METRO WWTP TOTAL PHOSPHORUS TREATMENT OPTIMIZATION PRE-IMPLEMENTATION STUDIES

ADDENDUM TO METRO WWTP OPTIMIZATION ANALYSIS OF TOTAL PHOSPHORUS TREATMENT REPORT DATED NOVEMBER 2011

Prepared For:
Onondaga County Department of Water Environment Protection
Syracuse, New York

Prepared by:
CRA Infrastructure & Engineering, Inc.
109 South Warren Street, Suite 220
Syracuse, New York 13202

Office: (315) 233-4270
Fax: (315) 425-4050

web: http:\\www.CRAworld.com

MAY 2013
REF. NO. 630742 (5)

EXECUTIVE SUMMARY

INTRODUCTION AND BACKGROUND

The 4th Stipulation Amended Consent Judgment (ACJ) was ratified in November 2009 stipulating modified requirements for Onondaga County's (County) combined sewer works to meet Federal Clean Water Act requirements. One key requirement of the ACJ was that an Optimization Analysis of the Metropolitan Syracuse Wastewater Treatment Plant's (Metro WWTP's) current phosphorus treatment processes be completed. Metro WWTP provides wastewater treatment for approximately 245,000 people and many industrial and commercial customers in the City of Syracuse and surrounding areas within Onondaga County. The Metro WWTP has a design capacity of 84.2 million gallons per day (mgd), and can provide full secondary and tertiary treatment for up to 126.3 mgd.

Onondaga County Department of Water Environment Protection (WEP) constructed the $128-million state-of-the-art Metro WWTP tertiary treatment facilities (completed in 2005) to meet very low effluent limits for ammonia and phosphorus as mandated by the ACJ. Ammonia removal is achieved using a biologically aerated filtration system (BAF). Phosphorus removal to very low levels is provided using a high-rate flocculated settling (HRFS) system. The design of these process improvements was to an effluent total phosphorus permit limit of 0.12 milligrams per liter (mg/L). However, the State Pollutant Discharge Elimination System (SPDES) permit total phosphorus limit was reduced to 0.10 mg/L, effective November 16, 2010.

WEP retained CRA Infrastructure & Engineering, Inc. (CRA) to complete the optimization analysis of phosphorus treatment in October 2010. Efforts in completing this report involved evaluating and recommending actions and improvements at the Metro WWTP that would promote optimizing phosphorus removal in terms of effluent concentration, operations and cost while staying within the practical operating limits of the existing facility.

The "*Metro WWTP Optimization Analysis of Total Phosphorus Treatment*" (CRA, 2011) was approved by the NYSDEC in December 2011. Recommended actions included modifications to the existing process, and adjustments for hydraulics, operations procedures and maintenance schedules related to optimizing the current facility in support of ACJ compliance. Implementation of the recommended actions are intended to provide Metro WWTP operations staff with the tools for improving phosphorus treatment performance and reliability while reducing effluent variability.

While performing the optimization analysis resulted in a significantly improved understanding of Metro WWTP phosphorus treatment processes and how inherent variability affects effluent concentrations, additional issues and potential refinements were identified near the end of the evaluation that could not be studied within the framework of the mandated schedule for the report. Therefore, the report recommended that a series of subsequent evaluations (Pre-Implementation Studies) be completed prior to proceeding with design of improvements. These evaluations were determined critical to verify key aspects of the recommended optimization plan.

WEP retained CRA in April 2012 to perform the recommended Pre-Implementation Studies. This report serves as an addendum to the 2011 Metro Optimization Analysis Report and summarizes the following evaluations:

1. An assessment of the potential use of smaller effective-size microsand in the HRFS system.
2. Evaluation of the potential feasibility of year-round polyaluminum (PAC) addition to the HRFS system, along with an assessment of the potential Onondaga Lake response from using PAC instead of ferric chloride as the coagulant.
3. Establishment of the Cross Channel isolation wall configuration that minimizes the need to change HRFS weir positions as the flow changes.
4. Performance of a mixer modifications pilot test.

For these efforts, optimization was defined as determining the recommended modifications that promote conditions leading to improved phosphorus treatment performance and reliability, while maintaining the ability of the WWTP to reliably meet all other treatment and performance requirements. The intent of optimization also is to identify opportunities for reducing effluent phosphorus variability.

The results of these studies were used to update the recommended improvements for optimizing phosphorus removal at the Metro WWTP and are summarized below. Also included in this report is an updated cost estimate and implementation schedule for the recommended optimization improvements.

MICROSAND EVALUATION

Bench-scale testing conducted during the 2011 optimization analysis showed that improved phosphorus removal may be possible using a smaller effective-size microsand (110 micron) than is currently being used in the HRSF process. However, preliminary bench testing did not simulate continuous flow conditions where the benefits of a smaller particle could be offset by increased solids carryover. Therefore, a full-scale evaluation was performed to confirm that improved phosphorus removal occurs along with the impact to solids carryover.

Phosphorus results from the performance testing period and operational data from June through December, 2012 confirmed that the 110 micron microsand resulted in lower total and particulate phosphorus concentrations in the HRFS effluent. Effluent variability of TP concentrations also appeared to be reduced by changing to the smaller microsand. Fixed solids and TSS measurements combined with visual observations showed that no additional solids carryover was apparent from using the smaller microsand.

WEP completed changeover to the smaller microsand in the entire HRFS system by January 2013. However, since the sand in all four HRFS trains was replaced, an increase in sand usage rate has been observed. Additional testing indicated that the sand loss appears to be primarily through the sludge and not from carryover in the effluent troughs. Modifying the apex tip diameter in the hydrocyclone may allow for optimizing sand recycle. Also, the higher sand usage rate remains within the expected operation of the HRFS system according to the O&M manual. Based on these results, use of a smaller microsand is expected to contribute to optimizing phosphorus removal at the Metro WWTP. Operations staff will continue to monitor the sand losses; additional operational changes will be explored if the sand losses exceed the manufacturer's estimated value.

POLYALUMINUM CHLORIDE ANALYSES

A full-scale demonstration conducted during the optimization analysis showed that PAC could be added at the HRFS influent boxes during periods of warmer temperatures. However, bench-scale testing and a literature review suggested that additional contact time may be needed during colder temperatures.

Under this project, a detailed bench-scale testing program was performed to evaluate if a PAC temperature dependency would exist at the Metro WWTP. Additionally, while using PAC during the full-scale demonstration was shown to have equal performance to ferric chloride with respect to phosphorus removal, no testing was conducted to determine if PAC-treated effluent would have similar bioavailability and settling characteristics as ferric chloride. The near-elimination of bioavailable phosphorus using ferric chloride was crucial to the development of the water quality models used in establishing a revised Onondaga Lake TMDL. Therefore, one of the Pre-Implementation Studies involved verifying if PAC treated effluent would have the same particulate bioavailability and settling characteristics as ferric chloride-treated effluent.

The results of the studies included the following:

1. Regardless of temperature, coagulant type or sand size, the HRFS process nearly eliminated total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP), which are key contributors to phosphorus bioavailability.
2. Bench-scale testing results show that PAC phosphorus removal is temperature dependent and has lower effectiveness in cold water temperatures when compared to ferric chloride. However, PAC jar testing performance appears to be equivalent to ferric chloride for warm temperatures.
3. Full-scale testing during warm weather found that PAC appeared to perform equivalently to ferric chloride.
4. Testing showed that HRFS effluent treated with PAC would have similar bioavailability and settling characteristics as effluent treated using ferric chloride. Because the testing results were similar to those reported in 2010, no adjustments to the Onondaga Lake water quality models would be necessary. Therefore, it appears that switching to PAC at the Metro WWTP would not impact the bases used in developing TMDL or in evaluating ACJ compliance actions.

In addition to similar warm temperature performance as well as bioavailability and settling characteristics, using PAC instead of ferric chloride is expected to yield the following benefits:

- Improved transmissivity of flows passing through the ultraviolet light (UV) disinfection system
- Mitigation of scaling on the UV system quartz sleeves, resulting in reduced maintenance
- Reduced corrosion impacts

- Reduced sludge generation and reduced release of phosphorus in the anaerobic digesters
- Significant reduction in iron discharge to Onondaga Lake

Based on the results of the testing presented herein, the use of PAC for the HRFS system is expected to contribute to phosphorus optimization. These studies also confirmed the 2011 Optimization Analysis Report operations recommendation that PAC should be used during disinfection season (warmer temperatures) and ferric chloride should be used during colder weather months.

MIXER PILOT TESTING

A combination of desk-top and preliminary tracer studies were completed during the 2011 optimization analysis as the basis for recommending modifications to the HRFS Injection and Coagulation Tank mixers. Based upon review of phosphorus removal treatment performance in each train, and the observation that all mixers rotated in the same direction, reversal of the mixer rotation in HRFS Trains 1 and 3 injection and coagulation tanks was recommended to match the counter-flow mixing regime of HRFS Trains 2 and 4. Also, installation of an upper impeller was recommended for the Coagulation and Injection Tanks in all four HRFS trains. However, it was acknowledged that care in mixer modification design would be essential to verify that the improvements would not promote floc shear, which could impede particle settling.

Under this project, pilot-scale testing using one HRFS train was performed to develop representative baseline design data for the mixer improvements. The pilot test included modifying the mixers in the Coagulation and Injection Tanks of HRFS Train 3 (reverse rotation and adding an upper impeller) to enable collection of the most appropriate data.

Operational and performance testing results showed a significant improvement to effluent TP levels and substantially reduced variability following implementation of the mixer modifications. These significant improvements continued during periods of higher flow at the plant, relative to flows in the sampling period prior to mixer modifications. As with microsand and PAC testing, TDP and SRP are nearly eliminated in the HRFS process, and concentrations do not appear to be affected by mixing configuration.

Particle characterization analyses did not show strong evidence of significantly greater particle shear in Train 3 following mixer modifications. Tracer testing indicates a substantial improvement in hydraulic response within the Injection Tank of Train 3 due to the mixer modifications. Since the modifications, Train 3 has a similar hydraulic regime to that of Train 2. The Coagulation Tank response also showed some minor improvement with respect to Train 2, although both trains had tracer response curves somewhat similar to the ideal response curve.

Based on the results of the mixer pilot testing, implementing the modifications recommended in the 2011 Metro Optimization Analysis Report is expected to contribute to phosphorus removal optimization. Additionally, a Stamford baffle, located at the end wall below the Lamella clarifier should be implemented to reduce short circuiting and facilitate optimizing the clarifier performance.

CFD ANALYSES

Balancing flow across the HRFS trains and managing dynamic hydraulic conditions within the Cross Channel is considered essential to Metro WWTP optimization to mitigate overloading of individual trains and to provide options to further optimize process. Computational Fluid Dynamics (CFD) modeling was used during the Metro WWTP 2011 optimization analysis to show that dynamic hydraulic conditions within the Cross Channel significantly impacted the ability of operations' staff to balance flow across the HRFS trains. Cross Channel hydraulic conditions and HRFS balancing are significantly affected by both the plant flow rate and BAF operational configuration (e.g., number of filters running, which filters operate, status of backwashing, etc.).

Installation of a longitudinal wall splitting the channels between the BAF and HRFS processes would allow for maintenance of the channels, BAFs, and HRFS system without removing the entire tertiary treatment system from service. When maintenance is performed under lower flow conditions, Metro WWTP effluent would receive full tertiary treatment, which would help to minimize effluent phosphorus excursions that would help with SPDES permit compliance. However, installation of a wall to isolate the BAF trains could significantly impact flow balancing across the four HRFS trains, particularly if unbalanced BAF operation continues. Another challenge may occur during periods of lower flow. The plant would be able to operate using three HRFS trains, thus reducing energy use; however, the isolation wall must be designed to allow reasonably balanced flow across all three trains.

Because of these challenges, additional CFD modeling was recommended to refine the design of the isolation wall between the BAF and HRFS systems. The objective of this modeling was to determine the wall configuration that mitigates large differences in weir gate positioning and minimizes the need to frequently change HRFS weir positions as the flow changes.

Discussions with HRFS system manufacturer indicated that the BAF operating program could be modified to allow balanced operation of the filters. It was also determined that BAF backwashing, under current practice, would not be affected by the lower flows experienced during summer 2012 nor by a reduction in available backwash supply volume should the isolation wall gates be closed. CFD modeling showed that without the ability to change weir elevations at the HRFS Influent Boxes, flow across the HRFS trains would be somewhat unbalanced. However, the use of adjustable weir gates would facilitate flow balancing under the full range of expected operating conditions. Installation of slide gates within the Cross Channel and isolation wall would allow one BAF train to be shut off and balanced flow to be delivered to the HRFS system. The gates also would permit shutdown of one HRFS train during periods of extended dry weather, which would result in reduced energy use. In addition to the weir gates, implementation of individual flow monitoring and coagulant feed flow pacing would facilitate balanced chemical dosing to each HRFS train.

Based on the results of the testing presented herein, implementing the refined dividing wall modifications outlined herein, as initially recommended in the 2011 Metro Optimization Analysis Report is expected to further contribute to phosphorus removal optimization.

STUDY LIMITATIONS AND LIMIT OF TECHNOLOGY IMPACT

It is critical to note that all of the Pre-Implementation Studies were short-term in nature and independent of one another (except for PAC addition with the smaller microsand). Each test was individually evaluated with respect to the following question: "Would the proposed modification contribute to optimization of phosphorus treatment at the Metro WWTP?" Each recommended modification has been shown to contribute towards optimization. While the full benefit of combining each recommended modification was not evaluated, it is expected that recommended modifications would be complementary.

Metro WWTP optimization is closely linked to the Limit of Technology (LOT) evaluation completed as part of the ACJ Compliance Plan development. The LOT evaluation involves using probability distribution analysis to establish Technology Performance Statistics (TPS) unique to the Metro WWTP. A key advantage of this approach is that actual treatment performance data are used to objectively and quantitatively evaluate the phosphorus treatment capability at Metro WWTP. The LOT is technology specific and plant specific – one treatment process will have a different LOT than another.

Based on the LOT, a statistical review of key phosphorus species (TPP, TDP and SRP) show that the current Metro WWTP processes are approaching the physical and practical limit of phosphorus treatment – a direct result of operational staff's commitment to excellence. This means that further reductions, even with optimization, would be limited. Determining statistical differences in treatment performance will require long-term monitoring.

Use of an approach, now or in the future, to predict what Metro WWTP can achieve based on existing data risks significant consequences to the County, given anti-backsliding regulations. For example, without actual data from an optimized facility, the ability to handle additional flow at Metro WWTP could be limited, which would impact the ability for growth in a struggling economy. An extended period of non-compliance, even with exemplary operation, could require additional treatment at a significant cost.

A more appropriate method for determining reliable LOT of the optimized facility would be to complete this analysis once recommended optimization upgrades are implemented and three years of data are collected. This method would allow evaluation based on actual data that suitably represents the conditions experienced and the variability encountered at Metro WWTP rather than by predictive methods. Additionally, changes to permit levels should be based on establishing that such a reduction would positively impact Onondaga Lake. Optimizing Metro WWTP for phosphorus removal would primarily involve reductions in particulate phosphorus, which is non-bioavailable. Therefore, additional particulate phosphorus removal from Metro WWTP effluent would not be expected to reduce the bioavailable phosphorus load to Onondaga Lake. This adaptive management approach is also appropriate given that Onondaga Lake has experienced significant recovery and is meeting its intended uses with respect to phosphorus.

SUMMARY OF RECOMMENDATIONS - UPDATED METRO WWTP PHOSPHORUS TREATMENT OPTIMIZATION PLAN

Implementing tertiary treatment improvements in 2005 has resulted in a dramatic improvement in Onondaga Lake water quality. This was recognized when the New York State Department of Environmental Conservation (NYSDEC) issued the revised Onondaga Lake Total Maximum Daily Load (TMDL) for United States Environmental

Protection Agency (USEPA) approval on May 25, 2012 pursuant to Section 303(d)(2) of the Clean Water Act. Approval of the TMDL was issued on June 29, 2012. The Metro WWTP waste load allocation (WLA) established in the TMDL represents a "revised effluent limit for total phosphorus" as stipulated in Paragraphs 9 and 12 of the ACJ, thus superseding the requirement for meeting the stated effluent total phosphorus limit of 0.02 mg/L by December 31, 2015. Therefore, compliance with the WLA and the implementation schedule proposed under the TMDL for the Metro WWTP equates to satisfying the respective requirements of the ACJ.

The TMDL set the Metro WWTP's SPDES limit for total phosphorus to remain 0.10 mg/L, less than the manufacturer's stated design rating for the HRFS system. Additionally, the NYSDEC will establish a total effluent phosphorus bubble permit limit for combined main and secondary bypass discharges from Metro WWTP, effective December 31, 2018. It is expected that compliance with the TMDL would result in assuring protection of the water quality goals that have been attained in Onondaga Lake, and fostering further water quality improvements to the end that any ACJ requirements with respect to Metro WWTP that may remain upon completion of the TMDL can be expeditiously and cost effectively satisfied.

An in-depth statistical analysis conducted on the behalf of WEP (CRA, 2012) was conducted to gain a more complete understanding on the impact of the TMDL on Metro WWTP, and determine the compliance probability for meeting the proposed phosphorus bubble permit. Under contemporary conditions (i.e., average daily flow of 62 mgd) this analysis indicated that the bubble permit load limit would be met with a statistical probability of approximately 97 percent. This result confirms that the Metro WWTP is, and has been, complying with the Metro WWTP TMDL bubble permit load limit. However, this analysis indicates that the probability of compliance would decrease as average flows increase or if current effluent phosphorus concentrations – which are below the 0.10 mg/L permit limit – increase. Another potential risk of permit non-compliance can come from increased secondary bypass discharges due to a wetter than normal precipitation year.

Implementing phosphorus treatment optimization at Metro WWTP is essential to further assure bubble permit compliance in terms of mitigating the potential for effluent total phosphorus concentrations to increase appreciably. This in turn will improve the County's flexibility in responding to growth or increased secondary bypass discharges using an adaptive approach. Such an adaptive approach would allow the County the time to focus on future compliance actions (should they be necessary) in a measured manner that emphasizes water quality trading and green infrastructure initiatives. Furthermore, the approach to optimize phosphorus treatment at Metro was incorporated into the TMDL as the implementation method of choice, thus alleviating the County of having to implement other ACJ compliance actions (e.g., additional treatment of diversion to Seneca River) that would cost tens to hundreds of millions of dollars more than optimization.

Based on the results of the Pre-Implementation Studies, the following optimization actions are recommended:

1. Implement the use of smaller 110 micron microsand in all four HRFS trains. This recommendation was implemented by Metro WWTP operations staff in January 2013.
2. Implement the use of PAC during disinfection season; the coagulant should be dosed at the HRFS influent boxes. Ferric chloride should continue to be dosed at the influent boxes during periods outside of the disinfection season. Metro WWTP staff should monitor PAC performance during the spring and fall when water temperatures are in transition.
3. Construct a longitudinal isolation wall along the entire length of the Cross Channel to the division wall between HRFS Trains 2 and 3; the wall should be designed to maximize the amount of backwash water available to the BAFs, as well as to provide operational flexibility. Slide gates should be provided in the Cross Channel to permit isolation of the two BAF trains, as well as in the isolation wall to facilitate flow balance when one BAF train or HRFS train is out of service. Access platforms should be provided to facilitate access to the gates.
4. Adjust SCADA programming for the BAF to force the filters to be turned on and off in pairs (one from each train) thus promoting balanced BAF operation.
5. Maintain use of the modifications to the HRFS Train 3 Coagulation and Injection Tank mixers.
6. Reverse the mixer rotation in the Coagulation and Injection Tanks for HRFS Train 1, including a new shaft and mirror image lower impeller to maintain downward flow. Install a second, upper impeller on the mixers for the Coagulation and Injection Tanks of Trains 1, 2 and 4 to match the configuration in Train 3.

These recommendations are incorporated into an updated Metro WWTP Phosphorus Removal Optimization Plan, which is described in greater detail in Section 6.6 of this report.

The estimated preliminary capital cost to install these modifications is approximately $14,600,000 (2016 dollars), including construction contingency allowance, and engineering, legal and administration fees. A summary breakdown of the preliminary capital cost is included in Appendix F. This amount is consistent with the cost reported in the report entitled "Metropolitan Syracuse WWTP Analysis of Phosphorus Treatment Technologies and Metro Diversion to the Seneca River", which presents the ACJ Compliance Plan for phosphorus treatment at Metro WWTP. The optimization improvements are included in the recommended ACJ Compliance Plan.

The phosphorus optimization strategies recommended in this report are intended to minimize impacts to Onondaga Lake by reducing effluent phosphorus variability. A component of these recommendations will help to maximize the wastewater receiving tertiary treatment during BAF, HRFS or connecting channel maintenance. However, a temporary shutdown of tertiary treatment will be essential to allow construction crews to safely and properly install the isolation wall for the BAF and HRFS units, inspect and rehabilitate the channel liner and install an access platform for the new isolation gates. Construction of the wall and liner replacement is made more complicated because confined space entry would be required. Another issue is that colder temperatures and a higher humidity environment will lengthen the cure time for the liner, although cure times may be accelerated with the use of a temporary enclosure with heaters and dehumidifiers. Additionally, time would be required to restart the BAF to effective treatment levels after an extended shutdown. Given these construction necessities, as noted in the 2011 Metro Optimization Analysis Report, it is recommended that WEP pursue a temporary permit limit variance from the NYSDEC for ammonia and phosphorus that reflects the construction activity restrictions. This variance would be applied for during the design phase and prepared in accordance with Paragraph 29 of the ACJ to minimize process downtime. A construction sequencing plan should be prepared that minimizes treatment operations downtime and potential impacts to Onondaga Lake during construction. Example actions are described in Section 6.5. Efforts to minimize impact Onondaga Lake must allow for high-quality construction, meet plant operational needs, be in accordance with applicable Standards and follow standard engineering and construction practices.

GLOSSARY

ACJ	Amended Consent Judgment
Al	aluminum
ASLF	Atlantic States Legal Foundation
BAF	biological aerated filtration
BOD	biochemical oxygen demand
CFD	computational fluid dynamics
C	Celsius
cm^2/L	square centimeters per liter
County	Onondaga County
CRA	CRA Infrastructure & Engineering, Inc.
CSTR	continuously stirred tank reactor
DO	dissolved oxygen
DOP	dissolved organic phosphorus
ELAP	Environmental Laboratory Approval Program
Fe	total iron
ft.	feet
g/L	grams per liter
gpd	gallons per day
gpm	gallons per minute
HDPE	high-density polyethylene
hp	horsepower
HRFS	high rate flocculated settling
HRT	hydraulic retention time
kWh	kilowatt-hour
lbs.	pounds
lbs./day	pound per day
LOT	Limit of Technology
Metro WWTP	Metropolitan Syracuse Wastewater Treatment Plant
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
MS/MSD	matrix spike/matrix spike duplicate
MTU	Michigan Technological University

NYCRR	New York State Code of Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
O&M	operations and maintenance
PAC	polyaluminum chloride
PAV	projected-area concentration per unit volume
PSD	particle size distribution
QA/QC	quality assurance/quality control
RAS	return activate sludge
rpm	revolutions per minute
SCADA	Supervisory Control and Data Acquisition System
SD	standard deviation
SEPS	Secondary Effluent Pump Station
SPDES	State Pollutant Discharge Elimination System
SRP	soluble reactive phosphorus
SV	settling velocity
TIP	total inorganic phosphorus
TMDL	Total Maximum Daily Load
TP	total phosphorus
TDP	total dissolved phosphorus
TPP	total particulate phosphorus
TPS	Technology Performance Statistic
TSS	total suspended solids
UFI	Upstate Freshwater Institute
USEPA	United States Environmental Protection Agency
UV	ultraviolet light
VFD	variable frequency drive
WEP	Onondaga County Department of Water Environment Protection
WERF	Water Environment Research Foundation
WWTP	wastewater treatment plant

TABLE OF CONTENTS

Page

LIST OF FIGURES
(Following Text)

LIST OF TABLES
(within Text)

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 AUTHORIZATION

Originally issued in January 1998, the 4th Stipulation Amended Consent Judgment (ACJ) between the New York State Department of Environmental Conservation (NYSDEC), the Atlantic States Legal Foundation (ASLF), and Onondaga County (County) was ratified in November 2009 (USDC, 2003) stipulating modified requirements for the County's combined sewer works to meet Clean Water Act requirements. A key requirement of the 4th Stipulation ACJ was that an optimization analysis of the Metropolitan Syracuse Wastewater Treatment Plant's (Metro WWTP's) current phosphorus treatment processes be completed. The results of the analysis must be submitted to the NYSDEC, United States Environmental Protection Agency (USEPA) and ASLF for review no later than August 31, 2011, followed by approval of a finalized report by the NYSDEC. In addition, the Metro WWTP effluent total phosphorus limit was reduced from 0.12 milligrams per liter (mg/L) to 0.10 mg/L, effective November 10, 2010.

The Onondaga County Department of Water Environment Protection (WEP) retained CRA Infrastructure & Engineering, Inc. (CRA) to complete the optimization analysis of phosphorus treatment in October 2010. Efforts in completing this report involved evaluating and recommending actions at the Metro WWTP that would promote optimizing phosphorus removal in terms of effluent concentration, operations and cost while staying within the operating limits of the existing facility.

The Metro WWTP Optimization Analysis of Total Phosphorus Treatment (CRA, 2011) optimization analysis for phosphorus treatment was approved by the NYSDEC in December 2011. Recommended actions included modifications to the existing process, hydraulics, operations procedures and maintenance schedules related to optimizing the current facility in support of ACJ compliance. Implementation of the recommended actions are intended to provide Metro WWTP operations staff with the tools for improving phosphorus treatment performance and reliability while reducing effluent variability.

While performing the optimization analysis resulted in a significantly improved understanding of Metro WWTP phosphorus treatment processes and how inherent variability affects effluent concentrations, additional issues and potential refinements were identified near the end of the evaluation that could not be studied within the framework of the mandated schedule for the report. Therefore, the report recommendations included a series of evaluations (Pre-Implementation Studies) to be completed prior to proceeding with design of improvements. These evaluations were determined critical to verify key aspects of the recommended optimization plan, including seasonal use of polyaluminum chloride (PAC), effectiveness of mixing modifications, refining the Cross Channel isolation wall layout and verification that PAC would provide the same benefit as ferric chloride with respect to bioavailability. The NYSDEC concurred with performing these studies as part of their review of The 2011 Metro Optimization Analysis Report.

WEP retained CRA in April 2012 to perform the recommended Pre-Implementation Studies. This report serves as an addendum to the 2011 Metro Optimization Analysis Report and summarizes the following Pre-Implementation Studies:

- An assessment of the potential use of smaller effective-size microsand in the high-rate flocculated settling (HRFS) system.
- Evaluation of the potential feasibility of year-round PAC addition to the HRFS system.
- Establishment of the Cross Channel isolation wall configuration that minimizes the need to change HRFS weir positions as the flow changes.
- Performance of a mixer modifications pilot test.
- An assessment of the potential Onondaga Lake response from using PAC instead of ferric chloride.

The results of these studies were used to update the recommended improvements for optimizing phosphorus removal at the Metro WWTP. Included in this report is an updated cost estimate and implementation schedule for the recommended optimization improvements.

1.2 SUMMARY OF METRO WWTP OPTIMIZATION ANALYSIS OF TOTAL PHOSPHORUS TREATMENT

1.2.1 BACKGROUND

The Metro WWTP provides wastewater treatment for approximately 245,000 people and many industrial and commercial customers in the City of Syracuse and surrounding areas of Onondaga County. The Metro WWTP has a design capacity of 84.2 million gallons per day (mgd), and can provide full secondary and tertiary treatment for up to 126.3 mgd. Overall, Metro WWTP influent undergoes preliminary treatment (screening and grit removal) followed by primary, secondary and tertiary treatment, as well as disinfection (see Process Flow Schematic on Figure 1-1). Sludge thickening, digestion and dewatering also are performed at Metro WWTP. Phosphorus treatment and removal occurs in the primary clarifiers, secondary clarifiers and the tertiary HRFS process. Metro WWTP processes that can be impacted by phosphorus treatment are disinfection and sludge handling.

A key focus of the 2011 optimization analysis involved the $128 million state-of-the-art tertiary treatment facilities (completed in 2005) to meet very low effluent limits for ammonia and total phosphorus as mandated by the ACJ. A plan view of the current biologically aerated filtration (BAF) and HRFS process configuration is illustrated in Figure 1-2. Ammonia removal is achieved using a BAF system. The BAF uses the BIOSTYR process developed by I. Kruger, Inc. (Kruger/Veolia) where nitrifying bacteria convert ammonia to nitrate and nitrite. The BAF process is comprised of 18 filter cells divided evenly into two trains (north cells 10 - 18; south cells 1 - 9). The BAF Supervisory Control and Data Acquisition System (SCADA) typically controls which filters are online, idle and backwashed based on numerous factors, including Secondary Effluent Pump Station (SEPS) flow, headloss, time in service and time idle. This leads to an apparent random operation of the filters where the filters in operation can become unbalanced between the two BAF trains. For example, one BAF train can have six filters operating while the other side can have three operating.

The manufacturer of the HRFS system (Kruger/Veolia) has stated that the process was designed to meet a total phosphorus State Pollutant Discharge Elimination System (SPDES) permit limit of 0.12 mg/L. Metro WWTP's HRFS system consists of four treatment trains, each with a capacity of 31.5 mgd. Each train consists of an Influent Box, Coagulation Tank, Injection Tank, Maturation Tank and Settling Tank that contains a Lamella clarifier. As a result of the optimization analysis, ferric chloride is added using a diffuser at the top of the Influent Box. Coagulant was previously added in the Cross Channel about halfway between the BAF and HRFS units. Relocation was performed to provide improved mixing energy and dispersion. Relocation of ferric chloride addition has also reduced corrosion impact to the HRFS influent gates and has mitigated the potential for drawing iron salts into the BAF units during filter backwashing.

Once in the HRFS system, flow enters the Coagulation Tank where pin floc is formed. The coagulation tanks are 16.5-feet (ft.) long by 13.5-ft. wide by 22.5-ft. deep and are equipped with a 20-horsepower (hp) downward pumping, clockwise rotating mixer. Flow then overflows the Coagulation Tank to the Injection Tank where microsand is dosed and mixed. Metro WWTP uses a 134-micron effective size microsand at a constant dose of 5 grams/liter (g/L). Microsand attaches to the pin floc to help promote formation of large floc and serves as ballast during clarification. The injection tanks are

16.5-ft. long by 13.5-ft. wide by 22.5-ft. deep and are equipped with a 20-hp downward pumping, clockwise rotating mixer.

The Maturation Tank, located downstream of the Injection Tank, is used for flocculation and to further increase floc size to facilitate settling. The maturation tanks are 24-ft. long by 28.6-ft. wide by 22.5-ft. deep and are equipped with a 25-hp downward pumping mixer. Polymer (Praestol A4040L) is added using a dose of 0.6 mg/L to promote flocculation. The polymer is injected into a diffuser pipe above the opening from the Injection Tank into the Maturation Tank. Flow passes from the Maturation Tank to a Settling Tank equipped with tube settlers and sludge removal equipment. Settled sludge is pumped to a hydrocyclone where the microsand is separated and re-applied at the Injection Tank. The HRFS sludge pumps are constant speed pumps that control sludge feed by turning on and off. HRFS sludge flow is approximately 2 mgd.

Implementing tertiary treatment has resulted in a dramatic improvement in Onondaga Lake water quality. This was recognized when the NYSDEC issued the revised Onondaga Lake Total Maximum Daily Load (TMDL) for USEPA approval on May 25, 2012 pursuant to Section 303(d)(2) of the Clean Water Act (NYSDEC, 2012). Approval of the TMDL was issued on June 29, 2012 (USEPA, 2012). The TMDL set the Metro WWTP's SPDES Limit for total phosphorus at 0.10 mg/L, which is less the manufacturer's stated design rating for the HRFS system. Additionally, the NYSDEC will establish a total effluent phosphorus bubble permit limit for combined main and secondary bypass discharges from Metro WWTP, effective December 31, 2018. The TMDL noted that implementation of the recommended Metro WWTP optimization improvements are expected to further assure bubble permit compliance in terms of mitigating the potential for effluent total phosphorus concentrations to increase appreciably. Therefore, the importance of optimizing existing phosphorus treatment at Metro WWTP is critical.

1.2.2 DEFINITION OF OPTIMIZATION

Metro WWTP optimization is one facet of ACJ compliance and is complementary to other efforts performed in parallel by WEP. Because these efforts are inter-related, key definitions were developed for this 2011 Metro Optimization Analysis Report to establish a consistent terminology and context. For these efforts, optimization was defined as determining the recommended modifications that promote conditions leading to improved treatment performance and reliability, while maintaining the ability of the WWTP to reliably meet all other treatment and performance requirements. The intent of optimization also is to identify opportunities for reducing effluent variability.

1.2.3 METRO WWTP OPTIMIZATION ISSUES AND EVALUATIONS

A two-day Process and Operations Workshop was initiated to establish a detailed understanding of current phosphorus treatment at the Metro WWTP, as well as significant process, hydraulic, mixing operations and maintenance issues. Results from this workshop were used as guidance in identifying and evaluating modifications for optimizing current phosphorus treatment. A key workshop discussion point was that the Engineer's Report (EEA, 2000) and manufacturer state that the installed HRFS system was designed to meet an effluent total phosphorus limit of 0.12 mg/L, which is greater than the SPDES permit limit of 0.10 mg/L.

Although compliance reporting show that the Metro WWTP has been meeting the revised 0.1 mg/L total phosphorus permit limit, effluent concentrations vary from day to day, sometimes significantly. This variability is to be expected for wastewater treatment plants that treat nutrients to very low phosphorus levels, and is especially true for facilities subject to significant wet weather variability (WERF 2010 and WERF 2011), like Metro WWTP. The NYSDEC's use of an annual rolling average is appropriate to facilitate attenuation of some process variability. However, the stated design limit, combined with inherent operational variability, raises concern for the ability of Metro WWTP to reliably meet a 0.10 mg/L permit limit without optimization and addressing identified operating and maintenance concerns. Additionally, modifications made to address one issue often have unintended consequences. Based on the results of the workshop, significant issues were identified for investigation as part of the 2011 optimization analysis.

1.2.4 EVALUATION FINDINGS AND ALTERNATIVES DEVELOPMENT

Findings from the hydraulic, mixing and process evaluations were integrated with the Metro WWTP operations and maintenance issues to develop a series of alternatives that would promote conditions for optimizing Metro WWTP phosphorus treatment while mitigating potential impacts to other plant facilities. Based on the evaluations, optimization alternatives must enable the following:

1. Maintaining a specific secondary effluent total phosphorus range to both minimize the amount of phosphorus requiring removal in the HRFS system while providing sufficient phosphorus to permit effective ammonia removal in the BAF process.

2. To the extent possible, providing balanced dosing and effective initial mixing of coagulant in the HRFS system for tertiary phosphorus removal.
3. Balancing hydraulic loading of the HRFS system to the extent possible to permit consistent performance across the trains and prevent overloading.
4. Optimizing the solids removal process within the HRFS trains.
5. Providing greater operational flexibility to enable maintenance to occur without process shutdown and maximize the amount of wastewater receiving tertiary treatment while reducing effluent variability.
6. Addressing operations and maintenance (O&M) issues due to corrosion and impact to UV disinfection.

Seven optimization alternatives were developed for evaluation that would address the range of options in the above considerations. Key variables between each alternative included coagulant type, coagulant addition location, seasonal versus year-round coagulant addition, mixing options and HRFS flow monitoring.

1.2.5 METRO WWTP PHOSPHORUS TREATMENT OPTIMIZATION PLAN

Because of the complex inter-relationships described in the previous sections, a matrix-type analysis was performed for selecting the most appropriate optimization alternative. In addition to improving phosphorus treatment, the evaluation considered impact to other Metro WWTP equipment and processes, as well as efforts to facilitate operations and maintenance. WEP staff were consulted when identifying evaluation parameters for the matrix, as well as ranking the importance of each parameter.

Alternative 7 (see Figure 1-3) was recommended as the most appropriate for WEP to implement for optimizing phosphorus treatment at the Metro WWTP. The recommended alternative focuses on use of polyaluminum chloride during disinfection season and ferric chloride during the rest of the year. Coagulant would be fed to the HRFS Influent Box. Baffles would be constructed within each influent box to promote thorough mixing. Coagulant feed would be flow paced based on flow meters located in the HRFS effluent launders. The existing ferric chloride feed system (pumps, piping and valves) would be replaced with a focus on reducing maintenance to the extent possible. In addition, a new PAC feed system would be provided. Other key modifications were recommended to enable maintenance of the HRFS and BAF system without complete shutdown, balancing flow and coagulant dosing to the HRFS system, improved HRFS mixing and addressing facilities impacted by corrosion.

A key benefit of the recommended alternative would be to reduce the impact to Onondaga Lake from variability in effluent phosphorus that results from maintenance of the BAF, HRFS or connecting channels, and thereby maximizing the wastewater receiving tertiary treatment. Additional issues and potential refinements were identified near the end of the evaluation that could not be studied within the framework of the ACJ mandated schedule for this project. While using PAC was shown to have equal performance to ferric chloride with respect to phosphorus removal, no testing was conducted to determine if PAC-treated effluent would have similar bioavailability and settling characteristics as ferric chloride. Therefore, a study prior to implementation would be necessary to verify that PAC-treated effluent would have the same particulate bioavailability as ferric chloride-treated effluent. In addition to the bioavailability/settling analysis, studies that could provide beneficial information prior to and during the design phase include full-scale testing to evaluate a smaller effective size microsand; computational fluid dynamics (CFD) modeling to refine Cross Channel isolation wall improvements; and physical modeling or full-scale testing to refine HRFS mixing improvements. These Pre-Implementation Studies were determined to be necessary before proceeding with final design.

1.3 PERFORMANCE OF PRE-IMPLEMENTATION STUDIES

1.3.1 PROJECT OBJECTIVES

The Pre-Implementation Studies focused on four areas:

1. **Use of a Smaller Microsand in the HRFS Process**
   Bench-scale testing conducted during the 2011 optimization analysis showed that improved phosphorus removal may be possible using a smaller effective-size microsand. However, the bench testing does not simulate continuous flow conditions where the benefits of a smaller particle could be offset by increased solids carryover. Therefore, a full-scale evaluation was performed during the Pre-Implementation Studies using smaller microsand to confirm that improved phosphorus removal occurs along with the impact to solids carryover.

2. **Impact of Using PAC Instead of Ferric Chloride**
   A full-scale demonstration conducted during the optimization analysis showed that PAC could be added at the HRFS influent boxes during periods of warmer temperatures. However, bench-scale testing and a literature review suggested that

additional contact time may be needed during colder temperatures. Under this project, a detailed bench-scale testing program was performed to evaluate if a PAC temperature dependency would exist at the Metro WWTP. If no dependency were found, WEP would have the flexibility to perform year-round PAC addition to the HRFS Influent Box.

Additionally, while using PAC during the full-scale demonstration was shown to have equal performance to ferric chloride with respect to phosphorus removal, no testing was conducted to determine if PAC-treated effluent would have similar bioavailability and settling characteristics as ferric chloride. Algal bioassays performed in 2010 on Metro WWTP effluent (UFI, 2010) indicated that the bioavailability of effluent particulate phosphorus is negligible (<1 percent). In addition, the particulate phosphorus in the Metro WWTP effluent was associated entirely with iron-rich particles formed in the phosphorus treatment process. These particles did not contribute to phosphorus concentrations in pelagic portions of Onondaga Lake because of local deposition associated with their large size and rapid settling velocity. The near-elimination of bioavailable phosphorus using ferric chloride was crucial to the development of the water quality models used in establishing a revised Onondaga Lake TMDL. Therefore, one of the Pre-Implementation Studies involved verifying if PAC-treated effluent would have the same particulate bioavailability and settling characteristics as ferric chloride-treated effluent.

3. **Modifications to HRFS Mixers**

A combination of desk-top and preliminary tracer studies were completed during the 2011 optimization analysis as the basis for recommending modifications to the HRFS Injection and Coagulation Tank mixers. Reversal of the mixer rotation in these two tanks for HRFS Trains 1 and 3 was recommended to match the mixing regime of HRFS Trains 2 and 4. Also, installation of an upper impeller was recommended for the Coagulation and Injection Tanks in all four HRFS trains. However, it was acknowledged that care in mixer modification design would be essential to verify that the improvements would not promote floc shear, which could impede particle settling. Under this project, pilot-scale testing using one HRFS train was performed to develop representative design data for the mixer improvements. The pilot test included modifying the mixers in the Coagulation and Injection Tanks of HRFS Train 3 (reverse rotation and adding an upper impeller) to enable collection of the most appropriate data.

4. **<u>Design Criteria Refinement for the Cross Channel Isolation Wall</u>**

   Computational fluid dynamics (CFD) modeling performed during the 2011 optimization analysis focused on alternatives for balancing flow across the HRFS trains. Based on these efforts, a wall dividing the Cross Channel was recommended to allow isolation of BAF and HRFS trains to allow tertiary treatment to operate while the Cross Channel or BAF system was partially removed for maintenance. The objective under the Pre-Implementation Studies was to perform additional CFD modeling to determine if the isolation wall configuration could be refined to minimize the need to change HRFS weir positions as the flow changes, and to facilitate placement of isolation gates.

1.3.2 PRE-IMPLEMENTATION TESTING CONDITIONS

Bench-scale and full-scale testing were completed between July 11, 2012 and January 7, 2013. The timeframe and HRFS train for each test is illustrated on Figure 1-4. Bench-scale testing was performed independent of the full-scale tests and was scheduled based on the need to perform testing at different water temperatures. Full-scale testing was scheduled to allow for plant configuration to be adjusted (e.g., installation of mixers), facilitate the logistics associated with bioavailable phosphorus bioassays and to prevent overlapping of testing (except for the second PAC test with smaller microsand).

HRFS Train 2 was selected as the control (Baseline Train) for all full-scale testing because historically, this train has had excellent phosphorus removal with relatively low variability compared to the other three trains. Train 3 was used to evaluate the mixer modifications. HRFS Train 4 was used for individually evaluating PAC addition and use of a smaller microsand, plus the combined impact of PAC with a smaller microsand.

A key challenge when collecting and evaluating full-scale testing data was the balance of flow between the HRFS trains. Variation in flow balance impacts the hydraulic load on each train and can result in unbalanced coagulant dosing. During the 2011 optimization analysis, the HRFS influent weir levels were modified to promote improved flow balance across all four trains, particularly at higher flow rates. The weir to Train 1 was left unchanged, while the weirs to Trains 2 and 3 are raised 1 inch and the weir to Train 4 was raised 3 inches.

Similar to the 2011 optimization analysis, Metro WWTP operations personnel installed velocity-area type flow meters in the effluent launders of the HRFS units for the Pre-Implementation Studies; one flow meter per train. Flow meter data were validated by comparing the temporary flow meters in the effluent launders to the permanently installed SEPS and WWTP effluent flow meters. The difference between calculating the total flow using the flow meters in the effluent launders and existing plant flow meters was typically between 3 and 9 percent.

Table 1-1 summarizes flow distribution during the study period (July 2, 2012 to December 28, 2012), as measured from the flow meters in the HRFS effluent launders in 10-mgd increments. Periods where only three trains were in operation were removed from this dataset. In general, Train 1 receives the most flow and Train 4 the least at lower plant flow rates. Flow balance improves significantly as flows increase. Also, Trains 2 and 3 typically receive approximately the same amount of flow throughout the plant operating range.

During the 2011 optimization analysis, when plant effluent flows were considered typical, flow across the HRFS trains was generally balanced. A typical frequency distribution of Metro WWTP's effluent flows (2007 to 2010) is shown on Figure 1-5. However, the Syracuse area experienced a very dry year during the Pre-Implementation Studies. Figure 1-6 shows the plant effluent flow frequency distribution during the Pre-Implementation Studies, which indicates substantially lower flows were received by the plant. This resulted in less flow being sent to Train 4 than typical.

Plant staff closely monitored flows into each train and adjusted coagulant feed rates to maintain a target ferric chloride dose of 40 mg/L (actual dose varies slightly per train) and a target PAC dose of 30 mg/L. This effort mitigated the potential for unbalanced chemical doses due to unbalanced flow across the HRFS trains. The lower flow to Train 4 (as compared to Trains 1 to 3) was also recognized during evaluation of the full-scale testing data.

TABLE 1-1

Summary of Flow Distribution Across HRFS Trains (7/2/12 to 12/28/12)
Train 4 Weir Raised 3 Inches and Trains 2 and 3 Weirs Raised 1 Inch

Total HRFS Flow (mgd)	*Measured Flow Distribution (%)*			
	Train 1	***Train 2***	***Train 3***	***Train 4***
< 10	47.7%	28.9%	19.3%	4.2%
10 to 19.9	37.1%	28.0%	26.0%	8.9%
20 to 29.9	32.7%	27.3%	26.0%	14.1%
30 to 39.9	30.9%	26.5%	25.4%	17.2%
40 to 49.9	29.9%	26.0%	25.1%	19.0%
50 to 59.9	29.3%	25.2%	24.9%	20.5%
60 to 69.9	29.3%	24.7%	24.3%	21.7%
70 to 79.9	29.2%	24.7%	24.4%	21.6%
80 to 89.9	28.4%	24.8%	24.5%	22.3%
90 to 99.9	27.1%	24.8%	24.7%	23.2%
100 to 109.9	27.3%	24.3%	24.4%	23.9%
110 to 119.9	28.4%	24.0%	23.7%	24.0%
120 to 129.9	27.7%	23.1%	22.2%	27.0%
> 129.9	27.2%	23.9%	23.0%	24.8%

2.0 MICROSAND EVALUATION

2.1 MICROSAND 2011 OPTIMIZATION REPORT FINDINGS AND PRE-IMPLEMENTATION STUDY GOALS

Jar testing performed in 2011 as part of the Metro WWTP optimization analysis indicated that a smaller effective-size microsand (110 microns) resulted in lower residual phosphorus concentrations in five out of six tests as compared to the microsand (134 micron effective size) currently used at Metro WWTP. However, concern was expressed that using a smaller and lighter-weight sand could result in increased solids washout under full-scale conditions, particularly at higher flow rates. Increased solids washout would lead to greater sand loss and, possibly, increased discharge of particulate phosphorus. Therefore, it was recommended that full-scale HRFS testing be performed to verify the findings of the microsand jar tests and determine if increased solids carryover would occur from using a smaller size sand.

2.2 MICROSAND EVALUATION METHODOLOGY

Trains 2 and 4 of the HRFS system were used for this evaluation. Train 2, containing 134 micron microsand was used as the control, while the microsand in Train 4 was replaced with 110 micron material. WEP staff ordered a full load of 110 micron sand from Manley Bros. On August 1, 2012, Metro WWTP operations' staff shut down Train 4, removed the existing sand from the process tanks and added the smaller microsand. One ton of makeup sand was also purchased in pallets of 50-pound bags; makeup sand was added by Metro WWTP staff on an as-needed basis. Train 4 was restarted on August 2, 2012. Data used for evaluating microsand performance included daily operational samples, specific performance testing samples and visual observations. All sample collection and analysis was performed by WEP personnel. Chain-of-custody records were maintained for all operational and performance testing samples collected.

Plant operational testing was used from June 1 through December 19, 2012. Except for the periods from July 11 to 25 and August 27 to September 4, ferric chloride was used as the coagulant in both trains. PAC was added to Train 4 instead of ferric chloride during these other two periods. Data collected included composite total phosphorus samples and flow data from the effluent troughs of each HRFS train. Composite total phosphorus samples also were collected for the BAF influent, BAF effluent/HRFS influent and plant final effluent. Composite samples were collected using auto-samplers with sample collection starting at 8:30 a.m. Composites were flow weighted and results are reported by start date. The individual HRFS train and plant effluent samples allowed for a full-scale comparison of the two microsand sizes on a day-to-day basis.

The BAF samples were collected to verify that HRFS influent total phosphorus levels were not overloading the process.

Performance testing of HRFS Trains 2 and 4 was performed on August 6, 10, 16 and 22 to evaluate how phosphorus speciation and solids carryover are affected by sand size at varying flow rates. Ferric chloride was added to both trains during the performance tests. Baseline testing (134 micron microsand in each train) was performed at the same sampling locations on July 10, 2012 as a reference. Data collection consisted of "grab" samples manually collected using the dip method; samples were collected from the effluent troughs of HRFS Trains 2 and 4, as well as the HRFS Influent Channel. One sample was collected during baseline testing and three samples were collected during performance testing for each of the following flow conditions: low (60-mgd target), medium (80-mgd target) and high (100-mgd target) flows. In order to simulate these flows, WEP staff strategically shut down HRFS trains to create the desired hydraulic conditions. The trains in operation during each of the testing events are noted in the data provided in Appendix A.

Chemical analyses were performed by the WEP Environmental Lab following methods specified in Standard Methods 18th Edition (1992) and outlined in Table 2-1. WEP's laboratory is certified by New York State's Environmental Laboratory Approval Program (ELAP) to perform total phosphorus analyses. Temperature measurements were collected in the field.

Additionally, HRFS effluent was tested for "cleaned and fixed solids". The purpose of this test was to identify the quantity of silca sand particles over 70 microns (minimum size found in Manley Bros. 110 micron sand) carrying over into the plant effluent. This analysis is not a standard laboratory analysis and was based on Standard Method 2540 E – Fixed and Volatile Solids Ignited at 500 degrees C. In general, the "cleaned, fixed-solids" analysis is a fixed-solids analysis that is modified to remove phosphorus and metal coagulant (aluminum or iron) so that the remaining particulates consist of (nearly 100%) silica sand. The procedure used consisted of collecting sample in a 250-milliliter (mL) plastic bottle from a representative, but turbulent mixing zone. Prior to analysis, the sample was digested using the phosphorus digestion method currently employed by WEP's laboratory for total phosphorus analysis. The sample needed to be acidic (pH <2) to verify that metals are in the dissolved state during filtration. One hundred milliliters of sample was filtered through a pre-weighed filter disk with a maximum pore size of 70 microns and washed. The fixed solids weight is assumed to equal the amount of sand carried over from the HRFS system.

A strict quality assurance/quality control (QA/QC) protocol was followed by WEP's laboratory on all samples analyzed. For phosphorus species analyses, one matrix spike/matrix spike duplicate (MS/MSD) sample was collected and analyzed for every ten samples. For non-phosphorus analyses, MS/MSD analyses were performed on one out of every 20 samples.

TABLE 2-1

Chemical Analyses Performed by WEP Environmental Lab

Compound	*Symbol*	*Analytical Method*	*Reporting Limit (mg/L)*
Phosphorus			
Total phosphorus	TP	Standards Methods 18th Ed. (4500-P E)	0.003
Total dissolved phosphorus	TDP	Standards Methods 18th Ed. (4500-P E)	0.003
Total particulate phosphorus	TPP	Calculated: TPP = TP – TDP	0.003
Total inorganic phosphorus	TIP	Standards Methods 18th Ed. (4500-P E)	0.003
Soluble reactive phosphorus	SRP	Standards Methods 18th Ed. (4500-P E)	0.001
Dissolved organic phosphorus	DOP	Calculated: DOP = TDP – TIP-diss	0.003
Conventional Parameters			
Total suspended solids	TSS	Standards Methods 18th Ed. (2540 D)	1
Flow		HRFS launder meters (American Sigma 950 Bubble, Area Velocity Flow Meters) and Parshall flume at UV system	
Metals			
Iron	Fe	EPA 1994 (200.7)	0.04

2.3 MICROSAND EVALUATION RESULTS AND DISCUSSION

2.3.1 MICROSAND WASHOUT POTENTIAL

Cleaned and fixed solids and TSS, along with visual observations were analyzed to compare solids washout for the two microsand sizes. Table 2-2 summarizes the cleaned and fixed solids and TSS data for each of the testing locations and microsand sizes. The values represent the average and standard deviation of all samples. Review of the raw data (included as Appendix A) suggests no discernible relationship between flow and TSS or fixed solids concentrations for the samples collected. Based on Table 2-2, the cleaned and fixed solids did not change between trains and sand sizes. The TSS varied minimally between trains and sand sizes. While the data does show a slight increase in TSS with the use of 110 micron microsand in Train 4, the average value and standard deviation are similar to Train 2.

TABLE 2-2

Cleaned and Fixed Solids and TSS Results Summary for Microsand Performance Testing

Sample Location	*Sand Size (microns)*	*Cleaned and Fixed Solids, Average (mg/L)*	*Cleaned and Fixed Solids, Standard Deviation*	*TSS, Average (mg/L)*	*TSS, Standard Deviation*
HRFS Influent	n/a	n/a	n/a	7.58	3.65
Train 2 Effluent	134	<5	0	5.67	1.67
Train 4 Effluent	134	<5	0	4.00	(one sample collected)
Train 4 Effluent	110	<5	0	5.11	2.15

Visual observations by CRA and WEP personnel showed that the effluent from Train 4 was clearer than Train 2 with no significant evidence of additional sand or solids. Operating staff also reported during the testing program no indication of additional sand loss using the smaller microsand. Only minimal sand replenishment was required between August and December, which is similar to the larger sand. Based on the above results, it does not appear that using smaller microsand would result in additional solids carryover as compared to the 134 micron sand.

2.3.2 COMPARISON OF PHOSPHORUS REMOVAL PERFORMANCE

Table 2-3 presents the HRFS influent phosphorus speciation data and simulated flow rates during each of the performance tests. This table also includes averages and standard deviations. The data shows that, regardless of flow, approximately 45 percent of the total phosphorus component is soluble reactive (SRP), and about 55 percent represents the total dissolved (TDP) fraction.

TABLE 2-3

HRFS Influent Phosphorus Speciation Data and Simulated Flow Rates

Date/Time	*Simulated Plant Flow Rate (mgd)*	*TP (mg/L)*	*TPP (mg/L)*	*TDP (mg/L)*	*SRP (mg/L)*	*DOP (mg/L)*	*TIP (mg/L)*	*TDP/TP (%)*	*SRP/TP (%)*
7/10/12 8:30 AM	59.1	0.43	0.165	0.265	0.235	0.021	0.244	62%	55%
7/10/12 11:05 AM	40.4	0.443	0.157	0.286	0.247	0.043	0.243	65%	56%
7/10/12 1:40 PM	69.3	0.473	0.184	0.289	0.249	0.031	0.258	61%	53%
8/6/12 12:45 PM	56.3	0.392	0.159	0.233	0.204	0.036	0.197	59%	52%
8/6/12 3:00 PM	65.3	0.351	0.150	0.201	0.196	0.013	0.188	57%	56%
8/6/12 5:20 PM	118	0.446	0.197	0.249	0.234	0.039	0.210	56%	52%
8/10/12 8:40 AM	69.9	0.707	0.458	0.249	0.232	0.038	0.211	35%	33%
8/16/12 12:40 PM	54.6	0.400	0.220	0.180	0.146	0.031	0.149	45%	37%
8/16/12 3:00 PM	74.5	0.470	0.272	0.198	0.154	0.037	0.161	42%	33%
8/16/12 5:20 PM	104.2	0.455	0.243	0.212	0.176	0.042	0.170	47%	39%
8/22/12 12:30 PM	71.98	0.42	0.224	0.196	0.15	0.046	0.15	47%	36%
8/22/12 3:10 PM	83.2	0.367	0.151	0.216	0.148	0.066	0.15	59%	40%
Average	**-**	**0.446**	**0.215**	**0.231**	**0.198**	**0.037**	**0.194**	**53%**	**45%**
S.D	**-**	**0.091**	**0.086**	**0.036**	**0.041**	**0.013**	**0.039**	**9**	**10**

Figures 2-1, 2-2 and 2-3 show the entire set of HRFS Train 2 and 4 effluent phosphorus results from the performance testing period under targeted low, medium and high flow conditions, respectively. When compared with the influent data in Table 2-3, regardless of sand size or flow rate, nearly all of the SRP and TDP are eliminated. Removals of SRP and TDP typically exceeded 95 percent and 90 percent, respectively. This shows that the HRFS process nearly eliminates the most important fractions of phosphorus, those associated with bioavailability. The data also show that variations in effluent total phosphorus are almost solely controlled by the removal of residual particulate phosphorus. These findings are similar to those found from the testing results obtained during the 2011 optimization analysis. Therefore, the comparison of the phosphorus removal performance of the two microsand sizes focuses on particulate phosphorus removal.

Table 2-4 summarizes the TP and TPP statistical reduction of the performance testing data. The data show lower average effluent TP and TPP concentrations using 110 micron microsand in Train 4 when compared to both the Train 4 baseline testing and Train 2 results, which involved the use of 134 micron microsand. Also, the standard deviation was lowest when using 110 micron microsand. This correlates to reduced effluent variability and improved process control.

TABLE 2-4

Summary TP and TPP Results During Microsand Performance Testing

Sample Location	*Sand Size (microns)*	*TP, Average (mg/L)*	*TP, Standard Deviation*	*TPP, Average (mg/L)*	*TPP, Standard Deviation*
HRFS Influent	n/a	0.446	0.091	0.215	0.086
Train 2 Effluent	134	0.076	0.016	0.052	0.015
Train 4 Effluent	134	0.068	0.013	0.042	0.011
Train 4 Effluent	110	0.053	0.010	0.033	0.008

Because of its positive performance, Metro WWTP staff opted to keep the 110 micron microsand in Train 4 after the performance testing period. Plant operating data for HRFS Trains 2 and 4 from June through December 2012 were reviewed. HRFS influent data was consistently below 0.5 mg/L, which is considered within the operating criteria of the HRFS process. Figure 2-4 shows the Train 2 and 4 effluent TP concentrations from June 1 through December 19, 2012; Table 2-5 summarizes the effluent TP statistics for this period. A significant decrease in Train 4 effluent TP concentrations was experienced after the smaller sand was installed. The standard deviation of the data also decreased, indicating lower variability. The effluent TP concentrations and standard deviation were also significantly lower in Train 4 than in Train 2 over this period of time.

TABLE 2-5

Effluent Total Phosphorus Concentrations for Trains 2 and 4
June 1 – December 19, 2012

Sample Location	*Sand Size (microns)*	*TP, Average (mg/L)*	*Standard Deviation*
Train 2 Effluent	134	0.089	0.032
Train 4 Effluent	134	0.090	0.036
Train 4 Effluent	110	0.062	0.023

As noted in Section 1.3, flow to Train 4 was typically lower than Train 2. In order to confirm that the 110 micron microsand performance was not primarily due to the lower flow in Train 4, performance testing period data effluent TP concentrations was plotted with respect to equivalent plant flow (see Figure 2-5). As shown in this figure, regardless of the total plant flow, the 110 micron microsand generally resulted in lower effluent TP concentrations than the 134 micron microsand. Also, Figure 2-4 showed that effluent TP concentrations and variability decreased in Train 4 after changing to 110 micron microsand even though flows increased in the fall. These results show that overall, the microsand appears to result in improved particulate phosphorus removal under full-scale operation.

2.4 ADDITIONAL FINDINGS AFTER THE TESTING PERIOD

Because of the improvement in total phosphorus removal performance using the smaller size microsand, Metro WWTP operators commenced ordering only 110 micron microsand. The 134 micron make-up microsand supply was depleted by January 2013 and, at this time the entire HRFS process was using only 110 micron microsand. Around the same time the operators noticed an increase in sand losses (more sand deliveries were needed).

Table 2-6 summarizes the HRFS make-up sand addition, volume of water treated and sand usage in 2012 compared to the first four months of 2013. As shown, the sand usage rate (in pounds per million gallons treated (lbs/MG)) was three times higher in the first four months of 2013 compared to 2012. However, the O&M manual for the HRFS system indicated that the typical design value for and usage rate was 24 lbs./MG. Therefore, while the sand usage has increased in 2013 it is still within the typical range of the HRFS process.

TABLE 2-6

HRFS Sand Usage 2012 and 2013

Time Period	*Make-up Sand Addition (lbs)*	*Volume Treated (MG)*	*Sand Usage (lbs/MG)*
January – December 2012	115,772	20147.9	5.7
January 2013 – April 15, 2013	143,477	7779.4	18.4

Additional testing was performed by WEP operations staff in April 2013 to determine where the additional sand was being lost from the system. Grab samples for clean and fixed solids analyses were taken from the HRFS effluent between April 22 and 28, 2013.

All samples had less than 5 mg/L of clean and fixed solids, which was the method detection limit. The average total suspended solids (TSS) and volatile suspended solids (VSS) concentrations in the HRFS clarifier underflow (two underflows total) in 2012 and 2013 also were compared; these values are summarized in Table 2-7. The 2013 TSS and VSS values decreased by approximately twenty percent compared to the same time period in 2012.

TABLE 2-7

Average TSS and VSS Concentrations of HRFS Clarifier Underflows

Time Period	*TSS (mg/L)*	*VSS (mg/L)*
January 2012 – December 2012	876	368
January 2012-April 2012	827	329
January 2013 – April 2013	672	257

The effluent clean and fixed solids along with the TSS and VSS data suggest that the sand is being lost through the clarifier underflows. This is supported by continued observations that the HRFS effluent appears clearer since starting use of the smaller microsand. Therefore, it appears that the additional sand is leaving the system with the process sludge. The 2011 Phosphorus Optimization Report discussed that the apex tip diameter on the hydrocyclone, which separates sand from sludge, can have an impact on the amount of sand and iron returned to the HRFS system. Monitoring sand loss as a function of apex tip diameter may permit operations staff to optimize sand recycle in combination with sludge removal. While the sand usage rate has increased, it is still within the manufacturer's allowable operating range. Metro WWTP staff will continue to monitor the sand loss and investigate operational modifications to optimize sand recycle.

2.5 MICROSAND IMPLEMENTATION SUMMARY

Phosphorus results from performance testing and operational data from June through December, 2012 confirm that the 110 micron microsand resulted in lower total and particulate phosphorus concentrations in the HRFS effluent. Fixed solids and TSS measurements combined with visual observations during testing showed that no additional solids carryover resulted from using the smaller microsand.

WEP completed changeover to the smaller microsand in the entire HRFS system by January 2013. However, since the sand in all four HRFS trains was replaced, an increase in sand usage rate has been observed. Additional testing indicated that the sand loss appears to be primary through the sludge and not from carryover in the effluent troughs. Modifying the apex tip diameter in the hydrocyclone may allow for optimizing sand recycle. Also, the higher sand usage rate remains within the expected operation of the HRFS system according to the O&M manual. Based on these results, use of a smaller microsand is expected to contribute to optimizing phosphorus removal at the Metro WWTP. Operations staff will continue to monitor the sand losses; additional operational changes will be explored if the sand losses exceed the manufacturer's estimated value.

3.0 POLYALUMINUM CHLORIDE EVALUATIONS

3.1 PAC 2011 OPTIMIZATION REPORT FINDINGS AND PRE-IMPLEMENTATION STUDY GOALS

Benefits of changing HRFS coagulants from ferric chloride to PAC include:

- Improved transmissivity of flows passing through the UV disinfection system.
- Mitigation of scaling on the UV system quartz sleeves.
- Reduced corrosion impacts.
- Reduced sludge generation and reduced release of phosphorus in the anaerobic digesters.
- Significant reduction in iron discharge to Onondaga Lake.

Bench and full-scale testing of HRFS coagulants performed during the 2011 optimization analysis showed that using PAC resulted in equivalent or slightly better phosphorus removal performance with respect to ferric chloride. Bench-scale testing, along with a literature review, also indicated that the formation kinetics of aluminum phosphates may be temperature dependent with colder temperatures resulting in slower kinetics. If no dependency were found, WEP would have the flexibility to perform year-round PAC addition to the HRFS influent box.

Algal bioassays performed in 2010 on Metro WWTP effluent indicated that the bioavailability of effluent particulate phosphorus is negligible (<1 percent). In addition, the particulate phosphorus in the Metro WWTP effluent was associated entirely with iron-rich particles formed in the phosphorus treatment process. These particles did not contribute to phosphorus concentrations in pelagic portions of Onondaga Lake because of local deposition associated with their large size and rapid settling velocity. The near-elimination of bioavailable phosphorus using ferric chloride was crucial to the development of the water quality models used in establishing a revised Onondaga Lake TMDL. However, it is not known if HRFS effluent particles treated with PAC would have similar characteristics. Therefore, testing of PAC-treated water was recommended to verify if it would have similar bioavailability and settling characteristics as ferric chloride-treated effluent. Additional full-scale testing also was recommended to verify the 2011 optimization analysis findings.

