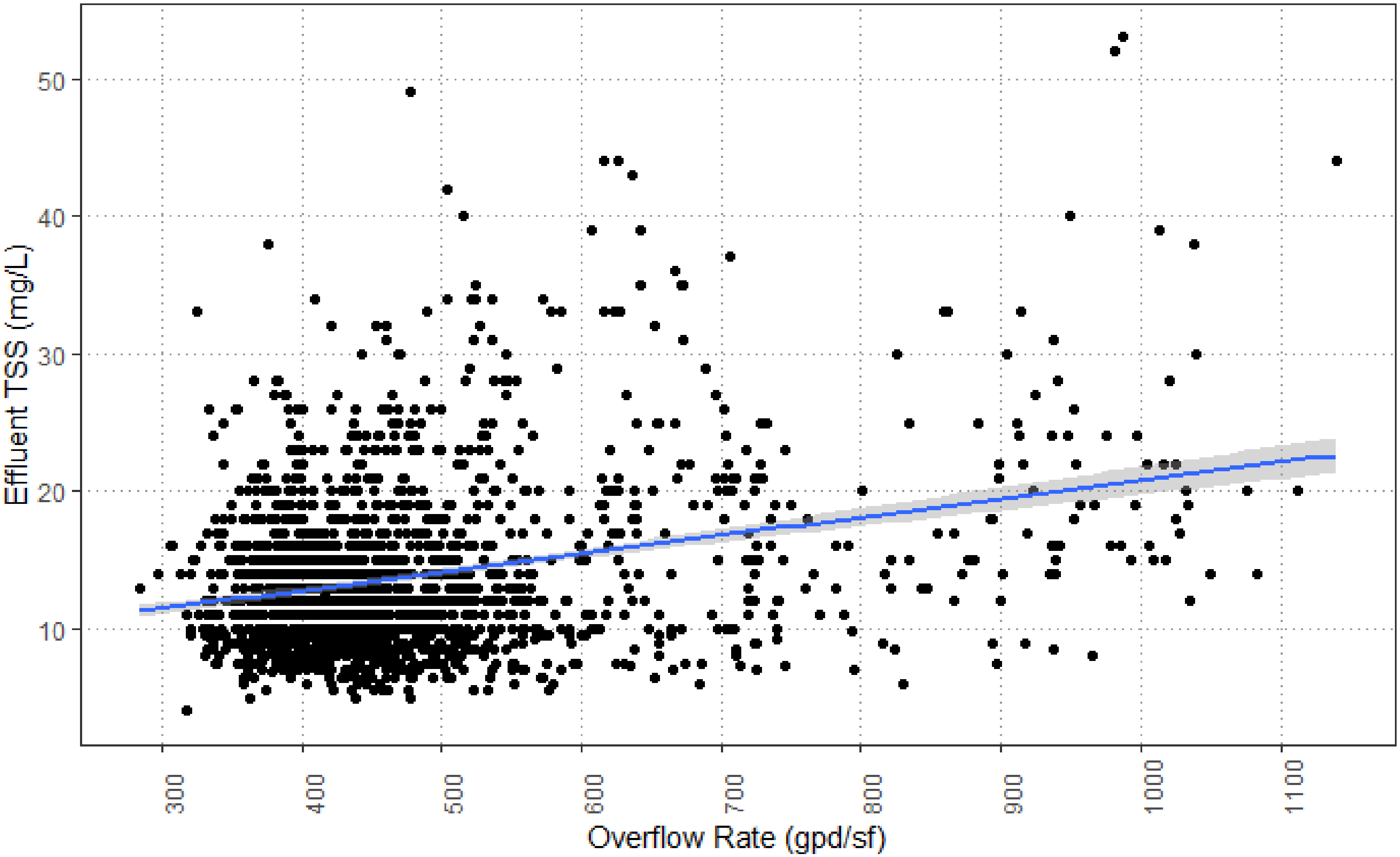


Figure E-7 Secondary Effluent TSS Concentration vs Overflow Rate

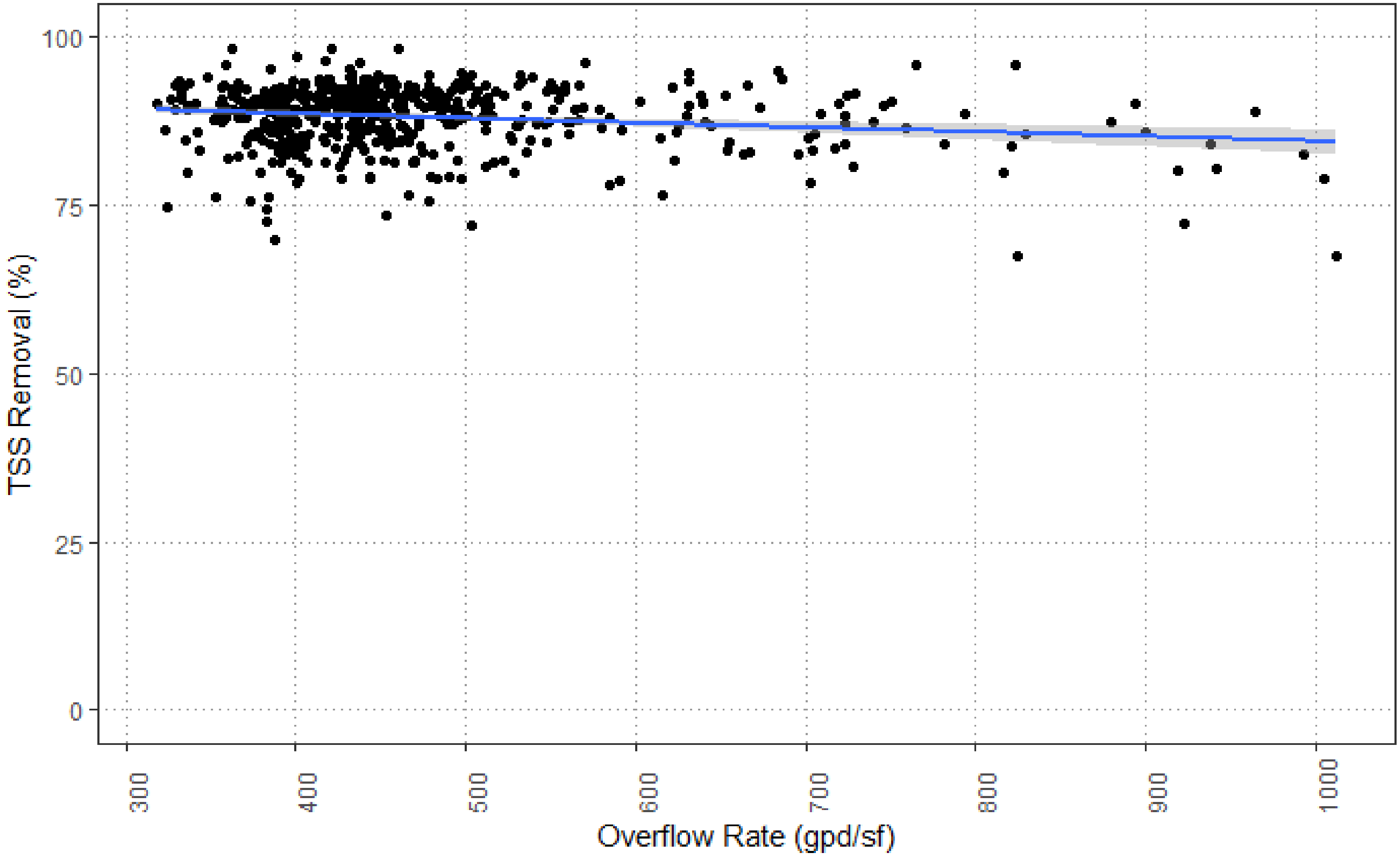
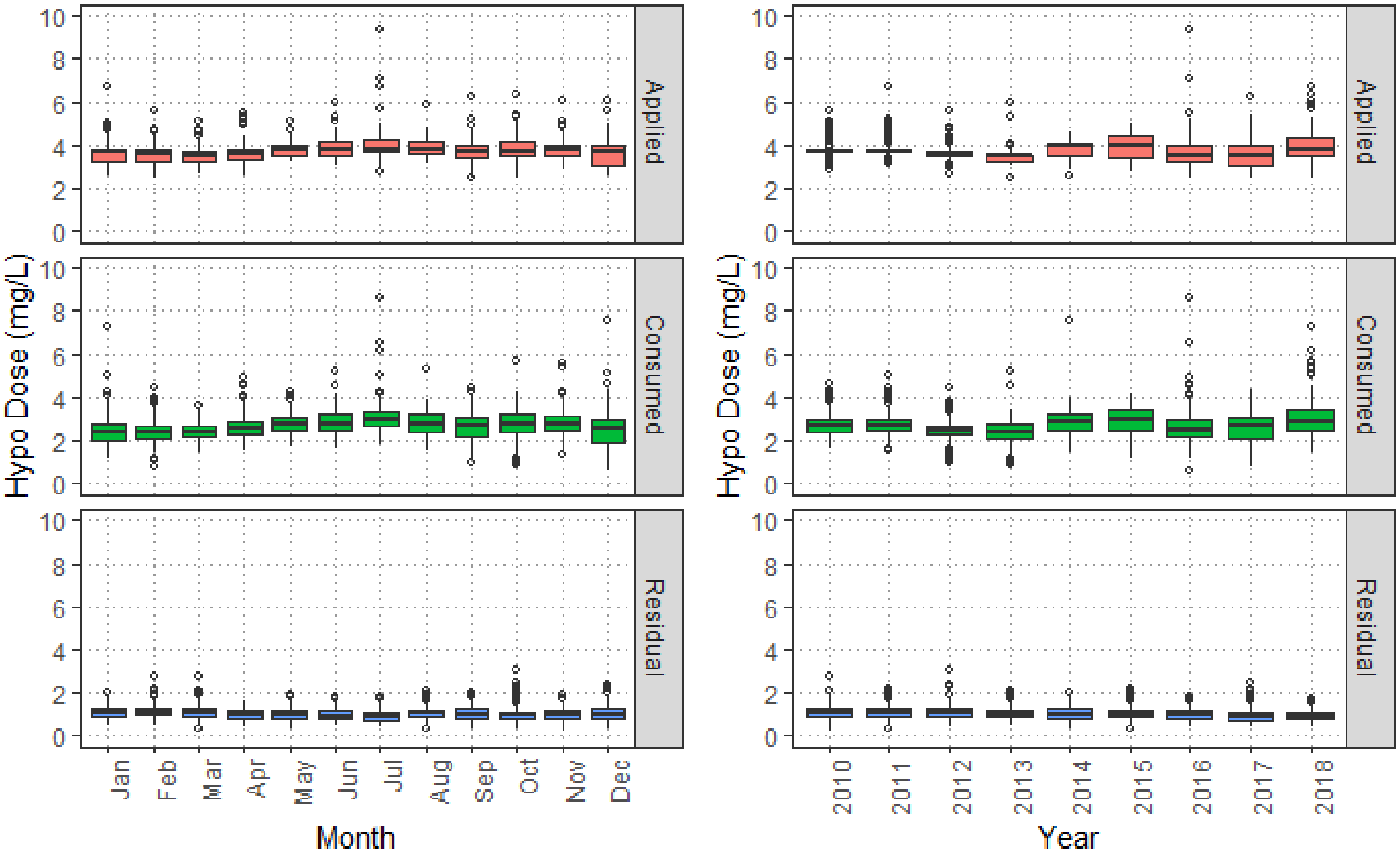


Figure E-8 Clarifier TSS Removal vs Overflow Rate

APPENDIX F - Disinfection Figures

This appendix provides additional figures for informational purposes only regarding the plant disinfection system.



Note: This graph indicates the total hypochlorite applied at the Secondary Effluent channel, the amount consumed, and the residual remaining prior to dechlorination (at the Dechlorination Building).

Figure F-1 Disinfection Hypochlorite Use (Monthly and Annual Averages)

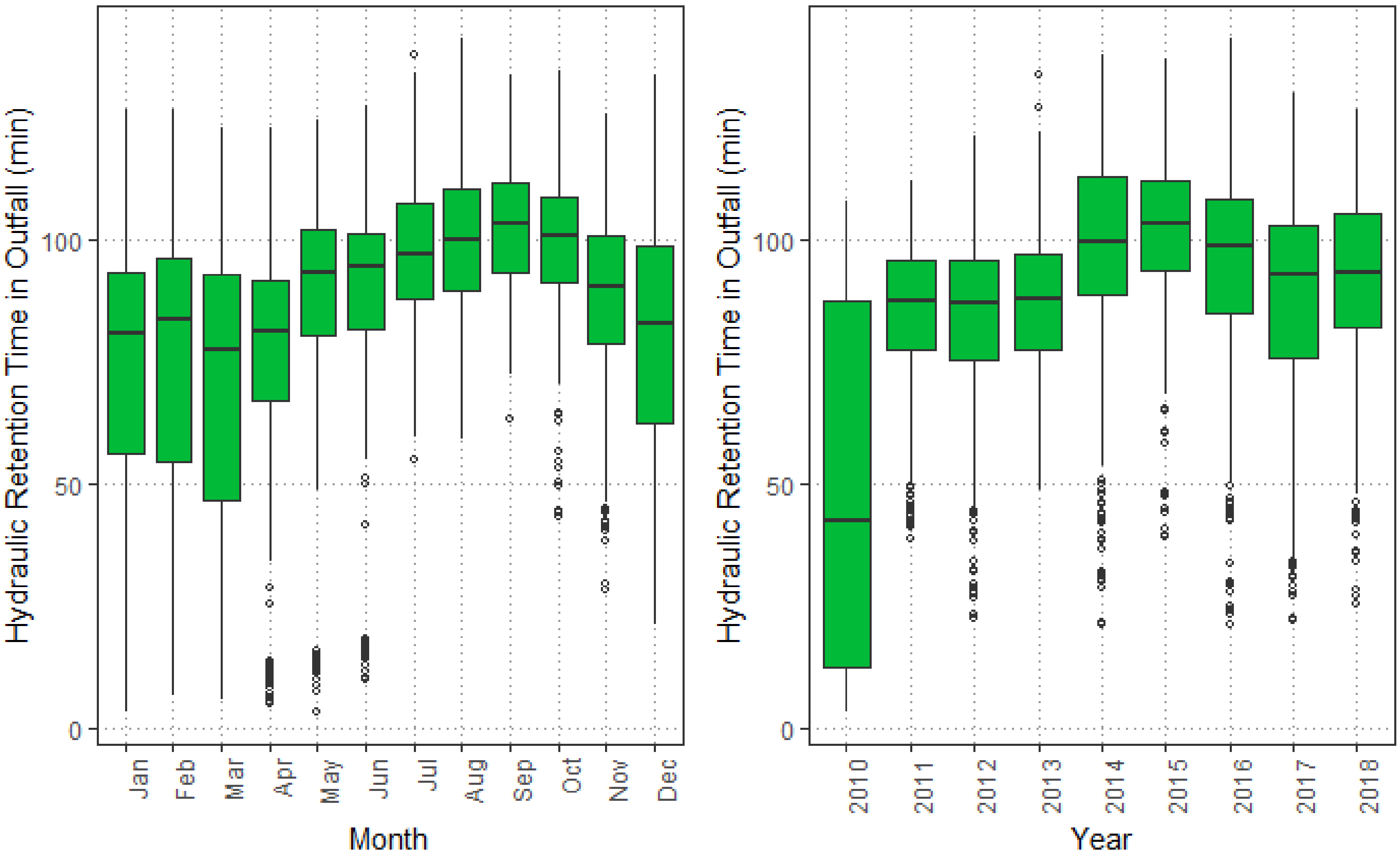


Figure F-2 Hydraulic Retention Time in Outfall (Monthly and Annual Averages)

APPENDIX G - Solids Treatment Figures

This appendix provides additional figures for informational purposes only regarding the solids treatment system.

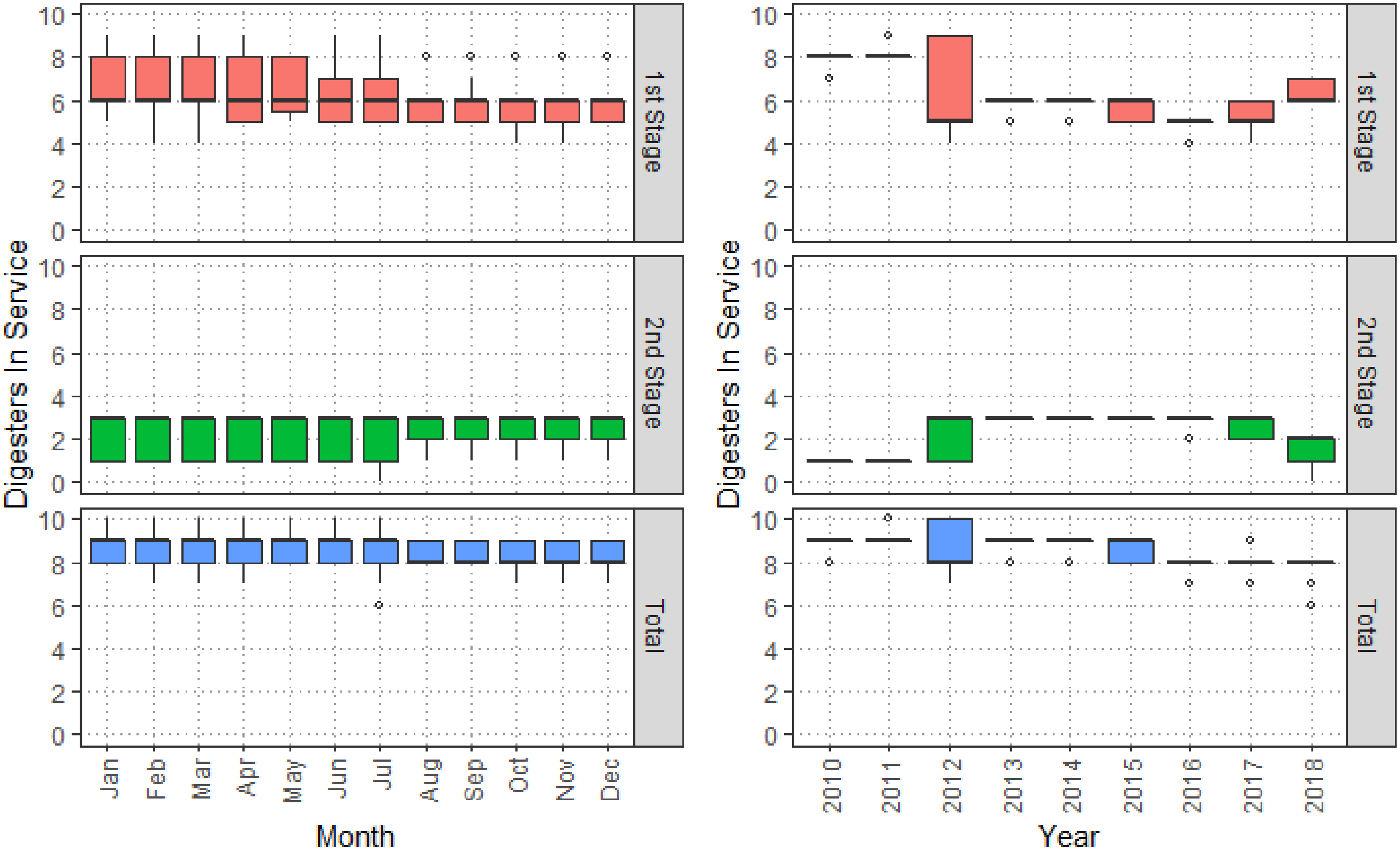
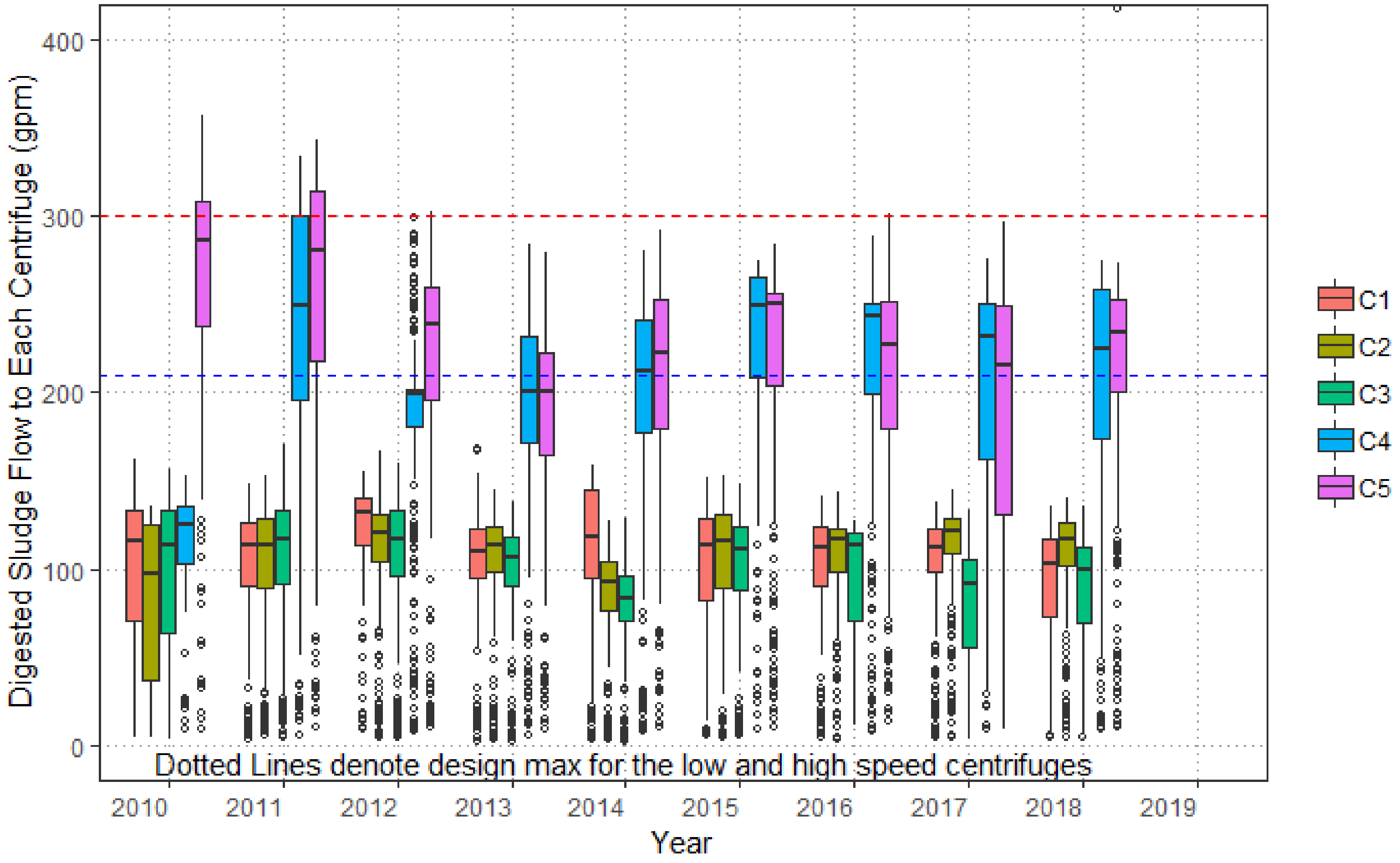


Figure G-1 Digesters In Service (Monthly and Annual Averages)



Notes: Centrifuges C1 to C3 have a rated maximum flow of 210 gpm and C4 to C5 at 300 gpm. In addition, C4 and C5 (high speed) centrifuge high flow rates in 2011/2012 were due to equipment testing to determine maximum performance.

Figure G-2 Centrifuge Influent Sludge Flows (Annual Average)

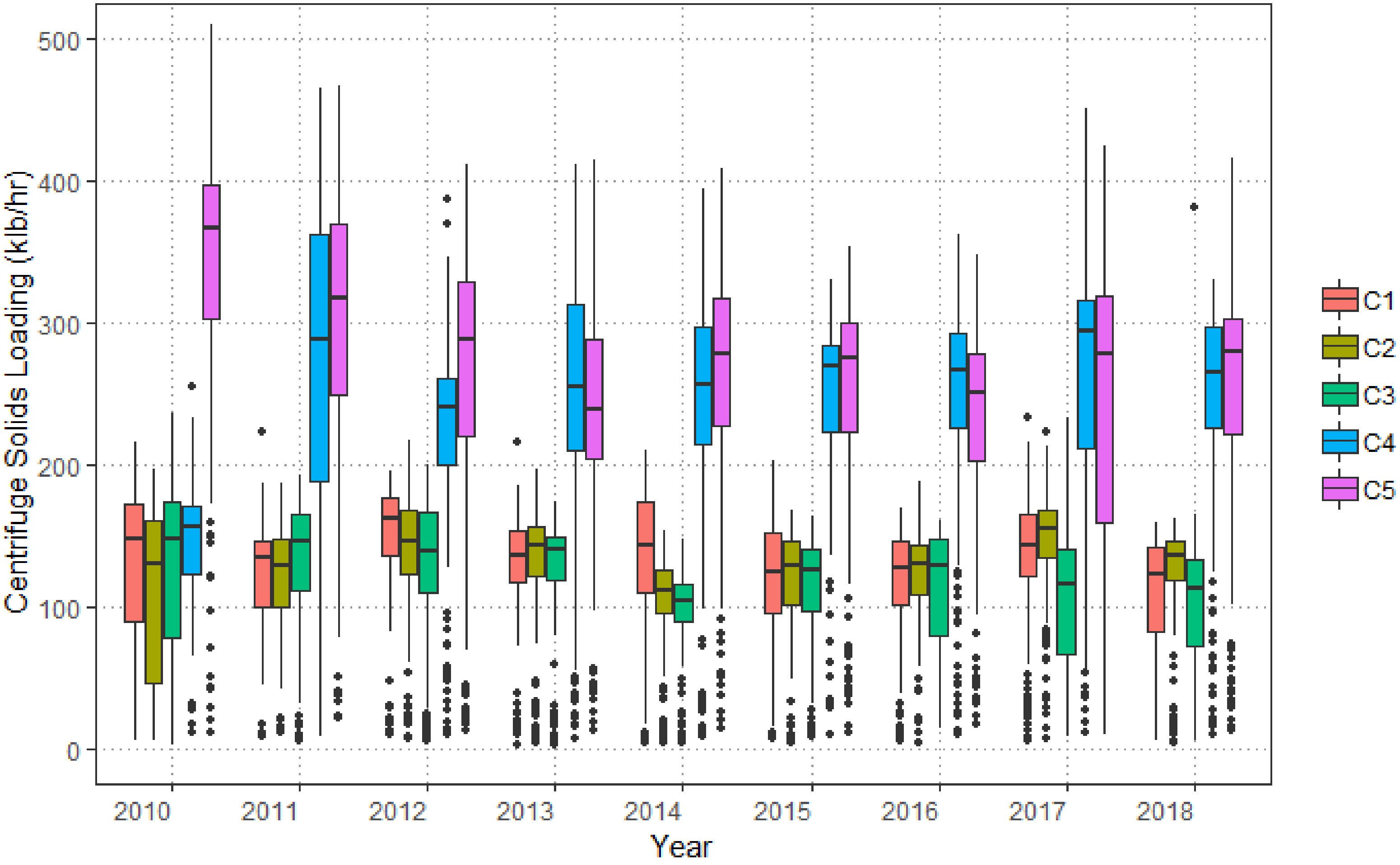


Figure G-3 Centrifuge Influent Solids Loading Rate (Annual Average)

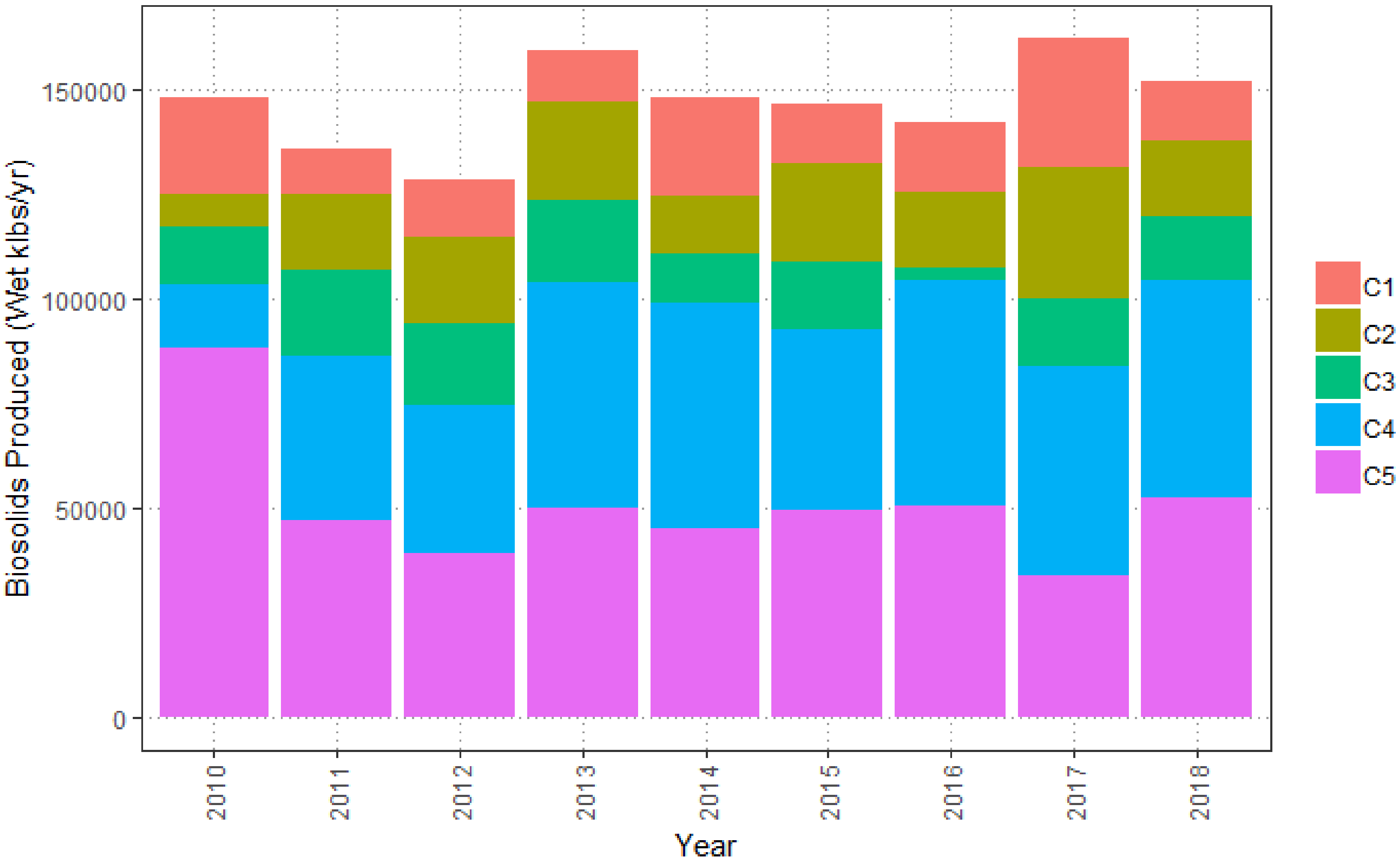


Figure G-4 Annual Biosolids (Cake) Production

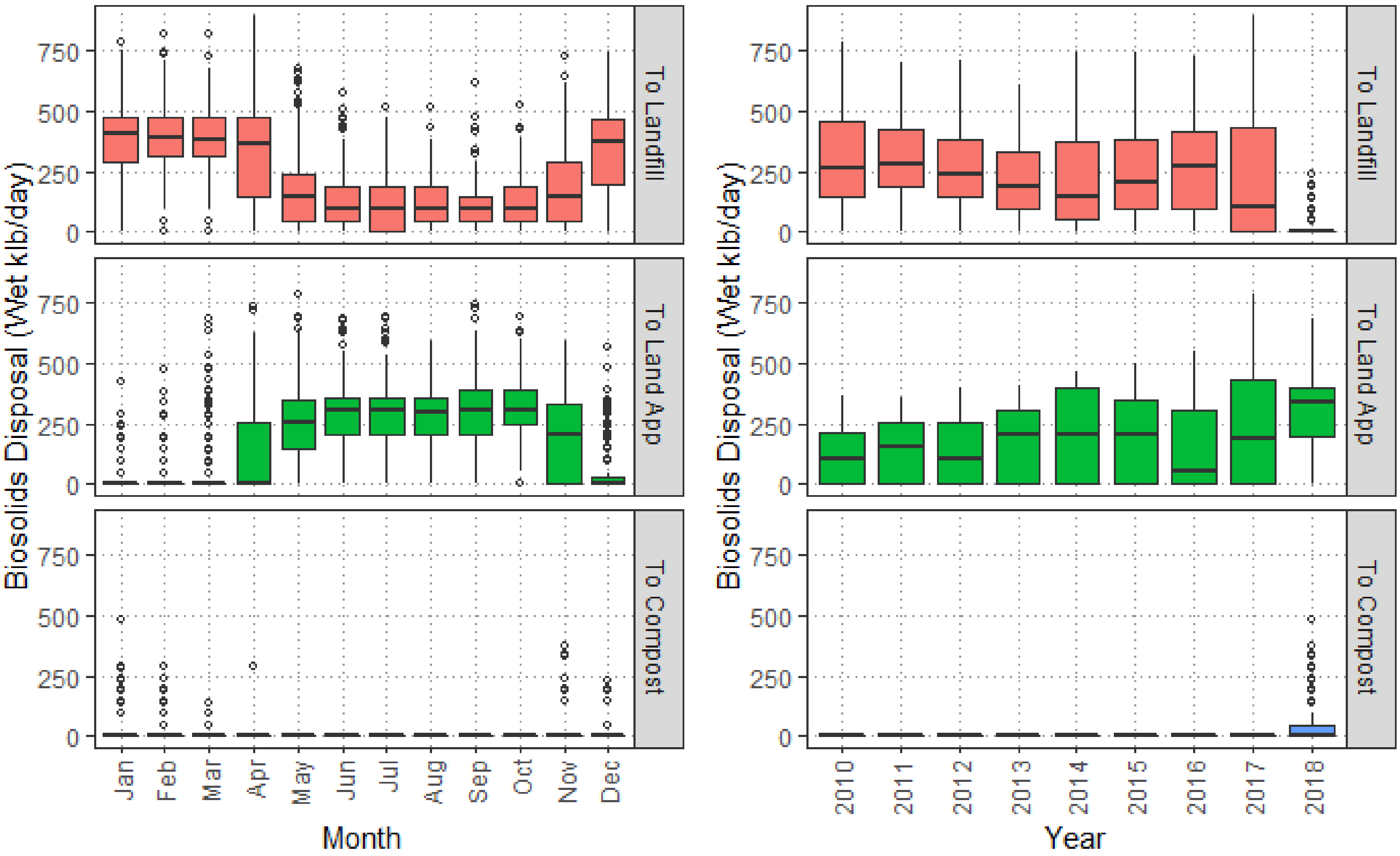


Figure G-5 Biosolids Disposal (Monthly and Annual Averages)

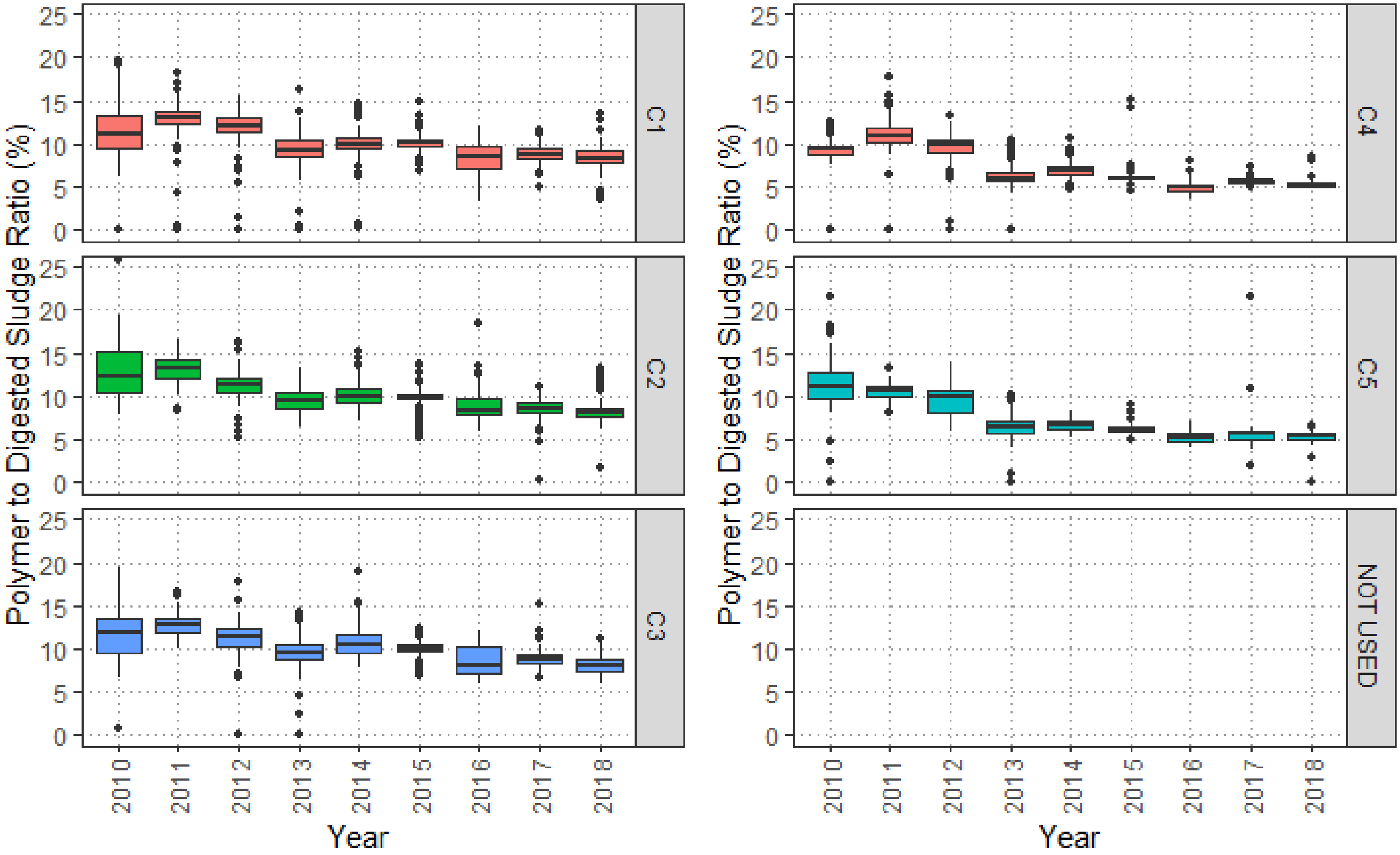


Figure G-6 Centrifuge Polymer to DSL Ratio (Monthly and Annual Averages)

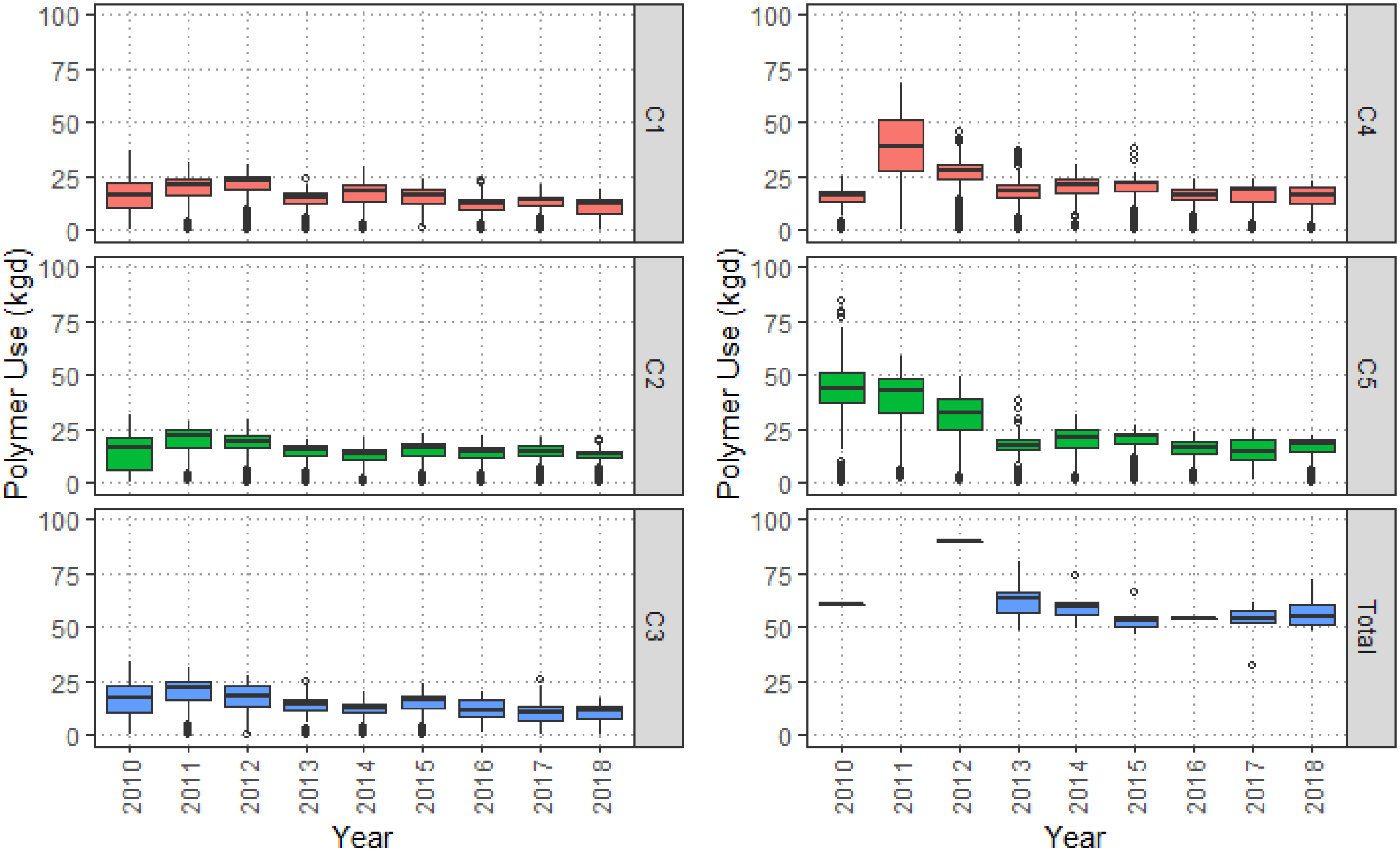


Figure G-7 Centrifuge Polymer Use (Monthly and Annual Averages)

APPENDIX H - References

Ackerly, D., Jones, A., Stacey, M., & Riordan, B. (2018). *San Francisco Bay Area summary report* (Publication number: CCCA4-SUM-2018-005). Retrieved from California's Fourth Climate Change Assessment website: http://www.climateassessment.ca.gov/

Hummel, M. A., Berry, M. S., & Stacey, M. T. (2018). Sea level rise impacts on wastewater treatment systems along the U.S. coasts. *Earth's Future, 6,* 622–633.doi:10.1002/2017EF000805

Core Writing Team, Pachauri, R.K. & Meyer, L.A. (Eds.). (2014). *Climate change 2014: Synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change.* Geneva, Switzerland: Intergovernmental Panel on Climate Change.

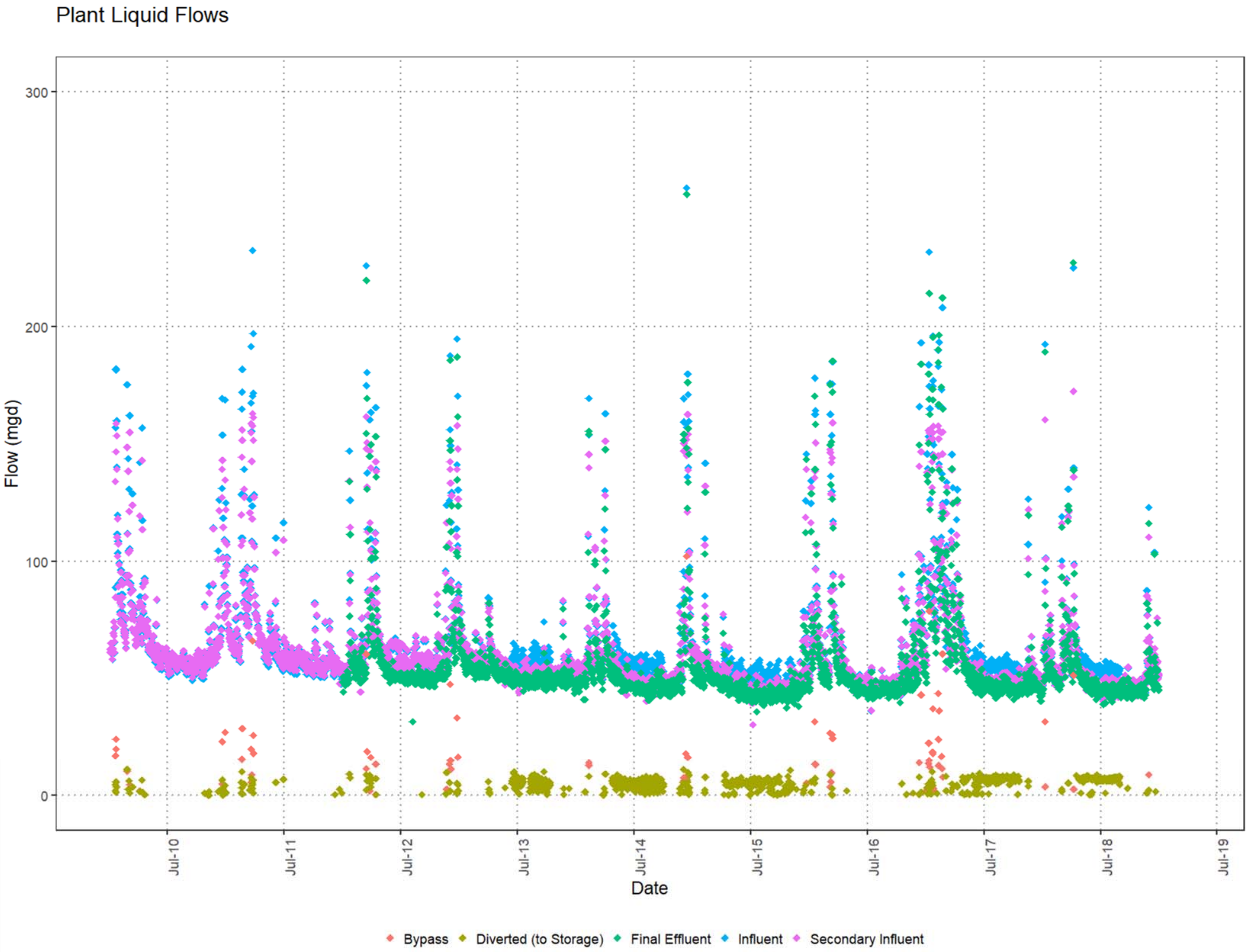
Solutionwerks (2018). Oxygen System Assessment. East Bay Municipal Utility District Waste Water Treatment Plant.

Metcalf & Eddy, et al., *Wastewater Engineering Treatment and Resource Recovery*, 2014.

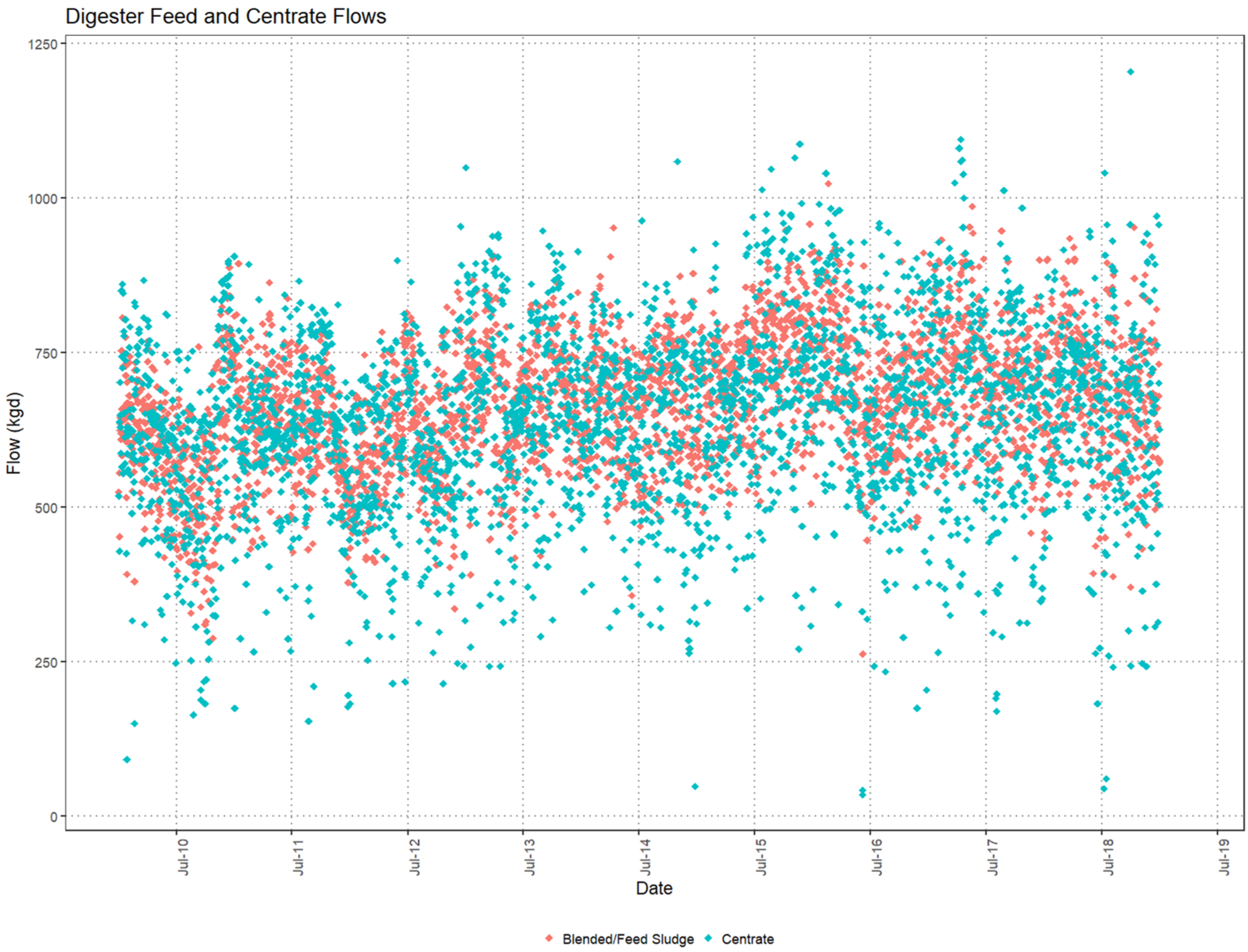
Water Environment Federation, et al., *Design of Water Resource Recovery Facilities*, Manual of Practice No. 8, 2018.

APPENDIX I - Select Additional Data Plots

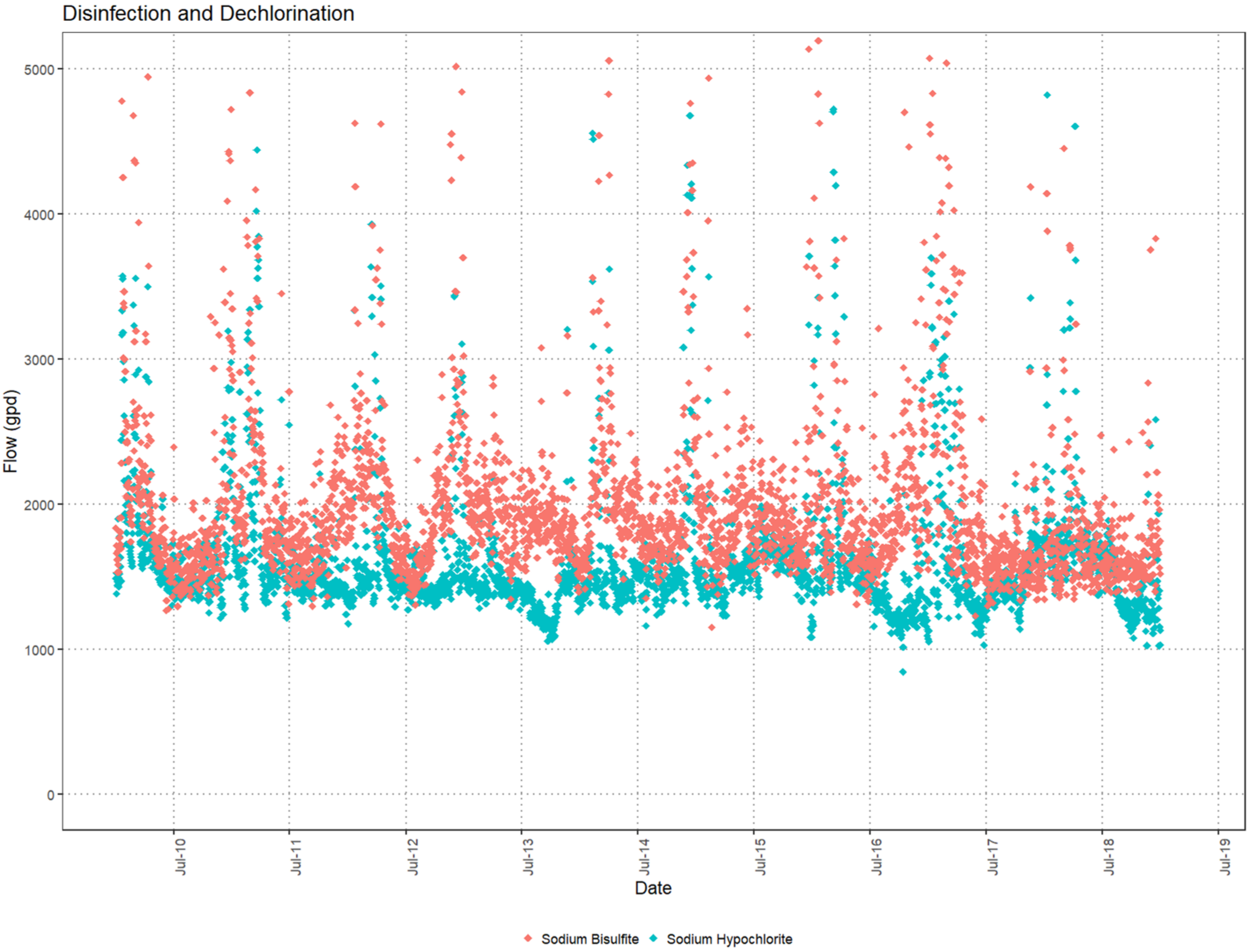
This appendix provides additional figures for informational purposes only.

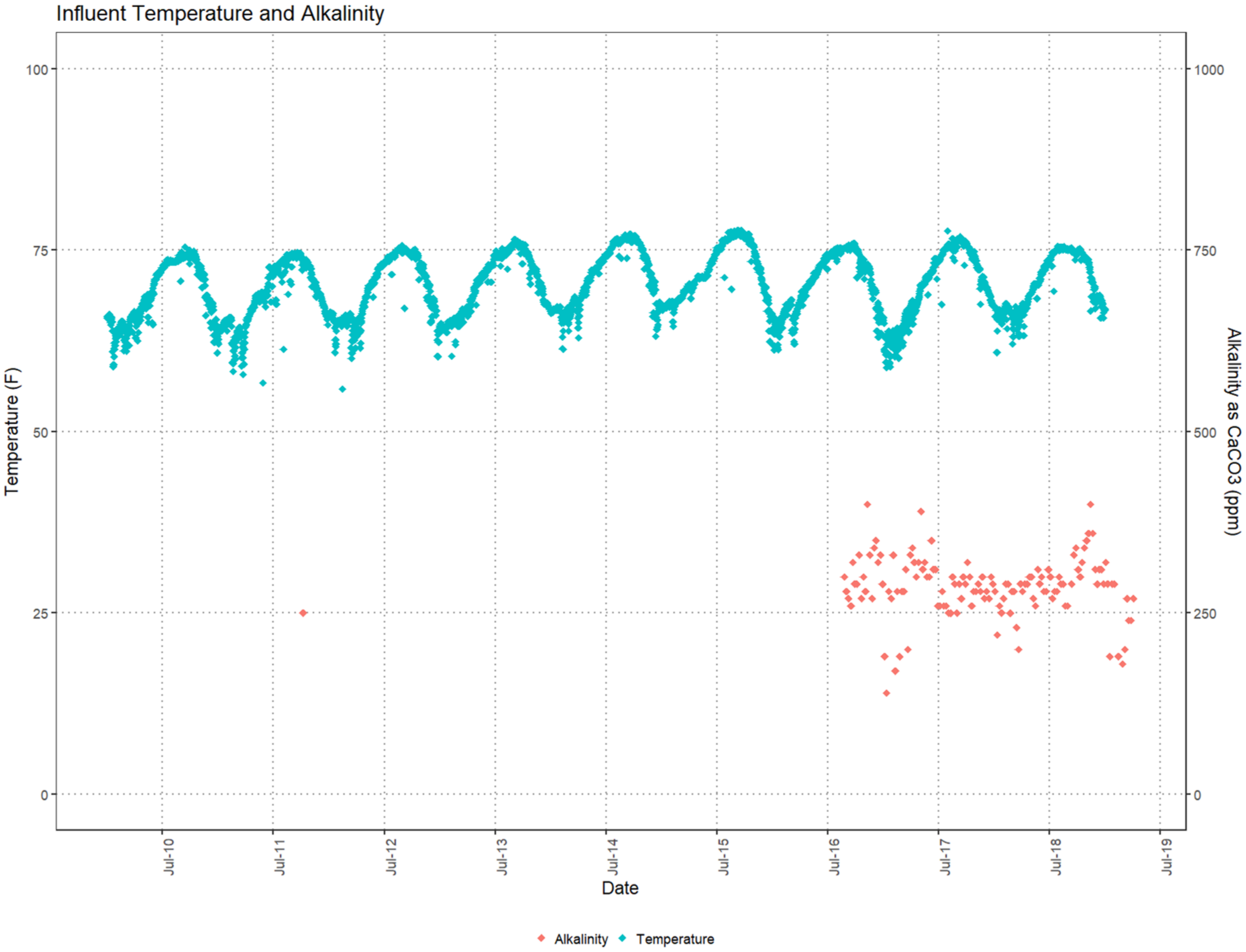

Plant Liquid Flows
Flow (mgd)
300
200
100
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
◆ Bypass
◆ Diverted (to Storage)
◆ Final Effluent
◆ Influent
◆ Secondary Influent


PS, TWAS, FOG, and HSW Flows
Flow (kgd)
600
400
200
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
FOG/HSL Receiving Station
Primary Sludge
Solids/Liquid Waste Receiving Station
TWAS

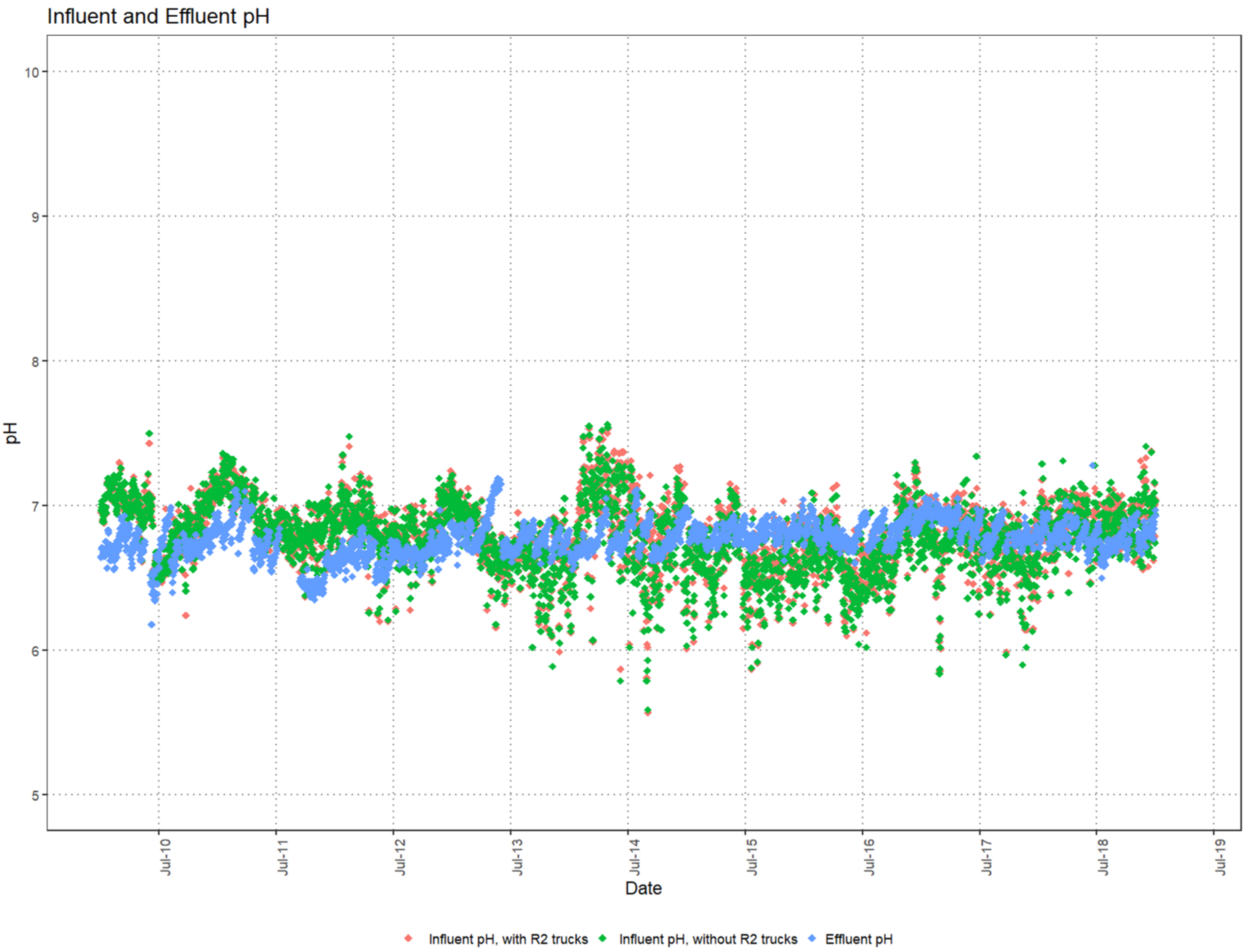


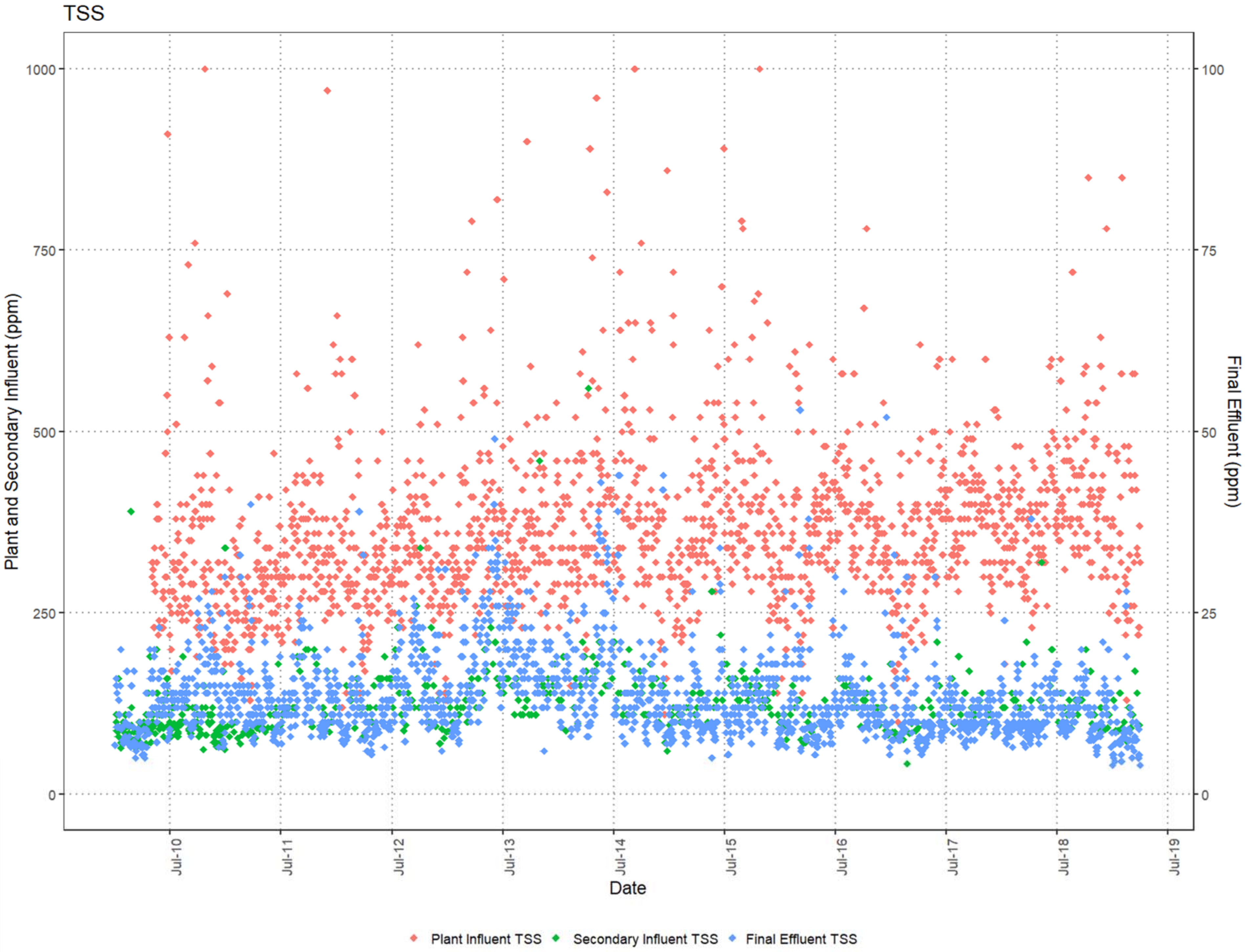
Digester Feed and Centrate Flows
1250
1000
750
500
250
0
Flow (kgd)
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
◆ Blended/Feed Sludge
◆ Centrate

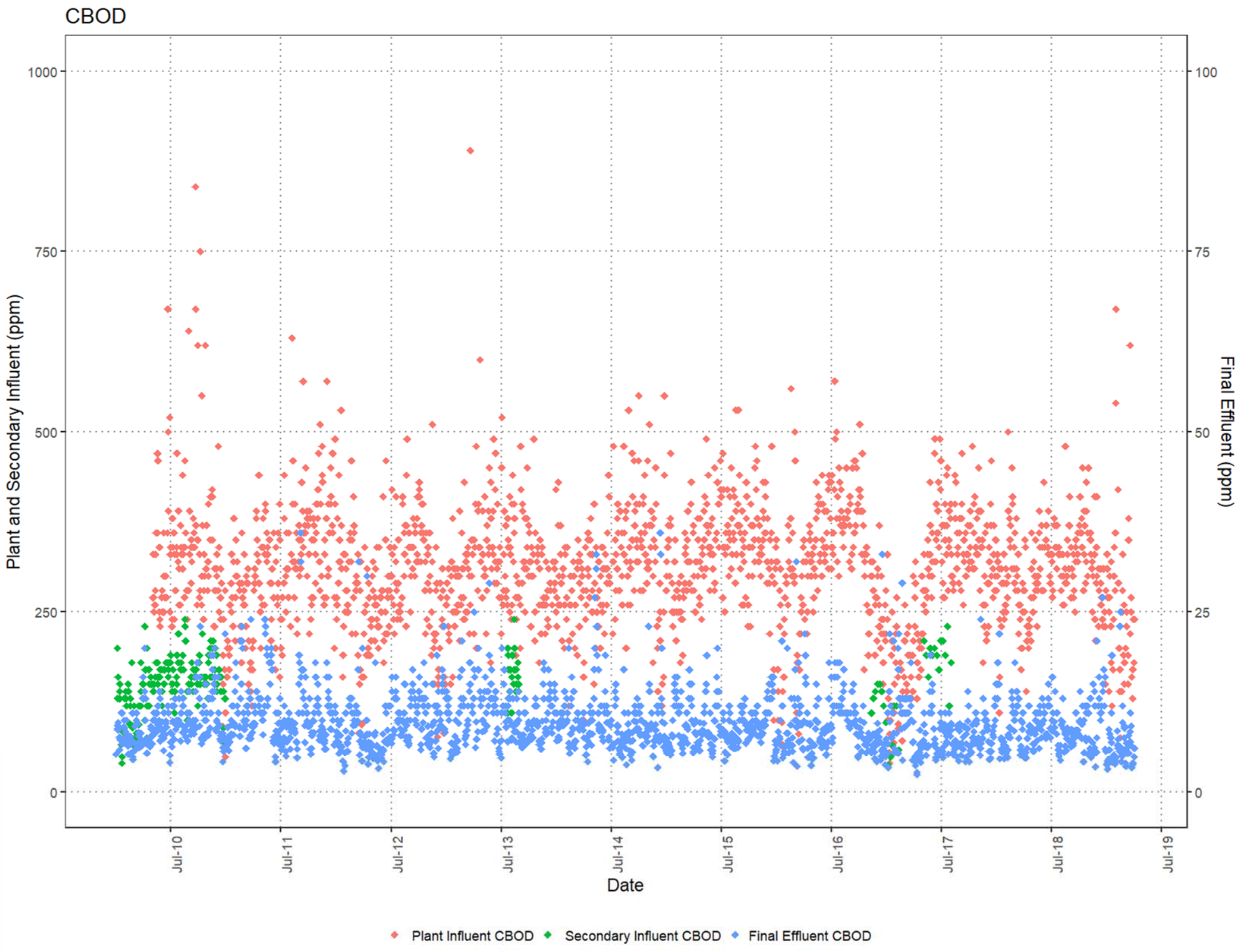

Disinfection and Dechlorination
Flow (gpd)
5000
4000
3000
2000
1000
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Sodium Bisulfite
Sodium Hypochlorite

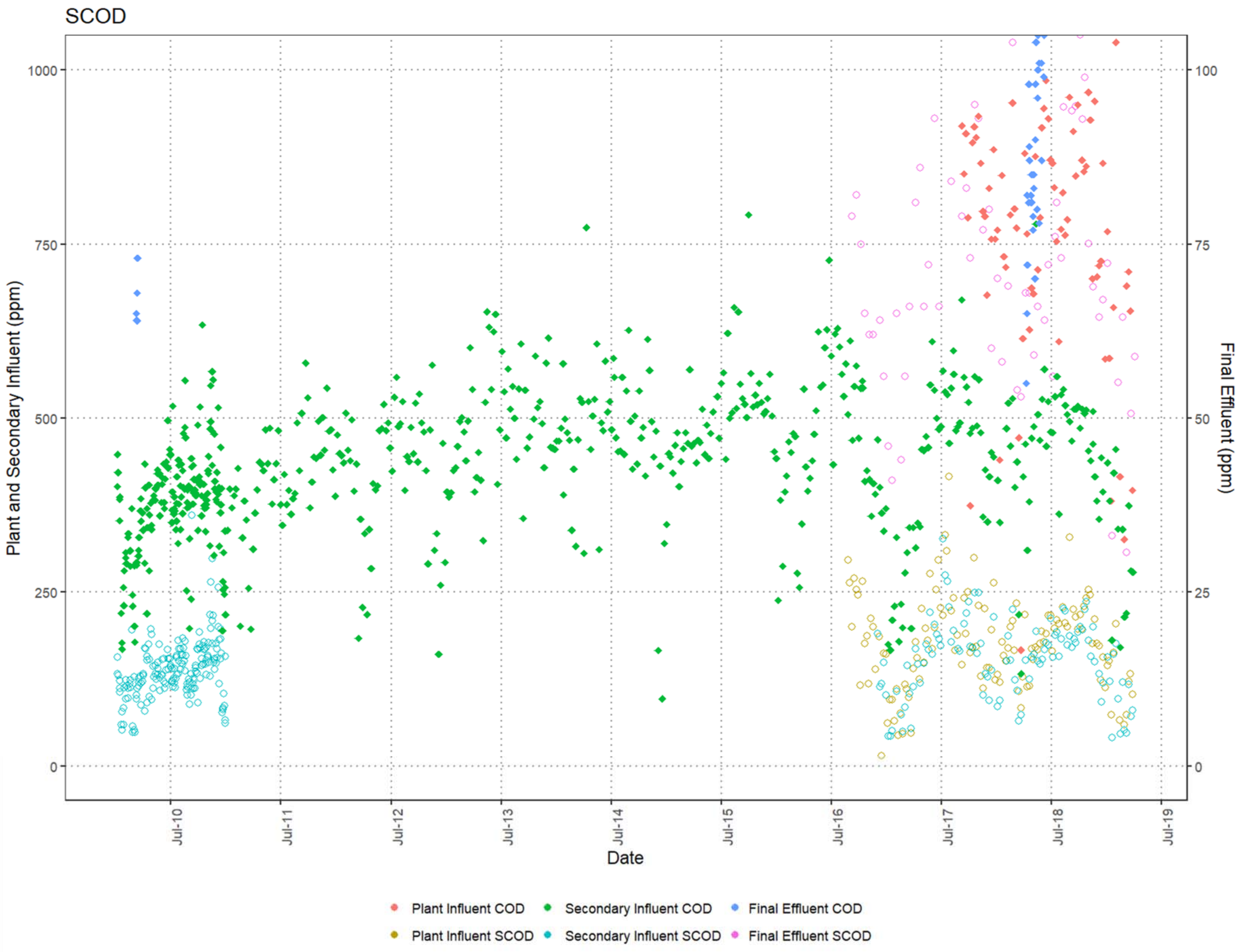


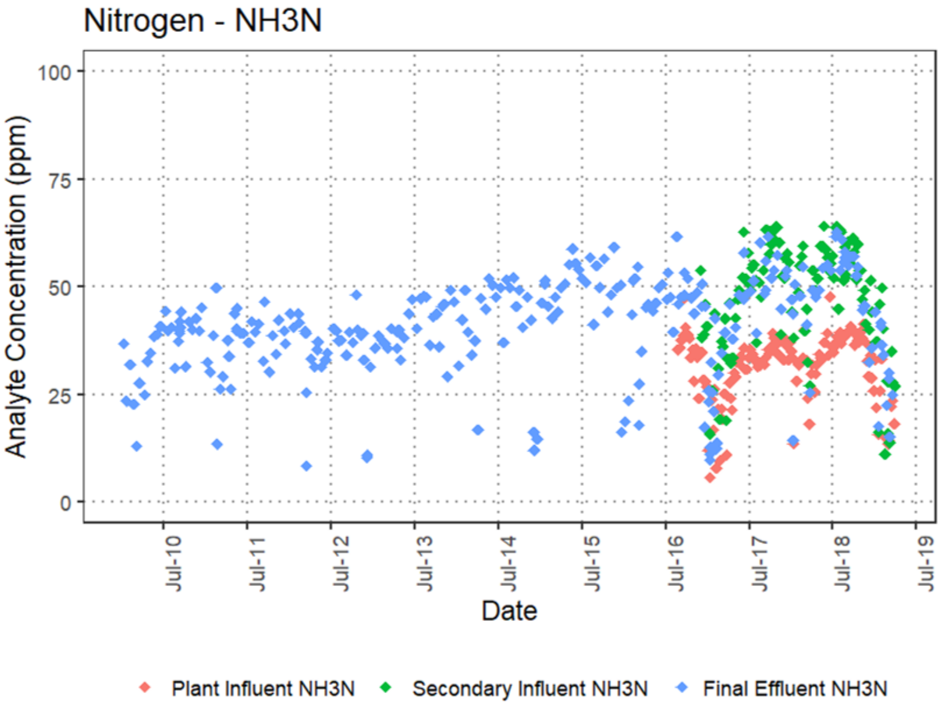
Influent Temperature and Alkalinity
Temperature (F)
100
75
50
25
0
Alkalinity as CaCO3 (ppm)
1000
750
500
250
0
Date
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
◆ Alkalinity
◆ Temperature

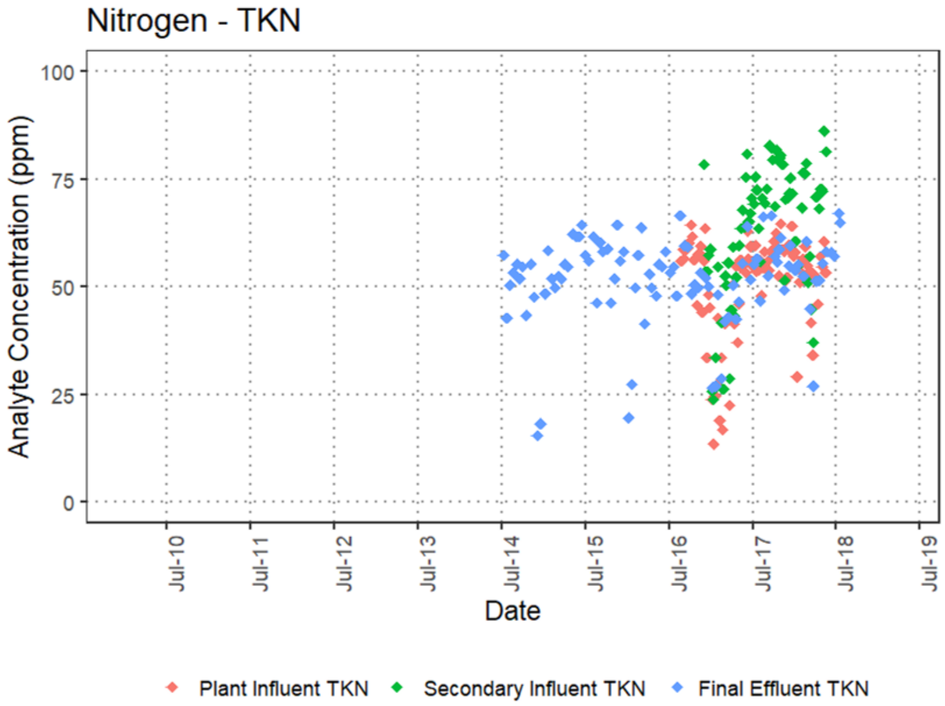

Influent and Effluent pH
pH
10
9
8
7
6
5
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Influent pH, with R2 trucks
Influent pH, without R2 trucks
Effluent pH

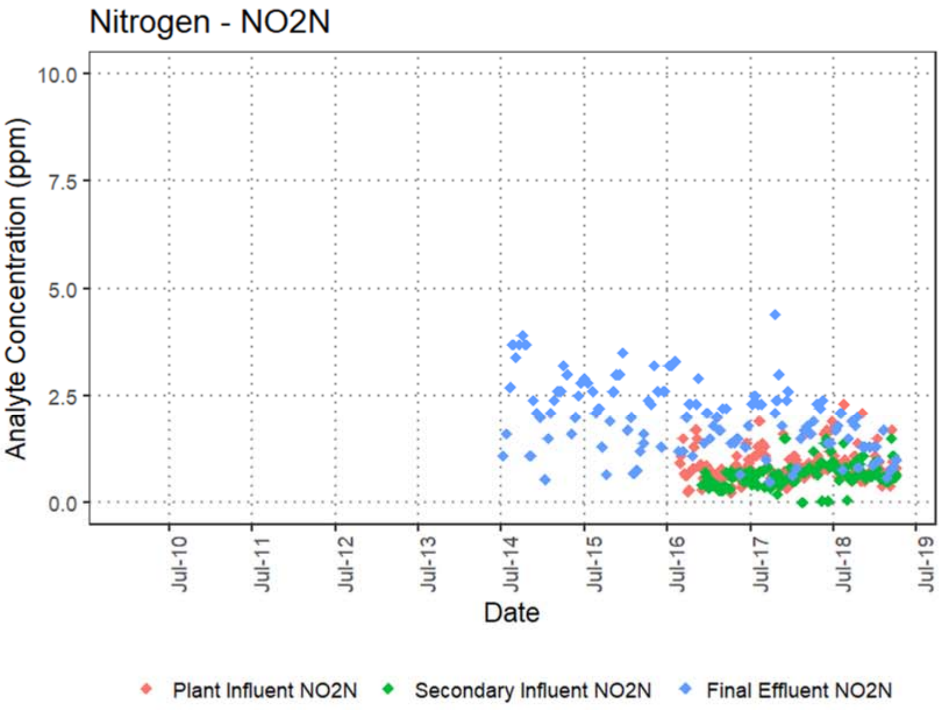

TSS
Plant and Secondary Influent (ppm)
Final Effluent (ppm)
1000
750
500
250
0
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent TSS
Secondary Influent TSS
Final Effluent TSS

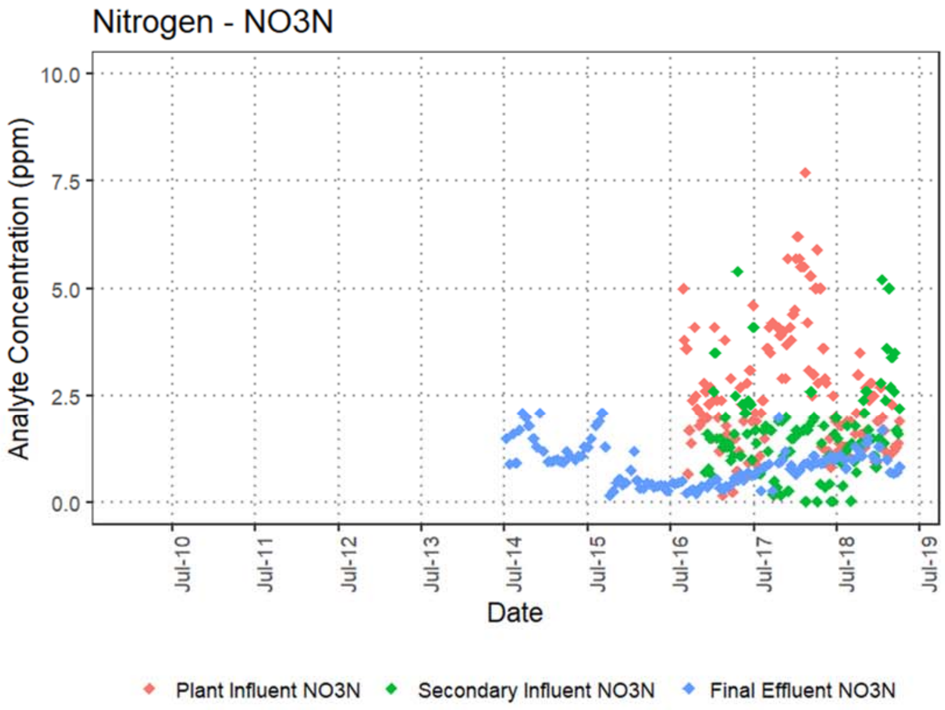

CBOD
Plant and Secondary Influent (ppm)
1000
750
500
250
0
Final Effluent (ppm)
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent CBOD
Secondary Influent CBOD
Final Effluent CBOD

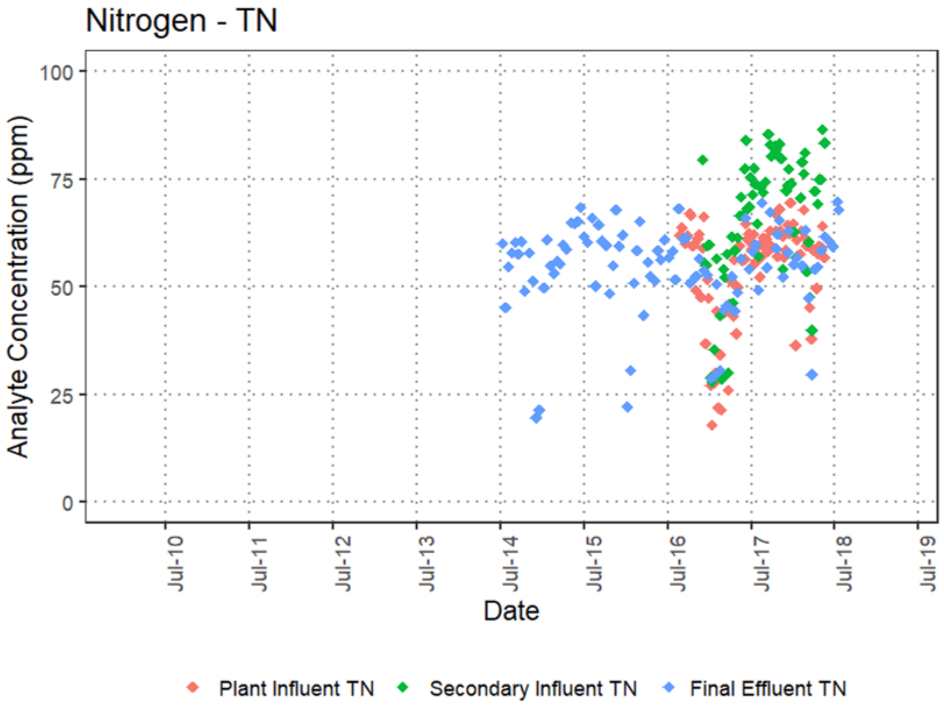

SCOD
Plant and Secondary Influent (ppm)
Final Effluent (ppm)
1000
750
500
250
0
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent COD
Secondary Influent COD
Final Effluent COD
Plant Influent SCOD
Secondary Influent SCOD
Final Effluent SCOD

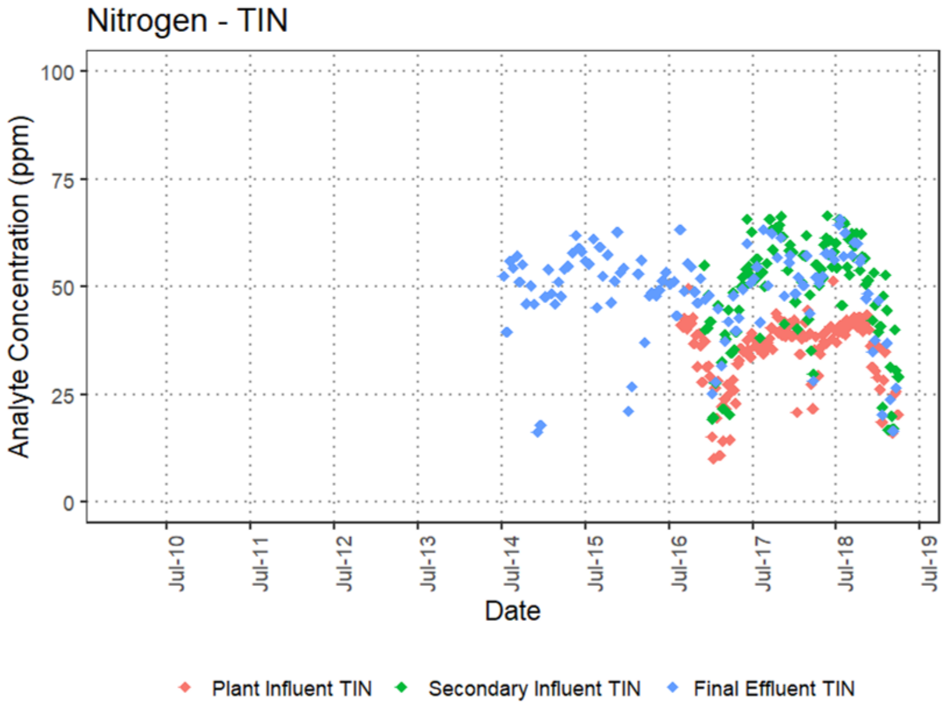

Nitrogen - NH3N
Analyte Concentration (ppm)
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent NH3N
Secondary Influent NH3N
Final Effluent NH3N

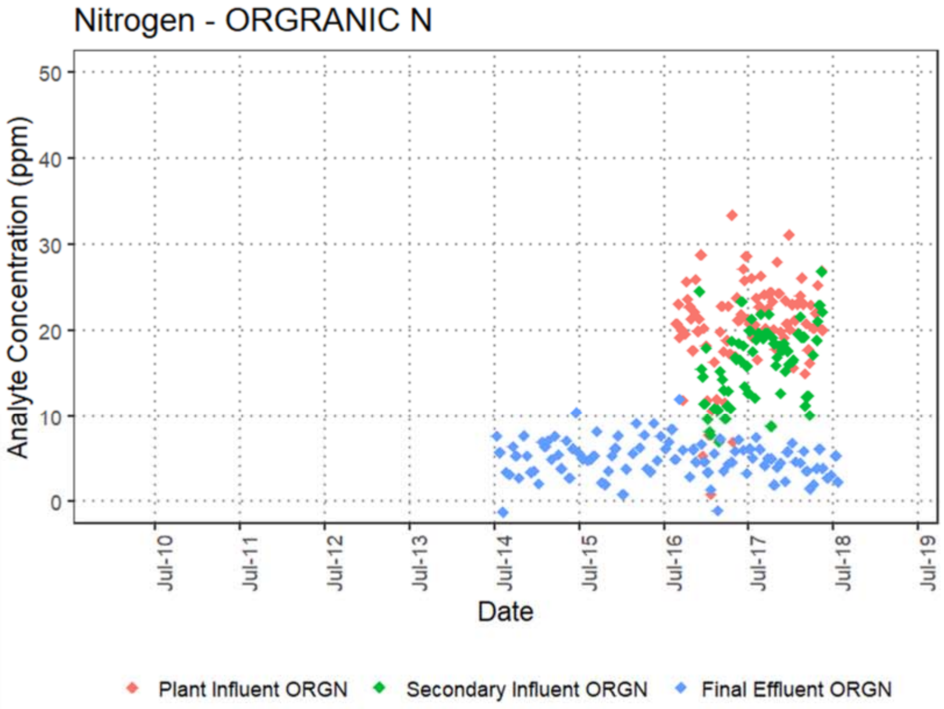

Nitrogen - TKN
Analyte Concentration (ppm)
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent TKN
Secondary Influent TKN
Final Effluent TKN

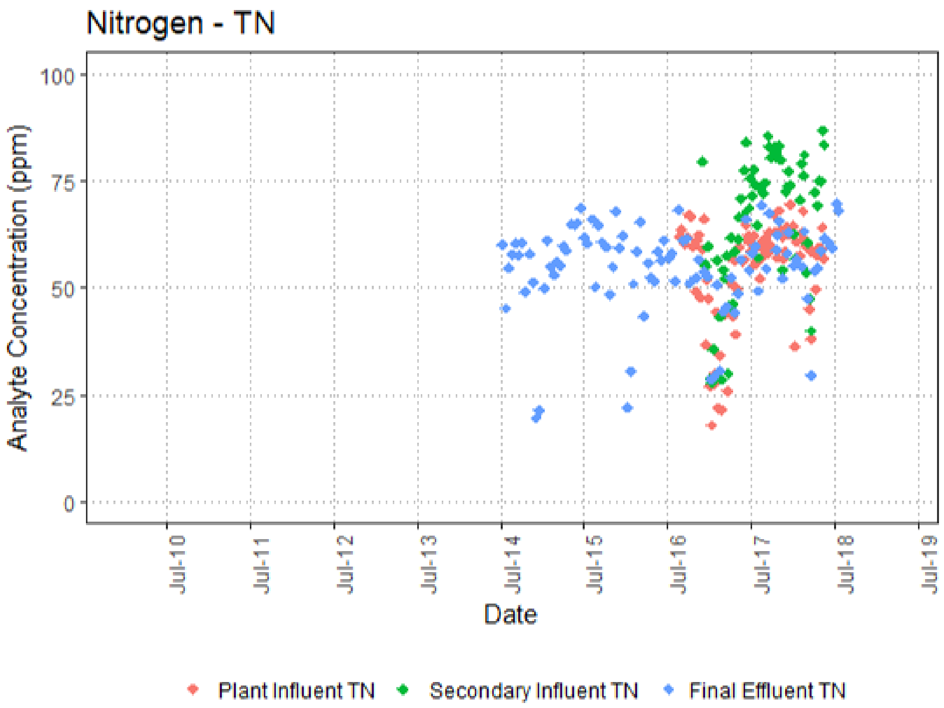

Nitrogen - NO2N
Analyte Concentration (ppm)
10.0
7.5
5.0
2.5
0.0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent NO2N
Secondary Influent NO2N
Final Effluent NO2N

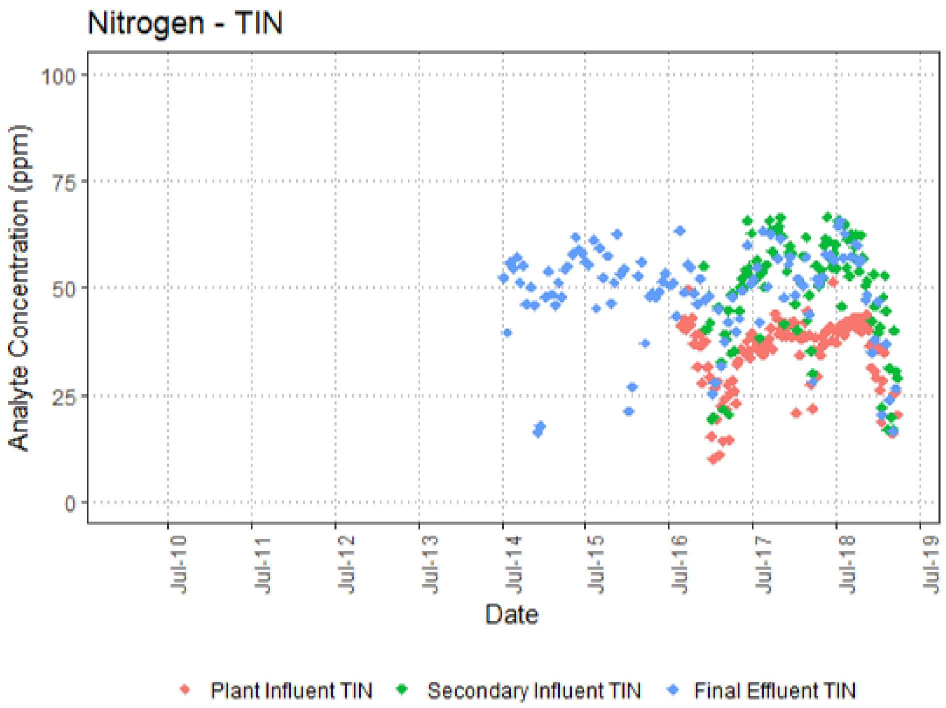

Nitrogen - NO3N
Analyte Concentration (ppm)
10.0
7.5
5.0
2.5
0.0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent NO3N
Secondary Influent NO3N
Final Effluent NO3N

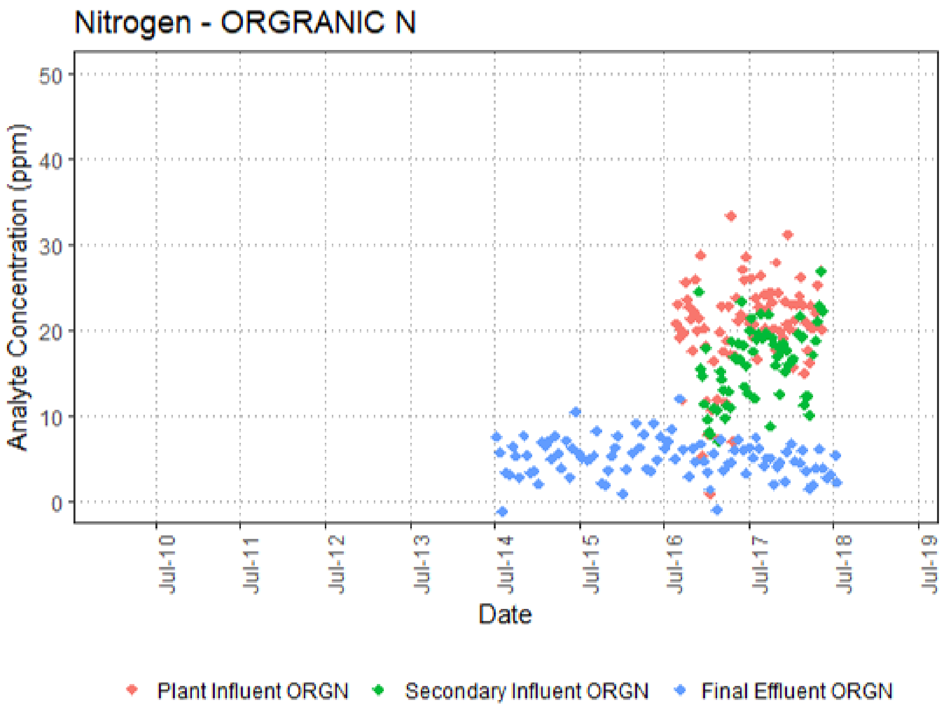

Nitrogen - TN

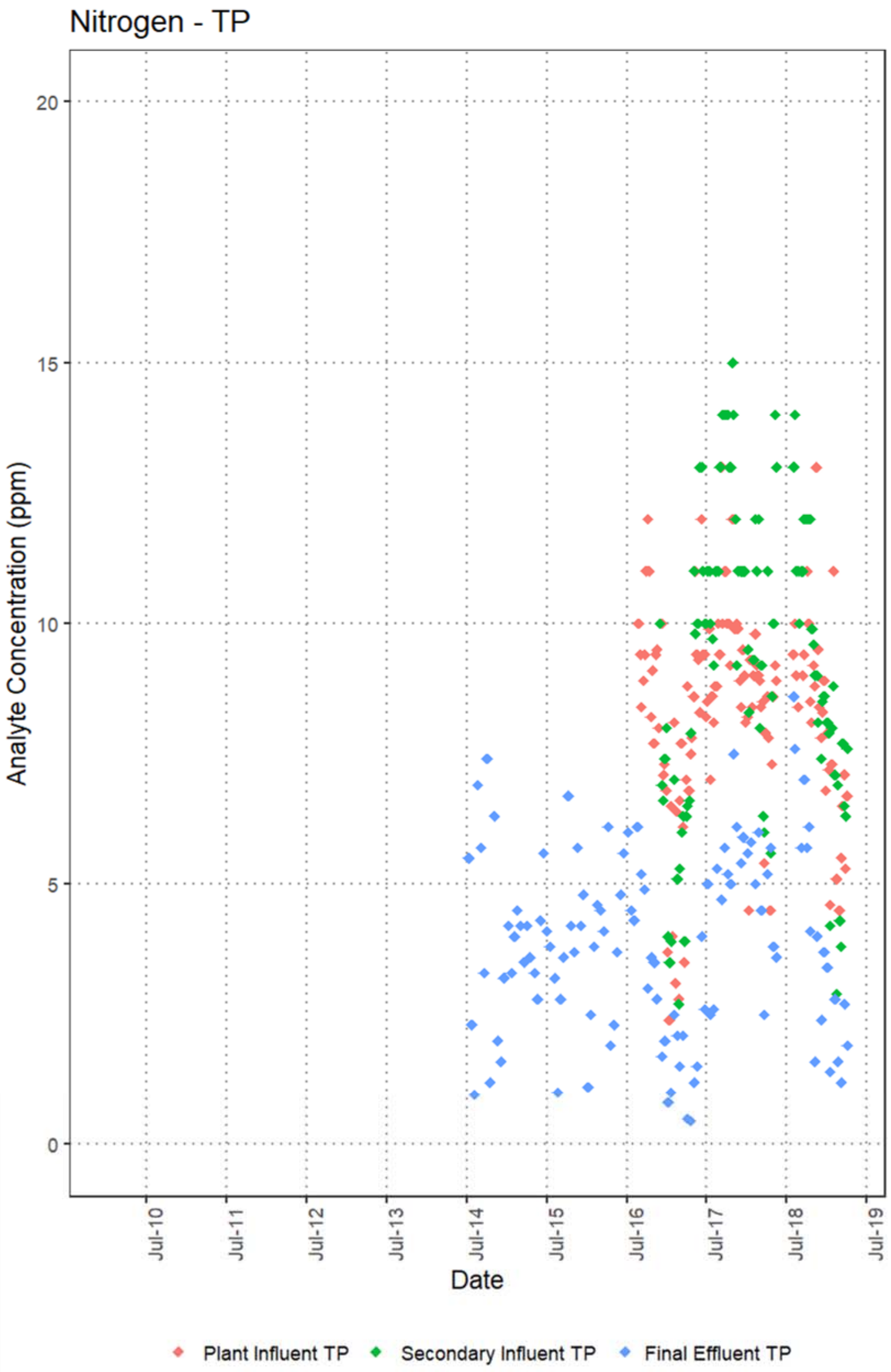

Nitrogen - TIN


Nitrogen - ORGRANIC N

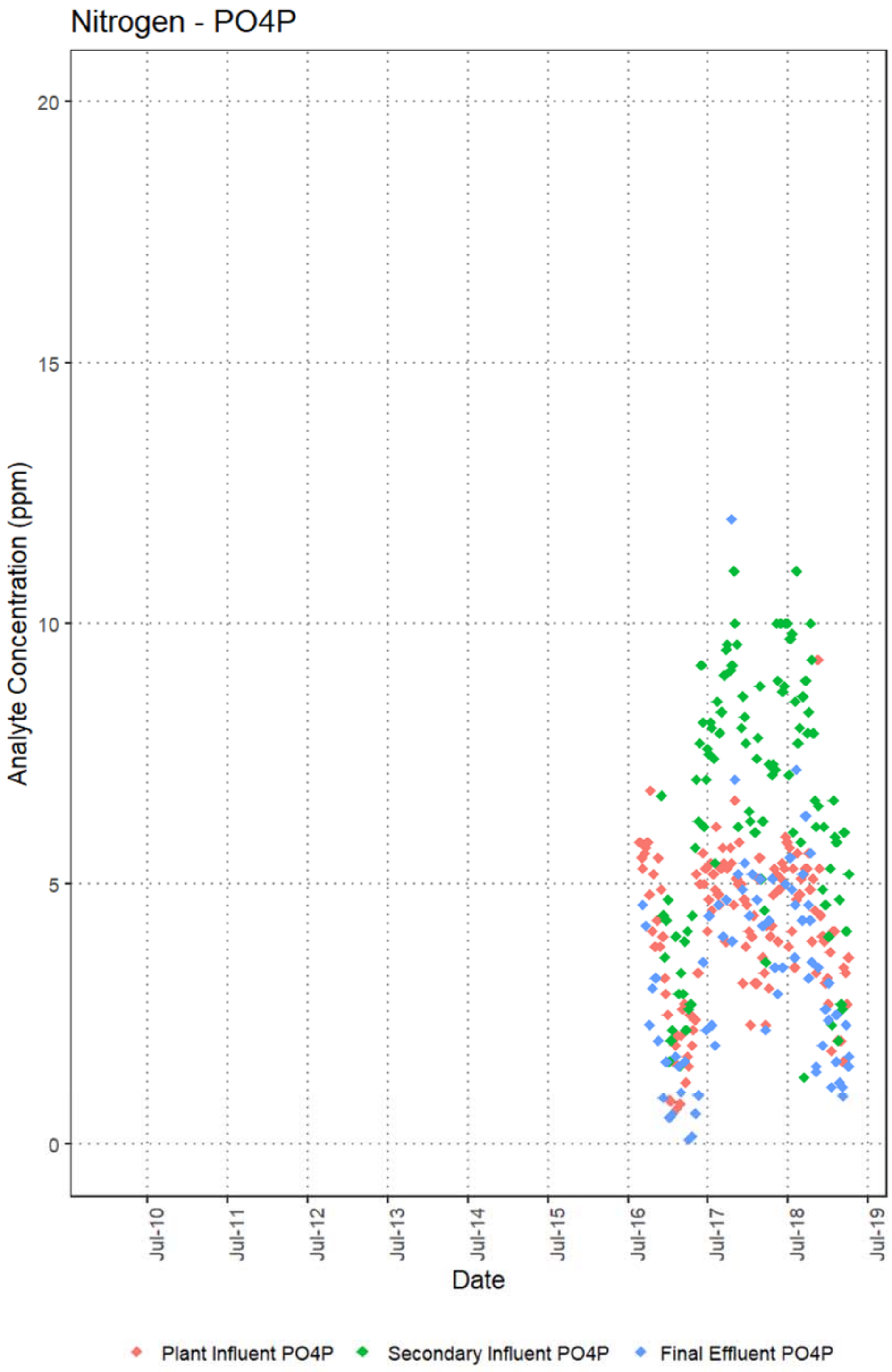

Nitrogen - TN
Analyte Concentration (ppm)
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent TN
Secondary Influent TN
Final Effluent TN


Nitrogen - TIN
Analyte Concentration (ppm)
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent TIN
Secondary Influent TIN
Final Effluent TIN

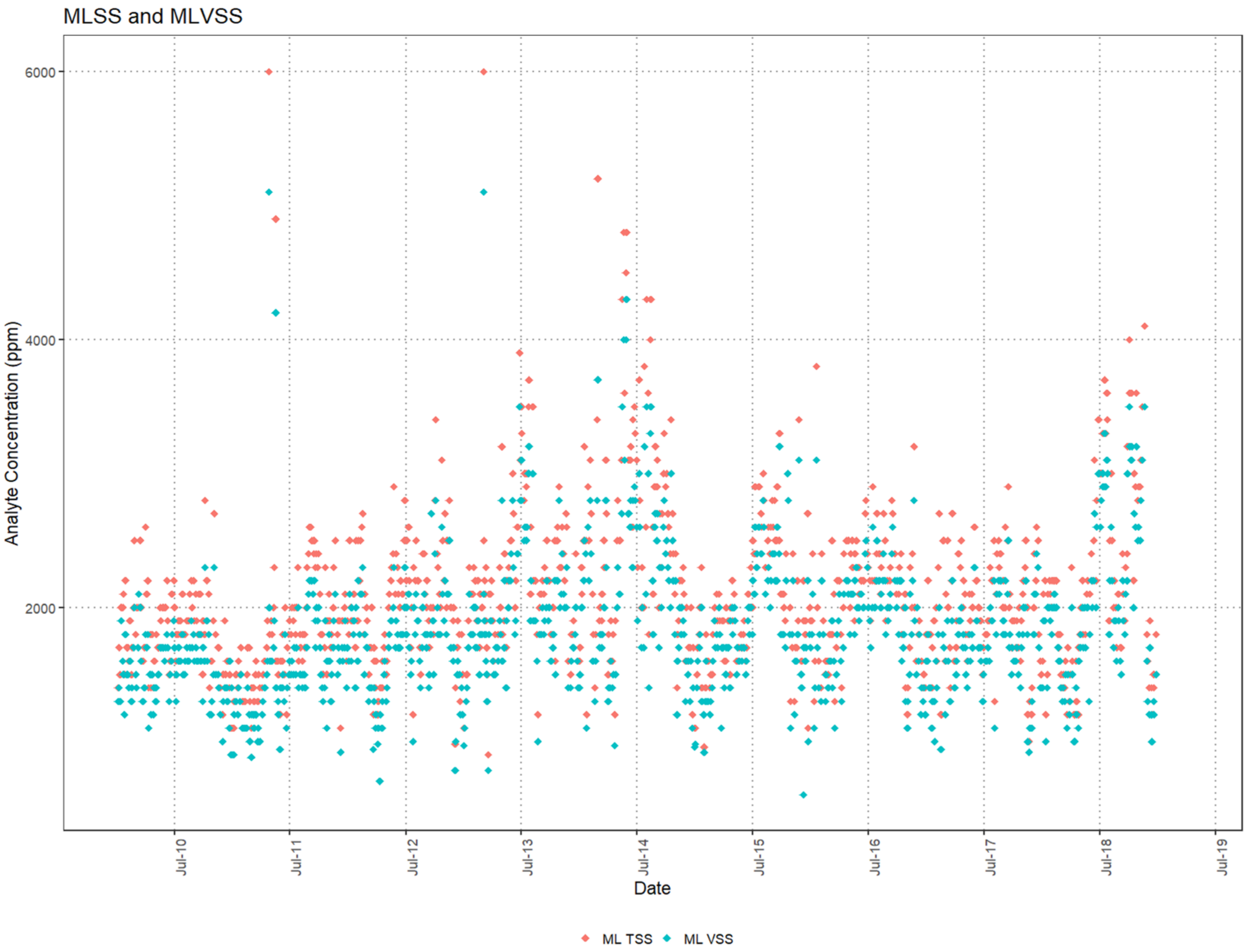

Nitrogen - ORGRANIC N
Analyte Concentration (ppm)
50
40
30
20
10
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent ORGN
Secondary Influent ORGN
Final Effluent ORGN

