Ultra-Low Phosphorus Removal Pilot Study

City of Mankato, Minnesota

June 15, 2016

Bolton & Menk, Inc. Project No. M24.109541

Prepared by:

Submitted by:
City of Mankato
in conjunction with
Bolton & Menk, Inc.
and
Minnesota State University Mankato

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I hereby certify that this plan, specification or report was prepared by me or under my direct supervision, and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Signature: ____________ Typed or Printed Name: Kristopher J. Swanson, P.E.

Date: June 15, 2016 Lic. No. 42626

Additional contributions by:

Signature: ____________ Typed or Printed Name: Stephen Druschel, Ph.D., MNSU

Signature: ____________ Typed or Printed Name: Josh Gad, City of Mankato

Signature: ____________ Typed or Printed Name: Jim Archer, City of Mankato

BOLTON & MENK, INC.
CONSULTING ENGINEERS AND LAND SURVEYORS

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PROJECT SUMMARY

This report evaluates the technological capacity and financial practicality of achieving ultra-low phosphorus removal at the City of Mankato's Wastewater Treatment and Reclamation Facilities. The experimental procedure included the use of the City of Mankato's full-scale treatment system, as well as various pilot-scale ultrafiltration membrane technologies for tertiary removal of phosphorus from the City's wastewater. The results and conclusions of this study provide technological information regarding phosphorus removal and its role in future permitting and regulatory decisions in the State of Minnesota. This report was written in collaboration with the City of Mankato, Minnesota State University – Mankato, and Bolton & Menk, Inc. The overall study was funded by the Minnesota Pollution Control Agency under the Emerging Contaminants Wastewater Initiative grant program.

The City of Mankato owns and operates a conventional activated sludge wastewater treatment facility that treats wastewater from the communities of Mankato, North Mankato, Eagle Lake, Madison Lake, South Bend Township, Skyline, and the Lake Washington Sanitary Sewer District – a total service population of approximately 60,000 residents and 16 significant industrial users (SIUs). The secondary treated wastewater effluent receives further treatment at the City's Water Reclamation Facility (WRF). This facility utilizes the Kruger Acti-Flo® process and Disc-Filtration to produce reclaimed water appropriate for industrial non-contact cooling water at the Calpine – Mankato Energy Center (MEC), as well as non-potable utility water at the treatment facility and irrigation water for green spaces such as Riverfront Park. The non-evaporated portion of MEC's cooling water is returned to the City's treatment system, where it is blended with non-utilized reclaimed water, disinfected, and then discharged to the Minnesota River under NPDES Permit No. MN0030171. The City's existing permit is in the process of being re-issued, which may include more stringent discharge limits for phosphorus in accordance with newly adopted River Eutrophication Standards (RES).

The City of Mankato's Wastewater Treatment and Reclamation Facilities are well equipped to remove phosphorus, having full-scale infrastructure in place that provides flexibility to remove phosphorus at various points in the treatment process through the addition of ferric chloride. Space availability in the Water Reclamation Facility also make it ideal for piloting various tertiary filtration technologies in addition to the City's existing full-scale infrastructure. Based on these potentials, the scope of the experimental analysis for this study was determined to include the following:

1) Ferric Chloride Feed Application Analysis
2) Comparison of Tertiary Treatment Methods
3) Evaluation of Ultra-Low Phosphorus Removal

Based on this scope, the proposal submitted to and accepted by the Minnesota Pollution Control Agency included a list of measurable outcomes that were to be evaluated in the results and conclusions of the study. These measureable outcomes are evaluated one-by-one in the following paragraphs, supported by the data and cost analyses conducted in Sections 5 and 6 of the report. Figure PS.1 presents an overview of the overall process flow schematic, including the various ferric chloride feed locations and sampling locations utilized in the experimental analysis.

Measurable Outcomes

1) Pounds of phosphorus removed with ultrafiltration membranes and concentrations achieved.

a. Results at normal ferric chloride dosages

Table PS.1 and Figure PS.2 summarize phosphorus concentration and removal efficiencies for each full-scale and pilot scale unit process over the duration of the study. These results are indicative of the overall performance of the treatment technologies under normal full-scale operating conditions and ferric chloride dosages. Removal efficiencies are presented in percentages for both cumulative phosphorus removal and removal of total phosphorus in each individual unit process. In order to determine pounds of phosphorus removed, the removal efficiencies can be multiplied by the average influent phosphorus loading of 268 lbs. TP/day.

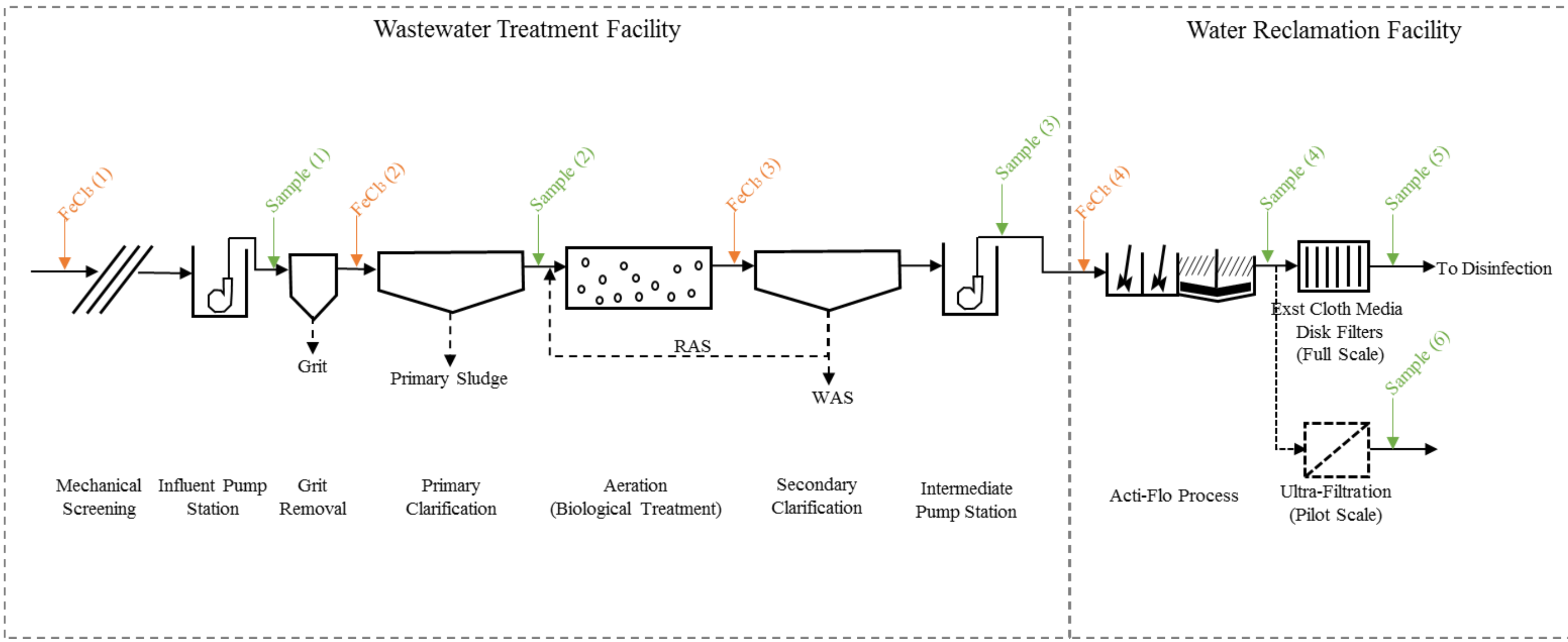

Figure PS.1 – Process Flow Schematic

TABLE PS.1
Ultra-Low Phosphorus Removal Results – Normal Operating Conditions

Sample Location	Sample Population (n)	TP Conc. (mg/L)			95% Confidence Lower Limit (mg/L)	95% Confidence Upper Limit (mg/L)	Cumulative % TP Removal	Average % Removal in Unit Process
		Minimum	Maximum	Average				
Wastewater Treatment Facility								
Influent	71	0.79	9.88	4.09	3.66	4.51	0.0%	0
Primary Effluent	66	0.59	5.24	2.67	2.40	2.93	34.8%	34.8%
Secondary Effluent	74	0.08	1.74	0.97	0.87	1.07	76.3%	41.5%
Water Reclamation Facility								
Acti-Flo Process	70	0.03	0.48	0.17	0.15	0.20	95.8%	19.5%
Disc-Filtration (10 µm)	70	0.02	0.56	0.17	0.14	0.20	95.9%	0.1%
Pilot-Scale Membranes								
Inge (0.02 µm)	46	0.01	0.50	0.12	0.09	0.14	97.1%	1.2%
Toray (0.01 µm)	51	0.03	0.32	0.11	0.09	0.13	97.2%	1.4%
DOW (0.03 µm)	33	0.00	0.56	0.13	0.10	0.17	96.8%	0.9%
Meiden Ceramic Filter (0.1 µm)	35	0.00	0.08	0.02	0.02	0.03	99.4%	3.6%

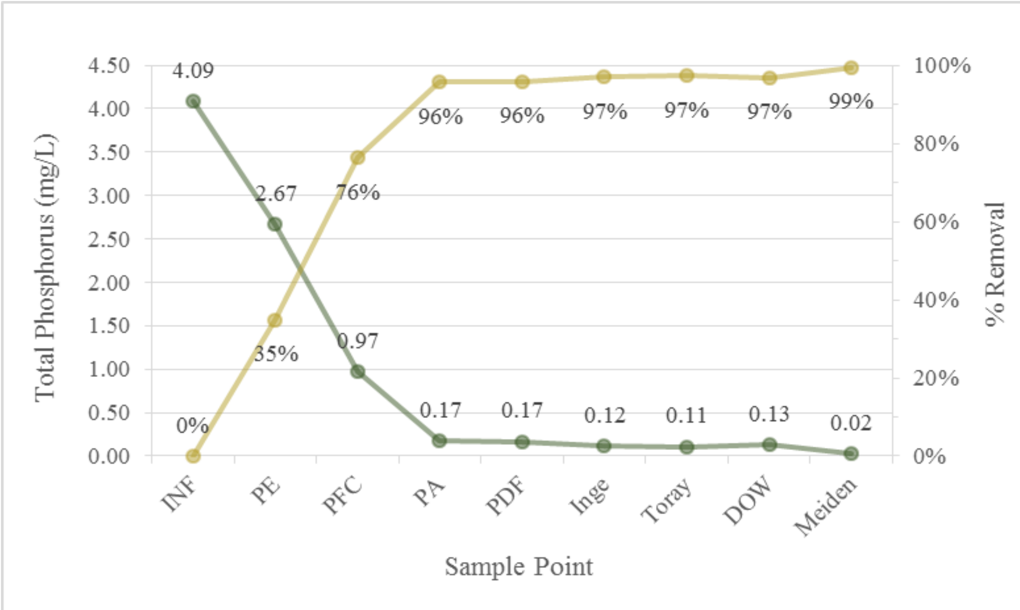

Figure PS.2 – Ultra-Low Phosphorus Removal Results – Normal Operating Conditions

Observations of phosphorus removal in the full-scale wastewater treatment facility:

- On average, 34.8% of the total influent phosphorus was removed in the Primary Clarifiers, while 41.5% of the total influent phosphorus was removed in the secondary treatment process (conventional activated sludge process with Secondary Clarification).

- On average, 76.3% of the total influent phosphorus was removed at the City's wastewater treatment facility, with an average secondary effluent concentration of 0.97 mg/L TP. This effluent phosphorus concentration is within the typical range for facilities that utilize chemical addition for phosphorus removal, and would be enhanced with higher dosages of ferric chloride.

Observations of phosphorus removal in the full-scale tertiary treatment system:

- At normal ferric chloride dosages to the tertiary treatment system (~20 mg/L as $FeCl_3$), the full-scale Acti-Flo® and Disc-Filtration system produced an average effluent total phosphorus concentration of 0.17 mg/L. This is on the low-end range of what the City typically achieves out of the system.

- On average, nearly 20% of the total influent phosphorus is removed in the existing full-scale tertiary treatment system, with a cumulative total of 96% removal after the processes.

- The Disc-Filtration units achieved virtually zero removal of phosphorus after the Acti-Flo® process.

- Ultra-low phosphorus removal ($\leq$ 0.1 mg/L TP) is not achieved in this system at typical operating dosages of ferric chloride (20-25 mg/L as $FeCl_3$)

- Minimum phosphorus concentration measurements indicate that the system may be able to consistently achieve ultra-low phosphorus removal under optimized operating conditions (i.e. chemical feed adjustments). "Optimized" chemical feed adjustments would include higher ferric chloride dosages and potential improvements to the polymer and microsand feed/recirculation in the Acti-Flo® system.

Observations of phosphorus removal in the pilot-scale ultrafiltration membranes supplied by Wigen Water Technologies:

- On average, the membranes produced filtrate phosphorus concentrations in the range of 0.11 – 0.13 mg/L TP, or an additional 0.9 – 1.4% total phosphorus removal after the full-scale tertiary system. Overall performance was not significantly different between the three ultrafiltration membranes.

- The pilot skid had issues treating the Acti-Flo® effluent water due to residual microsand clogging the cartridge pre-filters. The issue was resolved by switching the feed water to post-Disc Filtration. Since the Disc-Filters removed virtually zero phosphorus, switching feed points likely did not improve phosphorus removal at the ultrafiltration membranes. However, this does give insight into potential full-scale pre-treatment needs if ultrafiltration was implemented.

- All three ultrafiltration membranes produced filtrate with 0.1 mg/L TP within their 95% confidence interval of the true operating mean. Minimum TP testing values indicate that the membrane units could achieve much better and consistent performance under optimized operating conditions (i.e. chemical feed adjustments) than what was achieved with the pilot unit. "Optimized" chemical feed adjustments would likely include higher ferric chloride dosages and better use of clean-in-place chemicals to maintain consistent performance.

Observations of phosphorus removal in the bench-scale ceramic membrane supplied by Meiden America, Inc.:

- On average, the unit produced an average filtrate TP concentration of 0.02 mg/L, or an additional 3.6% removal compared to the full-scale tertiary system. Filtrate phosphorus concentrations remained consistent when switching between Acti-Flo® effluent and Secondary effluent feed water.

- The unit was maintenance intensive, requiring daily chemical soaking of the membrane modules in order to maintain flux rates. Light hand cleaning was also needed to remove staining on the membrane surface. Overall, fouling was a major issue with this bench-scale unit. Operation could not be sustained for much longer than 24 hours at the proposed flux rates.

- In terms of full-scale application, this submerged membrane process would require a larger footprint compared to a skid-mounted ultrafiltration membrane system. Significant improvements in fouling control would need to happen for it be viable for tertiary wastewater treatment. These considerations have implications on capital, operation, and maintenance costs.

- From strictly a phosphorus removal standpoint, the ceramic flat-sheet membrane performed excellent.

b. Results of increasing dosages of ferric chloride at the tertiary treatment processes (“Stress Test”)

Table PS.2 summarizes the phosphorus removal results for each full-scale and pilot-scale tertiary treatment process at increasing ferric chloride dosages over a three hour period, which was labeled the “stress test.” The purpose of this analysis was to determine the maximum capacity of the processes to remove phosphorus.

Observations of phosphorus removal for the "stress test" include the following:

- As expected, higher dosages of ferric chloride drastically improved phosphorus removal at all stages of tertiary treatment. pH of the finished water was not affected by the higher dosages, likely due to the presence of sufficient alkalinity to neutralize the production of free protons (H^+) from the reaction of ferric chloride and water.

- A dosage of 35 mg/L (as $FeCl_3$) reduced phosphorus below 0.1 mg/L at nearly all tertiary treatment processes, including Acti-Flo®. At this dosage, the City could potentially achieve ≤ 0.1 mg/L TP on a consistent basis using their existing tertiary treatment system. However, daily chemical usage would increase by approximately 75%.

- It appears the City's full-scale tertiary treatment system can reduce phosphorus concentrations below the experimental detection limit of 0.04 mg/L TP. This detection limit was determined in the Precision and Calibration Evaluation presented in Appendix D of the report.

- On average, the pilot-scale ultrafiltration modules removed 35% of the remaining phosphorus after the Acti-Flo® system. However, at high doses (35-75 mg/L), additional phosphorus was not significantly removed beyond the Acti-Flo® system.

- Graphical models of the experimental testing data were best fit by a power function, which follows the general theoretical dosage curve for phosphorus removal using ferric chloride. In other words, ferric chloride dosages increase exponentially in order to achieve lower and lower effluent phosphorus concentrations, theoretically never reaching zero.

TABLE PS.2 Ultra-Low Phosphorus Removal - Stress Test Results					
$FeCl_3$ Dose (mg/L as $FeCl_3$)	**Total Phosphorus (mg/L)**				
	Post Acti-Flo® (PA)	**Post Disc-Filter (PDF)**	**Inge (UF1)**	**Toray (UF2)**	**DOW (UF3)**
21	0.30	0.34	0.23	0.18	0.74
21	0.38	0.36	0.25	0.19	0.45
25	0.36	0.40	0.21	0.20	0.35
25	0.40	0.21	0.18	0.20	0.34
30	0.25	0.23	0.14	0.11	0.29
30	0.10	0.13	0.11	0.18	0.25
35	0.08	0.05	0.05	0.08	0.13
35	0.04	0.05	0.06	0.04	0.21
50	0.03	0.06	0.05	0.05	0.11
50	0.03	0.03	0.05	0.04	0.15
75	0.05	0.04	0.05	0.03	0.11
75	0.08	0.03	0.05	0.03	0.19
Averages at Specified Dosage Range					
Overall	0.17	0.16	0.12	0.11	0.28
21-30 mg/L	0.30	0.28	0.19	0.18	0.40
35-75 mg/L	0.05	0.04	0.05	0.04	0.15

2) Cost per pound of phosphorus removed using various tertiary filtration technologies

Table PS.3 summarizes incremental costs of phosphorus removal based on the testing results of the full-scale and pilot-scale treatment technologies and associated capital, operation, and maintenance cost estimates. The incremental costs assume a mechanical treatment process is already in place that is adaptable for chemical phosphorus removal and tertiary treatment. The costs do not include considerations for biosolids processing related to the additional sludge produced from chemical phosphorus removal.

Observations of the incremental cost analysis:

- The incremental cost of reducing phosphorus to ultra-low concentrations increases exponentially. This is because a majority of the phosphorus can be removed relatively cheaply in a conventional wastewater system with the addition of metal salts for chemical precipitation. Additionally, most mechanical treatment facilities with clarification processes can be easily adapted for chemical phosphorus removal. Incremental phosphorus removal beyond the technological capacity of metal salt addition requires expense treatment infrastructure that only removes a small portion of the phosphorus, thus, resulting in high incremental costs per lbs. TP removed.

- Achieving effluent phosphorus concentrations of 1 mg/L is relatively cost effective at an estimates $1.50/lbs. phosphorus removed.
- Ultra-low phosphorus removal using tertiary treatment infrastructure may range between $50-100/lbs. phosphorus removed, depending on the magnitude of phosphorus removed.
- Unit costs ($/lbs. TP removed) would decrease at larger facilities with the advantages of economies of scale, and vice-versa at smaller facilities. Costs will also vary based on the strength of raw wastewater treated and NPDES discharge permit requirements, which drive the design and infrastructure requirements in a treatment system.

TABLE ES.3

Incremental Cost Analysis of Phosphorus Removal - City of Mankato

Parameter	Unit	Influent	Treatment Processes				
			Secondary Effluent (Chemical Feed)	Acti-Flo®	Acti-Flo® + Disc-Filtration	Acti-Flo® + Ultrafiltration	Meiden Ceramic Membrane
TP Concentration	mg/L	4.09	0.97	0.17	0.17	0.11	0.02
% TP Removal	%	0.0%	76.3%	95.8%	95.9%	97.3%	99.5%
Process Effluent	lbs/day TP	320	76	14	13	9	2
Process Removal	lbs/day TP	0	244.1	62.3	62.7	67.3	74.3
Capital Cost Analysis							
Capital/Replacement Cost	$	--	$340,000	$10,390,000	$13,575,000	$20,755,000	$31,646,000
Annualized Cost (20 yrs @ 3%)	$/yr.	--	$23,000	$698,000	$912,000	$1,395,000	$2,127,000
Capital $ / gpd		--	$0.03	$0.92	$1.21	$1.84	$2.81
$ / lbs. TP Removed		--	$0.26	$30.67	$39.88	$56.81	$78.41
O&M Cost Analysis							
Average $FeCl_3$ Dose	mg/L as $FeCl_3$	--	12	22	22	22	22
Average $FeCl_3$ Usage	gpd	--	226	414	414	414	414
$FeCl_3$ Annual Cost ($1.05/gal)	$/yr.	--	$86,000	$159,000	$159,000	$159,000	$159,000
Electrical Costs	$/yr.	--	$2,000	$120,000	$170,000	$265,000	$265,000
CIP Chemical Costs	$/yr.	--	--	--	--	$12,000	$12,000
Polymer (0.6 mg/L dose)	$/yr.		--	$25,000	$25,000	$25,000	$25,000
Budgeted Replacement Costs	$/yr.	--	$22,667	$100,000	$150,000	$230,000	$250,000
Total Annual O&M Cost		--	$110,667	$404,000	$504,000	$691,000	$711,000
$ / lbs. TP Removed		--	$1.24	$17.75	$22.04	$28.14	$26.21
Total Estimated Annual Costs			133,667	1,102,000	1,416,000	2,086,000	2,838,000
Total $/lb TP Removal			$1.50	$48.43	$61.92	$84.95	$104.62

3) Benefits of ultrafiltration membranes versus the City's existing Disc-Filtration units for ultra-low phosphorus removal on a consistent, reliable basis in order to meet an NPDES permit requirement.

Based on the testing results summarized in Tables PS.1 and PS.2, the City's existing Disc-Filtration units achieved virtually zero phosphorus removal after the Acti-Flo® system. The only apparent benefit of the Disc-Filters is the removal of residual microsand that escapes the Acti-Flo® process. In comparison, the ultrafiltration units removed 35% of phosphorus that left the Acti-Flo® process under normal operating conditions, although this only accounted for an additional 1.4% of total influent phosphorus removed.

In general, the Acti-Flo® process was found to be highly effective for removal of phosphorus after the secondary wastewater treatment process. Based on the stress test results in Table PS.2, the City could achieve ultra-low phosphorus removal with their existing full-scale system under increased dosages of ferric chloride. If the City is subject to lower limits on effluent phosphorus in future NPDES permits, it is recommended that the City work with Kruger, Inc. to optimize the Acti-Flo® system before considering other options such as ultrafiltration.

Overall, the effectiveness of the Acti-Flo® system presented an experimental limitation by limiting the phosphorus removal potential of the tertiary filtration units. Space limitations of the full-scale setup did not allow the ultrafiltration membranes to directly filter secondary effluent, therefore, the pilot systems had to be installed downstream of the Acti-Flo® system. Shutdown of the Acti-Flo® system was not an option as the City needed to maintain discharge permit limits.

4) Test results included in the final report

Refer to the final report for a full description of testing procedures, results, and discussion.

5) Pounds of phosphorus removed with varying chemical feed points.

Table PS.4 summarizes the overall results of the ferric chloride feed point analysis. Four feed scenarios were testing within the duration of the daily phosphorus sampling conducted by Minnesota State University – Mankato. The feed points correspond to the locations shown in Figure PS.1.
The following bullet points highlight observations of the results:

- On average, all feed scenarios achieved at least 73% removal of influent phosphorus at the Secondary Clarifier effluent.

- The multi-point feed scenarios (5 and 6) produced higher removal compared to both single-point feed scenarios (2 and 3).

- Overall, Scenario 6 (triple-point feed) achieved the highest removal of 91.5% of influent phosphorus, on average; however, this feed scenario was also mistakenly dosed with the highest amount of chemical to the system. When going from two to three feed points, the dosage per feed point was maintained instead of being distributed. Thus, the overall dosage to the system was increased.

- Scenario 5 (multi-point feed to Primary and Secondary Clarifier influent) was approximately 5% more efficient than single-point feed to either clarifier at comparable dosages.

TABLE PS.4
Overall Results of Ferric Chloride Feed Point Analysis

Feed Scenario	Feed Points	Total Phosphorus (lbs/day)		% Removal	$FeCl_3$ Dose (mg/L as $FeCl_3$)	
		Influent	Secondary Effluent		Overall System	Per Feed Point
2	$FeCl_3$(2)	273	72 (1.17 mg/L)	73.6%	12	12
3	$FeCl_3$(3)	271	73 (1.19 mg/L)	73.1%	14.4	14.4
5	$FeCl_3$(2); $FeCl_3$(3)	243	52 (0.64 mg/L)	78.6%	14.8	7.4
6	$FeCl_3$(1); $FeCl_3$(2); $FeCl_3$(3)	388	33 (0.47 mg/L)	91.5%	23.1	8

6) Determine if chemical feed modifications can help achieve ultra-low phosphorus removal.

This measurable outcome can be addressed in two ways: 1) chemical feed modifications at the City's wastewater treatment facility and 2) chemical feed modifications at the City's tertiary treatment facility.

Based on the results in Table PS.4, the various chemical feed scenarios did *not* achieve ultra-low phosphorus removal (≤ 0.1 mg/L) in the secondary effluent at the wastewater treatment facility. Without tertiary polishing, the addition of ferric chloride alone is not enough to achieve ultra-low phosphorus removal in a secondary treatment process. A minimum average concentration of 0.47 mg/L TP was achieved in Feed Scenario 6, which also corresponded to the highest chemical dosage.

Based on the results in Table PS.2 (columns 2 and 3), increasing ferric chloride dosage to 35 mg/L (as $FeCl_3$) and beyond did achieve ultra-low phosphorus removal (≤ 0.1 mg/L) in the City's existing full-scale tertiary treatment system. Therefore, it appears the City could achieve ultra-low phosphorus removal on a consistent, reliable basis if they increased ferric chloride dosage by approximately 75%. This increase in dosage also had no effect on effluent pH over the 3 hour testing period.

7) Discussion of general cost analysis and its transferability to other communities

Table PS.5 presents general costs of phosphorus removal at various levels of treatment. The costs are presented as annual costs per 1,000 gallons of wastewater treated, and are presented in ranges to reflect variability in treatment schemes and technologies, as well as the effects of economies of scale for varying sized facilities. The annual costs consider capital, operation, and maintenance costs to upgrade a mechanical activated sludge treatment facility to achieve the effluent phosphorus concentrations shown. Capital costs include associated building costs, site work, and all other items contingent to the treatment process. Cost do not include considerations for additional biosolids processing related to increased sludge production from chemical phosphorus removal.

TABLE PS.5
General Cost Analysis of Phosphorus Removal

Effluent TP Conc. (mg/L)	Annual Costs ($/1,000 gallons)(2)
1.0	$0.04 - $0.25
0.5	$0.30 - $0.75
0.1	$0.60 - $1.00(1)
0.06	$0.80 - $2.00(1)

(1) For smaller communities less than 15,000 people, the costs could be significantly higher than the ranges calculated from the pilot study
(2) Sample calculation: $0.32/1,000 gal x (9,380,000 gpd x 365 days/yr) = $1,100,000/yr

The intent of these costs is to give communities and regulatory agencies a preliminary estimate of the funding needed to upgrade a mechanical treatment facility (with effluent comparable to the activated sludge process) to produce the effluent phosphorus concentrations shown. These costs should be used strictly as guidance in the decision-making process. If used to estimate costs beyond 2016 construction, the unit costs should be updated using general construction cost indices or other applicable inflation rates. Additional conditions are described in the following paragraphs.