3.2 PAC TEMPERATURE DEPENDENCY TESTING

3.2.1 PAC TEMPERATURE DEPENDENCY TESTING METHODOLOGY

Jar testing was performed to compare PAC and ferric chloride effectiveness under warm and cold temperature conditions. The protocol used was a modification of the process developed by Kruger/Veolia (located in WEP's HRFS O&M Manual). CRA varied the duration between the chemical and sand addition to simulate Cross Channel and HRFS Influent Box coagulant addition. This was the same method used during the 2011 optimization analysis. A programmable 4-paddle jar stirrer with square acrylic 2-liter testing jars was provided by WEP for this testing.

HRFS influent water was collected from the Cross Channel for the testing. The warm temperature jar test scenarios (average 23° Celsius) were performed on July 11, August 8, and August 21, 2012 while the cold temperature jar test scenarios (average 12° Celsius) were performed on December 18, 2012, January 3, 2013 and January 7, 2013. The same tests (discussed below) were repeated on each of the respective warm and cold temperature dates.

Warm temperature jar tests evaluated PAC (EPIC WW-70 provided by Holland Company, Inc.) and ferric chloride (provided by WEP) using 134 and 110 micron microsand under the following three dosing scenarios:

1) Dosing at the HRFS Influent Box under average flow (70 mgd) conditions.
2) Dosing in the Cross Channel at peak (130 mgd) flow.
3) Dosing in the Cross Channel under average flow conditions.

The cold temperature jar tests were performed after positive results were found regarding the 110 micron microsand. As a result, the 134 micron microsand tests were not performed for the cold temperature jar testing. Figures 3-1, 3-2 and 3-3 show the jar testing procedures that were used to simulate the three respective hydraulic scenarios.

Samples were collected by WEP staff from each of the jars after the testing protocol was performed, as well as from the raw water. The WEP Environmental Lab analyzed the samples for TP, TPP, TDP and SRP. See Section 2.2 of this report for additional information on WEP's QA/QC protocol and refer to Table 2-1 for additional information on the chemical analyses performed. Temperature and pH measurements were collected during the time of jar testing by CRA.

It should be noted that the results presented in this section are for comparative purposes only and should not be used to verify full-scale performance due to the large scale-up; Section 3.3 presents a discussion on full-scale testing results using PAC.

3.2.2 PAC TEMPERATURE DEPENDENCY TESTING RESULTS AND DISCUSSION

The average HRFS influent (untreated Cross Channel sample) TP during warm and cold temperature testing was 0.462 mg/L and 0.364 mg/L respectively. Figures 3-4 through 3-8 show the average influent warm and cold temperature TP, TPP, TDP and SRP in relation to the respective residual phosphorus concentrations after jar testing. The influent TDP was on average 60 percent of the TP during warm temperatures and 25 percent of TP during cold temperatures while influent SRP was 50 percent and 10 percent, respectively.

Results from the warm water temperature testing are contained in Appendix B and summarized in Table 3-1. Figure 3-4 shows the average residual TP from the three warm testing dates. In general, total phosphorus removal performance under warm water conditions for PAC and ferric chloride was equivalent. This is consistent with results from the 2011 optimization analysis. The PAC warm temperature indicated mixed results. When using 134 micron microsand, the longer contact time provided by applying PAC in the Cross Channel resulted in lower phosphorus concentrations. However, the Metro WWTP has changed from 134 to 110 micron microsand. At peak flows, PAC added to the HRFS Influent Box resulted in slightly lower phosphorus levels than when added at the Cross Channel. Under average flow conditions, phosphorus levels were lower when PAC was added to the Cross Channel. It is critical to note that bench-scale testing assumes ideal mixing conditions are provided, and that full scale testing conducted in 2011 clearly showed that thorough initial mixing was a more important driver in optimizing phosphorus removals in the HRFS process.

The majority of the testing data also shows improved performance using the 110 microns microsand, which is similar to the findings presented in Section 2.0. Based on these results and the full-scale microsand evaluation, 134 microns microsand was eliminated from the jar test scenarios for the cold water temperature testing. Therefore, the evaluation presented in this section focuses on the 110 micron microsand jar test results.

TABLE 3-1

Average Residual Total Phosphorus for 134 and 110 Micron Microsand During Warm Water Temperatures

Coagulant	*Dosing Scenario 1 (mg/L)*		*Dosing Scenario 2 (mg/L)*		*Dosing Scenario 3 (mg/L)*	
	134 micron Sand	**110 micron Sand**	**134 micron Sand**	**110 micron Sand**	**134 micron Sand**	**110 micron Sand**
PAC	0.165	0.115	0.110	0.120	0.103	0.077
Ferric Chloride	0.108	0.104	0.103	0.089	0.097	0.098

Table 3-2 summarizes a comparison of warm and cold temperature average residual TP results for each modeled scenario; all results are included in Appendix B. Figures 3-5, 3-6, 3-7 and 3-8 show these average TP, TPP, TDP and SRP results, respectively, for each dosing scenario. The results indicate that PAC effectiveness at reducing TP appears to decrease in cold temperatures, regardless of dosing location. The PAC cold temperature and ferric chloride warm and cold temperature results did not show a significant difference between Cross Channel and Influent Box coagulant addition. Jar testing also showed that TP removal using ferric chloride appears to improve under cold water conditions.

TABLE 3-2

Average Residual Total Phosphorus Concentrations for Warm and Cold Temperature PAC and Ferric Chloride Jar Testing

Coagulant, Temperature	*Scenario 1, 110 Micron Sand (mg/L)*	*Scenario 2, 110 Micron Sand (mg/L)*	*Scenario 3, 110 Micron Sand (mg/L)*
PAC, Warm	0.115	0.120	0.077
PAC, Cold	0.162	0.168	0.164
Ferric, Warm	0.104	0.089	0.098
Ferric, Cold	0.045	0.043	0.040

According to Figure 3-6, the majority of residual phosphorus is in the particulate form (TPP). As with the microsand testing, TDP and SRP are nearly eliminated using either PAC or ferric chloride (see Figures 3-7 and 3-8), which appear to perform equivalently. Furthermore, slightly lower effluent TDP and SRP concentrations were encountered in the cold water testing.

While bench-scale testing suggests it is possible that warm water TP removal performance using 110 micron microsand could improve as a result of cross channel dosing (although the results are not conclusive), it is critical to note that bench-scale testing assumes ideal mixing conditions are present. It was clearly shown in the 2011 optimization analysis that extensive channel modifications (including installation of static mixers) would be needed to ensure that proper initial mixing was provided and to provide balanced dosing across the four HRFS trains. These modifications would be difficult to optimize with the addition of a cross channel isolation wall (discussed in Section 5) and the presence of dynamic hydraulic conditions due to BAF operation. Also, the Cross Channel would be subject to floc settling and accumulation, and could continue to be exposed to the corrosive effects of ferric chloride. Comparatively, the HRFS Influent Box has a hydraulic jump and conditions readily conducive to thorough mixing. The chemical diffusers would be shorter, which improve the ability to properly disperse the coagulant and maintain the equipment. When adding to the Influent Box, each train would be flow paced by a flow meter to provide balanced dosing. Also, solids accumulation and corrosion effects in the Cross Channel would be mitigated.

3.3 FULL-SCALE TESTING OF PAC

3.3.1 FULL-SCALE PAC TESTING METHODOLOGY

Full-scale PAC testing was performed to achieve two objectives: 1) Verify the full-scale PAC demonstration results from the 2011 optimization analysis; and 2) Provide a suitable HRFS effluent to allow for determining if PAC-treated water has similar bioavailability and settling characteristics as ferric chloride-treated water. HRFS Train 4 was tested by adding the PAC into the Influent Box and Train 2 served as the control with ferric chloride addition. Full–scale PAC testing was conducted over two periods:

- PAC Test No. 1: July 11 to July 25, 2012
- PAC Test No. 2: August 27 to September 4, 2012

It is noteworthy that Train 1 was removed from service for much of PAC Test No. 1 due to low plant flows that made dosing with the existing chemical feed pumps difficult to control. Also, the PAC target dose was 10 mg/L from July 11 to July 16, 2012. The dosage was increased to 30 mg/L after July 16, 2012.

Effluent TP composite samples were collected from the HRFS Influent Channel and each HRFS effluent trough before, during and after each PAC testing period. Composite samples collected by WEP as part of its routine operations and compliance monitoring included secondary clarifier effluent TP; BAF influent TP; and final effluent TP, TDP, SRP, TSS and flow. These samples were analyzed by WEP's Environmental Lab in accordance with the methods summarized in Table 2-1.

UV transmissivity grab samples also were collected from HRFS Train 2 and Train 4 effluent troughs, as well as Metro WWTP's final effluent. A UV Photometer, Trojan P254-C Single Beam 0.0 to 100% T, as furnished by Koester Associates was used to field analyze the samples. Sampling was conducted on July 18, 2012 and September 4, 2012; three readings were taken on each day for each location.

3.3.2 FULL-SCALE PAC TESTING RESULTS AND DISCUSSION

Figures 3-9 and 3-10 show a comparison of Train 2 and Train 4 for PAC Test No. 1 and No. 2, respectively. The averages and standard deviations for both PAC tests as well as the time period (June 1, 2012 to July 10, 2012) before PAC Test No. 1 are provided in Table 3-3. During the period of time from June 1, 2012 through December 12, 2012 Metro WWTP's final effluent averages for SRP and TDP were 0.003 mg/L and 0.022 mg/L respectively, again showing that the HRFS process nearly eliminates these two parameters. This shows that the focus of TP removal through the HRFS process is optimizing particulate removals.

TABLE 3-3

Full-Scale PAC Testing Results for HRFS Train 2 and Train 4

Train	*Effluent TP (mg/L)*					
	Before PAC Test No. 1		*Test No. 1*		*Test No. 2*	
	Average	S.D.	Average	S.D.	Average	S.D.
2	0.103	0.031	0.101	0.011	0.077	0.022
4	0.088	0.038	0.084	0.014	0.046	0.011

Notes:
Before PAC Test No. 1 Dates: 6/1/12 - 7/10/12
Test No. 1 Dates: 7/16/12 - 7/25/12 (only includes samples under 30 mg/L PAC dose)
Test No. 2 Dates: 8/27/12 - 9/4/12

As shown in Figure 3-9, PAC dosed at 10 mg/L did not perform as well as ferric chloride (dosed at about 40 mg/L). Increasing the PAC dose to 30 mg/L, where it remained for the remainder of Test No. 1 and for Test No. 2, resulted in improved TP removal. At the higher dosage, the PAC-treated effluent had equivalent or slightly better TP removal than ferric chloride. During PAC Test No. 2 (see Figure 3-10), TP concentrations in Train 4 were distinctly and consistently lower than Train 2. The lower standard deviation in Train 4 during the second PAC test indicates lower variability as well. However, the relatively large TP difference between the trains during the second test may also be attributed to the smaller microsand size that was in Train 4.

Figure 3-11 shows the PAC test results along with the effluent TP before, between and after the two tests for comparison. This figure shows the PAC-treated train during Test No. 1 resulted in some improvement in phosphorus removal with respect to ferric chloride. The smaller microsand was added between the two PAC tests, which appeared to result in further improvement in effluent TP concentrations along with a general reduction in variability.

Test No. 2 consistently provided a lower effluent TP with lower variability than the ferric chloride-treated train. The smaller microsand was introduced between PAC tests. It should be noted that during Test No. 2 the 110 micron microsand was used in Train 4. It is likely that the smaller sand contributed to the observed improved performance rather than the PAC.

While these figures and the data in Table 3-3 show that the PAC-treated train performed better than the ferric chloride-treated train during both tests, this may be due to flow proportioning and associated coagulant dosing as well. From these data though, it can be concluded that PAC performed similarly to ferric chloride during the testing periods (warm weather dates) and may contribute to lower effluent TP variability. During the second PAC test, Train 4 had less variability than Train 2; however, it cannot be discerned if a further improvement of TP reductions was achieved due to the PAC addition.

A significant benefit of using PAC as the coagulant would be improved performance of the UV disinfection system. Iron absorbs UV light at the frequency used to disinfect water and wastewater, thus inhibiting performance. Table 3-4 summarizes the average UV transmissivity results from the two rounds of full-scale PAC testing. The PAC-treated effluent has a higher UV transmissivity than the ferric chloride-treated effluent. Note that it was expected the UV transmissivity would have been higher than measured; however, it is likely residual iron in Train 4 could have impacted the results since the PAC was added for a short period of time.

TABLE 3-4

UV Transmissivity Results During Full-Scale PAC Testing

Sample Location	*Average*	*St. Dev*
Train 2 Effluent (Ferric)	72	2
Train 4 Effluent (PAC)	77	1
UV Influent (Combined HRFS Effluent)	73	1

3.4 PAC BIOAVAILABILITY AND PARTICLE CHARACTERIZATION COMPARISON TO FERRIC CHLORIDE

A comparison of bioavailability of HRFS effluent treated with PAC and ferric chloride was performed by the Upstate Freshwater Institute (UFI) and Michigan Technological University (MTU). UFI also conducted particle characterization analyses of the PAC and ferric chloride-treated HRFS effluent. The complete reports of these comparisons are included as Appendix C; the reports were peer reviewed by AnchorQEA. Results from this data collection effort were used to determine if PAC-treated effluent had similar bioavailability and settling characteristics as effluent treated with ferric chloride. This would allow determining the need for adjusting the Onondaga Lake water quality models developed by UFI and AnchorQEA used in evaluating ACJ compliance actions and developing the TMDL.

3.4.1 BIOAVAILABILITY TESTING

3.4.1.1 METHODOLOGY

Soluble and particulate phase phosphorus bioavailability assays were performed on effluent from HRFS Train 2 (ferric chloride) and Train 4 (PAC). Sampling coincided with the two full-scale PAC tests described in Section 3.4. Pre-test samples were collected from the HRFS influent on June 26, 2012 and July 2, 2012. During each testing period paired samples of the Train 2 and Train 4 effluent were taken and analyzed. Paired samples were collected on July 18, 2012, July 25, 2012, August 28, 2012 and September 4, 2012. Figure 3-12 shows the sampling locations of the bioavailability and particle characteristics testing (Section 3.4.2). Samples were collected and processed by UFI; bioassays were performed by MTU. A photograph of a typical bioassay is shown on Figure 3-13. UFI also collected HRFS influent and Train 2 and Train 4 effluent samples which were analyzed for TP, TDP, and SRP. A detailed description of the analysis methodology is provided in Appendix C. The methodology was identical to the 2010 bioavailable phosphorus testing performed by UFI and MTU.

3.4.1.2 BIOAVAILABILITY TESTING RESULTS AND DISCUSSION

Table 3-5 summarizes the bioavailability assay results of the HRFS influent and effluent samples. Figure 3-14 shows a comparison of the particulate phosphorus bioavailability of the samples. These results, as noted in the full bioavailability report (Appendix C), illustrate the following:

- The soluble reactive phosphorus (SRP) is 100 percent bioavailable.
- The dissolved organic phosphorus (DOP) is not fully bioavailable; a refractory fraction was observed.
- The particulate phosphorus is not fully bioavailable; a refractory fraction was observed.

The bioavailability of the DOP component of the wastewater dropped from 79 percent in the HRFS influent samples to 21 percent and 15 percent in the ferric chloride-treated and PAC-treated effluent samples, respectively. The bioavailability of the particulate fraction dropped from 21 percent in the HRFS influent samples to 2 percent and 1 percent in the ferric chloride-treated and PAC-treated effluent samples, respectively. Although the bioavailable fractions of DOP and TPP were slightly lower in the PAC-treated effluent, they were not significantly different than the ferric chloride-treated effluent results. Based on this information it does not appear that the use of PAC would increase the bioavailability of the Metro WWTP effluent.

TABLE 3-5

Summary of Bioavailability Assay Results

Sample	*Designation*	*SRP f_{bio}*	*DOP f_{bio}*	*PP f_{bio}*
Screened Influent		1.00	0.84	0.17[1]
HRFS Influent	6/26/2012-A	1.00	0.85	0.18
	6/26/2012-B	1.00	0.86	0.29
	6/26/2012-C	1.00	0.76	0.24
	7/2/2012	1.00	0.67	0.14
Mean ± S.D.		1.00 ± 0.00	0.79 ± 0.09	0.21 ± 0.07
HRFS Effluent	7/18/2012	1.00	0.51	0.00
	7/25/2012	1.00	0.03	0.00
	8/28/2012	1.00	0.11	0.03
	9/4/2012	1.00	0.20	0.05
Mean ± S.D.		1.00 ± 0.00	0.21 ± 0.21	0.02 ± 0.02
HRFS Effluent PAC	7/18/2012	1.00	0.23	0.00
	7/25/2012	1.00	0.04	0.00
	8/28/2012	1.00	0.21	0.03
	9/4/2012	1.00	0.12	0.00
Mean ± S.D.		1.00 ± 0.00	0.15 ± 0.09	0.01 ± 0.02

Notes:

1. The Metro WWTP screened influent assay was lost due to membrane rupture. To provide a typical WWTP reference, results from a particulate phase bioassay of screened influent from the Portage Lake Water & Sewer Authority collected on June 9, 2011 was used.
2. f = bioavailability fraction of phosphorus species.

The impact of phosphorus on Onondaga Lake quality is dependent on both the concentration and bioavailability of phosphorus in the treatment plant effluent. As shown in Table 3-6, the Metro WWTP achieved an 88 percent reduction in total phosphorus and a 98 percent reduction in bioavailable phosphorus during the study period. The HRFS process converts the DOP and SRP fractions in the influent into the particulate, settleable and less bioavailable form.

TABLE 3-6

HRFS Phosphorus Concentration and Removal Efficiencies

		SRP (mg/L)	*DOP (mg/L)*	*PP (mg/L)*	*TP (mg/L)*
Phosphorus Concentration	HRFS Influent (μgP/L)	292.5	62.9	138.2	493.6
	HRFS Effluent (μgP/L)	2.1	26.3	31.4	59.7
	Removal (%)	99	58	77	88
Bioavailability Fraction	HRFS Influent	1.00	0.79	0.21	-
	HRFS Effluent	1.00	0.18	0.015	-
Bioavailable-P Concentration	HRFS Influent (μgP/L)	292.5	49.7	29.0	371.2
	HRFS Effluent (μgP/L)	2.1	4.7	0.5	7.3
	Removal (%)	99	91	98	98

3.4.2 PARTICLE SIZE CHARACTERIZATION ANALYSIS

3.4.2.1 METHODOLOGY

The particle characterization performed by UFI consisted of three analyses:

1. Particle size distribution (PSD) using scanning electron microscopy and X-ray analyses (SAX).
2. Particle projected-area concentration (PAV) per unit volume of water, which is used to quantify the concentration of suspended particle matter.
3. Particle settling velocity (SV) experiments.

Samples for particle characterization were collected concurrently with the bioavailable phosphorus samples. Samples were collected from the HRFS influent, as well as the effluent troughs in Train 2 and Train 4 (see Figure 3-12). Results from testing were compared to the settling characteristics of the ferric chloride-treated effluent determined during UFI's 2010 bioavailability testing program. UFI's particle size characterization report, which describes results and methodologies, is included in Appendix C.

3.4.2.2 PARTICLE CHARACTERIZATION RESULTS AND DISCUSSION

The goal of the particle characterization analysis is to compare the settling characteristics of the ferric chloride-treated and PAC-treated effluents and confirm that the use of PAC would not impact Onondaga Lake water quality differently than ferric chloride. Three analyses were performed to compare the characteristics of the particles: particle size distributions (PSD), particle project-area concentration (PAV), and settling velocity (SV) experiments.

Figure 3-15 shows the PSDs for the HRFS influent and HRFS effluent for ferric chloride-treated and PAC-treated (noted on the figure as Aluminum) samples. The PSD results indicated the following:

- Particle concentrations significantly decreased as a result of the HRFS treatment system.
- The concentrations of large-sized particles (e.g., > 8 micrometers [μm]) were much higher in the ferric chloride-treated effluent than those in the PAC-treated, while the differences in the 0.3 to 8 μm size range were minimal.
- The PSD shapes of 2010 and 2012 Metro WWTP effluent samples (ferric chloride-treated) were similar to each other.

The higher concentration of large-sized particles in the ferric chloride-treated train may be a result of image "break-up" in the analysis process. This process causes larger particles to be interpreted by the instrument as several smaller particles. Therefore, the results of the PSD analysis cannot be used as a sole indicator of particle characterization. PAV and SV studies help to further compare the difference between the ferric chloride and PAC-treated water.

PAV, with units of square centimeters per liter (cm^2/L), is a metric used to quantify the concentration of suspended particulate material. In general, the PAV levels in the effluent samples were low compared Onondaga Lake surface samples collected at the South Deep monitoring site. The PAV measurements of the HRFS influent, and ferric chloride and PAC-treated effluents show the following:

- PAV levels in the PAC-treated effluent were typically 3 to 4 times lower than the ferric chloride-treated effluent.
- All samples from the PAC-treated effluent contained iron. This iron may originate in the secondary treatment process or represent residual iron remaining on the microsand used in the HRFS train.

SV experiments were conducted on Metro effluent; five were conducted using retained 2010 samples and 15 were conducted using 2012 samples. Particle volume distributions were analyzed over time to determine the settling velocities of the different samples. Figure 3-16 shows a summary of the average particle density functions (number of particles per volume in a size class) for each type of effluent; this is an indicator of settling velocity. Table 3-7 summarizes the particle volume lost after 30 and 90 minutes of settling time. After 90 minutes the loss percentage is very similar for PAC-treated and ferric chloride-treated effluent samples.

TABLE 3-7

Percentage of Particle Volume Lost After 30 and 90 Minutes for Various Phosphorus Treatments

Treatment Period & Type	*% Particle Volume Lost After 30 Minutes of Settling*	*% Particle Volume Lost After 90 Minutes of Settling*
2010 HRFS Effluent FeCl	58%	75%
2012 HRFS Influent	63%	76%
2012 HRFS Effluent FeCl	61%	70%
2012 HRFS Effluent PAC	44%	71%

The SV experiments indicated the following:

- On the basis of the particle size distributions, there does not appear to be a significant difference between the ferric chloride-treated and PAC-treated effluent samples.
- Treatment with ferric chloride or PAC results in approximately the same SV for particles smaller than 49 microns; larger particles settled slower in the PAC samples.

In general, the particle characterization analyses do not show significant differences in settling velocities between the ferric chloride-treated and PAC-treated effluent. Within 90 minutes, approximately 70 to 75 percent of the particles were lost for all samples. This indicates that the particles in the effluent would settle quickly regardless of the coagulant used and hence not reach the pelagic zone of Onondaga Lake.

3.5 SUMMARY OF BIOAVAILABILITY AND PARTICLE CHARACTERIZATION COMPARISON

Testing results show that the bioavailability of particulate phosphorus in HRFS-treated effluent is extremely low using either PAC or ferric chloride as the coagulant. Particles in PAC-treated and ferric chloride-treated effluent also have similar particle characteristics, and would generally settle in Onondaga Lake before reaching the pelagic zone. These results are consistent with those reported by UFI in their 2010 bioavailability testing program (UFI, 2010). Therefore, it appears that HRFS effluent treated with PAC would have similar bioavailability and settling characteristics as effluent treated using ferric chloride.

UFI and AnchorQEA were asked to review the 2012 bioavailability and particle characteristic results and determine if any adjustments would be necessary to their respective water quality models of Onondaga Lake, which were used to facilitate evaluation of ACJ compliance actions and TMDL development. Both firms stated that, because the results were similar to those reported in 2010, no adjustments to the models are necessary. Therefore, it appears that switching to PAC at the Metro WWTP would not impact the bases used in developing the TMDL for phosphorus or in evaluating ACJ compliance actions.

3.6 PAC EVALUATION SUMMARY

These Optimization Pre-Implementation Studies sought to answer the following questions: 1) Is PAC effectiveness dependent on temperature? 2) Will PAC provide the same level of TP removal? 3) Does the use of PAC result in similar effluent bioavailability and particulate settling characteristics compared to ferric chloride? The studies summarized in this section found the following:

1. Regardless of temperature, coagulant type or sand size, the HRFS process nearly eliminated TDP and SRP, which are key contributors to phosphorus bioavailability.
2. Bench-scale testing results show that PAC phosphorus removal is temperature dependent and has lower effectiveness in cold water temperatures when compared to ferric chloride. However, PAC jar testing performance appears to be equivalent to ferric chloride for warm temperatures.
3. Full-scale testing (during warm weather) found that PAC appeared to perform equivalently to ferric chloride.
4. Testing showed that HRFS effluent treated with PAC would have similar bioavailability and settling characteristics as effluent treated using ferric chloride. Because the testing results were similar to those reported in 2010, no adjustments to the Onondaga Lake water quality models would be necessary. Therefore, it appears that switching to PAC at the Metro WWTP would not impact the bases used in developing TMDL or in evaluating ACJ compliance actions.

Furthermore, using PAC instead of ferric chloride is expected to yield the following benefits:

- Improved transmissivity of flows passing through the UV disinfection system.
- Mitigation of scaling on the UV system quartz sleeves.
- Reduced corrosion impacts.
- Reduced sludge generation and reduced release of phosphorus in the anaerobic digesters.
- Significant reduction in iron discharge to Onondaga Lake.

Based on the results of the testing presented herein, use of PAC for the HRFS system is expected to contribute to phosphorus optimization. However, in confirming the recommendation from the 2011 Optimization Analysis Report, PAC would be added during disinfection season and ferric chloride would be added during colder weather months.

4.0 HRFS MIXER PILOT TESTING

4.1 HRFS MIXERS: 2011 OPTIMIZATION REPORT FINDINGS AND PRE-IMPLEMENTATION STUDY GOALS

The 2011 optimization analysis showed that HRFS Trains 2 and 4 typically performed better than Trains 1 and 3. Some modifications such as relocation of the effluent sampler improved Train 3 TP removal, but Train 2 and Train 4 continued to have a lower mean effluent TP concentration. The analysis also identified that the physical configuration of Train 2 and Train 3 are mirror images of each other, but the mixers all rotate in the same direction (clockwise). Figure 4-1 shows the original configuration of the HRFS tanks. As a result, the mixing regimes in the coagulation and injection tanks appear to be different in Trains 1 and 3 than for Trains 2 and 4.

Tracer studies of the HRFS Coagulation Tanks for Trains 2 and 3, conducted in 2011, indicated that Train 3 may have a greater amount of short circuiting than Train 2. Lightnin Mixers and Kruger/Veolia were consulted at that time regarding the mirror image configurations and performance inconsistencies. Lightnin recommended reversing the mixer rotation in the Coagulation and Injection Tanks for Trains 1 and 3. The mixer blades would require replacement with mirror image propellers to maintain a downward pumping action. Additionally, Lightnin recommended adding a second propeller, located on the upper part of the shaft, to the Coagulation and Injection Tank mixers for all four trains to facilitate chemical-particle interactions. Kruger/Veolia did not oppose these changes.

The basis for the recommendations to modify the mixer impellers included the following:

1. Of primary importance are flow pattern changes that can reduce short circuiting in the Coagulation and Injection Tanks. Improved flow patterns, rather than significant additional mixer energy, are therefore needed to improve tank blending. Increasing mixer energy (i.e., increasing motor power) would result in increased shear rates, which would hinder the process goal of promoting floc formation.
2. Mixer reversal in Trains 1 and 3, and adding an upper impeller to all trains are not expected to increase impeller fluid shear rates.
3. Reversing the direction of mixer rotation in Trains 1 and 3 would result in a similar path for feed entering and flow exiting as in Trains 2 and 4 when the mixer rotation is considered.

4. The addition of an upper impeller would promote incorporation of surface fluid into the upper impeller and result in additional blending.

In 2011, full-scale pilot testing using one train was recommended to confirm the benefit and a design basis for proposed mixer modifications. An additional goal of pilot testing is to confirm that the modifications will not promote floc shear, which could result in increased solids carryover.

4.2 HRFS MIXER PILOT TESTING METHODOLOGY

Pilot testing included modifying the mixers in the Coagulation and Injection Tanks of the test train (HRFS Train 3) and comparing performance testing results to the control train (HRFS Train 2). Train 3 was selected because it has historically showed the highest average effluent TP concentrations and variability. Mixer modifications to Train 3 included installing a new mixer assembly (shaft, key and impellers) to reverse the mixer rotation while maintaining downward pumping. A second impeller (22.5 degree angle) was also installed on these assemblies. After a detailed selection process, John W. Danforth Company was contracted to implement the mixer modifications, which were completed between October 22 and 27, 2012. The submittal package for the new mixer assemblies is included in Appendix D.

A mixer evaluation testing plan development workshop was held on August 16, 2012 to discuss the proposed mixer modifications, as well as methods and logistics for performance testing. WEP, CRA, Siewert Equipment, SPX Lightnin and Kruger representatives were in attendance. During this meeting testing options were discussed and the testing plan components were determined. In addition to the testing plan, the addition of a Stamford baffle on the end wall below the Lamella clarifier was discussed. A baffle in this location would reduce short circuiting in the Lamella clarifier, as well as the potential for solids washout during a sudden increase in flow due to wet weather.

Data used for evaluating HRFS Train 3 mixer modifications performance included daily operational samples, specific performance testing samples and tracer testing of Trains 2 and 3. All sample collection and analysis were performed by WEP personnel. Operational and performance testing were performed in accordance with the sampling and analysis methods described in Section 2.2.

Specific performance testing grab samples were collected from the Train 2 and Train 3 clarifier effluent troughs and HRFS influent channel (see Figure 4-2 for sample locations). Samples were collected before mixer modifications on October 9, 10 and 11, 2012, and after mixer modifications on November 26, 27 and 28, 2012.

Trains 2 and 3 were operated at low (60 mgd target), medium (80 mgd target) and high (100 mgd target) flows before and after the mixer modifications in order to simulate the range of operating flows. Table 4-1 summarizes the target and simulated total HRFS influent flow on each of the sample dates. In order to simulate these flows, WEP staff strategically shut down HRFS trains to create the desired hydraulic conditions. The chemical analyses performed on these samples are listed in Table 2-1; PSD sampling and settleability tests were also performed to evaluate if the mixer modifications promote floc shear.

TABLE 4-1

Pilot Testing Period Influent Flow Data

Date	*Target HRFS Influent flow (mgd)*	*Simulated HRFS Influent flow (mgd)*
10/9/2012	60	60.7
10/10/2012	80	72.2
10/11/2012	100	103.4
11/26/2012	60	60.2
11/27/2012	100	102.4
11/28/2012	80	73.1

In addition to the analytical tests, tracer studies were performed on Train 2 and Train 3 to evaluate Coagulation and Injection Tank hydraulic conditions. One tracer study was performed on each train before mixer modifications on October 16, 2012, and three were performed on each train after mixer modifications on November 26, 27 and 28, 2012. Rhodamine B was used as the tracer; dosing was selected to balance the need to obtain measurable concentrations without discoloring the final effluent. The NYSDEC was informed of the anticipated rhodamine dye tests on September 25, 2012; approval for these tests was received on October 4, 2012. The City of Syracuse and Onondaga County Department of Health were also notified when testing would occur.

Samples were collected and rhodamine dye concentration measurements were taken at four locations in each train: three across the outlet of the coagulation tank and one in the center of the injection tank outlet (see Figure 4-3). The slug-dose method was used for testing. Nine grams of rhodamine dye was dumped into the flow stream as it entered the Influent Box. Samples were obtained from each sample point at the time of tracer addition; every 20 seconds for the first 9 minutes; every one minute for the next 9 minutes; and then every 2 minutes thereafter until 36 minutes elapsed. One WEP staff member was stationed at each sample location. Automatic sampler pumps, operating continuously, were used to lift the water from the tanks up to the operating floor. At the designated time interval, the pump discharge would be used to fill a 10-mm square cuvette. Samples were analyzed using a Turner Designs AquaFluor handheld fluorometer and turbidimeter after each set of paired tracer tests (Trains 2 and 3). The instrument has a rhodamine detection range of 0 to 400 ug/L.

4.3 HRFS MIXER PILOT TESTING RESULTS AND DISCUSSION

4.3.1 ANALYTICAL TESTING RESULTS

The analytical results collected during mixer testing are included as Appendix D. Table 4-2 summarizes the HRFS influent phosphorus speciation during performance testing. The influent total phosphorus is within the typical range and does not indicate that overloading took place during the testing period. As expected, influent TDP and SRP concentrations are significant portions of the influent TP.

TABLE 4-2

HRFS Influent Flow Data for Mixer Performance Testing Period

Date	*TP (mg/L)*	*TPP (mg/L)*	*TDP (mg/L)*	*SRP (mg/L)*	*Simulated HRFS Influent Flow (mgd)*
10/9/2012	0.310	0.181	0.129	0.077	60.7
10/10/2012	0.348	0.169	0.179	0.123	72.2
10/11/2012	0.334	0.166	0.168	0.131	103.4
11/26/2012	0.339	0.236	0.103	0.058	60.2
11/27/2012	0.284	0.192	0.092	0.037	102.4
11/28/2012	0.401	0.283	0.118	0.057	73.1
Average	0.336	0.205	0.132	0.081	-
S.D.	0.039	0.046	0.035	0.038	-
Average % of TP	-	61%	39%	24%	-

Figure 4-4 shows the Train 2 and Train 3 effluent total phosphorus results during the mixer performance testing. Table 4-3 summarizes the Train 2 and Train 3 phosphorus speciation data results during performance testing. As with microsand and PAC testing, TDP and SRP are substantially reduced and levels do not appear to be affected by mixing configuration. Particularly of note is the reduction of SRP from 24 percent of the influent TP to less than 4 percent of the effluent TP. This suggests that the chemical interactions used to reduce SRP and TDP levels occur within the Influent Box with rapid kinetics. The data also show that the difference in TP and TPP concentrations between Trains 2 and 3 were much smaller after the mixer modifications were completed. However, this represents a small number of data, particularly under varying flow conditions.

TABLE 4-3

Train 2 and 3 Average Effluent Phosphorus Species Concentrations for Mixer Performance Testing Period

Sampling Location		*TP (mg/L)*	*TPP (mg/L)*	*TDP (mg/L)*	*SRP (mg/L)*
Before Mixer Modifications	Train 2	0.052	0.031	0.020	0.002
	Train 3	0.081	0.060	0.021	0.003
After Mixer Modifications	Train 2	0.052	0.028	0.024	0.002
	Train 3	0.059	0.038	0.021	0.001

Note: The 10/9/12 TP and TPP data is an outlier and has been removed from this summary

Effluent TP operational data were used to enlarge the dataset for evaluating mixer modifications under varying flow conditions. Table 4-4 summarizes the effluent operational total phosphorus data (June 2012 to December 2012) for Trains 2 and 3 before and after mixer modifications. Figure 4-5 shows the Train 3 effluent TP and total plant flow before and after mixer modifications. Figure 4-6 shows the Train 2 and Train 3 effluent TP before and after mixer modifications. Train 2 (control) maintained a similar average TP concentration before and after the mixer modifications, as well as a similar standard deviation. This is expected since no changes were made to Train 2. Train 3, however, showed a greater than 25 percent reduction in TP concentration while the standard deviation decreased by more than half after the mixers were modified. More significantly, Metro WWTP HRFS influent flows were higher and more variable in the period after mixers modifications (see Table 4-4). Therefore, the mixer modifications appear to have resulted in reduced effluent TP levels, as well as reduced variability.

TABLE 4-4

Train 2 and Train 3 Average Effluent Total Phosphorus and HRFS Influent Flow Before and After Mixer Modifications (June 2012 – December 2012 data)

Sample Period	*Train 2 TP (mg/L)*		*Train 3 TP (mg/L)*		*HRFS Influent Flow (mgd)*	
	Average	*S.D.*	*Average*	*S.D.*	*Average*	*S.D.*
Before Mixer Modifications	0.091	0.031	0.107	0.035	48.899	7.155
After Mixer Modifications	0.086	0.034	0.079	0.016	54.178	13.730

4.3.2 PARTICLE CHARACTERIZATION RESULTS

Particle area per unit volume (PAV), particle size distributions (PSDs) and settleability analyses were performed on the Train 2 and Train 3 maturation tank effluent to determine if changes to particle and floc dynamics (formation and shear) occurred as a result of mixer modifications. UFI collected and analyzed the PAV and PSDs of the Train 2 and Train 3 effluent before (October 9 to 11, 2012) and after (November 26 to 28, 2012) mixer modifications. PSD and PAV were determined using the methods summarized in Section 3.4.2. UFI's report can be found in Appendix E. WEP collected and analyzed settleability samples after the mixer modifications were completed; these were collected on November 26, 27 and 28, 2012.

PAV represents the total surface area of the particles within a unit quantity of volume, represented as cm^2/L. Figure 4-7 shows the average effluent PAV of the Train 2 and Train 3 samples before and after mixer modifications. Table 4-5 summarizes the contribution of the different size classes to total PAV. Particles greater than 10 microns are typically associated with the coagulation process while particles smaller than 10 microns tend to be considered "natural" or not chemically enhanced.

TABLE 4-5
Contribution of Particles in Different Size Classes to PAV

Sample Location		*Size Class (microns)*				
		<1 (%)	***1–5 (%)***	***5–10 (%)***	***10–40 (%)***	***>40(%)***
Before Mixer Modifications	Train 2	1.5	19.0	13.5	52.7	13.3
	Train 3	1.1	15.3	12.7	48.3	22.6
After Mixer Modifications	Train 2	0.8	11.7	15.3	63.6	8.6
	Train 3	0.3	6.3	12.3	71.7	9.4

Before the mixer modifications, the grab samples collected over the 3-day period showed that Trains 2 and 3 had a similar effluent PAV, and the distribution of particles (greater than versus less than 10 microns) were similar. As shown in Figure 4-7, the effluent PAV of Train 3 after mixer modifications was double that of Train 2.

The effluent PSD trends for both trains were similar (see Figure 4-8 and Table 4-5). The percent of particles in the 10 - 40 micron range increased after mixer modifications (larger increase for Train 3) while the percent of particles in the >40 microns size class decreased. The percent of particles in the 1 - 10 micron size class also decreased after mixer modification (larger decrease for Train 3). In general, PSD results show the majority of particles in each train are a result from the coagulation process.

Table 4-6 summarizes the average TP, TSS and settleable solids of the two trains before and after mixer modifications during the six mixer performance testing dates. Note that the TSS from Trains 2 and 3 and TP from Train 3 collected on October 9, 2012 appeared abnormally high; these were considered outliers and removed from the analysis. While the PAVs were different between the trains after mixer modifications, the TSS results were similar between the trains before and after mixer modifications. The settleable solids of the Train 3 effluent were greater than those of Train 2.

TABLE 4-6

Average Effluent TP, TSS and Settleable Solids

Sample Location		*TP (mg/L)*	*TSS (mg/L)*	*Settleable Solids (mg/L)*
Before Mixer Modifications	Train 2	0.052	6.50	-
	Train 3	0.081	6.50	-
After Mixer Modifications	Train 2	0.052	6.67	0.67
	Train 3	0.059	6.50	1.53

These analyses were performed to determine if there is any clear evidence that the mixer modifications promote floc shear. The increased number of particles and greater settleable solids could suggest that the mixer modifications may promote some level of floc shear, but this may be within the typical variability of the process. PSDs also appear to shift, but were generally similar for both trains. Furthermore, performance and operational data show that Train 3 effluent TP concentrations decreased, as did variability upon implementation of the mixer modifications. Also, TSS levels between Train 2 and Train 3 are similar, which indicates similar performance.

4.3.3 TRACER STUDY RESULTS

Tracer testing was performed to evaluate the hydraulic response from the Trains 2 and 3 Coagulation and Injection Tanks due to the mixer modifications. The Coagulation and Injection Tanks are hydraulically designed to operate as two continuously-stirred tank reactors (CSTRs) in series. Figure 4-9 shows the theoretical ideal response of different numbers of CSTRs in series to a slug tracer input. The Coagulation Tank, being the initial tank (n=1), ideally should have an instantaneous spike to the target tracer concentration (C_o) followed by a gradual decline in tracer. The Injection Tank, being the second tank (n=2) ideally should have a rapid increase quick rate of change to the maximum concentration of tracer (less than C_o) followed by a more gradual uniform decline of tracer. A hydraulic response that closely approximates these theoretical curves represents the best mixing conditions.

Tracer testing performed on October 16, 2012 was used to evaluate Trains 2 and 3 mixer hydraulic response before modifications were implemented. Figures 4-10 and 4-11 show the tracer test results at Coagulation Tank sample location 2 and sample location 3 (reference Figure 4-3), respectively. Note that the initial lag in concentration from these tracer response curves is because tracer was added to the top of the Influent Box. For the purposes of this analysis, the Influent Box was assumed to have ideal plug flow conditions. At a dose of 9 grams, the initial concentration in the Coagulation Tanks should ideally be approximately 63 ug/L. In general, Train 2 and Train 3 had similar response curves for the Coagulation Tanks. At sample location 2, both trains had similar peaks (45 ug/L). At sample location 3, Train 2 had a higher peak concentration (51 ug/L vs. 42 ug/L) and the peak occurred sooner. Based on mixer rotation in Train 3, sample location 1 would likely see the peak concentration sooner and be higher than sample location 3, which is an indication of some short circuiting.

The tracer response of the Train 3 Coagulation Tank after the mixer modifications were completed as compared to Train 2 at sample location 2 and sample location 3 are shown on Figures 4-12 and 4-13, respectively. At sample location 2, HRFS Train 2 and Train 3 had similar peak concentrations (53 ug/L vs. 51 ug/L). At sample location 3, the peak for Train 3 was much closer to Train 2 (52 ug/L vs. 56 ug/L) than before the mixer modifications. The Train 3 peak also occurs sooner at sample location 3, a reflection of reversing mixer rotation. The response curves for Train 2 and Train 3 at both sample locations had similar response curves.

A more significant difference in hydraulic response between Trains 2 and 3 was identified in the Injection Tank, which is shown on Figure 4-14. The Train 2 response curve reasonably approximated the ideal curve. However, Train 3 showed a significantly poorer response. The curve for Train 3 had substantial swings in tracer concentration and a lower peak concentration as compared to Train 2. Discussions with SPX/Lightnin (mixer manufacturer) indicated this "pulsing" of tracer is representative of short circuiting within the Injection Tank.

Implementing mixer modifications resulted in a substantial improvement in Train 3 Injection Tank tracer response. Figure 4-15 shows the tracer response from the three post-mixer modifications tests as compared to the pre-modifications test. As can be seen, the peak concentration is much higher and pulsing is greatly reduced in the post-modifications samples. The curves for the post-modifications tests also closely resemble the ideal curve. When comparing to Train 2 (see Figure 4-16), the Train 3 curve has a similar shape and peak concentration. This indicates that mixer reversal and adding the second impeller has resulted in the Train 3 Injection Tank to have a similar hydraulic response as Train 2.

4.4 MIXER MODIFICATIONS SUMMARY

Operational and performance testing results showed a significant improvement to effluent TP levels and substantially reduced variability after implementation of the mixer modifications. These significant improvements continued during periods of higher flow at the plant relative to flows in the sampling period prior to mixer modifications. As with microsand and PAC testing, TDP and SRP are nearly eliminated in the HRFS process, and concentrations do not appear to be affected by mixing configuration. This suggests that the chemical interactions with the bioavailable fractions of phosphorus occur in the Influent Box with rapid reaction kinetics.

The PAV, PSD and settleability do not show strong evidence of significantly greater particle shear in Train 3 after mixer modifications. Tracer testing indicates a substantial improvement in hydraulic response within the Injection Tank of Train 3 due to the mixer modifications. Since the modifications, Train 3 has a similar hydraulic regime to that of Train 2. The Coagulation Tank response also showed some minor improvement with respect to Train 2, although both trains had tracer response curves somewhat similar to the ideal response curve.

Based on the results of the testing presented herein, implementing the modifications recommended in the 2011 Optimization Analysis Report is expected to contribute to phosphorus removal optimization. Additionally, a Stamford baffle, located at the end wall below the Lamella clarifier should be implemented to reduce short circuiting and facilitate optimizing the clarifier performance.

5.0 CROSS CHANNEL ISOLATION WALL EVALUATION

5.1 METRO WWTP 2011 OPTIMIZATION REPORT FINDINGS AND PRE-IMPLEMENTATION STUDY GOALS

Balancing flow across the HRFS trains and managing dynamic hydraulic conditions within the Cross Channel is considered essential for Metro WWTP optimization to mitigate overloading of individual trains and provide options to further optimize. Computational Fluid Dynamics (CFD) modeling was used during the 2011 optimization analysis to show that dynamic hydraulic conditions within the Cross Channel significantly impacted the ability of operations staff to balance flow across the HRFS trains. The flow imbalance can be seen visually on Figure 5-1, which represents the velocity contours at a flow rate of 70 mgd with all 18 BAF units operating (balanced BAF operation). In this figure, red and yellow represent the highest velocities and green and blue represent the lowest.

Cross Channel hydraulic conditions and HRFS balancing are significantly affected by both the plant flow rate and BAF operational configuration (e.g., number of filters running, which filters operate, backwashing, etc.). The BAF SCADA system typically controls which filters are online, idle and backwashed based on numerous factors, including SEPS flow, headloss, time in service and time idle. This leads to an apparent random operation of the filters where the filters in operation can become unbalanced between the two BAF trains. For example, one BAF train can have six filters operating while the other side has three. Figure 5-2 summarizes the percentage of time on a typical day that an unbalanced BAF configuration occurs with respect to flow. Unbalanced operation is defined as when more than 60 percent of the filters from one BAF train (nine filters per train) are operating. Unbalanced operation can occur between 20 and 50 percent of any given day, with unbalanced operation more frequently occurring under lower flows.

CFD modeling along with full-scale testing showed that the use of non-modulating, motorized adjustable weirs appears to be a means to promote improved flow balancing. Because small changes in weir height can induce large changes in flow, modulating weirs would be operationally complex and likely not successful. Full-scale testing indicated that at average and higher flows, a single weir setting may reasonably balance flow across the four trains. Figure 5-3 summarizes modeled and measured results from the 2011 optimization analysis with the Train 4 influent weir raised 4 inches and Trains 2 and 3 weirs raised 1 inch; flow across all four HRFS trains was reasonably balanced under average and high flow conditions. However, a significant flow imbalance could still occur under lower flows, which was shown in Section 1.3.2 (see Table 1-1). Low plant flows occurred for an extended period of time in 2012. Furthermore, other 2011 Optimization Analysis Report recommendations, along with energy reducing operational changes being considered by WEP, could add complexity to flow balancing efforts.

There is currently no means to isolate the BAF Effluent Channel, Cross Channel or HRFS Influent Channel for maintenance. Further complicating issues is that the HRFS bypass sluice gate has a damaged stem and is not operational. Therefore, if any channel must be shut down, or the BAF process or the HRFS system must be shut down, the entire tertiary treatment system (BAF, HRFS and UV systems) must be taken out of service. When this happens, elevated levels of ammonia and phosphorus are discharged and make permit compliance more challenging. Maintenance required in the channel also must be performed. Examples of maintenance needs include:

- Repair of the protective liner in the channels. This liner has reportedly been deteriorating, possibly as a result of poor surface preparation.
- Calibration and maintenance of instruments in the channels.
- Periodic cleaning of settled solids.
- Inspection and maintenance of the BAF cells and HRFS trains.
- Inspection and maintenance of 72 BAF cell isolation gates.

Installation of a wall splitting the channels between the BAF and HRFS processes would allow for maintenance of the channels, BAFs, and HRFS system without removing the entire tertiary treatment system from service. When maintenance is performed under lower flow conditions, Metro WWTP effluent would receive full tertiary treatment, which would help with SPDES permit compliance. However, installation of a wall to isolate the BAF trains could significantly impact flow balancing across the four HRFS trains, particularly if unbalanced BAF operation continues. Another challenge may occur during periods of lower flow. The plant would be able to operate using three HRFS trains thus reducing energy use; however, the isolation wall must be designed to allow reasonably balanced flow across all three trains.

Because of these challenges, additional CFD modeling was recommended to determine the need to refine the design of the isolation wall between the BAF and HRFS systems. The objective of this modeling is to determine the wall configuration that mitigates large differences in weir gate positioning and minimizes the need to frequently change HRFS weir positions as the flow changes.

5.2 CROSS CHANNEL WALL EVALUATION METHODOLOGY

A three-dimensional CFD model was developed and validated by HDR, Inc. during the 2011 optimization analysis to evaluate alternatives for improving flow balancing across the HRFS trains using FLUENT software. The model includes the effluent from the 18 BAF filters, BAF Effluent Channel, Cross Channel, HRFS Influent Channel and the influent weirs to each HRFS train. The model was constructed based on available record drawings. A survey was performed to confirm HRFS weir heights and lengths.

The CFD model was used to perform a series of steady state analyses to simulate the hydraulic conditions. Flow enters the system via the BAF cells and exits over the four weirs leading into the HRFS. Any combination of BAF cells can be simulated, which allows for modeling of the dynamic hydraulic conditions present at the Metro WWTP. The CFD model was calibrated to match the measured flow distribution to each HRFS train under low, average and high flow conditions (40 mgd, 70 mgd and 130 mgd, respectively).

The primary metric for the Pre-Implementation Studies was the HRFS flow distribution across the four trains. Modeling first focused on development of an isolation wall and channel configuration that would ideally reduce dead zones and result in flow balance across the HRFS trains with minimal or no weir gate adjustment at the HRFS Influent Box. The positive and negative impacts of the ideal configuration would then be considered and a final configuration selected. Once the final wall/channel configuration was selected, an analysis under varying flow, BAF and HRFS operating configurations was performed to verify that resulting weir adjustments to balance HRFS flow would not be considered excessive.

5.3 CFD SIMULATION RESULTS AND DISCUSSION

5.3.1 BAF OPERATION

The focus of the Pre-Implementation Studies CFD analysis involves determining physical and operational changes and impacts from installing an isolation wall to completely divide the BAF and HRFS trains in half. Metro WWTP staff indicated that any gates installed in the isolation wall would typically be left closed unless a BAF or HRFS train were taken out of service. This approach would require operation of the BAFs to be modified to require generally the same number of filters to be in operation on the north and south BAF trains. If the current operation were maintained, there would be significant portions of time where two of the HRFS trains would be underloaded while the other two would be overloaded.

Kruger/Veolia was consulted to determine if the BAF system operating program could be modified to implement balanced filter operation. For example, filters would turn on and off in pairs (one in each train) so that an equal number of filters from each train are typically running. Note that a small imbalance would continue to occur when a filter is being backwashed. Kruger/Veolia indicated that, while extensive, the operating program could be modified to provide balanced BAF operation. It is anticipated that programming changes would be completed and tested during construction of the optimization improvements when the tertiary treatment system would be out of service.

Another potential concern is the availability of water for backwashing the BAF units. As noted previously, the BAF Effluent, Cross Channel and HRFS Influent Channel are used as the supply well for BAF backwashing. When plant flow is less than backwash rates, the channels ensure sufficient water supply is available. Installation of a wall to isolate the BAF trains would reduce the volume available in the channels for filter backwashing, particularly when one side is down for maintenance or when the isolation gates are down.

An evaluation was performed during the 2011 optimization analysis of the impact that a backwash would have on water level in the channels. Assumptions were that one half of the filters are out of operation, Metro WWTP is treating a minimum daily flow of 40 mgd (33 mgd minimum hourly flow) and that backwashing procedures are similar to current practice. The analysis showed that sufficient water was being produced in the BAFs to offset losses through a filter backwash. Therefore, the water level was determined to not be impacted by the isolation wall.

However, unprecedented dry weather occurred in 2012. Minimum plant flows were substantially lower than previously anticipated. Therefore, potential impact to BAF backwashing was reevaluated based on a minimum hourly flow of approximately 25 mgd. Under the new minimum flow conditions and current backwashing practice, sufficient water would still be available for backwashing. However, changing backwash practices would need to be checked before implementation.

5.3.2 <u>ISOLATION WALL/CHANNEL CONFIGURATION</u>

The CFD modeling first focused on establishing the wall and channel configuration. For this analysis, no gates were included and balanced BAF operation was assumed, which is anticipated to be the typical mode of operation. The objective was to determine if a wall/channel configuration could be developed that would allow flow balancing across the HRFS trains with no weir gate adjustment. For this analysis, the originally designed weir gate elevations were used.

The initial test configuration, which includes square-cornered walls and no significant concrete fill was used, is shown on Figure 5-4. The wall was equidistant from both sides. Essentially, each side of the isolation wall operates independently; however, the flow balance changes with flow. In general, the flow balance was generally reasonable. The maximum difference in flow between Trains 3 and 4 was about 13 percent, while the difference between Trains 1 and 2 was approximately 5 percent.

The wall/channel configuration was modified using an iterative process to evaluate how changes in configuration impacted flow balance under average flow conditions. Modifications evaluated included:

- Using curved walls
- Installing flow splitting baffles
- Constructing fillets at sharp–edged corners
- Adjusting the flow path within the channels
- Changing the cross-sectional width of the channels

A key finding from this analysis showed that changes in configuration impact flow balancing. There were “trip points” on some curve sections that had a large effect on flow balance by making what would be considered a minor adjustment. Because of these potential impacts, the wall design would need to allow for post-construction adjustments to these trip points to fine-tune the flow balance.

Through this iterative process, an “optimal” wall configuration was determined. This configuration and resulting HRFS flow distribution are shown on Figure 5-5. With this configuration, excellent flow balance could be achieved throughout the typical flow range in the HRFS system, with a difference of less than 5 percent. This would mitigate the need for adjusting weir gates during conditions of balanced BAF operation and all four HRFS trains operating. However, a number of potential impacts were identified with this configuration that could limit flexibility, including:

- There could be substantial periods of time when only three HRFS trains would operate to reduce energy use during extended low flows. Another operating condition identified was that 90 mgd of flow could be generated from one BAF Train (the second train shut down) and that three HRFS trains would be in operation. The wall/channel configuration would not be designed for these conditions, thus requiring weir adjustments.
- The configuration induces constriction of the flow path to Train 4. This could potentially result in high headloss and subsequent use of the HRFS bypass.
- Installing the isolation wall effectively reduces available BAF backwash volume in half. Adding concrete fill would further reduce available backwash volume.
- Post-construction adjustments would likely be required to fine-tune the flow distribution.
- The optimized wall/channel configuration would require more time and cost to construct, thus increasing tertiary treatment downtime.

Based on this analysis, it was determined that maximizing operational flexibility was of significant importance to WEP, particularly as the initial wall configuration did not have a significant imbalance when compared to the optimized configuration. The optimization improvements already include adjustable weir gates and individual HRFS train flow monitoring and chemical feed flow pacing. These improvements would allow for balancing the hydraulic load and coagulant feed. Therefore, it was decided to use the initial wall configuration shown on Figure 5-4, provided that weir gate settings to balance flow would not be excessive.

5.3.3 VERIFICATION OF WALL/CHANNEL CONFIGURATION

Upon selection of the wall/channel configuration, CFD simulations were performed to verify that weir adjustments required to achieve balanced flow across the HRFS trains throughout the plant operating range would not be considered excessive. The first verification runs involved weir adjustments under balanced BAF operation and all four HRFS trains operating. As shown on Figure 5-6, adjusting the Train 1 weir upward by 3 inches and the Train 4 weir upward by 2 inches resulted in an excellent flow balance throughout the plant operating envelope. Note that the facility is currently operating without difficulty with the Train 4 weir 4 inches higher than the Train 1 weir.

The second set of verification runs involved selection of a worst case scenario. This scenario was identified as one BAF train out of service, the other BAF train treating 90 mgd of flow and three HRFS units in service. The train that required flow to travel the longest path was always kept in service. All HRFS weirs are at the original design elevation. To enable flow balancing under this scenario, four slide gates would need to be installed. Two gates (Gates 1 and 2 as shown on Figures 5-7 and 5-8) would be installed in the Cross Channel perpendicular to the flow, at the interface of the BAF Effluent and Cross Channel. This would allow isolation of each BAF train. These gates would be approximately 13-ft. wide. The other two gates (3 and 4) would be installed within the Cross Channel isolation wall to allow flow to all HRFS trains when a BAF train is out of service, facilitate flow balance when only three HRFS trains are operating or if the HRFS bypass is being used. These two gates would be 10-ft. wide. All four gates would have motorized actuators and be fabricated of corrosion resistant material (stainless steel or fiberglass). A grating system would be installed to allow operators to access the sluice gate actuators.

Figures 5-7 and 5-8 present the velocity contours and flow balance with BAF flow only from the North train and South train, respectively. The results show that a maximum difference in flow distribution (Train 4 vs. Train 1) would be about 20 percent. Based on the modeling efforts and full-scale testing conducted in 2011, small weir adjustments would be expected to balance flow.

5.4 CROSS CHANNEL ISOLATION WALL EVALUATION SUMMARY

Discussions with Kruger/Veolia indicated that the BAF operating program could be modified to allow balanced operation of the filters. It was also determined that BAF backwashing, under current practice, would not be affected by the lower flows experienced during summer 2012 or by a reduction in available backwash supply volume should the isolation wall gates be closed. CFD modeling showed that, without the ability to change weir elevations at the HRFS Influent Boxes, flow across the HRFS trains would be somewhat unbalanced. However, the use of adjustable weir gates would facilitate flow balancing under expected operating conditions. Installation of slide gates within the Cross Channel and isolation wall would allow one BAF train to be shut off and balanced flow to be delivered to the HRFS system. The gates also would permit shut down of one HRFS train during periods of extended dry weather, which would result in reduced energy use. In addition to the weir gates, implementation of individual flow monitoring and coagulant feed flow pacing would facilitate balanced coagulant dosing to each HRFS train.

Based on the results of the testing presented herein, implementing the modifications recommended in the 2011 Metro Optimization Analysis Report is expected to contribute to phosphorus removal optimization.

6.0 RESULTS AND RECOMMENDATIONS SUMMARY

The Metro WWTP Optimization Analysis of Total Phosphorus Treatment Report was approved by the NYSDEC in December 2011. Recommended actions included modifications to the existing process, hydraulics, operations procedures and maintenance schedules related to optimizing the current facility in support of ACJ compliance. Implementation of the recommended actions are intended to provide Metro WWTP operations staff with the tools for improving phosphorus treatment performance and reliability while reducing effluent variability.

While performing the optimization analysis resulted in a significantly improved understanding of Metro WWTP phosphorus treatment processes and how inherent variability affects effluent concentrations, additional issues and potential refinements were identified near the end of the evaluation that could not be studied within the framework of the mandated schedule for the report. Therefore, the report recommendations included the following evaluations (Pre-Implementation Studies) to be completed prior to proceeding with design of improvements:

1. An assessment of the potential use of smaller effective-size microsand in the HRFS system.
2. Evaluation of the potential feasibility of year-round PAC addition to the HRFS system, along with an assessment of the potential Onondaga Lake response from using PAC instead of ferric chloride as the coagulant.
3. Establishment of the Cross Channel isolation wall configuration that minimizes the need to change HRFS weir positions as the flow changes.
4. Performance of a mixer modifications pilot test.

For these efforts, optimization was defined as determining the recommended modifications that promote conditions leading to improved treatment performance and reliability, while maintaining the ability of the WWTP to reliably meet all other treatment and performance requirements. The intent of optimization also is to identify opportunities for reducing effluent variability.

The results of these Pre-Implementation Studies were used to update the recommended improvements for optimizing phosphorus removal at the Metro WWTP. The key findings and recommendations from these studies are presented in the following sections.

6.1 MICROSAND EVALUATION

Bench-scale testing conducted during the 2011 optimization analysis showed that improved phosphorus removal may be possible using a smaller effective-size microsand (110 micron). However, the bench testing does not simulate continuous flow conditions where the benefits of a smaller particle could be offset by increased solids carryover. Therefore, a full-scale evaluation was performed to confirm that improved phosphorus removal occurs along with the impact to solids carryover.

Phosphorus results from the performance testing period and operational data from June through December 2012 confirmed that the 110 micron microsand resulted in lower total and particulate phosphorus concentrations in the HRFS effluent. Effluent variability of TP concentrations also appeared to be reduced by changing to the smaller microsand. Fixed solids and TSS measurements combined with visual observations during testing showed that no additional solids carryover was apparent from using the smaller microsand.

WEP completed changeover to the smaller microsand in the entire HRFS system by January 2013. However, since the sand in all four HRFS trains was replaced, an increase in sand usage rate has been observed. Additional testing indicated that the sand loss appears to be primary through the sludge and not from carryover in the effluent troughs. Modifying the apex tip diameter in the hydrocyclone may allow for optimizing sand recycle. Also, the higher sand usage rate remains within the expected operation of the HRFS system according to the O&M manual. Based on these results, use of a smaller microsand is expected to contribute to optimizing phosphorus removal at the Metro WWTP. Operations staff will continue to monitor the sand losses; additional operational changes will be explored if the sand losses exceed the manufacturer's estimated value.

6.2 POLYALUMINUM CHLORIDE ANALYSES

A full-scale demonstration conducted during the optimization analysis showed that PAC could be added at the HRFS influent boxes during periods of warmer temperatures. However, bench-scale testing and a literature review suggested that additional contact time may be needed during colder temperatures. Under this project, a detailed bench-scale testing program was performed to evaluate if a PAC temperature dependency would exist at the Metro WWTP. Additionally, while using PAC during the full-scale demonstration was shown to have equal performance to ferric chloride with respect to phosphorus removal, no testing was conducted to determine if PAC-treated effluent would have similar bioavailability and settling characteristics as ferric chloride. The near-elimination of bioavailable phosphorus using ferric chloride was crucial to the development of the water quality models used in establishing a revised Onondaga Lake TMDL. Therefore, one of the Pre-Implementation Studies involved verifying if PAC treated effluent would have the same particulate bioavailability and settling characteristics as ferric chloride-treated effluent.

The temperature dependency question was evaluated using jar testing for the two coagulants (ferric chloride and PAC) at warm and cold temperatures. The effluent bioavailability and particle settling questions were evaluated through full-scale testing which used Train 2 as the control (continued use of ferric chloride) and Train 4 as the test (modified to use PAC). The results of the studies included the following:

1. Regardless of temperature, coagulant type or sand size, the HRFS process nearly eliminated TDP and SRP, which are key contributors to phosphorus bioavailability.
2. Bench-scale testing results show that PAC phosphorus removal is temperature dependent and has lower effectiveness in cold water temperatures when compared to ferric chloride. However, PAC jar testing performance appears to be equivalent to ferric chloride for warm temperatures.
3. Full-scale testing during warm weather found that PAC appeared to perform equivalently to ferric chloride.
4. Testing showed that HRFS effluent treated with PAC would have similar bioavailability and settling characteristics as effluent treated using ferric chloride. Because the testing results were similar to those reported in 2010, no adjustments to the Onondaga Lake water quality models would be necessary. Therefore, it appears that switching to PAC at the Metro WWTP would not impact the bases used in developing TMDL or in evaluating ACJ compliance actions.

In addition to similar warm temperature performance as well as bioavailability and settling characteristics, using PAC instead of ferric chloride is expected to yield the following benefits:

- Improved transmissivity of flows passing through the UV disinfection system
- Mitigation of scaling on the UV system quartz sleeves
- Reduced corrosion impacts
- Reduced sludge generation and reduced release of phosphorus in the anaerobic digesters
- Significant reduction in iron discharge to Onondaga Lake

Based on the results of the testing presented herein, the use of PAC for the HRFS system is expected to contribute to phosphorus optimization. These studies also confirmed the 2011 Optimization Analysis Report operations recommendation that PAC should be used during disinfection season (warmer temperatures) and ferric chloride should be used during colder weather months.