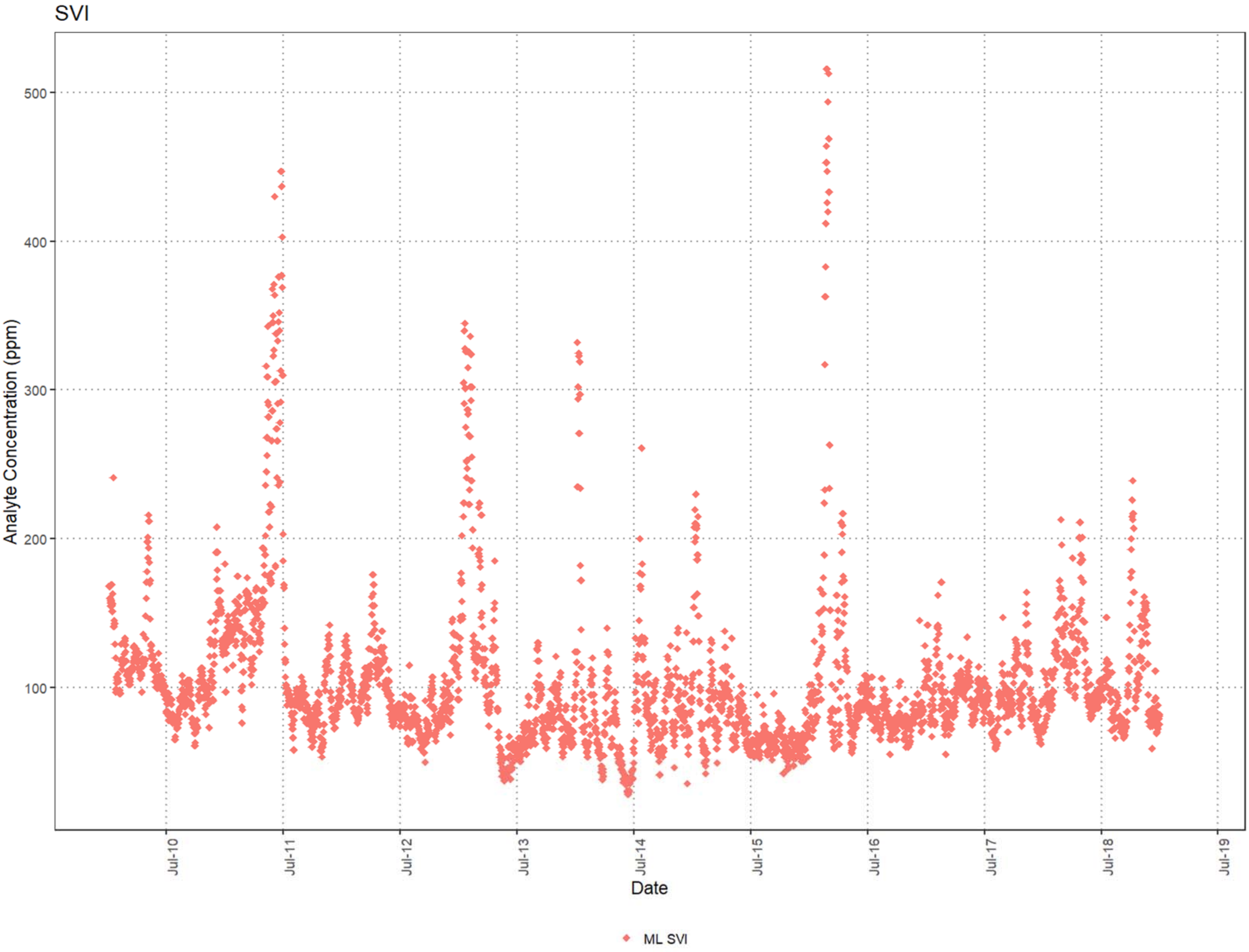


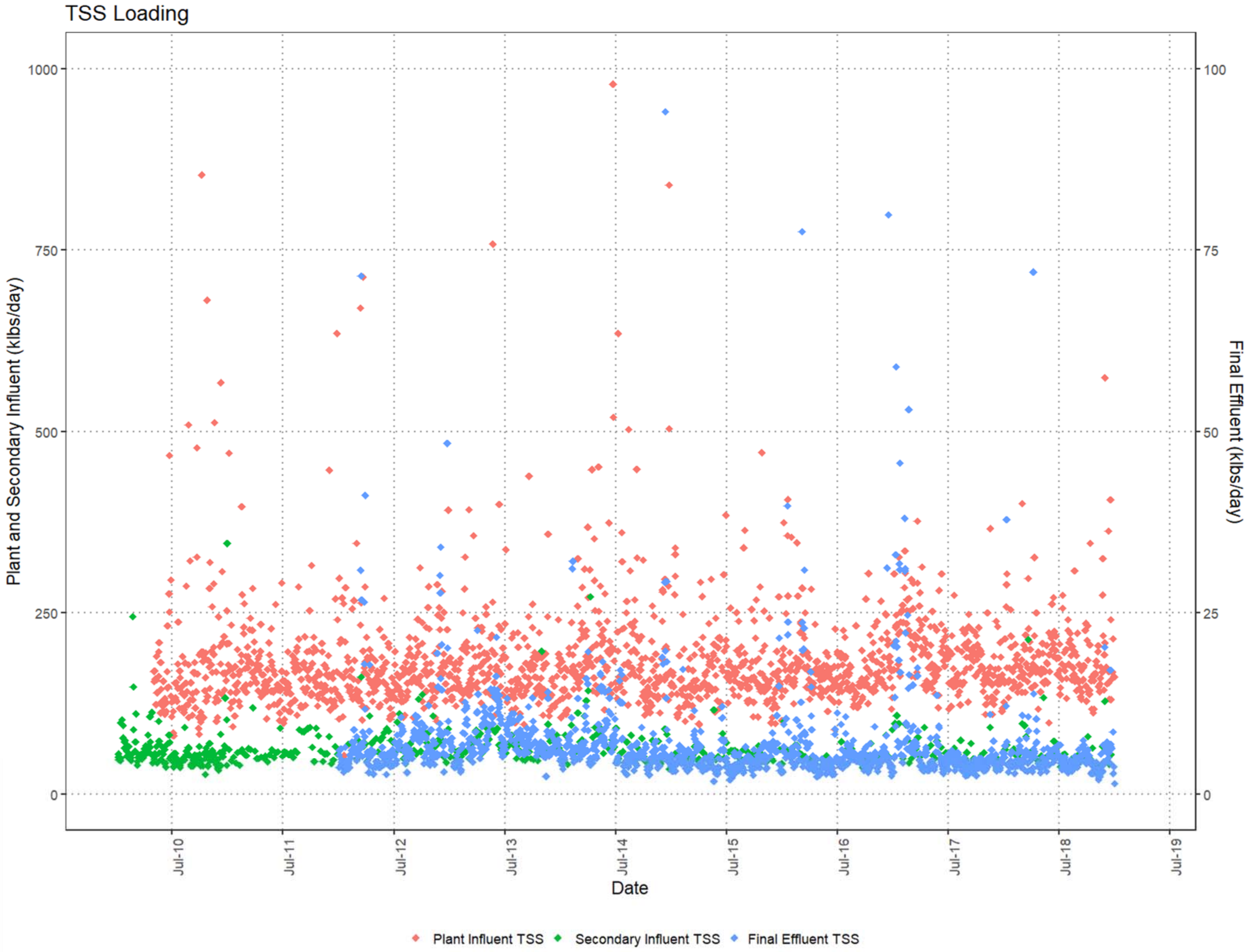
Nitrogen - TP

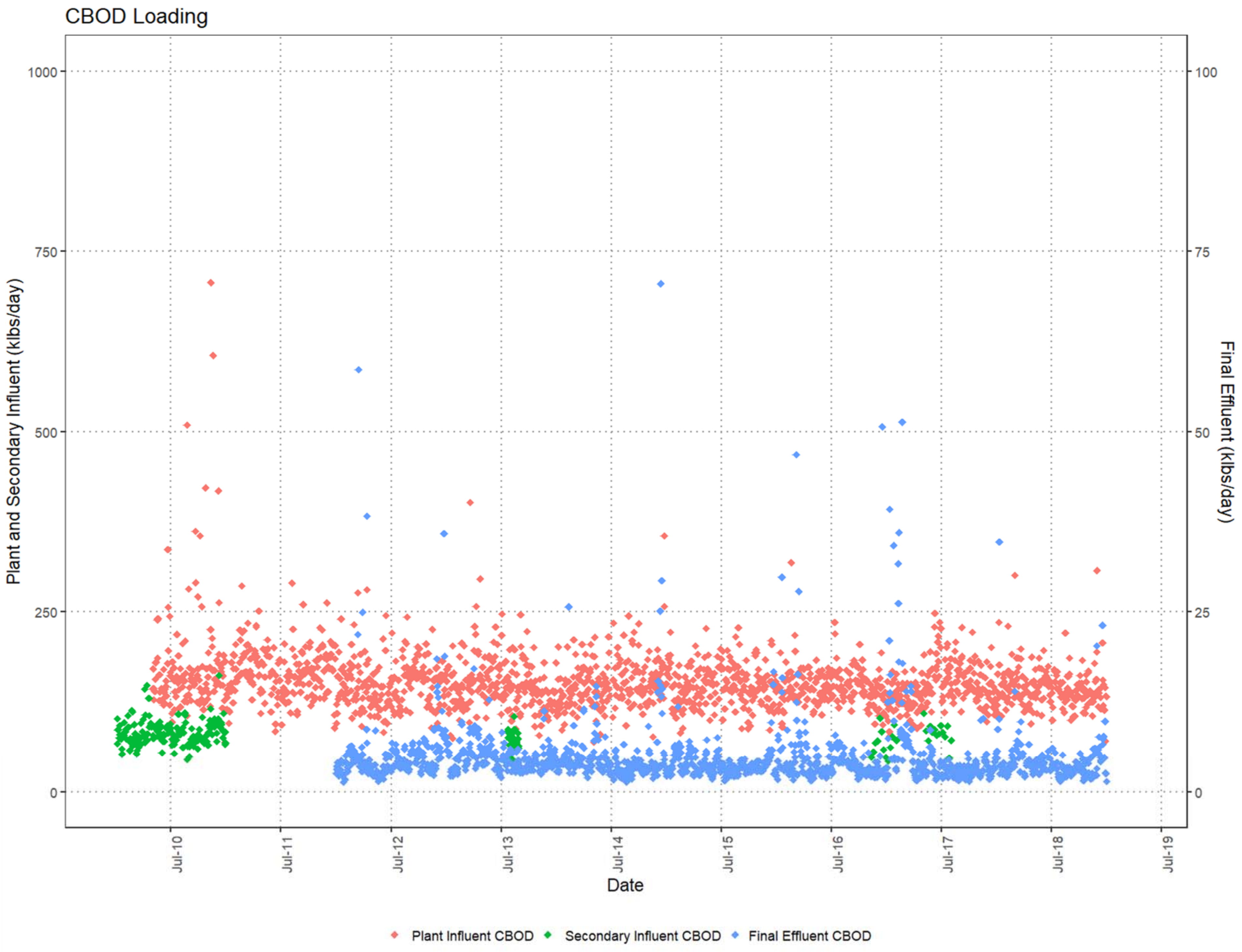


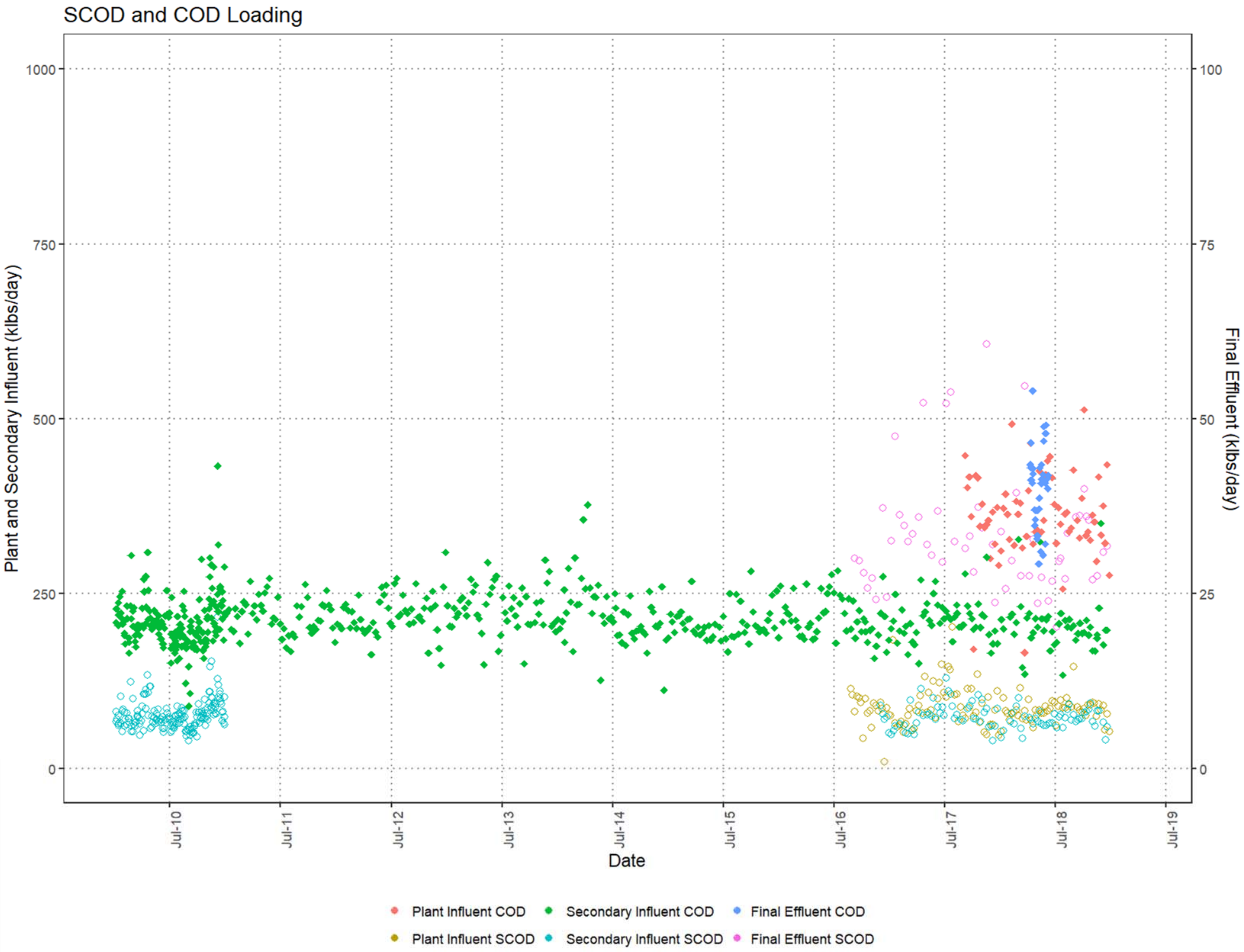
Nitrogen - PO4P

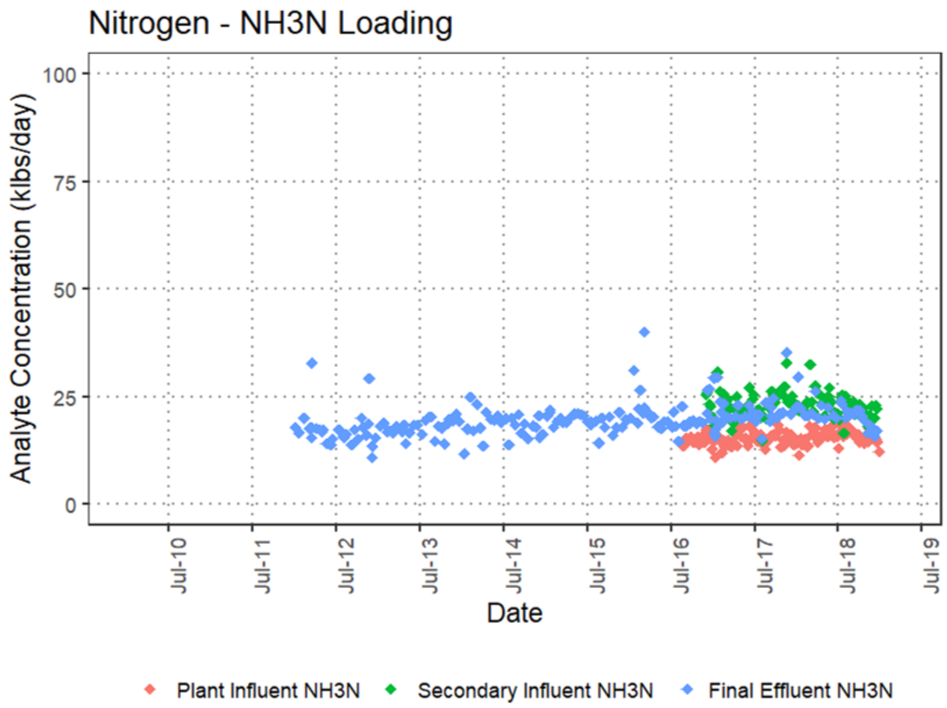

MLSS and MLVSS
Analyte Concentration (ppm)
6000
4000
2000
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
◆ ML TSS
◆ ML VSS

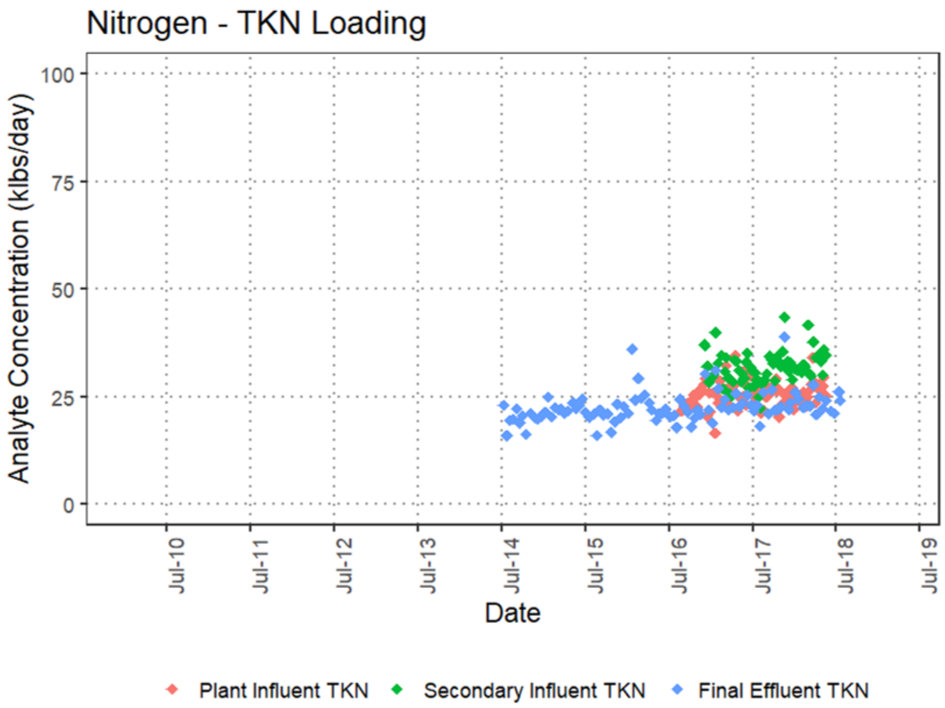

SVI
Analyte Concentration (ppm)
500
400
300
200
100
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
ML SVI

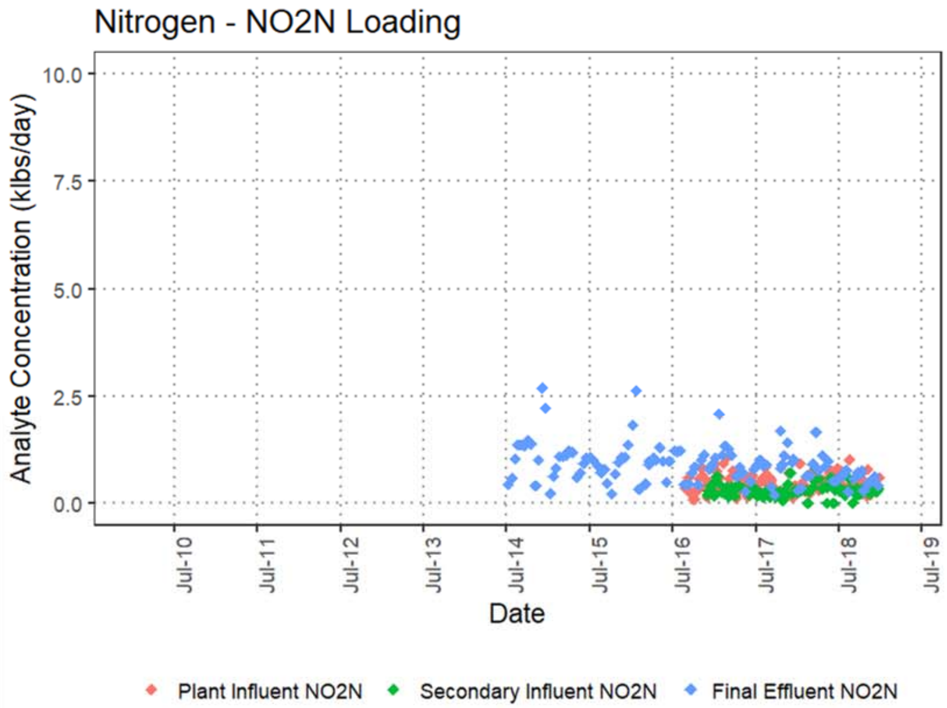

TSS Loading
Plant and Secondary Influent (klbs/day)
Final Effluent (klbs/day)
1000
750
500
250
0
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent TSS
Secondary Influent TSS
Final Effluent TSS

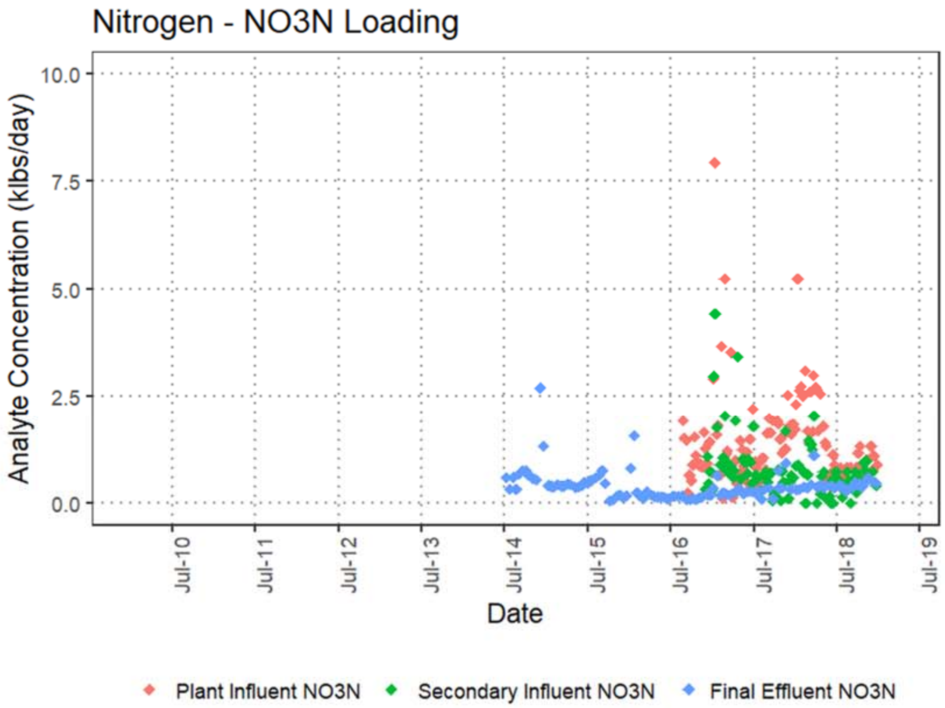

CBOD Loading
Plant and Secondary Influent (klbs/day)
Final Effluent (klbs/day)
1000
750
500
250
0
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent CBOD
Secondary Influent CBOD
Final Effluent CBOD

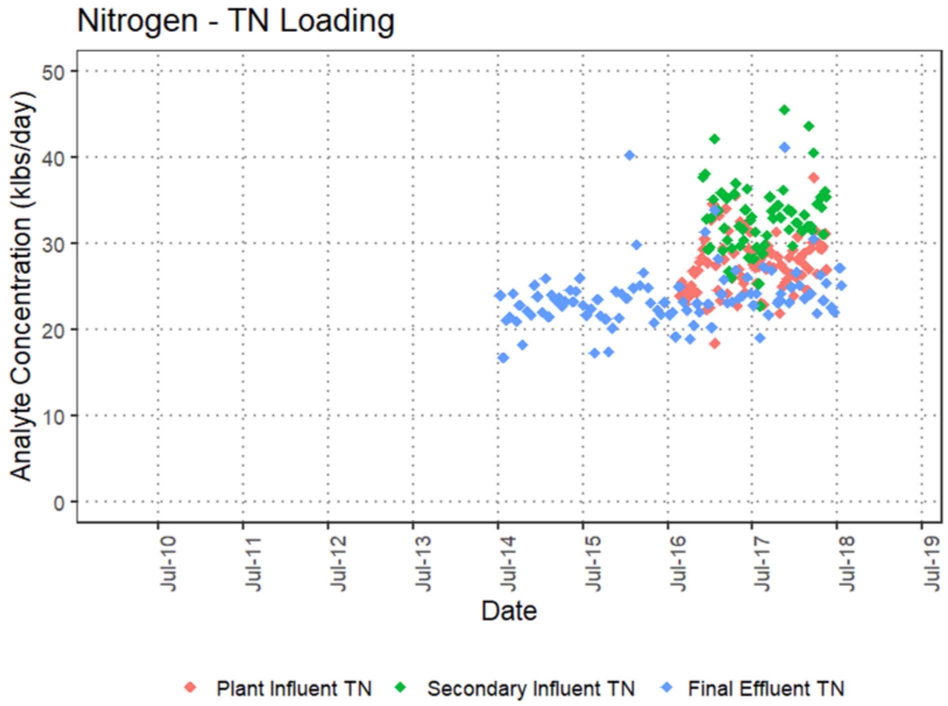

SCOD and COD Loading

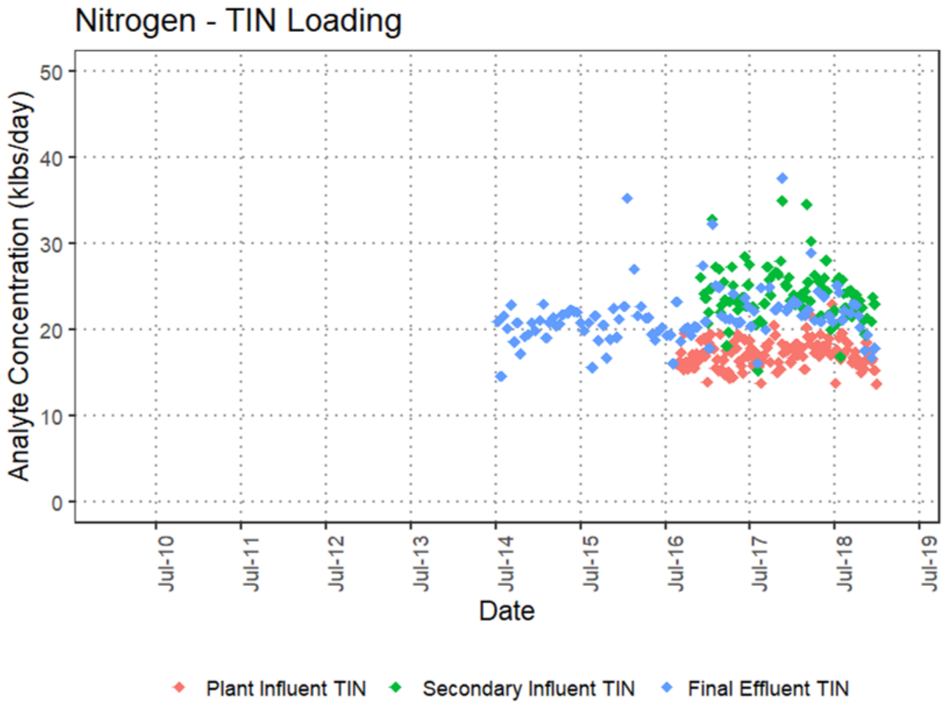

Nitrogen - NH3N Loading
Analyte Concentration (klbs/day)
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent NH3N
Secondary Influent NH3N
Final Effluent NH3N

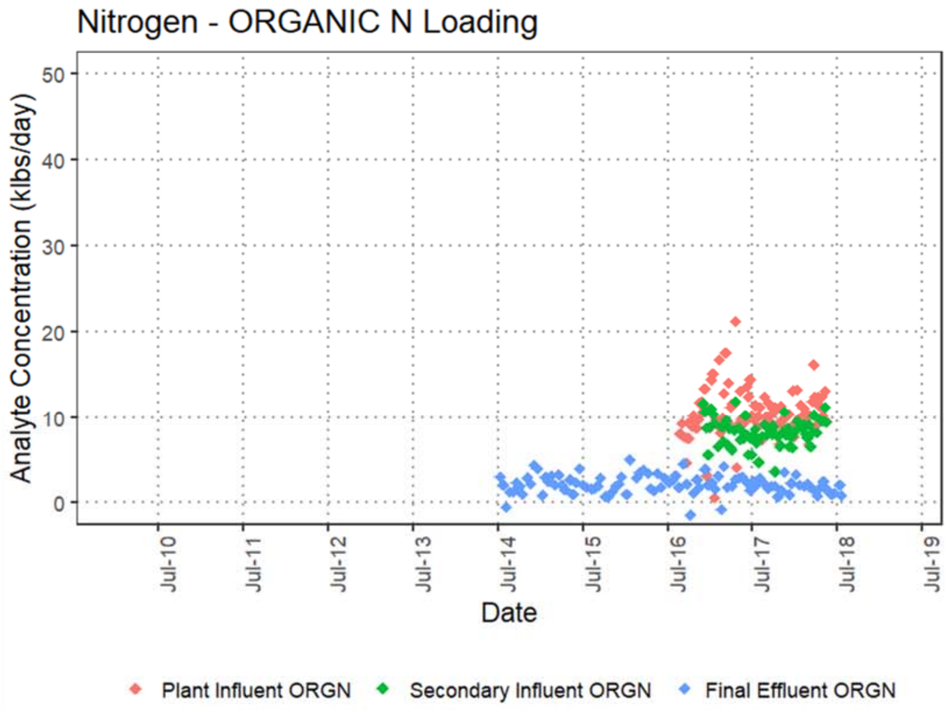

Nitrogen - TKN Loading
Analyte Concentration (klbs/day)
100
75
50
25
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent TKN
Secondary Influent TKN
Final Effluent TKN

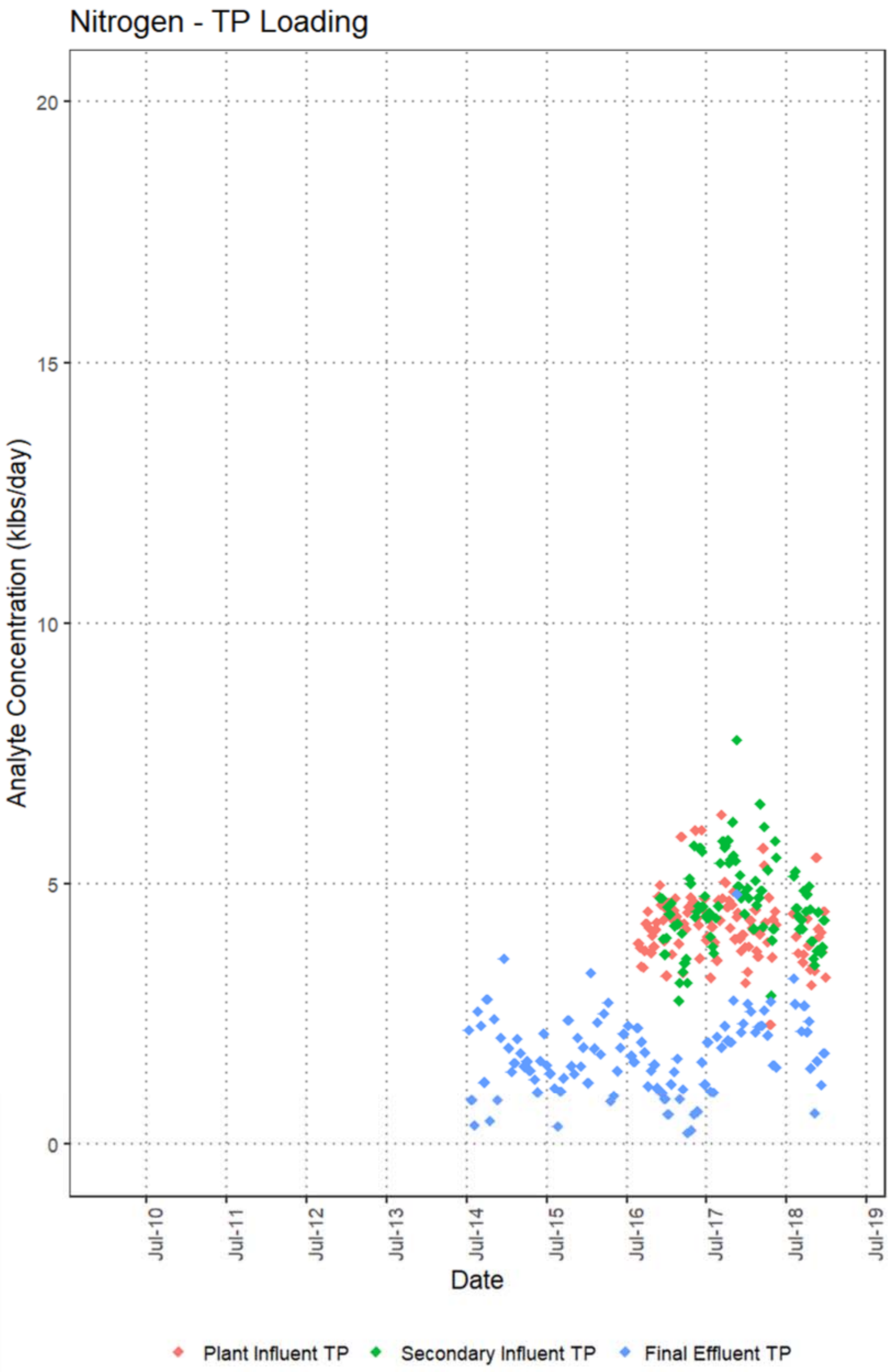

Nitrogen - NO2N Loading
Analyte Concentration (klbs/day)
10.0
7.5
5.0
2.5
0.0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent NO2N
Secondary Influent NO2N
Final Effluent NO2N

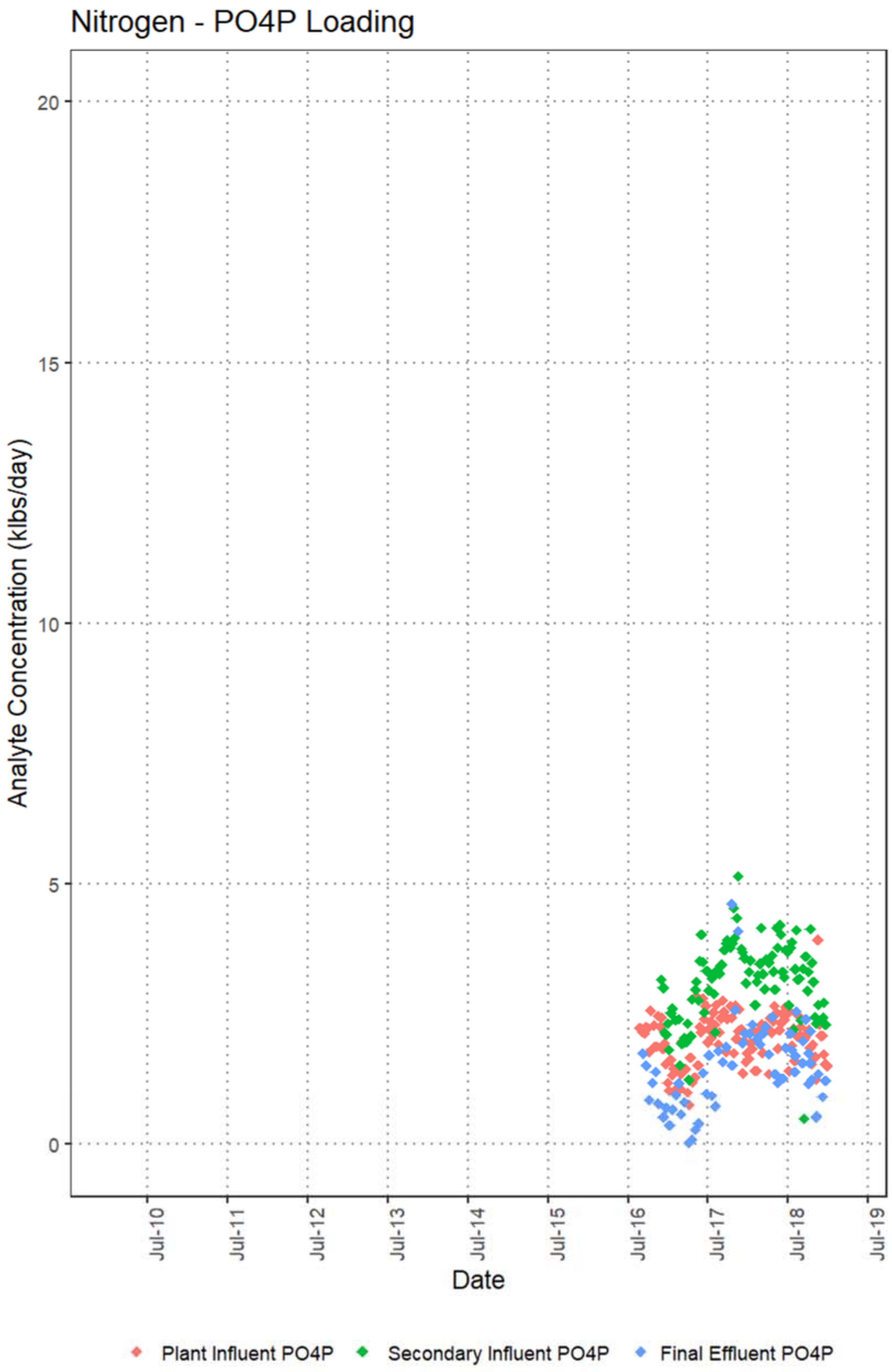

Nitrogen - NO3N Loading
Analyte Concentration (klbs/day)
10.0
7.5
5.0
2.5
0.0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent NO3N
Secondary Influent NO3N
Final Effluent NO3N

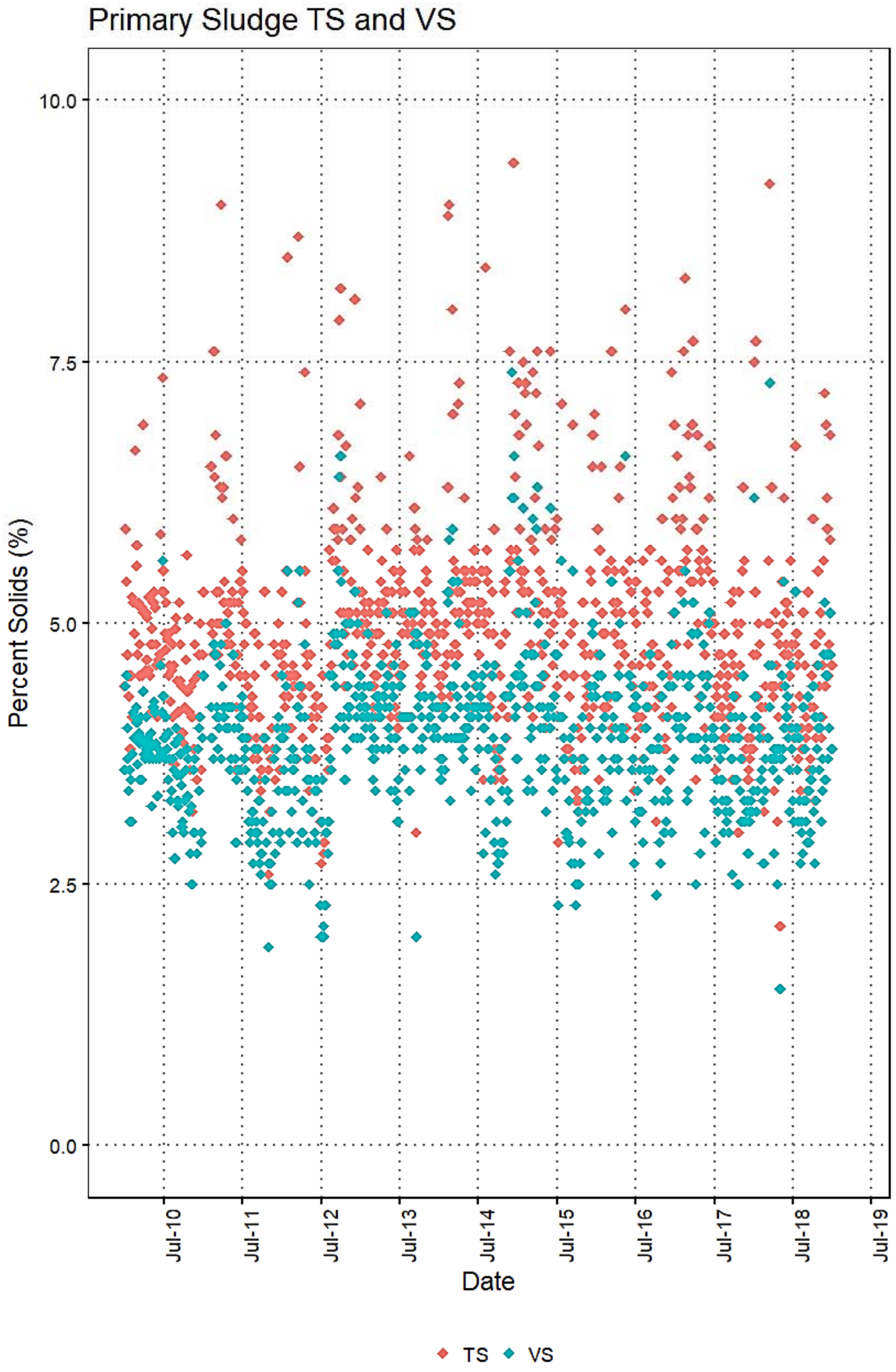

Nitrogen - TN Loading

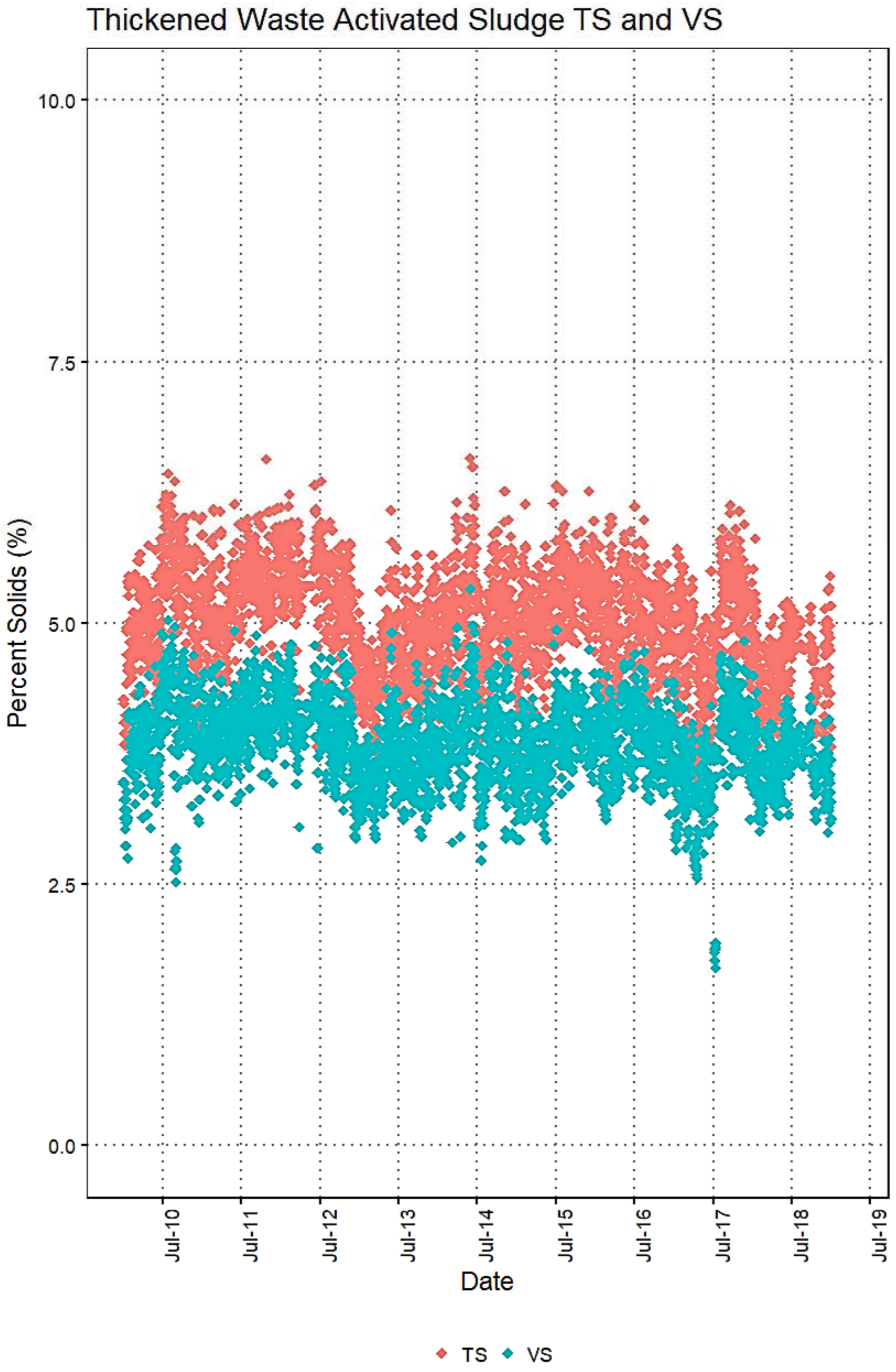

Nitrogen - TIN Loading

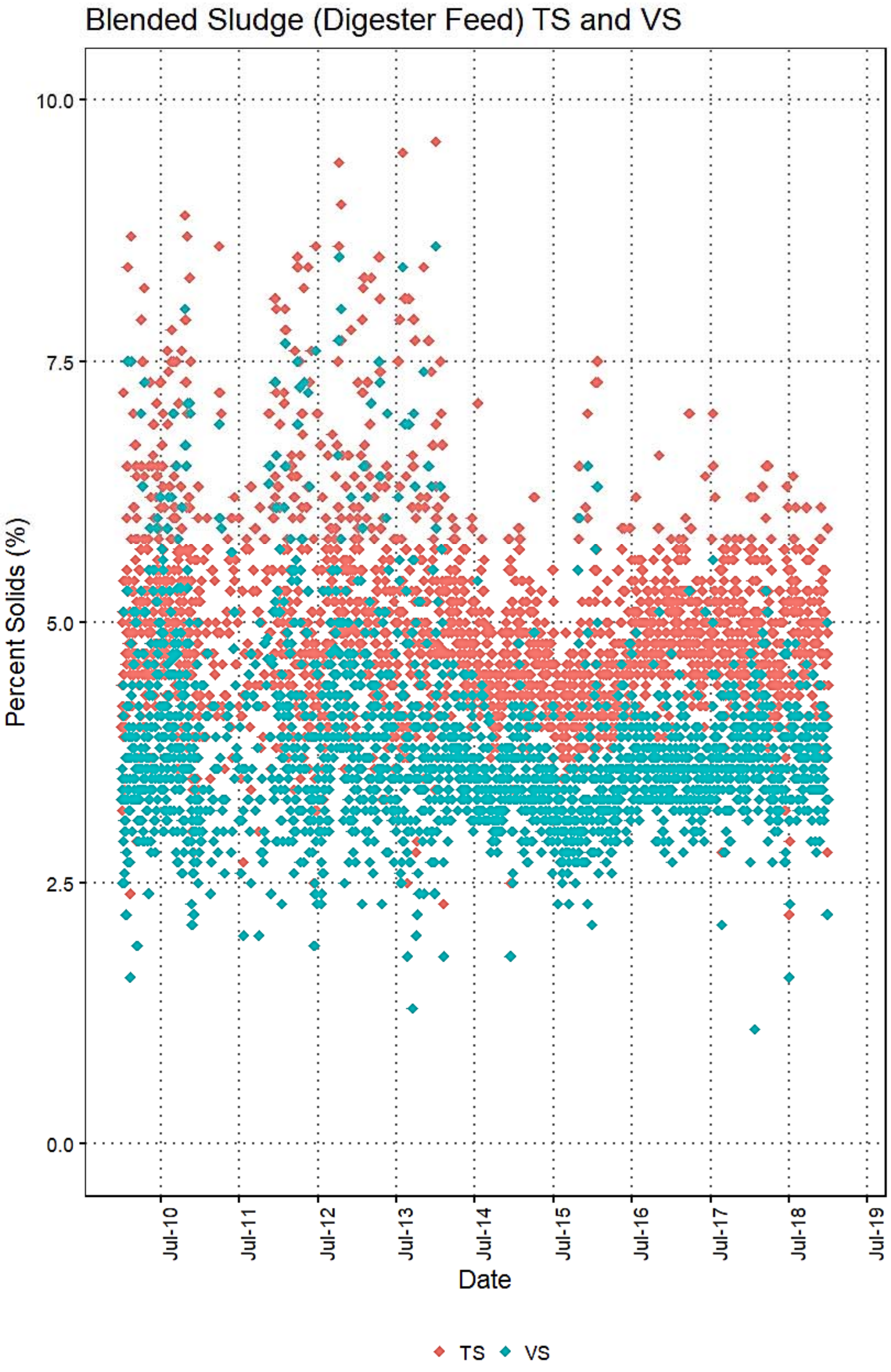

Nitrogen - ORGANIC N Loading

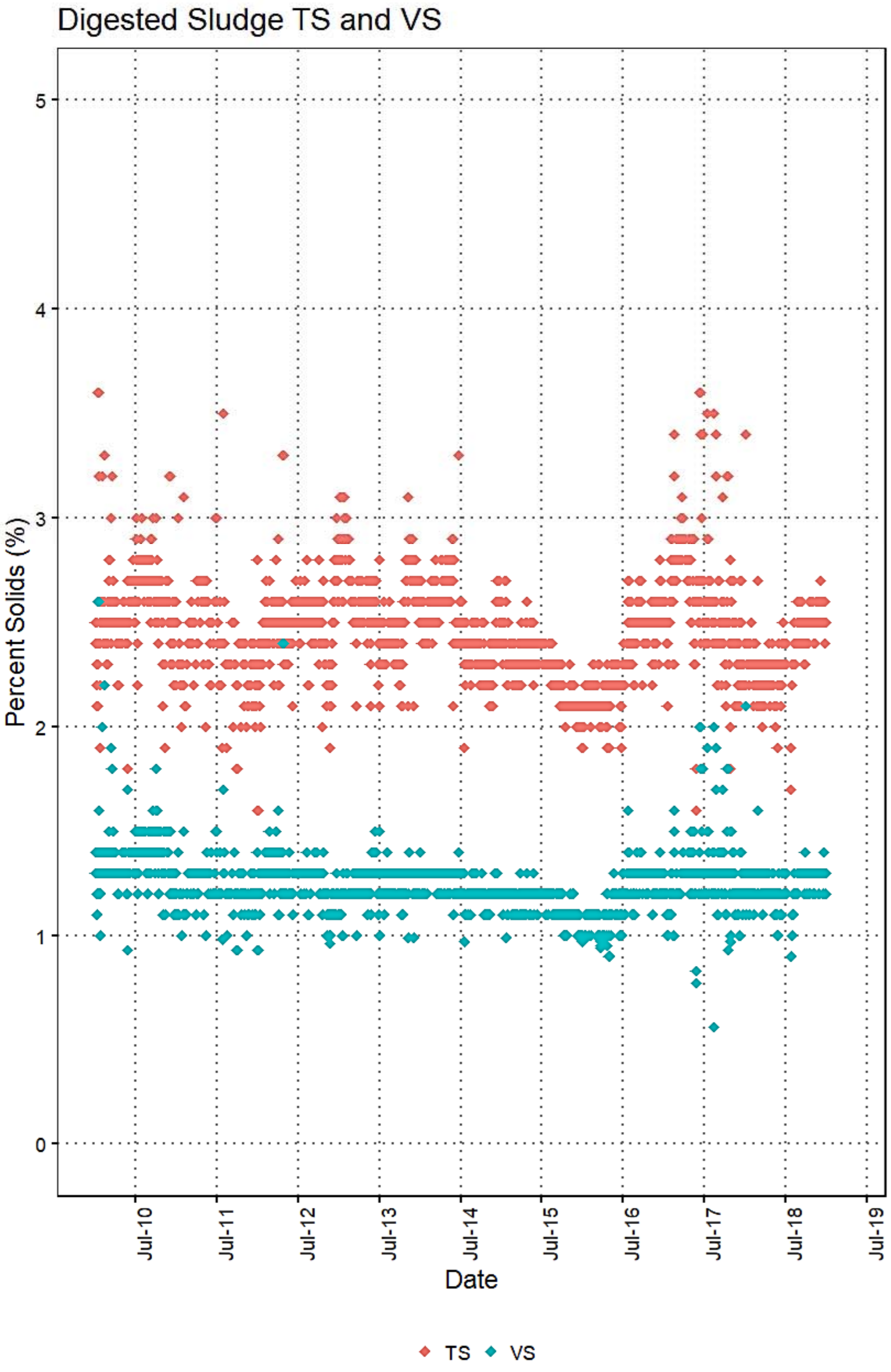

Nitrogen - TP Loading
Analyte Concentration (klbs/day)
20
15
10
5
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent TP
Secondary Influent TP
Final Effluent TP

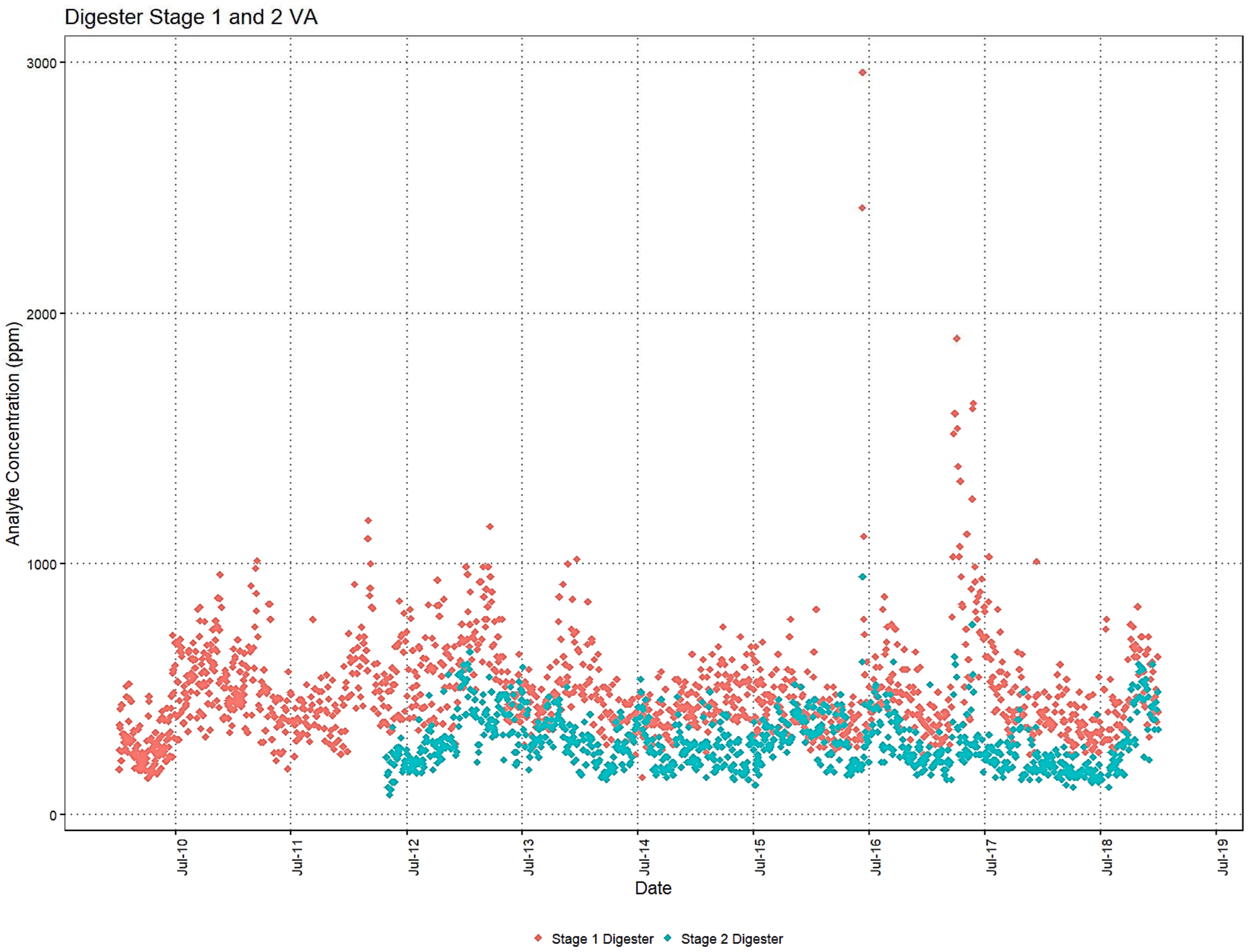

Nitrogen - PO4P Loading
Analyte Concentration (klbs/day)
20
15
10
5
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Plant Influent PO4P
Secondary Influent PO4P
Final Effluent PO4P


Primary Sludge TS and VS

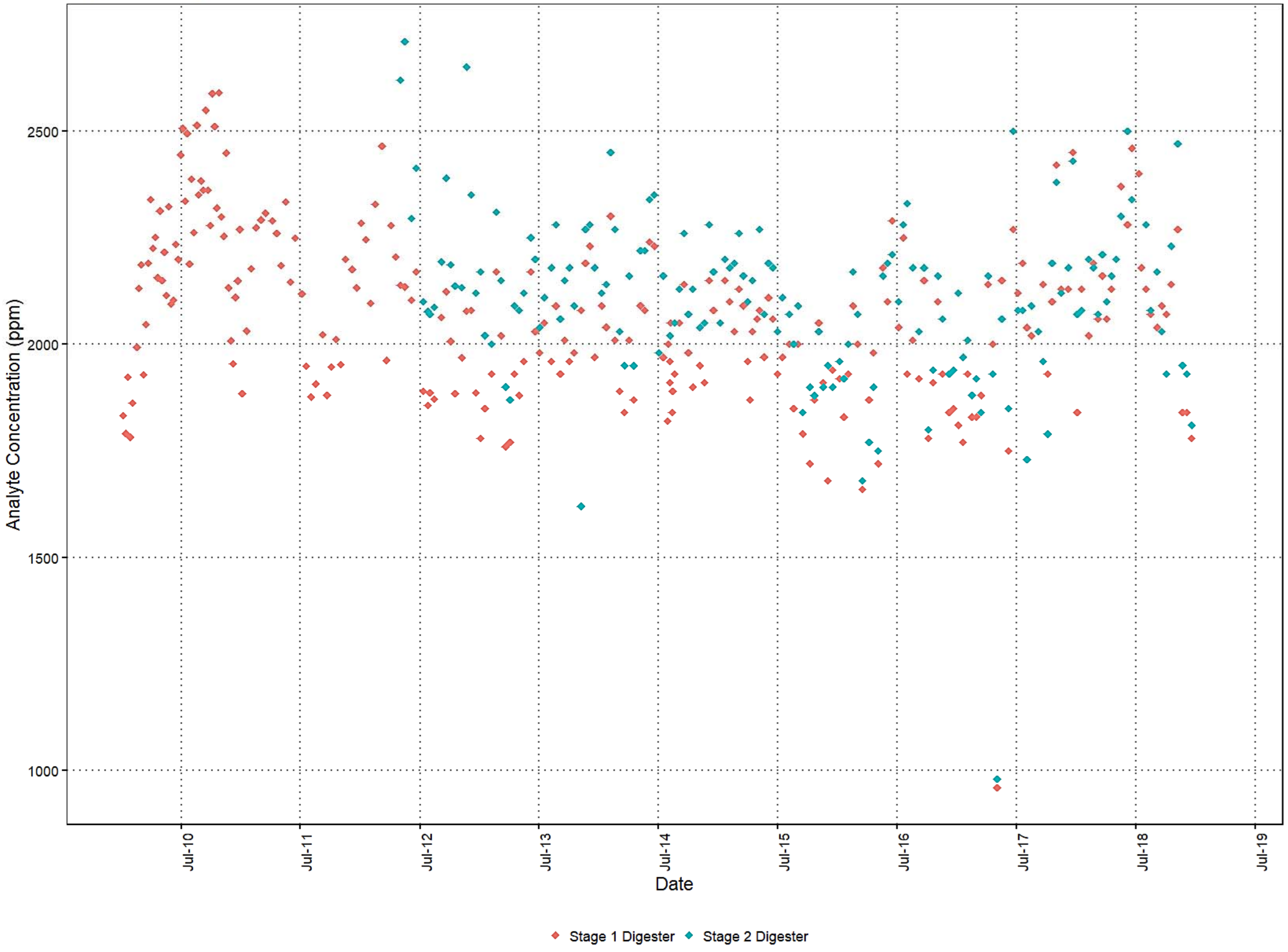

Thickened Waste Activated Sludge TS and VS


Blended Sludge (Digester Feed) TS and VS
Percent Solids (%)
10.0
7.5
5.0
2.5
0.0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
◆ TS ◆ VS

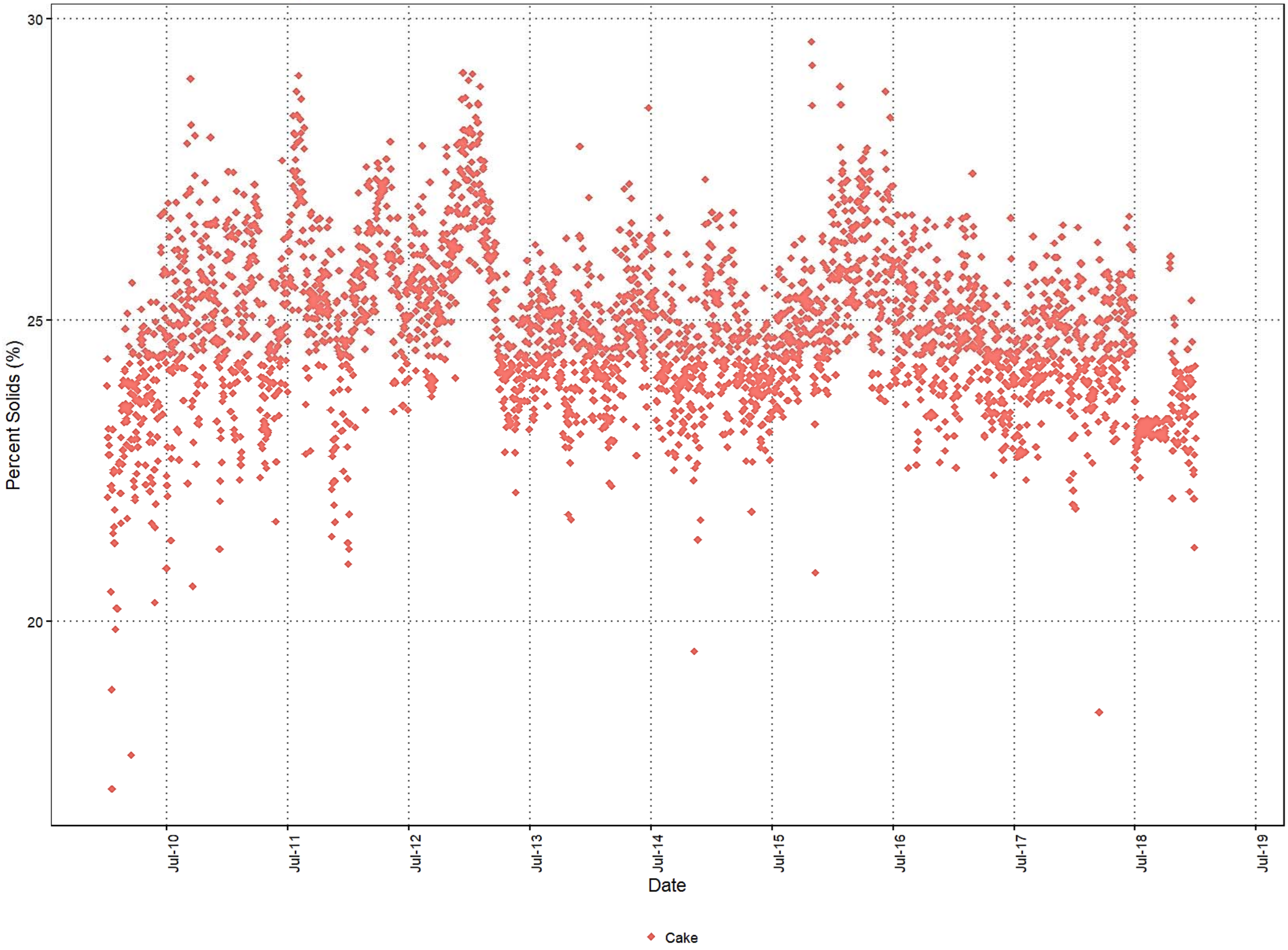

Digested Sludge TS and VS
Percent Solids (%)
5
4
3
2
1
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
◆ TS ◆ VS

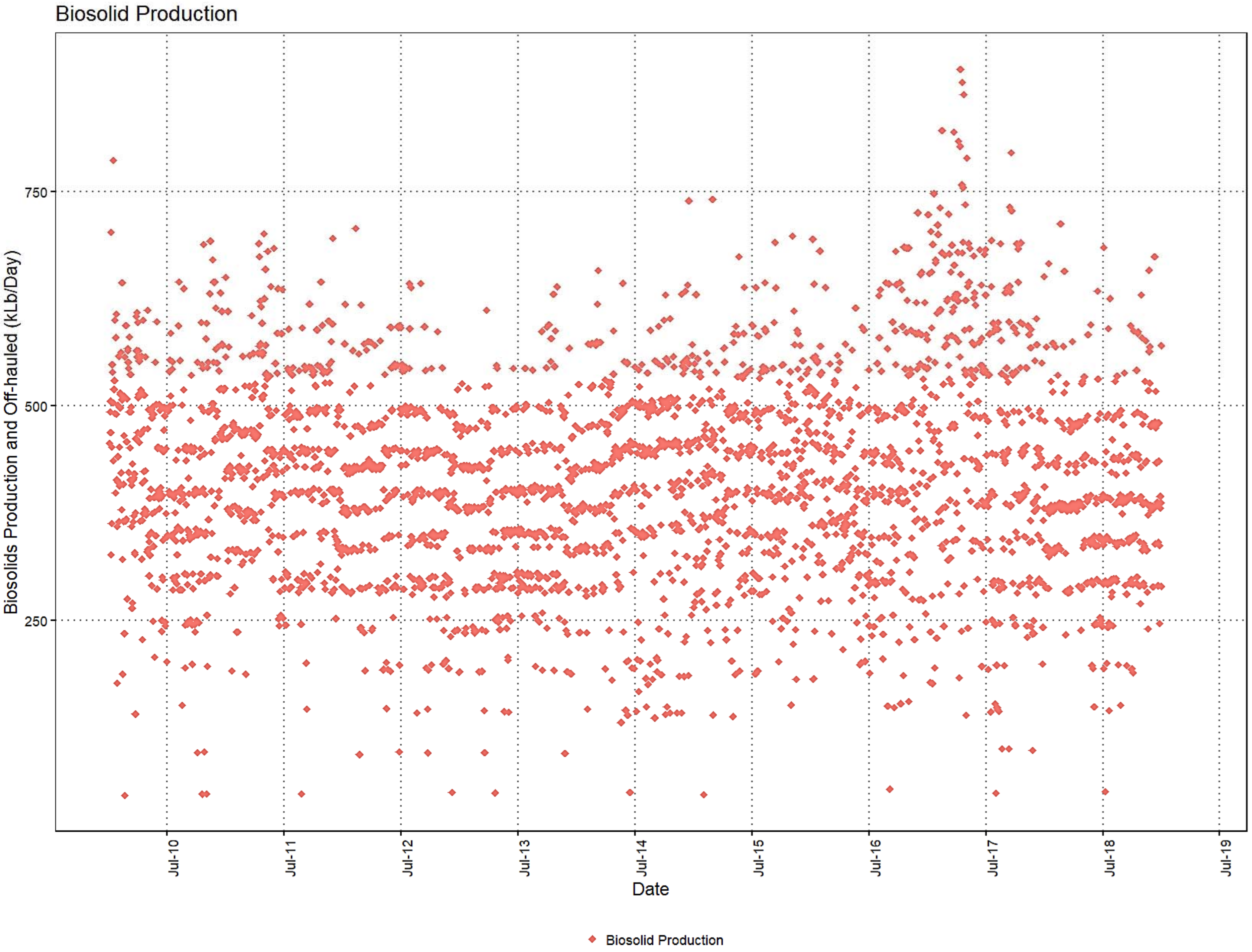

Digester Stage 1 and 2 VA
Analyte Concentration (ppm)
3000
2000
1000
0
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
Stage 1 Digester
Stage 2 Digester

Digester Stage 1 and 2 NH3



Dewatered Sludge (Cake)




Biosolid Production
Biosolids Production and Off-hauled (kLb/Day)
750
500
250
Jul-10
Jul-11
Jul-12
Jul-13
Jul-14
Jul-15
Jul-16
Jul-17
Jul-18
Jul-19
Date
◆ Biosolid Production

EAST BAY MUNICIPAL UTILITY DISTRICT
SPECIAL DISTRICT NO. 1
WASTEWATER DEPARTMENT

Main Wastewater Treatment Plant Load Study 2019

DECEMBER 2019

Prepared By: Syndi Luong (2011)
Checked By: Mike Nakamura (2011)
Approved By: Mike Nakamura (2011)
Updated By: Robert Mac (2019)

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1.0 EXECUTIVE SUMMARY

The purpose of this report is to present the findings from the electrical load study at the Main Wastewater Treatment Plant (MWWTP) as it is presently configured. The MWWTP's overall load has not changed significantly since the previous load studies were conducted. This load study will give Management and Operations an updated analysis of the plant's current load demand to assist in determining the best operation of existing systems as well as planning for future expansion of power systems. This load study will identify and evaluate if there are any issues with the substation transformer and feeder cable sizes.

The last load study conducted at the MWWTP was in 2011, eight years ago. Since the previous study, the overall load for the MWWTP has not changed significantly. Currently, the overall connected load has increased from 30 MVA to 30.4 MVA. The total connected load was gathered from single line diagrams and some random field verifications. Additional field verification is necessary to have accurate record. The following table summarizes the change in the overall connected plant load:

Load Study Year	Connected Load		Change in Connected Load (versus Previous Study)	
	kW	kVA	% kW	% kVA
1991	28,892	29,954	N/A	N/A
1996	24,730	25,689	-14.4	-14.2
2010	27,007	30,008	9.2	16.8
2019	27,287	30,319	1.0	1.0

Table 1 - Plant Connected Load

The following table summarizes the change in the load during the "wet" weather period. The maximum demand loads for 1991, 1996, and 2011 were gathered from the previous load study reports. The maximum demand load for 2019 was gathered from the DCS PI system.

Load Study Year	Wet Weather Maximum Demand Load		Change in Wet Weather Maximum Demand Load (versus Previous Study)	
	kW	kVA	% kW	% kVA
1991	24,805	25,477	N/A	N/A
1996	21,055	21,640	-15.1	-15.1
2010	9,615	12,019	-54.3	-44.5
2019	10,647	13,309	10.7	10.7

Table 2 - "Wet" Weather Power Demand[1]

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[1] See Appendix B – Table 9 for date in which maximum demand load occurred.

The following table summarizes the change in the load during the “dry” weather period. The maximum demand loads for 1991, 1996, and 2010 were gathered from the previous load study reports. The maximum demand load for 2019 was gathered from the DCS PI system.

Load Study Year	Dry Weather Maximum Demand Load		Change in Dry Weather Maximum Demand Load (versus Previous Study)	
	kW	kVA	% kW	% kVA
1991	24,805	25,477	N/A	N/A
1996	21,055	21,640	-15.1	-15.1
2010	5,999	7,499	-71.5	-65.3
2019	7,534	9,418	25.6	25.6

Table 3 - "Dry" Weather Power Demand[2]

Changes in the connected and demand loads can be attributed to:

- Demand factor discrepancies: In the load studies conducted in 1991 and 1996, the consultants used a demand factor of 0.90 for majority of the loads. Typical demand factor for the plant is around 0.60.
- Summary of loads included redundant loads: The load studies conducted in 1991 and 1996 included redundant process loads in the demand load. Typical demand load does not include redundant or standby loads in total demand load calculation.
- Plant Improvements: Over the past several years, the plant has made improvements in energy efficient processes and lighting which led to a lower connected load.
- Connected load modifications since 1996: The following projects altered the total connected load in the plant: SD 260 – Grit Improvements; SD 261 – Process Water Plant Demolition; SD 262 – East Bayshore Recycled Water; SD 271A – Solid/Liquid Waste Receiving Station; SD 288 – Centrifuge Addition; SD-316 Centrifuge Replacement.
- Connected load modifications since 2011: The following projects altered the total connected load in the plant: SD 316 – Centrifuge Replacement Phase 1; SD 317A – PGS Renewable Energy Expansion; SD 319 – Digester Upgrade Phase 2; SD 356 – Digester Upgrades Phase 3; SD 408 – MWWTP Solid Liquid Waste Tank 4 & 5 Recoating.

According to the DCS PI data since 2004 the maximum plant influent flow was 377 MGD on January 4, 2008 and the maximum power demand was 9.6 MW on December 28, 2010. The substation transformers and individual feeder cable sizes were found to meet maximum “wet” weather power demand.

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[2] See Appendix B – Table 9 for date in which maximum demand load occurred.

Based on the current maximum demand values from the fifteen years, all the substation transformers and cable feeders are sized adequately for the necessary load. This load study did not find any deficiencies which require corrective action. As the MWWTP power demand continues to grow, a similar load study will be conducted every five years to document the total plant demand load.

2.0 INTRODUCTION

2.1 Objective

The objective of this study is to provide an updated analysis of the electrical loads at the MWWTP. As part of this study, the following tasks were performed:

- Updated and evaluated power system loads at the 4,160 Volts level.
- Measured and recorded the main switchgear M1 circuit breaker feeders to determine "wet" and "dry" operational loads for the facility.
- Updated and documented the "wet" and "dry" weather plant loads for each feeder.
- Evaluated each substation transformer's sizing in comparison to the maximum demand load within the fifteen years period.
- Evaluated each feeder's cable sizing in comparison to the maximum demand load within the fifteen years period.
- Provided recommendations to improve the electrical distribution performance and correct any deficiencies found in this study.

2.2 Background

Previously, there were three load studies conducted at the MWWTP. The first load study performed at the MWWTP was completed December 1991. In that study, a load shed system was presented as a solution to the plant's inadequate power supply to meet the operating requirements during the wet weather. The second study performed at the MWWTP was completed October 1996. In that study, an analysis was completed on the MWWTP's overall power load and substation transformer sizing. The third study performed at the MWWTP was completed June 2011. In that study, an updated analysis of the electrical loads at the MWWTP was provided. PGS Expansion project (SD317A) and a few others CIP projects with electrical loads added to the plant are also included in the analysis.

This current load study will provide an updated analysis of the electrical loads at the MWWTP. All CIP projects with constructions from 2011 to 2019 are also updated and taken into account in this study.

2.3 Data Collection

Data collection for this study was based primarily on data gathered from two sources:

- DCS PI-Data Link historical data values for each M1 feeder
- Permanently installed Power Quality Meter (PQM) measured values from each M1 feeder.

Temporary power data logger to measure values for the following substation transformers (U4, U5, U12, U14, U15, U16, U22, and Maintenance Bldg) are not being performed in this study. Because there are no CIP projects work that make significant changes the loads to above substation transformers, this updated study uses the same data loggers collected data from the last study.

The majority of the M1 feeders continue to power only one substation transformer; therefore, the DCS PI historical data and the PQM measured data provide acceptable data for the historical load of the substation transformer. A feeder power more than one substation transformer, such as U4/U5/U12/U16, which previously required the installation of a temporary power recorder to measure the incoming load at each individual substation transformer to capture the necessary load data will not be required. The “Power Meter Replacement” project currently in construction will provide meters with power logging data functions that will eliminate the need to rent the loggers in the future studies.

2.4 Approach

The approach of the load study is to periodically update and evaluate the historical and present trends of each M1 feeder. The collected historical data from the DCS PI system started on January of 2004 and continued to May of 2019 (a fifteen years period). Measured data from a combination of sources, such as DCS PI system and PQMs were used in this study.

The evaluation of the substation transformer and cable feeder sizes were based on the plant’s maximum and average power demand data. Both the substation transformers and cable feeders are required to be sized adequately to handle the maximum demand. Since the date and time of maximum demand value for each of the M1 circuit breakers occurred at different time, the following analysis is based on each feeder’s maximum demand load from the past fifteen years.

The “wet” weather season was evaluated from October 1 to April 14. The “dry” weather season was evaluated from April 15 to September 30. In Table 3, the “dry” weather maximum demand value was evaluated during the months June, July, and August instead of the months noted earlier (April 15 to October 14). Detail studies of the historical power demand indicated that in the months of April and May, there has been heavy rain which skewed the “dry” demand load toward a higher value. To provide a more accurate assessment of the true “dry” weather, the “dry” weather maximum period demand was limited to the three months.

There are several occasions throughout the fifteen-year period where the DCS PI system did not display any data for any point for a specific time frame. The effect of this lack of data leads to insufficient data for various circuit breaker feeders. Unfortunately, those data are lost and cannot be retrieved. For a list of documented dates and time when PI system did not display any data, see Appendix A.

3.0 HISTORICAL POWER USAGE GRAPHS

The following graphs show the plant's influent flow throughout the last fifteen years based on the average daily value. The graphs provide an overview for a span of fifteen years period for planning and record purposes.

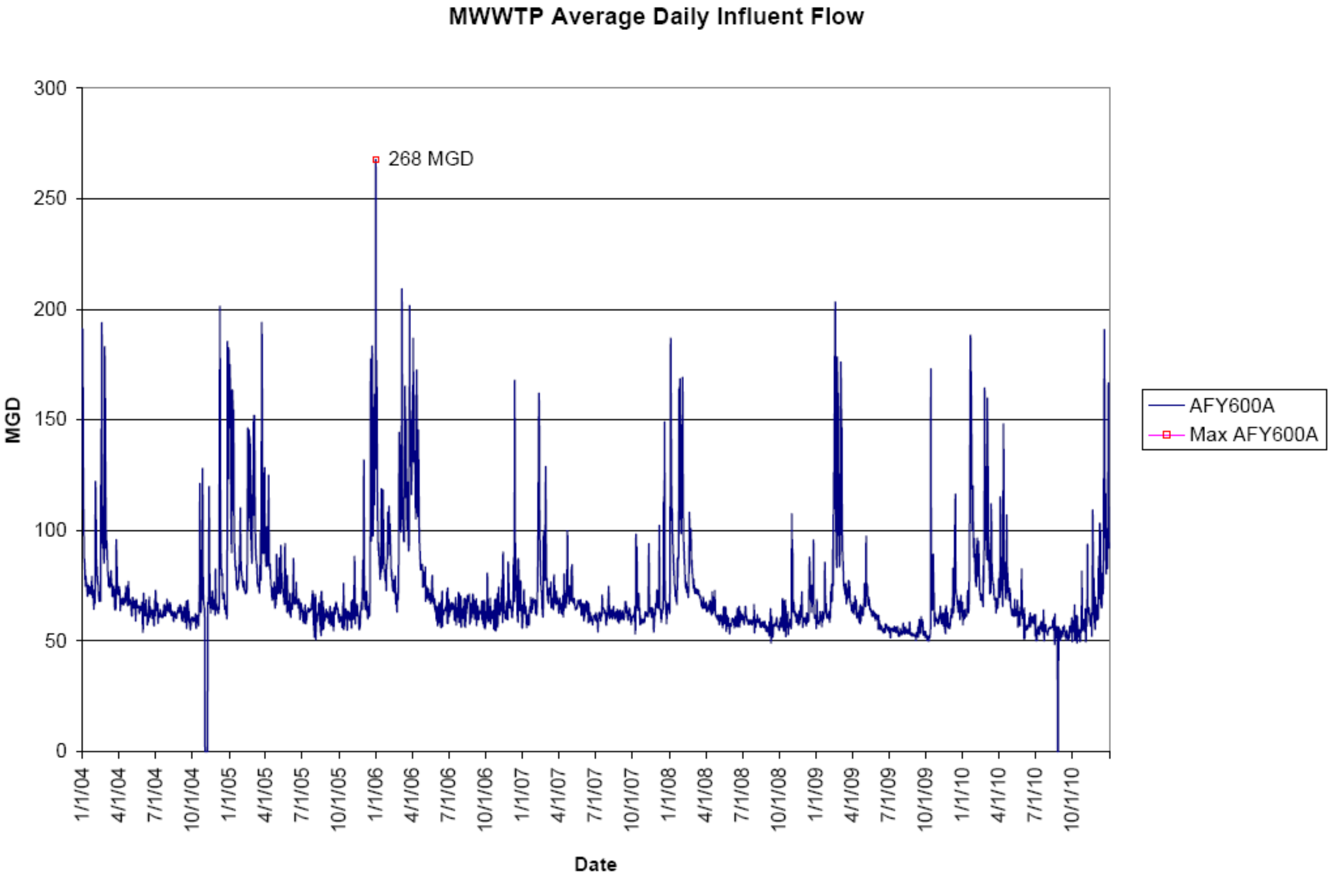

Figure 1 - MWWTP Average Daily Influent Flow[3]

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[3] See Appendix A for explanation on zero values.

The following graphs show the plant's power demand load throughout the last fifteen years based on the average daily value:

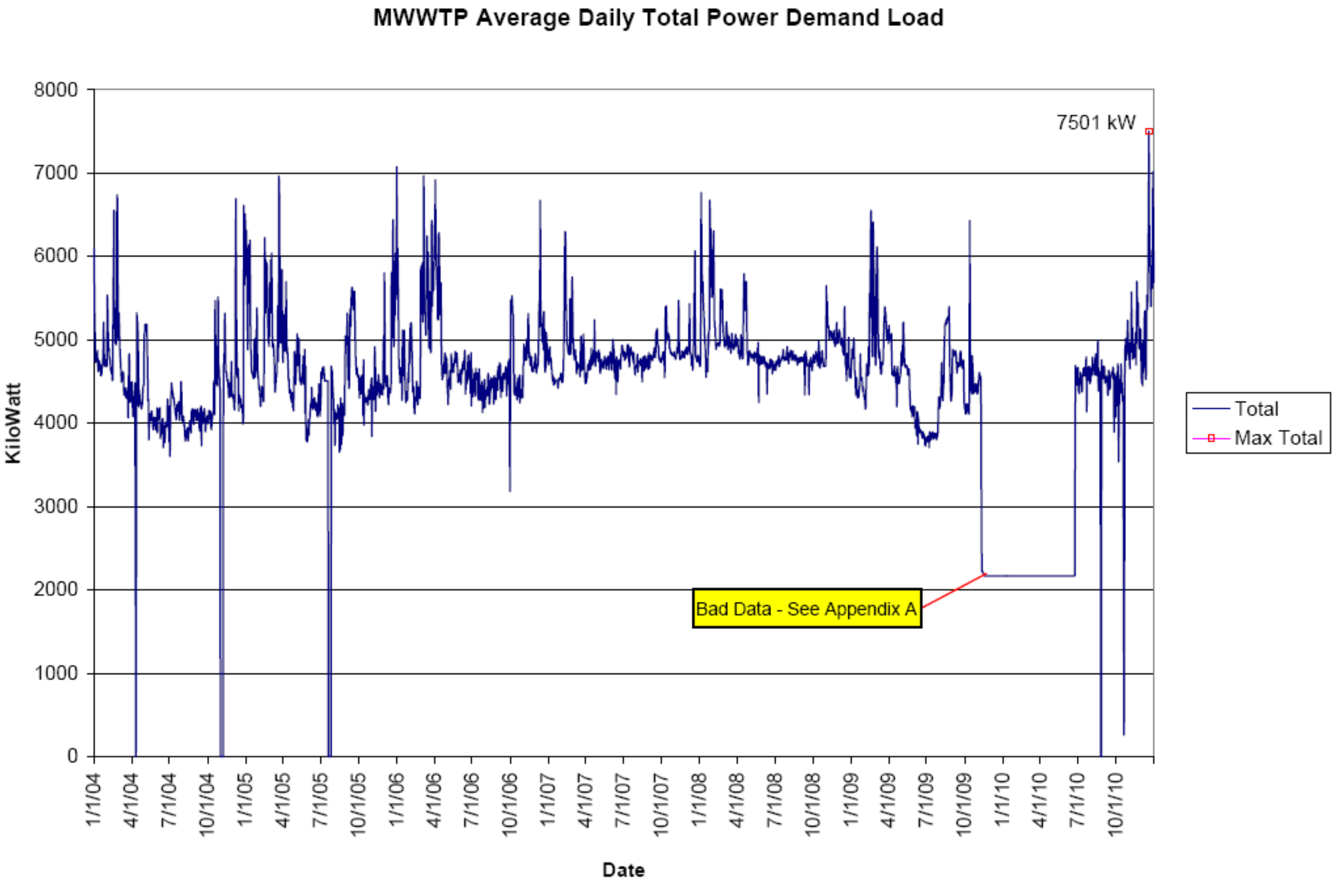

Figure 2 - MWWTP Average Daily Total Power Demand Load[4]

Based on the daily values, on December 31, 2005, the plant reached a maximum flow of 268 MGD. On that same day, the plant reached an overall power demand of 7.1 MW. On December 15, 2014, the plant reached a maximum power demand of 8.3 MW and an overall plant influent flow of 186 MGD.

Based on 15-minute averages, over the past fifteen years, the maximum flow was 377 MGD on January 4, 2008, while the power demand load for the plant on the same day was 9.4 MW. On December 11, 2014, the maximum power demand was 10.65 MW on while the plant influent reached 308 MGD. The follow pages show the graph for the day where the maximum flow and power demand was observed.

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[4] See Appendix A for explanation on zero values.

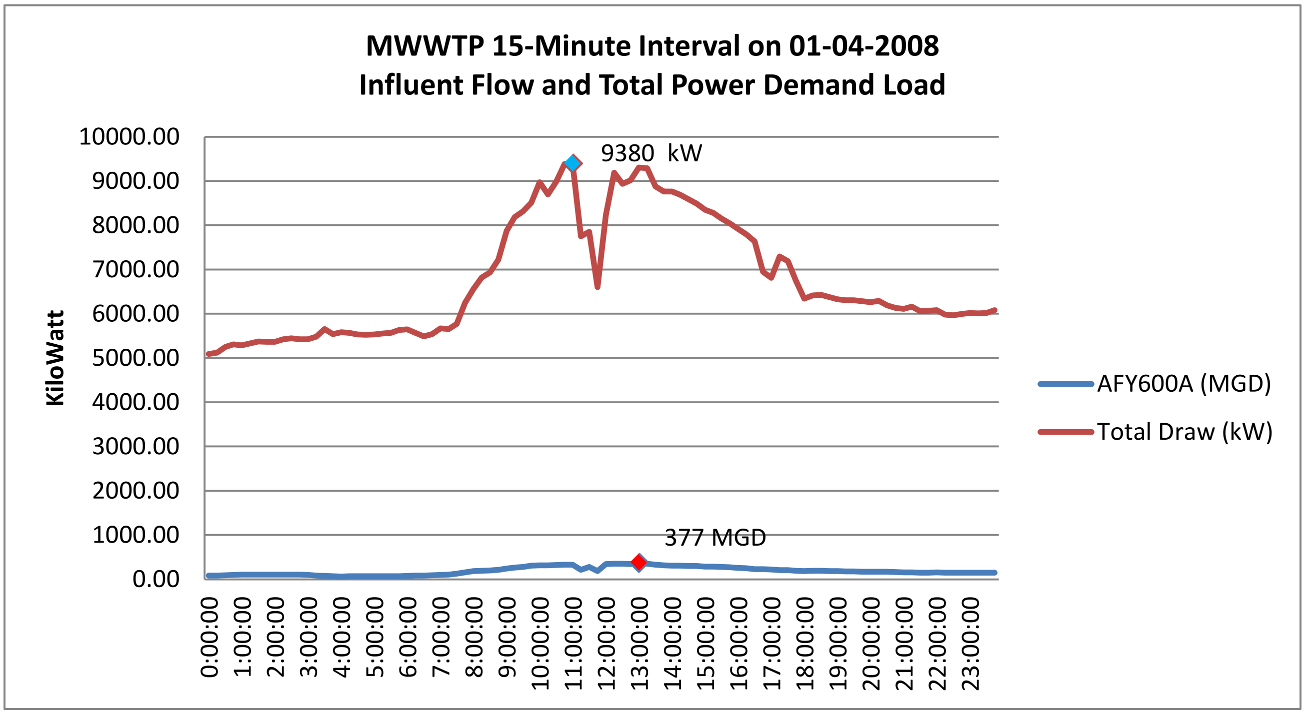

Figure 3 - MWWTP 15-Minute Interval on January 4, 2008 - Influent Flow and Total Power Demand Load

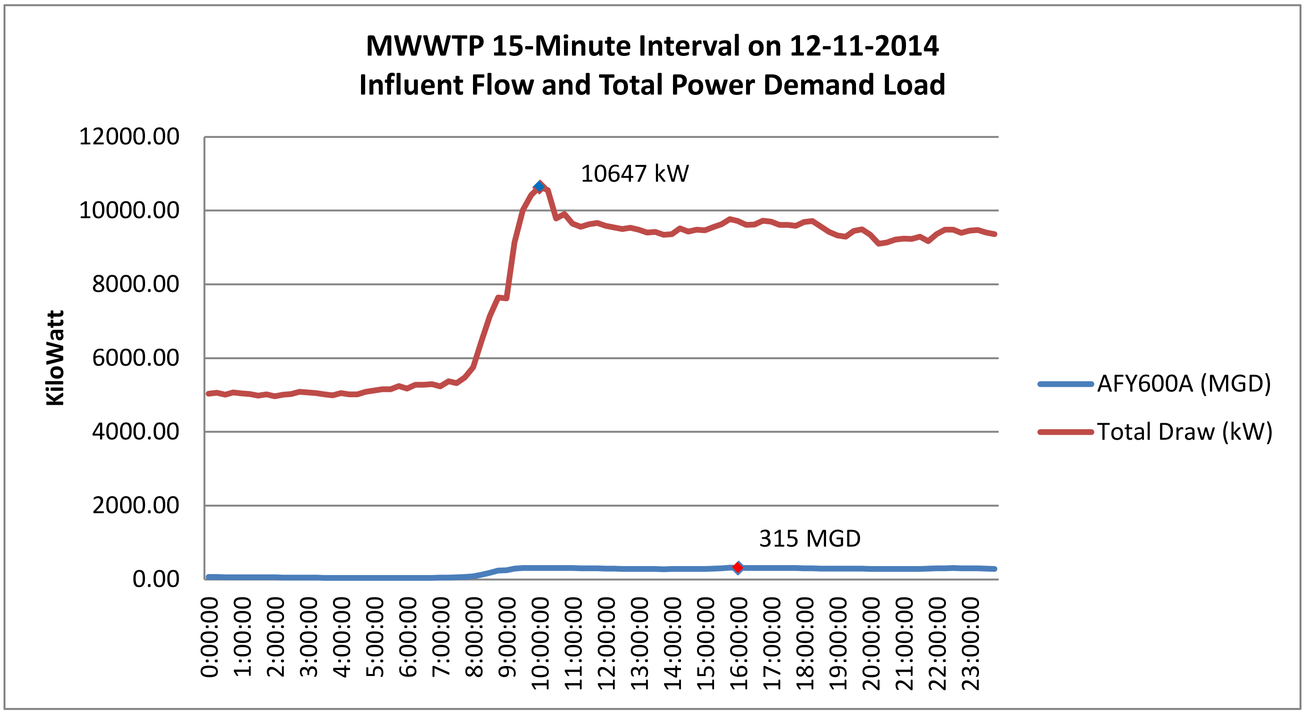

Figure 4 - MWWTP 15-Minute Interval on December 11, 2014 - Influent Flow and Total Power Demand Load

The following graphs show a detail analysis of the power demand for each feeder breaker and substation transformer for the “dry” and “wet” weather data logging period. The installed power data loggers provided measured real-time data that was used in the substation transformer graphs. The PQMs provided measured real-time data that was used in the feeder breaker graphs. DCS PI system was used for several feeder breakers where PQM data was unavailable.

3.1 "Dry" Weather Graphs

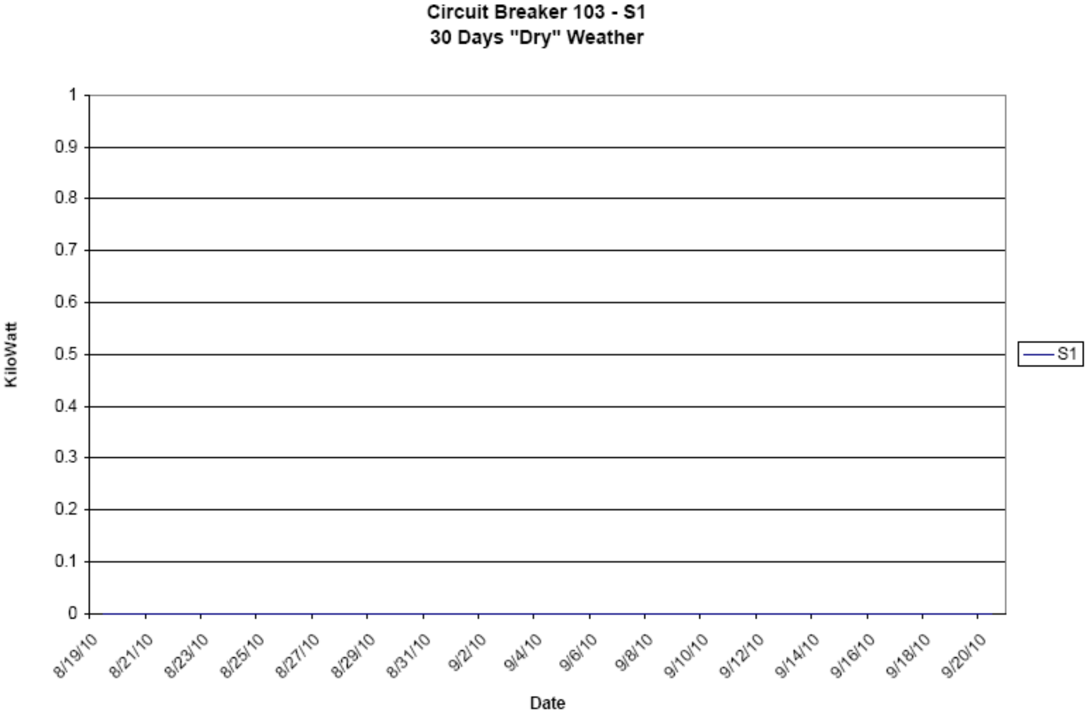

Figure 5 - Circuit Breaker 103 - S1 (Based on 15-Minute Power Demand – Dry Weather)

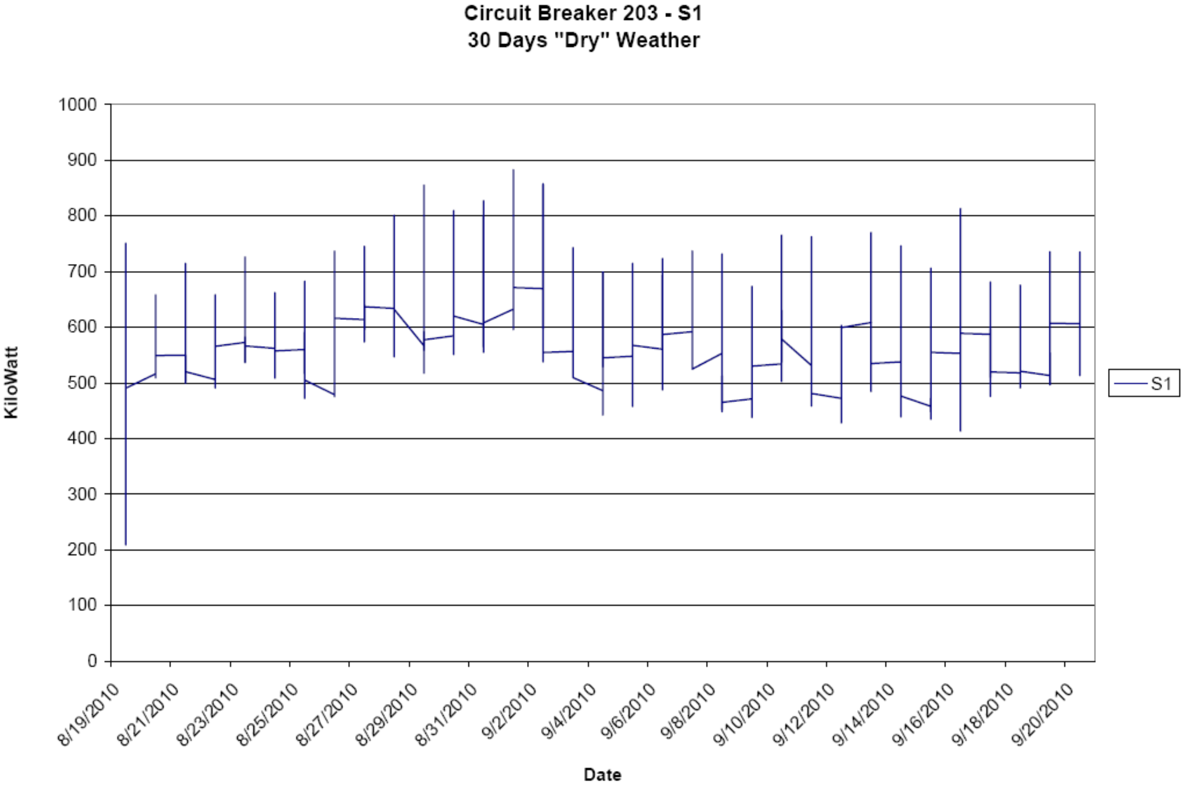

Figure 6 - Circuit Breaker 203 - S1 (Based on 15-Minute Power Demand – Dry Weather)

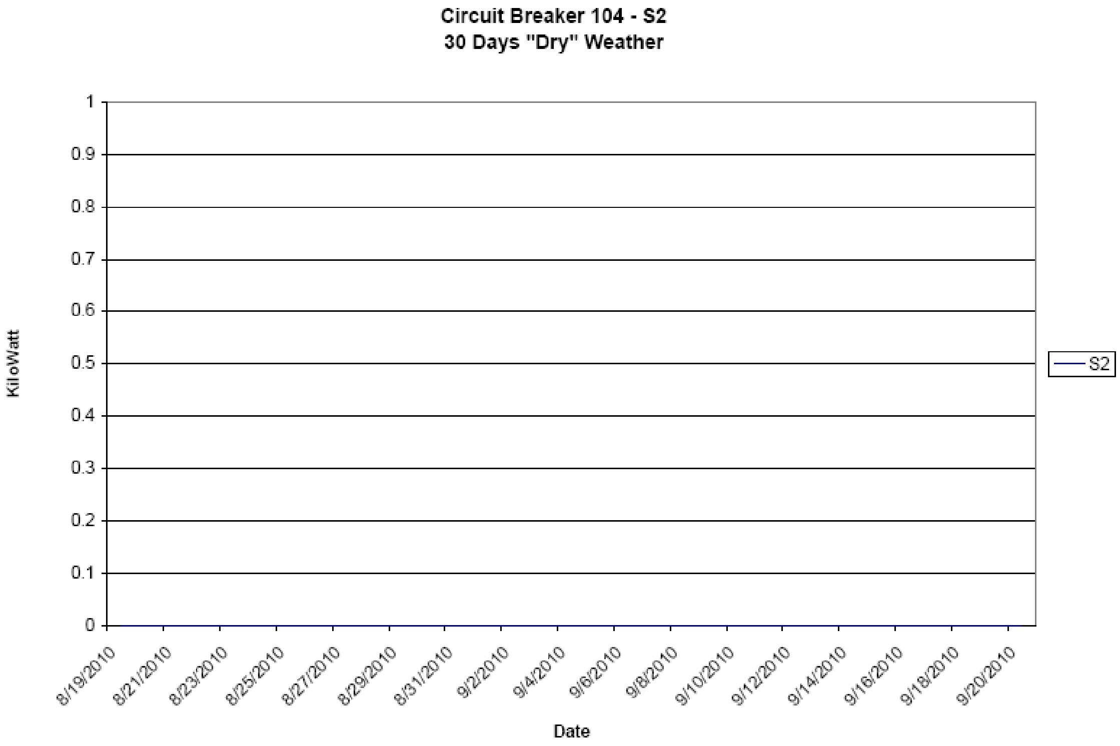

Figure 7 - Circuit Breaker 104 - S2 (Based on 15-Minute Power Demand – Dry Weather)

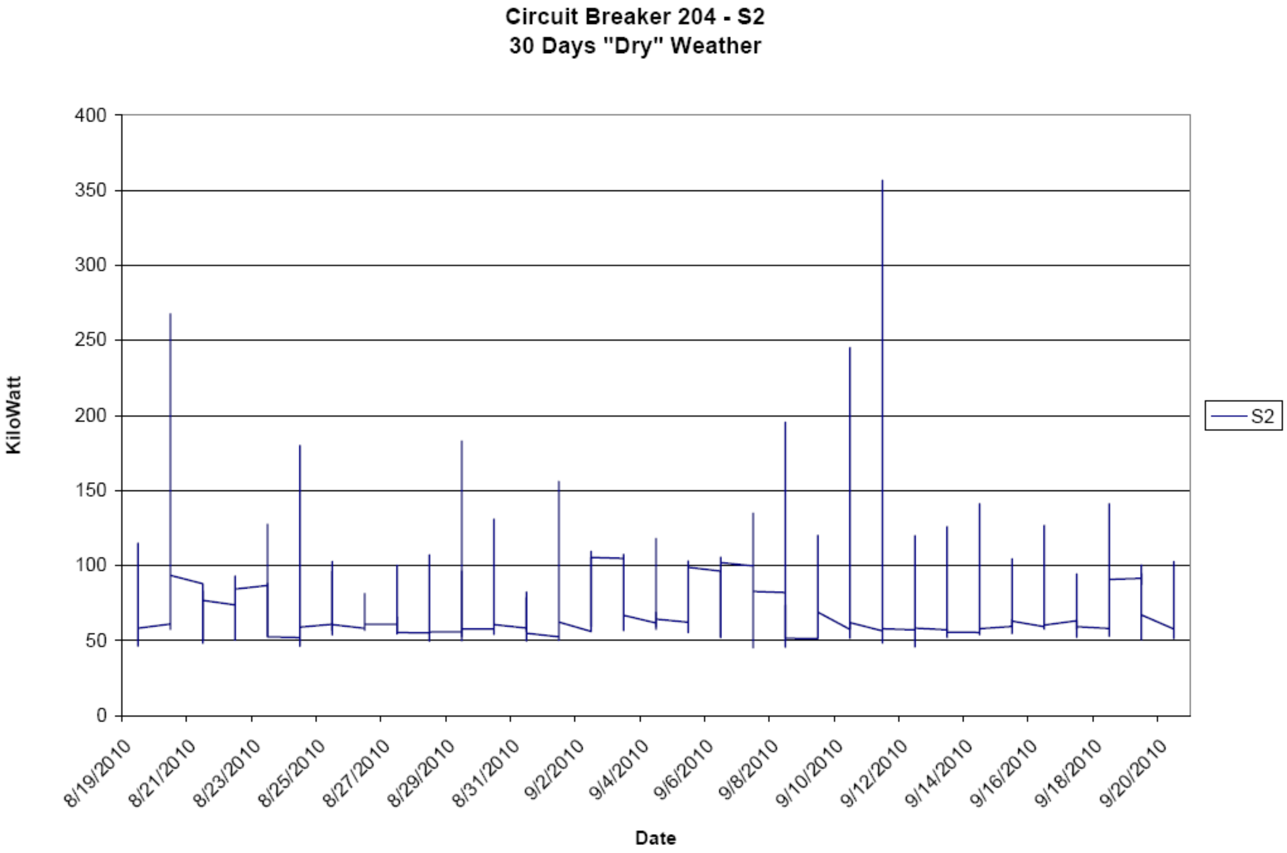

Figure 8 - Circuit Breaker 204 - S2 (Based on 15-Minute Power Demand – Dry Weather)

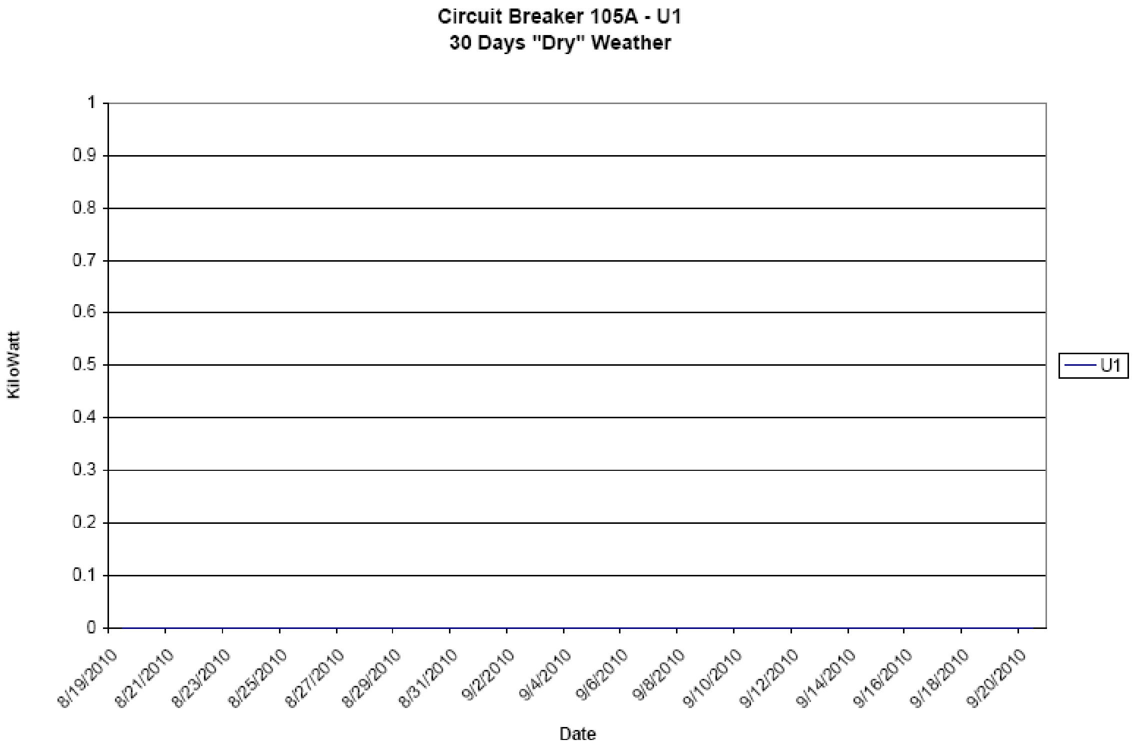

Figure 9 - Circuit Breaker 105A - U1 (Based on 15-Minute Power Demand – Dry Weather)

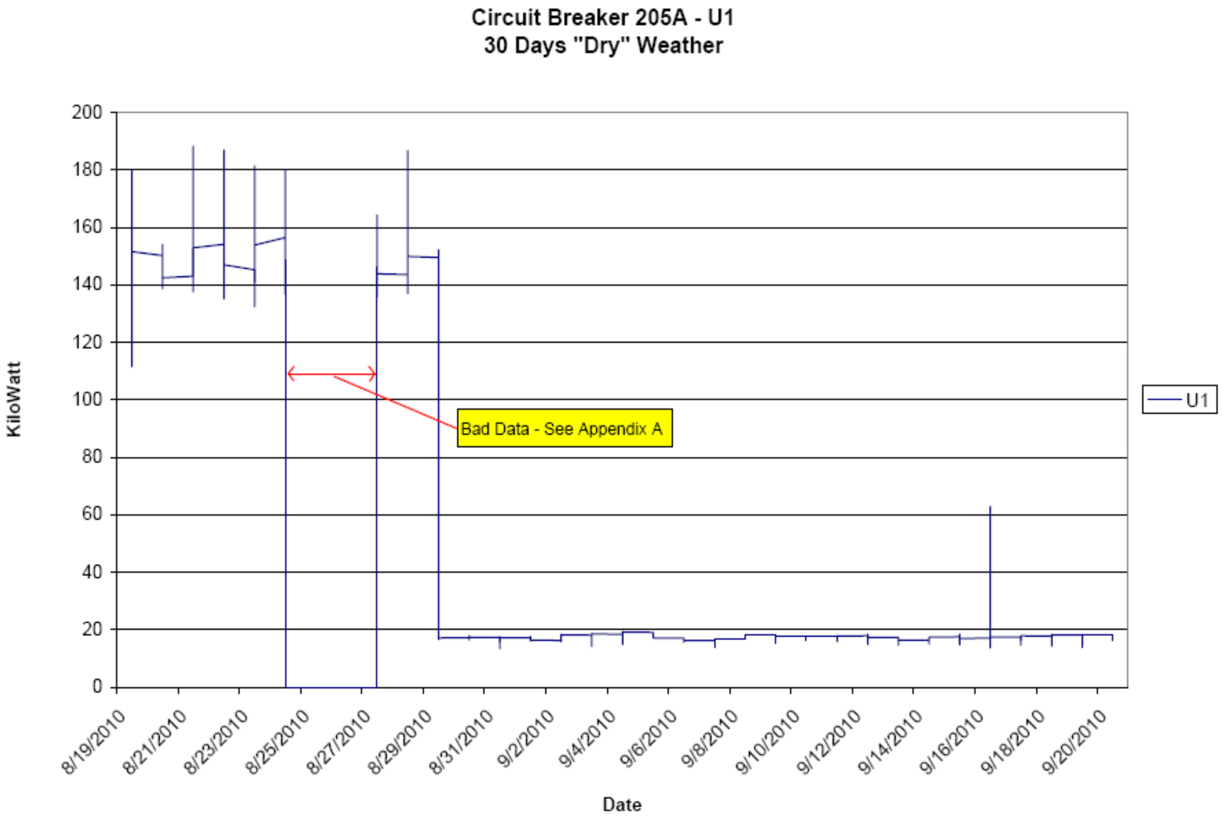

Figure 10 - Circuit Breaker 205A - U1 (Based on 15-Minute Power Demand – Dry Weather)

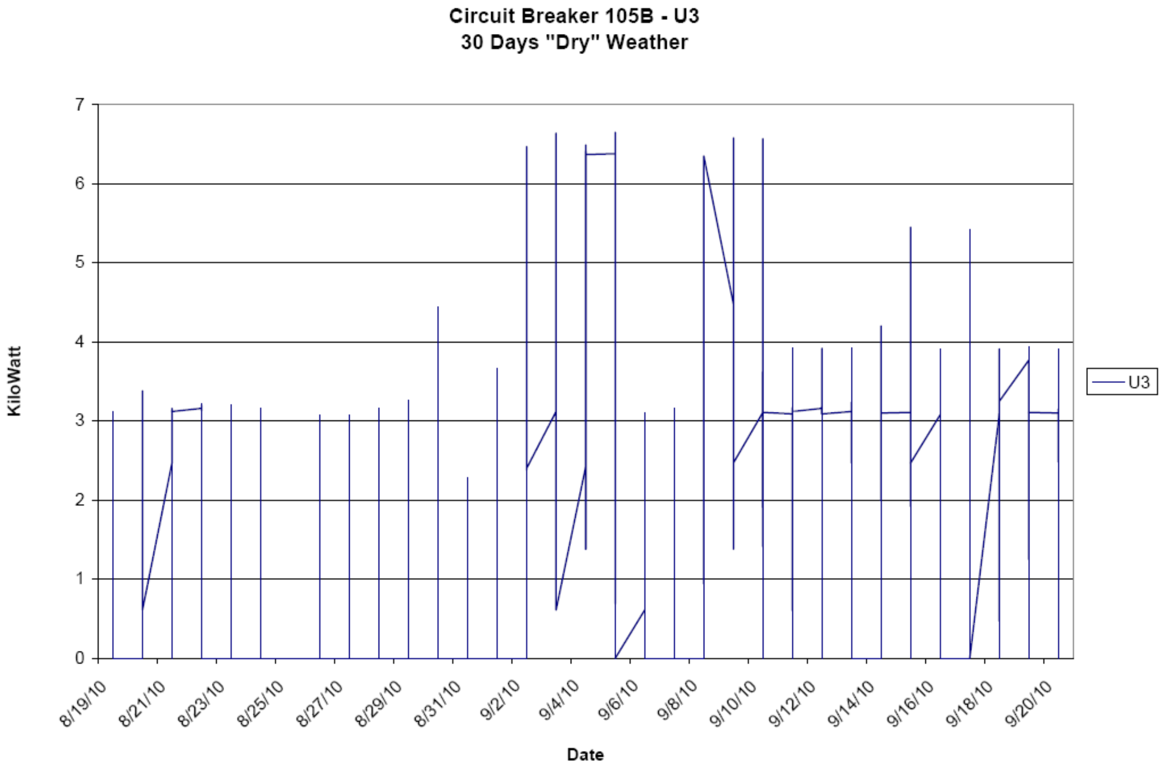

Figure 11 - Circuit Breaker 105B - U3 (Based on 15-Minute Power Demand – Dry Weather)

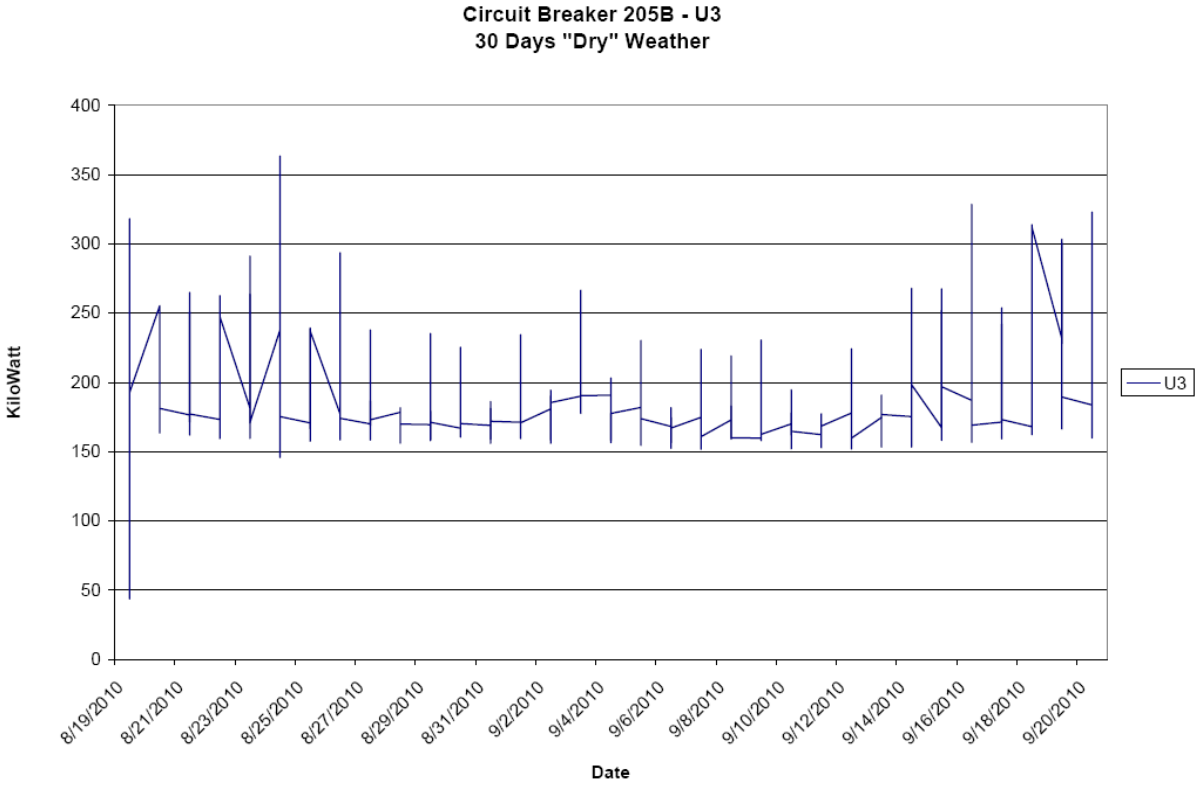

Figure 12 - Circuit Breaker 205B - U3 (Based on 15-Minute Power Demand – Dry Weather)

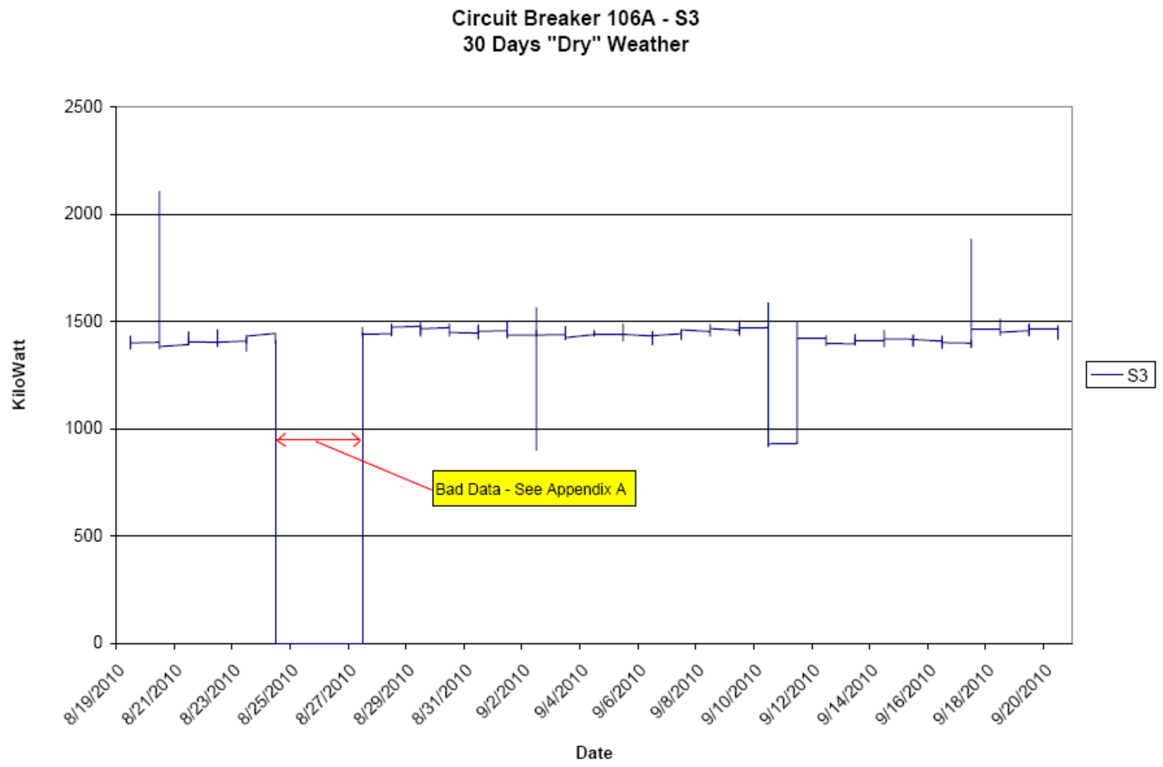

Figure 13 - Circuit Breaker 106A - S3 (Based on 15-Minute Power Demand – Dry Weather)