These costs ranges were developed from the incremental cost analysis presented in Table PS.3 and are based on the City of Mankato's full-scale liquid-stream treatment processes and associated incremental capacity to remove phosphorus. Effluent phosphorus removals ≤ 0.1 mg/L TP are based on the performance of side-stream pilot-scale technologies and their associated full-scale cost estimates.

In terms of transferability to other communities and treatment schemes, lower range costs ($/1,000 gal treated) at each respective phosphorus concentration should be used for larger communities (≥ 50,000 service population) where the advantages of economies of scale is a factor. Higher range costs are applicable to smaller communities where economies of scale is not a factor. Treatment systems have a high degree of variability in infrastructure and equipment, but the designs and associated costs are largely dependent on influent wastewater characteristics and discharge permit requirements. Therefore, systems that treat high-strength wastewater ($\geq$ 10 mg/L TP) should use higher cost ranges, while systems treating low-strength wastewater ($\leq$ 4 mg/L TP) should use lower ranges.

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SECTION 1 INTRODUCTION

A. PROJECT BACKGROUND

In 2014, the Minnesota Pollution Control Agency (MPCA) announced an Emerging Contaminants Wastewater Initiative with a Request for Proposals for Wastewater Treatment Plant (WWTP) Pilot Projects. The pilot project program was designed to generate practical, transferrable strategies for implementing water quality standards and/or reducing emerging contaminants in wastewater effluent. The pilot project program was developed to target chloride, phosphorus, nitrogen, sulfate, endocrine active compounds, parameters associated with pharmaceuticals or personal care products, and other unregulated chemical of emerging concern. The following report evaluates the technological capacity and practicality of achieving ultra-low phosphorus removal at the City of Mankato's Wastewater Treatment and Reclamation Facilities.

The City of Mankato's treatment facilities are well equipped to remove phosphorus, having infrastructure in place for both multi-point chemical precipitation and tertiary phosphorus removal at their Wastewater Reclamation Facility. Space availability in the Water Reclamation Facility also make it ideal for piloting various tertiary filtration technologies in addition to the City's existing full-scale infrastructure. This presents a unique opportunity to evaluate phosphorus removal at various levels of treatment. Through full-scale and pilot-scale operations and testing, the technological capacity of ultra-low phosphorus removal can be evaluated relative to current or proposed water quality standards. The financial practicality of ultra-low phosphorus removal can be evaluated by estimating the incremental cost of phosphorus removal at each level of treatment.

B. PHOSPHORUS STANDARDS AND EFFLUENT LIMITS

In 1972, the United States Environmental Protection Agency (EPA) amended the Federal Water Pollution Control Act (i.e. Clean Water Act) to regulate water quality standards and pollutant discharges from all point-source wastewater contributors through the creation of the National Pollutant Discharge Elimination System (NPDES) permit program. This law required all publicly-owned treatment works (POTW's) to comply with discharge regulations developed from both technological and water quality-based effluent limits (WQBELs). In the State of Minnesota, the NPDES permit program is administered by the Minnesota Pollution Control Agency (MPCA). Over the years, discharge regulations have become increasingly stringent as the MPCA is enforcing new WQBELs over the technological limitations of POTWs pre-existing treatment infrastructure.

In particular, the removal of phosphorus in accordance with Lake Eutrophication Standards (LES) and newly adopted River Eutrophication Standards (RES) are forcing POTWs to upgrade their treatment infrastructure to meet more stringent limits on phosphorus discharge. These eutrophication standards were implemented as part of improved Water Quality Standards (WQSs) as required by the Clean Water Act. WQSs are designed to be protective of the beneficial uses of groundwater and surface waters. In surface waters, protection encompasses normal growth and reproduction of aquatic populations, human recreational uses, consumption of aquatic biota, and sources of drinking water.

C. PURPOSE

The purpose of this study is to evaluate the technological capacity and practicality of achieving ultra-low phosphorus removal at the City of Mankato's Wastewater Treatment and Reclamation Facilities. The experimental procedure includes the use of the City of Mankato's full-scale treatment system, as well as various pilot-scale ultrafiltration membrane technologies for tertiary treatment. This study also includes the evaluation of multi-point ferric chloride feed application for the purpose of optimizing phosphorus removal efficiency and minimizing chemical usage at the City's treatment facility.

The results and conclusions of this study provide additional technological information regarding phosphorus removal and its role in future permitting and regulatory decisions in the State of Minnesota. This study is funded by the Minnesota Pollution Control Agency under the Emerging Contaminants Wastewater Initiative grant program.

D. REPORT ORGANIZATION

This report is structured into six sections to adequately address the various aspects of the study. Section 1 is this Introduction; Section 2 provides a review of literature related to phosphorus removal in wastewater treatment systems; Section 3 provides an overview of the City of Mankato's existing treatment system; Section 4 discusses the experimental plan and procedures used to analyze the objectives of the study; Section 5 presents the pilot study results; and Section 6 provides conclusions and cost considerations for achieving ultra-low phosphorus removal.

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SECTION 2 LITERATURE REVIEW

A. PRINCIPALS OF PHOSPHORUS TREATMENT

There are commonly understood principals of phosphorus treatment well described in wastewater treatment textbook references, two of such being Tchobanoglous, et al. (known as Metcalf & Eddy) (2003) and Davis and Cornwell (2012). Their principals of phosphorus treatment summarized here:

1. Phosphorus in dissolved or colloidal forms will not be removed by gravity settling, but can be removed by the colloidal removal process of coagulation and flocculation, described in the wastewater treatment literature since the 1880s.
2. Negatively charged particles that can be too small for removal by primary or secondary wastewater treatment processes can be aggregated (flocculation) after surface charge neutralization or reversal (coagulation).
3. Factors that influence coagulation and flocculation include:
   a. Surface charge and the nature of the particle;
   b. pH of the fluid media;
   c. Temperature;
   d. Organic constituents in the fluid media;
   e. Mixing energy; and,
   f. Time.
4. The best coagulants to remove phosphorus will be: positively charged (i.e., a cation in water), have lots of charge (e.g., a trivalent cation), be non-toxic, and be relatively insoluble at neutral pH as precipitation greatly enhances phosphorus removal processes. Typical coagulants are aluminum (as alum), lime or iron (as ferric chloride or ferric sulfate), though aluminum has aquatic toxicity issues and lime can need a substantial pH adjustment for optimum coagulation range. Lime is also associated with large volumes of sludge produced from use in coagulation.
5. Ferric chloride is a favored coagulant for phosphorus because it is a trivalent cation, not toxic in most forms and concentrations, of low solubility at neutral pH, readily available and with quick mixing characteristics. The chloride ion does not enter into the coagulation reaction after the initial disassociation, which may have

an impact on salty water discharge parameters that is outside the scope of this project.

6. Ferric chloride reactions include:

   a. In the presence of alkalinity:
   $FeCl_3 + 3HCO_3^- + 3H_20 \leftrightarrow Fe(OH)_3 \bullet 3H_2O (s) + 3CO_2 + 3Cl^-$

   b. Without alkalinity:
   $FeCl_3 + 6H_20 \leftrightarrow Fe(OH)_3 \bullet 3H_2O (s) + 3HCl$

7. If insufficient alkalinity is available when ferric chloride is used for coagulation, hydrochloric acid will form and the pH will drop and performance will become self-limiting as the effective range of ferric chloride treatment is pH = 5.5 to 7.0.

8. One of the most common methods to evaluate coagulation efficiency is to conduct jar tests, using side-by-side beakers (typically six beakers) with the same fluid conditions and similar mixing energy. Dose is evaluated by first holding the coagulant amount constant and varying the pH, then by holding the pH constant and varying the coagulant amount. However, because of variations between laboratory-bench scale and operational scale mixing and settling, and because of variations in wastewater constituents under actual flow, actual coagulation doses are typically 1.5 – 3.0 times the theoretical (stoichiometric) dose, with jar test-determined doses somewhere in between.

9. Particle removal by coagulation and flocculation requires reaction tanks and settling tanks, and can be done at several points within a wastewater treatment process:

   a. As a stand-alone tertiary process, similar to how drinking water is treated by coagulation and flocculation, called "post precipitation".

   b. With injection of the coagulant into a secondary aeration basin, called "co-precipitation":

      i. Aeration provides for good mixing and the secondary settlement basin provides for gravity removal of the flocs; but,

      ii. Excessive phosphorus removal in secondary treatment can impact biological processes of organic treatment by creating un-ideal nutrient ratios necessary for microbial metabolism.

c. With injection of the coagulant into the primary sedimentation basin, likely with mixing in perhaps an aerated grit removal step, called "pre-precipitation":

i. Reactions of the coagulant will be with organic materials (Biological Oxygen Demand, BOD) and total suspended solids (TSS) as well as phosphorus, greatly increasing the necessary dose;

ii. Mixing difficulties will be likely due to the high load in the wastewater in primary treatment; and,

iii. BOD and TSS-based flocs will likely bulk the sludge volume and create operational difficulties due to the high water content of the pre-precipitation sludge compared to ordinary primary treatment sludge.

10. Phosphorus can be removed using ferric chloride by creating ferric phosphate, $FePO_4$, according to the basic reaction:

$$Fe^{3+} + H_nPO_4^{3-n} \leftrightarrow FePO_4\,(s) + nH^+$$

Ferric phosphate has a minimum solubility of $10^{-5.6}$ moles, or 0.078 mg/L as total phosphorus. However, a practical limit of 0.5 mg/L as total phosphorus is commonly found, below which much higher doses of ferric chloride or effluent filtration are needed.

11. Phosphorus as polyphosphate, $P_2O_7^{4-}$, can be derived from plant or animal cells, particularly when released with processes that include molecular dehydration. In water, polyphosphate will gradually hydrolyze and revert to the ortho form of phosphorus, PO_4^{3-} or HPO_4^{2-}, that is much easier to remove;

12. Effluent filtration, when done, can be by:

a. Depth filtration – granular media with reverse-flow backwash;

b. Surface filtration ("disc filters") – cloth media with 10-30 um openings; or,

c. Membrane filtration – flow under pressure through a thin but tight filter material.

13. Effluent filtration will have issues of feasibility and design including: power requirements, efficiency, performance variability, reliability, long-term

degradation of filter media, reject (waste) proportion, and physical space requirements.

There are other references that also address principals of phosphorus treatment. In U.S. EPA (1987), phosphorus removal strategies are described, including biological phosphorus removal, a significant addition. Previous iterations of the phosphorus design manual only include chemical treatments for phosphorus removal.

U.S. EPA (2007) presents case studies of advanced wastewater treatment installed at 23 municipalities in the United States, with the aim of describing how chemical addition could be matched with a range of filtration techniques to be very effective at producing effluents containing low levels of phosphorus, with performance consistently near or below 0.01 mg/L total phosphorus. This document concludes with important guiding principles:

> *With proper design, there are no apparent reasons why any of these filtration technologies may not be installed in either small or large scale applications. Selection of a filtration technology includes the usual considerations such as: desired effluent quality; reliability of treatment equipment; capital, operating and maintenance costs; equipment footprint, and future expandability.*

Neethling, et al., 2008 defines tertiary phosphorus removal processes as physical and chemical processes used to polish effluents beyond conventional levels to achieve phosphorus removal to very low limits of below 0.05 mg/L or lower. In comparison, conventional phosphorus removal processes use chemical addition or Enhanced Biological Phosphorus Removal (EBPR) to achieve 0.5 – 1.0 mg/L phosphorus. The chemical processes in tertiary treatments convert soluble reactive phosphorus to solid particles that can be removed by physical processes. Five tertiary treatments are described:

- Chemical addition to react with the soluble phosphorus species and produce a solid precipitant;
- Chemical flocculants to capture small particles for removal in solid separation processes;
- Chemical removal onto a reactive surface of preformed precipitants or other surfaces such as iron oxide coated sand;

- Solids separation to remove particulate phosphate species; and,
- Adsorption through the contact of phosphorus in water phase to solid phase, such as the flocs retained by filters.

Neethling, et al. (2008) also notes that to achieve ultra-low levels of phosphorus in effluent, solids separation processes must be very efficient, producing effluent total suspended solids (TSS) to non-detectable levels. The solids separation device must also be able to handle the high chemical doses required for phosphorus removal. Further, as phosphorus removal limits are pushed lower to 0.05 mg/L or lower, the various forms of phosphorus will become more important and influence the effectiveness of particular treatments of both chemical and physical approaches.

Barnard, et al. (2011) describes how chemical phosphorus removal is the preferred option for reliable and consistent performance meeting ultra-low levels of total phosphorus in effluent from wastewater treatment plants. Balancing chemical removal with biological removal can reduce chemical use and associated costs, but biological approaches alone are unlikely to meet ultra-low levels. Additional information needed regarding: the optimal point of chemical addition; effects of the added chemicals on the alkalinity and subsequently the treatment biology; floc aging effects and the role of solids contact time on net chemical consumption; the value of recycling spent chemicals from tertiary processes to primary and secondary processes; and the impact of the added chemicals on process sludges, particularly the volumetric effects.

B. JAR TESTING AND REMOVAL PROCESS

Szabo, et al. (2008) describes laboratory evaluations of metal salt (i.e., ferric and alum) treatments for the removal of phosphorus, particularly assessing the import of factors including pH, alkalinity, metal dose, metal type, initial and residual phosphorus concentration, mixing, reaction time, age of flocs, and organic content of wastewater. Under optimal conditions, experimenters consistently achieved ultra-low residual phosphorus concentrations of 0.01 to 0.05 mg/L as orthophosphate, under the broad pH range of 5.0 to 7.0 representing many typical wastewaters. Experiments showed that significant savings in chemical dosing and subsequent cost could be achieved by improving the mixing at the point of chemical addition, providing a longer contact time between the metal hydroxide flocs and the phosphate contained in the wastewater.

Szabo, et al. (2008) further suggested that increasing metal dose levels increases phosphorus removal but with diminishing returns for increases to higher levels.

Nir, et al. (2009) investigates ferric chloride for coagulation followed by ultrafiltration for the removal of phosphorus from secondary effluent from a wastewater plant in southern Israel. Experiments were done using 150 mL cells and three different polysulfone flat sheet membranes. Ortho phosphorus was removed at levels from 35 mg/L down to approximately 5 mg/L, benefiting from a synergistic effect of the flocculation and the ultrafiltration as shown by a doubling from the removal by ultrafiltration alone. However, the overall phosphate removal was insufficient for use. Additionally, fouling patterns were observed to vary between filter media.

Gilmore, et al. (2011) uses a factorial design to study four factors (iron dose, pH, mixing and water hardness) thought to be significant in chemically mediated phosphorus removal in wastewater. Iron dose at 10 mg Fe/L was found to be orders of magnitude better at removal than 5 mg Fe/L, a pH of 6 was better than a pH of 8, and water hardness was found to be important but less so than the other factors. High mixing intensity was found to achieve better phosphorus removal than low mixing intensity, as iron flocs are kept small with higher intensity, providing more surface area for absorption.

Hauduc, et al. (2013) presents a dynamic physio-chemical model for chemical phosphorus removal in wastewater, building on the work of Szabo et al. (2008) and Smith et al. (2008). This model was developed as a tool to optimize chemical dosing simultaneously with insuring compliant phosphorus effluent concentration. This work allows consideration of effects from adjustments in mixing energy, mixing time, metal (ferric) dosing, and initial phosphorus concentration, and showed close correlation with laboratory results.

Maher et al. (2013) gives results of a laboratory study that considered recycling chemical precipitant sludge from an alum-based tertiary coagulation and flocculation proprietary (DensaDeg®) system for phosphorus removal. The study was done using operational waters and sludge from a treatment plant in Breckenridge, Colorado. Results showed a five-fold possible reduction (20% of original dose level) in alum dosing while still maintaining phosphorus removal to below 0.5 mg/L using a 5% recycle rate; studies were described as ongoing to evaluate effects of the recycle rate under full scale implementation.

Keeley et al. (2016) develops a synergistic approach using water treatment wastes for wastewater tertiary treatment of phosphorus that suggested a reduction in phosphorus removal costs by about 50%. The approach used ultrafiltration rejection/regeneration fluids, obtained from after metal salt coagulation and flocculation, and then treated in an acidification step, as "recovered coagulants" for use in coagulation and flocculation of wastewater. The study showed that reaction times were somewhat slowed with the recovered coagulants, meaning that mixing times would likely need increasing, but that the whole lifecycle cost savings made the process worth exploration.

C. PILOT TESTING

Benisch, et al. (2007) describes pilot tests of four proprietary filtration systems on secondary effluent from Coeur D'Alene, Idaho. No flow rates were provided, but systems were run concurrently and continually for 4 and 6 weeks in two separate pilot periods. Phosphorus was reduced from 0.8 mg/L to generally below 0.05 mg/L, with exceptions for days with operational difficulties. None of the treatment trains could reach a phosphorus reduction to 0.01 mg/L except on single days of optimal treatment. Alum or ferric chloride were added at rates between 38 – 200 ppm, and were adjusted to optimize each treatment system. Sludge production estimates were 360 lb/d per million gallons treated for alum at 165 ppm, and 210 lb/d per million gallons treated for ferric chloride at 38 ppm.

Newcombe, et al. (2008) evaluates phosphorus removal by chemically-enhanced tertiary filtration at a municipal wastewater plant in Idaho, using a secondary effluent side stream of 175 gallons per minute. Ferric chloride was injected into inline mix chambers before each of two 1.5 m bed depth sand filters. Filter reject streams of a combined total 30 gpm were returned to the top of the plant (oxidation ditches and secondary clarifiers) and incorporated into the 1.2 MGD average flow. Secondary effluent concentrations of total phosphorus were reduced from greater than 4 mg/L by 65 to 90% at iron doses of between 2.9 and 11.3 mg/L, reaching an average value of 0.011 mg/L (in the tertiary effluent) with time, in a behavior that suggested a steady state of reactive filtration was achieved. This observation was supported by a separate observation of how phosphorus concentrations in the tertiary effluent slowly climbed back to pre-pilot study levels after the iron injection ended.

Peeters, et al. (2010) evaluates ultrafiltration (GE ZeeWeed® 1000) for phosphorus removal in tertiary treatment using a pilot plant at an unnamed municipal wastewater treatment plant located in Ontario. The tertiary treatment train consisted of an inline strainer where alum was injected, an inline static mixer, a flocculation tank equipped with a mixer then a membrane tank with one ZW1000 membrane module. Over a six week pilot period, average total phosphorus was reduced from 0.46 mg/L to 0.023 mg/L using an alum dose of 82 – 85 mg/L. No mention if fouling occurred or discussion of other membrane operational details were provided.

deBarbadillo, et al. (2011) describes a pilot test for tertiary phosphorus removal by metal salt flocculation and filtration for a 9,000 m^3/d average flow wastewater plant in Innisfil, Ontario. Of particular interest was determining loading rates for design of four considered filtration systems:

- GE ZeeWeed® ultrafiltration membrane system,
- Blue Water Technologies BluePRO® reactive filtration series system,
- Veolia ACTIFLO® process followed by gravity filters, and,
- Parkson DynaSand® D2 dual filtration system.

The pilot study operated for four weeks using treatments in parallel, with Week 1 focused on optimization, Week 2 conducted at continuous flow rate, Week 3 testing a diurnal flow pattern, and Week 4 conducted to create two types of stress tests. Total phosphorus was reduced in the pilot system trains after four days of stress testing from 0.27 mg/L in the pilot influent to 0.016 mg/L for GE, 0.021 mg/L for Blue Water, 0.03 mg/L for Parkson, and 0.038 mg/L for Veolia. Design loading rates were developed as planned, and are presented in the paper.

Benisch, et al. (2011) describes pilot tests of three tertiary treatment systems in Coeur D'Alene, Idaho, running at 50,000 gallons per day for greater than one year. Phosphorus was reduced from 0.8 mg/L by treatments including: dual stage continuous upflow moving bed filter (average effluent total phosphorus 0.028 mg/L); membrane ultrafiltration (average effluent total phosphorus 0.020 mg/L); and a biological nutrient removal membrane bioreactor (average effluent total phosphorus 0.047 mg/L). Detailed description is included of the system optimizations and the operational incursions that result in temporary treatment disruptions.

Banerjee, et al. (2011) gives results from a pilot study on wastewater from Plantation, Florida, although no details of flow rates or unit construction were provided. A membrane bioreactor-reverse osmosis train reduced average total phosphorus from 2.1 to 0.02 mg/L, and an ultrafiltration-reverse osmosis train reduced average total phosphorus from 1.8 to 0.007 mg/L.

Zheng, et al. (2012) documents a pilot test for phosphorus removal at a wastewater treatment plant in Berlin, Germany. Secondary clarifier effluent had an average total phosphorus concentration of 0.27 mg/L. Ultrafiltration was used to polish the plant effluent. Ferric chloride dose was found to be significant in occurrence of membrane filtration fouling, and much effort went in to optimizing the dose, although 0.05 mg/L total phosphorus could be achieved consistently once dose was optimized. Filter fouling was determined to be an unavoidable effect of the phosphorus removal. Comparison of bench scale with pilot scale evaluations suggested that filters “seasoned” by initial ferric chloride fouling were more effective in phosphorus removal than new (unseasoned) filters.

D. COMPARISON OF OPERATIONAL PERFORMANCE

O’Shaughnessy, et al. (2009) describes how an advanced wastewater treatment facility of 36 MGD in Alexandria, Virginia consistently achieves total phosphorus concentrations in effluent at or below 0.06 mg/L over the past five years. The plant uses dual point chemical precipitation, first with ferric chloride prior to secondary settling tanks, then in a tertiary settling tanks where alum is added. The tertiary settling is followed by deep sand filtration.

Scherrenberg, et al. (2009a) and Scherrenberg, et al. (2009b) both evaluate phosphorus removal in filtered effluent as impacted by wastewater plant operation for nitrogen removal, for a treatment plant in The Netherlands of 26,000 m^3/d average flow. Ultra-low nitrogen treatment generally requires phosphorus in sufficient or even excess concentration so as not to limit the biological process needed for nitrogen removal. It was found that ortho phosphorus was reduced from 0.06 to 0.02 mg/L through the dual media filter from the filter influent to a 2 m bed depth, if the plant was operated in an approach that balanced the nitrogen and phosphorus removals. If operated for an optimized nitrogen removal using phosphorus flooding in the wastewater, the dual media filter could only achieve 0.24 mg/L ortho phosphorus; a proprietary (1-STEP©) filter under similar conditions could achieve 0.10 mg/L ortho phosphorus at a 2 m bed depth.

Parker, et al., (2011) describes a comprehensive study of ten nutrient removal plants designed and operated to meet very low effluent total phosphorus concentrations, in a study supported by WEF and WERF (called the Nutrient Challenge Research Program). Managers provided 3 years of operational data, analyzed in a consistent statistical approach that considered both process reliability and the permit limits applied. Using monthly average 95th percentiles of effluent data (not a value recommended for permit limits), plants were compared in terms of their ability to meet 0.1 mg/L total phosphorus. Plants were assessed by their treatment approach and results:

- Single Stage Chemical Addition (3 plants): total phosphorus 0.03 – 0.11 mg/L
- Multiple Stage Chemical Addition (5 plants): total phosphorus 0.09 – 0.16 mg/L
- No Chemical Addition (2 plants): total phosphorus 0.17 – 0.22 mg/L

Parker, et al., (2011) also notes that none of the plants achieving low phosphorus levels simultaneously achieved low total nitrogen. Plants also were not operated, for the most part, at their design flows and loadings, meaning conditions representing the limits of possible performance were not reached. Plants were also considered “well-operated”, models of treatment effectiveness within the limits of their design. Plants did represent a range of geographies and wastewater temperature conditions.

Johnson and Briggs (2011) describes the upgrade of a New South Wales, Australia wastewater plant from 2.6 to 6.0 MGD that was required to meet new effluent standard of 0.04 mg/L total phosphorus. The upgrade added two continuous-feed sequencing batch reactors for additional hydraulic capacity in secondary treatment, modifying the existing aerobic activated sludge system to a Modified Ludzack-Etttinger process, and adding alum-based coagulation and flocculation with tertiary clarification then dual media filtration. Tertiary clarification sludge is recycled back to the head of the secondary treatment works. As the plant went through startup and commissioning, total phosphorus in the effluent was reduced from an initial 0.08 mg/L maximum to a stable average of 0.02 mg/L after three months.

Kleemann, et al. (2015) evaluates phosphorus mass budgets and associated costs of treatment steps within several wastewater treatment plants in the United Kingdom. Of particular interest may be the evaluation of return or reject waters from each treatment step, and the analysis of phosphorus mass flow throughout the treatment process. The work concludes with a holistic evaluation of local and national effects of phosphorus treatment and recovery from wastewater treatment plants.

E. LAB METHODS

Neethling, et al. (2008) also addresses laboratory methods for phosphorus measurement, in particular summarizing Standard Methods 4500-P (Rice, et al., 2012; summarization about a previous edition with no major changes) in comparison of the three analyses typically used for phosphorus measurement. Direct colorimetry measures mostly orthophosphate (PO_4^{3-}), although some small quantity of other phosphorus compounds may respond, thus the result should be called "reactive phosphorus". Sulfuric acid digestion with colorimetry will include in the measurement "acid-hydrolyzable phosphorus", comprised mostly of condensed phosphates including polyphosphates (chain structure) and metaphosphates (ring structure). Persulfate digestion with colorimetry incorporates the "organic phosphorus" fraction, adding further the organically bound phospholipids, sugar phosphates, nucleotides and phosphoamides. Persulfate digestion with colorimetry will therefore return the highest measurement of phosphorus, incorporating all forms within the sampled liquid, thence termed "Total Phosphorus".

In an evaluation of phosphorus analytical methods, Smith (2015) compared digestion methods on phosphorus analyses for three phosphorus-bearing compounds (polyphosphate, phospholipid, and Andenosine-5-MonoPhosphate) representative of organically-bound phosphorus. Evaluations were done on standards over a range of concentrations from 50 to 500 parts per billion, and over a range of digestion times ranging from 30 to 75 minutes. In general, recoveries (a measure of accuracy) were at least 60% or greater except for phospholipid compounds, over the range of concentration evaluated. Increasing the digestion time beyond 30 minutes did not substantially change the recovery. This suggests that except for phosphorus contained in bacterial cell walls, made up of lipid bilayers, persulfate digestion of 30 minutes is generally comprehensive and of sufficient accuracy for wastewater analysis. An interpretation of this finding would be that persulfate digestion may underrepresent the amount of total phosphorus contained in activated sludge mixed liquor and effluent, prior to secondary settlement, and perhaps also for influent, but that good results may be achieved for analyses of tertiary treatment waters and effluents.

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SECTION 3 OVERVIEW OF TREATMENT SYSTEM

A. GENERAL

The City of Mankato owns and operates a conventional activated sludge wastewater treatment facility that treats wastewater from the communities of Mankato, North Mankato, Eagle Lake, Madison Lake, South Bend Township, Skyline, and the Lake Washington Sanitary Sewer District. Under normal conditions, the secondary treated effluent flow receives further treatment at the City's Water Reclamation Facility (WRF). On an as-needed basis, the Calpine – Mankato Energy Center (MEC), a local power plant, utilizes the reclaimed water for non-contact (single pass) cooling purposes at their industrial facility located approximately one mile to the north. The non-evaporated portion of the cooling water is returned to the City's treatment system, where it is blended with non-utilized reclaimed water, disinfected, and then discharged to the Minnesota River under NPDES Permit No. MN0030171.

Figures 3.1 and 3.2 provide a site plan overview and process flow diagram of the treatment process, respectively.

B. DESIGN FLOWS AND LOADINGS

A summary of the facility's existing design flows and loadings is presented in Table 3.1 below. These parameters are identified in the facility's contract documents as designed by Black & Veatch, Inc.