6.3 MIXER PILOT TESTING

A combination of desk-top and preliminary tracer studies were completed during the 2011 optimization analysis as the basis for recommending modifications to the HRFS Injection and Coagulation Tank mixers. Reversal of the mixer rotation in these two tanks for HRFS Trains 1 and 3 was recommended to match the mixing regime of HRFS Trains 2 and 4. Also, installation of an upper impeller was recommended for the Coagulation and Injection Tanks in all four HRFS trains. However, it was acknowledged that care in mixer modification design would be essential to verify that the improvements would not promote floc shear, which could impede particle settling. Under this project, pilot-scale testing using one HRFS train was performed to develop representative design data for the mixer improvements. The pilot test included modifying the mixers in the Coagulation and Injection Tanks of HRFS Train 3 (reverse rotation and adding an upper impeller) to enable collection of the most appropriate data.

Operational and performance testing results showed a significant improvement to effluent TP levels and substantially reduced variability after implementation of the mixer modifications. These significant improvements continued during periods of higher flow at the plant, relative to flows in the sampling period prior to mixer modifications. As with microsand and PAC testing, TDP and SRP are nearly eliminated in the HRFS process, and concentrations do not appear to be affected by mixing configuration. This suggests that the chemical interactions with the bioavailable fractions of phosphorus occur in the Influent Box with rapid reaction kinetics.

The PAV, PSD and settleability did not show strong evidence of significantly greater particle shear in Train 3 after mixer modifications. Tracer testing indicates a substantial improvement in hydraulic response within the Injection Tank of Train 3 due to the mixer modifications. Since the modifications, Train 3 has a similar hydraulic regime to that of Train 2. The Coagulation Tank response also showed some minor improvement with respect to Train 2, although both trains had tracer response curves somewhat similar to the ideal response curve.

Based on the results of the mixer pilot testing, implementing the modifications recommended in the 2011 Metro Optimization Analysis Report is expected to contribute to phosphorus removal optimization. Additionally, a Stamford baffle, located at the end wall below the Lamella clarifier should be implemented to reduce short circuiting and facilitate optimizing the clarifier performance.

6.4 CFD ANALYSES

Balancing flow across the HRFS trains and managing dynamic hydraulic conditions within the Cross Channel is considered essential to Metro WWTP optimization to mitigate overloading of individual trains and provide options to further optimize. CFD modeling was used during the Metro WWTP 2011 optimization analysis to show that dynamic hydraulic conditions within the Cross Channel significantly impacted the ability of operations staff to balance flow across the HRFS trains. Cross Channel hydraulic conditions and HRFS balancing are significantly affected by both the plant flow rate and BAF operational configuration (e.g., number of filters running, which filters operate, backwashing, etc.).

CFD modeling along with full-scale testing showed that the use of non-modulating, motorized adjustable weirs appears to be a means to promote improved flow balancing. Because small changes in weir height can induce large changes in flow, modulating weirs would be operationally complex and likely not successful. Full-scale testing indicated that at average and higher flows, a single weir setting may reasonably balance flow across the four trains.

Installation of a wall splitting the channels between the BAF and HRFS processes would allow for maintenance of the channels, BAFs, and HRFS system without removing the entire tertiary treatment system from service. When maintenance is performed under lower flow conditions, Metro WWTP effluent would receive full tertiary treatment, which would help with SPDES permit compliance. However, installation of a wall to isolate the BAF trains could significantly impact flow balancing across the four HRFS trains, particularly if unbalanced BAF operation continues. Another challenge may occur during periods of lower flow. The plant would be able to operate using three HRFS trains thus reducing energy use; however, the isolation wall must be designed to allow reasonably balanced flow across all three trains.

Because of these challenges, additional CFD modeling was recommended to determine the need to refine the design of the isolation wall between the BAF and HRFS systems. The objective of this modeling is to determine the wall configuration that mitigates large differences in weir gate positioning and minimizes the need to frequently change HRFS weir positions as the flow changes.

Discussions with Kruger/Veolia indicated that the BAF operating program could be modified to allow balanced operation of the filters. It was also determined that BAF backwashing, under current practice, would not be affected by the lower flows experienced during summer 2012 or by a reduction in available backwash supply volume should the isolation wall gates be closed. CFD modeling showed that without the ability to change weir elevations at the HRFS Influent Boxes, flow across the HRFS trains would be somewhat unbalanced. However, the use of adjustable weir gates would facilitate flow balancing under expected operating conditions. Installation of slide gates within the Cross Channel and isolation wall would allow one BAF train to be shut off and balanced flow to be delivered to the HRFS system. The gates also would permit shut down of one HRFS train during periods of extended dry weather, which would result in reduced energy use. In addition to the weir gates, implementation of individual flow monitoring and coagulant feed flow pacing would facilitate balanced chemical dosing to each HRFS train.

Based on the results of the testing presented herein, implementing the modifications recommended in the 2011 Metro Optimization Analysis Report is expected to contribute to phosphorus removal optimization.

6.5 STUDY LIMITATIONS AND LIMIT OF TECHNOLOGY IMPACT

It is critical to note that all of the Pre-Implementation Studies were short-term in nature and independent of one another (except for PAC addition with the smaller microsand). Each test was individually evaluated with respect to the following question: "Would the proposed modification contribute to optimization of phosphorus treatment at the Metro WWTP?" Each modification has been shown to contribute towards optimization. While the full benefit of combining each recommended modification was not evaluated, it is expected that recommended modifications would be complementary.

Metro WWTP optimization is closely linked to the Limit of Technology (LOT) evaluation completed as part of the ACJ Compliance Plan development (CRA, 2012). The LOT evaluation involves using probability distribution analysis to establish Technology Performance Statistics (TPS) unique to the Metro WWTP. A key advantage of this approach is that actual treatment performance data are used to objectively and quantitatively evaluate the phosphorus treatment capability at Metro WWTP. The LOT is technology specific and plant specific – one treatment process will have a different LOT than another.

Based on the LOT, a statistical review of key phosphorus species (TPP, TDP and SRP) show that the current Metro WWTP processes are approaching the physical and practical limit of phosphorus treatment – a direct result of operational staff's commitment to excellence. This means that further reductions, even with optimization, would be limited. Determining statistical differences in treatment performance will require long-term monitoring.

Use of an approach, now or in the future, to predict what Metro WWTP can achieve based on existing data risks significant consequences to the County, given anti-backsliding regulations. For example, without actual data from an optimized facility, the ability to handle additional flow at Metro WWTP could be limited, which would impact the ability for growth in a struggling economy. An extended period of non-compliance, even with exemplary operation could require additional treatment at a significant cost.

A more appropriate method for determining reliable LOT of the optimized facility would be to complete this analysis once recommended optimization upgrades are implemented and 3 years of data are collected. This method would allow evaluation based on actual data that suitably represents the conditions experienced and the variability encountered at Metro WWTP rather than by predictive methods. Additionally, changes to permit levels should be based on establishing that such a reduction would positively impact Onondaga Lake. The phosphorus guidance level for Onondaga Lake (summer average of 0.02 mg/L) has been met 3 of the past 4 years. Optimizing Metro WWTP for phosphorus removal would primarily involve reductions in particulate phosphorus, which is non-bioavailable. Therefore, additional particulate phosphorus removal from Metro WWTP effluent would not be expected to reduce the bioavailable phosphorus load to Onondaga Lake. This adaptive management approach is also appropriate given that Onondaga Lake has experienced significant recovery and is meeting its intended uses with respect to phosphorus.

6.6 RECOMMENDATIONS AND UPDATED METRO WWTP PHOSPHORUS TREATMENT OPTIMIZATION PLAN

Implementing tertiary treatment improvements in 2005 has resulted in a dramatic improvement in Onondaga Lake water quality. This was recognized when the New York State Department of Environmental Conservation (NYSDEC) issued the revised Onondaga Lake Total Maximum Daily Load (TMDL) for United States Environmental Protection Agency (USEPA) approval on May 25, 2012 pursuant to Section 303(d)(2) of the Clean Water Act. Approval of the TMDL was issued on June 29, 2012. The Metro WWTP waste load allocation (WLA) established in the TMDL represents a "revised effluent limit for total phosphorus" as stipulated in Paragraphs 9 and 12 of the ACJ, thus superseding the requirement for meeting the stated effluent total phosphorus limit of 0.02 mg/L by December 31, 2015. Therefore, compliance with the WLA and the implementation schedule proposed under the TMDL for the Metro WWTP equates to satisfying the respective requirements of the ACJ.

The TMDL set the Metro WWTP's SPDES limit for total phosphorus to remain 0.10 mg/L, less than the manufacturer's stated design rating for the HRFS system. Additionally, the NYSDEC will establish a total effluent phosphorus bubble permit limit for combined main and secondary bypass discharges from Metro WWTP, effective December 31, 2018. It is expected that compliance with the TMDL would result in assuring protection of the water quality goals that have been attained in Onondaga Lake, and fostering further water quality improvements to the end that any ACJ requirements with respect to Metro WWTP that may remain upon completion of the TMDL can be expeditiously and cost effectively satisfied.

An in-depth statistical analysis conducted on the behalf of WEP (CRA, 2012) was conducted to gain a more complete understanding on the impact of the TMDL on Metro WWTP, and determine the compliance probability for meeting the proposed phosphorus bubble permit. Under contemporary conditions (i.e., average daily flow of

62 mgd) this analysis indicated that the bubble permit load limit would be met with a statistical probability of approximately 97 percent. This result confirms that the Metro WWTP is, and has been, complying with the Metro WWTP TMDL bubble permit load limit. However, this analysis indicates that the probability of compliance would decrease as average flows increase or if current effluent phosphorus concentrations – which are below the 0.10 mg/L permit limit – increase. Another potential risk of permit non-compliance can come from increased secondary bypass discharges due to a wetter than normal precipitation year.

Implementing phosphorus treatment optimization at Metro WWTP is essential to further assure bubble permit compliance in terms of mitigating the potential for effluent total phosphorus concentrations to increase appreciably. This in turn will improve the County's flexibility in responding to growth or increased secondary bypass discharges using an adaptive approach. Such an adaptive approach would allow the County the time to focus on future compliance actions (should they be necessary) in a measured manner that emphasizes water quality trading and green infrastructure initiatives. Furthermore, the approach to optimize phosphorus treatment at Metro WWTP was incorporated into the TMDL as the implementation method of choice, thus alleviating the County of having to implement other ACJ compliance actions (e.g., additional treatment of diversion to Seneca River) that would cost tens to hundreds of millions of dollars more than optimization.

Based on the results of the Pre-Implementation Studies, the following optimization actions are recommended:

1. Implement the use of the smaller 110 micron microsand in all four HRFS trains. This recommendation was implemented by Metro WWTP operations staff in January 2013.
2. Implement use of PAC during disinfection season; the coagulant should be dosed at the HRFS influent boxes. Ferric chloride should continue to be dosed at the influent boxes outside of disinfection season. Metro WWTP staff should monitor PAC performance during the spring and fall when water temperatures are in transition.
3. Construct an isolation wall along the entire length of the Cross Channel to the division wall between HRFS Trains 2 and 3; the wall should be designed to maximize the amount of backwash water available to the BAFs, as well as operational flexibility. Slide gates should be provided in the Cross Channel to permit isolation of the two BAF trains, as well as in the isolation wall to facilitate flow balance when one BAF train or HRFS train is out of service. An access platform should be provided to facilitate access to the gates.

4. Adjust SCADA programming for the BAF to force the filters to be turned on and off in pairs (one from each train) thus promoting balanced BAF operation.
5. Maintain use of the modifications to the HRFS Train 3 Coagulation and Injection Tank mixers.
6. Reverse the mixer rotation in the Coagulation and Injection Tanks for HRFS Train 1, including a new shaft and mirror image lower impeller to maintain downward pumping. Install a second, upper impeller on the mixers for the Coagulation and Injection Tanks of Trains 1, 2 and 4.

These recommendations are incorporated into an updated Metro WWTP Phosphorus Removal Optimization Plan, as shown on Figure 6-1. In addition to the above modifications, the recommended modifications at Metro WWTP include:

- Installation of motorized non-modulating adjustable weirs at the HRFS influent boxes.
- Installation of permanent coagulant diffusers at each HRFS Influent Box.
- Installing flow meters on the HRFS clarifier effluent launders to verify flow balance and provide flow pacing of chemical feed.
- Installation of a new PAC feed system.
- Replacement of the existing ferric chloride feed system (pumps, piping and valves).
- Installation of baffles in the HRFS Influent Boxes.
- Installation of a Stamford baffle in each train on the end wall below the Lamella clarifier.
- Replacing the secondary treatment return activated sludge (RAS) lines from the suction side isolation valve of the six RAS pumps to their discharge. This includes replacing all suction and discharge valves with electric actuators.
- Installation of VFDs on the HRFS sludge pumps to improve control.
- Replacement of all exposed HRFS sludge piping within the HRFS building and thickener complex.
- Rehabilitation of the liner in the Cross Channel, BAF effluent channel and HRFS influent channel.
- Repair or replacement of the HRFS bypass sluice gate.
- Relocation of the suction for the effluent water pumps upstream of coagulant addition and replacement of the plant effluent water supply system.

- SCADA programming changes to facilitate BAF, HRFS and coagulant feed control based on operational experience.
- Rehabilitation of the microsand slurry tank in the HRFS trains.
- Replacement of the Parshall flume louvers in the UV Building and installing an access catwalk.
- Rehabilitation of the block wall in the effluent flume area of the UV Building, including cleaning, epoxy sealing, repointing as necessary, and installation of weeps.

The estimated preliminary capital cost to install these modifications is approximately $14,600,000 (2016 dollars), including a 25 percent construction contingency allowance, and an additional allowance of 20 percent for engineering, legal and administration fees. A summary breakdown of this cost is included as Appendix F. This amount is consistent with the cost reported in the report entitled Metropolitan Syracuse WWTP Analysis of Phosphorus Treatment Technologies and Metro Diversion to the Seneca River (CRA, 2012), which presents the ACJ Compliance Plan for phosphorus treatment at Metro WWTP. The optimization improvements presented above are included in the recommended ACJ Compliance Plan.

As noted in the 2011 Metro Optimization Analysis Report, scheduling must be considered to minimize water quality impacts to Onondaga Lake during facility modifications. An updated preliminary schedule for the optimization implementation is provided in Figure 6-2.

The phosphorus optimization strategies recommended in this report are intended to minimize impacts to Onondaga Lake by reducing effluent phosphorus variability. A component of these recommendations will help to maximize the wastewater receiving tertiary treatment during BAF, HRFS or connecting channel maintenance. However, a temporary shutdown of tertiary treatment will be essential to allow construction crews to safely and properly install the isolation wall for the BAF and HRFS units, inspect and rehabilitate the channel liner and install an access platform for the new isolation gates. Construction of the wall and liner replacement is made more complicated because confined space entry would be required, which impacts time. Another issue is that colder temperatures and a higher humidity environment lengthen the cure time for the liner, although cure times can be accelerated with the use of a temporary enclosure with heaters and dehumidifiers. Additionally, time would be required to restart the BAF to effective treatment levels after an extended shutdown.

Given these construction necessities, as noted in the 2011 Metro Optimization Analysis Report, it is recommended that WEP pursue a temporary permit limit variance from the

NYSDEC for ammonia and phosphorus that reflects the construction activity. This variance would be applied for during the design phase and prepared in accordance with Paragraph 29 of the ACJ to minimize process downtime. The following should be considered as part of the variance application to minimize the potential impact to Onondaga Lake:

- Require the contractor to focus all efforts on rapidly constructing the isolation wall, installing slide gates and inspecting the existing liner. Once the wall is complete, one half of the tertiary treatment facilities could be restored to service while construction focused on the other half. It is expected that wall construction could require three or four months to complete depending upon the fabrication time needed for the isolation gates. To reduce lead-time requirements, WEP could pre-purchase the gates near the end of the design phase. Requiring the gates to be delivered prior to tertiary treatment shutdown or requiring multiple shift construction are other options to reduce downtime. Limit full shutdown of tertiary treatment to between October 15 and April 1. UV disinfection would not be required and this time frame is outside the critical period for phosphorus and ammonia. This time frame also takes advantage of the short hydraulic retention time in Onondaga Lake.
- Temporarily modify operation of secondary treatment to promote nitrification and phosphorus removal to the extent possible. Efforts could include increasing MLSS concentrations, sludge retention time and increased ferric chloride addition.
- Although total shutdown of tertiary treatment would be minimized, half of the BAF and HRFS units would remain out of service for an extended period to allow completion of construction. Tertiary treatment would be provided except during times of peak flows (wet weather conditions) when a partial bypass would be required.

7.0 REFERENCES

CRA Infrastructure & Engineering, Inc. (2011) Metro WWTP Optimization Analysis of Total Phosphorus Treatment. Prepared for the Onondaga County Department of Water Environment Protection, Syracuse, NY.

CRA Infrastructure & Engineering, Inc. (2012) Metropolitan Syracuse WWTP Analysis of Phosphorus Treatment Technologies and Metro Diversion to the Seneca River. Prepared for the Onondaga County Department of Water Environment Protection, Syracuse, NY.

Environmental Engineering Associates, LLP (EEA) (2000), Preliminary Design Report, Ammonia and Stage II Phosphorus Removal Project – Metropolitan Syracuse Wastewater Treatment Plant.

NYSDEC (2012). Total Maximum Daily Load (TMDL) for Phosphorus in Onondaga Lake. New York State Department of Environmental Conservation. Albany, NY. May 2012.

Upstate Freshwater Institute and Michigan Technological University (2010) Contributions to the Effective Phosphorus Loading Issue: Particle Characterizations, Bioavailability, and Settling. Technical Memo to AnchorQEA.

USDC (2009), Case 3:88-cv-00066-FJS-DEP, Fourth Stipulation and Order Amending the Amended Consent Judgment, Atlantic States Legal Foundation, State of New York and Alexander B. Grannis vs. The Onondaga County Department of Drainage and Sanitation and Onondaga County, New York, Filed 11/16/2009.

USEPA, Region 2 (2012) Letter from Joan Leary Matthews of USEPA to Mr. Mark Klotz of NYSDEC approving Revised Onondaga Lake TMDL. June 29, 2012.

FIGURES

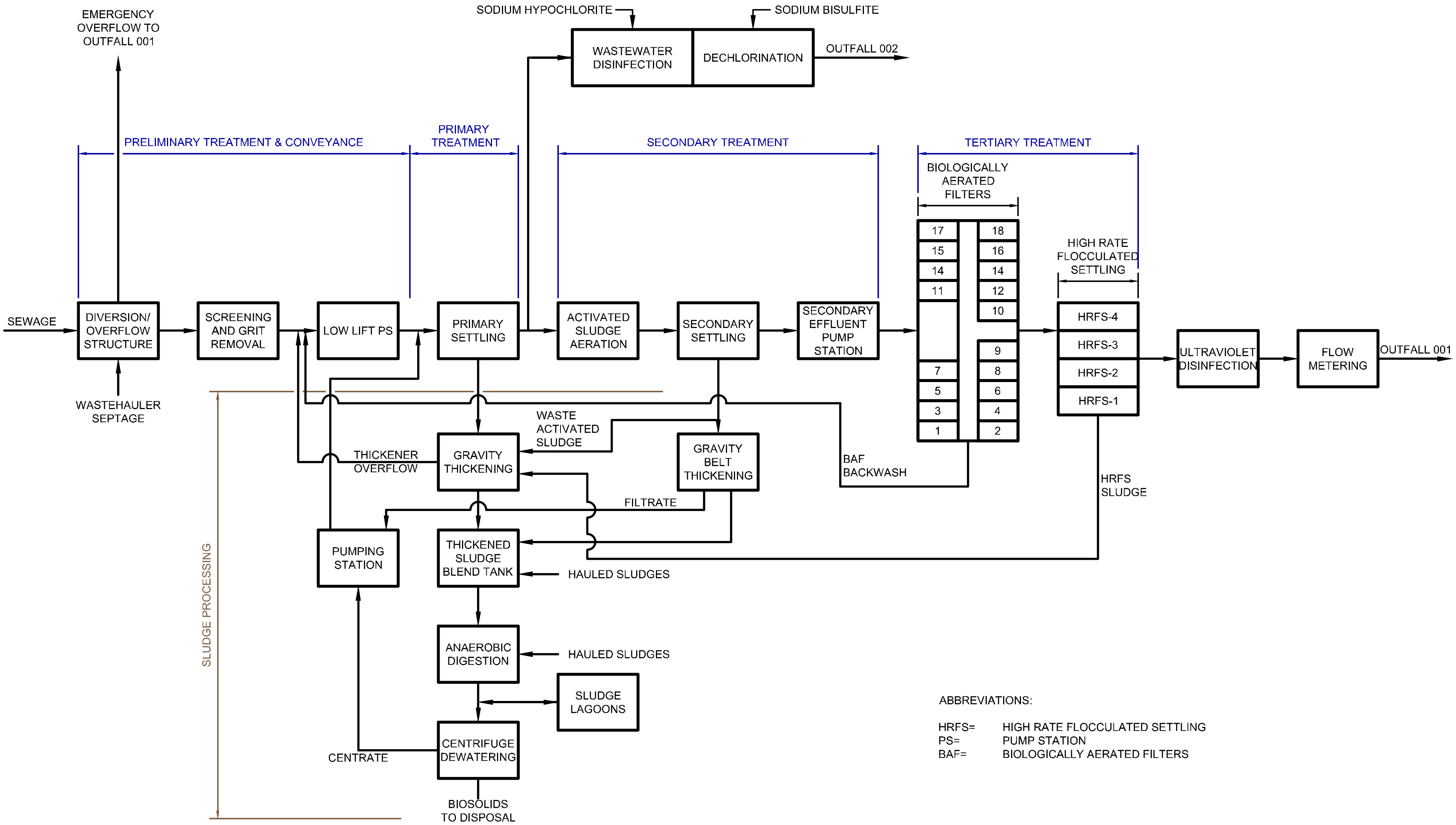


Figure 1-1

METRO WWTP EXISTING PROCESS FLOW SCHEMATIC
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU017 JAN 08/2013

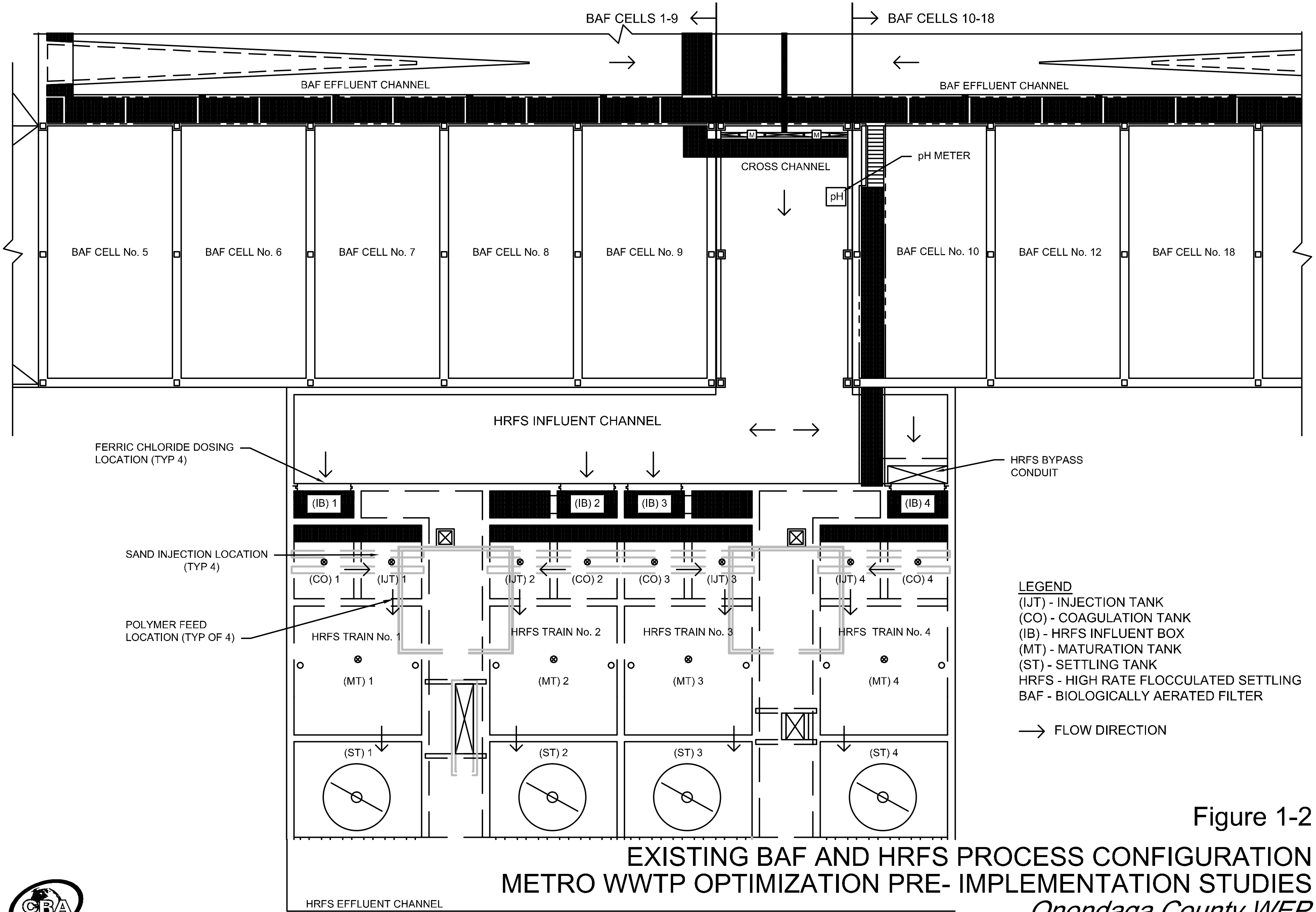
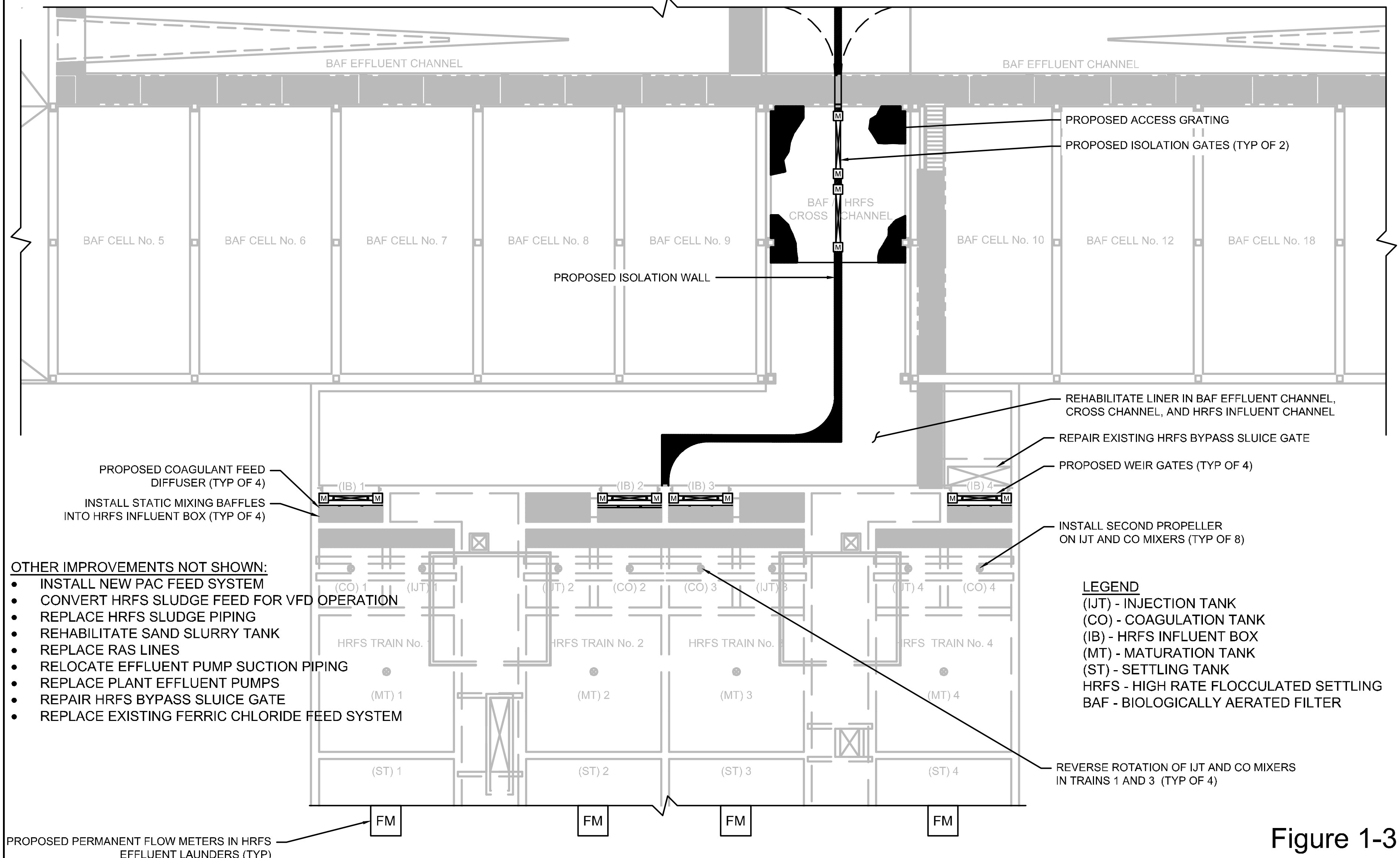


Figure 1-2

EXISTING BAF AND HRFS PROCESS CONFIGURATION
METRO WWTP OPTIMIZATION PRE- IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU011 JAN 24/2013



OTHER IMPROVEMENTS NOT SHOWN:

- INSTALL NEW PAC FEED SYSTEM
- CONVERT HRFS SLUDGE FEED FOR VFD OPERATION
- REPLACE HRFS SLUDGE PIPING
- REHABILITATE SAND SLURRY TANK
- REPLACE RAS LINES
- RELOCATE EFFLUENT PUMP SUCTION PIPING
- REPLACE PLANT EFFLUENT PUMPS
- REPAIR HRFS BYPASS SLUICE GATE
- REPLACE EXISTING FERRIC CHLORIDE FEED SYSTEM

LEGEND

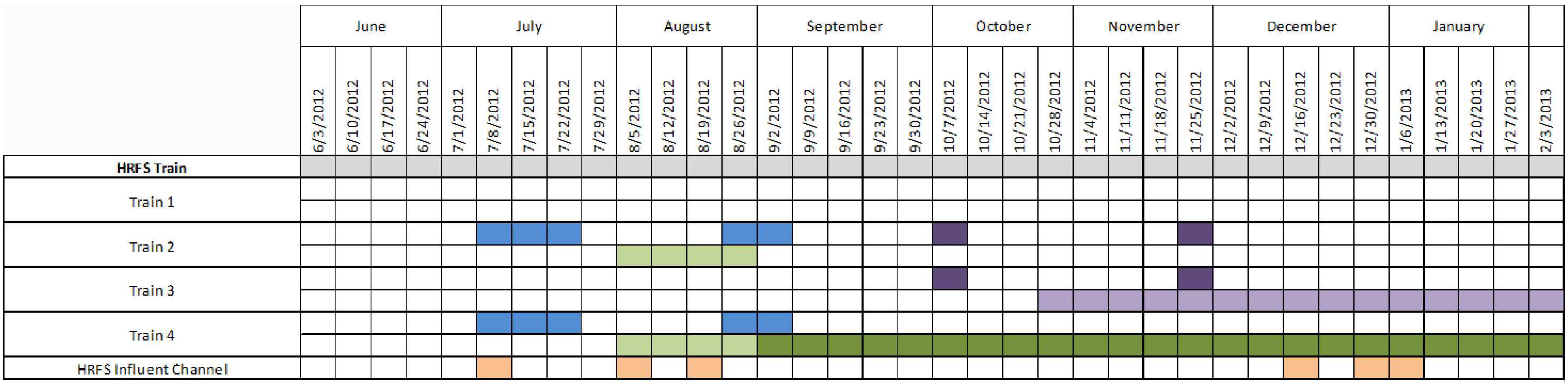
(IJT) - INJECTION TANK
(CO) - COAGULATION TANK
(IB) - HRFS INFLUENT BOX
(MT) - MATURATION TANK
(ST) - SETTLING TANK
HRFS - HIGH RATE FLOCCULATED SETTLING
BAF - BIOLOGICALLY AERATED FILTER

Figure 1-3

RECOMMENDED METRO WWTP OPTIMIZATION IMPROVEMENTS (ALTERNATIVE 7)
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU018 JAN 24/2013



Test/Modification	Baseline Train	Modified Train
Full Scale PAC Testing	2 (Ferric)	4 (PAC)
Full Scale Microsand Testing	2 (134)	4 (110)
110 Microsand Continued in Train	-	4
Mixer Analytical and Tracer Testing	2	4
Mixer Modifications and Operation	-	3
Jar Testing	n/a	n/a

NOTE:
FERRIC - FERRIC CHLORIDE
PAC - POLYALUMINUM CHLORIDE
134 - 134 MICRON MICROSAND
110 - 110 MICRON MICROSAND
N/A - NOT APPLICABLE

Figure 1-4

PRE-IMPLEMENTATION STUDIES TIMELINE
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

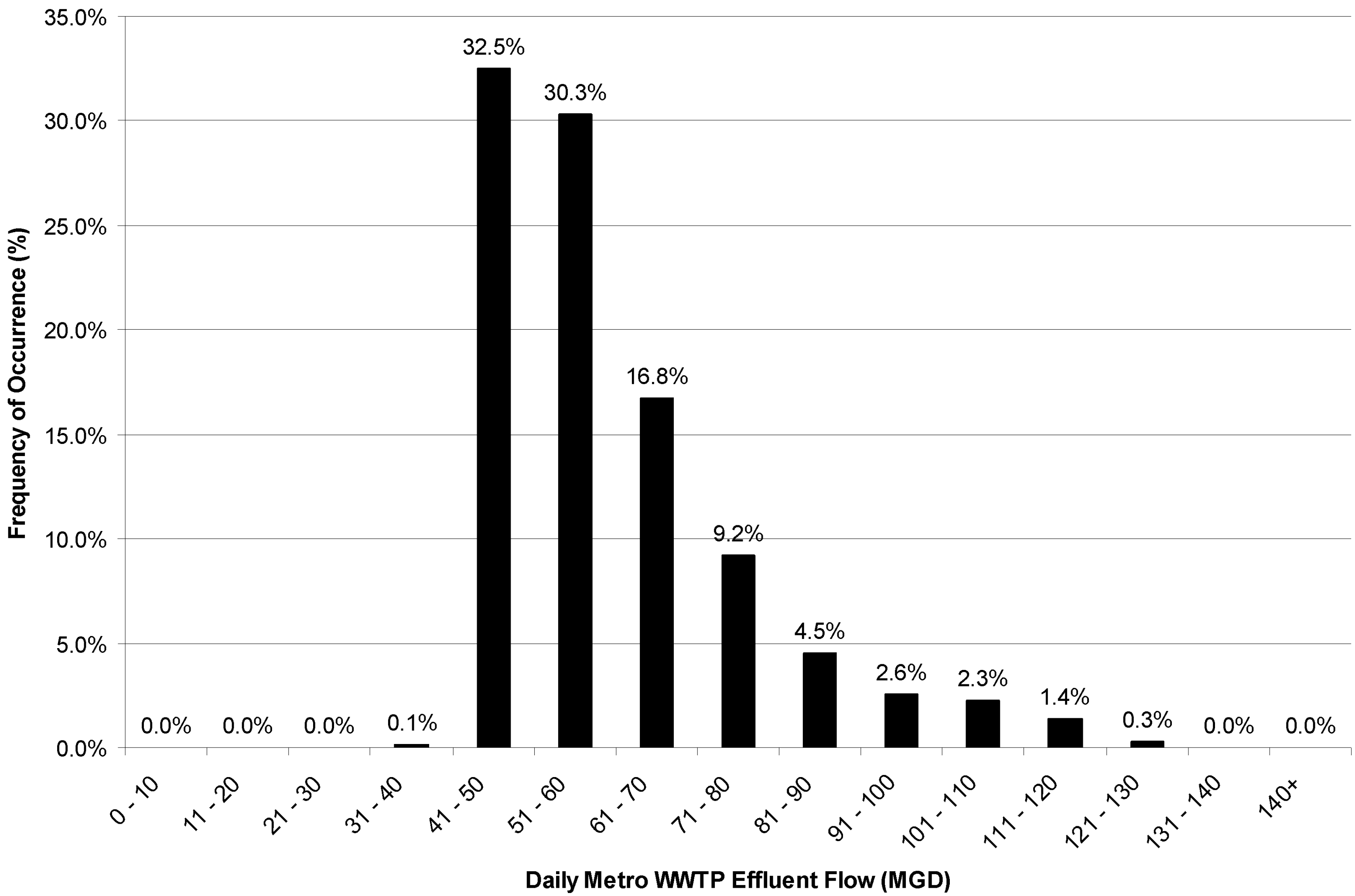


Figure 1-5

FREQUENCY DISTRIBUTION OF METRO WWTP EFFLUENT FLOW 2007 - 2010
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU019 JAN 24/2013

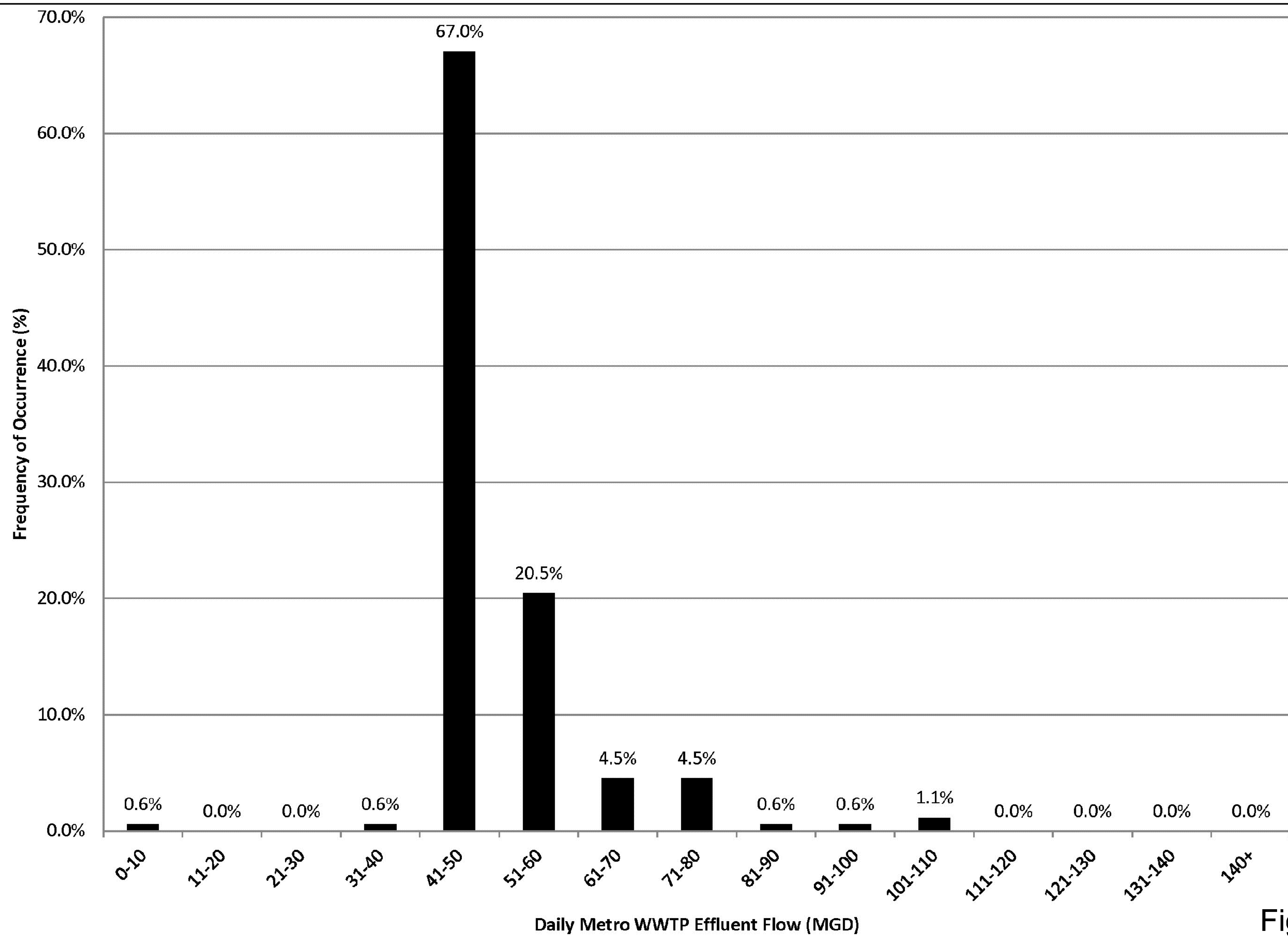


Figure 1-6

FREQUENCY DISTRIBUTION OF METRO WWTP DAILY
EFFLENT FLOW DURING PRE-IMPLEMENTATION STUDIES (JULY - DECEMBER 2012)
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU021 JAN 24/2013

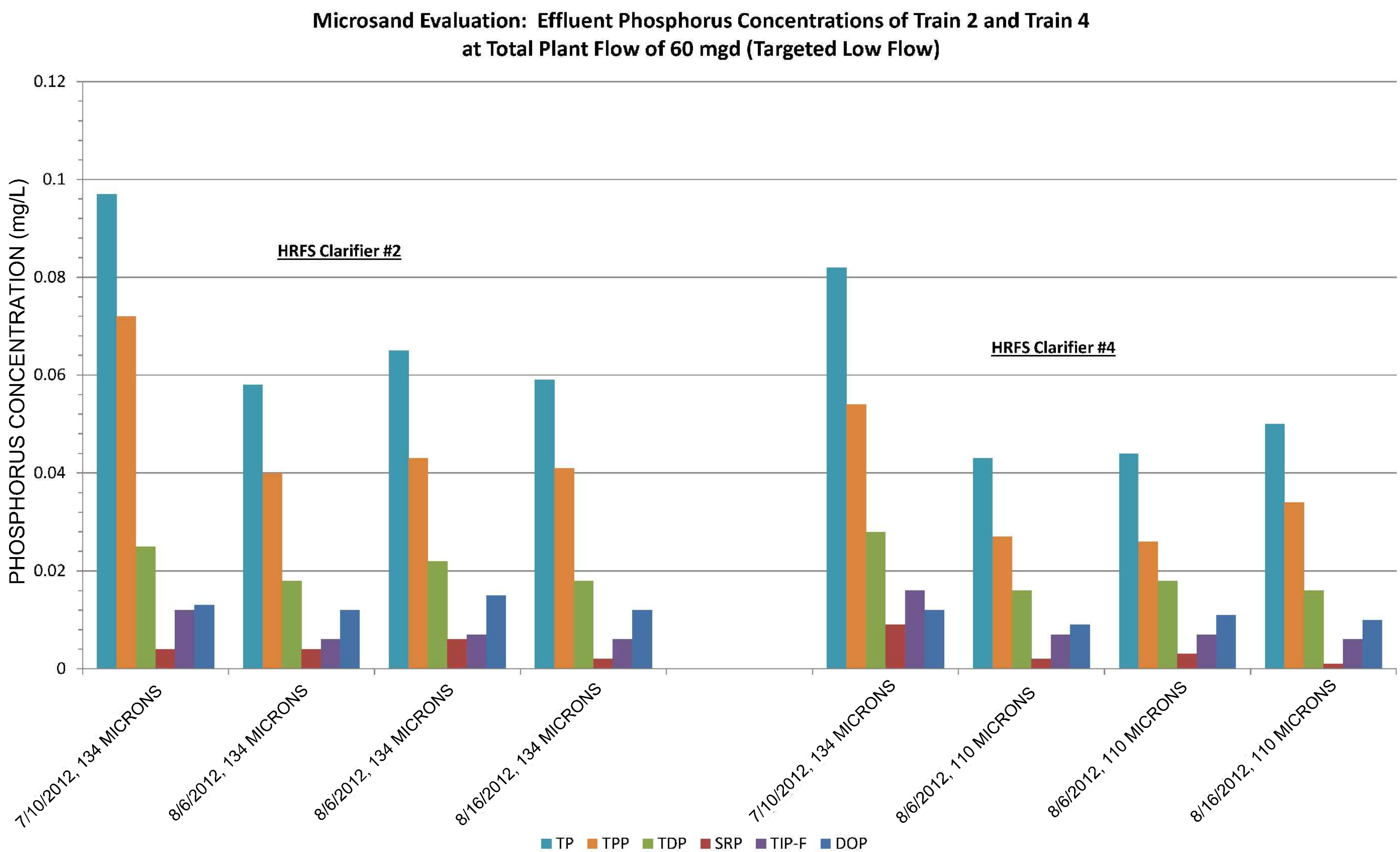


Figure 2-1

MICROSAND PERFORMANCE TESTING RESULTS
UNDER LOW FLOW (60 mgd) CONDITIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU022 JAN 24/2013

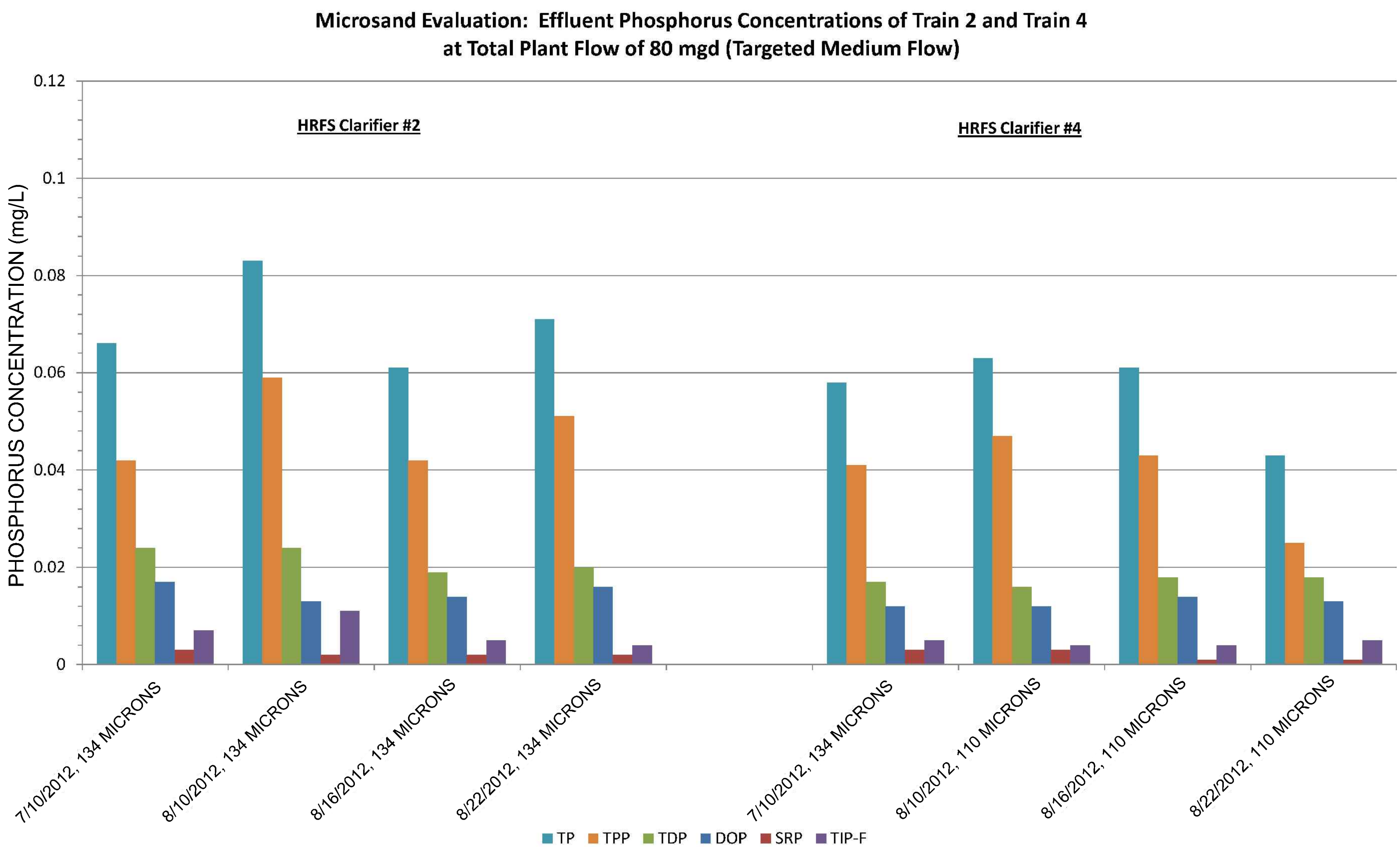


Figure 2-2

MICROSAND PERFORMANCE TESTING RESULTS
UNDER MEDIUM FLOW (80 mgd) CONDITIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU023 JAN 24/2013

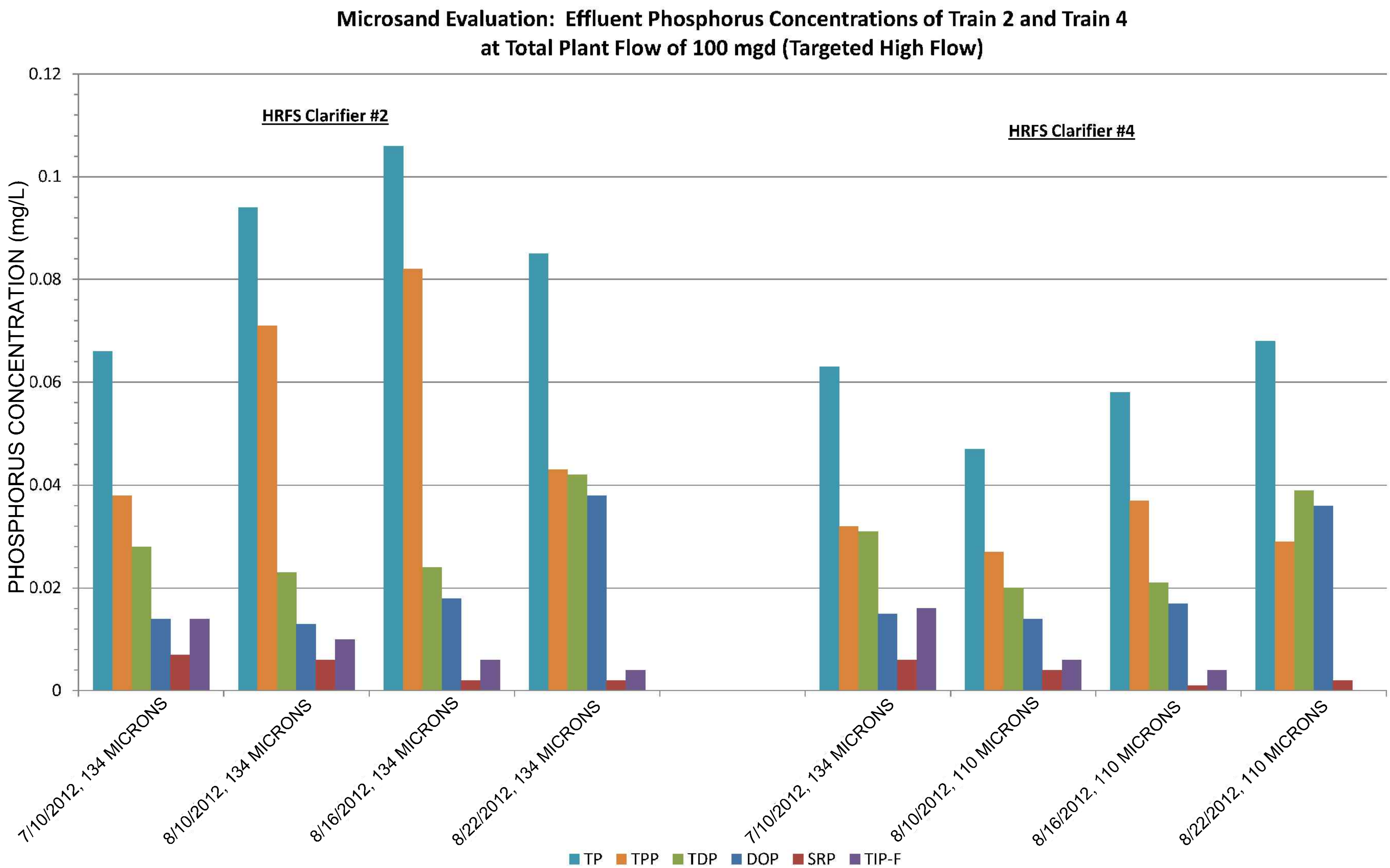


Figure 2-3

MICROSAND PERFORMANCE TESTING RESULTS
UNDER HIGH FLOW (100 mgd) CONDITIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

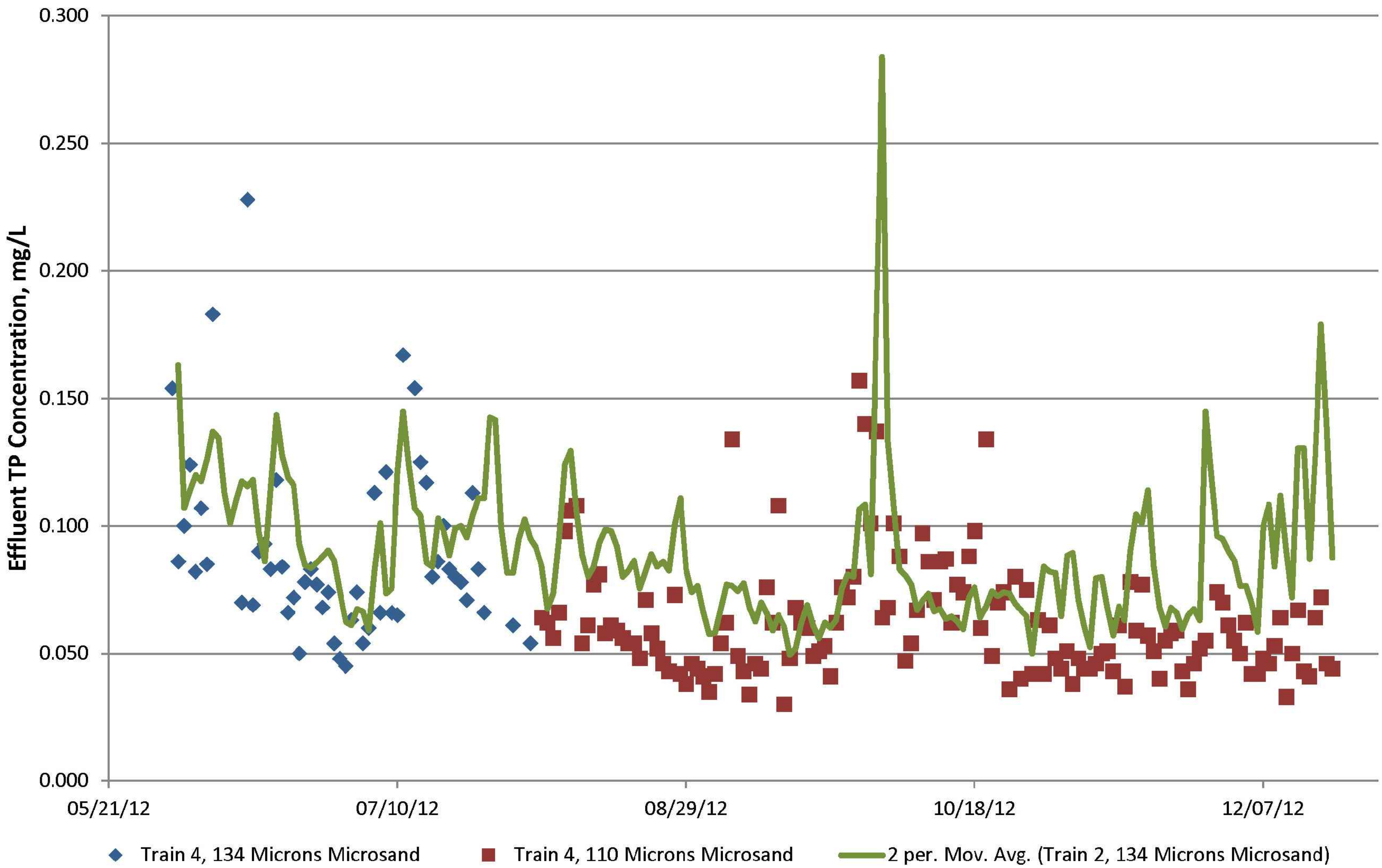


Figure 2-4

HRFS TRAIN 2 AND 4 EFFLUENT TOTAL
PHOSPHORUS CONCENTRATIONS JUNE 1 - DECEMBER 13, 2012
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU025 JAN 24/2013

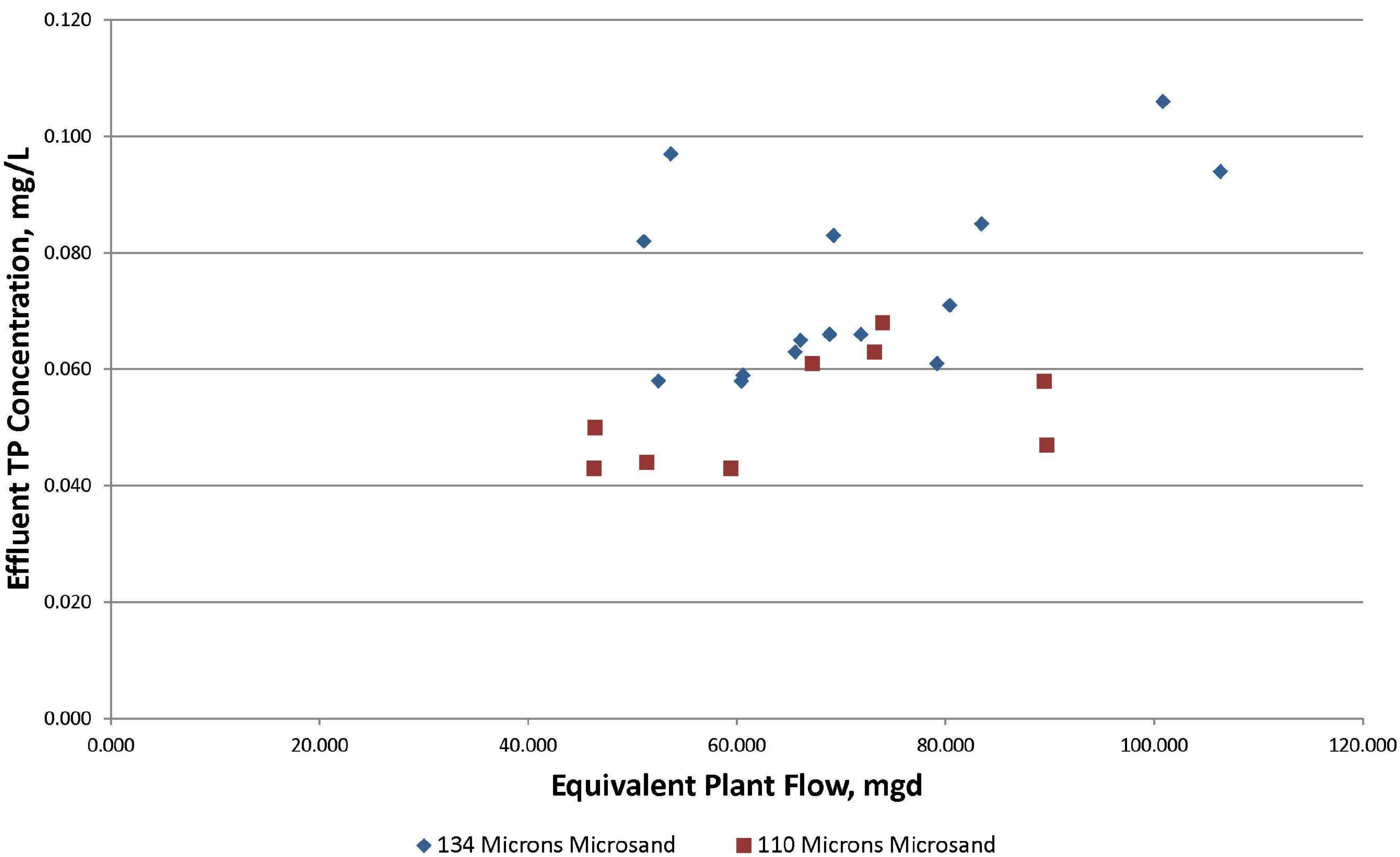
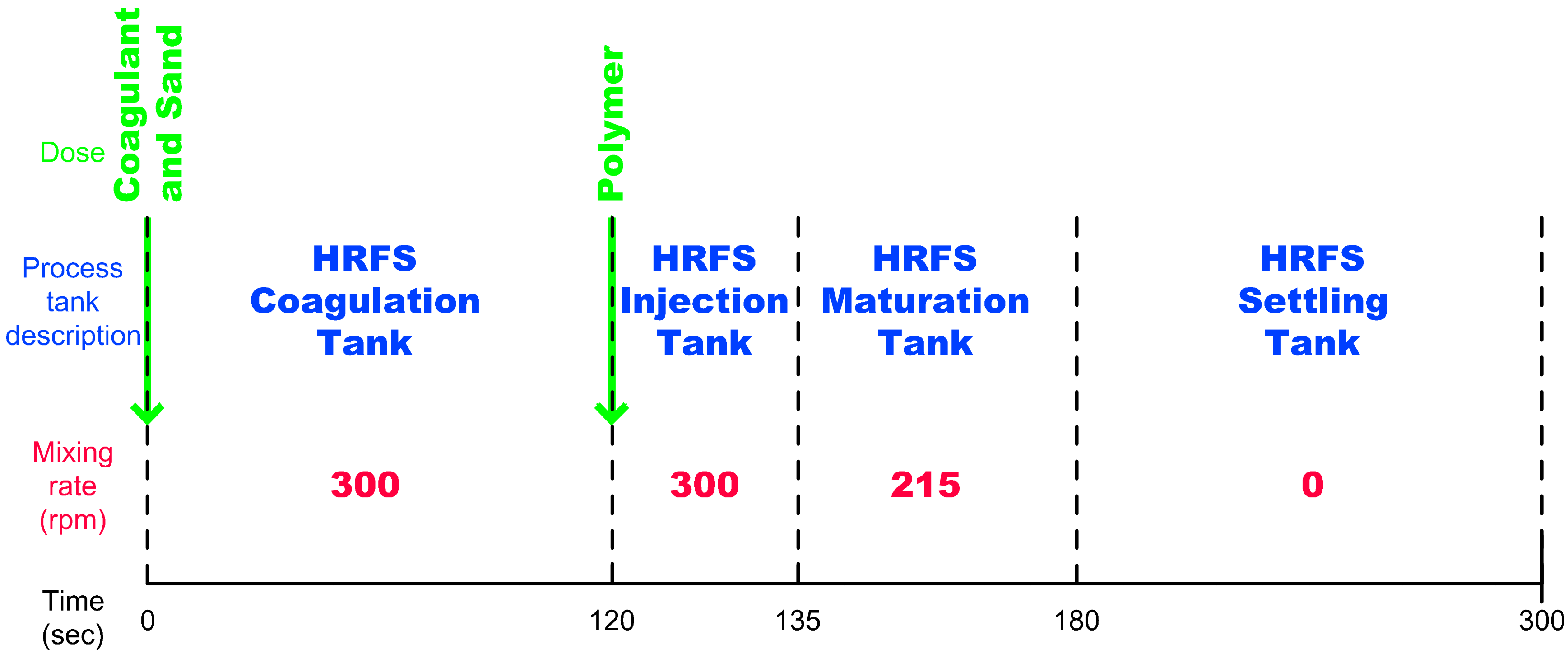


Figure 2-5

EFFLUENT TP VS. EQUIVALENT PLANT FLOW
FOR 134 AND 110 MICRON MICROSAND
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