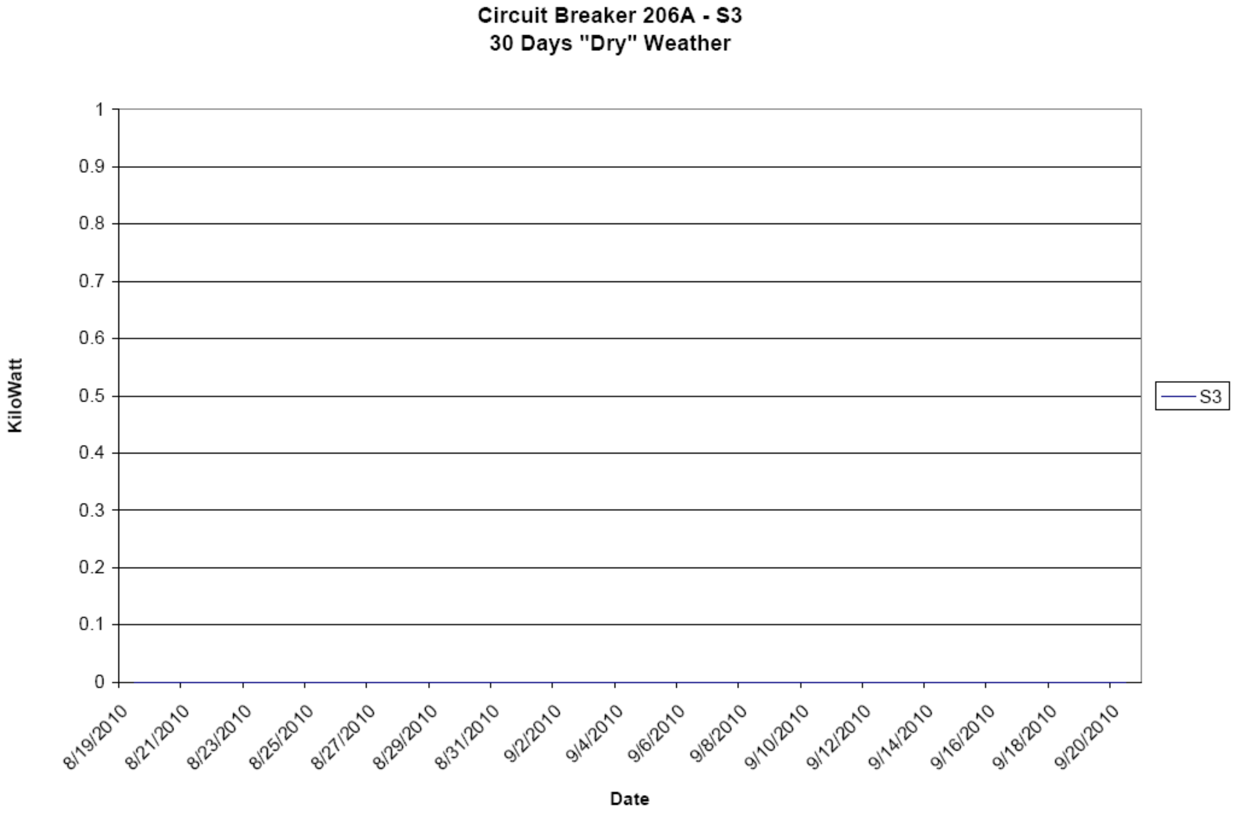

Figure 14 - Circuit Breaker 206A - S3 (Based on 15-Minute Power Demand – Dry Weather)

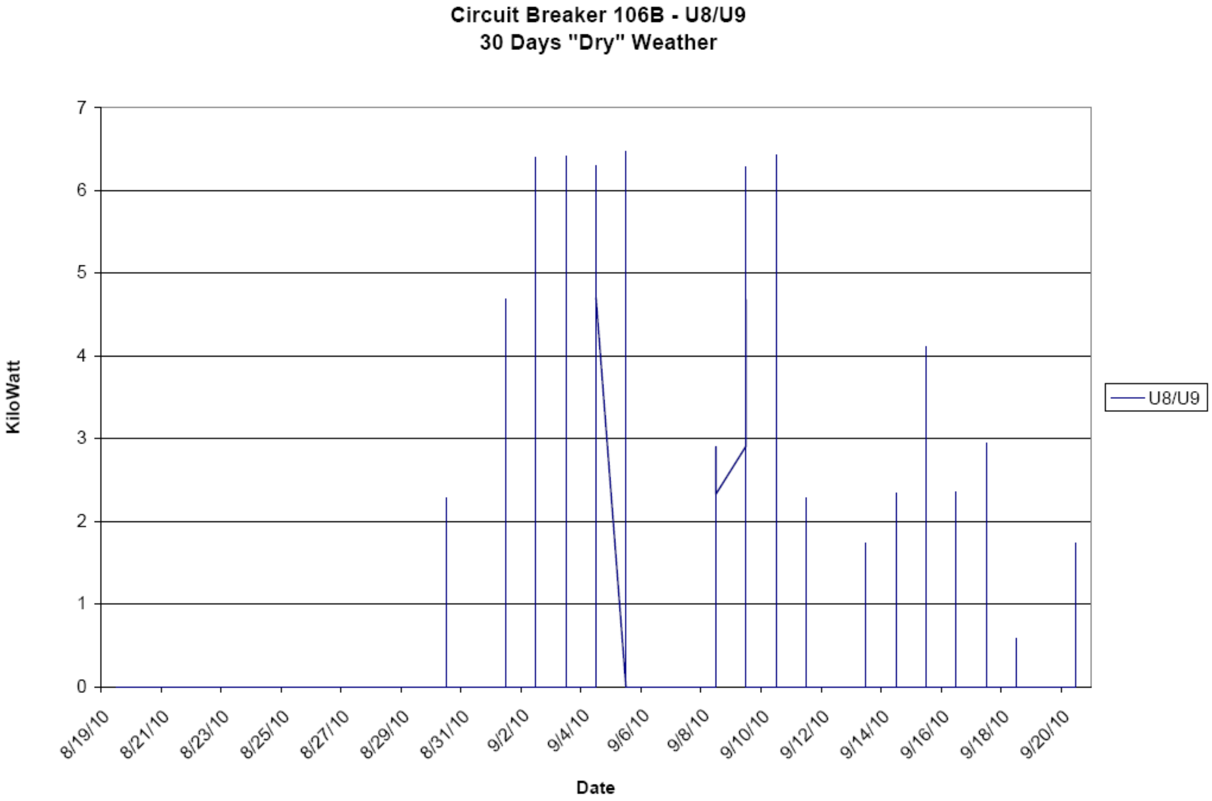

Figure 15 - Circuit Breaker 106B - U8/U9 (Based on 15-Minute Power Demand – Dry Weather)

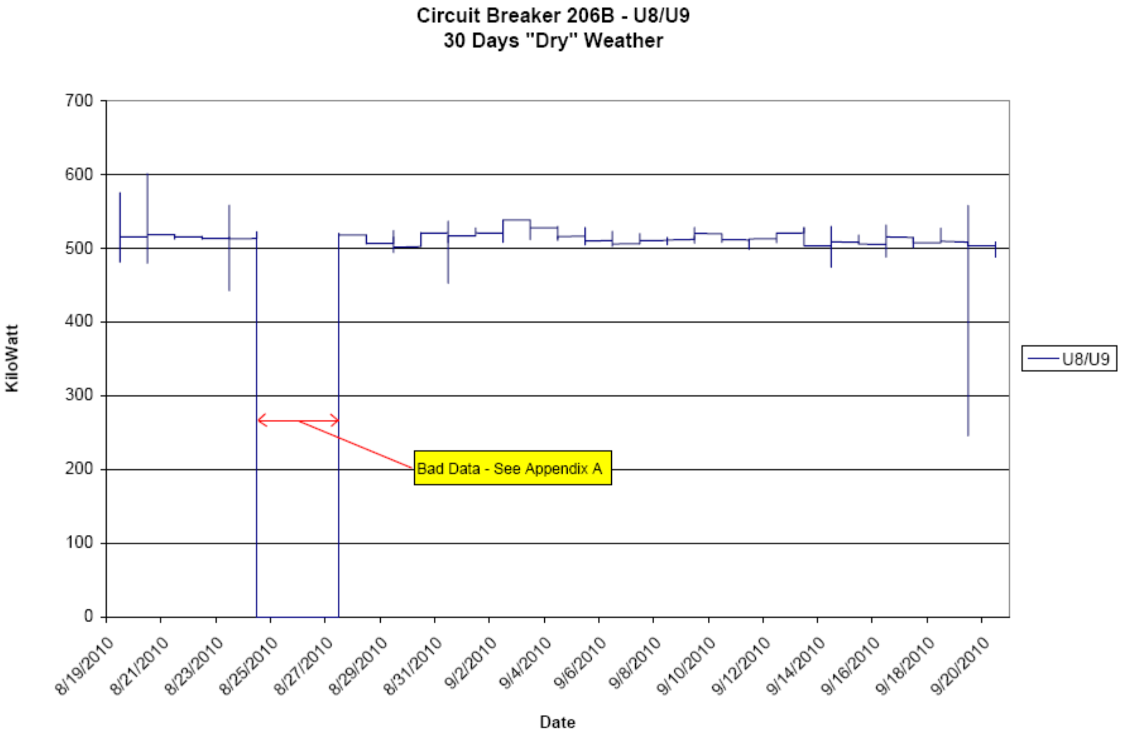

Figure 16 - Circuit Breaker 206B - U8/U9 (Based on 15-Minute Power Demand – Dry Weather)

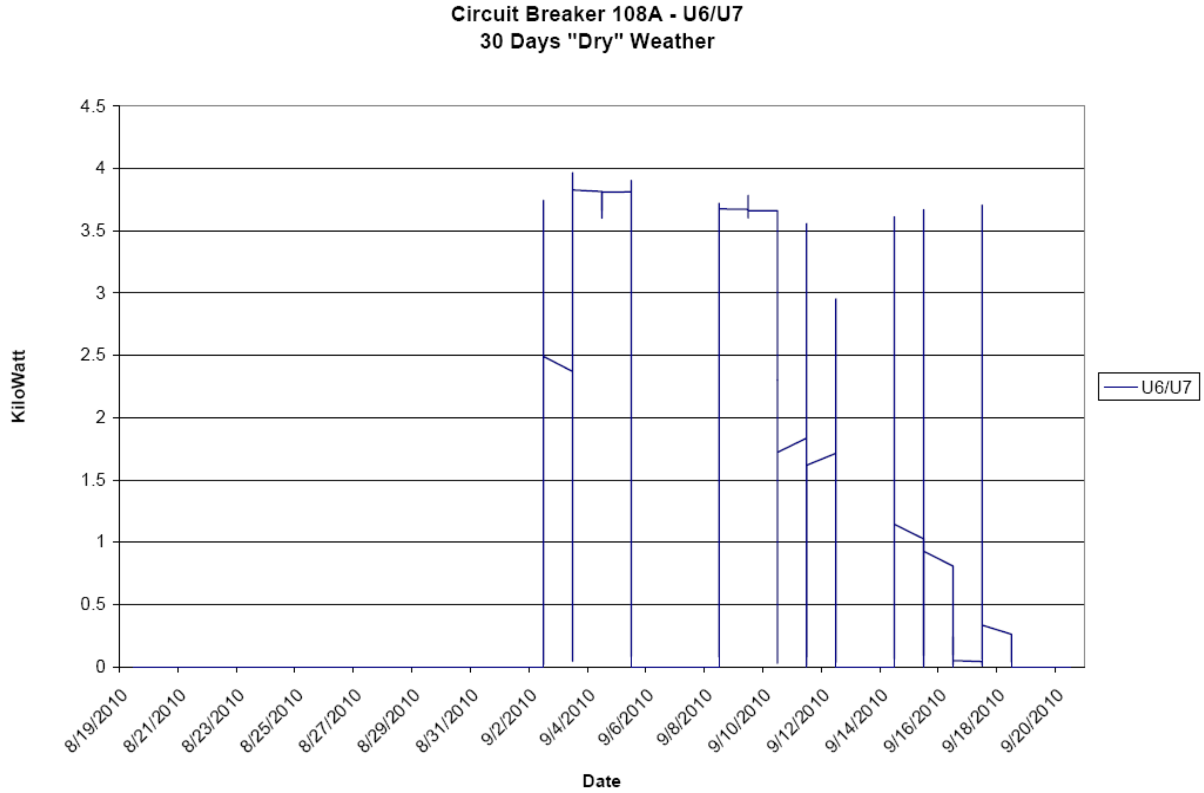

Figure 17 - Circuit Breaker 108A - U6/U7 (Based on 15-Minute Power Demand – Dry Weather)

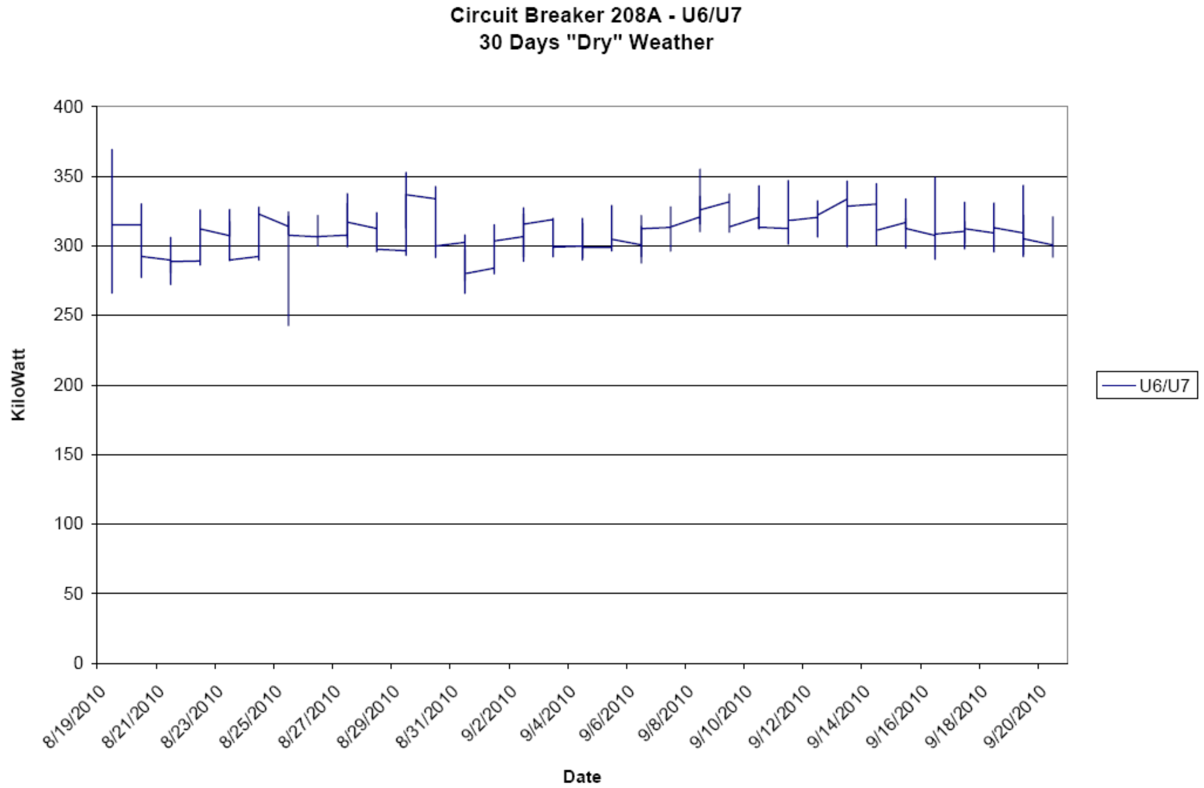

Figure 18 - Circuit Breaker 208A - U6/U7 (Based on 15-Minute Power Demand – Dry Weather)

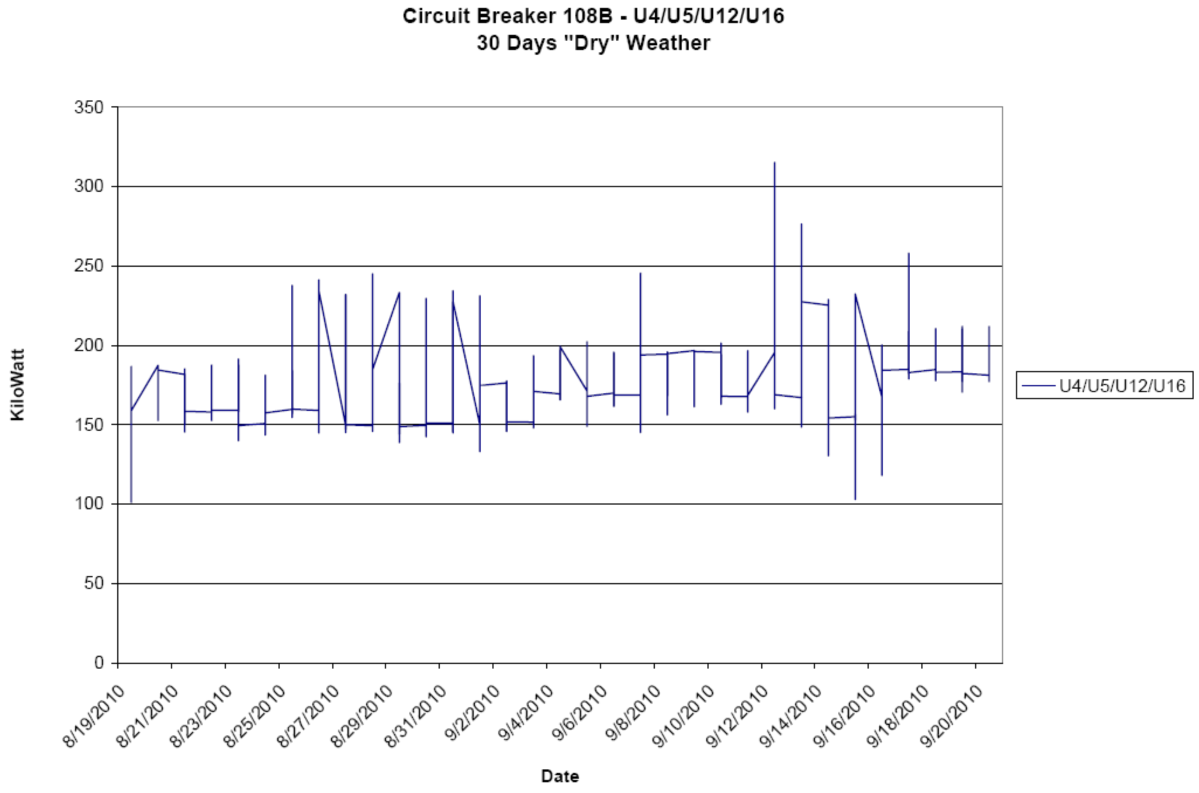

Figure 19 - Circuit Breaker 108B - U4/U5/U12/U16 (Based on 15-Minute Power Demand – Dry Weather)

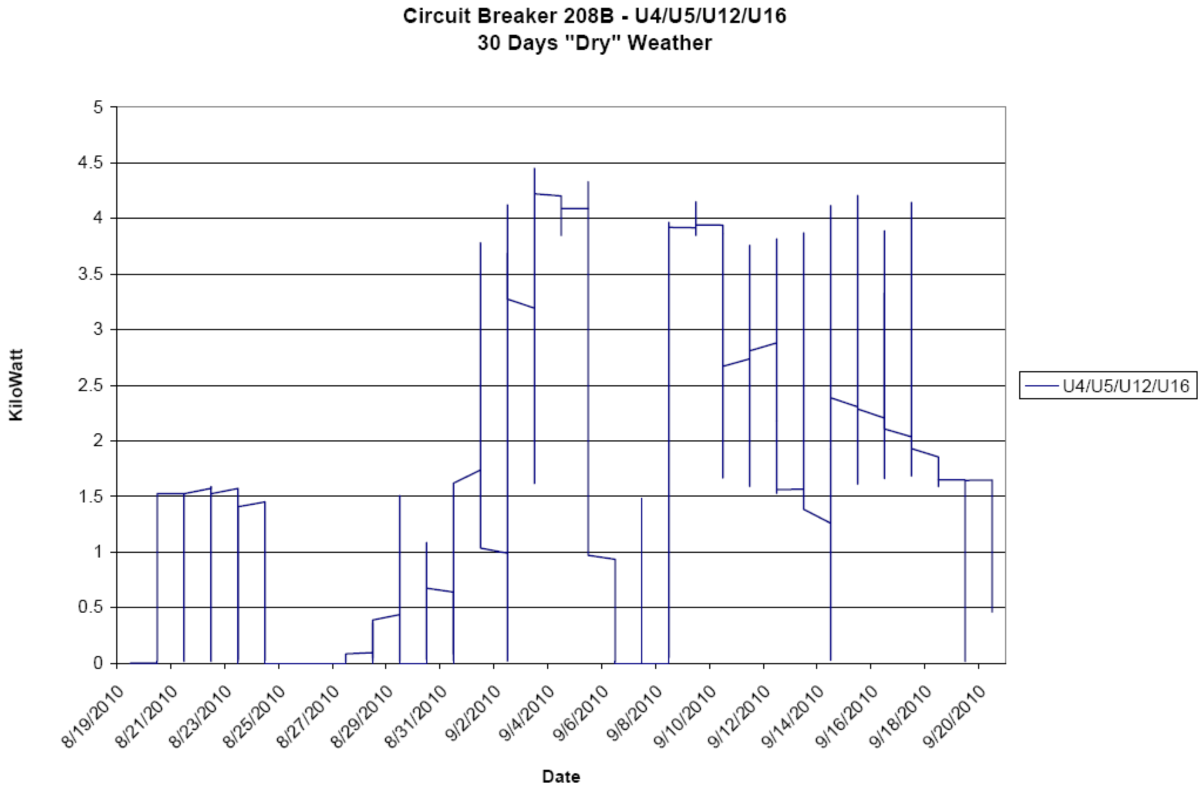

Figure 20 - Circuit Breaker 208B - U4/U5/U12/U16 (Based on 15-Minute Power Demand – Dry Weather)

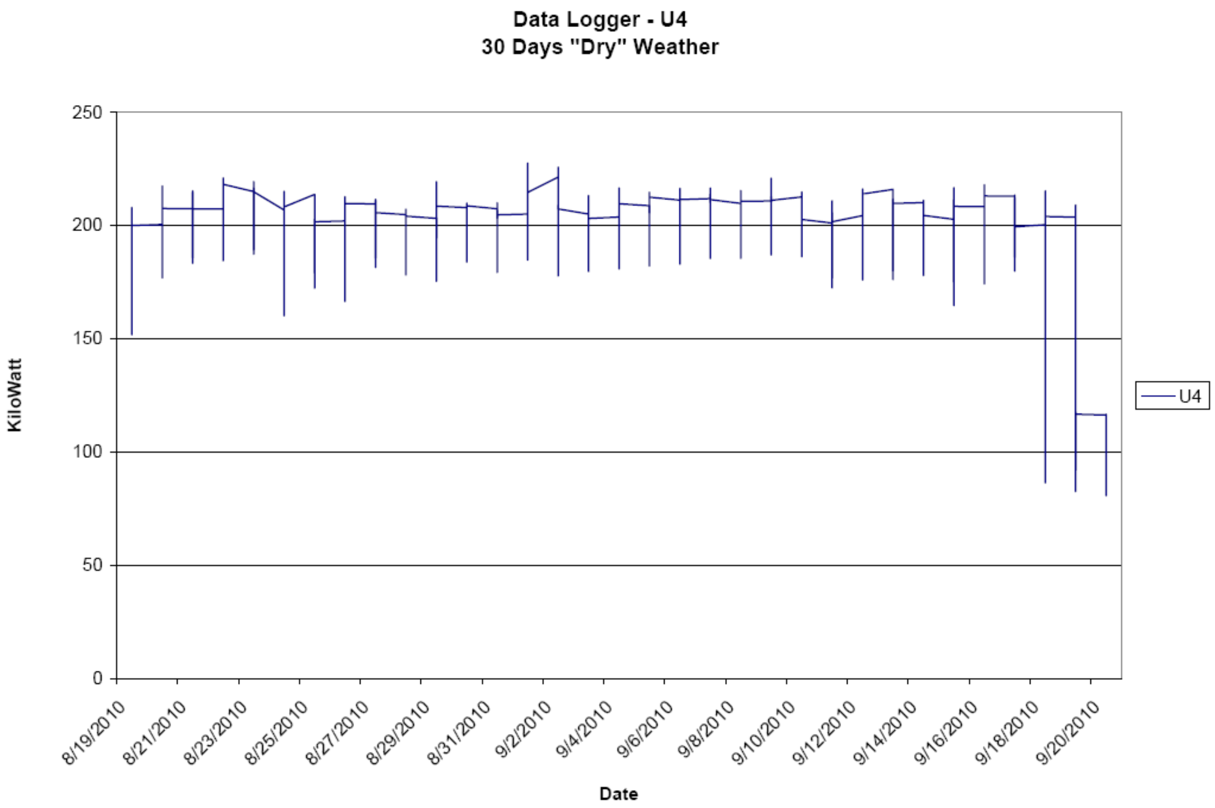

Figure 21 – Data Logger - U4 (Based on 15-Minute Power Demand – Dry Weather)

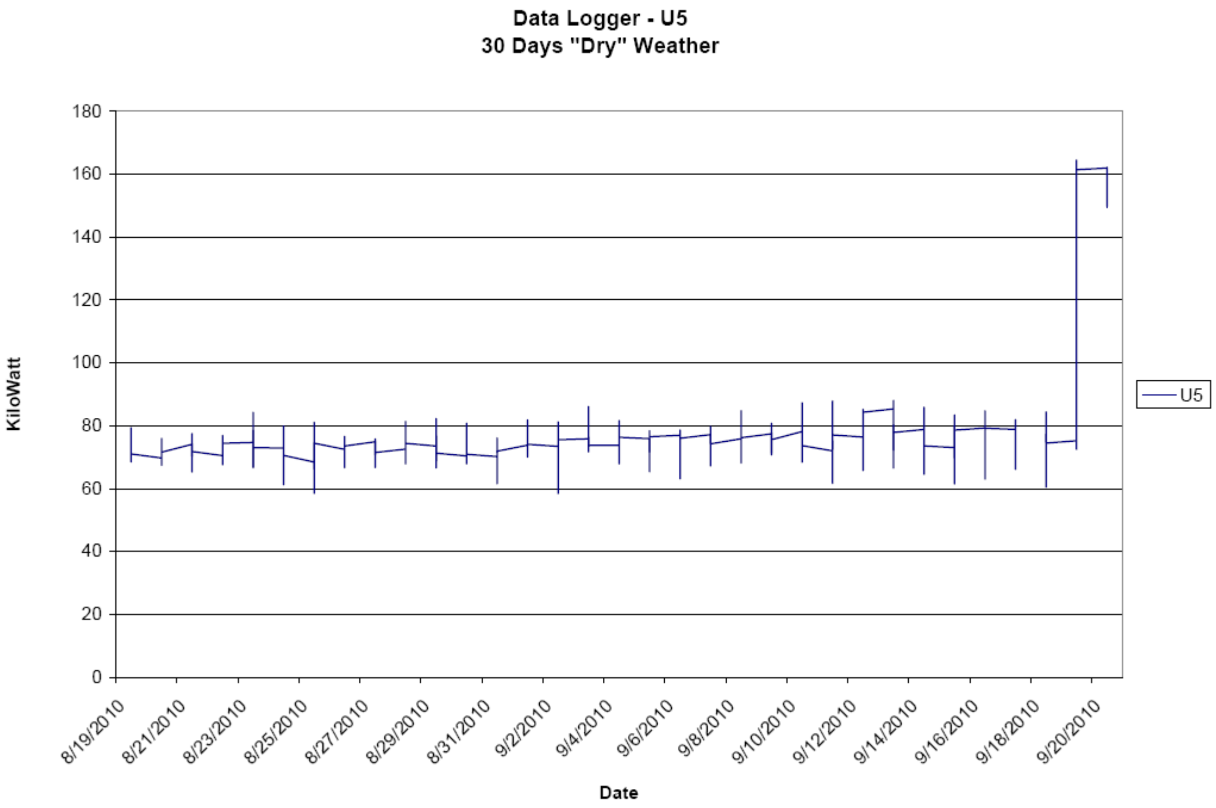

Figure 22 – Data Logger - U5 (Based on 15-Minute Power Demand – Dry Weather)

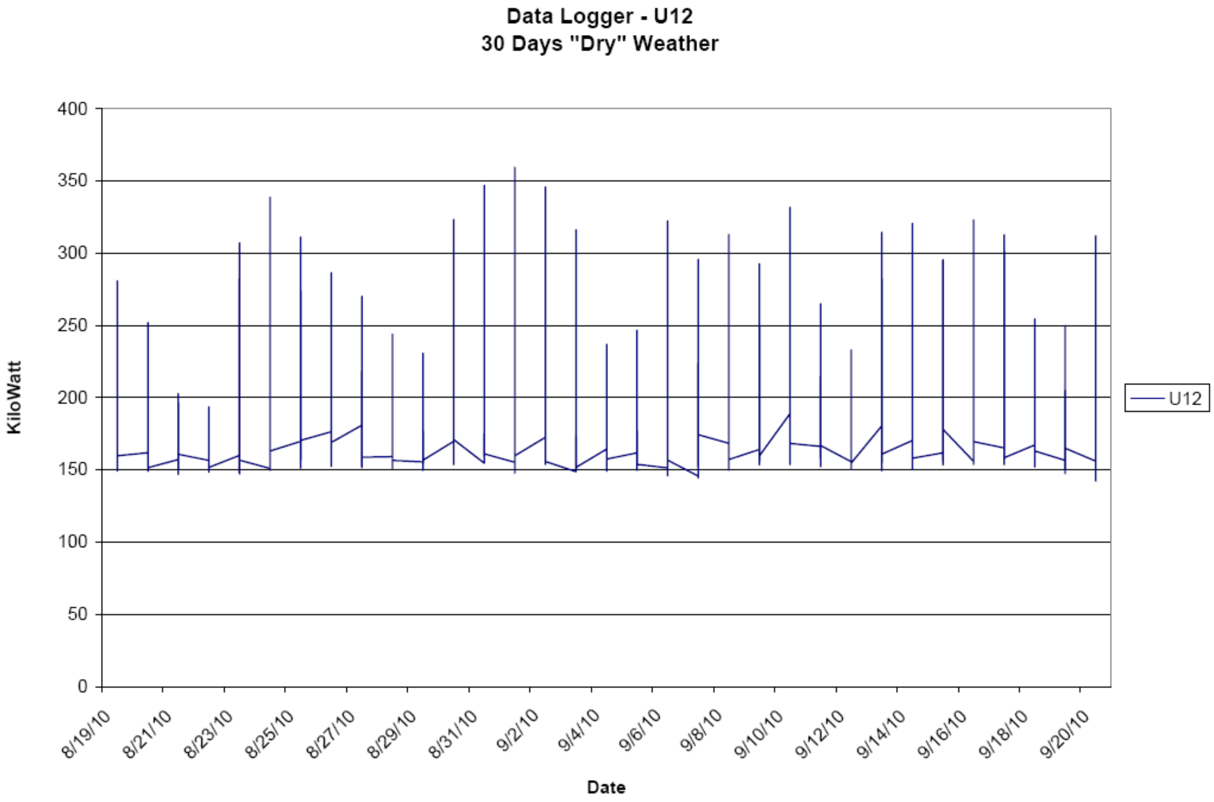

Figure 23 – Data Logger - U12 (Based on 15-Minute Power Demand – Dry Weather)

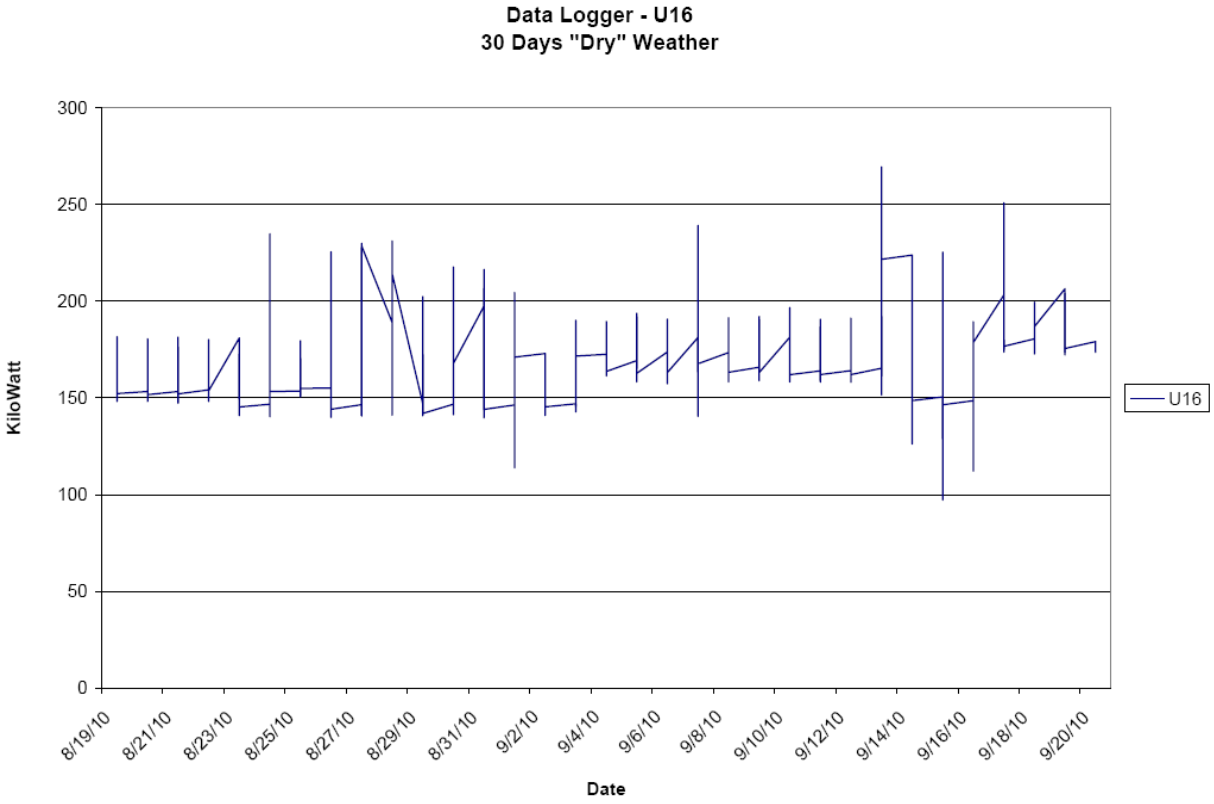

Figure 24 – Data Logger - U16 (Based on 15-Minute Power Demand – Dry Weather)

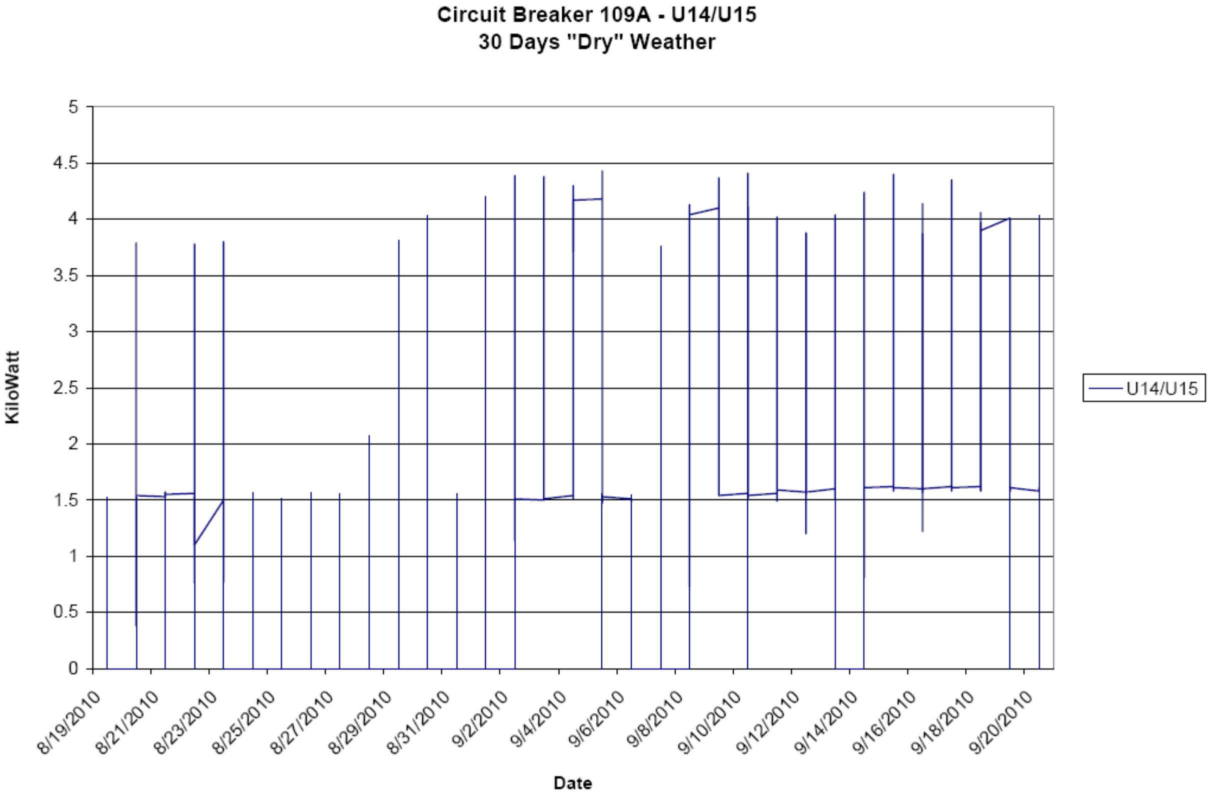

Figure 25 - Circuit Breaker 109A - U14/U15 (Based on 15-Minute Power Demand – Dry Weather)

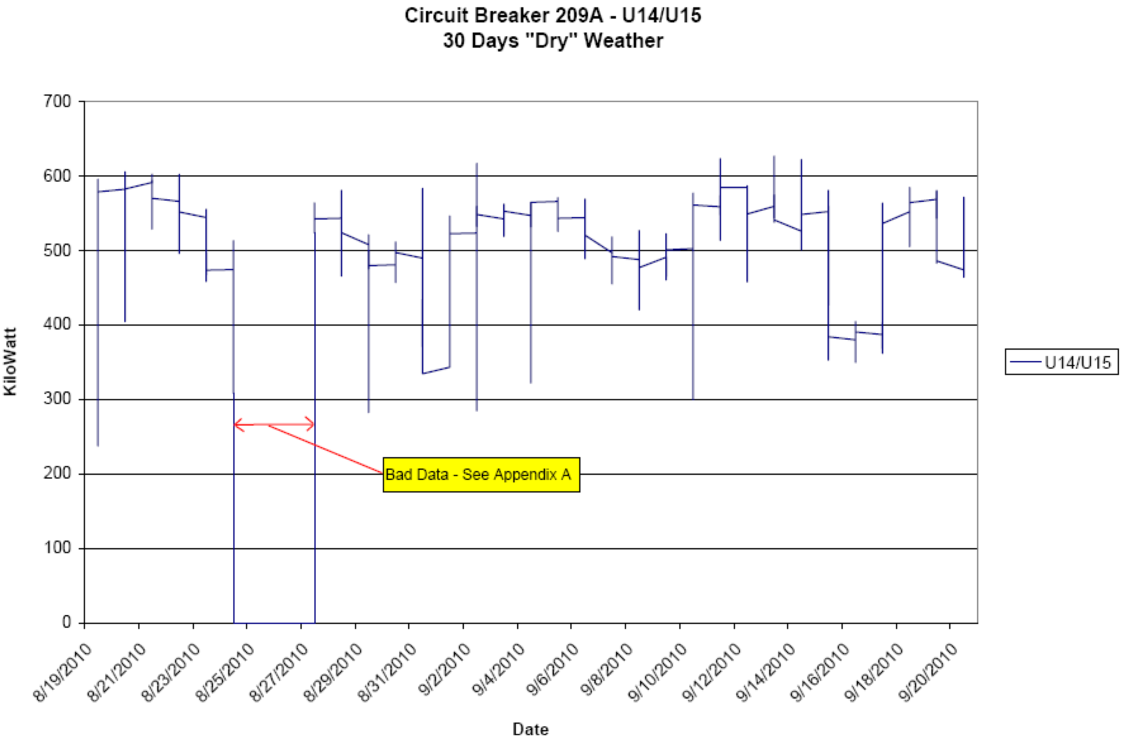

Figure 26 - Circuit Breaker 209A - U14/U15 (Based on 15-Minute Power Demand – Dry Weather)

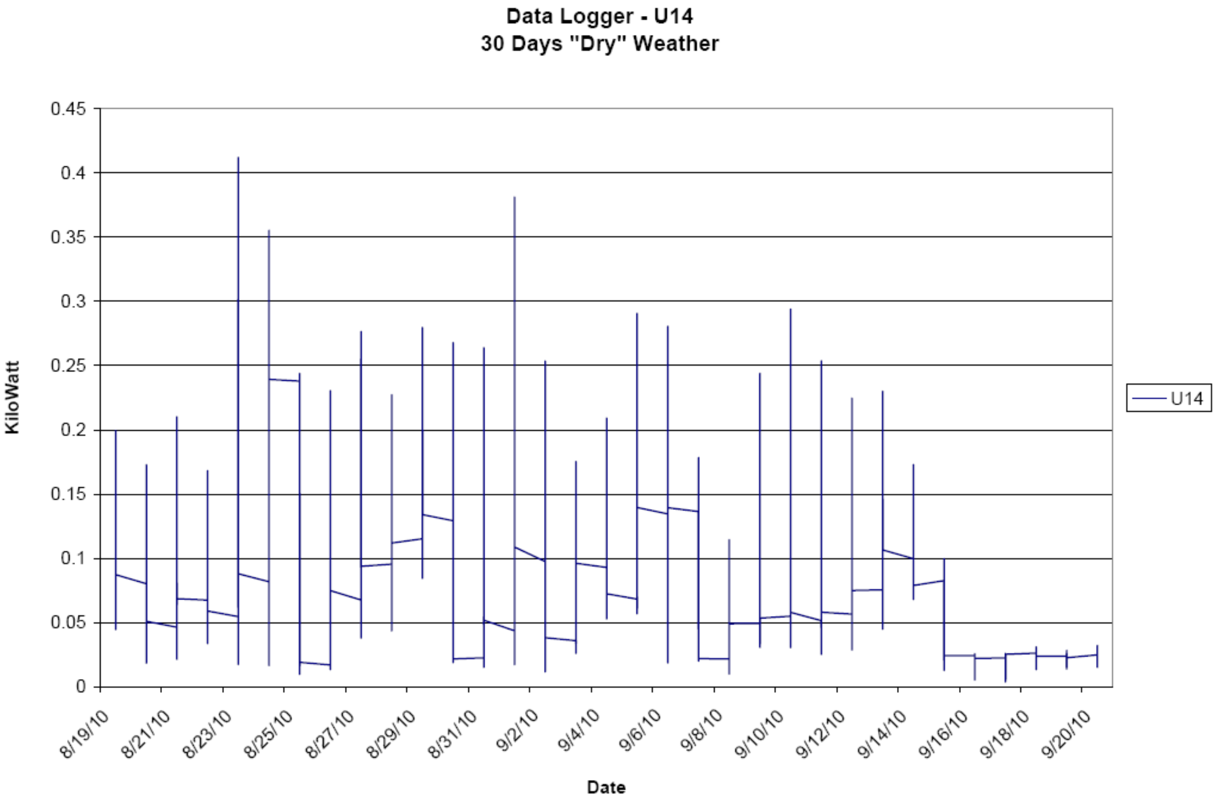

Figure 27 – Data Logger - U14 (Based on 15-Minute Power Demand – Dry Weather)

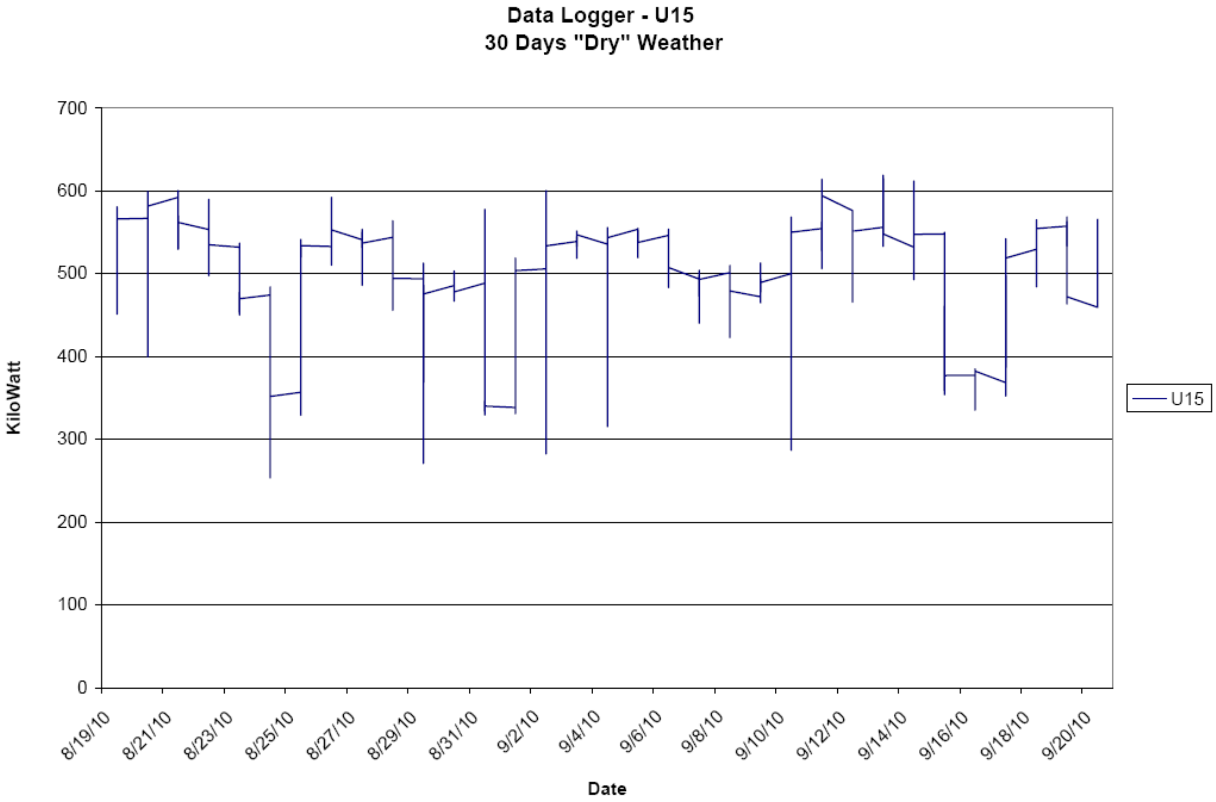

Figure 28 – Data Logger - U15 (Based on 15-Minute Power Demand – Dry Weather)

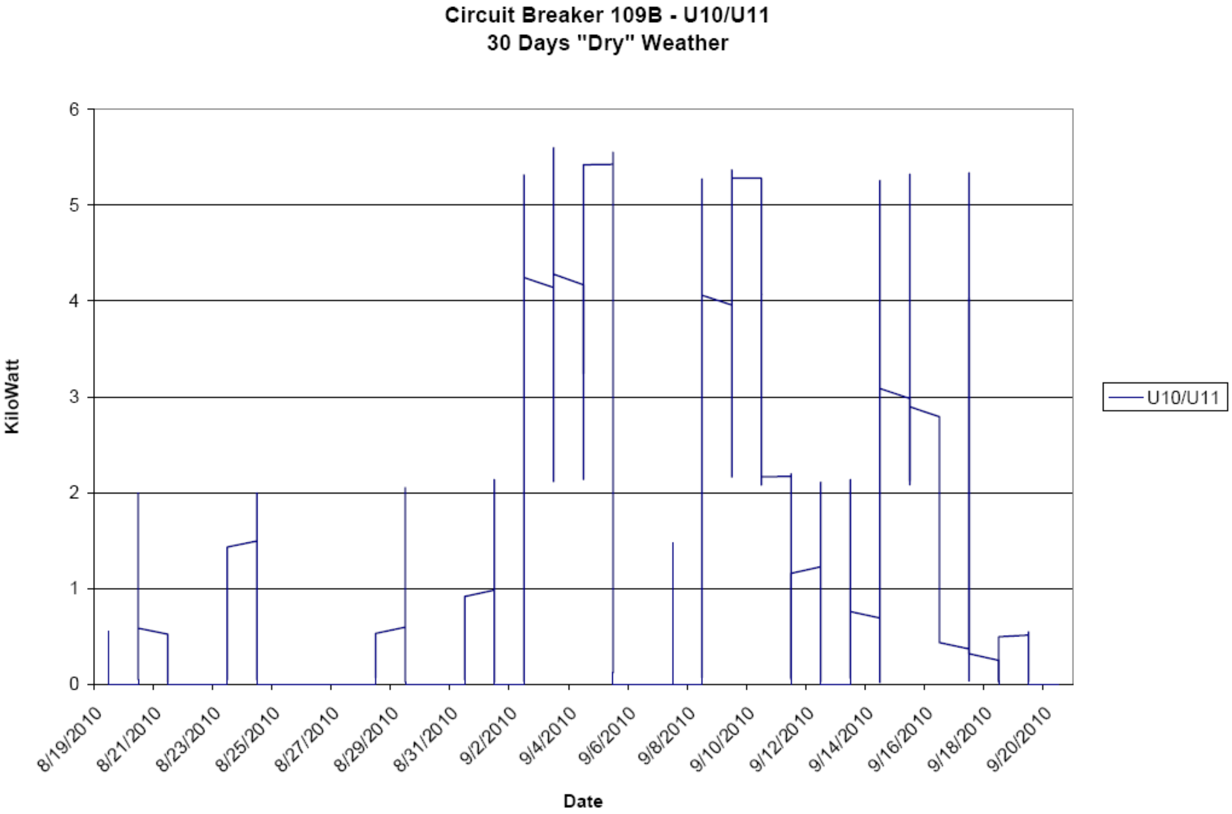

Figure 29 - Circuit Breaker 109B - U10/U11 (Based on 15-Minute Power Demand – Dry Weather)

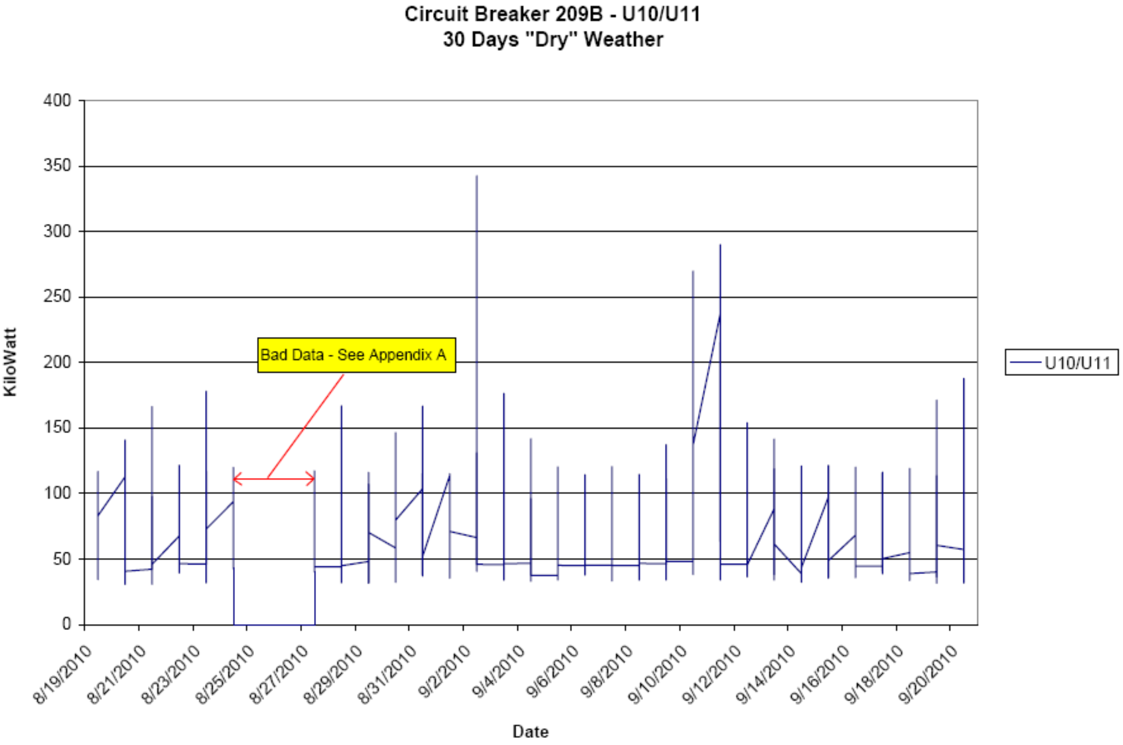

Figure 30 - Circuit Breaker 209B - U10/U11 (Based on 15-Minute Power Demand – Dry Weather)

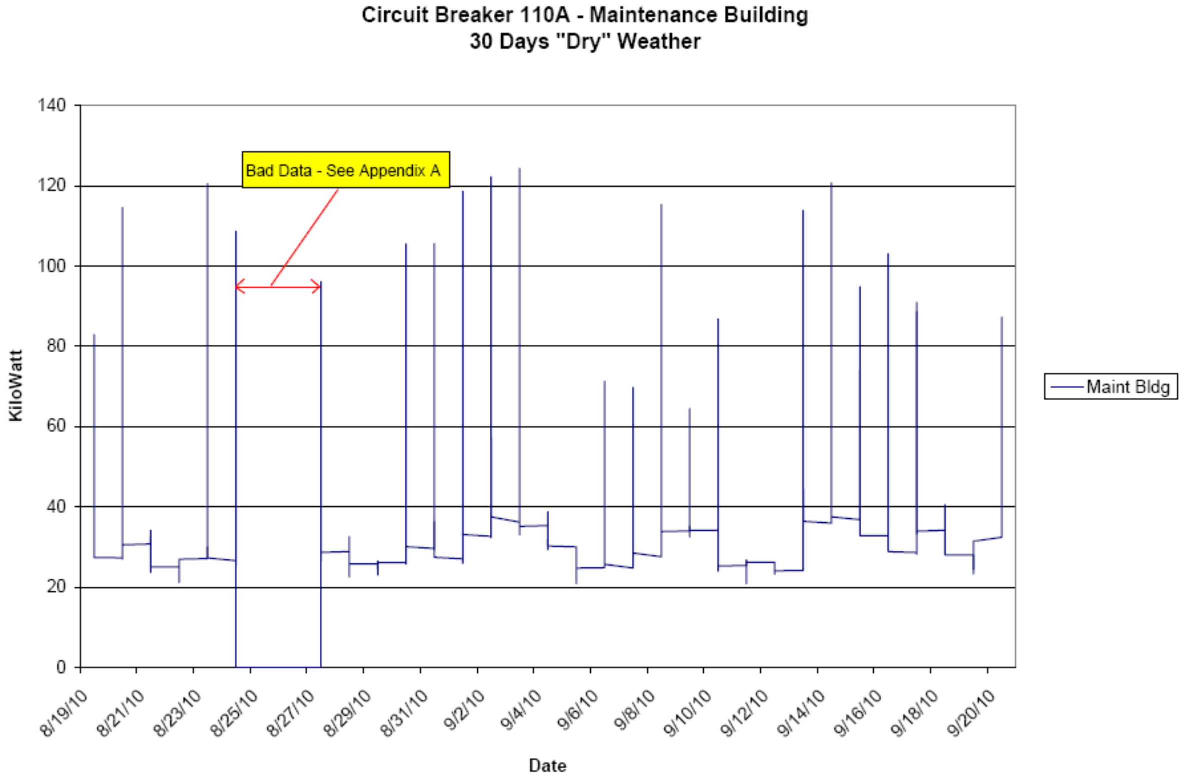

Figure 31 - Circuit Breaker 110A – Maintenance Building (Based on 15-Minute Power Demand – Dry Weather)

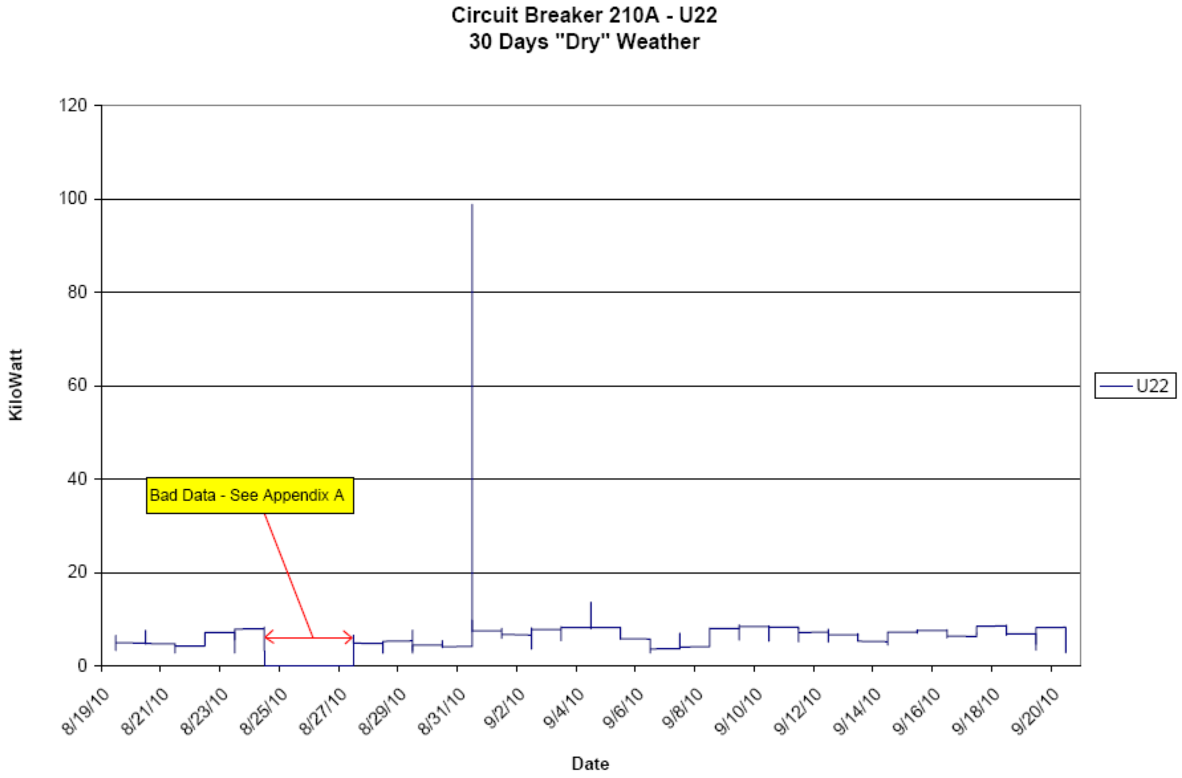

Figure 32 - Circuit Breaker 210A - U22 (Based on 15-Minute Power Demand – Dry Weather)

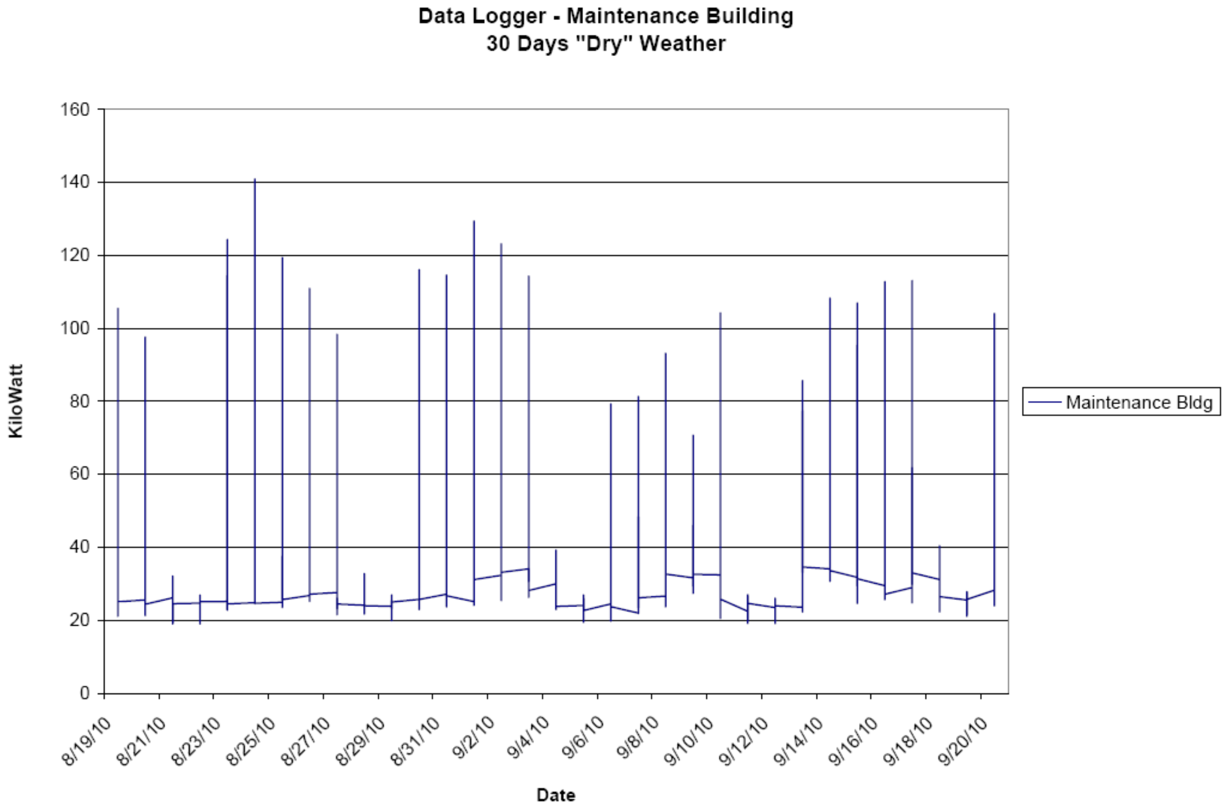

Figure 33 – Data Logger – Maintenance Building (Based on 15-Minute Power Demand – Dry Weather)

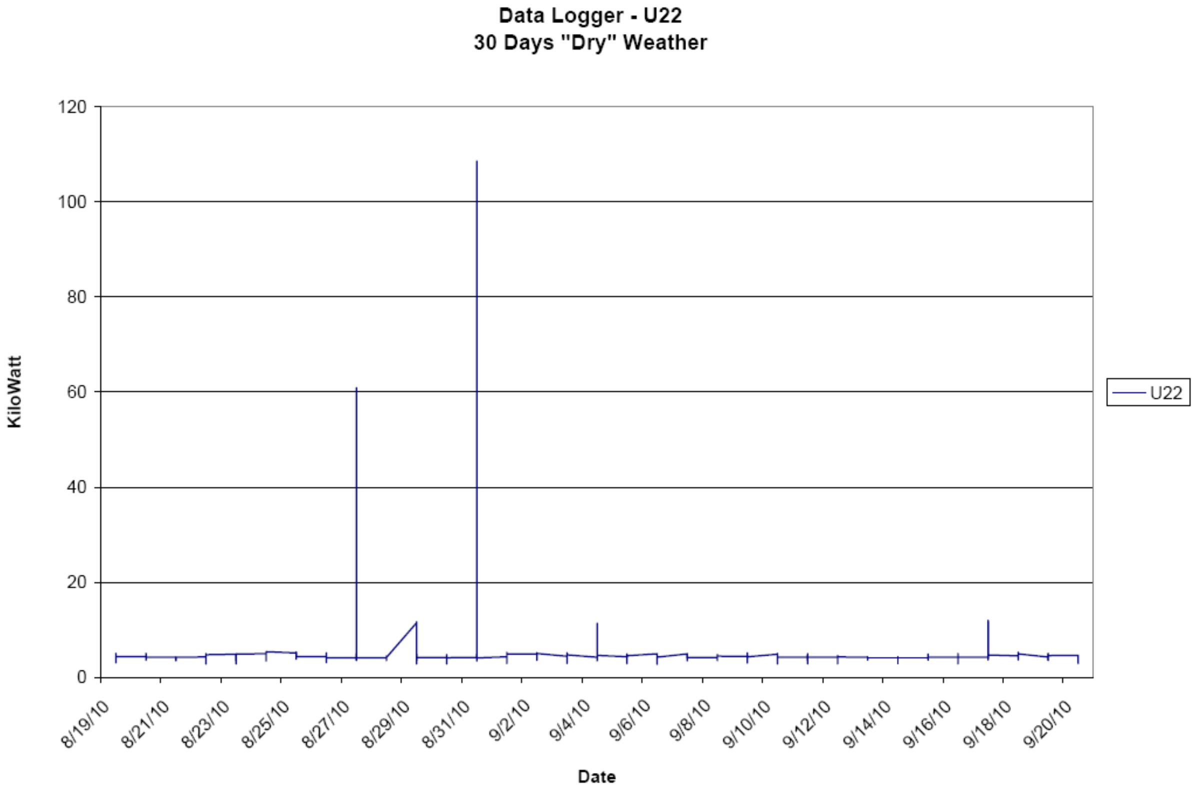

Figure 34 – Data Logger – U22 (Based on 15-Minute Power Demand – Dry Weather)

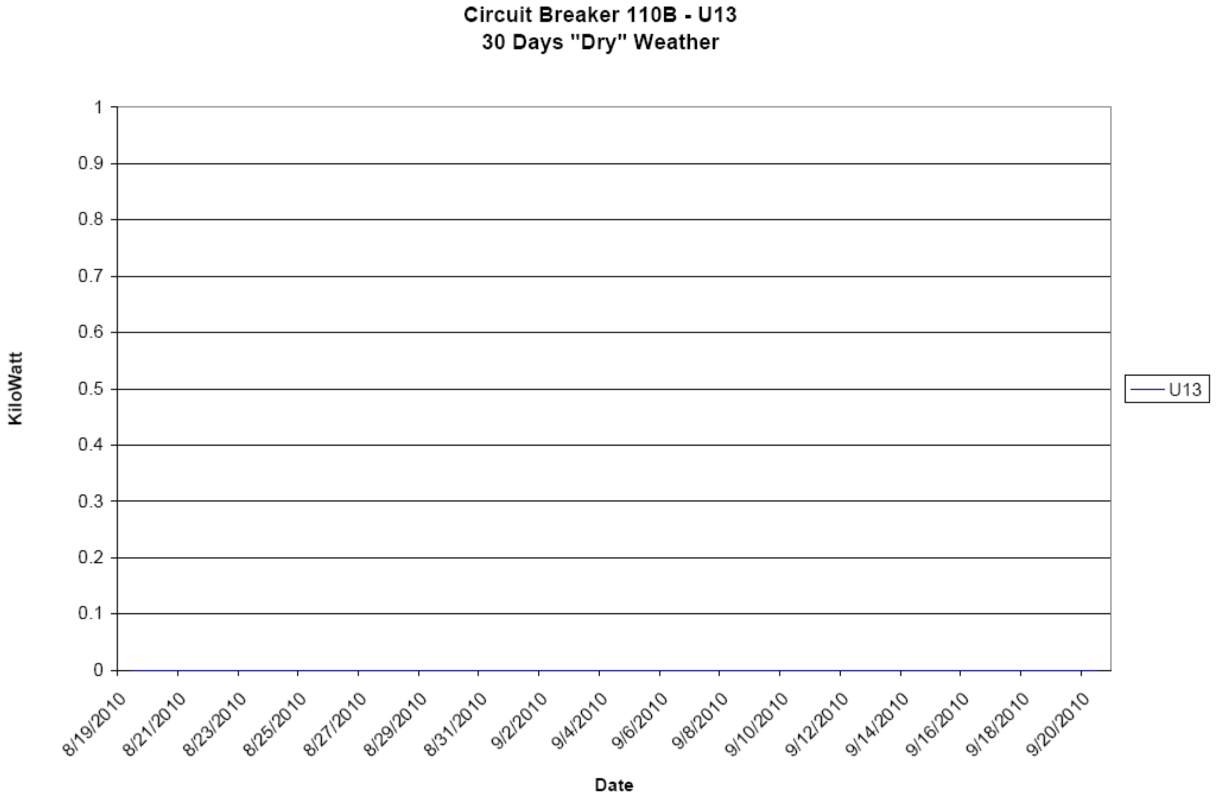

Figure 35 - Circuit Breaker 110B - U13 (Based on 15-Minute Power Demand – Dry Weather)

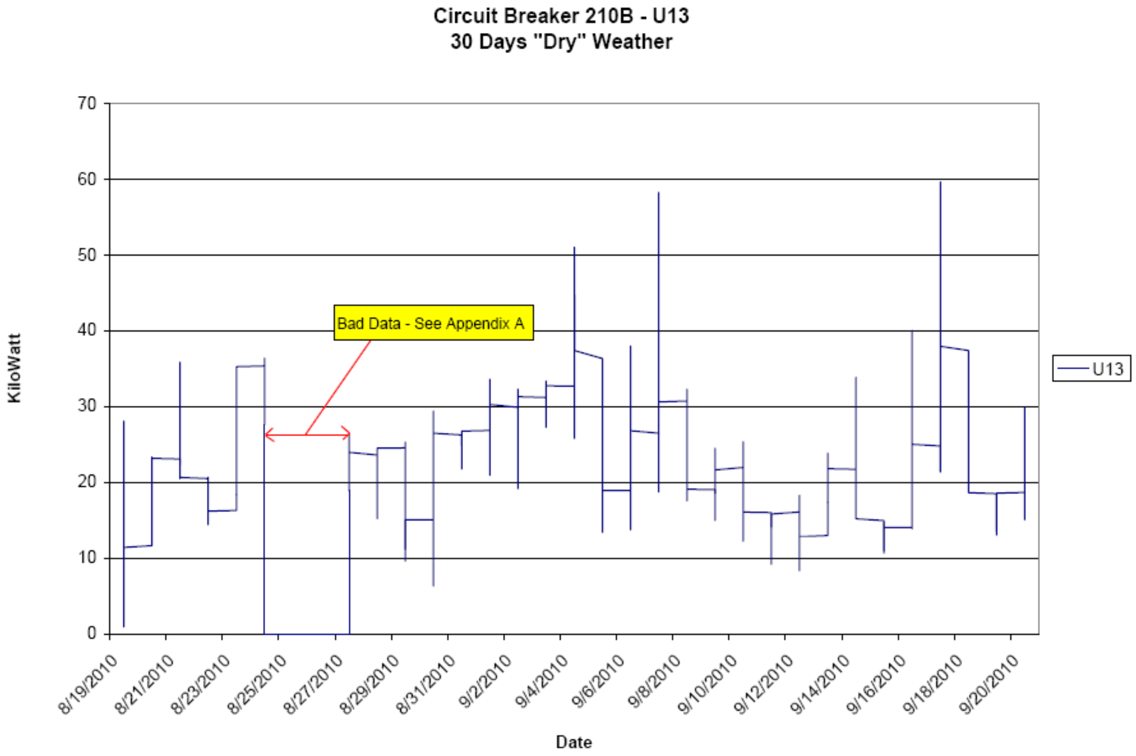

Figure 36 - Circuit Breaker 210B - U13 (Based on 15-Minute Power Demand – Dry Weather)

3.2 “Wet” Weather Graphs

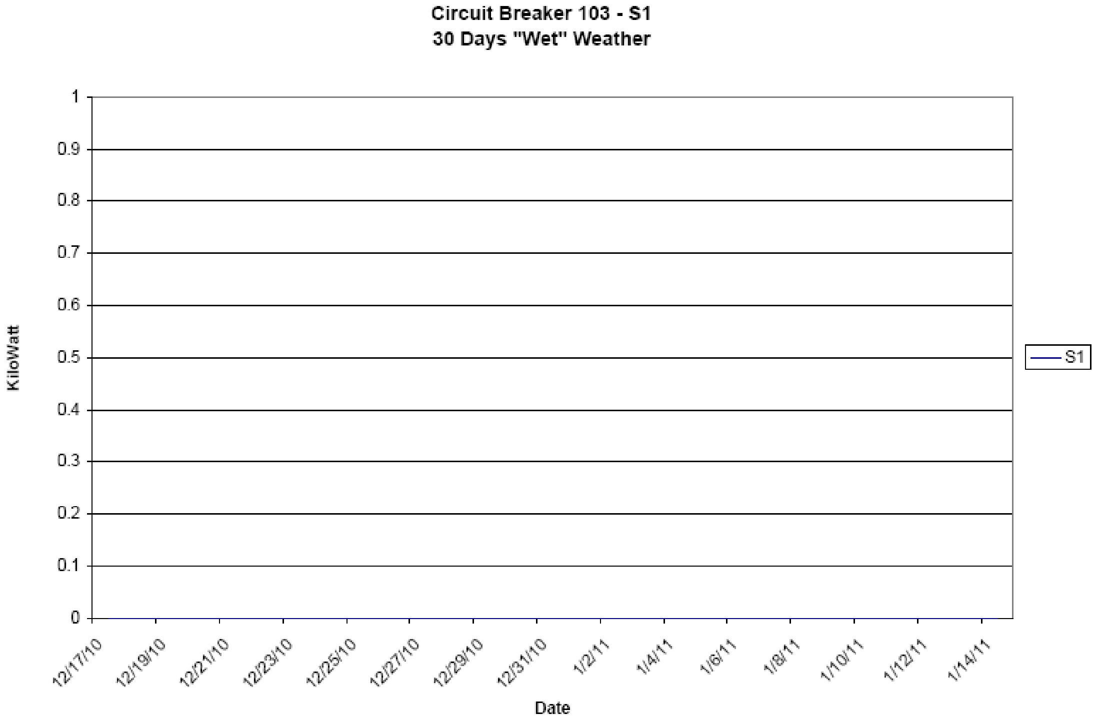

Figure 37 - Circuit Breaker 103 - S1 (Based on 15-Minute Power Demand – Wet Weather)

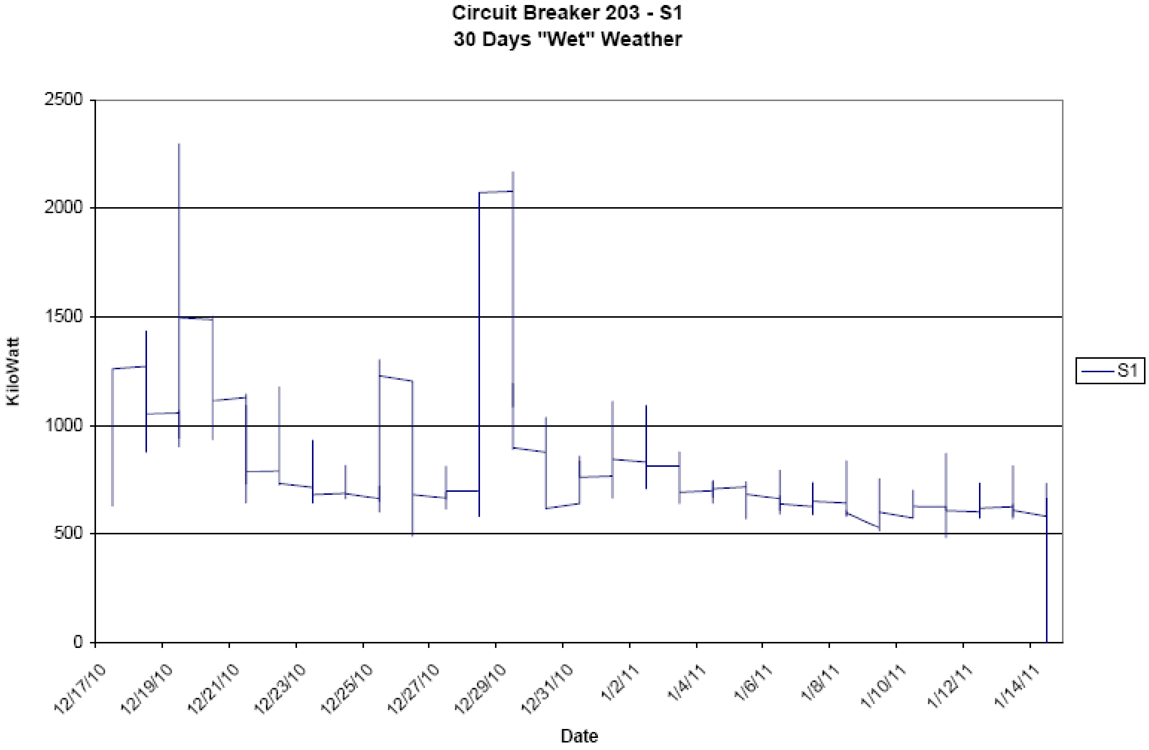

Figure 38 - Circuit Breaker 203 - S1 (Based on 15-Minute Power Demand – Wet Weather)

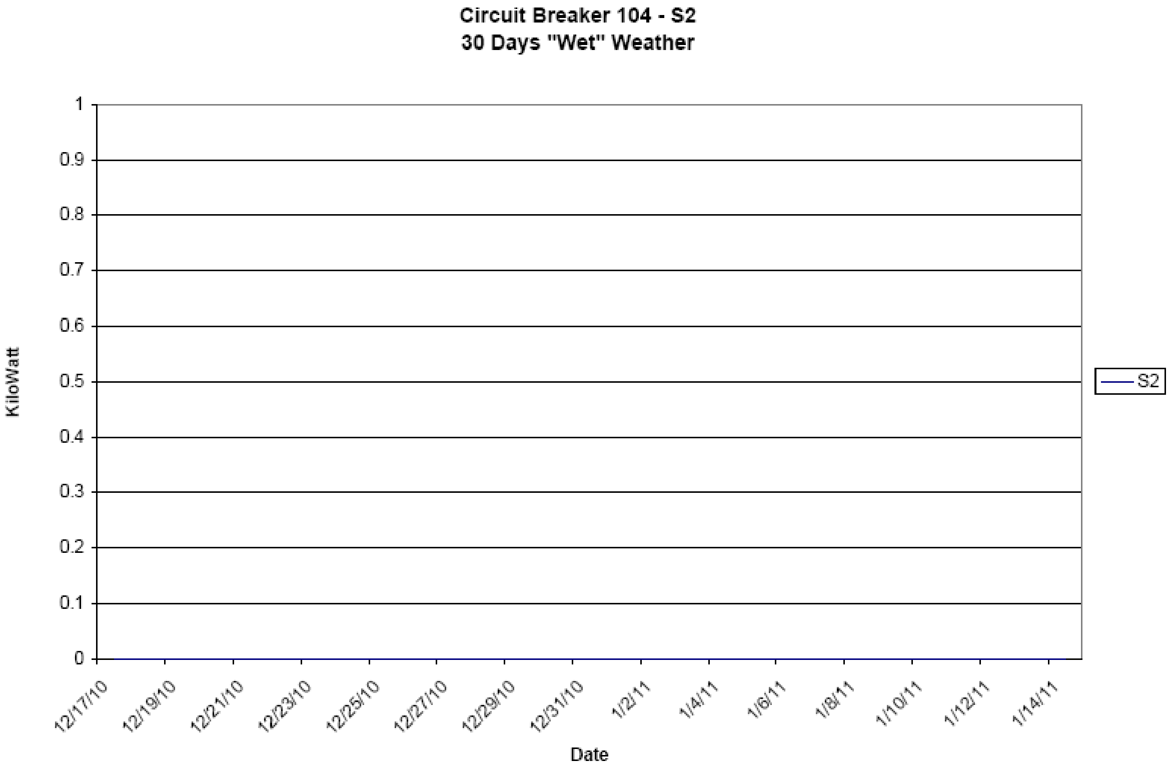

Figure 39 - Circuit Breaker 104 - S2 (Based on 15-Minute Power Demand – Wet Weather)

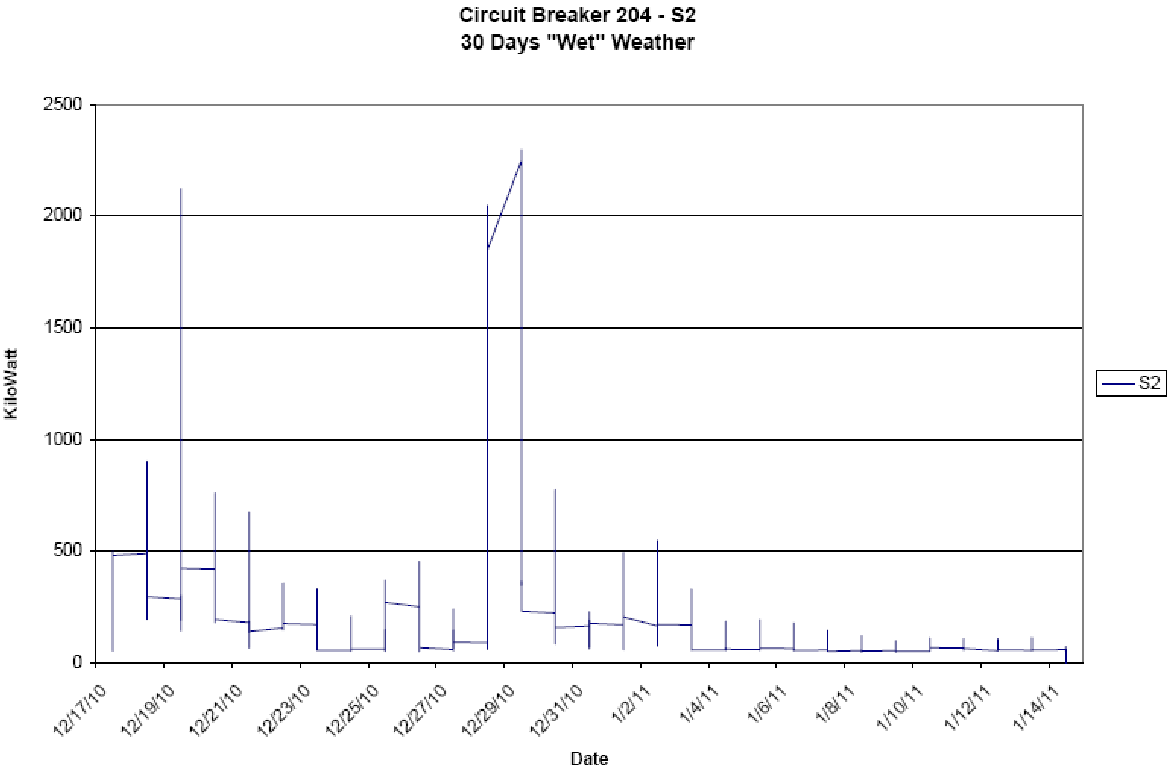

Figure 40 - Circuit Breaker 204 - S2 (Based on 15-Minute Power Demand – Wet Weather)

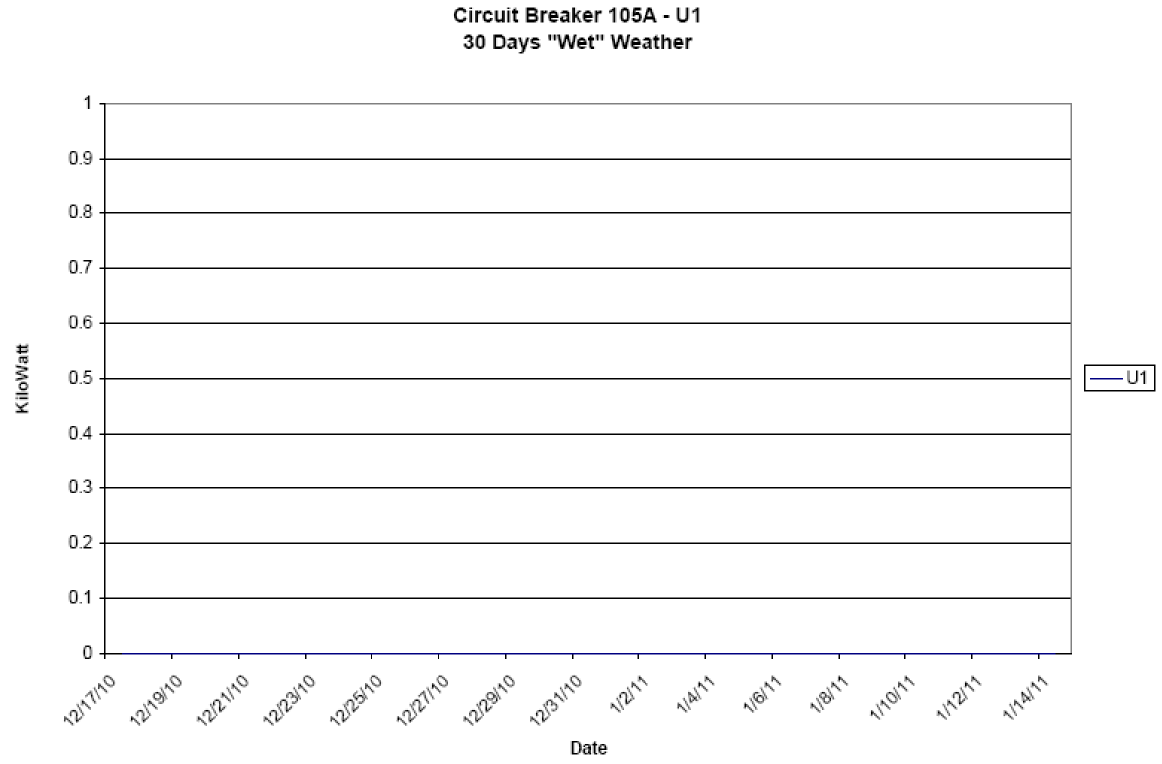

Figure 41 - Circuit Breaker 105A - U1 (Based on 15-Minute Power Demand – Wet Weather)

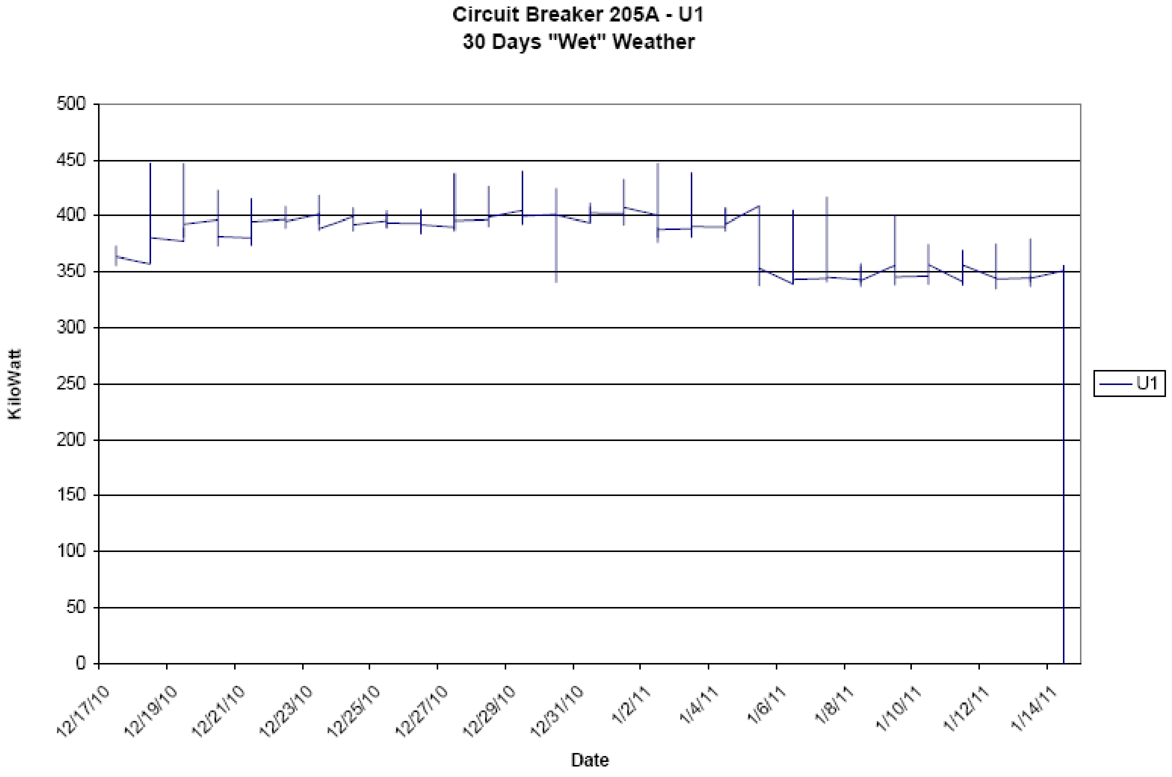

Figure 42 - Circuit Breaker 205A - U1 (Based on 15-Minute Power Demand – Wet Weather)

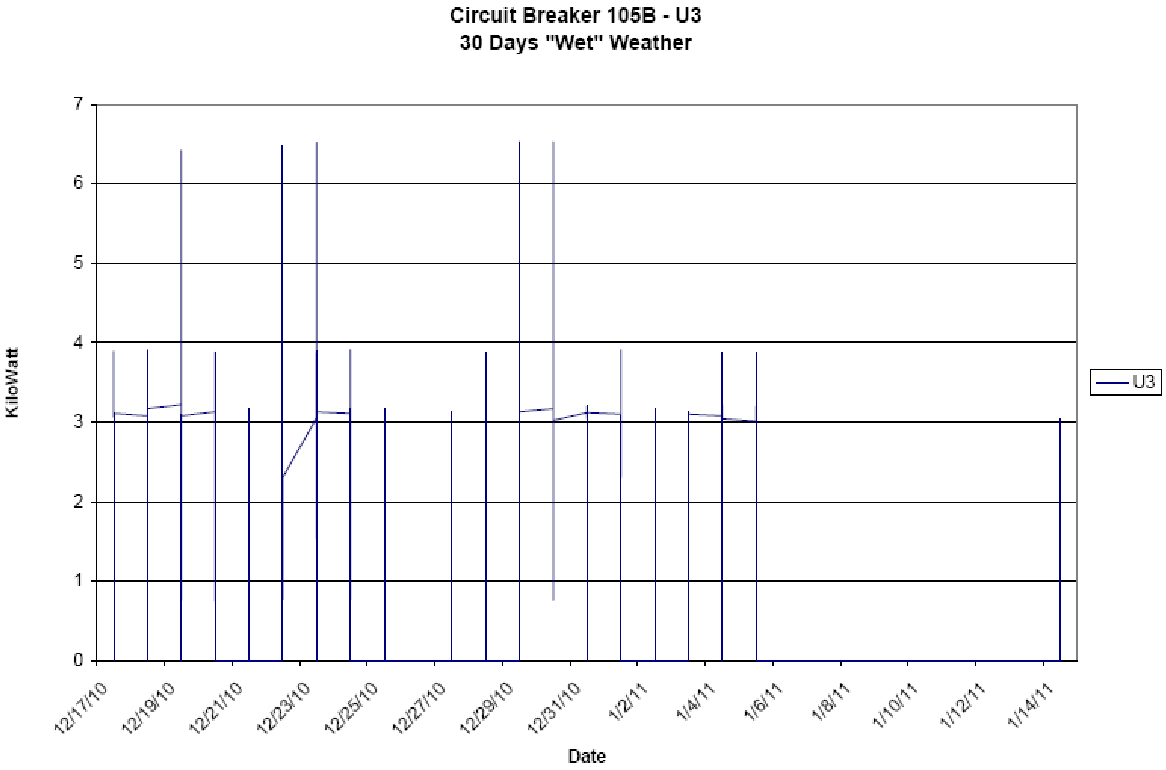

Figure 43 - Circuit Breaker 105B - U3 (Based on 15-Minute Power Demand – Wet Weather)

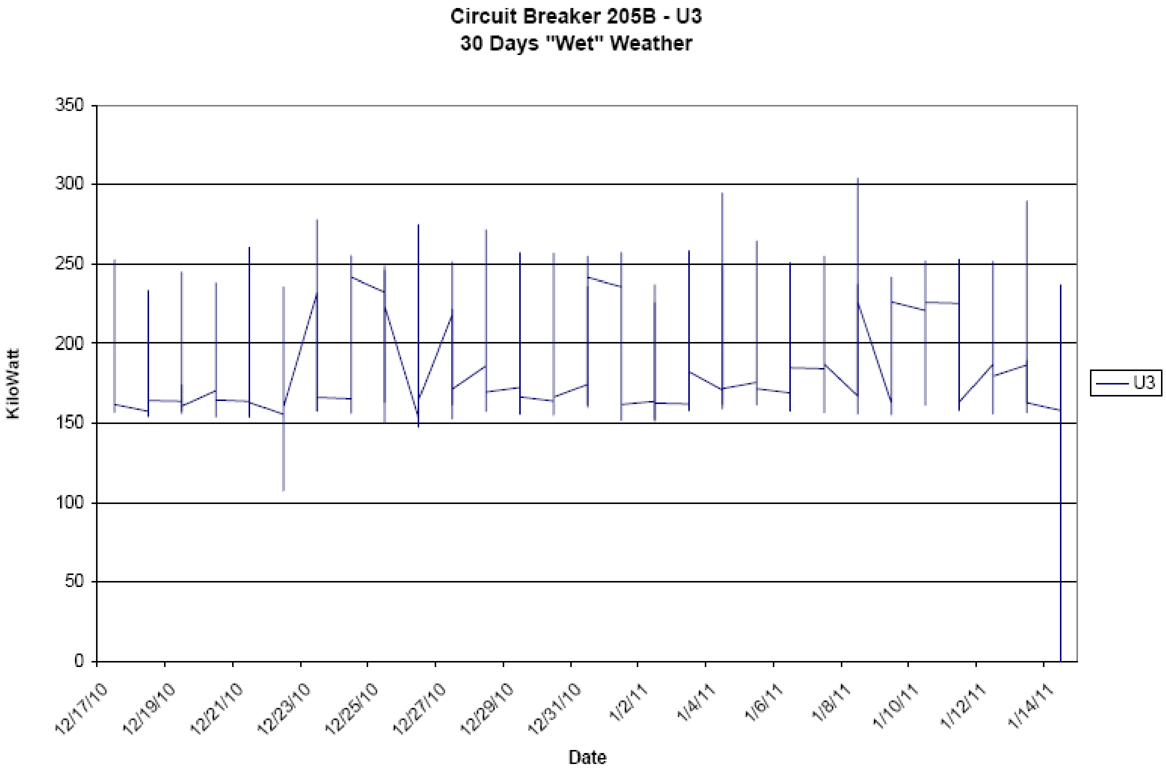

Figure 44 - Circuit Breaker 205B - U3 (Based on 15-Minute Power Demand – Wet Weather)

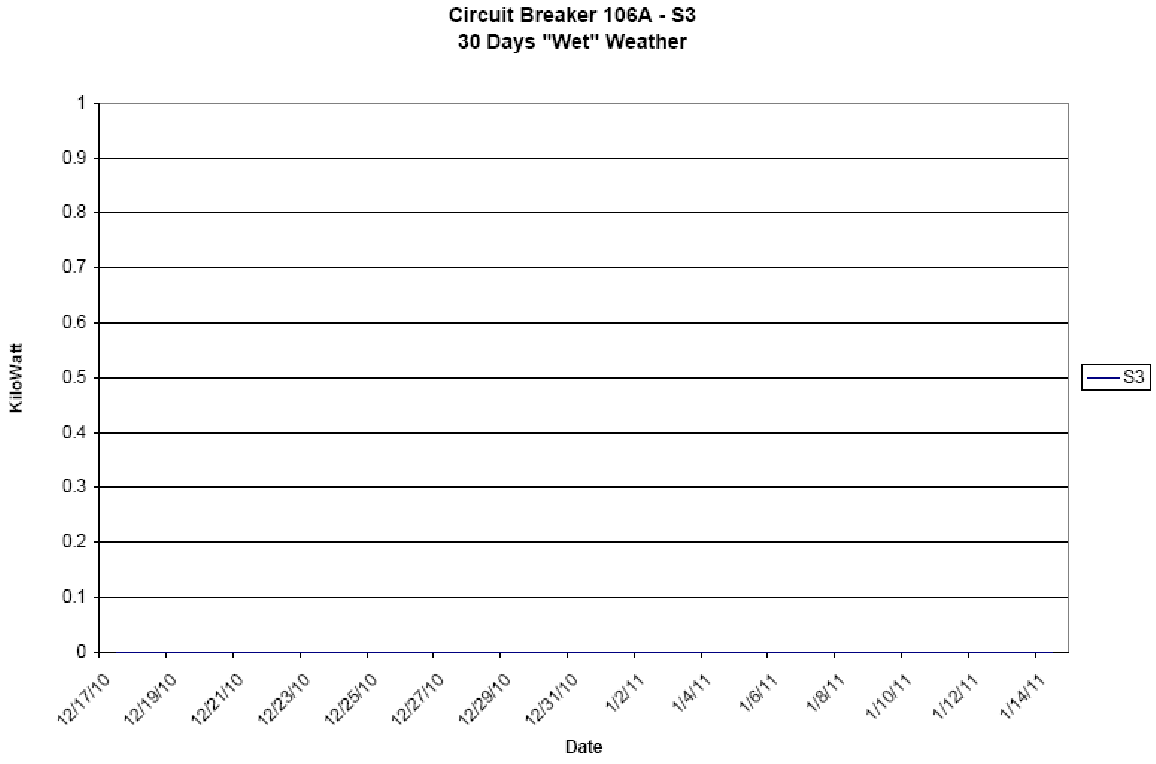

Figure 45 - Circuit Breaker 106A - S3 (Based on 15-Minute Power Demand – Wet Weather)

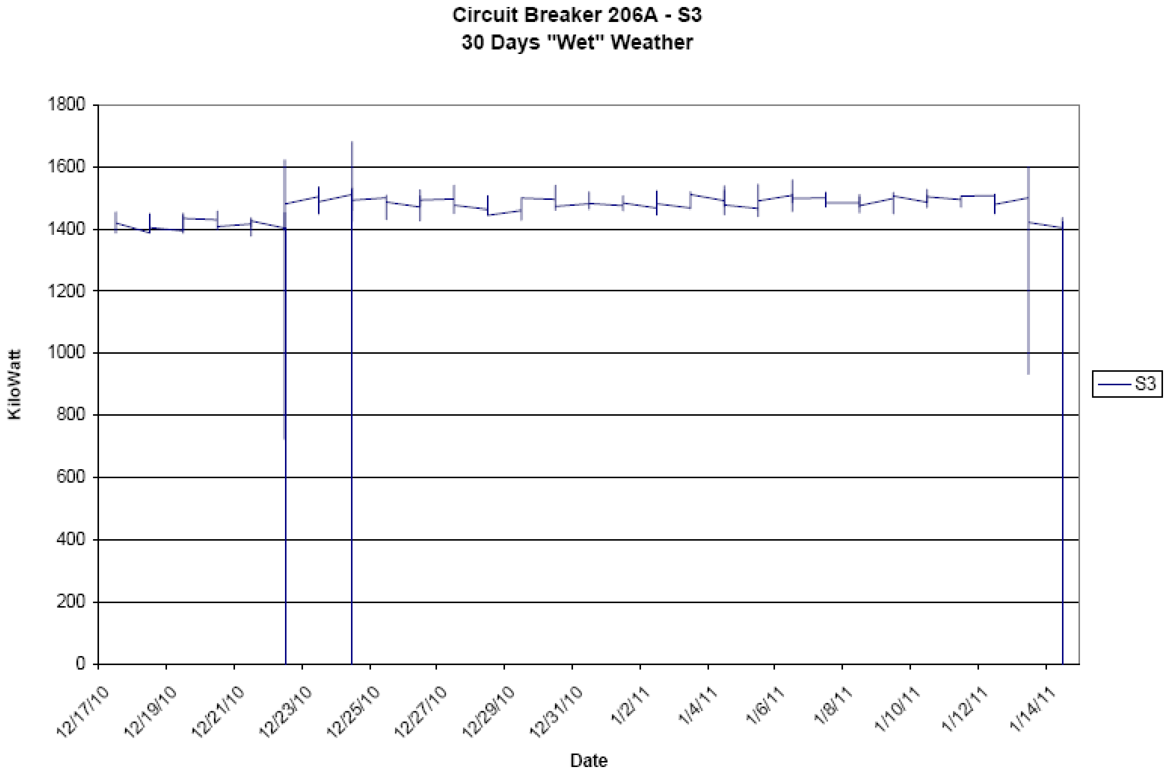

Figure 46 - Circuit Breaker 206A - S3 (Based on 15-Minute Power Demand – Wet Weather)

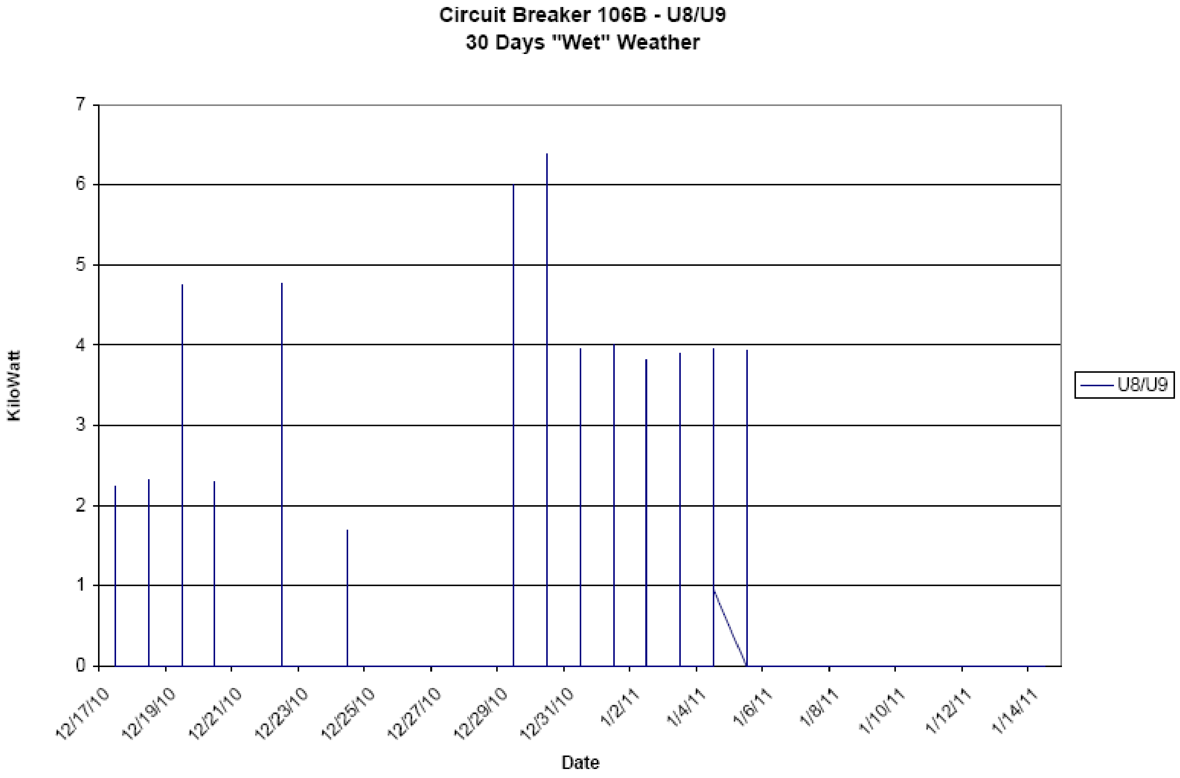

Figure 47 - Circuit Breaker 106B - U8/U9 (Based on 15-Minute Power Demand – Wet Weather)

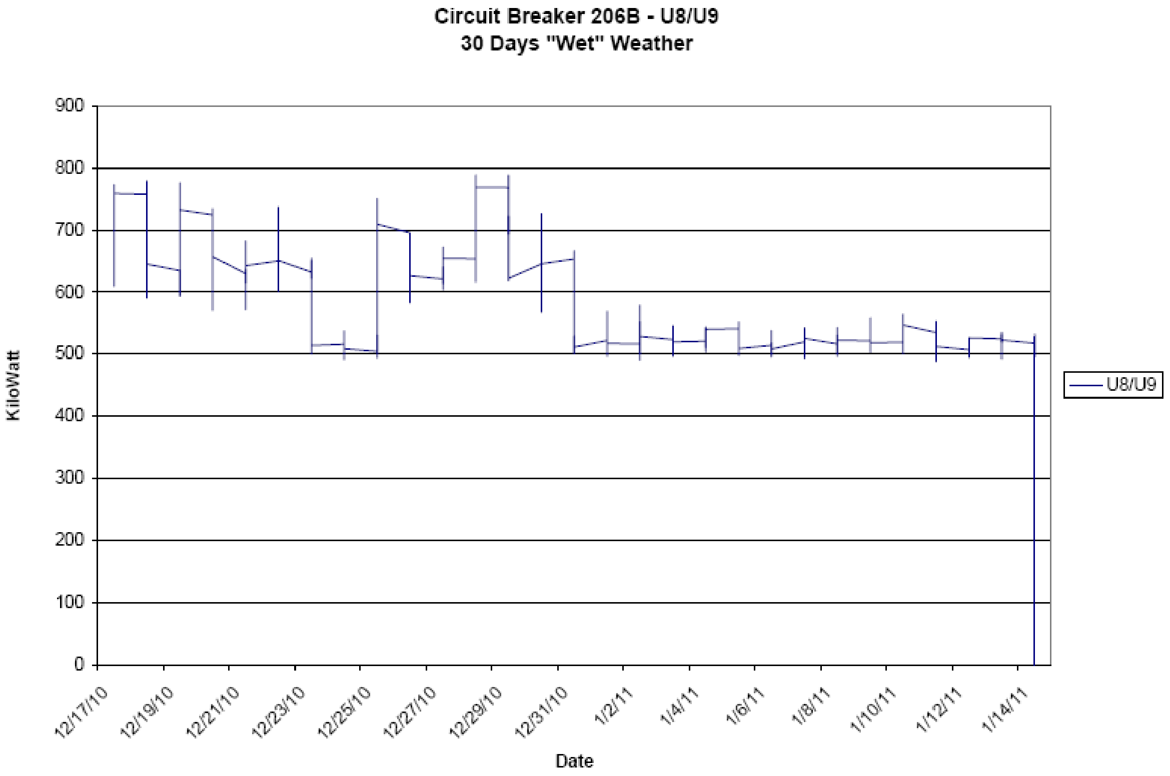

Figure 48 - Circuit Breaker 206B - U8/U9 (Based on 15-Minute Power Demand – Wet Weather)

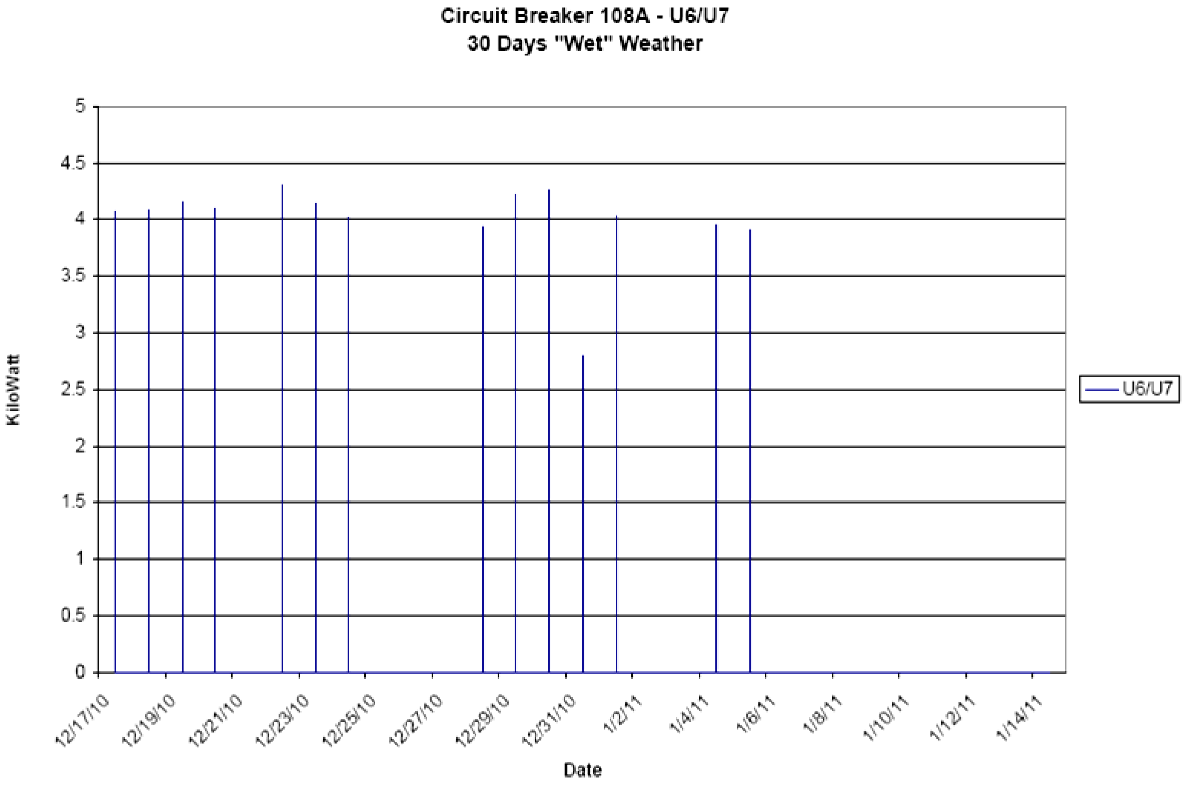

Figure 49 - Circuit Breaker 108A - U6/U7 (Based on 15-Minute Power Demand – Wet Weather)

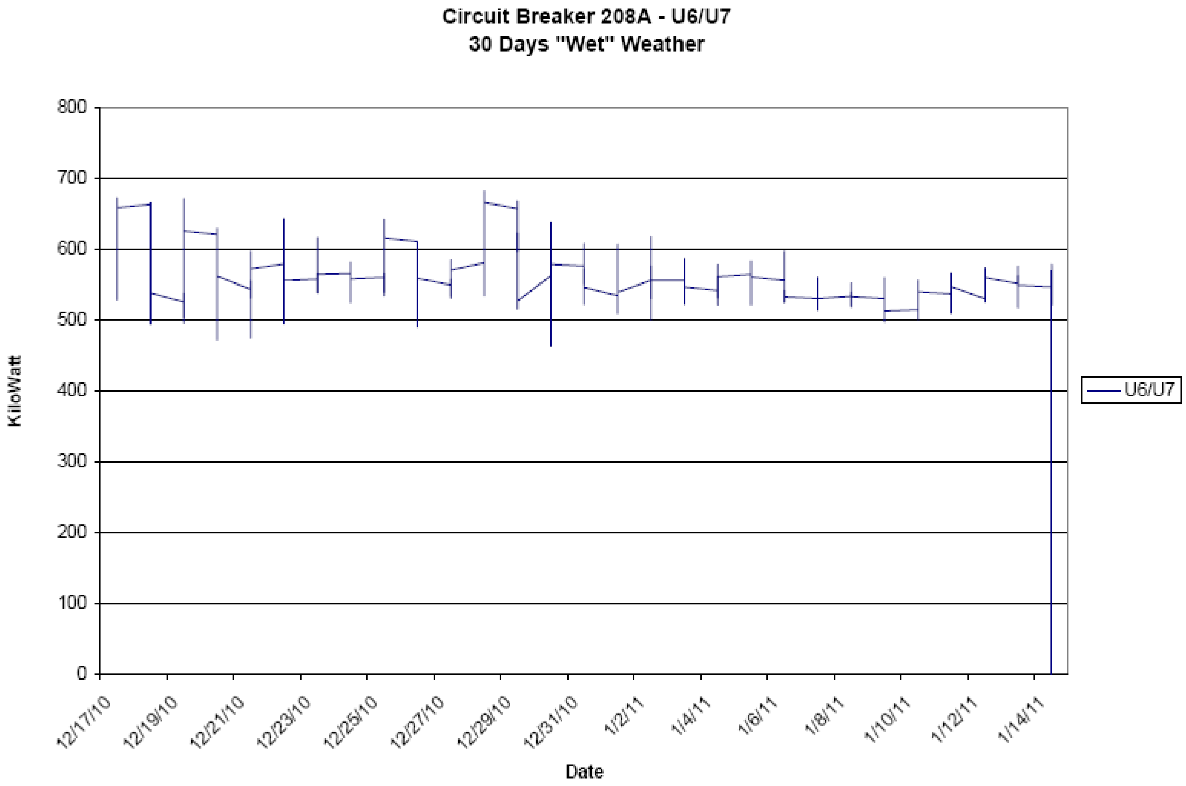

Figure 50 - Circuit Breaker 208A - U6/U7 (Based on 15-Minute Power Demand – Wet Weather)

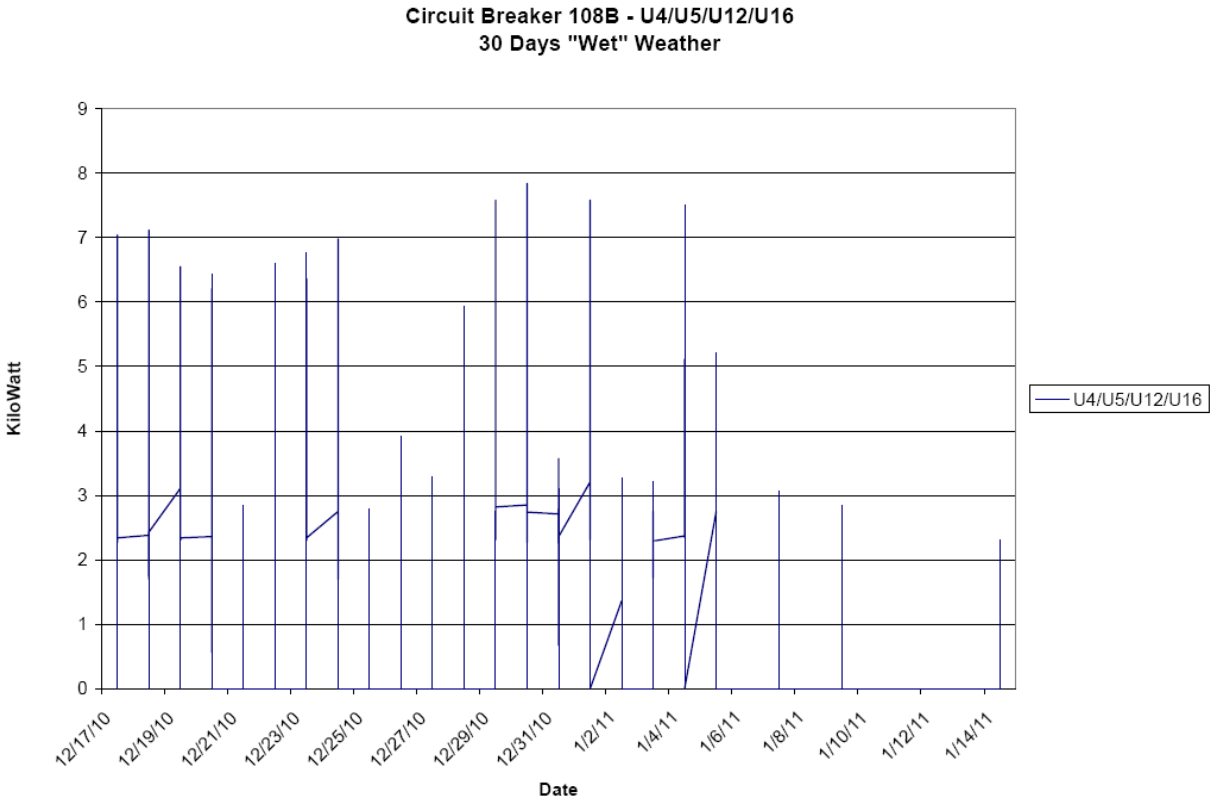

Figure 51 - Circuit Breaker 108B - U4/U5/U12/U16 (Based on 15-Minute Power Demand – Wet Weather)