TABLE 3.1
Summary of Facility Design Flows and Loadings - Mankato, MN

Design Parameter	Units	Annual Average	Maximum Month	Maximum Hydraulic	Peak Instantaneous
Wastewater Flow	MGD	9.38	11.25	22.5	42.0
5-day Biochemical Oxygen Demand (BOD_5)	mg/L	160	160	--	--
	lbs/day	12,500	15,000	--	--
Total Suspended Solids (TSS)	mg/L	200	200	--	--
	lbs/day	15,600	18,800	--	--
Ammonia-Nitrogen (NH_3-N)	mg/L	21	17(1)	--	--
	lbs/day	1,600	1,600	--	--
Temperature	°C	16	21	--	--

(1) At constant design loadings, maximum month NH_3-N concentration is lower than annual average based on higher wastewater flow.

C. NDPES PHOSPHORUS LIMITS

The current discharge limits for the Mankato Wastewater Treatment Facility are described in NPDES Permit No. MN0030171. A copy of the permit is included in Appendix A, which expired on August 31, 2015. At this time, a renewed permit has not been finalized by the MPCA; however, the City has received draft permit limits that are currently being reviewed. The existing and proposed draft discharge limits for phosphorus removal are summarized in Table 3.2 below.

TABLE 3.2
Phosphorus Discharge Limits – Mankato, MN

Parameter	Season	Limits
Existing Permit Phosphorus Limits		
SD001		
12-Month Moving Average	Jan.-Dec.	Monitor Only (kg/day)
Calendar Month Average	Jan.-Dec.	43.1 kg/day
Calendar Month Maximum	Jan.-Dec.	1.00 (ratio)(1)
Season-to-Date Total	Oct.-Apr.	8,895.6 kg/yr
WS002		
Calendar Month Average		0.9 mg/L
WS006		
12-Month Moving Average	Jan.-Dec.	Monitor Only (kg/day)
Calendar Month Average	Jan.-Dec.	Monitor Only (kg/day)
New Pre-Draft Permit Phosphorus Limits		
SD001		
Annual Phosphorus Loading	Jan.-Dec.	12,243 kg/yr(2)
Calendar Month Average	Jan.-Dec.	1.0 mg/L
Calendar Month Average	Jun.-Sept.	33.2 kg/day(3)
WS002		
Calendar Month Average	Jan.-Dec.	0.9 mg/L
WS006		
12-Month Moving Average	Jan.-Dec.	Monitor Only (kg/day)
Calendar Month Average	Jan.-Dec.	Monitor Only (mg/L; kg/day)

(1) Calculated as the ratio of SD001 12-month moving average divided by WS006 12-month moving average (with the WS006 value calculated using a concentration of 1 mg/L)
(2) Reflects phosphorus trade agreement with Granite Falls Energy, LLC. Actual pre-trading limit is 12,434 kg/yr
(3) Proposed Pre-draft permit limit for River Eutrophication Standards (RES)

The facility's permitted surface water discharge to the Minnesota River is designated as SD001. The existing season-to-date mass loading limit, effective between October and

Ultra-Low Phosphorus Removal Study

City of Mankato, MN

Figure 3.1 - Site Plan Overview of Treatment Process

May 2016

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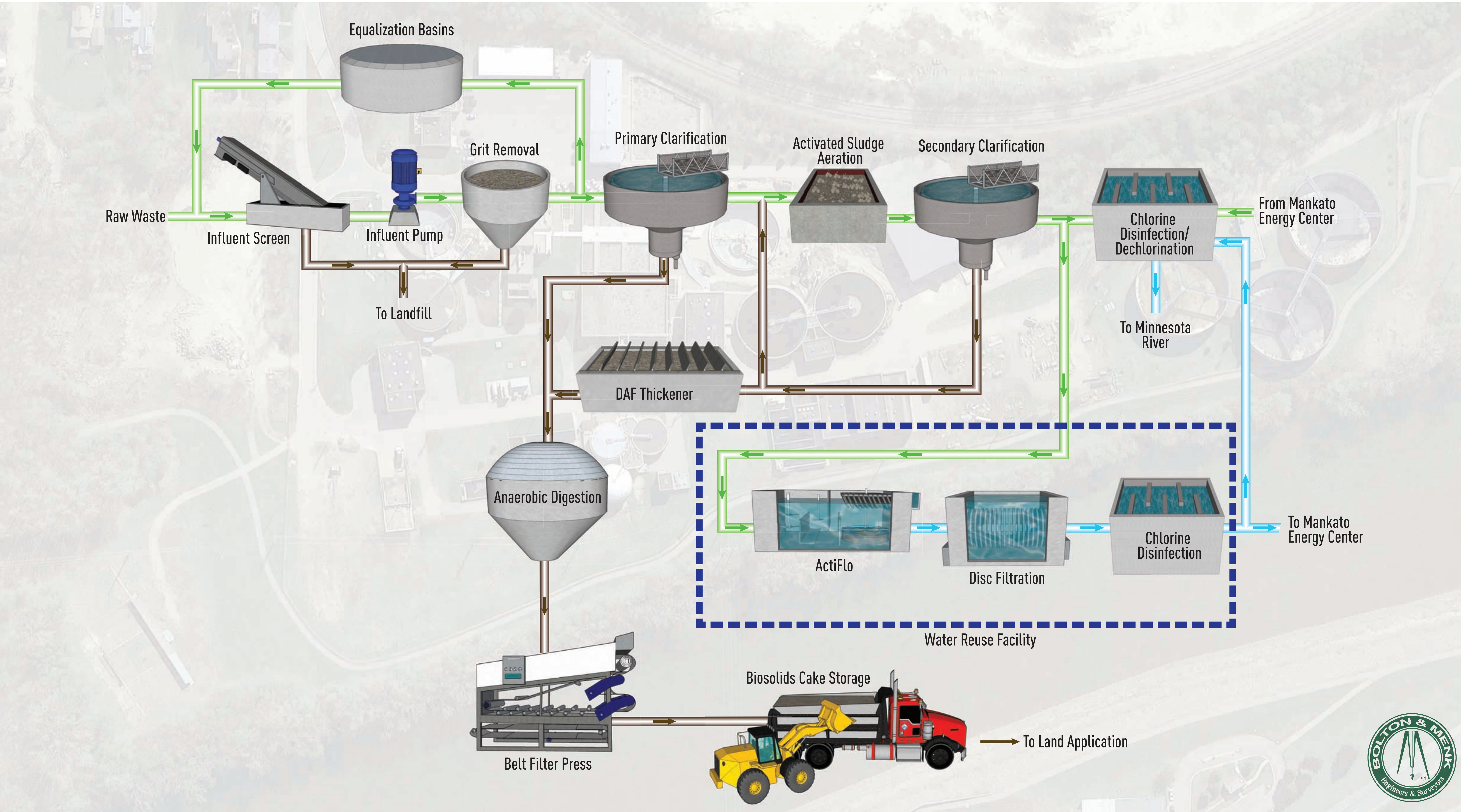
Wastewater Treatment Plant

Process Flow Diagram



April, is proposed to change to an annual mass limit of 12,243 kg/yr. This mass limit reflects the phosphorus trade agreement between the City of Mankato and Granite Falls Energy, LLC. The pre-draft permit limits also propose a more stringent mass limit of 33.2 kg/day between the months of June and September in accordance with newly adopted River Eutrophication Standards (RES). This amounts to a concentration of 0.78 mg/L at AWW flow conditions. Overall, a monthly average concentration limit of 1.0 mg/L is proposed for the combined total effluent discharge to the Minnesota River, which considers blending the effluent water with industrial cooling water returned from the Mankato Energy Center.

D. PRELIMINARY TREATMENT

The City of Mankato's raw wastewater enters the treatment facility from separate 36-inch and 42-inch sanitary sewer interceptors. The raw wastewater first enters the Screening Building/Influent Pumping Station, where it is mechanically screened to remove large solids such as sticks, rags, and other debris that may be present in the wastewater. The screened wastewater flows to the Influent Pumping Station wet well, where it is temporarily stored and then pumped to the Grit Removal Building. Historically, ferric chloride has been added to the 42-inch interceptor sewer for the purpose of odor control at the Grit Building, typically in the dosage range of 5-10 mg/L as $FeCl_3$. At annual average design flow, this dosage range equates to 90 – 180 gallons of 37.4% ferric chloride solution fed to the interceptor each day. Over time, this chemical feed point also evolved into the primary method of removing phosphorus in the City's wastewater treatment process (other than the tertiary treatment process). However, recently, the City added additional feed points immediately prior to the Primary and Secondary clarification processes in order to enhance phosphorus removal. Since these additions, the City has not been feeding ferric chloride to the interceptor sewer, which has not resulted in odor issues at the Grit Building. However, the reuse system waste discharges into the interceptor sewer, which likely creates a small ferric chloride residual in the Pretreatment process to help with odor.

At the Grit Removal Building, the wastewater enters a splitter structure where it is split into two separate flow streams. Each stream is metered by a Parshall flume and then flows to separate vortex grit chambers. The vortex grit chambers induce a circular wastewater flow pattern – utilizing centrifugal force to remove heavy inert solids such as sand and fine debris from the wastewater. As the heavy solids settle and accumulate at the bottom of the chambers, the grit is then pumped to a grit classifier where it is dewatered, compacted, and eventually disposed through landfilling.

During peak hydraulic loadings to the facility, wastewater is allowed to overflow the Grit Removal process and is bypassed to the City's equalization basins for temporary storage. This temporary storage allows the City to maintain consistent flows through the treatment process – ensuring proper treatment performance. As influent flows decrease, wastewater stored in the equalization basins is slowly incorporated back into the treatment process.

The permitted influent monitoring station (WS001) is located in the Grit Removal Building.

E. PRIMARY TREATMENT

After leaving the Preliminary Treatment Facilities, wastewater flows by gravity to the Primary Clarifiers. The flow is split equally between two (2) 80-foot diameter Primary Clarifiers by the use of modulating inlet valves, which also regulate the flow and control overflow to the equalization basins. In the Primary Clarifiers, less dense suspended solids are given time to settle and are removed from the wastewater by the clarifier sludge collection mechanisms. Floating solids, or scum, such as oil and grease are also removed by the surface skimming mechanisms. The clarified liquid overflows into the effluent launders and flows by gravity to a splitter structure, which splits the flow between the three (3) aeration basins. The Primary Clarifiers are designed to remove approximately 25 and 50 percent of influent organics and suspended solids, respectively.

The City feeds ferric chloride to the influent of each Primary Clarifier for chemical precipitation and removal of phosphorus.

F. SECONDARY TREATMENT

The City of Mankato utilizes the activated sludge process for Secondary Treatment of their wastewater. This process consists of the following basic components:

- Three (3) Aeration Basins (total capacity = 3.92 MG; 8.4 hrs. @ AWW)
- Three (3) 100-foot diameter Secondary Clarifiers
- Five (5) Return Activated Sludge (RAS) pumps
- Four (4) positive displacement blowers
- Post-aeration ferric chloride feed for phosphorus removal

The preceding processes utilize physical mechanisms to remove solids and a portion of the nutrients in the raw wastewater. The activated sludge process combines biological, chemical, and physical treatment to significantly reduce organics and nutrients, such as phosphorus, from the wastewater. If discharged directly to the Minnesota River without treatment, the bio-availability of excess organics and nutrients can result in excessive aquatic vegetative and algal growth. Respiration and decomposition of aquatic vegetation depletes dissolved oxygen in the water and, ultimately, degrades the overall aquatic environment. The purpose of the activated sludge process is to induce these reactions at the treatment facility so it does not occur in the natural environment.

In the Aeration Basins, a population of aerobic heterotrophic bacteria and protozoa is supported by oxygen that is supplied by the City's positive displacement blowers. These microorganisms metabolize the organic matter and nutrients (nitrogen and phosphorus) in the wastewater in order to grow, reproduce, and sustain life. The combination of the microorganism population and raw wastewater is known as mixed liquor.

Mixed liquor flows from the Aeration Basin to a common splitter structure, where the flow is divided between three (3) Secondary Clarifiers. The purpose of the Secondary Clarifiers is to separate the concentrated solids (sludge) from the treated liquid portion; thus, the clarifiers are sized to provide an upflow velocity small enough to allow for gravitational settling of the sludge. The treated liquid portion, containing minimal suspended solids and soluble organics, overflows into the clarifier launders and is conveyed to the Intermediate Pumping Station. The settled sludge is either returned to the Aeration Basins (i.e. return activated sludge) or wasted to the solids processing system (i.e. waste activated sludge).

The purpose of returning and/or wasting the activated sludge is to control the biological process in the Aeration Basins. The Aeration Basin are designed for a mixed liquor suspended solids (MLSS) concentration of 3,100 mg/L. The City also maintains a specific ratio of organics and biomass (i.e. food to microorganisms ratio – F/M) that creates ideal conditions for biological treatment. These parameters dictate the flow of return sludge back to the Aeration Basins and the amount of sludge wasted to the solids processing system. These parameters also dictate whether or not the City utilizes all of their Aeration Basins.

The conventional activated sludge process is effective for removal of soluble organics and suspended solids from influent wastewater. However, this process has limitations for removal of nitrogen and phosphorus, as the typical wastewater concentrations exceed the amount utilized by microbial metabolism. In order to reduce phosphorus to meet permit limits, the City also has the option to add ferric chloride upstream of the Secondary Clarifiers for chemical precipitation and removal of phosphorus in the wasted sludge.

G. WATER RECLAMATION AND REUSE

The treated liquid from the Secondary Treatment process flows to the Intermediate Pumping Station. Under normal conditions, this entire volume of water is pumped to the City of Mankato's Water Reclamation Facility (WRF) for further treatment. However, the water can also bypass the WRF and be discharged directly to the disinfection system. This typically only occurs during peak flows in order avoid hydraulically overloading the WRF process.

The Water Reclamation Facility utilizes the following processes for tertiary removal of phosphorus from the City's wastewater:

- Dual-train Acti-Flo® system (manufactured by Kruger, Inc.)
- Dual-train Disc-Filtration (manufactured by Kruger Hydrotech)
- Reclaimed water storage/disinfection
- Reclaimed water pumping to Mankato Energy Center

The Acti-Flo® system is a proprietary process manufactured by Kruger, Inc. (bought by Veolia Water Technologies in 2000). The Acti-Flo® system is a high-rate clarification process that utilizes microsand as a ballasting agent to remove additional phosphorus from the Secondary Effluent and to produce a finished water quality suitable for industrial reuse.

Ferric chloride is dosed to the pumped influent water, which is conveyed to the injection mixing tanks of the Acti-Flo® system. In the first mixing tank, ferric chloride is given time to react with the influent water and then overflows into the second mixing tank where polymer and microsand are added. The reaction of ferric chloride and water produces hydroxide flocculants which bind soluble phosphorus. These flocculants are ballasted with microsand with the help of polymer. This reaction is given time in the maturation tank where slow-mixing is provided to optimize contact between the particles without breaking them apart. Lastly, the water flows to a high-rate clarifier where the microsand is settled out – effectively removing phosphorus from the water.

From the Acti-Flo® process, the treated water flows to one of two cloth media Disc-Filtration units. The Disc-Filters have a nominal pore size of 10 microns, which provides additional removal of suspended solids that escape the Acti-Flo® process, although it does not provide removal of residual soluble phosphorus. Historically, the City of Mankato has achieved 75-80% removal of phosphorus from their Secondary wastewater using these tertiary treatment processes.

After filtration, the reclaimed water is conveyed to an exterior storage tank where it is stored and disinfected. On an as-needed basis, the Calpine – Mankato Energy Center (MEC) utilizes the reclaimed water for single-pass non-contact cooling water at their power plant facility located approximately 1 mile to the north. The reclaim pumps also supply the City's non-potable utility water system that is used throughout the facility to reduce potable water usage. Reclaimed water is also used to water green spaces such as Riverfront Park, and is used offsite for sod establishment and many other construction projects. The City has a reclaimed water loadout station that is free for anyone to pick up during operating hours.

Excess reclaimed water that is not reused overflows the storage tank and flows by gravity to the disinfection process.

H. DISINFECTION

The City of Mankato's effluent disinfection system consists of the following components:

- Two (2) Chlorine Contact Basins (total volume = 600,000 gallons; 38 min. detention at maximum hydraulic flow)

- One (1) Dechlorination Basin (total volume = 120,000 gallons; 7.5 min. detention at maximum hydraulic flow)
- Sodium Hypochlorite feed system (chlorination)
- Sodium Bisulfite feed system (dechlorination)

Under normal operating conditions, the Disinfection system receives water from two sources: 1) non-evaporated cooling water return from the Mankato Energy Center; and 2) reclaimed water not utilized for reuse. In emergency situations, raw wastewater can also be bypassed from the grit building directly to the Chlorine Contact Basin in lieu of being stored in the equalization basins.

After the effluent water is disinfected and dechlorinated, it is sampled at surface discharge station SD001. At this sampling location, the City must meet the permit phosphorus limits summarized in Table 3.2.

I. SOLIDS PROCESSING

The City of Mankato's solids processing system consists of the following general components:

- Primary sludge and scum pumping
- Two (2) Dissolved Air Flotation (DAF) units
- Secondary sludge and scum pumping
- Three (3) 50-foot diameter Primary Anaerobic Digesters
- One (1) 50-foot diameter Secondary Anaerobic Digester
- Two (2) Belt Filter Presses and associated polymer feed system
- Truck loadout for dewatering sludge
- Dewatered sludge storage structure

All phosphorus removed in the treatment process is removed through the residual biosolids, which is a beneficial byproduct that is spread/injected into agricultural fields for crop fertilizer. Phosphorus in removed through solids wasting under two mechanisms: 1) wasting of biomass that uptakes a portion of the influent phosphorus for cellular metabolism; and 2) wasting solids residuals produced from the addition of ferric chloride to the wastewater. Since the facility was not designed to achieve enhanced biological nutrient removal, a majority of phosphorus removal is done through the addition of ferric chloride at various points in the process.

J. PHOSPHORUS MONITORING AND REMOVAL

The City of Mankato utilizes the following equipment to monitor and control phosphorus removal in their wastewater system:

- Ferric Chloride Feed Application Points (9 total injection points)
  - (1) 42-inch Sanitary Sewer Interceptor
  - (2) Influent feed to Primary Clarifiers No. 1 and 2
  - (1) Influent feed to Secondary Clarifiers
  - (2) Belt Filter Presses No. 1 and 2
  - (1) Digester Feed Pump Wetwell
  - (2) Influent feed to Acti-Flo® system (2 trains)
- 24-hr Composite Sampling Locations
  - Raw influent (WS001 – Grit Removal Building)
  - Primary effluent (Primary tunnel area)
  - Secondary effluent (Water Reclamation Facility)
  - Final effluent sampler (SD001 – Dechlorination Basin)
- Phosphorus Analyzers
  - Primary Effluent: HACH Phosphax SC Analyzer – 0.05 to 15 mg/L PO_4-P (0.05 mg/L lower limit of detection)
  - Acti-Flo® Effluent: HACH 5500SC Phosphate Analyzer (4 channel, low range) – 0 to 3 mg/L (0.004 mg/L lower limit of detection)
- Ferric Chloride Feed System (located in Solids Processing Building)
  - Feeds all injection points other than the Acti-Flo® system in the Water Reclamation Facility
  - (1) Fiberglass reinforced plastic storage tank – 9,300 gallons
  - (4) Diaphragm metering pumps (39.1 gph capacity)
  - Associated piping, valves, and pump skids
- Ferric Chloride Feed System (located in Water Reclamation Facility)
  - Only feeds the two (2) Acti-Flo® system injection points
  - (2) Fiberglass reinforced plastic storage tanks – 12,000 gallons (each.)

- (3) Diaphragm metering pumps (2.4 – 58 gph capacity range)
- Associated piping, valves, and pump skids

K. PHOSPHORUS DISCHARGE & INDUSTRIAL BLENDING

The City of Mankato's treated effluent discharged to the Minnesota River is a blend of reclaimed water and cooling water returned from the Mankato Energy Center. Historically, the City has not had issues meeting the permit limits described in Table 3.2. Table 3.3 summarizes historical effluent monitoring data over the study period between September 8th and November 23rd.

TABLE 3.3
Historical Effluent Monitoring Data & Industrial Blending

Parameter	Unit	Influent	Effluent	MEC Return
Average Flow	MGD	7.68	7.02	0.29
Phosphorus				
Concentration	mg/L	4.45	0.42	0.71
Loading	lbs/day	285.28	24.69	1.72
% of Effluent Loading	%	--	--	7.0

Over the duration of the study period, MEC's cooling water return contributed 4.1% of the total flow and 7.0% of the total phosphorus loading to the Minnesota River, respectively. Thus, when MEC uses small amounts of reclaimed water relative to overall production, condensed concentrations of phosphorus in the cooling water return (due to evaporation) have insignificant effects on the final effluent water after blending.

However, according to the City's discharge permit, MEC is allowed to take up to 6.2 MGD of reclaimed water, or approximately 66% of the total design annual average flow. At this proportion, evaporation losses can make up nearly 50% of the total daily flow (assuming a maximum 75% evaporation loss rate as specified in the permit). If the mass balance of phosphorus is maintained after tertiary treatment, the City could not discharge over 0.50 mg/L TP from the tertiary treatment process in order to maintain a blended concentration of ≤ 1.0 mg/L. If MEC is not utilizing their full capacity of reclaimed water, the City has some leeway in the operation of their Water Reclamation Facility. Increased usage by MEC coupled with a lower phosphorus limit in the permit may cause a phosphorus discharge problem in the future.

SECTION 4 EXPERIMENTAL PLAN AND PROCEDURES

A. GENERAL

The evaluation of ultra-low phosphorus removal and related subjects have been well documented in research studies conducted over the past 10 years as described in Section 2. Based on these studies, it is apparent that ultra-low phosphorus removal at or below 0.1 mg/L is achievable using various combinations of chemical and physical treatment processes, with potential low-range removal capabilities of 0.01-0.02 mg/L under optimal conditions. The results of these studies should be no surprise when considering the advances made in membrane filtration technologies, particularly when considering that well established technologies such as reverse osmosis are used to remove dissolved ions in a variety of drinking water applications. Therefore, the evaluation of ultra-low phosphorus removal from wastewater is a matter of technological practicality, process optimization, and financial feasibility.

The City of Mankato's Wastewater Treatment and Reclamation Facilities are well equipped to remove phosphorus, having full-scale infrastructure in place that provides flexibility to remove phosphorus at various points in the treatment process. Space availability in the Water Reclamation Facility also make it ideal for piloting various tertiary filtration technologies in addition to the City's existing full-scale infrastructure. Based on these potentials, the scope of the experimental analysis for this study was determined to include the following:

1) Ferric Chloride Feed Application Analysis
2) Comparison of Tertiary Treatment Methods
3) Evaluation of Ultra-Low Phosphorus Removal

The remainder of this Section will explain the experimental plan and testing procedures used to guide the fieldwork and collection of data for the analyses identified above.

B. EXPERIMENTAL PLAN

The following paragraphs describe the experimental plan and testing procedures for each of the three areas of analysis in this Study. Due to time constraints, the experimental procedures were conducted simultaneously. Figure 4.1 presents an overview of the overall process flow schematic that includes the various ferric chloride feed locations and sampling locations utilized in the experimental procedures.

1) Ferric Chloride Feed Application Analysis

i. Overview and Purpose

Past studies have shown that various dosing applications of metal salts may have advantages and disadvantages in terms of optimizing phosphorus removal, reducing chemical usage, and potential effects on sludge production. The City of Mankato recently added ferric chloride dosing injection points to the influent of their Primary and Secondary Clarifiers – providing flexibility to remove phosphorus at four separate points in their wastewater treatment process (highlighted in Figure 4.1). However, the City has not identified a dosing scheme that is most advantageous to their specific treatment operations.

The purpose of this analysis is to determine potential advantages and disadvantages of utilizing various ferric chloride dosing schemes within Mankato's full-scale treatment system. This analysis was conducted simultaneously with the other two analyses.

ii. Procedure

Ferric chloride feed points and sampling locations referenced in the procedure are identified in Figure 4.1. Ferric chloride feed scenarios referenced in the procedure are summarized in Table 4.1.

The experimental procedure for this analysis is as follows:

1) Two days prior to starting the testing procedure, ferric chloride feed points $FeCl_3$ (1), $FeCl_3$ (2), and $FeCl_3$ (3) shall be shut off. During this time, the operators will only dose ferric chloride at $FeCl_3$ (4) in order to maintain permit requirements for total phosphorus discharge. Once the testing procedure begins, operators shall use feed point $FeCl_3$ (4) as needed in order to meet discharge requirements.
2) Beginning with Scenario 1, start feeding the specified "Starting Dosage" at the specified "Feed Point(s)."

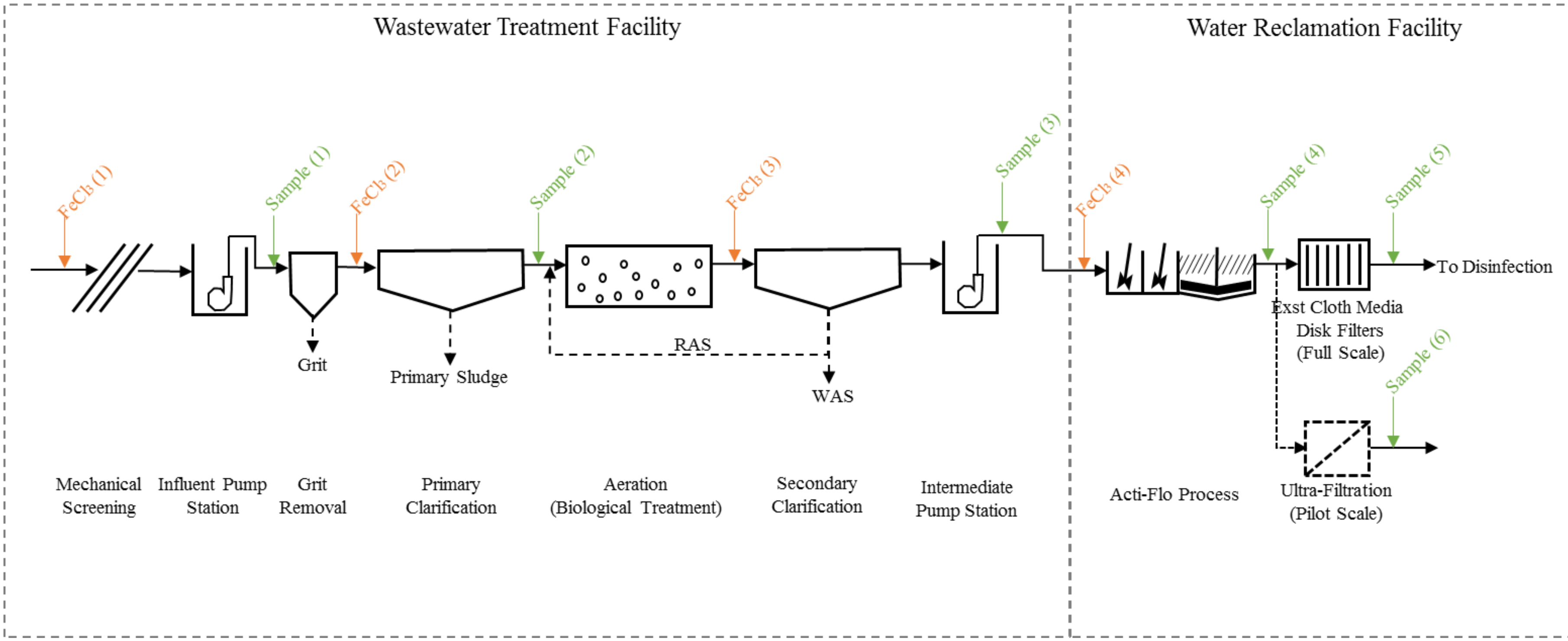


Figure 4.1 – Process Flow Schematic

TABLE 4.1
Ferric Chloride Feed Point Scenarios

Scenario(1)	Feed Point(s)	Starting Dosage (mg/L as $FeCl_3$)(2)	Ending Dosage (mg/L as $FeCl_3$)(2)
Single Feed Point (w/ $FeCl_3$(4))			
1	$FeCl_3$ (1)	10	TBD
2	$FeCl_3$ (2)	10	TBD
3	$FeCl_3$ (3)	10	TBD
Double Feed Points (w/ $FeCl_3$(4))			
4	$FeCl_3$ (1); $FeCl_3$ (3)	5 (each)	TBD
5	$FeCl_3$ (2); $FeCl_3$ (3)	5 (each)	TBD
Triple Feed Points (w/ $FeCl_3$(4))			
6	$FeCl_3$ (1); $FeCl_3$ (2); $FeCl_3$ (3)	3 (each)	TBD

(1) Under all scenarios, $FeCl_3$(4) must be monitored and recorded
(2) Dosage based on 100% $FeCl_3$ solution. City of Mankato feeds 37.4% $FeCl_3$, however, system dosing controls are based on pure solution.