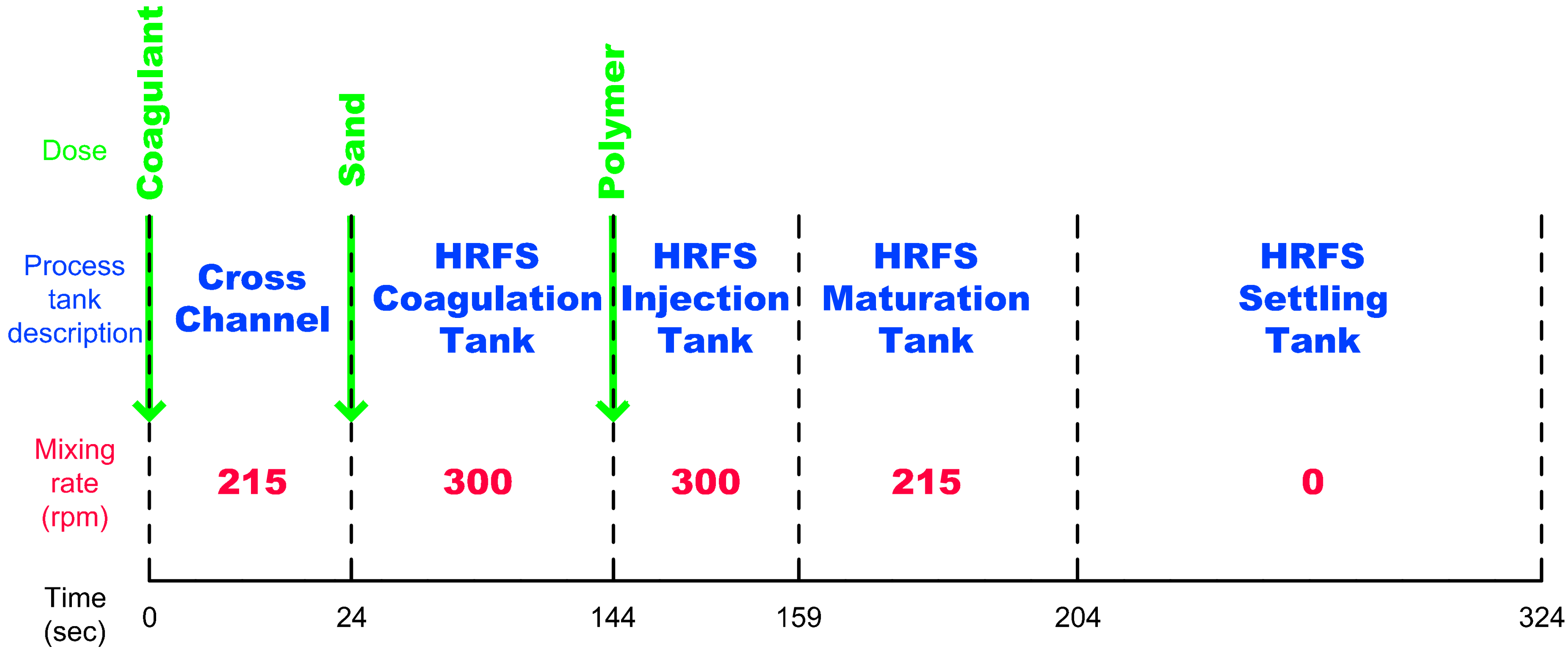
630742-00(005)GN-BU026 JAN 24/2013



JAR TEST PROCEDURE

Figure 3-1

STANDARD JAR TESTING PROCEDURE - DOSING SCENARIO NO. 1
SIMULATES COAGULANT ADDITION AT THE INFLUENT BOX AT AVERAGE FLOW
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

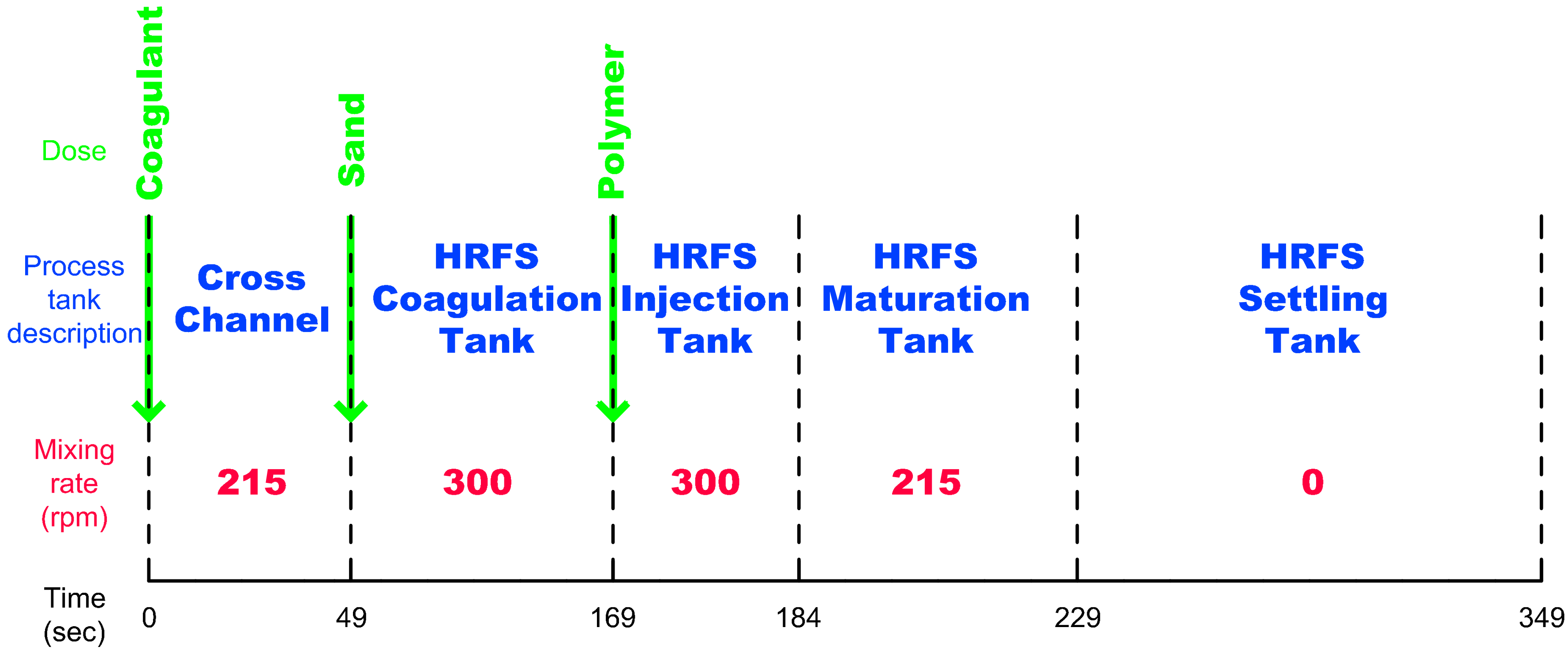


JAR TEST PROCEDURE

Figure 3-2

STANDARD JAR TESTING PROCEDURE - DOSING SCENARIO NO. 2
SIMULATES COAGULANT ADDITION AT THE CROSS CHANNEL AT PEAK FLOW
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU002 JAN 08/2013



JAR TEST PROCEDURE

Figure 3-3

STANDARD JAR TESTING PROCEDURE - DOSING SCENARIO NO. 3
SIMULATES COAGULANT ADDITION AT THE CROSS CHANNEL AT AVERAGE FLOW
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU003 JAN 08/2013

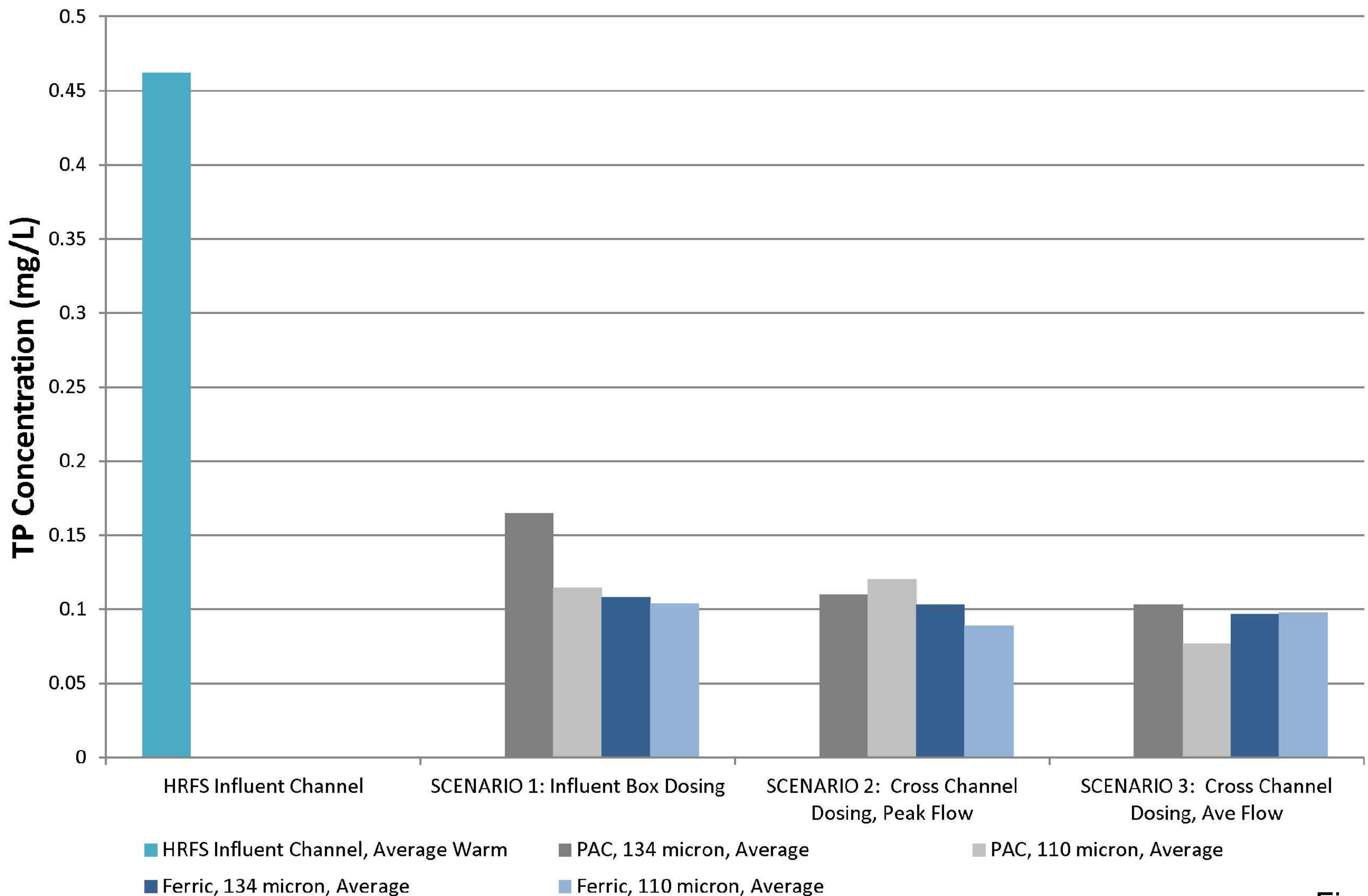


Figure 3-4

AVERAGE RESIDUAL TOTAL PHOSPHORUS FOR EACH DOSING SCENARIO
WARM TEMPERATURE DATA (AVE 23° C)
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU027 JAN 24/2013

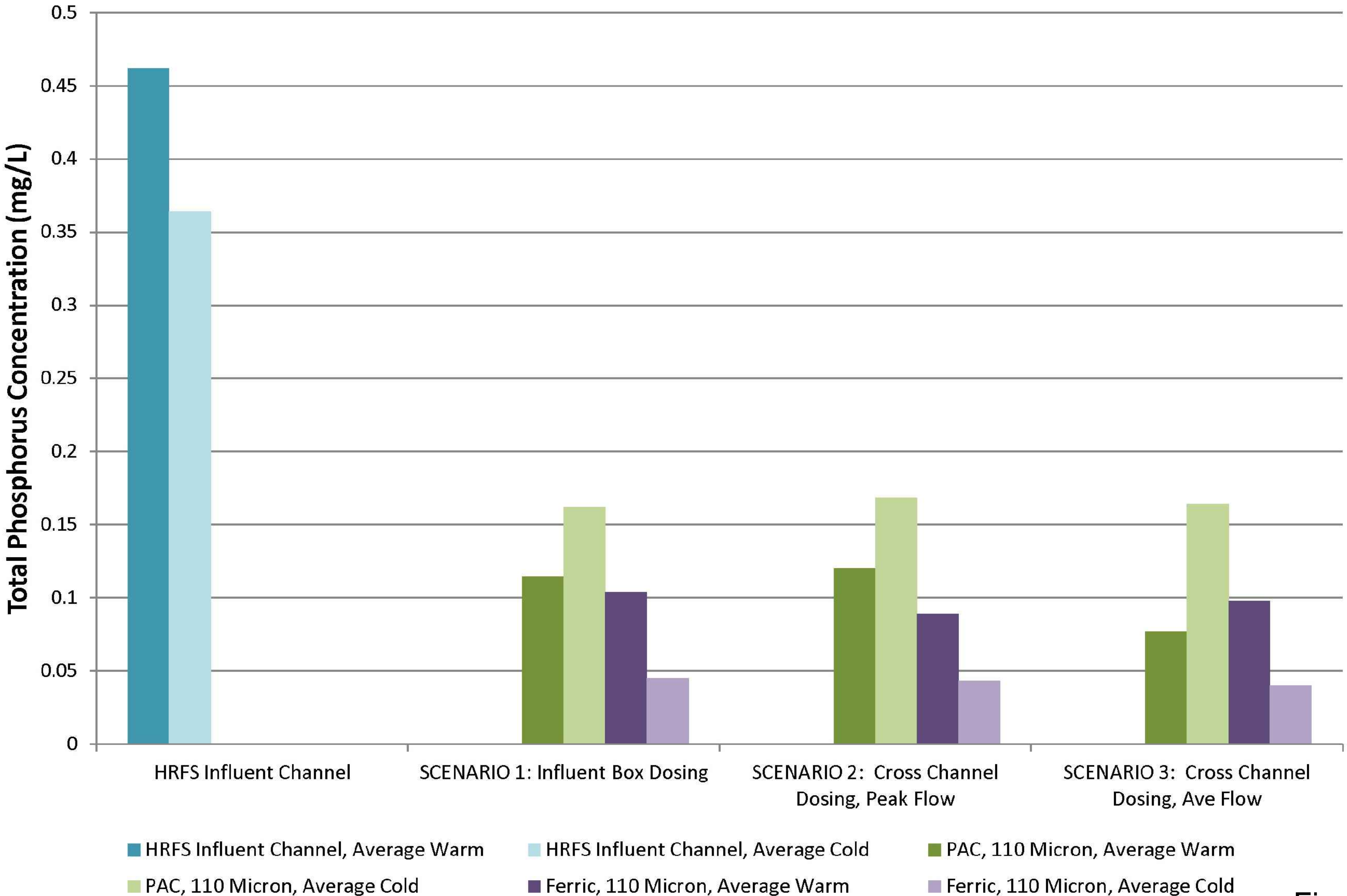


Figure 3-5

AVERAGE RESIDUAL TOTAL PHOSPHORUS FOR EACH DOSING SCENARIO
WARM (AVE 23° C) VS. COLD (AVE 12° C) WATER
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU028 JAN 24/2013

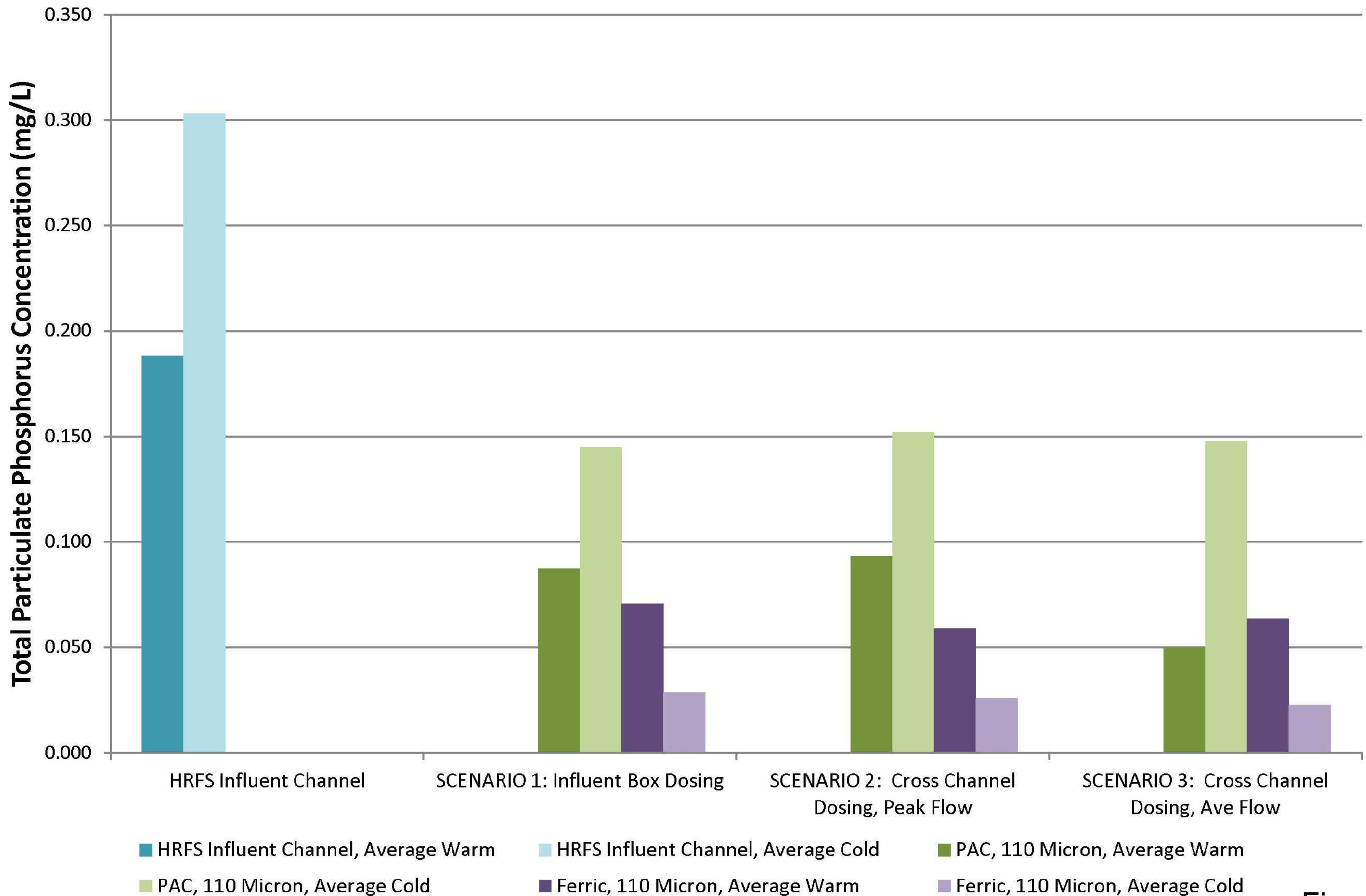


Figure 3-6

AVERAGE RESIDUAL TOTAL PARTICULATE PHOSPHORUS FOR EACH DOSING SCENARIO
WARM (AVE 23° C) VS. COLD (AVE 12° C) WATER
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU029 JAN 24/2013

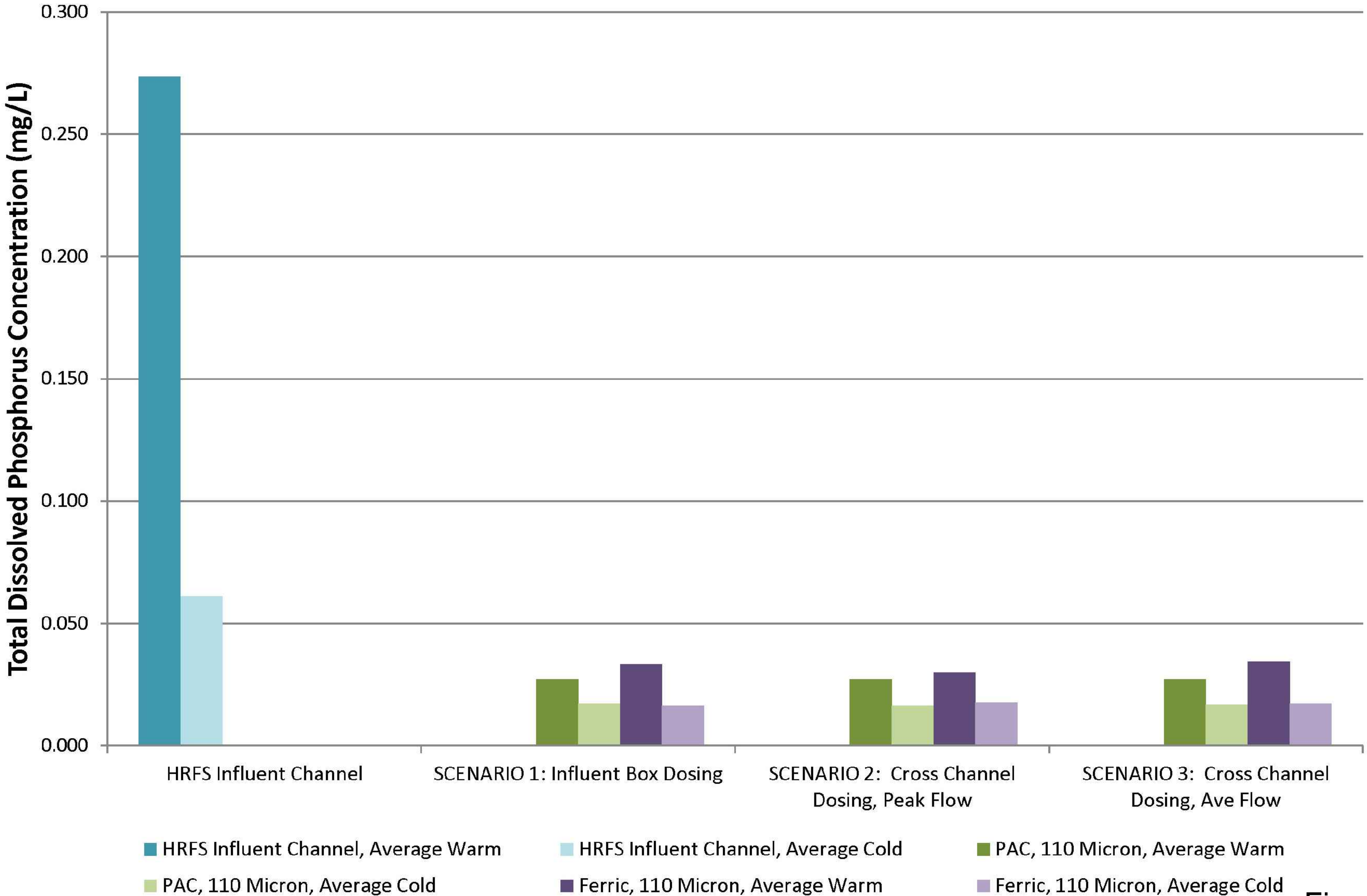


Figure 3-7

AVERAGE RESIDUAL TOTAL DISSOLVED PHOSPHORUS FOR EACH DOSING SCENARIO
WARM (AVE 23° C) VS. COLD (AVE 12° C) WATER
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU030 JAN 24/2013

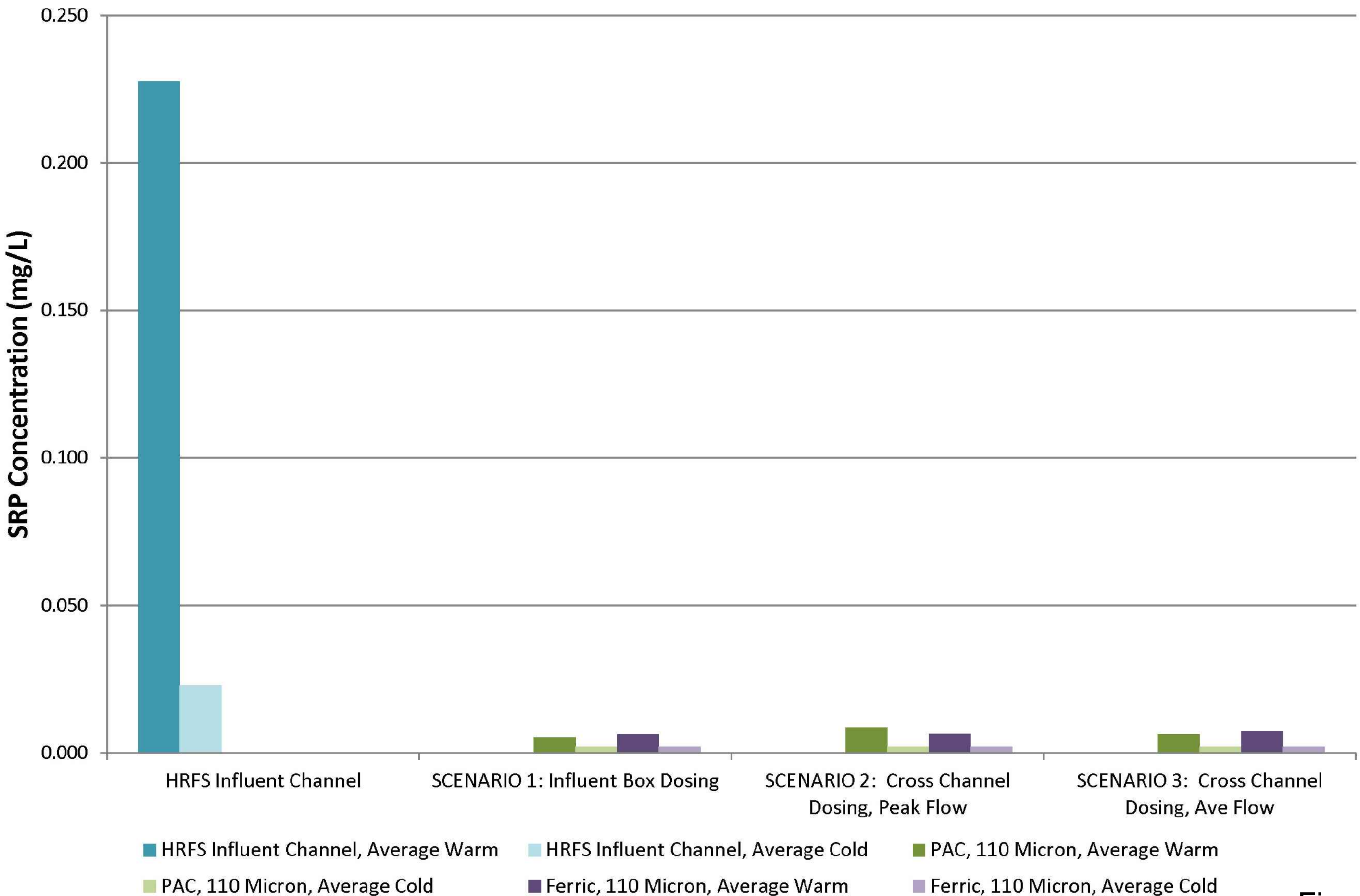


Figure 3-8

AVERAGE RESIDUAL SOLUBLE REACTIVE PHOSPHORUS FOR EACH DOSING SCENARIO
WARM (AVE 23° C) VS. COLD (AVE 12° C) WATER
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

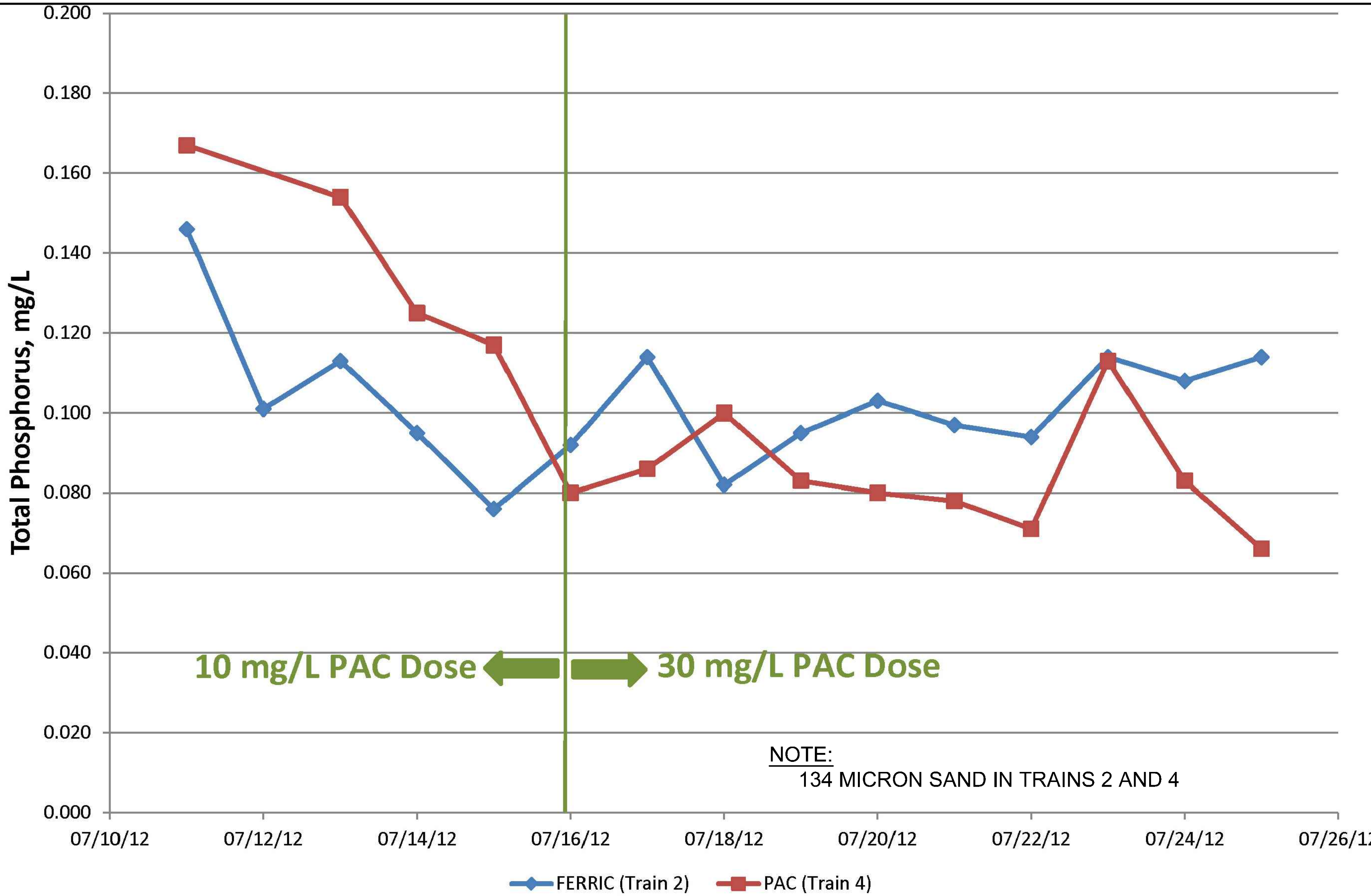


Figure 3-9

FULL SCALE PAC TEST NO. 1 EFFLUENT TOTAL PHOSPHORUS FOR HRFS TRAIN 2 AND 4
METRO WWTP OPTIMIZATION PRE- IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU032 JAN 28/2013

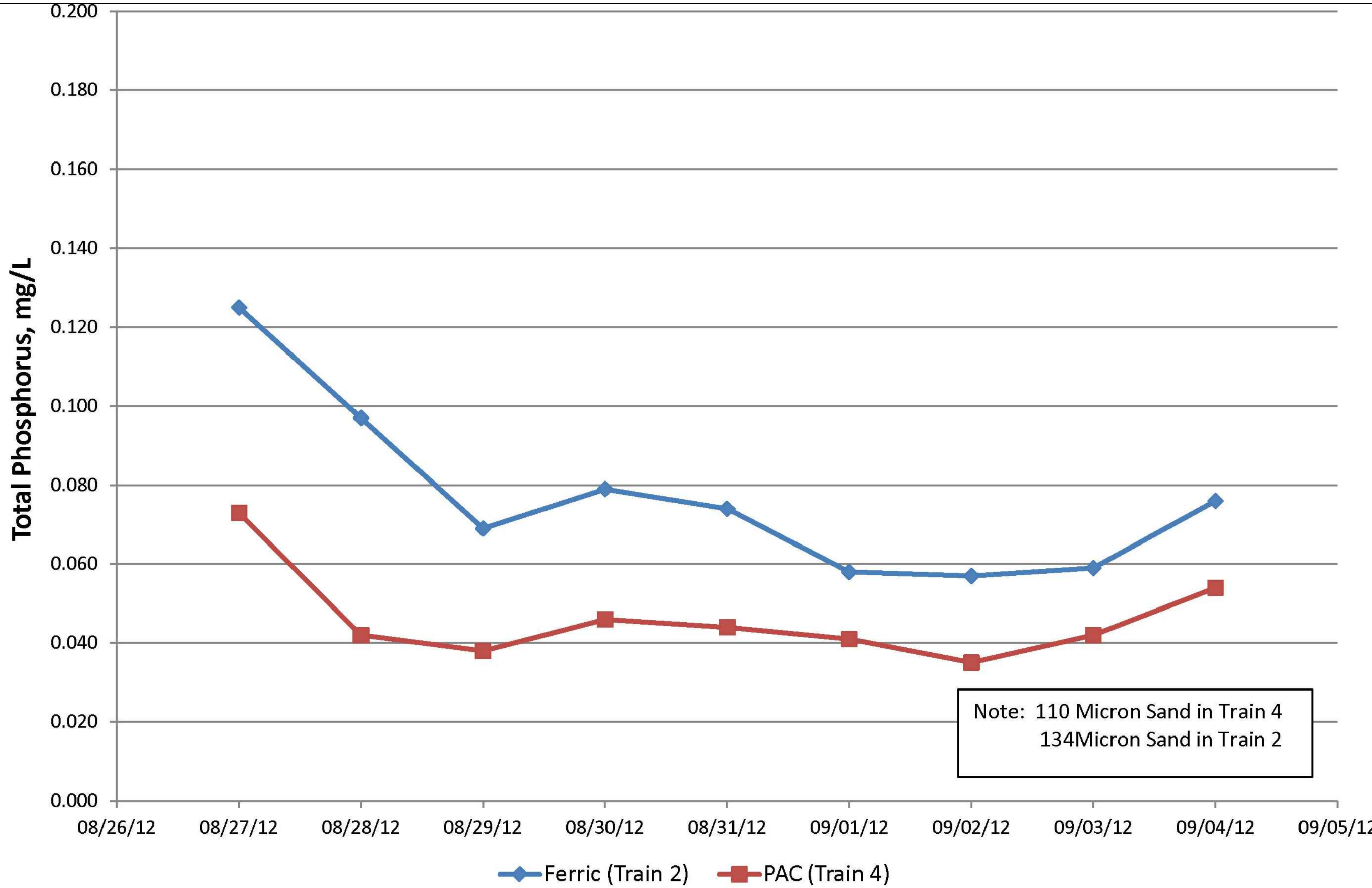


Figure 3-10

FULL SCALE PAC TEST NO. 2 EFFLUENT TOTAL PHOSPHORUS FOR HRFS TRAIN 2 AND 4
METRO WWTP OPTIMIZATION PRE- IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU033 JAN 28/2013

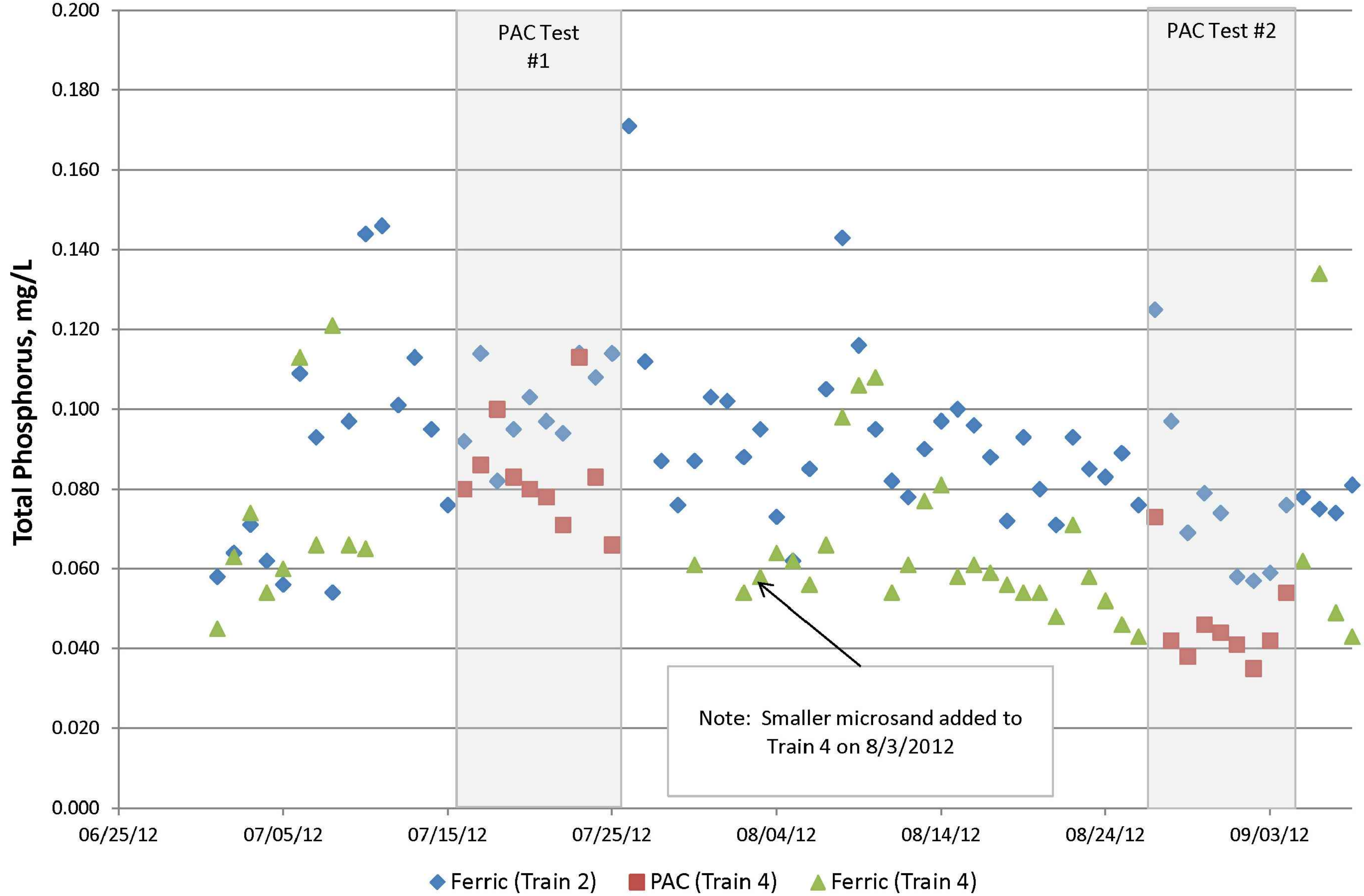


Figure 3-11

EFFLUENT TOTAL PHOSPHORUS IN TRAIN 2 AND TRAIN 4 JULY - SEPTEMBER 2012
METRO WWTP OPTIMIZATION PRE- IMPLEMENTATION STUDIES
Onondaga County WEP

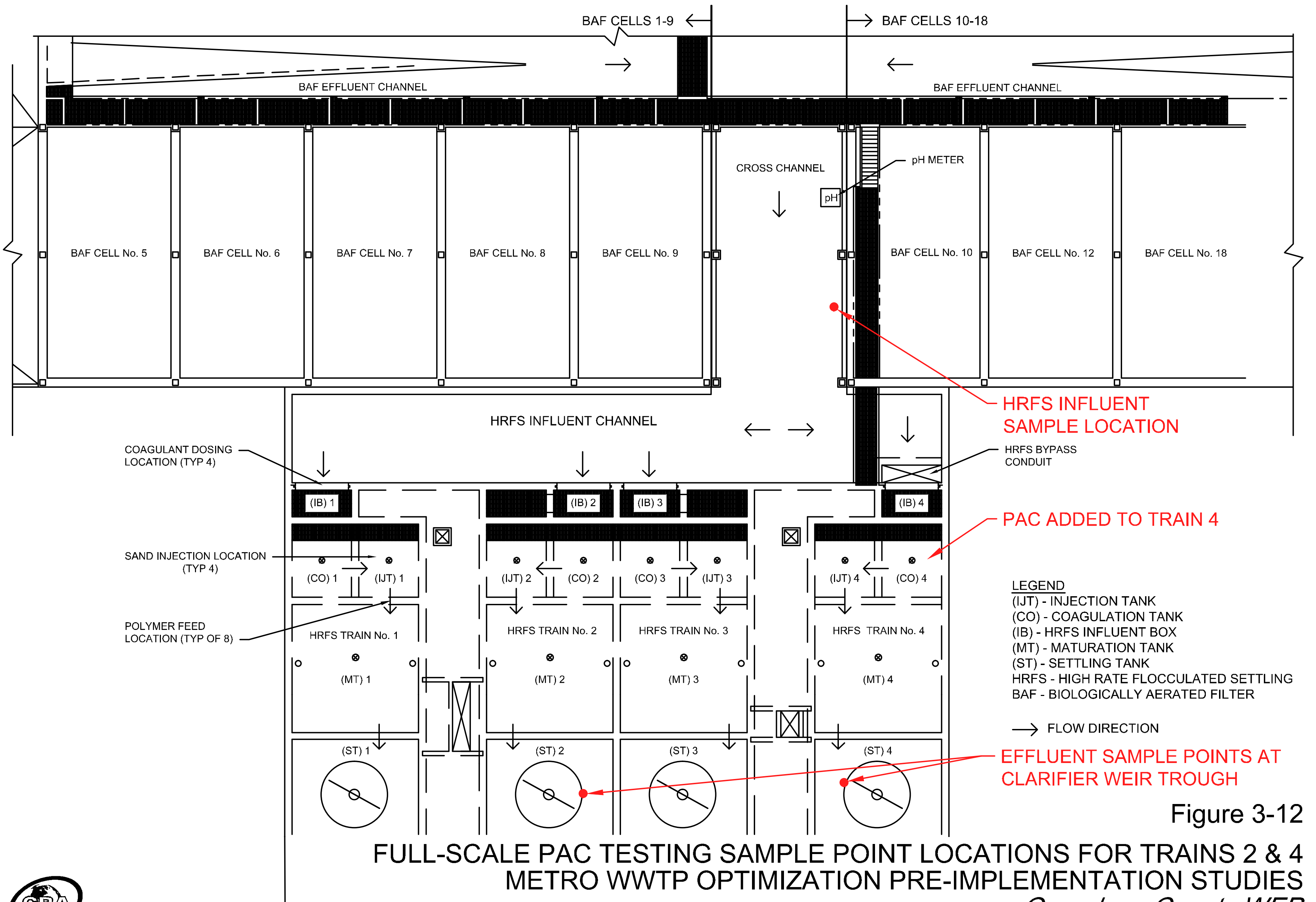


Figure 3-12

FULL-SCALE PAC TESTING SAMPLE POINT LOCATIONS FOR TRAINS 2 & 4
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU013 JAN 24/2013

Figure 3-13

IMAGE OF BIOAVAILABILITY TESTING COMPARING PRE-HRFS AND POST-HRFS SAMPLES
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

UPSTATE FRESHWATER INSTITUTE

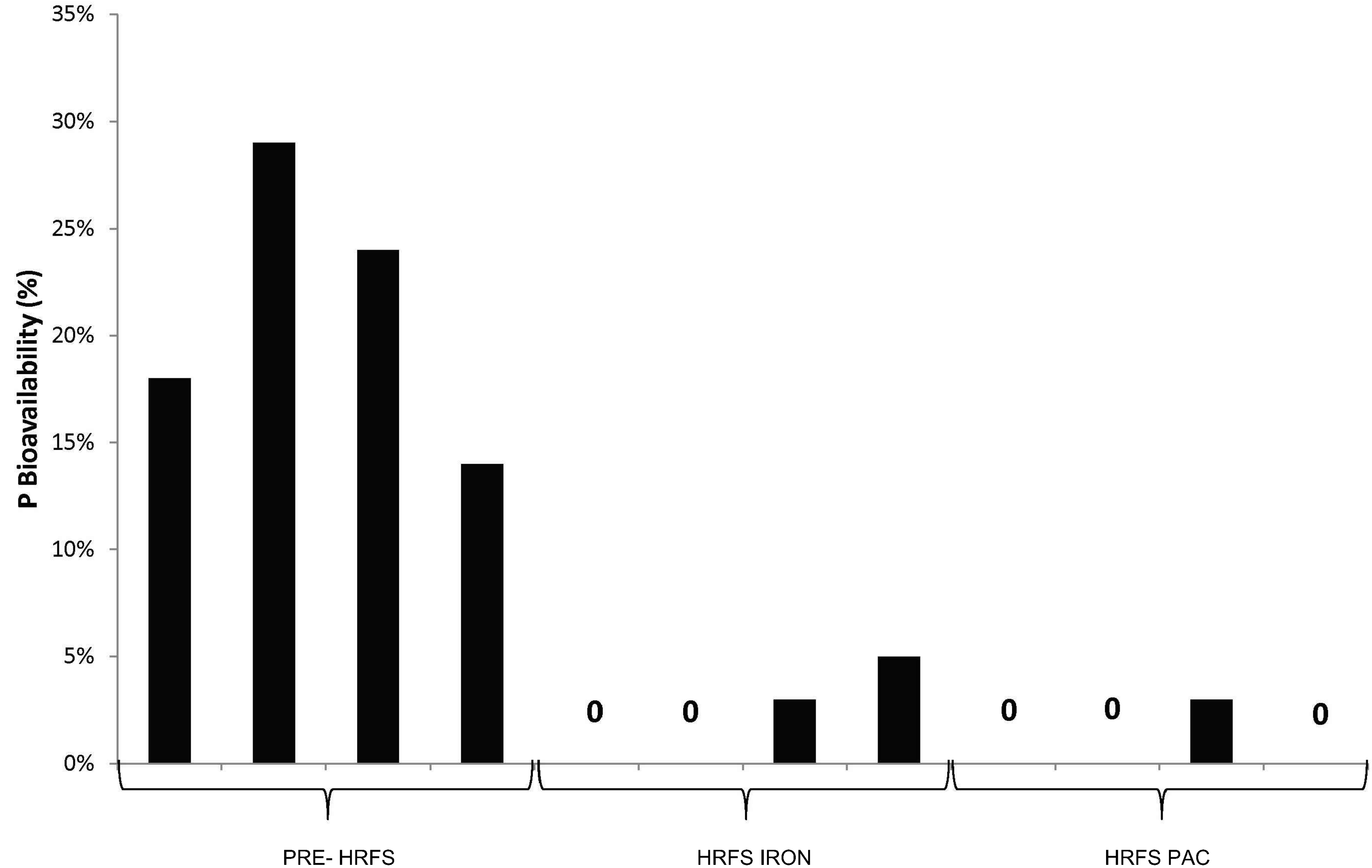


Figure 3-14

PHOSPHORUS BIOAVAILABILITY OF HRFS EFFLUENT USING FERRIC CHLORIDE AND PAC
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

UPSTATE FRESHWATER INSTITUTE

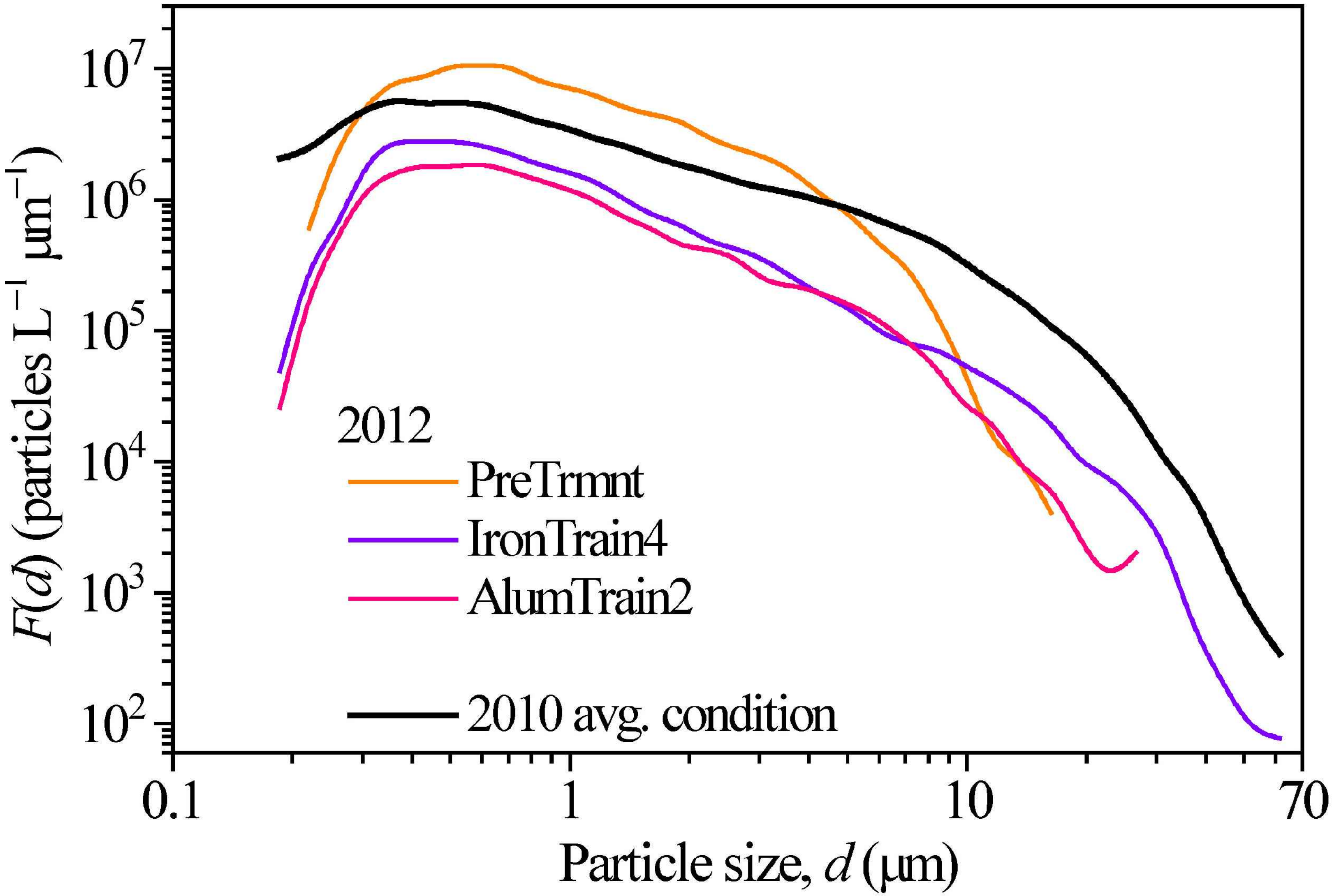


Figure 3-15

PARTICLE SIZE DISTRIBUTIONS FROM SAX OF HRFS INFLUENT AND HRFS EFFLUENT USING FERRIC CHLORIDE AND PAC
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

UPSTATE FRESHWATER INSTITUTE

630742-00(005)GN-BU036 JAN 28/2013

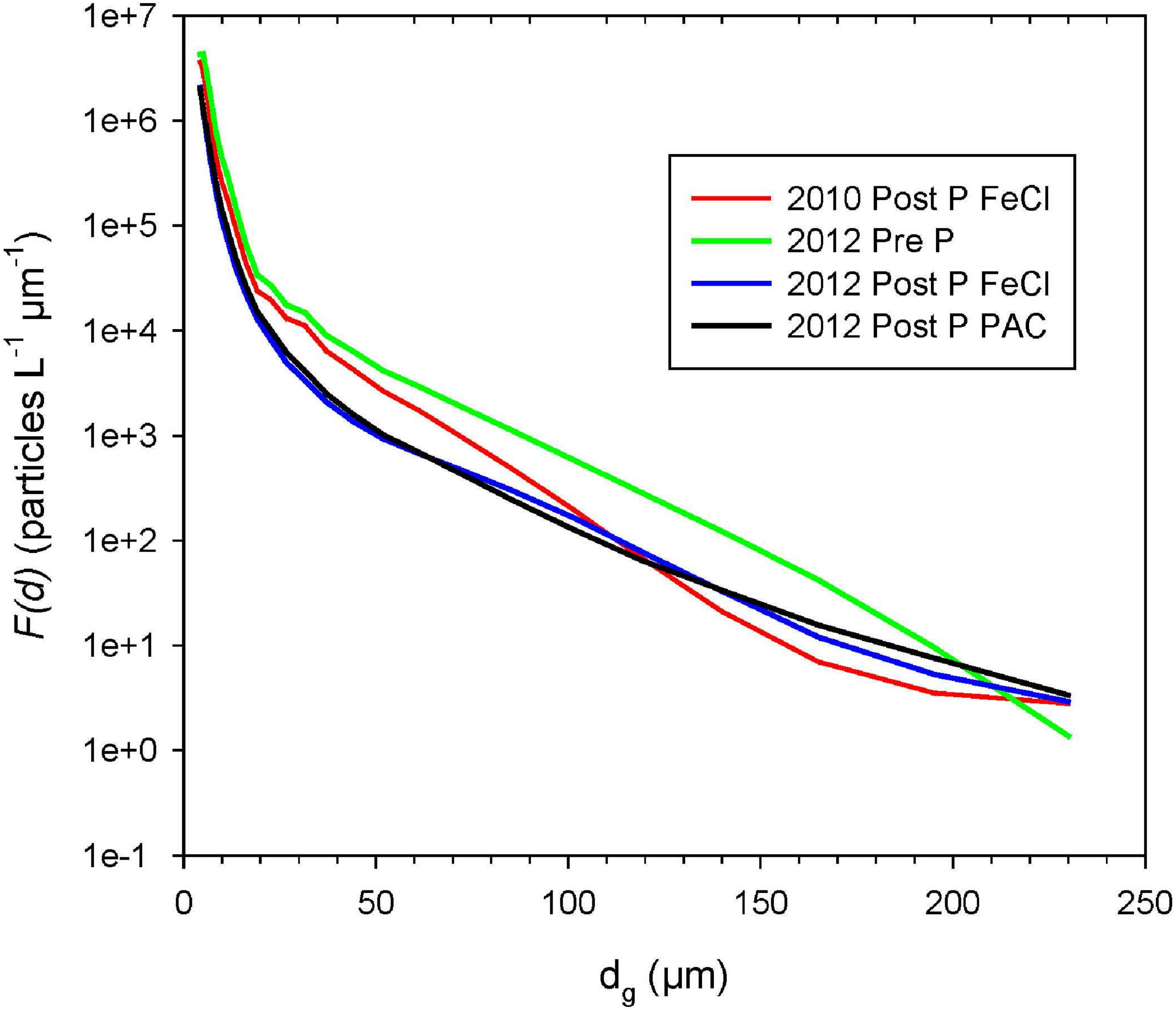


Figure 3-16

COMPARISON OF THE AVERAGE PARTICLE DENSITY FUNCTION FOR EACH EFFLUENT TYPE
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

UPSTATE FRESHWATER INSTITUTE

630742-00(005)GN-BU037 JAN 28/2013

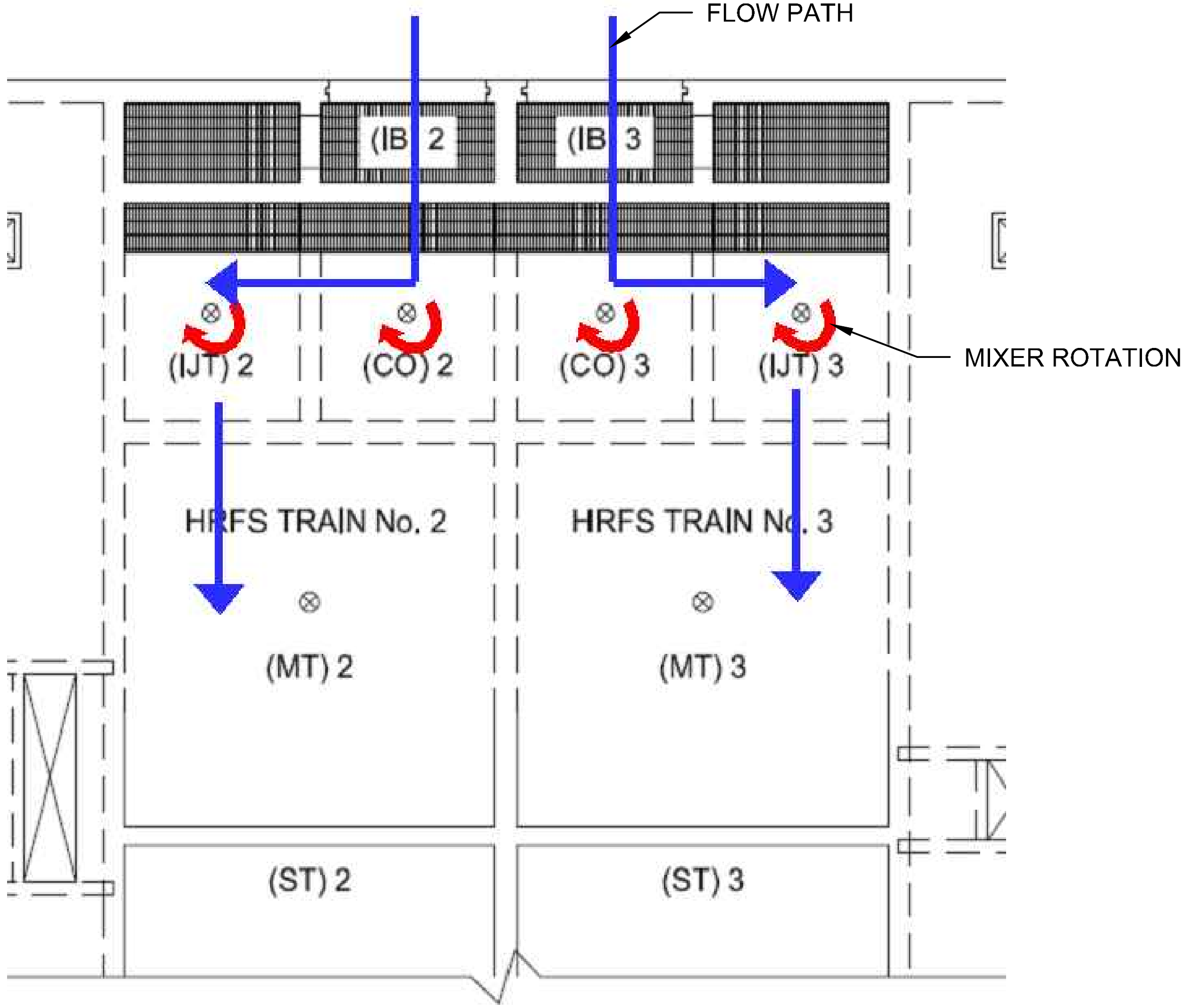


Figure 4-1

HRFS TRAINS 2 AND 3 FLOW AND MIXER CONFIGURATIONS BEFORE MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU004 JAN 08/2013