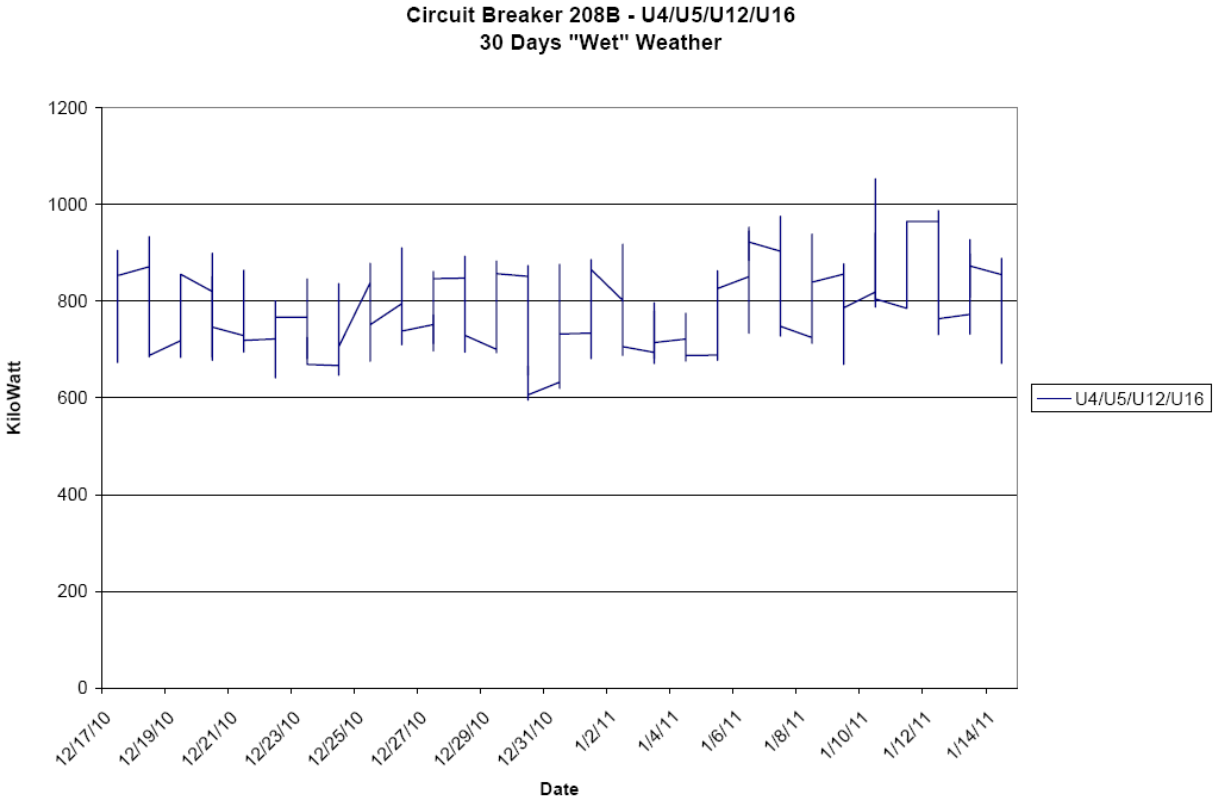

Figure 52 - Circuit Breaker 208B - U4/U5/U12/U16 (Based on 15-Minute Power Demand – Wet Weather)

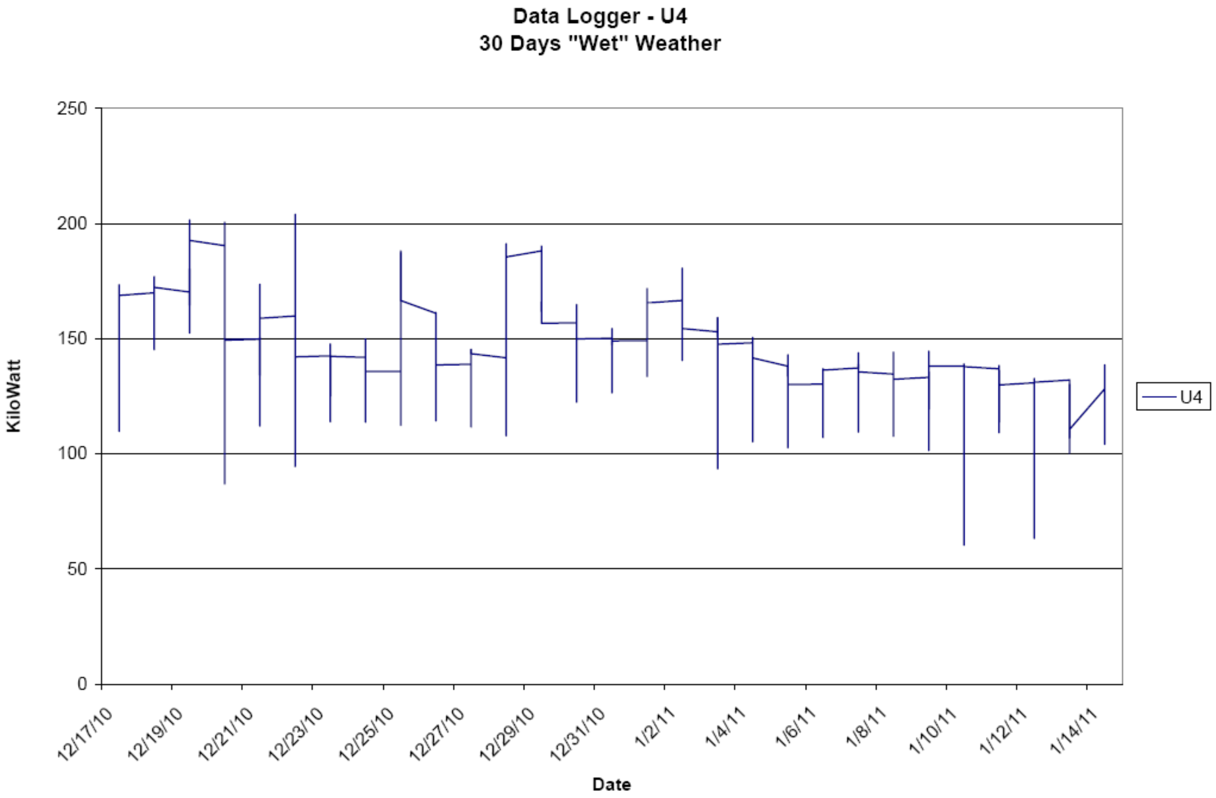

Figure 53 – Data Logger - U4 (Based on 15-Minute Power Demand – Wet Weather)

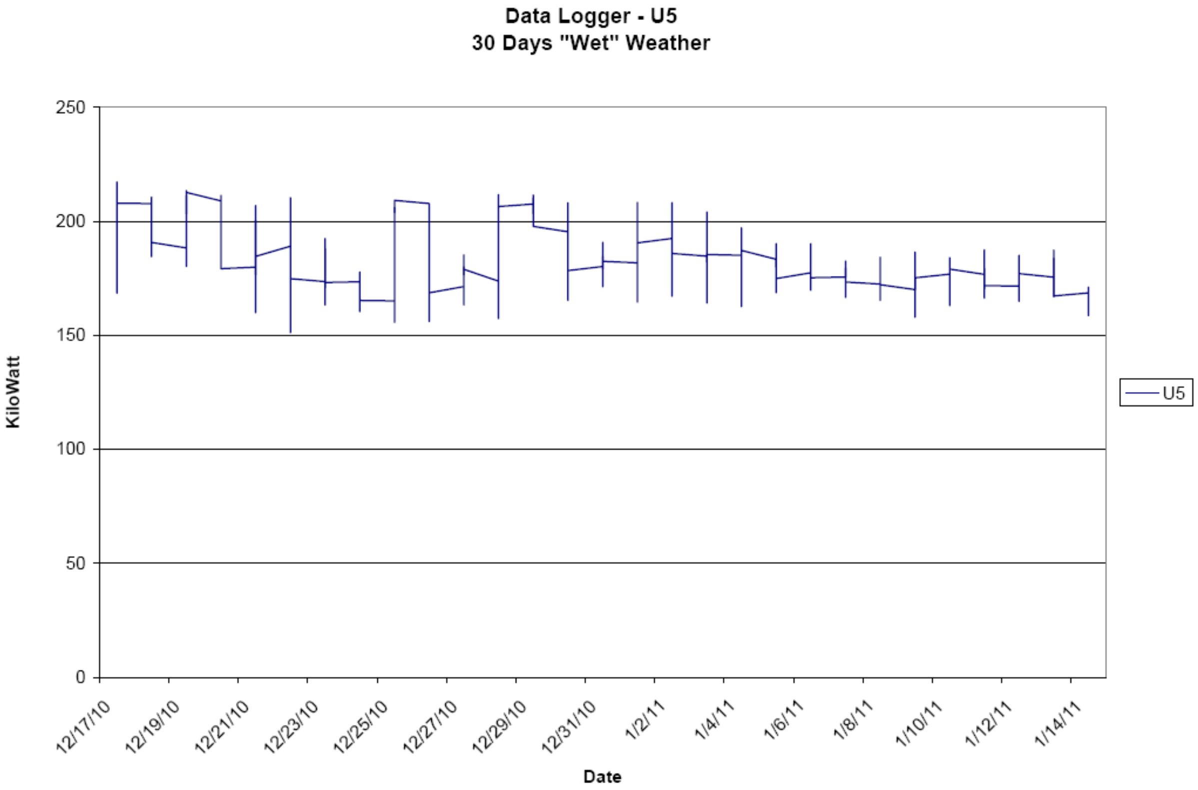

Figure 54 – Data Logger - U5 (Based on 15-Minute Power Demand – Wet Weather)

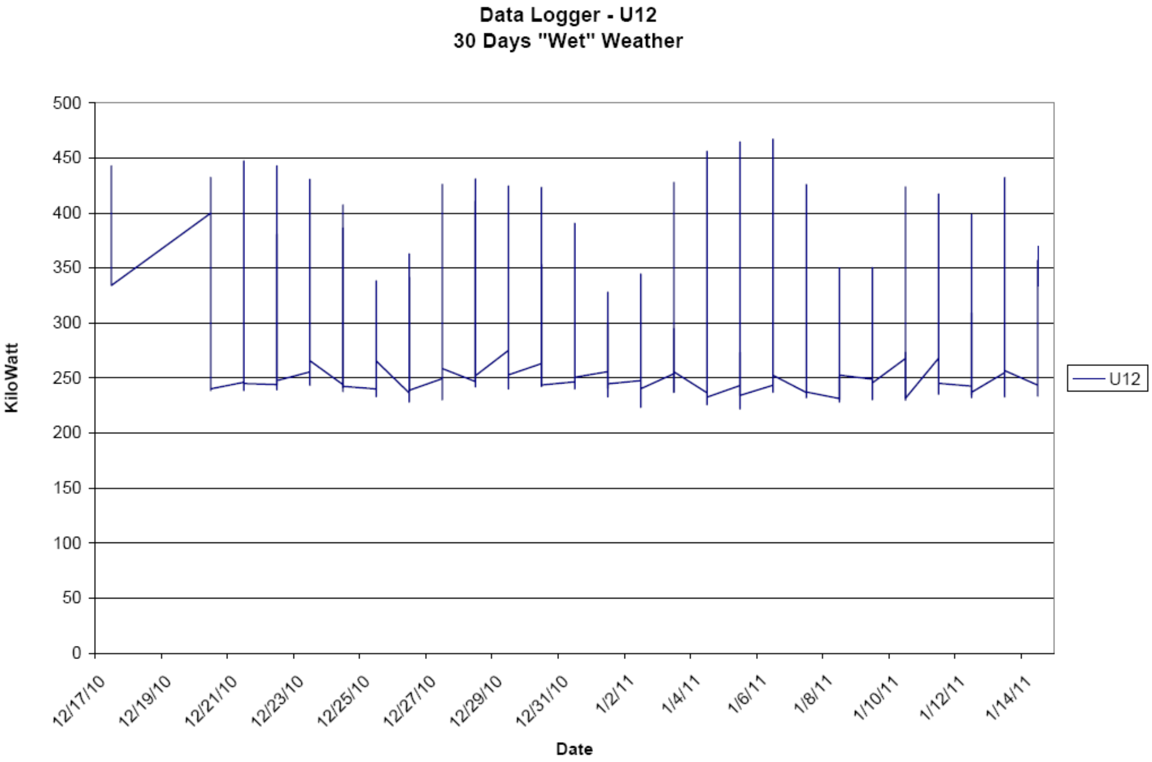

Figure 55 – Data Logger - U12 (Based on 15-Minute Power Demand – Wet Weather)

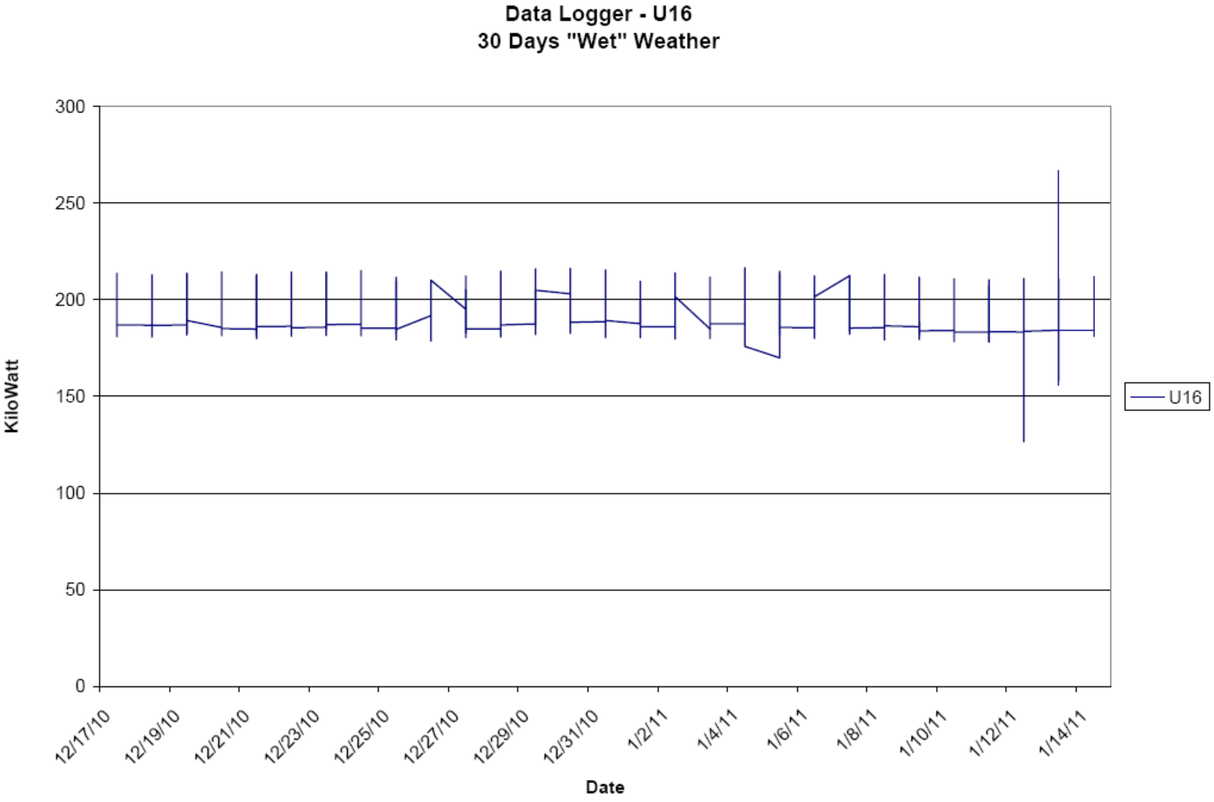

Figure 56 – Data Logger - U16 (Based on 15-Minute Power Demand – Wet Weather)

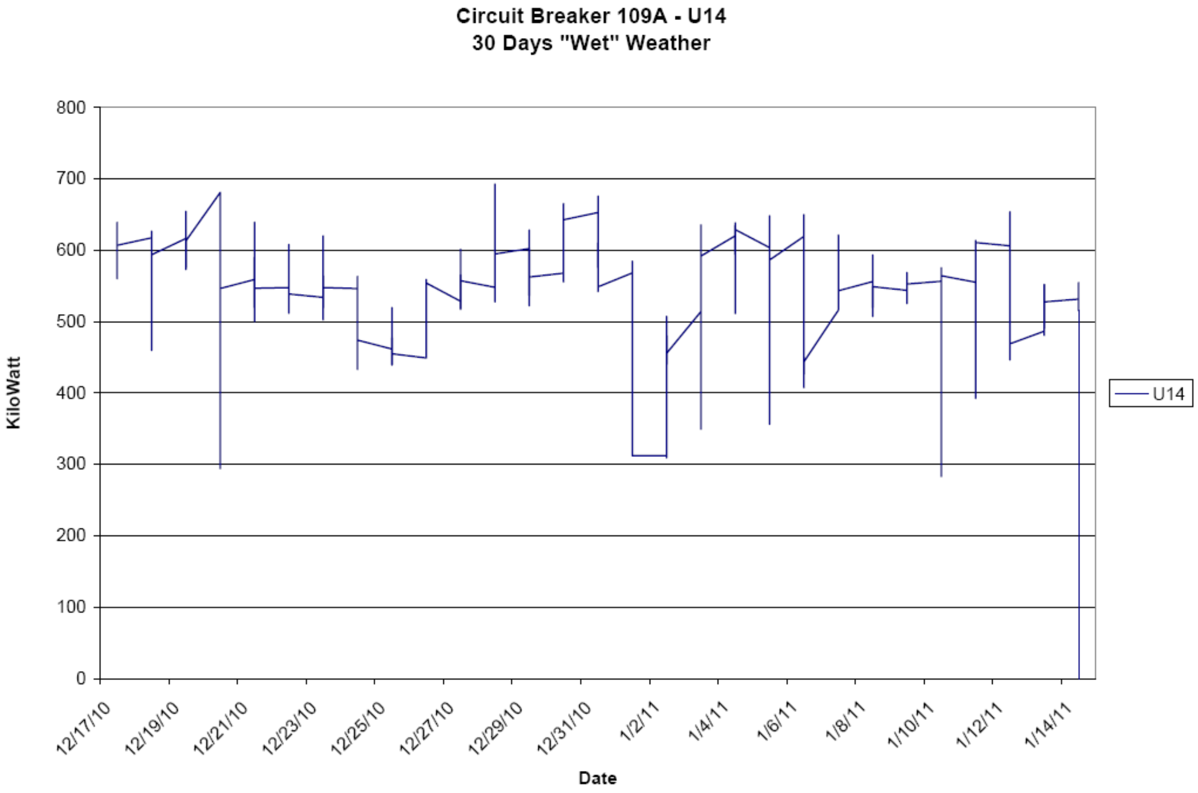

Figure 57 - Circuit Breaker 109A - U14 (Based on 15-Minute Power Demand – Wet Weather)

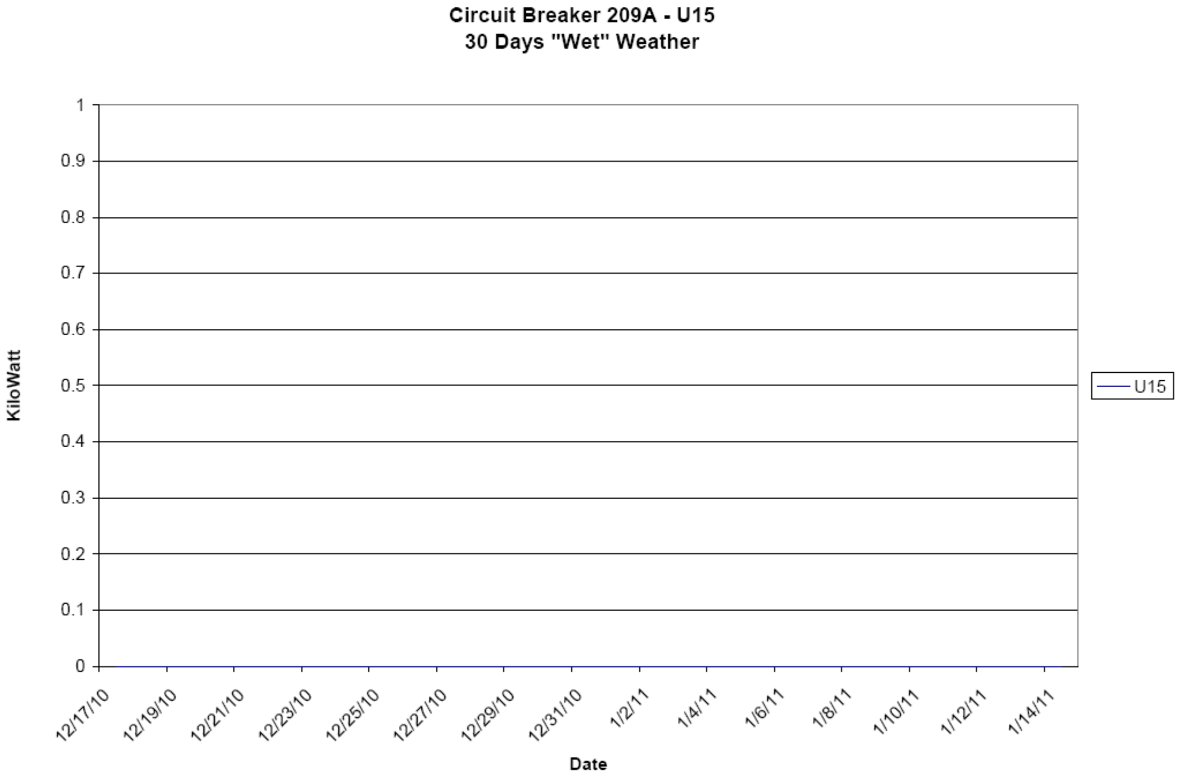

Figure 58 - Circuit Breaker 209A - U15 (Based on 15-Minute Power Demand – Wet Weather)

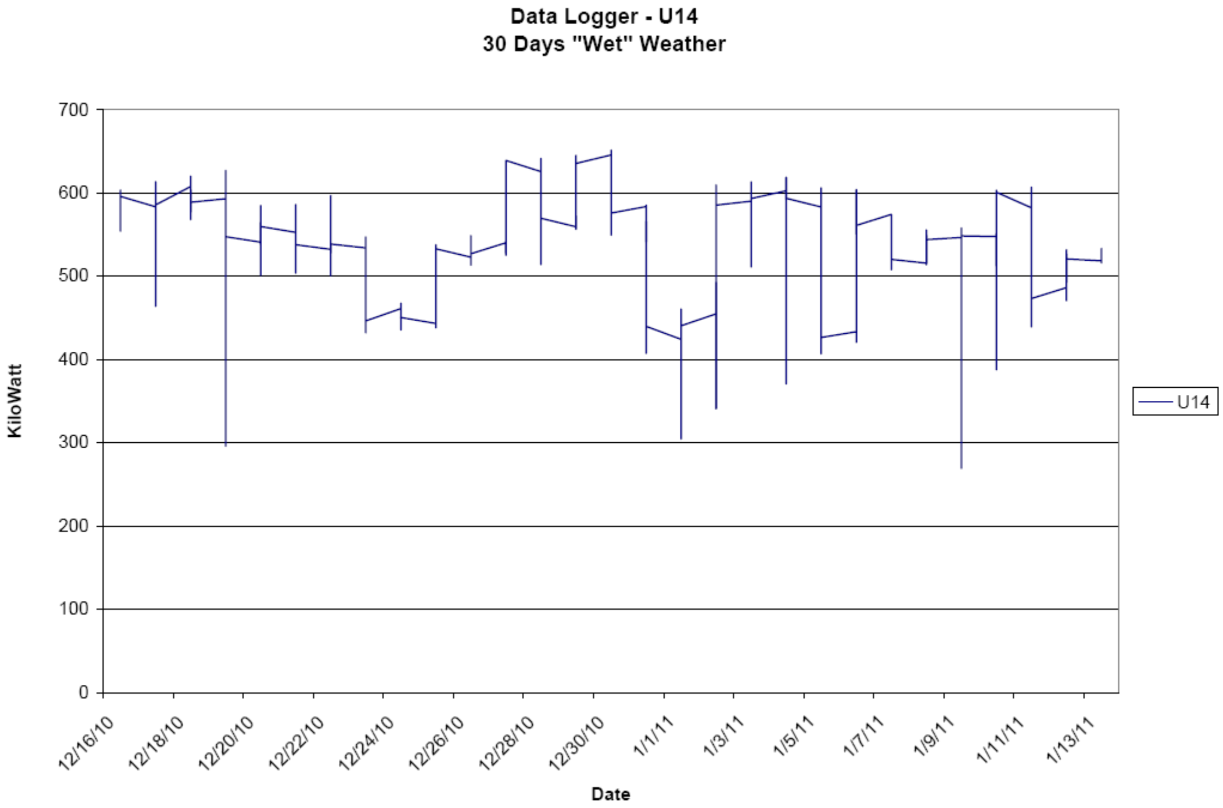

Figure 59 – Data Logger - U14 (Based on 15-Minute Power Demand – Wet Weather)

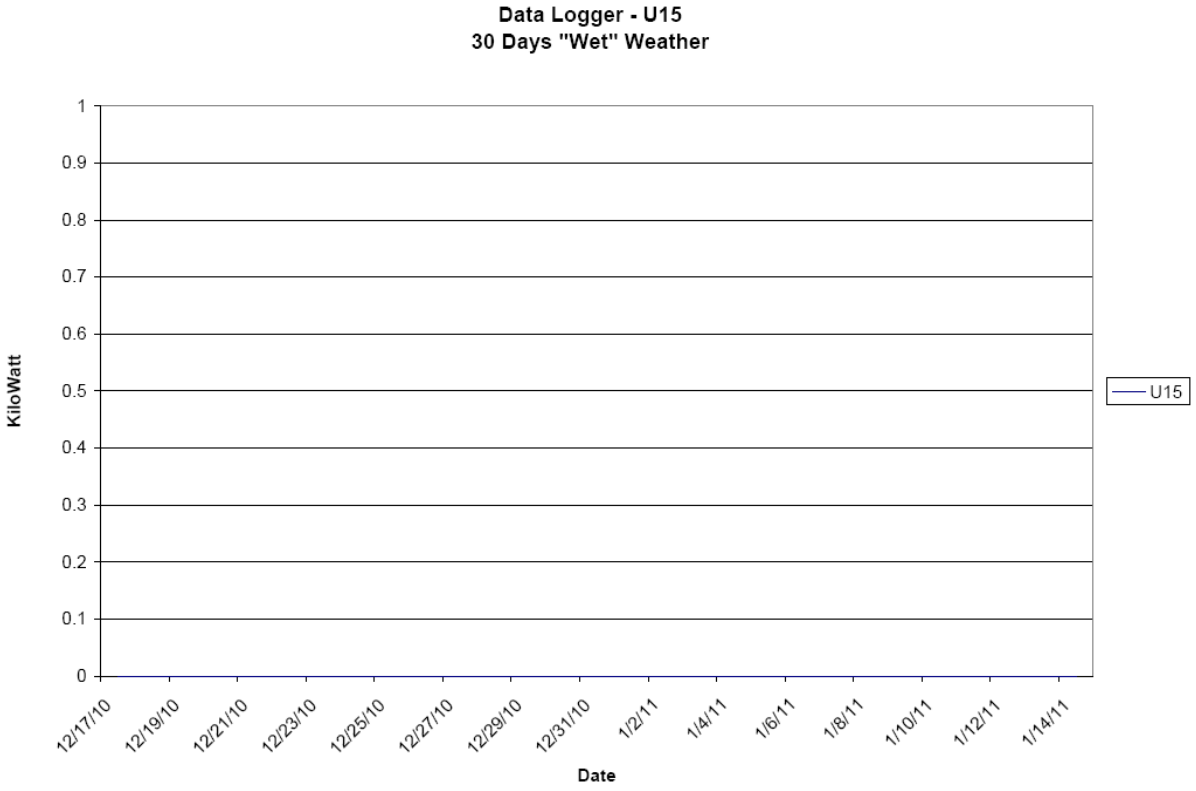

Figure 60 – Data Logger - U15 (Based on 15-Minute Power Demand – Wet Weather)

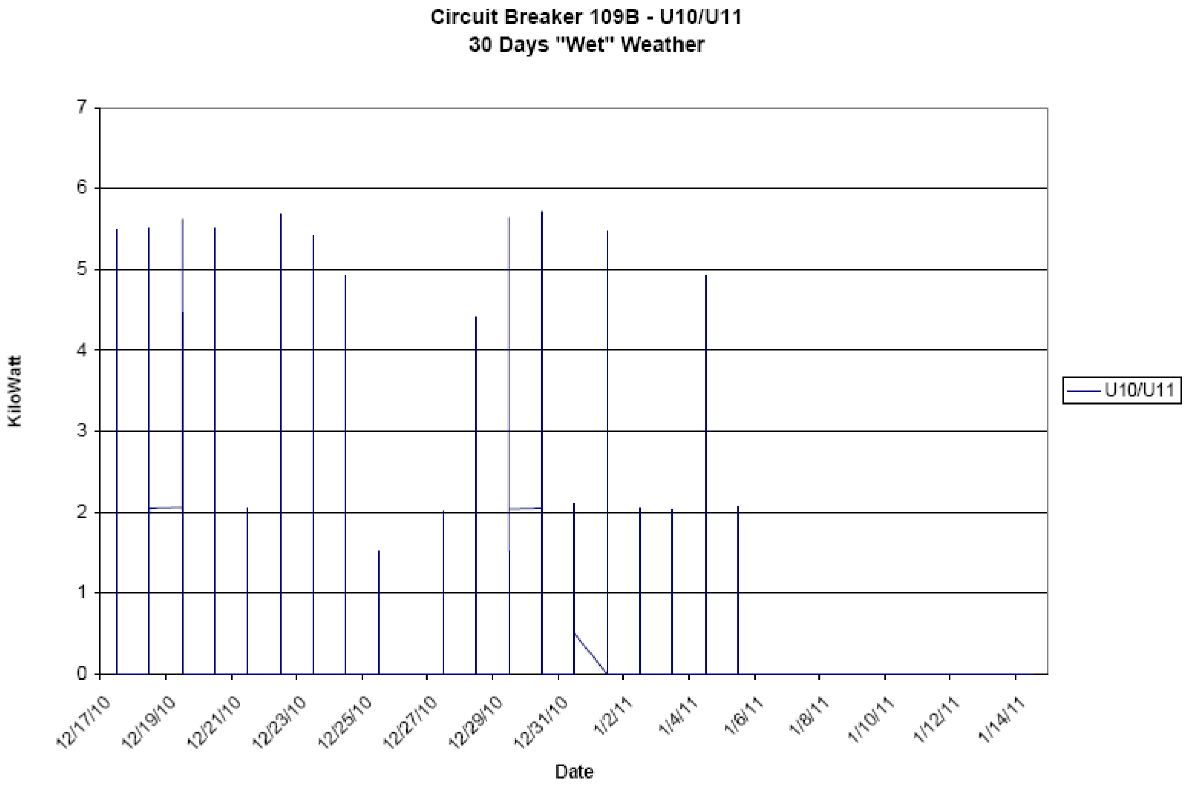

Figure 61 - Circuit Breaker 109B - U10/U11 (Based on 15-Minute Power Demand – Wet Weather)

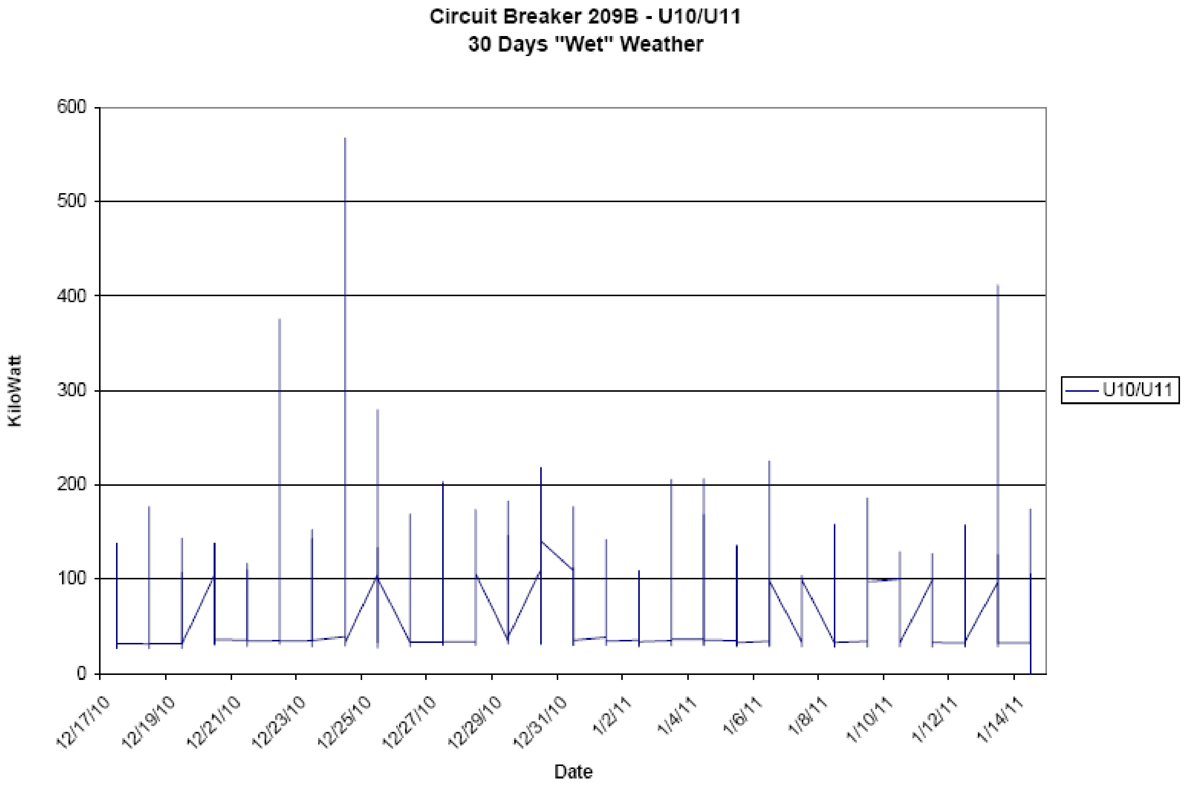

Figure 62 - Circuit Breaker 209B - U10/U11 (Based on 15-Minute Power Demand – Wet Weather)

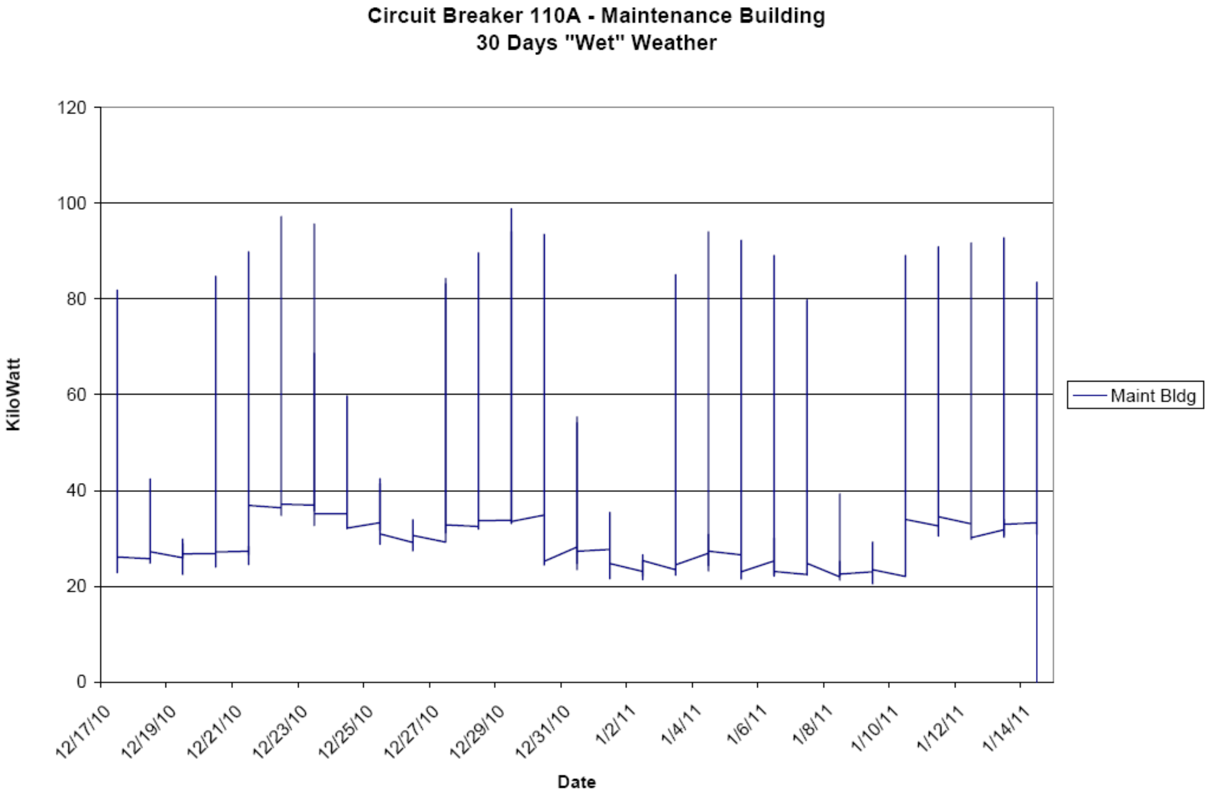

Figure 63 - Circuit Breaker 110A – Maintenance Building (Based on 15-Minute Power Demand – Wet Weather)

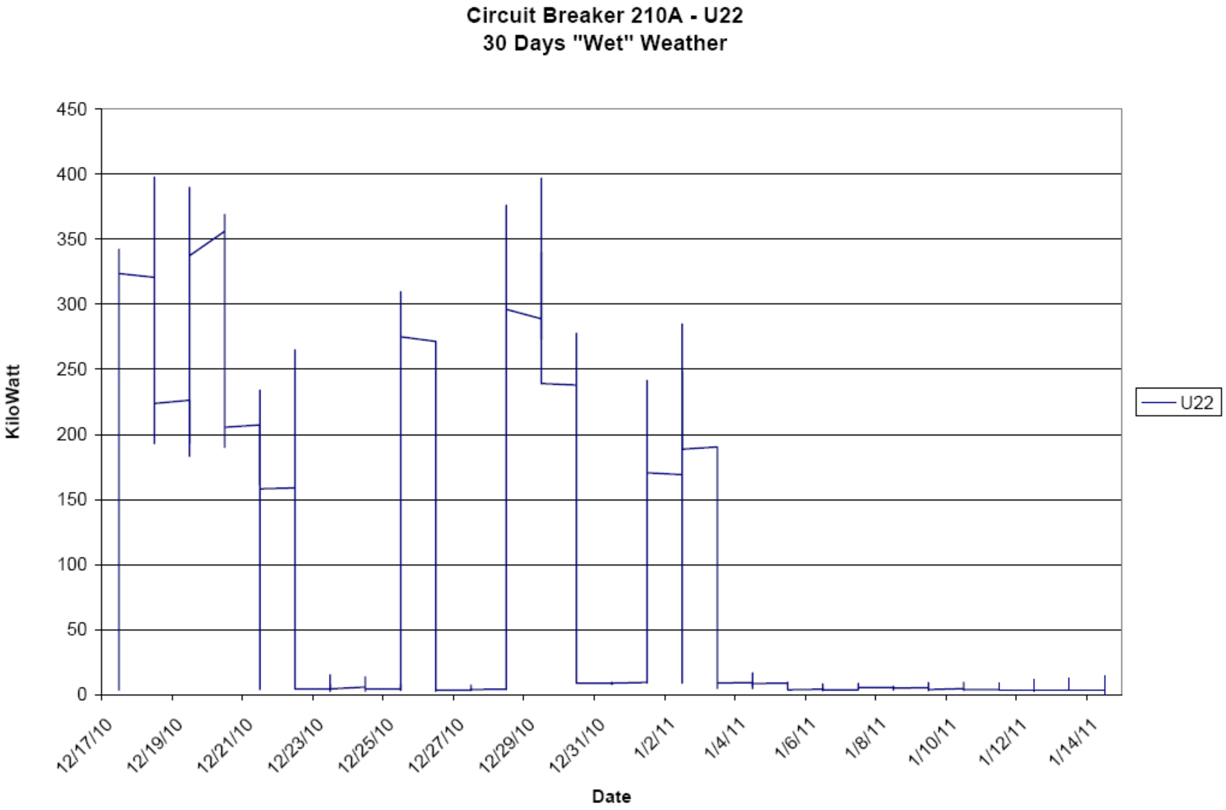

Figure 64 - Circuit Breaker 210A - U22 (Based on 15-Minute Power Demand – Wet Weather)

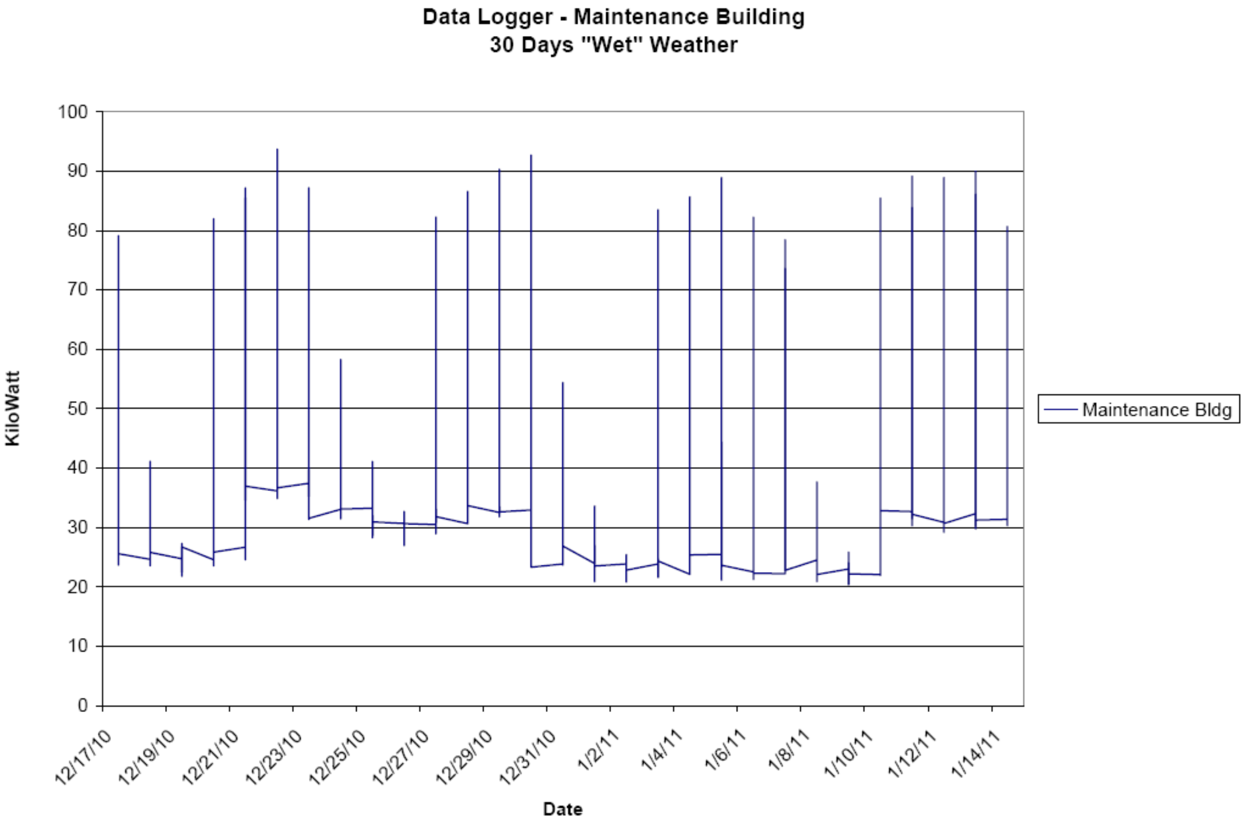

Figure 65 – Data Logger – Maintenance Building (Based on 15-Minute Power Demand – Wet Weather)

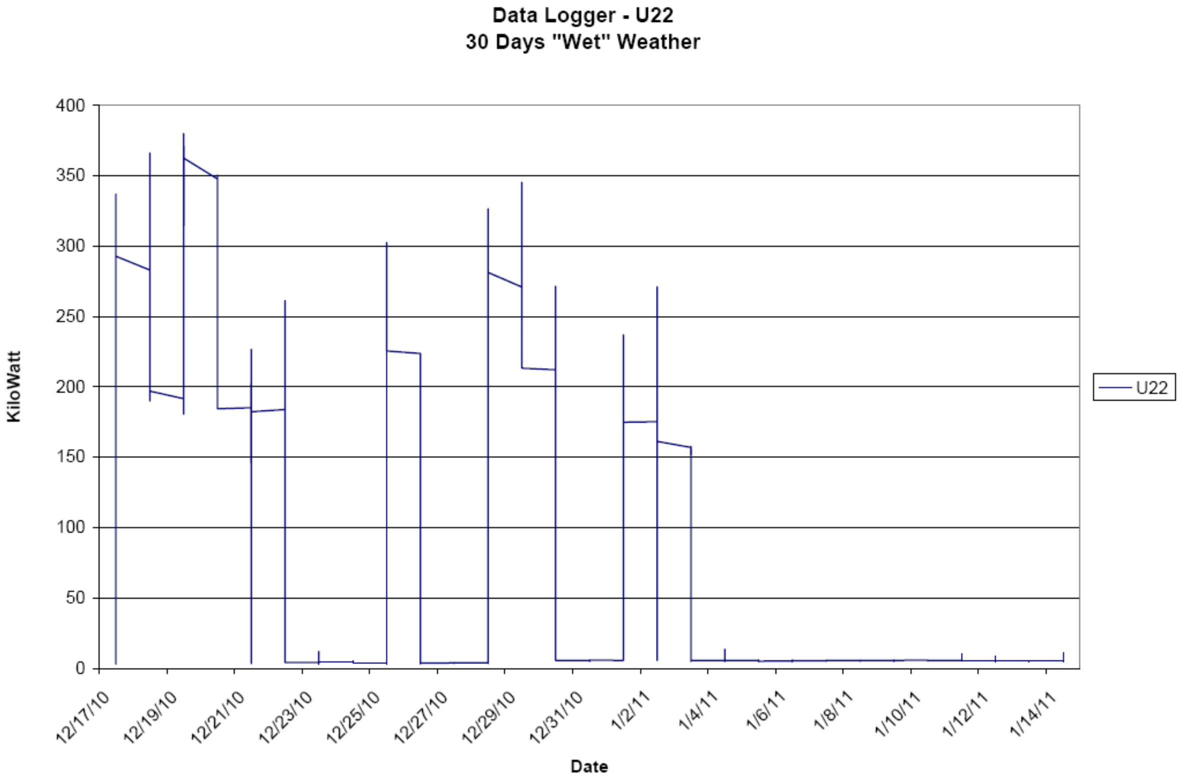

Figure 66 – Data Logger – U22 (Based on 15-Minute Power Demand – Wet Weather)

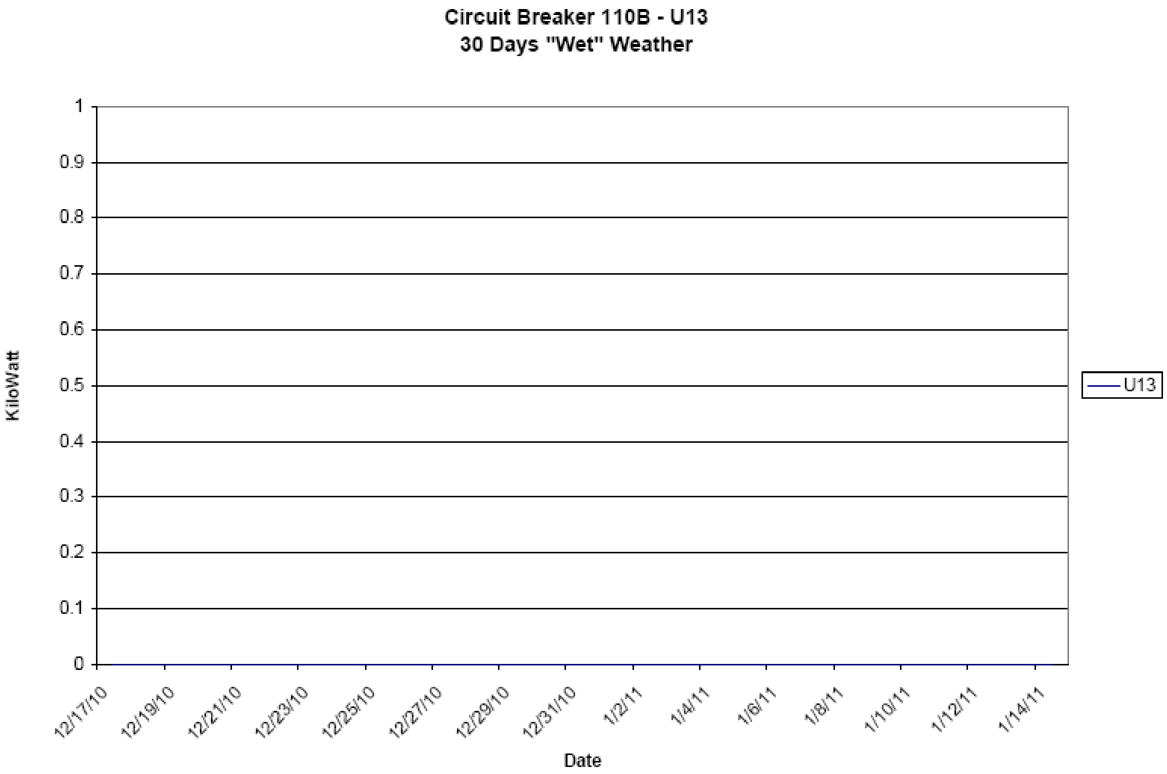

Figure 67 - Circuit Breaker 110B - U13 (Based on 15-Minute Power Demand – Wet Weather)

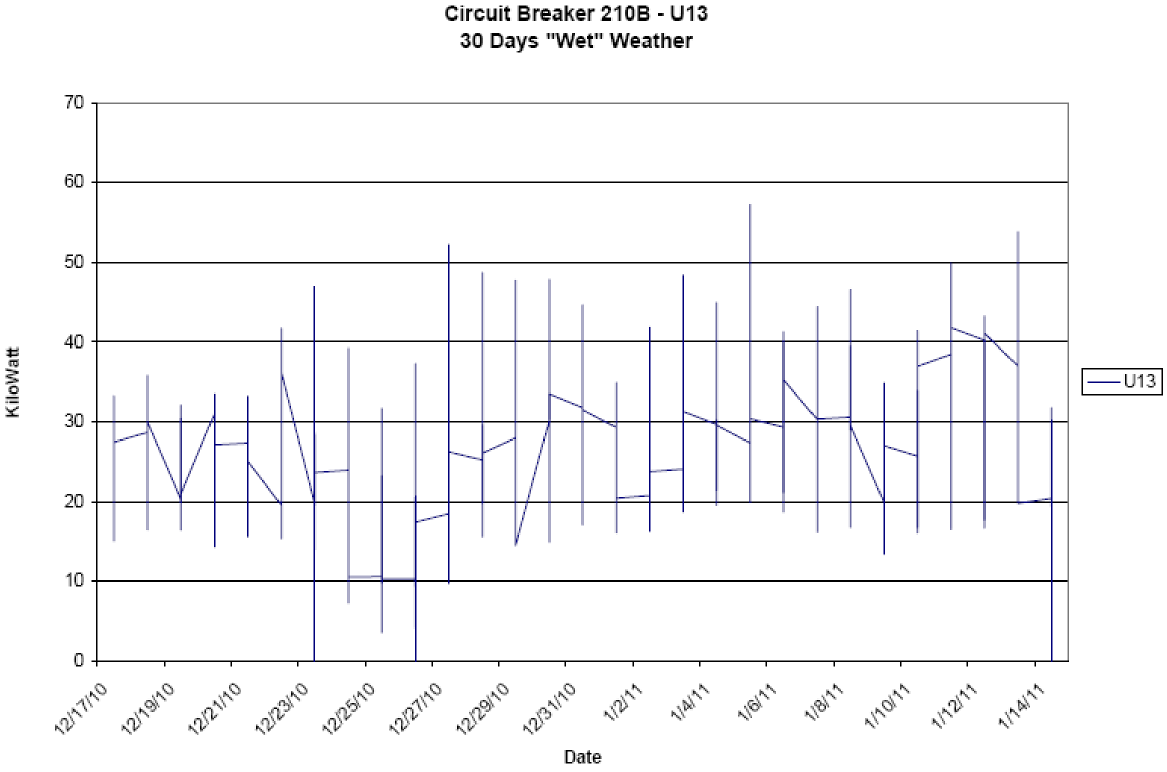

Figure 68 - Circuit Breaker 210B - U13 (Based on 15-Minute Power Demand – Wet Weather)

4.0 SUMMARY OF RESULTS

4.1 Substation Transformer Sizing

The following table summarizes the substation transformer sizes in comparison to the maximum demand loads. The total connected load at each substation transformer includes all loads, such as continuous loads and redundant loads. The maximum kW demand values were gathered from the DCS PI system and were based on a 15-minute interval from the past fifteen-year period. The maximum kVA values were calculated from the given kW values assuming a 0.8 power factor. The substation transformer usage percentage is based on the maximum demand value compared to the actual transformer size:

Substation Transformer	Transformer Size	Connected Load	Maximum Demand		Transformer Utilization
	kVA	kVA	kW	kVA	%
Substation U1	1,500	1.452	501	626	42
Substation U3	1,500	1,857	477	596	40
Substation U4/U5	1,000	1,404	1259 Footnote[5]	1,574	157
Substation U12	1,000	2,023	602 Footnote[6]	753	75
Substation U16	2,000	1,672	352 Footnote[7]	440	22
Substation U6/U7	2,000	1,662	960	1200	60
Substation U8/U9	2,000	1,446	873	1091	55
Substation U10/U11	1,500	1,462	760	950	63
Substation U13	750	655	299	374	50
Substation U14/U15	2,000	3,598	749	936	47
Substation U22	1,000	467	526 Footnote[8]	658	66
Maintenance	500	641	156 Footnote[9]	195	39
U20	1,500	906	Footnote 11	Footnote 11	Footnote 11
U21	1,500	607	Footnote 11	Footnote 11	Footnote 11
T5	500	169	Footnote 11	Footnote 11	Footnote 11
T6	500	245	Footnote 11	Footnote 11	Footnote 11

Table 4 - Transformer Sizing[10, 11]

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[5] Maximum demand is a combined value from three substations U4/U12/U16.
[6] Data is based on the 2011 report. No power usage is being recorded between 2011 and 2019.
[7] Data is based on the 2011 report. No power usage is being recorded between 2011 and 2019.
[8] Maximum demand is a combined value from two substations U22/Maintenance.
[9] Data is based on the 2011 report. No power usage is being recorded between 2011 and 2019.
[10] See Appendix B – Table 11 for dates in which maximum demand load occurred.
[11] Maximum demand load data is not available where indicated with Footnote 11.

The evaluation of each transformer's size shows that all the transformers are adequately sized to handle the maximum demand load along with sufficient capacity to handle future loads.

4.2 Feeder Cable Sizing

The following table summarizes the feeder cable size in comparison to the maximum demand load. The total connected load includes all loads, such as continuous loads and redundant loads. The maximum kW demand values were gathered from the DCS PI system and were based on a 15-minute interval from the past fifteen-year period. The maximum kVA values were calculated from the given kW values assuming a 0.8 power factor. The feeder cable ampacity usage percentage is based on the maximum demand value compared to the feeder ampacity value per the NEC:

Feeder Cable	Feeder Cable Size[7]	Feeder Ampacity per NEC	Connected Load	Maximum Demand		Ampacity Utilization
		Amps	Amps	kW	Amps	%
Cable for 103/203	12-750KCM CU	1200	2178	2575	447	37
Cable for 104/204	12-750KCM CU	1200	883	2387	414	35
Cable for 105A/205A	3-750KCM, 1#4/0 GND CU	400	1717	511	87	22
Cable for 105B/205B	3-750KCM, 1#4/0 GND CU	400	2234	477	83	21
Cable for 106A/206A	6-500KCM, 2#4/0 GND CU	640	639	2952	512	80
Cable for 106B/206B	6-500KCM, 2#4/0 GND CU	640	1793	873	151	24
Cable for 108A/208A	6-500KCM, 2#4/0 GND CU	640	1999	960	166	26
Cable for 108B/208B	6-500KCM, 2#4/0 GND CU	640	6134	1259	219	34
Cable for 109A/209A	6-500KCM, 2#4/0 GND CU	640	4449	749	130	20
Cable for 109B/209B	6-500KCM, 2#4/0 GND CU	640	1759	760	132	21
Cable for 110A/210A	3-750KCM, 1#4/0 GND CU	400	1550	526	91	23
Cable for 110B/210B	3-500KCM, 1#4/0 GND CU	320	787	299	52	16

Table 5 - Feeder Cable Sizing[12]

The evaluation of each feeder cable's size shows that all the feeders are adequately sized to handle the maximum weather demand load along with sufficient capacity to handle future loads.

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[12] See Appendix B – Table 12 for dates in which maximum demand load occurred.

4.3 Summary Sheet – “Dry” Weather Operation for 2019

The following table summarizes the “dry” weather operation for 2019 on all the feeder circuit breaker Connected Load, Maximum 15-minute Demand Load, and Average 15-minute Demand Load. The maximum and average demand loads were evaluated from the data retrieved from each feeder’s PQM:

Circuit Breaker	Connected Load	Maximum Demand Load	Average Demand Load
	kW	kW	kW
103	3273	1097	616
104	3058	286	42
105A	1162	0	0
105B	1486	229	138
106A	1842	1958	990
106B	1157	0	0
108A	1330	0	0
108B	1126	0	0
109A	2878	618	496
109B	1170	0	0
110A	1031	152	55
110B	524	0	0
203	3273	0	0
204	3058	261	26
205A	1162	169	44
205B	1486	2	0
206A	1842	720	0
206B	1157	581	436
208A	1330	563	479
208B	1126	1112	903
209A	2878	7	2
209B	1170	293	74
210A	1031	209	11
210B	524	139	26

Table 6 - "Dry" Weather Summary

4.4 Summary Sheet – “Wet” Weather Operation for 2019

The following table summarizes the “wet” weather operation for 2019 on all the feeder circuit breaker Connected Load, Maximum 15-minute Demand Load, and Average 15-minute Demand Load. The maximum and average demand loads were evaluated from the data retrieved from each feeder’s PQM:

Circuit Breaker	Connected Load	Maximum Demand Load	Average Demand Load
	kW	kW	kW
103	3273	2323	680
104	3058	1538	74
105A	1162	0	0
105B	1486	329	160
106A	1842	1928	682
106B	1157	686	143
108A	1330	591	126
108B	1126	0	0
109A	2878	749	527
109B	1170	0	0
110A	1031	152	50
110B	524	0	0
203	3273	0	0
204	3058	775	33
205A	1162	511	258
205B	1486	2	0
206A	1842	1719	393
206B	1157	730	320
208A	1330	785	389
208B	1126	1166	896
209A	2878	7	2
209B	1170	676	76
210A	1031	432	45
210B	524	152	22

Table 7 - "Wet" Weather Summary

5.0 RECOMMENDATIONS

Based on the current maximum demand values from the last fifteen years, all the substation transformers and cable feeders are sized adequately for the necessary load. This load study did not find any deficiencies which require corrective action. As the MWWTP power demand continues to grow, it is recommended that a similar load study be conducted every five years to document the total plant demand load.

As stated in Table 1, the current connected load of 30.0 MVA is based on the present configuration. Currently the plant has several projects under construction that will increase the connected load in the plant. The new connected load is already accounted for in this study.

APPENDICES

Appendix A – List of dates and times where no data was displayed in DCS PI System

Appendix B – List of dates and times where Maximum Demand occurred in DCS PI

Appendix C – Average Daily Value Graphs for each Feeder Breaker

Appendix D – Load Demand Distribution by Area from 2004 to 2019

Appendix A – List of dates and times where no data was displayed in DCS PI System

From	To	Notes
2/3/2004 8:45	2/3/2004 9:45	No data
2/4/2004 10:30	2/4/2004 11:00	No data
4/10/2004 9:45	4/12/2004 9:30	Bad data
7/2/2004 7:15	7/2/2004 10:00	Bad data
8/29/2004 10:30	8/29/2004 11:00	No data
10/31/2004 3:00	11/8/2004 10:00	No data
7/10/2005 9:30	7/18/2005 8:00	Bad data
7/18/2005 8:00	7/26/2005 8:15	No data
12/18/2005 5:45	12/18/2005 7:15	Bad data
11/9/2006 12:00	11/10/2006 12:15	No data
11/21/2006 8:15	11/21/2006 10:45	No data
11/22/2006 18:45	11/27/2006 2:30	Bad data
1/9/2007 10:15	1/9/2007 16:00	No data
1/9/2007 19:00	1/9/2007 19:45	No data
1/10/2007 9:45	1/10/2007 11:15	No data
6/13/2007 2:15	6/13/2007 2:45	No data
6/13/2007 3:00	6/13/2007 3:30	No data
6/13/2007 9:30	6/13/2007 10:15	No data
6/13/2007 15:00	6/13/2007 15:15	No data
8/15/2007 6:00	8/15/2007 7:30	No data
5/22/2008 11:15	5/22/2008 14:45	Bad data
10/25/2008 0:30	10/31/2008 13:15	Bad data
6/11/2009 9:30	6/11/2009 11:00	No data
9/22/2009 3:15	9/22/2009 6:15	No data
11/10/2009 7:30	6/24/2010 9:00	Bad data
8/24/2010 8:15	8/27/2010 14:00	No data
9/30/2010 1:30	9/30/2010 6:00	Bad data
10/12/2010 2:00	10/12/2010 6:30	Bad data
10/19/2010 8:30	10/21/2010 12:45	Bad data
9/15/2011 8:30	9/21/2011 14:30	Bad data
9/21/201114:30	9/28/2011 3:00	No data
6/24/2014 9:45	6/24/2014 10:30	No data
12/4/2014 9:30	12/4/2014 5:00	Bad data
12/4/2014 5:00	12/9/2014 7:45	No data
9/29/2015 8:30	9/29/2015 15:00	No data
12/16/2015 10:00	12/16/2015 15:15	No data
12/23/2015 13:30	12/23/2015 14:00	No data
1/22/2016 12:30	1/25/2016 16:00	No data
8/3/2016 11:30	8/3/2016 11:45	No data
8/16/2016 12:15	8/19/2016 13:15	No data
8/19/2016 2:30	8/25/2016 11:30	No data
8/26/2016 10:45	8/26/2016 11:00	No data
9/16/2016 18:45	9/16/2016 19:30	No data
10/11/2016 14:45	10/12/2016 10:00	No data
1/10/2017 23:30	1/11/201 1:30	Bad data
3/14/2017 14:15	3/14/2017 14:45	No data
3/27/2017 8:45	3/28/2017 10:30	No data
6/23/2017 3:00	6/23/2017 3:45	Bad data
6/18/2018 2:45	6/20/2018 12:30	No data

Table 8 - List of dates and times where no data was displayed in DCS PI system

Appendix B – List of dates and times where Maximum Demand occurred in DCS PI within that last fifteen years

Weather Period	Date	Maximum Demand Load
		kW
Wet	12/11/2014 10:00	10,647
Dry	6/4/2011 12:45	7,534

Table 9 - "Wet" and "Dry" Weather Maximum Demand Load

Substation	Date	Maximum Demand Load
		kW
Substation U1	4/5/2018 12:30	501
Substation U3	4/3/2008 9:45	477
Substation U4/U5/U12/U16	9/6/2013 13:45	1259
Substation U6/U7	12/27/2004 5:45	960
Substation U8/U9	10/19/2004 11:00	873
Substation U10/U11	2/15/2005 21:00	760
Substation U12	12/29/2010 10:35	602, Footnote[13]
Substation U13	5/22/2009 21:30	299
Substation U14/U15	3/1/2019 11:30	749
Substation U16	9/13/2010 12:00	352, Footnote[14]
Substation U22/Maintenance	3/7/2006 10:00	526
Maintenance	8/24/2010 15:23	156, Footnote[15]

Table 10 - Substation Transformer Maximum Demand Load

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[13] Data is based on the 2011 report. No power usage is being recorded between 2011 and 2019.
[14] Data is based on the 2011 report. No power usage is being recorded between 2011 and 2019.
[15] Data is based on the 2011 report. No power usage is being recorded between 2011 and 2019.

Feeder Cable	Date	Maximum Demand Load
		A
Cable for 103/203	1/4/2008 13:00	447
Cable for 104/204	10/13/2009 16:30	414
Cable for 105A/205A	5/4/2018 12:30	87
Cable for 105B/205B	4/3/2008 9:45	83
Cable for 106A/206A	8/14/2009 14:00	512
Cable for 106B/206B	10/19/2004 11:00	151
Cable for 108A/208A	12/27/2004 5:45	166
Cable for 108B/208B	9/6/2013 13:45	219
Cable for 109A/209A	3/3/2019 11:30	130
Cable for 109B/209B	5/15/2005 21:00	132
Cable for 110A/210A	12/19/2010 21:45	91
Cable for 110B/210B	5/22/2009 21:30	52

Table 11 **- Feeder Cable Maximum Demand Load**

Appendix C - Average Daily Value Graphs for each Feeder Breaker

The data for the following graphs were gathered from DCS PI system. The data is the average daily value from January 1, 2004 to December 15, 2019. The graphs provide a perspective of the power demand load trend for each feeder over the past fifteen years.

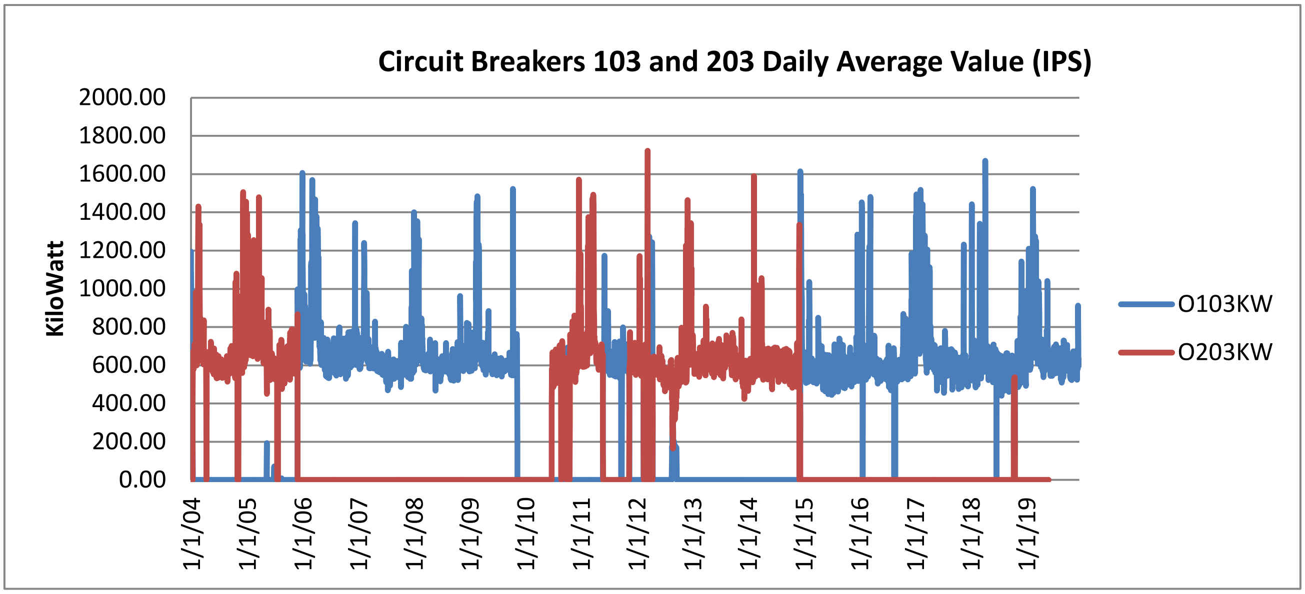

Figure 69 - Circuit Breakers 103 and 203 (Average Daily Power Demand)

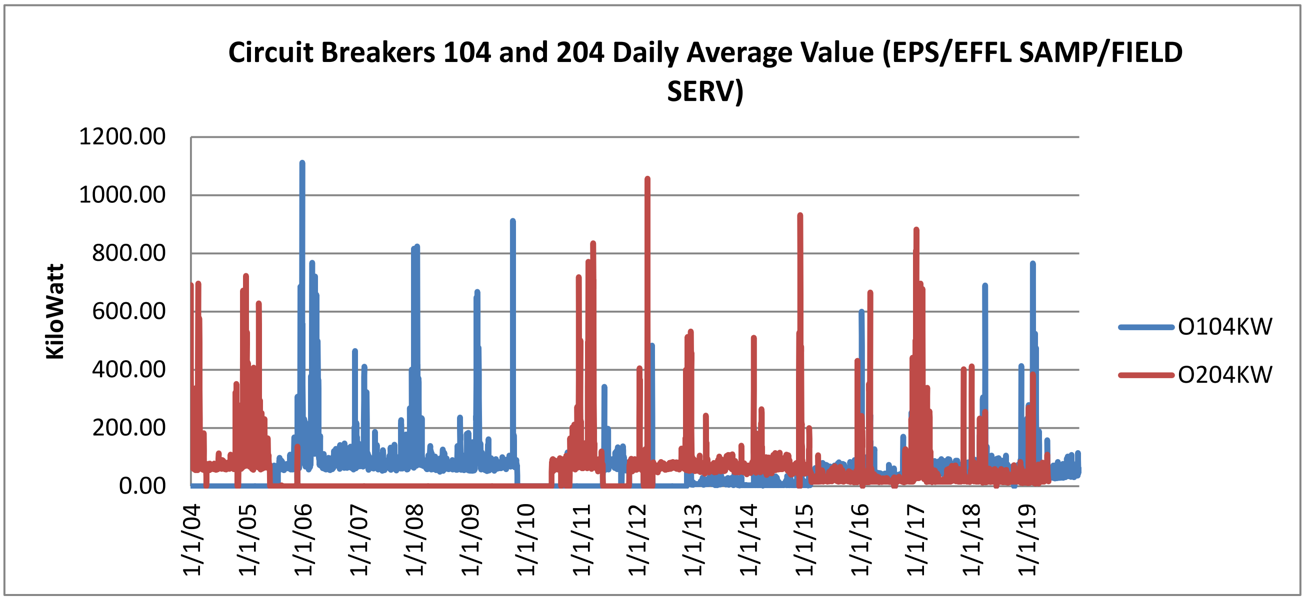

Figure 70 - Circuit Breakers 104 and 204 (Average Daily Power Demand)

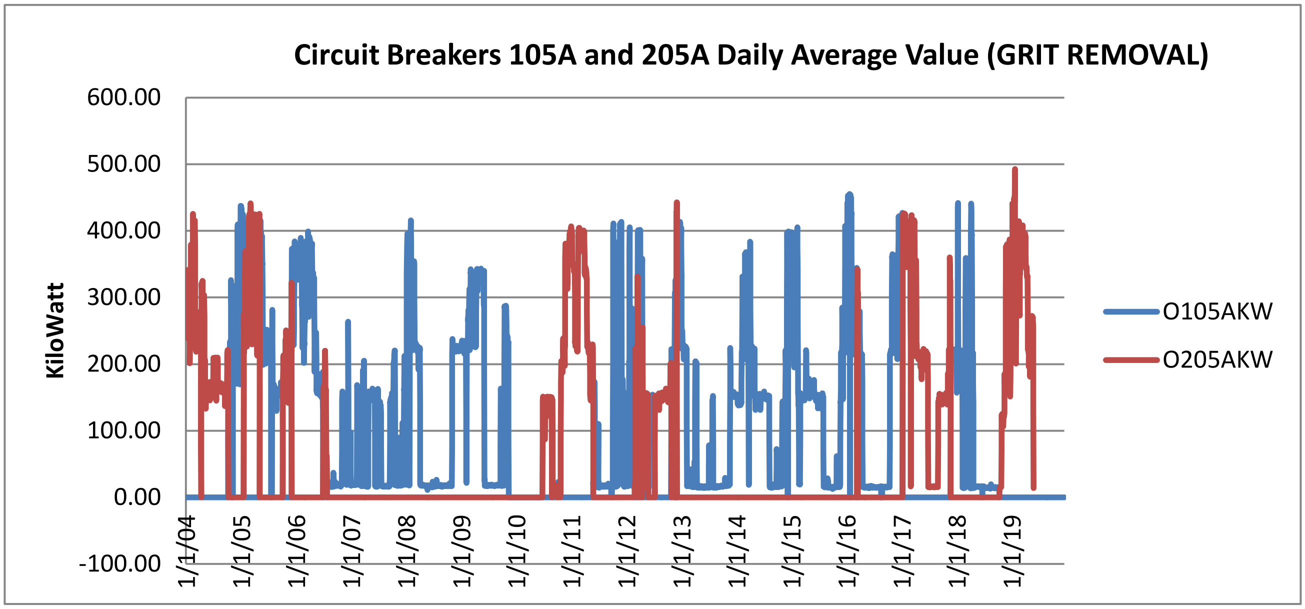

Figure 71 - Circuit Breakers 105A and 205A (Average Daily Power Demand)

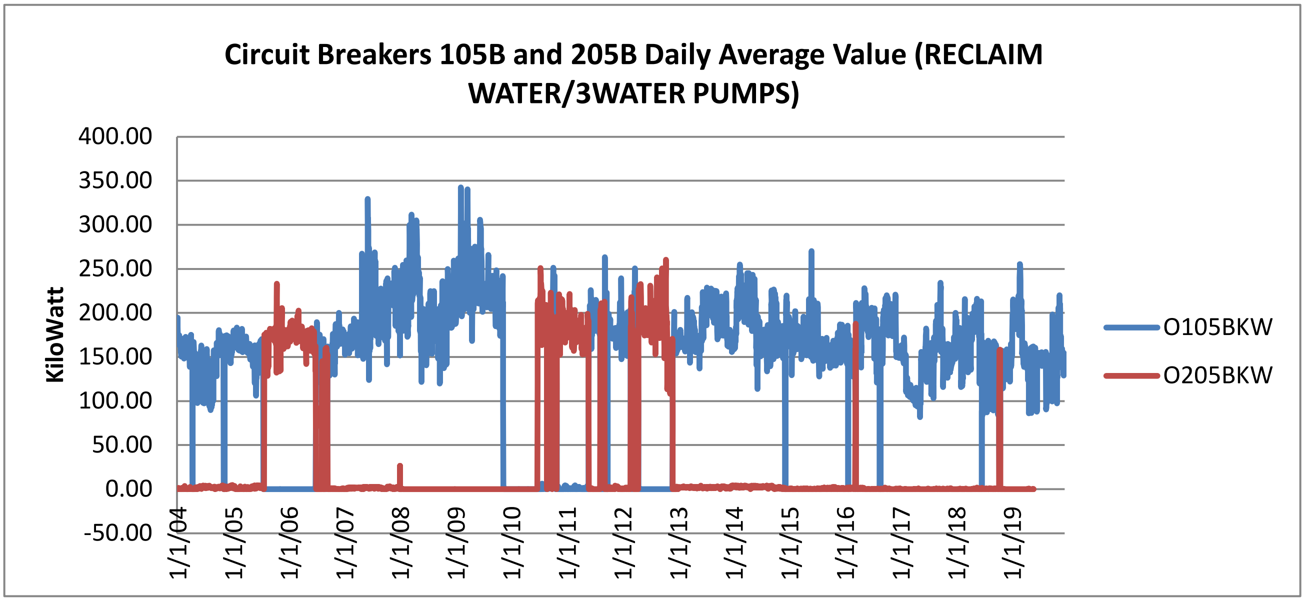

Figure 72 - Circuit Breakers 105B and 205B (Average Daily Power Demand)

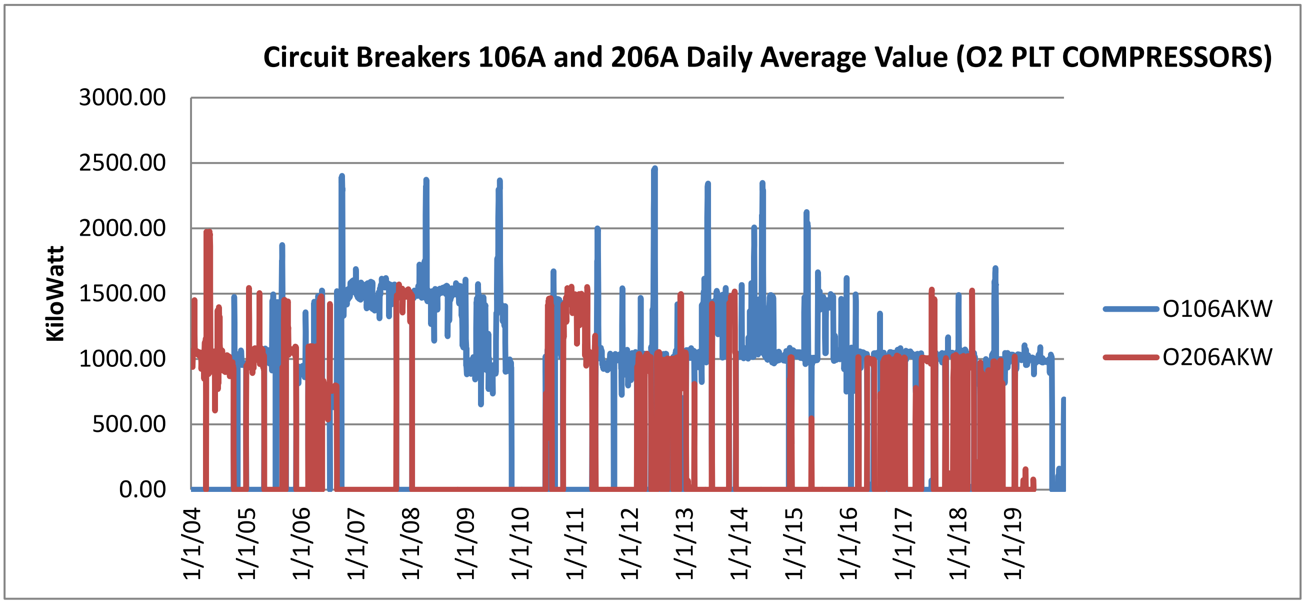

Figure 73 - Circuit Breakers 106A and 206A (Average Daily Power Demand)

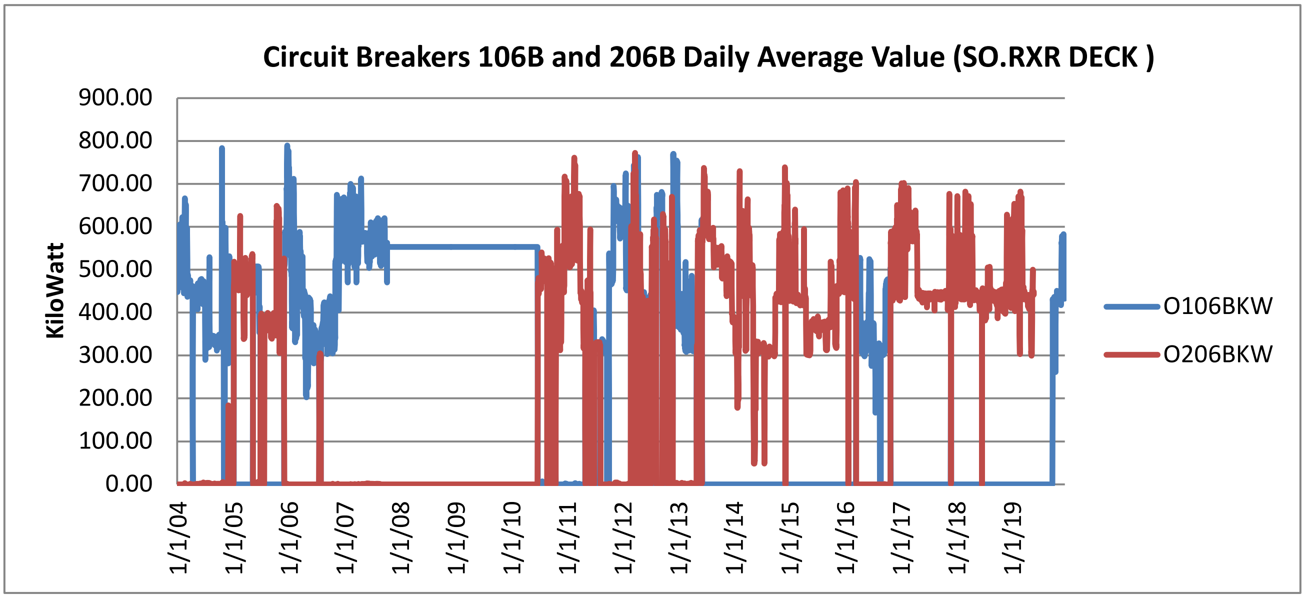

Figure 74 - Circuit Breakers 106B and 206B (Average Daily Power Demand)

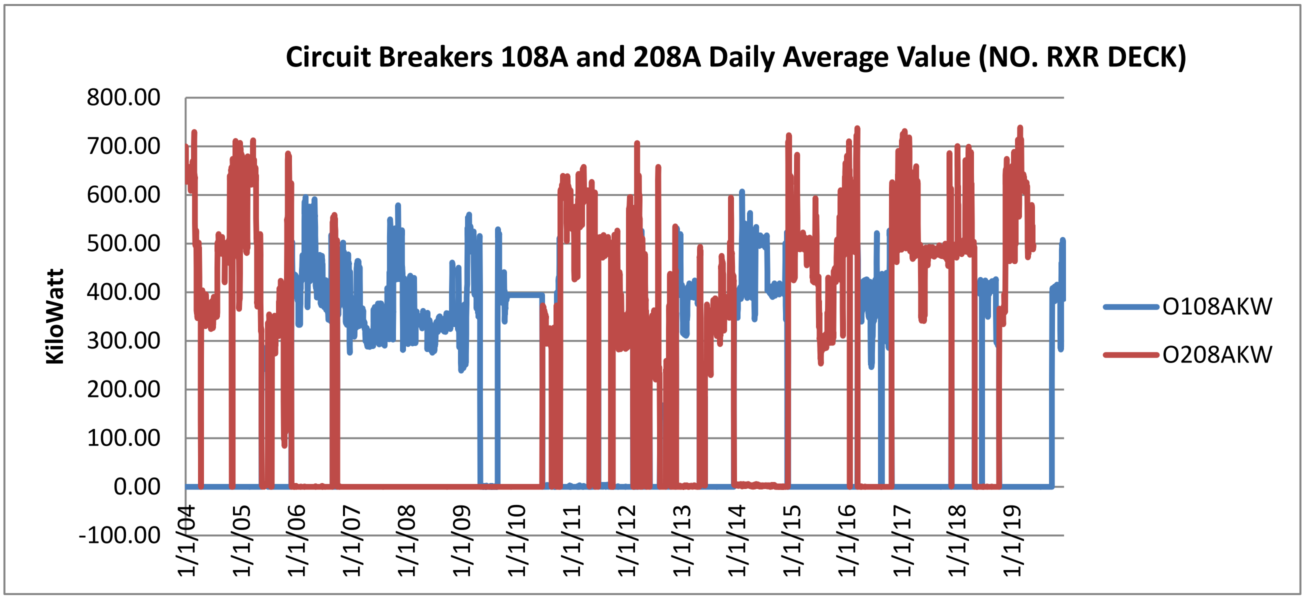

Figure 75 - Circuit Breakers 108A and 208A (Average Daily Power Demand)

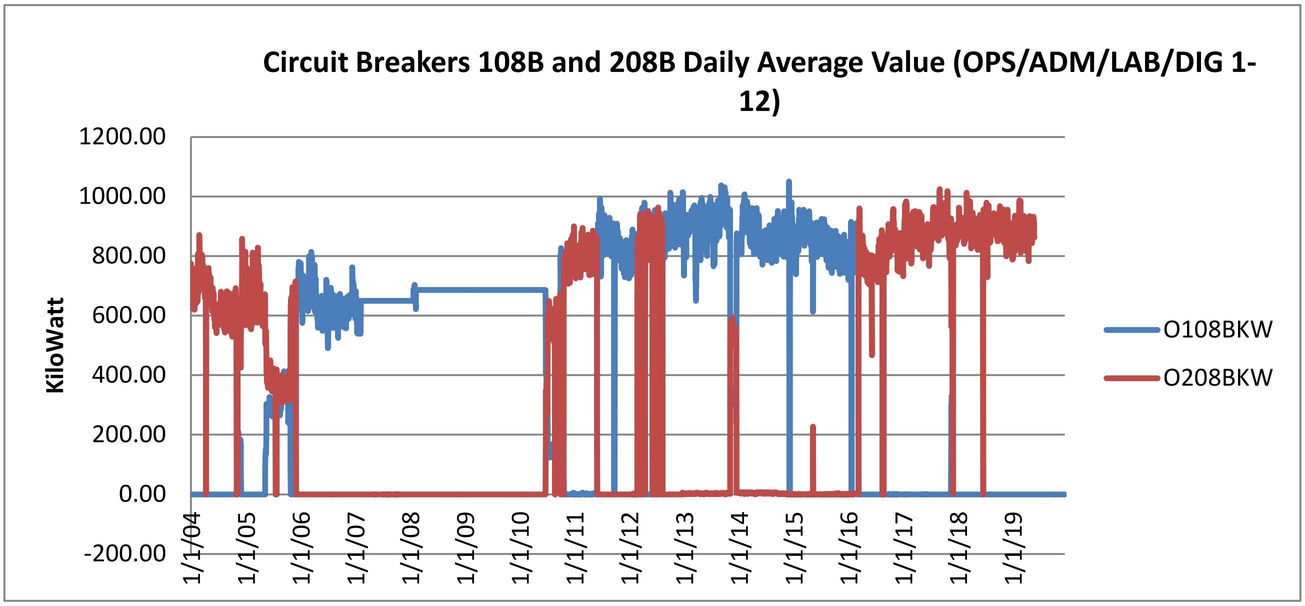

Figure 76 - Circuit Breakers 108B and 208B (Average Daily Power Demand)

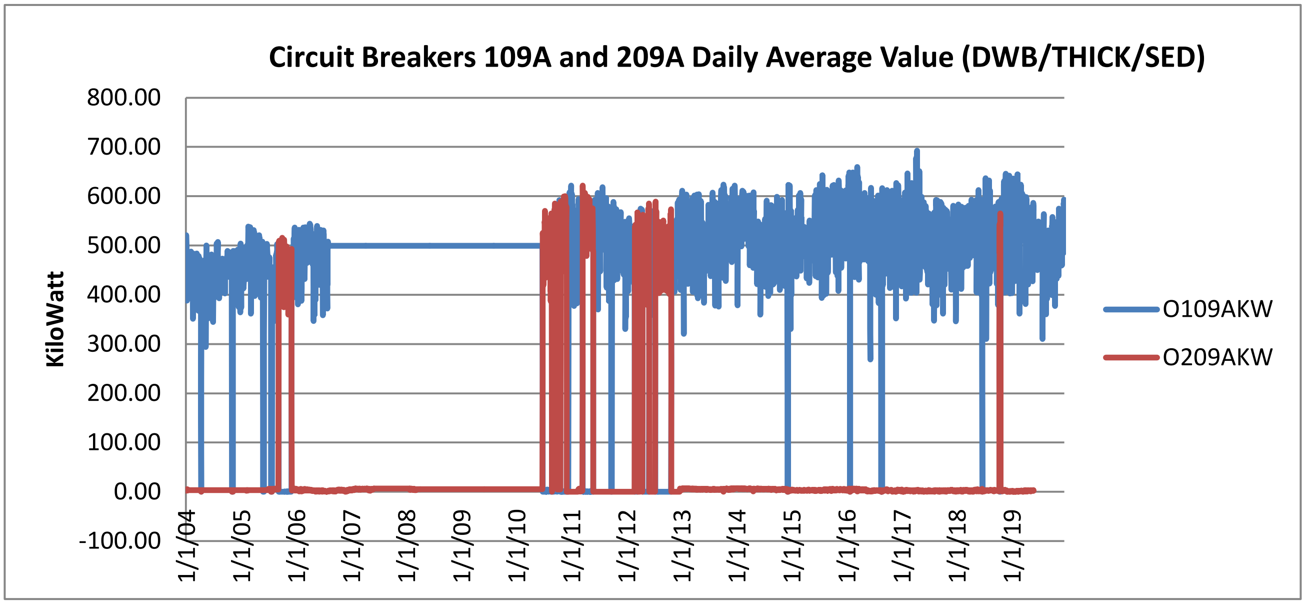

Figure 77 - Circuit Breakers 109A and 209A (Average Daily Power Demand)

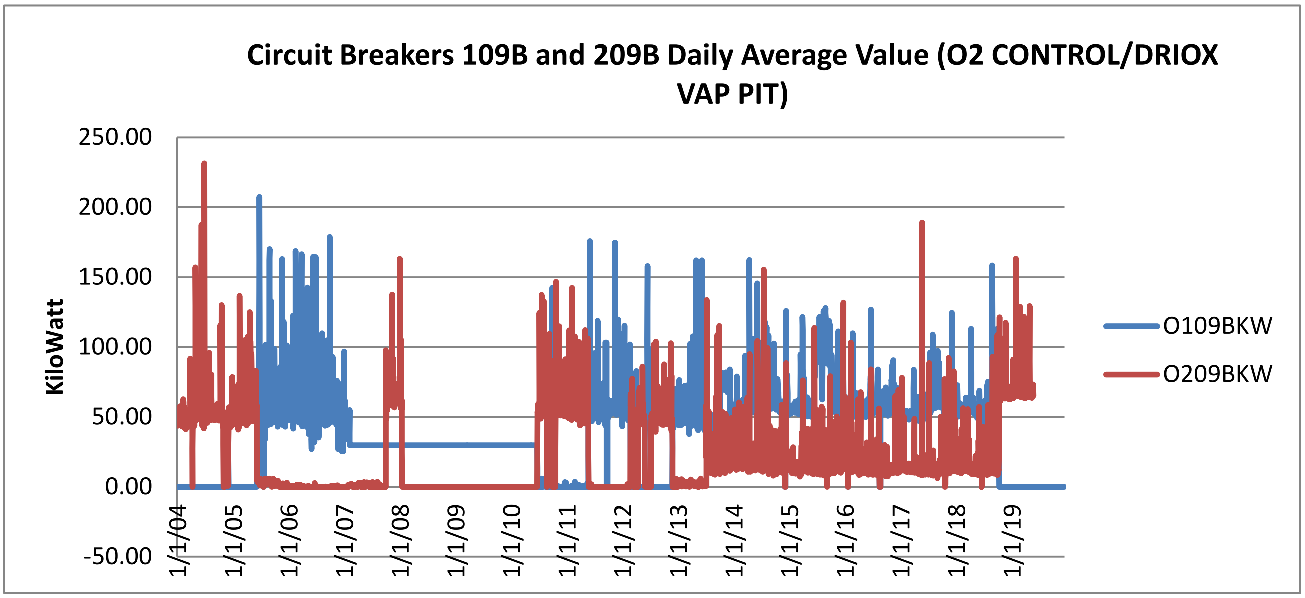

Figure 78 - Circuit Breakers 109B and 209B (Average Daily Power Demand)

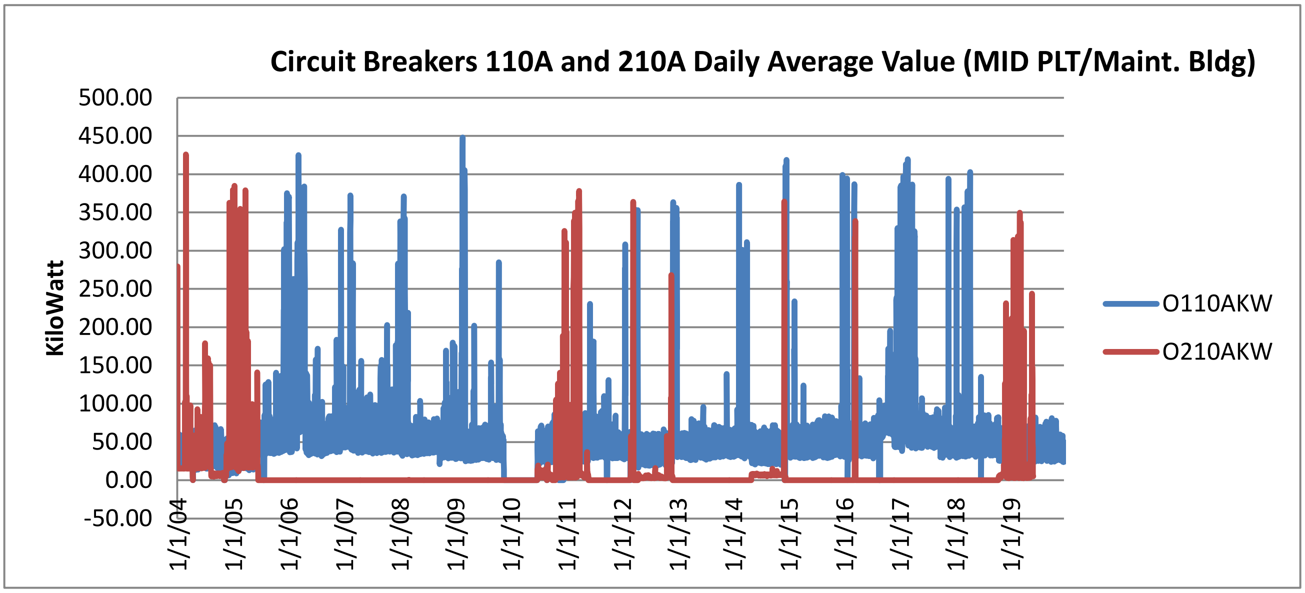

Figure 79 - Circuit Breakers 110A and 210A (Average Daily Power Demand)

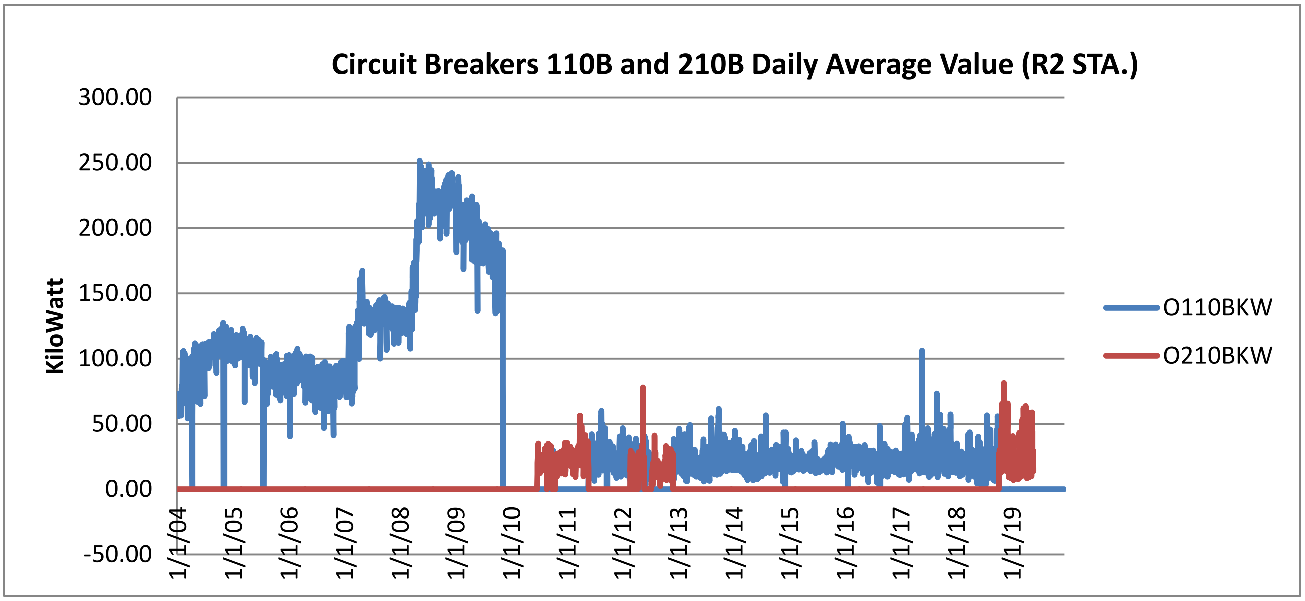

Figure 80 - Circuit Breakers 110B and 210B (Average Daily Power Demand)

Appendix D - Load Demand Distribution by Area from 2004 to 2019

The follow pie chart data were gathered from the DCS PI system. The data is the average daily value for each area for the entire year. The pie charts provide a perspective of the power demands for various process areas for the past fifteen years.

Legends:
Pumping – IPS / EPS/ Field Services / Midplant
Grit – Grit Removal
Recycled Water – Reclaimed (3-Water)
O2 / Secondary – O2 Plant / S. Reactor / N. Reactor / O2 Control / Driox VAP PIT
OPS / Admin / Lab / Dig – OPS Center / Administration Bldg / Laboratory / Digester
R2 – R2 Station
Dewatering – Dewatering / Thickening / Sedimentation Tanks

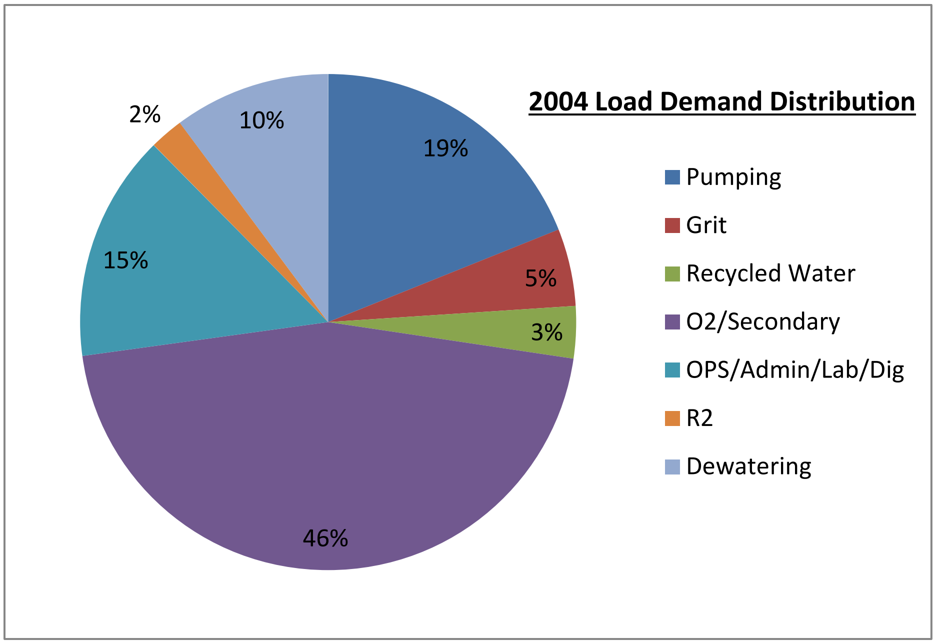

Figure 81 – 2004 Load Demand Distribution

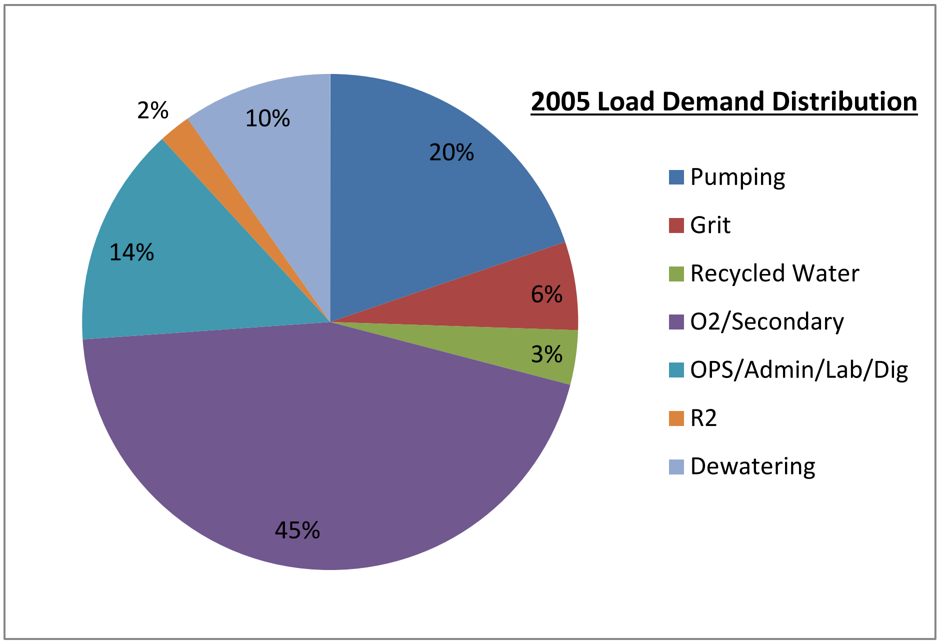

Figure 82 – 2005 Load Demand Distribution

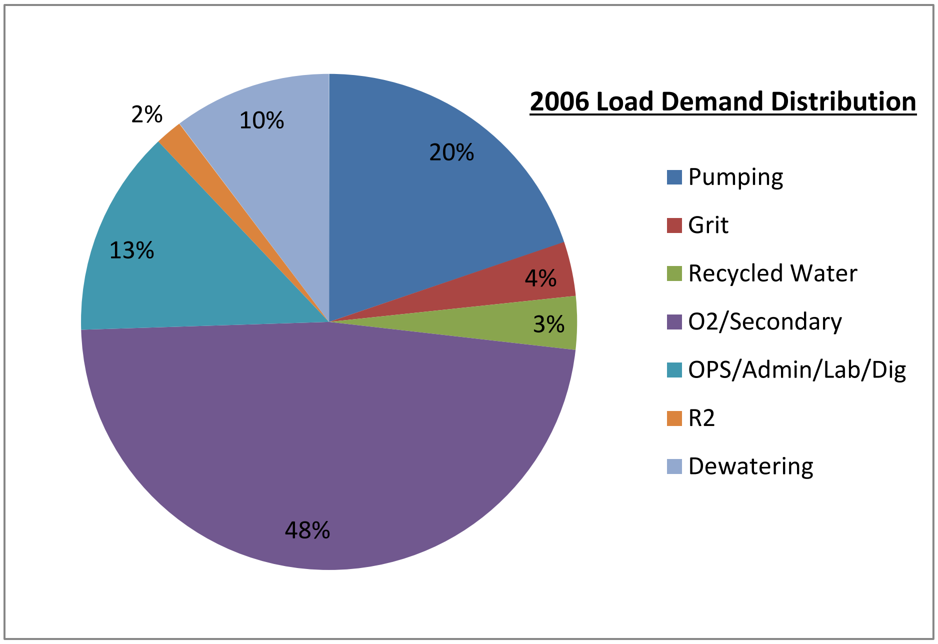

Figure 83 – 2006 Load Demand Distribution

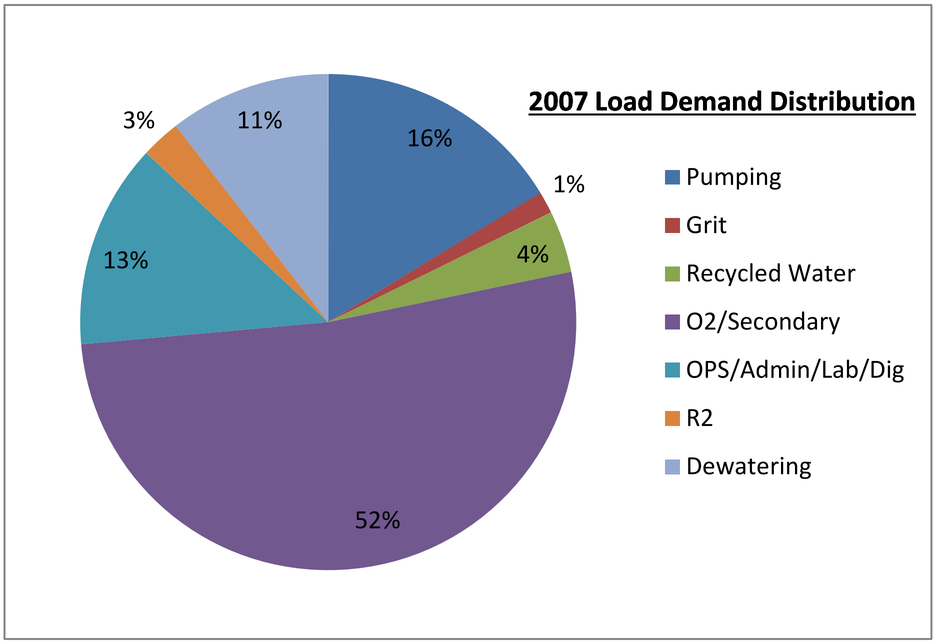

Figure 84 – 2007 Load Demand Distribution

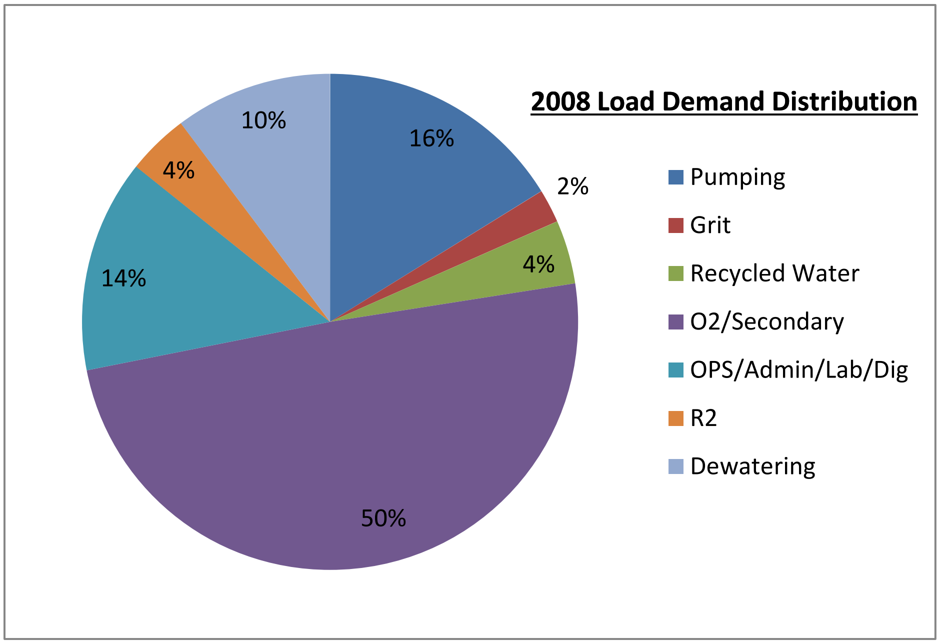

Figure 85 – 2008 Load Demand Distribution

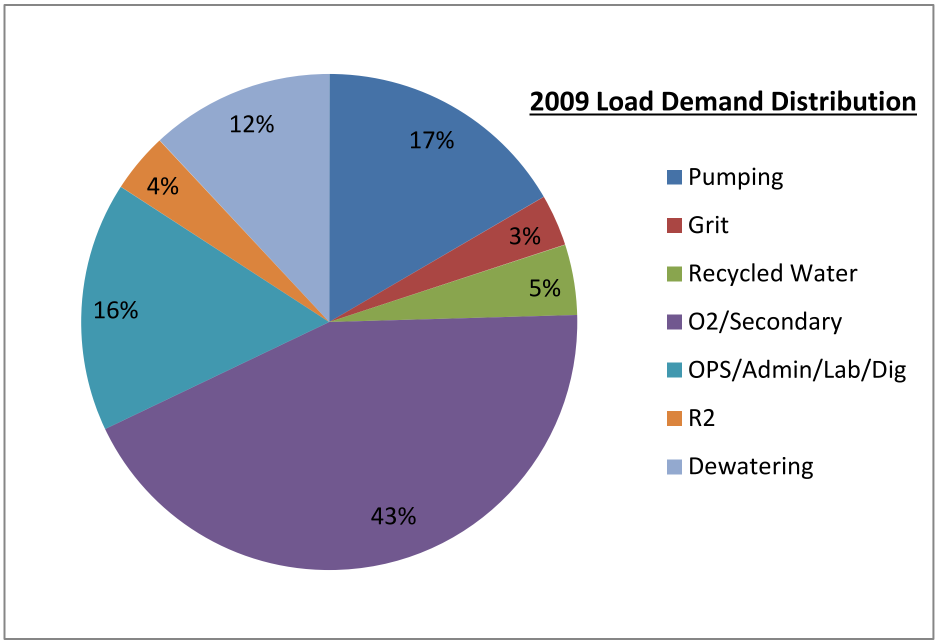

Figure 86 – 2009 Load Demand Distribution

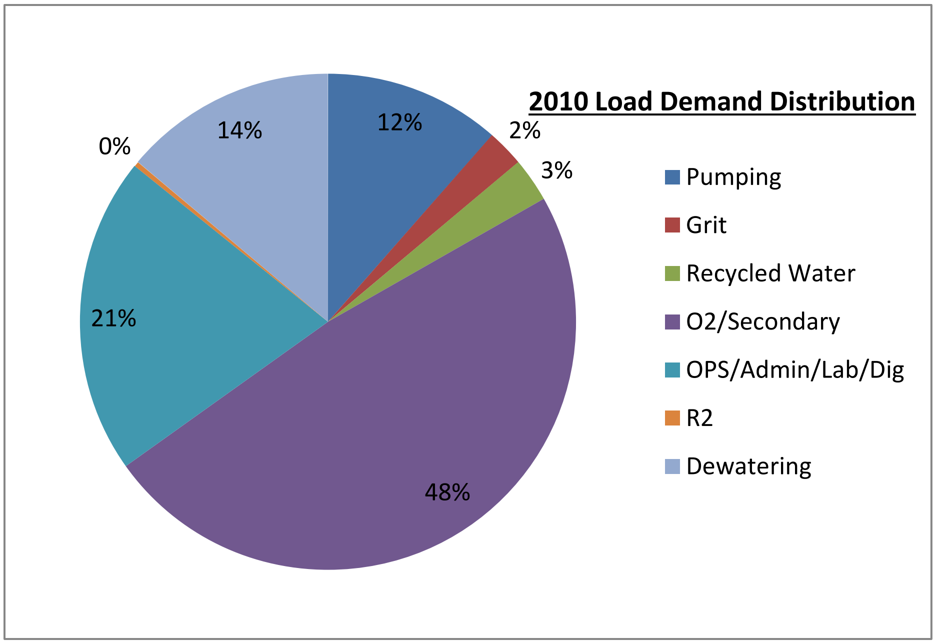

Figure 87 – 2010 Load Demand Distribution

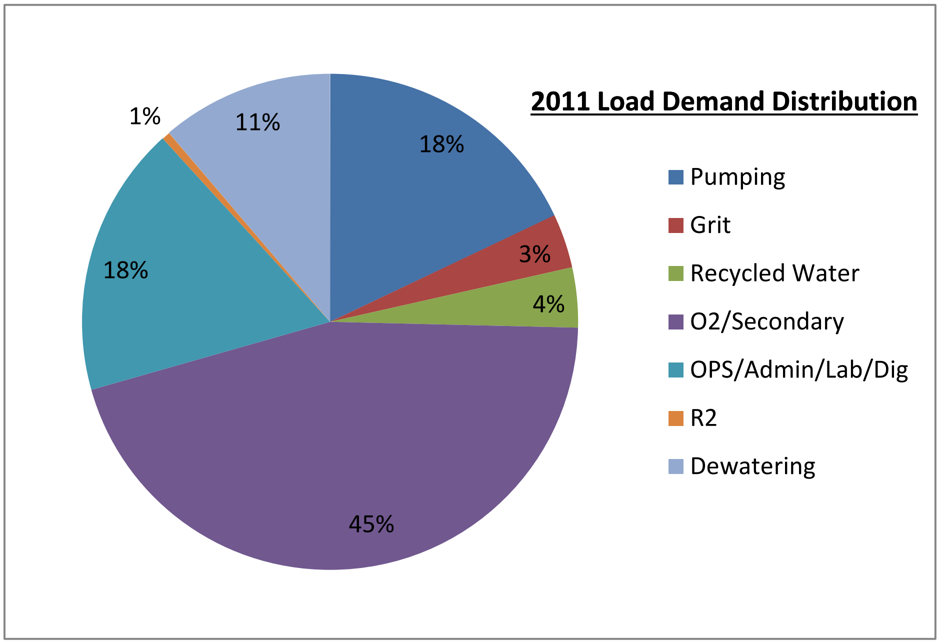

Figure 88 – 2011 Load Demand Distribution

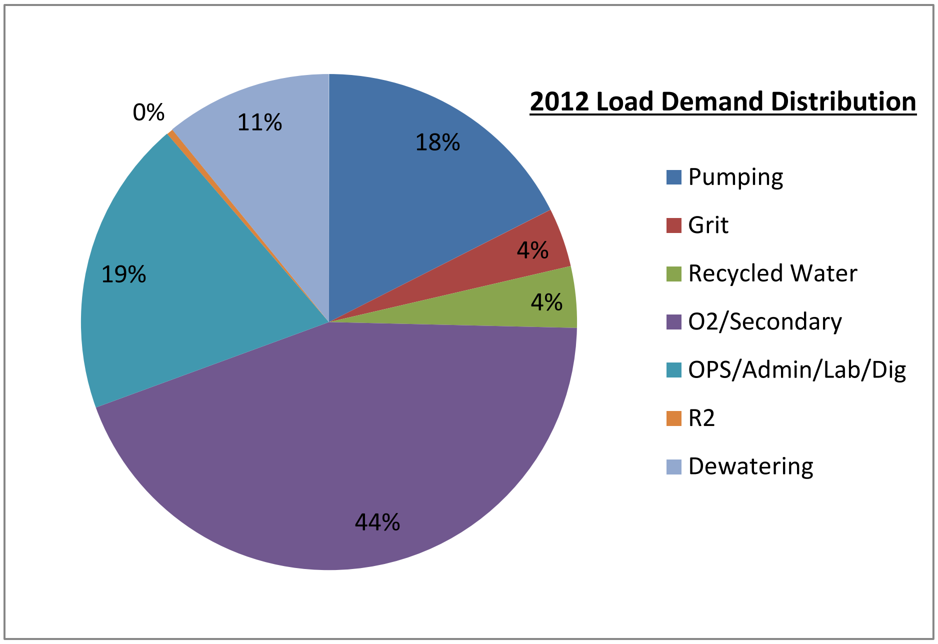

Figure 89 – 2012 Load Demand Distribution

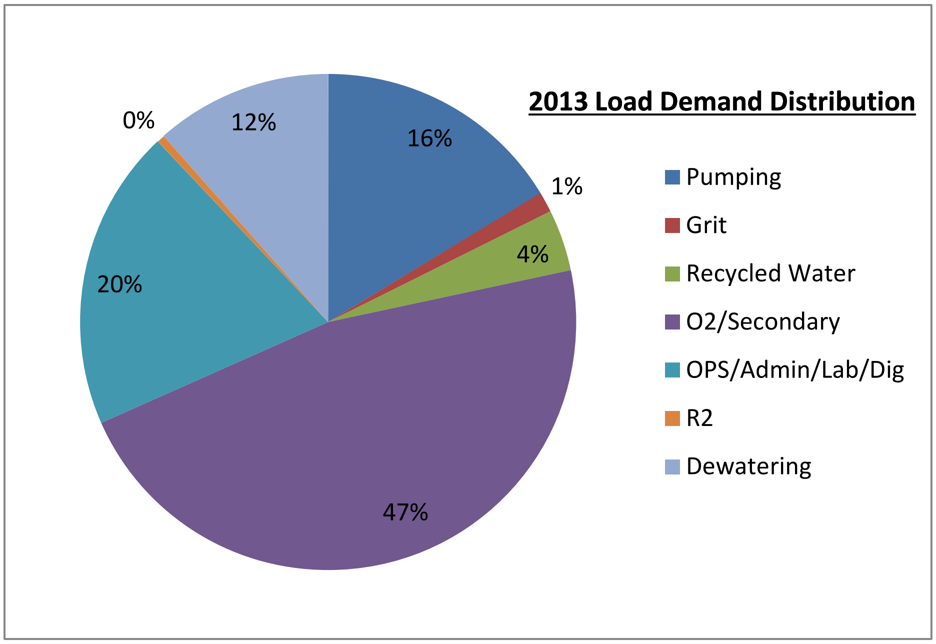

Figure 90 – 2013 Load Demand Distribution

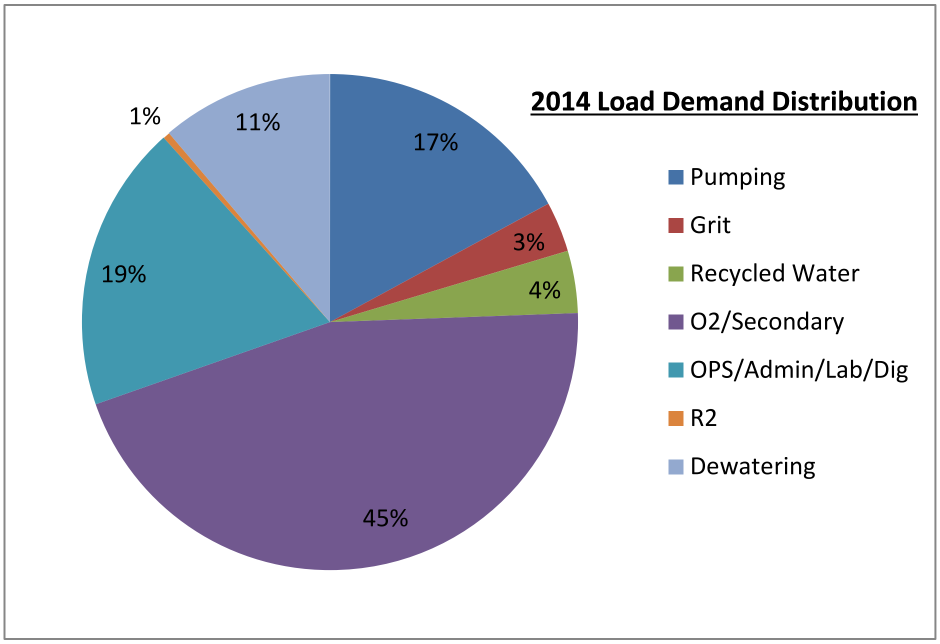

Figure 91 – 2014 Load Demand Distribution

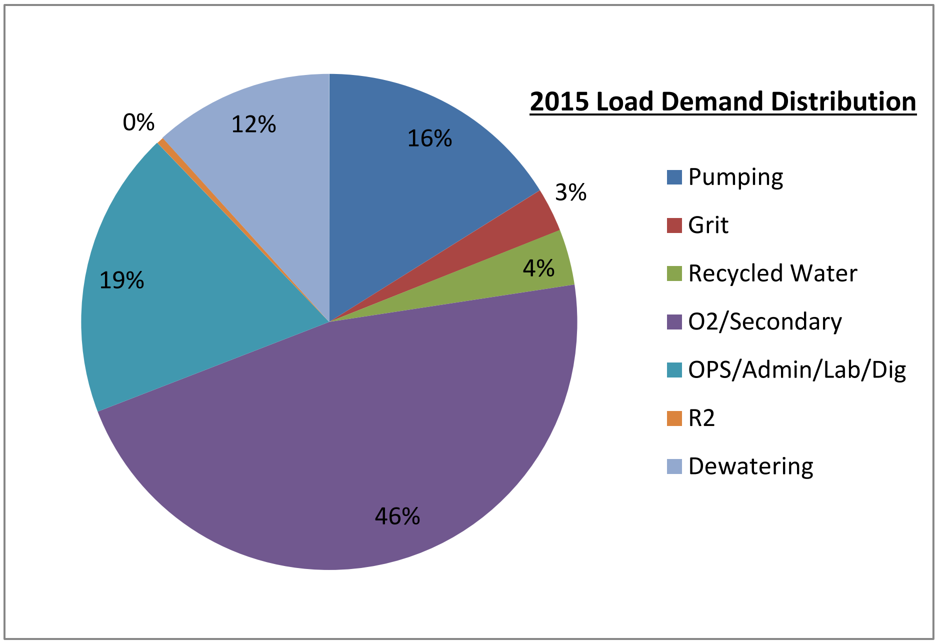

Figure 92 – 2015 Load Demand Distribution

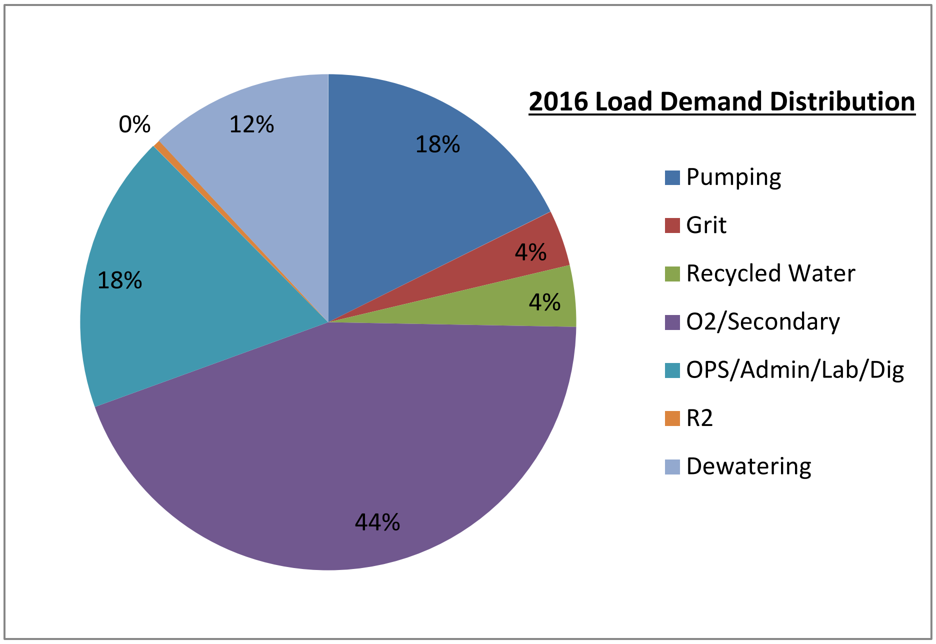

Figure 93 – 2016 Load Demand Distribution

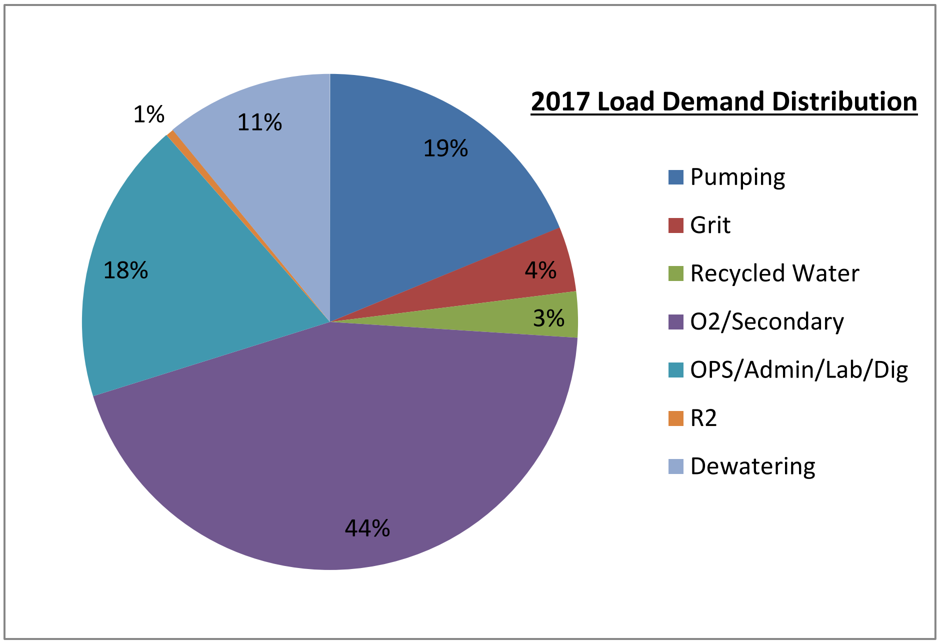

Figure 94 – 2017 Load Demand Distribution

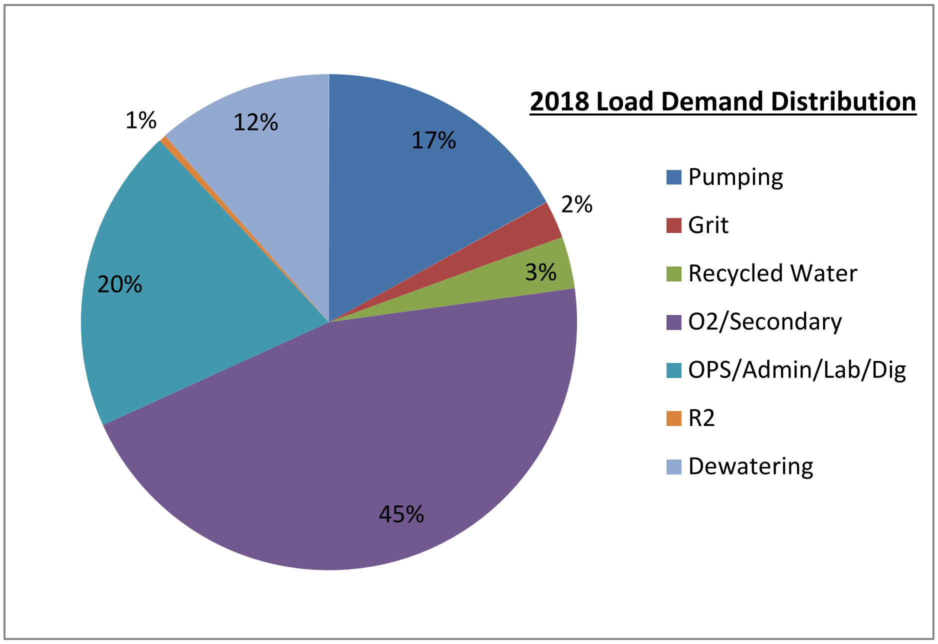

Figure 95 – 2018 Load Demand Distribution

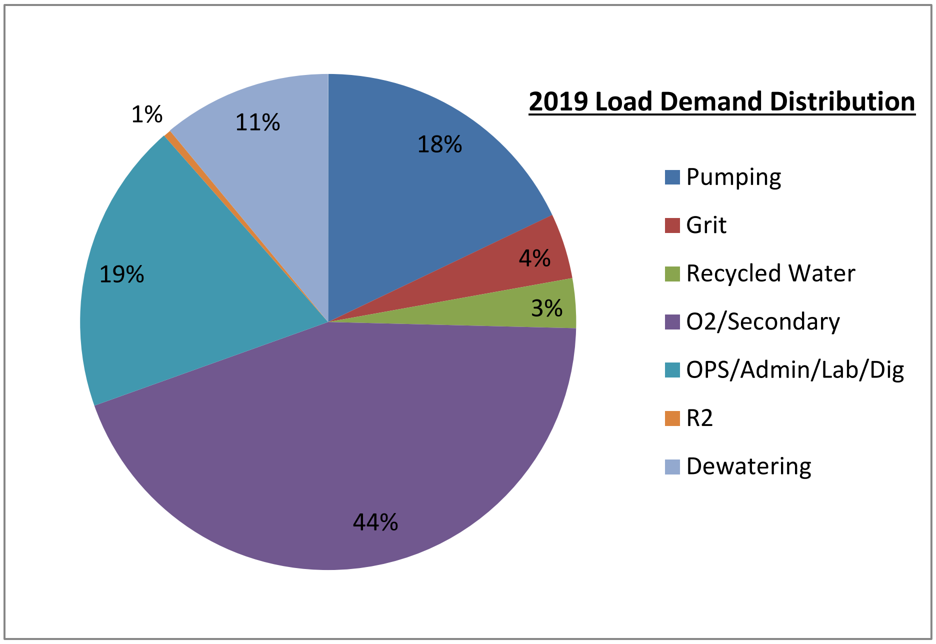

Figure 96 – 2019 Load Demand Distribution

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INTEGRATED MASTER PLAN *for the* MAIN WASTEWATER TREATMENT PLANT

C50: Evaluation Process and Criteria

May 2021

EBMUD

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EXECUTIVE SUMMARY

The goal of the East Bay Municipal Utility District (District) Integrated Main Wastewater Treatment Plant (MWWTP) Master Plan Project (Master Plan) is to provide a 30-year roadmap for the MWWTP. The roadmap will serve as a guide for prioritizing projects to address rehabilitation and renewal needs, future regulations, capacity constraints, and climate change resiliency.