3) Over a two day period, slowly and uniformly increase dosage(s) at specified feed point(s) until a total phosphorus concentration of 0.7 mg/L is achieved at Sample Point 3.
4) Over the next four days, uniformly adjust dosage(s) to maintain steady-state total phosphorus concentration of 0.7 mg/L TP or lower at Sample Point 3.
5) Once the steady-state period is over, shut off the specified feed point(s) for a period of 24 hours, only adjusting $FeCl_3$ (4) to meet permit requirements.
6) Repeat steps 1-5 for every ferric chloride feed scenario. Each scenario shall take approximately 7 days to complete.

The following data is to be collected for this analysis:

- Total Phosphorus (mg/L)
  - 24-hour composite samples (once daily) – Sample Points 1, 2, 3, and 4
- Daily Ferric Chloride chemical usage
  - Ferric chloride dosage (mg/L) – each feed point
  - Ferric chloride usage (gal/day) – each feed point

By maintaining a steady-state phosphorus concentration at Sample Point 3, the efficiency of the ferric feed points can be compared in terms of chemical usage needed to maintain a constant performance. The steady-state Secondary effluent concentration of 0.7 mg/L TP was chosen as a target value by the City's operating staff, as this is a typical value the City aims to achieve prior to the Water Reclamation Facility.

Sample Point 3 (Secondary effluent) was chosen as a control point in order to separate phosphorus removal between the Wastewater Treatment Facility and the Water Reclamation Facility. Under normal operations, the City uses ferric feed at the Water Reclamation Facility ($FeCl_3$ (4)) to ensure NPDES permit limits are met after tertiary treatment. Therefore, Sample Point 3 was a logical separation point in the system in order test ferric chloride feed applications at the wastewater facility, while also having the flexibility to maintain permit limits at the reclamation facility.

2) Comparison of Tertiary Treatment Methods

i. Overview and Purpose

As discussed in Section 3, the City of Mankato owns and operates a Water Reclamation Facility that includes tertiary treatment processes (Acti-Flo® and Disc-Filtration) designed to achieve low-range phosphorus removal (0.2 to 0.3 mg/L TP). The City believes much of this phosphorus removal is done in the Acti-Flo® process, while the Disc-Filtration units remove a small amount residual solids that escape the clarification step. Since its construction in the mid-2000's, the City has had no issues meeting permit limits for total phosphorus using this tertiary treatment system.

However, if permit limits become more stringent in the future, the City may need to consider new technologies to further remove phosphorus from their wastewater and determine how to handle additional biosolids. This is especially important considering the limited control the City has over the quality of non-contact cooling water returned from the Mankato Energy Center. Evaporation losses in the cooling water (up to 75% of total volume) condenses the concentration of phosphorus returned to the treatment facility. MEC is allowed to take up to 6.2 million gallons of reclaimed water per day. After evaporation losses, this can amount to up to 25% of the total water discharged to the Minnesota River. In order to ensure the blended water meets permit limits, the Water Reclamation Facility must produce water that is well below phosphorus limits. Historically, the facility produces water in the range of 0.2 to 0.3 mg/L TP. Reducing phosphorus concentrations below this may be pushing the practical limitations of their tertiary treatment process due to the costs associated with significantly increasing chemical dosages. Overdosing ferric chloride may also reduce pH below permit limits, which presents another potential practical limitation.

In light of these realizations, it is beneficial for the City to evaluate alternative options for tertiary treatment – particularly, tertiary membrane filtration in lieu of the existing Disc-Filters that provide minimal phosphorus removal after the Acti-Flo® process. Based on the discussion in Section 2, ultrafiltration technology has been successful in achieving ultra-low phosphorus removal ($\leq$ 0.1 mg/L) in multiple pilot-scale and full-scale applications. With pore sizes up to 1,000 times smaller than the City's Disc-Filtration units, ultrafiltration is expected to provide improved phosphorus removal.

The purpose of this analysis is to compare various pilot-scale ultrafiltration membranes against the performance of the City's full-scale tertiary treatment system.

ii. Procedure

(a) Pilot-scale Ultrafiltration (supplied by Wigen Water Technologies)

Three (3) pilot-scale ultrafiltration units were operated in parallel to treat both post-Acti-Flo® and post-Disc-Filtration effluent water. The ultrafiltration units were assembled onto a single pilot skid that was supplied by Wigen Water Technologies out of Chaska, MN. Table 4.2 summarizes manufacturer information for each of the ultrafiltration membranes. Figure 4.2 is a photo of the membrane skid after it was assembled.

Operation of the ultrafiltration units was performed simultaneously with the ferric chloride feed point analysis. Total feed flow to the skids was approximately 50 gallons per minutes (gpm). Table 4.3 summarizes operational information on filtration/backwash cycles for each membrane module used in the piloting process. Technical specifications of the membrane modules are provided in Appendix B.

TABLE 4.2
Ultrafiltration Membrane Information

Parameters	Units	Manufacturers		
		Inge (UF1)	**Toray (UF2)**	**DOW (UF3)**
Nominal Pore Size	microns	0.02	0.01	0.03
Active Membrane Surface Area	Sq. Ft.	645	775	829
Flow Direction	--	Inside-Out	Outside-In	Outside-In
Approx. Dimensions (Dia. x L)	inches	9.9" x 66"	8.5" x 96"	8.9" x 93"
Weight	--			
Full of Water	lbs	--	243	220
Empty	lbs	120	148	135
Material	--			
Membrane	--	PESM(1)	PVDF(2)	PVDF(2)
Casing	--	PVC(3)	PVC(3)	PVC(3)
Potting	--	Epoxy Resin	Epoxy Resin	Epoxy Resin
Membrane Fiber Dimensions	--			
Inside Diameter (ID)	mm	0.9	0.9	0.7
Outside Diameter (OD)	mm	4	1.4	1.3
Design Operating Pressure	psi	0 to 70	0 to 44	0 to 45
Operating Temperature	°C	1 to 40	1 to 40	1 to 40
Operating pH Range	Units	1 to 13	1 to 10	2 to 11
Oxidation Resistance	mg/L NaOCl	2,000	3,000	2,000
Maximum Instant Flux	GFD @ 20°C	35 to 105	100	65

(1) Polyethersulfone membrane
(2) Polyvinylidene fluoride
(3) Polyvinyl chloride

Figure 4.2 – Photo of Ultrafiltration Pilot Skid (Wigen)

TABLE 4.3
Ultrafiltration Operating Parameters

Parameters	Units	Manufacturers		
		Inge (UF1)	**Toray (UF2)**	**DOW (UF3)**
Filtration				
Flowrate	gpm	15.9	16.1	17.8
Flux	gfd	35	30	31
Filtration Time	minutes	30	30	30
Recovery	%	92	95	95
Backwash				
Backwash Flow	gpm	60	18.4	33
Backwash Flux	gfd	133	34	57
Backwash Duration	seconds	40	30	30
Air Scour Flow	scfm	0	3.8	3.8
Air Scour Duration	seconds	0	30	30
Forward Flush Flow	scfm	15	15	15
Forward Flush Duration	seconds	30	30	30

Components of the pilot skid included the following:

- Three (3) Membrane modules as specified in Table 4.2
- Three (3) Feed/CIP Pumps (3 HP, 50 gpm @ 47 psi, VFD drive)
- Three (3) Amiad TAF750 300 micron automatic backwashing feed strainers
- One (1) Backwash Pump (3 HP, 90 gpm @ 30 psi)
- One (1) 300 gallon HDPE feed water tank
- One (1) 300 gallon HDPE backwash tank
- One (1) 105 gallon HDPE CIP tank
- One (1) 1.5 HP air compressor
- One (1) Allen Bradley PLC and HMI for system operation and data recording
- One (1) HACH turbidimeter (feed water)
- Three (3) HACH turbidimeter (filtrate water)
- Four (4) 10 gallon PVC chemical storage tanks and peristaltic dosing pumps with calibration columns for CIP chemicals (sodium hypochlorite and citric acid)
- Skid dimensions: 200" (L) x 54" (W) x 120" (H)
- Skid weight: 5000 lbs. (approximately)

General operating/testing information for this analysis included the following:

1) Operating responsibilities were performed by Wigen Water Technologies both remotely and onsite between the dates of August 10th and November 12th. The City of Mankato assisted with troubleshooting and re-filling clean-in-place (CIP) chemicals for the pilot skid as needed. The pilot skid was to be operated continuously between 7 a.m. – 3 p.m. (at a minimum), 7-days per week.
2) City was responsible for supplying feed water to the membrane skids from the Acti-Flo® effluent chamber, as well as electrical supply for the skids. As described in Section 5, the feed water was re-routed to the Disc-Filter effluent due to issues with solids plugging the pre-filters.

3) Phosphorus sampling:

   a. Samples for total phosphorus were taken by Minnesota State University-Mankato once per day during membrane operation over the duration of the testing period.

   b. Sampling locations, as shown in the process flow diagram in Figure 4.3, are as follows:

      i. Post Acti-Flo® (PA) – 24-hr composite sample

      ii. Post Disc-Filtration (PDF) – grab sample

      iii. Inge Filtrate (UF1) – grab sample

      iv. Toray Filtrate (UF2) – grab sample

      v. DOW Filtrate (UF3) – grab sample

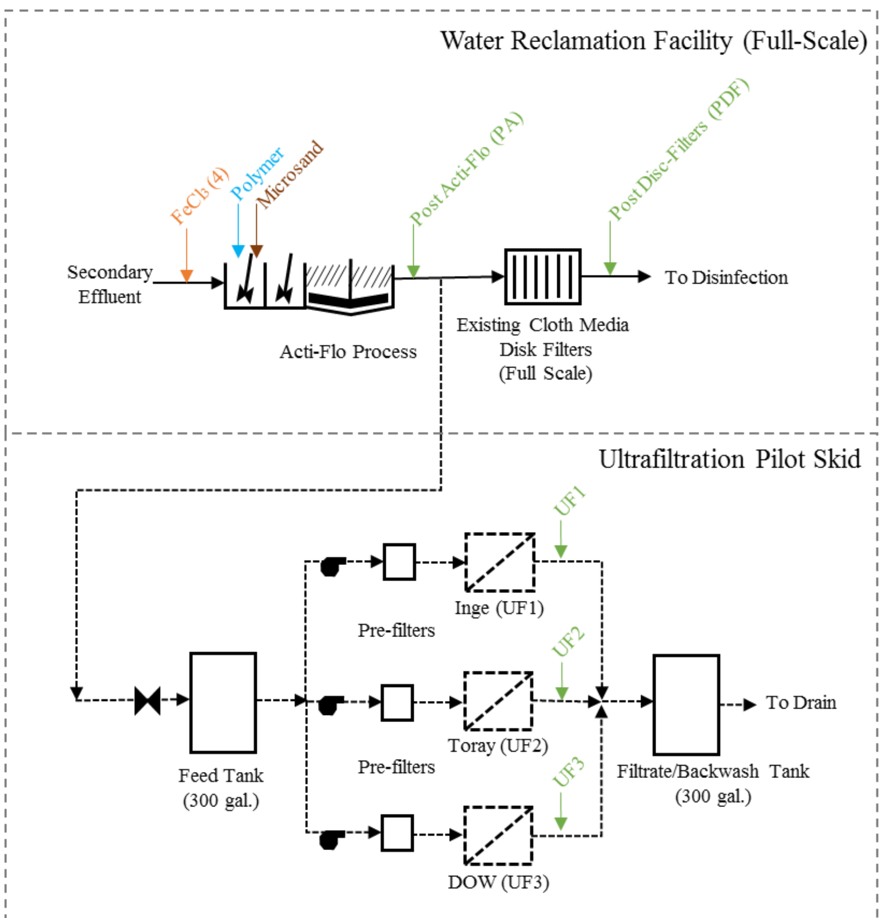


Figure 4.3 – Process Flow Diagram of Pilot-Scale Ultrafiltration

(b) Bench-Scale (supplied by Meiden America, Inc.)

One (1) bench-scale flat-sheet ceramic membrane unit supplied by Meiden America, Inc. (Northville, MI) was piloted to treat post-Acti-Flo® and Secondary effluent water. Table 4.4 summarizes manufacturer information for the ceramic membrane unit. Figure 4.4 is a photo of the bench-scale unit after it was assembled.

TABLE 4.4
Ceramic Membrane Information

Parameters	Units	Meiden Ceramic Membrane
Nominal Pore Size	microns	0.1
Active Membrane Surface Area	Sq. Ft.	0.431
Flow Direction	--	Outside-In
Style	--	Flat-sheet; Submerged
Membrane Flux Rate	gfd	29.4
Material	--	Alumina Ceramic

Figure 4.4 – Photo of Bench-Scale Ceramic Membrane Unit (Meiden)

General operating/testing information for this analysis included the following:

1) A representative from Meiden America, Inc. was onsite the week of November 9th to setup and operate the bench-scale membrane module, as well as train the City's operators. The City operated the module between the days of November 16th and December 18th.

2) Detailed operation and maintenance procedures are included in Meiden's pilot testing report in Appendix C.
3) Phosphorus sampling:
   a. Samples for total phosphorus were taken by Minnesota State University-Mankato 1 to 2 times per day during membrane operation over the timeframe of November 11th to November 23rd. The City completed the remaining testing up until December 18th.
   b. Sampling locations, as shown in the process flow diagram in Figure 4.5, are as follows:
      i. Meiden Filter Influent (MF INF) – grab sample
      ii. Meiden Filter Effluent (MF EFF) – grab sample
   c. The bench-scale unit was setup in two separate locations in order to vary the influent feed phosphorus concentrations:
      i. Acti-Flo® effluent (November 9th to December 1st)
      ii. Secondary effluent (December 7th to December 18th)

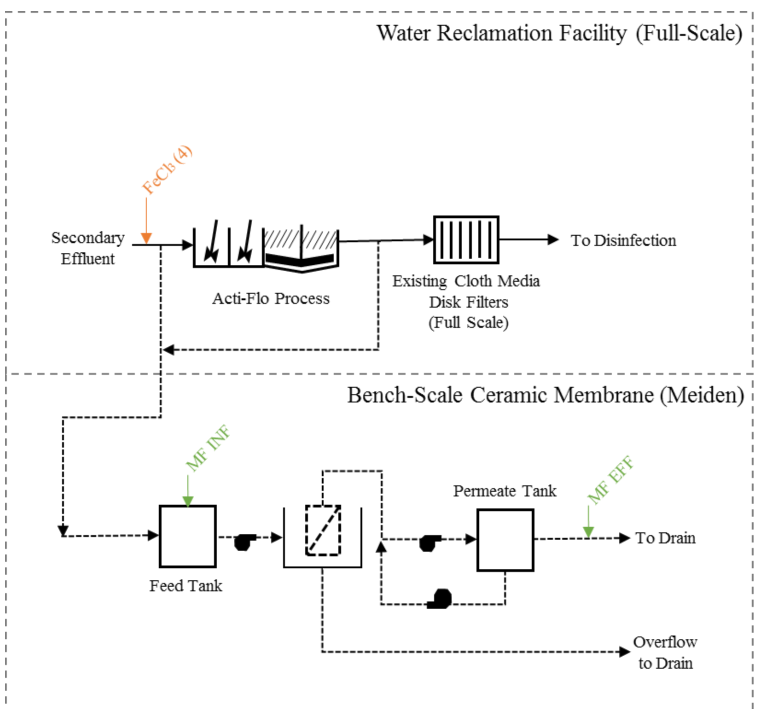


Figure 4.5 – Process Flow Diagram of Bench-Scale Ceramic Membrane System

3) Evaluation of Ultra-Low Phosphorus Removal

i. Overview and Purpose

Past studies have shown that ultra-low phosphorus removal (≤ 0.1 mg/L) is achievable using a combination of chemical and physical treatment processes in both pilot-scale and full-scale applications. The City of Mankato typically can achieve an effluent phosphorus concentration in the range of 0.2 to 0.3 mg/L TP after their tertiary treatment process. Phosphorus removal below this range is likely possible, but would require significant dosage increases of ferric chloride. This is because the required molar ratio of ferric iron and soluble phosphorus (mole Fe^{3+}/mole soluble P) increases as less soluble phosphorus is available to remove. For example, the theoretical dosage of ferric chloride needed to remove phosphorus to 0.1 mg/L is over 6 times greater than 1.0 mg/L. Dosages increase exponentially at even lower phosphorus concentrations. This presents a practical limitation through the cost of chemical usage, as well as its potential effect on lowering pH below permit limits (pH > 6.0). Increased chemical dosages will also impact the operation and maintenance of tertiary filtration equipment. Therefore, the full-scale practicality of ultra-low phosphorus removal is dependent on the optimization of chemical and physical treatment processes in conjunction with one another.

The evaluation of ultra-low phosphorus removal at the City of Mankato's treatment facilities includes the use of the City's full-scale system and pilot-scale tertiary filtration equipment. This evaluation is an extension of the procedures described in the previous analysis, as it includes the adjustment of ferric chloride dosages to maximum the removal of phosphorus.

The purpose of this analysis is to determine: 1) the technological capacity of ultra-low phosphorus at the Mankato treatment facilities; and 2) the practicality of full-scale implementation in terms of operational considerations and costs.

ii. Procedure

This analysis required operational adjustments in the City's full-scale tertiary treatment system, which presented potential issues with reclaim water quality and meeting permit requirements. Therefore, the experimental procedure described below was performed over a short duration when the Mankato Energy Center was not taking reclaim water. The equipment, process flow diagram, chemical feed points, and sampling locations in the procedure are the same as shown in Figure 4.3. The experimental procedure is as follows:

(a) Ultra-low phosphorus removal

Over a 3 hour time frame, the operators shall increase ferric chloride dosage at $FeCl_3$ (4) until a steady-state minimum phosphorus concentration is reached after the pilot-scale ultrafiltration units, or an effluent pH of 6 is reached (permitted minimum). The dosage shall start at typical operating values (~20 mg/L) and shall be increased every 30 minutes.

Sampling procedures:

i. Due to time constraints, *orthophosphate* samples shall be taken in lieu of total phosphorus. Grab samples shall be taken approximately every 15 minutes throughout the 3 hour duration at the following locations:
   1. Post Acti-Flo® (PA)
   2. Post Disc-Filtration (PDF)
   3. Inge Filtrate (UF1)
   4. Toray Filtrate (UF2)
   5. DOW Filtrate (UF3)

ii. Total iron (mg/L) shall be tested along with each orthophosphate sample.

iii. Post-Disc-Filter (PDF) pH and turbidity shall be monitored throughout the duration of the testing analysis.

iv. Upon completion, the full-scale tertiary treatment system shall be returned to normal operating conditions.

C. PHOSPHORUS TESTING PROCEDURES

All sampling and laboratory testing for this study was conducted by Minnesota State University – Mankato. The following paragraphs discuss the methods, materials, procedures, and evaluation of precision and calibration of the phosphorus sampling and testing analysis. All analyses were done in the Environmental Engineering Laboratory, 382 Trafton Science Center North, under the direction of Stephen Druschel, PhD, PE, Associate Professor of Civil Engineering. Laboratory analysts under Dr. Druschel's supervision were Bridget Anderson, Thu (Amy) Nguyen, Mohsen Alibrahim, and Kacie Zangel, all civil engineering undergraduates. Analytical guidance and demonstration was provided by Jim Archer, Industrial Chemist, City of Mankato Wastewater Treatment Plant.

1) Method of Analysis

The analysis of phosphorus in water samples was done using persulfate and acid digestion and colorimetric analysis according to Method 4500-P, Sections A, B and C of Standard Methods (Rice et al., 2012), with modifications proposed by Hach (2015a and 2015b) (modifications listed below). Summarizing from Standard Methods:

- Phosphorus can stimulate the growth of algae and other aquatic microorganisms in nuisance quantities, when discharged into receiving waters where phosphate is a growth limiting nutrient;
- Phosphorus occurs in natural waters and wastewaters as orthophosphates, condensed (poly) phosphates and organically bound phosphates. Organically bound phosphates are typically presented as within the structure of organic cells, tissue or detritus.
- Colorimetric analysis responds primarily to orthophosphate, but not to condensed phosphates and organically bound phosphates.
- Digestion releases and converts condensed phosphates and organically bound phosphates to orthophosphate where it can measured using colorimetric analyses and termed "total phosphorus".
- Colorimetric analysis of non-digested samples measures the phosphate fraction termed "reactive phosphorus", largely a measure of orthophosphate but likely with a small fraction of condensed phosphate.

Selected for this study are digestion by persulfate and sulfuric acid at 150° C for 30 minutes, neutralization with sodium hydroxide, then molybdate-ascorbic acid colorization followed by colorimetric measurement at 880 nm wavelength. Colorimetric measurement was done using a Hach DR 6000 spectrophotometer.

The modifications proposed by Hach include:

- The combination of the persulfate with sulfuric acid for digestion rather than either method individually (Hach 2015a);
- The molybdate-ascorbic acid combination for colorization, rather than alternative colorization agents (Hach 2015b); and,
- The use of spectrophotometric measurement at 880 nm, rather than an alternative wavelength corresponding to the response of the alternative colorization agents (Hach 2015b).

2) Materials

Glassware used in this study were dedicated for these analyses and removed from general laboratory practice. Analysis vials, 60 mL beakers, 25 mL graduated flasks, gas-tight glass syringes in 5 mL and 10 mL volume, and syringe pipet needles were all taken from previously unused stocks. 100 mL graduated flasks were acid washed with extended acidification to discourage any prior phosphate contamination.

Analysis vials were obtained from Hach as part of a phosphorus analysis kit. Vials came pre cleaned and preloaded with sulfuric acid.

Glassware was cleaned prior to use (including new syringes, needles, flasks and beakers but not vials) using acid wash technique suggested in Standard Methods: 6.0 N hydrochloric (HCl) acid was flushed over all glass surfaces likely to touch liquid to be analyzed, followed by triple rinsing with MSU laboratory deionized (DI) water. Analysis vials were capped for acid flushing and inverted to confirm acid flushing of cap interior surfaces; inversion was done for at least 1 full minute. Acid washed glassware was allowed to air dry then capped or covered with aluminum foil for protection against dust or other contaminates.

Deionized water for cleaning was obtained from the MSU laboratory DI system. Deionized water for dilutions and mixing was supplied by the City of Mankato from their wastewater treatment plant laboratory DI system. Sulfuric acid was supplied by Hach preloaded in analysis vials used for the first time; sulfuric acid (1.54 N, phosphate free) was thereafter obtained from NC Labs of Birnamwood, WI. Sodium hydroxide was supplied by Hach in combination with the analysis vials used for the first time; sodium hydroxide (1.54 N, phosphate free) was thereafter obtained from NC Labs. Potassium persulfate was obtained from Hach in "powder pillow" form consisting of premeasured individual analytical doses contained in sealed foil packets.

Phosphate standard was obtained from NC Labs in the following concentrations:

- 1 ppm as P (1.00 mL = 1 ug P)
- 5 ppm as P (1.00 mL = 5 ug P)
- 50 ppm as P (1.00 mL = 50 ug P)
- 1000 ppm as P (1.00 mL = 1 mg P)

3) Analysis

The method steps for the analysis of total phosphorus included:

1. Acid wash glassware, including analysis vials and caps, syringes, and 60 mL beakers if used for transfer.
2. Load 2.00 mL of 1.54 N sulfuric acid into analysis vials using auto pipet (two 1 mL aliquots).
3. Pipet 5.00 mL of sample liquid into vial using glass syringe. Record vial number with tabulation of sample. Sample may be stored in this condition for up to 28 days according to Standard Methods. Acid wash glass syringe in preparation for next sample measurement.
4. Add contents of potassium persulfate powder pillow and cap; shake vial vigorously for 20 to 30 seconds.
5. Load vials (up to 12) into heater block pre-warmed to 150° C. Set timer to 30 minutes.

6. Upon completion of 30 minute period, remove vial and cool. Check vial for “boil off” of more than 1 mL (about 1 cm level drop); if so, note on vial tabulation.
7. Load 2.00 mL of 1.54 N sodium hydroxide into analysis vials using auto pipet (two 1 mL aliquots).
8. Clean and dry vial exterior with Kim wipe.
9. Place vial into spectrophotometer and press read (zero).
10. Add contents of PhosVer® 3 powder pillow and cap; shake vial vigorously for 20 to 30 seconds. Sample may exhibit blue tint.
11. Place vial into spectrophotometer and press read. Timer will count down 2:00 minutes then beep when reading will be displayed in ppm-P. Record reading on vial tabulation.
12. Dispose of vial contents into dedicated waste container. Return glassware for acid washing.

Note: Should reactive phosphorus be required for measurement rather than total phosphorus, steps 2 through 7 are omitted.

Prior to evaluating water samples from the Mankato Wastewater Treatment Plant, this analytical method was evaluated using approximately 200 laboratory-prepared samples. Specific evaluations included: response of blank samples; responses from two deionized water sources; analytical drift, contaminant drag-through after acid wash and triple deionized water rinse; precision; and calibration. Samples above 2.00 ppm-P were recommended for ten-fold in-tube dilution to bring results onto linear calibration range. A minimum detection level of 0.04 ppm-P was determined. Analytical method steps and quality control procedures were established and systematized.

A copy of the Precision Evaluation and Calibration Analysis is included in Appendix D of this report.

4) Quality Control

Analytical samples were checked using quality control procedures related to checks on the reagent addition, reagent mixing, and prevention of "boil down" during digestion. When volumes within an analytical vial were reduced by more than 10% or about 1 mL during digestion, the analysis was not accepted.

Matrix effects were evaluated as samples were collected and analyzed. Two matrix spikes were run per every sampling sequence, with 1 ppm-P and 2 ppm-P final concentration spikes being added as 50 uL aliquots, an adjustment of 1% of the specimen volume (10 mL of 1000 ppm-P diluted to 100 mL and 20 mL of 1000 ppm-P diluted to 100 mL, respectively, used as 50 uL spikes into 5 mL samples). Measurement of matrix spikes were checked against the non-spiked measurement, adjusting for the additional mass and the dilution caused by the spike. Additional quality control samples included a blank and a 0.20 ppm-P standard in every digestion sequence (12 total vials per digestion heating cycle).