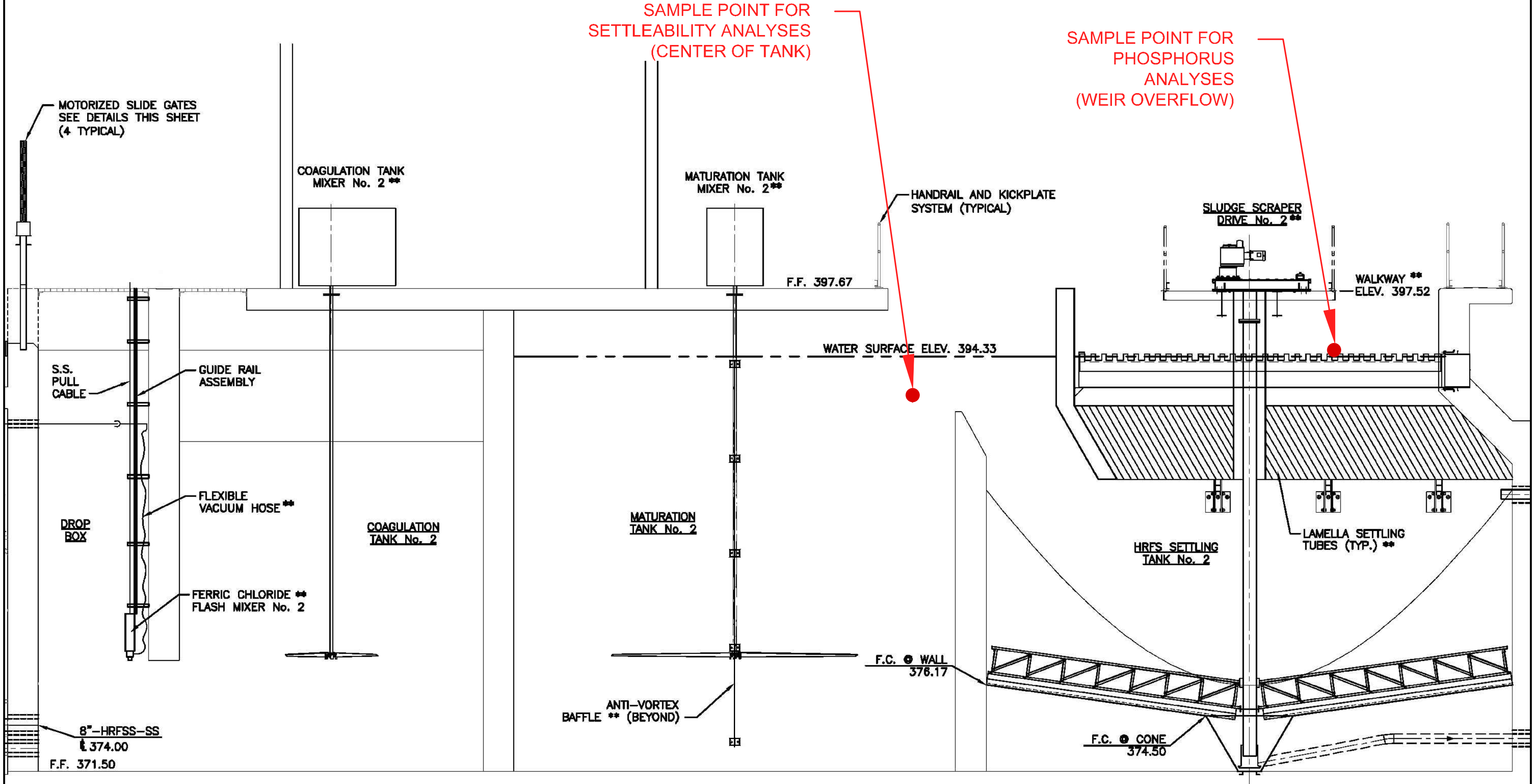


Figure 4-2

MIXER ANALYTICAL TESTING SAMPLE POINT LOCATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU007 JAN 08/2013

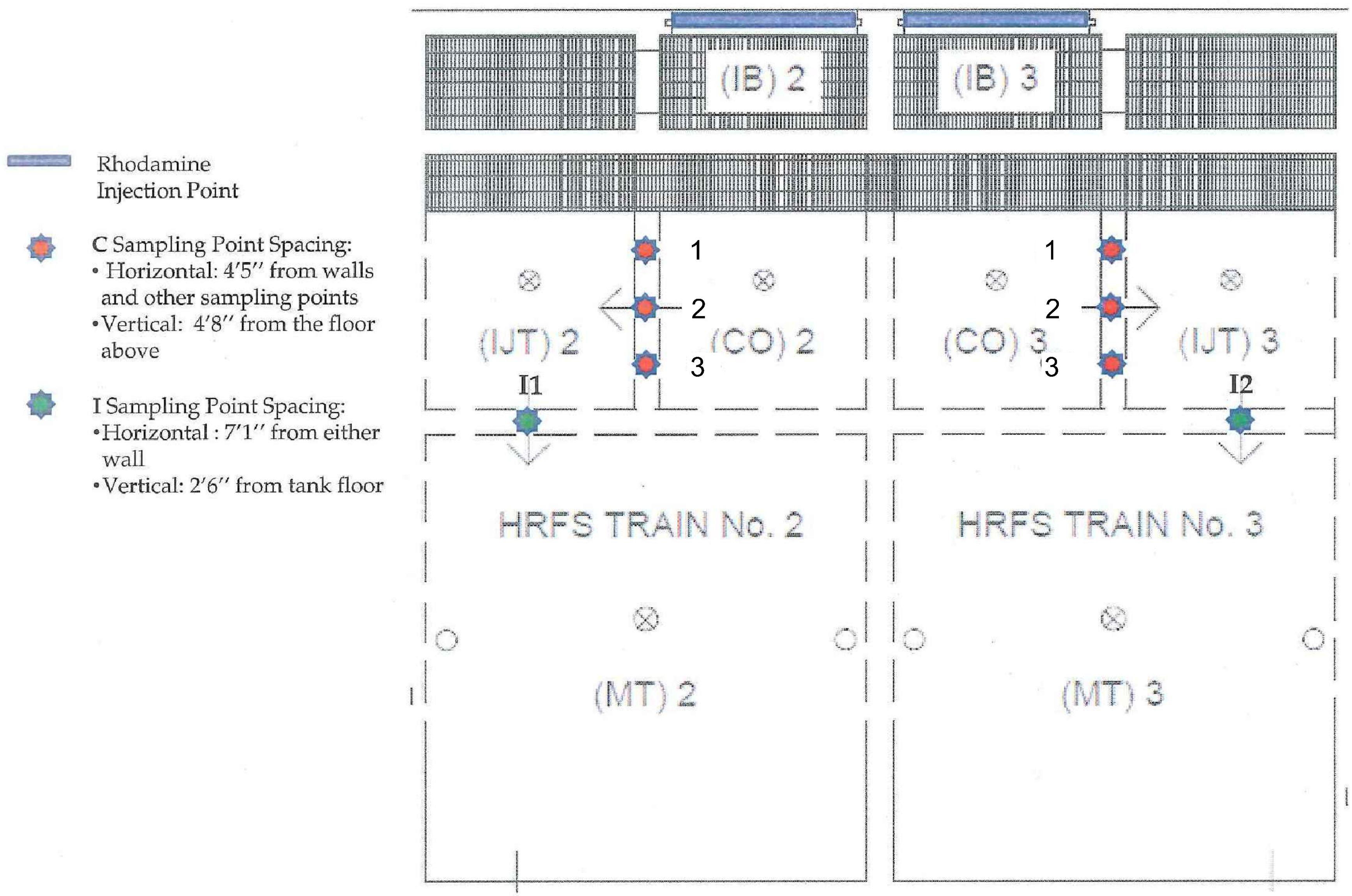


Figure 4-3

MIXER TRACER TESTING SAMPLE POINT LOCATION PLAN
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU015 JAN 29/2013

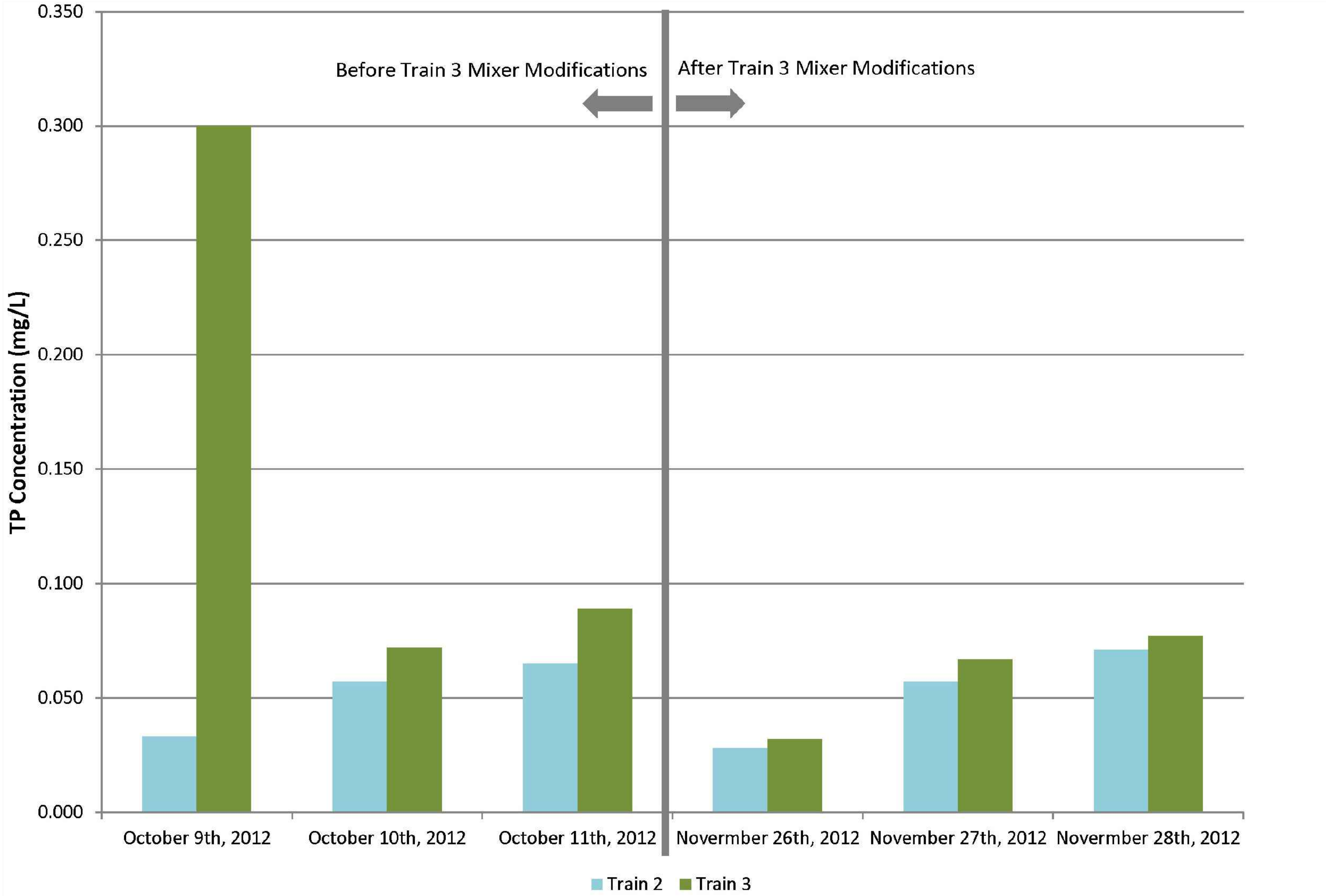


Figure 4-4

TRAIN 2 AND 3 EFFLUENT TOTAL PHOSPHORUS FOR THE MIXER PERFORMANCE TESTING
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU039 JAN 08/2013

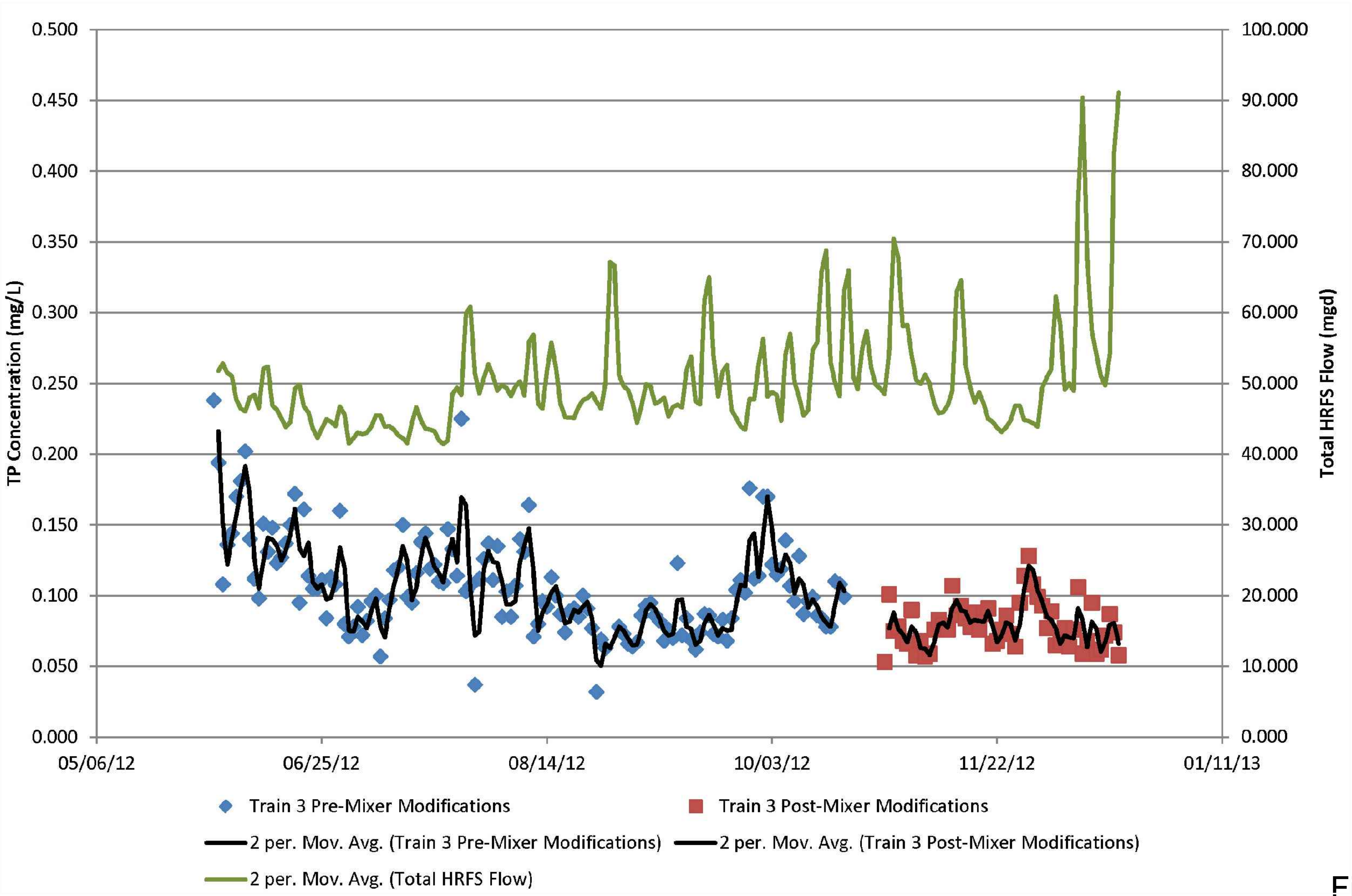


Figure 4-5

TRAIN 3 EFFLUENT TOTAL PHOSPHORUS AND TOTAL PLANT FLOW
BEFORE AND AFTER MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

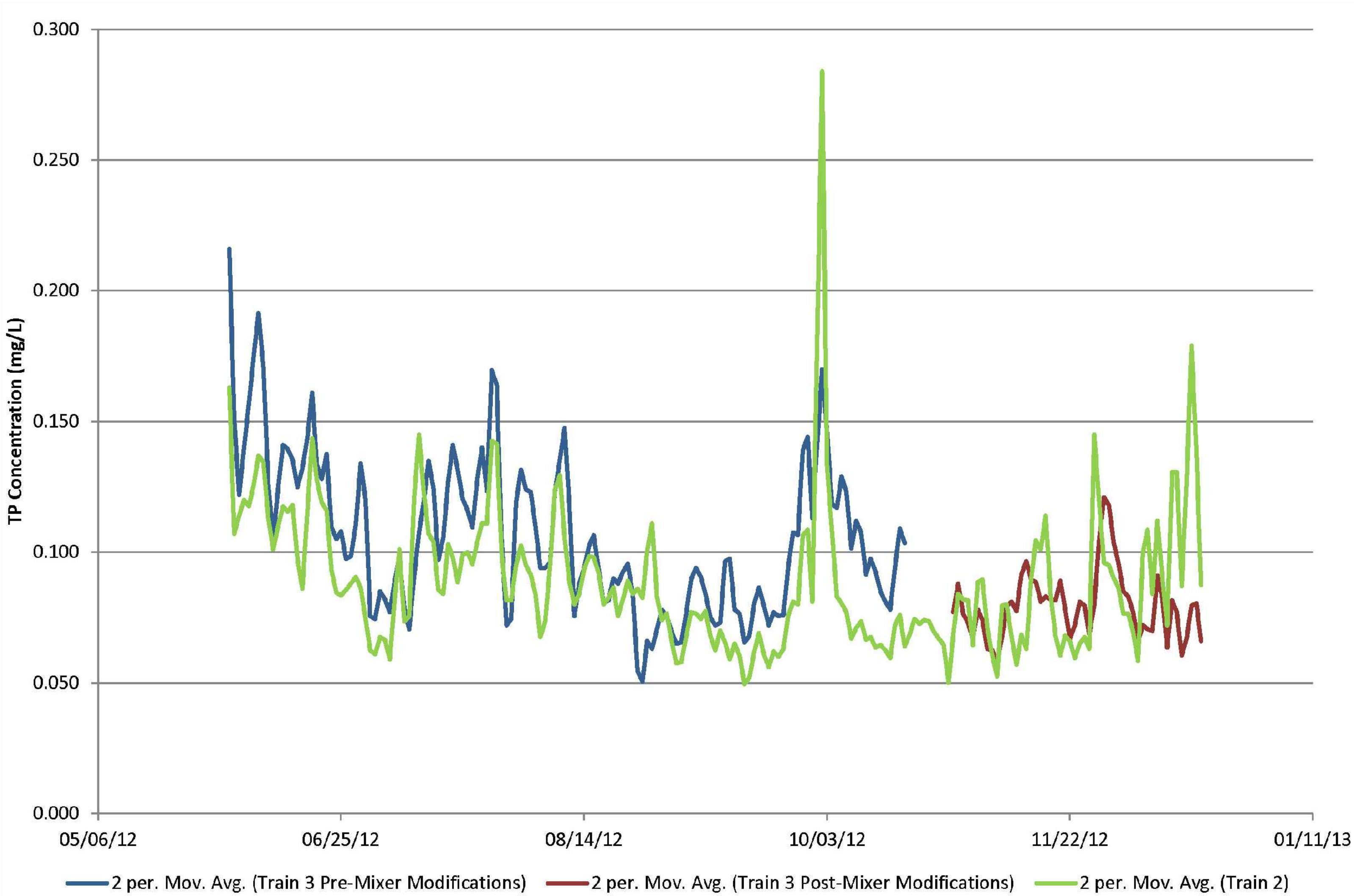


Figure 4-6

TRAIN 2 AND 3 EFFLUENT TOTAL PHOSPHORUS BEFORE AND AFTER MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU040 JAN 08/2013

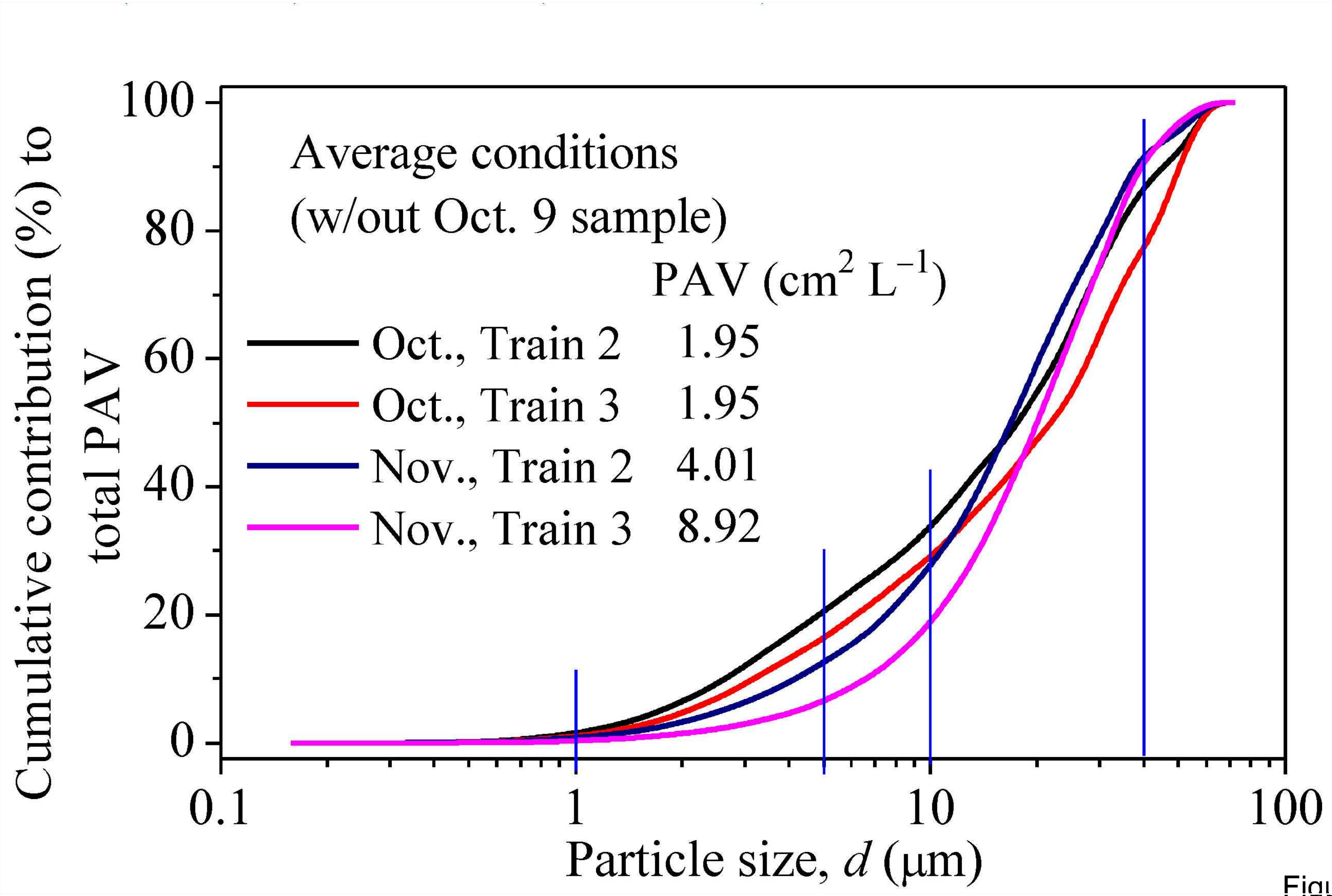


Figure 4-7

AVERAGE PAV OF TRAIN 2 AND 3 EFFLUENT SAMPLES COLLECTED
BEFORE (OCTOBER) AND AFTER (NOVEMBER) MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

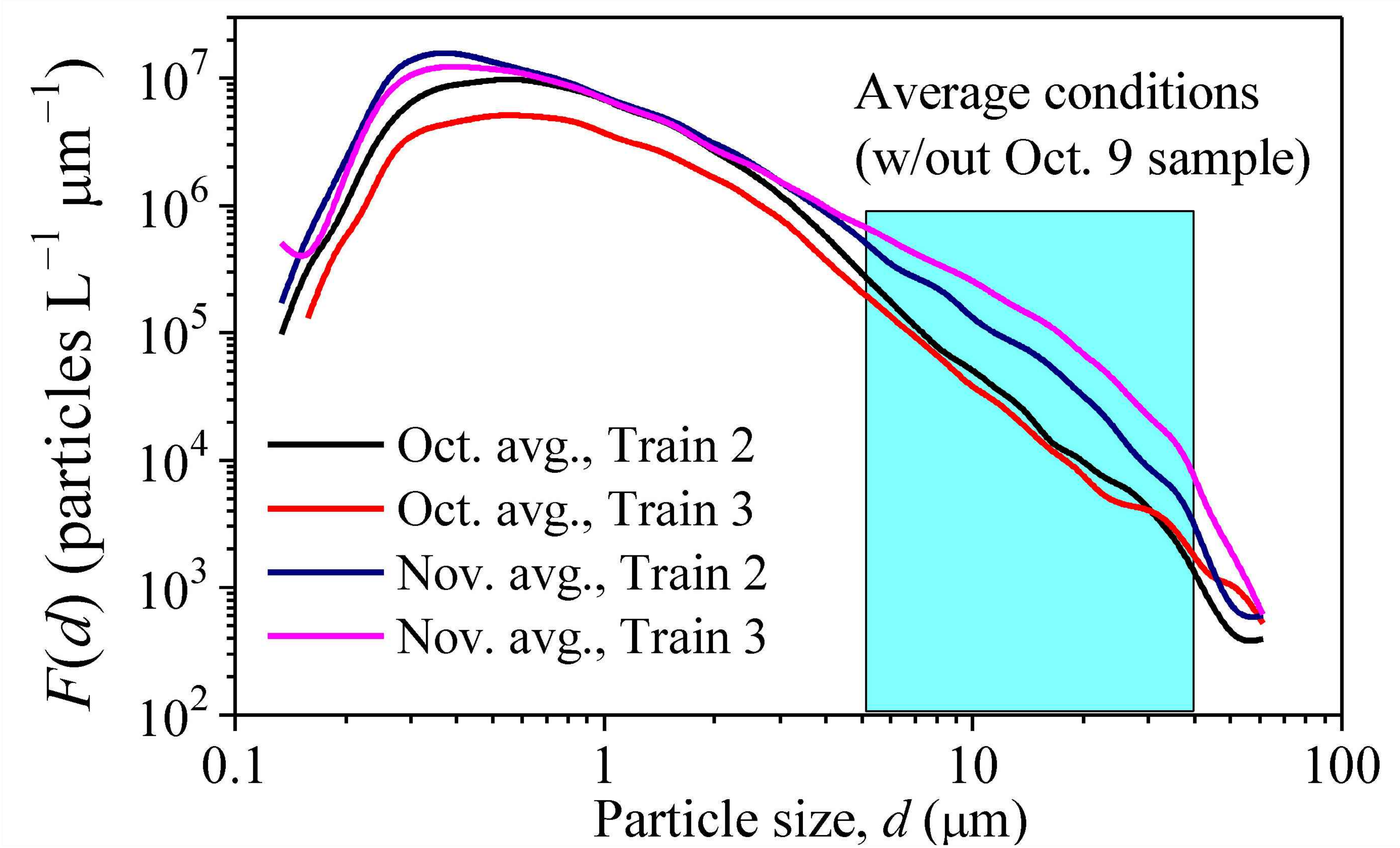
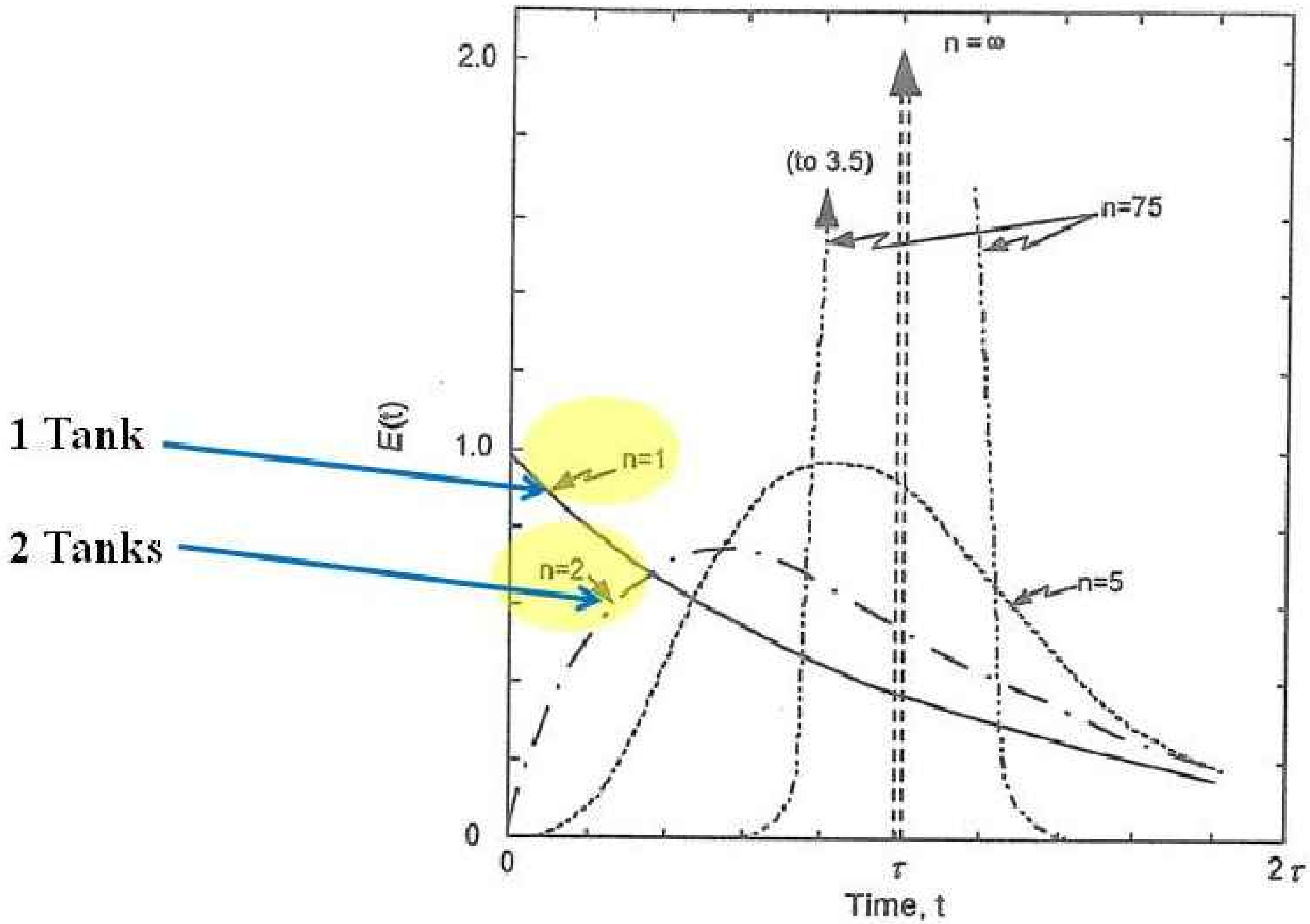


Figure 4-8

AVERAGE PARTICLE SIZE DISTRIBUTIONS OF TRAIN 2 AND 3 EFFLUENT SAMPLES COLLECTED BEFORE (OCTOBER) AND AFTER (NOVEMBER) MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

UPSTATE FRESHWATER INSTITUTE



Source: Grady, C.P., Diagger, G.T., Lim, H.C. (1999) Biological Wastewater Treatment, Second Edition.

Figure 4-9

THEORETICAL CURVES
TRACER RESPONSES TO N CSTR'S IN SERIES A SLUG IMPULSE TRACER INPUT
Onondaga County WEP

630742-00(005)GN-BU020 JAN 08/2013

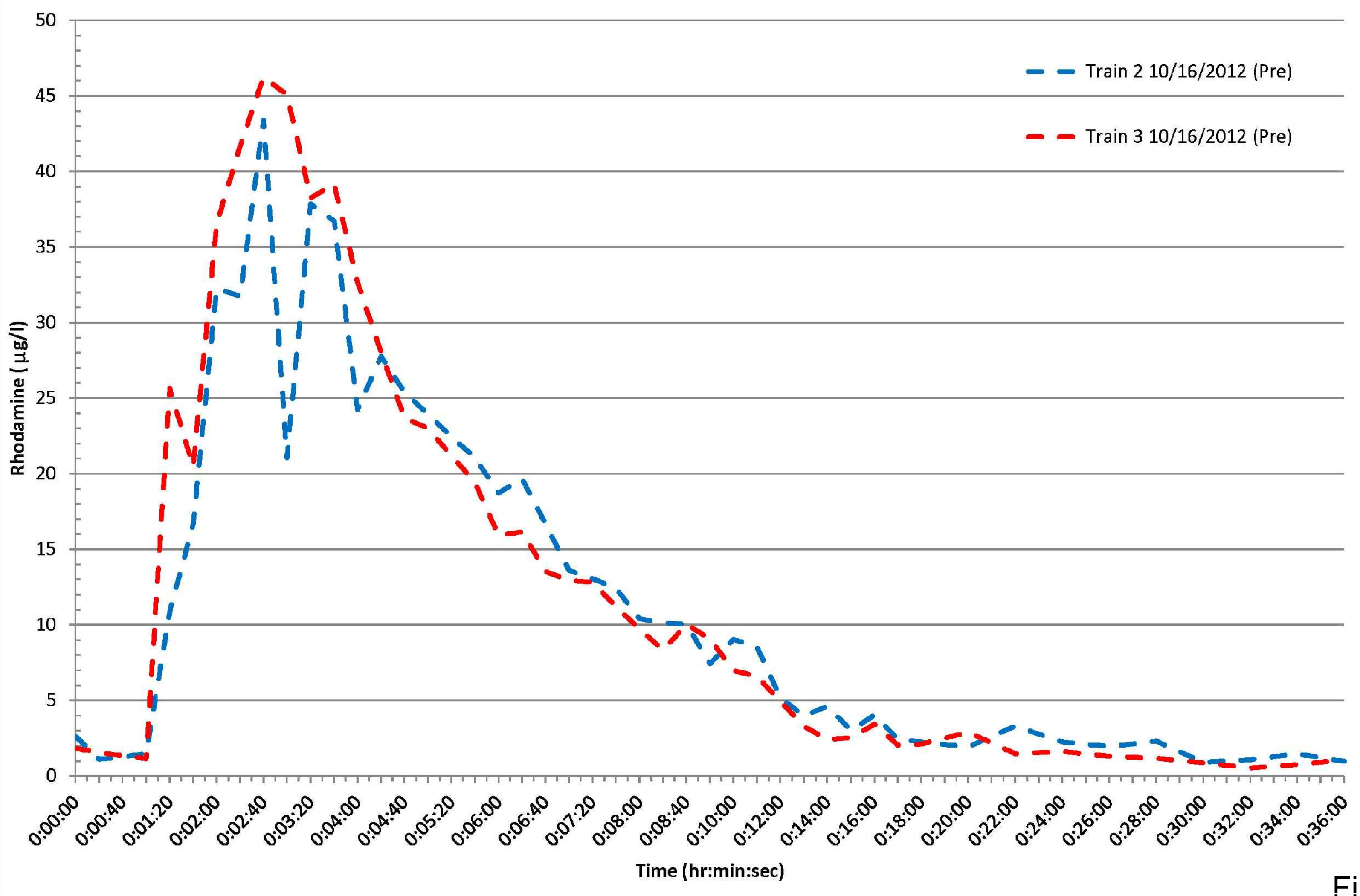


Figure 4-10

TRACER RESPONSE IN HRFS TRAINS 2 & 3 COAGULATION
TANK LOCATION 2 BEFORE MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU043 JAN 08/2013

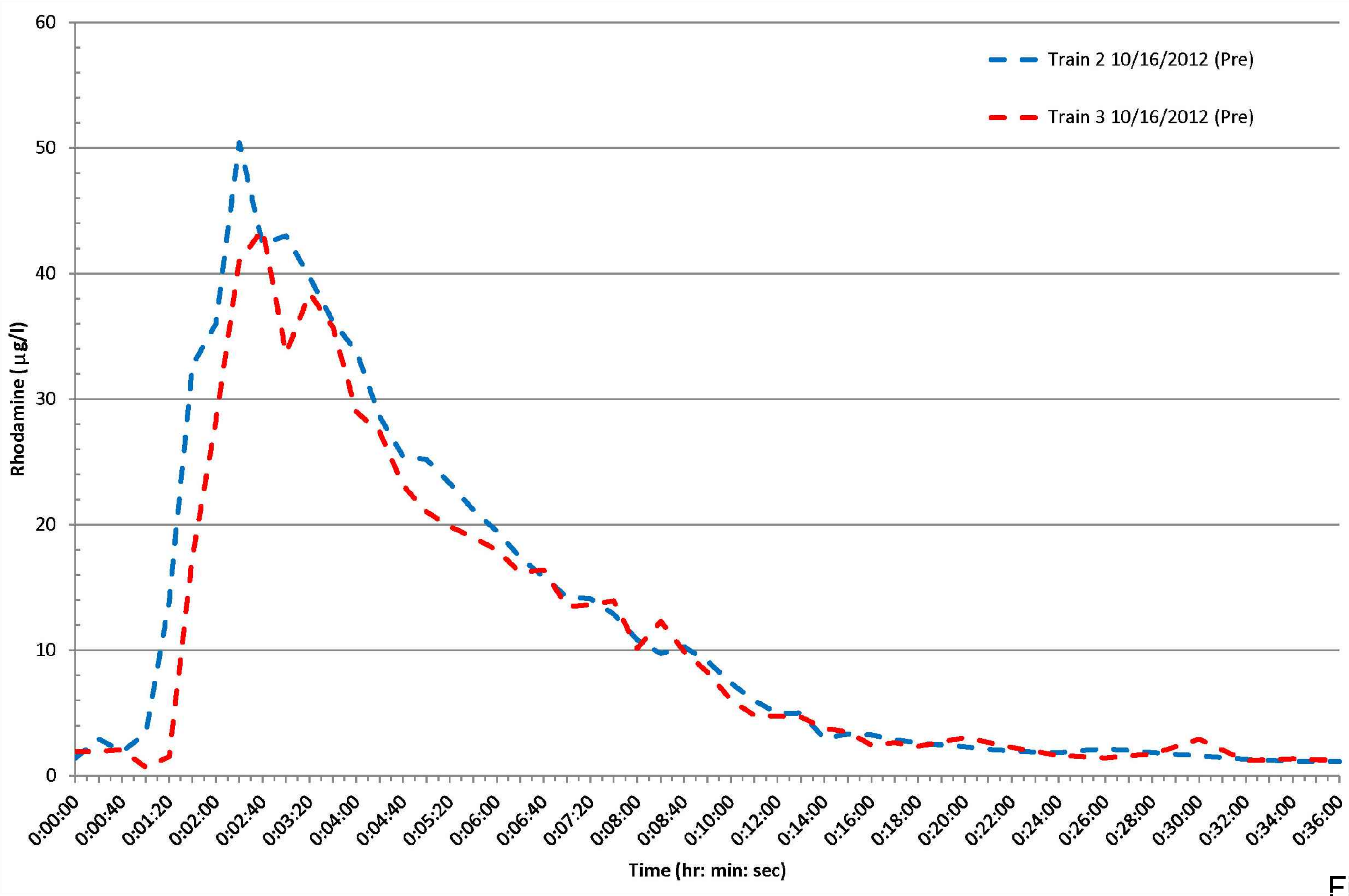


Figure 4-11

TRACER RESPONSE IN HRFS TRAINS 2 & 3 COAGULATION TANK LOCATION 3 BEFORE MIXER MODIFICATIONS

METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES

Onondaga County WEP

CRA

630742-00(005)GN-BU046 JAN 08/2013

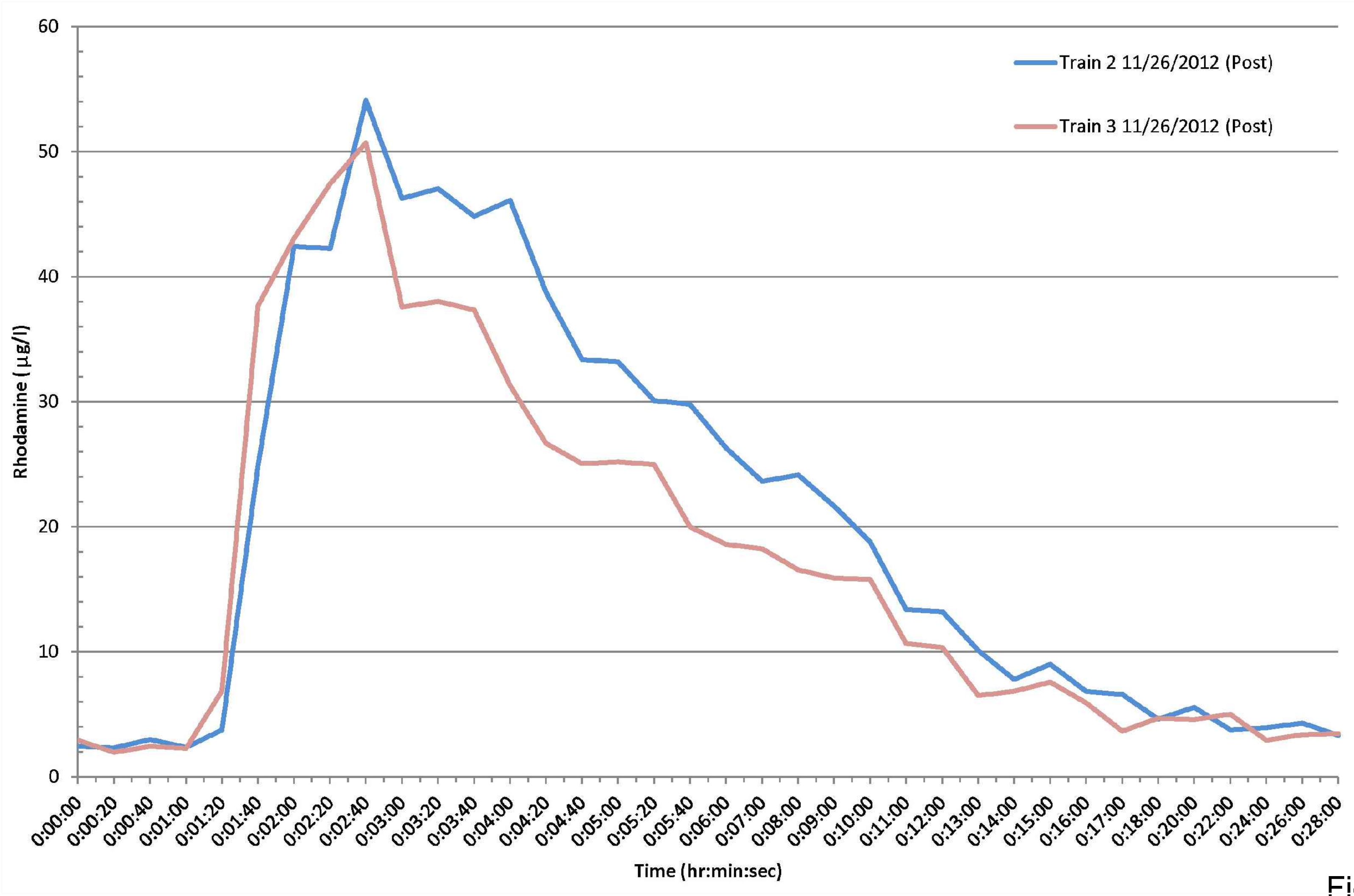


Figure 4-12

TRACER RESPONSE IN HRFS TRAINS 2 & 3 COAGULATION
TANK LOCATION 2 AFTER MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU044 JAN 08/2013

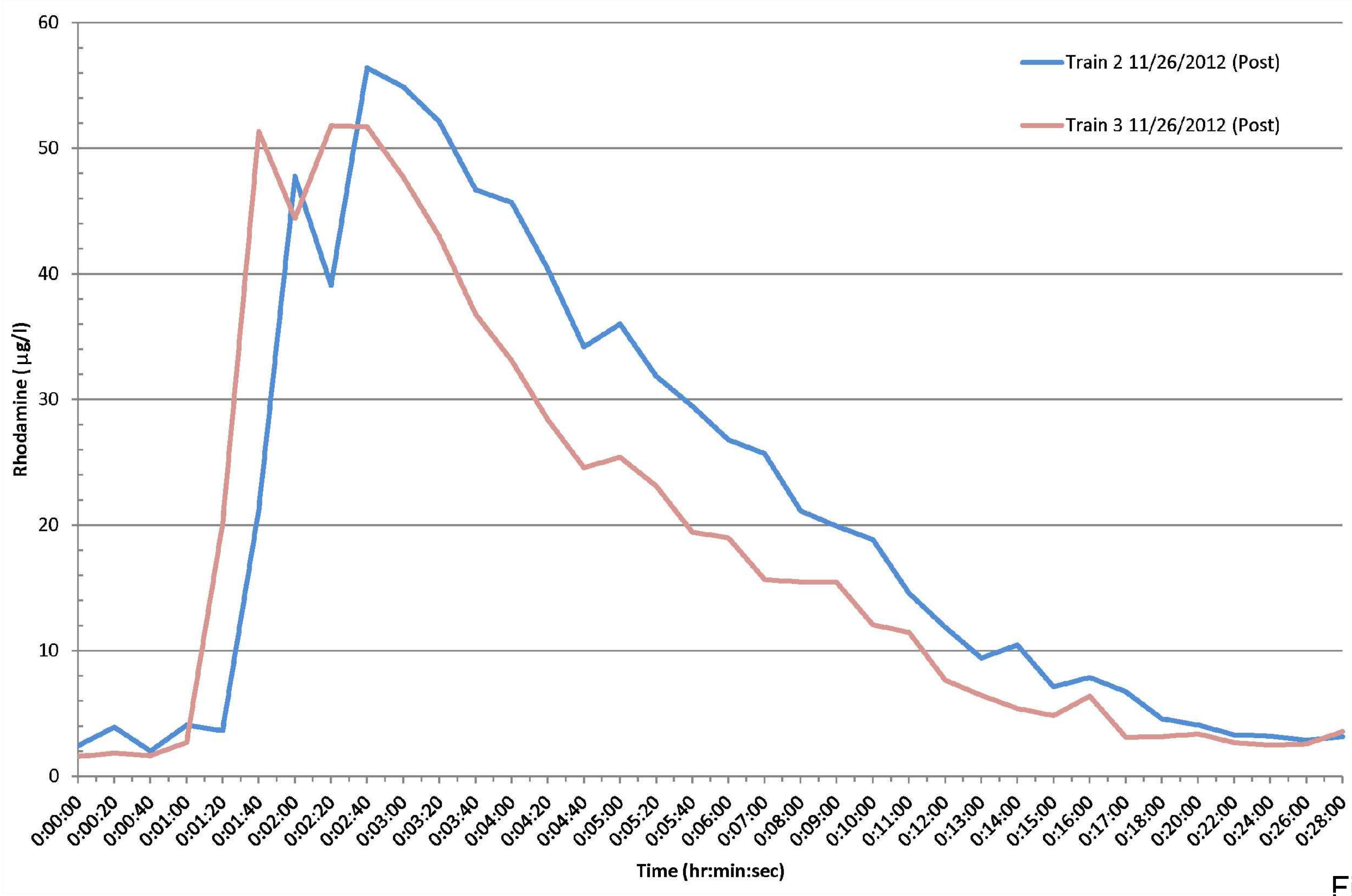


Figure 4-13

TRACER RESPONSE IN HRFS TRAINS 2 & 3 COAGULATION
TANK LOCATION 3 AFTER MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU045 JAN 08/2013

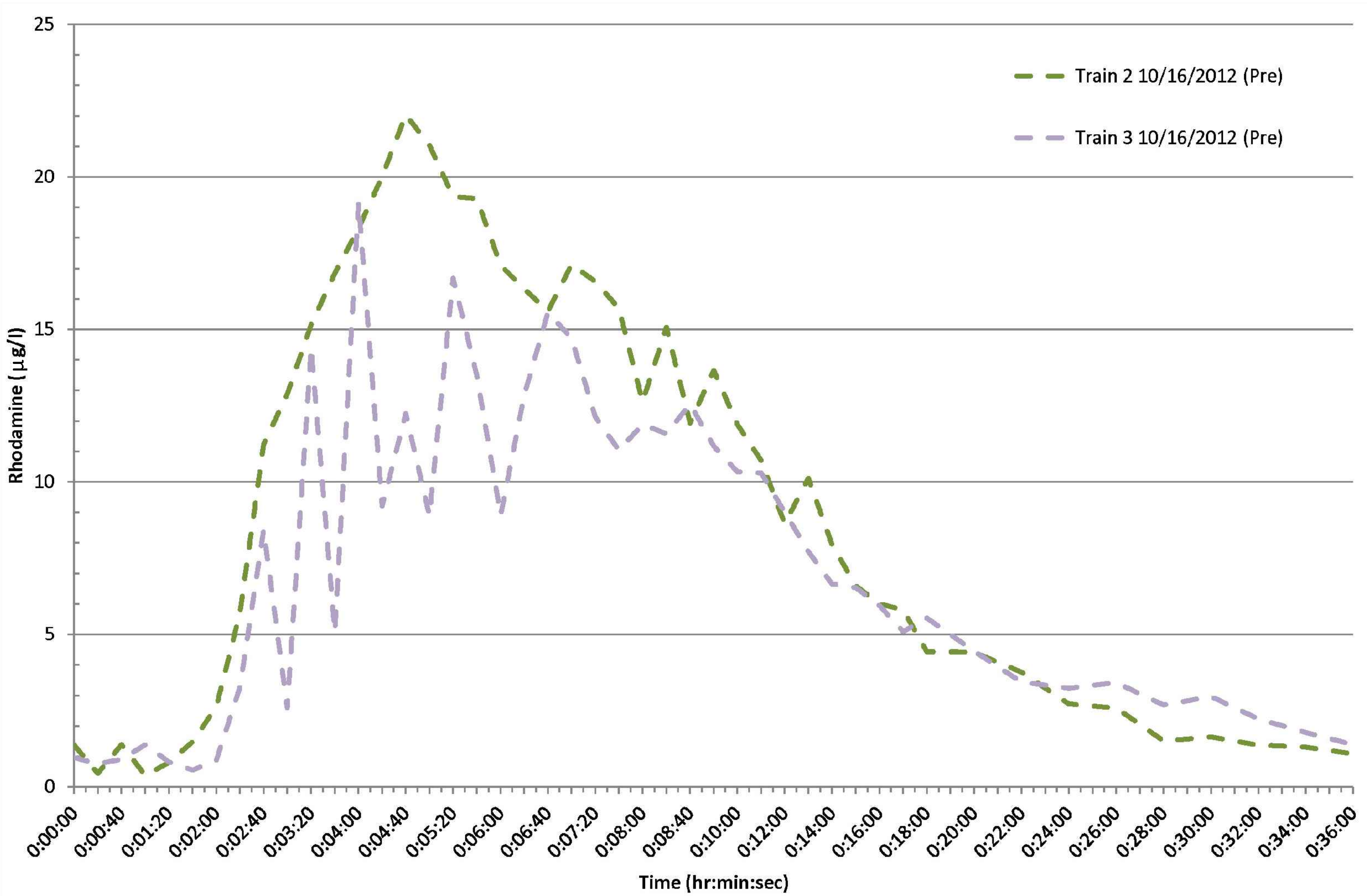


Figure 4-14

TRACER RESPONSE IN HRFS TRAINS 2 & 3 INJECTION TANK BEFORE MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU047 JAN 08/2013

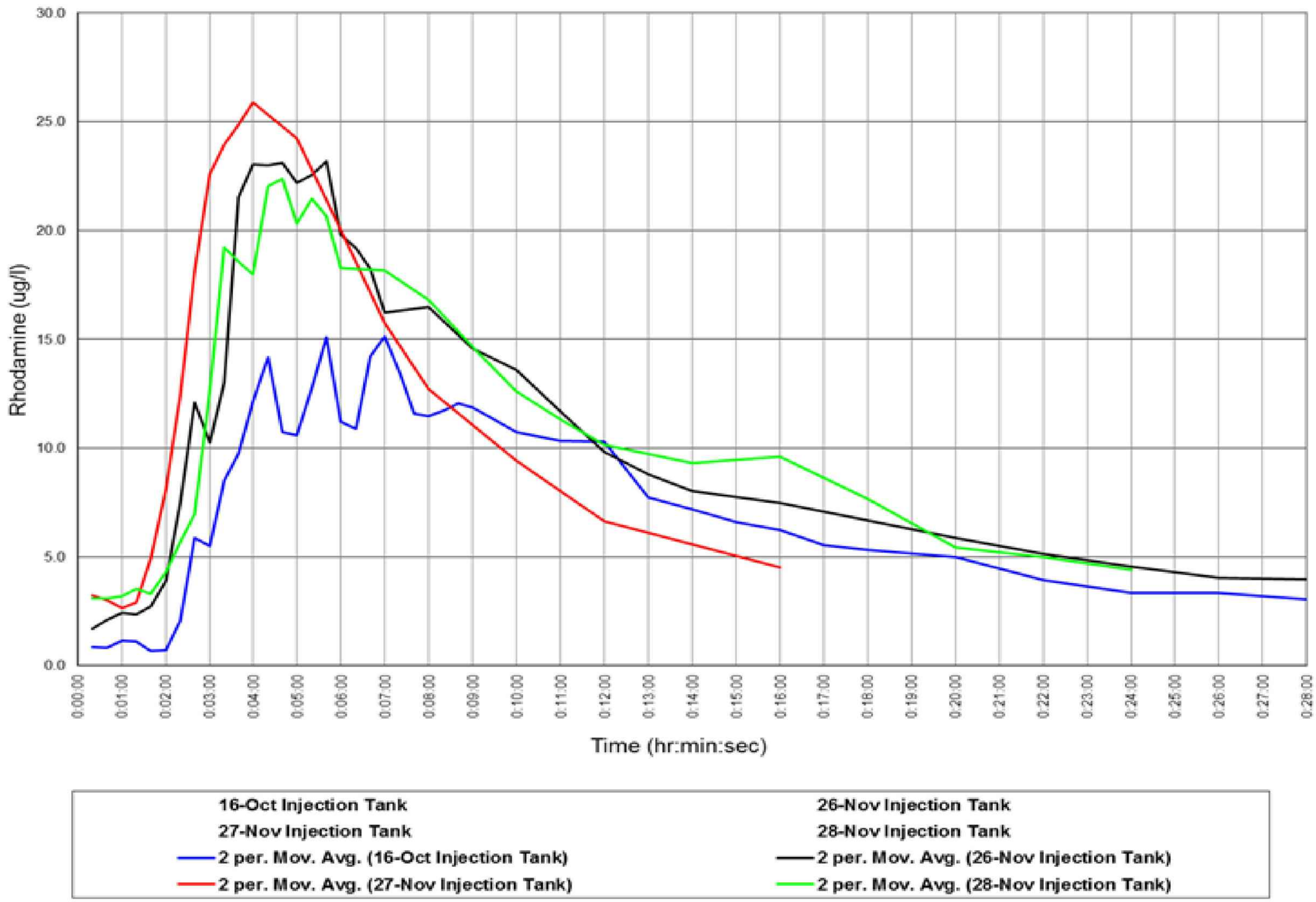


Figure 4-15

TRACER RESPONSE IN HRFS TRAIN 3 INJECTION TANK BEFORE MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

Figure 4-16

TRACER RESPONSE IN HRFS TRAINS 2 & 3 INJECTION TANK AFTER MIXER MODIFICATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

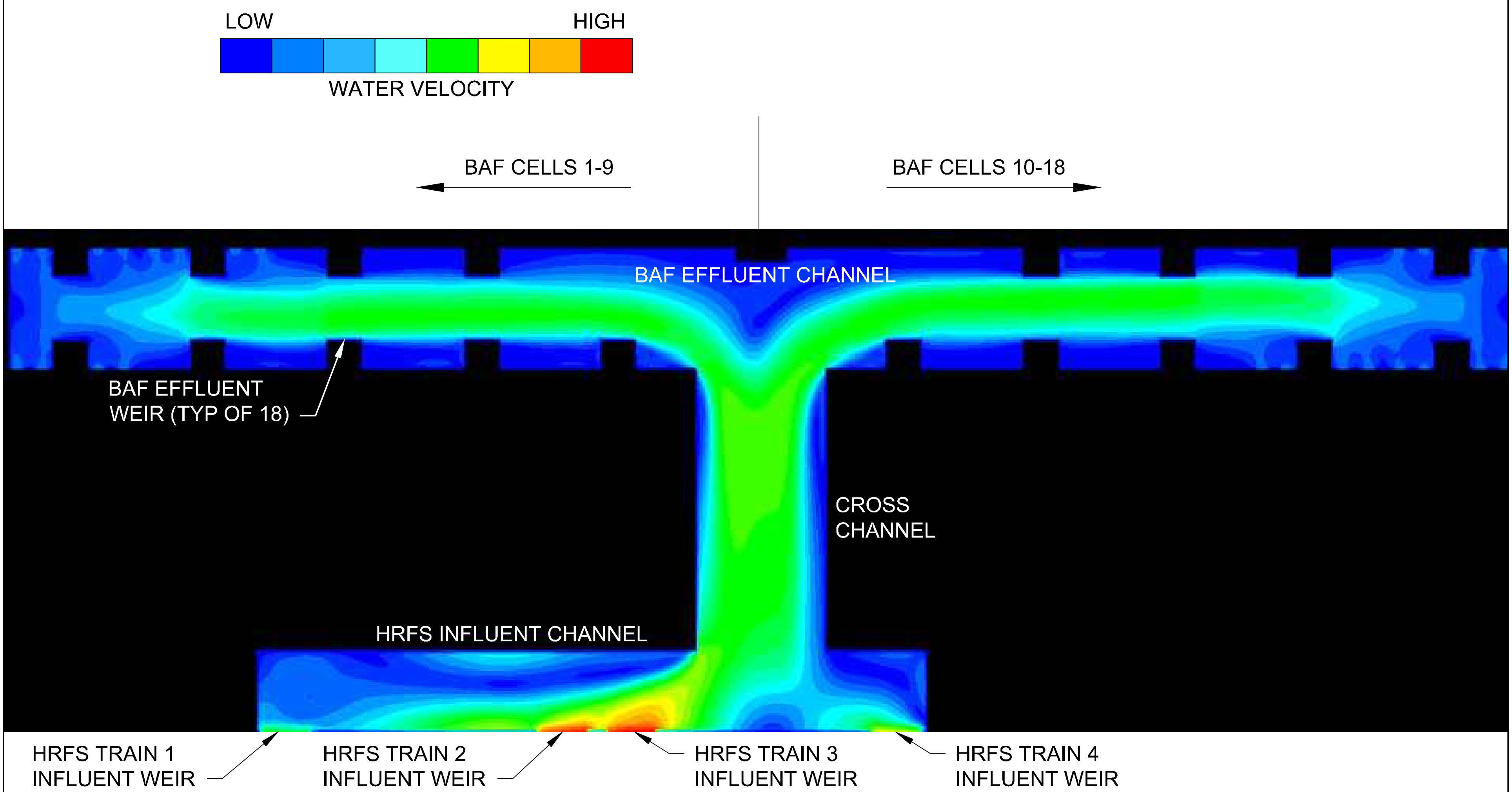


Figure 5-1

VELOCITY CONTOURS FROM CFD SIMULATION
BALANCED BAF FLOW CONDITION AT METRO WWTP FLOW OF 70 MGD
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU051 MAR 26/2013

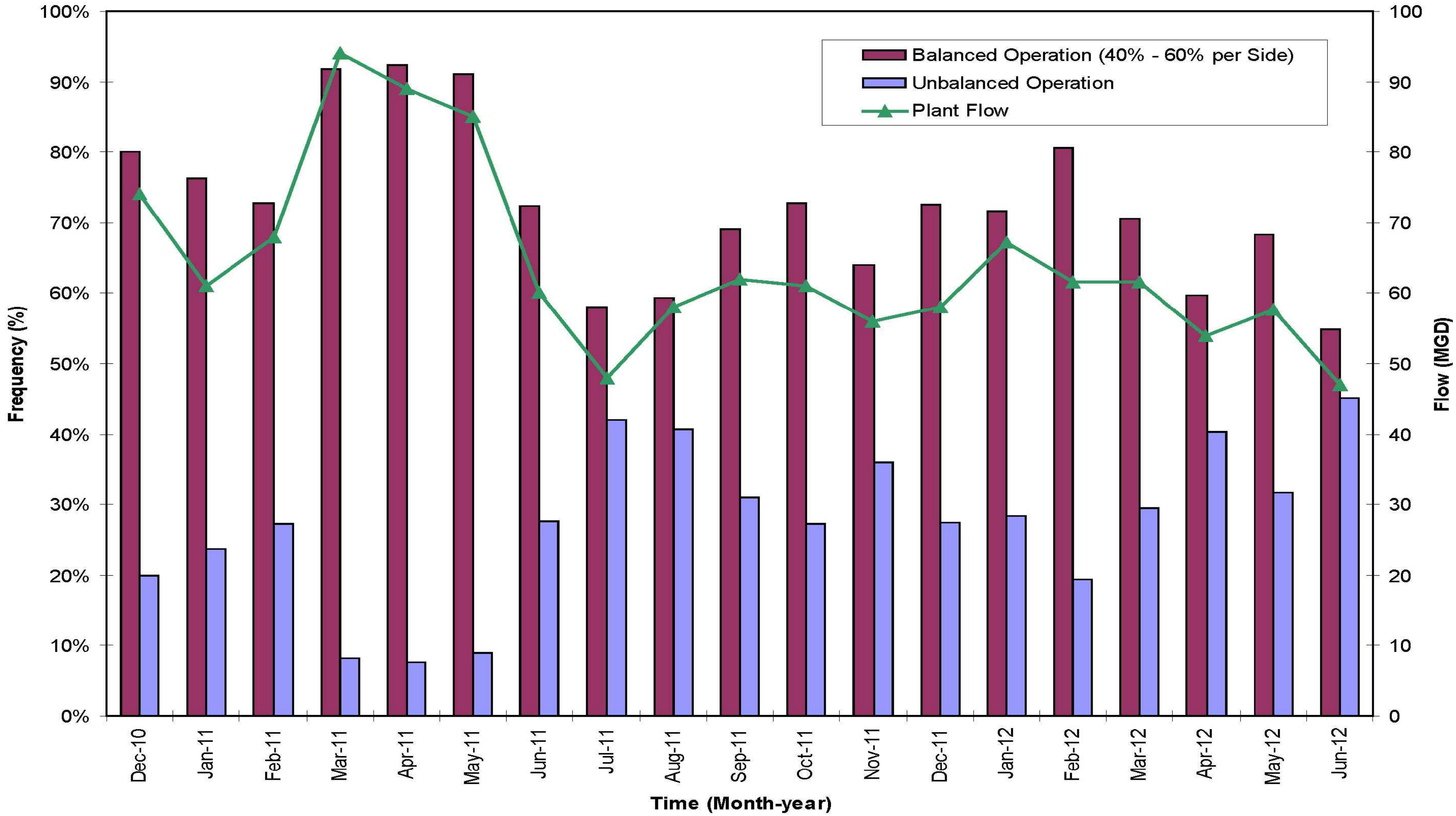
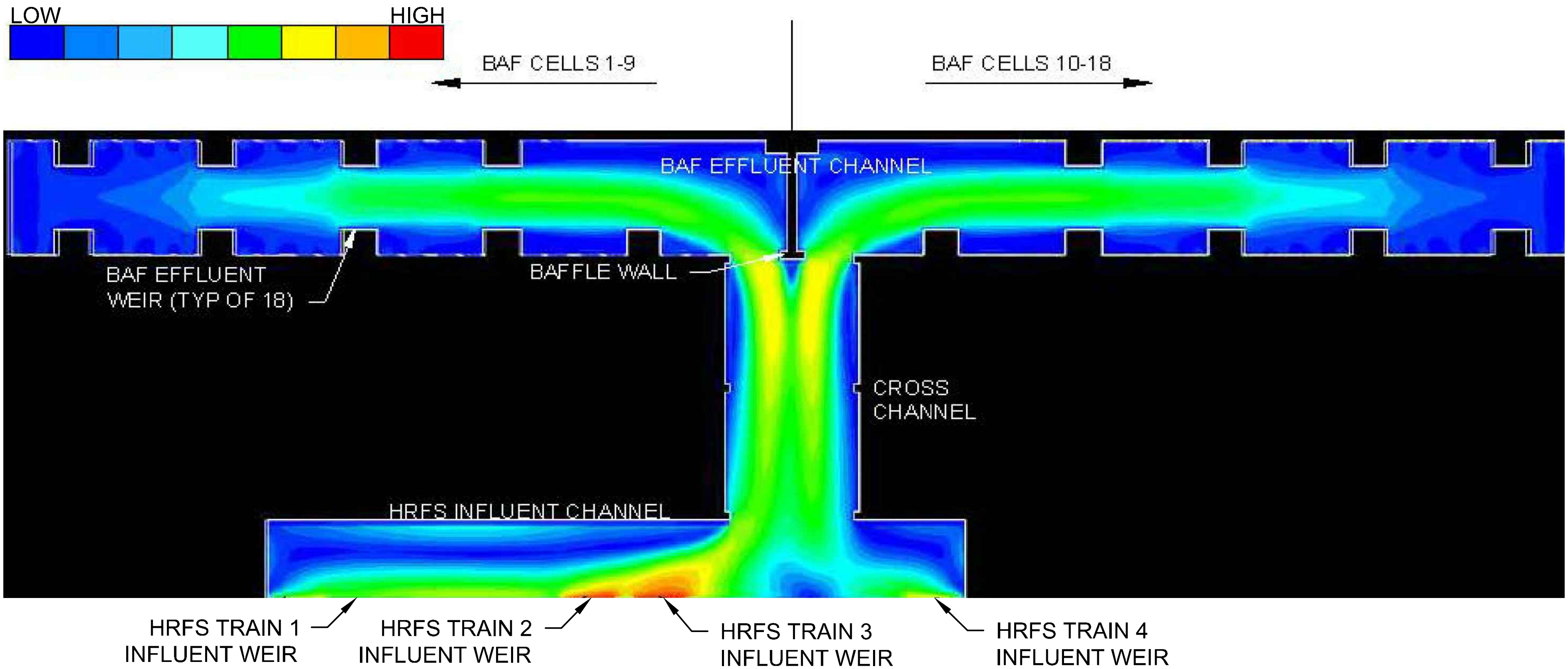


Figure 5-2

SUMMARY OF BAF FILTER OPERATION CONFIGURATION (DECEMBER 2010- JUNE 2012)
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU052 JAN 08/2013



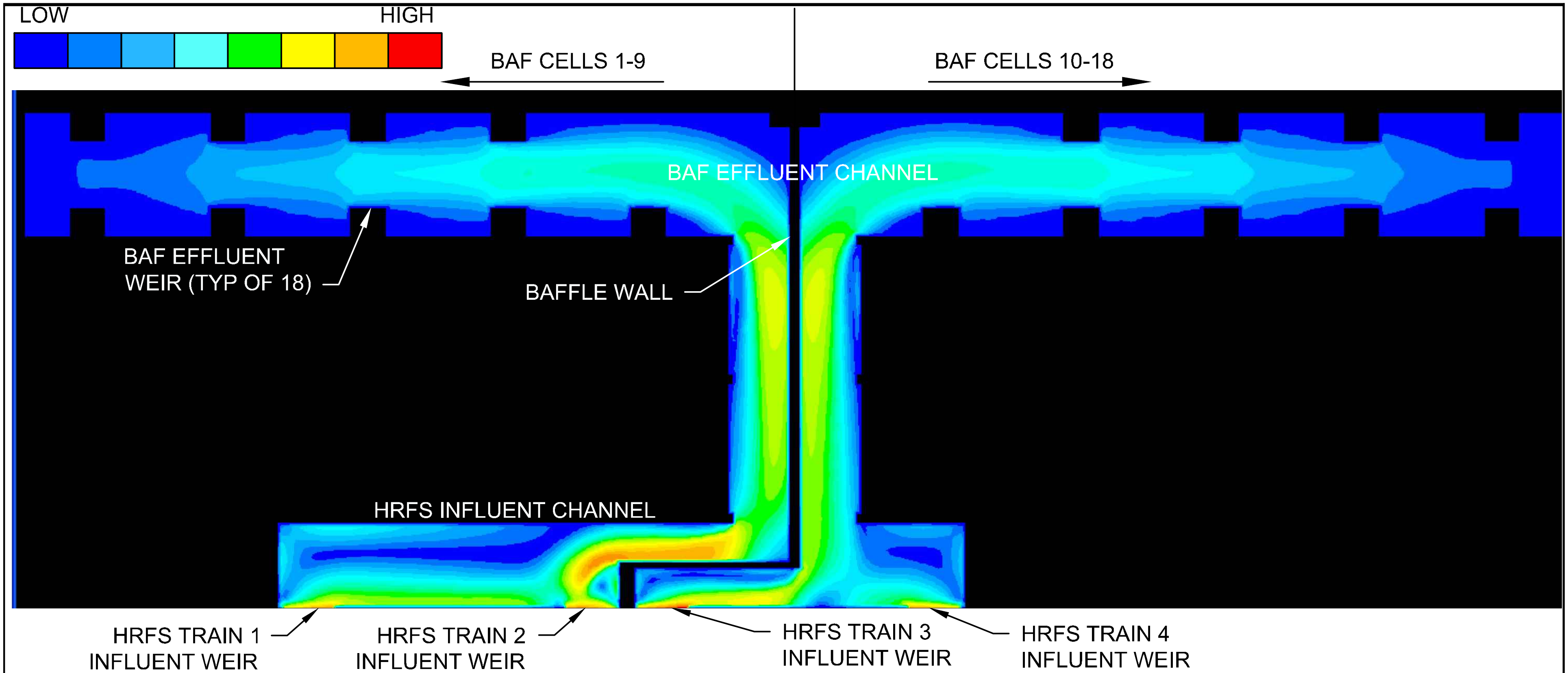
RUN	TRAIN 1	TRAIN 2	TRAIN 3	TRAIN 4
Model: 70 mgd	24.5%	26.5%	25.5%	23.5%
Full Scale: 70 - 80 mgd	25.6%	24.9%	26.2%	23.2%
Model: 130 mgd	25.5%	25.5%	24.4%	24.4%
Full Scale: 120 - 130 mgd	25.6%	24.3%	24.3%	25.7%
Full Scale: Average All Data	25.4%	24.8%	25.9%	23.9%