This report documents the evaluation process and criteria developed to assess and compare alternatives considered as part of this Master Plan. The Master Plan goals and objectives informed and served as the basis for the evaluation criteria, and are discussed in detail in the Master Plan Vision, Goals, Objectives, and Outcomes Report. The evaluation process and criteria were used to evaluate alternatives to address several major needs across the MWWTP, including nutrient removal, biosolids management, and infrastructure renewal. Through the evaluation process, alternatives were identified, screened, evaluated, and ultimately selected for the Master Plan roadmap.

Evaluation Process

The major phases of the evaluation process are illustrated in Figure ES-1, and include:

- **Brainstorm/Identify Alternatives.** Early on in the Master Plan process, District staff and the Consultant Team brainstormed potential technological options that could be considered to address the District's future needs at the MWWTP. This set of potential solutions is referred to in this Master Plan as the "universe of alternatives."
- **Screen Alternatives**. The universe of alternatives was screened to eliminate alternatives deemed infeasible or impractical, and only viable alternatives were carried forward for further analysis.
- **Evaluate Alternatives.** An evaluation of the viable alternatives was conducted to select the preferred alternative for the MWWTP Master Plan roadmap. The selected alternative was then further refined. Different implementation strategies for the selected alternative were developed and evaluated to assess the sensitivity of various planning assumptions and to select the preferred implementation strategy.

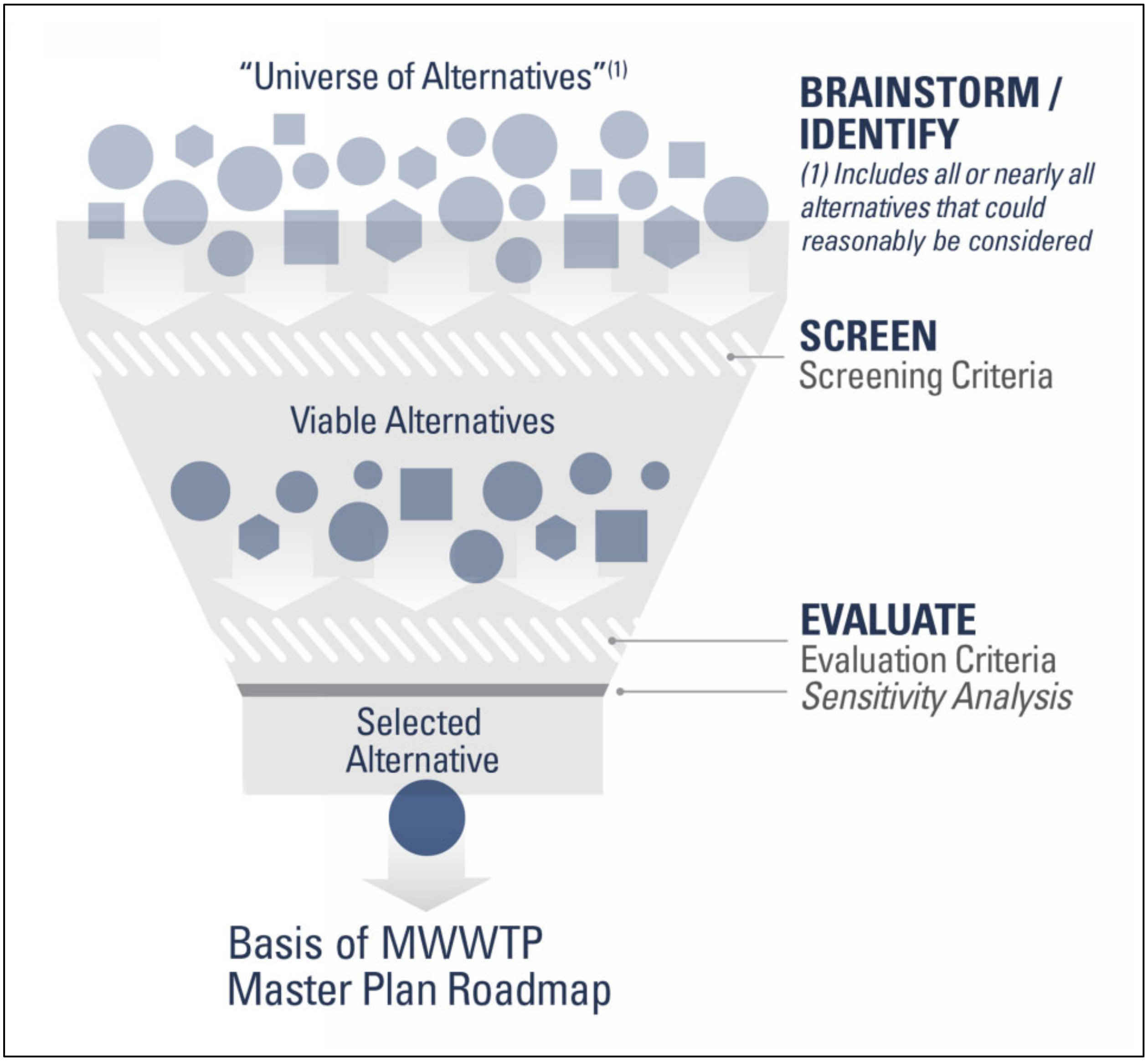

Figure ES-1. Overview of Evaluation Process Used to Identify, Screen, Evaluate, and Select Alternatives for the Master Plan Roadmap

Evaluation Approach

The District considered several approaches for evaluating alternatives (i.e., how to apply the evaluation criteria to conduct the initial and detailed alternatives evaluation). Approaches considered included:

- **Quantitative:** Score each alternative for each evaluation criterion based on a measurable metric. With this approach, the evaluation criteria could be either weighted or un-weighted.
- **Qualitative:** Score each alternative for each evaluation criterion based on professional judgment. With this approach, the evaluation criteria could be either weighted or un-weighted.

- **Pairwise Comparison:** Compare the evaluation criteria in pairs to determine their importance relative to each other. This comparison generates relative weighting scores for all evaluation criteria. During the alternatives evaluation, each alternative is scored under each evaluation criteria, and those relative weighting scores are applied. A total score for each alternative is then calculated.
- **Hybrid:** This approach includes quantitative, qualitative, and pairwise comparison elements. Compare the evaluation criteria in pairs to determine their relative importance (i.e., weight). Then, score each alternative for each evaluation criterion based on a measurable metric (quantitative) and/or professional judgment (qualitative). With this approach, the evaluation criteria would be weighted.

The District selected the hybrid approach, as it is thorough, flexible, defensible, and builds consensus within the organization. In addition, this approach is suitable for the high number of evaluation criteria and alternatives considered.

Screening and Evaluation Criteria

Over a series of four workshops, District staff developed the screening and evaluation criteria to be used to analyze alternatives. The screening criteria, summarized in Table ES-1, establish the minimum criteria that all alternatives must meet in order to be considered viable and evaluated further. As an example, for the nutrient reduction and biosolids alternatives analysis, the screening criteria were used to reduce the universe of alternatives to twelve viable alternatives (including seven nutrient reduction alternatives and five biosolids alternatives).

Table ES-1. Screening Criteria

Criteria	Description	Metric [(a)]
Ability to Meet Regulations	Complies with near-term water, air, and land related regulations, and can be adapted to meet anticipated regulations.	Pass/Fail
Technology Maturity & Risk[(b)]	Proposed technology/approach has at least one installation with a capacity of 20 mgd or greater, with at least one year of successful operation (within the last 10 years) at 90% capacity.	Pass/Fail
Ease of Permitting	Technology has been permitted at a WWTP.	Pass/Fail
Site Constraints	Structures, equipment, etc. fit within the existing MWWTP boundaries.	Pass/Fail
Independent Operations	Facilities can be fully operated by District staff (i.e., contract operations by independent entities are not required).	Pass/Fail

a. The screening criteria were applied on a pass/fail basis – the alternative either met the criterion (passed) or did not (failed). Alternatives had to meet all criteria to be considered viable and evaluated further.

b. To facilitate screening, technologies were grouped into three categories of technology maturity: embryonic, emerging, and established.

The evaluation criteria, summarized in Table ES-2, support each Master Plan goal and objective. In alignment with the Master Plan goals, the evaluation criteria are based on a “triple bottom line-plus” framework, which considers environmental, social, and economic impacts, as well as technical feasibility. This type of framework is commonly used across the wastewater sector to ensure the selected alternative has been evaluated holistically. District staff used the pairwise comparison method to determine the relative importance (i.e., weighting) of each evaluation criterion. The resulting weighting is shown in Table ES-2.

The evaluation criteria were used to evaluate the viable alternatives and select the alternative with the best score for the roadmap. As an example, for the nutrient reduction and biosolids alternatives analysis, one nutrient reduction alternative and one biosolids alternative were selected for the roadmap.

The evaluation criteria were also used to refine the selected alternatives. The criteria were used to evaluate various implementation strategies and to select the implementation strategy with the best score. As an example, for the selected nutrient reduction alternative, various near-term implementation strategies were developed and evaluated, and one near-term implementation strategy was ultimately selected for the roadmap.

Table ES-2. Master Plan Goals, Objectives, and Evaluation Criteria

Guiding Principles/Goals	Objectives	Evaluation Criteria	
		Criteria	Weight
TECHNICAL			
Maintain reliable wastewater treatment by preserving, implementing, and utilizing assets that provide sufficient treatment capacity and are resilient to changing conditions, both imminent and gradual (e.g., seismic events and sea level rise).	Preserve/replace assets, maintain an efficient site layout, and optimize land utilization to facilitate reliable wastewater treatment operations and maintenance.	Efficient and Well Integrated Site Layout	6%
		Ease of Constructability	3%
	Provide reliable capacity to manage and treat wastewater flows within the existing wastewater service area, such that regulations are met under a variety of operating conditions.	Technology Maturity/ Reliability	12%
		Flexibility/Ease of O&M	6%
	Maintain and improve resiliency of MWWTP and wastewater infrastructure such that interruptions of service are minimized and it can retain its essential function (i.e., protect life safety and convey wastewater flows to San Francisco Bay) under imminent changing conditions (e.g., seismic event, flooding) and gradual changing conditions (e.g., sea level rise).	Resiliency	9%
ENVIRONMENTAL			
Protect the environment, public health, and safety through reliable wastewater treatment that can proactively meet future regulations and minimize impacts to the local (San Francisco Bay) and global environment.	Continue to meet increasingly stringent water quality and environmental regulations and upgrade wastewater facilities to address future regulatory requirements.	Reliability and Flexibility to Meet Current and Potential Future Regulations	15%

Guiding Principles/Goals	Objectives	Evaluation Criteria	
		Criteria	**Weight**
Promote resource recovery as a sustainable enterprise benefitting the region through responsible waste management and renewable energy generation.	Support sustainability goals by maximizing resource recovery and energy production, and minimizing energy consumption, greenhouse gas emissions, and use of non-renewable resources.	Maximize Recoverable Resources	6%
		Minimize Treatment Process GHG Emissions 3a. Minimize energy purchases (electricity and natural gas) 3b. Minimize N_2O emissions (under consideration)	10%
		Minimize Chemical Use	5%
SOCIAL			
Maintain positive relationships with community groups and minimize adverse community impacts through improved aesthetics, noise abatement, reduced truck traffic, and odor controls.	Minimize adverse visual, noise, truck traffic, and odor impacts from the MWWTP operations to neighbors to the extent practicable.	Community Acceptability	9%
Maintain safe and engaging work environment at District facilities.	Prioritize worker safety and maintain an engaging work environment at District facilities.	Facility Safety	17%
		Facility and Public Engagement	2%

Guiding Principles/Goals	Objectives	Evaluation Criteria	
		Criteria	Weight
ECONOMIC			
Maintain fair and reasonable rates for customers by maximizing economic benefits through operating efficiencies and cost-effective alternatives.	Maintain fair and reasonable rates, including determining the role of resource recovery and beneficial use of treatment byproducts.	Life Cycle Cost	N/A
	Maintain transparent and accurate cost accounting and financial reporting.		
	After meeting service area needs, utilize additional capacity for ratepayer benefit (i.e., to reduce ratepayer costs).		
	Maintain cost-effective, “no-regrets” investments in wastewater facilities (e.g., through asset management, system upgrades, efficient operations, land utilization, assimilation of new technologies, etc.).		

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CHAPTER 1 - INTRODUCTION

The goal of the East Bay Municipal Utility District (District) Integrated Main Wastewater Treatment Plant (MWWTP) Master Plan is to provide a 30-year roadmap for the MWWTP. The roadmap will serve as a guide for prioritizing projects to address rehabilitation and renewal needs, future regulations, capacity constraints, and climate change resiliency.

The purpose of this report is to document the evaluation process and criteria developed to assess and evaluate the alternatives considered as part of this Master Plan. The evaluation process and criteria were used to evaluate alternatives to address several major needs across the MWWTP, including nutrient removal, biosolids management, and infrastructure renewal. Through the evaluation process, alternatives were identified, screened, evaluated, and ultimately selected for the Master Plan roadmap.

This report is organized as follows:

- Executive Summary
- Chapter 1: Introduction
- Chapter 2: Evaluation Process and Criteria.
    - This chapter includes:
        - A description of the evaluation process and criteria
        - A description of each step of the evaluation process
        - Evaluation approaches considered and the approach selected
        - How the screening and evaluation criteria were applied
        - How the evaluation criteria were weighted
        - How the sensitivity analysis was performed to refine the selected alternatives and optimize the implementation strategies and planning assumptions included in the roadmap

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CHAPTER 2 - EVALUATION PROCESS & CRITERIA

The evaluation process and criteria were developed to establish how alternatives will be screened, evaluated, and selected for the Master Plan roadmap. Figure 2-1 outlines the major phases of the evaluation process. The major phases of the evaluation process are described in the sections below and include:

- Brainstorm/Identify Alternatives
- Screen Alternatives
- Evaluate Alternatives

2.1 Brainstorm/Identify Alternatives

In this phase, a wide range of potential alternatives was identified in a series of workshops. The set of alternatives is referred to as the "universe of alternatives" and encompasses all or nearly all technological options that could reasonably be considered for analysis.

2.2 Screen Alternatives

In this phase, the District developed and applied screening criteria to eliminate alternatives that were deemed infeasible, impractical, not proven yet, or not aligned with the Master Plan goals and objectives. The screening criteria, summarized in Table 2-1, were developed by District staff and the Consultant Team through a series of workshops. The screening criteria establish minimum criteria that all alternatives had to meet in order to be considered viable. If an alternative did not meet one or more criteria, it was eliminated from further consideration. If an alternative met all criteria, it was deemed viable and carried forward for further evaluation. As an example, for the nutrient reduction and biosolids alternatives analysis, the screening criteria were used to reduce the universe of alternatives and carry forward twelve viable alternatives for further evaluation (including 7 nutrient reduction alternatives and 5 biosolids alternatives).

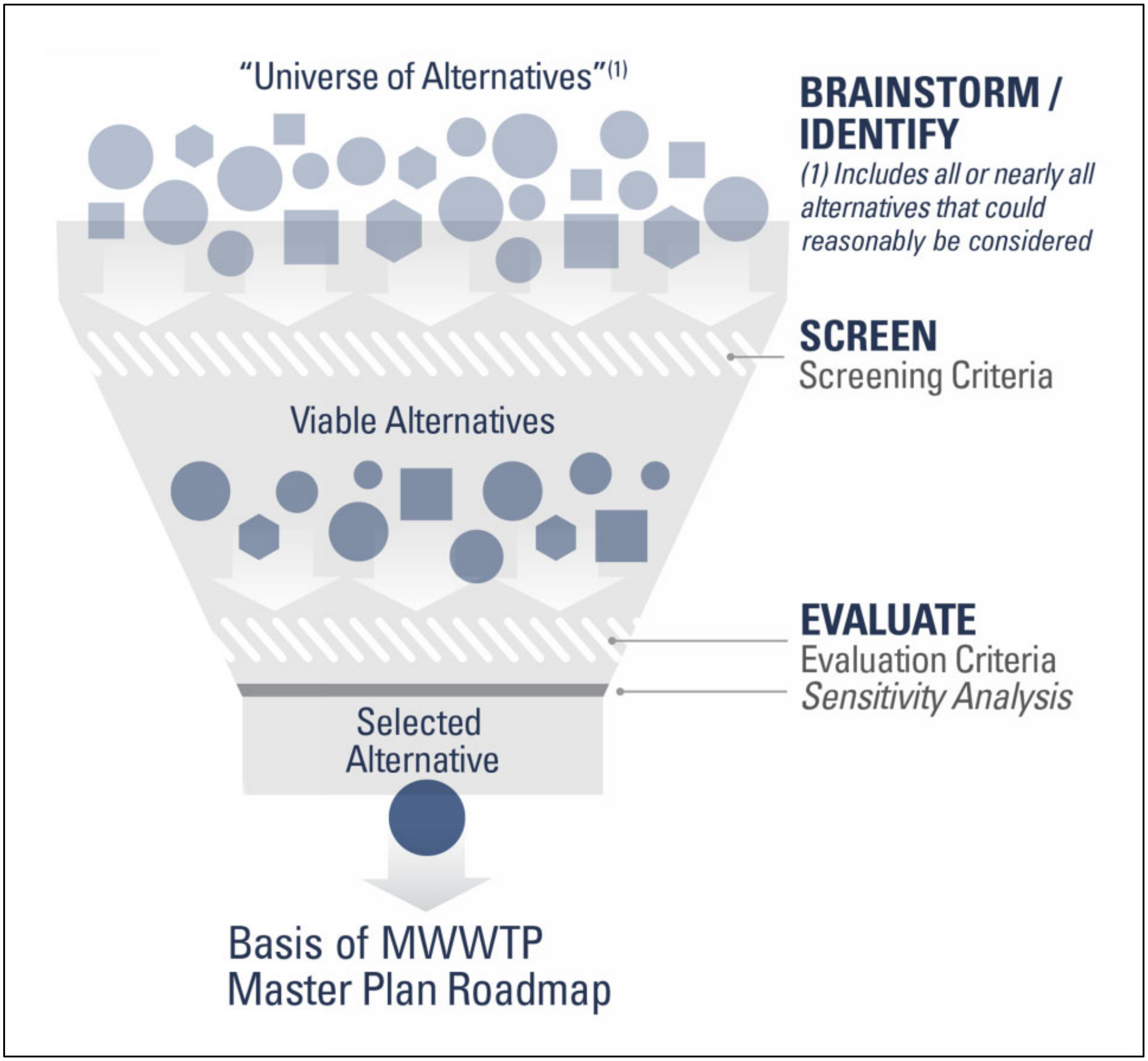

Figure 2-1. Overview of the Evaluation Process Used to Identify, Screen, Evaluate, and Select Alternatives for the Master Plan Roadmap

Table 2-1. Screening Criteria

Criteria	Description	Metric [a]
Ability to Meet Regulations	Complies with near term water, air, and land related regulations, and can be adapted to meet anticipated regulations.	Pass/Fail
Technology Maturity & Risk (at this size) [b]	Proposed technology/approach has at least one installation with a capacity of 20 mgd or greater, with at least one year of successful operation (within the last 10 years) at 90% capacity.	Pass/Fail
Ease of Permitting	Technology has been permitted at a WWTP.	Pass/Fail
Site Constraints	Structures, equipment, etc., fit within the existing MWWTP boundaries.	Pass/Fail
Independent Operations	Facilities can be fully operated by District staff (i.e., contract operations by independent entities is not required).	Pass/Fail

a. The screening criteria were applied on a pass/fail basis – the alternative either met the criteria (passed) or did not (failed). Alternatives had to meet all criteria to be considered viable and evaluated further.

b. To facilitate screening, technologies were grouped into three categories of technology maturity: embryonic, emerging, and established.

2.3 Evaluate Alternatives

In this phase, the District selected an evaluation approach and developed and applied evaluation criteria to evaluate the viable alternatives and select the alternative with the best score for the roadmap. The alternatives evaluation included the following steps:

1. Select Evaluation Approach
2. Develop Evaluation Criteria
3. Weigh Non-Economic Evaluation Criteria
4. Score Alternatives and Estimate Life Cycle Cost
5. Refine Selected Alternative and Conduct Sensitivity Analysis

The approach for each of these steps is described in the sections below. Steps 4 and 5 were completed as part of the specific alternatives evaluation efforts and the results are summarized in the associated alternatives evaluation reports.

2.3.1 Step 1: Select Evaluation Approach

For this evaluation effort, the District first considered several evaluation approaches, which are summarized in Table 2-2. Ultimately, the District selected the hybrid approach for its thoroughness, flexibility, defensibility, tendency to build consensus, and time efficiency, given the number of criteria and alternatives considered. Pairwise comparison was used to assist the District in determining the relative importance of each criterion.

Using a combination of quantitative and qualitative scoring for each criterion allowed the District to consider each alternative in a holistic way, addressing all the key considerations defined by the evaluation criteria.

The District also decided to evaluate economic and non-economic criteria separately, which has been done by other agencies for similar planning efforts. This approach is more aligned with the triple bottom line-plus framework, which includes technical, environmental, and social, considerations in addition to economics. With this approach, a total score was developed for the non-economic criteria. In parallel, the life cycle cost was estimated for each alternative. The total non-economic criteria score and the summary economic criteria metric (e.g., life cycle cost) were then considered together to determine which alternative(s) were best aligned with the evaluation criteria, and ultimately the Master Plan goals and objectives.

Table 2-2. Approaches for Evaluating Alternatives

Evaluation Approach	Description	Advantages	Disadvantages
Quantitative	• Score each criterion on a scale of 0 to 5 based on a measurable metric • Criterion is weighted or un-weighted	• Measurable • Defensible • Can include weighting of evaluation criteria	• Can be time intensive if there are multiple criteria or multiple levels of evaluation
Qualitative	• Score each criterion on a scale of 0 to 5 based on professional judgment • Criterion is weighed or un-weighted	• Time-efficient • Group-oriented, decision making (consensus building) • Can include weighting of evaluation criteria	• Requires additional documentation to be defensible, given scoring is based on professional judgment
Pairwise Comparison	• Compare criteria in pairs to determine their relative importance • Compare alternatives in pairs to determine their relative performance for each criterion • Criterion is weighted	• Group-oriented, decision making (consensus building) • Defensible • Includes weighting of criteria	• Requires multiple full group sessions of decision-makers • Not recommended where number of evaluation criteria exceeds 15 • Not recommended where number of alternatives exceeds 6 • Not recommended for multiple levels of evaluation
Hybrid	• Use pairwise comparison to weight evaluation criteria only • Score each alternative for each criterion based on measurable metric (quantitative) and/ or professional judgment (qualitative)	• Time-efficient • Group-oriented, decision making (consensus building) • Defensible • Flexible • Includes weighting of criteria	• Requires additional documentation to be defensible, given some scoring is based on professional judgment

2.3.2 Step 2: Develop Evaluation Criteria

To ensure alignment with the Master Plan goals and objectives, the District developed evaluation criteria, including considerations and metrics, over several workshops with the Consultant Team. Similar to the Master Plan goals and objectives, the evaluation criteria are grouped into four major categories that follow the “triple bottom line-plus” framework:

- Technical
- Environmental
- Social
- Economic

To measure sustainability, businesses across industries, commonly use a triple bottom line (TBL) framework (or some variation of a TBL framework). Developed in 1994 by John Elkington, the TBL framework includes consideration of environmental and social impacts, in addition to economic impacts. While traditional business accounting solely considers financial impacts, which are commonly referred to as the “bottom line”, considering these three factors together (economic, environmental, and social) results in a “triple bottom line” analysis.

The evaluation criteria and metrics are summarized in Table 2-3.

Table 2-3. Master Plan Evaluation Criteria and Metrics by Master Plan Goal and Objective

Guiding Principles/ Goals	Objectives	Evaluation Criteria				
		Criteria	Weight	Considerations	Metric(s)	Basis for Score(a)
TECHNICAL						
Maintain reliable wastewater treatment by preserving, implementing, and utilizing assets that provide sufficient treatment capacity and are resilient to changing conditions, both imminent and gradual (e.g., seismic events and sea level rise).	Preserve/replace assets, maintain an efficient site layout, and optimize land utilization to facilitate reliable wastewater treatment operations and maintenance.	Efficient and Well Integrated Site Layout	6%	• Does it minimize the footprint required per mgd of influent? • Does it leave space for future improvements, expansion, or upgrades? • How well do future facilities integrate with existing facilities?	• Acreage of treatment facilities • Synergies in facility placement and logical flow	Qualitative
		Ease of Constructability	3%	• How easily can the future facilities be constructed? • How easy will it be to continue operating the existing processes during construction?	• Simplicity of construction phasing (Simple, moderate, or complex)	Qualitative
	Provide reliable capacity to manage and treat wastewater flows within the existing wastewater service area, such that regulations are met under a variety of operating conditions.	Technology Maturity/ Reliability	12%	• How many existing WWTPs have the proposed technology/approach? • How large are they and how long have they been operating successfully? • Will the treatment process be reliable with respect to meeting current and future regulations under a variety of flow/load conditions? • Does this alternative have flexibility to handle high peaking factors/wet weather flows?	• Minimal, moderate or several ○ Number of installations ○ Size of installations ○ Years of successful, reliable operation meeting similar regulations • Effluent quality consistently meets potential effluent limits under variable flow/load conditions	Qualitative
		Flexibility/ Ease of O&M	6%	• Will O&M labor hours be minimized? • Is staff already familiar with the process or will it require substantial staff training? • Is the technology serviceable in the United States, or does it require parts from outside the country? • Will reliance on third parties be minimized (e.g., for special maintenance, management /marketing the product(s), etc.)? • Will a third party manage or market the product?	• Increase, decrease, or minimal change in: ○ O&M labor hours ○ O&M training ○ Monitoring/ instrumentation ○ Wait time for parts/support ○ Specialized staff required and reliance on third parties ○ Complexity/difficulty of O&M activities	Qualitative

Guiding Principles/ Goals	Objectives	Evaluation Criteria				
		Criteria	**Weight**	**Considerations**	**Metric(s)**	**Basis for Score[a]**
	Maintain and improve resiliency of MWWTP and wastewater infrastructure such that interruptions of service are minimized and it can retain its essential function (i.e., protect life safety and convey wastewater flows to San Francisco Bay) under imminent changing conditions (e.g., seismic event, flooding) and gradual changing conditions (e.g., sea level rise.	Resiliency	9%	• Does it maximize the ability to protect life safety and convey wastewater flows to SF Bay during the following events? ○ Seismic event (It is assumed new construction will have greater ability.) ○ Storm surge/flood event • Does it maximize the ability to maintain typical function under latest projected changes in sea/tide levels? • Does it enhance the ability to meet regulations and safety goals by providing resiliency?	• Increase, decrease, or minimal change in relative cost to protect life safety and convey wastewater flows to SF Bay • Increase, decrease, or minimal change in relative cost to maintain typical function	Qualitative
ENVIRONMENTAL						
Protect the environment, public health, and safety through reliable wastewater treatment that can proactively meet future regulations and minimize impacts to the local (San Francisco Bay) and global environment.	Continue to meet increasingly stringent water quality and environmental regulations and upgrade wastewater facilities to address future regulatory requirements.	Reliability and Flexibility to Meet Current and Potential Future Regulations	15%	• Can it reliably meet current regulations? • Does the alternative have flexibility to be modified to meet increasingly stringent regulations (including water quality, biosolids, and air regulations)?	• Minimal, moderate, or several alternate configurations/future technologies can be easily implemented over time	Qualitative
Promote resource recovery as a sustainable enterprise benefitting the region through responsible waste management and renewable energy generation.	Support sustainability goals by maximizing resource recovery and energy production, and minimizing energy consumption, greenhouse gas emissions, and use of non-renewable resources	Maximize Recoverable Resources	6%	• Does it maximize utilization of the R2 Program? • Does it support beneficial use of biosolids? • Does it support nutrient recovery? • Does it support water reuse?	• Increase, decrease, or minimal change in R2 Program • Increase, decrease, or minimal change in beneficial use of biosolids • Minimal, moderate, or high utilization of recoverable resources (treatment byproducts)	Qualitative (low, medium, high) Qualitative score based on mass for all categories (R2, biosolids, nutrient recovery, water reuse)
		Minimize Treatment Process GHG Emissions 3a. Minimize energy purchases (electricity and	10%	• Will it result in a change in GHG emissions?	• Increase, decrease, or minimal change in GHG emissions	Qualitative (low, medium, high)
				• Will it minimize flaring of biogas? • Will it increase the biogas/energy generation potential? • Will it be energy efficient?	• Low, medium, or high energy purchase	Quantitative score based on kWh or Btu purchased per year

Guiding Principles/ Goals	Objectives	Evaluation Criteria				
		Criteria	Weight	Considerations	Metric(s)	Basis for Score[a]
		natural gas) 3b. Minimize N_2O emissions (under consideration)		• Will it decrease the N_2O at the plant and the receiving water (San Francisco Bay)?	• Increase, decrease, or minimal change in N_2O emissions both at the MWWTP and at San Francisco Bay	Quantitative score based on GHGs from N_2O emissions per year
		Minimize Chemical Use	5%	• Does it minimize chemical addition for treatment?	• Increase, decrease, or minimal change in chemical usage	Qualitative
SOCIAL						
Maintain positive relationships with community groups and minimize adverse community impacts through improved aesthetics, noise abatement, reduced truck traffic, and odor controls.	Minimize adverse visual, noise, truck traffic, and odor impacts from the MWWTP operations to neighbors to the extent practicable.	Community Acceptability	9%	• Will the alternative introduce a source of odors, noise, and/or other emissions? • Will the alternative result in adverse visual impacts? • Will the alternative increase or decrease local truck traffic? • Will the alternative provide a community benefit (e.g., product the community can use)?	• Decrease, increase, or minimal change in negative community impacts: ○ Noise ○ Odor emissions ○ Number of structures negatively impacting views or visual aesthetics ○ Truck traffic • Decrease, increase, or minimal change in positive community impacts: ○ Community benefits	Qualitative
Maintain safe and engaging work environment at District facilities.	Prioritize worker safety and maintain an engaging work environment at District facilities.	Facility Safety	17%	• Does the alternative promote staff safety?	• Increase, decrease, or minimal change in the safety of the facilities/ work environment	Qualitative
		Facility and Public Engagement	2%	• Does the MWWTP promote staff and public engagement (e.g., functional and aesthetic site layout, adequate space for staff collaboration and public visitors)?	• Increase, decrease, or minimal change in factors/ amenities promoting staff and public engagement • Increase, decrease, or minimal change in potential for highly functional and aesthetic site layout/facilities	Qualitative
ECONOMIC						
Maintain fair and reasonable rates for customers by maximizing economic benefits through operating efficiencies and cost-effective alternatives.	Maintain fair and reasonable rates, including determining the role of resource recovery and beneficial use of treatment byproducts.	Life Cycle Cost	NA	• Does it minimize life cycle cost (capital and O&M cost) at Build-Out in 2020 U.S. dollars?	• Life cycle cost (capital and O&M cost) at Build-Out in 2020 U.S. dollars	Quantitative score scaled based on least life cycle cost at Build-Out
	Maintain transparent and accurate cost accounting and financial reporting.					
	After meeting service area needs, utilize additional capacity for ratepayer benefit (i.e., to reduce ratepayer costs).					
	Maintain cost-effective, “no-regrets” investments in wastewater facilities (e.g., through asset management, system upgrades, efficient operations, land utilization, assimilation of new technologies, etc.).					

a. Scoring to be assigned where 5 is the highest (best alignment with criteria) and 1 is the lowest (least alignment with criteria).

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2.3.3 Step 3: Weigh Non-Economic Evaluation Criteria

In this step, the District determined the relative importance of the evaluation criteria, resulting in a weighting score for each criterion. Weighting scores were only determined for the non-economic criteria. To build consensus among the diverse stakeholders, the pairwise comparison exercise was conducted in a workshop setting with District staff representing a wide range of groups within the District's Wastewater Division.

Two evaluation criteria were considered at a time. For each pair of evaluation criteria, the group assigned a score quantifying the relative importance. The scoring that was used is summarized in Table 2-4.

Table 2-4. Scoring for Pairwise Comparison

Score	Meaning
5	Criterion "A" is **much more important than** Criterion "B"
3	Criterion "A" is **more important than** Criterion "B"
1	Criterion "A" is **equally important to** Criterion "B"
1/3	Criterion "A" is **less important than** Criterion "B"
1/5	Criterion "A" is **much less important than** Criterion "B"

a. Criterion "A" is the criteria listed in the row of the pairwise comparison matrix.
b. Criterion "B" is the criteria list in the column of the pairwise comparison matrix.
c. As needed intermediate scores were assigned.

Once all pairs of evaluation criteria were scored, the total score for each criterion was determined and then normalized to the grand total to determine each criterion's relative weight. Table 2-5 summarizes the results of the pairwise comparison process, including the weighting score of each evaluation criterion. The following three criteria were identified as the most important from this exercise and make up 44 percent of the total:

- Facility Safety (17 percent)
- Reliability and Flexibility to Meet Current/ Potential Future Regulations (15 percent)
- Technology Maturity/ Reliability (12 percent)

A sensitivity analysis was performed to assess the effect of changing the evaluation criteria weighting (i.e., does the scoring for each pair of evaluation criteria impact the overall ranking of the evaluation criteria). The sensitivity analysis effort and findings are summarized in Appendix A. The findings from the sensitivity analysis indicate that large changes to weighting scores are required to affect the resulting alternative scores. Therefore, the weighting is not considered sensitive.

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Table 2-5. Pairwise Comparison and Weighting Results of Non-Economic Evaluation Criteria

			B (columns) [a]												**Total Score**	**Relative Weight [c]**
			Environmental				**Social**			**Technical**						
		Criteria	Reliability and Flexibility to Meet Current/ Potential Future Regulations	Maximize Recoverable Resources	Minimize Treatment Process GHG Emissions	Minimize Chemical Use	Community Acceptability	Facility Safety	Facility and Public Engagement	Efficient and Well Integrated Site Layout	Ease of Construct-ability	Technology Maturity/ Reliability	Flexibility / Ease of O&M	Resiliency		
A (rows) [a]	**Environmental**	Reliability and Flexibility to Meet Current/ Potential Future Regulations	1	5.0	3.0	5.0	3.0	1.0	5.0	3.0	3.0	1.0	2.0	2.0	**34**	**15%**
		Maximize Recoverable Resources	0.20	1	0.5	1.0[b]	0.3	0.2	3.0	2.0	3.0[b]	0.3	2.0	1.0	**15**	**6%**
		Minimize Treatment Process GHG Emissions	0.33	2.00	1	4.0	1.0	0.2	5.0	3.0[b]	3.0	0.3	2.0	2.0	**24**	**10%**
		Minimize Chemical Use	0.20	1.00	0.25	1	0.3	0.2	4.0	0.3	2.0	0.3	0.3	1.0[b]	**11**	**5%**
	Social	Community Acceptability	0.33	3.00	1.00	3.00	1	0.3	3.0	3.0	3.0	0.5	3.0	1.0[b]	**22**	**9%**
		Facility Safety	1.00	5.00	5.00	5.00	3.00	1	5.0	5.0	5.0	1.0	3.0	1.0	**40**	**17%**
		Facility and Public Engagement	0.20	0.33	0.20	0.25	0.33	0.20	1	0.3	0.3	0.2	0.3	0.2	**4**	**2%**
	Technical	Efficient and Well Integrated Site Layout	0.33	0.50	0.33	3.00	0.33	0.20	3.00	1	3.0	0.3	1.0	0.3	**13**	**6%**
		Ease of Constructability	0.33	0.33	0.33	0.50	0.33	0.20	3.00	0.33	1	0.3	0.3	0.2	**7**	**3%**
		Technology Maturity/ Reliability	1.00	3.00	3.00	3.00	2.00	1.00	5.00	3.00	3.00	1	3.0	1.0	**29**	**12%**
		Flexibility/ Ease of O&M	0.50	0.50	0.50	3.00	0.33	0.33	3.00	1.00	3.00	0.33	1	0.5[b]	**14**	**6%**
		Resiliency	0.50	1.00	0.50	1.00	1.00	1.00	5.00	3.00	5.00	1.00	2.00	1	**22**	**9%**
		Grand Total													**235**	**100%**

a. Values assigned based on comparing the criterion in the rows (A) with the criterion in the columns (B).

b. A sensitivity analysis was conducted on the value assigned.

c. Colors used for criteria weighting indicate:

##	##	##	##	##	##	##	##	##

Lower Values Higher Values

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2.3.4 Step 4: Score Alternatives and Estimate Life Cycle Cost

In this step, a total weighted, non-economic criteria score and life cycle cost estimate were developed for each alternative. The total weighted, non-economic criteria score was used as a summary metric to determine how well the alternative aligned with the non-economic criteria. Similarly, the life cycle cost was used as a summary metric to assess how well the alternative aligned with the economic criteria. The total non-economic criteria score and the life cycle cost were then considered together to determine which alternative(s) best aligned with the evaluation criteria overall, and ultimately the Master Plan goals and objectives.

2.3.4.1 Non-Economic Criteria Score

The total weighted non-economic criteria score was developed in the following steps:

- Assigned a score of 1 to 5 for each alternative for each non-economic evaluation criteria.
    - A score of 1 meant the alternative was least aligned with the criterion, and a score of 5 meant the alternative was most aligned with the criterion.
    - Table 2-3 describes the basis for the scoring (qualitative or quantitative).
    - For quantitative scores, the measurable metric was normalized, using min-max scaling, to assign a score.
- Multiplied the score for each criterion by the criterion weighting.
- Summed the weighted criteria scores to determine the total weighted non-economic criteria score for the alternative.

2.3.4.2 Life Cycle Cost

The life cycle cost developed for each alternative included capital costs, operation and maintenance (O&M) costs, and revenue. The basis for the life cycle cost is described in detail in the Basis of Cost Report.

2.3.5 Step 5: Refine Selected Alternative and Conduct Sensitivity Analysis

In this step, the selected alternatives were further refined. Different implementation strategies were developed and evaluated to assess the sensitivity of various planning assumptions and to select the preferred implementation strategy. The same evaluation process and criteria were applied and the implementation strategy that most aligned with the District's goals and objectives was selected for the roadmap. In some cases, the life cycle cost of the strategies considered were so different that the economic criteria was primarily used to select the preferred implementation strategy.

The implementation strategies developed and evaluated are described in detail in the Roadmap Report. As an example, for the nutrient reduction alternatives analysis, various near-term implementation strategies were developed and evaluated to optimize the scope and timing of changes to the existing resource recovery (R2) program and the scope and timing of side stream treatment improvements. One near-term implementation strategy was ultimately selected for the roadmap.

APPENDIX A - Sensitivity Analysis of Evaluation Criteria Weighting

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SENSITIVITY ANALYSIS OF EVALUATION CRITERIA WEIGHTING

During the pairwise comparison exercise, the District determined the relative importance of the evaluation criteria, resulting in a weighting score for each criterion. Of the 66 pairwise comparison scores developed, District staff determined alternate scores should be considered for six of the evaluation criteria pairs. To understand how the alternate scores could impact the weighting of the evaluation criteria, a sensitivity analysis was performed on the six evaluation criteria pairs. The results of this sensitivity analysis are presented below. Based on the results below, it was determined that weighting would have to change significantly in order for the results to be different. As such the weighting is not considered to be sensitive.

Criteria Chosen for Sensitivity Analysis

The six pairs chosen for the sensitivity analysis were identified by District staff as pairs where scores were more difficult to assign a value and where alternative scores were considered. Table A.1 shows the alternate scores discussed for the six pairs considered in this sensitivity analysis.

Table A-1. Alternate Pairwise Comparison Scores

Evaluation Criteria Pair	Chosen Score	Alternate Scores Considered
"Maximize Recoverable Resources" compared to "Minimize Chemical Usage"	1	1/2 or 1/3
"Maximize Recoverable Resources" compared to "Ease of Constructability"	3	1
"Minimize Treatment Process GHG Emissions" compared to "Efficient Land Use and Site Layout"	3	1
"Minimize Chemical Use" compared to "Resiliency"	1	1/2, 1/3, 2, or 3
"Community Acceptability" compared to "Resiliency"	1	1/2 or 1/3
"Flexibility/Ease of O&M" compared to "Resiliency"	0.5	1

Sensitivity Analysis

The goal of the sensitivity analysis was to evaluate if changing the scores of the six pairs affected the top three criteria, which were previously identified as:

- Facility Safety (17 percent)
- Reliability and Flexibility to Meet Current/ Potential Future Regulations (15 percent)
- Technology Maturity/ Reliability (12 percent)

Table A.2 summarizes the results of this sensitivity analysis, with cells in red indicating a difference between the original and alternative ranking. None of the alternate scores affected the ranking of the top three criteria; thus, the original scores chosen are not considered sensitive. It should be noted that the 4th highest weighted criterion does change under certain circumstances. However, given the top three criteria comprise 44% of the total criteria weighting the resulting ranking of the alternatives is largely driven by the top three criteria. As an additional test of confidence in the results, when the evaluation process resulted in alternatives and implementation strategies being similarly ranked, the District staff and Consultant Team reconsidered the planning assumptions to see if modifying them would impact the ranking of the alternatives.

Table A-2. Sensitivity Analysis Results

Criteria	Original Rank	Alternate Rank										
		"Maximize Recoverable Resources" compared to "Minimize Chemical Usage"		"Maximize Recoverable Resources" compared to "Constructability"	"Minimize Treatment Process GHG Emissions" compared to "Efficient Land Use and Site Layout"	"Minimize Chemical Use" compared to "Resiliency"				"Community Acceptability" compared to "Resiliency"		"Flexibility/Ease of O&M" compared to "Resiliency"
		Alternate Score: 1/2	Alternate Score: 1/3	Alternate Score: 1	Alternate Score: 1	Alternate Score: 1/2	Alternate Score: 1/3	Alternate Score: 2	Alternate Score: 3	Alternate Score: 1/2	Alternate Score: 1/3	Alternate Score: 1
Facility Safety	1	1	1	1	1	1	1	1	1	1	1	1
Reliability and Flexibility to Meet Current/ Potential Future Regulations	2	2	2	2	2	2	2	2	2	2	2	2
Technology Maturity/ Reliability	3	3	3	3	3	3	3	3	3	3	3	3
Minimize Treatment Process GHG Emissions	4	4	4	4	6	4	5	4	4	4	5	4
Community Acceptability	5	5	5	5	4	6	6	5	5	6	6	5
Resiliency	6	6	6	6	5	5	4	6	6	5	4	6
Maximize Recoverable Resources	7	7	8	9	7	7	7	7	7	7	7	7
Flexibility/ Ease of O&M	8	8	7	7	9	8	8	8	8	8	8	8
Efficient and Well Integrated Site Layout	9	9	9	8	8	9	9	9	9	9	9	9
Minimize Chemical Use	10	10	10	10	10	10	10	10	10	10	10	10
Ease of Constructability	11	11	11	11	11	11	11	11	11	11	11	11
Facility and Public Engagement	12	12	12	12	12	12	12	12	12	12	12	12

a. Cells highlighted in red indicate the alternative ranking is different from the original ranking.

b. The original ranking is considered good, given the ranking of the top three criteria is the same for all alternative ranking scenarios.

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INTEGRATED MASTER PLAN *for the* MAIN WASTEWATER TREATMENT PLANT

C60: Plant-Wide Process Model

June 2021

EBMUD

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EXECUTIVE SUMMARY

The goal of the East Bay Municipal Utility District's (District) Integrated Main Wastewater Treatment Plant (MWWTP) Master Plan Project (Master Plan) is to provide a 30-year roadmap that identifies capital improvement program (CIP) projects that address aging infrastructure, new regulations, capacity constraints, and climate change resiliency.

As part of the Master Plan, a plant-wide process model was developed and validated using historical data. The validated model was then used during the plant-wide capacity assessment, and when developing biosolids management, sidestream treatment and nutrient reduction alternatives. This report summarizes the development of the plant-wide process model, the model validation and recommendations for future wastewater characterization and process model refinement.

Process Model Development

BioWin was selected to develop the plant-wide process model. A screenshot of the BioWin model is provided on Figure ES-1. The BioWin model was configured as follows:

- Input elements were provided for both influent wastewater (raw influent plus low-strength waste [LSW]) and LSW trucked streams (termed Future LSW). During model validation, the Future LSW was set to zero because the historical plant influent (PI) data already includes influent wastewater and LSW contributions.
- In general, the primary sedimentation tanks (PST), oxygen reactors (high-purity oxygen activated sludge [HPOAS] reactors), secondary clarifiers, anaerobic digesters, and thickening and dewatering trains were each modeled as a single element as shown on Figure ES-1.
- The HPOAS stages were modeled individually; the first stage was modeled as anaerobic; stages 2 through 4 were modeled as aerobic.
- A single element for high-strength waste (HSW) streams was provided. An aggregate of the various HSW stream qualities was developed using the average quantities and characteristics of each HSW category.
- An input element was added for brine waste streams that are diverted to the final effluent (FE) channel (termed K2 waste streams).

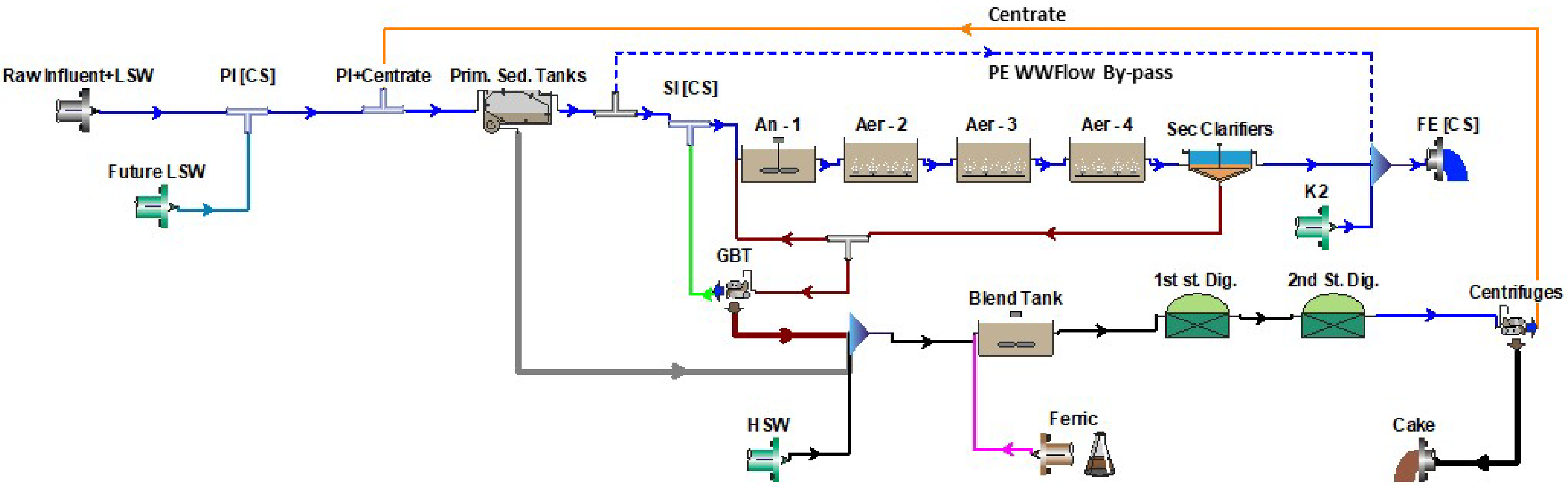

Figure ES-1. BioWin schematic for the MWWTP

Processes with multiple tanks or units are modeled as a single element. These include Primary Sedimentation (Prim. Sed.) Tanks, HPOAS reactors (Anaerobic [An] and Aerobic [Aer] stages 1 through 4). Secondary (Sec) Clarifiers, Gravity Belt Thickeners (GBT), Blend Tank(s), 1st and 2nd Stage (St.) Digesters (Dig.), and Centrifuges.

Wastewater Characteristics

Historical wastewater characterization data from 2010 through 2019 were used to develop and validate the process model. Additional wastewater characterization was not performed as part of this effort. The following assumptions and adjustments were made during process model development and validation:

- The PI 5-day carbonaceous biochemical oxygen demand ($cBOD_5$) used for the model was increased by approximately 19 percent to account for low $cBOD_5$ (and low $cBOD_5$: total suspended solids [TSS] ratio) measurements. Low $cBOD_5$ measurements were assumed to be the result of adding a nitrification inhibitor during the laboratory analysis.
- The historical data set does not include PI flocculated and filtered chemical oxygen demand (ffCOD), which represents the truly soluble fraction of the total COD. A typical ffCOD:COD ratio of 0.21 was assumed.
- To estimate the true soluble non-biodegradable COD fraction, the soluble COD (sCOD) (sCOD or 0.45 micron filtered secondary effluent) secondary effluent data were adjusted (multiplied by 86 percent). This was assumed to represent the truly sCOD (or ffCOD) in the secondary effluent, which represents the non-biodegradable COD.
- A non-biodegradable sCOD fraction (represented as F_{us}) of 0.078 was assumed. It should be noted that HSW may contribute to the effluent sCOD through the centrate. The HSW and centrate historical data suggest that the contribution is approximately less than 15 percent of the sCOD concentration.
- HSW total solids (TS) loads were reduced to provide more accurate model predictions. A mass balance around the Blend Tank identified that TS entering the Blend Tank (sum of thickened waste activated sludge [TWAS], primary sludge [PS], and HSW) was higher than TS exiting the Blend Tank. This provided a basis for reducing HSW TS loads. The HSW TS load was reduced to close the mass balance around the Blend Tank.
- The HSW increases total dissolved solids (TDS) at the MWWTP such that there is a notable difference between TS and TSS in solids samples. The TSS model predictions from BioWin were adjusted and converted to TS assuming a TDS concentration of 15,000 milligrams per liter (mg/L) in the HSW.

Process Model Validation Results

The process model was validated under both steady state and dynamic conditions for 2017 through 2018. The following summarizes conclusions and findings from the steady-state and dynamic model validations:

- Overall, the model predicts most parameters within 10 percent of historical data, which is suitable for master planning purposes.
- The model predicts total inorganic nitrogen (TIN) within 10 percent of the historical TIN data. The model underpredicts organic nitrogen (ON) in secondary influent (SI) and FE. The HSW and LSW likely influence the underprediction; however, there are limited historical data available to justify adjusting nitrogen fractions in the HSW or LSW. For the development of future scenarios that consider meeting a TN limit, additional adjustment to

the content of HSW should be made to correctly project effluent TN concentrations. Adjustments to meet FE TIN concentrations are not needed.

- The model underestimates orthophosphate (OP) in SI and FE, despite providing a good match in the PI and centrate streams. This may be related to the estimation of organic phosphorus in HSW (values were estimated due to data limitations). Because the model prediction for OP in centrate matched historical data, no further modifications were made to the phosphorus fractions in HSW or PI. When using the model to develop future alternatives that consider meeting a FE TP limit, it is recommended that the HSW phosphorus fractions be adjusted so that FE TP concentrations are not underestimated.
- The model slightly overpredicts the ammonia (NH_3) and total Kjeldahl nitrogen (TKN) concentrations in the centrate. The overprediction is slight, and additional adjustments are not recommended because it provides some conservatism when estimating sidestream treatment requirements.
- The model provides a good match for HPOAS mixed liquor suspended solids (MLSS) inventory. Dynamic model predictions provided a closer match in summer periods than wet periods, which suggests that wastewater characteristics vary seasonally. Future seasonal (wet and dry weather) wastewater characterization is recommended.
- The model provides a good match for digester feed and gas production (on an annual average basis). The model overpredicts cake production by 22 percent after adjustments are made to account for struvite deposition and TSS conversion to TS. This provides a conservative approach to solids projections for the master planning effort.

Recommended Future Efforts

As part of the model development and validation, future wastewater characterization is recommended to refine the model. The wastewater characterization effort should be performed in advance of project design and implementation. The following characterization efforts are recommended in the future:

- Conduct wastewater characterization to quantify COD fractions in both the wet and dry season. Sampling of PI and SI should include COD, filtered COD (fCOD or 1.2 micron glass fiber filtered), ffCOD, TSS, volatile suspended solids (VSS), $cBOD_5$, and filtered $cBOD_5$ ($fcBOD_5$ or 1.2 micron glass fiber filter). In addition, SE samples for fCOD and ffCOD would also be collected. Typical wastewater characterization efforts include daily sampling over a two-week period at minimum. The two weeks of data can be used to calibrate the model and adjust PI nutrient and carbon fractions. It is recommended that future efforts include collecting fraction data using the same sample on the same day.
- To better quantify HSW loading, routine composite sampling of the Blend Tank effluent is recommended for TS, TSS, volatile solids (VS), VSS, sCOD, TKN, soluble TKN, NH_3, TP, and OP.
    - It is also recommended that additional characterization of the HSW and LSW streams be performed to refine the process model and to confirm the impact that various types of trucked waste streams have on nutrient discharges, plant capacity and struvite formation.

- To improve the solids projections, long-term sampling of TS, TSS, TDS, VS, VSS, and sCOD through the solids handling processes is recommended (from gravity belt thickeners [GBT] through to dewatered cake).

Appendix C provides a preliminary wastewater characterization plan at the MWWTP for wastewater streams and resource recovery (R2) streams. Additional development of the wastewater characterization plan is needed to confirm sampling locations, frequency and duration.

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CHAPTER 1 - INTRODUCTION

The goal of the East Bay Municipal Utility District's (District) Integrated Main Wastewater Treatment Plant (MWWTP) Master Plan Project (Master Plan) is to provide a 30-year roadmap that identifies capital improvement program (CIP) projects that address aging infrastructure, new regulations, capacity constraints, and climate change resiliency.

As part of the Master Plan, a plant-wide process model was developed and validated using historical data. The validated model was then used during the plant-wide capacity assessment, and development of biosolids management, sidestream treatment and nutrient reduction alternatives. This report summarizes the development of the plant-wide process model, the model validation, and recommendations for future wastewater characterization and process model refinement.

This report is organized as follows:

- Executive Summary
- Chapter 1: Introduction
- Chapter 2: Background
- Chapter 3: Process Model Development
- Chapter 4: Wastewater Characterization
- Chapter 5: Process Model Validation
- Chapter 6: Conclusions and Recommendations
- Chapter 7: References

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CHAPTER 2 - BACKGROUND

A process flow schematic of the MWWTP with routine sampling locations is provided on Figure 2-1. A complete description of the District's treatment facilities is included in the Wastewater System Overview Report and in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report (EBMUD, 2019).

The liquid stream process consists of screening and grit removal followed by primary sedimentation, secondary treatment (high-purity oxygen activated sludge [HPOAS]), chlorine disinfection and dechlorination prior to discharge to the Bay. The HPOAS system is operated with an anaerobic selector. During peak wet weather events, primary effluent (PE) bypasses secondary treatment as shown on Figure 2-1.

The solids system includes waste activated sludge (WAS) thickening with gravity belt thickeners (GBT), anaerobic digestion and centrifuge dewatering. The GBT filtrate is returned to the PE channel, upstream of the secondary influent (SI) sampling location. The dewatering centrate is returned to the front of the primary sedimentation tanks (PST), downstream of the primary influent sampling location. The dewatering centrate can be returned to multiple PSTs but is typically only returned to one or two PSTs.

The District operates a resource recovery (R2) program that accepts trucked wastes at three locations at the MWWTP. Low-strength waste (LSW) trucked is accepted upstream of the plant headworks and typically includes water treatment sludge, septage and brine waste streams (low total dissolved solids [TDS] concentration). The plant influent or primary influent (PI) sample location is such that it includes the LSW trucked contribution as well as influent wastewater.

High-TDS brine waste streams are also received at the MWWTP and are directly routed to the final effluent (FE) channel, upstream of the effluent pump station (EPS). High-strength waste (HSW) trucked is discharged to one of two receiving stations and pumped to the solids Blend Tank where it is combined with primary sludge (PS) and thickened WAS (TWAS) and pumped to the anaerobic digesters. HSW trucked typically includes protein; fats, oil and grease (FOG); dairy wastes; and winery wastes. Additional details of the volumes and characteristics of the various R2 waste streams is provided in R2 Summary and Coarse Level Projection Report (EBMUD, 2019).

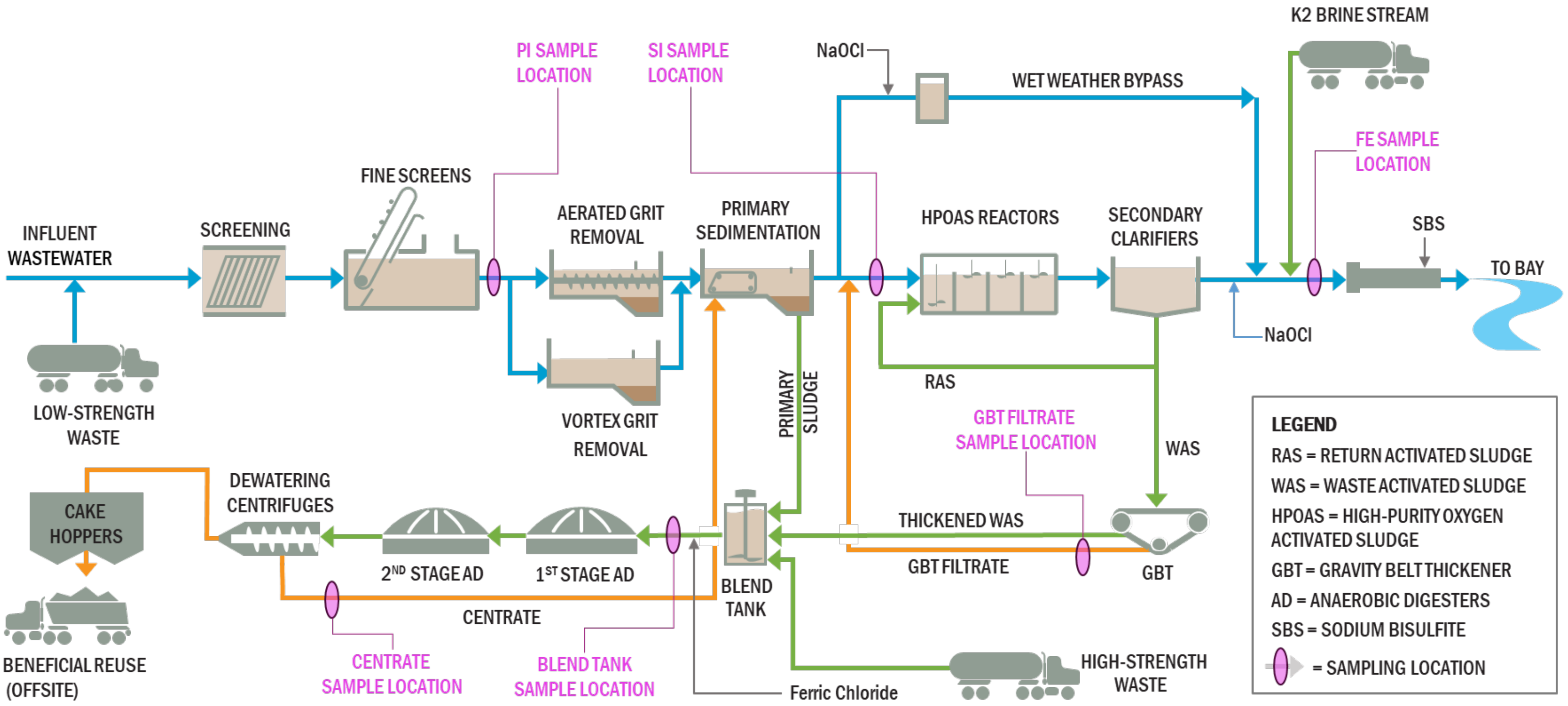

Figure 2-1. Process flow schematic

CHAPTER 3 - PROCESS MODEL DEVELOPMENT

This section provides an overview of the process model selection considerations and development. The purpose of the plant-wide process model is to develop a tool that can be used to define projects needed to meet potential future regulations and/or future capacity constraints.

3.1 Process Model Selection

The following process models were considered for use on the Master Plan:

- BioWin (Envirosim Associates, LTD)
- GPS-X (Hydromantis)
- SUMO (Dynamita)
- SIMBA# (inCTRL Solutions)
- WEST (DHI)

Each of the process models noted above have graphical user interfaces. The process simulators were all originally developed for low-rate activated sludge processes (e.g., solids retention time [SRT] > 3 days for carbon oxidation and nutrient removal). The models have all been modified to provide the ability to simulate high-rate activated sludge. Table 3-1 provides a comparison of the process models.

Table 3-1. Considerations for process model options

Consideration	BioWin	GPS-X	SUMO	SIMBA	WEST
Targeted markets	Whole-plant modeling	Whole-plant modeling	Research and development	Development of controls and biogas application	Whole-plant modeling
HPOAS modeling capabilities	Yes, parameter for percent of oxygen in headspace	Yes, specific HPOAS module	No	Yes, parameter for percent of oxygen in headspace	To be determined (under development)
Dynamic and steady-state modeling capabilities	Yes	Yes	Yes	Yes	Yes
Whole plant model capabilities	Yes	Yes	Yes	Yes	Yes
Ability to use for operator training	Yes, not ideal for training	Yes	Yes, not ideal for training	Yes, not ideal for training	Yes, not ideal for training
Industry standard	Yes	Yes	No	No	No
Ability for annual lease	Yes	Yes	Yes	Yes	Yes

At the Brainstorming and Evaluation Criteria Workshop 1 (conducted August 20, 2019), the five process models were reviewed with the District, and the advantages and disadvantages of each software were discussed. BioWin was selected for the Master Plan because it is widely used at municipal wastewater treatment facilities across the country. The District has experience with the model, which provides the ability for District Staff to use the model in the future.

3.2 Process Model Configuration

The process model was developed using BioWin 6.0. Figure 3-1 provides the BioWin model schematic. The model was configured as follows:

- Input elements were provided for both influent wastewater and LSW trucked streams (termed Future LSW). During model validation, the Future LSW was set to zero because the historical PI data already includes influent wastewater and LSW contributions.
- The PSTs were combined into one primary clarifier element with an aggregate surface area and solids pumping rate. This approach assumes equal PI loading and performance among the in-service PSTs.
- The oxygen reactors were modeled as a single train. One model element provided for each stage within the oxygen reactor. The first stage was modeled as anaerobic; stages 2 through 4 were modeled as aerobic.
- Secondary clarifiers were combined into a single clarifier element with an aggregate surface area and return activated sludge (RAS) pumping rate. Differences in performance among the secondary clarifiers was not accounted for in the model.
- The GBT units were combined into one thickening element with an aggregate TWAS pumping rate.
- All first-stage and second-stage anaerobic digesters were combined into single first- and second-stage anaerobic digester elements of aggregate volume.
- The centrifuge units were combined into one element with an aggregate performance.
- A single element for HSW was provided. Due to variability in volumes and loads of the HSW streams, an aggregate of the various HSW streams was used based on the annual average volume and loads.
- A bypass splitter element around the secondary treatment system was included for peak wet weather flow events. This splitter allows PE to bypass the secondary system during peak wet weather events.
- An input element was added for brine waste streams that were diverted to the FE channel (termed K2 waste streams). The brine waste streams historically have been less than 50,000 gallons per day (gpd) and were included in the FE sample location.
- Dewatering centrate was routed to the front of the PSTs; GBT filtrate was routed to the PE channel (upstream of the SI sample location).
- An input element for ferric chloride was included at the solids Blend Tank based on confirmation from District Staff on the dosing location.

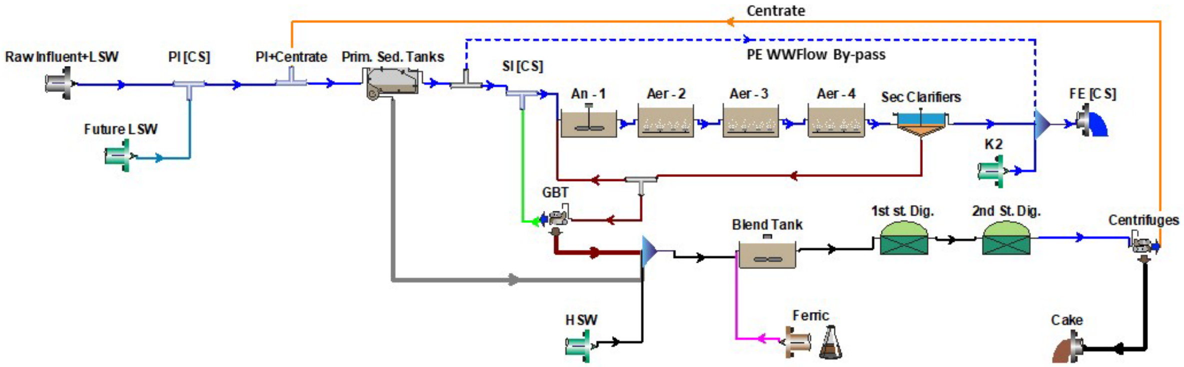

Figure 3-1. BioWin™ schematic for the MWWTP

Table 3-2 summarizes the basin volumes that were used for the steady-state model validation. The basin volumes and number of online units were based on historical operational data provided by the District. The number of units online varies throughout the year based on influent flows and loads, as well as ongoing maintenance and construction activities. The steady-state modeling that was performed (described in chapter 5) uses the average tank volumes for the 2017-18 calendar years. Dynamic model validations (refer to chapter 5) account for the varying volumes/number of units online for the HPOAS reactors, which are critical secondary treatment units in the model.

Table 3-2. Unit process area volumes used for steady-state model validation

Unit Process Area	Total Number of Units	Volume per Tank/Unit (MG)	Assumptions for Steady-State Model Validation[b]	
			Units In-Service[c]	Volume (MG)
PSTs	16	0.5	10	4.8
HPOAS reactors [a]				
Zone 1 (anaerobic)	8	0.4	6	2.5
Zone 2 (aerobic)	8	0.4	6	2.5
Zone 3 (aerobic)	8	0.4	6	2.5
Zone 4 (aerobic)	8	0.4	6	2.5
Secondary clarifiers	12	1.6	10	16
Solids Blend Tank	2	0.2	1	0.2
Anaerobic digesters				
1st stage	8	1.7	6	10.2
2nd stage	3	1.7	2	3.6

All values are rounded to nearest tenth, unless otherwise stated.

a. Number of online HPOAS reactors varies over the year. Refer to chapter 5, which discusses assumptions during dynamic model validation.

b. Represents annual average for years 2017 and 2018 based on historical operational data.

c. Values rounded to nearest whole number.

MG = million gallon(s)

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CHAPTER 4 - WASTEWATER CHARACTERIZATION

Wastewater characterization of influent and internal return streams, important in model calibration and validation, is used to determine wastewater fractions for carbon (i.e., chemical oxygen demand [COD] and 5-day biochemical oxygen demand [BOD_5]), nitrogen and phosphorus. Appendix A provides details of the carbon and nutrient fractions that are identified during wastewater characterization. Typically, a two-week wastewater characterization campaign is performed to collect nutrient and carbon data of influent streams and internal plant streams. In preparation for the Master Plan, District Staff conducted nutrient and carbon profiling of influent and internal plant streams from 2016 to 2019. In discussions with District staff, it was determined that the existing data set would be used for the process model validation. Model validation results were used to identify locations for future, targeted nutrient or carbon profiling to refine and improve model predictions. The following sections provide a detailed review of the historical data and associated wastewater fractions that were used in the model.

4.1 Primary Influent Wastewater

Historical data from January 2010 through March 2019 was used to develop PI wastewater fractions. As noted in chapter 2, the PI sample location includes influent wastewater and LSW contributions. In discussions with District Staff, it is difficult to collect a sample of raw influent wastewater upstream of LSW and, therefore, has rarely been performed. The PI data set includes 5-day carbonaceous BOD ($cBOD_5$) and TSS, collected four times per week. In 2016, COD and nutrient sampling began and was continued through March 2019. Table 4-1 presents the PI annual average concentrations from 2010 through 2019; Table 4-2 presents PI ratios that were calculated.

Table 4-1. PI annual average wastewater characteristics (2010-19)

Year	$cBOD_5$	TSS	VSS	COD	sCOD	TKN	NH_3	TP	OP
2010	351	371	--	--	--	--	--	--	--
2011	314	319	--	--	--	--	--	--	--
2012	287	328	--	--	--	--	--	--	--
2013	317	377	--	--	--	--	--	--	--
2014	310	418	--	--	--	--	--	--	--
2015	337	390	--	--	--	--	--	--	--
2016	319	373	321	--	192	54.8	34	9.1	4.7
2017	286	362	308	815	177	49.1	29	8.4	3.8
2018	309	397	--	799	184	51.4	34	8.7	4.5
2019	257	423	--	602	117	--	21	6.6	2.9

TSS = total suspended solids, VSS = volatile suspended solids, sCOD = soluble COD (0.45 micron filter), TKN = total Kjeldahl nitrogen, NH_3 = ammonia, TP = total phosphorus, OP = orthophosphate

Annual average values are provided. Data for 2019 is from January through March.

Table 4-2. PI annual average wastewater ratios (2010-19)

Year	$cBOD_5$: TSS	COD: $cBOD_5$	sCOD: COD	fCOD:VSS	NH_3:TKN	COD:TKN	TP:COD	OP:TP
2010	0.95	--	--	--	--	--	--	--
2011	0.99	--	--	--	--	--	--	--
2012	0.87	--	--	--	--	--	--	--
2013	0.84	--	--	--	--	--	--	--
2014	0.74	--	--	--	--	--	--	--
2015	0.86	--	--	--	--	--	--	--
2016	0.85	--	--	--	0.63	--	--	0.52
2017	0.79	2.6	0.22	2.1	0.59	16.6	0.010	0.46
2018	0.78	2.6	0.23	--	0.67	15.5	0.011	0.52
2019	0.61	2.3	0.19	--	--	--	0.011	0.44
Average	0.83	2.6	0.21	2.1	0.63	16.06	0.011	0.49

fCOD = filtered COD (filtered through 1.2 micron glass fiber filter). The fCOD was estimated using available data. The sCOD is filtered through a 0.45-micron filter.

Annual average values are provided. Data for 2019 is from January through March.

4.1.1 COD and BOD Fractions

As noted in Table 4-1, data were available for $cBOD_5$, total COD, sCOD, VSS and TSS. Some parameters were available for limited time periods. For example, VSS was available for 2016 through September 2017 and total COD data were only available starting in September 2017. Wastewater fractions or ratios are typically more accurate if all parameters are collected on the same day and same sample.

The sCOD measurement at the plant is carried out using 0.45 micron filter and does not represent the true sCOD fraction as defined in the BioWin model. The flocculated and filtered COD (ffCOD) represents the total soluble fraction of the COD. Since historical values of ffCOD were not measured, a typical ffCOD:COD ratio of 0.21 was assumed. fCOD data were also not available (sample is filtered with a 1.2-micron glass fiber filter), but a value was estimated in order to calculate a fCOD:VSS ratio (Table 4-2).

The PI COD, $cBOD_5$ and TSS concentrations averaged approximately 740, 310 and 376 milligrams per liter (mg/L), respectively. The PI COD data were only collected between 2017 through 2019. During this period, the COD:$cBOD_5$ ratio averaged 2.5, with values ranging from 2.3 to 2.6. This ratio is slightly higher than typical values, which are typically in the range of 2.0 to 2.2. The PI $cBOD_5$:TSS ratio averaged 0.82, which is considered low compared to values from other facilities with typical values in the range of 1.0 to 1.2. The lower $cBOD_5$:TSS may suggest that the $cBOD_5$ data are lower than expected, which could be caused by the nitrification inhibitor used during the $cBOD_5$ test, which partially inhibits heterotrophic organisms. District Staff confirmed using the inhibited $cBOD_5$ test;therefore, the $cBOD_5$ concentrations were corrected by dividing by 0.84 to estimate the true $cBOD_5$ concentration. After the correction, the revised

$cBOD_5$:TSS and the COD:$cBOD_5$ ratios were approximately 1.0 and 2.2, which are within the range of typical values.

The PI sCOD:COD ratio averaged 0.21, which is lower than typical. The fCOD:COD ratio is typically between 35 to 45 percent. Since fCOD data were unavailable, a ratio of 30 percent was used in the model. It is recommended that future efforts include PI characterization of noted parameters; the characterization should be performed using the same sample or on the same day to confirm the fractions.

4.1.2 Nitrogen Fraction

The PI ammonia-nitrogen (NH_3-N) and TKN concentrations were used to estimate the average NH_3-N:TKN ratio [F_{na}] of 0.64. The PI COD:TKN and COD:NH_3-N ratios from the MWWTP averaged 16.1 and 26.4, respectively. These values are within a typical range; therefore, the BioWin default values for influent organic nitrogen (ON) fractions were used.

4.1.3 Phosphorus Fraction

The PI TP:COD ratio averaged 0.011. The average OP:TP ratio, which is referred to as F_{PO4}, measured at the MWWTP was 0.49, which is within the typical range for municipal wastewater. Accordingly, the BioWin default values for phosphorus fractions were used in the model validation.

4.1.4 Suspended Solids Fractions

The average VSS fraction of the PI TSS calculated during the 2016-17 period is 0.85, which is typical; however, the VSS: TSS ratio was lower during high flow periods (Figure 4-1). To account for this decrease, a VSS:TSS ratio of 0.85 was assumed during normal conditions, and a VSS:TSS ratio of 0.75 was assumed for flows exceeding 60 million gallons per day (mgd). Influent VSS fractions have been observed at other municipal WWTPs to vary seasonally. As the District moves toward project implementation in the future, it is recommended that wastewater characterization be performed both in the dry and wet weather seasons.

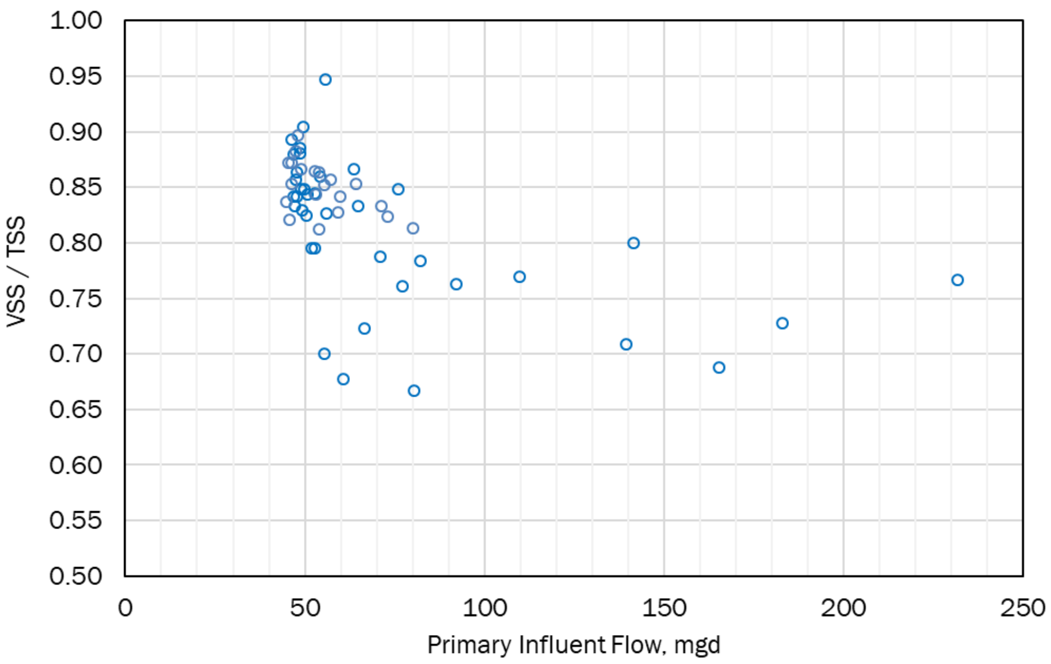

Figure 4-1. VSS:TSS fraction with respect to PI flow

4.1.5 Summary of PI Fractions

The historical PI data are comprehensive and provided adequate characterization of the influent wastewater to the MWWTP (Table 4-3). Based on the historical PI data, the following ratios were used for the BioWin process model:

- COD:cBOD$_5$ of 2.2
- cBOD$_5$:TSS of 1.0
- fCOD:COD of 0.38

Several assumptions and adjustments were made based on the historical data set:

- The PI cBOD$_5$ was increased by approximately 19 percent to account for low cBOD$_5$ (and low cBOD$_5$:TSS ratio) measurements that were assumed to be the result of the nitrification inhibitor added to the samples.
- The historical data for the MWWTP does not include measurements for PI ffCOD, which represents the truly soluble fraction of the total COD; hence, for this study, it was assumed that the typical ffCOD:COD ratio of 0.21 applies.
- To estimate the true soluble non-biodegradable COD fraction, the sCOD secondary effluent data were adjusted (multiplied by 86 percent). This was assumed to represent the truly sCOD (or ffCOD) in the secondary effluent, which represents the non-biodegradable COD. A non-biodegradable sCOD fraction (represented as F_{us}) of 0.078 was assumed. It should be noted that HSW may contribute to the effluent sCOD through the centrate; however, HSW and centrate data indicate that the contribution is approximately less than 15 percent of the sCOD concentration.

It is recommended that additional wastewater characterization be performed during future preliminary design efforts as follows:

- Collect total COD, sCOD, fCOD (1.2 micron glass fiber filtered) and ffCOD measurements on the same day and/or sample for PI and secondary effluent. This additional data will confirm assumptions made in this model validation and will confirm the non-biodegradable COD fraction in the secondary effluent.
- Perform wastewater characterization during summer and winter months to confirm seasonal variability in wastewater characteristics.

Table 4-3. Summary of PI fractions

Fraction	BioWin Default Value	Value Used for Model Validation
Fbs - Readily biodegradable (including acetate) [gCOD/g of total COD]	0.16	0.127
Fxsp - Non-colloidal slowly biodegradable [gCOD/g of slowly degradable COD]	0.75	0.700
Fus - Unbiodegradable soluble [gCOD/g of total COD]	0.05	0.078
Fup - Unbiodegradable particulate [gCOD/g of total COD]	0.13	0.200
Fna - Ammonia [gNH3-N/gTKN]	0.66	0.640
FupN - N:COD ratio for unbiodegradable part. COD [gN/gCOD]	0.035	0.035
Fpo4 - Phosphate [gPO4-P/gTP]	0.5	0.494
FupP - P:COD ratio for unbiodegradable part. COD [gP/gCOD]	0.011	0.011
Particulate COD:VSS ratio	1.6	1.630

4.2 LSW and HSW Waste Streams

As noted in Chapter 2, the LSW and raw influent wastewater are sampled together at the PI sample location. For the purposes of model validation, the influent wastewater and LSW were not separated out.

HSW characterization was prepared by District Staff for each category of HSW that enters the plant. The characterization effort was based on historical sampling from individual trucks that discharge to the R2 solid liquid waste and HSW receiving stations. Similar to LSW, a combined HSW characterization was calculated based on the volume and characteristics of each category of HSW that was discharged at the plant in 2017 and 2018. Table 4-4 provides a summary of the calculated HSW profile that was used for model validation. Due to the variability in HSW streams, it is recommended that the District perform additional characterization at the solids Blend Tank to confirm nutrient, volatile solids (VS) and TS loading to the anaerobic digesters. This additional characterization should be performed over a long-term period prior to project implementation to confirm variability and/or trends in the digester feed characteristics.

Table 4-4. HSW characteristics

Parameter	Units	Historical Data (2017-18)[a]
Flow	mgd	0.23
TSS[b,c]	mg/L	--
	klbs/day	--
TS[c]	mg/L	67,514
	klbs/day	131
VSS[b]	mg/L	--
	klbs/day	--
VS	mg/L	54,336
	klbs/day	106
sCOD [0.45 µm]	mg/L	84,072
	klbs/day	163
TKN	mg/L	3,193
	klbs/day	6.2
NH_3	mg/L	583
	klbs/day	1.2
Nitrate	mg-N/L	186
	klbs/day	0.4
Nitrite	mg-N/L	24
	klbs/day	0.1
Total N	mg-N/L	3,403
	klbs/day	6.6
OP	mg-P/L	546
	klbs/day	1.1
Alkalinity	mg-$CaCO_3$/L	6,199
	klbs/day	12

a. Flow weighted average based on HSW characteristics by category in 2017 and 2018. Refer to R2 Summary and Coarse Level Projection Report (EBMUD, 2019) for HSW characteristics and volumes by each category.

b. BioWin is based on TSS but does not account for TDS.

c. Model input assumes a TDS of 15,000 mg/L.

klbs/day = kips per day, $CaCO_3$ = calcium carbonate, mg-N/L = milligrams nitrogen per liter,
mg-P/L = milligrams phosphorus per liter, µm = micrometer(s)

CHAPTER 5 - PROCESS MODEL VALIDATION

The BioWin model was validated using historical operational data from 2017 through 2018. Steady-state and dynamic model validations were performed. The model inputs and results are detailed in the sections below.

5.1 Model Inputs

This section provides a summary of model inputs assumed for model validation. For each of the inputs, key assumptions and/or modifications to historical data are noted.

5.1.1 Primary Influent

Table 5-1 presents the PI model values used for the model validation and compares the model values to historical data. Total COD data were not available from January 1, 2017, through September 5, 2018. There were data available during this time period for $cBOD_5$; the $cBOD_5$ values were used to calculate COD PI data for the noted time period. As noted in section 4, the $cBOD_5$:COD ratio was assumed to remain constant across the year. For days when $cBOD_5$ data were also not available, a value that was equal to the previous 14 days was assumed. The TKN and TP model inputs were also calculated using the identified COD:TKN and COD:TP ratios described in chapter 4.

Table 5-1. PI model inputs (historical data versus model)

Parameter	Units	Historical Average (standard deviation in parenthesis)	Model Value [a]
Flow rate	mgd	60 (2.7)	60
TSS	mg/L	380 (92)	362
VSS[b]	mg/L	308 (87)	296
Total COD[c]	mg/L	803 (163)	785
sCOD [0.45 µm]	mg/L	180 (64)	--
Measured cBOD	mg/L	297 (84)	--
Total cBOD (corrected)[d]	mg/L	354	337
Total nitrogen (as N)	mg/L	--	52
TKN (as N)	mg/L	50 (12)	49
NH_3 (as N)	mg/L	32 (8)	31
Nitrate + Nitrite (as N)	mg/L	3.6 (1.6)	3.5
Total (as P)	mg/L	8.5 (2.1)	8.4
OP (as P)	mg/L	4.2 (1.5)	4.2
Alkalinity (as $CaCO_3$)	mg/L	287 (40)	285
pH	--	6.8 (0.2)	6.8

a. Values shown are for steady state. Steady-state inputs were calculated from the average of the dynamic inputs, so dynamic results are similar.

b. VSS was only measured for a portion of 2017.

c. COD was not measured from January 1, 2017, through September 5, 2018. Model value is based on CBOD5 measurements for days where data were unavailable.

d. cBOD5 is the corrected value to account for inhibition in the analytical method used.

5.1.2 HSW

As noted in section 2, an influent element was used for the HSW loads routed to the Blend Tank. Iron, calcium and magnesium concentrations identified during the 2016 struvite control investigation (Hazen and Sawyer, 2016) were used in the model to more accurately predict phosphorus chemical precipitants.

BioWin predicts TSS but does not account for TDS. The District's historical solids data are based on TS analyses. In most cases, TDS concentrations in solids streams are not high enough to result in a significant difference in TS and TSS concentrations. The HSW does include significant concentrations of TDS such that there is a notable difference between the TS and TSS in the solids streams. Therefore, the model results (in TSS) were converted to TS (discussed further in section 5.2.3); this correction was based on preliminary TDS data that was available at the time of model validation. Table 5-2 provides a summary of the historical HSW data as well as the assumptions and model inputs for the HSW element.

Table 5-2. HSW characteristics and model inputs

Parameter	Units	Historical Data [a]	Model Input
Flow rate	mgd	0.23	0.23
TSS[b,c]	mg/L	--	20,577
	klbs/day	--	40
TS[c]	mg/L	67,514	35,691
	klbs/day	131	68
VSS[b]	mg/L	--	18,018
	klbs/day	--	35
VS	mg/L	54,336	--
	klbs/day	106	--
sCOD [0.45 µm]	mg/L	84,072	84,072
	klbs/day	163	162
TKN	mg/L	3,193	3,052
	klbs/day	6.2	5.9
NH_3	mg/L	583	576
	klbs/day	1.2	1.2
Nitrate	mg-N/L	186	193
	klbs/day	0.4	0.4
Nitrite	mg-N/L	24	24
	klbs/day	0.1	0.1
Total N	mg-N/L	3,403	3,269
	klbs/day	6.6	6.3
OP	mg-P/L	546	549
	klbs/day	1.1	1.1
Alkalinity	mg-$CaCO_3$/L	6,199	5,914
	klbs/day	12	12

a. Flow-weighted average based on HSW characteristics by category in 2017 through 2018. Refer to R2 Summary and Coarse Level Projection Report (EBMUD, 2019) for HSW characteristics and volumes by each category.

b. BioWin tracks TSS but does not account for dissolved solids.

c. BC model input assumes a TDS of 15,000 mg/L.

The District has noted that the chemical composition of HSW streams is variable. For the model validation, TS and VS concentrations in the HSW were adjusted to close the mass balance around the Blend Tank and to improve model prediction as compared to historical data.

As noted in section 4.2, long-term (6 to 12 months minimum) monitoring of HSW is recommended. Composite samples of the Blend Tank effluent are recommended to confirm COD, nitrogen and phosphorus fractions. This profiling would be in addition to the TS and VS routine samples of the Blend Tank effluent. It is also recommended that TDS samples be collected to provide additional data for conversion of model-predicted TSS concentrations to TS concentrations.

5.1.3 Ferric Chloride Addition

Ferric chloride (40 percent by weight) is added to the Blend Tanks to control hydrogen sulfide formation in the anaerobic digesters. Historical daily consumption (gpd) data provided by District Staff were used in the model. The average ferric chloride consumption for 2017 and 2018 was 1,700 gpd.

5.2 Solids Mass Balance Confirmations

Mass balances were performed using historical data to provide a data quality check and to determine the performance of solids separation processes, including primary sedimentation and secondary clarifiers. The mass balance around the Blend Tank was also performed to verify the solids loading associated with HSW.

5.2.1 PST Solids Mass Balance

A mass balance around the PSTs was performed to confirm assumptions and model inputs as it relates to PST removal efficiency. The mass balance compares the TSS removal across the PSTs with the PS TSS load; in theory these values would be similar. The historical PI load was modified to include the centrate load. The SI load was also adjusted to subtract the GBT filtrate; the adjusted SI was then assumed to represent the PE quality. Table 5-3 provides the results of the PST mass balance. The mass balance illustrates that there is a 12 percent different between the solids load entering the primaries versus the calculated solids leaving the primaries (i.e., TSS in PS and PE). The difference in the mass balance is acceptable for planning-level calibration of the BioWin model, especially because adjustments to PI and SI load using centrate and GBT filtrate data, respectively, were expected to propagate sampling errors in the calculated primary influent and effluent values.

For the purposes of the model validation, the PI and PE TSS concentrations were assumed to be more reliable than PS flow meters. Thus, the TSS removal across the PSTs (model input) was based on PI and PE concentrations.

Table 5-3. PST solids mass balance

Parameter	Units	Solids Mass Balance Value
Total TSS mass rate entering the PST	klbs/day	184
PS TS mass rate[a]	klbs/day	101
PE TSS mass rate	klbs/day	62
Total TSS mass rate exiting the PST[b]	klbs/day	162
Total TSS mass rate difference	%	-12

a. Based on PS flow and TS, the PS mass is 101 klbs/d. Based on the PI and PE TSS, PS mass is 122 klbs/day. Model is based on the influent and PE loadings.

b. Assuming PS TS is approximately equal to TSS (TDS is small compared to TSS).

5.2.2 Secondary Clarifier Solids Mass Balance

A similar solids balance around the secondary clarifiers was performed using the average mixed liquor suspended solids (MLSS) concentration, RAS concentration and the SI flow. Table 5-4 shows the mass balance results, which were reasonably within 3 percent; accordingly, no adjustments were made to the performance of the secondary clarifiers.

Table 5-4. Secondary clarifier solids mass balance

Parameter	Units	Solids Mass Balance Value
Total TSS mass rate entering the secondary clarifier	klbs/day	1,389
RAS TSS mass rate	klbs/day	1,422
SE TSS mass rate	klbs/day	6
Total TSS mass rate exiting the secondary clarifier	klbs/day	1,428
Total TSS mass rate difference	%	3

5.2.3 Blend Tank Solids Mass Balance

A TS mass balance was performed using historical data of the TWAS, PS and HSW pumped to the Blend Tank. These values were compared to the Blend Tank effluent. The data indicates that more solids enter the Blend Tank than exit. As noted in Section 5.1.2, the HSW influent was adjusted to improve the model validation; the adjustments were made to the TS of the HSW only.

Table 5-5. Blend tank solids mass balance

Parameter	Units	Solids Mass Balance Value	Modified Value (used in Model)
TWAS TS mass rate entering the Blend Tank	klbs/d	96	--
PS TSS mass rate entering the Blend Tank[a]	klbs/d	122	----
HSW TS mass rate entering the Blend Tank[b]	klbs/d	112	68
Total TS mass rate entering the Blend Tank (sum of TWAS, PS, and HSW TS)	klbs/d	330	--
Total TS mass rate exiting the Blend Tank (measured)	klbs/d	286	--
Total TSS mass rate difference	%	-13	--

a. Based on the influent and PE TSS mass, assuming PS TS is approximately equal to TSS (TDS is small compared to TSS).

b. HSW TS was adjusted to 68 klbs/d to match the Blend Tank TS. Model TSS inputs calculated assuming 15,000 mg/L of TDS in the HSW.

5.3 Steady-State Model Validation

A steady state model validation of the annual average influent flow and loading conditions was performed for 2017-18. Figure 5-1 presents a comparison between the MWWTP plant data during the 2017-18 operational period and the steady state model results. For most parameters, the model outputs were within 10 percent of the historical data. The following summarizes the key conclusions of the steady state model validation:

- The model predictions for COD removal in the PSTs and secondary system, as well as the COD and VSS destruction in the anaerobic digesters, matched historical data set within 10 percent.
- In the HPOAS system, no significant NH_3 removal was observed from historical data. Although nitrate and nitrite may be produced from moderate nitrification activity, the specific growth rate for NH_3-oxidizing organisms (AOB) was reduced to 0.5 d^{-1} to inhibit nitrification. It must be noted here that the repression of the AOB growth rate is specific to the HPO process. The model predicts that nitrate and nitrite in PI are removed in the HPOAS anaerobic stage.
- There was a discrepancy in ON between the model and the historical data in the SI and FE. The model under predicts the ON by approximately 9 mgN/L in the FE. The sources of ON are the PI, LSW, and HSW, which is recycled back to the PSTs in the centrate. The model total nitrogen prediction in the biosolids cake matches historical data well. Historical centrate data were available for TKN and NH_3. The model overestimates these two parameters by 11 percent and 13 percent, respectively. For the purpose of evaluating sidestream treatment alternatives, this is considered conservative and acceptable. Additional characterization of the HSW and LSW (or Blend Tank contents) is needed to confirm necessary adjustments for

better model prediction of ON in the FE. For the purpose of preparing the master plan, the model prediction of TIN in the FE is considered acceptable and should be used for alternatives evaluation.

- The model underestimates OP in the SI and FE. The HSW may be a significant source of phosphorus; however, the centrate TP and OP results match historical data (within 10 percent). During the model validation, it was observed that the historical OP in the PI and centrate was 2,100 pounds per day (lb/day) and 900 lb/day, respectively, which is a total of 3,000 lb/day entering the PSTs. The SI measured 3,500 lb/day of OP. In discussions with District Staff, there was not an identified source of the increase in OP in the SI.
- The model predicts the PI and centrate OP values well; however, the OP in the SI does not closely match historical data. For the purpose of master planning, the model prediction of effluent OP and TP is considered acceptable, and no further adjustments were made. To improve model prediction for future projects, additional wastewater characterization of the HSW is recommended to confirm what parameters and ratios to adjust.
- The model underpredicted MLSS inventory in HPOAS by approximately 4 percent. SRT was calculated using the solids inventory in the HPOAS reactors (not including inventory in the secondary clarifiers) and the TSS mass leaving through the waste activated sludge (WAS) and effluent streams. Since SRT was also underestimated (by 8 percent), the model was determined to be suitable for predicting the process inventory for capacity assessment purposes.
- BioWin models TSS and VSS, but the historical solids data are measured as TS and VS. The TDS is significant at the MWWTP from the HSW and LSW and, therefore, needs to be accounted for in the model predicted TSS and VSS concentrations. Figure 5-1 includes estimates of TS made using preliminary TDS concentrations. Additional characterization is recommended to confirm the TDS correction factor.
- BioWin has a unit for mesophilic type digestion with maximum temperature of 40 degrees Celsius (°C). To reflect the higher rates in the digesters due to operating at temperatures of approximately 50 °C, key kinetic parameters for methanogens, propionic acetogens and hydrolysis were increased for the first-stage digesters. With the adjustment to the HSW input (Section 5.1.2) and conversion of TSS to TS, the model provides a good prediction (within 10 percent difference) of combined solids loading to the digesters (sum of PS, TWAS and HSW).
- The model predicts the volatile suspended solids reduction (VSSR) in the digesters, which does not account for dissolved volatile solids associated with the sCOD component of the HSW. If the model accounted for these additional volatile solids entering the digester, then the VSR would be higher, since the sCOD components are mostly removed across the digester. The model output was also compared to the plant digesters performance with respect to COD reduction (CODR). A value obtained from a testing period with a single digester showed a 67 percent CODR. The model predicted an average CODR of 70 percent for 2017-18. Model predictions of biogas production were within 7 percent of measured values. The specific biogas production rate was calculated in the model at 26 cubic feet per pound (ft^3/lb) VSS destroyed, and from the plant data at 27 cft/lb VS destroyed.
    - The model overpredicts both digested solids and cake solids by about 30 klbs/day (after correcting for TDS). Model-predicted cake production was 32 percent higher

than measured; however, it is a known issue at the plant that phosphorus precipitates as struvite in the sludge treatment processes. If the cake production mass rates are reduced by the amount of precipitates predicted by the model, the difference between the model and the data are reduced to approximately 22 percent. For the purpose of master planning, the solids handling model predictions are considered acceptable and should be used for alternatives evaluation. To improve model prediction for future projects, long-term sampling to quantify TS, TSS, TDS, VS, VSS, and sCOD through solids handling is recommended.

1 Primary Influent [Plant Inf. + LSW]

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	60	60	0
Temperature	Celsius	21	21	0
TSS	mg/L	380	362	-5
VSS	mg/L	308	301	-2
cBOD*	mg/L	354	337	-5
COD (total)	mg/L	803	785	-2
sCOD (0.45 µm)	mg/L	180	--	
FCOD (1.2 µm)	mg/L	--	296	
TN	mgN/L	53	52	-2
TKN	mgN/L	50	49	-2
Ammonia	mgN/L	32	31	-1
Nitrate	mgN/L	2.7	3.5	
Nitrite	mgN/L	0.9	0	
Nitrate+Nitrite	mg/N	3.6	3.5	-2
TP	mgP/L	8.5	8.4	-1
OP	mgP/L	4.2	4.2	-1
Alk	mg/L	287	285	-1
pH	-	6.8	6.8	-1

*Historical cBOD was corrected --> True cBOD = cBOD/0.84

2 Secondary Influent [Prim. Eff + GBT Recycle]

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	60	62	3
TSS	mg/L	123	133	8
VSS	mg/L	108	110	1
cBOD	mg/L	--	211	
COD (total)	mg/L	446	474	6
sCOD (0.45 µm)	mg/L	162		
FCOD (1.2 µm)	mg/L	--	298	
TKN	mgN/L	64	59	-7
Ammonia	mgN/L	50	49	-2
Nitrate	mgN/L	2.6	3.4	
Nitrite	mgN/L	0.7	0	
Nitrate+Nitrite	mg/N	3.2	3.4	4
TP	mgP/L	9.9	7.6	-23
OP	mgP/L	7.0	5.9	-16

3 Secondary Reactors [HPO]

Parameter	Unit	Data	Model	%Diff.
MLSS*	mg/L	2123	1993	-6
MLVSS	mg/L	1862	1637	-12
TSS Inventory	klbs/d	177	169	-4
SRT	days	1.7	1.6	-8

*Probe data

4 Final Effluent

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	58	60	4
TSS	mg/L	12	11	-1
VSS	mg/L	--	9	
cBOD	mg/L	8.9	7.2	-19
COD (total)	mg/L	91	86	-6
sCOD (0.45 µm)	mg/L	76	--	
FCOD (1.2 µm)	mg/L	--	72	
TN	mgN/L	56	46	-18
TIN	mgN/L	46	44	-6
Ammonia	mgN/L	44	43	0
Nitrate	mgN/L	0.9	0.1	
Nitrite	mgN/L	1.8	0.01	
TP	mgP/L	4.1	3.1	-25
OP	mgP/L	3.6	2.8	-22
Alk	mg/L	349	357	2

5 Centrate

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	0.66	0.64	
TSS	mg/L	1,045	1,049	0
VSS	mg/L	--	633	
COD (total)	mg/L	--	1,927	
sCOD (0.45 µm)	mg/L	938	--	
FCOD (1.2 µm)	mg/L	--	950	
TKN	mgN/L	1,596	1,772	11
Ammonia	mgN/L	1,527	1,722	13
TP	mgP/L	195	203	4
TP	klbs/d	1.1	1.1	1
OP	mgP/L	157	172	9
OP	klbs/d	867	917	6

6 PS

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	0.25	0.25	0
TSS	klbs/d		124	
TDS*	mg/L		500	
TDS	klbs/d		1	
TS**	klbs/d	101	125	24
TS	%	4.9	6.0	
VSS	klbs/d		102	
VS**	klbs/d	78	102	30
VS/TS ratio	%	78	82	5

*TDS concentrations were assumed.

**The balance around the clarifiers indicates that primary sludge mass was underpredicted. Model is based on primary influent and secondary influent characteristics.

6 TWAS

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	0.22	0.22	0
TSS	klbs/d		95	
TDS*	mg/L		500	
TDS	klbs/d		1	
TS	klbs/d	96	96	0
TS	%	5.3	5.2	
VSS	klbs/d		78	
VS	klbs/d	75	78	5
VS/TS ratio	%	78	81	

*TDS concentrations were assumed.

8 HSW

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	0.23	0.23	-1
TSS	klbs/d		39.50	
sCOD	klbs/d	163	161	
TDS*	mg/L		15,000	
TDS	klbs/d		29	
TS	klbs/d	130	68	-48
TS	%		3.6	
VSS	klbs/d		35	
VS	klbs/d	105		
TN	klbs/d	6.6	6.3	-5
OP	klbs/d	1.1	1.1	-4
TP	klbs/d		1.4	

*TDS concentrations were assumed.

9 Blend Tank

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	0.70	0.70	0
TSS	klbs/d		267	
TDS	mg/L		5,264	
TDS*	klbs/d		31	
TS	klbs/d	286	298	4
TS	%	4.9	5.1	
VSS	klbs/d		216	
VS	klbs/d	213	216	1
VS/TS ratio	%	74	73	-2

*TDS loadings assume that TDS mass is conserved.

10 Digesters

Parameter	Unit	Data	Model	%Diff.
VSR (VSSR)*	%	66	61	-7
CODR**	%	67	70	4
Gas prod.***	scfm/d	2,244	2,390	7
TSS	klbs/d		139	
TDS****	klbs/d		31	
TDS	mg/L		5,264	
TS	klbs/d	143	170	19
TS*****	klbs/d	143	160	12
VS	klbs/d	73	84	16
VS/TS	%	51	49	-2
Specific Gas Yield	scf/lb_VS_des	27	26	-3
Specific Gas Yield	scf/lb_COD_des	--	9	

*Model tracks volatile suspended solids reduction (VSSR). The contribution of sCOD is not included in model VSS, and relation between sCOD and VS is not known.

**Data obtained from 2011 WEFTEC paper titled "NEW (FIRST EVER) SITE SPECIFIC PSRP-EQUIVALENT ANAEROBIC DIGESTION PROCESS INCREASES DIGESTION CAPACITY BY FIFTY PERCENT" - 1st dtage Dig at 50 °C

***Plant biogas production was corrected for moisture (assumed 11% reduction in volume due to moisture at 121 F)

****TDS loadings assume that TDS mass is conserved.

*****Correcting for phosphorus precipitates trapped in the Digesters

11 Cake

Parameter	Unit	Data	Model	%Diff.
Flowrate	MGD	--	0.070	
TSS	klbs/d		134	
TDS	mg/L		5,264	
TDS*	klbs/d		3	
TS	klbs/d	104	137	32
TS**	klbs/d	104	127	22
Cake weight	WT/d	215	--	
% Cake solids	%	24	23	
P-Precipitate	klbs/d	--	10	
TKN	% DW	5.2	5.4	4
Org N	% DW	3.8	4.7	22
Ammonia	% DW	1.3	0.7	-48
Nitrate	% DW	0.0	0.0	
Phosphorus	% DW	4.2	3.0	-27

*TDS loadings assume that TDS mass is conserved.

**Correcting for phosphorus precipitates trapped in the Digesters

***The cake dry solids mass is based on 24% solids in the wet cake. If cake solids were actually 26%, then the TS mass would be 112 klbs/d.