Quality control limits were established as: blanks must have a total phosphorus measurement of 0.02 mg/L or less; standards must have a difference in total phosphorus measurement from the standard concentration of no more than 0.07 mg/L (absolute), and no more than one occurrence within five consecutive digestion/analysis cycles of 0.04 mg/L difference in total phosphorus measurement from the standard concentration. Analyses with results beyond quality control limits were not accepted for evaluation.

5) References

Hach (2015a). Phosphorus, Total, USEPA PhosVer® 3 with Acid Persulfate Digestion, Method 8190. Hach Company, Loveland, CO. Downloaded August 30, 2015 from www.hach.com/asset-get.download.jsa?id=7639983829

Hach (2015b). Phosphorus, Reactive (Orthophosphate), USEPA PhosVer® 3 (Ascorbic Acid), Method 8048. Hach Company, Loveland, CO. Downloaded August 30, 2015 from www.hach.com/asset-get.download.jsa?id=7639983836

Rice, E.W., Baird, R.B., Eaton, A.D., Clesceri, L.S., editors. 2012. Standard Methods for the Examination of Water and Wastewater. 22nd Edition. American Public Health Association. Washington, DC.

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SECTION 5 RESULTS AND DISCUSSION

A. GENERAL

This Section provides a summary of the results and discussion items for each experimental analysis described in Section 4. Experimental testing data and operational information can be found in Appendix E of this report.

B. INFLUENT FLOWS AND PHOSPHORUS LOADINGS

Raw wastewater flows and phosphorus loadings over the duration of the testing period are summarized in Table 5.1 and shown in Figures 5.1 and 5.2, respectively. Figure 5.3 graphs raw influent flow versus phosphorus concentration. As expected, there is a weak inverse correlation between influent flow and phosphorus concentration ($R^2 = 0.0826$). In other words, at a given mass loading (e.g. lbs/day), the phosphorus concentration is determined by the magnitude of flow. During high flows, phosphorus concentrations are generally lower due to dilution (and vice versa). Since phosphorus mass loading is more independent of flow, it is used to evaluate removal efficiencies between treatment processes and to compare phosphorus removal on a day-to-day basis.

TABLE 5.1
Influent Flow and Phosphorus Loadings

Parameter	Daily Flow (MGD)	Total Phosphorus	
		mg/L	lbs/day
Average	8.02	4.09	268
Minimum	6.05	0.79	50
Maximum	11.56	9.88	576

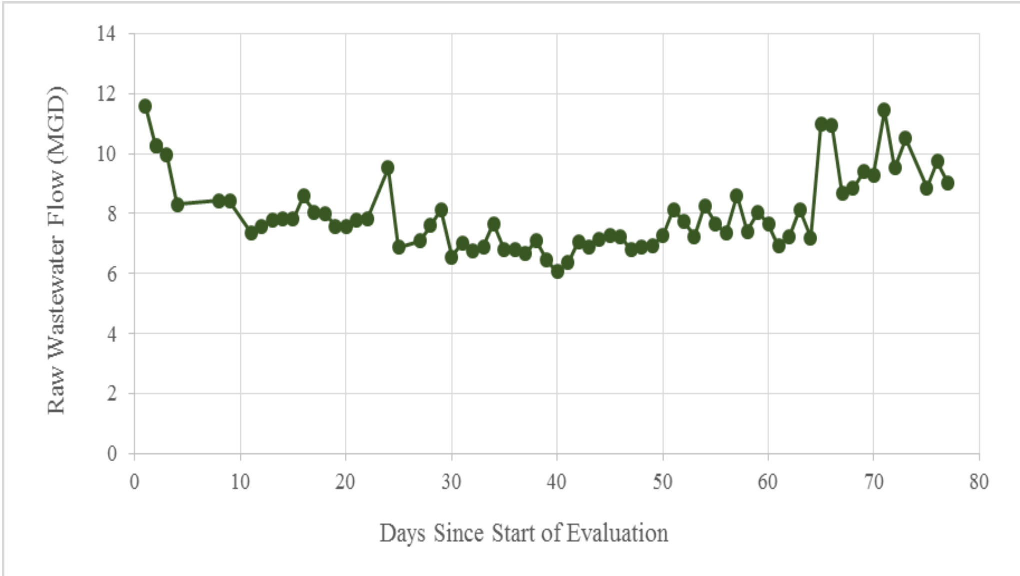

Figure 5.1 – Raw Wastewater Flow Over Duration of Testing Period

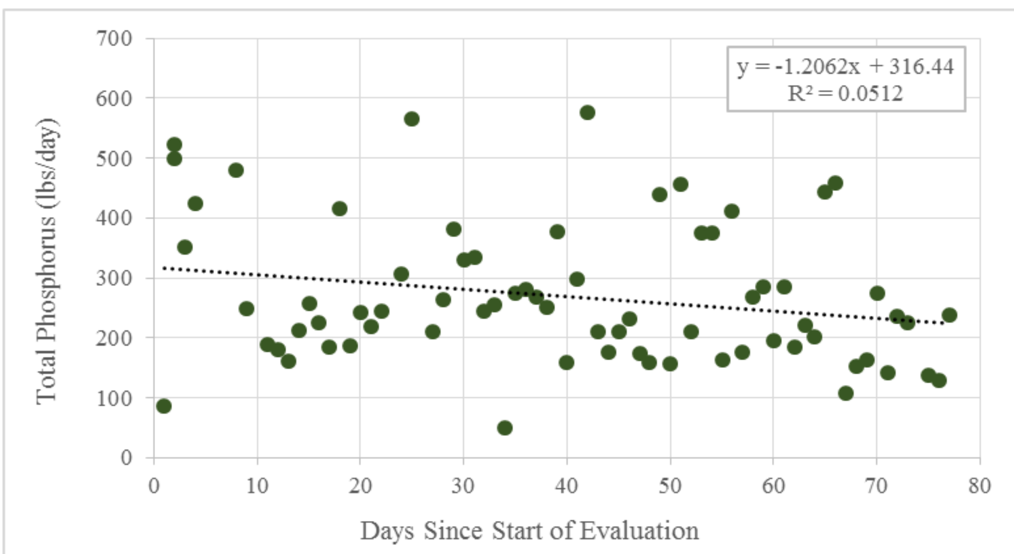

Figure 5.2 – Influent Total Phosphorus Loadings

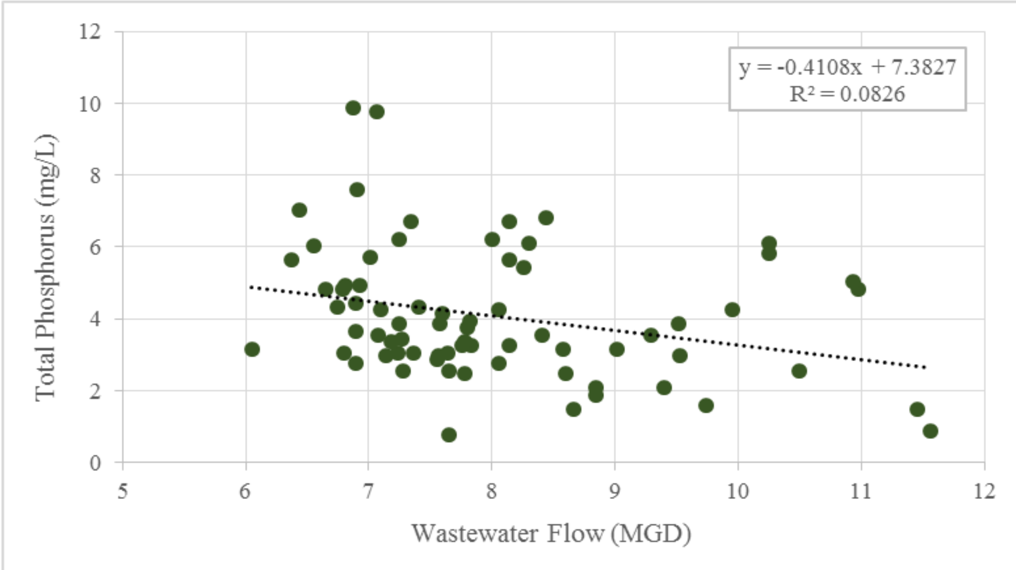

Figure 5.3 – Influent Wastewater Flow vs. Total Phosphorus Loadings

C. FERRIC CHLORIDE FEED APPLICATION ANALYSIS

Over the duration of the phosphorus sampling analysis (September 7th to November 23rd, 2015), ferric chloride feed application scenarios were tested as described in the Table 5.2 below.

TABLE 5.2
Experimental Time Frame of Ferric Chloride Feed Point Analysis

Time Frame (days)	Feed Scenario(1)	Feed Points(2)
0 to 11	6	FeCl3(2)
12 to 41	2	FeCl3(3)
42 to 62	3	FeCl3(2); FeCl3(3)
63 to 77	5	FeCl3(1); FeCl3(2); FeCl3(3)

(1) Subsequent figures illustrate these feed scenarios in chronological order
(2) See Figure 4.1 for feed point locations

The City of Mankato uses 37.4% $FeCl_3$ solution (1.42 S.G.; 11.9 lbs/gal) as supplied by Hawkins, Inc. of Roseville, MN. All ferric chloride dosages reported in this study are presented as pure $FeCl_3$ solution (or 100% $FeCl_3$ solution), which is how the City's control system is configured to control chemical metering pump operation with respect to wastewater flow at each feed point. A sample calculation of chemical pumping feed rate is as follows:

Given: Dosage = 10 mg/L as $FeCl_3$

Wastewater flowrate = 9.38 MGD

37.4% $FeCl_3$ Solution Unit weight = 88.61 lbs/ft^3

Unit Weight of Water = 8.34 lbs/gal

Calculation:

$$\frac{(10 \text{ mg/L } FeCl_3 \times 8.34 \times 9.38 \text{ MGD}) \times 7.48 \text{ gal/ft}^3}{(88.61 \text{ lbs/gal}) \times 0.374} = 177 \text{ gal/day of 37.4\% } FeCl_3 \text{ solution}$$

Due to time constraints with conducting daily phosphorus sampling, Scenarios 1 and 4 in Table 4.1 were not evaluated for phosphorus removal. The experimental time frame for each feed scenario was originally estimated to take 7 days. This time frame was found to be inadequate due to issues with adjusting dosages and trying to reach a steady-state total phosphorus concentration at the Secondary Clarifier effluent, which was only sampled once per day. This provided the operators little control over phosphorus removal in the wastewater treatment system and, ultimately, steady-state concentrations were not consistently achieved. Upon this realization, it was determined that feed point applications would be compared in terms of removal efficiency at similar dosages.

Phosphorus removal trends with respect to ferric chloride dosage is affected by a number of uncontrollable variables in the City's full-scale system. In particular, variable influent phosphorus loadings can have a significant impact on experimental correlations. The City of Mankato receives discharge from 16 industrial users that generate a highly variable phosphorus loading on a day-to-day basis. The City doses ferric chloride based on flow-pacing (i.e. variable wastewater flow) and not phosphorus loading. Since chemical removal of phosphorus is dependent on the molar ratio of ferric ions and soluble phosphorus (irrespective of flow), this dosing setup provides limited control over phosphorus removal in an experimental setting, although it's sufficient for meeting permit limits and highly common in full-scale applications.

1) Phosphorus Removal in Unit Processes

i. Influent

Based on testing data provided by the City, influent phosphorus measurements were not found to be strongly correlated to ferric chloride dosing to the 42-inch interceptor sewer (sample point $FeCl_3$(1)). Historically, the City operators have used this feed point for odor control at the screening and grit buildings. These processes do not provide the physical means to significantly remove precipitated phosphorus from the liquid wastewater stream. At sufficient ferric chloride dosages, phosphorus removal is not accomplished until the Primary Clarification process. At low dosages (<5 mg/L as $FeCl_3$), the creation of hydroxyl precipitates and subsequent removal of phosphorus is unlikely as it has to compete with sulfides in the raw wastewater.

ii. Removal in Primary Clarifiers

Figure 5.4 shows total phosphorus measurements (mg/L and lbs/day) on the Primary Clarifier effluent over the duration of the study. On average, the Primary Clarifiers removed 34.8% of the total influent phosphorus in the system. As shown in Figure 5.5, there was a general positive correlation between phosphorus removal and ferric chloride dosage at $FeCl_3$ (2). As expected, percent removal increased in the Primary Clarifiers as ferric dosage was increased at feed point $FeCl_3$ (2) in Scenario 2.

Figure 5.4 shows some notable trends in Primary effluent phosphorus, which are highlighted in the following bullet points:

- Starting on Day 11, phosphorus concentration steadily increases after the Primary Clarifiers, which is likely associated with the decrease in ferric chloride dosage from 14-16 mg/L to 5-6 mg/L.
- After Day 30, phosphorus concentration steadily decreases after the Primary Clarifiers, which is likely associated with the increase in ferric chloride dosage back to 14-16 mg/L.

- When switching to Feed Scenario 3 on Day 42, Primary effluent phosphorus measurements become highly random since ferric chloride is not being fed prior to the Primary Clarifiers.

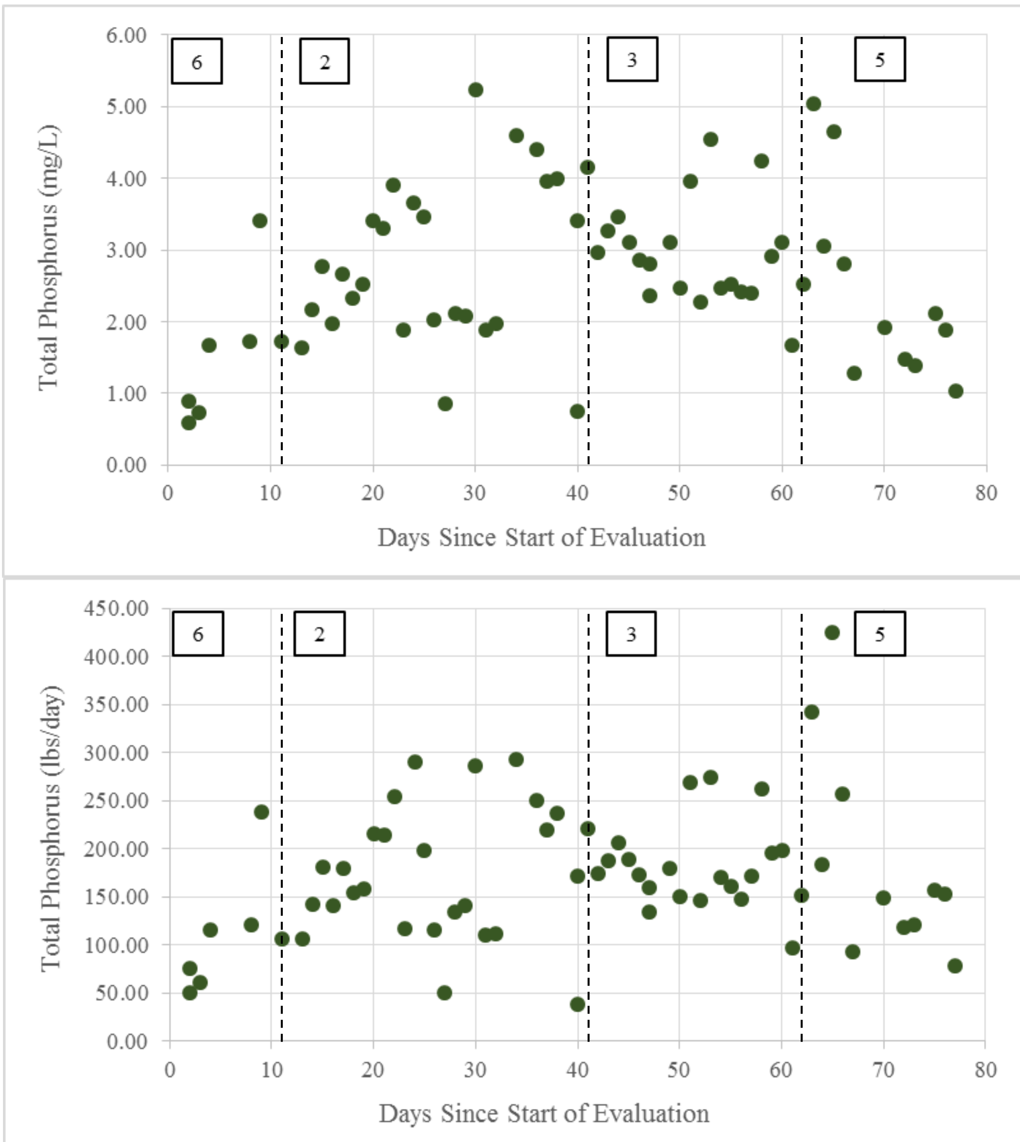

Figure 5.4 – Primary Clarifier Effluent
Total Phosphorus Concentration (top) and Loading (bottom)

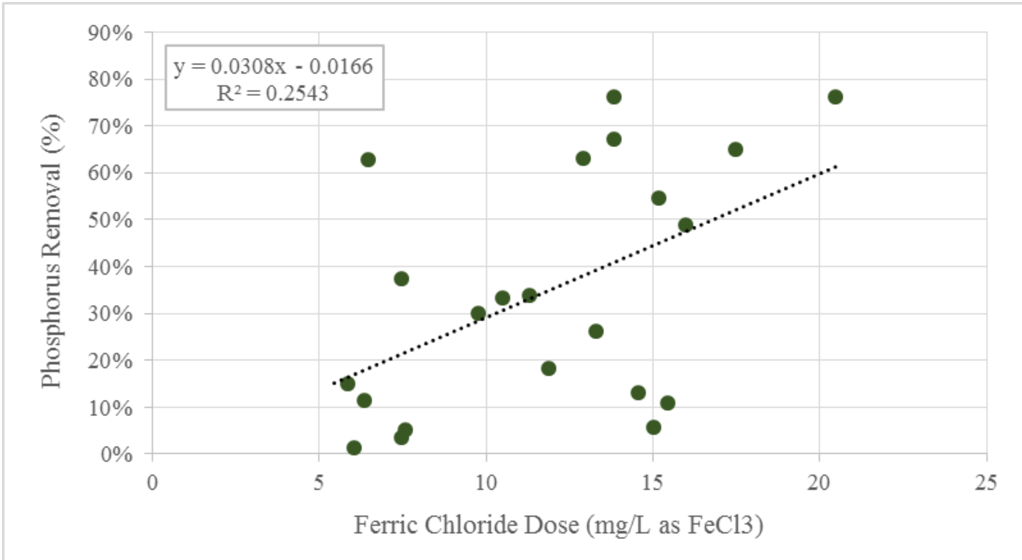

Figure 5.5 - Percent Removal in Primary Clarifiers vs. Ferric Chloride Dose at $FeCl_3$ (2)

There was no correlation ($R^2 = 0.0086$) between ferric dosage and Primary effluent phosphorus concentration. This was expected since the City doses ferric chloride based on flow-pacing (i.e. variable wastewater flow) and not influent phosphorus loading. Thus, variable phosphorus loading is unaccounted for, resulting in poor correlations. At constant phosphorus loading, ferric chloride dosage is expected to be strongly correlated to effluent phosphorus concentration. However, this is an uncontrollable variable in this full-scale experiment.

Table 5.3 summarizes phosphorus removal in the Primary Clarifiers for each feed scenario tested. Overall correlations between the feed scenarios were not well defined. Scenario 6 produced the highest removals, but was also mistakenly dosed with the highest amount of chemical to the system. Instead of maintaining a constant overall dosage to the system, the dosage was increased when going to three feed points (i.e. dosage per feed point was maintained). Overall, feeding ferric chloride to the Primary clarifier influent (Scenario 2) resulted in good phosphorus removal (37%). However, Scenario 3 also showed that phosphorus is removed irrespective of ferric chloride dosing prior to the Primary Clarifiers.

TABLE 5.3
Average Phosphorus Removal in Primary Clarifiers

Feed Scenario	Feed Points	Total Phosphorus (lbs/day)		% Removal	$FeCl_3$ Dose (mg/L as $FeCl_3$)	
		Raw Influent	Primary Effluent		Overall System	Per Feed Point
2	$FeCl_3$(2)	273	172	37.0%	12.0	12.0
3	$FeCl_3$(3)	271	181	33.2%	14.4	14.4
5	$FeCl_3$(2); $FeCl_3$(3)	243	189	22.2%	14.8	7.4
6	$FeCl_3$(1); $FeCl_3$(2); $FeCl_3$(3)	388	110	71.6%	23.1	7.7

iii. Removal in Secondary Clarifiers

Figure 5.6 shows total phosphorus measurements (mg/L and lbs/day) on the Secondary Clarifier effluent over the duration of the study. On average, the activated sludge process removed 41.5% of total phosphorus introduced into the system (biological uptake and chemical precipitation in the Secondary Clarifiers). As shown in Figure 5.7, there was a general positive correlation between phosphorus removal and ferric chloride dosage at $FeCl_3$ (3). As expected, removals increased in the Secondary Clarifiers as ferric chloride dosage was increased at feed point $FeCl_3$(3) in Scenario 3. Compared to the Primary Clarifier removals in Figure 5.5, phosphorus removal was higher in the Secondary Clarifiers likely due to the oxidation of sulfide in the aeration basins; thus, less competition for reaction with ferric chloride.

Figure 5.6 shows some notable trends in Secondary effluent phosphorus, which are highlighted in the following bullet points:

- Starting on Day 11, phosphorus concentration steadily increased after the Secondary Clarifiers, which is associated with a decrease in ferric chloride dosage from 14-16 mg/L to 5-6 mg/L as well as switching the feed point to pre-Primary Clarifiers.
- On Day 25, phosphorus concentration rapidly decreased, which is associated with an increase in ferric chloride dosage back to the 14-16 mg/L range.

- On Day 41, Feed Scenario 3 (single-point feed to Secondary Clarifier influent) began. From this day on, effluent phosphorus was consistently reduced.
- On Day 63, multi-point ferric chloride feed to the Primary and Secondary Clarifiers began. An initial uptick in phosphorus resulted, but decreased substantially after Day 67 when raw influent phosphorus loadings significantly decreased. Overall, multiple feed point application enhanced phosphorus removal after the Secondary clarifiers compared to single-point feed.

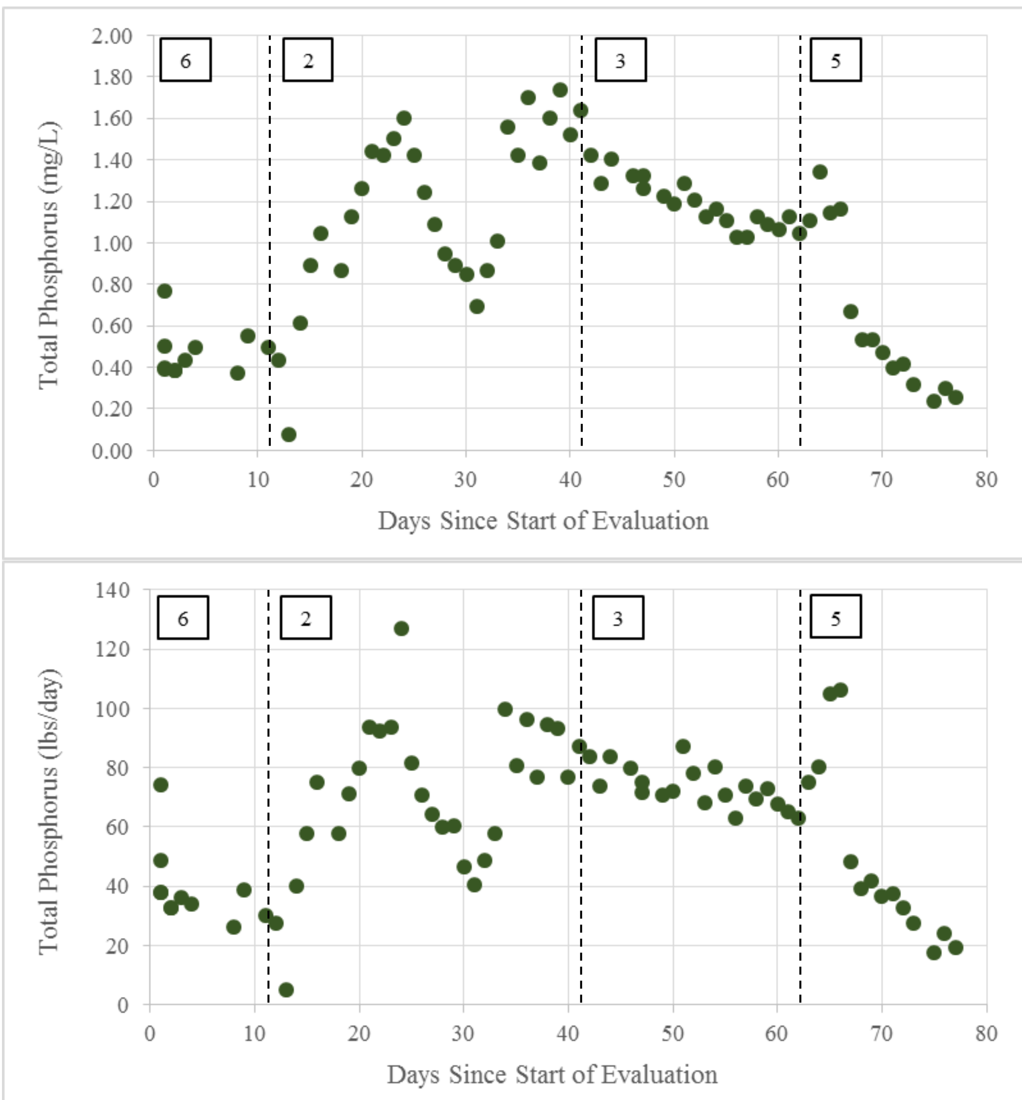

Figure 5.6 – Secondary Clarifier Effluent
Total Phosphorus Concentration (top) and Loading (bottom)

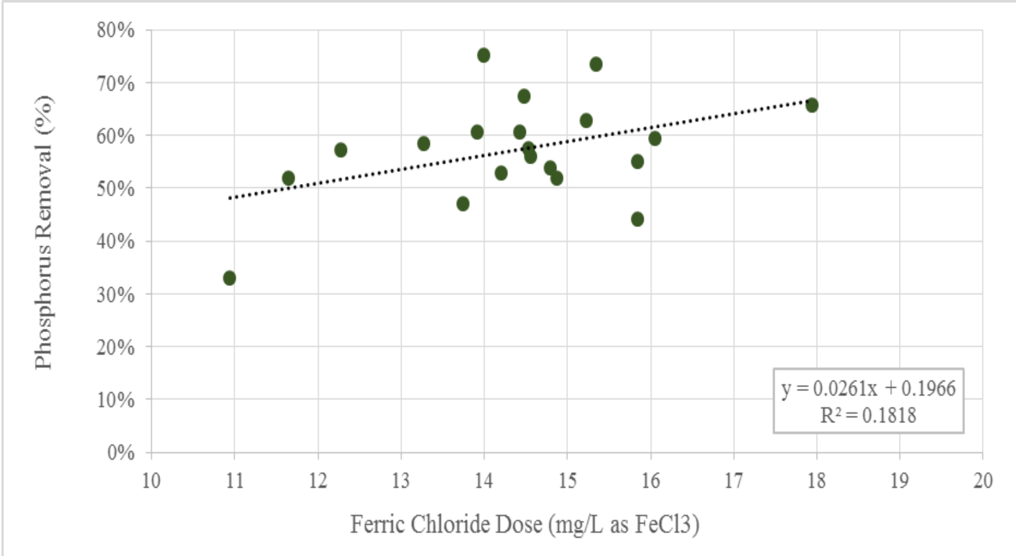

Figure 5.7 - Percent Removal in Secondary Clarifiers vs. Ferric Chloride Dose at $FeCl_3$ (3)

Table 5.4 summarizes phosphorus removal in the Secondary Clarifiers for each feed scenario tested. On average, the multi-feed points in Scenarios 5 and 6 produced the best removal efficiencies in the Secondary Clarifiers (≥70% of Primary effluent phosphorus).