Figure 5-3

VELOCITY CONTOURS AND HRFS FLOW BALANCE SUMMARY
BALANCED BAF OPERATION, HRFS TRAIN 4 RAISED 4", HRFS TRAIN 2 AND 3 WEIRS RAISED 1"
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU053 JAN 08/2013



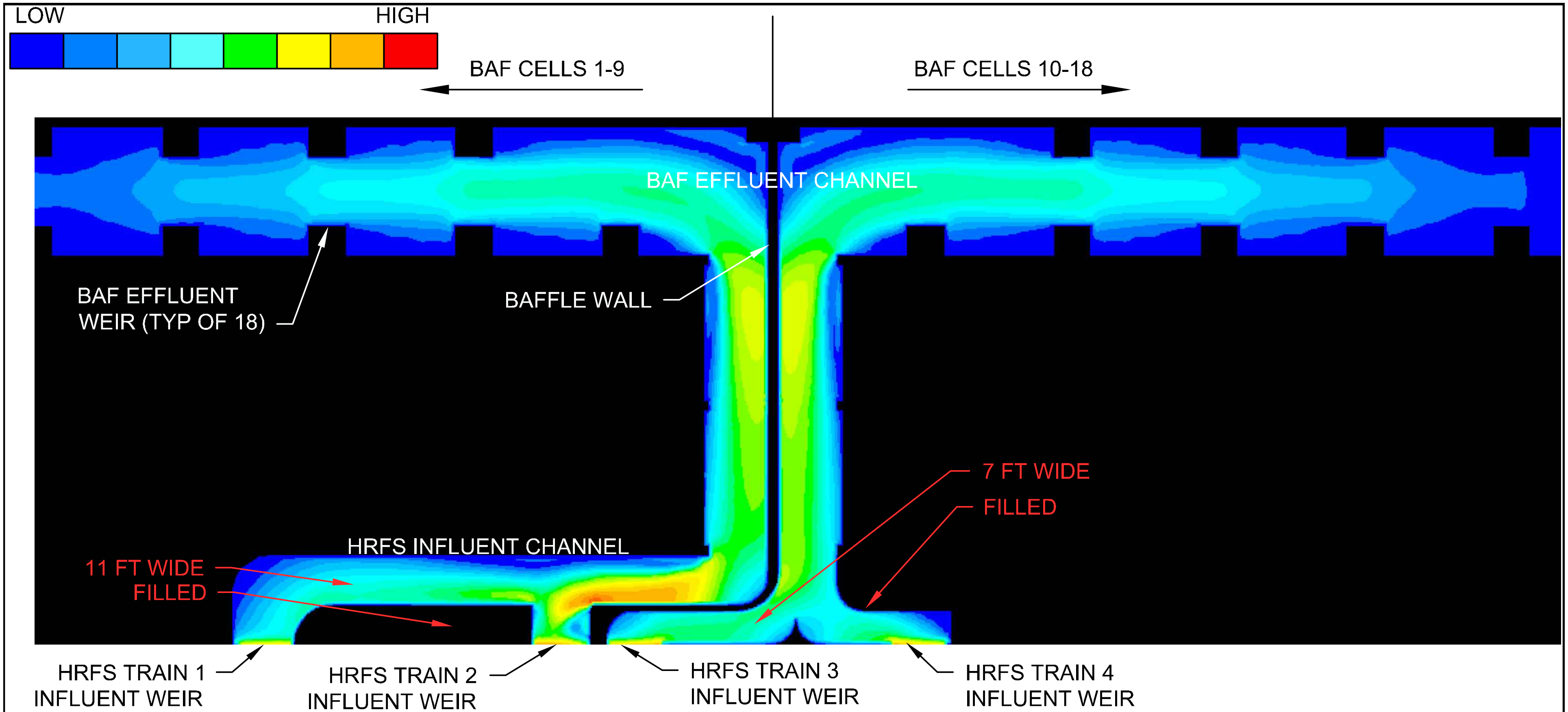
	HRFS FLOW DISTRIBUTION			
	TRAIN 1	TRAIN 2	TRAIN 3	TRAIN 4
40 MGD:	26.5%	23.5%	24.5%	25.5%
70 MGD:	26.5%	23.5%	24.5%	25.5%
130 MGD:	26.0%	24.0%	24.5%	25.5%

Figure 5-4

VELOCITY CONTOURS AND HRFS FLOW BALANCE SUMMARY
INITIAL WALL/ CHANNEL CONFIGURATION
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

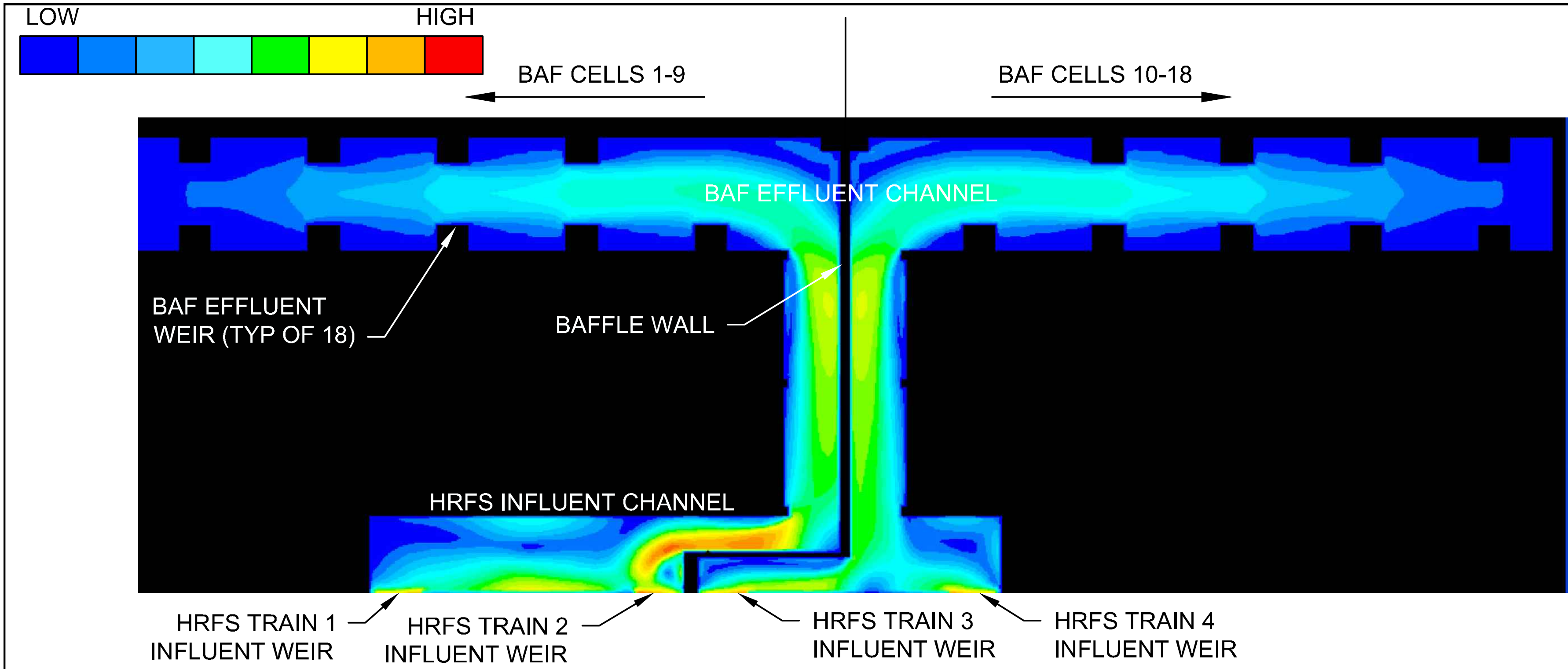
630742-00(005)GN-BU054 JAN 08/2013



	HRFS FLOW DISTRIBUTION			
	TRAIN 1	TRAIN 2	TRAIN 3	TRAIN 4
40 MGD:	25.5%	24.5%	26.5%	23.5%
70 MGD:	25.5%	24.5%	25.5%	24.5%
130 MGD:	25.5%	24.5%	26.0%	24.0%

Figure 5-5

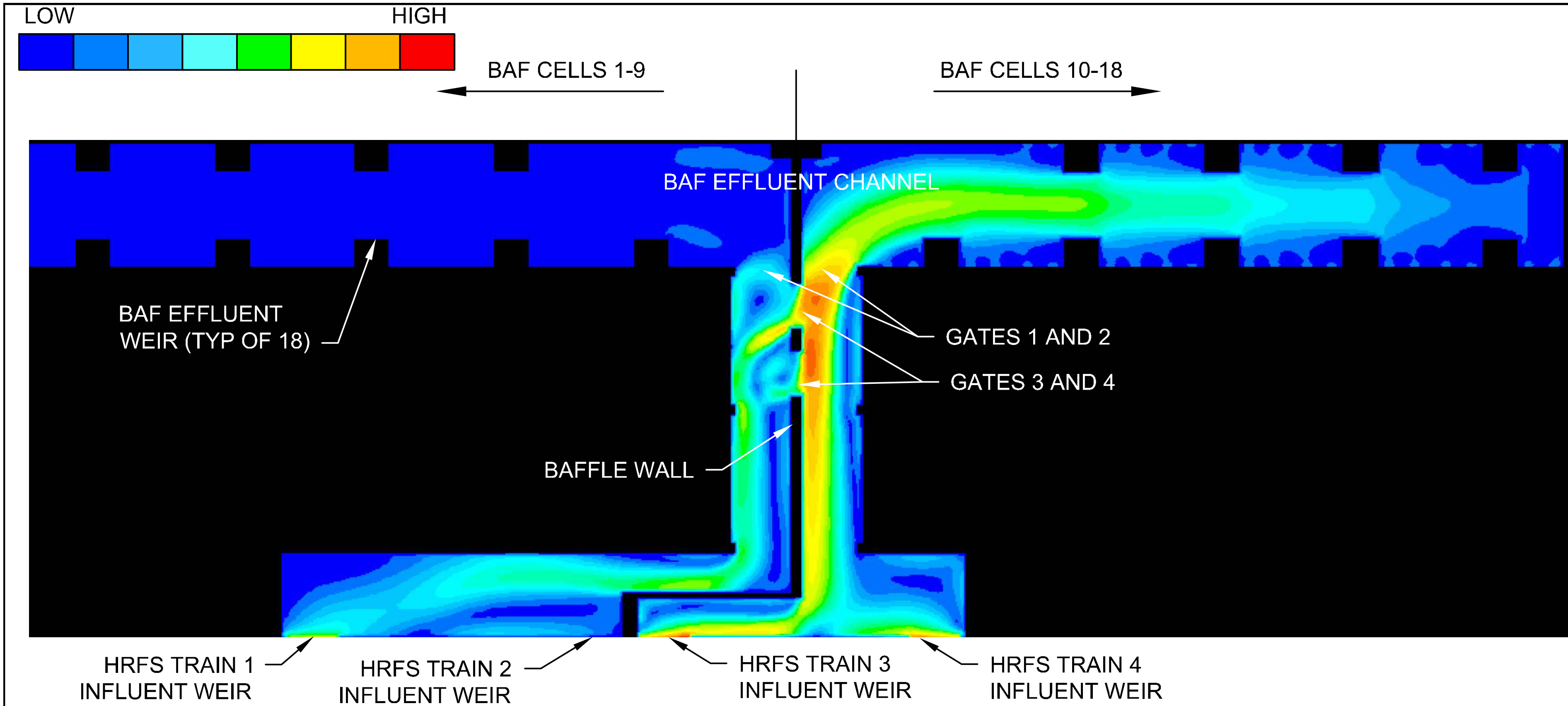
VELOCITY CONTOURS AND HRFS FLOW BALANCE SUMMARY
OPTIMIZED WALL/CHANNEL CONFIGURATION
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP



	HRFS FLOW DISTRIBUTION			
	TRAIN 1	TRAIN 2	TRAIN 3	TRAIN 4
40 MGD:	24.5%	25.5%	24.5%	25.0%
70 MGD:	25.5%	24.5%	25.0%	25.0%
130 MGD:	25.0%	25.0%	25.0%	25.0%

Figure 5-6

VELOCITY CONTOURS AND HRFS FLOW BALANCE SUMMARY
SELECTED WALL/ CHANNEL CONFIGURATION RAISE WEIR 1 BY 3" AND WEIR 4 BY 2"
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

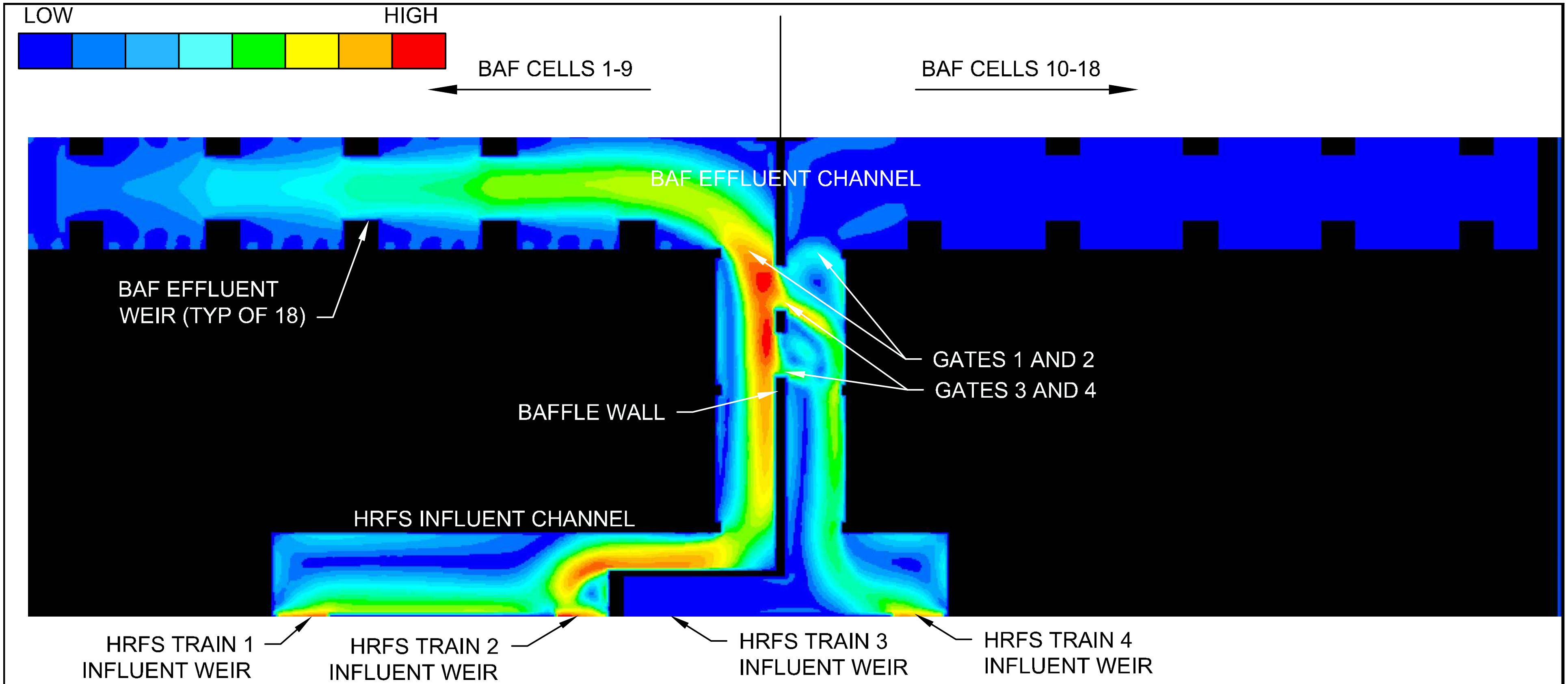


	HRFS FLOW DISTRIBUTION			
	TRAIN 1	TRAIN 2	TRAIN 3	TRAIN 4
90 MGD:	30%	N/A	34%	36%

Figure 5-7

VELOCITY CONTOURS AND HRFS FLOW BALANCE
90 MGD THROUGH NORTH BAF, NO FLOW IN SOUTH BAF, HRFS TRAIN 2 OFF
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

630742-00(005)GN-BU057 JAN 08/2013



	HRFS FLOW DISTRIBUTION			
	TRAIN 1	TRAIN 2	TRAIN 3	TRAIN 4
90 MGD:	35%	32%	N/A	33%

Figure 5-8

VELOCITY CONTOURS AND HRFS FLOW BALANCE
90 MGD THROUGH SOUTH BAF, NO FLOW IN NORTH BAF, HRFS TRAIN 3 OFF
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU058 JAN 08/2013

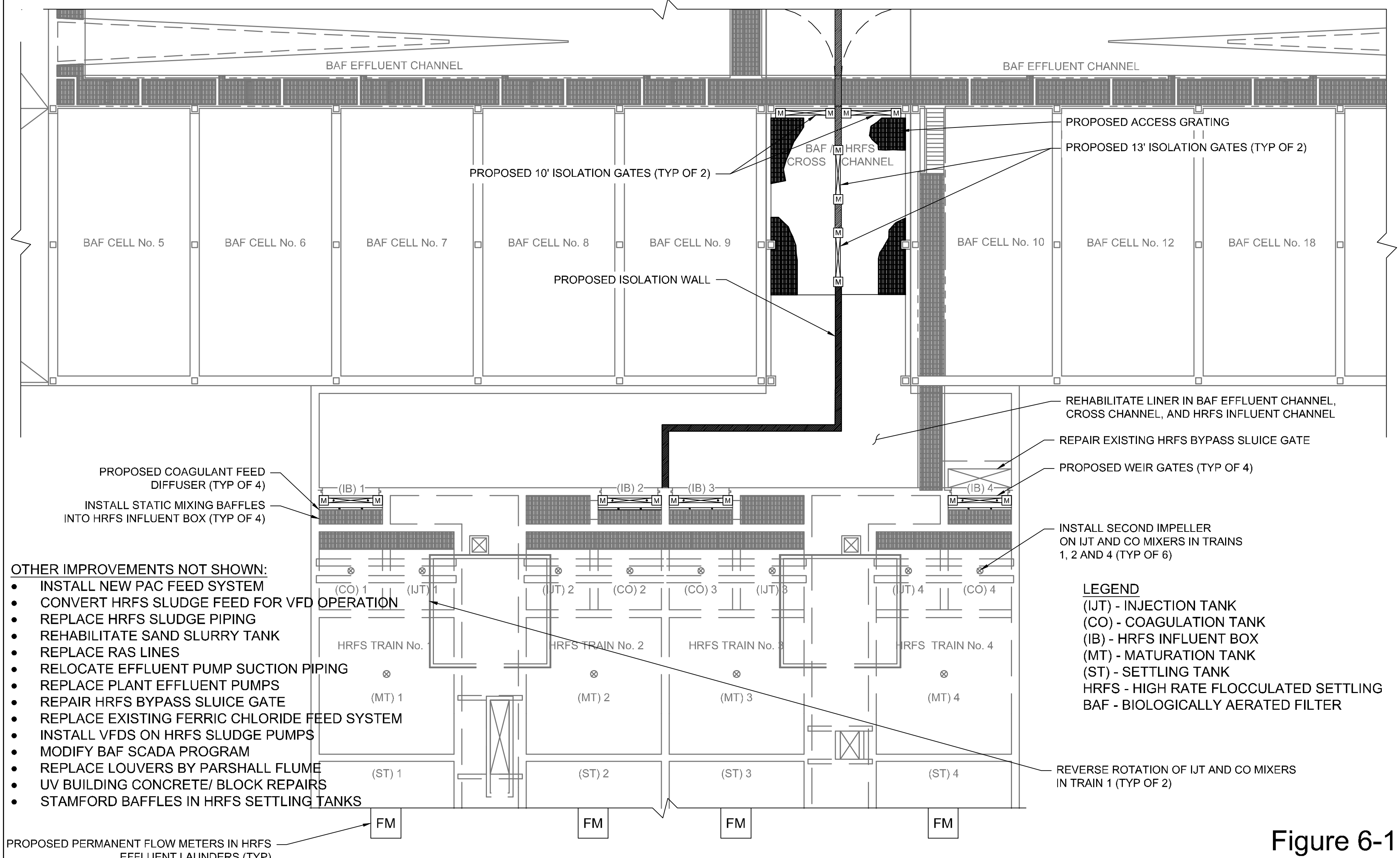


Figure 6-1

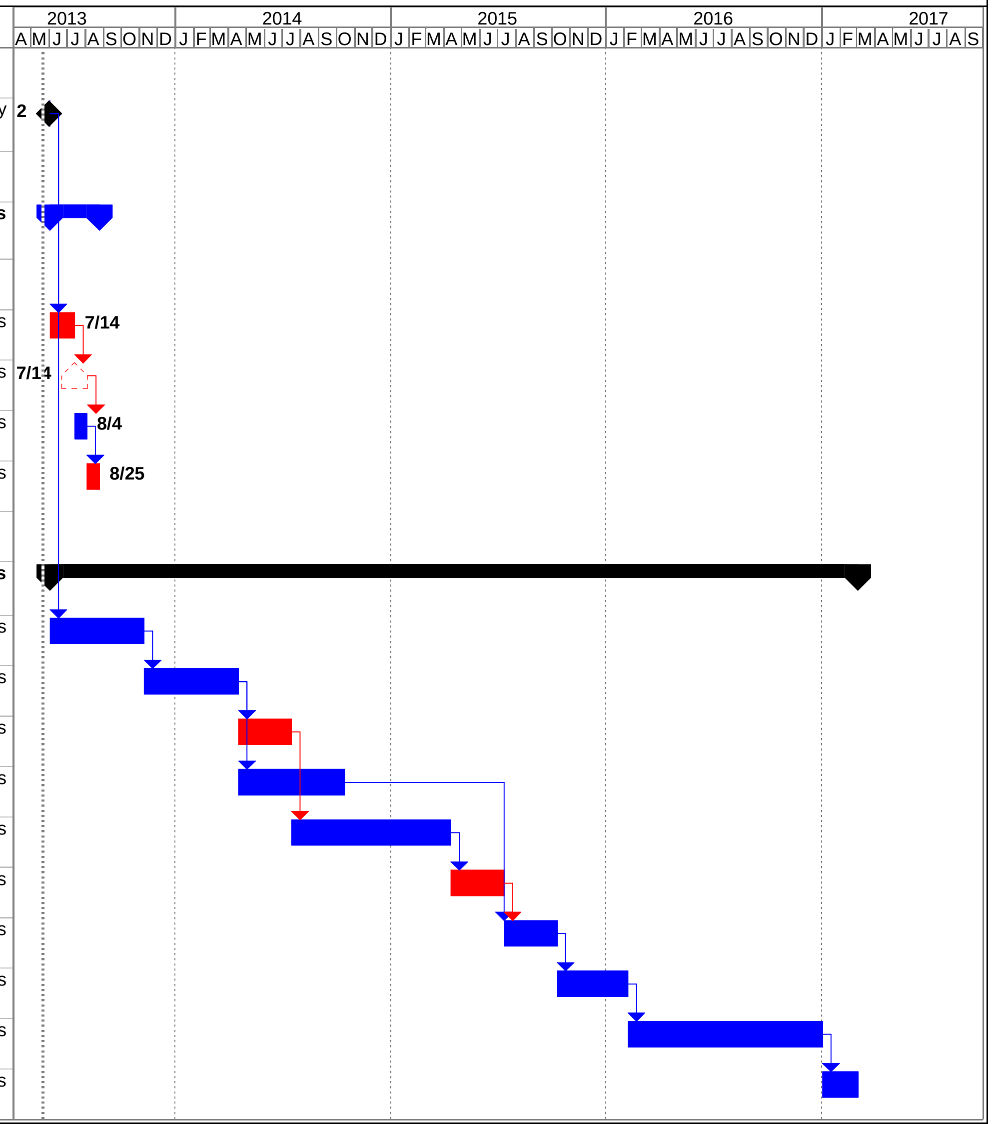
UPDATED METRO WWTP OPTIMIZATION IMPROVEMENT RECOMMENDATIONS
METRO WWTP OPTIMIZATION PRE-IMPLEMENTATION STUDIES
Onondaga County WEP

CRA

630742-00(005)GN-BU059 JAN 24/2013

Figure 6-2
Onondaga County Department of Water Environment Protection
Metro WWTP Phosphorus Treatment Optimization
Updated Preliminary Implementation Schedule (Dates are Approximate)

ID	Task Name	Duration
1		
2	**Submit Optimization Pre-Implementation Report to NYSDEC**	1 day
3		
4	**Finalizing Pre-Implementation Report**	**84 days**
5		
6	NYSDEC Review	42 days
7	Receive Pre-Implementation Report Comments from NYSDEC	0 days
8	Response to Comments/Finalize Pre-Implementation Report	21 days
9	NYSDEC Approval of Final Report	21 days
10		
11	**Metro Phosphorus Treatment Optimization Implementation**	**1370 days**
12	Consultant Procurement	160 days
13	Prepare Preliminary Design Report	160 days
14	NYSDEC Review Period	90 days
15	Variance Application and Approval	180 days
16	Prepare Detailed Design and Contract Documents	270 days
17	NYSDEC Review Period	90 days
18	Bid/Award Phase	90 days
19	Construction of Isolation Wall (full tertiary bypass required)	120 days
20	Complete Construction	330 days
21	Start-Up and Commissioning	60 days



Project: Metro Optimization
Date: Mon 5/20/13

WEP Task		Completed Milestone		Target Date		NYSDEC Effort	
Progress		Summary		Rolled Up Progress			

Note: All dates are subject to change based on submittal of NYSDEC comments and approval.

APPENDICES

APPENDIX A

A.1 MICROSAND PRE-IMPLEMENTATION STUDY PERFORMANCE TEST DATA

A.2 METRO WWTP OPERATIONAL DATA

APPENDIX A

A.1 MICROSAND PRE-IMPLEMENTATION STUDY PERFORMANCE TEST DATA

MICROSAND PRE-IMPLEMENTATION STUDY PERFORMANCE TEST DATA

Baseline Testing Data

HRFS Clarifier Eff 2: 134 microns microsand

HRFS Clarifier Eff 4: 134 microns microsand

SOURCE	IC	START_TIME	Cleaned and Fixed Solids	DOP, mg/L	Fe, mg/L	pH-field	SRP, mg/L	TDP, mg/L	Temp-field, deg C	TIP-F, mg/L	TP, mg/L	TPP, mg/L	TSS, mg/L	UV Flow over Sample Period, MGD	Flow Equivalent and Flow % Distribution[1]
Metro HRFS Influent	769	7/10/12 8:30 AM	NC	0.021	NC	6.91	0.235	0.265	20.54	0.244	0.43	0.165	4		Three (3) trains in service - No.2
HRFS Clarifier Eff 2	764	7/10/12 8:40 AM	<5	0.017	0.895	6.62	0.003	0.024	20.61	0.007	0.066	0.042	5	44.3	(36.5%), 3 (34.6%), and 4 (28.9%).
HRFS Clarifier Eff 4	766	7/10/12 8:50 AM	<5	0.012	1.24	6.51	0.003	0.017	20.57	0.005	0.058	0.041	4		**Equivalent Flow 59.1 MGD**
Metro HRFS Influent	769	7/10/12 11:05 AM	NC	0.043	NC	6.88	0.247	0.286	20.69	0.243	0.443	0.157	6		All trains in service - No.1 (29.7%),
HRFS Clarifier Eff 2	764	7/10/12 11:20 AM	<5	0.013	1.09	6.58	0.004	0.025	20.67	0.012	0.097	0.072	<4	40.4	No.2 (26.5%), 3 (23.9%), and 4 (19.9%)
HRFS Clarifier Eff 4	766	7/10/12 11:30 AM	<5	0.012	0.946	6.49	0.009	0.028	20.68	0.016	0.082	0.054	4		- **Flow 40.4 MGD**
Metro HRFS Influent	769	7/10/12 1:40 PM	NC	0.031	NC	6.88	0.249	0.289	20.82	0.258	0.473	0.184	5		Three (3) trains in service No.1
HRFS Clarifier Eff 2	764	7/10/12 1:50 PM	<5	0.014	0.963	6.57	0.007	0.028	20.82	0.014	0.066	0.038	<4	52.0	(39.2%), 2 (33.6%), and 4 (27.2%).
HRFS Clarifier Eff 4	766	7/10/12 2:00 PM	<5	0.015	1.18	6.54	0.006	0.031	20.82	0.016	0.063	0.032	4		**Equivalent Flow 69.3 MGD**

Microsand Evaluation: Performance Testing Data

HRFS Clarifier Eff 2: 134 microns microsand

HRFS Clarifier Eff 4: 110 microns microsand

SOURCE	IC	START_TIME	Cleaned and Fixed Solids	DOP, mg/L	Fe, mg/L	pH-field	SRP, mg/L	TDP, mg/L	Temp-field, deg C	TIP-F, mg/L	TP, mg/L	TPP, mg/L	TSS, mg/L	UV Flow over Sample Period, MGD	Flow Equivalent and Flow % Distribution[1]
Metro HRFS Influent	769	8/6/12 12:45 PM		0.036		6.66	0.204	0.233	22.52	0.197	0.392	0.159	6		All trains in service - No.1 (30.06%), 2
HRFS Clarifier #2	764	8/6/12 12:50 PM	<5	0.012	1.07	6.38	0.004	0.018	22.38	0.006	0.058	0.040	<4	56.3	(24.64%), 3 (23.43%), and 4 (21.88%).
HRFS Clarifier #4	766	8/6/12 1:00 PM	<5	0.009	0.925	6.26	0.002	0.016	22.56	0.007	0.043	0.027	<4		**Flow 56.3 MGD**
Metro HRFS Influent	769	8/6/12 3:00 PM		0.013		6.56	0.196	0.201	22.60	0.188	0.351	0.150	5		Three (3) trains in service - No.2
HRFS Clarifier #2	764	8/6/12 3:10 PM	<5	0.015	1.26	7.02	0.006	0.022	22.18	0.007	0.065	0.043	5	49.0	(36.24%), 3 (34.79%), and 4 (29.00%).
HRFS Clarifier #4	766	8/6/12 3:15 PM	<5	0.011	3.960	7.02	0.003	0.018	22.18	0.007	0.044	0.026	4		**Equivalent Flow 65.3 MGD**
Metro HRFS Influent	769	8/6/12 5:20 PM		0.039		6.34	0.234	0.249	22.81	0.210	0.446	0.197	6		Two (2) trains in service - No.2
HRFS Clarifier #2	764	8/6/12 5:35 PM	<5	0.013	1.73	6.66	0.006	0.023	22.84	0.010	0.094	0.071	9	59.0	(53.25%) and 4 (46.75%). **Equivalent**
HRFS Clarifier #4	766	8/6/12 5:30 PM	<5	0.014	0.870	6.32	0.004	0.020	22.82	0.006	0.047	0.027	6		**Flow 118.0 MGD**
Metro HRFS Influent	769	8/10/12 8:40 AM		0.038		6.63	0.232	0.249	21.62	0.211	0.707	0.458	17		All trains in service - No.1 (29.48%), 2
HRFS Clarifier #2	764	8/10/12 8:45 AM	<5	0.013	1.19	6.22	0.002	0.024	21.90	0.011	0.083	0.059	6	69.9	(24.44%), 3 (24.13%), and 4 (21.96%).
HRFS Clarifier #4	766	8/10/12 8:55 AM	<5	0.012	0.765	6.21	0.003	0.016	22.00	0.004	0.063	0.047	5		**Flow 69.9 MGD**
Metro HRFS Influent	769	8/16/12 12:40 PM		0.031		6.66	0.146	0.180	22.58	0.149	0.400	0.220	8		All trains in service - No.1 (28.99%), 2
HRFS Clarifier #2	764	8/16/12 12:50 PM	<5	0.012	1.17	6.38	0.002	0.018	22.58	0.006	0.059	0.041	6	54.6	(24.71%), 3 (24.65%), and 4 (21.66%).
HRFS Clarifier #4	766	8/16/12 12:55 PM	<5	0.010	0.709	6.26	0.001	0.016	22.59	0.006	0.050	0.034	10		**Flow 54.6 MGD**
Metro HRFS Influent	769	8/16/12 3:00 PM		0.037		6.69	0.154	0.198	22.73	0.161	0.470	0.272	12		Three (3) trains in service - No.2
HRFS Clarifier #2	764	8/16/12 3:10 PM	<5	0.014	1.19	6.38	0.002	0.019	22.64	0.005	0.061	0.042	7	55.9	(36.43%) , No.3 (35.14%) and 4
HRFS Clarifier #4	766	8/16/12 3:15 PM	<5	0.014	0.919	6.33	0.001	0.018	22.72	0.004	0.061	0.043	6		(28.43%). **Equivalent Flow 74.5 MGD**
Metro HRFS Influent	769	8/16/12 5:20 PM		0.042		6.65	0.176	0.212	22.74	0.170	0.455	0.243	9		Two (2) trains in service - No.2
HRFS Clarifier #2	764	8/16/12 5:30 PM	<5	0.018	1.70	6.37	0.002	0.024	22.74	0.006	0.106	0.082	8	52.1	(53.95%) and 4 (46.05%). **Equivalent**
HRFS Clarifier #4	766	8/16/12 5:35 PM	<5	0.017	0.799	6.33	0.001	0.021	22.75	0.004	0.058	0.037	5		**Flow 104.2 MGD**
Metro HRFS Influent	769	8/22/12 12:30 PM		0.046		6.61	0.15	0.196	22.31	0.15	0.42	0.224	7		Three (3) trains in service - No.2
HRFS Clarifier #2	764	8/22/12 12:35 PM	<5	0.016	1.62	6.3	0.002	0.02	22.3	0.004	0.071	0.051	6	54.0	(35.30%) , No.3 (36.74%) and 4
HRFS Clarifier #4	766	8/22/12 12:40 PM	<5	0.013	0.669	6.25	0.001	0.018	22.29	0.005	0.043	0.025	3		(27.95%). **Equivalent Flow 71.98**
Metro HRFS Influent	769	8/22/12 3:10 PM		0.066		6.64	0.148	0.216	22.49	0.15	0.367	0.151	6		Two (2) trains in service - No.2
HRFS Clarifier #2	764	8/22/12 3:15 PM	<5	0.038	1.55	6.28	0.002	0.042	22.55	0.004	0.085	0.043	4	41.6	(54.03%) and 4 (45.97%). **Equivalent**
HRFS Clarifier #4	766	8/22/12 3:20 PM	<5	0.036	0.875	6.24	0.002	0.039	22.53	<0.003	0.068	0.029	3		**Flow 83.2 MGD**

APPENDIX A

A.2 METRO WWTP OPERATIONAL DATA

METRO WWTP OPERATIONAL DATA
SECONDARY, BAF, HRFS and FINAL EFFLUENT TOTAL PHOSPHORUS DATA

Date	Total Phosphorus (mg/l)										
	Secondary Clarifier 1 IC 641	Secondary Clarifier 2 IC 642	Secondary Clarifier 3 IC 643	Secondary Clarifier 4 IC 644	BAF Influent IC 631	BAF Effluent/HRFS Influent IC 769	HRFS Clarifier 1 IC 763	HRFS Clarifier 2 IC 764	HRFS Clarifier 3 IC 765	HRFS Clarifier 4 IC 766	Final Effluent IC 789
06/01/12					1.100	1.030	0.268	0.208	0.238	0.154	0.22
06/02/12					0.608	0.694	0.216	0.118	0.194	0.086	0.129
06/03/12					0.501	0.783	0.160	0.096	0.108	0.100	0.156
06/04/12					0.615	0.831	0.154	0.132	0.136	0.124	0.140
06/05/12					0.605	0.890	0.164	0.108	0.144	0.082	0.143
06/06/12					0.681	0.963	0.189	0.127	0.170	0.107	0.119
06/07/12					0.721	0.925	0.183	0.125	0.181	0.085	0.130
06/08/12					0.943	1.210	0.149	0.149	0.202	0.183	
06/09/12					0.707	0.926	0.191	0.120	0.140		0.136
06/10/12					0.597	0.957	0.133	0.106	0.112		0.126
06/11/12	0.804	0.668	0.776		0.706	0.951	0.114	0.096	0.098		0.124
06/12/12	1.020	0.615	0.820	0.815	0.722	0.939	0.160	0.124	0.151		0.150
06/13/12	0.725	0.590	0.665	0.765	0.614	0.984	0.124	0.111	0.131	0.070	0.119
06/14/12	0.918	0.618	0.751	0.851	0.663	0.901	0.178	0.120	0.148	0.228	0.094
06/15/12					0.647	0.934	0.153	0.116	0.123	0.069	0.130
06/16/12					0.655	0.792	0.172	0.079	0.127	0.090	0.128
06/17/12	0.850	0.580	0.565	0.630	0.538	0.780	0.170	0.093	0.137	0.093	0.098
06/18/12	0.980	0.750	0.775	0.960	0.761	1.100	0.179	0.137	0.150	0.083	0.142
06/19/12	0.964	0.786	0.697	0.761	0.715	0.881	0.182	0.150	0.172	0.118	0.161
06/20/12	0.945	0.700	0.715	0.680	0.716	0.939	0.138	0.105	0.095	0.084	0.116
06/21/12	0.837	0.758	0.710	0.685	0.706	0.923	0.185	0.133	0.161	0.066	0.127
06/22/12					0.533	0.766	0.147	0.099	0.114	0.072	0.101
06/23/12					0.460	0.720	0.109	0.087	0.105	0.050	0.087
06/24/12	0.519	0.434	0.414	0.460	0.419	0.607	0.107	0.082	0.105	0.078	0.086
06/25/12	0.551	0.451	0.508	0.508	0.470	0.531	0.107	0.085	0.111	0.083	0.097
06/26/12	0.585	0.425	0.615	0.585	0.502	0.622	0.110	0.086	0.084	0.077	0.089
06/27/12	0.535	0.415	0.585	0.715	0.479	0.629	0.106	0.090	0.113	0.068	0.097
06/28/12	0.650	0.405	0.565	0.700	0.578	0.650	0.120	0.091	0.108	0.074	0.104
06/29/12					0.595	0.558	0.116	0.082	0.160	0.054	0.082
06/30/12					0.449	0.465	0.084	0.067	0.080	0.048	0.073
07/01/12	0.397	0.360	0.382	0.383	0.407	0.358	0.077	0.058	0.071	0.045	0.067
07/02/12	0.481	0.312	0.459	0.470	0.467	0.389	0.081	0.064	0.078	0.063	0.071
07/03/12					0.476	0.429	0.088	0.071	0.092	0.074	0.076
07/04/12	0.496	0.760	0.518	0.495	0.487	0.420	0.066	0.062	0.072	0.054	0.07
07/05/12	0.470		0.400	0.449	0.519	0.371	0.087	0.056	0.082	0.060	0.067

Date	Total Phosphorus (mg/l)										
	Secondary Clarifier 1 IC 641	Secondary Clarifier 2 IC 642	Secondary Clarifier 3 IC 643	Secondary Clarifier 4 IC 644	BAF Influent IC 631	BAF Effluent/HRFS Influent IC 769	HRFS Clarifier 1 IC 763	HRFS Clarifier 2 IC 764	HRFS Clarifier 3 IC 765	HRFS Clarifier 4 IC 766	Final Effluent IC 789
07/06/12					0.727	0.462	0.104	0.109	0.096	0.113	0.1
07/07/12					0.575	0.387	0.102	0.093	0.100	0.066	0.079
07/08/12	0.532	0.633	0.493	0.390	0.628	0.348	0.063	0.054	0.057	0.121	0.072
07/09/12	0.535	0.647	0.478	0.503	0.596	0.403		0.097	0.084	0.066	0.074
07/10/12	0.778	1.030	0.760	0.627	0.808	0.462	0.099	0.144	0.097	0.065	0.096
07/11/12	0.629	0.814	0.926	0.920	0.731	0.507	0.122	0.146	0.118	0.167	0.123
07/12/12	0.643	0.798	0.504		0.704	0.489		0.101	0.120		0.10
07/13/12					0.713	0.528		0.113	0.150	0.154	0.113
07/14/12					0.411	0.420		0.095	0.099	0.125	0.085
07/15/12	0.426	0.686	0.346	0.328	0.434	0.393		0.076	0.095	0.117	0.090
07/16/12	0.540	0.487	0.442	0.461	0.453	0.368	0.114	0.092	0.116	0.080	0.078
07/17/12	0.532	0.673	0.448	0.478	0.543	0.606		0.114	0.138	0.086	0.099
07/18/12	0.612	0.462	0.482		0.472	0.495		0.082	0.144	0.100	0.097
07/19/12	0.580	0.451	0.479	0.391	0.495	0.423		0.095	0.119	0.083	0.083
07/20/12					0.559	0.456		0.103	0.122	0.080	0.095
07/21/12					0.352	0.321		0.097	0.110	0.078	0.085
07/22/12	0.611	0.346	1.120	nc	0.606	0.483		0.094	0.109	0.071	0.080
07/23/12	0.900	0.521	1.760	0.603	0.711	0.572		0.114	0.147	0.113	0.090
07/24/12	0.413	0.510	0.490	0.410	0.306	0.362		0.108	0.133	0.083	0.088
07/25/12	0.618	0.555	0.492	0.462	0.487	0.442	0.112	0.114	0.114	0.066	0.097
07/26/12	0.880	0.582	1.090	0.758	0.963	0.735	0.218	0.171	0.225		0.169
07/27/12					0.379	0.336	0.099	0.112	0.103		0.097
07/28/12					0.570	0.361	0.098	0.087	0.107		0.089
07/29/12	0.442	0.489	0.714	0.421	0.443	0.478	0.087	0.076	0.037		0.072
07/30/12	0.630	0.378	0.618	0.473	0.551	0.426	0.099	0.087	0.112	0.061	0.089
07/31/12	0.618	0.381	0.546	0.447	0.505	0.454	0.114	0.103	0.126		0.088
08/01/12	0.650	0.218	0.520	0.532	0.530	0.472	0.120	0.102	0.137		0.103
08/02/12	0.478	0.318	0.403	0.408	0.483	0.489	0.116	0.088	0.111	0.054	0.086
08/03/12					0.730	0.534	0.085	0.095	0.135	0.058	0.089
08/04/12					0.512	0.546	0.084	0.073	0.085	0.064	0.079
08/05/12	0.672		0.332	0.352	0.493	0.463	0.100	0.062	0.103	0.062	0.074
08/06/12	0.500		0.423	0.447	0.492	0.478	0.102	0.085	0.085	0.056	0.090
08/07/12	0.824		0.528	0.570	0.643	0.558	0.129	0.105	0.107	0.066	0.103
08/08/12	0.950			0.426	0.706	0.635	0.176	0.143	0.140	0.098	0.126
08/09/12	1.110		0.715	0.812	0.960	0.762	0.154	0.116	0.131	0.106	0.110
08/10/12					0.481	0.521	0.244	0.095	0.164	0.108	0.098
08/11/12					0.446	0.473	0.135	0.082	0.071	0.054	0.090
08/12/12	0.425	0.382	0.460	0.467	0.384	0.495	0.109	0.078	0.080	0.061	0.075

Date	Total Phosphorus (mg/l)										
	Secondary Clarifier 1 IC 641	Secondary Clarifier 2 IC 642	Secondary Clarifier 3 IC 643	Secondary Clarifier 4 IC 644	BAF Influent IC 631	BAF Effluent/HRFS Influent IC 769	HRFS Clarifier 1 IC 763	HRFS Clarifier 2 IC 764	HRFS Clarifier 3 IC 765	HRFS Clarifier 4 IC 766	Final Effluent IC 789
08/13/12	0.484	0.614	0.421	0.478	0.624	0.483	0.109	0.090	0.096	0.077	0.078
08/14/12	0.676	0.792	0.565	0.684	0.751	0.593	0.123	0.097	0.092	0.081	0.090
08/15/12	0.584	0.618	0.489	0.524	0.557	0.605	0.109	0.100	0.113	0.058	0.077
08/16/12	nc	0.580	0.495	0.520	0.544	0.523	0.113	0.096	0.100	0.061	0.078
08/17/12					0.522	0.451	0.120	0.088	0.087	0.059	0.080
08/18/12					0.383	0.376	0.085	0.072	0.074	0.056	0.064
08/19/12	0.405	0.430	0.680	0.635	0.585	0.442	0.062	0.093	0.089	0.054	0.080
08/20/12	0.400	0.520	0.492	0.513	0.516	0.456	0.101	0.080	0.091	0.054	0.076
08/21/12	0.392	0.275	0.425	0.434	0.295	0.390	0.096	0.071	0.085	0.048	0.068
08/22/12	0.376	0.288	0.384	0.412	0.319	0.363	0.109	0.093	0.100	0.071	0.084
08/23/12	0.648	0.338	0.579	0.684	0.511	0.365	0.103	0.085	0.091	0.058	0.076
08/24/12					0.466	0.400	0.046	0.083	0.077	0.052	0.077
08/25/12					0.450	0.407	0.123	0.089	0.032	0.046	0.069
08/26/12	0.513	0.332	0.282	0.284	0.523	0.263	0.110	0.076	0.069	0.043	0.064
08/27/12	0.459	0.392	0.567	0.383	0.861	0.313	0.125	0.125	0.063	0.073	0.097
08/28/12	0.240	0.344	0.193	0.206	0.318	0.207	0.089	0.097		0.042	NA
08/29/12	0.284	0.219	0.236	0.235	0.346	0.390	0.091	0.069		0.038	0.035
08/30/12	0.379	0.193	0.330	0.300	0.393	0.352	0.110	0.079	0.078	0.046	0.062
08/31/12					0.353	0.270	0.095	0.074	0.073	0.044	0.067
09/01/12					0.445	0.204	0.092	0.058	0.066	0.041	0.048
09/02/12					0.406	0.445	0.080	0.057	0.064	0.035	0.054
09/03/12	0.440	0.375	0.460	0.390	0.395	0.349	0.088	0.059	0.067	0.042	0.051
09/04/12	0.525	0.380	0.415	0.390	0.351	0.358	0.093	0.076	0.086	0.054	0.065
09/05/12	0.425	0.390	0.395	0.410	0.488	0.329	0.088	0.078	0.093	0.062	0.078
09/06/12	0.445	0.395	0.445	0.385	0.497	0.321	0.084	0.075	0.095	0.134	0.064
09/07/12	0.360	0.295	0.280	0.465	0.480	0.327	0.126	0.074	0.086	0.049	0.073
09/08/12	0.505	0.410	0.390	0.330	0.363	0.379	0.086	0.081	0.082	0.043	0.074
09/09/12	0.427	0.381	0.368	0.304	0.416	0.307	0.072	0.055	0.068	0.034	0.048
09/10/12	0.423	0.318	0.351	0.290	0.451	0.353	0.092	0.070	0.076	0.046	0.055
09/11/12	0.383	0.403	0.400	0.271	0.412	0.320	0.078	0.070	0.070	0.044	0.058
09/12/12	0.423	0.318	0.351	0.290	0.367	0.341	0.070	0.061	0.123	0.076	0.061
09/13/12	0.383	0.403	0.400	0.271	0.330	0.269	0.075	0.057	0.072	0.062	0.060
09/14/12					0.524	0.326	0.112	0.073	0.084	0.108	0.052
09/15/12					0.246	0.270	0.108	0.048	0.069	0.030	0.047
09/16/12	0.388	0.262	0.246	0.214	0.304	0.301	0.065	0.051	0.062	0.048	0.037
09/17/12	0.457	0.389	0.308	0.254	0.378	0.259	0.075	0.053	0.074	0.068	0.039
09/18/12	0.689	0.360	0.489	0.337	0.611	0.363	0.072	0.071	0.087	0.062	0.056
09/19/12	0.447	0.329	0.276	0.254	0.367	0.236	0.088	0.067	0.086	0.060	0.069

Date	Total Phosphorus (mg/l)										
	Secondary Clarifier 1 IC 641	Secondary Clarifier 2 IC 642	Secondary Clarifier 3 IC 643	Secondary Clarifier 4 IC 644	BAF Influent IC 631	BAF Effluent/HRFS Influent IC 769	HRFS Clarifier 1 IC 763	HRFS Clarifier 2 IC 764	HRFS Clarifier 3 IC 765	HRFS Clarifier 4 IC 766	Final Effluent IC 789
09/20/12	0.470	0.323	0.317	0.258	0.401	0.262	0.069	0.055	0.073	0.049	0.040
09/21/12					0.394	0.277	0.084	0.057	0.071	0.051	0.060
09/22/12					0.379	0.306	0.083	0.067	0.083	0.053	0.066
09/23/12	0.298	0.212	0.322	0.232	0.315	0.263	0.077	0.053	0.068	0.041	0.061
09/24/12	0.464	0.267	0.538	0.398	0.533	0.342	0.096	0.073	0.084	0.062	0.083
09/25/12	0.505	0.310	0.585	0.410	0.551	0.383	0.115	0.078	0.104	0.076	0.094
09/26/12	0.463	0.487	0.558	0.399	0.570	0.358	0.115	0.084	0.111	0.072	0.088
09/27/12	0.453	0.372	0.466	0.390	0.485	0.363	0.113	0.076	0.102	0.080	0.060
09/28/12					0.749	0.625	0.190	0.137	0.176	0.157	0.151
09/29/12					0.480	0.407	0.231	0.080	0.112	0.140	0.091
09/30/12	0.670	0.420	0.415	0.435	0.658	0.425	0.112	0.082	0.114	0.101	0.051
10/01/12	0.728	0.530	0.726	0.556	0.693	0.473	0.150	0.284	0.170	0.137	0.100
10/02/12	0.514	0.447	0.456	0.402	0.476	0.433	0.139		0.170	0.064	0.087
10/03/12	0.482	0.326	0.373	0.335	0.450	0.345	0.100	0.133	0.122	0.068	0.071
10/04/12	0.557	0.323	0.499	0.425	0.496	0.401	0.111	0.083	0.115	0.101	0.073
10/05/12					0.508	0.362	0.118	0.083	0.119	0.088	0.093
10/06/12					0.535	0.388	0.066	0.078	0.139	0.047	0.048
10/07/12	0.565	0.400	0.470	0.590	0.541	0.417	0.085	0.076	0.107	0.054	0.066
10/08/12	0.494	0.360	0.391	0.398	0.497	0.057	0.053	0.058	0.096	0.067	0.064
10/09/12	0.642	0.418	0.380	0.404	0.520	0.360	0.160	0.084	0.128	0.097	0.069
10/10/12	0.399	0.322	0.418	0.450	0.433	0.365	0.083	0.063	0.087	0.086	0.068
10/11/12	0.644	0.571	0.362	0.333	0.447	0.372	0.098	0.070	0.096	0.071	0.072
10/12/12					0.610	0.399	0.098	0.065	0.099	0.086	0.070
10/13/12					0.412	0.361	0.086	0.062	0.086	0.087	0.064
10/14/12	0.620	0.410	0.525	0.345	0.754	0.335	0.075	0.067	0.084	0.062	0.067
10/15/12	0.415	0.280	0.590	0.235	0.375	0.271	0.086	0.058	0.078	0.077	0.066
10/16/12	0.488	0.430		0.335	0.504	0.291	0.082	0.061	0.078	0.074	0.065
10/17/12	0.415	0.315		0.513	0.364	0.296	0.104	0.083	0.110	0.088	0.084
10/18/12	0.665	0.420	0.570	0.450	0.602	0.304	0.095	0.069	0.108	0.098	0.080
10/19/12					0.632	0.323	0.094	0.059	0.099	0.060	0.071
10/20/12					0.421	0.255	0.102	0.078		0.134	0.070
10/21/12	0.427	0.306	0.430	0.359	0.426	0.334	0.074	0.071		0.049	0.065
10/22/12	0.378	0.272	0.439	0.375	0.408	0.269	0.105	0.074		0.070	0.070
10/23/12	0.570	0.308	0.386	0.380	0.548	0.318	0.093	0.074		0.074	0.048
10/24/12	0.475	0.267	0.388	0.311	0.397	0.288	0.100	0.073		0.036	0.049
10/25/12	0.395	0.295	0.415	0.300	0.340	0.235	0.084	0.066		0.080	0.049
10/26/12					0.375	0.303	0.086	0.068		0.040	0.054
10/27/12					0.378	0.348	0.106	0.061		0.075	0.053

Date	Total Phosphorus (mg/l)										
	Secondary Clarifier 1 IC 641	Secondary Clarifier 2 IC 642	Secondary Clarifier 3 IC 643	Secondary Clarifier 4 IC 644	BAF Influent IC 631	BAF Effluent/HRFS Influent IC 769	HRFS Clarifier 1 IC 763	HRFS Clarifier 2 IC 764	HRFS Clarifier 3 IC 765	HRFS Clarifier 4 IC 766	Final Effluent IC 789
10/28/12	0.350	0.290	0.450	0.260	0.332	0.265	0.079	0.039	0.053	0.042	0.036
10/29/12	0.805	0.565	0.705	0.700	0.508	0.458	0.092	0.098	0.101	0.063	0.055
10/30/12	0.370	0.265	0.360	0.310	0.401	0.364	0.073	0.070	0.075	0.042	0.043
10/31/12	0.350	0.303	0.392	0.325	0.376	0.333	0.094	0.094	0.078	0.061	0.082
11/01/12	0.480	0.335	0.400	0.385	0.472	0.311	0.083	0.069	0.068	0.048	0.067
11/02/12					0.452	0.346	0.079	0.060	0.066	0.044	0.058
11/03/12					0.383	0.262	0.135	0.117	0.090	0.051	0.057
11/04/12	0.209	0.146	0.206	0.220	0.498	0.169	0.072	0.062	0.058	0.038	0.048
11/05/12	0.219	0.151	0.209	0.203	0.212	0.179	0.078	0.080	0.068	0.048	0.058
11/06/12	0.244	0.153	0.376	0.222	0.795	0.173	0.080	0.041	0.057	0.044	0.059
11/07/12	0.285	0.150	0.240	0.240	0.426	0.248	0.084	0.064	0.059	0.044	0.057
11/08/12	0.248	0.173	0.897	0.265	0.556	0.278	0.089	0.095	0.076	0.046	0.065
11/09/12					0.649	0.461	0.092	0.065	0.083	0.050	0.067
11/10/12					0.345	0.214	0.086	0.070	0.079	0.051	0.061
11/11/12					0.769	0.555	0.078	0.044	0.076	0.043	0.064
11/12/12	1.200	0.970	2.280	1.170	1.190	0.672	0.093	0.093	0.107	0.061	0.096
11/13/12	0.298	0.364	0.407	0.309	0.365	0.426	0.044	0.033	0.086	0.037	0.061
11/14/12	0.630	0.441	0.618	0.391	0.608	0.461	0.114	0.147	0.093	0.078	0.084
11/15/12	0.673	0.474	0.694	0.446	0.666	0.451	0.114	0.062	0.084	0.059	0.080
11/16/12					0.335	0.439	0.168	0.140	0.078	0.077	0.073
11/17/12					0.402	0.410	0.110	0.088	0.088	0.057	0.068
11/18/12	0.645	0.525	0.695	0.485	0.314		0.084	0.080	0.076	0.051	0.061
11/19/12	0.627	0.484	0.692	0.428	0.666	0.377	0.092	0.056	0.087	0.040	0.063
11/20/12	0.414	0.378	0.492	0.383	0.491	0.418	0.071	0.065	0.091	0.055	0.054
11/21/12					0.580	0.403	0.088	0.071	0.066	0.058	0.068
11/22/12					0.479	0.360	0.089	0.061	0.068	0.059	0.061
11/23/12					0.379	0.330	0.082	0.058	0.076	0.043	0.065
11/24/12					0.433	0.314	0.078	0.072	0.086	0.036	0.066
11/25/12	0.855	0.870	1.210	0.705	0.561	0.431	0.073	0.063	0.073	0.046	0.058
11/26/12	0.640	0.348	0.716	0.412	0.608	0.368			0.064	0.052	0.057
11/27/12					0.553	0.353	0.093	0.145	0.095	0.055	0.080
11/28/12	0.758	0.356	0.832	0.594	0.560	0.356	0.115	0.094	0.114		0.097
11/29/12	0.816	0.469	0.679	0.554	0.588	0.401	0.107	0.098	0.128	0.074	0.093
11/30/12					0.606	0.482	0.110	0.092	0.108	0.070	0.089
12/01/12					0.721	0.475	0.100	0.088	0.099	0.061	0.081
12/02/12	0.855	0.415	0.305	0.595	0.781	0.502	0.096	0.085	0.093	0.055	0.072
12/03/12	0.525	0.375	0.425	0.425	0.491	0.429	0.102	0.068	0.077	0.050	0.072
12/04/12	0.436	0.454	0.384	0.888	0.831	0.635	0.057	0.085	0.089	0.062	0.072

Date	Total Phosphorus (mg/l)										
	Secondary Clarifier 1 IC 641	Secondary Clarifier 2 IC 642	Secondary Clarifier 3 IC 643	Secondary Clarifier 4 IC 644	BAF Influent IC 631	BAF Effluent/HRFS Influent IC 769	HRFS Clarifier 1 IC 763	HRFS Clarifier 2 IC 764	HRFS Clarifier 3 IC 765	HRFS Clarifier 4 IC 766	Final Effluent IC 789
12/05/12	0.277	0.308	0.276	0.249	0.339	0.396	0.085	0.054	0.065	0.042	0.061
12/06/12	0.446	0.307	0.351	0.329	0.593	0.433	0.087	0.063	0.067	0.042	0.073
12/07/12					0.577	0.410	0.074	0.137	0.077	0.048	0.079
12/08/12					0.489	0.364	0.077	0.080	0.064	0.046	
12/09/12	1.160	0.592	1.670	1.020	0.783	0.588	0.087	0.088	0.076	0.053	0.075
12/10/12	0.748	0.544	0.296	0.764			0.035	0.136	0.106	0.064	0.070
12/11/12	0.296	0.353	0.272	0.254			0.027	0.045	0.059	0.033	0.05
12/12/12	0.634	0.456	0.364	0.385			0.088	0.099	0.068	0.050	0.07
12/13/12	0.675	0.413	0.368	0.395			0.082	0.162	0.095	0.067	0.082
12/14/12							0.076	0.099	0.059	0.043	0.064
12/15/12							0.076	0.075	0.062	0.041	0.064
12/16/12	1.040	0.368	0.399	0.612			0.097	0.179	0.072	0.064	0.077
12/17/12	0.780	0.530	0.759	0.610			0.095	0.179	0.087	0.072	0.07
12/18/12	0.318	0.317	0.360	0.299			0.084	0.099	0.074	0.046	0.052
12/19/12	0.270	0.261	0.277	0.290			0.077	0.076	0.058	0.044	0.053

APPENDIX B

PAC TEMPERATURE DEPENDENCY BENCH-SCALE TESTING RESULTS

PAC TEMPERATURE DEPENDENCY BENCH-SCALE TESTING RESULTS

Polymer used for all tests: Praestol A 4040L

Warm Temperature Testing Round 1, July 11, 2012

Sample code	Coagulant	Effective Sand Size, microns	pH	Temperature (˚C)	Total Phosphorus, mg/L	Total Dissolved Phosphorus, mg/L	Total Particulate Phosphorus, mg/L	Soluble Reactive Phosphorus, mg/L
630742-40-Initial	-	-	6.93	21.6	0.534	0.326	0.208	0.255
630742-41-1	PAC WW-70	135	6.93	22.7	0.204	0.03	0.174	0.008
630742-41-2	PAC WW-70	110	6.96	22.5	0.142	0.03	0.112	0.006
630742-41-3	Ferric Chloride	135	6.93	22.4	0.135	0.033	0.102	0.007
630742-41-4	Ferric Chloride	110	6.94	22.7	0.124	0.034	0.09	0.007
630742-42-1	PAC WW-70	135	7.07	22.5	0.108	0.03	0.078	0.008
630742-42-2	PAC WW-70	110	7.26	23.2	0.207	0.03	0.177	0.008
630742-42-3	Ferric Chloride	135	7.24	23.8	0.123	0.038	0.085	0.008
630742-42-4	Ferric Chloride	110	-	-	-	-	-	-
630742-43-1	PAC WW-70	135	7.07	22.6	0.135	0.03	0.105	0.008
630742-43-2	PAC WW-70	110	7.14	23.0	0.105	0.032	0.073	0.009
630742-43-3	Ferric Chloride	135	7.04	22.9	0.124	0.038	0.086	0.006
630742-43-4	Ferric Chloride	110	7.05	22.8	0.115	0.032	0.083	0.006

Warm Temperature Testing Round 2, August 8, 2012

Sample code	Coagulant	Effective Sand Size, microns	pH	Temperature (˚C)	Total Phosphorus, mg/L	Total Dissolved Phosphorus, mg/L	Total Particulate Phosphorus, mg/L	Soluble Reactive Phosphorus, mg/L
630742-50-Initial	-	-	6.85	23.3	0.476	0.291	0.185	0.261
630742-51-1	PAC WW-70	135	6.81	23.6	0.17	0.031	0.139	0.009
630742-51-2	PAC WW-70	110	6.93	23.8	0.124	0.03	0.094	0.007
630742-51-3	Ferric Chloride	135	6.84	23.3	0.121	0.04	0.081	0.016
630742-51-4	Ferric Chloride	110	6.81	23.3	0.124	0.042	0.082	0.009
630742-52-1	PAC WW-70	135	7.01	23.7	0.11	0.033	0.077	0.012
630742-52-2	PAC WW-70	110	7.07	23.8	0.089	0.031	0.058	0.015
630742-52-3	Ferric Chloride	135	6.93	24.1	0.112	0.035	0.077	0.008
630742-52-4	Ferric Chloride	110	7.02	24.4	0.111	0.038	0.073	0.009
630742-53-1	PAC WW-70	135	7.05	23.4	0.095	0.027	0.068	0.007
630742-53-2	PAC WW-70	110	7.01	23.4	0.07	0.03	0.04	0.007
630742-53-3	Ferric Chloride	135	6.93	23.5	0.103	0.038	0.065	0.011
630742-53-4	Ferric Chloride	110	6.96	23.9	0.12	0.046	0.074	0.012

Warm Temperature Testing Round 3, August 21, 2012

Sample code	Coagulant	Effective Sand Size, microns	pH	Temperature (˚C)	Total Phosphorus, mg/L	Total Dissolved Phosphorus, mg/L	Total Particulate Phosphorus, mg/L	Soluble Reactive Phosphorus, mg/L
630742-60-Initial	-	-	6.88	22.9	0.376	0.204	0.172	0.167
630742-61-1	PAC WW-70	135	6.93	23.1	0.121	0.021	0.1	0.004
630742-61-2	PAC WW-70	110	6.92	23.2	0.078	0.022	0.056	0.003
630742-61-3	Ferric Chloride	135	6.85	23	0.068	0.022	0.046	0.004
630742-61-4	Ferric Chloride	110	6.89	23.1	0.064	0.024	0.04	0.003
630742-62-1	PAC WW-70	135	6.87	23.1	0.113	0.021	0.092	0.002
630742-62-2	PAC WW-70	110	7.03	23.3	0.065	0.021	0.044	0.003
630742-62-3	Ferric Chloride	135	6.95	23.2	0.075	0.023	0.052	0.003
630742-62-4	Ferric Chloride	110	6.87	22.9	0.067	0.022	0.045	0.004
630742-63-1	PAC WW-70	135	6.92	22.5	0.08	0.02	0.06	0.003
630742-63-2	PAC WW-70	110	7	22.7	0.056	0.02	0.036	0.003
630742-63-3	Ferric Chloride	135	6.86	22.7	0.063	0.025	0.038	0.003
630742-63-4	Ferric Chloride	110	6.87	22.7	0.059	0.025	0.034	0.004

Cold Temperature Testing Round 1, December 18, 2012

Sample code	Coagulant	Effective Sand Size, microns	pH	Temperature (˚C)	Total Phosphorus, mg/L	Total Dissolved Phosphorus, mg/L	Total Particulate Phosphorus, mg/L	Soluble Reactive Phosphorus, mg/L
630742-70-Initial	-	-	6.8	10	0.536	0.055	0.481	0.021
630742-71-1	PAC WW-70	110	6.71	12.9	0.214	0.013	0.201	0.002
630742-71-2	Ferric Chloride	110	6.66	12.1	0.042	0.01	0.032	0.002
630742-72-1	PAC WW-70	110	6.74	13.2	0.277	0.011	0.266	0.002
630742-72-2	Ferric Chloride	110	6.68	13.3	0.037	0.011	0.026	0.002
630742-73-1	PAC WW-70	110	6.74	11.2	0.236	0.012	0.224	0.002
630742-73-2	Ferric Chloride	110	6.7	11.2	0.031	0.01	0.021	0.002

Cold Temperature Testing Round 2, January 3, 2013

Sample code	Coagulant	Effective Sand Size, microns	pH	Temperature (˚C)	Total Phosphorus, mg/L	Total Dissolved Phosphorus, mg/L	Total Particulate Phosphorus, mg/L	Soluble Reactive Phosphorus, mg/L
630742-80-Initial	-	-	6.83	11	0.192	0.067	0.125	0.025
630742-81-1	PAC WW-70	110	6.9	12.1	0.16	0.021	0.139	0.002
630742-81-2	Ferric Chloride	110	6.8	12.7	0.051	0.021	0.03	0.002
630742-82-1	PAC WW-70	110	6.88	12.1	0.134	0.021	0.113	0.002
630742-82-2	Ferric Chloride	110	6.8	11.6	0.05	0.023	0.027	0.002
630742-83-1	PAC WW-70	110	6.84	11.8	0.158	0.021	0.137	0.002
630742-83-2	Ferric Chloride	110	6.8	11.3	0.045	0.022	0.023	0.002

Cold Temperature Testing Round 3, January 7, 2013

Sample code	Coagulant	Effective Sand Size, microns	pH	Temperature (˚C)	Total Phosphorus, mg/L	Total Dissolved Phosphorus, mg/L	Total Particulate Phosphorus, mg/L	Soluble Reactive Phosphorus, mg/L
630742-90-Initial	-	-	-	-	-	-	-	-
630742-91-1	PAC WW-70	110	6.85	12.8	0.113	0.018	0.095	0.002
630742-91-2	Ferric Chloride	110	6.81	12.2	0.042	0.018	0.024	0.002
630742-92-1	PAC WW-70	110	6.91	13.1	0.094	0.017	0.077	0.002
630742-92-2	Ferric Chloride	110	6.86	12.9	0.043	0.019	0.024	0.002
630742-93-1	PAC WW-70	110	6.94	11.9	0.099	0.017	0.082	0.002
630742-93-2	Ferric Chloride	110	6.88	13.2	0.044	0.02	0.024	0.002

APPENDIX C

C.1 UFI REPORT – BIOAVAILABLE PHOSPHORUS REMOVAL AT THE SYRACUSE METROPOLITAN TREATMENT PLANT A COMPARISON OF ACTIFLO TREATMENT WITH ALUM AND IRON

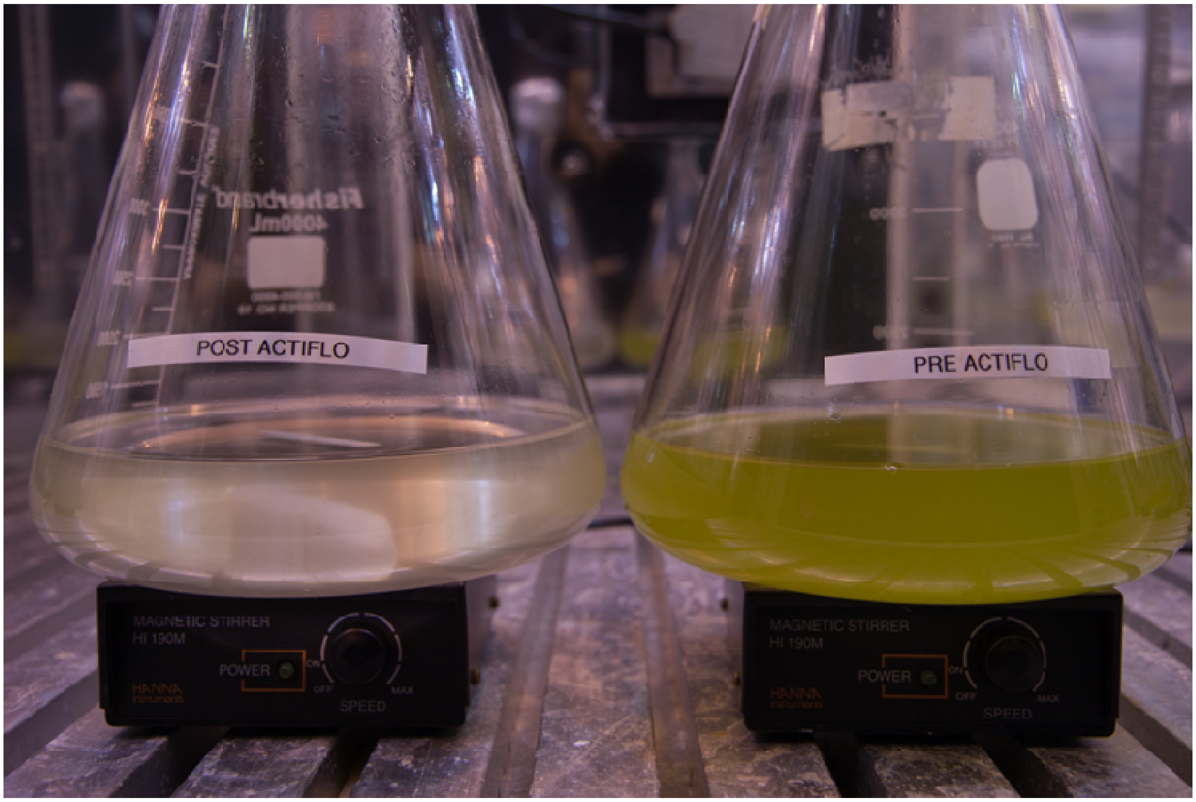
C.2 UFI REPORT – CHARACTERIZATION OF METRO PARTICLES USING FERRIC CHLORIDE AND POLYALUMINUM CHLORIDE AS COAGULANTS IN PHOSPHORUS TREATMENT

APPENDIX C

C.1 UFI REPORT – BIOAVAILABLE PHOSPHORUS REMOVAL AT THE SYRACUSE METROPOLITAN TREATMENT PLANT A COMPARISON OF ACTIFLO TREATMENT WITH ALUM AND IRON

Bioavailable Phosphorus Removal at the Syracuse Metropolitan Treatment Plant

A Comparison of Actiflo Treatment with Alum and Iron



A Data Report Prepared for Anchor QEA, Conestoga-Rovers & Associates, and Onondaga County

Prepared by:

Martin T. Auer, Benjamin E. Downer and Rachael E. Pressley
Michigan Technological University

and

David A. Matthews, Craig A. Hurteau and Steven W. Effler
Upstate Freshwater Institute

9 January 2013

Motivation

Phosphorus (P) is the nutrient limiting algal growth in freshwater systems and thus the appropriate target for management of cultural eutrophication. Targets for phosphorus management have historically been based on the total phosphorus (TP) analyte despite the fact that a significant fraction of TP may not be available to support algal growth. Of the three components of TP, soluble reactive phosphorus (SRP) is generally considered to be completely bioavailable, while dissolved organic (DOP) and particulate (PP) phosphorus less so. The concept of bioavailability rests on the tenet that cost effective P management should be based on the fraction of the TP analyte which is, in fact, bioavailable.