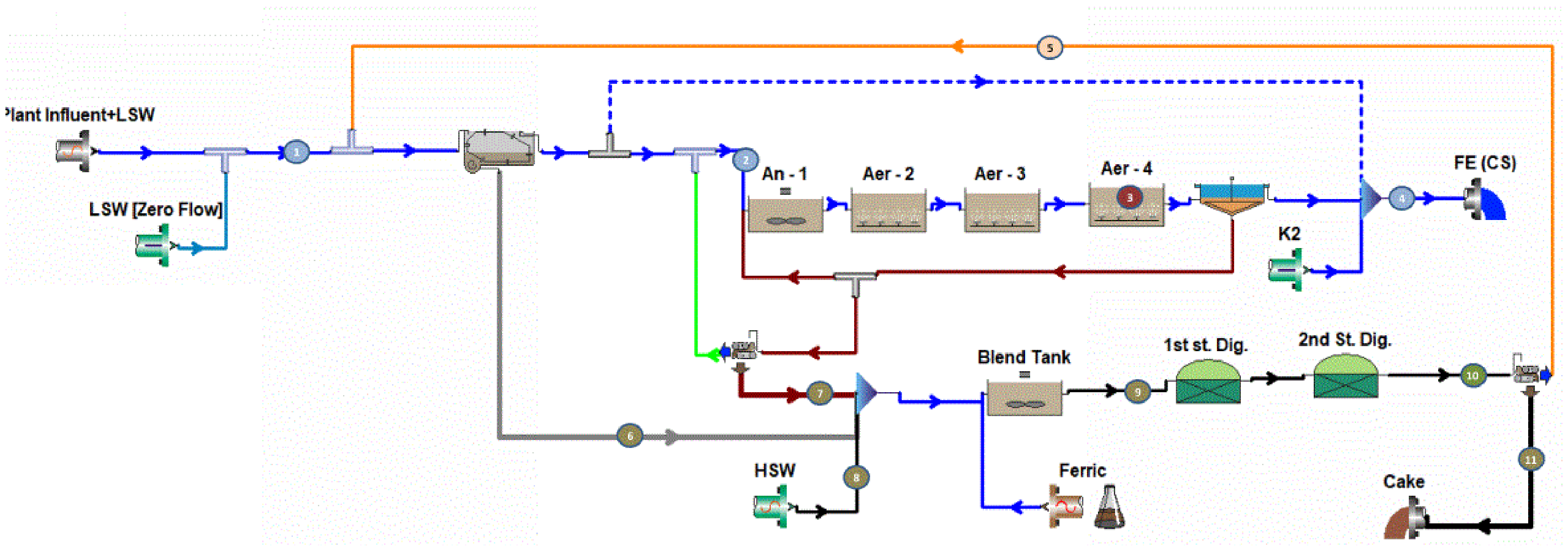

Figure 5-1. Steady state model results compared to historical plant data (2017-18 average).

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5.4 Dynamic Model Validation

The model was evaluated under dynamic conditions using daily data from the beginning of 2017-18. Since the plant operates with a variable number of reactors, especially during wet weather events, the model was also run using a sequence of dynamic models with variable HPOAS reactor volume to more accurately represent the plant operation. Table 5-6 shows the periods of each dynamic run and the average reactor volume assumed.

Table 5-6. Dynamic model runs with variable HPOAS reactor volumes

Period	Average Number of Reactors In-Service[a]	Total Volume (MG)[a]	Volume per Stage (MG)
1/1/17 - 4/20/17	8	12	3.0
4/21/17 - 11/14/17	6	9	2.5
11/15/17 - 4/22/18	7	11	2.7
4/23/18 - 09/19/18	6	10	2.4
9/20/18 - 11/21/18	5	8	2.0
11/21/18 - 12/31/18	7	12	2.9

a. Values rounded to nearest whole number.

Figure 5-2 shows the daily PI flow and wastewater temperatures for 2017-18. The model predictions are represented in a continuous solid line; plant data are represented by discrete boxes. The plant received frequent and significant wet weather events during 2017 with temperatures dropping below 16 °C.

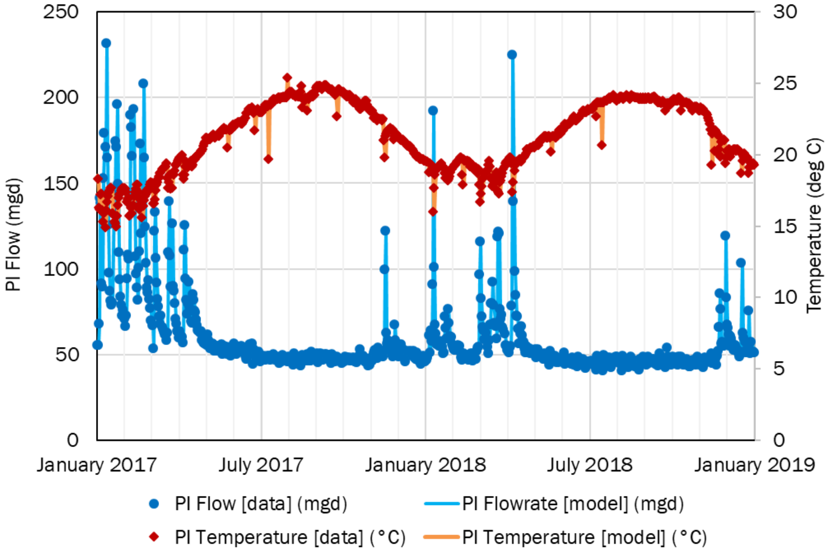

Figure 5-2. Dynamic model validation results - PI flow and wastewater temperatures (2017-18).

Figure 5-3 provides the historical PI COD and the model output. As noted in chapter 4, the COD model input was calculated based on first correcting historical cBOD$_5$ data for the inhibitor, followed by multiplying the corrected cBOD$_5$ by the total COD:corrected cBOD$_5$ ratio. Appendix B provides additional figures that compare the PI model prediction and PI historical data for TSS, cBOD$_5$, TKN, NH$_3$, TP and OP. In general, the model was able to predict these parameters closely.

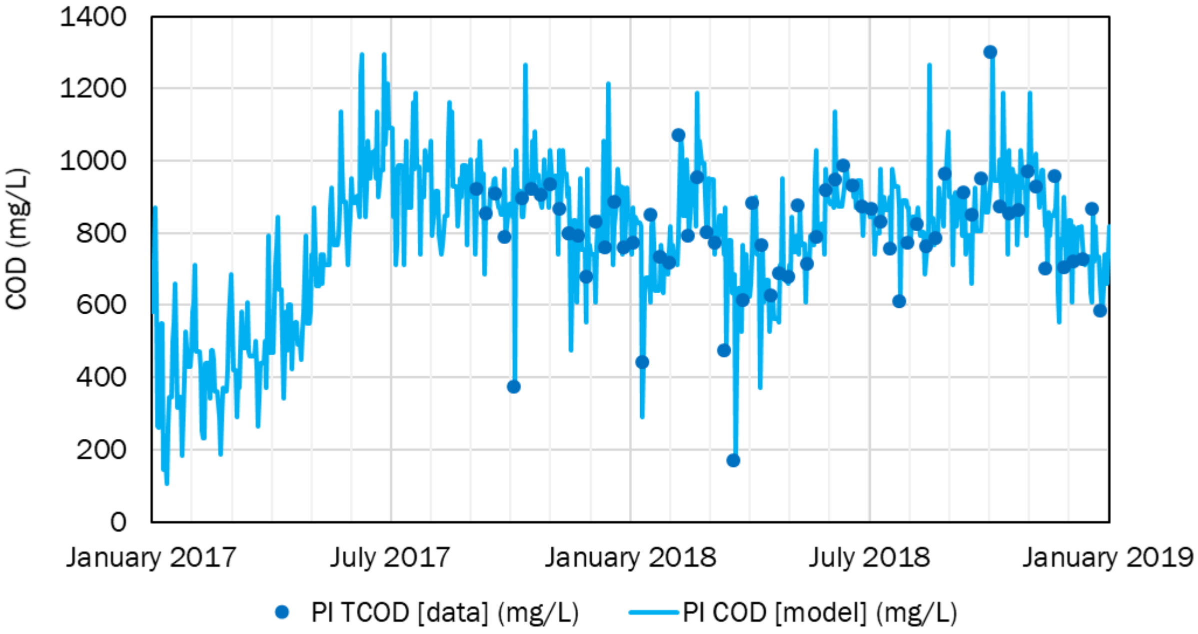

Figure 5-3. Dynamic model validation results - PI total COD (2017–18)

Figures 5-4 and 5-5 provide the model output for SI TSS, COD and cBOD$_5$ compared to historical data. The model outputs matched the historical data well for these parameters. There is limited cBOD$_5$ SI data.

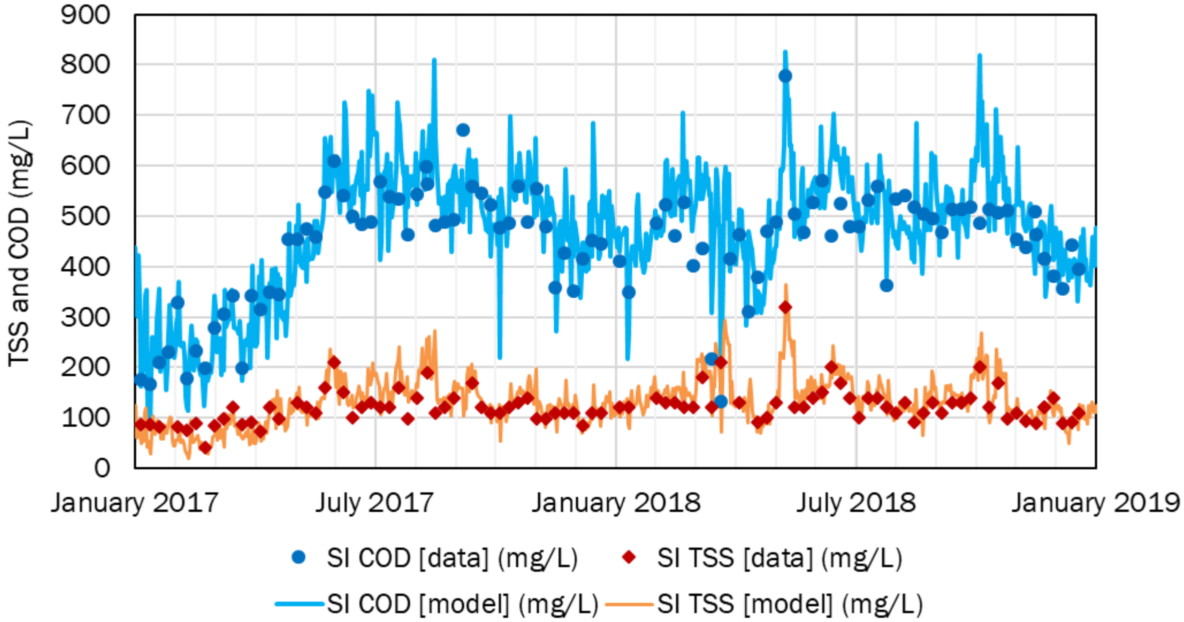

Figure 5-4. Dynamic model validation results - SI total COD and TSS (2017-18)

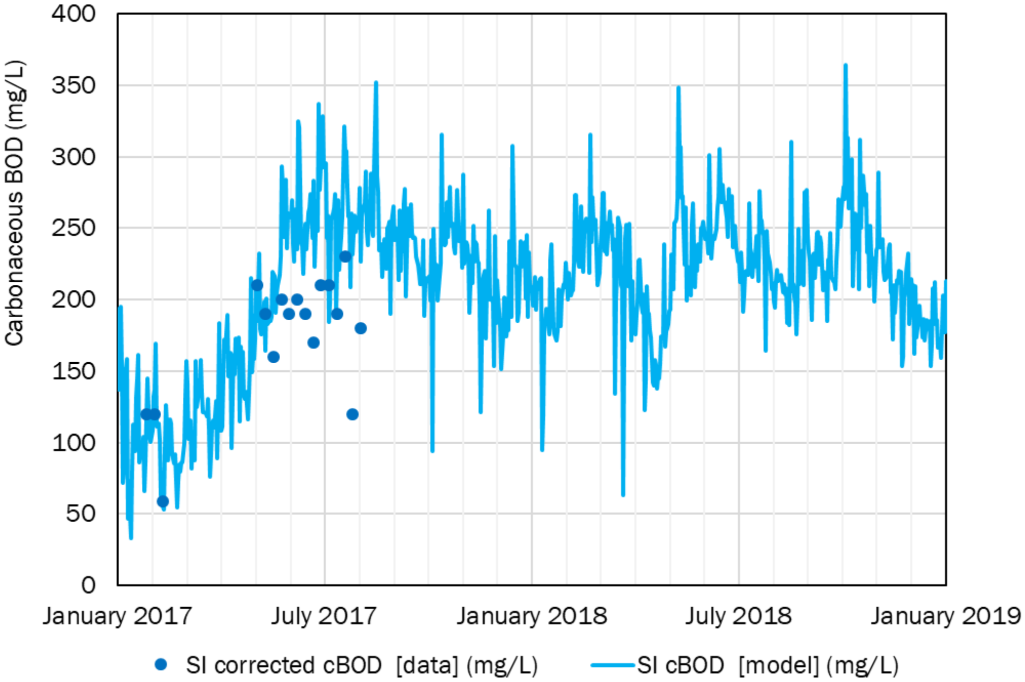

Figure 5-5. Dynamic model validation results - $CBOD_5$ (2017-18)

Plotted $cBOD_5$ data are corrected, where true $cBOD_5$ = measured $cBOD_5/0.84$.

Figure 5-6 shows the historical MLSS concentrations and HPOAS SRT versus modeled values. SRT was calculated using the solids inventory in the HPOAS reactors (not including inventory in the secondary clarifiers), and the TSS mass leaving with WAS and effluent. MLSS model predictions are not as good of a match during the wet seasons, which may indicate that wastewater characteristics are different in the wet seasons.

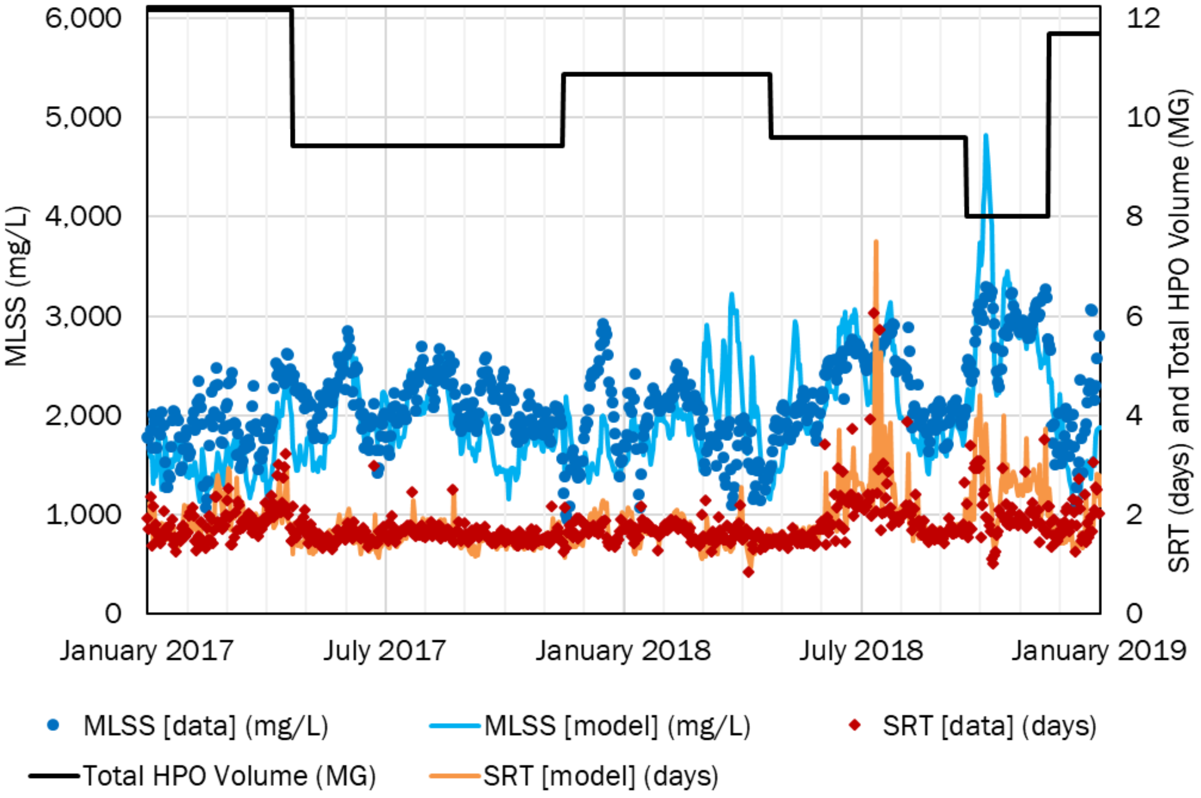

Figure 5-6. Dynamic model validation results - secondary MLSS and SRT (2017-18)

Figure 5-7 provides the model prediction against plant data for FE cBOD5 and sCOD (0.45 micron). The model predicted these parameters, as well as TSS (refer to Appendix B for FE TSS plot).

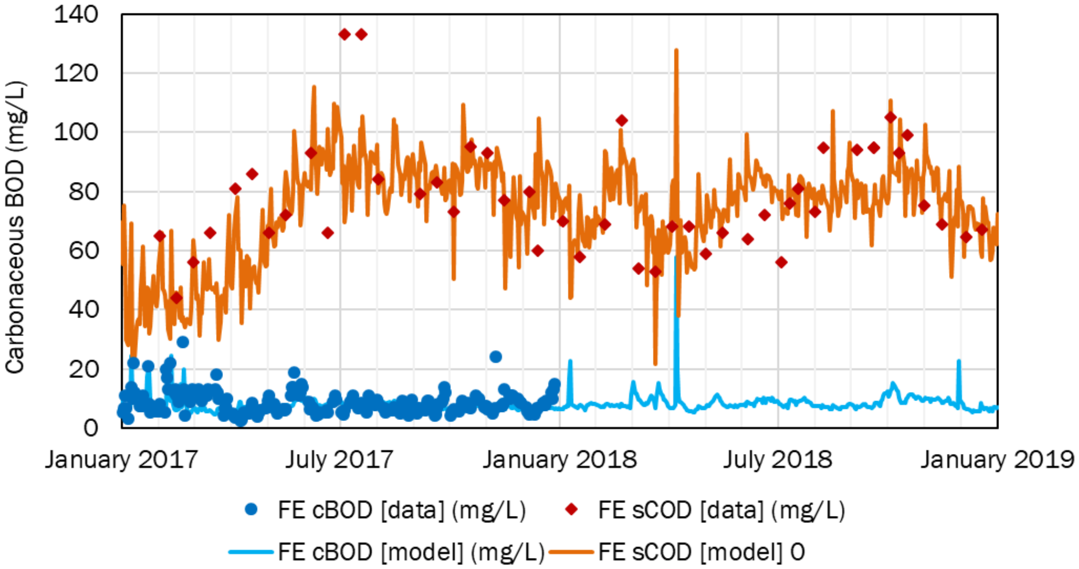

Figure 5-7. Dynamic model validation results - FE CBOD5 and sCOD [0.45 micron] (2017-18)

Figure 5-8 shows the model prediction of effluent TP and OP. The default specific growth rate for polyphosphate accumulating organisms of 0.95 was used in steady state and dynamic modeling scenarios. The model predicts little biological phosphorus removal, so low phosphorus predictions are related to the assumed input values.

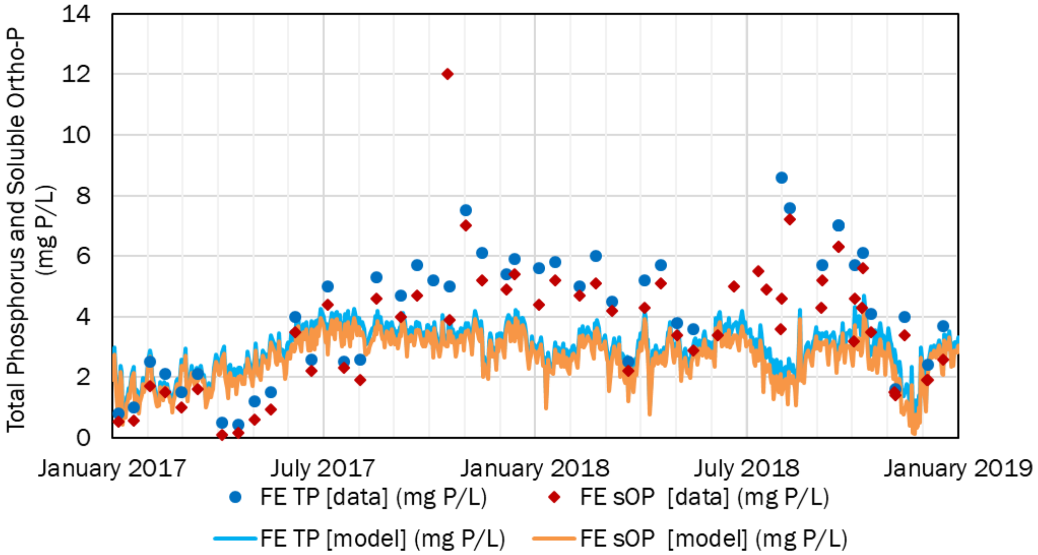

Figure 5-8. Dynamic model validation results - FE TP and OP (2017-18)

Figure 5-9 shows the model prediction of FE TN and NH_3 against plant data. The model predicts NH_3 well. As with the steady-state evaluation, the model underpredicts TN, which is likely due to the ON discrepancy described in section 5.3.

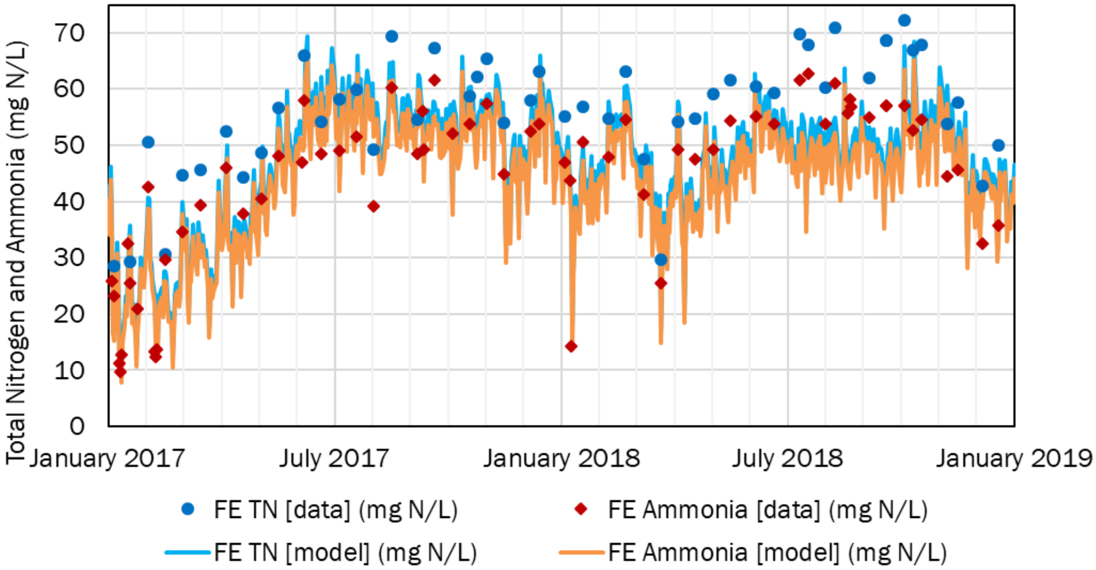

Figure 5-9. Dynamic model validation results-FE TN and NH_3 (2017-18)

The model outputs for biosolids cake and biogas production were compared to daily data and figures of the model output and historical data are included in Appendix B. Due to the variability in the R2 HSW, the model output for biogas and biosolids cake was focused on developing a good correlation for steady-state model runs.

CHAPTER 6 - CONCLUSIONS AND RECOMMENDATIONS

BioWin was selected as the software for the development of a plant-wide process model. After developing the model and characterizing influent wastewater and HSW, the process model was validated using the historical data from the years 2017-18. Assumptions that were made for model input streams are:

- The inhibited influent $cBOD_5$ concentrations measured were assumed to be 84 percent of the truly (uninhibited) $cBOD_5$ concentration. The historical data were adjusted to uninhibited $cBOD_5$. The COD to uninhibited cBOD5 ratio was 2.2.
- A mass balance was performed for TS around the Blend Tank. The TS entering the Blend Tank (sum of TWAS, PS and HSW) was determined to be higher than the TS exiting the Blend Tank. The HSW TS load was reduced to close the mass balance around the Blend Tank.
- The HSW increases TDS at the MWWTP such that there is a notable difference between TS and TSS in solids samples. The TSS model predictions from BioWin were adjusted and converted to TS, assuming the TDS concentration in the HSW is 15,000 mg/L.

The process model was validated under steady-state and dynamic conditions for 2017-18. The following provides a summary of the conclusions and findings from the steady-state and dynamic model validations:

- Overall, the model predicts most parameters within 10 percent of historical data, making it suitable for master planning purposes.
- The model predicts TIN within 10 percent of the historical TIN data and is a good predictor for TIN. The model underpredicts ON in SI and FE. The HSW and LSW likely influence the underprediction; however, there is limited historical data available to adjust nitrogen fractions in the HSW or LSW. For the development of future scenarios that consider meeting a TN limit, additional adjustment to the ON content of HSW are recommended to correctly project effluent TN concentrations. Adjustments to meet FE TIN concentrations are not needed.
- The model underestimates OP in SI and FE, despite providing a good match in the PI and centrate streams. This may be related to the estimation of organic P in HSW (values were estimated due to data limitations). Since the model prediction for OP in centrate matched historical data, no further modifications were made to the P fractions in HSW or PI. When using the model to develop future alternatives that consider meeting a TP limit, it is recommended that the HSW phosphorus fractions be adjusted so that FE TP concentrations are not underestimated.
- The model slightly overpredicts the NH_3 and TKN concentrations in the centrate. The overprediction is slight, and additional adjustments are not recommended because it provides some conservatism when estimating sidestream treatment requirements.

- The model provides a good match for HPOAS MLSS inventory. Dynamic model predictions provided a closer match in summer periods than wet periods, which suggest that wastewater characteristics varies seasonally. Future seasonal wastewater characterization is recommended to improve match for wet periods.
- The model provides a good match for digester feed and gas production (on an annual average basis). The model overpredicts cake production by 22 percent, after adjustments are made to account for struvite deposition and TSS conversion to TS. This provides a conservative approach to solids projections for the master planning effort. Further wastewater characterization of the HSW is expected to improve the model prediction.

Additional wastewater characterization is expected to improve model predictions. A wastewater characterization effort is recommended in advance of project design and implementation. The following future characterization efforts are recommended:

- Conduct sampling campaigns to quantify COD fractions in both the wet and dry season. PI and SI samples should include COD, fCOD (1.2 micron glass fiber filter), ffCOD, TSS, VSS, $cBOD_5$, and $fcBOD_5$ (1.2 micron glass fiber filter). In addition, SE samples should include fCOD and ffCOD. Typical wastewater characterization efforts include daily sampling over a two-week period minimum. The two weeks of data can be used to calibrate the model and adjust PI nutrient and carbon fractions. It is recommended that future campaigns collect the fraction data using the same sample on the same day. Appendix C provides a recommended wastewater characterization campaign for the MWWTP.
- To better quantify HSW loading, routine composite sampling of the Blend Tank effluent is recommended for TS, TSS, VS, VSS, sCOD, TKN, soluble TKN, NH_3, TP and OP.
- To improve the solids projections, long-term sampling of TS, TSS, TDS, VS, VSS and sCOD through the solids handling processes is recommended (from GBTs through to dewatered cake).

CHAPTER 7 - REFERENCES

East Bay Municipal Utility District, MWWTP Wastewater System Overview, May 2019.

East Bay Municipal Utility District, R2 Summary and Coarse-Level Projection, May 2019.

East Bay Municipal Utility District, Preliminary Capacity Assessment Report E80/E90, July 2019.

Hazen and Sawyer, Struvite Control Investigation, February 2016.

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APPENDIX A - WASTEWATER FRACTIONS

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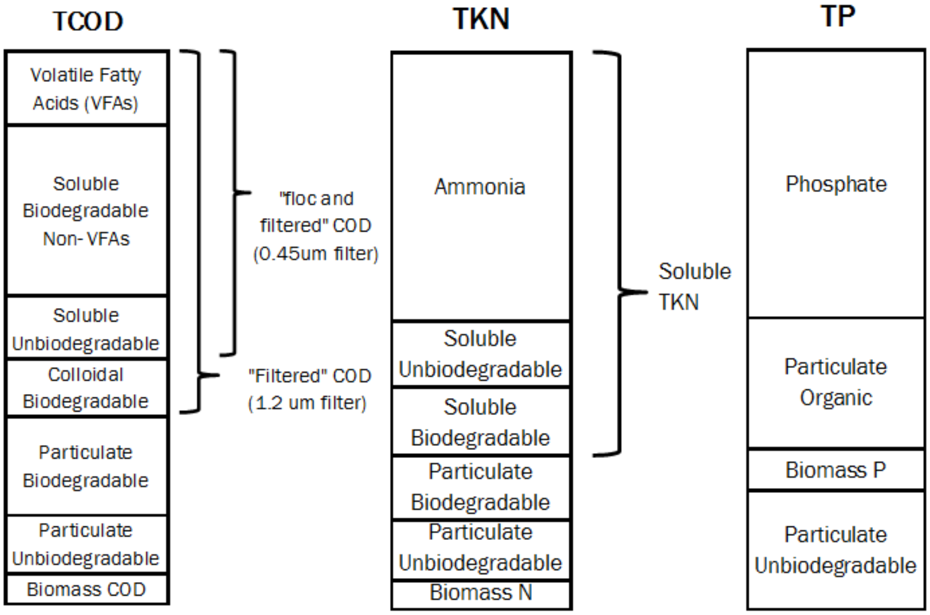

Figure A-1. Graphical representation of BioWin influent COD, TKN, and TP fractions

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APPENDIX B - DYNAMIC MODEL VALIDATION RESULTS

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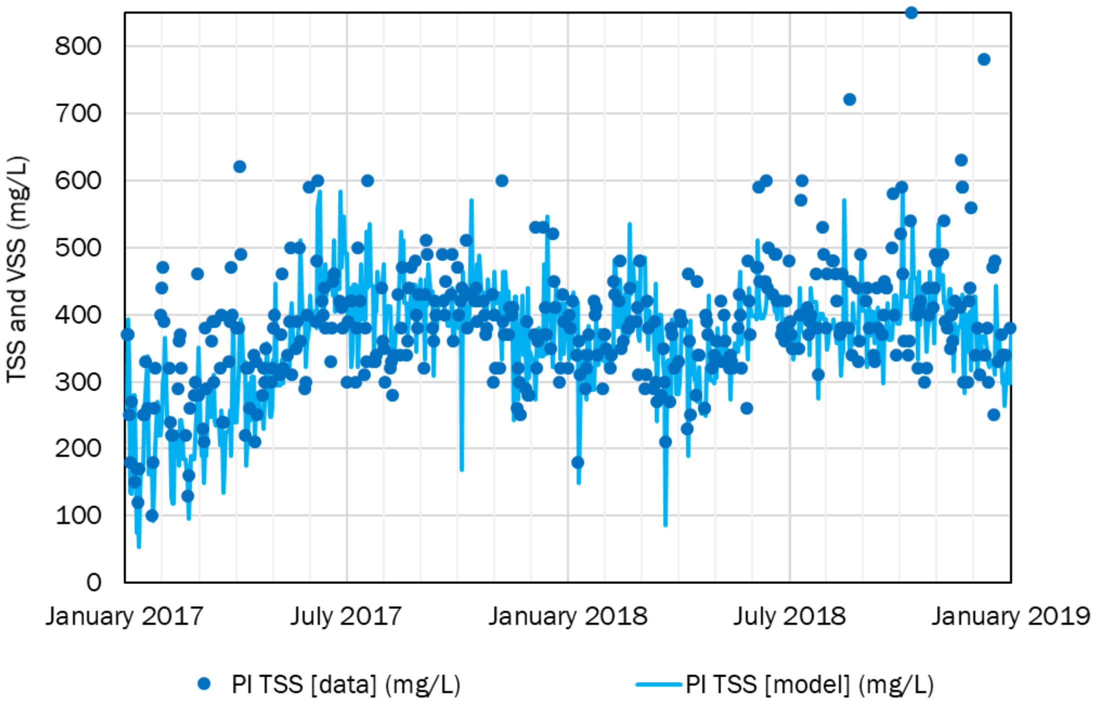

Figure B-1. Dynamic model validation results - PI TSS (2017-18)

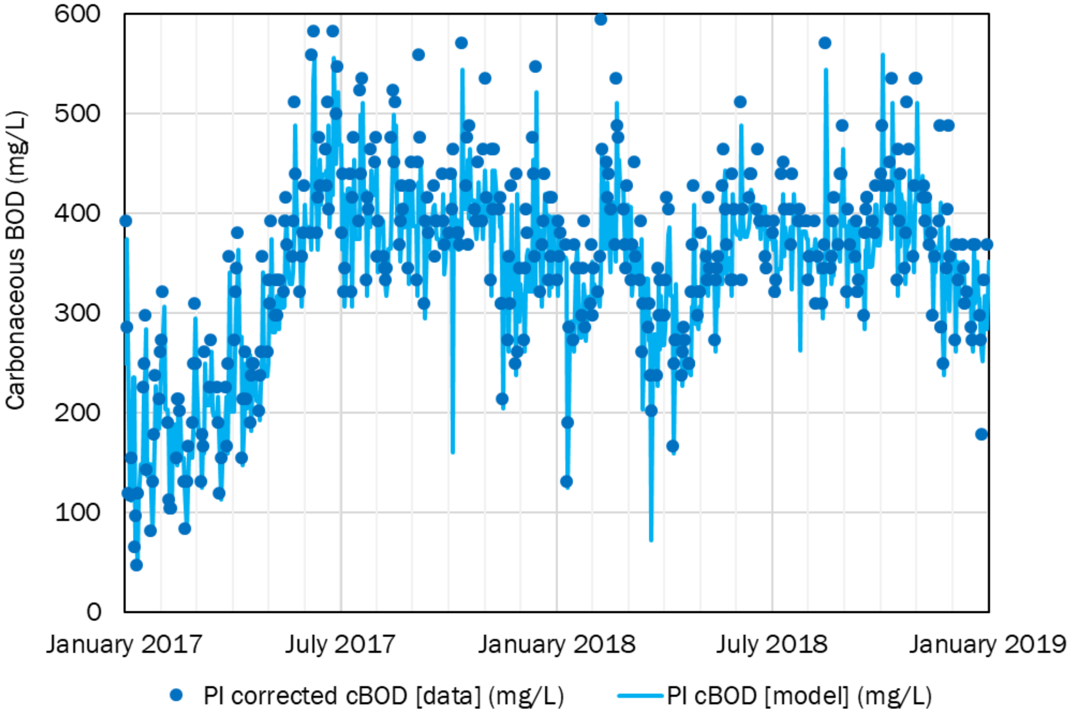

Figure B-2. Dynamic model validation results - PI $CBOD_5$ [corrected for inhibited test].

Plotted $CBOD_5$ data are corrected, where true $cBOD_5$ = measured $cBOD_5/0.84$.

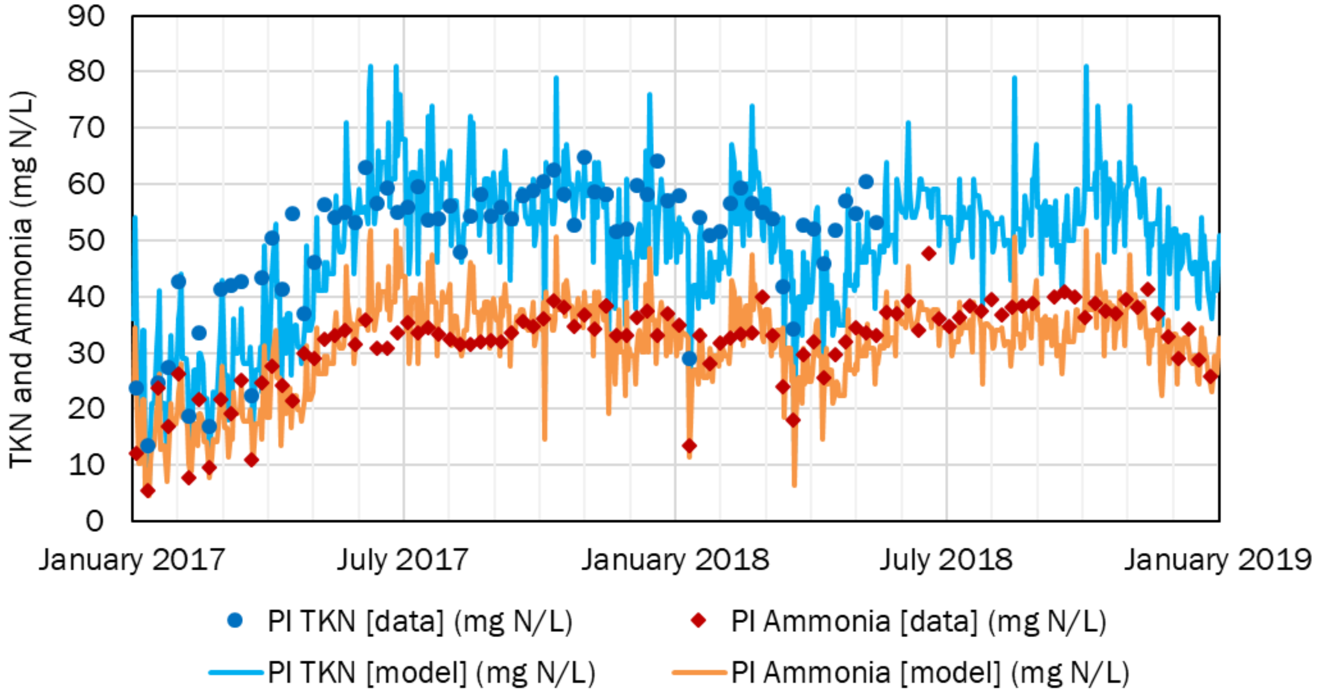

Figure B-3. Dynamic model validation results - PI TKN and NH_3 (2017-18)

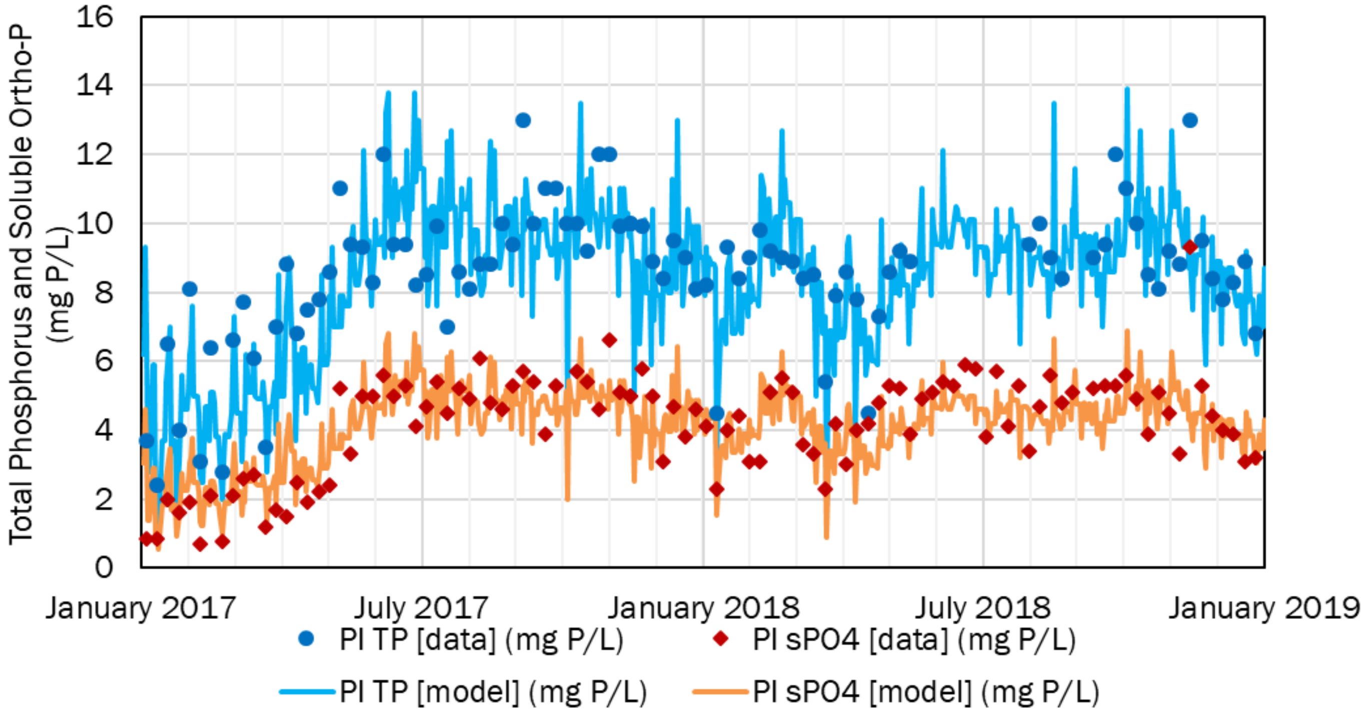

Figure B-4. Dynamic model validation results - PI TP and OP (2017-18)

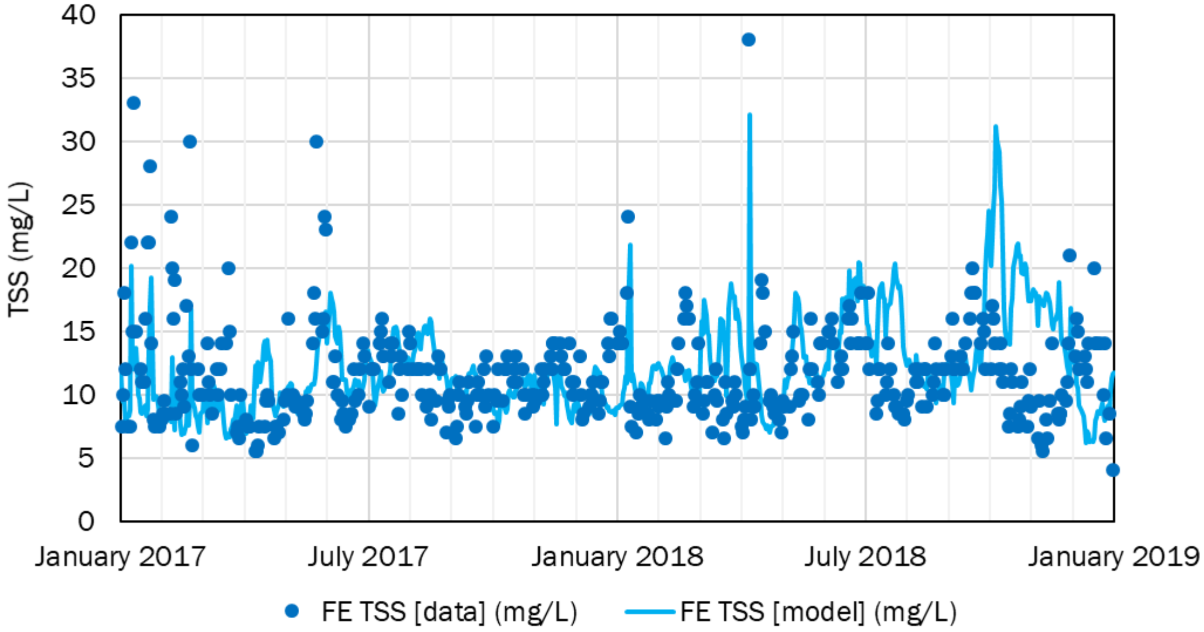

Figure B-5. Dynamic model validation results - FE TSS (2017-18)

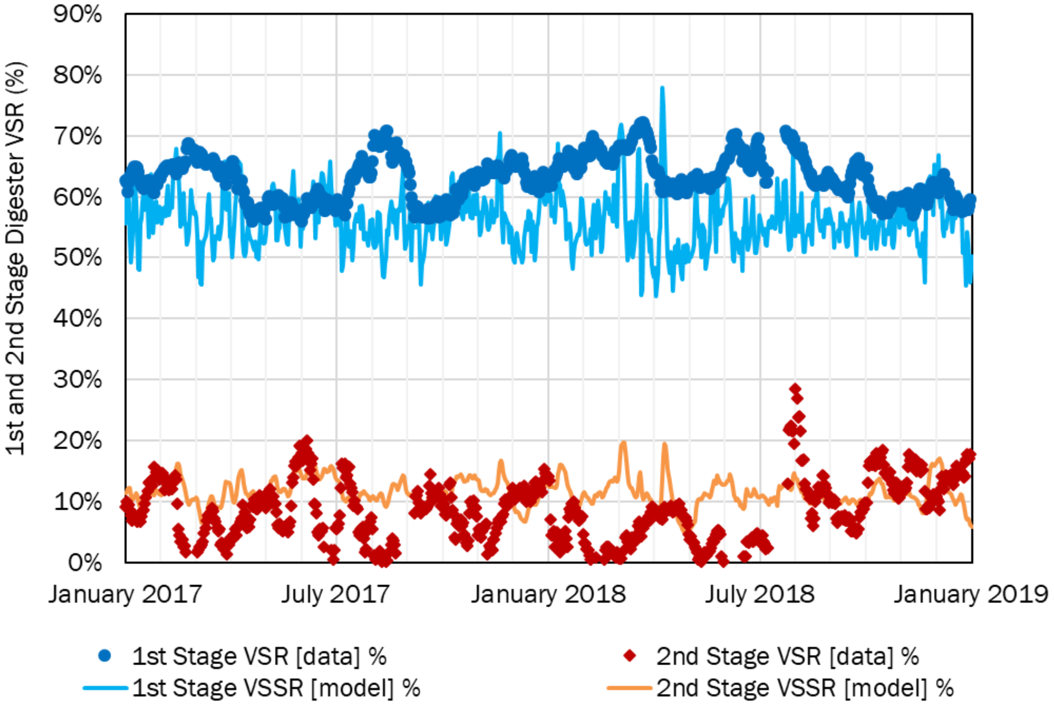

Figure B-6. Dynamic model validation results - anaerobic digester VSR (2017-18)

Model-predicted VSSR does not account for dissolved volatile solids associated with the sCOD component of the HSW.

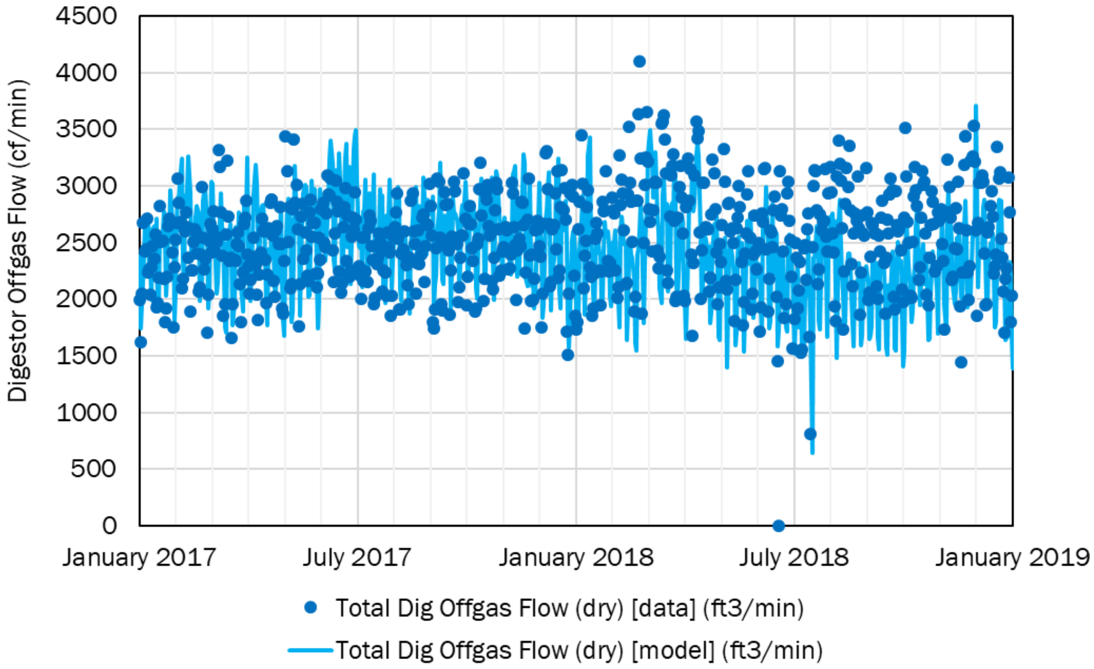

Figure B-7. Dynamic model validation results - biogas production rates (2017-18)

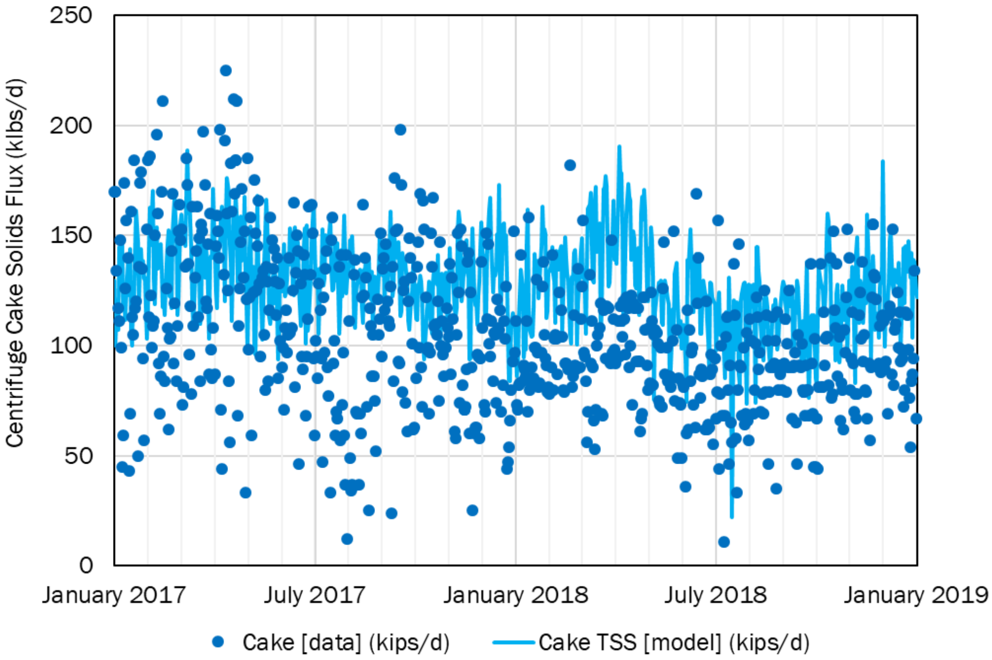

Figure B-8. Dynamic model validation results - cake production (2017-18)

APPENDIX C - EXAMPLE WASTEWATER CHARACTERIZATION PLAN

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C.1 Overview and Rationale

This is an example of a future wastewater characterization plan. This example plan is intended as a template for further development and is not a finalized plan. It is recommended that this plan is developed and performed prior to completing future project designs and implementations. This wastewater characterization plan is designed to address the following objectives:

- **Refine the process model for improved calibration**. The process model presented in this report is appropriate for planning level evaluations; however, improved precision is recommended prior to the creation of refined design criteria for design projects. This sampling plan intends to resolve uncertainty around LSW and HSW wastewater characteristics and may provide a reason for observed differences. Composite sampling of PE is expected to improve calibration of the primary clarifiers; however, centrate is not returned to all primary clarifiers, so sampling of TSS and COD is recommended on clarifiers with and without centrate return if evaluation on the impact of return streams to primary clarifier performance is desired.
- **Refine the MWWTP performance projections for scenarios where R2 streams may be reduced.** Greater characterization of R2 streams, or HSW and LSW, will help confirm timing and need of capacity projects. Obtaining representative samples of trucked waste is inherently difficult. This sampling plan proposes composite sampling at locations that would allow for a mass balance to determine wastewater fractions more accurately in HSW and LSW.
- **Establish baseline for R2 wastewater characteristics prior to implementing future projects.** Uncertainty in the wastewater characteristic of LSW and HSW impact the precision of projected capacity for certain processes in the MWWTP. Establishing a baseline of R2 wastewater characteristics will help confirm projected capacity if R2 streams are reduced.

Wastewater samples and analyses are detailed in the wastewater characterization sampling matrix shown in Table C-1. The sampling locations are shown in Figure C-1. It is recommended that a two-week sampling campaign is completed. At least 10 data points should be acquired to accommodate potential outliers or anomalies during the sampling and analysis. Sampling of raw influent, raw influent plus LSW, PE, and FE should be completed as 24-hour composite samples. Following the 14 days of sampling proposed in Table C-1, the District could sample specific HSW and LSW streams (e.g., protein) to better characterize the wastewater. This could be performed over several weeks, as needed. It is important to note that characteristics can be different in summer and winter. Ideally, sampling would be completed in both the summer and winter period.

In addition to the sampling shown in Table C-1, diurnal sampling can be performed to determine the variability of select pollutants throughout a day. Typically, diurnal sampling is performed on one weekend day and two weekdays. Grab samples are collected every two hours over a 24-hour period using an auto sampler. Diurnal sampling could be performed for raw influent, raw influent and LSW, PE and FE. Parameters that are commonly measured influent COD, ammonia, TSS and TP.

Table C-1. Example wastewater characterization sampling matrix.

Parameter	**Number of Samples**	**Raw Influent (composite; see Section C.3)**	**Raw Influent + LSW (composite)**	**PE (composite)**	**PS (grab)**	**TWAS (grab)**	**HSW (see Section C.2)**	**BSL (Blend Tank; grab)**
Flow	10 to 14	X	X	X	X	X	X	X
TSS	10 to 14	X	X	X				
VSS	10 to 14	X	X	X				
TS	10 to 14				X	X	X	X
VS	10 to 14				X	X	X	X
TDS [a]	10 to 14	X	X	X		X	X	X
TKN	10 to 14	X	X	X	X	X	X	X
sTKN	10 to 14	X	X	X		X	X	X
NH_3	10 to 14	X	X	X		X	X	X
Nitrate [b]	10 to 14	X	X	X			X	X
Nitrite [b]	7	X	X	X			X	X
TP	10 to 14	X	X	X	X	X	X	X
PO_4-P [c]	10 to 14	X	X	X	X	X	X	X
Total COD	10 to 14	X	X	X	X	X	X	X
sCOD [c]	10 to 14	X	X	X			X	X
ffCOD	10 to 14	X	X	X			X	X

Parameter	Number of Samples	Raw Influent (composite; see Section C.3)	Raw Influent + LSW (composite)	PE (composite)	PS (grab)	TWAS (grab)	HSW (see Section C.2)	BSL (Blend Tank; grab)
cBOD5	7	X	X	X	X	X	X	X
soluble cBOD5[b]	7	X	X	X			X	X
Dissolved Sulfides[d]	10 to 14	X	X	X				X
Chloride[e]	7	X	X	X			X	X

a. LSW and HSW may include significant dissolved solids. Measure TDS for mass balance validation around LSW/HSW (assumes TDS is conserved).
b. Assume concentration in PS is equal to Raw Influent + LSW concentration. Assume negligible concentration in TWAS.
c. Assume concentration in PS is equal to Raw Influent + LSW concentration.
d. Combined with nitrate, these measurements may indicate a change in odor control chemical use if LSW is eliminated.
e. Chloride may interfere with COD measurements. Include parameter for quality assurance.

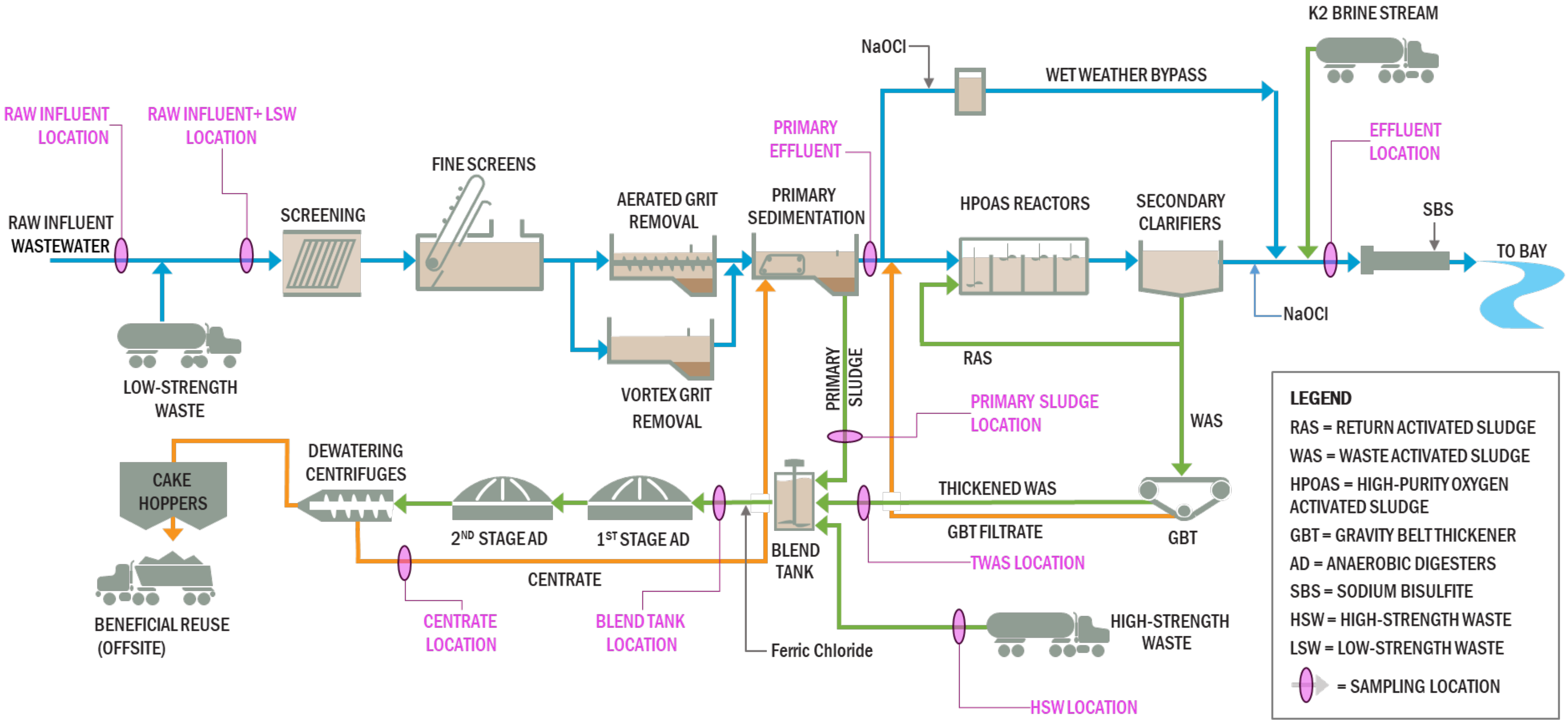

Figure C-1. Example wastewater characterization sampling locations

Recommended HSW sampling location is shown in greater detail in Figure C-2

C.2 High-Strength Waste Sampling

HSW sampling is challenging due to the inherent difficulty of obtaining a representative wastewater sample from the discharge location of truck. Heavy material can settle within trucks and be discharged first during unloading and light, scum material will float and be discharged at the end of unloading.

Sampling directly from the hauled trucks at EBUMD is difficult due to 1) the need to coordinate with truck drivers, 2) the need to predict HSW delivery schedules, and 3) the ability to obtain a representative sample for the entire truck volume (e.g., heavier material discharges from trucks first and lighter material discharges last for FOG waste).

With these considerations in mind, it is recommended to sample from a FOG Tank pump discharge line, at a location within the recirculation loop or between the FOG Tank and Blend Tank (See Figure C-2). To target specific HSW loads for wastewater characterization, the District could coordinate with the R2 program and MWWTP operations to collect a number of truckloads of desired HSW material within a specified tank to produce a composite of several deliveries. The following requirements would be required:

- District staff identifies period for HSW truck routing to specific FOG Tank
- District staff coordinates selected HSW trucks to specific FOG Tank
- MWWTP Operations operates recirculation loop for specific FOG Tank and manages other FOG Tank level to avoid overflow between FOG Tanks
- District staff samples from recirculation loop location (or discharge side of FOG Pump)

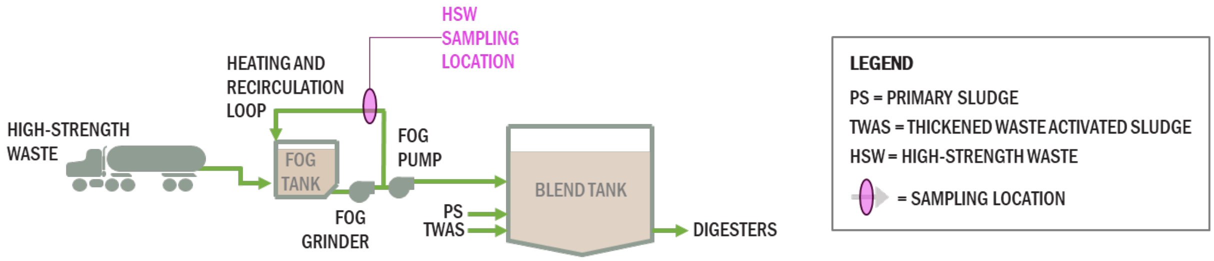

Figure C-2. Proposed sampling location for homogenized HSW

C.3 Low Strength Waste Sampling

LSW is received at a different receiving station than HSW. The LSW is blended with influent wastewater and the current influent sampling location captures both influent wastewater and LSW. The LSW streams are comprised of different sources that include septage, water treatment plant sludge, and brine waste. An improved characterization of LSW is recommended to refine projected capacity estimates and TIN discharges if LSW is considered for reduction or elimination. Figure C-1 identifies additional sampling upstream of the LSW receiving station, which would characterize the influent wastewater. This delta between the PI and the influent wastewater data would represent the LSW streams. Further coordination is required to determine an optimal sampling location for individual LSW streams.

INTEGRATED MASTER PLAN *for the* MAIN WASTEWATER TREATMENT PLANT

C70: Existing Plant Capacity

January 2021

EBMUD

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EXECUTIVE SUMMARY

The goal of the East Bay Municipal Utility District (District) Integrated Main Wastewater Treatment Plant (MWWTP) Master Plan Project (Master Plan) is to provide a 30-year roadmap for the MWWTP. The roadmap will help guide project prioritization to address future regulations, capacity constraints, rehabilitation, and renewal. Potential future regulations regarding nutrient discharges to the San Francisco Bay (Bay) and biosolids management could impact future upgrades at the MWWTP.

As part of the Master Plan, a capacity assessment was performed to identify capacity limitations and predict the year in which limitations would occur at the MWWTP. The District prepared in 2020 the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020), which provides an analysis of the historical performance of each unit process and hydraulic capacities for the liquids and solids unit processes.

The purpose of this report is to summarize the analyses that were performed to confirm the timing of treatment and hydraulic capacity constraints and to identify potential optimizations that could alleviate capacity constraints. The capacity assessment focused on:

- Liquid stream treatment capacity for: primary sedimentation tanks (PST), high-purity oxygen activated sludge (HPOAS) reactors, secondary clarifiers, disinfection, and dechlorination.
- Hydraulic capacity for an influent pump station (IPS), fine screens, vortex grit tanks (VGT), aerated grit tanks (AGTs), mid-plant pumping station (MPPS), and effluent pump station (EPS).
- Solids stream treatment capacity for secondary sludge thickening, blend tank, anaerobic digesters, dewatering, and cake hoppers.

Capacity Assessment Approach

The capacity assessment assumes current operating conditions and current National Pollutant Discharge Elimination System (NPDES) permit limitations. Blending of influent flows greater than 150 million gallons per day (mgd) was assumed. Secondary treatment was assumed to only treat currently regulated compounds (e.g., biochemical oxygen demand [BOD] and total suspended solids [TSS]), and not nutrients such as nitrogen and phosphorous. The District developed influent and trucked waste flow and loading projections in 10-year increments for the planning period of 2020 through 2050 (Appendix A).

A total and firm capacity were determined for each unit process as defined in Table ES-1. Unit process capacity limitations were defined as the lesser of either treatment capacity or hydraulic capacity. The hydraulic capacity was determined by the District, with results presented in Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). Treatment capacity was determined by the amount of flow and/or pollutant load that can be processed and still provide acceptable performance to either meet permit limitations or provide sufficient pretreatment for downstream processes.

Table ES-1. Summary of total and firm capacity assumptions

Parameter	Total Number of Units	Total Capacity	Firm Capacity
IPS	5 pumps	5 pumps	4 pumps
Influent screening	5 screens	5 screens	4 screens
VGTs	2 tanks	2 tanks	2 tanks
AGTs	8 tanks	8 tanks	6 tanks
PSTs	16 tanks	16 tanks	14 tanks
MPPS	3 pumps	3 pumps	2 pumps
HPOAS reactors	8 reactors	8 reactors	7 reactors
Oxygen generation plant	2 towers	2 towers or 1 tower with supplemental oxygen[a]	1 tower [a]
Secondary clarifiers	12 clarifiers	12 clarifiers	11 clarifiers
Disinfection	1 channel	1 channel	1 channel
EPS	4 pumps	4 pumps[b]	3 pumps[b]
Gravity belt thickeners (GBT)	3 units	3 units	3 units
Sludge blend tanks	2 tanks; 3 pumps	2 tanks; 3 pumps	1 tank; 2 pumps
1st and 2nd stage digesters	8 and 3 digesters	8 and 3 digesters	7 and 2 digesters
Low- and high-speed dewatering centrifuges	3 and 2 centrifuges	3 and 2 centrifuges	2 and 1 centrifuges
Cake hoppers	3 hoppers	3 hoppers	2 hoppers

a. Firm capacity assumes one tower; total capacity assumes either two towers or that supplemental on-site liquid oxygen can be used with one tower for a combined equivalent capacity of two towers.
b. Assumes 4 pumps can operate at reduced speed, and 3 pumps can operate at full speed.

Since unit processes are rated on different criteria (e.g., peak day flow, peak week loading), and wastewater strength is projected to increase with time, the unit process capacity limitations are reported to the year at which capacity is reached. The headworks processes (IPS, influent screening, and grit removal) were rated based on peak hour flow rates. For the unit processes downstream of grit removal, it was assumed that the IPS is operated to equalize flows to the peak day condition. Table ES-2 summarizes the capacity criteria assumed for each unit process.

Table ES-2. Summary of capacity criteria for each unit process

Parameter	Capacity Criteria
IPS[a]	Peak flow rate of 85 mgd, each
Influent screening[b]	Peak hour flow of 106 mgd, each
VGT[b]	Peak hour flow of 35 mgd, each
AGTs[c]	Minimum 10-minute hydraulic residence time (HRT)
PSTs[c]	Peak day flow at a surface overflow rate (SOR) of 2,500 gallons per day per square foot (gpd/ft^2) (sludge thickening) and 3,000 gpd/ft^2 (no sludge thickening)
MPPS[b]	Flow rate of 84 mgd, each
HPOAS reactors[b]	Two cryogenic oxygen generation towers (250 tons per day) with peak day secondary influent loading and average dry weather (ADW) flow
Secondary clarifiers[d]	Combination of: • One clarifier out of service • Peak secondary influent flow at sludge volume index (SVI) of 133 milliliters per gram (mL/g) • Peak 7-day flow and peak 7-day load
Disinfection	Combination of: • 8 milligrams per minute per liter (mg-min/L) concentration-time (CT) for 4-log heterotrophic bacteria removal • Minimum 15-minute contact time
EPS[a]	325-mgd pumping capacity, total
GBTs	• 350 gallons per minute per meter (gpm/m) flow capacity[e], each • 1,887 pounds total solids (TS) per hour-meter loading capacity[e], each
Sludge blend tanks	Maximum 12-hour HRT
Sludge blend tank pumps[b]	360 gpm (derated by 40%) flow capacity, each
1st and 2nd Stage Digesters	• Minimum 15-day HRT • Maximum 0.35 pounds volatile solids per cubic feet per day (lb-VS/ft^3-d)
Dewatering Flow	• 250-gpm derated Flottweg (high-speed) capacity[b], each 125-gpm derated Humbolt (low-speed) capacity[b], each
Dewatering Loading	• 288,000 pounds per day (lb/d) Flottweg capacity, each[f] 468,000 lb/d Humbolt capacity, each[g]
Cake Hoppers[b]	1.5 days of storage at peak day loading

a. Capacity per February 20, 2020, Capacity Assessment Workshop meeting notes.

b. Observed hydraulic capacity per the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020).

c. Capacity per Water Environmental Federation Manuals of Practice (WEF MOP) 8, 6th Edition.

d. Capacity per 90th percentile SVI value and maximum mixed liquor suspended solids (MLSS) from Appendix E.

e. Capacity per vendor correspondence with Alfa Laval.

f. Capacity per vendor correspondence with Flottweg (high-speed centrifuges).

g. Capacity per vendor correspondence with Andritz Separation (low-speed centrifuges).

The validated plantwide BioWin model (C60: Plant-Wide Process Model, Brown and Caldwell, 2021) was used to project key parameters for each decade: 2020, 2030, 2040, and 2050. For liquid treatment processes, the steady-state BioWin model was used to simulate multiple averaging periods (i.e., ADW, peak week, peak day, etc.). For the solids handling processes, the ADW model results were with solids handling peaking factors. Peaking factors were calculated using historical data and are summarized in Appendix C. This approach provides a more accurate projection of future solids loads under different averaging periods, given the variability in trucked waste loads at the plant and the natural attenuation of solids streams across the treatment processes. All capacity calculations were completed using predictions from the BioWin model and are summarized in Appendix C.

The HPOAS capacity was determined using predictions from the BioWin model and a calibrated Excel-based HPOAS model. One week of field-testing data was used to develop and calibrate the spreadsheet model to assess capacity of the existing aerators and high-purity oxygen (HPO) production facilities. Secondary clarifier capacity was determined using BioWin predictions and computational fluid dynamic (CFD) modeling results. The CFD modeling was performed by Hazen and Sawyer (Appendix E).

Summary of Findings

Capacity Study results are summarized in Figure ES-1. Several optimizations that were identified as part of the capacity assessment are presented in Table ES-3. The optimizations represent relatively low-cost modifications that could increase capacity. Details on the basis and timing of the capacity limitations are provided below.

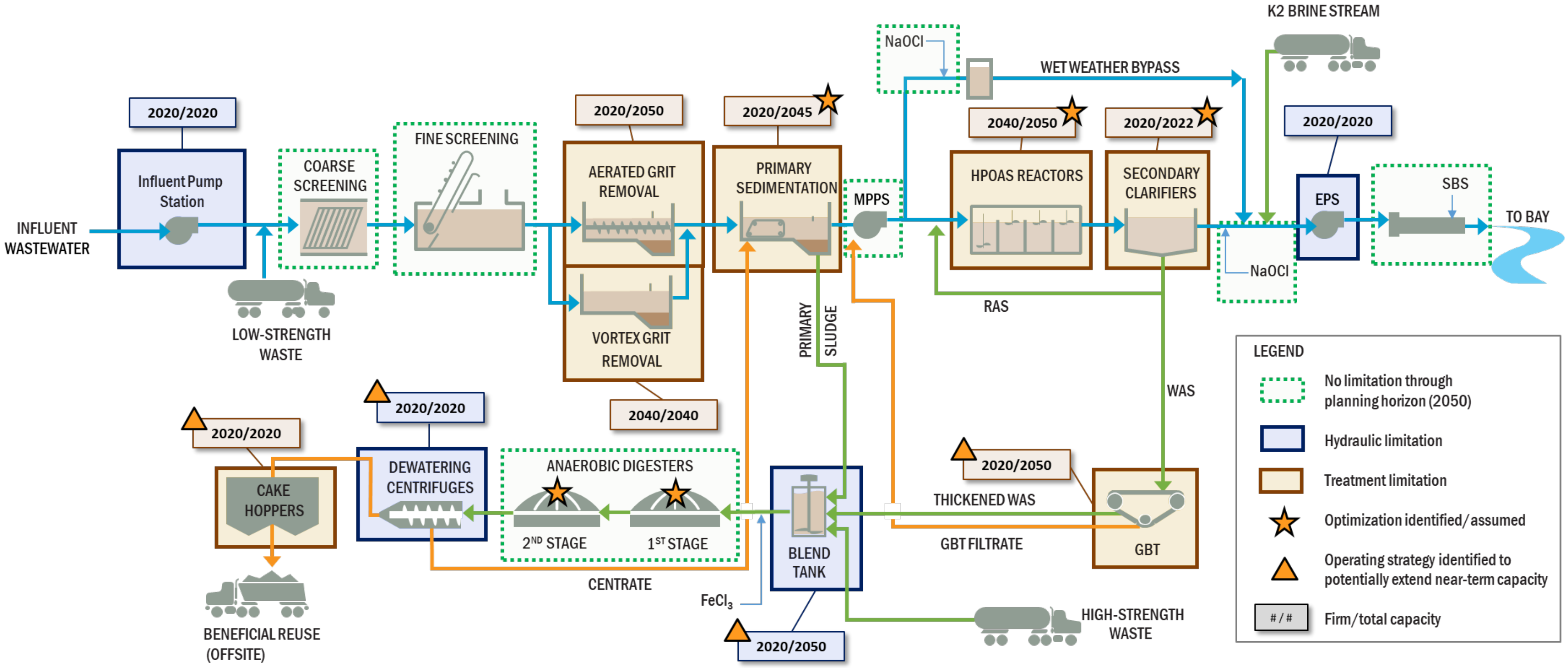

Figure ES-1. MWWTP process flow diagram with capacity assessment results

Optimizations identified for first-stage and second-stage digester operations were assumed as implemented in the capacity assessment.

Table ES-3. Optimization strategies identified for processes with capacity limitation

Process	Capacity Limitation	Optimization(s) Identified	Optimization Effect(s)
PSTs	Lower removal efficiency at higher SORs	Implement chemically enhanced primary treatment (CEPT)	Enhanced primary removal efficiency to allow for operation at higher SOR
		Do not thicken primary sludge in the PST during peak flows	Allows for operation at higher SOR; thinner sludge is sent to blend tanks and digesters
HPOAS reactors	Inadequate oxygen transfer rate to HPOAS from the oxygen generation facility	Implement CEPT	Enhanced primary removal efficiency decreases loading to secondary treatment HPOAS reactors
		Install new, more efficient surface aerators	Greater standard aeration efficiency with new equipment provides more oxygen transfer
Secondary clarifiers	High MLSS results in high solids loading rate (based on 2Dc CFD model results)	Install baffling improvements, increase RAS pumping, implement CEPT	Baffling improvements increase capacity and have been performed on some of the clarifiers with others planned for the future, CEPT decreases loading to the secondary system, increased RAS pumping allows for higher treatment capacity

Liquid Treatment Capacity

- **IPS:** The pumping capacity criteria was evaluated based on a peak hour flow rate criteria of 425 mgd. District Staff determined a total IPS flow capacity of 390 mgd. This pumping capacity was below the peak hour flow rate in the year 2020. Therefore, firm and total flow capacity was insufficient in 2020.
- **Fine Screens:** Fine screening capacity is sufficient through 2050.
- **VGTs:** The VGTs were evaluated based on the peak day dry weather flow rate. VGTs have identical firm and total capacities of 70 mgd total and are only used during dry weather conditions. The VGT firm and total capacity is sufficient until 2040. District Staff has noted that existing performance does not remove fine grit.
- **AGTs:** The AGTs were evaluated based on minimum HRT during peak hour flowrate. There is sufficient total capacity (eight AGTs) for grit removal through the 2050, and firm capacity (six AGTs) was insufficient in 2020. District Staff has noted that existing performance does not remove all coarse grit. The existing AGTs can be modified to improve performance, as discussed in the Integrated MWWTP Roadmap Report (EBMUD, 2020).

- **PSTs:** The PSTs were evaluated based on operation with primary sludge thickening (maximum SOR of 2,500 gpd/ft^2) and without primary sludge thickening (maximum SOR of 3,000 gpd/ft^2). The evaluation suggests primary sludge cannot be thickened in PSTs during peak day flows with the existing PSTs. PST operation without primary sludge thickening has a firm capacity (14 PSTs) that is insufficient in 2020 and a total capacity (16 PSTs) that is sufficient until 2045.
    - **Optimization:** CEPT was identified as a potential optimization strategy to improve removal efficiency across the PSTs and increase capacity. CEPT could be implemented during wet weather events when higher influent flows are observed to decrease operating costs relative to a year-round CEPT implementation.
- **MPPS:** The MPPS has sufficient capacity through 2050.
- **HPOAS Reactors:** The HPOAS reactors were evaluated based on HiPure modeling results, which were used to suggest whether capacity is limited by oxygen transfer (i.e., aerators) or oxygen production (i.e., cryogenic towers). Capacity was evaluated at peak day loading condition during dry weather flow and peak day temperature. The firm capacity (150 mgd through HPOAS reactors with seven reactors online) is sufficient until 2040. The total capacity (168 mgd through all eight reactors) is sufficient through 2050. Oxygen transfer limitations were identified as the bottleneck for capacity.
    - **Optimization:** Two optimization strategies were identified: 1) CEPT was identified as a potential optimization strategy to improve primary removal performance and decrease BOD loading to the HPOAS reactors, and 2) new surface-mounted aerators could be installed to improve oxygen transfer efficiency.
- **Secondary Clarifiers:** The secondary clarifiers were evaluated based on peak week flow and loading condition with a 90th percentile SVI value of 133 mL/g and 1.5-day SRT. The firm capacity (seven HPOAS reactors; 13.6 mgd per clarifier) was limited in 2020. The total capacity (eight HPOAS reactors; 14 mgd per clarifier) is limited in 2022.
    - **Optimization:** Two optimizations were identified that could increase secondary treatment capacity: 1) implement CEPT to reduce organic loading to the secondary process, and 2) increase RAS pump capacity to increase solids loading capacity of the clarifiers.
- **Disinfection:** Disinfection capacity is sufficient through 2050.
- **EPS:** The EPS has a capacity criterion of 325 mgd. The maximum flow rate of EPS is 278 mgd due to hydraulic bottlenecks that occur during a 10-year return frequency tidal elevation. The maximum flow rate of EPS is lower than the capacity criterion; therefore, EPS capacity was insufficient in 2020. Additional hydraulic analyses are recommended to confirm improvements that will alleviate hydraulic bottlenecks, thereby increasing EPS capacity.

Solids Treatment Capacity

- **WAS Thickening:** The WAS thickening process was evaluated based on hydraulic and solids loading rate capacities during maximum day flows and loads, respectively. The firm capacity (two GBTs) was insufficient in 2020. The total capacity (three GBTs) is sufficient through 2050. Operational strategies could be implemented during peak conditions to reduce the flow to the GBTs, thereby addressing the firm capacity constraint through 2050.
- **Blend Tanks:** The Blend Tanks were evaluated based on pumping capacity and HRT criteria at peak day and ADW flows, respectively. Based on pumping capacity, the firm capacity (two digester feed pumps) was insufficient in 2020 and total capacity (three digester feed pumps) is sufficient through 2050. Blend tank volume is sufficient through the planning period, but operation of one blend tank is required in the near term to maintain an HRT below 12 hours. Operational strategies could be implemented during peak conditions to balance peak day flows with only two digester feed pumps.
- **Anaerobic Digestion:** Anaerobic digestion was evaluated based on HRT and OLR criteria, and was determined to have sufficient capacity through 2050. The digester capacity assumes that the second-stage digesters are operated at the full operating liquid level and that the digesters can be operated at a 10-day HRT using the patented process developed by the District (Gray and Shang, 2013). The Digester Phase 3 Basis of Design Report (Beyaz and Patel, 2018) recommends seismic improvements (i.e., post-tensioning improvements) are to be performed to operate the second-stage digesters at the maximum liquid level.
- **Dewatering Centrifuges:** The dewatering centrifuges were evaluated based on hydraulic and solids loading rate capacities during maximum day and ADW flow and loads. The firm capacity (three centrifuges) was insufficient in 2020 due to hydraulic limitations at ADW flow rates. The total capacity (five centrifuges) was insufficient in 2020 due to hydraulic limitations at peak day flow rates. Peak day flows to dewatering could be equalized in the second-stage digesters to reduce the capacity limitation in the near term. Additionally, in the interim, the District could assume firm capacity is defined with only one centrifuge out of service at a time instead of the current definition that firm capacity is defined with two centrifuges out of service. These measures could alleviate capacity constraints in the near term until the dewatering capacity is increased.
- **Cake Hoppers:** The cake hoppers were evaluated based on a storage criterion of 1.5 days. The firm capacity (two hoppers) and total capacity (three hoppers) were insufficient in 2020. The District currently uses the second-stage digesters to equalize peak flows to dewatering and, subsequently, to the cake hoppers. This practice could continue to alleviate capacity constraints in the near term until the cake hopper capacity is addressed.

CHAPTER 1 - INTRODUCTION

The goal of the East Bay Municipal Utility District (District) Integrated Main Wastewater Treatment Plant (MWWTP) Master Plan Project (Master Plan) is to provide a 30-year roadmap for the MWWTP. The roadmap will help guide project prioritization to address future regulations, capacity constraints, rehabilitation, and renewal. Potential future regulations regarding nutrient discharges to the San Francisco Bay (Bay) and biosolids management could impact future upgrades at the MWWTP.

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- Hydraulic capacity for the influent pump station (IPS), fine screens, vortex grit tanks (VGT), aerated grit tanks (AGTs), mid-plant pumping station (MPPS), and effluent pump station (EPS).
- Solids stream treatment capacity for secondary sludge thickening, blend tank, anaerobic digesters, dewatering, and cake hoppers.

This report is organized as follows:

- Executive Summary
- Chapter 1: Introduction
- Chapter 2: Capacity Assessment Approach
- Chapter 3: Liquid Treatment Capacity
- Chapter 4: Solids Treatment Capacity
- Chapter 5: Conclusions
- Chapter 6: References

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CHAPTER 2 - CAPACITY ASSESSMENT APPROACH

The capacity assessment assumes current operating conditions and existing National Pollutant Discharge Elimination System (NPDES) permit limitations. Blending of primary effluent and secondary effluent during peak flow events (150 million gallons per day [mgd] or greater) was assumed. Secondary treatment was assumed to only treat for currently regulated compounds (e.g., biochemical oxygen demand [BOD] and total suspended solids [TSS]), and not nutrients such as nitrogen and phosphorus.

The process treatment capacity approach varied by unit process. In some instances, design criteria or field observations were used to determine the capacity. In other cases, process models were used (e.g., BioWin). Details of the process capacity approach are provided below.

2.1 Definition of Capacity

For purposes of this evaluation, the capacity was defined as the lesser of treatment capacity or hydraulic capacity. Hydraulic capacity is the amount of flow that can be conveyed without flooding upstream systems.[1] Treatment capacity is determined by the amount of flow and/or pollutant load that can be processed and still provide acceptable performance to either meet discharge limitations or provide sufficient pretreatment for downstream processes.

In some instances, some unit processes were determined to have insufficient capacity at existing conditions, which may seem counterintuitive since the MWWTP is not in violation of the NPDES permit. This is because capacity is defined by a specific set of conditions as detailed in Section 2.4 that are considered conservative, yet appropriate, for determining future capital investments. For instance, the secondary clarifier capacity was determined assuming a combination of the following conditions: (1) peak week organic loading, (2) secondary influent flow of 150 mgd, (3) one clarifier out of service and (4) the 90th percentile sludge volume index (SVI). If these four events do not coincide, treatment capacity would be higher; however, it is possible, although a low likelihood, that these four events could coincide based on a review of historical data demonstrating all conditions occurred separately within a three-week period. To be conservative, these four criteria were used to define firm capacity.

2.2 Flow and Loading Assumptions

Appendix A provides a summary of the flow and loading projections for the capacity assessment that were developed by the District. Flows and loads were determined for the planning period 2020 through 2050. Projections for high-strength waste and for raw influent plus low-strength waste were determined for each decade (i.e., 2020, 2030, 2040, and 2050). In addition, peaking factors (peak day, peak month, etc.) were developed for specific solids processing units and are included in Appendix B. Table 2-1 presents the baseline assumptions for current influent flow and loading conditions.

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[1] Hydraulic evaluation was a District-led task and is summarized the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020).

Table 2-1. Average dry weather flows and loads for capacity analysis

Parameter	2020	2030	2040	2050
Influent and Low-strength Waste				
Flow rate, mgd	52.2	56.0	60.5	66.0
COD load, lb/d	401,200	452,400	509,400	575,600
BOD load, lb/d	172,500	194,500	219,000	247,400
TSS load, lb/d	181,300	204,400	230,200	260,100
Ammonia load, lb-N/d	16,900	19,200	21,600	24,400
TKN load, lb-N/d	26,400	30,000	33,700	38,200
High-strength Waste				
Flow rate, mgd	0.24	0.24	0.24	0.24
COD load, lb/d	239,700	257,200	262,400	267,700
sCOD load, lb/d	266,800	291,300	295,200	299,200
TSS load, lb/d	43,200	45,050	46,000	46,890
Ammonia load, lb-N/d	1,2010	1,230	1,260	1,280
TKN load, lb-N/d	6,430	6,550	6,680	6,810

COD = chemical oxidation demand
sCOD = soluble COD
TKN = total Kjeldahl nitrogen
lb/d = pounds per day
lb-N/d = pounds nitrogen per day

2.3 Process Capacity Approach

Appendix C provides the assumptions and calculations used to determine treatment capacity for the unit processes. Since unit processes are rated on different criteria (e.g., peak day flow, peak week loading), and wastewater strength is projected to increase with time, the capacity of each unit process has been reported to the year at which capacity is reached. For the unit processes downstream of grit removal, it was assumed that the on-site equalization is used to equalize peak flows to the peak day condition.

The validated, whole-plant BioWin model was used to project key parameters for each decade (2020 through 2050). For liquid treatment processes, the steady-state BioWin model was run for multiple conditions depending on the process (average dry weather [ADW], peak week, peak day, etc.). For the solids handling processes, the ADW model results were used, along with historical solids handling peaking factors. The HPOAS reactor capacity was determined using predictions from the BioWin model and evaluating the oxygen requirements using data from field testing. The results from the field testing were used to develop a spreadsheet model to assess capacity using existing aerators. Results of the field testing and a description of the oxygen model are presented in Appendix D. Secondary clarifier capacity was determined using computational fluid dynamic (CFD) modeling performed by Hazen and Sawyer (Appendix E).

2.4 Total and Firm Capacity Assumptions

The assumptions used to determine unit process capacity based on total and firm capacity are summarized in Table 2-2. For purposes of the capacity assessment, total capacity refers to the total number of units that can be placed into operation. Firm capacity refers to the number of units in operation with a unit or units out of service to allow for unplanned outages or maintenance requirements. Table 2-3 summarizes the criteria that was used to determine the capacity of each unit process.

Table 2-2. Summary of total and firm capacity assumptions

Parameter	Total Number of Units	Total Capacity	Firm Capacity
IPS	5 pumps	5 pumps	4 pumps
Influent screening	5 screens	5 screens	4 screens
VGTs	2 tanks	2 tanks	2 tanks
AGTs	8 tanks	8 tanks	6 tanks
PSTs	16 tanks	16 tanks	14 tanks
MPPS	3 pumps	3 pumps	2 pumps
HPOAS reactors	8 reactors	8 reactors	7 reactors
Oxygen generation plant	2 towers	2 towers or 1 tower with supplemental oxygen[a]	1 tower [a]
Secondary clarifiers	12 clarifiers	12 clarifiers	11 clarifiers
Disinfection	1 channel	1 channel	1 channel
EPS	4 pumps	4 pumps[b]	3 pumps[b]
Gravity belt thickeners (GBT)	3 units	3 units	3 units
Sludge blend tanks	2 tanks; 3 pumps	2 tanks; 3 pumps	1 tank; 2 pumps
1st and 2nd stage digesters	8 and 3 digesters	8 and 3 digesters	7 and 2 digesters
Low- and high-speed dewatering centrifuges	3 and 2 centrifuges	3 and 2 centrifuges	2 and 1 centrifuges
Cake hoppers	3 hoppers	3 hoppers	2 hoppers

a. Firm capacity assumes one tower; total capacity assumes either two towers or that supplemental on-site liquid oxygen can be used with one tower for a combined equivalent capacity of two towers.

b. Assumes 4 pumps can operate at reduced speed, and 3 pumps can operate at full speed.

Table 2-3. Summary of capacity criteria for each unit process

Parameter	Capacity Criteria
IPS[a]	Peak flow rate of 85 mgd, each
Influent screening[b]	Peak hour flow of 106 mgd, each
VGT[b]	Peak hour flow of 35 mgd, each
AGTs[c]	Minimum 10-minute hydraulic residence time (HRT)
PSTs[c]	Peak day flow at a surface overflow rate (SOR) of 2,500 gallons per day per square foot (gpd/ft^2) (sludge thickening) and 3,000 gpd/ft^2 (no sludge thickening)
MPPS[b]	Flow rate of 84 mgd, each
HPOAS reactors[b]	Two cryogenic oxygen generation towers (250 tons per day) with peak day secondary influent loading and average dry weather (ADW) flow
Secondary clarifiers[d]	Combination of: • One clarifier out of service • Peak secondary influent flow at sludge volume index (SVI) of 133 milliliters per gram (mL/g) • Peak 7-day flow and peak 7-day load
Disinfection	Combination of: • 8 milligrams per minute per liter (mg-min/L) concentration-time (CT) for 4-log heterotrophic bacteria removal • Minimum 15-minute contact time
EPS[a]	325-mgd pumping capacity, total
GBTs	• 350 gallons per minute per meter (gpm/m) flow capacity[e], each • 1,887 pounds total solids (TS) per hour-meter loading capacity[e], each
Sludge blend tanks	Maximum 12-hour HRT
Sludge blend tank pumps[b]	360 gpm (derated by 40%) flow capacity, each
1st and 2nd Stage Digesters	• Minimum 15-day HRT • Maximum 0.35 pounds volatile solids per cubic feet per day (lb-VS/ft^3-d)
Dewatering Flow	• 250-gpm derated Flottweg (high-speed) capacity[b], each 125-gpm derated Humbolt (low-speed) capacity[b], each
Dewatering Loading	• 288,000 pounds per day (lb/d) Flottweg capacity, each[f] 468,000 lb/d Humbolt capacity, each[g]
Cake Hoppers[b]	1.5 days of storage at peak day loading

a. Capacity per February 20, 2020, Capacity Assessment Workshop meeting notes.

b. Observed hydraulic capacity per the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020).

c. Capacity per Water Environmental Federation Manuals of Practice (WEF MOP) 8, 6th Edition.

d. Capacity per 90th percentile SVI value and maximum mixed liquor suspended solids (MLSS) from Appendix E.

e. Capacity per vendor correspondence with Alfa Laval.

f. Capacity per vendor correspondence with Flottweg (high-speed centrifuges).

g. Capacity per vendor correspondence with Andritz Separation (low-speed centrifuges).

CHAPTER 3 - LIQUID TREATMENT CAPACITY

The process treatment capacity was determined for liquid processes. Opportunities to increase capacity through process optimization are identified where feasible.

3.1 Influent Pump Station

Capacity was rated according to criteria provided in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). The IPS capacity was evaluated by District Staff. Pumps at the IPS are tested annually to assess performance of each pump under peak conditions and to determine if any of the pumps need maintenance work to improve performance. Each year, typically two of the five pumps are performing below their rated capacity of 85 mgd. Based on review of historical performance, District Staff determined a total IPS flow of 390 mgd is a reasonable assumption for peak capacity; however, the peak hour flow is 425 mgd, which made the IPS hydraulic capacity deficient in the year 2020.

Opportunities for Process Optimization: Continue current practice of rebuilding pumps and motors annually, based on pump test results, to maximize total capacity of IPS. Further detailed study of IPS hydraulics is necessary to determine additional opportunities.

3.2 Fine Screens

Capacity was rated according to criteria provided in the MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). There are five fine screens, each with a capacity of 106 mgd. Two of the screens have ¼-inch openings and three of the screens have ¾-inch openings. The fine screens have a total capacity of 530 mgd and firm capacity of 424 mgd, which means capacity is sufficient through the planning period. Operations and maintenance staff have noted the screens wear out quickly. A capital project has been previously included in the District's Capital Improvement Program (CIP) to replace the ¾-inch screens with ¼-inch screens but has not yet been implemented due to hydraulic performance degradation under some high flow conditions that result in blinding of the ¼-inch screens, as well as overloading of the screenings conveyors. As part of the further detailed hydraulic study of IPS hydraulics, the influence of new fine screens on overall IPS and downstream hydraulics should be evaluated. During that evaluation, the hydraulic capacity of the fine screens with all or more ¼-inch screens can be further confirmed.

Opportunities for Process Optimization: Evaluate hydraulics if existing ¾-inch screens are replaced with ¼-inch screens as part of a more detailed study of IPS hydraulics.

3.3 Vortex Grit Tanks

Capacity was rated according to criteria provided in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). The VGTs are only used during dry weather conditions. Total and firm capacity is assumed identical with both VGT units in service. The peak flow capacity is 70 mgd total, which exceeds the 2050 dry weather flow (Figure 3-1). A diurnal peaking factor of 1.15 was calculated based on average IPS diurnal flow rates from 2015 to 2018 during dry weather. The 1.15 factor was used to estimate peak hour ADW flow rates through the VGTs. The VGTs have sufficient capacity until 2040, when peak hour flows during dry weather exceed the 70-mgd peak flow capacity.

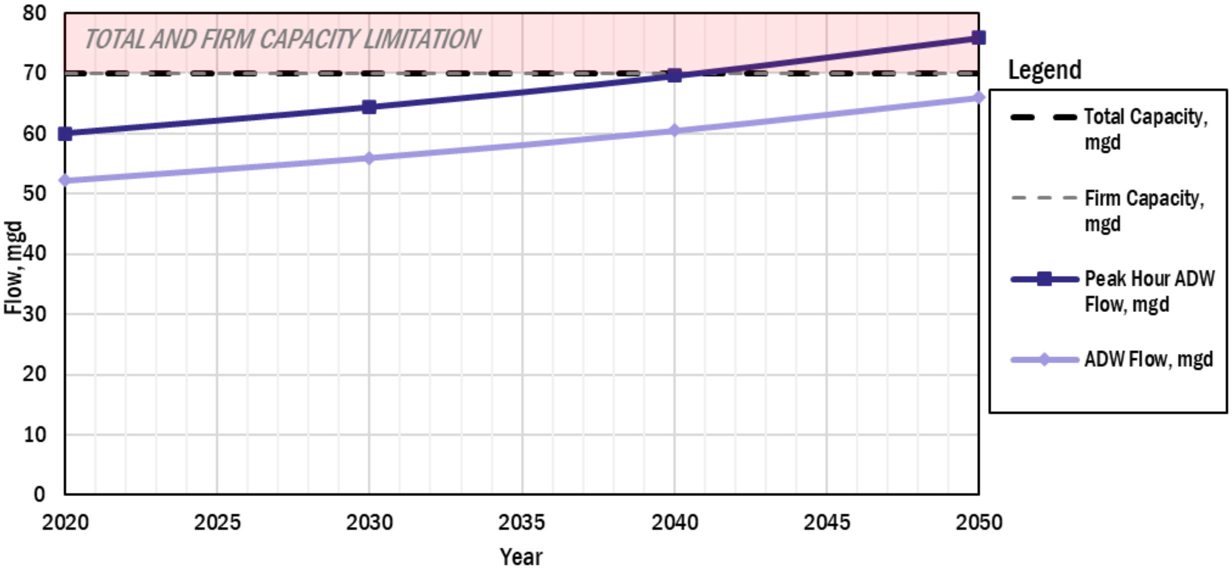

Figure 3-1. VGT capacity based on average daily and peak hour ADW flows

Opportunities for Process Optimization: None identified; however, it should be noted that District Staff has noted existing VGTs do not remove fine grit. Therefore, although capacity is sufficient until 2040, the process performance is not sufficient for fine grit removal. See process optimization recommendations in Section 3.4 for recommendations to improve overall grit capture in AGTs.

3.4 Aerated Grit Tanks

The AGTs are used during wet weather conditions. Capacity was determined assuming a 10-minute HRT at peak hour flow conditions (WEF, 2017) and rated according to criteria provided in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). The peak hour flow condition is 425 mgd and can occur at any time in the planning horizon (i.e., from 2020 through 2050). Based on a 10-minute minimum HRT, there is sufficient total capacity throughout the planning period if eight AGTs are in operation; however, with only six AGTs in operation there is a peak hour HRT of 7.6 minutes and firm capacity was exhausted in 2020.

It should be noted that a 10-minute HRT criterion is for removing coarse grit, and the District has observed large grit pass through AGTs at higher flow rates (Figure 3-2). Therefore, although the assessment demonstrates that total capacity is sufficient through the planning period based on typical AGT design criteria, the District's AGT process performance has been observed as deficient, and process optimizations may be considered to improve total grit removal.

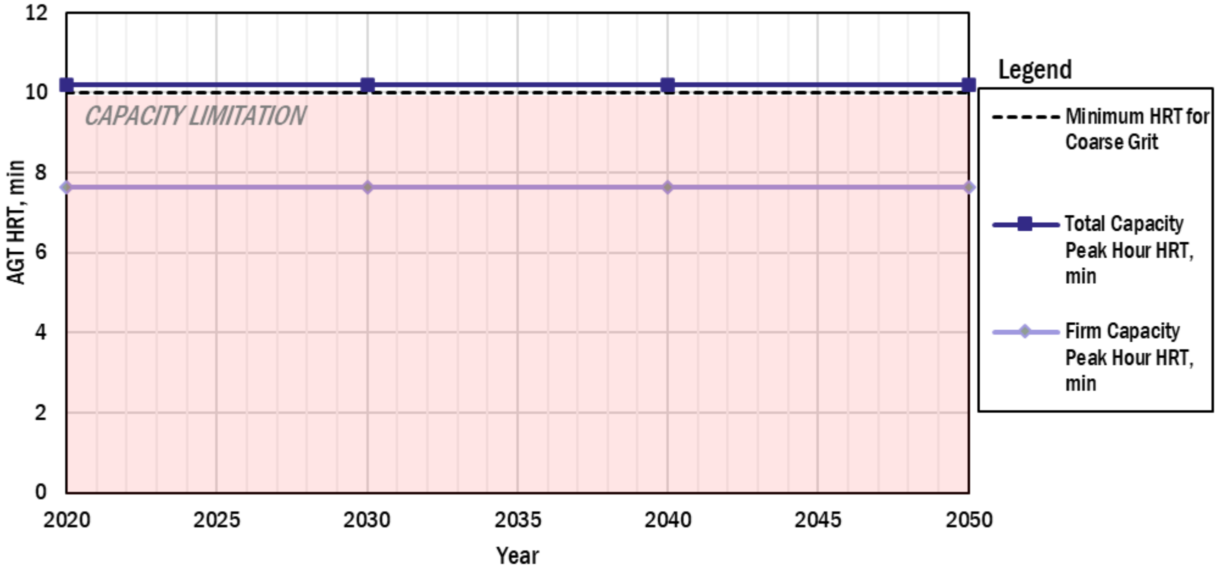

Figure 3-2. AGT capacity based on minimum HRT during peak hour flows

Opportunities for Process Optimization: The existing AGTs could be modified to improve performance; however, a detailed analysis of grit capture efficiency for both AGTs and the grit dewatering units should be completed to identify whether improvements to grit dewatering equipment would also enhance overall capture performance. Potential AGT modifications are presented in the Integrated MWWTP Roadmap Report (EBMUD, 2020).

3.5 Primary Sedimentation Tanks

The PSTs were evaluated assuming a peak SOR of 2,500 gpd/ft^2, which is a typical peak value assumed for a PST that thickens primary sludge in the tank upstream of digestion (WEF, 2017). Since the PSTs at the MWWTP thicken in the tanks, this criterion was assumed for determining both firm and total capacity. Assuming thickening occurs, the PST total and firm capacity to treat peak day flow is exhausted in 2020 (Figure 3-3). A SOR of 3,000 gpd/ft^2 represents a typical peak value for a PST that does not thicken primary sludge in the tanks (WEF, 2017). If PSTs are not used to thicken primary sludge, there is sufficient total capacity (16 PSTs in service) throughout the planning period, and the firm capacity (14 PSTs in service) was exhausted in the year 2020.

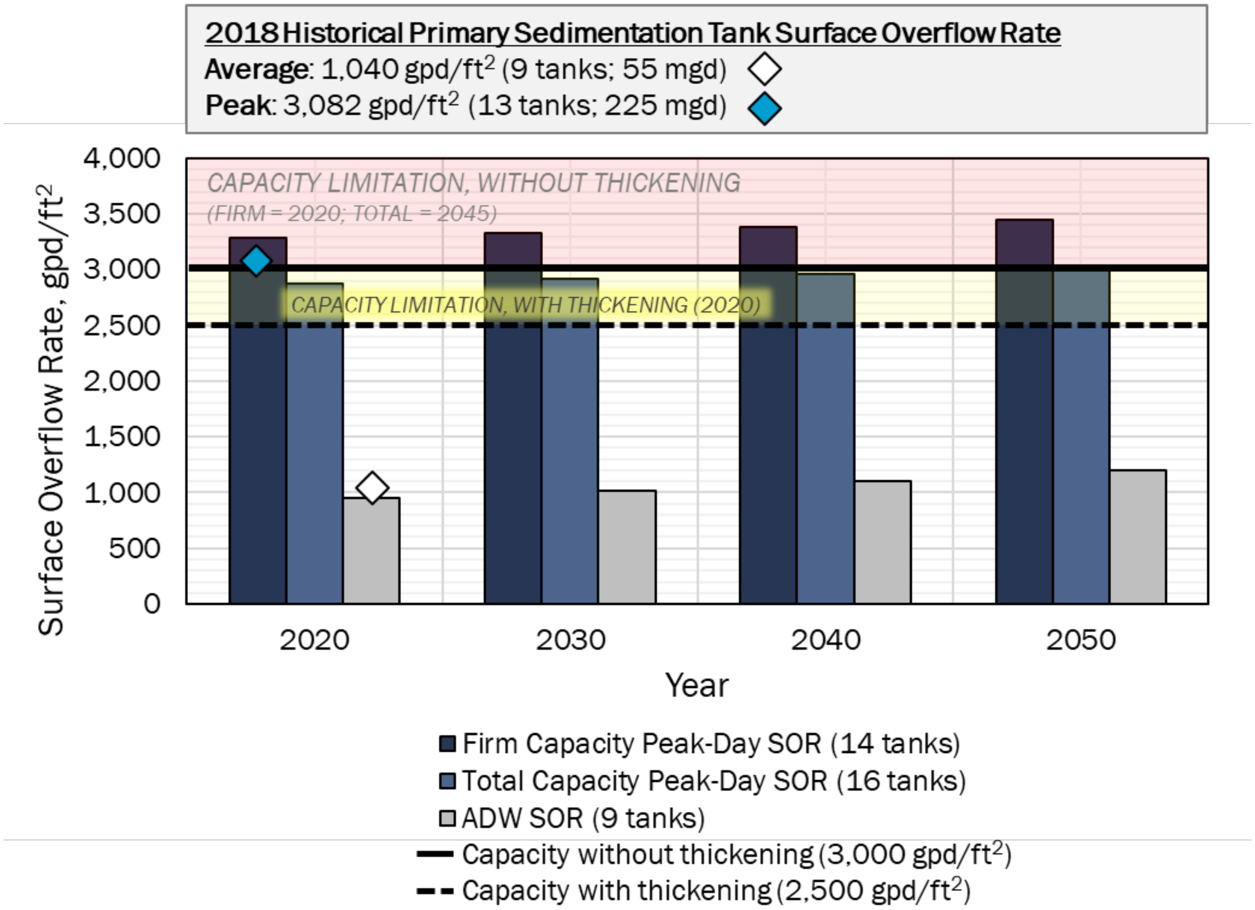

Figure 3-3. PST Capacity based on critical SOR values of 2,500 gpd/ft^2 and 3,000 gpd/ft^2

2018 historical data is presented for reference.

Currently, the District increases primary sludge pumping in advance of a peak flow event to lower the primary sludge blanket and provide capacity to capture high TSS loadings. Since the digesters have sufficient hydraulic capacity (See Chapter 4), no thickening in the PSTs could be implemented during peak wet weather events. As such, a higher SOR of 3,000 gpd/ft^2 can be assumed during peak flow events and the PSTs have adequate capacity through 2045.

Opportunities for Process Optimization: Higher SOR values could be realized during peak flow events with the implementation of chemically enhanced primary treatment (CEPT). CEPT would include metal salt addition (e.g., ferric chloride) and polymer addition upstream of the PST during peak flow events to improve TSS and BOD removal at elevated SOR conditions. Increased capture of TSS would result in an increase in primary sludge to the solids processing systems, which would impact capacity of those systems. CEPT could also remove additional BOD and therefore reduce loads to the secondary process. Adding ferric chloride as part of CEPT could also benefit struvite precipitation in the solids processes.

3.6 Mid-Plant Pumping Station

The MPPS was evaluated as part of the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). The MPPS section of that report states a flow of 84 mgd per MPPS pump for two duty plus one standby pumps. Peak flow into the MPPS is 168 mgd; therefore, the MPPS has sufficient capacity for all conditions for total and firm capacity.

3.7 High-purity Oxygen Activated Sludge Reactors

The HPOAS reactor firm capacity was determined assuming one cryogenic oxygen generation tower is in service; total capacity assumes two cryogenic towers are in service or one cryogenic tower is in service with supplemental liquid oxygen being used. The District currently can store liquid oxygen in four tanks, with each tank having approximately 50 tons of storage.

For firm capacity, a peak flow of 150 mgd was assumed with flows in excess being diverted around the secondary system. For total capacity, a peak flow of 168 mgd was assumed, with flows in excess being diverted and blended with secondary effluent. A solids retention time (SRT) of 1.7 days was assumed based on typical operating conditions of the secondary system.[2]

The HPOAS reactor capacity was evaluated by considering two peak conditions: (1) peak day loading occurring during peak day flow (i.e., wet weather conditions) and (2) peak day loading occurring during dry weather conditions. Table 3-1 shows that the organic loading to the HPOAS reactors is equivalent for either condition, but the average dry weather flow (ADWF) condition has higher temperature. Because this means higher oxygen demands will occur in Zone 2 for the ADWF condition, the ADWF condition was used to determine capacity.

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[2] An average SRT of 1.66 days was calculated for 2017 and 2018 calendar year data. The SRT calculation considered inventory within all four zones of each HPO train in service and the waste rate of solids to the GBTs. This calculation mirrored the calculation performed in BioWin and years used to validate the BioWin model.

Table 3-1. Evaluation of projected 2020 peak day HPOAS reactor BOD loading conditions at dry weather and wet weather conditions

Parameter	Peak Day Flow (Total Capacity)	Peak Day Flow (Firm Capacity)	Dry Weather Flow (Total Capacity)	Dry Weather Flow (Firm Capacity)
Influent flow, mgd	168	150	52.2	52.2
PST removal[a]	61%	61%	64%	64%
Secondary influent carbonaceous biochemical oxygen demand (cBOD) loading, klb/d	248	248	242	242
Temperature[b], degrees Celsius	16.6	16.6	24.6	24.6

a. For flows equal to or in excess of maximum monthly flow, a 61% BOD removal by PST was assumed based on historical data evaluation. For flows less than maximum monthly flow, 64% BOD removal was assumed.

b. For peak day flow, the minimum month temperature was assumed as determined from the historical data. For dry weather conditions, the peak month temperature was assumed.

An evaluation of historical data was conducted to confirm that peak day loading events have occurred during dry weather conditions. Figure 3-4 shows the 10 highest secondary influent BOD loading events in the last 10 years. On March 21, 2013, the secondary influent cBOD loading was 234,000 lbs/d and the influent flow was 54.1 mgd. These values are within 5% of loading and flow values for the 2020 conditions determined from the flow and loading analysis. Figure 3-4 also demonstrates that historical temperatures during peaking secondary influent loading have approached the 24.6 degrees Celsius value used in this evaluation. Historical data supports the capacity assessment assumption of peak day loading during dry weather flow and maximum month temperature.

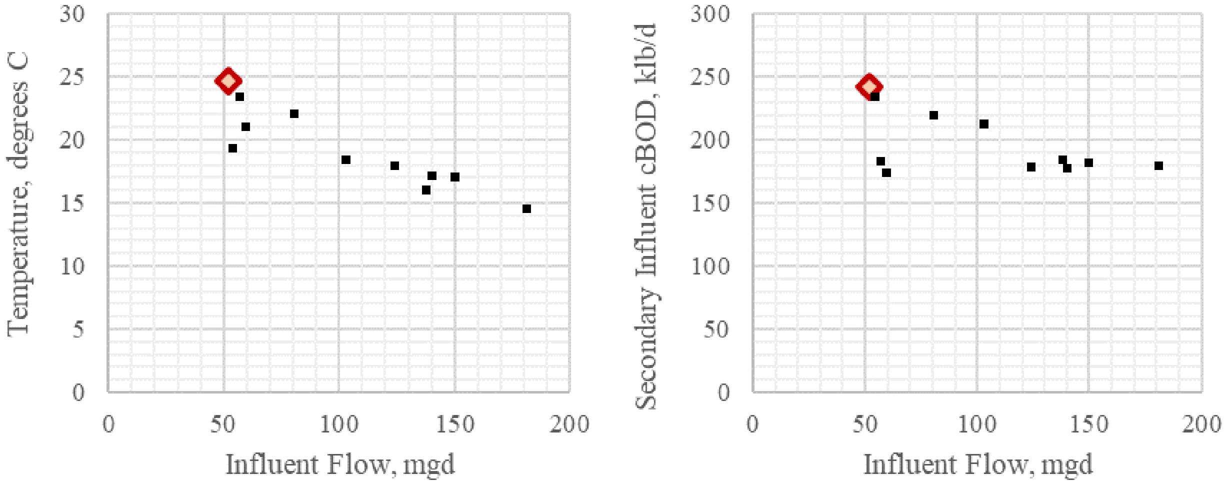

Figure 3-4. Historical peak day secondary influent cBOD loading comparison to 2020 evaluation projections

Red diamond indicates projected flow, load, and temperature used for the 2020 capacity evaluation, and black squares are historical data.

For total capacity, it was assumed that supplemental liquid oxygen conveyance is not a limiting factor such that it could be conveyed to the oxygen reactors at a rate of 125 tons/d at the same time that 125 tons/d of generated oxygen is conveyed to the reactors. Therefore, it is assumed a total of 250 tons/d of oxygen can be conveyed to the oxygen reactors with only one cryogenic tower in operation. Figure 3-5 shows total capacity is sufficient until 2050 and firm capacity is sufficient until 2040.

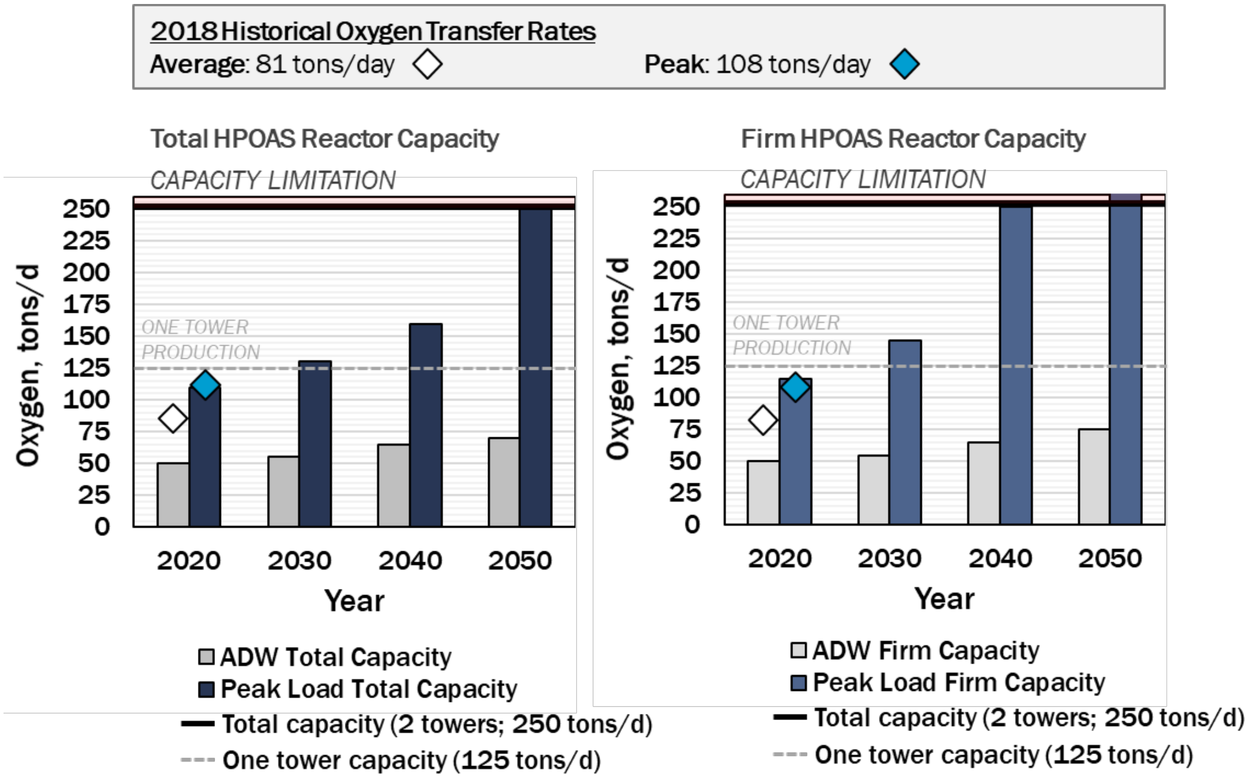

Figure 3-5. HPOAS reactor capacity at peak day loading during dry weather conditions

2018 historical data is presented for reference. Values displayed at or above 250 tons/d in 2040 and 2050 for firm capacity and in 2050 for total capacity will results in dissolved oxygen (DO) concentrations below 2 mg/L due to insufficient oxygen supply.

Comparison of historical data to modeled results shows that historical peak day oxygen use for 2018 matched the model-predicted 2020 usage; however, the average oxygen use in 2018 was higher than the model predictions for average use in 2020. This is attributed to the limitations in oxygen turndown with the existing system.