TABLE 5.4
Average Phosphorus Removal in Secondary Clarifiers

Feed Scenario	Feed Points	Total Phosphorus (lbs/day)		% Removal	$FeCl_3$ Dose (mg/L as $FeCl_3$)	
		Primary Effluent	Secondary Effluent		Overall System	Per Feed Point
2	$FeCl_3$(2)	172	72	58.1%	12	12
3	$FeCl_3$(3)	181	73	59.7%	14.4	14.4
5	$FeCl_3$(2); $FeCl_3$(3)	189	52	72.5%	14.8	7.4
6	$FeCl_3$(1); $FeCl_3$(2); $FeCl_3$(3)	110	33	70.0%	23.1	8

2) Overall Performance of Ferric Feed Applications

Figure 5.8 illustrates overall phosphorus removal (% removed from influent) as a function of time. Across all feed scenarios, the average total phosphorus removal after the Secondary Clarifiers was 76.3% of influent loading. Figure 5.9 shows Secondary effluent phosphorus concentration as a function of overall ferric chloride dosing to the system. As expected, higher dosages of ferric chloride (irrespective of feed location and allocation) increased phosphorus removal in the overall wastewater system. However, it is clear that variable phosphorus loading had an impact on the correlation.

Table 5.5 summarizes overall phosphorus removal for each feed scenario tested. The following bullet points highlight observations of the results:

- On average, all feed scenarios achieved at least 73% removal of influent phosphorus at the Secondary Clarifier effluent.
- The multi-point feed scenarios (5 and 6) produced higher removal compared to both single-point feed scenarios.
- Overall, Scenario 6 (triple-point feed) achieved the highest removal efficiency of 91.5%, on average; however, this feed scenario was also mistakenly dosed with the highest amount of chemical to the system. Instead of maintaining a constant overall dosage to the system, the dosage was increased when going to three feed points (i.e. dosage per feed point was maintained).
- Scenario 5 (multi-point feed to Primary and Secondary Clarifier influent) was approximately 5% more efficient than single-point feed to either clarifier at comparable dosages.

TABLE 5.5

Overall Phosphorus Removal in Wastewater Treatment System

Feed Scenario	Feed Points	Total Phosphorus (lbs/day)		% Removal	$FeCl_3$ Dose (mg/L as $FeCl_3$)	
		Influent	Secondary Effluent		Overall System	Per Feed Point
2	$FeCl_3$(2)	273	72	73.6%	12	12
3	$FeCl_3$(3)	271	73	73.1%	14.4	14.4
5	$FeCl_3$(2); $FeCl_3$(3)	243	52	78.6%	14.8	7.4
6	$FeCl_3$(1); $FeCl_3$(2); $FeCl_3$(3)	388	33	91.5%	23.1	8

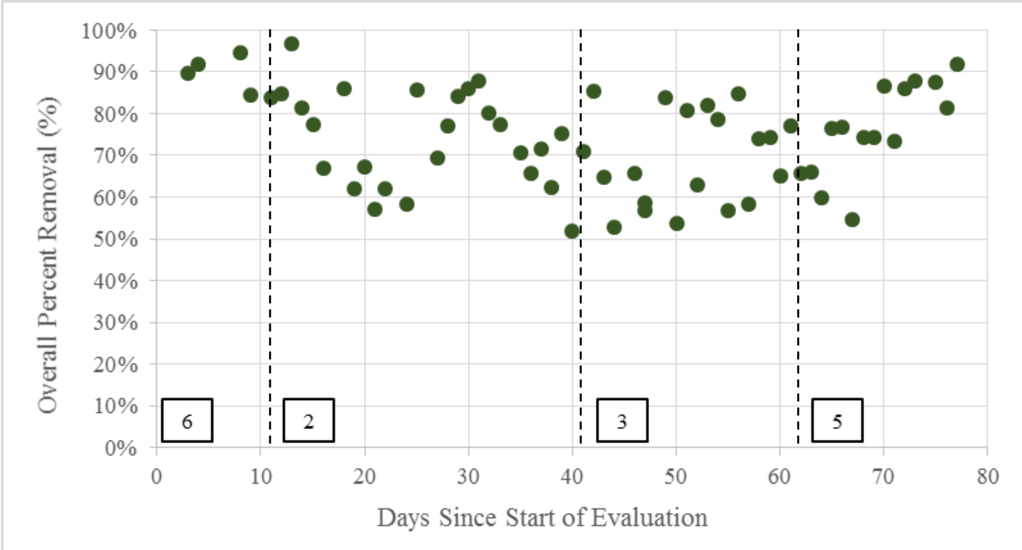

Figure 5.8 – Overall Percent Phosphorus Removal in Wastewater Treatment System

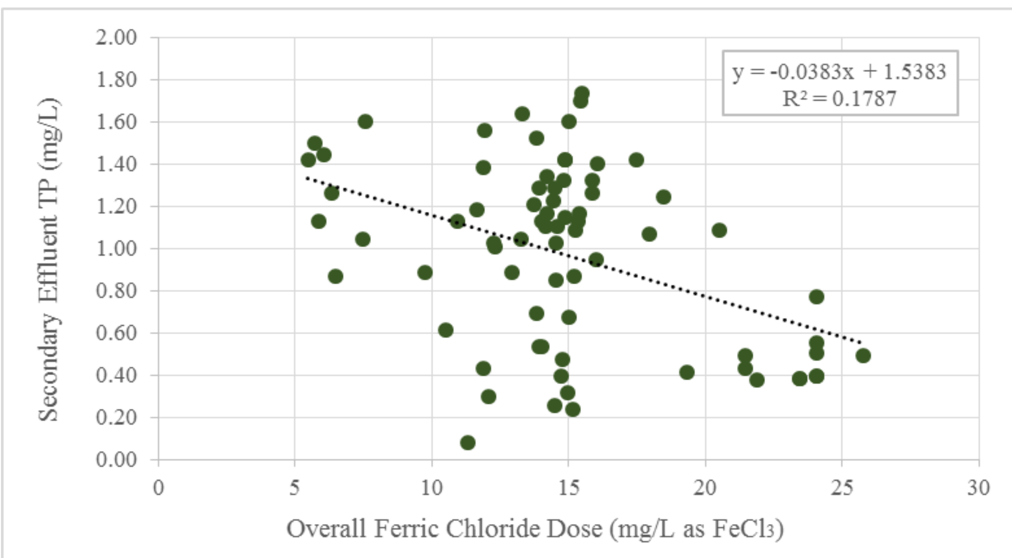

Figure 5.9 – Secondary Effluent TP (mg/L) vs. Ferric Chloride Dose

D. ULTRA-LOW PHOSPHORUS REMOVAL

1) Comparison of Tertiary Treatment Technologies Under Normal Operating Conditions

Table 5.6 summarizes phosphorus concentration and removal efficiencies measured at each sampling point over the duration of the pilot study, including testing results of the full-scale and pilot-scale tertiary treatment technologies. Figure 5.10 illustrates average phosphorus removal and percent removal at each sampling point. These results are indicative of the overall performance of the full-scale and pilot-scale treatment technologies under normal full-scale operating conditions and ferric chloride dosages at feed point $FeCl_3$(4).

Observations of the full-scale tertiary treatment system:

- At normal ferric chloride dosages (~20 mg/L as $FeCl_3$), the full-scale Acti-Flo® and Disc-Filtration system produced an average effluent total phosphorus concentration of 0.17 mg/L. This is on the low-end range of what the City typically achieves out of the system.
- The Disc-Filtration units achieved virtually zero removal of phosphorus after the Acti-Flo® process.
- Overall phosphorus removal in the system was nearly 96% of the total influent phosphorus.
- The 95% confidence interval lower limit indicates that, on average, ultra-low phosphorus removal (≤ 0.1 mg/L TP) is not achieved in this system at the current operating conditions.
- Minimum phosphorus concentration measurements indicate that the system may be able to consistently achieve ultra-low phosphorus removal under optimized operating conditions (i.e. chemical feed adjustments).

TABLE 5.6

Ultra-Low Phosphorus Removal – Results Under Normal Operating Conditions

Sample Location	Sample Population (n)	TP Conc. (mg/L)			95% Confidence Lower Limit (mg/L)	95% Confidence Upper Limit (mg/L)	% TP Removal
		Minimum	Maximum	Average			
Wastewater Treatment Facility							
Influent	71	0.79	9.88	4.09	3.66	4.51	0.0%
Primary Effluent	66	0.59	5.24	2.67	2.40	2.93	34.8%
Secondary Effluent	74	0.08	1.74	0.97	0.87	1.07	76.3%
Water Reclamation Facility							
Post ActiFlo (full-scale)	70	0.03	0.48	0.17	0.15	0.20	95.8%
Post Disc Filter (full-scale)	70	0.02	0.56	0.17	0.14	0.20	95.9%
Inge (0.02 µm)	46	0.01	0.50	0.12	0.09	0.14	97.1%
Toray (0.01 µm)	51	0.03	0.32	0.11	0.09	0.13	97.2%
DOW (0.03 µm)	33	0.00	0.56	0.13	0.10	0.17	96.8%
Meiden Ceramic Filter (0.1 µm)	35	0.00	0.08	0.02	0.02	0.03	99.4%

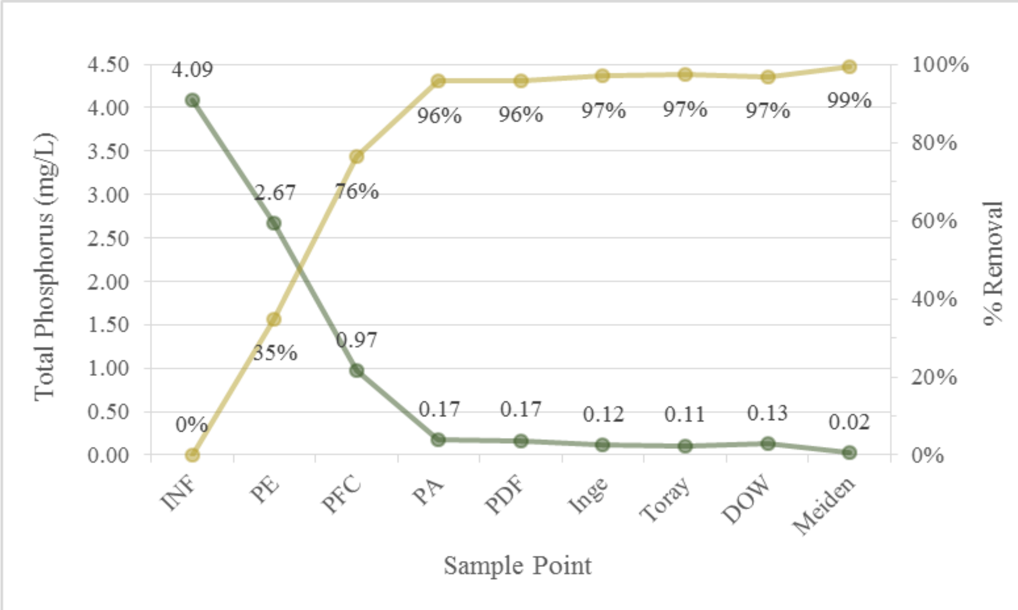

Figure 5.10 – Ultra-Low Phosphorus Removal – Normal Operating Conditions

Observations of the pilot-scale ultrafiltration membranes supplied by Wigen Water Technologies (see Appendix B for copy of pilot report):

- The pilot skid had issues treating the Acti-Flo® effluent water due to residual microsand clogging the cartridge filters. Larger pore filters were used to alleviate this issue, but it was ultimately decided that the sand could damage the ultrafiltration membranes. This issue was resolved by switching the feed water to post Disc-Filtration.

- At normal ferric chloride dosages (~20 mg/L as 100% $FeCl_3$), the membranes produced filtrate phosphorus concentrations in the range of 0.11 – 0.13 mg/L TP. This amounts to an additional 1.2% phosphorus removed compared to the full-scale tertiary system.

- Since virtually zero phosphorus was removed in the Disc-Filtration units, switching the feed water likely did not improve phosphorus removal results at the ultrafiltration membranes. However, this does give insight into potential full-scale pre-treatment needs prior to ultrafiltration.

- All three ultrafiltration membranes produced filtrate with 0.1 mg/L TP within the 95% confidence interval of the true mean. Therefore, under these normal operating conditions, the membranes could consistently achieve ultra-low phosphorus removal of at or slightly below 0.1 mg/L TP.

- Minimum values indicate that the filtration performance could improve under optimized operating conditions (i.e. chemical feed adjustments).

- Overall phosphorus removal was not significantly different between the three ultrafiltration membranes. On average, the Toray membrane removed slightly more phosphorus than the other two membranes.

- The number of filtrate samples taken from the ultrafiltration units were limited by operating issues throughout the duration of the study. These issues were associated with equipment failures on the skid opposed to the actual membranes; Issues included:

    - System lockout for low chemical feed tank alarms
    - Low air pressure and air compressor failure for operation of pneumatic values and air-washing of the Toray and DOW membranes
    - Leaking check value
    - System lockout for feed tank level transmitter failure

- Performance of all three membranes declined over the duration of the study. This is illustrated in Figure 5.11 for the Toray membrane. The other two membranes had similar trends in performance decline. Although not statistically significant, this could be attributed to insufficient chemical cleaning in order to maintain initial performance. It also could be attributed to the general increase in Disc-Filter effluent phosphorus over the duration of the study.

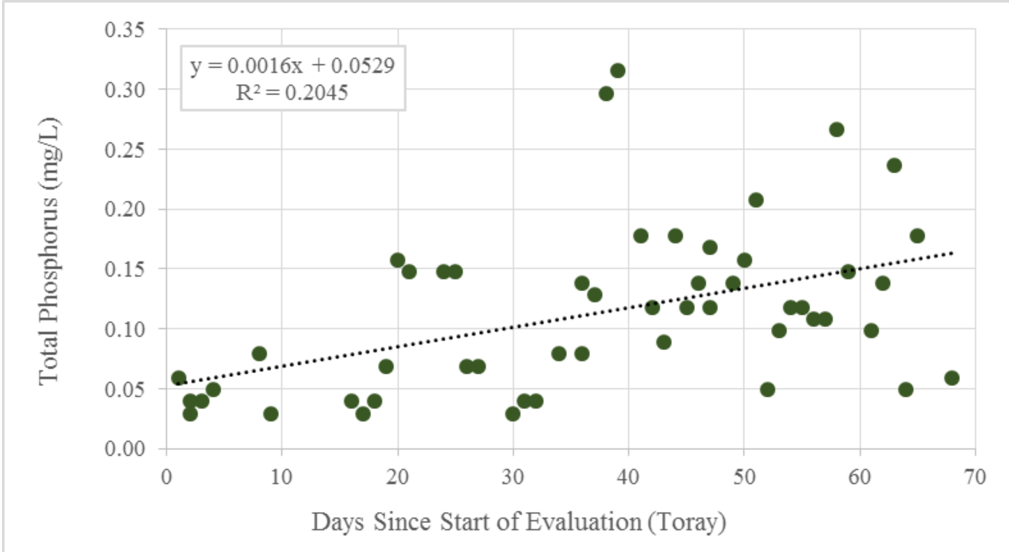

Figure 5.11 – Total Phosphorus Concentration (Toray UF Filtrate)

Observations of the bench-scale ceramic flat-sheet membrane system supplied by Meiden America, Inc. (see Appendix C for copy of pilot report):

- The bench-scale unit produced a filtrate phosphorus concentration of 0.02 mg/L TP, on average. This is below the minimum detection limit of 0.04 mg/L TP as determined in the Precision Evaluation performed by Minnesota State University-Mankato (included in Appendix D). This amounts to an additional 3.6% of total influent phosphorus removed compared to the full-scale tertiary system.

- Filtrate phosphorus concentrations remained consistent when switching between Acti-Flo® effluent and Secondary effluent feed water. However, both locations required daily chemical cleaning (15 min. to 1 hour soak of 0.1-0.2% NaOCl) of the membrane module in order to maintain flux rates. Light hand cleaning was also needed to remove staining on the membrane surface.

- When treating Acti-Flo® effluent, the initial proposed flux of 29.4 gfd had to be decreased to 23.5 gfd in order to achieve 24 hours of continuous operation before a chemical clean was needed. Air scouring for continuous maintenance cleaning was found to increase fouling rates – likely due to the reaction with dissolved iron.

- Operations improved when switching to the Secondary effluent feed water. Flux rates up to 30.6 gfd could be sustained for 24 hours with minimal increase in transmembrane pressure (TMP). Higher flux rates (37.6 – 43 gfd) could not be maintained over a 24 hour period. Daily chemical cleans of 15 minutes were required (doses varied). Air scouring improved operations in this location. Without scouring, thick foulant sheets accumulated at the membrane surface.

- Overall, fouling was the primary concern with this bench-scale unit. Operation of the unit could not be sustained for much longer than 24 hours at the proposed flux rates. Pretreatment measures need to be considered to reduce fouling and sustain flux rates.

- In terms of treatment performance, the ceramic flat-sheet membrane performed excellent for removing phosphorus from both feed points.

2) Stress Test of Tertiary Treatment Technologies

Table 5.7 summarizes ferric chloride dosing and phosphorus removal results for the "stress test" analysis performed on October 29th, 2015. This analysis evaluates the maximum potential to remove phosphorus from the City's wastewater using both full-scale and pilot-scale tertiary treatment technologies.

Due to concerns with full-scale performance and meeting effluent requirements for industrial use, the time frame of this analysis was limited to three hours. As a result of this experimental restriction, all phosphorus measurements were taken as grab samples from each of the processes. Grab sampling is in essence a snapshot of the process in a given moment in time. This "snapshot" concept presents limitations when evaluating data trends as it does not always capture the interdependency of the treatment processes at a given moment in time. For instance, when dosing 50 mg/L ferric chloride, the phosphorus measurements in the downstream treatment processes were found to slightly increase. As another example, at 75 mg/L ferric chloride dosage, the Post Acti-Flo phosphorus measurements actually increased compare to the lower 50 mg/L dosage. Based on what we know about the mechanisms of chemical phosphorus removal, these results are clearly affected by other unaccounted-for variables and do not represent causal relationships. Unaccounted-for variables include influent phosphorus concentration, operational variability, and sampling variability.

TABLE 5.7

Ultra-Low Phosphorus Removal - Stress Test Results

$FeCl_3$ Dose (mg/L as $FeCl_3$)	Total Phosphorus (mg/L)				
	Post Acti-Flo® (PA)	**Post Disc-Filter (PDF)**	**Inge (UF1)**	**Toray (UF2)**	**DOW (UF3)**
21	0.30	0.34	0.23	0.18	0.74
21	0.38	0.36	0.25	0.19	0.45
25	0.36	0.40	0.21	0.20	0.35
25	0.40	0.21	0.18	0.20	0.34
30	0.25	0.23	0.14	0.11	0.29
30	0.10	0.13	0.11	0.18	0.25
35	0.08	0.05	0.05	0.08	0.13
35	0.04	0.05	0.06	0.04	0.21
50	0.03	0.06	0.05	0.05	0.11
50	0.03	0.03	0.05	0.04	0.15
75	0.05	0.04	0.05	0.03	0.11
75	0.08	0.03	0.05	0.03	0.19
Averages at Specified Dosage Range					
Overall	0.17	0.16	0.12	0.11	0.28
21-30 mg/L	0.30	0.28	0.19	0.18	0.40
35-75 mg/L	0.05	0.04	0.05	0.04	0.15

(1) Samples taken as orthophosphate and converted to total phosphorus based on average ratio of 0.80 Ortho P/total P at effluent using historical monitoring results (included in Appendix E)

The following bullet points are observations of the stress testing results. These observations are made in acknowledgment of the presence of experimental variability of grab sampling:

- As expected, higher ferric chloride dosages drastically improved phosphorus removal results in all tertiary treatment technologies.

- A dosage of 35 mg/L (as $FeCl_3$) reduced phosphorus below 0.1 mg/L TP at all phases of tertiary treatment, with exception to the DOW pilot-scale membrane. At this dosage, the City could potentially achieve $\leq$ 0.1 mg/L TP on a consistent basis using their existing tertiary treatment system. However, daily chemical usage would increase by around 75%.

- At ferric chloride dosages of up to 75 mg/L as $FeCl_3$, the pH of the finished water was not affected. In the absence of alkalinity, the production of free protons (H^+) from the reaction of ferric chloride and water would theoretically decrease the pH of the finished water. The City of Mankato's wastewater contains sufficient alkalinity to neutralize acidic production from ferric chloride dosages needed for ultra-low phosphorus removal (≤ 0.1 mg/L TP)

- Based on the results, it appears the City's full-scale tertiary treatment system can reduce phosphorus concentrations below the experimental detection limit of 0.04 mg/L TP. This detection limit was determined in the Precision and Calibration Evaluation presented in Appendix D.

- Once again, much of the phosphorus removal occurred in the City's full-scale Acti-Flo® system. The Disc-Filtration units did not significantly reduce phosphorus after the Acti-Flo® system.

- On average, the pilot-scale ultrafiltration modules removed 35% of the remaining phosphorus after the Acti-Flo® system. However, at high doses of ferric chloride, additional phosphorus was not significantly removed beyond the Acti-Flo® system.

- The relatively poor performance of the DOW membrane is inexplicable in this analysis and likely not indicative of the membrane's capacity to remove phosphorus. Based on its overall performance during normal dosing conditions, it was expected to perform comparable to the other pilot-scale membranes. Considering the Acti-Flo® feed water had a lower concentration of phosphorus than the DOW filtrate, it is clear something was not functioning properly with this membrane at the time of this test.

- Figure 5.12 graphs total phosphorus concentration as a function of ferric chloride dosage for the Inge membrane. This data set is best fit by a power function, as is the data sets for the other tertiary treatment processes. As expected, this follows the general theoretical dosage curve for phosphorus removal using ferric chloride.

Dosages increase exponentially in order to achieve lower and lower effluent phosphorus concentrations, theoretically never reaching zero.

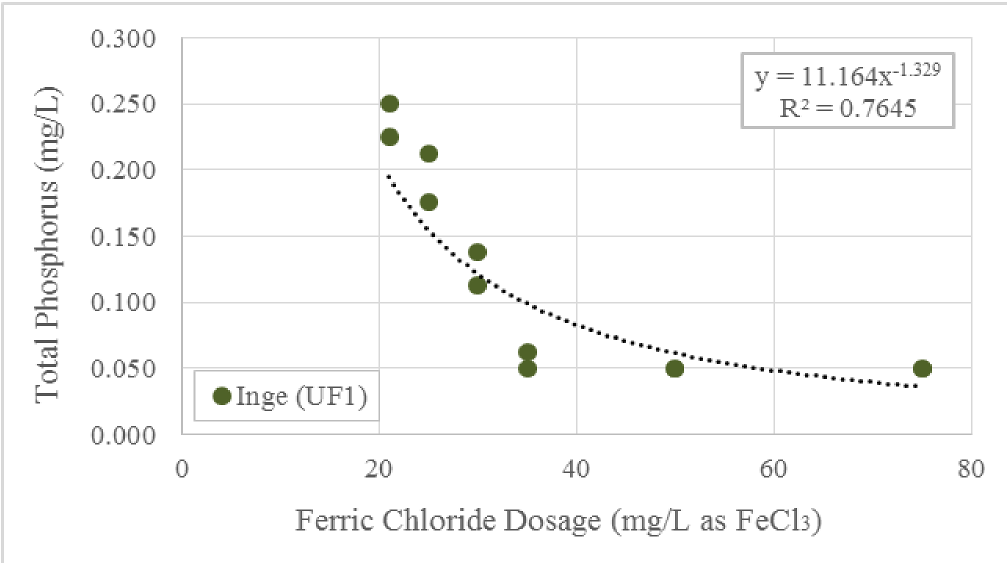

Figure 5.12 – Ferric Dosage vs. Total Phosphorus Concentration (Inge UF1)

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SECTION 6 SUMMARY AND COST ANALYSIS

A. GENERAL

This Section provides a general summary of the experimental findings, including an incremental cost analysis of phosphorus removal for the full-scale and pilot-scale treatment technologies that were evaluated.

B. FERRIC CHLORIDE FEED APPLICATION ANALYSIS

The experimental time frame for each ferric chloride feed scenario was originally estimated to take 7 days. This time frame was found to be inadequate due to issues with adjusting dosages and trying to reach a steady-state (i.e. constant) phosphorus concentration at the Secondary Clarifier effluent as described in Section 4, which was only sampled once per day. This provided the operators little control over phosphorus removal in the wastewater treatment system and, ultimately, steady-state concentrations were not consistently achieved. Upon this realization, it was determined that feed point applications were best compared in terms of removal efficiency at similar dosages. The following bullet points summarize the results of this analysis:

- On average, all feed scenarios achieved at least 73% removal of influent phosphorus at the Secondary Clarifier effluent.

- As expected, when isolating the Primary and Secondary Clarifiers, higher dosages of ferric chloride increased removal efficiencies in these individual processes.

- Multi-point feed scenarios produced higher removal efficiencies compared to the single-point feed scenarios.

- Multi-point feed to the Primary and Secondary Clarifier influent was approximately 5% more efficient than single-point feed to either clarifier at comparable dosages.

- Overall, Scenario 6 (triple-point feed) achieved the highest removal of 91.5% of influent phosphorus, on average; however, this feed scenario was also mistakenly dosed with the highest amount of chemical to the system. When going from two to three feed points, the dosage per feed point was maintained instead of being distributed. Thus, the overall dosage to the system was increased.

C. COMPARISON OF TERTIARY FILTRATION TECHNOLOGIES

This analysis compared the performance of full-scale and pilot-scale tertiary treatment technologies under normal ferric chloride dosages (~20 mg/L as $FeCl_3$) at the City of Mankato's Wastewater Reclamation Facility. The experimental results of this analysis are presented in Table 5.5 in the previous section.

1) Full-Scale Tertiary Treatment

The following bullet points summarize the experimental testing results of the City's full-scale Acti-Flo® and Disc-Filtration system:

- This system produced an average effluent total phosphorus concentration of 0.17 mg/L. This is on the low-end range of what the City typically achieves out of the system. Overall phosphorus removal in the system was nearly 96% of the total influent phosphorus.

- The Disc-Filters achieved virtually zero removal of phosphorus after the Acti-Flo® process.

- Ultra-low phosphorus removal (≤ 0.1 mg/L TP) is not achieved in this system at typical operating dosages of ferric chloride (20-25 mg/L as $FeCl_3$)

- Minimum phosphorus concentration measurements indicate that the system may be able to consistently achieve ultra-low phosphorus removal under optimized operating conditions (i.e. increased dosages of ferric chloride).

2) Pilot-Scale Tertiary Filtration

i. Ultrafiltration Membrane Skid

The following bullet points summarize the experimental testing results of the three (3) pilot-scale ultrafiltration membranes supplied by Wigen Water Technologies (see Appendix B for copy of report):

- The pilot skid had issues treating the Acti-Flo® effluent water due to residual microsand clogging the cartridge pre-filters. The issue was resolved by switching the feed water to post-Disc Filtration. Since the Disc-Filters removed virtually zero phosphorus, switching feed points likely did not improve phosphorus removal at the ultrafiltration membranes. However, this does give insight into potential full-scale pre-treatment needs if ultrafiltration was implemented.

- At normal ferric chloride dosages, the membranes produced filtrate phosphorus concentrations in the range of 0.11 – 0.13 mg/L TP, or an additional 1.2% removal compared to the full-scale tertiary system. Overall performance was not significantly different between the three ultrafiltration membranes.