Section 303 of the Clean Water Act Amendments of 1977 requires identification of waters remaining polluted after the application of technology-based effluent limitations. Subsequently, Total Maximum Daily Loads (TMDLs) are to be developed to meet receiving water quality standards in those systems. It is in the TMDL process that quantification of bioavailability finds its application. Effler et al. (2002) considered bioavailability as one of several factors contributing to a total effective phosphorus loading rate for Onondaga Lake, New York. Determination of that effective rate then formed the basis for comparison of loading sources (e.g. point versus nonpoint inputs) with respect to their selection as targets for remediation activities. Subsequently, Effler et al. (2012) described the manner in which the effective load approach could be integrated into a TMDL analysis through appropriate representation in a supporting mechanistic water quality model.

In 2005, the Syracuse Metropolitan Treatment Plant (Metro) completed installation of a high rate flocculated settling process (HRFS, i.e. Actiflo), utilizing ferric chloride, polymer and microsand to promote formation and removal of particles containing phosphorus. In 2010, the Upstate Freshwater Institute and Michigan Technological University collaborated in a study of phosphorus bioavailability in the Metro effluent. A series of algal bioassays performed on six effluent samples demonstrated that the bioavailability of the remaining particulate phase phosphorus was negligible (<1%). This is a striking reduction from the 58-65% P bioavailability determined by UFI/MTU in 1996 when the plant was operating with conventional phosphorus removal technologies, i.e. precipitation with ferric chloride.

Objective and Approach

It has recently been proposed, for operational reasons, to replace ferric chloride with polyaluminum chloride (PAC) as the coagulant. The objective of this study is to compare the efficacy of Actiflo with PAC to that achieved previously with the ferric chloride coagulant. In addition, this study provides an opportunity to conduct assays of the bioavailability of the SRP and DOP analytes which together account for 72% of the influent P.

The approach is to conduct soluble and particulate phase phosphorus bioavailability assays on Metro influent and replicate assays on samples collected immediately before and after Actiflo treatment. Two process trains would be operated and sampled: one using the ferric chloride coagulant and one using the PAC coagulant. Bioavailability percentages so determined would then be applied to influent and effluent measurements of SRP, DOP and PP to determine the removal efficiency as P and as bioavailable P. This approach has been applied to municipal wastewater treatment plant effluents by Young et al. (1982), to tributaries to Great Lakes waters by DePinto et al. (1981) and Young et al. (1985) and as described above for the Metro effluent.

Methods

Sample collection and processing - samples of screened influent and treated pre- and post-Actiflo wastewater were collected at Metro by UFI personnel working with Metro personnel. Samples were transported to UFI and stored in the dark at 4 °C until processed, usually within 2-3 days of collection. Each 40-L sample was passed under positive pressure through a 142 mm, 0.45 µm cellulose acetate filter (GE Osmonics Labstore). Filtrate was collected and refrigerated at 4°C. Particulate matter was scraped off of the filters and placed in glass bottles containing a small amount of filtrate to create a slurry. Filtrate and particulate slurry were shipped overnight express to MTU where they were stored at 4°C. Particulate samples were split into aliquots supporting two analyses: phosphorus richness (mass P per mass dry solids), particulate phase bioassays, and particulate phase chemical fractionation assays.

Analytical methods - SRP was measured spectrophotometrically by the ascorbic acid method (APHA, 2005). PP and TDP samples were digested by the persulfate method (APHA, 2005), converting the phosphorus to SRP. Dissolved organic phosphorus (DOP) is defined operationally as TDP minus SRP.

Soluble phase bottle test assay - soluble phase assays were conducted using a modification of the bottle test procedure of Miller et al. (1978). The initial SRP and DOP content of filtered water samples were determined and 2-3 L of sample was placed into a 4-L Erlenmeyer flask (cover figure). P-starved algae (*Selenastrum capricornutum*) were added to the flask and the sample was incubated in the light (PAR = 600 $\mu E \cdot m^{-2} \cdot s^{-1}$, 24 hour light) at 20 °C. SRP and DOP were measured at intervals of 1-7 days (more frequent at the beginning) and the incubation was continued for 30 days. The amount of SRP and DOP taken up by the algae is expressed as a fraction (f_{bio}) of the initial SRP and DOP concentration.

Particulate phase Dual Culture Diffusion Apparatus assay - The Dual Culture Diffusion Apparatus (DCDA) is a device developed by DePinto (1982) which can be used to perform algal bioassays. The DCDA consists of two chambers bolted together (1.6 L total) with a 90 mm, 0.45 µm black mixed cellulose ester (MCE) filter placed between them (Figure 1). One chamber is dark and contains an aliquot of particulate sample diluted with P-free algal growth medium (described in APHA, 2005). The other chamber is exposed to light (PAR = 600 $\mu E \cdot m^{-2} \cdot s^{-1}$, 24 hour light) and contains P-free algal growth medium inoculated with P-starved algae (*Selenastrum capricornutum*).

The initial PP concentration in the particulate and algal chambers is measured and the system is incubated for 30 days at 20 °C with continuous stirring. Algae are harvested every three days, and replaced with fresh, P-starved algae. The PP concentration of the algae removed from and added to the DCDA is measured at each harvest. The change in the phosphorus content of the algae over each incubation interval ($C_{t=3} - C_{t=0}$) is calculated and added to that for previous harvests to yield the cumulative algal P uptake. As the assay proceeds and the bioavailable P pool is depleted, algal uptake ceases. The cumulative uptake represents the bioavailable P and is expressed as a fraction (f_{bio}) of the total phosphorus content of the sediment sample added.

Figure 1. Dual Culture Diffusion Apparatus.

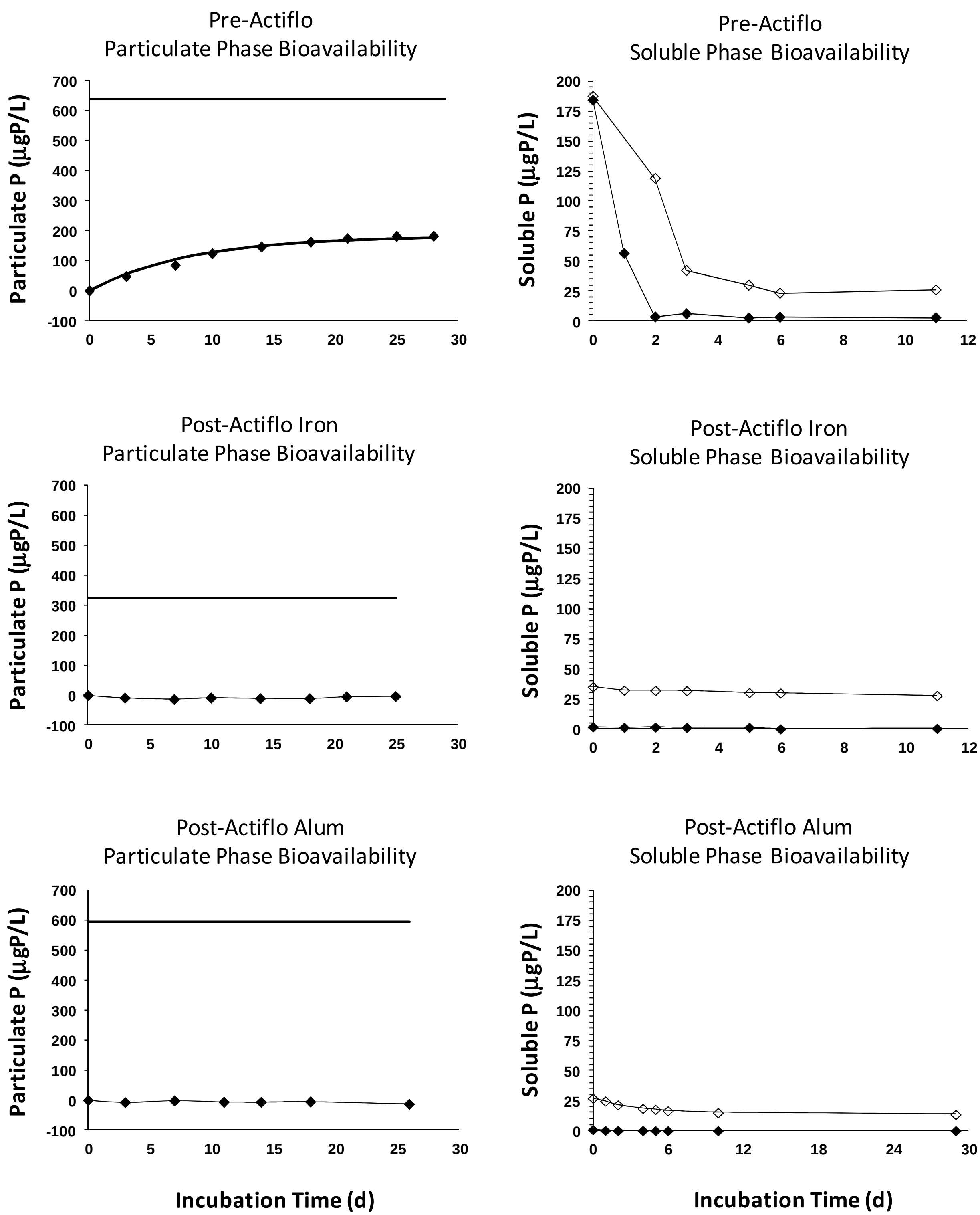
Results and Discussion

Soluble and particulate phase assays were conducted for a single screened influent sample, in triplicate for a single pre-Actiflo sample and for four paired (iron and alum) post-Actiflow samples collected on 7/18, 7/25, 8/28 and 9/4/2012. The results from selected assays are presented in Figure 2, illustrating,

- the essentially total bioavailability of soluble reactive phosphorus;
- the incomplete bioavailability of dissolved organic phosphorus, i.e. the presence of a refractory fraction; and
- the incomplete bioavailability of particulate phosphorus, again demonstrating the presence of a refractory fraction.

The stable nature of and low phosphorus levels associated with post-Actiflo samples are also readily apparent from the results presented in Figure 2.

Figure 2. Representative particulate and soluble phase assay results. Solid line in left column represents the maximum amount of phosphorus that could be released. Open diamonds in right column are dissolved organic P and filled diamonds are soluble reactive P.



Results obtained from all 36 bioavailability assays are summarized in Table 1. The soluble reactive phosphorus component was found to be 100% bioavailable. The bioavailability of the dissolved organic phosphorus component fell from 84 and 79% in the influent and pre-Actiflo samples to 21 and 15% in the post-Actiflo iron and alum samples, respectively, a reduction of ~75%. The change in the particulate phosphorus component was most striking, falling from 17 and 21% in the influent and pre-Actiflo samples, respectively, to negligible bioavailability (1-2%, essentially the limit of detection) in post-Actiflo samples. The difference in bioavailability of the various phosphorus fractions was not significantly different depending on the coagulant used.

Table 1. Summary of bioavailability assay results.

Sample	**Designation**	**SRP f_{bio}**	**DOP f_{bio}**	**PP f_{bio}**
Screened Influent		1.00	0.84	0.17[1]
Pre-Actiflo	6/26/2012-A	1.00	0.85	0.18
	6/26/2012-B	1.00	0.86	0.29
	6/26/2012-C	1.00	0.76	0.24
	7/2/2012	1.00	0.67	0.14
Mean ± S.D.		*1.00 ±0.00*	*0.79 ±0.09*	*0.21 ±0.07*
Post-Actiflo Iron	7/18/2012	1.00	0.51	0.00
	7/25/2012	1.00	0.03	0.00
	8/28/2012	1.00	0.11	0.03
	9/4/2012	1.00	0.20	0.05
Mean ± S.D.		*1.00 ±0.00*	*0.21 ±0.21*	*0.02 ±0.02*
Post-Actiflo Alum	7/18/2012	1.00	0.23	0.00
	7/25/2012	1.00	0.04	0.00
	8/28/2012	1.00	0.21	0.03
	9/4/2012	1.00	0.12	0.00
Mean ± S.D.		*1.00 ±0.00*	*0.15 ±0.09*	*0.01 ±0.02*

[1] the Metro screened influent assay was lost due to membrane rupture. Here, we use results from a particulate phase bioassay of screened influent from the Portage Lake Water & Sewer Authority collected on 9 June 2011. The Metro screened influent assay will be repeated.

The efficacy of treatment in reducing the impact of the final discharge on the receiving water is influenced by reductions in both bioavailability and concentration. Utilizing influent and effluent phosphorus component concentrations measured during this project (Table 2), Metro is seen to achieve an 88% reduction in phosphorus (with considerable variation among components) and a 98% reduction (with less variation among components) with Actiflo.

Table 2. Waste stream phosphorus concentrations and removal efficiencies.

	SRP	DOP	PP	TP
P				
Pre-Actiflo (µgP/L)	292.5	62.9	138.2	493.6
Post-Actiflo (µgP/L)	2.1	26.3	31.4	59.7
Removal (%)	99	58	77	***88***
Bioavailability				
Pre-Actiflo	1.00	0.79	0.21	-
Post-Actiflo	1.00	0.18	0.015	-
Bioavailable-P				
Pre-Actiflo (µgP/L)	292.5	49.7	29.0	371.2
Post-Actiflo (µgP/L)	2.1	4.7	0.5	7.3
Removal (%)	99	91	98	**98**

Applying an average discharge of 3 m^3/s for Metro, P is reduced from 128 kgP/d for the influent to 16 kgP/d for the effluent and bioavailable P is reduced from 96 kgP/d to 2 kgP/d.

References

APHA, American Public Health Association, 2005. Standard Methods for the Examination of Water and Wastewater in: Franson, M. A. H. (Ed.), 21 ed. American Public Health Association, American Water Works Association, Water Environment Federation Washington, DC.

DePinto, J.V. 1982. An experimental apparatus for evaluating kinetics of available phosphorous release from aquatic particulates. Water Research, 16: 1065-1070.

DePinto, J. V., T. C. Young, and S. C. Martin. 1981. Algal-available phosphorus in suspended sediments from lower Great Lakes tributaries. Journal of Great Lakes Research, 7:311-325.

Effler, S.W., Auer, M.T., Feng, P., Perkins, M., O'Donnell, S.M., Prestigiacomo, A.R., Matthews, D.A., DePetro, P.A., Lambert, R.S. and S.M. Larson. 2012. Factors diminishing the effectiveness of phosphorus loading from municipal effluent: Critical information for TMDL analyses. Water Environment Research, 84(3): 254-264.

Effler, S.W., O'Donnell, S.M., Matthews, D.A., O'Donnell, D.M., Owens, E.M. and M.T. Auer. 2002. Limnological and loading information and a phosphorus Total Maximum Daily Load (TMDL) analysis for Onondaga Lake. Lake and Reservoir Management, 18: 87-108.

Tomasoski, K.A. 1997. Phosphorus Bioavailability: A Comparison of Biological and Chemical Assays. M.S. Thesis, Department of Civil & Environmental Engineering, Michigan Technological University.

Young, T. C., J. V. DePinto, S. E. Flint, M. S. Switzenbaum, J. K. Edzwald. 1982. Algal availability of phosphorus in municipal wastewater. Journal of the Water Pollution Control Federation, 54: 1505-1516.

Young, T. C., J. V. DePinto, S. C. Martin, and J. S. Bonner. 1985. Algal-available particulate phosphorus in the Great Lakes basin. Journal of Great Lakes Research, 11: 434-446.

APPENDIX C

C.2 UFI REPORT – CHARACTERIZATION OF METRO PARTICLES USING FERRIC CHLORIDE AND POLYALUMINUM CHLORIDE AS COAGULANTS IN PHOSPHORUS TREATMENT

Characterization of Metro Particles using Ferric Chloride and Polyaluminum Chloride as Coagulants in Phosphorus Treatment

A data report prepared by the Upstate Freshwater Institute for Anchor-QEA, Conestoga-Rovers & Associates and Onondaga County

November 2, 2012

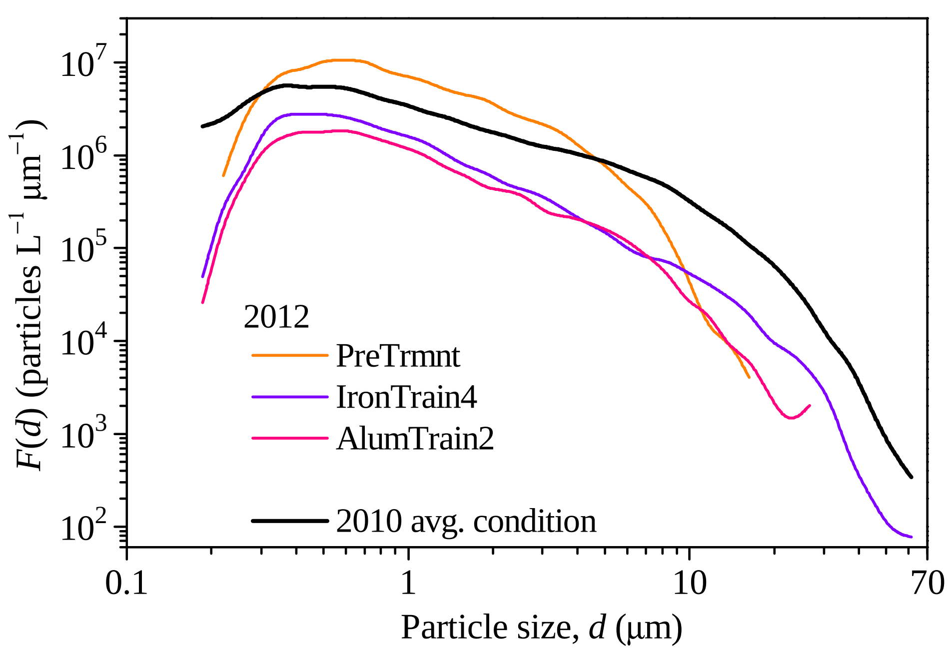
Individual Particle Analysis (IPA) by SAX*

*Scanning electron microscopy interfaced with Automated image and X-ray analyses

An individual particle analysis technique that provides both morphometric and elemental characterizations, scanning electron microscopy interfaced with automated image and X-ray analyses (SAX; Peng and Effler 2005, 2007, Peng et al. 2009, Effler and Peng 2012), was applied to Metro effluent samples. These measurements result in particle size distributions (PSD), and thereby provide a basis to guide specification of settling rates. In addition, this technique provides chemical characterizations that may resolve associations between phosphorus and particles with sizes and composition of particles.

<u>Particle Size Distribution (PSD) of Metro Effluent Samples</u>

Particle size distributions (PSD) are presented as density functions, *F*(*d*), defined as number of particle per unit volume of water in each size bin normalized by the width of the bin. The average PSD of pre-Actiflo, post-Actiflo (FeCl), and post-Actiflo (PAC) samples are plotted below, with the results from 2010 added for reference.



Some initial impressions:

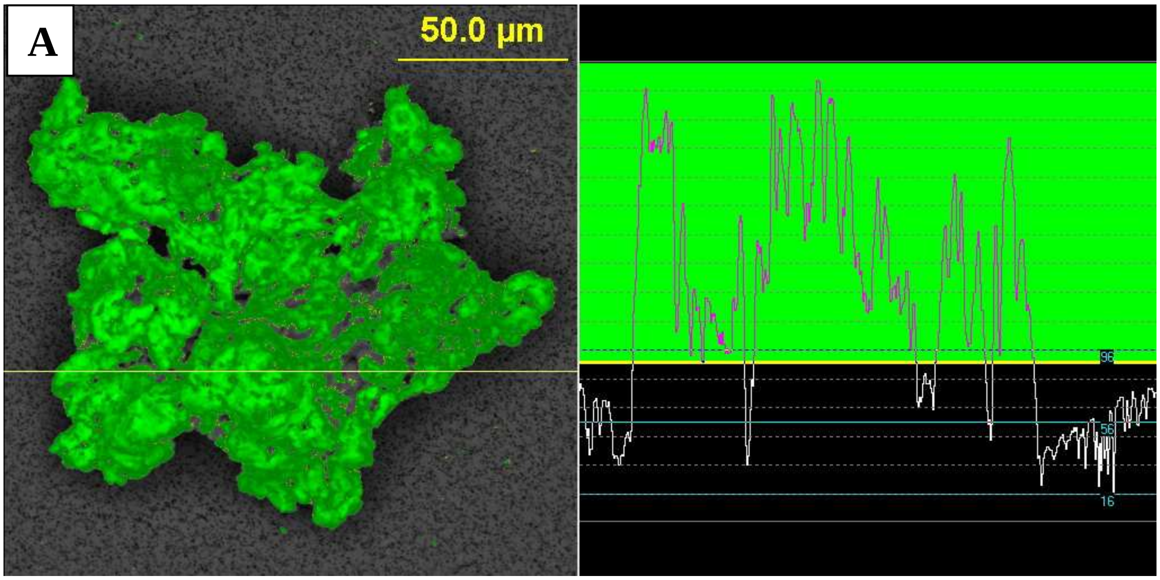
1. Particle concentrations decreased substantially (note log scale) as a result of Actiflo treatment (more later with report of PAV, the particle projected area per unit volume);
2. The concentrations of large-sized particles (e.g., > 8 µm) were much higher in the iron-train effluent than those in the aluminum-train counterpart, whereas differences in the 0.3–8 µm size range were minimal; and

3. The PSD shapes of 2010 and 2012 Metro effluent samples (iron-train) were similar to each other. Due to the lack of a pre-Actiflo sample from 2010, the lower post-Actiflo particle concentrations observed in 2012 cannot be ascribed to more efficient particle removal.

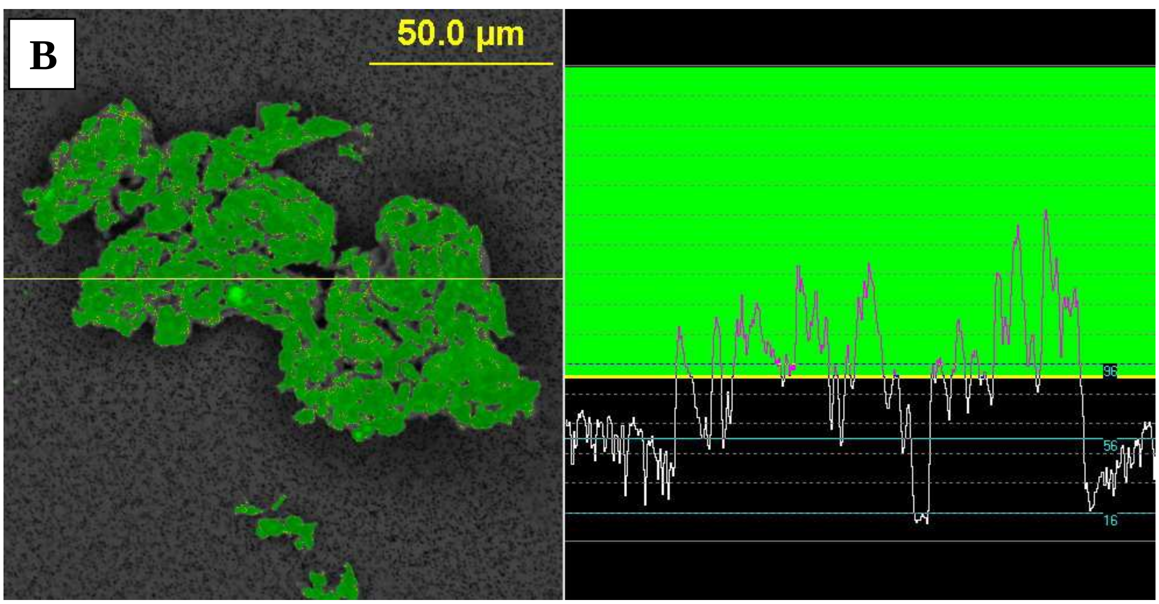
<u>Insights on Metro Effluent Particles</u>

1. Difference in iron- and aluminum-train particles as perceived by the instrument

Because of the difference in atomic numbers of aluminum and iron (13 vs. 26), effluent particles from the iron-train appeared to be brighter than those from the aluminum-train under the microscope. This might result in image "break-up" in the analysis process (i.e., a large aluminum particle is seen and interpreted by the instrument as several smaller ones), as illustrated in the following graphics. Here, the effects of thresholding during analysis are shown; pixels with brightness levels (which depend on the atomic number of the particle material when instrument settings are uniform) exceeding a certain use-defined level are recognized as parts of a feature and painted as green. There appear to be more void spaces (dark pixels) in the large particle shown in panel (B); this suggests that the lower concentrations of large particles in the aluminum train sample (*see* PSD figure) are, at least in part, due to the imperfect representation of the particles during analysis. In addition, the aluminum flocs appeared to have more surface area than those of iron.



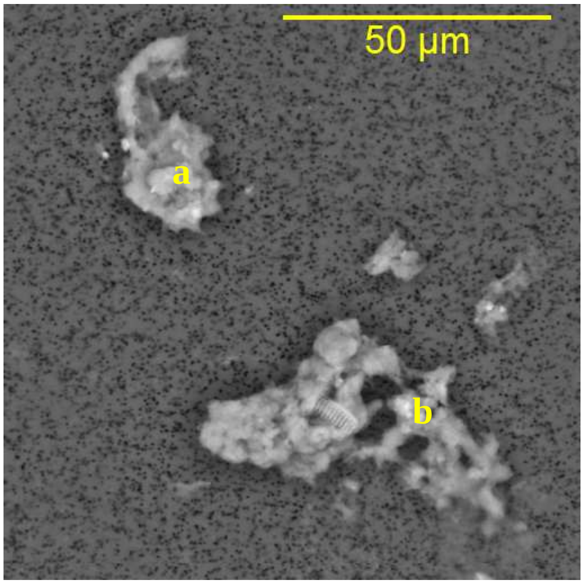
(A) A large particle from train 2 - iron (Aug. 28, 2012).

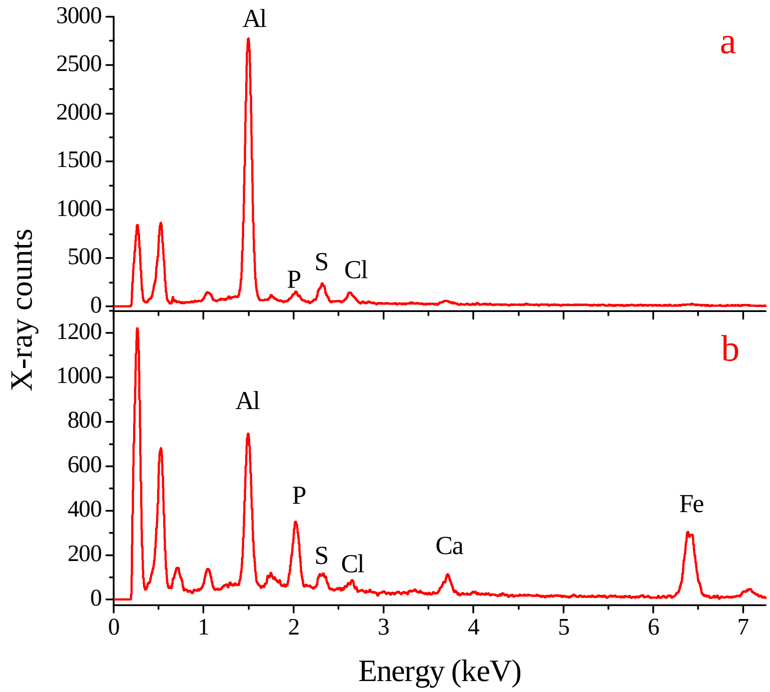


(B) A large particle from train 4 - PAC (Aug. 28, 2012).

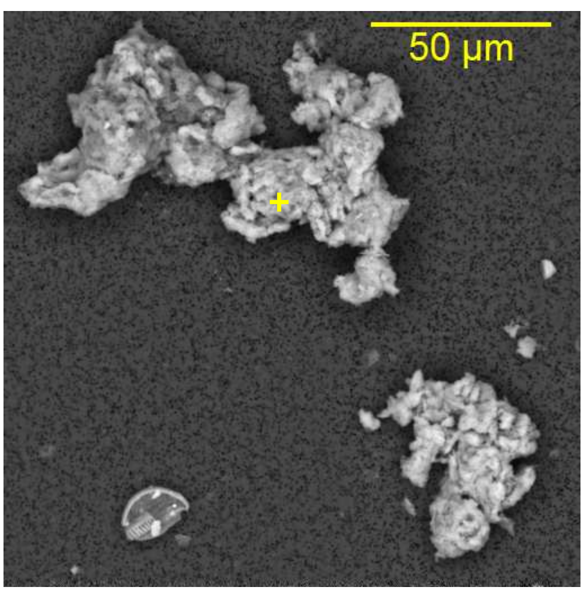
2. X-ray microanalysis of particle composition

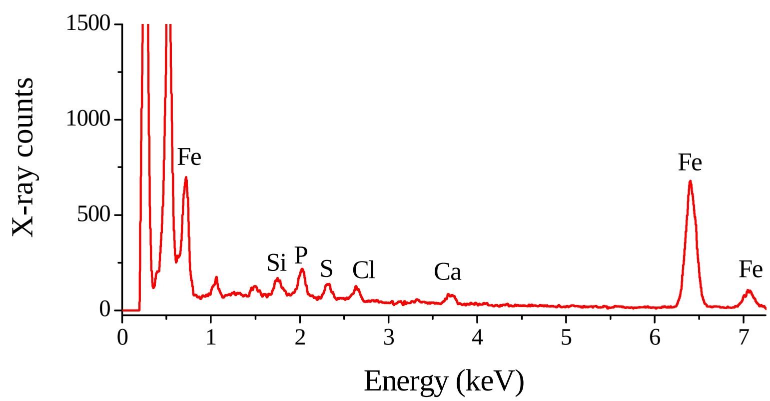
Effluent particles from train 4 - PAC (Aug. 28, 2012): Acquired X-rays (‘a’ and ‘b’ indicate points of acquisition) not only show the expected Al presence, but also a significant number of Fe X-rays (spectrum ‘b’); the latter occurrence was observed, to varying degrees, for all aluminum train effluent particles.





Effluent particles from train 2 - iron (Aug. 28, 2012): This particle ('+' indicates point of acquisition) is mostly composed of Fe, according to X-ray relative intensities (XRI) of elements (72% Fe, 7% P, and traces of other elements).





3. Particle projected-area concentration (PAV) and type distribution

Total particle projected area per unit volume of water (PAV; $cm^2\ L^{-1}$), or particle projected-area concentration, is a summary metric used in the IPA technique to quantify the concentration of suspended particulate material. The results (*see* the following Table) indicate that PAV levels of the effluent samples were low (as compared with lake surface samples collected at the South Deep monitoring site, where turbidities were mostly observed to be ~2 NTU). In addition, the PAV levels measured for PAC treated effluent samples were often about 3–4 times lower than those for the iron treated samples.

PAV was partitioned into generic particle type contributions on the basis of particle's elemental X-ray composition. The following generic particle types are used in data summary: 'Organics', 'Clay', 'Quartz', 'Diatom', 'Ca-rich', 'Iron-Train', 'Alum-Train', 'Al+Fe', 'Fe/P/Ca/Mn', and 'Misc'.

- the 'Organics' class is characterized by particles with low X-ray counts (i.e., low atomic number composition);
- the next four groups are often used to classify suspended particle populations in natural aquatic systems;
- 'Iron-Train' (Fe XRI ≥ 55%) and 'Alum-Train' (Al XRI ≥ 50%, and Al *plus* Cl ≥ 70%) types are defined to represent Metro effluent particles - iron and -alum treatments, respectively;
- 'Al+Fe' class, defined by the combined XRIs of both Al and Fe to be no less than 70%, captures particles containing noticeable amount of Fe in the alum treatment effluent;
- 'Fe/P/Ca/Mn' class (with combined Fe, P, Ca, and Mn XRIs ≥ 55%) represents the compositional characteristics of the pre-Actiflo particles; and
- 'Misc' class contains all miscellaneous, unspecified particles.

Summary of PAV Measurements of Metro Effluent Particles

Sample	Date/Time	PAV (cm^2 L^{-1})	PAV Type Composition (%)									
			Organics	Clay	Quartz	Diatom	Ca-rich	Iron-Train	Alum-Train	Al+Fe	Fe/P/Ca/Mn	Misc
Pre-P removal A	6/26/2012 9:10	0.73	3.2	5.4	1.4	0.9	2.2	0.9	0.1	0.0	75.2	10.7
Pre-P removal B	6/26/2012 9:10	0.92	5.5	4.5	1.1	1.7	2.3	0.5	0.0	0.0	77.0	7.3
Pre-P removal C	6/26/2012 9:10	1.98	3.2	6.9	0.5	0.1	0.9	3.2	0.0	0.0	77.0	8.3
Post Train 2	6/26/2012 9:20	2.14	10.6	1.2	0.2	4.2	0.1	69.4	0.0	0.1	2.2	12.2
Alum (Train 4)	7/18/2012 9:20	0.20	2.7	16.3	3.4	4.2	5.3	0.5	47.2	0.5	0.6	19.4
Iron (Train 2)	7/18/2012 9:35	1.44	13.8	26.3	1.3	2.4	0.1	45.0	0.0	0.0	5.3	5.8
Alum (Train 4)	7/25/2012 9:25	1.29	2.0	0.4	0.0	0.2	0.2	0.1	84.6	0.4	1.1	11.0
Iron (Train 2)	7/25/2012 9:15	1.32	24.9	3.6	0.1	0.8	0.5	61.9	0.5	0.0	5.0	2.8
Iron (Train 2)	8/21/2012 9:15	0.39	6.7	8.3	0.2	1.8	0.3	78.8	0.6	0.0	2.3	1.0
Alum (Train 4)	8/28/2012 9:10	0.41	2.2	33.4	0.6	4.3	0.3	0.6	23.7	7.6	1.0	26.3
Iron (Train 2)	8/28/2012 9:25	1.59	12.5	6.2	0.2	0.9	0.0	75.5	0.0	0.1	3.7	1.0
Alum (Train 4)	9/4/2012 8:55	0.26	1.9	0.7	0.1	0.9	0.3	14.0	70.4	3.1	1.2	7.4
Iron (Train 2)	9/4/2012 9:13	0.99	14.7	2.7	0.1	0.2	0.2	77.2	0.0	0.0	4.3	0.6

Summary Findings of LISST-ST Settling Velocity Experiments

A total of 20 settling velocity (SV) experiments were conducted on Metro samples between 2010 (n=5) and 2012 (n=15). Settling velocities were determined using a LISST-STX instrument with a 30 cm settling column, fully submerged in a tank of tap water. The instrument and samples were acclimated to the tank water temperature before each experiment began. The LISST-STX uses laser diffraction to count and size particles. Each experiment was set up to run over a 24 hour period. The LISST-STX makes measurements at geometrically spaced time intervals (83 total measurements) over 32 geometrically spaced size classes from 1.25 µm to 250 µm. Once the experiment is finished the data is processed using the manufacturer's (Sequoia Scientific) proprietary software "SOP v5". To properly measure the SV, the concentration measurement in each size class must be totally independent of each other. For the LISST-ST this means the 32 size classes are collapsed to 8 geometrically spaced size classes and the settling velocities are calculated. One SV experiment (7/18/12 Post-P treatment polyaluminum chloride (PAC) Train 4) exhibited anomalous behavior during the course of the experiment and is not included in this analysis. Summary graphs and salient findings are presented below.

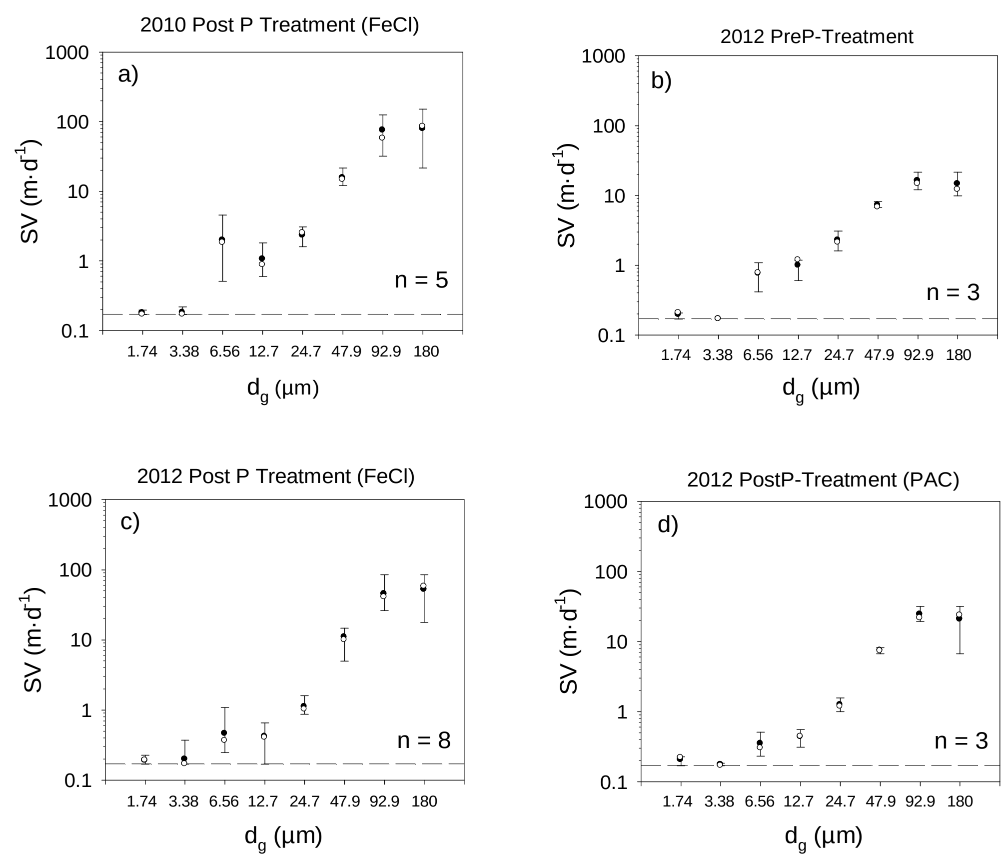
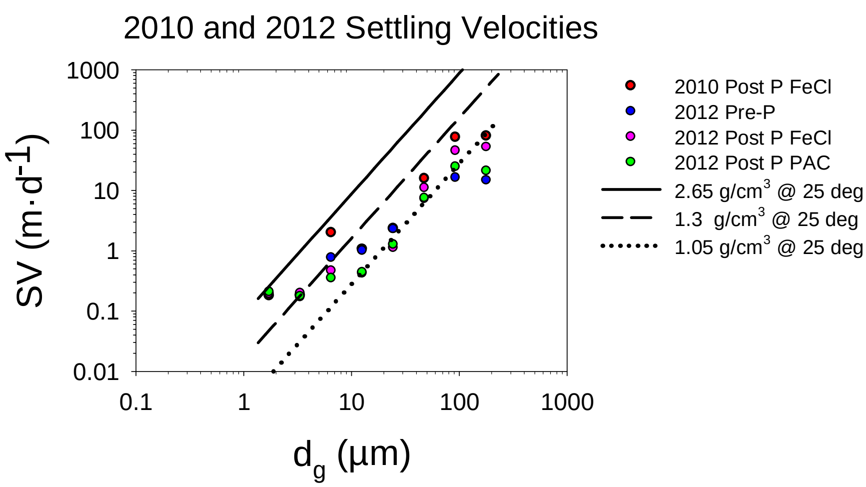


Figure 1. Average (black circle), median (open circle), minimum and maximum settling velocities are presented for eight size classes with geometric mean diameters (d_g) of 1.74, 3.38, 6.56, 12.7, 24.7, 47.9, 92.9, and 180 µm. Results are shown for (a) 2010 post-Actiflo treatment with ferric chloride (FeCl), (b) 2012 before Actiflo treatment, (c) 2012 post-Actiflo treatment with FeCl, and (d) 2012 post-Actiflo treatment with PAC. The dashed line (SV = 0.17 $m \cdot d^{-1}$) is the SV "detection limit" for the instrument.

Salient Findings:

- The variability among settling velocity (SV) experiments for each treatment time is small relative to the potential variability in the composition of the effluent, the temperature range the experiments took place over (22 - 29°C), and the temporal differences between experiments.
- SV generally increases with size; ranging from 0.17 to 100 m·d^{-1}.
- Effluent particles can be non-spherical with varying degrees of void space. The nature and size of the particle will influence its SV and contribute to some of the variability seen.



d_g	range
1.74	1.25 – 2.42
3.38	2.42 – 4.70
6.56	4.70 – 9.12
12.74	9.12 – 17.68
24.7	17.68 – 34.28
47.91	34.28 – 66.48
92.91	66.48 – 128.92
180.17	128.92 - 250

Figure 2. The colored points represent the average SVs for the four effluent types. The three lines represent Stoke's Law settling velocities for homogenous spheres across the size range of interest for different particle densities.

Salient Findings:

- Stoke's Law calculations (not shown) indicate the impact of the temperature range over which the experiments took place (22 – 29°C ambient water temperatures) had no impact on settling rates during the experiments.
- The (average) effective densities of the particles in each of the effluent types is estimated (Figure 2) by comparing the settling velocities observed to the settling velocity predicted by Stoke's Law using various particle densities. Particle densities range from 2.65 (quartz-clay mix) to 1.3 (sewage solids; Wu and He, 2010) to 1.05 g/cm^3 (almost neutrally buoyant).
- From the limited number of experiments, it appears that treatment with either FeCl or PAC results in approximately the same SV for particle sizes smaller than the d_g = 47.9 µm size class.

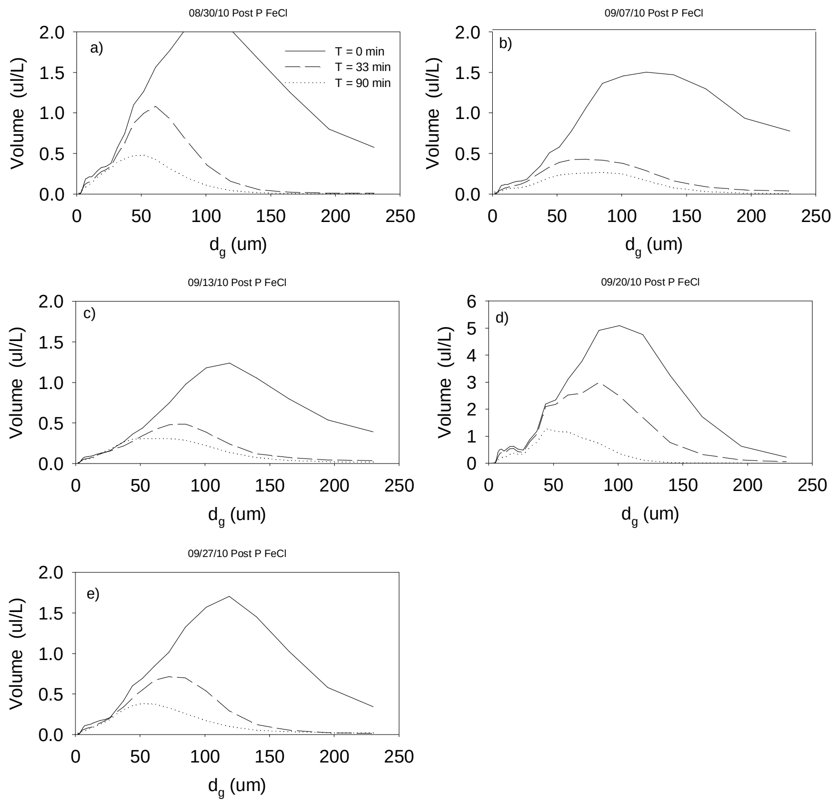


Figure 3: 2010 post-Actiflo treated effluent. Figures a – e show the initial (solid line) 32 class particle volume distribution for each SV experiment performed, and the volume of particles lost during two time periods; 30 minutes (dashed line) and 90 minutes (dotted line).

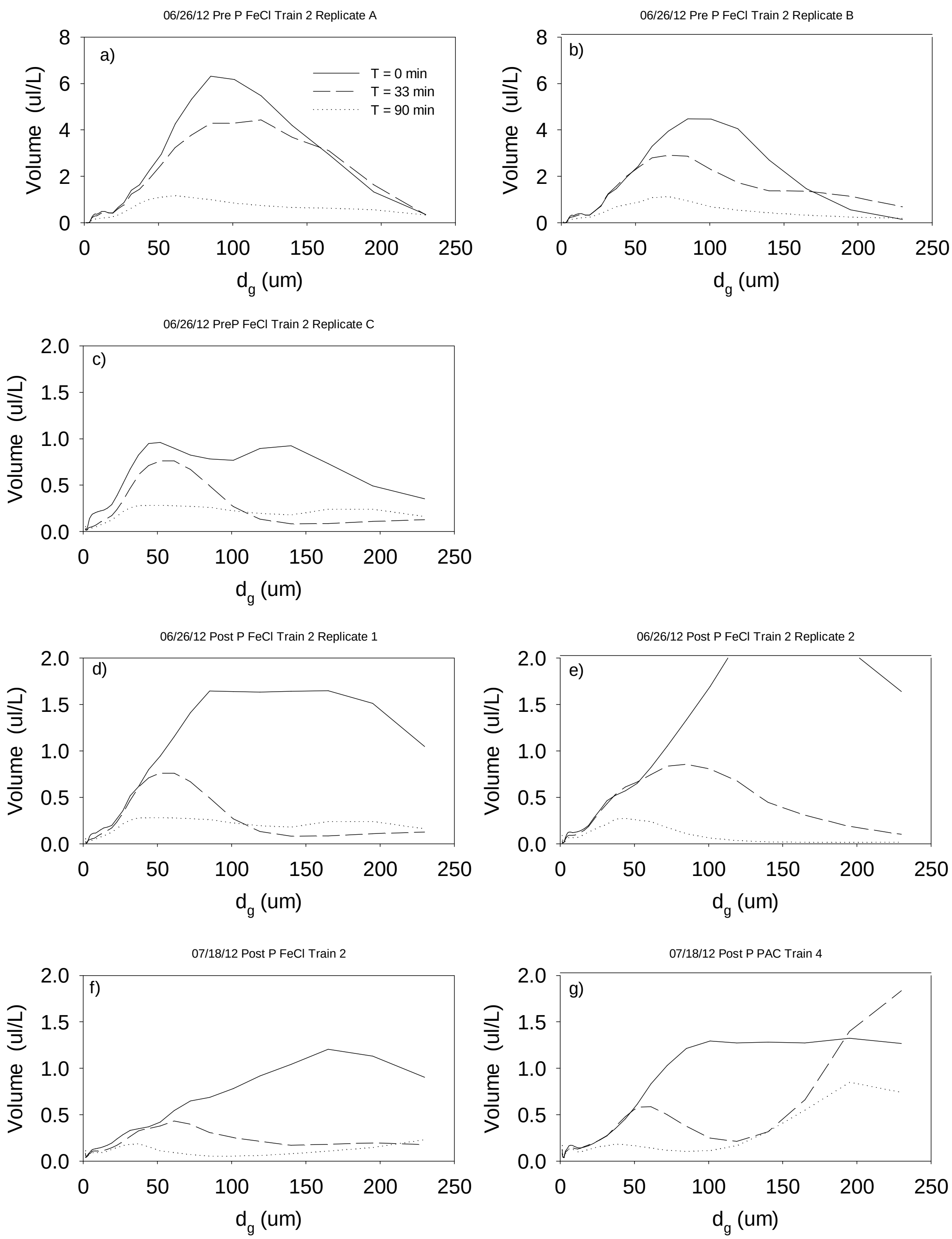


Figure 4: 2012 pre- and post-Actiflo treated effluent. Figures a – g show the initial (solid line) 32 class particle volume distribution for each SV experiment performed, and the volume of particles lost during two time periods; 30 minutes (dashed line) and 90 minutes (dotted line).

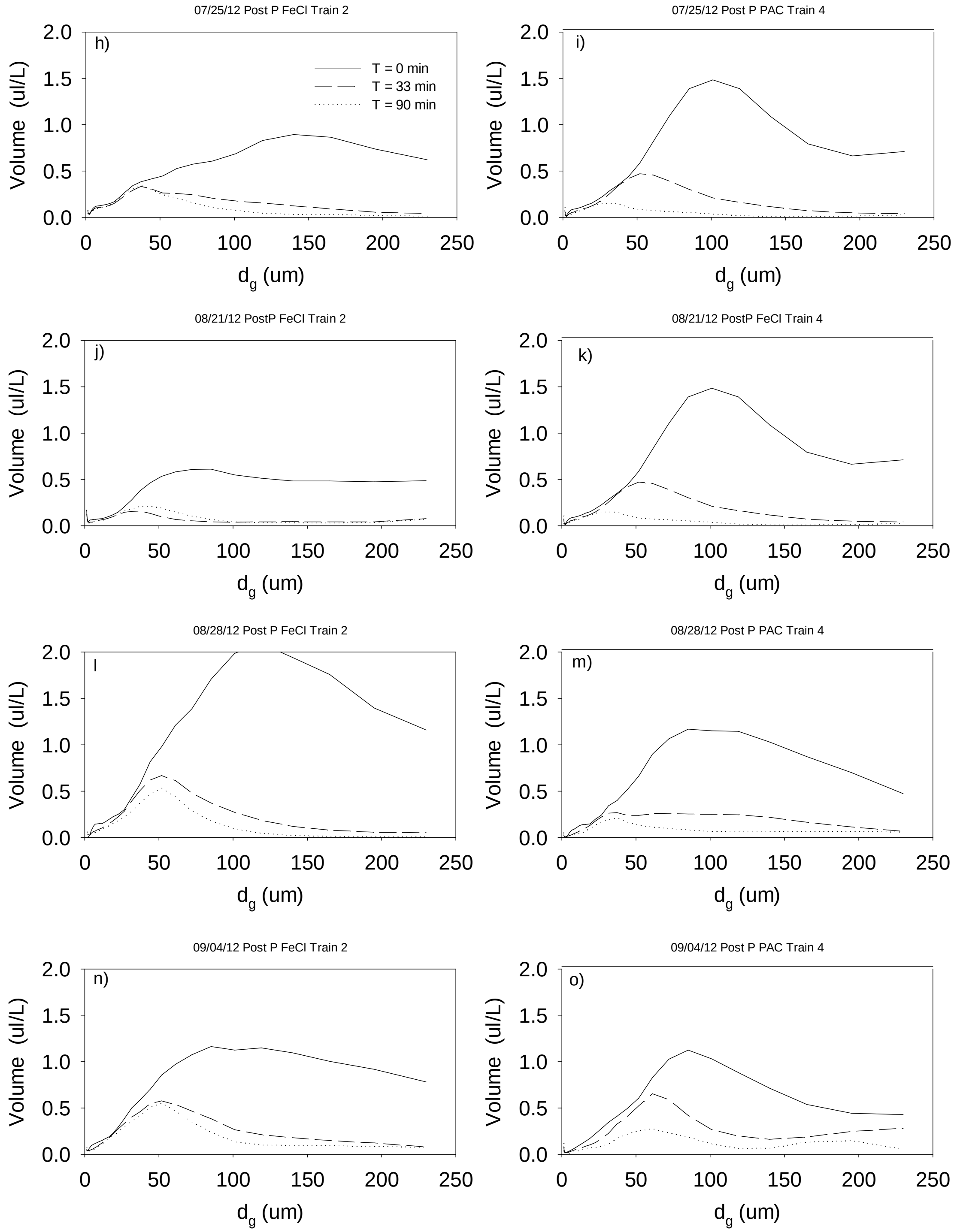


Figure 4 (continued): 2012 pre- and post-Actiflo treated effluent. Figures a – g show the initial (solid line) 32 class particle volume distribution for each SV experiment performed, and the volume of particles lost during two time periods; 30 minutes (dashed line) and 90 minutes (dotted line).

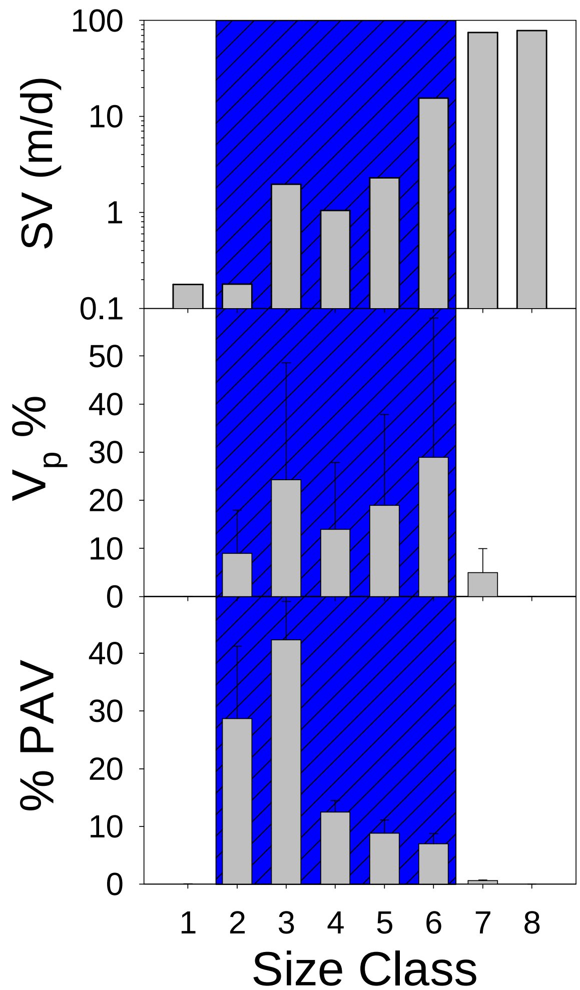


Figure 5. Particle volume percentage and PAV (projected area per unit volume of water) for the 2010 SV experiments according to individual size classes.

Salient Findings Related to Figures 3, 4, and 5:

- The particle volume distributions over time indicate the rapid loss of particles associated with larger (> 30 µm) particle volume (Figures 3 and 4). The loss percentage of particles lost over 30 minutes is generally between ~ 45 – 60% and the particle volume lost by 90 minutes is ~ 70 – 75%, so the majority of observed large particles were settling out in the first 90 minutes of the 24 hour experiment.
- Figure 5 is a representative example demonstrating that the size classes of importance related to surface area of phosphorus and SV are the sizes from ~ 4 µm to ~ 50 µm (blue shading).
- Lastly, these loss rates are generally consistent with those observed by Hu and We (2010) (Table 1).

Table 1. Percentage of particle volume lost after 30 and 90 minutes for various phosphorus treatments.