Opportunities for Process Optimization: Implementing CEPT at the PSTs could increase the BOD removal upstream of the HPOAS reactors and could increase the capacity by lowering the oxygen demand. In addition, the aerators of each HPOAS train could be replaced with a larger aerator capable of transferring more oxygen. Figure 3-6 shows the change in oxygen demand with new aerators (3.2 pounds of oxygen per horsepower per hour [lb O_2/hp-hr] aerators compared to the existing aerators which were calibrated to 1.9, 3.0, and 2.8 lb O_2/hp-hr for stages 2, 3, and 4, respectively [Appendix D]). Under this condition, where aerators are upgraded, the total and firm capacity would be sufficient throughout the planning period. These results suggest that during the planning period, oxygen transfer efficiency is the limiting factor and not oxygen production capacity.

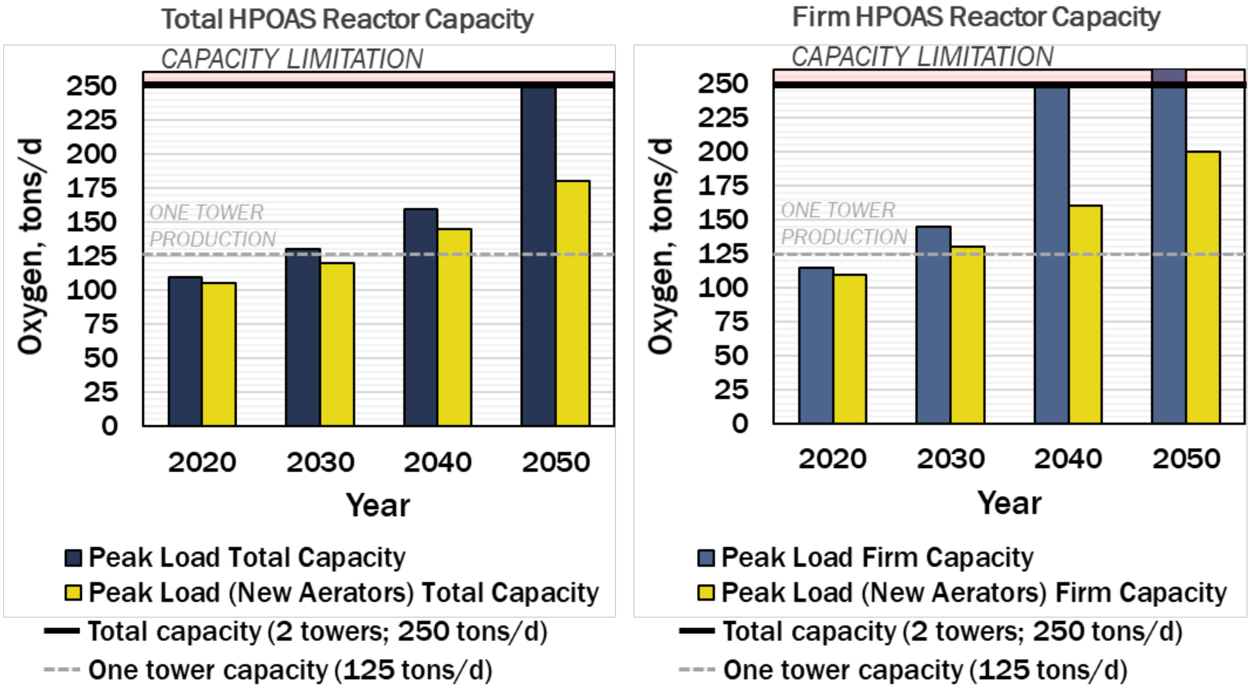

Figure 3-6. Impact of replacing HPOAS reactor stage 2 aerators with larger aerators

Values displayed at or above 250 tons/d in 2040 and 2050 for firm capacity and in 2050 for total capacity will results in dissolved oxygen (DO) concentrations below 2 mg/L due to insufficient oxygen supply.

3.7.1 Considerations for Near-term Operations

The District is currently evaluating a modified secondary reactor mode at full scale, referred to as “split battery” wherein the secondary reactors and clarifiers are hydraulically separated and operated in two different modes: (1) status quo HPOAS, and (2) nitrification. The current evaluation is testing the feasibility of the nitrification mode and would require further capital improvements to implement. The concept is envisioned to operate only during the dry weather season, and could potentially alter the assumptions for when the status quo HPOAS mode experiences peak loading. As a result, following completion of the split battery evaluation and during the activities to identify specific capital improvements to implement the split battery mode, this capacity assessment should be revisited to determine the status quo HPOAS side peak loading conditions.

3.8 Secondary Clarifiers

Secondary clarifier capacity was determined assuming the peak week flow and loading condition. The peak flow for total capacity was 168 mgd of flow and for firm capacity 150 mgd. The historical 90th percentile SVI of 133 mL/g was assumed for the capacity assessment. An SRT of 1.5 days was assumed, which is less than what was assumed for the HPOAS reactor evaluation (see Section 3.7), but is based on review of historical data where a 1.5-day SRT is a common setpoint. Figure 3-7 presents 5 years of historical data and shows that the 90th percentile

SVI of 133 mL/g can occur during peak flow events. Figure 3-7 supports the assumption that elevated SVI values can coincide with peak flow events. Figure 3-8 shows historical data during December 2014 to demonstrate that peak flow, loading, and SVI values can potentially occur simultaneously during wet weather months.

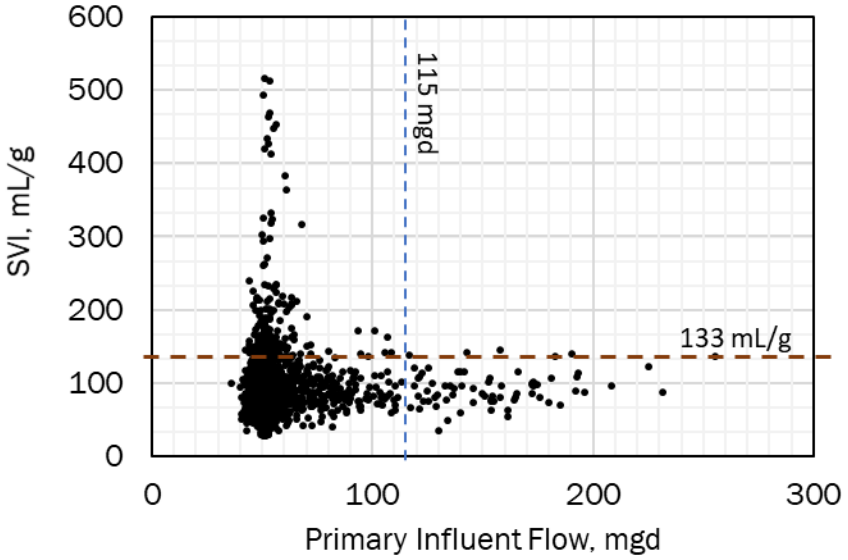

Figure 3-7. Summary of 5 years of SVI historical data versus primary influent flow

Demonstrates that elevated SVI values can occur at peak flow conditions

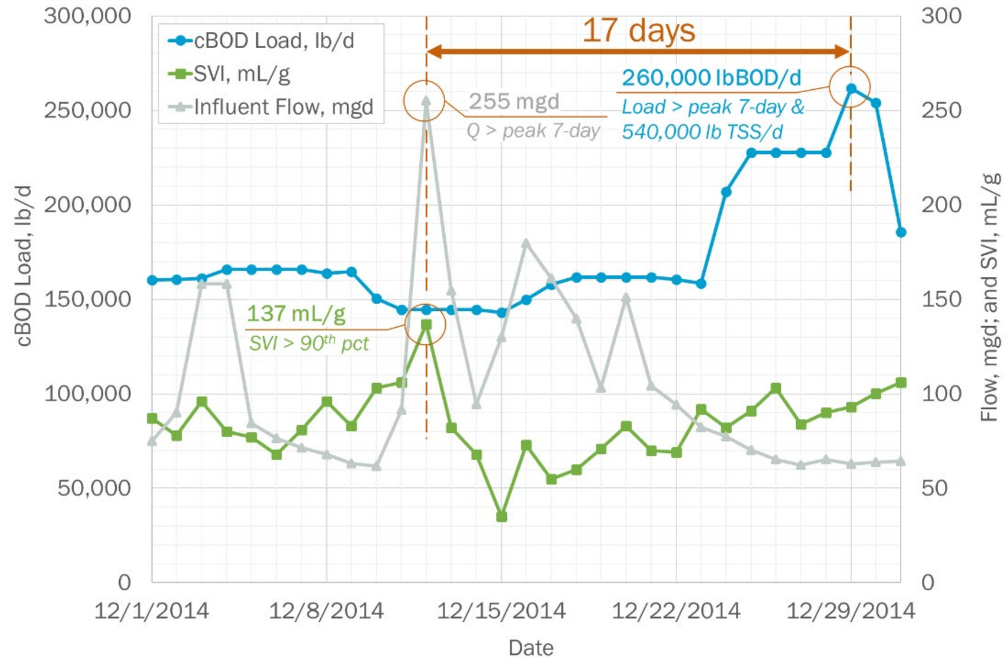

Figure 3-8. Historical flow, SVI, and BOD loading in December 2014

Demonstrates near occurrence of critical condition for capacity exhaustion

The CFD modeling (see Appendix E) was performed for both the existing clarifier configuration before baffling improvements, and the configuration with all secondary clarifiers reconfigured with baffling improvements.[3] For purposes of the capacity assessment, it was assumed that all secondary clarifiers were retrofitted, because projects to implement these retrofits are scheduled to occur on the remaining clarifiers at a rate of two per phase until completion in FY2029. It is further assumed that an equivalent return activated sludge (RAS) pumping capacity of 6 mgd per secondary clarifier was available.

The CFD modeling predicted a total capacity of 14 mgd per clarifier (168 mgd, total) and a peak MLSS concentration of 2,600 mg/L. For firm capacity of 13.6 mgd per clarifier (150 mgd total), the model predicted a maximum MLSS concentration of 2,700 mg/L. Figure 3-9 presents the results of the model-predicted MLSS concentration; it shows total capacity is exceeded in 2022 and firm capacity was exceeded in 2020. Comparing the 2018 data to the model predictions shows that actual peak MLSS values were slightly higher, which could be due to operating at higher SRT conditions than what was assumed for the capacity assessment.

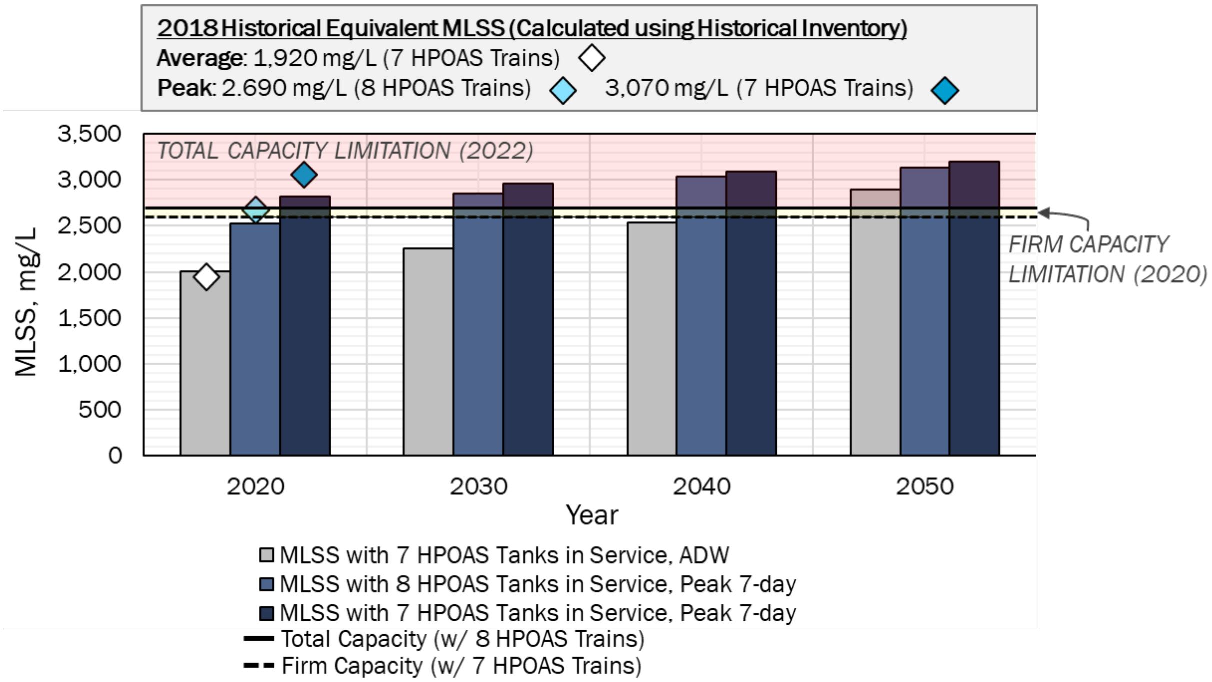

Figure 3-9. Secondary clarifier capacity at peak week loading and flow
(150 mgd firm, 168 mgd total)

2018 historical data is presented for reference. MLSS concentration was determined using historical solids inventory and assuming seven and eight HPOAS reactors for firm and total conditions, respectively.

Opportunities for Process Optimization: The capacity analysis was performed assuming that all clarifiers are retrofitted with baffling improvements, since such improvements are already scheduled for implementation in the District’s CIP. This optimization, therefore, should be considered a way to increase capacity. CEPT would be another optimization that could be used

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[3] Two of the 12 clarifiers have been retrofitted to improve performance. Details of this evaluation can be found in Appendix E.

in peak loading conditions to reduce the MLSS concentration in the HPOAS reactors and increase secondary clarifier capacity. In addition, increasing the RAS capacity would increase secondary clarifier capacity (described in Attachment E).

Considerations for Near-Term Operations: Similar to the HPOAS system, if the split battery mode were to be implemented, three clarifiers would be devoted to the nitrification side, and nine clarifiers would be devoted to the status quo HPOAS side. This reconfiguration could potentially affect the assumptions for the peak loading conditions that were used in this evaluation. For example, the nitrification side would require a higher SRT than assumed in BioWin simulations. Following completion of the split battery evaluation, clarifier loading assumptions should be revisited for the split battery configuration as a consideration in the design of any subsequent capital improvements.

3.9 Disinfection

The existing chlorine disinfection system capacity was assessed based on CT value criterion. A conservative CT value of 8 mg-min/L was assumed for 4-log removal of heterotrophic bacteria with a baffle factor of 0.5. Historical data provided by the District for this analysis indicated that the MWWTP regularly meets the effluent coliform target with a minimum contact time as low as 3.4 minutes. Process assumptions are summarized in Table 3-2. The new sodium hypochlorite and existing sodium bisulfite pump capacities described in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020) and an assumed background chlorine demand of 4 to 7 mg/L were used in the analysis. Both the secondary effluent channel plus bypass channel can deliver CT values well above the minimum criteria, even at 288 mgd (7 feet/second (ft/sec) velocity through the outfall pipeline), with a flow split of 118 and 170 mgd, respectively. The analysis results suggest there is adequate disinfection and dechlorination capacity for the projected peak day flow through 2050.

Table 3-2. Disinfection capacity assessment assumptions

Parameter	Assumption
Maximum Velocity through Pipe	7 ft/sec
Sodium Hypochlorite Capacity Assumptions	
NaOCl strength	12.5%
Solution specific gravity	1.21
Solution tank volume	207,000 gal
Number of duty pumps	2
Capacity per pump	29 gpm
Sodium Bisulfite Capacity Assumptions	
$NaHSO_3$ strength	25.0%
Solution specific gravity	1.48
Solution tank volume	45,600 gal
Number of duty pumps	1
Capacity per pump	18.3 gpm

3.10 Effluent Pumping Station

The EPS capacity was rated according to criteria provided in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). The total capacity assumes four pumps in-service but operating at a reduced speed. If all four pumps operate simultaneously at full speed, the hydraulic grade line rises above the elevation of the surge chamber at EPS, causing flow to spill over. The firm capacity assumes three pumps in-service operating at full speed. The maximum total capacity is 325 mgd, which is the maximum EPS flow rate that can be pumped. The ability to achieve this capacity varies with tidal elevations; at the 10-year recurrence frequency tidal elevation the EPS capacity is 278 mgd, and at mean sea level the EPS capacity is 300 mgd.[4]

Opportunities for Process Optimization: Identify hydraulic bottlenecks downstream of EPS to increase EPS capacity. A future capital project has been created and included in the District's CIP to evaluate the hydraulics of EPS and potentially identify improvements.

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[4] Per February 20, 2020, Capacity Assessment Workshop meeting notes and Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020).

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CHAPTER 4 - SOLIDS TREATMENT CAPACITY

The process treatment capacity was determined for the solids unit processes. Opportunities for capacity increase through process optimization are identified where feasible.

4.1 Waste Activated Sludge Thickening

The waste activated sludge (WAS) is thickened with GBTs. Using capacity criteria provided by the vendor and model predictions for secondary sludge production, the firm capacity was exceeded in 2020 and total capacity is sufficient through the planning period. The capacity limit is due to hydraulic loading to the GBTs (Figure 4-1); solids loading is sufficient for most conditions (Figure 4-2). Firm capacity for solids loading is exceeded approximately in 2043, and total capacity for solids loading is sufficient through the planning period.

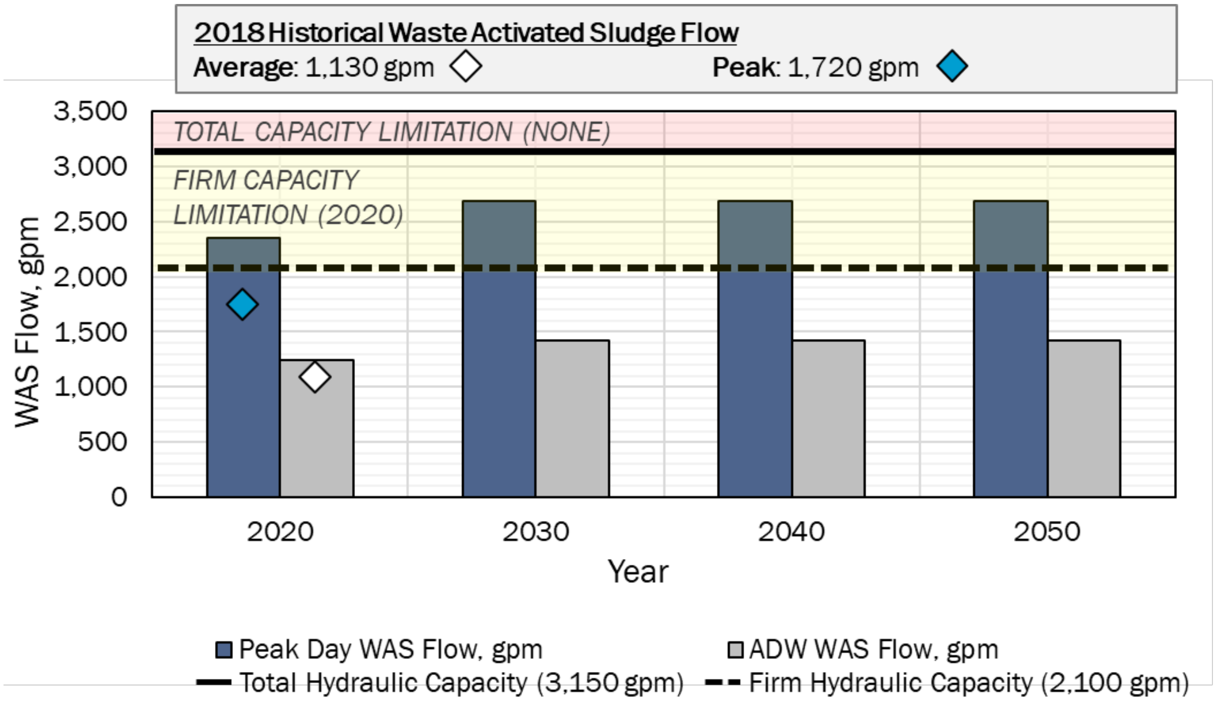

Figure 4-1. GBT hydraulic capacity at peak day and ADW conditions

2018 historical data is presented for reference.

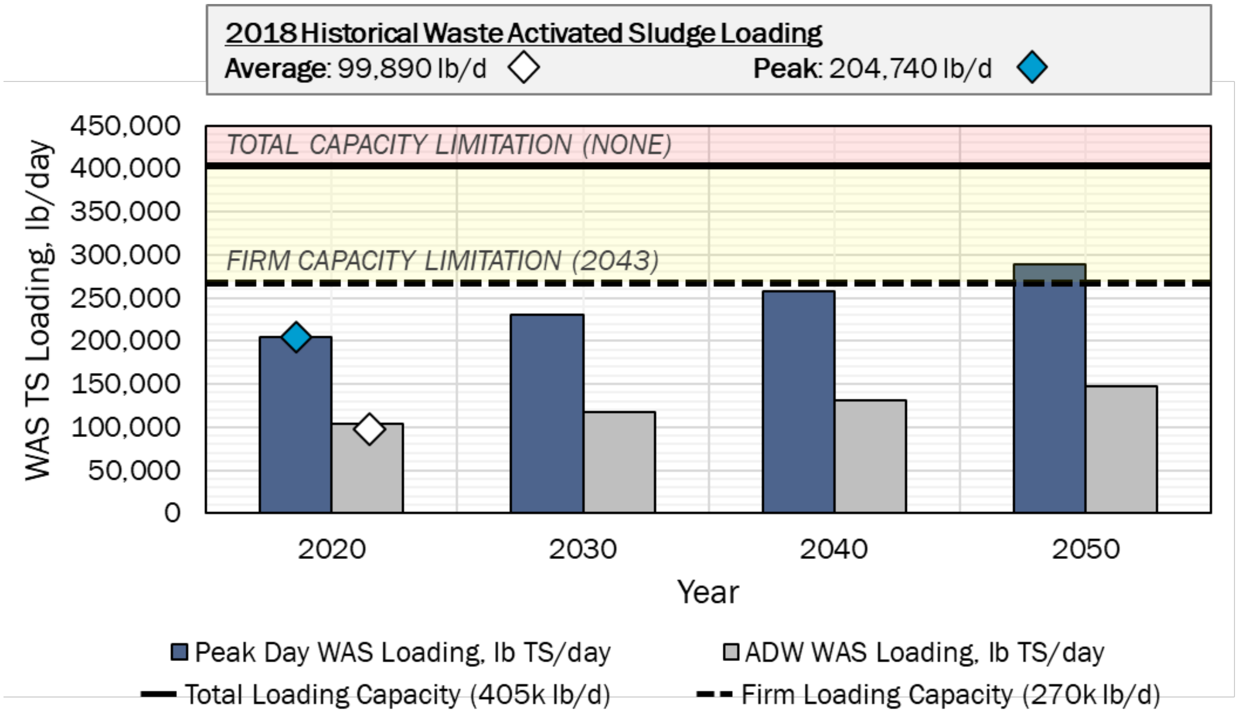

Figure 4-2. GBT TS loading capacity at peak day and ADW

2018 historical data is presented for reference.

When considering the 2018 historical data, there is a good match for model predictions and field observations for secondary sludge loading; however, the observed WAS flow was lower than model predictions. The WAS flows will be determined by the number of HPOAS reactors in service, the RAS flow, and the SRT. The capacity evaluation conditions do not necessarily match field conditions, which vary depending on the operating parameters previously listed.

Opportunities for Process Optimization: Even though the GBT firm capacity shows to be hydraulically limited in 2020, operators have methods to manage a peak day condition (e.g., reduce RAS rate). Strategies similar to this should be documented and could be used to manage capacity at peak conditions.

4.2 Blend Tank

The blend tank capacity was determined based on maintaining an HRT no higher than 12 hours to prevent substantial biological activity and a maximum flow of 1.04 mgd, which reflects current firm pumping capacity. Figure 4-3 shows there is sufficient capacity with respect to HRT. A peak HRT above 12 hours is expected if both blend tanks are operated during ADW conditions; however, this can be mitigated by operating a single blend tank, so there is not a capacity limitation in this respect. Figure 4-4 shows that there is sufficient total pumping capacity through the planning period. Firm pumping capacity is exceeded in 2020 for peak day conditions.

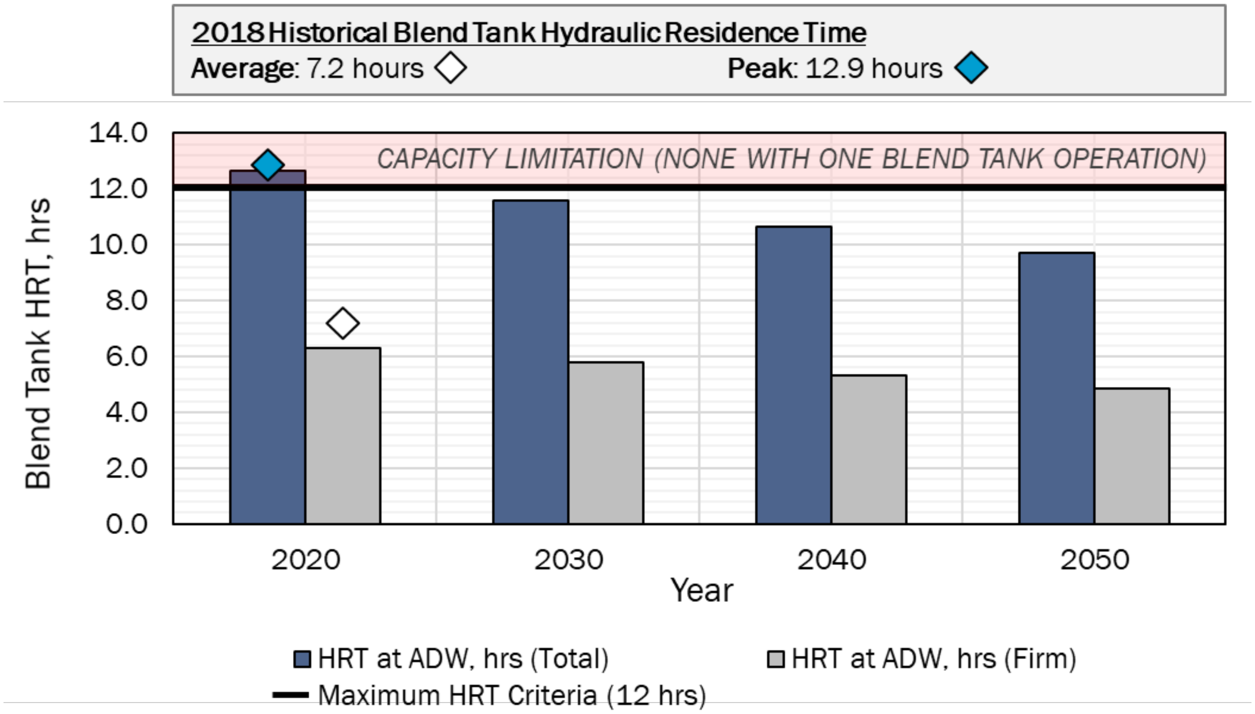

Figure 4-3. Blend tank capacity with respect to HRT

2018 historical data is presented for reference.

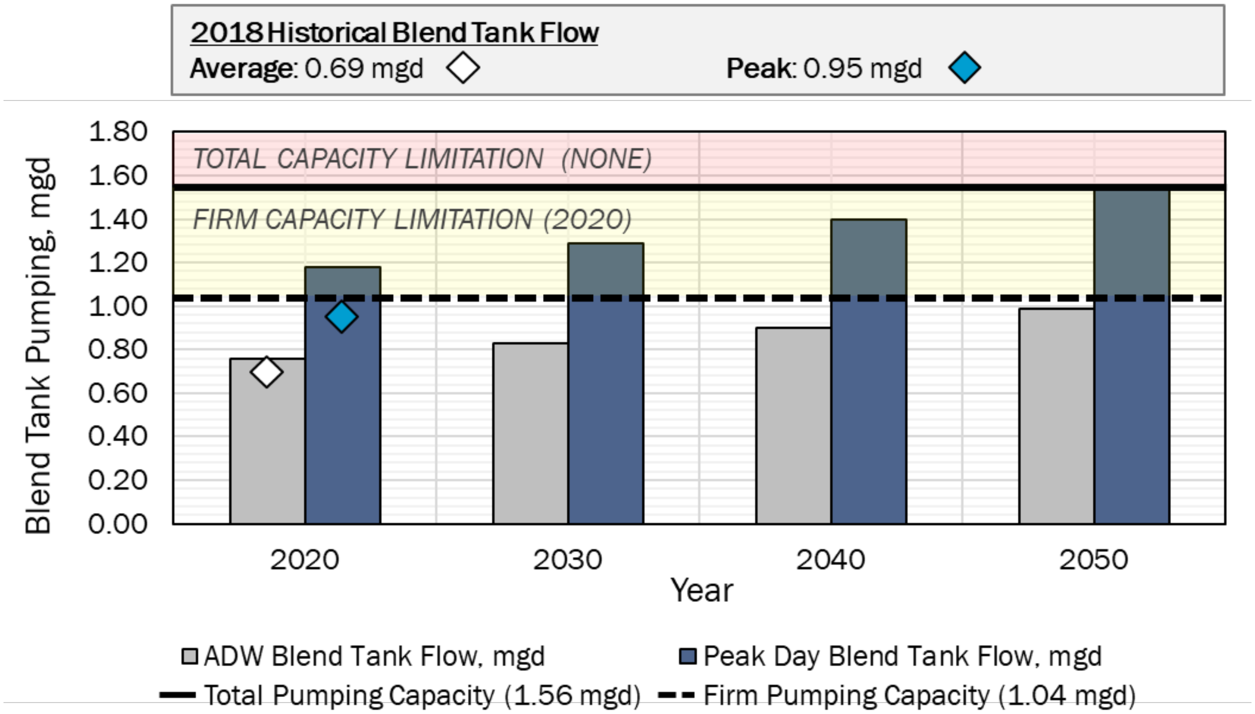

Figure 4-4. Blend tank capacity with respect to pumping capacity

2018 historical data is presented for reference.

Opportunities for Process Optimization: With respect to hydraulic capacity, the blend tanks have sufficient capacity for both total and firm conditions. To mitigate the amount of biological activity, only one tank should be in service under all conditions.

4.3 Anaerobic Digestion

Anaerobic digestion capacity was determined based on HRT and organic loading rate (OLR). The capacity criteria are 15 days for HRT and 0.35 pounds volatile solids per cubic feet per day (lb VS/ft^3-d) for OLR. The HRT capacity assessment accounted for total volume of both the first- and second-stage digesters. Digester volumes used in the capacity calculations were based on the average operating levels noted in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020).[5] Figure 4-5 shows firm capacity is sufficient until 2035, and total capacity is sufficient throughout the planning period with respect to a minimum HRT of 15 days; however, the District has determined that a 10-day mean cell residence time (i.e., HRT) is sufficient to achieve target VS reduction and biogas production (Gray and Shang, 2013). Operating at 10-day minimum HRT provides sufficient firm capacity through the planning period.

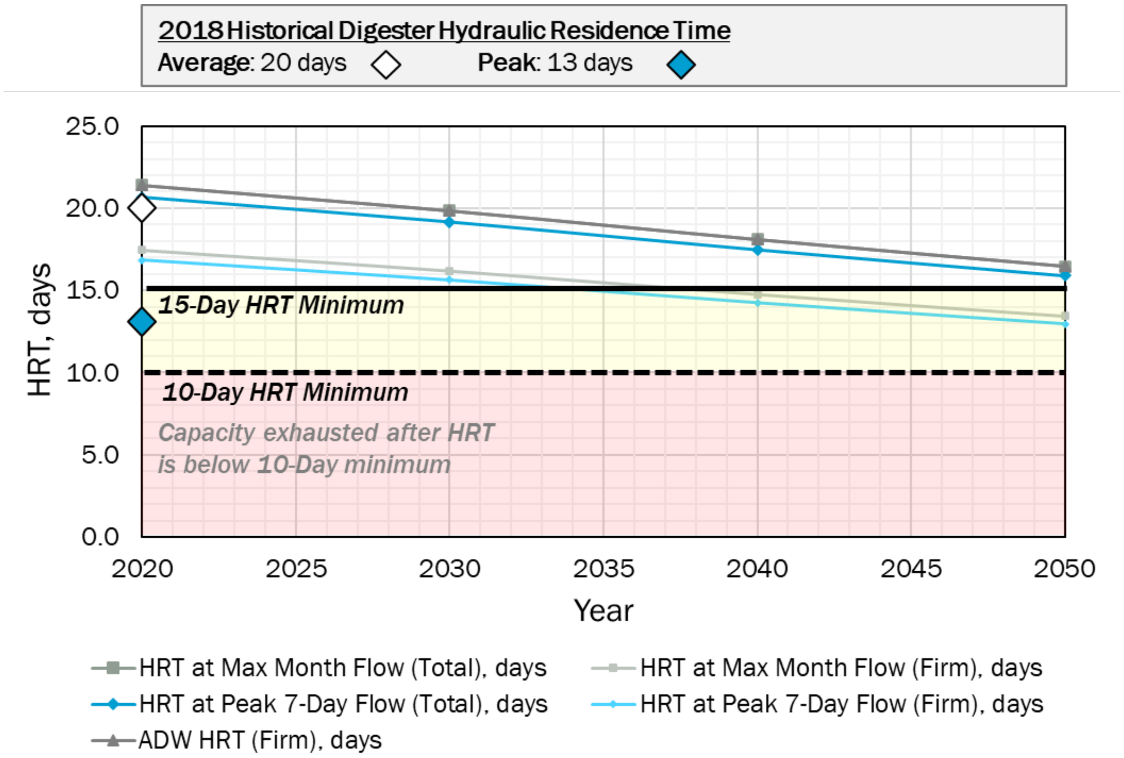

Figure 4-5. HRT in first- and second-stage anaerobic digesters

Yellow indicates an HRT below15-day criteria; however, District can operate under 15 and above 10 days. Red indicates HRT values that would result in a capacity limitation.

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[5] Digester volumes provided based on the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). Values for first-stage and second-stage digesters account for effective volume reduction due to grit accumulation. Second-stage digester volume was reported as 1.90 million gallons (MG) on average. First-stage digester volume was reported as 1.81 MG.

The OLR capacity assessment considered projected VS loading rates to the total first-stage digester volume for digester operation at total and firm capacity. Figure 4-6 shows either firm or total capacity digester operation is sufficient to maintain the OLR below 0.35 lb VS/ft^3-d throughout the planning period.

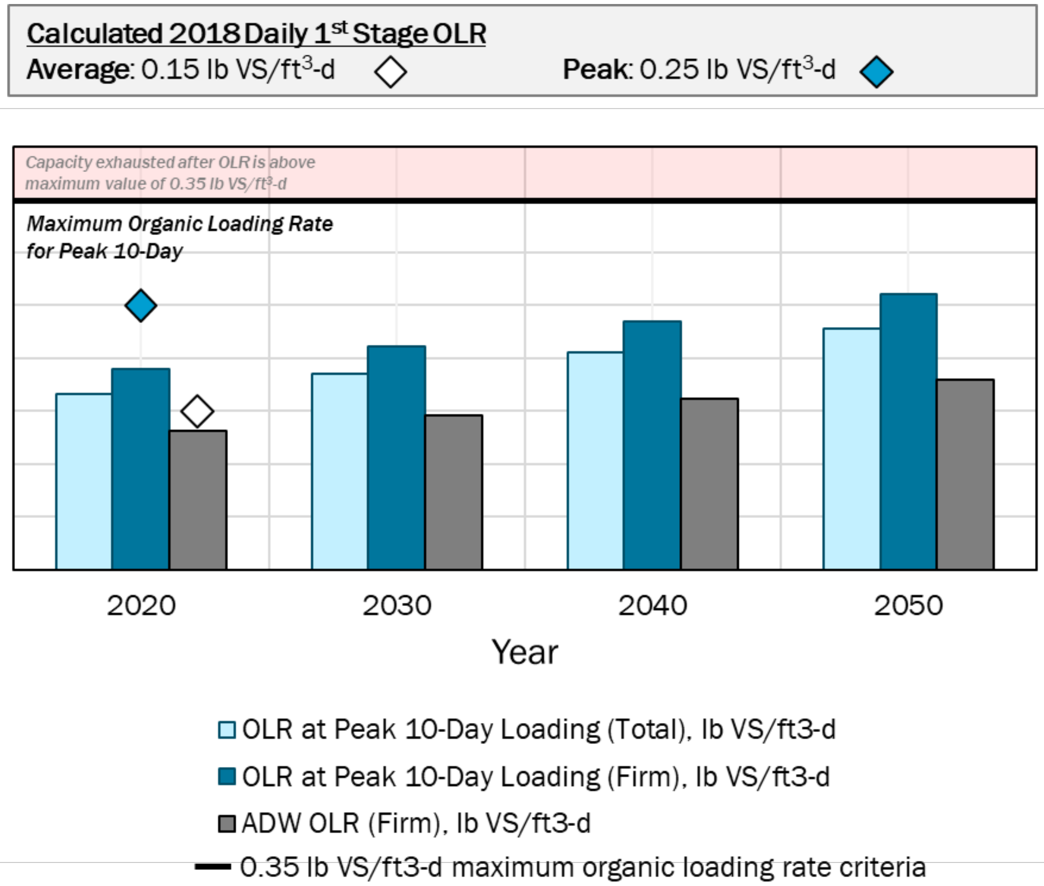

Figure 4-6. OLR in first-stage anaerobic digesters

2018 historical data is presented for reference.

In 2018 the second-stage digesters were evaluated for structural stability. A maximum water depth of 24 feet was identified to maintain digester integrity during a seismic event (Beyaz and Patel, 2018). The design maximum depth for second-stage digesters is 33 feet. Capacity results shown in Figure 4-5 assumes second-stage digesters are operated without water depth limitations; however, without seismic retrofit the second-stage digester volume is approximately 22% lower. If seismic upgrades are not completed and second-stage digesters are operated at a lower water depth of 24 feet in alignment with operating recommendations for structural safety during a potential seismic event, then firm digester capacity would be less.

4.4 Dewatering

Dewatering centrifuge capacity was determined based on hydraulic and solids loading. The dewatering centrifuge capacity was evaluated using observed flows by operations staff, as recorded in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). Solids loading capacity was evaluated based on vendor information. Figure 4-7 shows that with respect to hydraulic capacity, the centrifuges do not have sufficient capacity under any scenario. Figure 4-8 shows that with respect to solids loading, the centrifuges have sufficient capacity; however, solids loading capacity received by vendors is not derated and the observed, derated hydraulic capacity governs.

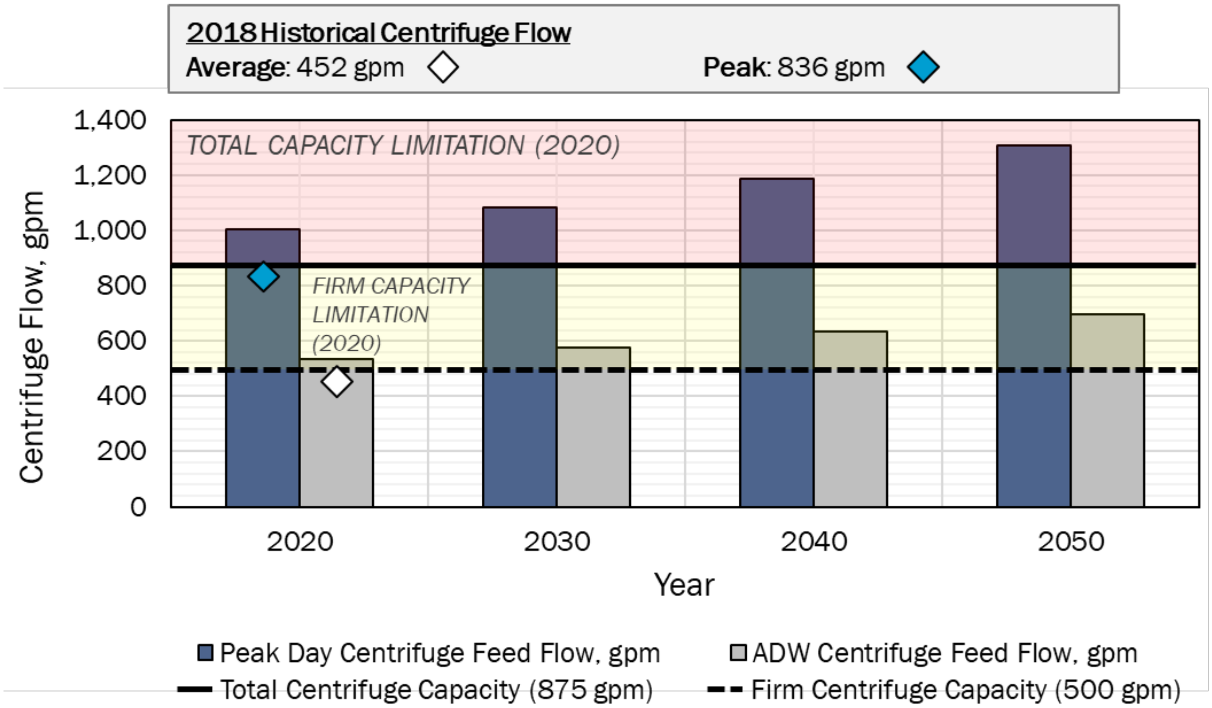

Figure 4-7. Dewatering centrifuge capacity with respect to flow

2018 historical data is presented for reference.

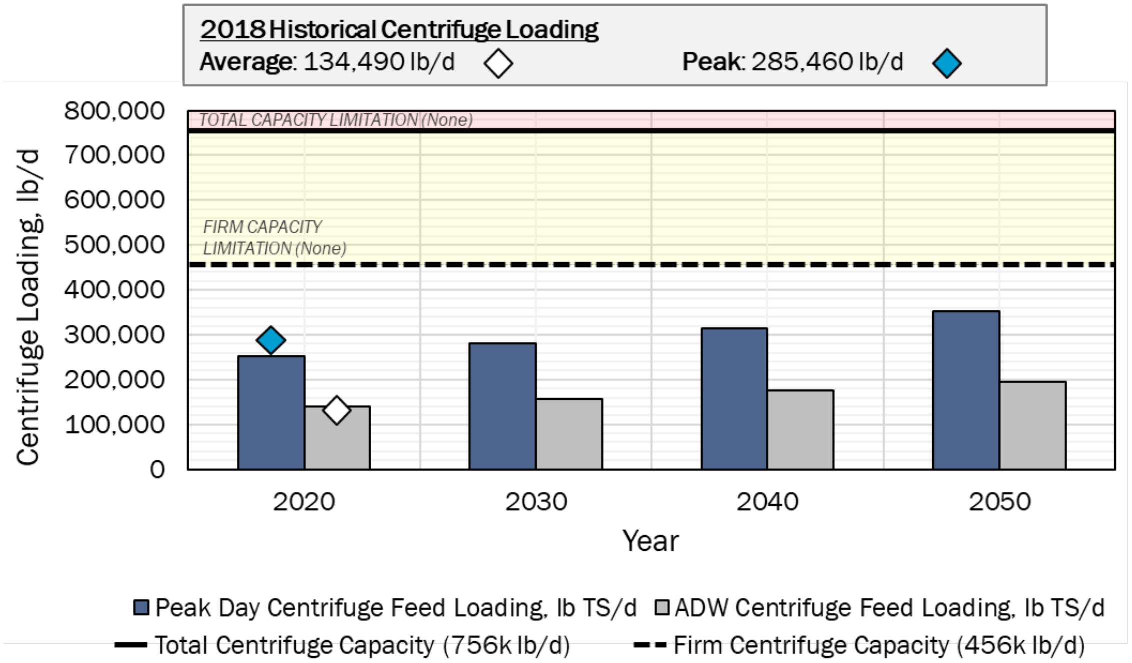

Figure 4-8. Dewatering centrifuge capacity with respect to TS loading

2018 historical data is presented for reference.

The 2018 data shows that peak day flows were lower than model predictions. This is due to the assumption in the capacity evaluation that digester feed solids concentrations are lower than observed. For example, a thickened waste activated sludge (TWAS) concentration of 5.0% was matched based on the concentration reported in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020). Review of historical data shows that an average of 5.7% is typical for MWWTP operations. Overall, this translated to a model-predicted concentration approximately 10% lower than 2018 historical data.

Opportunities for Process Optimization: Dewatering was evaluated based on peak day flow and loading. The capacity limitation at peak day could be addressed with equalization in the second-stage digesters. A review of the historical data demonstrates that the firm hydraulic capacity is reached under current conditions; therefore, the dewatering capacity limitation would need to be addressed in the near-term. The following strategies were identified as potential optimizations that could address the near-term capacity limitation: (1) use equalization in second-stage digesters for peak flows, (2) reduce trucked waste deliveries to reduce digested sludge flows and loads, and (3) increase the solids concentration in the digesters to reduce flows to the dewatering system.

4.5 Cake Hoppers

The cake hopper capacity was determined at peak day conditions, assuming a minimum of 1.5 days of storage. A storage capacity of 1.5 days was reported as the current available storage in the Draft MWWTP Existing Performance and Preliminary Capacity Assessment Report E80/E90 (EBMUD, 2020).

Figure 4-9 shows there is not sufficient storage capacity in the future. The projected cake from the BioWin process model was adjusted and lowered by approximately 29% to account for the overprediction in the validated process model. As shown in Figure 4-9, the 2018 observed data was higher than the corrected model prediction and is likely attributed to variability in cake dryness. Regardless, there is insufficient capacity under all conditions. If the model values were not adjusted, the projected storage time with the existing cake hoppers would be lower than the values shown in Figure 4-9.

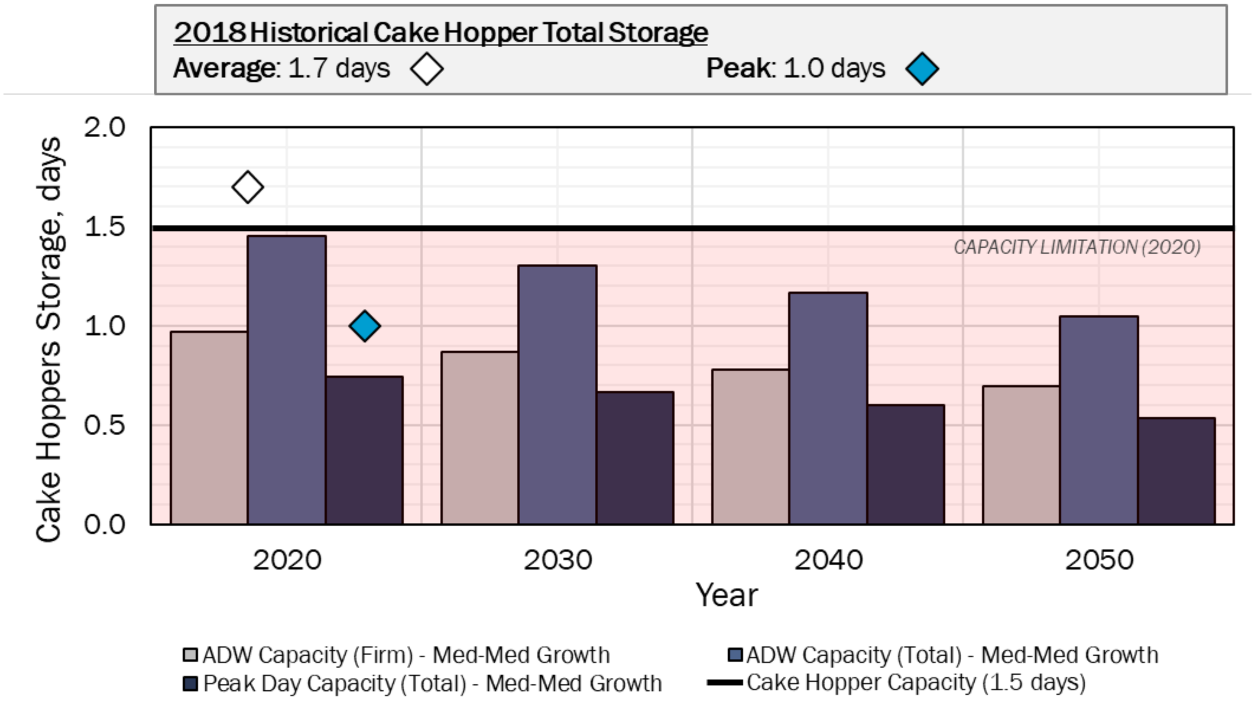

Figure 4-9. Cake hoppers storage capacity

2018 historical data is presented for reference.

Opportunities for Process Optimization: Prior work by BC included a survey of agencies of similar size to the District. This survey showed maximum onsite cake storage was reported as high as 3 days. Longer storage durations and exposure of solids to moisture and destabilization will inevitably promote odor; therefore, designing solids hoppers for the minimum number of days needed is recommended to mitigate odors. A storage expansion should consider hopper covers with headspace connected to an odor control system to mitigate increased odor potential associated with longer biosolid holding times.

CHAPTER 5 - CONCLUSIONS

The capacity of MWWTP was determined with respect to process treatment capacity and hydraulic capacity. Figure 5-1 presents the capacity of each unit process with respect to total and firm capacity and year at which capacity is reached. Figure 5-2 shows the capacity limitations on a process flow diagram of the MWWTP. The process flow diagram also highlights unit processes that had potential opportunities for optimization identified. Conclusions are summarized in Sections 5.1 and 5.2 for the liquid treatment capacities and solids treatment capacities, respectively.

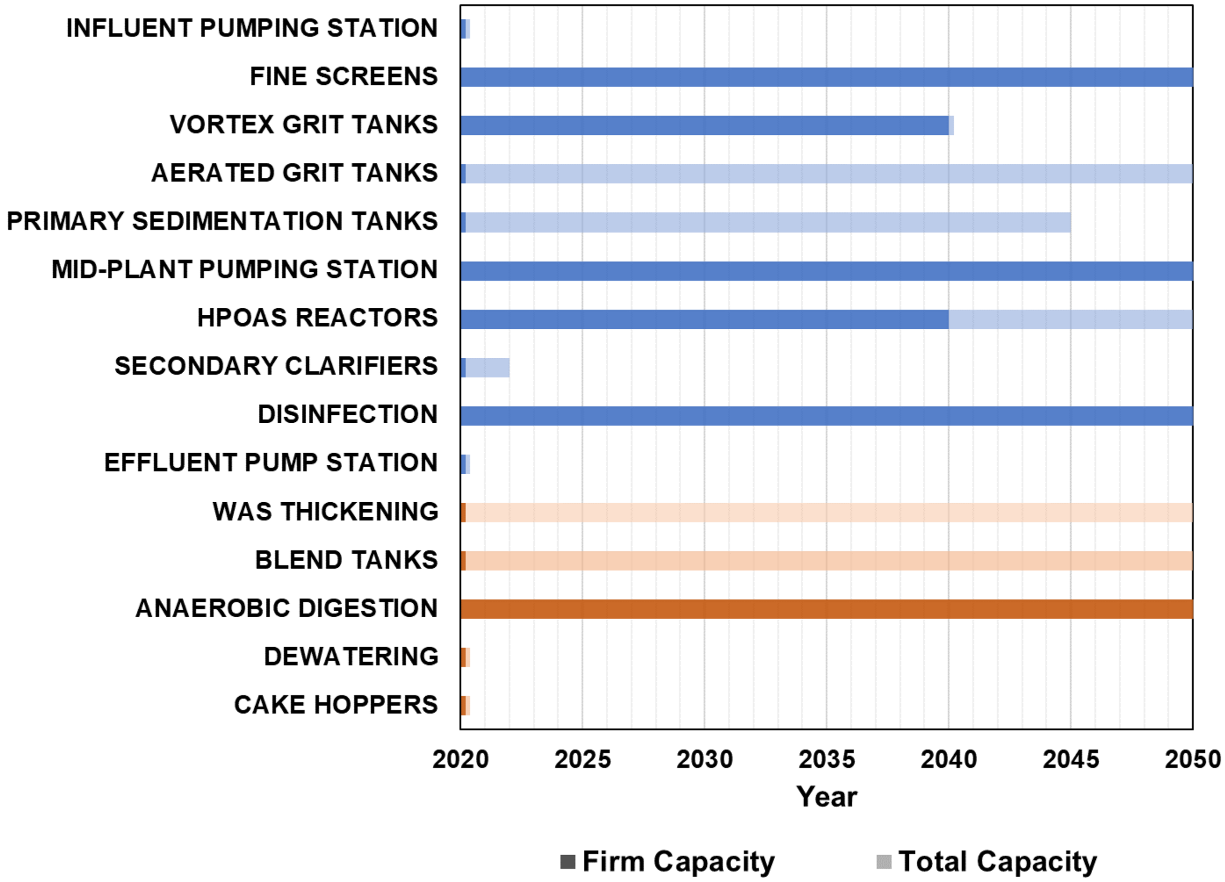

Figure 5-1. Year at which capacity is reached for each unit process at the MWWTP

Blue bars represent the liquid treatment stream and orange represents the solids treatment stream. Total capacity is represented by lighter bars and firm by darker bars, as depicted in the legend.

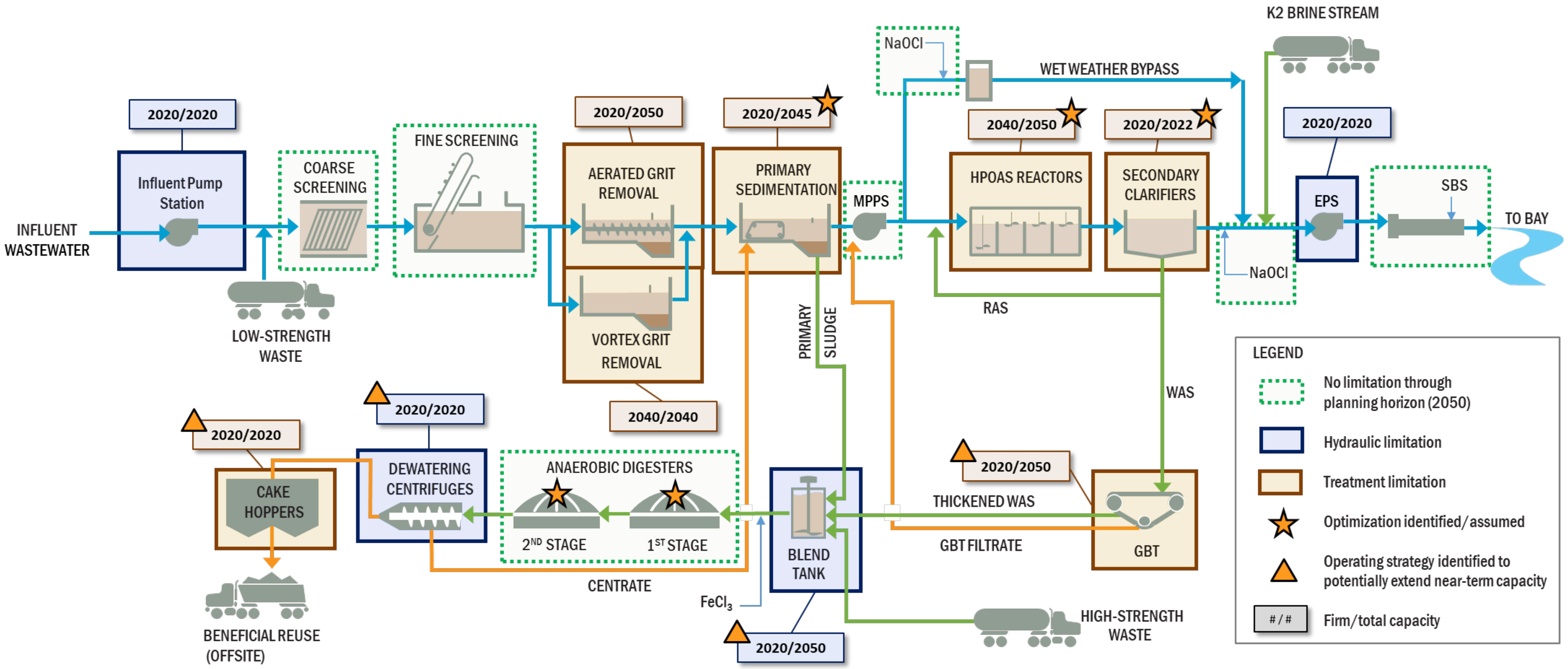

Figure 5-2. MWWTP process flow diagram with capacity assessment results

5.1 Summary of Liquid Treatment Capacity

- **IPS:** The pumping capacity criteria was evaluated based on a peak hour flow rate criteria of 425 mgd. District Staff determined a total IPS flow capacity of 390 mgd. This pumping capacity was below the peak hour flow rate in the year 2020. Therefore, firm and total flow capacity was insufficient in 2020.
- **Fine Screens:** Fine screening capacity is sufficient through 2050.
- **VGTs:** The VGTs were evaluated based on the peak day dry weather flow rate. VGTs have identical firm and total capacities of 70 mgd total and are only used during dry weather conditions. The VGT firm and total capacity is sufficient until 2040. District Staff has noted that existing performance does not remove fine grit.
- **AGTs:** The AGTs were evaluated based on minimum HRT during peak hour flowrate. There is sufficient total capacity (eight AGTs) for grit removal through the 2050, and firm capacity (six AGTs) was insufficient in 2020. District Staff has noted that existing performance does not remove all coarse grit. The existing AGTs can be modified to improve performance, as discussed in the Draft Integrated MWWTP Roadmap Report (EBMUD, 2021).
- **PSTs:** The PSTs were evaluated based on operation with primary sludge thickening (maximum SOR of 2,500 gpd/ft^2) and without primary sludge thickening (maximum SOR of 3,000 gpd/ft^2). The evaluation suggests primary sludge cannot be thickened in PSTs during peak day flows with the existing PSTs. PST operation without primary sludge thickening has a firm capacity (14 PSTs) that is insufficient in 2020 and a total capacity (16 PSTs) that is sufficient until 2045.
    - **Optimization:** CEPT was identified as a potential optimization strategy to improve removal efficiency across the PSTs and increase capacity. CEPT could be implemented during wet weather events when higher influent flows are observed to decrease operating costs relative to a year-round CEPT implementation.
- **MPPS:** The MPPS has sufficient capacity through 2050.
- **HPOAS Reactors:** The HPOAS reactors were evaluated based on HiPure modeling results, which were used to suggest whether capacity is limited by oxygen transfer (i.e., aerators) or oxygen production (i.e., cryogenic towers). Capacity was evaluated at peak day loading condition during dry weather flow and peak day temperature. The firm capacity (150 mgd through HPOAS reactors with seven reactors online) is sufficient until 2040. The total capacity (168 mgd through all eight reactors) is sufficient through 2050. Oxygen transfer limitations were identified as the bottleneck for capacity.
    - **Optimization:** Two optimization strategies were identified: 1) CEPT was identified as a potential optimization strategy to improve primary removal performance and decrease BOD loading to the HPOAS reactors, and 2) new surface-mounted aerators could be installed to improve oxygen transfer efficiency.

- **Secondary Clarifiers:** The secondary clarifiers were evaluated based on peak week flow and loading condition with a 90th percentile SVI value of 133 mL/g and 1.5-day SRT. The firm capacity (seven HPOAS reactors; 13.6 mgd per clarifier) was limited in 2020. The total capacity (eight HPOAS reactors; 14 mgd per clarifier) is limited in 2022.
    - **Optimization:** Two optimizations were identified that could increase secondary treatment capacity: 1) implement CEPT to reduce organic loading to the secondary process, and 2) increase RAS pump capacity to increase solids loading capacity of the clarifiers.
- **Disinfection:** Disinfection capacity is sufficient through 2050.
- **EPS:** The EPS has a capacity criterion of 325 mgd. The maximum flow rate of EPS is 278 mgd due to hydraulic bottlenecks that occur during a 10-year return frequency tidal elevation. The maximum flow rate of EPS is lower than the capacity criterion; therefore, EPS capacity was insufficient in 2020. Additional hydraulic analyses are recommended to confirm improvements that will alleviate hydraulic bottlenecks, thereby increasing EPS capacity.

5.2 Summary of Solids Treatment Capacity

- **WAS Thickening:** The WAS thickening process was evaluated based on hydraulic and solids loading rate capacities during maximum day flows and loads, respectively. The firm capacity (two GBTs) was insufficient in 2020. The total capacity (three GBTs) is sufficient through 2050. Operational strategies could be implemented during peak conditions to reduce the flow to the GBTs, thereby addressing the firm capacity constraint through 2050.
- **Blend Tanks:** The Blend Tanks were evaluated based on pumping capacity and HRT criteria at peak day and ADW flows, respectively. Based on pumping capacity, the firm capacity (two digester feed pumps) was insufficient in 2020 and total capacity (three digester feed pumps) is sufficient through 2050. Blend tank volume is sufficient through the planning period, but operation of one blend tank is required in the near term to maintain an HRT below 12 hours. Operational strategies could be implemented during peak conditions to balance peak day flows with only two digester feed pumps.
- **Anaerobic Digestion:** Anaerobic digestion was evaluated based on HRT and OLR criteria, and was determined to have sufficient capacity through 2050. The digester capacity assumes that the second-stage digesters are operated at the full operating liquid level and that the digesters can be operated at a 10-day HRT using the patented process developed by the District (Gray and Shang, 2013). The Digester Phase 3 Basis of Design Report (Beyaz and Patel, 2018) recommends seismic improvements (i.e., post-tensioning improvements) are to be performed to operate the second-stage digesters at the maximum liquid level.
- **Dewatering Centrifuges:** The dewatering centrifuges were evaluated based on hydraulic and solids loading rate capacities during maximum day and ADW flow and loads. The firm capacity (three centrifuges) was insufficient in 2020 due to hydraulic limitations at ADW flow rates. The total capacity (five centrifuges) was insufficient in 2020 due to hydraulic limitations at peak day flow rates. Peak day flows to dewatering could be equalized in the second-stage digesters to reduce the capacity limitation in the near term. Additionally, in the interim, the District could assume firm capacity is defined with only one centrifuge out of service at a time instead of the current definition that firm capacity is defined with two

centrifuges out of service. These measures could alleviate capacity constraints in the near term until the dewatering capacity is increased.

Cake Hoppers: The cake hoppers were evaluated based on a storage criterion of 1.5 days. The firm capacity (two hoppers) and total capacity (three hoppers) were insufficient in 2020. The District currently uses the second-stage digesters to equalize peak flows to dewatering and, subsequently, to the cake hoppers. This practice could continue to alleviate capacity constraints in the near term until the cake hopper capacity is addressed.

5.3 Summary of Optimizations

Table 5-1 presents several optimizations that were identified as part of the capacity assessment. These optimizations represent relatively low-cost modifications that could improve capacity.

Table 5-1. Optimization strategies identified for processes with capacity limitation

Process	Capacity Limitation	Optimization(s) Identified	Optimization Effect(s)
PSTs	Lower removal efficiency at higher SORs	Implement CEPT	Enhanced primary removal efficiency to allow for operation at higher SORs
		Do not thicken primary sludge in the PST during peak flows	Allows for operation at higher SORs; thinner sludge is sent to blend tanks and digesters
HPOAS reactors	Inadequate oxygen transfer rate to HPOAS from the oxygen generation facility	Implement CEPT	Enhanced primary removal efficiency decreases loading to secondary treatment HPOAS reactors
		Install new, more efficient surface aerators	Greater standard aeration efficiency with new equipment provides more oxygen transfer
Secondary clarifiers	High MLSS based on 2Dc CFD model analysis	Install baffling improvements, increase RAS pumping, implement CEPT	Baffling improvements increase capacity and have been performed on some of the clarifiers with others planned for the future, CEPT decreases loading to the secondary system, increased RAS pumping allows for higher treatment capacity

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CHAPTER 6 - REFERENCES

Beyaz and Patel, Technical Memorandum. Digester 2, 3, and 4 Seismic Evaluation. EBMUD Digester Upgrade Phase 3, East Bay Municipal Utility District, 2018.

East Bay Municipal Utility District, Integrated Master Plan for the Main Wastewater Treatment Plant E120: Draft Integrated MWWTP Roadmap, March 2021.

East Bay Municipal Utility District, Integrated Master Plan for the Main Wastewater Treatment Plant Draft Main Wastewater Treatment Plant Existing Performance and Preliminary Capacity Assessment Report E80/E90, February 2020.

Gray, Donald M. D., Shang, Y., Low Mean Cell Residence Time Anaerobic Digestion Process. US Patent 2013/0105390 A1, 2013.

Water Environment Federation, American Society of Civil Engineers, Design of Water Resource Recovery Facilities, Sixth Edition, McGraw-Hill Education, 2017.

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APPENDIX A – INFLUENT AND HIGH-STRENGTH WASTE FLOWS AND LOADINGS

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Table A-1. Raw influent plus low-strength waste flow and loading by EBMUD (medium projection)

Parameter	Year				Peaking Factors				
	2020	2030	2040	2050	30-day	10-day	7-day	3-day	1-day
Flow, mgd	52.2	56.0	60.5	66.0	2.21	2.99	2.93	3.57	228 mgd + ADWF[a]
TSS Loading, lb/d	194,000	218,000	247,000	278,000	1.46	1.89	1.89	3.11	3.11
COD Loading, lb/d	401,000	452,000	510,000	575,000	1.22	1.38	1.41	2.15	2.15
cBOD Loading, lb/d	170,000	192,000	218,000	246,000	1.22	1.38	1.41	2.15	2.15
TKN Loading, lb/d	26,500	30,000	33,700	38,100	1.20	1.32	1.32	1.32	1.32
Ammonia Loading, lb-N/d	16,500	18,700	21,200	23,800	1.10	1.28	1.28	1.28	1.28
Nitrate Loading, lb-N/d	1,080	1,210	1,370	1,520	4.13	7.34	7.34	7.34	7.34
Nitrite Loading, lb-N/d	485	551	617	683	1.82	2.50	2.50	2.50	2.50
Ortho-Phosphate Loading, lb-P/d	2,270	2,560	2,890	3,240	1.17	1.77	1.77	1.77	1.77
Total Phosphorus Loading, lb/d	4,300	4,870	5,510	6,220	1.25	1.40	1.40	1.40	1.40

a. Peak day flow projections were not based on a peaking factor but based on historical inflow and infiltration (I/I) data analysis. Per email from James Hake dated February 3, 2020 the I/I flow contribution in the future is equal to 228 mgd. Peak day flow to be calculated by adding average dry weather flow (ADWF) contribution to the I/I flow contribution (228 mgd + 66 mgd = 294 mgd in 2050).

Table A-2. High-strength waste flow and loading by EBMUD (medium projection)

Parameter	Year				Peaking Factors				
	2020	2030	2040	2050	30-day	10-day	7-day	3-day	1-day
Flow, gpd	241,000	235,000	240,000	245,000	1.20	1.30	1.30	1.60	1.70
TSS Loading, lb/d	141,000	148,000	151,000	154,000	1.20	1.30	1.30	1.60	1.70
COD Loading, lb/d	115,000	122,000	125,000	127,000	1.20	1.30	1.30	1.60	1.70
cBOD Loading, lb/d	178,000	193,000	197,000	201,000	1.20	1.30	1.30	1.60	1.70
TKN Loading, lb/d	6,860	6,980	7,120	7,270	1.20	1.30	1.30	1.60	1.70

APPENDIX B – SOLIDS PROCESS PEAKING FACTORS

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Solids peaking factors generally tend to be different than liquid stream peaking factors because of how the treatment system is operated and because of attenuation through the treatment process. At the MWWTP, high-strength waste streams also impact solids peaking factors and contribute to different peaking factors than the liquid stream. For this reason, solids peaking factors were developed using historical data from 2015 through 2018. Peak solids loading rates were calculated for different averaging periods (peak week, peak 10-day, peak 2-week, and peak month) by calendar year and peaking factors were then calculated by dividing the respective averaging period by the ADW value. Peaking factor results are summarized in Tables B-1 and B-2. A complete summary of annual peaking factors determined for solids handling processes are shown in Tables B-3 through B-13.

As noted in the C60: Plant-Wide Process Model report, the model prediction of the total solids of the cake was approximately 29% greater than the 2018 historical data. To assess the capacity of the cake hoppers, the future cake projections were reduced by 29% to avoid potential for overstating the capacity constraints.

Table B-1. Peak day peaking factors

Parameter	Primary Sludge	Waste Activated Sludge	Digester Feed	Centrifuge Feed	Cake Hopper Feed
Flow, mgd	1.77	1.89	1.55	1.88	1.92
TS Loading, lb/d	1.87	1.96	2.07	1.80	1.95
VS Loading, lb/d	Not Assessed	Not Assessed	2.30	Not Assessed	Not Assessed

Table B-2. Peak day peaking factors

Parameter	Digester Feed TS Load, lb/d	Digester Feed VS Load, lb/d	Digester Feed Flow, mgd
Peak 1-day	2.07	2.30	1.55
Peak 7-day	1.53	1.57	1.27
Peak 10-day	1.52	1.45	1.26
Peak 30-day	1.24	1.28	1.23

Table B-3. Primary sludge flow (mgd) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.52	1.41	1.39	1.38	1.24
2016	1.77	1.36	1.34	1.34	1.28
2017	1.73	1.35	1.34	1.28	1.16
2018	1.47	1.29	1.25	1.22	1.17

Table B-4. Waste activated sludge flow (mgd) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.63	1.46	1.43	1.40	1.35
2016	1.89	1.64	1.62	1.57	1.53
2017	1.51	1.32	1.24	1.21	1.17
2018	1.65	1.50	1.46	1.47	1.38

Table B-5. Digester feed flow (mgd) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.31	1.13	1.13	1.11	1.08
2016	1.55	1.27	1.26	1.25	1.23
2017	1.39	1.17	1.14	1.12	1.09
2018	1.43	1.22	1.20	1.15	1.14

Table B-6. Centrifuge feed flow (mgd) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.55	1.24	1.19	1.16	1.10
2016	1.66	1.36	1.32	1.29	1.25
2017	1.65	1.27	1.29	1.20	1.14
2018	1.88	1.22	1.23	1.16	1.14

Table B-7. Cake feed flow (mgd) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.53	1.23	1.19	1.14	1.08
2016	1.74	1.41	1.35	1.34	1.27
2017	1.92	1.43	1.47	1.39	1.31
2018	1.77	1.42	1.34	1.30	1.26

Table B-8. Primary sludge loading (lb TS/d) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.68	1.66	1.51	1.46	1.42
2016	1.75	1.69	1.63	1.60	1.45
2017	1.65	1.60	1.60	1.44	1.33
2018	1.87	1.72	1.61	1.61	1.38

Table B-9. Waste activated sludge loading (lb TS/d) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.72	1.32	1.27	1.21	1.13
2016	1.81	1.60	1.54	1.48	1.32
2017	1.64	1.32	1.27	1.24	1.13
2018	1.96	1.50	1.36	1.26	1.16

Table B-10. Digester feed TS loading (lb TS/d) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.74	1.27	1.28	1.20	1.14
2016	2.07	1.53	1.52	1.36	1.21
2017	1.53	1.29	1.24	1.15	1.13
2018	1.84	1.37	1.31	1.26	1.24

Table B-11. Digester feed VS loading (lb VS/d) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	2.17	1.40	1.26	1.28	1.18
2016	2.30	1.57	1.45	1.40	1.23
2017	1.64	1.26	1.13	1.12	1.08
2018	1.90	1.38	1.30	1.31	1.28

Table B-12. Centrifuge feed loading (lb TS/d) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.49	1.24	1.22	1.21	1.10
2016	1.63	1.37	1.36	1.29	1.20
2017	1.80	1.48	1.48	1.40	1.32
2018	1.61	1.37	1.27	1.24	1.12

Table B-13. Cake hopper loading (lb TS/d) peaking factors

Year	Peak Daily	Peak 7-Day	Peak 10-Day	Peak 14-Day	Peak 30-Day
2015	1.50	1.21	1.10	1.11	1.06
2016	1.67	1.36	1.26	1.28	1.25
2017	1.95	1.43	1.37	1.38	1.31
2018	1.75	1.40	1.29	1.30	1.26

APPENDIX C – CAPACITY ASSESSMENT CALCULATIONS

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Assumptions used in the capacity assessment calculations shown in this section are listed in Tables C-1 and C-2. The capacity assessment calculations are included following the assumptions and model inputs below.

Table C-1. BioWin tank volumes, removal efficiencies, and inputs

BioWin Element	Value	Basis
PST	9 tanks input for ADW or 14 tanks input for peak flows	Based on Average for ADW or Peak Condition
HPOAS System	7 trains for firm capacity; 8 trains for total capacity	Based on EBMUD direction for total and firm capacity
Secondary Clarifiers	11 clarifiers for firm capacity; 12 clarifiers for total capacity	Based on EBMUD direction for total and firm capacity
Digesters	7 1st stage and 2 2nd stage digesters for firm capacity; 8 1st stage and 3 2nd stage digesters for total capacity.	Based on EBMUD direction for total and firm capacity
PST Removal	64% TSS removal for ADWF; 61% TSS removal for non-ADWF	Based on average removal during 2015-2018 for ADW flow and non-ADW flow
GBT Removal	95%	Based on average removal during 2015-2018
Dewatering Centrifuge Removal	96%	Based on average removal during 2015-2018
Influent + LSW Element TSS	~ 7% lower for ADWF conditions; ~ 17% lower for non-ADWF conditions	Match 0.85 VSS/TSS ratio for ADWF conditions; Match 0.75 VSS/TSS ratio for non-ADWF conditions

Table C-2. TSS loading correction factors from BioWin output to TS loading in capacity assessment calculations

Parameter	Assumption	Calculation Correction	Parameter	Assumption	Calculation Correction
Primary sludge (PS)	Assumed **500 mg/L** based on influent TDS sampling (563 mg/L)	**No correction;** Assumed TSS loading = TS loading	1st Stage Digester Feed	Assumed TDS mass is conserved through upstream processes	**No correction;** Assumed VSS loading = VS loading
Waste activated sludge (WAS)	Assumed **500 mg/L** based on influent TDS sampling (563 mg/L)	**No correction;** Assumed TSS loading = TS loading	Centrifuge Feed	Assumed TDS mass is conserved through upstream processes	**No correction;** TSS loading matched closely with historical TS loading
Thickened waste activated sludge (TWAS)	Assumed **500 mg/L** based on influent TDS sampling (563 mg/L)	**No correction;** Assumed TSS loading = TS loading	Cake Solids	Assumed TDS mass is conserved through upstream processes.	**Correction applied:** TSS loading* 1.29 = TS loading
High strength waste/ Trucked waste (HSW)	Measured 40,734 mg/L, but assumed lower value of **15,000 mg/L** to better match centrate TDS	TDS loading assumptions for PS, TWAS, and HSW used to determine Cake Solids correction.	Centrate Return Stream	Assumed 5,300 mg/L based on average TDS from 3 data points of sampling (5300 mg/L)	Not Applicable for Calculations

*Correction applied based on BioWin model validation and historical data; BioWin model overpredicts solids by approximately 29%.

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	001

Project	Subject
EBMUD MWWTP Master Plan	Grit Tank Capacity

Problem Statement

Evaluate the existing process capacity of the grit tanks at EBMUD MWWTP for Med Influent+LSW/Med HSW projections.

Vortex Grit Tank Information

Parameter	Design Criteria	Reference
Type	Vortex	Existing Plant Capacity and Performance TM, July 2019
Number of Units	2	Existing Plant Capacity and Performance TM, July 2019
Units in Service (Total Capacity)	2	
Units in Service (Firm Capacity)	2	

Vortex Grit Tank Capacity Criteria

Capacity of the system is determined by maximum flow rate.

Parameter	Design Criteria	Notes
Derated Flow	35 mgd	Existing Plant Capacity and Performance TM, July 2019

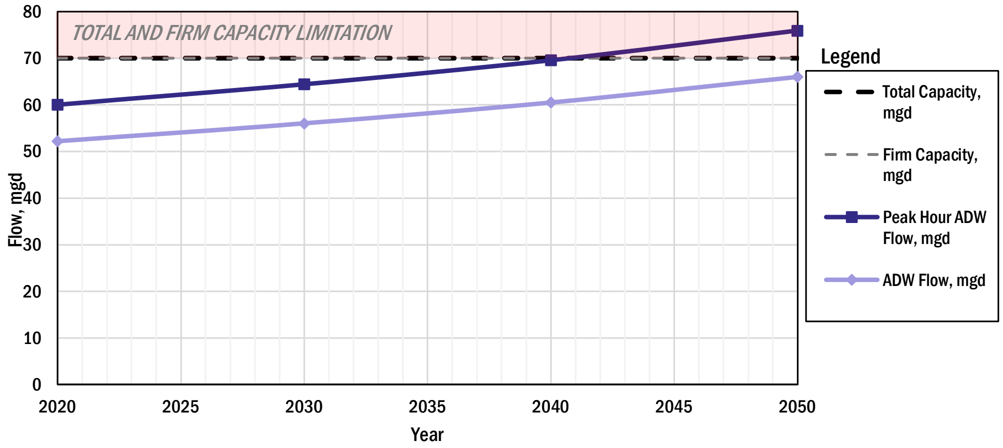
Peaking Factors

Condition	PF	Reference
Diurnal Peak Flow: ADWF	1.15	Diurnal peaking factor based on average diurnal flowrate values at IPS provided by District for 2015-2018.

Vortext Grit Tank Predictions & Capacity (Dry Weather Only)

Capacity

Condition	2020	2030	2040	2050
ADW Flow, mgd	52	56	61	66
Peak Hour ADW Flow, mgd	60	64	70	76
Firm Capacity, mgd	70	70	70	70
Total Capacity, mgd	70	70	70	70



Interpolate to Determine Year at Which Capacity Runs Out

Condition	ADW	ADW*Diurnal PF
Med LSW/Med HSW	2050	2040

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Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	001
Project			Subject		
EBMUD MWWTP Master Plan			Grit Tank Capacity		

Aerated Grit Tank Information

Parameter	Design Criteria	Reference
Type	Aerated	Existing Plant Capacity and Performance TM, July 2019
Number of Units	8	Existing Plant Capacity and Performance TM, July 2019
Volume per Unit	0.38 MG	EBMUD Historical Consolidated MWWTP Data
Units in Service (Total Capacity)	8	
Units in Service (Firm Capacity)	6	

Aerated Grit Tank Capacity Criteria

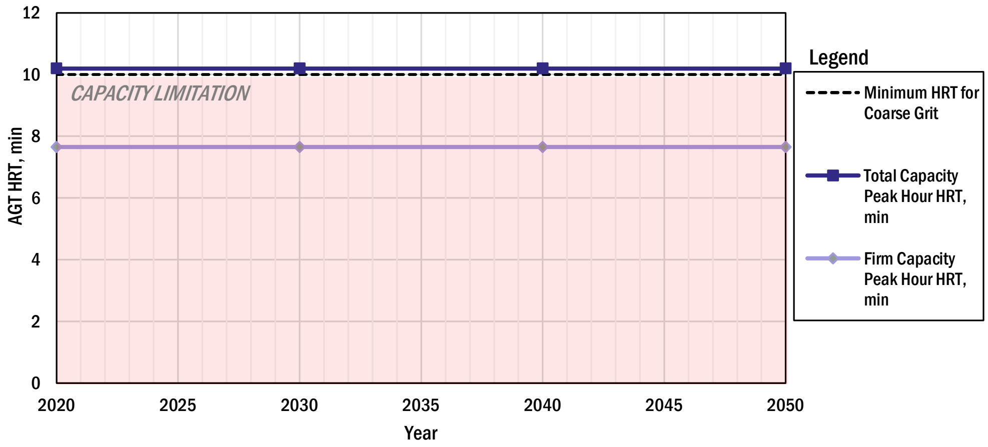
Capacity of the system is determined by minimum hydraulic residence time (HRT)

Parameter	Design Criteria	Notes
Minimum HRT for Coarse Grit	10 minutes	WEF MOP No. 8, 6th Ed., Chapter 9 Section 4.3.1 (Aerated Grit Basins)

Aerated Grit Tank Predictions & Capacity (Wet Weather Only)

Capacity

Condition	2020	2030	2040	2050
Peak Daily Flow, mgd	281	284	289	294
Peak Hour Flow, mgd	425	425	425	425
Total Capacity, MG	3.01	3.01	3.01	3.01
Firm Capacity, MG	2.26	2.26	2.26	2.26
Total Capacity Peak Day HRT, min	15.5	15.2	15.0	14.7
Firm Capacity Peak Day HRT, min	11.6	11.4	11.3	11.0
Total Capacity Peak Hour HRT, min	10.2	10.2	10.2	10.2
Firm Capacity Peak Hour HRT, min	7.65	7.65	7.65	7.65



Interpolate to Determine Year at Which Capacity Runs Out

Condition	Firm	Total
Med LSW/Med HSW	2020	2050

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Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	002
Project			Subject		
EBMUD MWWTP Master Plan			Primary Sedimentation Tank Capacity		

Problem Statement

Evaluate the existing process capacity of the primary sedimentation tanks at EBMUD MWWTP for Med Influent+LSW/Med HSW projections.

Primary Sedimentation Tank Information

Parameter	Design Criteria	Reference
Type	Rectangular	Existing Plant Capacity and Performance TM, July 2019
Length	174 ft	Existing Plant Capacity and Performance TM, July 2019
Width	36 ft	Existing Plant Capacity and Performance TM, July 2019
Number of Units	16	Existing Plant Capacity and Performance TM, July 2019
Units in Service (Total Capacity)	16	
Units in Service (Firm Capacity)	14	

Primary Sedimentation Tank Capacity Criteria

Capacity of the system is determined by maximum surface overflow rate (SOR).

Parameter	Design Criteria	Notes
Maximum SOR (with sludge thickening)	2,500 gpd/ft2	Maximum SOR for tanks that thicken primary sludge (ref: MOP 8)
Maximum SOR (no thickening)	3,000 gpd/ft2	

Peaking Factors

Condition	PF	Reference
Return Stream: ADWF	1.03	Centrate is routed upstream of PST (2.7% of influent at max load average flow)

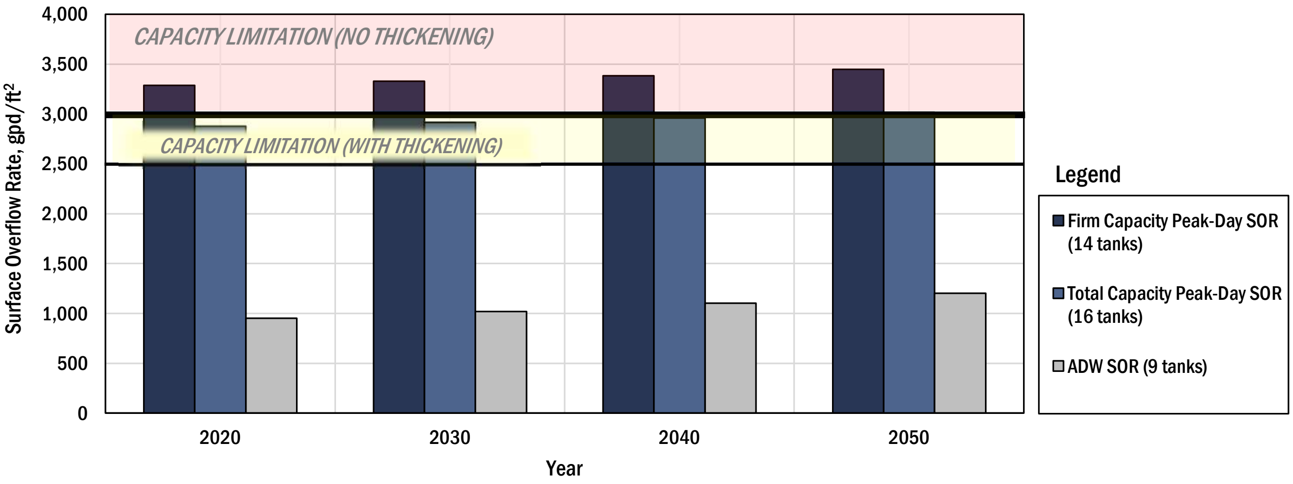
Brown AND Caldwell

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	002
Project			Subject		
EBMUD MWWTP Master Plan			Primary Sedimentation Tank Capacity		

Primary Sedimentation Tank Predictions & Capacity

Capacity assessment based on flows from BioWin model input and PST dimensions.

Condition	2020	2030	2040	2050	Reference
ADW Flows, mgd	52.2	56.0	60.5	66.0	
ADW Flows with Centrate Return, mgd	53.6	57.5	62.2	67.8	
Peak 1-day Flows, mgd	281	284	289	294	Peak 1-day flow rate projections
Peak 1-day Flows with Centrate Return,	288	292	297	302	
Capacity SOR (with thickening)	2,500	2,500	2,500	2,500	
Capacity SOR (no thickening)	3,000	3,000	3,000	3,000	
ADW SOR (9 tanks)	951	1,021	1,103	1,203	Uses 9 tanks, based on historical 2018 average
Firm Capacity Peak-Day SOR (14 tanks	3,286	3,330	3,384	3,447	
Total Capacity Peak-Day SOR (16 tanks	2,875	2,913	2,961	3,016	



Interpolate to Determine Year at Which Capacity Runs Out

Condition	Total Capacity	Firm Capacity
Thickening in PST	2020	2020
No Thickening in PST	2045	2020

Date Checked	Checked By	Job Number	By	Date	Calc No
3/4/2020	A. Klein	153728	R. Merlo	3/12/2020	003

Project	Subject
EBMUD MWWTP Master Plan	HPOAS Reactors Capacity

Problem Statement

Evaluate the existing process capacity of the HPOAS Reactors at EBMUD MWWTP for Med Influent+LSW/Med HSW projections.

HPOAS Reactor Information

Parameter	Design Criteria		Reference
Stages per Tank	4		Existing Plant Capacity and Performance TM, July 2019
Volume per Stage	0.40	MG	Existing Plant Capacity and Performance TM, July 2019
Number of Tanks	8		Existing Plant Capacity and Performance TM, July 2019
Tanks in Service (Total Capacity)	8		Existing Plant Capacity and Performance TM, July 2019
Tanks in Service (Firm Capacity)	7		Existing Plant Capacity and Performance TM, July 2019
Number of Oygen Generation Plants	2		Existing Plant Capacity and Performance TM, July 2019
Size of One Oxygen Generation Plant	125	tons/d	Existing Plant Capacity and Performance TM, July 2019
Size of Two Oxygen Generation Plants	250	tons/d	Existing Plant Capacity and Performance TM, July 2019
Supplemental Liquid Oxygen	125	tons/d	
Second Stage Vent Purity	95	percent	Based on field measurements
Fourth Stage Vent Purity Minimum	40	percent	Assumption by BC to mitigate inhibitory or corrosive reactor conditions
Minimum DO Concentration	2.0	mg/L	Assumption by BC to mitigate filamentous growth and bulking sludge

HPOAS Capacity Criteria

Capacity of the system is determined by the Oxygen Supply Requirements and the Oxygen Transfer Requirement.

Parameter	Design Criteria		Notes
Size of One Oxygen Generation Plant	125	tons/d	See table above
Size of Two Oxygen Generation Plants	250	tons/d	See table above
Supplemental Liquid Oxygen	125	tons/d	See table above

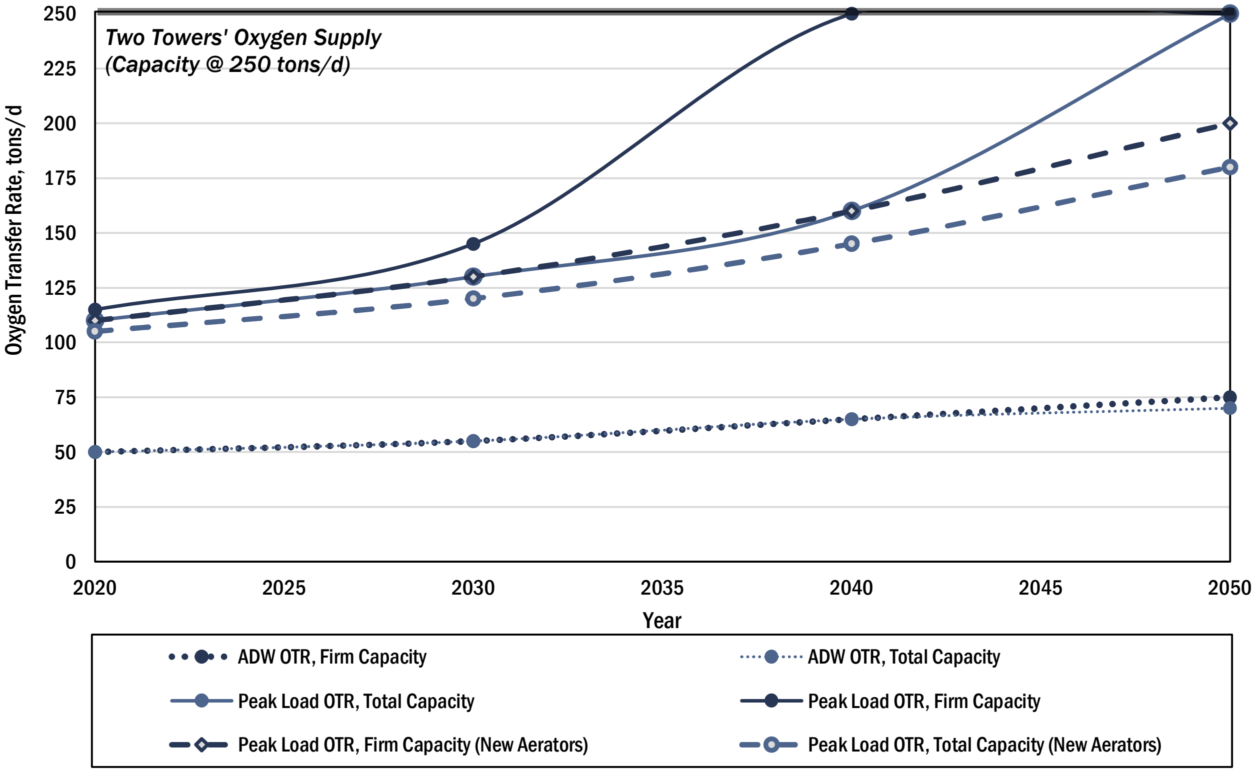
HPOAS Predictions & Capacity

HPOAS oxygen transfer rate (tons/d) requirement to satisfy minimum vent purity and DO values based on calibrated HiPure model with BioWin model outputs.

Condition	2020	2030	2040	2050	Notes
ADW OTR, Firm Capacity	50	55	65	75	Values assessed using High Purity Oxygen calibrated model (HiPure) and output from BioWin model for firm (7 HPOAS Trains) and total (8 HPOAS Trains) capacity for the HPO system.
ADW OTR, Total Capacity	50	55	65	70	
Peak Load OTR, Firm Capacity	115	145	250	250	
Peak Load OTR, Total Capacity	110	130	160	250	
Peak Load OTR, Firm Capacity (New Aerators)	110	130	160	200	
Peak Load OTR, Total Capacity (New Aerators)	105	120	145	180	

Brown AND Caldwell

Date Checked	Checked By	Job Number	By	Date	Calc No
3/4/2020	A. Klein	153728	R. Merlo	3/12/2020	003
Project			Subject		
EBMUD MWWTP Master Plan			HPOAS Reactors Capacity		



Interpolate to Determine Year at Which Capacity Runs Out for Oxygen Supply

Condition	250 tons/d Capacity	
	Total Capacity	Firm Capacity
Med LSW/Med HSW	2050	2040
Med LSW/Med HSW (with New Aerators Installed)	2050	2050

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Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	004

Project	Subject
EBMUD MWWTP Master Plan	Secondary Clarifier Capacity

Problem Statement

Evaluate the existing process capacity of the secondary clarifiers at EBMUD MWWTP for Med Influent+LSW/Med HSW projections.

Secondary Clarifier Information

Parameter	Design Criteria	Reference
Type	Circular	Existing Plant Capacity and Performance TM, July 2019
Diameter	140 ft	Existing Plant Capacity and Performance TM, July 2019
Number of Units	12	Existing Plant Capacity and Performance TM, July 2019
Units in Service (Total Capacity)	12	
Units in Service (Firm Capacity)	11	
RAS Capacity	6 mgd per clarifier	Upper range of EBMUD RAS pumps/clarifier reported

Secondary Clarifier Capacity Criteria

Capacity of the system is determined by critical MLSS concentration from 2Dc modeling.

Parameter	Design Criteria	Notes
6-mgd RAS Max Firm Capacity	2,700 mg/L	6-mgd RAS per Clarifier and Upgraded Clarifiers; 150 mgd Secondary Influent
8.5-mgd RAS Max Firm Capacity	3,000 mg/L	Proportional RAS per Clarifier and Upgraded Clarifiers; 150 mgd Secondary Influent
6-mgd RAS Max Total Capacity	2,600 mg/L	6-mgd RAS per Clarifier and Upgraded Clarifiers; 168 mgd Secondary Influent
8.5-mgd RAS Max Total Capacity	2,900 mg/L	Proportional RAS per Clarifier and Upgraded Clarifiers; 168 mgd Secondary Influent

Secondary Clarifier Predictions & Capacity

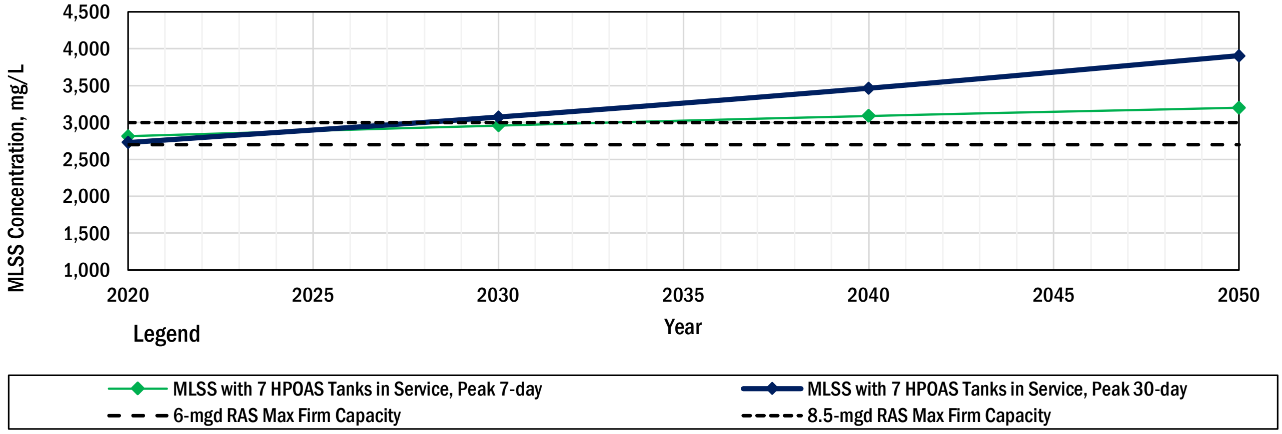
MLSS predictions for 2020 through 2050 based on flow and loading scenarios.

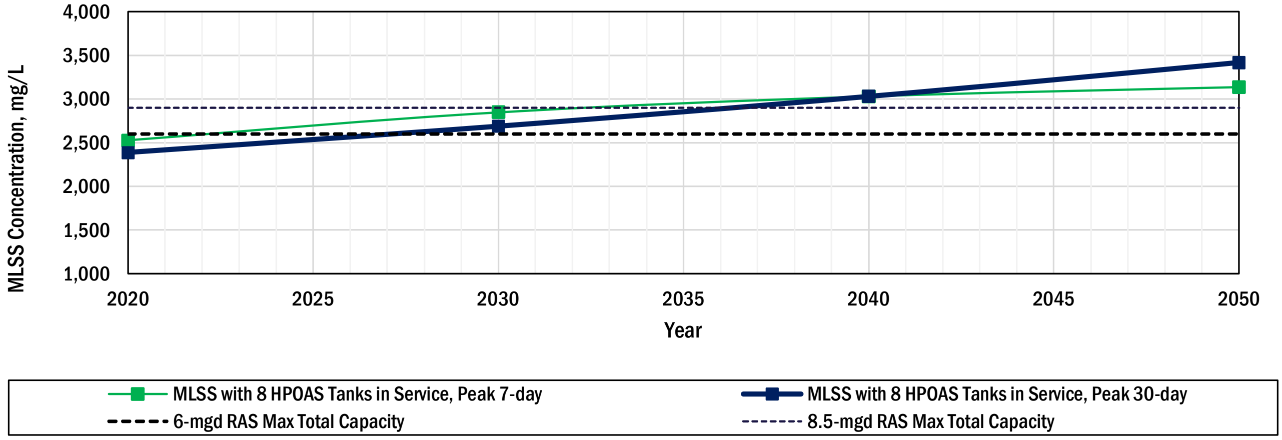
Condition	2020	2030	2040	2050
MLSS with 8 HPOAS Tanks in Service, Peak 7-day	2,527	2,849	3,030	3,138
MLSS with 7 HPOAS Tanks in Service, Peak 7-day	2,817	2,959	3,089	3,199
MLSS with 8 HPOAS Tanks in Service, Peak 3-day	3,498	3,657	3,836	3,969
MLSS with 7 HPOAS Tanks in Service, ADW	2,007	2,259	2,540	2,891
MLSS with 8 HPOAS Tanks in Service, Peak 30-day	2,387	2,689	3,031	3,417
MLSS with 7 HPOAS Tanks in Service, Peak 30-day	2,728	3,073	3,464	3,905
6-mgd RAS Max Firm Capacity	2,700	2,700	2,700	2,700
8.5-mgd RAS Max Firm Capacity	3,000	3,000	3,000	3,000
6-mgd RAS Max Total Capacity	2,600	2,600	2,600	2,600
8.5-mgd RAS Max Total Capacity	2,900	2,900	2,900	2,900

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	004

Project	Subject
EBMUD MWWTP Master Plan	Secondary Clarifier Capacity

Secondary Clarifier Capacity (continued)





Interpolate to Determine Year at Which Capacity Runs Out

Condition	6-mgd/Clarifier RAS	8.5-mgd/Clarifier RAS
Total Capacity, Peak 7-day	2022	2032
Firm Capacity, Peak 7-day	2020	2033
Total Capacity, Peak 30-day	2026	2036
Firm Capacity, Peak 30-day	2020	2027

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	005

Project	Subject
EBMUD MWWTP Master Plan	Waste Activated Sludge (WAS) Thickening Capacity

Problem Statement

Evaluate the existing process capacity of the WAS thickening process at EBMUD MWWTP. Gravity Belt Thickeners (GBTs) are used for WAS thickening.

WAS Thickening Information

Parameter	Design Criteria	Reference
Type	Ashbrook Simon-Hartley Aquabelt 3.0 M	Existing Plant Capacity and Performance TM, July 2019
Belt width	3 m	Existing Plant Capacity and Performance TM, July 2019; 6.6 ft dimension given
Quantity total	3	Existing Plant Capacity and Performance TM, July 2019
Quantity in service (total)	3	Existing Plant Capacity and Performance TM, July 2019
Quantity in service (firm)	2	
Design Condition	Max Day	Assumed
Maximum hydraulic loading	350 gpm/m	based on correspondance with Alfa Laval Field Service Technician, John Moccero
Maximum solids loading	1,877 lb/hr-m	based on 1.5% TS and 250 gpm for 5630 lb/hr-machine maximum

WAS Thickening Capacity Criteria

Capacity of the system may be limited by hydraulic loading or solids loading.

Parameter	Design Criteria	Notes
Hydraulic capacity (total):	3,150 gpm	hydraulic loading (gpm/m) * belt width (m) * quantity in service (total)
Hydraulic capacity (firm):	2,100 gpm	hydraulic loading (gpm/m) * belt width (m) * quantity in service (firm)
Solids capacity (total):	405,360 lb/day	solids loading (lb/hr-m) * belt width (m) * quantity in service (total)
Solids capacity (firm):	270,240 lb/day	solids loading (lb/hr-m) * belt width (m) * quantity in service (firm)

WAS Thickening Peaking Factors & Predictions

Review of Historical WAS Peaking Factors (PF)

Condition	PF	Reference
Maximum Day Flow	1.89	based on 2015-2018 historical data
Maximum Day Load	1.96	based on 2015-2018 historical data

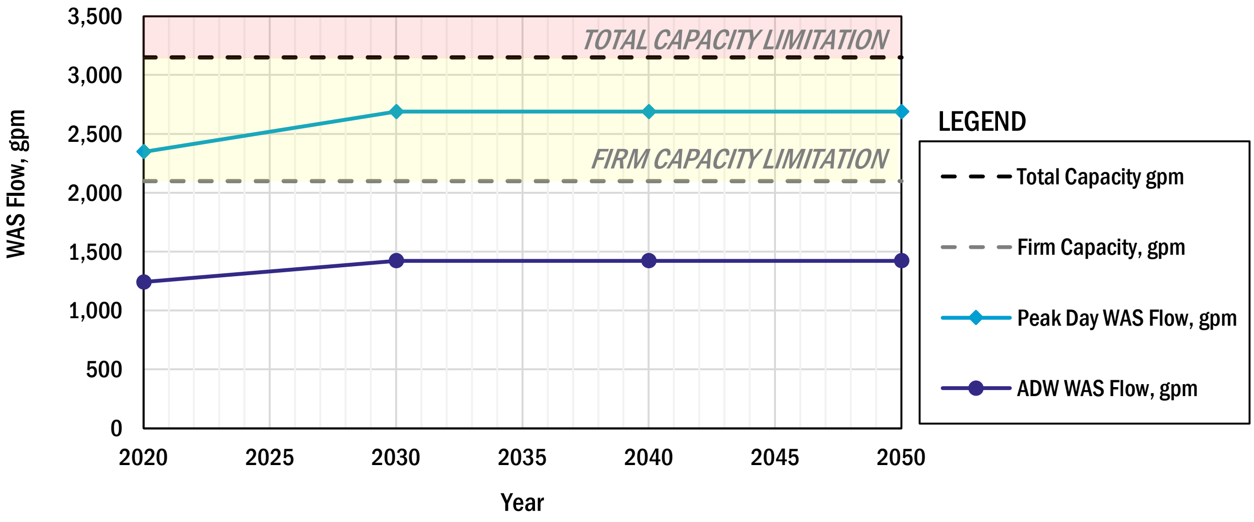
Parameter	2020	2030	2040	2050	Reference
ADW WAS Flow, gpm	1,243	1,424	1,424	1,424	from BioWin model
Peak Day WAS Flow, gpm	2,349	2,690	2,690	2,690	for Firm capacity
Total Capacity gpm	3,150	3,150	3,150	3,150	
Firm Capacity, gpm	2,100	2,100	2,100	2,100	
ADW WAS Loading, lb TS/day	104,025	117,063	131,495	147,504	from BioWin model
Peak Day WAS Loading, lb TS/day	204,106	229,686	258,003	289,414	for Firm capacity
Total Capacity, lb/day	405,360	405,360	405,360	405,360	
Firm Capacity, lb/day	270,240	270,240	270,240	270,240	

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	005

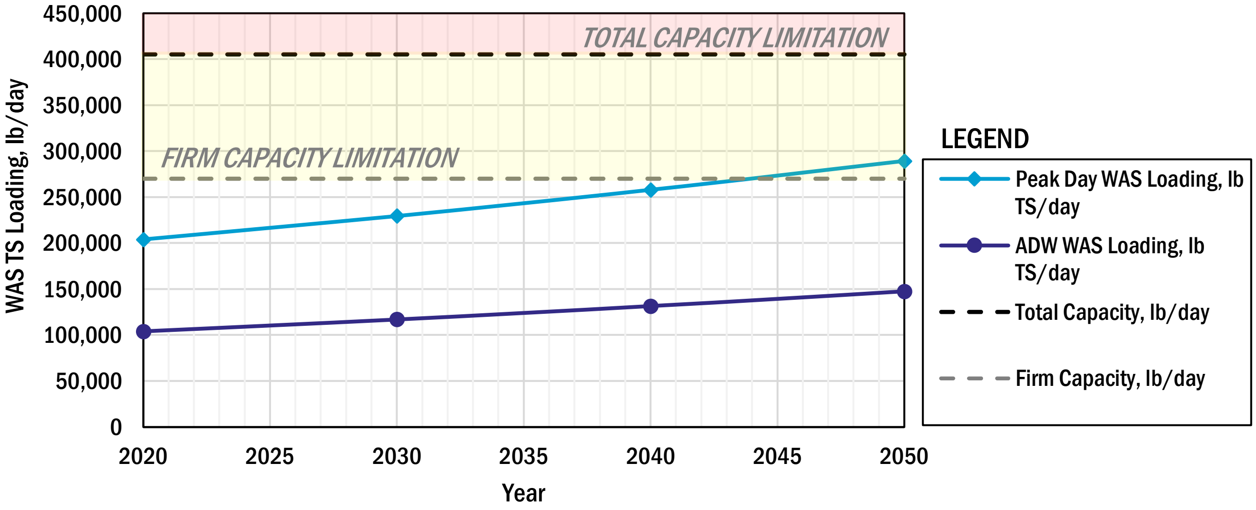
Project	Subject
EBMUD MWWTP Master Plan	Waste Activated Sludge (WAS) Thickening Capacity

WAS Thickening Capacity

Hydraulic Loading



Solids Loading



Interpolate to Determine Year at Which Capacity Runs Out

Condition	Total Capacity	Firm Capacity
Hydraulic Loading	Sufficient Capacity to 2050	2020
Solids Loading	Sufficient Capacity to 2050	2043

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	006

Project	Subject
EBMUD MWWTP Master Plan	Blend Tank Capacity

Problem Statement

Evaluate the existing process capacity of the blend tanks at EBMUD MWWTP for Med Influent+LSW/Med HSW projections.

Blend Tank Information

Parameter	Design Criteria	Reference
Blend Tank Volume, each	0.20 MG	
Quantity total	2	Existing Plant Capacity and Performance TM, July 2019
Quantity in service (Total)	2	
Quantity in service (Firm)	1	
Design Condition		
Maximum HRT	12 hrs	Conversation with Adam Ross (Brown and Caldwell)

Blend Tank Pump Information

Parameter	Design Criteria	Reference
Pump Capacity (derated), each	360 gpm	40% derating. Existing Plant Capacity and Performance TM, July 2019
Quantity in service (Total)	3	Existing Plant Capacity and Performance TM, July 2019
Quantity in service (Firm)	2	Existing Plant Capacity and Performance TM, July 2019
Design Condition		
Maximum Flow (Total)	1,080 gpm	Assume under max conditions, there is no return flow
Maximum Flow (Firm)	720 gpm	Assume under max conditions, there is no return flow

Digester Feed Peaking Factors

Review of historical peaking factors (PF).

Condition	PF	Reference
Peak Day Flow	1.55	Based on 2015-2018 historical data; calculated digester feed TS peaking factor

Blend Tank Predictions

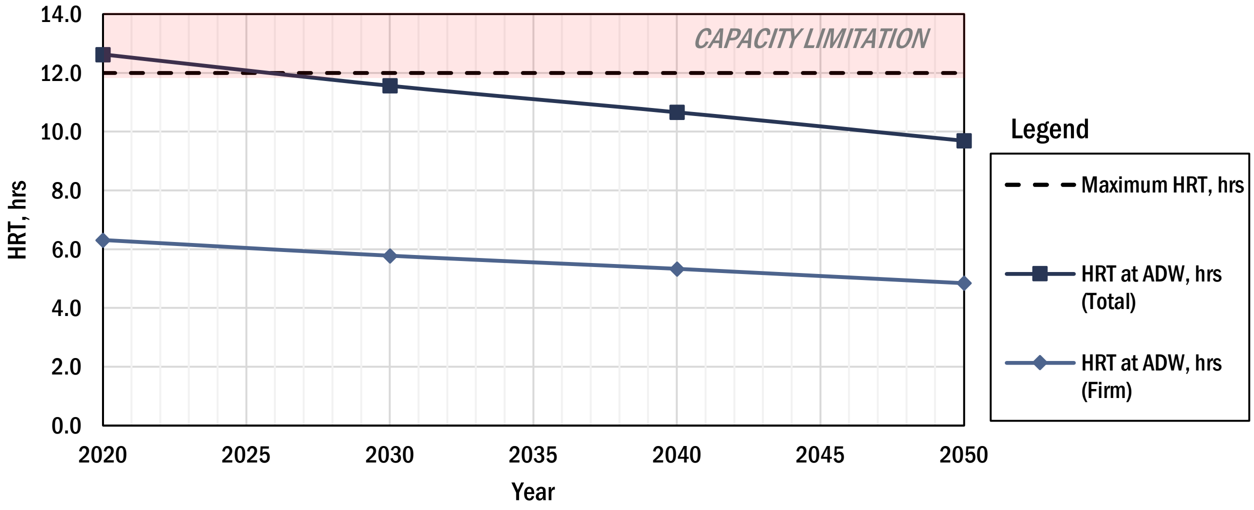
Year	2020	2030	2040	2050	Reference
ADW Blend Tank Flow, mgd	0.76	0.83	0.9	1.0	from BioWin model
Peak Day Blend Tank Flow, mgd	1.18	1.29	1.40	1.53	
HRT at ADW, hrs (Total)	12.6	11.6	10.7	9.7	
HRT at ADW, hrs (Firm)	6.32	5.78	5.33	4.85	
Maximum HRT, hrs	12.0	12.0	12.0	12.0	
Maximum Flow (Total), mgd	1.56	1.56	1.56	1.56	Total pump capacity
Maximum Flow (Firm), mgd	1.04	1.04	1.04	1.04	Firm pump capacity

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	006

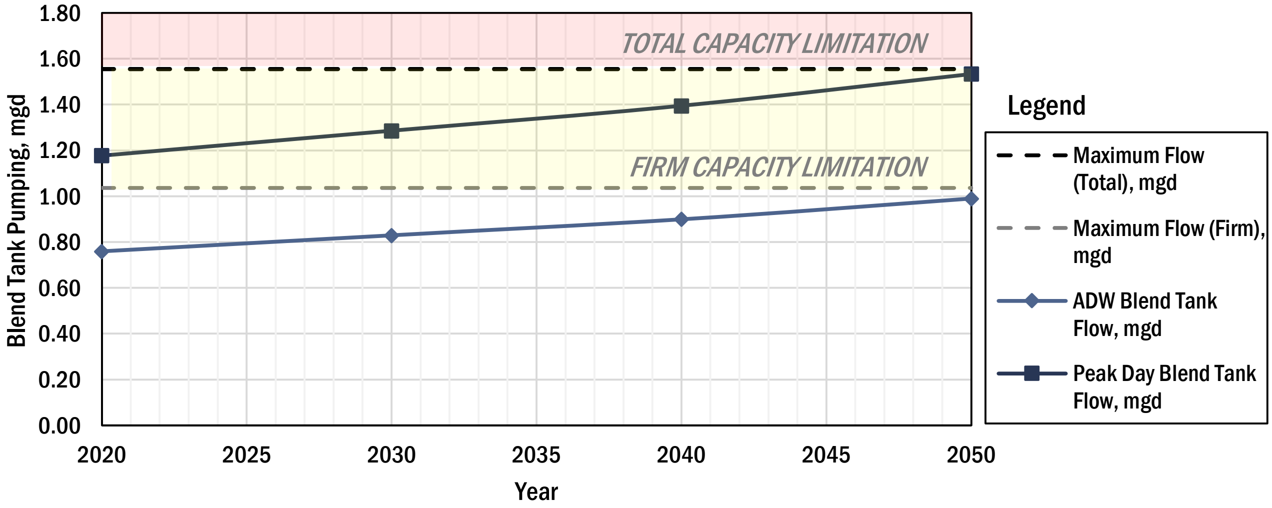
Project	Subject
EBMUD MWWTP Master Plan	Blend Tank Capacity

Blend Tank Capacity

Hydraulic Residence Time



Blend Tank Pumping



Interpolate to Determine Year at Which Capacity Runs Out

Condition	Total Capacity	Firm Capacity
Hydraulic Residence Time	Sufficient Capacity to 2050	Sufficient Capacity to 2050
Blend Tank Pumping	Sufficient Capacity to 2050	2020

Brown AND Caldwell

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	007

Project	Subject
EBMUD MWWTP Master Plan	Anaerobic Digestion Capacity

Problem Statement

Evaluate the existing process capacity of the anaerobic digesters at EBMUD MWWTP for Med Influent+LSW/Med HSW projections.
For purposes of capacity, assume all digesters are heated and mixed.

Anaerobic Digestion Information

Parameter	Design Criteria	Reference
Type	two stages: (8) 1st stage, (3) 2nd stage	Existing Plant Capacity and Performance TM, July 2019
1st Stage Digester Volume (average level with grit)	1.81 MG	1st stage digesters D5-12, per July 2019 TM, with grit at average level
2nd Stage Digester Volume (average level with grit)	1.90 MG	2nd stage digesters D2-4, per July 2019 TM, with grit at average level
2nd Stage Digester Volume without seismic retrofit	1.48 MG	
1st Stage Digester Volume (average level with grit)	241,962 ft3	
2nd Stage Digester Volume (average level with grit)	253,993 ft3	
2nd Stage Digester Volume without seismic retrofit	197,847 ft3	
Quantity total	11	
Quantity in service (Total)	11	Existing Plant Capacity and Performance TM, July 2019
Quantiy of 1st Stage in Service (Total)	8	Existing Plant Capacity and Performance TM, July 2019
Quantiy of 2nd Stage in Service (Total)	3	Existing Plant Capacity and Performance TM, July 2019
Quantity in service (Firm)	9	
Quantity of 1st Stage in Service (Firm)	7	
Quantity of 2nd Stage in Service (Firm)	2	
Design Condition		
Critical Maximum OLR	0.35 lb VS/ft3-day	BC assumption for thermophilic digesters
Typical Minimum HRT	15 days	Typical minimum HRT required to produce Class B biosolid
Critical Minimum HRT	10 days	Minimum HRT required to produce Class B biosolid

Digester Feed Peaking Factors

Review of historical digester feed peaking factors (PF).