- All three ultrafiltration membranes produced filtrate with 0.1 mg/L TP within their 95% confidence interval of the true operating mean. Minimum TP testing values indicate that the membrane units could achieve much better and consistent performance under optimized operating conditions (i.e. chemical feed adjustments) than what was achieved with the pilot unit. "Optimized" chemical feed adjustments would likely include higher ferric chloride dosages and better use of clean-in-place chemicals to maintain consistent performance.

ii. Bench-Scale Ceramic Membrane

The following bullet points summarize the experimental testing results of the bench-scale ceramic flat-sheet membrane (CFM) supplied by Meiden America, Inc. (see Appendix C for copy of report):

- This unit produced an average filtrate TP concentration of 0.02 mg/L, or an additional 3.6% removal compared to the full-scale tertiary system. Filtrate phosphorus concentrations remained consistent when switching between Acti-Flo® effluent and Secondary effluent feed water.

- The unit was maintenance intensive, requiring daily chemical soaking of the membrane modules in order to maintain flux rates. Light hand cleaning was also needed to remove staining on the membrane surface. Overall, fouling was a major issue with this bench-scale unit. Operation could not be sustained for much longer than 24 hours at the proposed flux rates.

- In terms of full-scale application, this submerged membrane process would require a larger footprint compared to a skid-mounted ultrafiltration membrane system. Significant improvements in fouling control would need to happen for it be viable for tertiary wastewater treatment. These considerations have implications on capital, operation, and maintenance costs.

- From strictly a phosphorus removal standpoint, the ceramic flat-sheet membrane performed excellent.

D. ULTRA-LOW PHOSPHORUS REMOVAL

This analysis compared the performance of full-scale and pilot-scale tertiary treatment technologies under steadily increasing dosages of ferric chloride, which was labeled the "stress test." The experimental results are presented in Table 5.6 in the previous section. The following bullets point summarize the results of this analysis:

- As expected, higher dosages of ferric chloride drastically improved phosphorus removal at all stages of tertiary treatment. pH of the finished water was not affected by the higher dosages due to the presence of sufficient alkalinity to neutralize the production of free protons (H^+) from the reaction of ferric chloride and water.

- A dosage of 35 mg/L (as $FeCl_3$) reduced phosphorus below 0.1 mg/L at nearly all tertiary treatment processes, including Acti-Flo®. At this dosage, the City could potentially achieve ≤ 0.1 mg/L TP on a consistent basis using their existing tertiary treatment system. However, daily chemical usage would increase by approximately 75%.

- Based on the results, it appears the City's full-scale tertiary treatment system can reduce phosphorus concentrations below the experimental detection limit of 0.04 mg/L TP. This detection limit was determined in the Precision and Calibration Evaluation presented in Appendix D.

- On average, the pilot-scale ultrafiltration modules removed 35% of the remaining phosphorus after the Acti-Flo® system. However, at high doses (35-75 mg/L), additional phosphorus was not significantly removed beyond the Acti-Flo® system.

- Graphical models of the experimental testing data were best fit by a power function, which follows the general theoretical dosage curve for phosphorus removal using ferric chloride. In other words, ferric chloride dosages increase exponentially in order to achieve lower and lower effluent phosphorus concentrations, theoretically never reaching zero.

E. COST ANALYSIS

An incremental cost analysis of various levels of phosphorus removal was performed

1) Chemical Removal of Phosphorus in Secondary Treatment

Capital and O&M costs required for chemical removal of phosphorus in Secondary wastewater treatment include the following:

Capital Costs	**O&M Costs**
Chemical pumping equipment	Chemical costs
Chemical storage	Electrical usage ($0.076/kWh)
Associated piping/valves	Biosolids processing
Biosolids storage capacity	

The relatively low cost of chemical feed and storage equipment makes chemical phosphorus removal highly cost effective to produce effluent concentration as low as 1.0 mg/L. Mechanical treatment facilities with clarification processes are easily upgraded to provide chemical phosphorus removal. Overall capital costs generally range from $0.03-$0.15/gpd of treatment capacity, or $0.20-$0.75/lb. TP removed. Due to economies of scale, larger treatment facilities are typically on the lower end of this range.

O&M costs of chemical phosphorus removal are generally proportional to the amount of chemical used at the treatment facility. The City of Mankato currently pays $1.05/gallon for bulk delivery of ferric chloride. Electrical usage is minimal compared to the costs of chemical usage.

A hidden O&M cost for chemical phosphorus removal is the additional sludge production, which has associated pumping and processing costs. These costs can be assessed as the total O&M cost to operate the sludge processing facilities multiplied by the portion of total solids generated from chemical phosphorus removal. Most of this additional sludge is produced in the Secondary treatment process and removed in the clarifiers. In this cost analysis, all incremental costs for tertiary treatment processes assume chemical removal of phosphorus in the Secondary treatment system. Therefore, sludge production is constant in all scenarios and not directly factored into costs.

Based on the City of Mankato's existing ferric chloride feed and storage equipment at the wastewater treatment facility, a capital cost value of $0.03/gpd treatment capacity is used for this cost analysis. This is consistent with the Technical Support Document entitled *Cost Estimate of Phosphorus Removal at Wastewater Treatment Plants* developed by Tetra Tech in May 2013. This document cites $0.03/gpd as a capital cost value for chemical removal at treatment facilities with a 10 MGD capacity (1-point chemical addition, no filtration, 0.5 TP target value). The City of Mankato's average wet-weather design flow is a comparable value of 11.25 MGD.

2) Cost Analysis of Ultra-Low Phosphorus Removal

i. Incremental Costs based on Experimental Testing Data

This portion of the cost analysis focuses on incremental costs of phosphorus removal using the experimental data described in Section 5. This analysis is specific to the City of Mankato's treatment system and includes costs estimates of the various levels of treatment, assuming new construction for all capital costs. Table 6.1, on the following page, summarizes incremental costs of phosphorus removal for this portion of the analysis. The incremental costs assume a mechanical treatment process is already in place that is adaptable for chemical phosphorus removal and tertiary treatment. The costs also do not include considerations for biosolids processing related to the additional sludge produced from chemical phosphorus removal.

ii. Incremental Chemical Costs of existing Acti-Flo® System

Based on the experimental results in Section 5, the City's existing Acti-Flo® system performed well when increasing ferric chloride dosages in the "stress" test analysis. Table 6.2 shows incremental chemical costs of phosphorus removal in the existing system at varying dosages of ferric chloride. These costs do not reflect other O&M costs to operate the process.

TABLE 6.2
Incremental Cost of Ferric Dosing at Acti-Flo® System

$FeCl_3$ Dose (mg/L)	Acti-Flo TP (mg/L)	$FeCl_3$ (gpd)	$FeCl_3$ $/yr	$/lb TP Removed(1)
21	0.25	370	$141,612	$6.89
25	0.2	440	$168,586	$7.67
30	0.15	528	$202,303	$8.64
35	0.06	616	$236,020	$9.08
50	0.04	880	$337,172	$12.70
75	0.035	1320	$505,758	$18.94

(1) Removed from Secondary treated wastewater at 0.97 mg/L TP

Incremental costs increase at lower concentrations of effluent phosphorus. This is a reflection of the theoretical dosage requirements to remove phosphorus using ferric chloride, which increases exponentially at lower levels of effluent phosphorus, resulting in higher incremental costs.

TABLE 6.1

Incremental Cost Analysis of Phosphorus Removal - City of Mankato

Parameter	Unit	Influent	Secondary Effluent (Chemical Feed)	Acti-Flo®	Acti-Flo® + Disc-Filtration	Acti-Flo® + Ultrafiltration	Meiden Ceramic Membrane
			Treatment Processes				
TP Concentration	mg/L	4.09	0.97	0.17	0.17	0.11	0.02
% TP Removal	%	0.0%	76.3%	95.8%	95.9%	97.3%	99.5%
Process Effluent	lbs/day TP	320	76	14	13	9	2
Process Removal	lbs/day TP	0	244.1	62.3	62.7	67.3	74.3
Capital Cost Analysis							
Capital/Replacement Cost	$	--	$340,000	$10,390,000	$13,575,000	$20,755,000	$31,646,000
Annualized Cost (20 yrs @ 3%)	$/yr.	--	$23,000	$698,000	$912,000	$1,395,000	$2,127,000
Capital $ / gpd		--	$0.03	$0.92	$1.21	$1.84	$2.81
$ / lbs. TP Removed		--	$0.26	$30.67	$39.88	$56.81	$78.41
O&M Cost Analysis							
Average $FeCl_3$ Dose	mg/L as $FeCl_3$	--	12	22	22	22	22
Average $FeCl_3$ Usage	gpd	--	226	414	414	414	414
$FeCl_3$ Annual Cost ($1.05/gal)	$/yr.	--	$86,000	$159,000	$159,000	$159,000	$159,000
Electrical Costs	$/yr.	--	$2,000	$120,000	$170,000	$265,000	$265,000
CIP Chemical Costs	$/yr.	--	--	--	--	$12,000	$12,000
Polymer (0.6 mg/L dose)	$/yr.		--	$25,000	$25,000	$25,000	$25,000
Budgeted Replacement Costs	$/yr.	--	$22,667	$100,000	$150,000	$230,000	$250,000
Total Annual O&M Cost		--	$110,667	$404,000	$504,000	$691,000	$711,000
$ / lbs. TP Removed		--	$1.24	$17.75	$22.04	$28.14	$26.21
Total Estimated Annual Costs			133,667	1,102,000	1,416,000	2,086,000	2,838,000
Total $/lb TP Removal			$1.50	$48.43	$61.92	$84.95	$104.62

3) General Cost Analysis of Phosphorus Removal

Table 6.3 presents general costs of phosphorus removal at various levels of treatment. The costs are presented as annual costs per 1,000 gallons of wastewater treated, and are presented in ranges to reflect variability in treatment schemes and technologies, as well as the effects of economies of scale for varying sized facilities. The annual costs consider capital, operation, and maintenance costs to upgrade a mechanical activated sludge treatment facility to achieve the effluent phosphorus concentrations shown. Capital costs include associated building costs, site work, and all other items contingent to the treatment process. Cost do not include considerations for additional biosolids processing related to increased sludge production from chemical phosphorus removal.

TABLE 6.3
General Cost Analysis of Phosphorus Removal

Effluent TP Conc. (mg/L)	Annual Costs ($/1,000 gallons)(2)
1.0	$0.04 - $0.25
0.5	$0.30 - $0.75
0.1	$0.60 - $1.00(1)
0.06	$0.80 - $2.00(1)

(1) For smaller communities less than 15,000 people, the costs could be significantly higher than the ranges calculated from the pilot study
(2) Sample calculation: $0.32/1,000 gal x (9,380,000 gpd x 365 days/yr) = $1,100,000/yr

The intent of these costs is to give communities and regulatory agencies a preliminary estimate of the funding needed to upgrade a mechanical treatment facility (with effluent comparable to the activated sludge process) to produce the effluent phosphorus concentrations shown. These costs should be used strictly as guidance in the decision-making process. If used to estimate costs beyond 2016 construction, the unit costs should be updated using general construction cost indices or other applicable inflation rates. Additional conditions are described in the following paragraphs.

These costs ranges were developed from the incremental cost analysis presented in Table 6.1 and are based on the City of Mankato's full-scale liquid-stream treatment processes and associated incremental capacity to remove phosphorus. Effluent phosphorus removals ≤ 0.1 mg/L TP are based on the performance of side-stream pilot-scale technologies and their associated full-scale cost estimates.

In terms of transferability to other communities and treatment schemes, lower range costs ($/1,000 gal treated) at each respective phosphorus concentration should be used for larger communities (≥ 50,000 service population) where the advantages of economies of scale is a factor. Higher range costs are applicable to smaller communities where economies of scale is not a factor. Treatment systems have a high degree of variability in infrastructure and equipment, but the designs and associated costs are largely dependent on influent wastewater characteristics and discharge permit requirements. Therefore, systems that treat high-strength wastewater (≥ 10 mg/L TP) should use higher cost ranges, while systems treating low-strength wastewater (≤ 4 mg/L TP) should use lower ranges.

APPENDIX A

Mankato Wastewater Treatment Facility
NPDES/SDS Discharge Permit

Minnesota Pollution Control Agency

Rochester Office | 18 Wood Lake Drive SE | Rochester, MN 55904 | 507-285-7343

800-657-3864 | 651-282-5332 TTY | www.pca.state.mn.us | Equal Opportunity Employer

June 24, 2011

The Honorable John Brady
Mayor, City of Mankato
P.O. Box 3368
Mankato, MN 56002-3368

RE: Final Minor Modified NPDES/SDS Permit Number MN0030171
Mankato Wastewater Treatment Facility
T108N, R26W, Section 6, Mankato, Blue Earth County, Minnesota

Dear Mayor Brady:

Enclosed is the final National Pollutant Discharge Elimination System (NPDES) / State Disposal System (SDS) Permit for your facility. This permit supersedes an earlier NPDES/SDS Permit that was issued on September 22, 2010.

It is the responsibility of the Permittee to maintain compliance with all of the terms and conditions of this permit. Please carefully review the entire permit. A "Submittals Checklist" that is specific for your facility is also enclosed for your use. You may find this checklist to be a convenient tool in tracking the due dates and status of submittals required by the final issued permit.

Special attention should be directed to the following:

Limits and Monitoring Requirements
Your permit was modified to correct an error in the Influent (WS001) monitoring requirements. Quarterly monitoring for total mercury was added to this station. We apologize for any inconvenience this may have caused. New Discharge Monitoring Report forms will be mailed to your facility separately containing the correct monitoring requirements.

Your permit was also modified to change the season to date total of phosphorus due to a change in the trade agreement with Granite Falls Energy. The new limit is 8,895.6 kilograms per year, October - April, effective upon the issuance date of this modification. Please be aware that any future changes to the amount of phosphorus traded in the agreement will require a permit modification.

Questions about your permit should be directed to the appropriate staff contacts listed on the first page of your permit.

Sincerely,

Marni Karnowski
Supervisor, Southeast Regional Unit
Municipal Wastewater Section
Municipal Division

MRK/NH:cme

Enclosures

cc: Mary Fralish, City of Mankato (w/enclosures)
Jim Bruender, City of Mankato (w/enclosures)

STATE OF MINNESOTA

Minnesota Pollution Control Agency

Municipal Division

**National Pollutant Discharge Elimination System (NPDES)/
State Disposal System (SDS) Permit MN0030171**

PERMITTEE:	City of Mankato		
FACILITY NAME:	Mankato Wastewater Treatment Facility		
RECEIVING WATER:	Minnesota River (Class 2B,3C,4A,4B,5,6 water)		
CITY OR TOWNSHIP:	Mankato	**COUNTY:**	Blue Earth
ISSUANCE DATE:	September 22, 2010	**EXPIRATION DATE:**	August 31, 2015
MODIFICATION DATE:	**June 24, 2011**		

The state of Minnesota, on behalf of its citizens, through the Minnesota Pollution Control Agency (MPCA), authorizes the Permittee to operate a disposal system at the facility named above and to discharge from this facility to the receiving water named above, in accordance with the requirements of this permit.

The goal of this permit is to reduce pollutant levels in point source discharges and protect water quality in accordance with Minnesota and U.S. statutes and rules, including Minn. Stat. chs. 115 and 116, Minn. R. chs. 7001, 7041, 7049, 7050, 7053, 7060, and the U.S. Clean Water Act.

This permit is effective on the issuance date identified above, as modified on June 24, 2011. This permit expires at midnight on the expiration date identified above.

Signature: ____________________ *for* The Minnesota Pollution Control Agency

Marni Karnowski, Supervisor
Supervisor, Southeast Regional Unit
Municipal Wastewater Section
Municipal Division

Submit DMRs to:
Attention: Discharge Monitoring Reports
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

Submit Other WQ Reports to:
Attention: WQ Submittals Center
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

Questions on this permit?

- For DMR and other permit reporting issues, contact: Jennifer Satnik, 651-757-2692.
- For specific permit requirements or permit compliance status, contact: Teresa L. Roth, 507-344-5252.
- General permit or NPDES program questions, contact: MPCA, 651-282-6143 or 1-800-657-3938.

Table of Contents

Facility Description

The Mankato Wastewater Treatment Facility (Facility) is located at the SE¼ of the SE¼ of Section 6, Township 108 North, Range 26 West, Mankato, Blue Earth County, Minnesota. This is a Class A facility.

The application indicates that the existing Facility consists of primary treatment (two bar screens, a ginder, a compactor, and mechanical grit removal); flow equalization (three equalization basins); primary treatment (two primary clarifiers); secondary treatment (four complete mix-activated sludge aeration basins and four secondary clarifiers); tertiary treatment (ballasted flocculation for phosphorus removal and chlorination) and disinfection (chlorination and dechlorination equipment). Sludge treatment consists of two dissolved air floatation thickening tanks, two belt filter presses that include a gravity thickener phase and a press phase and anaerobic digesters. On-site biosolids storage consists of a dewatered solids bunker. Biosolids are land applied to approved sites.

The Facility has a continuous discharge (station SD001) to the Minnesota River (Class 2B water). It is designed to treat an average dry weather flow of 6.0 million gallons per day (mgd), an average wet weather (AWW) flow of 11.25 mgd, a peak hourly wet weather flow of 36.0 mgd, and a peak instantaneous wet weather flow of 42.0 mgd, with a five-day carbonaceous biochemical oxygen demand strength of 160 milligrams per liter, based on AWW design flow.

The Facility is further described in plans and specifications (Permit Number 6771 dated March 1, 1971) and in an engineering report by the firm of Rieke Carroll Muller and Associates, Inc., and is further described in various reports and correspondence, in plans and specifications dated July 7, 1997, by the firms of Black and Veatch and Howard R. Green Company, and in a plans and specifications approval letter dated December 18, 1997. The location of the Facility is shown on the map on page 5.

There are currently 14 significant industrial users of the Facility. The Permittee is delegated by the MPCA to administer its own pretreatment program. The MPCA has been delegated authority to approve local Publicly Owned Treatment Works pretreatment programs by the U.S. Environmental Protection Agency.

The Facility has entered into an agreement to provide a portion of the treated effluent from the Facility for use as non-contact cooling water at the Mankato Energy Center (MEC). The amount of effluent supplied to the MEC will vary due to energy demand, operational status of the MEC, and seasonal and daily conditions affecting the cooling efficiency and evaporation rate of water at the MEC cooling towers. Depending upon these conditions, up to three-fourths of the cooling water will be lost to evaporation. The remaining water will be returned to the Facility and commingled with treated effluent prior to dechlorination and discharge to the Minnesota River via the existing facility outfall (SD001).

The Facility has proposed to use part of its treated effluent. Potential uses for the treated effluent include irrigation, landscaping, vehicle and equipment washing, internal equipment cooling, cooling towers, industrial uses (including those in which the water may come into contact with workers), pipeline testing, air conditioning, toilet and urinal flushing, priming drain traps, structural fire fighting, decorative fountains, commercial laundries, consolidation and backfill around potable water pipelines, artificial snow making, commercial car washes (including unheated hand washes), industrial boiler feed, soil compaction, mixing concrete, dust control, cleaning of roads, sidewalks, and outdoor work areas, and flushing sanitary sewers. Other uses not specifically listed may be allowed on a case-by-case basis without permit modification, with prior MPCA approval. Wastewater that is reused will be effluent from the treatment plant that is also filtered and disinfected a second time, and treated to the same level as the effluent sent to MEC. Wastewater that does not meet these limits will not be reused.

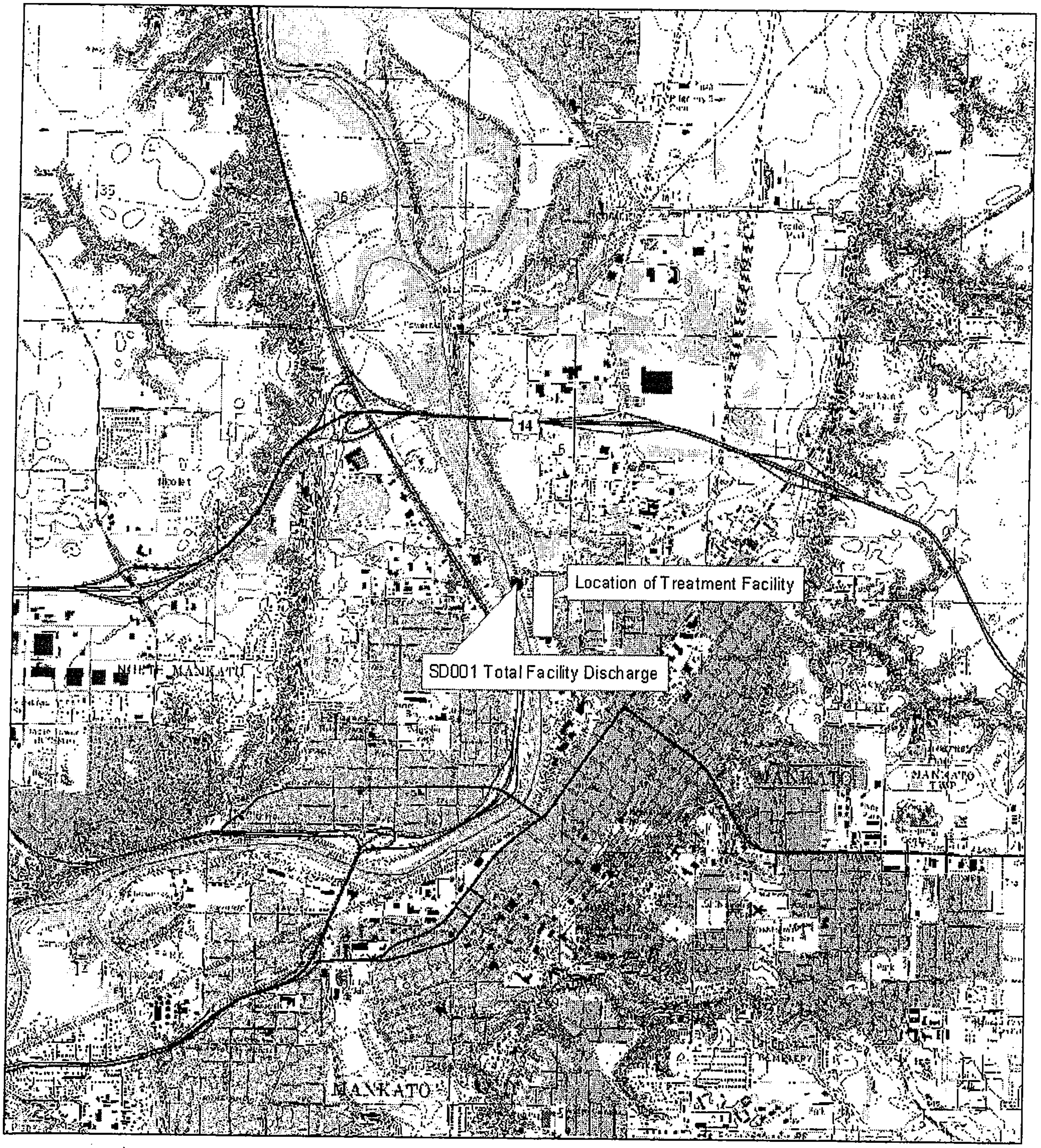
The Facility is also listed in the Minnesota River Basin General Phosphorus Permit and is required to meet specific reductions and limits, as specified in that permit. With the acquisition of the wastewater from the city of Madison Lake, a portion of the phosphorus load allocation for Madison Lake under the general permit has been transferred to the Mankato Facility.

In accordance with MPCA rules regarding nondegradation for all waters that are not Outstanding Resource Value Waters, nondegradation review is required for any new or expanded significant discharge (Minn. R. 7050.0185). A significant discharge is 1) a new discharge (not in existence before January 1, 1988) that is greater than 200,000 gallons per day (gpd) to any water other than a Class 7 water, or 2) an expanded discharge that expands by greater than 200,000 gpd that discharges to any water other than a Class 7 water, or 3) a new or expanded discharge containing any toxic pollutant at a mass loading rate likely to increase the concentration of the toxicant in the receiving water by greater than one percent over the baseline quality. The flow rate used to determine significance is the design AWW flow. The January 1, 1988, design AWW flow for this Facility is 10.0 mgd. An expansion of the Facility occurred in 1997, during which the AWW design flow was increased to the current level of 11.25 mgd. A nondegradation review was completed for the project.

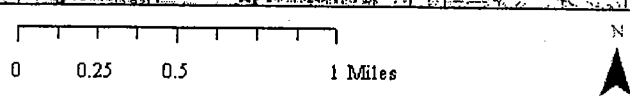
This Permit also complies with Minn. R. 7053.0275 regarding anti-backsliding. Any point source discharger of sewage, industrial or other wastes for which a National Pollutant Discharge Elimination System Permit has been issued by the agency that contains effluent limits more stringent than those that would be established by parts 7053.0215 to 7053.0265, shall continue to meet the effluent limits established by the permit, unless the permittee establishes that less stringent effluent limits are allowable pursuant to federal law, under section 402(o) of the Clean Water Act, United States Code, title 33, section 1342.

Topographic Map of Permitted Facility

MN0030171, Mankato WWTP
T108N, R26W, Section 6
Mankato, Blue Earth County, Minnesota



Map produced by: MPCA Staff, 6/15/09
Source: USGS Mankato East and West Quads
Scale: 1:24,000



Mankato WWTP
Summary of Stations

Surface Discharge Stations

Station	Type of Station	Local Name	PLS Location
SD001	Effluent To Surface Water	Total Facility Discharge	SW Quarter of the SW Quarter of Section 6, Township 108 North, Range 26 West

Waste Stream Stations

Station	Type of Station	Local Name	PLS Location
WS001	Influent Waste	Influent Waste Stream	SW Quarter of Section 6, Township 108 North, Range 26 West
WS002	Internal Waste Stream	Phosphorus removal monitoring station	
WS003	Internal Waste Stream	Post-filtration turbidity mont pt.	
WS004	Internal Waste Stream	Post Chlorine water to MEC	
WS005	Internal Waste Stream	Flow return from MEC	
WS006	Internal Waste Stream	P-loading for WS002 using 1 mg/L	
WS007	Intermediate: WW to Land	Disinfected Tertiary Recycled Water	SW Quarter of Section 6, Township 108 North, Range 26 West

The Permittee shall comply with the limits and monitoring requirements as specified below.