Treatment Period & Type	% Particle Volume Lost After 30 Minutes of Settling	% Particle Volume Lost After 90 Minutes of Settling
2010 Post P FeCl	58%	75%
2012 Pre-P	63%	76%
2012 Post P FeCl	61%	70%
2012 Post P PAC	44%	71%

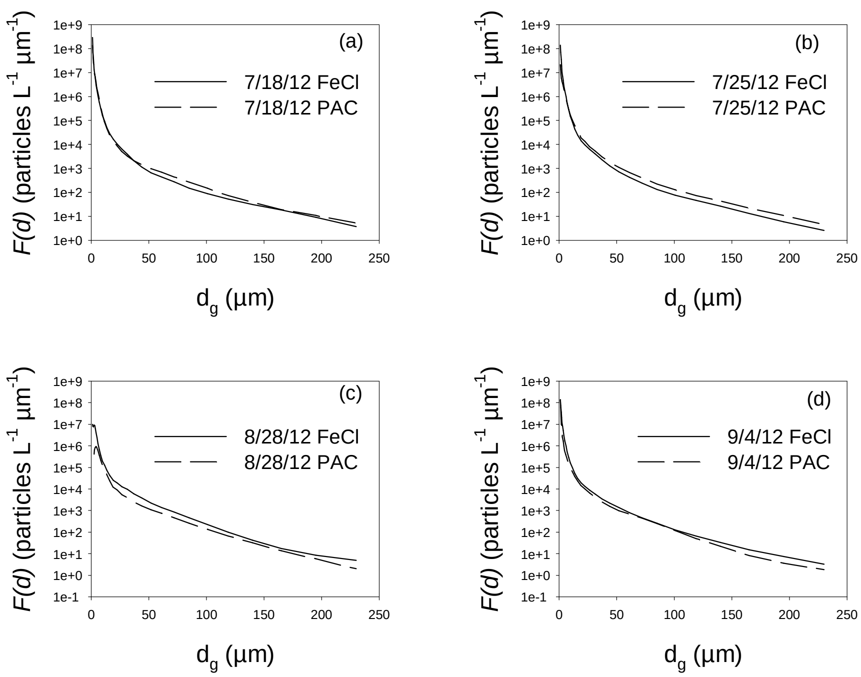


Figure 6. The particle density function (*F(d)*) is defined as the number of particles per volume in a size class and normalized to the size range of the size class. Particle density functions are compared for each of the effluent treatment types, (a) July 18, 2012, (b) July 25, 2012, (c) August 28, 2012, and (d) September 4, 2012.

Salient Findings:

- On the basis of particle size distributions, there does not appear to be a significant difference or particular advantage in the post-Actiflo treatment using either FeCl or PAC.

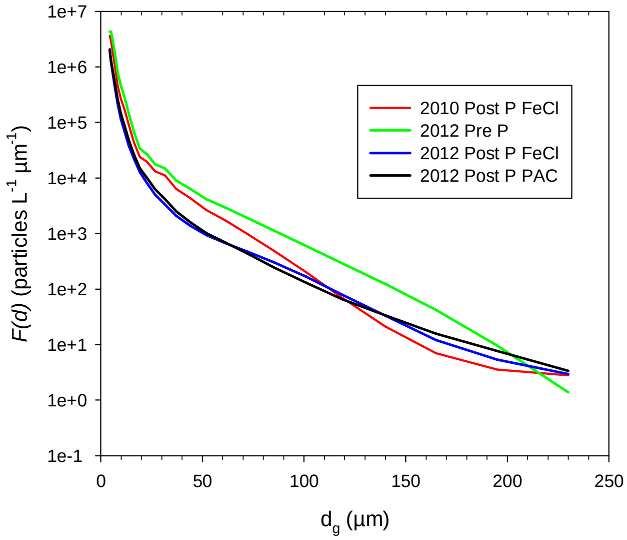


Figure 7. Comparison of the average particle density function for each of the effluent types.

Salient Findings:

- There are more particles per unit volume in the pre-treatment effluent than in the treated effluent regardless of treatment type (FeCl or PAC).
- The 2010 Actiflo process did not include PAC, so no comparison can be made; the difference in particle density could be due to a variety of factors.
- The differences in particle densities between FeCl and PAC are small.

References:

Effler, S.W. and F. Peng. 2012. Light-scattering components and Secchi depth implications in Onondaga Lake, New York, USA. Fundamental and Applied Limnology 179: 251-265.

Mikkelsen, O. and M. Pejrup. 2001. The use of a LISST-100 laser particle sizer for in-situ estimates of floc size, density and settling velocity. Geo-Marine Letters. 20:187-195.

Peng, F. and S.W. Effler. 2005. Inorganic tripton in the Finger Lakes of New York: Importance to optical characteristics. Hydrobiologia 543: 259-277.

Peng, F. and S.W. Effler. 2007. Suspended minerogenic particles in a reservoir: Light-scattering features from individual particle analysis. Limnology and Oceanography 52: 204-216.

Peng, F., S.W. Effler, D.M. O'Donnell, A.D. Weidemann, and M.T. Auer. 2009. Characterization of minerogenic particles in support of modeling light scattering in Lake Superior through a two-component approach. Limnology and Oceanography 54: 1369-1381.

Peng, F., M.G. Perkins, D. A. Matthews, A.R. Prestigiacomo, S.M. O'Donnell, and S.W. Effler. 2010. Factors Affecting the Availability of the Metro Phosphorus Load to Support Phytoplankton Growth. Presentation at the 12th Annual Onondaga Lake Scientific Forum, November, 2010.

Sequoia Scientific. 2010. LISST-ST Particle Size Analyzer User's Manual (for LISST-ST based on LISST-100x). Bellevue, Washington. 33pp.

Sequoia Scientific. 2010. LISST-100x Particle Size Analyzer User's Manual. Bellevue, Washington. 91pp.

Wu, J. and c. He. 2010. Experimental and modeling investigation of sewage solids sedimentation based on particle size distribution and fractal dimension. Int. J. Environ. Sci. Tech. 7(1):37-46.

APPENDIX D

MIXER PILOT STUDY PERFORMANCE TESTING DATA

SPX
WHERE IDEAS MEET INDUSTRY

INSTRUCTION MANUAL

98" A510E IMPELLER - CCW/DOWN P

Ship To: Syracuse Metro WWTP
Customer: JW DANFORTH
PO Number: 56821

Order: 0001540057 Line: 000010

READ AND UNDERSTAND THIS DOCUMENT PRIOR TO OPERATING OR SERVICING THIS PRODUCT.

Lightnin

SPX
WHERE IDEAS MEET INDUSTRY

Table of Contents

IMPORTANT: READ THIS SECTION THOROUGHLY
SAFETY INSTRUCTIONS / CHECKLIST

IF YOU DO NOT UNDERSTAND ANY PORTION OF THESE INSTRUCTIONS **DO NOT** ATTEMPT TO INSTALL OR OPERATE THIS MIXER! CONTACT YOUR ***LIGHTNIN***® REPRESENTATIVE FOR ANY QUESTIONS YOU MAY HAVE CONCERNING SAFETY OR THESE INSTRUCTIONS.

Your ***LIGHTNIN***® mixer is equipped with safety labels which contain specific instructions pertaining to the safe handling and operation of the mixer. For your protection, you must understand that failure to follow the safety instructions imprinted on the safety labels or failure to follow the safety instructions printed in this instruction manual may result in serious personal injury or death. In addition, failure to adhere to safety instructions may cause damage to property or equipment.

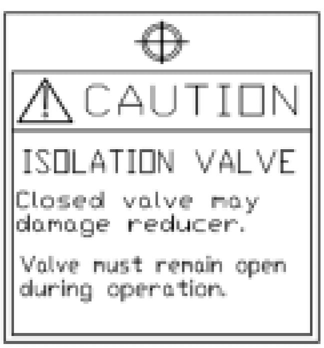
In this publication, and on the mixer safety labels, the words DANGER, WARNING and CAUTION may be used to signify special instructions to be observed by the installer or user. These instructions warn of potential hazards concerning service, installation or operation if the instructions are performed incorrectly, carelessly or are ignored. Safety instructions alone cannot eliminate the hazards they signal. Strict compliance with these special instructions, along with safe work habits and simple "common sense" are major accident prevention measures.

CAUTION - Signals unsafe practices or hazards which **could** cause **minor** personal injury or property damage.

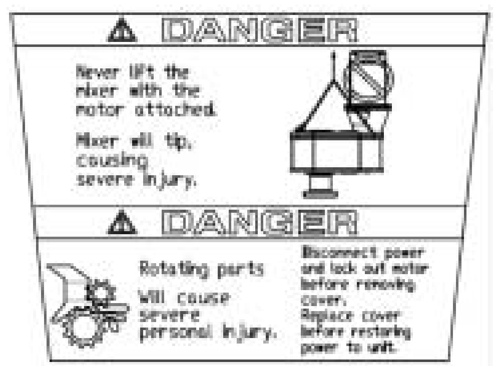
WARNING - Signals unsafe practices or hazards which **could** cause **severe** personal injury or death.

DANGER - Signals immediate hazards which **will** probably cause **severe** personal injury or death.

This mixer should be equipped with safety or instructional labels similar to those shown below. If any of the labels are missing, damaged or otherwise illegible, **DO NOT** install, service or operate the mixer. Contact your ***LIGHTNIN***® representative immediately for instructions.



EXAMPLES:



LIGHTNIN
AN SPX BRAND

SAFETY CHECK LIST

IMPORTANT WARNINGS

All ***LIGHTNIN®*** Mixers and Aerators are provided with properly designed lifting devices and safety covers to avoid potential injury and/or equipment damage. The following SAFETY CHECK LIST should be THOROUGHLY REVIEWED AND ADHERED TO before installing, operating or performing maintenance on the mixer. FAILURE TO FOLLOW THESE INSTRUCTIONS COULD RESULT IN SERIOUS INJURY. Ensure the use of qualified, quality trained and safety conscious personnel.

1. **WARNING**: When moving, installing or lifting this mixer, always use equipment which is rated to carry the full load of the mixer. Use only the lifting device, if provided, on your unit to install the mixer. Failure to follow these instructions could cause severe injury, death or damage to property. Consult the appropriate section of this manual for lifting and installation instructions.

2. **WARNING**: DO NOT attempt to connect a power source to this mixer unless you are licensed or certified to do so. Failure to follow this instruction could cause severe injury, death or damage to property.

3. **WARNING**: DO NOT connect the motor to the power source until all components are assembled, the mixer is installed, and all hardware is tightened to the proper torque which is specified in the operation and maintenance manuals supplied by ***LIGHTNIN®***.

4. DO NOT operate shaft sealing devices at temperatures higher than those specified in the manual or on the nameplates.

5. DO NOT service the mixer until you have followed your "Control of Hazardous Energy Sources" (lockout, tagout procedure) as required by OSHA.

6. **WARNING**: Never touch a mixer, which has an electric motor, or any part of an electrical service line cord or conduit, while your hands or feet are wet or if you are standing on a wet or damp surface. Failure to follow this instruction may result in severe electrical shock or death.

7. **WARNING**: DO NOT touch any part of mixer that has the potential of having a hot surface including the motor, gear drive housing, seal, shafting and flange. When a mixer is running, the motor temperature rises. This is a normal occurrence, but the motor temperature may be high enough to cause burns to the hands or any other part of the body. DO NOT touch a mixer motor until it cools for at least one hour. Failure to follow these instructions may result in severe personal injury.

8. **DANGER**: Never touch any rotating part of a mixer with bare hands, gloved hands or any other part of your body, or with any hand held object. Rotating parts include, but are not limited to, the mixer shaft, impeller(s), set screws, hardware, couplings, mechanical seals and motor fans.

9. **WARNING**: DO NOT operate mixer for service other than its intended use, that being fluid mixing with the mixer attached to a rigid structure and connected to a power source appropriate to operate the mixer drive motor.

10. **WARNING**: Never attempt to move or adjust a mixer while it is running.

SAFETY CHECK LIST, cont'd.

IMPORTANT WARNINGS, cont'd.

11. DO NOT make any field changes or modifications (horsepower, seal material components, output speed, shaft lengths, impellers, etc.) without reviewing the changes with your ***LIGHTNIN®*** Sales Representative or the ***LIGHTNIN®*** Customer Service Department.

12. DO NOT install an aftermarket Variable Frequency Drive without first consulting your ***LIGHTNIN®*** Sales Representative or the ***LIGHTNIN®*** Customer Service Department to determine the compatibility of the existing motor with the Variable Frequency Drive.

13. DO NOT operate mixer until you have checked the following items:
    A. Make sure the mixer is properly grounded.
    B. Ensure all protective guards and covers are installed.
       Guarding of the mixer shaft below the mixer mounting surface is the responsibility of the customer.
    C. Ensure all detachable components are securely coupled to the mixer.
    D. Thoroughly REVIEW and ADHERE TO the mixer operating instructions supplied by ***LIGHTNIN®***.
    E. Ensure the mixer output shaft rotates freely by hand.
    F. Ensure all personnel and equipment are clear of rotating parts.
    G. Ensure all external connections(electrical, hydraulic, pneumatic, etc.) have been completed in accordance with all applicable codes and regulations.

14. DO NOT enter the mixing vessel UNLESS:
    A. The mixer power supply is locked out (follow item number 5).
    B. The mixer shaft is firmly attached to the mixer drive or the shaft is supported securely from below.
    C. You have followed applicable confined space regulations.

15. **WARNING**: Eye protection must be worn at all times while servicing this mixer. Failure to follow this instructions may result in severe injury or death.

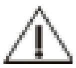
16. **WARNING**: Never attempt to clean or service the mixer, or any part of it, while the mixer is running, or while it is connected to a power source. Always turn the mixer off and disconnect the power before cleaning or servicing.

17. **CAUTION**: When repairing the mixer, or replacing parts, use factory authorized parts and procedures. Failure to do so may result in damage to the mixer or injury to the user.

CE COMPLIANCE

If the mixer nameplate has a CE marking on it, then the equipment furnished conforms to the following directives:

Machinery Directive: 2006/42/EC
Electro-Magnetic Compatibility: 2004/108/EC
Low Voltage Directive: 2006/95/EC
Noise: 2000/14/EC



CAUTION: When applicable specific markings required by Pressure Equipment Directive 97/23/EC (PED) and/or Equipment for Use in Potential Explosive Atmospheres Directive 94/9/EC (ATEX) will be indicated on supporting nameplates. If there is any doubt relating to the intended use of this equipment please contact ***LIGHTNIN®*** before installation and operation.

Any CE marking and/or associated documentation applies to the mixer only. This has been supplied on the basis that the mixer is a unique system. When the mixer is installed, it becomes an integral part of a larger system which is not within the scope of supply and CE marking is the responsibility of others.

NOISE LEVELS

SOUND PRESSURE LEVELS

Portable Series: ECL, EV - maximum 80 dBA @ 1 meter.

Heavy Series: S10, 70/80, 500/600 - maximum 85 dBA @ 1 meter.

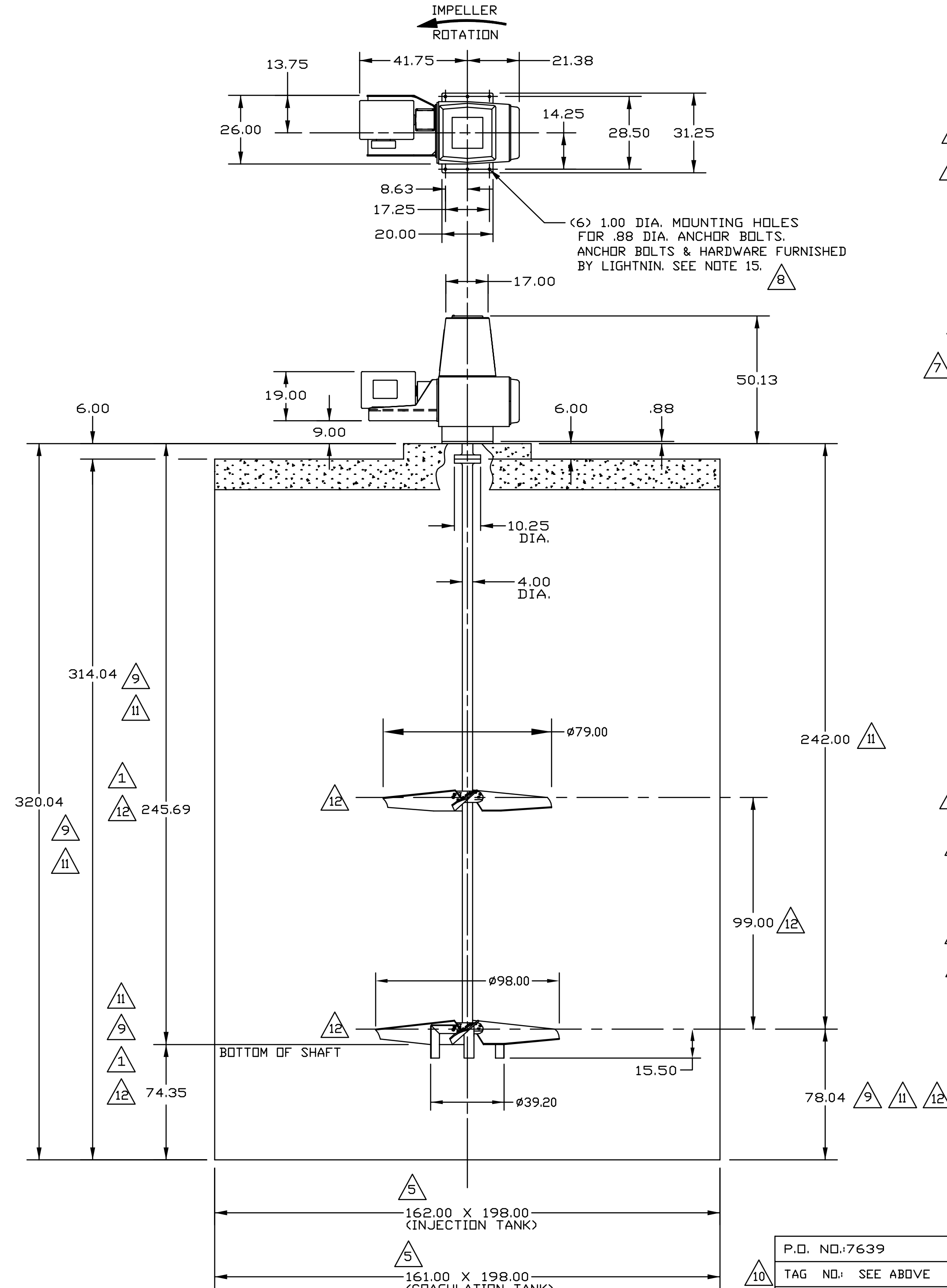
PATENTS

THIS PRODUCT MAY BE COVERED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS:

5152606	5501523	6517233	6860474	7168848	7387431	7550120
5152934	5511881	6517246	6877750	7168849	7407322	7572112
5203630	5568975	6742923	6986507	7278799	7473025	7726946
5344235	5779359	6746147	7001063	7328809	7481573	7753215
5368390	5925293	6789314	7056095	7329065	7488137	7874719
5470152	5988604	6796707	7114844	7331704	7507028	
5480228	6158722	6796770	7168641	7384551	7547135	

ENVIRONMENTAL NOTICE

Dispose of equipment responsibly at the end of its service, in accordance with local laws and directives. Correct disposal is the responsibility of the end user. If in doubt, consult with local environmental agencies for advice on the best method of disposal.



1. MIXER DESIGNATION: MODEL-86 Q 20, GEAR DRIVE REDUCTION-TRIPLE, RATIO-47.40:1, CASE SIZE-86. (3)
2. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
3. MATERIAL: OF MIXER PARTS IN THE TANK IS 316 SS.
4. IMPELLERS: (12) (13)
   37 R.P.M.
   UPPER IMPELLER: TYPE A510E, 3 BLADES WITH A 22° TIP CHORD ANGLE
   LOWER IMPELER: TYPE A510E, 3 BLADES WITH A 32° TIP CHORD ANGLE
   THE IMPELLER BLADES ARE BOLTED TO THE IMPELLER HUBS.
   THE UPPER IMPELLER HUB IS ADJUSTABLE 36" UPWARD AND 51" DOWNWARD FROM POSITION SHOWN, IN 3" INCREMENTS.
   THE LOWER IMPELLER HUB IS ADJUSTABLE 48" UPWARD AND 0" DOWNWARD FROM POSITION SHOWN, IN 3" INCREMENTS.
   DOWNWARD FLOW SPECIFIED.
5. MOTOR: (1)
   20 H.P. 1800 R.P.M. 256T FRAME TEFC ENCLOSURE
6. MIXER WEIGHT: 4,208 LBS. (TOTAL) (3) (4) (7) (5)
   DRIVE: 2,197 LBS., MOTOR: 250 LBS., SHAFT: 1,194 LBS., IMPELLERS: 567 LBS. (3)
7. MIXER MOUNTING DESIGN DATA:
   A. DESIGN LOADS: (4)
      VERTICAL DOWNWARD LOAD: 11,000 LBS.
      TORQUE: 65,000 IN.-LBS.
      BENDING MOMENT: 125,000 IN.-LBS.
      DESIGN LOADS ARE GREATER THAN ACTUAL LOADS BY A SUITABLE FACTOR, CONSISTENT WITH CONSTRUCTION CODES AND *LIGHTNIN* EXPERIENCE.
   B. WARRANTIES AND GUARANTEES APPLY FOR THOSE ITEMS FURNISHED BY *LIGHTNIN*. ALL OTHER EQUIPMENT AND DESIGNS ARE THE RESPONSIBILITY OF OTHERS.
8. BAFFLES: NOT FURNISHED BY *LIGHTNIN*. (1)
9. MINIMUM OPENING: (12)
   TANK MUST HAVE A MINIMUM OPENING SIZE OF 19.50 DIA. TO PASS DISASSEMBLED MIXER PARTS.
10. REFER TO INSTRUCTIONS FOR SAFE LIFTING OF MIXER.
11. SPARE SHAFT, IMPELLER AND "MIXER-FIXER" KIT FURNISHED ON PARTS ORDER R264812.
12. THE IMPELLER STRESS IS LESS THAN 11000 PSI. THE SHAFT STRESS IS LESS THAN 8000 PSI.
13. THE L-10 BEARING LIFE IS GREATER THAN 100,000 HOURS AND THE AGMA SERVICE FACTOR IS 2.17 .
14. THE NORMALLY PAINTED PARTS ON THE MIXER IS PREPARED AND PRIMED WITH THE FOLLOWING: (2) (5)
   A. SURFACE PREPARATION: SSPC-SP6 COMMERCIAL BLAST.
   B. PRIMER COAT: TNEMEC SERIES 66-1211 HI-BUILD EPOXOLINE DFT 3.0-5.0 MILS
   C. INTERMEDIATE COAT: TNEMEC SERIES 66 HI-BUILD EPOXOLINE DFT 4.0-6.0 MILS
   D. FINISH COAT: TNEMEC SERIES 66 HI-BUILD EPOXOLINE DFT 3.0-5.0 MILS
   E. ALL THREE COATS TO HAVE A TOTAL DFT 12 MILS MINIMUM
15. REFER TO DRAWING NO. R264811-M FOR ANCHOR BOLT MOUNTING DETAIL. (8)
16. SHAFT AND IMPELLER REPLACED AND CHANGED TO CCW ROTATION PER LIGHTNIN ORDER 1540057. (12)

PROJECT NAME: ONONDAGA COUNTY, N.Y. - ACTIFLO
CONTRACT NO.: 329911
MANUFACTURER: LIGHTNIN
DATE: 10/13/00

(10) TAG: CTM-30102 ITM-30103
CTM-30202 ITM-30203
CTM-30302 ITM-30303
CTM-30402 ITM-30403

ISO 9001 CERTIFIED
LIGHTNIN
MIXERS AND AERATORS

P.O. NO.:7639	CUSTOMER: I. KRUGER INC.		DRAWING TITLE: INSTALLATION DRAWING
TAG NO.: SEE ABOVE (10)			
LIGHTNIN SALES NO.:758501	DRWN.: T.LOLLER	DATE: 10/9/00	DRAWING NO.: R264811-A
LIGHTNIN PROJ. NO.:264811	CERT.:	DATE:	REV. 13

SPX

Lightnin®

INSTALLATION OF A510 AND A510E AXIAL FLOW IMPELLER KEYED HUB / BOLTED ON BLADES

SECTION 1 - GENERAL

1.1 Refer to appropriate table for the minimum diameter opening that the impeller will pass through. Opening shown is based on disassembled impellers with the hub on the shaft.

1.2 A510 type impellers are shipped disassembled for ease of shipment and handling at the job site. Refer to Section 2 for impeller assembly guides.

SECTION 2 - IMPELLER ASSEMBLY

2.1 Mate the three blades (convex side up) on the hub ears. If fins (168) are furnished, mount them before installing hex nuts (167).

WARNING: Before securing the hardware, apply pressure to the blade so that its edge is firmly seated against the raised shoulder on each hub ear. After tightening hardware, check to make sure that the blade has not shifted away from the hub ear shoulder. PROPER BLADE POSITIONING IS IMPORTANT TO IMPELLER FUNCTION.

2.2 **IT IS ESSENTIAL** that the hardware securing the blades to the hub is tightened to the specific torques in Table 1. It is important that tight connections are maintained as impellers are usually subjected to a wide range of adverse loading conditions imposed by fluid force reactions.

2.3 It is good practice to RETIGHTEN all bolted connections after the equipment has been in operation. It is recommended that all hardware be checked for tightness 12 hours after assembly, and at each scheduled shut down thereafter.

TABLE 1 - IMPELLER TIGHTENING TORQUES

BOLT THREAD SIZE	TORQUE (FT-LBS)	
	GRADE 2, 3 OR 304 / 316 SS BOLTS	GRADE 5 BOLTS
3/8-16	17	26
1/2-13	41	64
5/8-11	83	128
3/4-10	120	226
7/8-9 (1)	142	365
1-8	212	547
1-1/8-7	301	675
1-1/4-7	425	952

Torque must be applied to the hex nuts. Restrain the bolt heads and tighten the hex nuts.
Torque values are based on hardware, threads and bearing surfaces lubricated with a light oil.
LIGHTNIN standard steel material is SAE Grade 5.
(1) Allowable bolt stress values change at these locations and this is reflected in the torque values.

SECTION 3 - IMPELLER ASSEMBLY TO SHAFT

3.1 Coat the shaft with a lubricant to facilitate movement and slide the impeller(s) up the shaft to the desired location as shown on the Installation drawing. THE HUB FACE STAMPED “MOTOR END” MUST FACE TOWARDS THE DRIVE END.

NOTE: All shafts are provided with pin holes in the shaft keyway for the impeller hook key and most shafts are multiple drilled for impeller field adjustment. Refer to the installation drawing for correct impeller positioning.

3.2 Insert the hook key (162) pin into the shaft keyway pin hole.

3.3 Lower the impeller **GENTLY** over the hook key (162) until the hub is resting on the protruding pin. **DO NOT ALLOW THE IMPELLER TO DROP ON THE PIN.** The pin is a safety device designed to support the weight of the impeller, **BUT NOT** to withstand impacts.

3.4 Install the set screw (163). After the set screw is properly seated in the countersunk hole in the hook key (162), tighten the set screw against the key.

SECTION 4 - REPOSITIONING

4.1 Remove the set screw (163).

4.2 Raise the impeller until the hook key (162) is exposed.

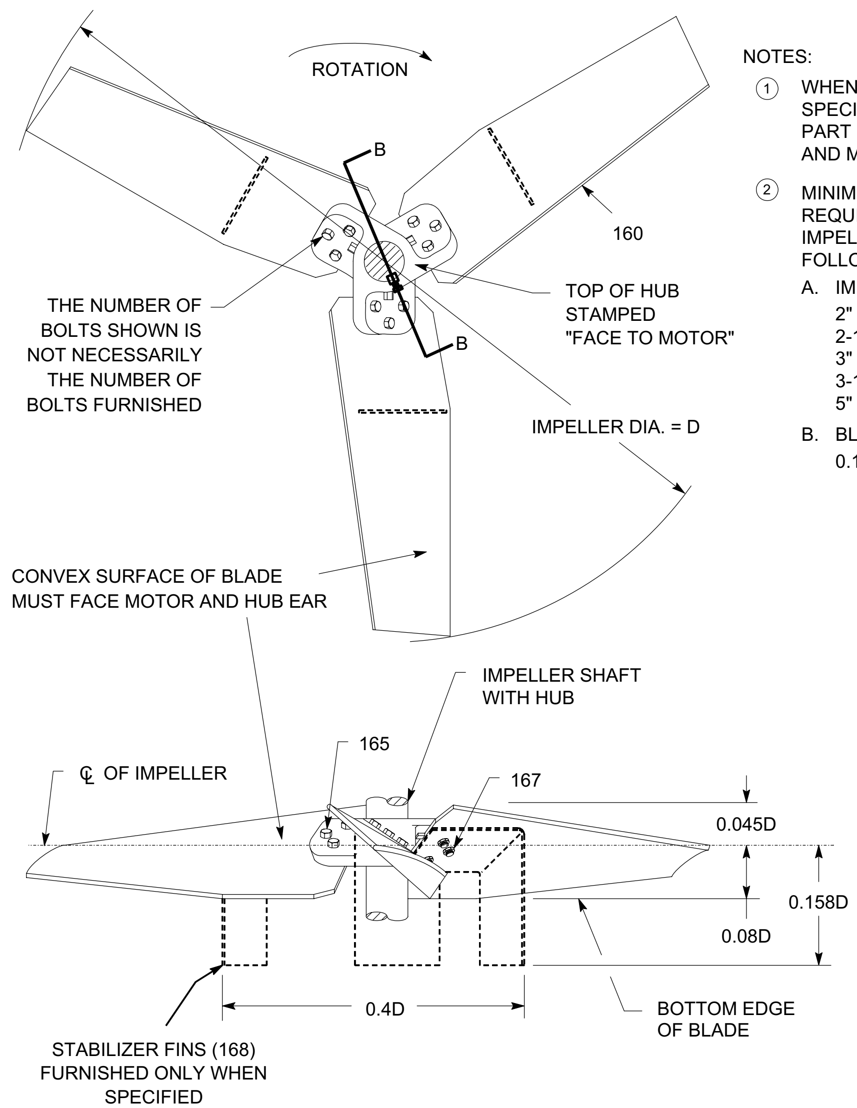
4.3 Relocate the hook key (162) in the desired position.

4.4 Retighten all hardware as noted in steps 3.3 and 3.4 .

4.5 It is good practice to RETIGHTEN all bolted connections after the equipment has been in operation. It is recommended that all hardware be checked for tightness 12 hours after assembly, and at each scheduled shut down thereafter.

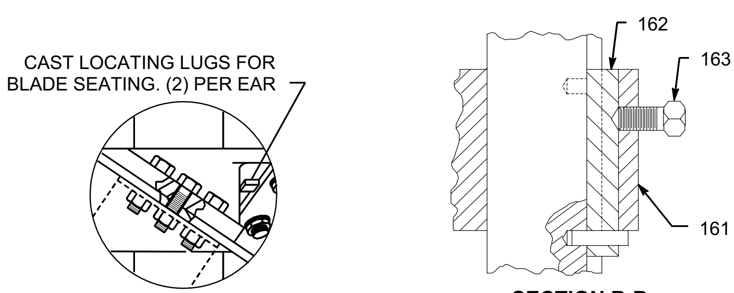
FIGURE 1 - A510 AND A510E AXIAL FLOW IMPELLER

KEYED HUB / BOLTED ON BLADES



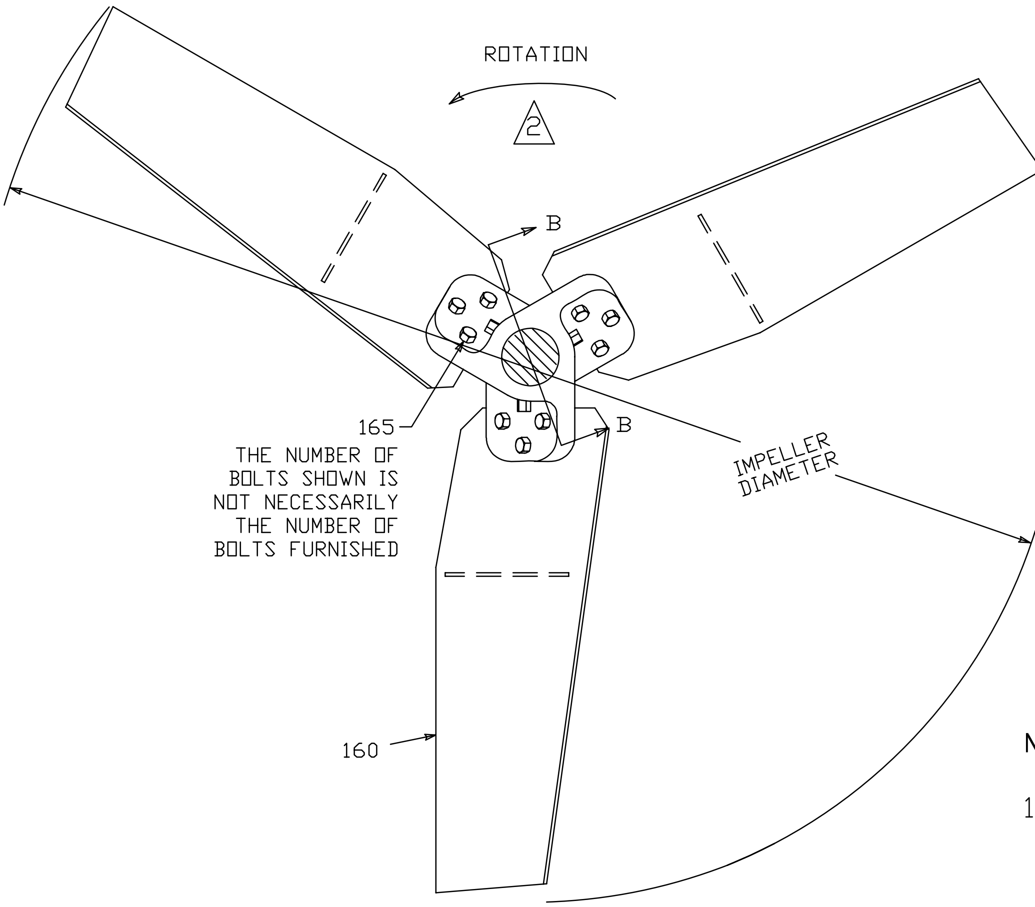
NOTES:

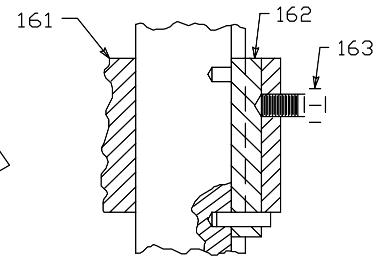
1. WHEN ORDERING PARTS, SPECIFY DRAWING NUMBER, PART NAME, ITEM NUMBER, AND MACHINE SERIAL NUMBER
2. MINIMUM DIAMETER OPENING REQUIRED TO PASS DISASSEMBLED IMPELLER IS THE LARGER OF THE FOLLOWING:
   A. IMPELLER SHAFT WITH HUB:
      2" SHAFT - 9" DIA.
      2-1/2" SHAFT - 13" DIA.
      3" SHAFT - 15" DIA.
      3-1/2" THRU 4-1/2" SHAFT - 17" DIA.
      5" & 5-1/2" SHAFT - 20" DIA.
   B. BLADE (160) OFF HUB:
      0.165D



SECTION B-B

168	STABILIZER FIN
167	HEX NUT
165	HEX HD. CAP SCREW
163	SET SCREW
162	HOOK KEY
161	HUB
160	BLADE
ITEM	PART NAME

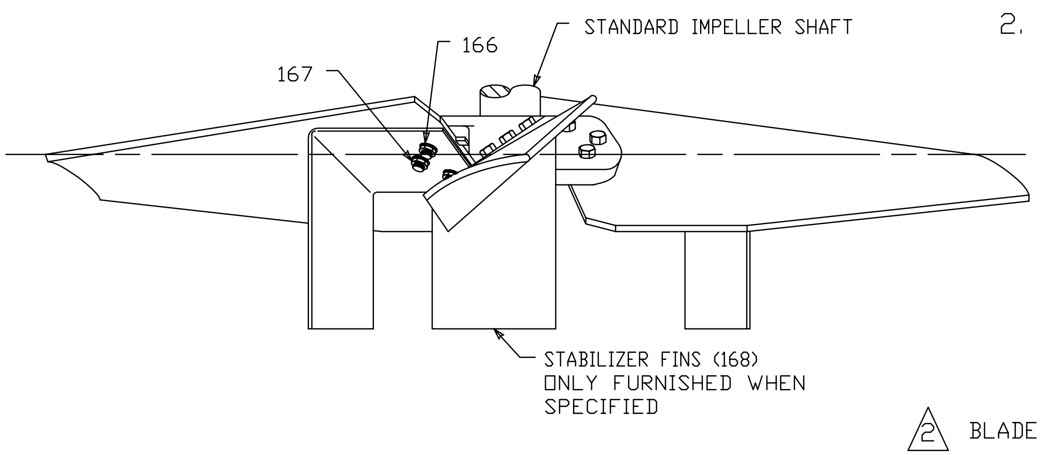




1 SECTION B-B
KEYED HUB

NOTES: 3

1. UPPER IMPELLER HAS A 22° TIP CHORD ANGLE LOWER IMPELLER HAS A 32° TIP CHORD ANGLE.
2. DOWNWARD FLOW SPECIFIED.



2 BLADES ARE FOR CCW ROTATION

WHEN ORDERING PARTS, SPECIFY:
DRAWING NUMBER, PART NAME, ITEM NUMBER AND SERIAL NUMBER

ITEM	PART NAME	
168	STABILIZER FIN	
167	HEX NUT	
166	LOCKWASHER	
165	HEX HEAD CAP SCREW	
163	SET SCREW	KEYED HUB
162	HOOK KEY	KEYED HUB
161	HUB	KEYED HUB
160	BLADE	

PROJECT NAME: ONONDAGA COUNTY, N.Y. - ACTIFLO
CONTRACT NO.: 329911
MANUFACTURER: LIGHTNIN
DATE: 10/13/00

ISO 9001 CERTIFIED

LIGHTNIN®
MIXERS AND AERATORS

ASSEMBLY DRAWING

A510E AXIAL FLOW IMPELLER ONE PIECE HUB w/ BOLTED BLADES CCW ROTATION

DRAWING NO. R264811-D 3

FOR AN UP TO DATE REPRESENTATIVE LIST

PLEASE GO TO: www.lightnin-mixers.com

-OR-

CALL: 1-888-649-2378

1-888-MIX-BEST

Notes

LIMITED WARRANTY

Unless otherwise noted on the face hereof, SPX goods, auxiliaries and parts thereof are warranted to the original purchaser against defective workmanship and material for a period of twelve (12) months from date of installation or (18) months from date of shipment from factory, whichever expires first. If the goods or services do not conform to the warranty stated above, then as Buyer s sole remedy, SPX shall, at SPX s option, either repair or replace the defective goods or re-perform defective services. Third party goods furnished by SPX will be repaired or replaced as Buyer s sole remedy, but only to the extent provided in and honored by the original manufacturer s warranty. Unless otherwise agreed to in writing, SPX shall not be liable for breach of warranty or otherwise in any manner whatsoever for: (i) normal wear and tear; (ii) corrosion, abrasion or erosion; (iii) any good or services which, following delivery or performance by SPX, has been subjected to accident, abuse, misapplication, improper repair, alteration, improper installation or maintenance, neglect, or excessive operating conditions; (iv) defects resulting from Buyer s specifications or designs or those of Buyer s contractors or subcontractors other than SPX; or (v) defects resulting from the manufacture, distribution, promotion or sale of Buyer s products.
THE WARRANTIES CONTAINED HEREIN ARE THE SOLE AND EXCLUSIVE WARRANTIES AVAILABLE TO BUYER AND SPX HEREBY DISCLAIMS ANY OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE FOREGOING REPAIR, REPLACEMENT AND REPERFORMANCE OBLIGATIONS STATE SPX S ENTIRE AND EXCLUSIVE LIABILITY AND BUYER S EXCLUSIVE REMEDY FOR ANY CLAIM IN CONNECTION WITH THE SALE AND FURNISHING OF SERVICES, GOODS OR PARTS, THEIR DESIGN, SUITABILITY FOR USE, INSTALLATION OR OPERATIONS.

TECHNICAL SERVICES

The Lightnin brand dedicated after sales support teams are on hand to offer advice and support. With more than 85 years' experience in the manufacture and supply of agitation equipment, we know what parts need to be on hand to support our customer base so that your downtime is minimized. Our team of highly experienced field service technicians is on call to support the on-site servicing of equipment, or supervise and train your maintenance staff in best practice care of equipment.

INSTALLATION AND COMMISSIONING

Proper installation of your Lightnin mixer is critical to its long term performance and reliability. To ensure that installation procedures are followed, a certified technician will:

- Audit the equipment
- Supervise job-site contractors
- Perform a final inspection

SERVICE SUPPORT & REFURBISHMENT

The equipment audit is specifically designed to identify potential mechanical problems before they occur. Using many forms of modern technology and drawing on our mixer manufacturing experience, our technicians can identify the onset of bearing and gear failures, misalignment and system problems without the need to interrupt production. Factory gearbox exchange and refurbishment programs offer a fast and cost-effective route to extending equipment life.

SPX FLOW TECHNOLOGY
35 Mt. Read Blvd.
Rochester, NY 13511
P: (888) 649-2378 (MIX-BEST) or +1 (585) 436-5550
F: (585) 436-5589
E: lightnin@spx.com • www.lightninmixers.com

ISSUED 2012

MIXER PILOT STUDY PERFORMANCE TESTING DATA

Testing Data Before Mixer Modifications

SOURCE	IND_CODE	START_TIME	DOP, mg/L	Fe, mg/L	pH-field	Settleable Solids, mg/L	SRP, mg/L	TDP, mg/L	Temp-field (°C)	TIP-F, mg/L	TP, mg/L	TPP, mg/L	TSS, mg/L	UV Flow over Sample Period, MGD	Flow Equivalent and Flow % Distribution	Comments
Metro HRFS Influent	769	10/9/12 9:20	0.035		6.77	-	0.077	0.129	19.06	0.094	0.310	0.181	<4		All trains in service - No.1 (29.9%), 2 (24.2%), 3 (24.6%), and 4 (21.3%). **Flow 60.7 MGD**	Planned power outage AM, before sampling, PLC failure
HRFS Clarifier Eff 2	764	10/9/12 9:45	0.015	9.35	6.48	-	0.001	0.019	19.10	0.004	0.033	0.014	29	60.7		
HRFS Clarifier Eff 3	765	10/9/12 9:30	0.009	11.8	6.54	-	0.001	0.020	19.10	0.011	0.300	0.280	30			
Metro HRFS Influent	769	10/10/12 10:00	0.053		6.97	-	0.123	0.179	19.55	0.126	0.348	0.169	4		Three (3) trains in service - No.1 (39.0%), 2 (30.6%), and 3 (30.5%). **Equivalent Flow 72.2 MGD**	
HRFS Clarifier Eff 2	764	10/10/12 10:10	0.015	1.21	6.63	-	0.003	0.021	19.55	0.006	0.057	0.036	4	54.2		
HRFS Clarifier Eff 3	765	10/10/12 10:20	0.012	1.76	6.58		0.004	0.021	19.55	0.009	0.072	0.051	7			
Metro HRFS Influent	769	10/11/12 10:00	0.040		7.01	-	0.131	0.168	18.67	0.128	0.334	0.166	3		Two (2) trains in service - No.2 (48.5%) and 3 (51.5%). **Equivalent Flow 103.4 MGD**	
HRFS Clarifier Eff 2	764	10/11/12 10:10	0.016	1.36	6.85	-	0.003	0.021	18.69	0.005	0.065	0.044	9	51.7		
HRFS Clarifier Eff 3	765	10/11/12 10:20	0.017	1.84	6.96	-	0.003	0.021	18.68	0.004	0.089	0.068	6			

Testing Data After Mixer Modifications

Train 2 (Clarifier Eff 2): No mixer modifications
Train 4 (Clarifier Eff 4): Mixer modifications

SOURCE	IND_CODE	START_TIME	DOP, mg/L	Fe, mg/L	pH-field	Settleable Solids, mg/L	SRP, mg/L	TDP, mg/L	Temp-field (°C)	TIP-F, mg/L	TP, mg/L	TPP, mg/L	TSS, mg/L	UV Flow over Sample Period, MGD	Flow Equivalent and Flow % Distribution	Comments
Metro HRFS Influent	769	11/26/12 9:30	0.036		6.88		0.058	0.103	14.59	0.067	0.339	0.236	9		All trains in service - No.1 (28.5%), 2 (25.7%), 3 (24.7%), and 4 (21.1%). **Flow 60.2 MGD**	
HRFS Clarifier Eff 2	764	11/26/12 9:40	0.017	1.43	6.55	0.2	0.001	0.024	14.61	0.007	0.028	0.004	6	60.2		
HRFS Clarifier Eff 3	765	11/26/12 9:50	0.011	1.2	6.45	1.5	0.001	0.015	14.61	0.004	0.032	0.017	<3			
Metro HRFS Influent	769	11/27/12 9:30	0.048		6.46		0.037	0.092	14.67	0.044	0.284	0.192	8		Two (2) trains in service - No.2 (49.7%) and 3 (50.3%). **Equivalent Flow 102.4 MGD**	
HRFS Clarifier Eff 2	764	11/27/12 9:40	0.017	1.5	6.21	1.5	0.003	0.023	14.67	0.006	0.057	0.034	6	51.2		
HRFS Clarifier Eff 3	765	11/27/12 9:50	0.017	1.68	6.22	1.9	0.002	0.021	14.67	0.004	0.067	0.046	6			
Metro HRFS Influent	769	11/28/12 11:50	0.052		6.52		0.057	0.118	14.9	0.066	0.401	0.283	8		Three (3) trains in service - No.1 (36.6%), 2 (30.8%), and 3 (32.6%). **Equivalent Flow 73.1 MGD**	Coagulant diffuser on Train 3 was taken out of service for repair
HRFS Clarifier Eff 2	764	11/28/12 12:00	0.021	1.5	6.34	0.3	0.001	0.026	14.92	0.005	0.071	0.045	8	54.8		
HRFS Clarifier Eff 3	765	11/28/12 12:10	0.021	1.78	6.35	1.2	0.001	0.026	14.91	0.005	0.077	0.051	7			

APPENDIX E

UFI REPORT - PARTICLE SIZE DISTRIBUTIONS OF THE METRO EFFLUENT: RESULTS FROM HRFS MIXER PILOT TESTING

Particle Size Distributions of the Metro Effluent: Results from HRFS Mixer Pilot Testing

A data report prepared by the Upstate Freshwater Institute for Anchor-QEA, Conestoga-Rovers & Associates and Onondaga County

January 9, 2013

Metro Optimization: HRFS Mixer Pilot Testing — Particle Size Distribution (PSD) Results

- Six samples of the Metro effluent (three each from Train 2 and Train 3) were collected in October 2012 and again in November 2012 and sized by scanning electron microscopy interfaced with automated image and X-ray analyses (SAX)
- Results are presented in terms of particle size distribution (PSD) density function and contributions by different size classes to total particle area concentration (i.e., total particle projected area per unit volume of water, PAV)
- a brief summary of the results:
  a. Fig. 1: the general PSD patterns are similar (e.g., peak size ~0.5 μm, right-skewed, long tail); particle concentrations of the Oct. 9 samples were significantly higher than those of all other samples; on average, there were more large particles (>5 μm) in the November samples, especially from Train 3
  b. Fig. 2: particles in the size range of 10–40 μm made the largest contributions to PAV (related to total particle surface area and mass concentration)
  c. Fig. 3: size distribution patterns of cumulative PAV indicate the quartile sizes (μm) for the four average conditions were as follows:

	*Q*1	Q2	*Q*3
Oct. Train 2	6.47	17.53	30.36
Oct. Train 3	8.10	21.81	37.59
Nov. Train 2	9.07	16.81	27.45
Nov. Train 3	12.05	20.0	30.15

Contribution (%) to PAV by particles in different size classes:

	<1	1–5	5–10	10–40	>40 μm
Oct. Train 2	1.5	19.0	13.5	52.7	13.3
Oct. Train 3	1.1	15.3	12.7	48.3	22.6
Nov. Train 2	0.8	11.7	15.3	63.6	8.6
Nov. Train 3	0.3	6.3	12.3	71.7	9.4

These results show that PSDs of the November samples from both trains shifted towards larger sizes, especially in Train 3. For the November samples, particles in the size range of 10–40 μm contributed most significantly to total PAV. In addition, PAVs were 2-4 times higher for November samples than those for October samples. PAV in Train 3 was more than two-fold higher than that in Train 2 for the November samples, whereas the magnitudes of PAV in the two trains were similar for the October samples.

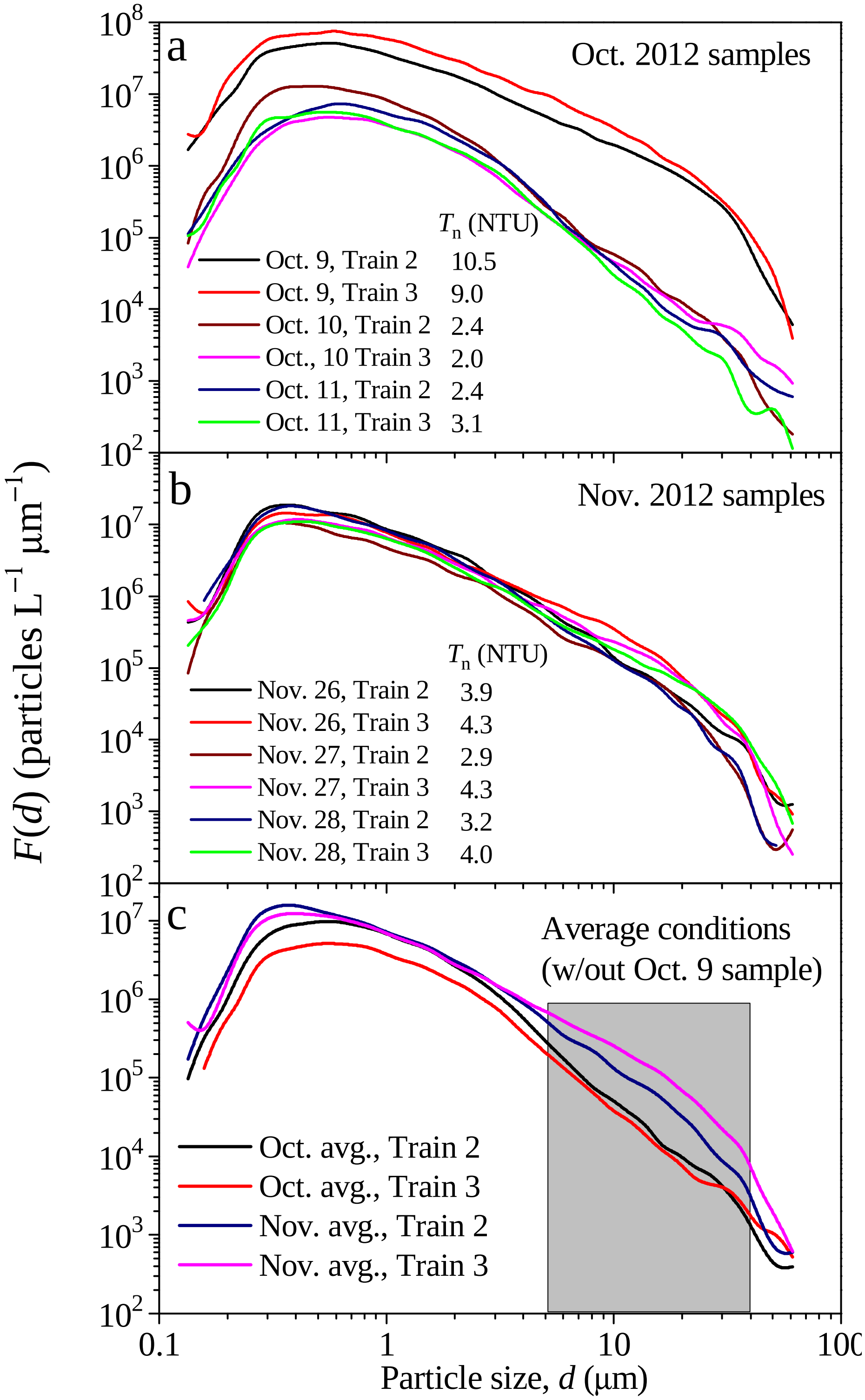


Fig. 1. Particle size distributions (PSD, in density function) of Metro samples collected in October and November: (a) October samples, (b) November samples, and (c) average conditions of October (without Oct. 9 samples) and November samples; the shaded area indicates the size range (5–40 µm) for which differences in PSD would result in significant implications for size distribution patterns of PAV. Turbidity (T_n) of each sample is listed in (a) and (b).

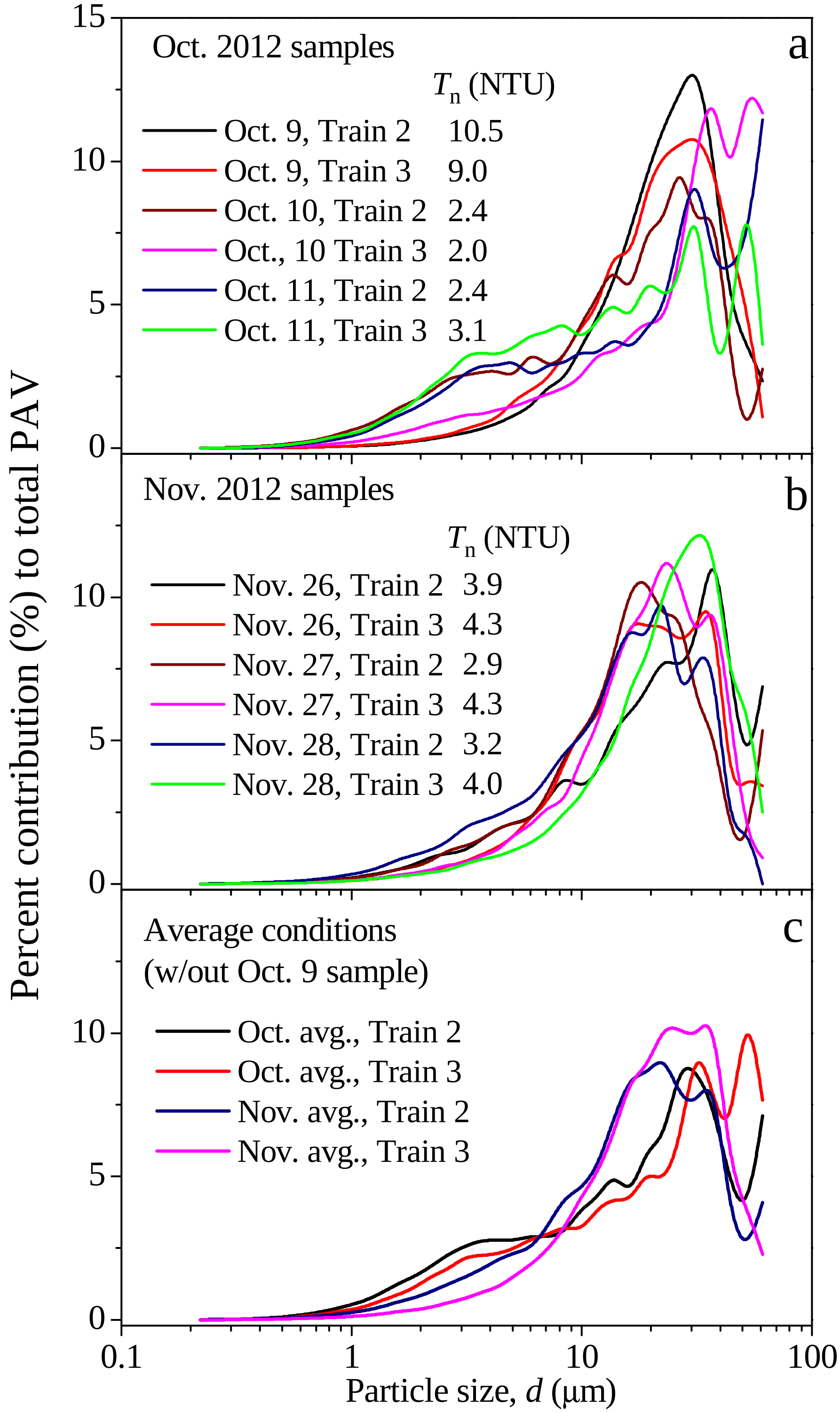


Fig. 2. Same as in Fig. 1, except for relative contributions of particle size classes to PAV, the total particle projected area per unit volume of water.

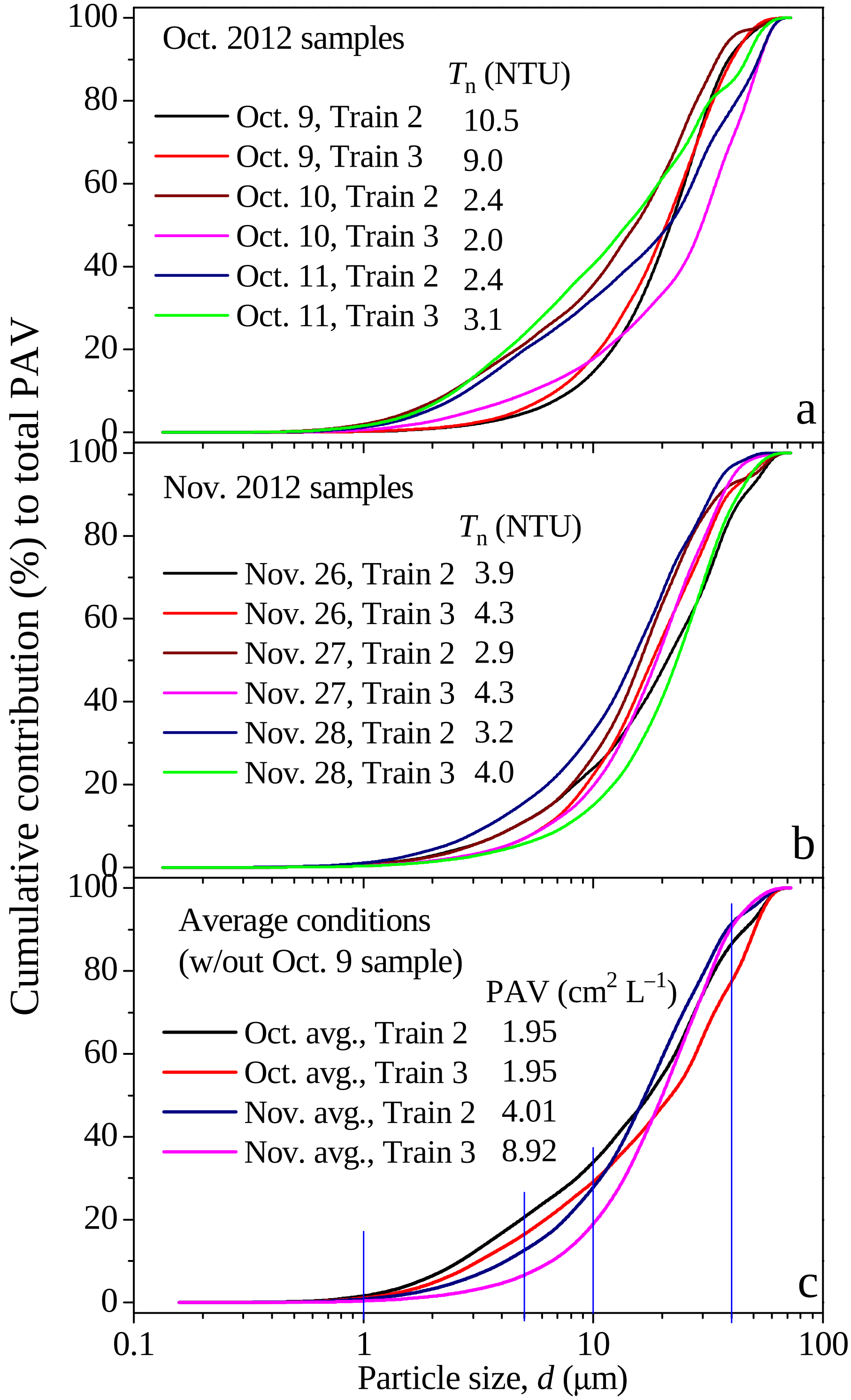


Fig. 3. Same as in Fig. 1, except for contributions of particle size classes to cumulative PAV. In addition, PAV results are listed in (c), and the vertical lines represent demarcations of particle sizes at 1, 5, 10, and 40 μm.

APPENDIX F

SUMMARY BREAKDOWN OF PRELIMINARY CAPITAL COST ESTIMATE FOR RECOMMENDED IMPROVEMENTS

UPDATED CONSTRUCTION COST ESTIMATE

(2016 Dollars)

Onondaga County Department of Water Environment Protection

Metropolitan Syracuse WWTP Optimization Analysis of Total Phosphorus

Project N0. 630742

RECOMMENDED METRO WWTP OPTIMIZATION IMPROVEMENTS - COST ESTIMATE

Description	Quantity	Units	Materials Unit Cost	Materials Total	Labor Unit Cost	Labor Total	Total Cost
Coagulant Feed System Modifications							
HRFS Influent Upward Acting Weir Gates	4	EA	40,000	160,000	15,000	60,000	220,000
HRFS Drop Box Baffles	4	EA	12,000	48,000	12,000	48,000	96,000
Effluent Launder Flow Meters	4	EA	12,000	48,000	6,000	24,000	72,000
Replace Ferric Chloride Feed System	6	EA	40,000	240,000	20,000	120,000	360,000
Install PAC Feed System (Pumps and Piping)	6	EA	40,000	240,000	20,000	120,000	360,000
Miscellaneous Shutdown/Bypassing Provisions	1	LS	400,000	400,000	400,000	400,000	800,000
SCADA Modifications	1	LS	70,000	70,000	140,000	140,000	210,000
Cross Channel Modifications							
Cross Channel Isolation Gates	4	EA	45,000	180,000	24,000	96,000	276,000
Isolation Gate Access Platform	2,500	SF	120	300,000	50	125,000	425,000
Cross Channel Concrete Wall Construction	60	CY	880	52,800			52,800
Concrete Cross Channel Liner Rehabilitation	32,000	SF	6	192,000	6	192,000	384,000
HRFS Chemical Mixing Modifications							
Reverse Rotation of Train 1 Coag Mixer	1	EA	104,000	104,000	26,000	26,000	130,000
Reverse Rotation of Train 1 Injection Mixer	1	EA	104,000	104,000	26,000	26,000	130,000
Modify Train 2& 4 Coag Mixers	2	EA	65,000	130,000	23,000	46,000	176,000
Modify Train 2 & 4 Inj Tank Mixers	2	EA	65,000	130,000	23,000	46,000	176,000
Other Modifications							
Sludge Pump Upgrades (VFD and Motor)	4	EA	18,000	72,000	5,000	20,000	92,000
Sand Slurry Tank Rehabilitation	1	LS	18,000	18,000	18,000	18,000	36,000
Replace RAS Lines Corroded by Ferric Chloride	2	EA	300,000	600,000	150,000	300,000	900,000
Effluent Pump Suction Piping and Pump Replacement	1	LS	64,000	64,000	32,000	32,000	96,000
HRFS By-Pass Gate Repairs	1	LS	60,000	60,000	60,000	60,000	120,000
Stamford Baflles in HRFS Clarifiers	4	EA	35,000	140,000	15,000	60,000	200,000
Replace Parshall Flume Louvers with FRP	3	LS	15,000	45,000	10,000	30,000	75,000
Install Catwalk over Parshall Flume/Effluent Channel	1	LS	36,000	36,000	18,000	18,000	54,000
Repair Concrete and Brick/Block Wall	1	LS	10,000	10,000	24,000	24,000	34,000
Replace Stainless Steel Sludge Line	1	LS	400,000	400,000	200,000	200,000	600,000
Electrical and Instrumentation	20%	of sum of all modifications					1,215,000
Subtotal							***7,289,800***
Mobilization, Bonding, Insurance, Etc.	8%						584,000
Contractor Profit	20%						1,458,000
Contingency and Allowances	25%						1,823,000
Construction Subtotal							***11,155,000***
Engineering, Consulting & Legal Fees	20%						2,231,000
Total (2011 Dollars)							***13,386,000***
					ESTIMATE (2016 Dollars - Rounded)		**14,628,000**

Alternative 7: Seasonal Use of PAC and Ferrice Chloride Option B

Alternative 7 involves seasonal use of PAC and ferric chloride. Both coagulants would be added via a diffuser above the HRFS influent box. Baffles would be constructed within each influent box to promote initial mixing. Coagulant feed would be flow paced based on flow measured by meters located in the HRFS effluent launders. The existing ferric chloride feed system (pumps, piping, and valves and diffuser) would be replaced with a focus on reduced maintenance to the extent possible. In addition, a new PAC feed system would be provided.