Condition	PF	Reference
Maximum Month Flow	1.23	based on 2015-2018 historical data
Peak 10-Day Flow	1.26	based on 2015-2018 historical data
Peak 7-Day Flow	1.27	based on 2015-2018 historical data
Maximum Month VS Loading	1.28	based on 2015-2018 historical data
Peak 10-Day VS Loading	1.45	based on 2015-2018 historical data
Peak 7-Day VS Loading	1.57	based on 2015-2018 historical data

Brown AND Caldwell

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	007

Project	Subject
EBMUD MWWTP Master Plan	Anaerobic Digestion Capacity

Anaerobic Digestion Predictions

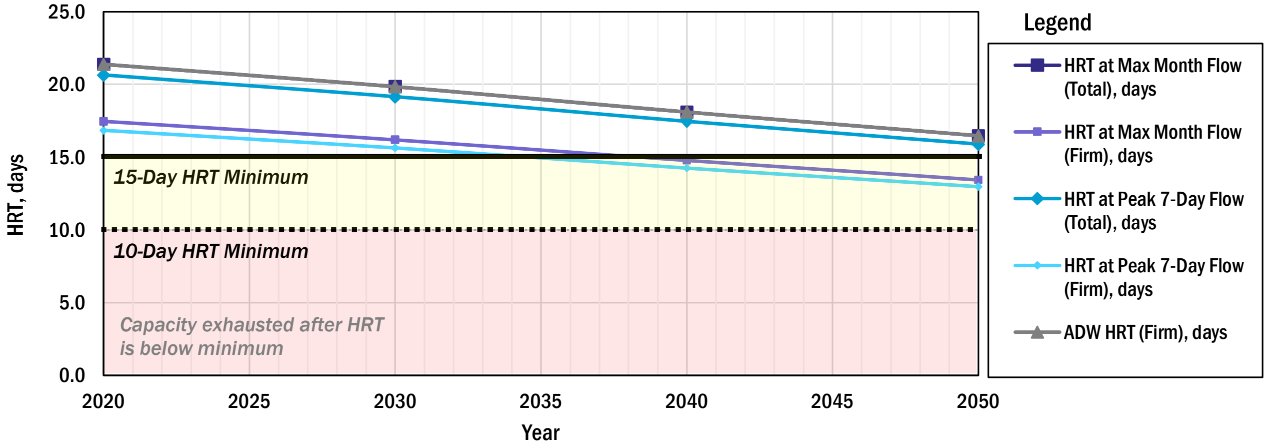
Year	2020	2030	2040	2050	Reference
ADW Digester Feed Flow, mgd	0.77	0.83	0.91	1.00	from BioWin model
Max Month Digester Feed Flow, mgd	0.94	1.02	1.12	1.23	
Peak 10-Day Digester Feed Flow, mgd	0.97	1.05	1.15	1.26	
Peak 7-Day Digester Feed Flow, mgd	0.98	1.05	1.16	1.27	
ADW HRT (Firm), days	21.4	19.8	18.1	16.5	
HRT at Max Month Flow (Total), days	21.4	19.8	18.1	16.5	
HRT at Peak 10-Day Flow (Total), days	20.7	19.2	17.5	16.0	
HRT at Peak 7-Day Flow (Total), days	20.6	19.2	17.5	15.9	
HRT at Max Month Flow (Firm), days	17.5	16.2	14.8	13.4	
HRT at Peak 10-Day Flow (Firm), days	16.9	15.7	14.3	13.0	
HRT at Peak 7-Day Flow (Firm), days	16.8	15.6	14.3	13.0	
Typical Minimum 15-Day HRT, days	15.0	15.0	15.0	15.0	Criteria
Critical Minimum 10-Day HRT, days	10.0	10.0	10.0	10.0	Criteria
ADW Digester Feed VS Loading, lb/d	222,015	246,787	273,366	303,696	from BioWin model
Max Month Digester Feed VS Loading, lb/d	284,019	315,708	349,711	388,511	
Peak 10-Day Digester Feed VS Loading, lb/d	322,177	358,124	396,695	440,708	
Peak 7-Day Digester Feed VS Loading, lb/d	348,177	387,025	428,709	476,274	
ADW OLR (Firm), lb VS/ft3-d	0.13	0.15	0.16	0.18	
OLR at MM Loading (Total), lb VS/ft3-d	0.15	0.16	0.18	0.20	
OLR at Peak 10-Day Loading (Total), lb VS/ft3-d	0.17	0.19	0.20	0.23	
OLR at Peak 7-Day Loading (Total), lb VS/ft3-d	0.18	0.20	0.22	0.25	
OLR at MM Loading (Firm), lb VS/ft3-d	0.17	0.19	0.21	0.23	
OLR at Peak 10-Day Loading (Firm), lb VS/ft3-d	0.19	0.21	0.23	0.26	
OLR at Peak 7-Day Loading (Firm), lb VS/ft3-d	0.21	0.23	0.25	0.28	
Critical OLR, lb VS/ft3-d	0.35	0.35	0.35	0.35	Criteria

Brown AND Caldwell

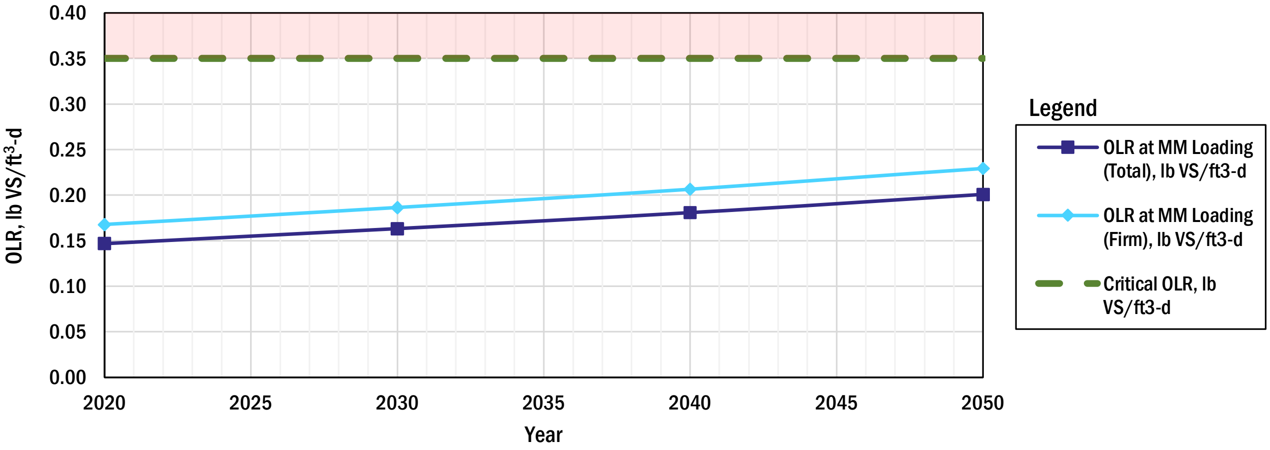
Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	007
Project			Subject		
EBMUD MWWTP Master Plan			Anaerobic Digestion Capacity		

Anaerobic Digestion Capacity

Hydraulic Residence Time

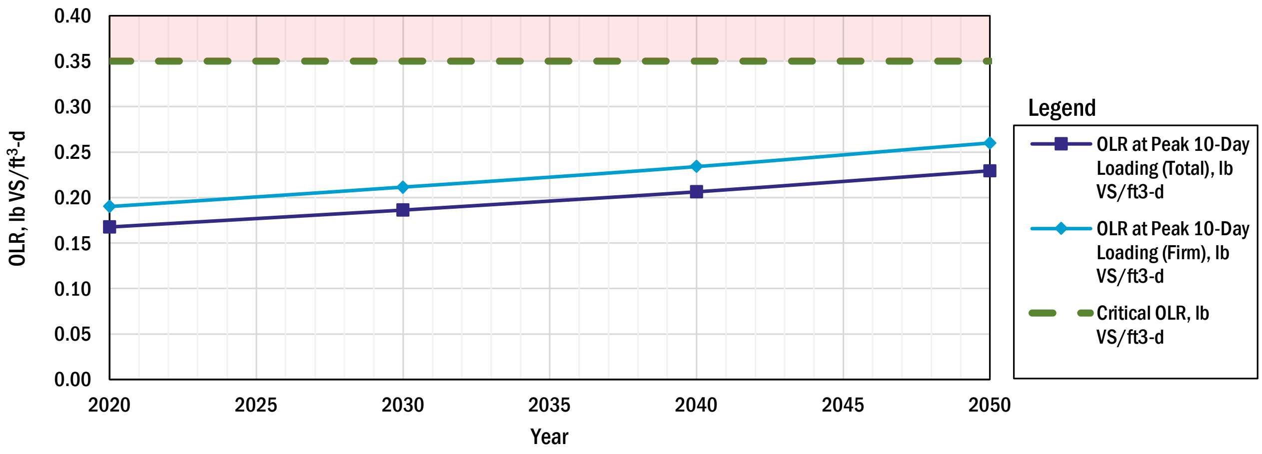


Organic Loading at Max Month



Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	007
Project			Subject		
EBMUD MWWTP Master Plan			Anaerobic Digestion Capacity		

Organic Loading at Peak 10-Day



Interpolate to Determine Year at Which Capacity Runs Out

Condition	Total Capacity	Firm Capacity
10-Day Hydraulic Residence Time	Sufficient Capacity to 2050	Sufficient Capacity to 2050
15-Day Hydraulic Residence Time	2036	Sufficient Capacity to 2050
Organic Loading at Max Month	Sufficient Capacity to 2050	Sufficient Capacity to 2050
Organic Loading at Peak 10-Day	Sufficient Capacity to 2050	Sufficient Capacity to 2050

Brown AND Caldwell

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	008
Project			Subject		
EBMUD MWWTP Master Plan			Dewatering Capacity		

Problem Statement

Evaluate the existing process capacity of the dewatering centrifuges at EBMUD MWWTP for Med Influent+LSW/Med HSW projections.

Dewatering Centrifuge Information

Parameter	Design Criteria	Reference
Type	Humboldt S4-1 (Low Speed)	Existing Plant Capacity and Performance TM, July 2019
Quantity total	3	Existing Plant Capacity and Performance TM, July 2019; Corresponds with C-1, 2, and 3.
Nameplate Flow Capacity	210 gpm	Existing Plant Capacity and Performance TM, July 2019
Derated Flow Capacity	125 gpm	Existing Plant Capacity and Performance TM, July 2019 (2015-2018 operations)
Vender Loading Capacity	468,000 lb/d	Correspondance with Andritz Separation Tehnical Sales Engineer
Type	Flottweg Z73-4/454	
Quantity total	2	Existing Plant Capacity and Performance TM, July 2019; Corresponds with C-4 and 5.
Nameplate Flow Capacity	300 gpm	Existing Plant Capacity and Performance TM, July 2019
Derated Flow Capacity	250 gpm	Existing Plant Capacity and Performance TM, July 2019 (2015-2018 operations)
Vender Loading Capacity	288,000 lb/d	Correspondance with Flottweg Sales Manager
Quantity in service (Total)	5	All units in service
Total Flow Capacity (derated)	875 gpm	
Total Loading Capacity	756,000 lb/d	
Quantity in service (Firm; 3 units)	3	Two Humbolt S4-1 (low speed) and one Flottweg Z73-4/454 in service
Firm 3-unit Flow Capacity (derated	500 gpm	
Firm 3-unit Loading Capacity	456,000 lb/d	

Digested Sludge Peaking Factors

Review of historical digested sludge peaking factors (PF).

Condition	PF	Reference
Maximum Day Flow, gpm	1.88	based on 2015-2018 historical data
Maximum Day Loading, lb TS/d	1.80	based on 2015-2018 historical data

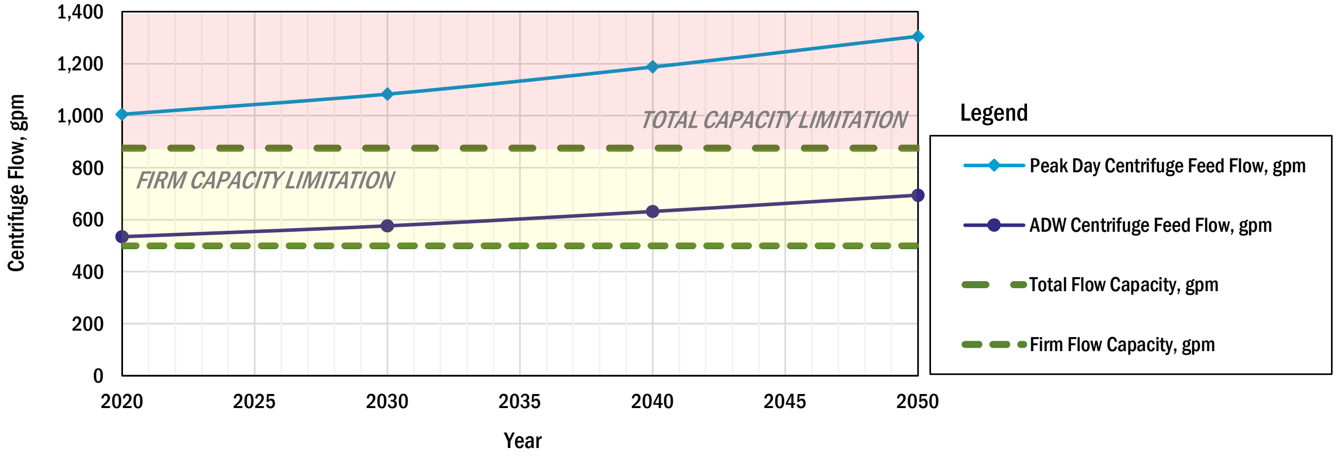
Dewatering Centrifuge Predictions

BioWin outputs concentration and loading as TSS instead of TS. Output TSS loading for 2020 matches closely to historical TS loading average.

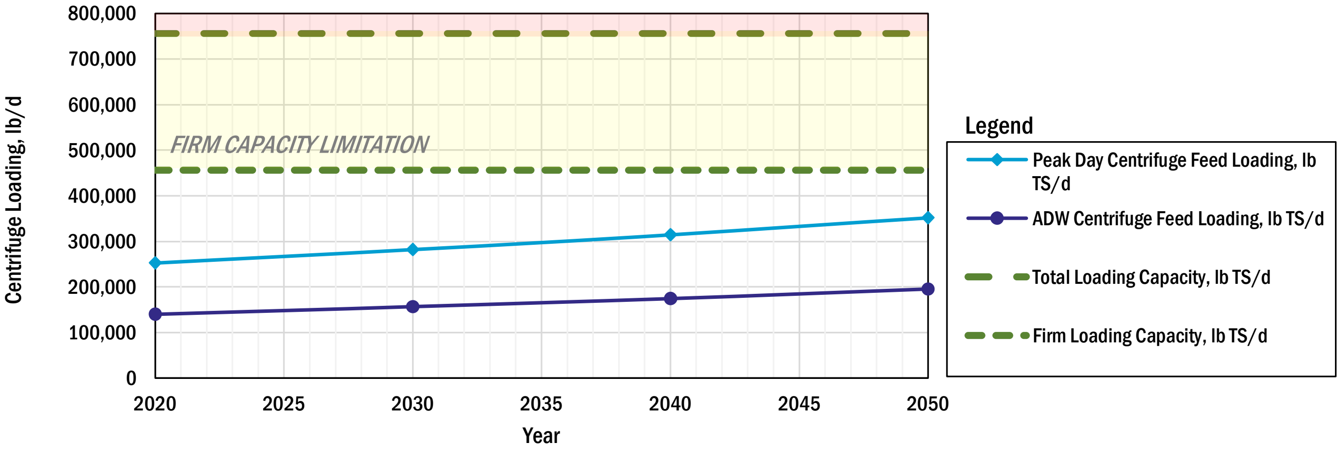
Parameter	2020	2030	2040	2050	Reference
ADW Centrifuge Feed Flow, gpm	535	576	632	694	--> from BioWin model
Peak Day Centrifuge Feed Flow, gpm	1,005	1,084	1,188	1,306	(based on max of
Total Flow Capacity, gpm	875	875	875	875	either firm or total)
Firm Flow Capacity, gpm	500	500	500	500	
ADW Centrifuge Feed Loading, lb TS/d	140,312	156,590	174,618	195,462	--> from BioWin model
Peak Day Centrifuge Feed Loading, lb TS/d	252,561	281,862	314,312	351,832	(based on max of
Total Loading Capacity, lb TS/d	756,000	756,000	756,000	756,000	either firm or total)
Firm Loading Capacity, lb TS/d	456,000	456,000	456,000	456,000	

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	008
Project			Subject		
EBMUD MWWTP Master Plan			Dewatering Capacity		

Dewatering Centrifuge Hydraulic Capacity



Dewatering Centrifuge Loading Capacity



Interpolate to Determine Year at Which Capacity Runs Out

Condition	Total Capacity	Firm Capacity
Dewatering Centrifuge Hydraulic Capacity	2020	2020
Dewatering Centrifuge Loading Capacity	Capacity Sufficient to 2050	Capacity Sufficient to 2050

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	009

Project	Subject
EBMUD MWWTP Master Plan	Cake Hopper Capacity

Problem Statement

Evaluate the existing process capacity of the dewatering centrifuge reject (biosolids; solids; cake) hoppers at EBMUD MWWTP for Med Influent+LSW/Med HSW.

Cake Hopper Information

Parameter	Design Criteria	Reference
Quantity total	3 hoppers	Existing Plant Capacity and Performance TM, July 2019
Quantity firm	2 hoppers	
Total Capacity	460 CY	Existing Plant Capacity and Performance TM, July 2019
Firm Capacity	307 CY	Existing Plant Capacity and Performance TM, July 2019
Minimum Storage	1.5 d	Existing Plant Capacity and Performance TM, July 2019
Cake Dryness	25% TS	Existing Plant Capacity and Performance TM, July 2019

Digested Sludge Peaking Factors

Review of historical digested sludge peaking factors (PF).

Condition	PF	Reference
Maximum Day Flow	1.92	based on 2015-2018 historical data
Maximum Day Load	1.95	based on 2015-2018 historical data

Cake Hopper Predictions

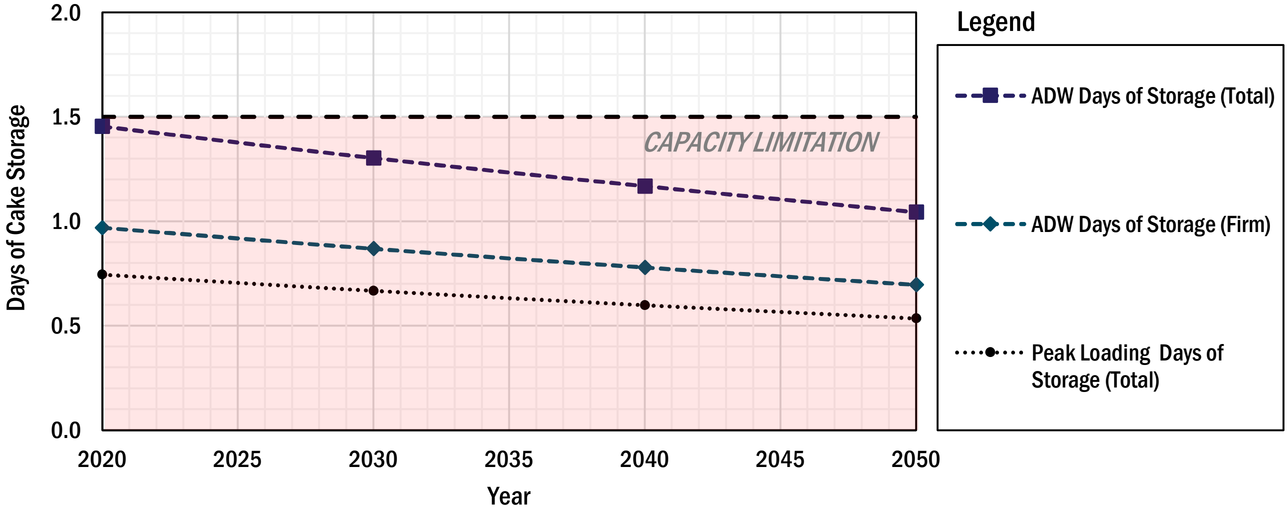
The model predicted dewatered digested sludge loading is corrected by a 29 percent to account for struvite and adjustments for HSW variability such that centrate TDS and TSS values were matched.

Year	2020	2030	2040	2050	Notes
ADW Dewatered Digested Sludge, lb/d	104,418	116,532	129,948	145,460	See note above
ADW Dewatered Cake, DT/d	52	58	65	73	
ADW Dewatered Cake, WT/d	209	233	260	291	
ADW Flow, CY/d	316	353	394	441	Assume weight of dry cake at 55 lb/cf
Peak Day Dewatered Cake, DT/d	102	114	127	142	
Peak Day Dewatered Cake, WT/d	408	455	507	568	
Peak Day Flow, CY/d	618	689	769	861	Assume weight of dry cake at 55 lb/cf
Minimum Days of Storage	1.5	1.5	1.5	1.5	
ADW Days of Storage (Firm)	1.0	0.9	0.8	0.7	
ADW Days of Storage (Total)	1.5	1.3	1.2	1.0	
Peak Loading Days of Storage (Firm)	0.5	0.4	0.4	0.4	
Peak Loading Days of Storage (Total)	0.7	0.7	0.6	0.5	

Date Checked	Checked By	Job Number	By	Date	Calc No
2/14/2020	J. Jimenez	153728	R. Merlo	3/12/2020	009

Project	Subject
EBMUD MWWTP Master Plan	Cake Hopper Capacity

Cake Hopper Capacity



Interpolate to Determine Year at Which Capacity Runs Out

Condition	Total ADW Capacity	Firm ADW Capacity
1.5-Day Cake Hopper Capacity (Correction Applied to BioWin Load)	2020	2020

APPENDIX D – HPOAS REACTOR SAMPLING AND MODELING

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BioWin and HiPure Model

The aeration requirements for MWWTP were estimated using a combination of BioWin and HiPure steady-state simulations. HiPure, developed by Dr. Michael Stenstrom of the University of California, Los Angeles (UCLA), is a mathematical model used to simulate the high purity oxygen activated sludge processes. The model simulates 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. In the HiPure model, oxygen consumption, carbon dioxide production, and nitrogen stripping create varying gas composition in the reactors, which requires the model to include gas phase material balances and gas-liquid phase interactions. Molecular oxygen is consumed while carbon dioxide is produced, and nitrogen is stripped from the influent. The net production and stripping of gases are always smaller than oxygen consumption, which means gas flow decreases through the stages. Changes in gas phase composition affect the aeration capacity of the process as well as mixed liquor pH levels inside the bioreactor.

For this analysis, the BioWin simulator was used to estimate the oxygen requirements (oxygen uptake rates, OUR) under critical planning conditions. A steady-state HiPure model was calibrated using field data collected by Brown and Caldwell at the MWWTP comprising DO concentrations, headspace oxygen purity and existing aerators' horsepower. The HiPure model was used to determine the existing aerators standard oxygen transfer efficiency (SOTE) and capacity of the system based on the following boundary conditions: 1) minimum 4th stage vent oxygen headspace purity of 40%, 2) maximum total oxygen production of 250 tons/d, and 3) minimum bulk liquid DO concentration of 2 mg/L.

The BioWin simulations allowed for different conditions to be modeled (e.g., MLSS concentration, temperature, influent flowrate, firm or total HPO tank capacity, etc.). The HiPure model allowed for different surface aerator SOTE assumptions to be input to account for either existing/calibrated surface aerator efficiencies or an improved aerator efficiencies with upgraded surface aerators.

- The DO concentrations were setpoints in the steady-state HiPure model when used to predict performance at future conditions.
- The setpoints were set at levels of 8, 8, and 3 mg/L DO for HPO Stages 2, 3, and 4, respectively, for the ADW condition.
- The setpoints were set at levels of 2 mg/L for all stages for Peak Day condition (Simultaneous peak 1-day BOD load, ADW flow, and maximum month temperature condition).
- A DO of 0 mg/L was assumed in HPO Stage 1 (therefore, the increase in DO from Stage 1 to Stage 2 increased the oxygen requirement in the HiPure Model for Stage 2).
- It appears for ADW conditions, maintaining a sufficient vent purity in Stage 4 was the main criteria driving our estimated oxygen production requirement for those model results.
- It appears for Peak Day conditions, transferring adequate oxygen in Stage 2 for a sufficient DO was the main criteria driving our estimate oxygen production requirement for those model results.

DO Monitoring Recommendations for Onsite Field Testing

The main critical DO set point is in Stage 2 (assuming Stage 1 is anaerobic) since we need to maintain high DO in such zone to avoid bulking. To control the HPO we would need DO in stage 2 and oxygen purity in Stage 4. If more DO readings are desirable, then Stages 2 and 3 would be important. Stage 4 is not important unless the reactors are modified to do CO2 stripping and open to the atmosphere.

Onsite Field Testing

Sampling and onsite field testing were performed to develop and to calibrate the HiPure model. The HiPure model was calibrated using field measurements during a 5-day testing period at EBMUD for Trains 1 and 8 of the HPOAS system. The following text briefly describes field sampling, model calibration, and model analysis.

Field Sampling

The goal of field sampling was to provide information necessary for calibrating the HiPure HPOAS process model and to determine oxygen transfer efficiency parameters for the existing mechanical surface aerators at the MWWTP.

Testing was performed over a 5-day period starting October 29, 2019 and ending November 2, 2019. The data collected was used to calibrate the HiPure model, which was then used to evaluate capacity. The model was also used to determine how potential upgrades of the mechanical surface aerators will increase capacity of the system.

HPOAS train off-gas testing consisted of measuring the following:

1. DO,
2. pH,
3. temperature,
4. headspace oxygen concentration (O2 purity), and
5. vent gas velocity.

These parameters were measured for HPOAS Trains 1 and 8. Measurements were taken every 4 hours during the sampling period. In addition, quality assurance checks of displayed SCADA DO and O_2 purity readings were recorded, where available.

The DO and pH measurements were made in each stage using a calibrated probe inserted into sampling ports in stages 3 and 4. There was no accessible sampling port to measure DO or pH for stage 2, but DO values were recorded from the SCADA display. The oxygen purities were measured using a Teledyne 320 portable oxygen analyzer, which was inserted into the headspace via a EBMUD-constructed custom sampling port on the aerator pad. The final vent velocities were measured using a General® hot wire anemometer. Further sampling plan details were recorded and transmitted to EBMUD as part of the Main Wastewater Treatment Plant High Purity Oxygen Activated Sludge Process Sampling Plan Technical Memorandum dated on October 22, 2019. Field sampling results are displayed later in this appendix.

Model Calibration

The HiPure model was calibrated using the follow average sampling data parameters:

- O_2 purity:
    - Stage 1 (anaerobic): not measured
    - Stage 2: 79%
    - Stage 3: 75%
    - Stage 4: 69%
- DO concentration:
    - Stage 1 (anaerobic): not measured
    - Stage 2: 16 mg/L
    - Stage 3: 15 mg/L
    - Stage 4: 13 mg/L
- Surface aerator horsepower:
    - Stage 1 (anaerobic): 100 hp/train
    - Stage 2: 100 hp/train
    - Stage 3: 50 hp/train
    - Stage 4: 50 hp/train
- Purity of O_2 feed:
    - 95% (assumed)

The calibration resulted in the following parameters:

- O_2 (tons/d) at end of HPOAS stages:
    - Stage 1 (anaerobic): 80.3
    - Stage 2: 63.4
    - Stage 3: 47.6
    - Stage 4: 32.8
- O_2 transferred (tons/d) to MLSS in each stage:
    - Stage 1 (anaerobic): 0
    - Stage 2: 16.9
    - Stage 3: 15.9
    - Stage 4: 14.7
- Oxygen transfer rate (OTR) from sampling data and calibration (data/calibration):
    - Stage 1 (anaerobic): 0 lb/hr per sampling data / 0 lb/hr per calibration

  - Stage 2: 1405 lb/hr per sampling data / 1431 lb/hr per calibration
  - Stage 3: 1321 lb/hr per sampling data / 1320 lb/hr per calibration
  - Stage 4: 1229 lb/hr per sampling data / 1201 lb/hr per calibration
- Standard aeration efficiency (SAE) per stage:
  - Stage 1: 0.0 lb O_2/hp-hr
  - Stage 2: 1.9 lb O_2/hp-hr
  - Stage 3: 3.0 lb O_2/hp-hr
  - Stage 4: 2.8 lb O_2/hp-hr

Model Calculations

The HPOAS capacity analysis considered the following assumptions:

- Alpha and beta correction factors:
  - Stage 1: 0.00 alpha and 0.98 beta
  - Stage 2: 0.70 alpha and 0.98 beta
  - Stage 3: 0.85 alpha and 0.98 beta
  - Stage 4: 0.85 alpha and 0.98 beta
- Minimum Stage 4 O2 purity of 40%
- Minimum Stage 2-4 DO concentration 2.0 mg/L
- Default DO concentrations assumed for OTR analysis (DO concentration decreased to 2 mg/L if needed; DO concentrations in calculation set to match values used in BioWin):
  - Stage 2: 8 mg/L
  - Stage 3: 8 mg/L
  - Stage 4: 3 mg/L
- The OTR supplied must be greater than OTR consumed per stage
- OTR consumed is equal to OUR demand plus O_2 transfer required to maintain DO concentration (see DO concentration per stage above)

Field Sampling Results

Field sampling results are presented in the pages following the model calculation sheets. Field sampling results were used to calibrate the model calculation sheets.

Model Calculations

Model calculations, completed using Excel, are displayed in calculation sheets shown on the pages following the field sampling results.

Model Results

Model results are presented in the HPOAS Reactor Capacity calculation sheets in Appendix C and the report body. Note that peak conditions may have resulted in insufficient Stage 2 DO concentrations (DO concentration below 2 mg/L minimum criteria). Any result presented as a demand of 250 tons/d OTR requirement may actually require greater than 250 tons/d or will result in lower than 2 mg/L DO concentrations in the reactor basins.

				10/29/2019					
				Train 1					
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM	12:00PM	4:00PM	8:00PM	12:00AM
Actual Time				4:20:00 AM	8:15:00 AM	12:18:00 PM	4:08:00 PM	8:00:00 PM	12:00:00 AM
Final Vent Gas Velocity	m/s	Anemometer		6.3	7.5	6.4	6.4	6.0	5.9
Final Vent Gas Temp	°C	Anemometer (Thermometer)		22.8	22.5	23.4	23.4	23.3	23.1
Stage 4 DO	mg/L	SCADA	T1	17.27	18.95	17.15	19.69	13.79	12.85
			T2		19.27	17.22	14.18	13.76	12.47
Stage 4 DO	mg/L	DO probe (check)							
Stage 4 pH		pH Probe							
Stage 4 Temp	°C	pH Probe							
Stage 4 O_2 purity	%	SCADA	T1	60.92	63.06	60.44	55.27	54.83	54.64
			T2	N/A	62.8	60.48	60.66	60.08	58.61
Stage 4 O_2 purity	%	Teledyne 320 (check)				55	62	67	70
Stage 4 O_2 purity	%	Post Measurement		24	22	22	N/A		
Actual Time				4:20:00 AM	8:35:00 AM	12:45:00 PM	4:23:00 PM	8:12:00 PM	12:17:00 AM
Stage 3 DO of MLSS	mg/L	DO Probe		13.33	13.4	14.2	12.3	11.5	11.76
Stage 3 O_2 purity	%	Teledyne 320				64	68	74	79
Stage 3 O_2 purity	%	Post Measurement		24	20	21	N/A	N/A	N/A
Stage 3 pH		pH Probe				6.84	6.89	6.86	6.88
Stage 3 Temp	°C	pH Probe		24.3	N/A	24.1	24.2	24.4	24.1
Actual Time				4:20:00 AM	9:00:00 AM	1:11:00 PM	4:33:00 PM	8:18:00 PM	12:24:00 AM
Stage 2 DO	mg/L	SCADA	T1	17.03	17.17	15.77	12.12	12.34	12.23
			T2	N/A	12.23	8.57	3.09	14.14	14.58
Stage 2 O_2 purity	%	Teledyne 320				68	81	77	100
Stage 2 O_2 purity	%	Post Measurement		N/A	22	22	N/A	N/A	N/A

				10/29/2019					
				Train 8					
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM	12:00PM	4:00PM	8:00PM	12:00AM
Actual Time				4:00:00 AM	8:46:00 AM	1:17:00 PM	4:39:00 PM	8:26:00 PM	12:33:00 AM
Final Vent Gas Velocity	m/s	Anemometer		7.1	7.7	7.1	6.7	6.7	6.8
Final Vent Gas Temp	°C	Anemometer (Thermometer)		21.5	23.2	23.9	23.6	23.4	23.1
Stage 4 DO	mg/L	SCADA	T1	18.34	19.91	18.59	15.15	14.71	13.85
			T2	OFL	OFL	OFL	19.55	OFL	OFL
Stage 4 DO	mg/L	DO probe (check)							
Stage 4 pH		pH Probe							
Stage 4 Temp	°C	pH Probe							
Stage 4 O_2 purity	%	SCADA	T1	69.6	70.4	71	70	69.3	68.5
			T2	67.1	70.1	67.2	62.8	61.6	59.7
Stage 4 O_2 purity	%	Teledyne 320 (check)				68	70	76	93
Stage 4 O_2 purity	%	Post Measurement			22		N/A		
Actual Time				4:45:00 AM	9:00:00 AM	12:20:00 PM	4:55:00 PM	8:40:00 PM	12:40:00 AM
Stage 3 DO of MLSS	mg/L	DO Probe		18.5	N/A	18.6	16.47	15.77	18.52
Stage 3 O_2 purity	%	Teledyne 320				72	74.2	79	94
Stage 3 O_2 purity	%	Post Measurement				22	N/A	N/A	N/A
Stage 3 pH		pH Probe				6.74	6.82	6.81	6.83
Stage 3 Temp	°C	pH Probe		24		24.2	24.3	24.3	24.1
Actual Time				5:00:00 AM	9:15:00 AM	1:35:00 PM	5:01:00 PM	8:46:00 PM	12:52:00 AM
Stage 2 DO	mg/L	SCADA	T1		6.45	N/A	9.33	8.44	11.55
			T2	17.2	16.89	15.63	11.33	9	14.05
Stage 2 O_2 purity	%	Teledyne 320		62	62	74	83	86	100
Stage 2 O_2 purity	%	Post Measurement		26	22	22	N/A	N/A	N/A

				10/30/2019						
				Train 1						
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM	Re-DO	12:00PM	4:00PM	8:00PM	12:00AM
Actual Time				3:58:00 AM	8:27:00 AM	9:57:00 AM	12:14:00 PM	4:05:00 PM	8:01:00 PM	12:05:00 AM
Final Vent Gas Velocity	m/s	Anemometer		6.1	6.2	6.3	5.7	5.4	5.4	5
Final Vent Gas Temp	°C	Anemometer (Thermometer)		23.2	23.2	23.3	23.2	23.6	22.3	22.7
Stage 4 DO	mg/L	SCADA	T1	15.23	19.6	19.37	16.62	15.1	13.6	14.23
			T2	15.78	18.87	18.08	16.11	14.89	13.51	13.94
Stage 4 DO	mg/L	DO probe (check)							12.61	14
Stage 4 pH		pH Probe							6.76	6.77
Stage 4 Temp	°C	pH Probe							24.2	24,0
Stage 4 O_2 purity	%	SCADA	T1	56.91	60.53	60.09	55.11	55.17	55.87	57.46
			T2	60.48	64.11	63.62	60.98	58.16	57.65	58.87
Stage 4 O_2 purity	%	Teledyne 320 (check)		74	69	64	63	64	62.5	66
Stage 4 O_2 purity	%	Post Measurement		22		21	22	22	21	22.5
Actual Time				4:12:00 AM	8:41:00 AM	10:04:00 AM	12:21:00 PM	4:14:00 PM	8:16:00 PM	12:15:00 AM
Stage 3 DO of MLSS	mg/L	DO Probe		12.4	13.7	16.2	15	12.4	12.2	14.5
Stage 3 O_2 purity	%	Teledyne 320		84	81	71.5	68	69	70	71
Stage 3 O_2 purity	%	Post Measurement		22	23	21	22	22	22	21
Stage 3 pH		pH Probe		6.81	6.86	6.9	6.91	6.87	6.78	6.81
Stage 3 Temp	°C	pH Probe		24.2	23.7	24.2	24.1	24.2	24.1	24.5
Actual Time				4:18:00 AM	8:42:00 AM	10:15:00 AM	12:31:00 PM	4:24:00 PM	8:26:00 PM	12:22:00 AM
Stage 2 DO	mg/L	SCADA	T1	13.91	18.63	15.63	17.24	13.76	12.56	14.12
			T2	15.37	18.16	13.9	17.93	12.94	13.06	14.54
Stage 2 O_2 purity	%	Teledyne 320		92		75	89	89	75	75
Stage 2 O_2 purity	%	Post Measurement		24	N/A	21	22	22.5	22	22

				10/30/2019						
				Train 8						
Parameter	Unit	Instrument/SCADA		4:00AM	No 8:00AM readings	Re-Do	12:00PM	4:00PM	8:00PM	12:00AM
Actual Time				4:25:00 AM		9:22:00 AM	12:35:00 PM	4:31:00 PM	8:52:00 PM	12:32:00 AM
Final Vent Gas Velocity	m/s	Anemometer		6.3		6.3	6.6	6.3	6.1	5.6
Final Vent Gas Temp	°C	Anemometer (Thermometer)		23.1		23.3	23.4	23.6	22.9	21.9
Stage 4 DO	mg/L	SCADA	T1	16.01		OFL	16.86	17.36	14.27	13.84
			T2	OFL		OFL	OFL	OFL	OFL	14.26
Stage 4 DO	mg/L	DO probe (check)							16.3	15.8
Stage 4 pH		pH Probe							6.71	6.72
Stage 4 Temp	°C	pH Probe							24.3	24.1
Stage 4 O_2 purity	%	SCADA	T1	69.5		71.6	70.5	71.6	69.9	69
			T2	62.1		69.9	63.4	64.2	62.4	63
Stage 4 O_2 purity	%	Teledyne 320 (check)		84		78	74	82	72	71
Stage 4 O_2 purity	%	Post Measurement		23		21.7	22	22	21	22
Actual Time				4:32:00 AM		9:33:00 AM	12:42:00 PM	4:35:00 PM	9:03:00 PM	12:38:00 AM
Stage 3 DO of MLSS	mg/L	DO Probe		17.5		19.7	19.5	20	17.3	17.9
Stage 3 O_2 purity	%	Teledyne 320		89		80	77	84	77	75
Stage 3 O_2 purity	%	Post Measurement		23		20	20	21.5	22	21
Stage 3 pH		pH Probe		2.7		6.83	6.86	6.87	6.78	6.76
Stage 3 Temp	°C	pH Probe		24.3		24.3	24.1	24.2	24.1	24
Actual Time				4:39:00 AM		9:33:00 AM	12:48:00 PM	4:45:00 PM	9:13:00 PM	12:46:00 AM
Stage 2 DO	mg/L	SCADA	T1	11.94		15.86	14.31	11.53	9.72	11.3
			T2	15.67		18.34	18.44	16.41	11.76	13.2
Stage 2 O_2 purity	%	Teledyne 320		95		88	79	84.5	83	80
Stage 2 O_2 purity	%	Post Measurement		24		21	22	21.5	22	22

				10/31/2019					
				Train 1					
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM	12:00PM	4:00PM	8:00PM	12:00AM
Actual Time				4:00:00 AM	8:47:00 AM	12:15:00 PM	4:00:00 PM	8:00:00 PM	12:00:00 AM
Final Vent Gas Velocity	m/s	Anemometer		5.8	5.2	5.7	5.6	5.1	5.3
Final Vent Gas Temp	°C	Anemometer (Thermometer)		23	22.9	23.1	23.4	23.6	23.1
Stage 4 DO	mg/L	SCADA	T1	16.05	18.73	16.36	16.59	14.93	15.22
			T2	16.99	19.35	16.04	15.75	14.21	15.08
Stage 4 DO	mg/L	DO probe (check)		14.9	17.4	14.6	12.4	13.4	13.3
Stage 4 pH		pH Probe		6.72	6.72	6.7	6.71	6.71	6.62
Stage 4 Temp	°C	pH Probe		24,2	22.3	23.4	24.2	24.2	24.1
Stage 4 O_2 purity	%	SCADA	T1	59.28	61.91	57.62	56.95	59.75	60.58
			T2	59.78	61.64	62.19	60.61	60.61	59.87
Stage 4 O_2 purity	%	Teledyne 320 (check)		65	65	68	65	65	64
Stage 4 O_2 purity	%	Post Measurement		22	22	22	21.5	21.5	21.5
Actual Time				4:15:00 AM	9:10:00 AM	12:20:00 PM	4:09:00 PM	8:05:00 PM	12:05:00 AM
Stage 3 DO of MLSS	mg/L	DO Probe		14.4	16.7	15.3	13.2	13.2	12.8
Stage 3 O_2 purity	%	Teledyne 320		76	72	75	75	73	73
Stage 3 O_2 purity	%	Post Measurement		22	22	22	22	21.5	22
Stage 3 pH		pH Probe		6.75	6.72	6.78	6.73	6.69	6.65
Stage 3 Temp	°C	pH Probe		23.4	24.2	24	24.2	23.5	23.9
Actual Time				4:22:00 AM	9:17:00 AM	12:33:00 PM	4:15:00 PM	8:13:00 PM	12:14:00 AM
Stage 2 DO	mg/L	SCADA	T1	14.07	16.83	15.05	14.24	13.85	13.13
			T2	15.05	17.71	15.63	12.8	12.84	11.48
Stage 2 O_2 purity	%	Teledyne 320		77	78	76	79	78	78
Stage 2 O_2 purity	%	Post Measurement		22	22	22	22	22	22

				10/31/2019					
				Train 8					
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM	12:00PM	4:00PM	8:00PM	12:00AM
Actual Time				4:28:00 AM	9:21:00 AM	12:40:00 PM	4:21:00 PM	8:18:00 PM	12:18:00 AM
Final Vent Gas Velocity	m/s	Anemometer		6.5	9.4	6.5	6.1	6.6	5.7
Final Vent Gas Temp	°C	Anemometer (Thermometer)		22.5	23.2	23.5	23.2	22.7	22.4
Stage 4 DO	mg/L	SCADA	T1	16.61	19.02	15.83	15.53	15.35	15.23
			T2	OFL	OFL	OFL	OFL	OFL	OFL
Stage 4 DO	mg/L	DO probe (check)		18.3	19.19	16.9	14.6	15.7	15.4
Stage 4 pH		pH Probe		6.7	6.64	6.9	6.65	6.64	6.58
Stage 4 Temp	°C	pH Probe		24.3	24.3	24.1	24.2	24.2	24.2
Stage 4 O_2 purity	%	SCADA	T1	69.8	71.8	71.5	70.8	70.5	68.9
			T2	64.6	67.3	63.2	63.4	65.9	65
Stage 4 O_2 purity	%	Teledyne 320 (check)		74	72	75	74	73	74
Stage 4 O_2 purity	%	Post Measurement		21	21	21	21	21	22
Actual Time				4:43:00 AM	9:40:00 AM	12:45:00 PM	4:27:00 PM	8:25:00 PM	12:25:00 AM
Stage 3 DO of MLSS	mg/L	DO Probe		19.2	20	19.1	15.9	16.2	17.1
Stage 3 O_2 purity	%	Teledyne 320		77	72	78	78	77	76
Stage 3 O_2 purity	%	Post Measurement		22	22	21	21	22	21
Stage 3 pH		pH Probe		6.74	6.67	6.7	6.68	6.7	6.61
Stage 3 Temp	°C	pH Probe		24.2	23.5	42.1	24.2	23.5	24
Actual Time				4:53:00 AM	10:00:00 AM	12:57:00 PM	4:36:00 PM	8:33:00 PM	12:33:00 AM
Stage 2 DO	mg/L	SCADA	T1	12	15.41	12.26	9.98	10.13	9.11
			T2	14.5	17.73	15.04	11.95	11.62	9.65
Stage 2 O_2 purity	%	Teledyne 320		82	84	98	82	82.5	80.5
Stage 2 O_2 purity	%	Post Measurement		22	22	23	22	21	21.5

				11/1/2019					
				Train 1					
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM	12:00PM	4:00PM	8:00PM	12:00AM
Actual Time				4:07:00 AM	8:27:00 AM	12:03:00 PM	4:00:00 PM	8:00:00 PM	12:00:00 AM
Final Vent Gas Velocity	m/s	Anemometer		6.3	5.5	7.1	5.9	6.1	6.4
Final Vent Gas Temp	°C	Anemometer (Thermometer)		23.2	22.6	19.5	23.4	22.9	22.3
Stage 4 DO	mg/L	SCADA	T1	17.95	OFL	18.43	14.64	15.41	14.9
			T2	18.01	OFL	18.41	14.67	14.48	14.51
Stage 4 DO	mg/L	DO probe (check)		13.7	16.9	14.1	13.7	12.9	13.4
Stage 4 pH		pH Probe		6.61	6.64	6.75	6.81	6.72	6.7
Stage 4 Temp	°C	pH Probe		24.2	24.2	24	24.1	24.1	24
Stage 4 O_2 purity	%	SCADA	T1	63.4	67.17	62.19	56.89	58.65	58.85
			T2	62.48	65.33	62.61	59.13	60.09	59.61
Stage 4 O_2 purity	%	Teledyne 320 (check)		62	60	66.5	67	65	63
Stage 4 O_2 purity	%	Post Measurement		21	6.64	21	21.5	22	21
Actual Time				4:28:00 AM	8:41:00 AM	12:12:00 PM	4:05:00 PM	8:05:00 PM	12:04:00 AM
Stage 3 DO of MLSS	mg/L	DO Probe		12.6	16.9	14.9	13.4	12.3	13.2
Stage 3 O_2 purity	%	Teledyne 320		70	68	71	74	73	70
Stage 3 O_2 purity	%	Post Measurement		22		20.5	22	21	21.5
Stage 3 pH		pH Probe		6.7	6.71	6.82	6.81	6.74	6.73
Stage 3 Temp	°C	pH Probe		24.1	24.1	23.9	24	24	23.9
Actual Time				4:36:00 AM	11/1/8:45	12:16:00 PM	4:12:00 PM	8:13:00 PM	12:13:00 AM
Stage 2 DO	mg/L	SCADA	T1	15.58	16.26	10.76	13.87	13.23	14.32
			T2	12.12	12.53	9.72	15.07	13.76	15.62
Stage 2 O_2 purity	%	Teledyne 320		77	74	77	75.5	73	77
Stage 2 O_2 purity	%	Post Measurement				22	21.5	21.5	22

				11/1/2019					
				Train 8					
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM	12:00PM	4:00PM	8:00PM	12:00AM
Actual Time				4:44:00 AM	8:50:00 AM	12:21:00 PM	4:18:00 PM	8:18:00 PM	12:17:00 AM
Final Vent Gas Velocity	m/s	Anemometer		6.5	6.2	6.8	7	7.3	7.6
Final Vent Gas Temp	°C	Anemometer (Thermometer)		22.7	21.7	22.1	23.5	23	22.8
Stage 4 DO	mg/L	SCADA	T1	17.93	OFL	18.36	14.13	14.5	14.44
			T2	OFL	OFL	OFL	19.03	OFL	OFL
Stage 4 DO	mg/L	DO probe (check)		16.3	17.5	13.7	15.9	15.3	14.1
Stage 4 pH		pH Probe		6.58	6.61	6.7	6.73	6.7	6.68
Stage 4 Temp	°C	pH Probe		24.1	24.2	24.1	24.2	24.2	24.1
Stage 4 O_2 purity	%	SCADA	T1	70.5	72	71.5	68.8	69.1	68.6
			T2	67.5	71.3	67.8	60.5	62	61.7
Stage 4 O_2 purity	%	Teledyne 320 (check)		74	64	75	72	71	72
Stage 4 O_2 purity	%	Post Measurement				21.5	21	22	22
Actual Time				4:50:00 AM	8:58:00 AM	12:26:00 PM	/1/2019 16:25:00	8:24:00 PM	12:23:00 AM
Stage 3 DO of MLSS	mg/L	DO Probe		16.3	18.3	16.3	17.6	16.7	16.5
Stage 3 O_2 purity	%	Teledyne 320		74.5	68	79	76.5	75	75
Stage 3 O_2 purity	%	Post Measurement		22	21	20.5	21	21.5	21
Stage 3 pH		pH Probe		6.61	6.65	6.74	6.71	6.7	6.67
Stage 3 Temp	°C	pH Probe		24	24.1	24	24.1	24	24.1
Actual Time				5:00:00 AM	9:06:00 AM	12:30:00 PM	4:31:00 PM	8:31:00 PM	12:30:00 AM
Stage 2 DO	mg/L	SCADA	T1	11.8	13.07	11.82	6.23	2.76	13.1
			T2	9.92	8.2	2.33	14.74	13.84	16.57
Stage 2 O_2 purity	%	Teledyne 320		79	73	80	88	84.5	80
Stage 2 O_2 purity	%	Post Measurement			22	22	22	21	21

				11/2/2019					
				Train 1					
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM				
Actual Time				4:00:00 AM	8:00:00 AM				
Final Vent Gas Velocity	m/s	Anemometer		6.9	6.7				
Final Vent Gas Temp	°C	Anemometer (Thermometer)		22	22.3				
Stage 4 DO	mg/L	SCADA	T1	17.56	OFL				
			T2	18.65	OFL				
Stage 4 DO	mg/L	DO probe (check)		15.5	17.9				
Stage 4 pH		pH Probe		6.68	6.68				
Stage 4 Temp	°C	pH Probe		24.2	24.1				
Stage 4 O_2 purity	%	SCADA	T1	61.44	64.99				
			T2	61.29	65.78				
Stage 4 O_2 purity	%	Teledyne 320 (check)		66	72				
Stage 4 O_2 purity	%	Post Measurement		22	22				
Actual Time				4:09:00 AM	8:08:00 AM				
Stage 3 DO of MLSS	mg/L	DO Probe		15.1	17.5				
Stage 3 O_2 purity	%	Teledyne 320		77	78				
Stage 3 O_2 purity	%	Post Measurement		23	22				
Stage 3 pH		pH Probe		6.68	6.72				
Stage 3 Temp	°C	pH Probe		24.1	24				
Actual Time				4:16:00 AM	8:17:00 AM				
Stage 2 DO	mg/L	SCADA	T1	15.75	17.83				
			T2	16.29	17.59				
Stage 2 O_2 purity	%	Teledyne 320		78	80				
Stage 2 O_2 purity	%	Post Measurement		22	24.5				

				11/2/2019					
				Train 8					
Parameter	Unit	Instrument/SCADA		4:00AM	8:00AM				
Actual Time				4:27:00 AM	8:24:00 AM				
Final Vent Gas Velocity	m/s	Anemometer		7	6.4				
Final Vent Gas Temp	°C	Anemometer (Thermometer)		22.6	22.1				
Stage 4 DO	mg/L	SCADA	T1	16.75	18.88				
			T2	OFL	OFL				
Stage 4 DO	mg/L	DO probe (check)		17.5	18.1				
Stage 4 pH		pH Probe		6.61	6.6				
Stage 4 Temp	°C	pH Probe		24.3	24.2				
Stage 4 O_2 purity	%	SCADA	T1	69.1	70.9				
			T2	63.2	67				
Stage 4 O_2 purity	%	Teledyne 320 (check)		72	73				
Stage 4 O_2 purity	%	Post Measurement			21.5				
Actual Time				4:34:00 AM	8:30:00 AM				
Stage 3 DO of MLSS	mg/L	DO Probe		8.8	19.2				
Stage 3 O_2 purity	%	Teledyne 320		75	77				
Stage 3 O_2 purity	%	Post Measurement		23	21.5				
Stage 3 pH		pH Probe		6.64	6.64				
Stage 3 Temp	°C	pH Probe		24.1	24.1				
Actual Time				4:39:00 AM	8:36:00 AM				
Stage 2 DO	mg/L	SCADA	T1	13.84	15.38				
			T2	15.56	18.01				
Stage 2 O_2 purity	%	Teledyne 320		79	81				
Stage 2 O_2 purity	%	Post Measurement		22	21.5				

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm
Year: 2050
Load: Peak Flow

🟨 = input

Total Stage 2 Flow	68.2	MGD
RAS	26.4	MGD
Total O2 Flow	300	tons/day
MLSS Temp	24.6	deg C
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	OTR Low	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	68.2	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	700	2.77	68.2	1.90	0.70	0.98	9.07	8.32	2	79	30.7	28.7	4.60	3,217	77,198
3	350	2.77	68.2	3.00	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.33	2,917	69,998
4	350	2.77	68.2	2.80	0.85	0.98	9.07	8.32	2	69	26.8	24.8	7.11	2,488	59,720

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	300	25,000	0	0	0	0	0	0	0	25,000	948	0.95	37.8
2	6.34	6.92	300	25,000	172	3,967	4,033	3,603	85.8	1,984	150	21,033	799	0.86	34.2
3	5.01	5.46	300	21,033	110	2,546	2,546	3,166	55.1	1,273	150	18,486	799	0.79	31.5
4	4.67	5.10	300	18,486	103	2,383	2,383	2,697	51.5	1,192	0	16,103	799	0.73	28.9

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm
Year: 2040
Load: Peak Flow

= input

Total Stage 2 Flow	68.0	MGD
RAS	26.4	MGD
Total O2 Flow	250	tons/day
MLSS Temp	24.6	deg C
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		**Criteria**	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	68.0	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	700	2.77	68.0	1.90	0.70	0.98	9.07	8.32	2	79	30.7	28.7	4.60	3,217	77,198
3	350	2.77	68.0	3.00	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.33	2,917	69,998
4	350	2.77	68.0	2.80	0.85	0.98	9.07	8.32	2	69	26.8	24.8	7.11	2,488	59,720

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	250	20,833	0	0	0	0	0	0	0	20,833	945	0.95	37.8
2	6.34	6.92	250	20,833	152	3,503	3,569	3,573	75.8	1,751	149	17,330	796	0.85	33.9
3	5.01	5.46	250	17,330	98	2,258	2,258	3,113	48.8	1,129	149	15,072	796	0.78	31.0
4	4.67	5.10	250	15,072	91	2,110	2,110	2,626	45.6	1,055	0	12,962	796	0.71	28.2

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm
Year: 2030
Load: Peak Flow

= input

Total Stage 2 Flow	58.0	MGD
RAS	22.4	MGD
Total O2 Flow	145	tons/day
MLSS Temp	24.6	deg C
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 24.6 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	700	2.77	58.0	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	700	2.77	58.0	1.90	0.70	0.98	9.07	8.32	2	79	30.7	28.7	4.60	3,217	77,198
3	350	2.77	58.0	3.00	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.33	2,917	69,998
4	350	2.77	58.0	2.80	0.85	0.98	9.07	8.32	2	69	26.8	24.8	7.11	2,488	59,720

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	145	12,083	0	0	0	0	0	0	0	12,083	806	0.95	37.8
2	6.34	6.92	145	12,083	134	3,105	3,161	3,314	67.2	1,553	127	8,978	679	0.80	31.6
3	5.01	5.46	145	8,978	87	2,007	2,007	2,645	43.4	1,004	127	6,971	679	0.67	26.6
4	4.67	5.10	145	6,971	81	1,872	1,872	1,945	40.5	936	0	5,099	679	0.54	21.4

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Firm
Year:	2020
Load:	Peak Flow

	= input

Total Stage 2 Flow	54.3	MGD
RAS	20.88	MGD
Total O2 Flow	115	tons/day
MLSS Temp	24.6	deg C
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	54.3	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	700	2.77	54.3	1.90	0.70	0.98	9.07	8.32	2	79	30.7	28.7	4.60	3,217	77,198
3	350	2.77	54.3	3.00	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.33	2,917	69,998
4	350	2.77	54.3	2.80	0.85	0.98	9.07	8.32	2	69	26.8	24.8	7.11	2,488	59,720

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	115	9,583	0	0	0	0	0	0	0	9,583	754	0.95	37.8
2	6.34	6.92	115	9,583	119	2,754	2,806	3,217	59.6	1,377	119	6,829	635	0.77	30.7
3	5.01	5.46	115	6,829	77	1,788	1,788	2,460	38.7	894	119	5,041	635	0.63	24.9
4	4.67	5.10	115	5,041	72	1,663	1,663	1,666	36.0	831	0	3,378	635	0.47	18.6

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr

O2 flow is input tons/day for reactor 1, then calc'd for later reactors

CO2 stripping is assumed to be 50% of O2 absorption

N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4

O2 remaining is the input to a reactor - the OUR

Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm
Year: 2050
Load: Average Dry Weather

= input

Total Stage 2 Flow	67.9	MGD
RAS	26.4	MGD
Total O2 Flow	75	tons/day
MLSS Temp	21.3	deg C
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 21.3 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	67.9	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	700	2.77	67.9	1.90	0.70	0.98	9.07	8.85	8	79	32.7	24.7	3.71	2,599	62,383
3	350	2.77	67.9	3.00	0.85	0.98	9.07	8.85	8	75	31.1	23.1	6.64	2,325	55,796
4	350	2.77	67.9	2.80	0.85	0.98	9.07	8.85	3	69	28.6	25.6	6.88	2,406	57,754

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	75	6,250	0	0	0	0	0	0	0	6,250	944	0.95	40.3
2	6.34	6.50	75	6,250	85	1,969	2,231	2,427	42.6	984	149	4,281	795	0.74	31.1
3	5.01	5.13	75	4,281	51	1,171	1,171	1,698	25.3	585	149	3,111	795	0.59	24.8
4	4.67	4.79	75	3,111	46	1,072	908	1,498	23.2	536	0	2,039	795	0.45	18.9

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm
Year: 2040
Load: Average Dry Weather

= input

Total Stage 2 Flow	62.5	MGD
RAS	24.2	MGD
Total O2 Flow	65	tons/day
MLSS Temp	21.3	deg C
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	700	2.77	62.5	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	700	2.77	62.5	1.90	0.70	0.98	9.07	8.85	8	79	32.7	24.7	3.71	2,599	62,383
3	350	2.77	62.5	3.00	0.85	0.98	9.07	8.85	8	75	31.1	23.1	6.64	2,325	55,796
4	350	2.77	62.5	2.80	0.85	0.98	9.07	8.85	3	69	28.6	25.6	6.88	2,406	57,754

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	65	5,417	0	0	0	0	0	0	0	5,417	868	0.95	40.3
2	6.34	6.50	65	5,417	75	1,728	1,969	2,405	37.4	864	137	3,689	731	0.73	30.9
3	5.01	5.13	65	3,689	45	1,033	1,033	1,663	22.3	516	137	2,656	731	0.58	24.5
4	4.67	4.79	65	2,656	41	943	793	1,456	20.4	472	0	1,712	731	0.44	18.5

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Firm
Year:	2030
Load:	Average Dry Weather

= input

Total Stage 2 Flow	58.0	MGD
RAS	22.4	MGD
Total O2 Flow	55	tons/day
MLSS Temp	21.3	deg C
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	700	2.77	58.0	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	700	2.77	58.0	1.90	0.70	0.98	9.07	8.85	8	79	32.7	24.7	3.71	2,599	62,383
3	350	2.77	58.0	3.00	0.85	0.98	9.07	8.85	8	75	31.1	23.1	6.64	2,325	55,796
4	350	2.77	58.0	2.80	0.85	0.98	9.07	8.85	3	69	28.6	25.6	6.88	2,406	57,754

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	55	4,583	0	0	0	0	0	0	0	4,583	806	0.95	40.3
2	6.34	6.50	55	4,583	66	1,529	1,752	2,342	33.1	764	127	3,055	678	0.72	30.3
3	5.01	5.13	55	3,055	40	920	920	1,560	19.9	460	127	2,134	678	0.56	23.5
4	4.67	4.79	55	2,134	36	839	699	1,319	18.1	419	0	1,295	678	0.40	17.0

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr

O2 flow is input tons/day for reactor 1, then calc'd for later reactors

CO2 stripping is assumed to be 50% of O2 absorption

N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4

O2 remaining is the input to a reactor - the OUR

Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm
Year: 2020
Load: Average Dry Weather

🟨 = input

Total Stage 2 Flow	54.4	MGD
RAS	20.88	MGD
Total O2 Flow	50	tons/day
MLSS Temp	21.3	deg C
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 21.3 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	54.4	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	700	2.77	54.4	1.90	0.70	0.98	9.07	8.85	8	79	32.7	24.7	3.71	2,599	62,383
3	350	2.77	54.4	3.00	0.85	0.98	9.07	8.85	8	75	31.1	23.1	6.64	2,325	55,796
4	350	2.77	54.4	2.80	0.85	0.98	9.07	8.85	3	69	28.6	25.6	6.88	2,406	57,754

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	50	4,167	0	0	0	0	0	0	0	4,167	756	0.95	40.3
2	6.34	6.50	50	4,167	58	1,352	1,561	2,367	29.2	676	119	2,815	636	0.72	30.5
3	5.01	5.13	50	2,815	35	819	819	1,603	17.7	409	119	1,996	636	0.57	23.9
4	4.67	4.79	50	1,996	32	745	614	1,389	16.1	373	0	1,251	636	0.42	17.8

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Total
Year:	2050
Load:	Peak Load

	= input

Total Stage 2 Flow	68.2	MGD
RAS	26.4	MGD
Total O2 Flow	250	tons/day
MLSS Temp	24.6	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	800	3.17	68.2	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	800	3.17	68.2	1.90	0.70	0.98	9.07	8.32	1.7	79	30.7	29.0	4.64	3,714	89,148
3	400	3.17	68.2	3.00	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.33	3,333	79,998
4	400	3.17	68.2	2.80	0.85	0.98	9.07	8.32	2	69	26.8	24.8	7.11	2,844	68,252

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	250	20,833	0	0	0	0	0	0	0	20,833	948	0.95	37.8
2	6.34	6.92	250	20,833	151	3,984	4,039	4,052	75.4	1,992	150	16,850	799	0.84	33.4
3	5.01	5.46	250	16,850	97	2,567	2,577	3,433	48.6	1,284	150	14,282	799	0.76	30.0
4	4.67	5.10	250	14,282	91	2,393	2,393	2,823	45.3	1,196	0	11,890	799	0.67	26.7

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total
Year: 2040
Load: Peak Load

= input

Total Stage 2 Flow	62.8	MGD
RAS	24.2	MGD
Total O2 Flow	160	tons/day
MLSS Temp	24.6	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 24.6 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	62.8	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	800	3.17	62.8	1.90	0.70	0.98	9.07	8.32	2	79	30.7	28.7	4.60	3,676	88,227
3	400	3.17	62.8	3.00	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.33	3,333	79,998
4	400	3.17	62.8	2.80	0.85	0.98	9.07	8.32	2	69	26.8	24.8	7.11	2,844	68,252

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	160	13,333	0	0	0	0	0	0	0	13,333	873	0.95	37.8
2	6.34	6.92	160	13,333	133	3,507	3,568	3,769	66.4	1,754	138	9,826	735	0.79	31.5
3	5.01	5.46	160	9,826	86	2,270	2,270	2,985	43.0	1,135	138	7,556	735	0.66	26.3
4	4.67	5.10	160	7,556	80	2,112	2,112	2,166	40.0	1,056	0	5,444	735	0.53	20.9

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total
Year: 2030
Load: Peak Load

= input

Total Stage 2 Flow	58.3	MGD
RAS	22.4	MGD
Total O2 Flow	130	tons/day
MLSS Temp	24.6	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	800	3.17	58.3	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	800	3.17	58.3	1.90	0.70	0.98	9.07	8.32	2	79	30.7	28.7	4.60	3,676	88,227
3	400	3.17	58.3	3.00	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.33	3,333	79,998
4	400	3.17	58.3	2.80	0.85	0.98	9.07	8.32	2	69	26.8	24.8	7.11	2,844	68,252

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	130	10,833	0	0	0	0	0	0	0	10,833	811	0.95	37.8
2	6.34	6.92	130	10,833	117	3,089	3,146	3,687	58.5	1,545	128	7,744	683	0.78	30.8
3	5.01	5.46	130	7,744	76	2,004	2,004	2,831	37.9	1,002	128	5,740	683	0.63	25.1
4	4.67	5.10	130	5,740	71	1,863	1,863	1,932	35.3	932	0	3,877	683	0.48	18.9

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total
Year: 2020
Load: Peak Load

= input

Total Stage 2 Flow	54.5	MGD
RAS	20.88	MGD
Total O2 Flow	110	tons/day
MLSS Temp	24.6	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	800	3.17	54.5	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	800	3.17	54.5	1.90	0.70	0.98	9.07	8.32	2	79	30.7	28.7	4.60	3,676	88,227
3	400	3.17	54.5	3.00	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.33	3,333	79,998
4	400	3.17	54.5	2.80	0.85	0.98	9.07	8.32	2	69	26.8	24.8	7.11	2,844	68,252

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	110	9,167	0	0	0	0	0	0	0	9,167	758	0.95	37.8
2	6.34	6.92	110	9,167	104	2,747	2,799	3,632	52.0	1,373	120	6,420	638	0.77	30.4
3	5.01	5.46	110	6,420	68	1,790	1,790	2,722	33.9	895	120	4,630	638	0.61	24.2
4	4.67	5.10	110	4,630	63	1,658	1,658	1,767	31.4	829	0	2,972	638	0.44	17.4

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Total
Year:	2050
Load:	Average Dry Weather

🟨 = input

Total Stage 2 Flow	68.0	MGD
RAS	26.4	MGD
Total O2 Flow	70	tons/day
MLSS Temp	21.3	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	68.0	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	800	3.17	68.0	1.90	0.70	0.98	9.07	8.85	8	79	32.7	24.7	3.71	2,971	71,295
3	400	3.17	68.0	3.00	0.85	0.98	9.07	8.85	8	75	31.1	23.1	6.64	2,657	63,767
4	400	3.17	68.0	2.80	0.85	0.98	9.07	8.85	3	69	28.6	25.6	6.88	2,750	66,005

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	70	5,833	0	0	0	0	0	0	0	5,833	945	0.95	40.3
2	6.34	6.50	70	5,833	74	1,959	2,221	2,684	37.1	979	149	3,875	796	0.72	30.3
3	5.01	5.13	70	3,875	44	1,169	1,169	1,789	22.1	584	149	2,706	796	0.56	23.5
4	4.67	4.79	70	2,706	40	1,068	904	1,501	20.2	534	0	1,637	796	0.40	17.0

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Total
Year:	2040
Load:	Average Dry Weather

🟨 = input

Total Stage 2 Flow	62.5	MGD
RAS	24.2	MGD
Total O2 Flow	65	tons/day
MLSS Temp	21.3	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	62.5	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	800	3.17	62.5	1.90	0.70	0.98	9.07	8.85	8	79	32.7	24.7	3.71	2,971	71,295
3	400	3.17	62.5	3.00	0.85	0.98	9.07	8.85	8	75	31.1	23.1	6.64	2,657	63,767
4	400	3.17	62.5	2.80	0.85	0.98	9.07	8.85	3	69	28.6	25.6	6.88	2,750	66,005

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	65	5,417	0	0	0	0	0	0	0	5,417	869	0.95	40.3
2	6.34	6.50	65	5,417	65	1,730	1,971	2,747	32.7	865	137	3,687	731	0.73	30.9
3	5.01	5.13	65	3,687	39	1,038	1,038	1,895	19.7	519	137	2,649	731	0.58	24.5
4	4.67	4.79	65	2,649	36	947	797	1,655	17.9	474	0	1,701	731	0.44	18.4

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total
Year: 2030
Load: Average Dry Weather

= input

Total Stage 2 Flow	58.2	MGD
RAS	22.4	MGD
Total O2 Flow	55	tons/day
MLSS Temp	21.3	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	58.2	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	800	3.17	58.2	1.90	0.70	0.98	9.07	8.85	8	79	32.7	24.7	3.71	2,971	71,295
3	400	3.17	58.2	3.00	0.85	0.98	9.07	8.85	8	75	31.1	23.1	6.64	2,657	63,767
4	400	3.17	58.2	2.80	0.85	0.98	9.07	8.85	3	69	28.6	25.6	6.88	2,750	66,005

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	55	4,583	0	0	0	0	0	0	0	4,583	809	0.95	40.3
2	6.34	6.50	55	4,583	58	1,530	1,754	2,675	29.0	765	128	3,053	681	0.72	30.3
3	5.01	5.13	55	3,053	35	925	925	1,776	17.5	463	128	2,128	681	0.55	23.4
4	4.67	4.79	55	2,128	32	842	702	1,498	15.9	421	0	1,286	681	0.40	16.9

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total
Year: 2020
Load: Average Dry Weather

🟨 = input

Total Stage 2 Flow	54.4	MGD
RAS	20.88	MGD
Total O2 Flow	50	tons/day
MLSS Temp	21.3	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 21.3 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	800	3.17	54.4	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	800	3.17	54.4	1.90	0.70	0.98	9.07	8.85	8	79	32.7	24.7	3.71	2,971	71,295
3	400	3.17	54.4	3.00	0.85	0.98	9.07	8.85	8	75	31.1	23.1	6.64	2,657	63,767
4	400	3.17	54.4	2.80	0.85	0.98	9.07	8.85	3	69	28.6	25.6	6.88	2,750	66,005

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	50	4,167	0	0	0	0	0	0	0	4,167	757	0.95	40.3
2	6.34	6.50	50	4,167	51	1,353	1,563	2,704	25.6	677	120	2,813	637	0.72	30.5
3	5.01	5.13	50	2,813	31	823	823	1,827	15.6	412	120	1,990	637	0.56	23.9
4	4.67	4.79	50	1,990	28	748	617	1,578	14.2	374	0	1,242	637	0.42	17.7

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm, New Aerators
Year: 2050
Load: Peak Load

🟨	= input

Total Stage 2 Flow	68.2	MGD
RAS	26.4	MGD
Total O2 Flow	200	Tons/day
MLSS Temp	24.6	
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 24.6 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	700	2.77	68.2	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	700	2.77	68.2	3.20	0.70	0.98	9.07	8.32	2	79	30.7	28.7	7.74	5,417	130,018
3	350	2.77	68.2	3.20	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.89	3,111	74,665
4	350	2.77	68.2	3.20	0.85	0.98	9.07	8.32	2	69	26.8	24.8	8.13	2,844	68,252

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	200	16,667	0	0	0	0	0	0	0	16,667	948	0.95	37.8
2	10.68	11.65	200	16,667	172	3,967	4,033	5,684	85.8	1,984	150	12,699	799	0.81	32.1
3	5.34	5.82	200	12,699	110	2,546	2,546	2,944	55.1	1,273	150	10,153	799	0.70	27.7
4	5.34	5.82	200	10,153	103	2,383	2,383	2,416	51.5	1,192	0	7,770	799	0.58	23.1

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Firm, New Aerators
Year:	2040
Load:	Peak Load

🟨 = input

Total Stage 2 Flow	68.0	MGD
RAS	26.4	MGD
Total O2 Flow	160	Tons/day
MLSS Temp	24.6	
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	68.0	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	700	2.77	68.0	3.20	0.70	0.98	9.07	8.32	2	79	30.7	28.7	7.74	5,417	130,018
3	350	2.77	68.0	3.20	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.89	3,111	74,665
4	350	2.77	68.0	3.20	0.85	0.98	9.07	8.32	2	69	26.8	24.8	8.13	2,844	68,252

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	160	13,333	0	0	0	0	0	0	0	13,333	945	0.95	37.8
2	10.68	11.65	160	13,333	152	3,503	3,569	5,549	75.8	1,751	149	9,830	796	0.79	31.4
3	5.34	5.82	160	9,830	98	2,258	2,258	2,785	48.8	1,129	149	7,572	796	0.66	26.3
4	5.34	5.82	160	7,572	91	2,110	2,110	2,166	45.6	1,055	0	5,462	796	0.53	20.9

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm, New Aerators
Year: 2030
Load: Peak Load

🟨 = input

Total Stage 2 Flow	58.0	MGD
RAS	22.4	MGD
Total O2 Flow	130	Tons/day
MLSS Temp	24.6	
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 24.6 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	700	2.77	58.0	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	700	2.77	58.0	3.20	0.70	0.98	9.07	8.32	2	79	30.7	28.7	7.74	5,417	130,018
3	350	2.77	58.0	3.20	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.89	3,111	74,665
4	350	2.77	58.0	3.20	0.85	0.98	9.07	8.32	2	69	26.8	24.8	8.13	2,844	68,252

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	130	10,833	0	0	0	0	0	0	0	10,833	806	0.95	37.8
2	10.68	11.65	130	10,833	134	3,105	3,161	5,427	67.2	1,553	127	7,728	679	0.78	30.8
3	5.34	5.82	130	7,728	87	2,007	2,007	2,636	43.4	1,004	127	5,721	679	0.63	25.0
4	5.34	5.82	130	5,721	81	1,872	1,872	1,920	40.5	936	0	3,849	679	0.47	18.8

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm, New Aerators
Year: 2020
Load: Peak Load

🟨 = input

Total Stage 2 Flow	54.3	MGD
RAS	20.88	MGD
Total O2 Flow	110	Tons/day
MLSS Temp	24.6	
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	54.3	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	700	2.77	54.3	3.20	0.70	0.98	9.07	8.32	2	79	30.7	28.7	7.74	5,417	130,018
3	350	2.77	54.3	3.20	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.89	3,111	74,665
4	350	2.77	54.3	3.20	0.85	0.98	9.07	8.32	2	69	26.8	24.8	8.13	2,844	68,252

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	110	9,167	0	0	0	0	0	0	0	9,167	754	0.95	37.8
2	10.68	11.65	110	9,167	119	2,754	2,806	5,348	59.6	1,377	119	6,413	635	0.76	30.4
3	5.34	5.82	110	6,413	77	1,788	1,788	2,539	38.7	894	119	4,625	635	0.61	24.2
4	5.34	5.82	110	4,625	72	1,663	1,663	1,762	36.0	831	0	2,962	635	0.44	17.4

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Firm, New Aerators
Year:	2050
Load:	Average Dry Weather

🟨	= input

Total Stage 2 Flow	67.9	MGD
RAS	26.4	MGD
Total O2 Flow	75	Tons/day
MLSS Temp	21.3	
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 21.3 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	67.9	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	700	2.77	67.9	3.20	0.70	0.98	9.07	8.85	8	79	32.7	24.7	6.25	4,378	105,067
3	350	2.77	67.9	3.20	0.85	0.98	9.07	8.85	8	75	31.1	23.1	7.09	2,480	59,515
4	350	2.77	67.9	3.20	0.85	0.98	9.07	8.85	3	69	28.6	25.6	7.86	2,750	66,005

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	75	6,250	0	0	0	0	0	0	0	6,250	944	0.95	40.3
2	10.68	10.94	75	6,250	85	1,969	2,231	4,088	42.6	984	149	4,281	795	0.74	31.1
3	5.34	5.47	75	4,281	51	1,171	1,171	1,811	25.3	585	149	3,111	795	0.59	24.8
4	5.34	5.47	75	3,111	46	1,072	908	1,712	23.2	536	0	2,039	795	0.45	18.9

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr

O2 flow is input tons/day for reactor 1, then calc'd for later reactors

CO2 stripping is assumed to be 50% of O2 absorption

N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4

O2 remaining is the input to a reactor - the OUR

Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm, New Aerators
Year: 2040
Load: Average Dry Weather

🟨 = input

Total Stage 2 Flow	62.5	MGD
RAS	24.2	MGD
Total O2 Flow	65	Tons/day
MLSS Temp	21.3	
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 21.3 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	62.5	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	700	2.77	62.5	3.20	0.70	0.98	9.07	8.85	8	79	32.7	24.7	6.25	4,378	105,067
3	350	2.77	62.5	3.20	0.85	0.98	9.07	8.85	8	75	31.1	23.1	7.09	2,480	59,515
4	350	2.77	62.5	3.20	0.85	0.98	9.07	8.85	3	69	28.6	25.6	7.86	2,750	66,005

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	65	5,417	0	0	0	0	0	0	0	5,417	868	0.95	40.3
2	10.68	10.94	65	5,417	75	1,728	1,969	4,051	37.4	864	137	3,689	731	0.73	30.9
3	5.34	5.47	65	3,689	45	1,033	1,033	1,774	22.3	516	137	2,656	731	0.58	24.5
4	5.34	5.47	65	2,656	41	943	793	1,665	20.4	472	0	1,712	731	0.44	18.5

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Firm, New Aerators
Year:	2030
Load:	Average Dry Weather

🟨	= input

Total Stage 2 Flow	58.0	MGD
RAS	22.4	MGD
Total O2 Flow	55	Tons/day
MLSS Temp	21.3	
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	700	2.77	58.0	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	700	2.77	58.0	3.20	0.70	0.98	9.07	8.85	8	79	32.7	24.7	6.25	4,378	105,067
3	350	2.77	58.0	3.20	0.85	0.98	9.07	8.85	8	75	31.1	23.1	7.09	2,480	59,515
4	350	2.77	58.0	3.20	0.85	0.98	9.07	8.85	3	69	28.6	25.6	7.86	2,750	66,005

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	55	4,583	0	0	0	0	0	0	0	4,583	806	0.95	40.3
2	10.68	10.94	55	4,583	66	1,529	1,752	3,945	33.1	764	127	3,055	678	0.72	30.3
3	5.34	5.47	55	3,055	40	920	920	1,664	19.9	460	127	2,134	678	0.56	23.5
4	5.34	5.47	55	2,134	36	839	699	1,508	18.1	419	0	1,295	678	0.40	17.0

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Firm, New Aerators
Year: 2020
Load: Average Dry Weather

	= input

Total Stage 2 Flow	54.4	MGD
RAS	20.88	MGD
Total O2 Flow	50	Tons/day
MLSS Temp	21.3	
Number of Trains	7	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 21.3 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	700	2.77	54.4	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	700	2.77	54.4	3.20	0.70	0.98	9.07	8.85	8	79	32.7	24.7	6.25	4,378	105,067
3	350	2.77	54.4	3.20	0.85	0.98	9.07	8.85	8	75	31.1	23.1	7.09	2,480	59,515
4	350	2.77	54.4	3.20	0.85	0.98	9.07	8.85	3	69	28.6	25.6	7.86	2,750	66,005

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	50	4,167	0	0	0	0	0	0	0	4,167	756	0.95	40.3
2	10.68	10.94	50	4,167	58	1,352	1,561	3,986	29.2	676	119	2,815	636	0.72	30.5
3	5.34	5.47	50	2,815	35	819	819	1,710	17.7	409	119	1,996	636	0.57	23.9
4	5.34	5.47	50	1,996	32	745	614	1,588	16.1	373	0	1,251	636	0.42	17.8

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 2, 20% more for reactor 3, none for reactor 4
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total, New Aerators
Year: 2050
Load: Peak Load

	= input

Total Stage 2 Flow	68.2	MGD
RAS	26.4	MGD
Total O2 Flow	180	tons/day
MLSS Temp	24.6	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	800	3.17	68.2	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	800	3.17	68.2	3.20	0.70	0.98	9.07	8.32	2	79	30.7	28.7	7.74	6,191	148,592
3	400	3.17	68.2	3.20	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.89	3,555	85,331
4	400	3.17	68.2	3.20	0.85	0.98	9.07	8.32	2	69	26.8	24.8	8.13	3,250	78,002

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	180	15,000	0	0	0	0	0	0	0	15,000	948	0.95	37.8
2	10.68	11.65	180	15,000	151	3,984	4,049	6,336	75.4	1,992	150	11,016	799	0.79	31.4
3	5.34	5.82	180	11,016	97	2,567	2,567	3,173	48.6	1,284	150	8,449	799	0.66	26.3
4	5.34	5.82	180	8,449	91	2,393	2,393	2,455	45.3	1,196	0	6,056	799	0.52	20.8

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total, New Aerators
Year: 2040
Load: Peak Load

🟨 = input

Total Stage 2 Flow	62.8	MGD
RAS	24.2	MGD
Total O2 Flow	145	tons/day
MLSS Temp	24.6	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 24.6 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	62.8	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	800	3.17	62.8	3.20	0.70	0.98	9.07	8.32	2	79	30.7	28.7	7.74	6,191	148,592
3	400	3.17	62.8	3.20	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.89	3,555	85,331
4	400	3.17	62.8	3.20	0.85	0.98	9.07	8.32	2	69	26.8	24.8	8.13	3,250	78,002

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	145	12,083	0	0	0	0	0	0	0	12,083	873	0.95	37.8
2	10.68	11.65	145	12,083	133	3,507	3,568	6,184	66.4	1,754	138	8,576	735	0.77	30.7
3	5.34	5.82	145	8,576	86	2,270	2,270	2,989	43.0	1,135	138	6,306	735	0.63	24.8
4	5.34	5.82	145	6,306	80	2,112	2,112	2,153	40.0	1,056	0	4,194	735	0.47	18.5

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total, New Aerators
Year: 2030
Load: Peak Load

🟨 = input

Total Stage 2 Flow	58.3	MGD
RAS	22.4	MGD
Total O2 Flow	120	tons/day
MLSS Temp	24.6	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 24.6 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	800	3.17	58.3	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	800	3.17	58.3	3.20	0.70	0.98	9.07	8.32	2	79	30.7	28.7	7.74	6,191	148,592
3	400	3.17	58.3	3.20	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.89	3,555	85,331
4	400	3.17	58.3	3.20	0.85	0.98	9.07	8.32	2	69	26.8	24.8	8.13	3,250	78,002

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	120	10,000	0	0	0	0	0	0	0	10,000	811	0.95	37.8
2	10.68	11.65	120	10,000	117	3,089	3,146	6,064	58.5	1,545	128	6,911	683	0.76	30.1
3	5.34	5.82	120	6,911	76	2,004	2,004	2,842	37.9	1,002	128	4,907	683	0.60	23.7
4	5.34	5.82	120	4,907	71	1,863	1,863	1,910	35.3	932	0	3,044	683	0.42	16.6

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total, New Aerators
Year: 2020
Load: Peak Load

🟨 = input

Total Stage 2 Flow	54.5	MGD
RAS	20.88	MGD
Total O2 Flow	105	tons/day
MLSS Temp	24.6	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 24.6 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	54.5	0	0	0.98	9.07	8.32	0	95	37.0	37.0	0	0.00	0.00
2	800	3.17	54.5	3.20	0.70	0.98	9.07	8.32	2	79	30.7	28.7	7.74	6,191	148,592
3	400	3.17	54.5	3.20	0.85	0.98	9.07	8.32	2	75	29.2	27.2	8.89	3,555	85,331
4	400	3.17	54.5	3.20	0.85	0.98	9.07	8.32	2	69	26.8	24.8	8.13	3,250	78,002

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	105	8,750	0	0	0	0	0	0	0	8,750	758	0.95	37.8
2	10.68	11.65	105	8,750	104	2,747	2,799	6,027	52.0	1,373	120	6,003	638	0.76	30.0
3	5.34	5.82	105	6,003	68	1,790	1,790	2,795	33.9	895	120	4,213	638	0.59	23.4
4	5.34	5.82	105	4,213	63	1,658	1,658	1,835	31.4	829	0	2,555	638	0.40	16.0

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total, New Aerators
Year: 2050
Load: Average Dry Weather

🟨 = input

Total Stage 2 Flow	68.0	MGD
RAS	26.4	MGD
Total O2 Flow	70	tons/day
MLSS Temp	21.3	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	68.0	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	800	3.17	68.0	3.20	0.70	0.98	9.07	8.85	8	79	32.7	24.7	6.25	5,003	120,076
3	400	3.17	68.0	3.20	0.85	0.98	9.07	8.85	8	75	31.1	23.1	7.09	2,834	68,018
4	400	3.17	68.0	3.20	0.85	0.98	9.07	8.85	3	69	28.6	25.6	7.86	3,143	75,434

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	70	5,833	0	0	0	0	0	0	0	5,833	945	0.95	40.3
2	10.68	10.94	70	5,833	74	1,959	2,221	4,521	37.1	979	149	3,875	796	0.72	30.3
3	5.34	5.47	70	3,875	44	1,169	1,169	1,909	22.1	584	149	2,706	796	0.56	23.5
4	5.34	5.47	70	2,706	40	1,068	904	1,715	20.2	534	0	1,637	796	0.40	17.0

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition: Total, New Aerators
Year: 2040
Load: Average Dry Weather

	= input

Total Stage 2 Flow	62.5	MGD
RAS	24.2	MGD
Total O2 Flow	65	tons/day
MLSS Temp	21.3	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

Stage/reactor	Actual Horsepower (hp)	Volume (MG)	Q (MGD)	SAE (lbO2/hp-hr)	Alpha	Beta	C*20 (mg/L)	C*T at 21.3 degC and 21% O2 (mg/L)	Set Point DO (mg/L)	Assumed Head Space Purity (%O2)	HPO DO sat.* beta C*T (mg/L)	Process AE Driving Force Force	Process AE (lbO2/hp-hr)	OTR (lb/hr)	OTR (lb/day)
1	800	3.17	62.5	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	800	3.17	62.5	3.20	0.70	0.98	9.07	8.85	8	79	32.7	24.7	6.25	5,003	120,076
3	400	3.17	62.5	3.20	0.85	0.98	9.07	8.85	8	75	31.1	23.1	7.09	2,834	68,018
4	400	3.17	62.5	3.20	0.85	0.98	9.07	8.85	3	69	28.6	25.6	7.86	3,143	75,434

Stage/reactor	KLA (20) (1/hr)	KLA (T) (1/hr)	O2 Flow (lbs/day) (t/day)	Into the stage (lbs/hr)	OUR (mg/L-hr)	OUR (lbs/hr)	OTR Consumed (lbs/hr)	OTR Supplied (lbs/hr)	CO2 (mg/L-hr)	CO2 (lbs/hr)	N2 Stripped (lbs/hr)	O2 Remaining (lbs/hr)	N2 Remaining in the liquid (lbs/hr)	Purity (fraction)	Saturation (mg/L)
1	0	0	65	5,417	0	0	0	0	0	0	0	5,417	869	0.95	40.3
2	10.68	10.94	65	5,417	65	1,730	1,971	4,627	32.7	865	137	3,687	731	0.73	30.9
3	5.34	5.47	65	3,687	39	1,038	1,038	2,022	19.7	519	137	2,649	731	0.58	24.5
4	5.34	5.47	65	2,649	36	947	797	1,892	17.9	474	0	1,701	731	0.44	18.4

Assumptions
OUR is assumed, total CBOD and NBOD, mg/L-hr
O2 flow is input tons/day for reactor 1, then calc'd for later reactors
CO2 stripping is assumed to be 50% of O2 absorption
N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3
O2 remaining is the input to a reactor - the OUR
Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Total, New Aerators
Year:	2030
Load:	Average Dry Weather

🟨 = input

Total Stage 2 Flow	58.2	MGD
RAS	22.4	MGD
Total O2 Flow	55	tons/day
MLSS Temp	21.3	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	58.2	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	800	3.17	58.2	3.20	0.70	0.98	9.07	8.85	8	79	32.7	24.7	6.25	5,003	120,076
3	400	3.17	58.2	3.20	0.85	0.98	9.07	8.85	8	75	31.1	23.1	7.09	2,834	68,018
4	400	3.17	58.2	3.20	0.85	0.98	9.07	8.85	3	69	28.6	25.6	7.86	3,143	75,434

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	55	4,583	0	0	0	0	0	0	0	4,583	809	0.95	40.3
2	10.68	10.94	55	4,583	58	1,530	1,754	4,505	29.0	765	128	3,053	681	0.72	30.3
3	5.34	5.47	55	3,053	35	925	925	1,895	17.5	463	128	2,128	681	0.55	23.4
4	5.34	5.47	55	2,128	32	842	702	1,712	15.9	421	0	1,286	681	0.40	16.9

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr

O2 flow is input tons/day for reactor 1, then calc'd for later reactors

CO2 stripping is assumed to be 50% of O2 absorption

N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3

O2 remaining is the input to a reactor - the OUR

Purity calculation includes 5% of the influent O2 tonnage as N2

High Purity Oxygen Activated Sludge - Steady State HiPure Simulation

Condition:	Total, New Aerators
Year:	2020
Load:	Average Dry Weather

🟨 = input

Total Stage 2 Flow	54.4	MGD
RAS	20.88	MGD
Total O2 Flow	50	tons/day
MLSS Temp	21.3	deg C
Number of Trains	8	

N2 stripping in stages 1	0
N2 stripping in stages 2	20
N2 stripping in stages 3	20
N2 stripping in stages 4	0

Total O2 Flow Check		Criteria	
OTR:	Good	OTRsupplied ≥	OTRconsumed
Purity:	Good	Purity ≥	0.4

	Actual Horsepower	Volume	Q (MGD)	SAE	Alpha	Beta	C*20	C*T at 21.3 degC and 21% O2	Set Point DO	Assumed Head Space Purity	HPO DO sat.* beta C*T	Process AE Driving Force	Process AE	OTR	OTR
Stage/reactor	(hp)	(MG)		(lbO2/hp-hr)			(mg/L)	(mg/L)	(mg/L)	(%O2)	(mg/L)	Force	(lbO2/hp-hr)	(lb/hr)	(lb/day)
1	800	3.17	54.4	0	0	0.98	9.07	8.85	0	95	39.3	39.3	0	0.00	0.00
2	800	3.17	54.4	3.20	0.70	0.98	9.07	8.85	8	79	32.7	24.7	6.25	5,003	120,076
3	400	3.17	54.4	3.20	0.85	0.98	9.07	8.85	8	75	31.1	23.1	7.09	2,834	68,018
4	400	3.17	54.4	3.20	0.85	0.98	9.07	8.85	3	69	28.6	25.6	7.86	3,143	75,434

	KLA (20)	KLA (T)	O2 Flow (lbs/day)	Into the stage	OUR	OUR	OTR Consumed	OTR Supplied	CO2	CO2	N2 Stripped	O2 Remaining	N2 Remaining in the liquid	Purity	Saturation
Stage/reactor	(1/hr)	(1/hr)	(t/day)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(mg/L-hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(lbs/hr)	(fraction)	(mg/L)
1	0	0	50	4,167	0	0	0	0	0	0	0	4,167	757	0.95	40.3
2	10.68	10.94	50	4,167	51	1,353	1,563	4,553	25.6	677	120	2,813	637	0.72	30.5
3	5.34	5.47	50	2,813	31	823	823	1,948	15.6	412	120	1,990	637	0.56	23.9
4	5.34	5.47	50	1,990	28	748	617	1,803	14.2	374	0	1,242	637	0.42	17.7

Assumptions

OUR is assumed, total CBOD and NBOD, mg/L-hr

O2 flow is input tons/day for reactor 1, then calc'd for later reactors

CO2 stripping is assumed to be 50% of O2 absorption

N2 is the stripping of influent dissolved N2, assume 20% for Reactor 1, 20% more for reactor 2, none for reactor 3

O2 remaining is the input to a reactor - the OUR

Purity calculation includes 5% of the influent O2 tonnage as N2

APPENDIX E – SECONDARY CLARIFIER CFD MODELING

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April 22, 2020

To: Mallika Ramanathan, PE

From: Alonso Griborio, PhD, PE

Reviewed: Chris Portner, PE; Marc Solomon, PE, Kaitlin McGovern, EIT

Re: East Bay Municipal Utility District Secondary Clarifier Master Plan Secondary Clarifiers Scenarios

1. Introduction

The East Bay Municipal Utility District (District) owns and operates the Main Wastewater Treatment Plant (MWWTP), a high purity oxygen activated sludge (HPOAS) facility. The MWWTP treats an annual average flow of 63 million gallons per day (mgd) but is designed to treat up to 168-mgd through secondary treatment. The MWWTP has twelve 140-ft diameter peripheral feed, peripheral overflow secondary clarifiers that were constructed in the 1970s. These clarifiers are arranged in a semicircle with Clarifier 1, 2, 3, 4, 9, and 10 on Side A and Clarifier 5, 6, 7, 8, 11, and 12 on Side B, as shown in **Figure 1-1**.

Figure 1-1: MWWTP Secondary Clarifiers

The District is currently developing an integrated master plan for the MWWTP. As part of that effort, Hazen was tasked with modeling a variety of scenarios for both current and future conditions to determine the capacity of the secondary clarifiers (SCs). The modeling effort utilized a calibrated 2Dc model that had previously been developed for the District's secondary clarifiers.

Job no

2. 2014 Field Testing and Model Development

In 2014, Hazen developed and calibrated a computational fluid dynamic (CFD) model of the MWWTP SCs based on extensive dye testing, field sampling, and stress testing with the District. Field testing was undertaken for both Side A and B clarifiers for three days, during which time a range of surface overflow rates (SORs) and loading conditions were achieved. The model was used to identify improvements to the clarifier internal structure that would improve performance and increase capacity.

Based on the findings of the model, the following recommendations were made:

- Extend the density baffle from 12 inches to between 24 and 36 inches for all clarifiers.
- Add the target baffles back to Clarifier 1.
- Revisit the clarifier effluent flow meter calibration process to improve flow distribution to the clarifiers.

The field testing, and modeling calibration and findings were documented in the MWWTP Secondary Clarifier Technology Assessment Report dated February 2015.

3. 2017 Clarifier Improvements

In 2017, the District designed and retrofitted two of the twelve secondary clarifiers at the MWWTP, Clarifier 1 and Clarifier 10, based on the recommendations from the 2014 study discussed above. The improvements included new mechanisms, concrete repair, density baffle extension from 12 inches to 30 inches, and new target baffles. Additionally, as part of the repair and rehabilitation program, the District replaced three of the twelve clarifier effluent flow meters with new, factory-calibrated flow meters, including the one for Clarifier 10. This program is ongoing and will continue until all twelve flow meters have been replaced. After the modifications, it was anecdotally noted by operational staff that Clarifier 1 and Clarifier 10 showed treatment improvement.

4. 2019 Validation Testing and Model Validation

In 2018, the District retained Hazen to validate the 2017 improvements by comparing the unmodified clarifiers to modified Clarifiers 1 and 10 through field testing. Validation testing was conducted in October 2019 and included baseline testing, stress testing, and dye testing. For a comprehensive description of the validation testing performed in 2019, refer to the EBMUD Secondary Clarifier Validation Memorandum (February 2020). The loading conditions observed during 2019 validation testing were similar to the conditions observed during the 2014 field testing, as shown in **Table 4-1** below.

Table 4-1: Comparison of 2014 and 2019 Loading Conditions

Date	SOR (gpd/sf)	MLSS (mg/L)	RAS TSS (mg/L)	SVI (mL/g)
2014 Baseline	350	3,220	10,300	88
2019 Baseline	370	2,300	8,300	81
2014 Stress Testing	970	2,530	10,100	84
2019 Stress Testing	900	2,400	8,600	83

During baseline testing (SORs ranging from 300 to 400 gpd/sf), it was noted that Clarifier 1 outperformed the unmodified clarifiers throughout the baseline, while Clarifier 10 performed on par with the unmodified clarifiers during low flow conditions (a significant improvement for Clarifier 10, which was the most significant underperforming clarifier during the 2014 field testing). During stress testing (SORs reaching greater than 900 gpd/sf), all but two clarifiers, Clarifiers 1 and 10, were taken out of service. As a result, a comparison of modified and unmodified clarifiers could only be made up to an SOR of 600 gpf/sf, which represent moderately stressed conditions. Under these conditions, Clarifier 1 and 10 outperformed the unmodified clarifiers. Overall, the validation testing process successfully tested modified Clarifiers 1 and 10 over a range of flow conditions. **Table 4-2** summaries the average effluent TSS for both baseline and stressed conditions observed during the 2019 validation testing.

Table 4-2: Comparison of Modified and Unmodified Clarifiers during 2019 Validation Testing

Condition	Modified C1 Effluent TSS (mg/L)	Modified C10 Effluent TSS (mg/L)	Other Side A Clarifiers Effluent TSS (mg/L)
Baseline (Avg. SOR = 370 gpd/sf)	10	17	14
Moderate Stress Testing (Avg. SOR = 600 gpd/sf)	9	12	13
Stress Testing (Avg. SOR = 900 gpd/sf)	11	15	N/A

The validation testing also allowed for the comparison between unmodified (2014 field testing) and modified (2019 validation testing) clarifier performance over a range of SORs. The comparison shows that over a range of SORs, the modified Clarifiers 1 and 10 performed significantly better than the unmodified clarifiers with regards to effluent TSS. Additionally, validation testing showed that both the compact and total (dispersed plus compact) blanket levels for Clarifiers 1 and 10 decreased after modifications were made, which was observed for both baseline and stressed conditions. Finally, dye testing results from the 2019 validation testing, showed improvements in hydraulic efficiency for both Clarifiers 1 and 10. The data collected in the 2019 event was used for the validation of the clarifier model.

5. Master Plan Scenarios – Capacity Assessment

As part of the District's Integrated MWWTP Master Plan, Hazen was tasked with utilizing the existing 2Dc model developed in 2014, and validated in 2019, to determine the process capacity of the secondary clarifiers. Criteria, to define if a specific loading condition is acceptable, included an effluent total suspended solids (TSS) concentration less than 30 mg/L and a sludge blanket depth less than or equal to 50% of the side water depth (SWD). Secondary clarifier capacity was determined for both the existing high purity oxygen (HPO; non-nitrifying mode) condition and future nutrient removal conditions. Additionally, each scenario for both conditions was modeled at three different return activated sludge (RAS) flows per clarifier: 5-mgd, 6-mgd, and proportional to the influent flow (varied for each MLSS concentration and condition).

For the existing HPO condition, three different mixed liquor suspended solids (MLSS) concentrations, i.e., 1,500 mg/L, 2,250 mg/L and 3,000 mg/L, were modeled under two scenarios. Scenario A, which determined the capacity of the retrofitted clarifiers, and Scenario B, which determined the capacity of the unmodified clarifiers. A sludge volume index (SVI) equal to 133 mL/g was used in these analyses. This SVI, which corresponds to the historical 90th percentile SVI based on operational data from 2014 to 2018, was provided by the Master Planning team. This resulted in six total data points for each RAS flow which are summarized in **Table 5-1** below.

Table 5-1: Summary of Parameters for HPO Condition Model

Condition	SVI (mL/g)	MLSS (mg/L)	RAS Flow per Clarifier	Scenario
1	133	1,500	5 mgd; 6 mgd; 30% Inf Flow	A
2		2,250	5 mgd; 6 mgd; 50% Inf Flow	
3		3,000	5 mgd; 6 mgd; 60% Inf Flow	
4		1,500	5 mgd; 6 mgd; 30% Inf Flow	B
5		2,250	5 mgd; 6 mgd; 50% Inf Flow	
6		3,000	5 mgd; 6 mgd; 60% Inf Flow	

For the future nutrient removal scenarios, all clarifiers were assumed to have been retrofitted. Two SVI values were provided by the Master Planning team to be evaluated by the model; one for a biological nutrient removal (BNR) plant at an SVI of 150 mL/g and one for a BNR plant with an anerobic selector at an SVI of 125 mL/g. Three MLSS concentrations were modeled for each of the SVI concentrations, resulting in six total data points for each RAS flow which are summarized in **Table 5-2** below.

Table 5-2: Summary of Parameters for Future Nutrient Removal Condition Model

Condition	SVI (mL/g)	MLSS (mg/L)	RAS Flow per Clarifier
1	125	2,000	5 mgd; 6 mgd; 40% Inf Flow
2		3,000	5 mgd; 6 mgd; 50% Inf Flow
3		4,000	5 mgd; 6 mgd; 60% Inf Flow
4	150	2,000	5 mgd; 6 mgd; 40% Inf Flow
5		3,000	5 mgd; 6 mgd; 50% Inf Flow
6		4,000	5 mgd; 6 mgd; 60% Inf Flow

5.1 HPO Mode Condition

The results of the secondary clarifier capacity assessment for the existing HPO mode condition are detailed in **Table 5-3** and **Figure 5-1** and **Figure 5-2** below.

Table 5-3 details the calculated clarifier capacity (flow / clarifier) and acceptable SOR for each of the six scenarios at the three different RAS flows. In most scenarios, the RAS flow tended to limit the clarifier capacity, with the exception of the two lower MLSS concentrations at higher RAS flows.

Table 5-3: Capacity Analysis Results HPO Mode - SVI = 133 mL/g

		Unmodified Clarifier		Retrofitted Clarifier	
MLSS (mg/L)	RAS Flow	Capacity (mgd)	SOR (gpd/sf)	Capacity (mgd)	SOR (gpd/sf)
1,500	5 mgd	20.0	1,300	22.5	1,460
	6 mgd	20.5	1,330	23.0	1,490
	30%	20.5	1,330	24.0	1,560
2,250	5 mgd	13.5	880	14.5	940
	6 mgd	14.5	940	16.0	1,040
	50%	16.0	1,040	19.0	1,230
3,000	5 mgd	10.0	650	11.0	710
	6 mgd	11.5	750	12.5	810
	60%	12.0	780	13.5	880

Figure 5-1 and **Figure 5-2** show the MLSS concentration versus clarifier flow for the unmodified and upgraded clarifiers at three different RAS flows. Clarifier capacity was found to be the highest for a given MLSS concentration at the proportional RAS flow and lowest at 5-mgd RAS flow. Similarly, for a given clarifier flow, the MLSS concentration was highest at the proportional RAS flow and lowest at 5-mgd RAS flow. In general, clarifier capacity was also found to be higher for a given MLSS concentration in Scenario B in which the clarifiers were assumed to have been upgraded. The increase in capacity for the upgraded clarifiers ranged from approximately 10 to 20% depending upon the RAS flow and MLSS concentration.

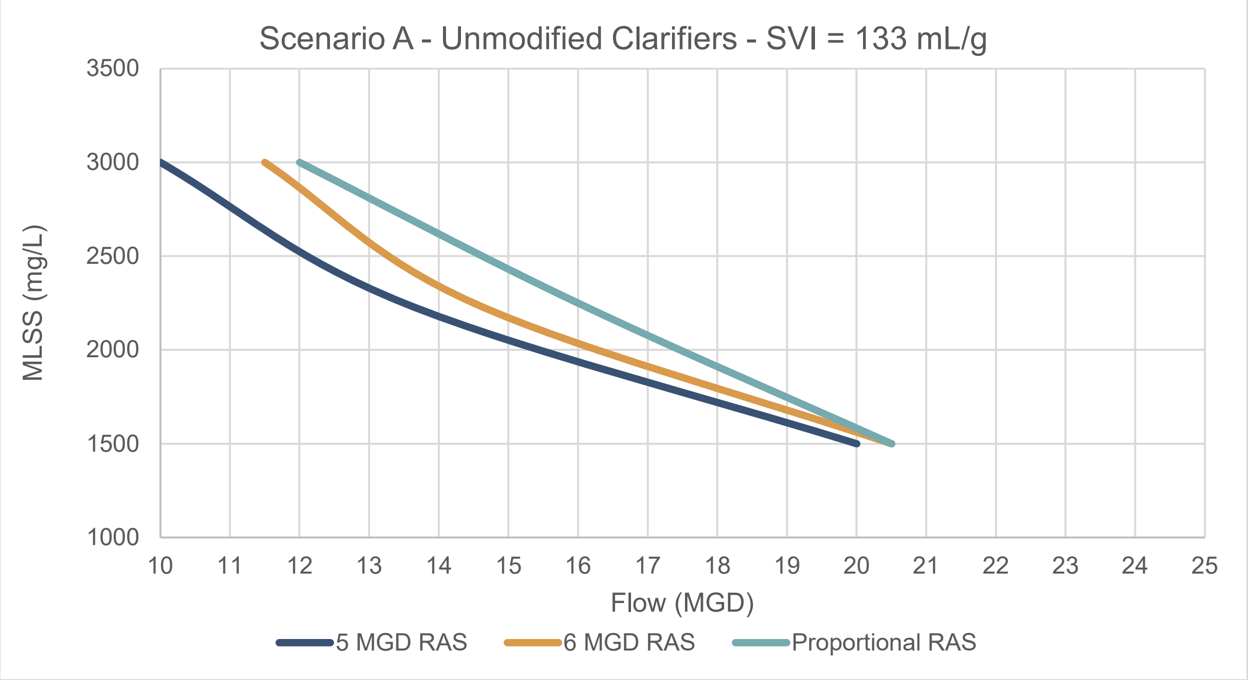

Figure 5-1: Scenario A - Unmodified Clarifiers at SVI 133 mL/g (HPO Mode)

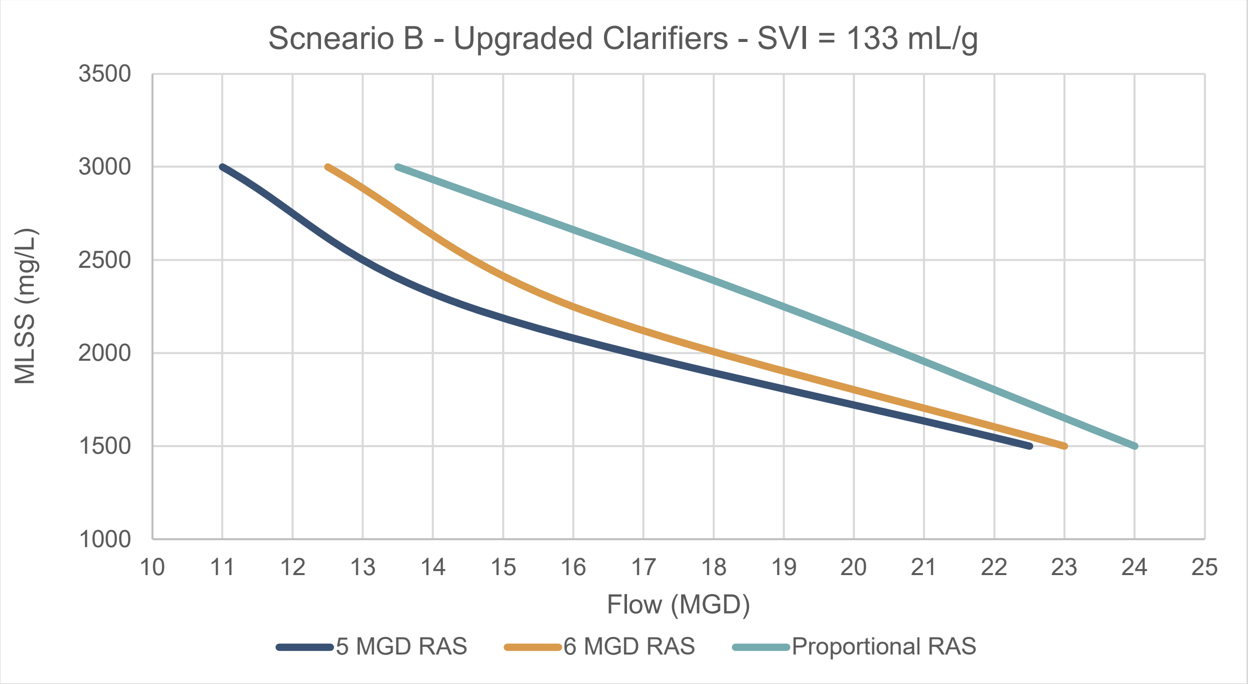

Figure 5-2: Scenario B - Upgraded Clarifiers at SVI 133 mL/g (HPO Mode)

5.2 Future Nutrient Removal Condition

The results of the secondary clarifier capacity assessment for the future nutrient removal condition are detailed in **Table 5-4** and **Figure 5-3** and **Figure 5-4** below.

Table 5-4 details the calculated clarifier capacity (flow/clarifier) for each of the six scenarios at the three different RAS flows. Similar to the HPO mode condition, the capacity of the clarifiers was limited by the RAS flow in most cases. For the nutrient removal condition, capacity was only determined for the upgraded clarifiers.

Table 5-4: Capacity Analysis Results Nutrient Removal Mode - SVIs = 125 and 150 mL/g

			Retrofitted Clarifier	
MLSS (mg/L)	**SVI (mL/g)**	**RAS Flow**	**Capacity (mgd)**	**SOR (gpd/sf)**
2,000	125	5 mgd	17.0	1,100
		6 mgd	19.5	1,270
		40%	21.5	1,400
2,000	150	5 mgd	14.5	940
		6 mgd	16.5	1,070
		45%	17.5	1,140
3,000	125	5 mgd	13.0	840
		6 mgd	14.5	940
		50%	17.0	1,100
3,000	150	5 mgd	10.5	680
		6 mgd	11.5	750
		60%	13.0	840
4,000	125	5 mgd	10.0	650
		6 mgd	11.5	750
		60%	12.5	810
4,000	150	5 mgd	8.0	520
		6 mgd	9.0	580
		67%	9.0	580

Figure 5-3 and **Figure 5-4** show the MLSS concentration versus clarifier flow for the two SVI conditions at three different RAS flows. Similar to the HPO mode condition, clarifier capacity was found to be the highest for a given MLSS concentration at the proportional RAS flow and lowest at 5-mgd RAS flow. For a given clarifier flow, the MLSS concentration was highest at the proportional RAS flow and lowest at 5-mgd RAS flow. As expected, clarifier capacity was found to be significantly higher at the lower SVI value of 125 mL/g. The effect of improved SVI was pronounced across all MLSS concentrations with capacity increases ranging from approximately 20 to 40% with relative capacities increasing the most as MLSS concentration increased.

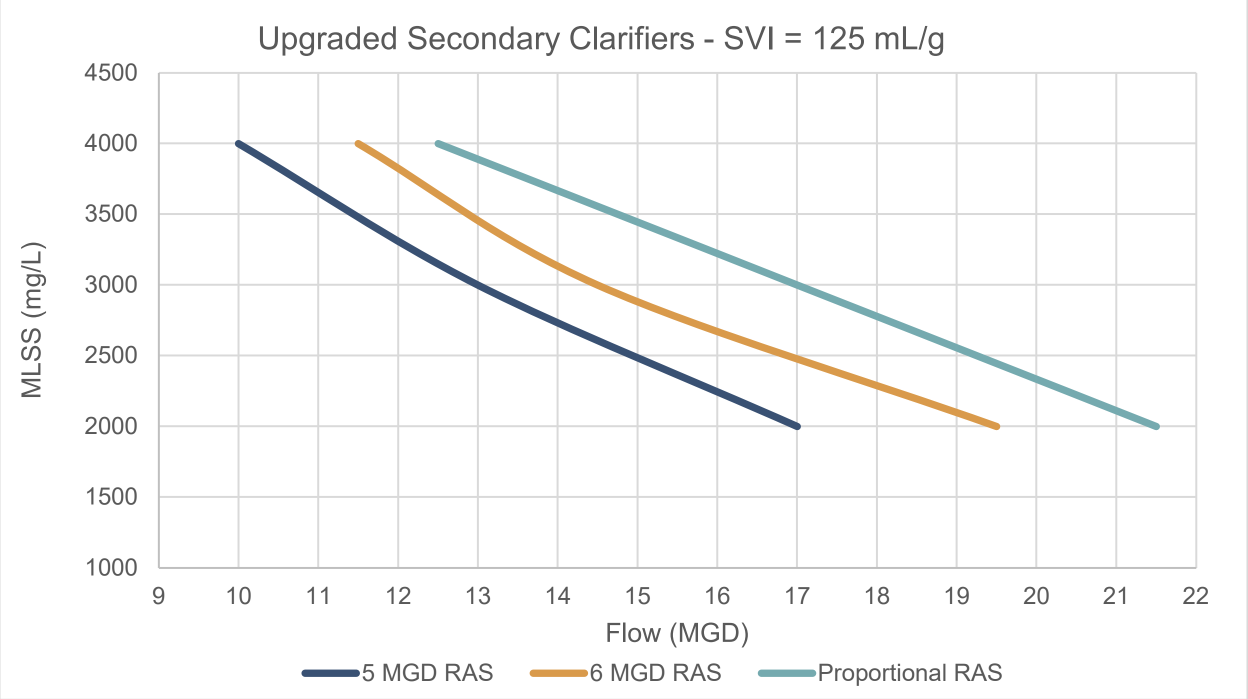

Figure 5-3: Upgraded Clarifiers at SVI 125 mL/g (Nutrient Removal Mode)

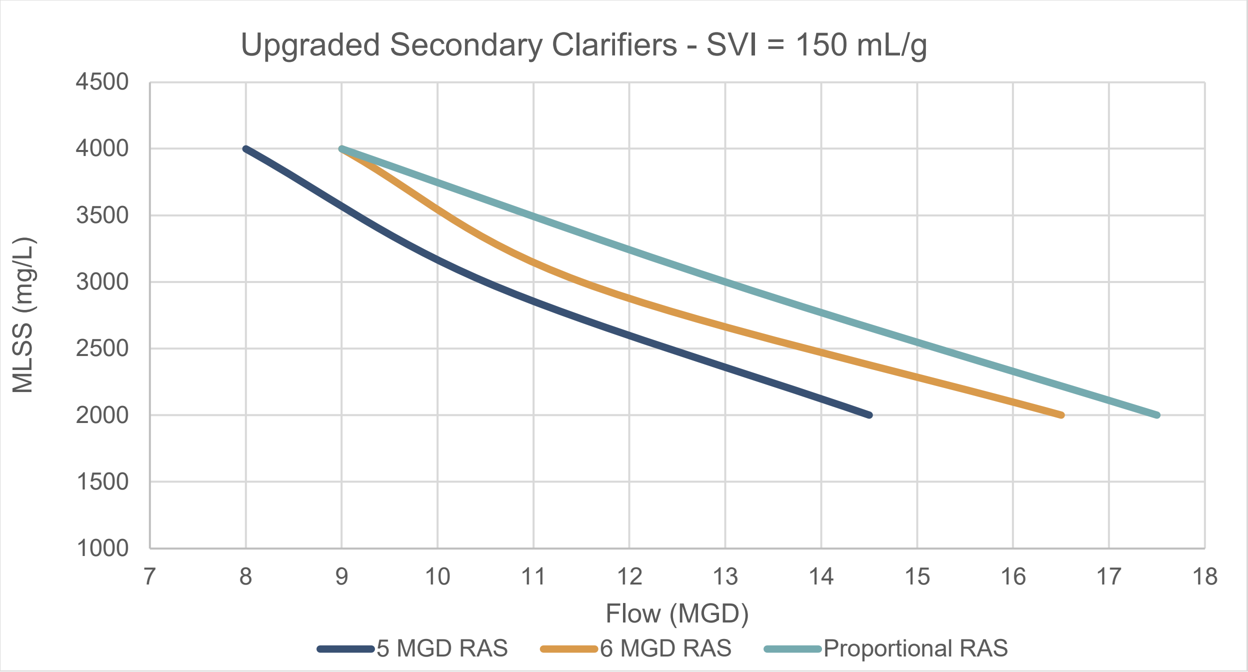

Figure 5-4: Upgraded Secondary Clarifiers at SVI 150 mL/g (Nutrient Removal Mode)

6. Summary

Based upon the results of the CFD modeling, under current HPO mode operating conditions it is expected that the upgraded clarifiers will have a capacity increase of 10 -20% over the existing/unmodified clarifiers as shown in **Table 6-1**. Over the range of scenarios modeled, the clarifier capacity for current conditions for the unmodified clarifiers was 10- to 20.5-mgd depending on SVI and RAS rate. For the upgraded clarifiers the clarifier capacity ranged from 11- to 24-mgd with clarifier capacity improving at higher RAS flow rates.

Table 6-1 Summary of Capacity Analysis for HPO

Summary of Capacity Analysis Results in HPO Mode		
Capacity Range Unmodified Clarifiers (mgd)	**Capacity Range Modified Clarifiers (mgd)**	**Range of capacity Increase for modified clarifiers across all RAS rates (%)**
10 – 20.5	11 – 24	10 to 20

For the future scenarios modeled, the implementation of an anaerobic selector is expected to increase clarifier capacity by approximately 20 to 40% as shown in **Table 6-2**. Over the range of scenarios modeled, the clarifier capacity range for future conditions without an anaerobic selector (SVI of 150 mL/g as indicated by the Master Planning team) was 8- to 17.5-mgd while the range of clarifier capacity with an anaerobic selector (SVI of 125 mL/g as indicated by the Master Planning team) was 10- to 21.5-mgd.

Table 6-2 Summary of Capacity Analysis for Nutrient Removal

Summary of Capacity Analysis Results in Nutrient Mode		
Capacity Range SVI 150 mL/g	**Capacity Range SVI 125 mL/g**	**Range of capacity Increase from SVI of 150 to 125 mL/g (%)**
8 – 17.5	10 – 21.5	17 to 40