Period: Limits Applicable in the Final Period

SD 001: Total Facility Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
BOD, Carbonaceous 05 Day (20 Deg C)	936	kg/day	Calendar Month Average	Jun-Mar	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C)	22	mg/L	Calendar Month Average	Jun-Mar	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C)	1404	kg/day	Maximum Calendar Week Average	Jun-Mar	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C)	33	mg/L	Maximum Calendar Week Average	Jun-Mar	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C)	1064	kg/day	Calendar Month Average	Apr-May	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C)	25	mg/L	Calendar Month Average	Apr-May	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C)	1596	kg/day	Maximum Calendar Week Average	Apr-May	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C)	40	mg/L	Maximum Calendar Week Average	Apr-May	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C) Percent Removal	85	%	Minimum Calendar Month Average	Jan-Dec	Calculation	3 x Week	
Chlorine, Total Residual	0.038	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Day	20
Chronic Toxicity Testing	9.9	TUc	Annual WET Testing	Jan-Dec, effective July 01, 2010	24-Hour Flow Composite	1 x Year	
Copper, Total (as Cu)	Monitor Only	ug/L	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	6
Fecal Coliform, MPN or Membrane Filter 44.5C	200	#100ml	Calendar Month Geometric Mean	Apr-Oct	Grab	3 x Week	
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	
Flow	Monitor Only	mgd	Calendar Month Maximum	Jan-Dec	Measurement, Continuous	1 x Day	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Day	
Mercury, Total (as Hg)	Monitor Only	ng/L	Calendar Quarter Maximum	Jan-Dec	Grab	1 x Quarter	5
Nitrite Plus Nitrate, Total (as N)	Monitor Only	mg/L	Calendar Month Average	Apr, Sep	24-Hour Flow Composite	1 x Month	
Nitrogen, Ammonia, Total (as N)	2640	kg/day	Calendar Month Average	Dec-Mar	24-Hour Flow Composite	2 x Week	
Nitrogen, Ammonia, Total (as N)	62.1	mg/L	Calendar Month Average	Dec-Mar	24-Hour Flow Composite	2 x Week	
Nitrogen, Ammonia, Total (as N)	2670	kg/day	Calendar Month Average	Apr-May	24-Hour Flow Composite	2 x Week	
Nitrogen, Ammonia, Total (as N)	62.7	mg/L	Calendar Month Average	Apr-May	24-Hour Flow Composite	2 x Week	
Nitrogen, Ammonia, Total (as N)	238	kg/day	Calendar Month Average	Jun-Sep	24-Hour Flow Composite	2 x Week	
Nitrogen, Ammonia, Total (as N)	5.6	mg/L	Calendar Month Average	Jun-Sep	24-Hour Flow Composite	2 x Week	
Nitrogen, Ammonia, Total (as N)	872	kg/day	Calendar Month Average	Oct-Nov	24-Hour Flow Composite	2 x Week	
Nitrogen, Ammonia, Total (as N)	20.5	mg/L	Calendar Month Average	Oct-Nov	24-Hour Flow Composite	2 x Week	
Nitrogen, Kjeldahl, Total	Monitor Only	mg/L	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	12
Nitrogen, Nitrate, Total (as N)	Monitor Only	mg/L	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	12

Mankato WWTP
Limits and Monitoring Requirements

The Permittee shall comply with the limits and monitoring requirements as specified below.

Period: ***Limits Applicable in the Final Period***

SD 001: Total Facility Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Oxygen, Dissolved	5.0	mg/L	Calendar Month Minimum	Jun-Mar	Grab	1 x Day	1
Oxygen, Dissolved	Monitor Only	mg/L	Calendar Month Minimum	Apr-May	Grab	1 x Week	1
pH	9.0	SU	Calendar Month Maximum	Jan-Dec	Grab	1 x Day	1
pH	6.0	SU	Calendar Month Minimum	Jan-Dec	Grab	1 x Day	1
Phosphorus, Total (as P)	Monitor Only	kg/day	12 Month Moving Average	Jan-Dec	24-Hour Flow Composite	3 x Week	4
Phosphorus, Total (as P)	43.1	kg/day	Calendar Month Average	Jan-Dec	24-Hour Flow Composite	3 x Week	
Phosphorus, Total (as P)	1.00	ratio	Calendar Month Maximum	Jan-Dec	24-Hour Flow Composite	3 x Week	3
Phosphorus, Total (as P)	8895.6	kg/yr	Season To Date Total	Oct-Apr	Calculation	3 x Week	8
Solids, Total Dissolved (TDS)	Monitor Only	mg/L	Calendar Month Average	Apr, Sep	24-Hour Flow Composite	1 x Month	
Solids, Total Suspended (TSS)	1277	kg/day	Calendar Month Average	Jan-Dec	24-Hour Flow Composite	3 x Week	
Solids, Total Suspended (TSS)	30	mg/L	Calendar Month Average	Jan-Dec	24-Hour Flow Composite	3 x Week	
Solids, Total Suspended (TSS)	1916	kg/day	Maximum Calendar Week Average	Jan-Dec	24-Hour Flow Composite	3 x Week	
Solids, Total Suspended (TSS)	45	mg/L	Maximum Calendar Week Average	Jan-Dec	24-Hour Flow Composite	3 x Week	
Solids, Total Suspended (TSS) Percent Removal	85	%	Minimum Calendar Month Average	Jan-Dec	Calculation	3 x Week	

Period: ***Limits Applicable in the Final Period, Variability of Operation - Secondary***

SD 001: Total Facility Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Beryllium, Total (as Be)	No Limit No	ug/L	No Limit, No Monitoring	Jan-Dec			19
Cadmium, Total (as Cd)	No Limit No	ug/L	No Limit, No Monitoring	Jan-Dec			19
Chromium, Total (as Cr)	No Limit No	ug/L	No Limit, No Monitoring	Jan-Dec			19
Cyanide, Total (as CN)	No Limit No	ug/L	No Limit, No Monitoring	Jan-Dec			19
Selenium, Total (as Se)	No Limit No	ug/L	No Limit, No Monitoring	Jan-Dec			19
Silver, Total (as Ag)	No Limit No	ug/L	No Limit, No Monitoring	Jan-Dec			19

Period: ***Limits Applicable in the Final Period, Variability of Operation - Tertiary***

SD 001: Total Facility Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Beryllium, Total (as Be)	Monitor Only	ug/L	Single Value	Jan-Dec	24-Hour Flow Composite	1 x Month	13

The Permittee shall comply with the limits and monitoring requirements as specified below.

Period: ***Limits Applicable in the Final Period, Variability of Operation - Tertiary***

SD 001: Total Facility Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Cadmium, Total (as Cd)	Monitor Only	ug/L	Single Value	Jan-Dec	24-Hour Flow Composite	1 x Month	14
Chromium, Total (as Cr)	Monitor Only	ug/L	Single Value	Jan-Dec	24-Hour Flow Composite	1 x Month	15
Cyanide, Total (as CN)	Monitor Only	ug/L	Single Value	Jan-Dec	24-Hour Flow Composite	1 x Month	18
Selenium, Total (as Se)	Monitor Only	ug/L	Single Value	Jan-Dec	24-Hour Flow Composite	1 x Month	16
Silver, Total (as Ag)	Monitor Only	ug/L	Single Value	Jan-Dec	24-Hour Flow Composite	1 x Month	17

Period: ***Limits Applicable in the Final Period***

WS 001: Influent Waste Stream

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
BOD, Carbonaceous 05 Day (20 Deg C)	Monitor Only	mg/L	Calendar Month Average	Jan-Dec	24-Hour Flow Composite	3 x Week	
BOD, Carbonaceous 05 Day (20 Deg C)	Monitor Only	mg/L	Calendar Month Maximum	Jan-Dec	24-Hour Flow Composite	3 x Week	
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	
Flow	Monitor Only	mgd	Calendar Month Maximum	Jan-Dec	Measurement, Continuous	1 x Day	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Day	
Mercury, Total (as Hg)	Monitor Only	ng/L	Calendar Quarter Maximum	Jan-Dec	Grab	1 x Quarter	5
pH	Monitor Only	SU	Calendar Month Maximum	Jan-Dec	Grab	1 x Day	1
pH	Monitor Only	SU	Calendar Month Minimum	Jan-Dec	Grab	1 x Day	1
Phosphorous, In Total Orthophosphate (as P)	Monitor Only	mg/L	Calendar Month Average	Jan-Dec	24-Hour Flow Composite	1 x Week	
Phosphorus, Total (as P)	Monitor Only	mg/L	Calendar Month Average	Jan-Dec	24-Hour Flow Composite	1 x Week	
Precipitation	Monitor Only	in	Calendar Month Total	Jan-Dec	Measurement	1 x Day	
Solids, Total Suspended (TSS)	Monitor Only	mg/L	Calendar Month Average	Jan-Dec	24-Hour Flow Composite	3 x Week	
Solids, Total Suspended (TSS)	Monitor Only	mg/L	Calendar Month Maximum	Jan-Dec	24-Hour Flow Composite	3 x Week	

WS 002: Phosphorus removal monitoring station

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	7
Flow	Monitor Only	mgd	Calendar Month Maximum	Jan-Dec	Measurement, Continuous	1 x Day	7
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Day	7

The Permittee shall comply with the limits and monitoring requirements as specified below.

Period: ***Limits Applicable in the Final Period***

WS 002: Phosphorus removal monitoring station

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Phosphorus, Total (as P)	0.9	mg/L	Calendar Month Average	Jan-Dec	24-Hour Flow Composite	3 x Week	7

WS 003: Post-filtration turbidity mont pt.

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Week	7
Flow	Monitor Only	mgd	Calendar Month Maximum	Jan-Dec	Measurement, Continuous	1 x Week	7
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Week	7
Turbidity	2	NTU	Daily Average	Jan-Dec	Measurement, Continuous	6 x Day	2
Turbidity	10	NTU	Instantaneous Maximum	Jan-Dec	Measurement, Continuous	6 x Day	11

WS 004: Post Chlorine water to MEC

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Coliform, Total, MPN, Confirmed (1)	240	#100ml	Instantaneous Maximum	Jan-Dec	Grab	1 x Day	7
Coliform, Total, MPN, Confirmed (2)	2.2	#100ml	Maximum Calendar Week Average	Jan-Dec	Grab	1 x Day	7
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	7
Flow	Monitor Only	mgd	Calendar Month Maximum	Jan-Dec	Measurement, Continuous	1 x Day	7
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Day	7

WS 005: Flow return from MEC

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	7
Flow	Monitor Only	mgd	Calendar Month Maximum	Jan-Dec	Measurement, Continuous	1 x Day	7
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Day	7
Temperature, Water (F)	Monitor Only	Deg F	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	7

WS 006: P-loading for WS002 using 1 mg/L

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Phosphorus, Total (as P)	Monitor Only	kg/day	12 Month Moving Average	Jan-Dec	Calculation	3 x Week	7

The Permittee shall comply with the limits and monitoring requirements as specified below.

Period: ***Limits Applicable in the Final Period***

WS 006: P-loading for WS002 using 1 mg/L

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Phosphorus, Total (as P)	Monitor Only	kg/day	Calendar Month Average	Jan-Dec	Calculation	3 x Week	9

WS 007: Disinfected Tertiary Recycled Water

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Coliform, Total, MPN, Confirmed (1)	240	#100ml	Instantaneous Maximum	Jan-Dec	Grab	1 x Day	
Coliform, Total, MPN, Confirmed (2)	2.2	#100ml	Maximum Calendar Week Average	Jan-Dec	Grab	1 x Day	
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	
Flow	Monitor Only	mgd	Calendar Month Maximum	Jan-Dec	Measurement, Continuous	1 x Day	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Day	
Turbidity	2	NTU	Daily Average	Jan-Dec	Measurement, Continuous	6 x Day	2
Turbidity	Monitor Only	NTU	Daily Maximum	Jan-Dec	Measurement, Continuous	6 x Day	10

The Permittee shall comply with the limits and monitoring requirements as specified below.

Notes:
1 -- Analyze immediately.
2 -- Average not to exceed 2 NTU within a 24- hour period. Compliance with the daily average operating filter effluent turbidity shall be determined by averaging the turbidity taken at four-hour intervals over at 24-hour period. If conditions are such that a sample cannot be taken during normal operating hours, check the "No Flow" box on the DMR form.
3 -- Calculate as the SD001 kg/day 12-month moving average reported value divided by the WS006 kg/day 12-month moving average reported value (with the WS006 value calculated using a concentration of 1 mg/L).
4 -- Calculated by adding all of the monthly average values during the last twelve months, starting with the monthly average value for the month of the current reporting period, and dividing by twelve.
5 -- EPA method 1631, with clean techniques method 1669, and any revisions to those methods. Please refer to Chapter 2, Mercury Minimization plan for further information.
6 -- EPA method 220.2 with a method detection level of 1.0 ug/l.
7 -- If conditions are such that a sample cannot be taken during normal operating hours, check the "No Flow" box on the DMR form.
8 -- Limit reflects the November 16, 2010 phosphorus trade agreement between the Permittee and Granite Falls Energy (permit #MN0066800). The limit was reduced by 170.4 kg/year from the facility's caclulated Oct-April load limit of 9066 kg/year. This limit applies from October 1 through April 30 of each calendar year, for the duration of the trade agreement. Any future changes in the trade agreement will require a permit modification. See Chapter 1, Special Requirements.
9 -- Loading (in kilograms per day) = 1 mg/L x WS002 flow (in million gallons per day) x 3.78 kilograms per gallon. THE MONTHLY AVERAGE KG/MONTH VALUES MUST BE CALCULATED USING THE REPORTED FLOWS FOR WS002 AND A CONCENTRATION OF 1 MG/L. If conditions are such that a sample cannot be taken during normal operating hours, check the "No Flow" box on the DMR form.
10 -- Not to exceed 10 NTU at any time.
11 -- Not to exceed 10 NTU at any time. If conditions are such that a sample cannot be taken during normal operating hours, check the "No Flow" box on the DMR form.
12 -- Samples may be taken any time during each calendar quarter but must be reported on the DMR for the last month of each quarter (e.g. the sample for the first calendar quarter of Jan - Mar should be reported on the March DMR).
13 -- When NSP ash disposal leachate is accepted at the facility. Use EPA Method 210.2.
14 -- When NSP ash disposal leachate is accepted at the facility. Use EPA Method 213.2.
15 -- When NSP ash disposal leachate is accepted at the facility. Use EPA Method 218.2.
16 -- When NSP ash disposal leachate is accepted at the facility. Use EPA Method 270.2.
17 -- When NSP ash disposal leachate is accepted at the facility. Use EPA Method 272.2.
18 -- When NSP ash disposal leachate is accepted at the facility. Use EPA Method 335.2 or 335.3.
19 -- When NSP ash disposal leachate is not accepted at the facility.
20 -- Whenever chlorine is added. Analyze immediately. This means within 15 minutes or less of sample collection. A Method Detection Limit and a Reporting Limit must be established for this parameter. The Reporting Limit cannot be greater than 0.1 mg/L.

Chapter 1. Special Requirements

1. Special Requirements

Effluent Reuse Water

1.1 Any use of recycled water shall comply with the following:

1) Any irrigation runoff shall be confined to the recycled water use area, unless the runoff does not pose a public health threat and is authorized by the regulatory agency.

2) Spray, mist, or runoff shall not enter dwellings, designated outdoor eating areas, or food handling facilities.

3) Drinking water fountains shall be protected against contact with recycled water spray, mist, or runoff.

1.2 Uses of Recycled Water

(a) Exceptions
The requirements set forth in this chapter shall not apply for use of recycled water onsite at a water recycling plant, or wastewater treatment plant, provided access by the public to the area of onsite recycled water use is restricted.

(b) Use of recycled water for irrigation.
(a) Recycled water used for the surface irrigation of the following shall be a disinfected tertiary recycled water.
(1) Food crops, including all edible root crops, where the recycled water comes into contact with the edible portion of the crop; Parks and playgrounds; School yards; Residential landscaping; Unrestricted access golf courses; and Any other irrigation use not specified in this section.
(2) Other uses as approved by the MPCA on a case-by-case basis.

1.3 Where feasible, areas where recycled water is used for irrigation that are accessible to the public shall be posted with signs that are visible to the public, in a size no less than 4 inches high by 8 inches wide, that include the following wording: "RECYCLED WATER - DO NOT DRINK". Each sign shall display an international symbol. The MPCA may accept alternative signage and wording, or an educational program, provided the applicant demonstrates to the MPCA that the alternative approach will assure an equivalent degree of public notification.

1.4 The recycled water flow to a land application site shall not have physical or chemical characteristics that prevent the proper operation of the land disposal system. The recycled water shall be free of material that interferes with the operation of nozzles, orifices or flow measurement devices.

1.5 A vegetative cover shall be seeded and maintained on the sprayfield during the entire application season unless otherwise approved by the MPCA.

1.6 Recycled water shall not be applied after vegetative cover has become dormant as a result of frost or below freezing temperatures.

1.7 Recycled water shall be applied so as not to harm vegetative cover and so that prolonged saturated soil conditions do not develop due to the application. Recycled wtaer shall not be applied during precipitation periods.

1.8 The Permittee shall prevent the surface runoff of recycled water, and precipitation runoff mixed with recycled water, from the land application site(s). The Permittee shall provide runoff collection and re-application systems as appropriate to prevent the discharge of surface runoff.

Chapter 1. Special Requirements

1. Special Requirements

1.9 No irrigation with disinfected tertiary recycled water shall take place within 50 feet of any domestic water supply well unless all of the following conditions have been met:

1) A geological investigation demonstrates that an aquitard exists at the well between the uppermost aquifer being drawn from and the ground surface.

2) The well contains an annular seal that extends from the surface into the aquitard.

3) The well is housed to prevent any recycled water spray from coming into contact with the wellhead facilities.

4) The ground surface immediately around the wellhead is contoured to allow surface water to drain away from the well.

5) The owner of the well approves of the elimination of the buffer zone requirement.

1.10 If odor or aerosol drift resulting from operation of the recycled water disposal system creates a nuisance condition, the Permittee shall immediately take appropriate action to control or abate the odor or aerosol drift. The Permittee shall notify the Agency of a nuisance condition within five (5) days of discovery.

1.11 No impoundment of disinfected tertiary recycled water shall occur within 100 feet of any domestic water supply well.

1.12 The portions of the recycled water piping system that are in areas subject to access by the general public shall not include any hose bibbs. Only quick couplers that differ from those used on the potable water system shall be used on the portions of the recycled water piping system in areas subject to public access. A sign shall be permanently posted at each piping system quick coupler connection point, or other distribution outlet to indicate that the water is "Recycled Water - DO NOT DRINK."

1.13 No physical connection shall be made or allowed to exist between any recycled water system and any separate system conveying potable water.

1.14 The permittee must have a contingency plan which will assure that no untreated or inadequately treated recycled water will be delivered to the use area. There shall be no bypassing of untreated or partially treated wastewater from the wastewater treatment facility to the point of use. Any such discharge must be reported immediately to the Agency.

1.15 Submit an Effluent Reuse Annual Report by January 21 of each year following permit issuance. This report shall contain the amount of recyceld water that was reused, where it was reused, and the total acres on which it was applied.

Phosphorus Trading

1.16 The outfall SD001 monitoring and limits for Season to Date Phosphorus in units of kg/year reflect the November 16, 2010, phosphorus trade agreement between the Permittee and Granite Falls Energy (permit MN0066800). These monitoring and limits apply from October 1 through April 30 of each calendar year, for the duration of the trade agreement.

If the trade agreement is discontinued, the Permittee shall submit an application for a permit modification to restore the phosphorus limits back to its pre-trade agreement level.

Chapter 1. Special Requirements

1. Special Requirements

1.17 The outfall SD001 Season to Date Total Phosphorus limit in units of kg/year is calculated as follows: For each month, multiply the total volume of effluent flow (in million gallons) by the monthly average concentration of effluent phosphorus (in mg/L) and by a 3.785 conversion factor (liters per gallon) to obtain phosphorus in units of kg/month. Then add all monthly values from the first month in the effective period to the end date of the reporting period. For example, if the "effective period" is Oct-Apr and the reporting period ends January 31, add the monthly values from October through January, and report that value as the Season to Date Total.

Chapter 2. Non-waste Streams -- Mercury Minimization Plan

1. Mercury Pollutant Minimization Plan

1.1 Mercury is present in all municipal and many industrial wastewater discharges. Mercury is a powerful neurotoxin that affects human health and the environment. A naturally-occurring element, mercury does not break down into less-harmful substances over time. Instead, mercury released into the environment accumulates in fish and animal tissues, a process known as bioaccumulation. Widespread mercury contamination has prompted the Minnesota Department of Health (MDH) to issue fish consumption advisories throughout the state. Most of Minnesota's impaired waters are contaminated by mercury and other bioaccumulative toxins. The MPCA is carefully evaluating all mercury discharges in the state.

1.2 The Permittee is required to complete and submit a Mercury Pollutant Minimization Plan (MMP) to the MPCA as detailed in this section. If the Permittee has previously submitted a MMP, it must update its MMP and submit the updated MMP to the MPCA. The purpose of the MMP is to evaluate collection and treatment systems to determine possible sources of mercury as well as potential mercury reduction options. Guidelines for developing a MMP are detailed in this section.

1.3 The Permittee shall submit a Pollutant Minimization Plan by 180 days after permit issuance. At a minimum, the MMP must include the following:

a) A summary of mercury influent and effluent concentrations and biosolids monitoring data using the most recent five years of monitoring data, if available.

b) Identification of existing and potential sources of mercury concentrations and/or loading to the facility. As appropriate for your facility, you should consider residential, institutional, municipal, and commercial sources (such as dental clinics, hospitals, medical clinics, nursing homes, schools, and industries with potential for mercury contributions). You should also consider other influent mercury sources, such as stormwater inputs, ground water (inflow & infiltration) inputs, and waste streams or sewer tributaries to the wastewater treatment facility.

c) An evaluation of past and present WWTF operations to determine those operating procedures that maximize mercury removal.

d) A summary of any mercury reduction activities implemented during the last five years.

e) A plan to implement mercury management and reduction measures during the next five years.

1.4 In addition to the sampling required in the Limits and Monitoring section of this permit, the Permittee shall sample effluent from the total facility discharge station for Dissolved Mercury and TSS on a quarterly basis throughout the life of this permit. The sampling method is a concurrent grab sample for the two parameters. Dissolved Mercury shall be analyzed using an EPA approved low level mercury analysis method. Samples shall be taken at any time during the calendar quarter and reported on the custom supplemental form provided by the MPCA. The custom supplemental form must be submitted with the DMR for the last month of each quarter.

Chapter 3. Total Residual Oxidants - Domestic

1. General Requirements

1.1 "Daily Maximum" for Total Residual Chlorine (TRC) concentration limits means:

a. The value of a single sample in a 24-hour period if the concentration of TRC in that sample is 0.038 mg/L or less, or below the Reportable Limit (RL).

b. If the concentration of TRC in the first sample is greater than 0.038 mg/L or greater than the RL, reporting the average of two to twelve samples analyzed in a 24-hour period is allowed. The second sample must be taken two hours after the first sample and subsequent samples are to be taken at one-hour intervals thereafter, not to exceed a total of twelve samples in a 24-hour period. Values below the Reportable Limit for TRC are assumed to be zero for averaging purposes only. Whenever daily TRC values are averaged, the 0.038 mg/L limit must be met and the average value must be reported, not < the RL.

c. The average value of multiple daily TRC effluent sample analyses must meet the 0.038 mg/L limit to be in compliance.

1.2 Total Residual Chlorine must be analyzed immediately. This means within 15 minutes or less of sample collection. (40 CFR Part 136 and Standard Methods for the Examination of Water and Wastewater, Latest Edition).

1.3 A Method Detection Limit (MDL) must be established for this parameter.

1.4 The Reportable Limit must be established for this parameter. This should be based on the Method Detection Limit and laboratory, analyst, and equipment used in the analysis. The Reportable Limit cannot be greater than 0.1 mg/L.

1.5 The Method Detection Limit and Reportable Limit should be reassessed when the method, equipment, laboratory, or analyst changes.

1.6 Monitoring results below the Reportable Limit should be reported as "<" the Reportable Limit. For example, if the Reportable Limit is 0.01 mg/L and a parameter is not detected at a value of 0.01 mg/L or greater, the concentration shall be reported as "<0.01mg/L." The symbol "<" means "less than."

1.7 The equipment should be checked against a known standard at least monthly.

Chapter 4. Whole Effluent Toxicity (WET) Testing - Chronic

1. General Requirements

1.1 The Permittee shall conduct annual chronic toxicity test batteries on Discharge SD001 beginning with the issuance date of the permit. The first set of annual results are due one year from the end of the first full calendar quarter following permit issuance and annually thereafter. (For example, if the permit is issued April 28, the first test results are due October 1 of the following year.)

1.2 Any test that exceeds 9.9 TUc shall be re-tested according to the Positive Toxicity Results requirement(s) that follow to determine if toxicity is still present above 9.9 TUc (RWC< 10%).

2. Species and Procedural Requirements

2.1 Tests shall be conducted in accordance with procedures outlined in EPA-821-R-02-013 "Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms" - Fourth Edition (Chronic Manual) and any revisions to the Manual. Any test that is begun with an effluent sample that exceeds a total ammonia concentration of 5 mg/l shall use the carbon dioxide-controlled atmosphere technique to control pH drift.

Chapter 4. Whole Effluent Toxicity (WET) Testing - Chronic

2. Species and Procedural Requirements

2.2 Test organisms for each test battery shall include the fathead minnow (Pimephales promelas)-Method 1000.0 and Ceriodaphnia dubia-Method 1002.0.

2.3 Static renewal chronic serial dilution tests of the effluent shall consist of a control, 6, 12, 25, 50 and 100% effluent. A 10% Receiving Water Concentration (RWC) may be substituted for the 12% effluent concentration or provided in addition to the above dilution series.

2.4 All effluent samples shall be flow proportioned, 24-hour composites. Test solutions shall be renewed daily. Testing of the effluent shall begin within 36 hours of sample collection. Receiving water collected outside of the influence of discharge shall be used for dilution and controls. Chronic toxicity tests shall be conducted in accordance with procedures outlined in EPA-821-R-02-013 "Short-term Methods for Measuring the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms" - Fourth Edition (Chronic Manual) and any revisions to the Manual.

2.5 Any other circumstances not addressed in the previous requirements or that require deviation from that specified in the previous requirements shall first be approved by the MPCA.

3. Quality Control and Report Submittals

3.1 Any test that does not meet quality control measures, or results which the Permittee believes reflect an artifact of testing shall be repeated within two (2) weeks. These reports shall contain information consistent with the report preparation section of the Chronic Manual. The MPCA shall make the final determination regarding test validity.

4. Positive Toxicity Result for WET

4.1 Should a test exceed 9.9 TUc for whole effluent toxicity based on results from the most sensitive test species, the Permittee shall conduct two repeat test batteries on all species. The repeat tests are to be completed within forty-five (45) days after completion of the positive test. These tests will be used to determine if toxicity exceeding 9.9 TUc remains present for any test species. If no toxicity is present above 9.9 TUc for any test species, the Permittee shall return to the test frequency specified by the permit. If the repeat test batteries indicate toxicity above 9.9 TUc for any test species, the Permittee shall submit for MPCA review a plan for conducting a Toxicity Reduction Evaluation (TRE), including the Facility Performance Review (to be submitted to the MPCA WQ Submittals Center within 60 days after toxicity discovery date) and, at a minimum, provide quarterly reports starting from the date of TRE submittal, regarding progress towards the identity, source, and any plans for the removal of the toxicity. The TRE shall be consistent with EPA guidance or subsequent procedures approved by the MPCA in attempting to identify and remove the source of the toxicity. Routinely scheduled chronic toxicity test batteries required in this permit section shall be suspended for the duration of the TRE. The return to routine chronic toxicity testing is subject to successful completion of conformation testing, as determined by the MPCA. Amendments to the initial TRE shall be approved by MPCA staff and the schedules identified therein.

Chapter 4. Whole Effluent Toxicity (WET) Testing - Chronic

5. WET Data and Test Acceptability Criteria (TAC) Submittal

5.1 All WET test data and TAC must be submitted to the MPCA by the dates required by this section of the permit using the following form(s) and associated instruction forms:
Minnesota Pollution Control Agency Ceriodaphnia dubia Chronic Toxicity Test Report/ Minnesota Pollution Control Agency Fathead Minnow Chronic Toxicity Test Report. Data not submitted on the correct form(s), or submitted incomplete, will be returned to the permittee and deemed incomplete until adequately submitted on the designated form (identified above). Data should be submitted to:

MPCA
Attn: WQ Submittals Center
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

6. Permit Re-opening for WET

6.1 Based on the results of the testing, the permit may be modified to include additional toxicity testing and a whole effluent toxicity limit.

7. Whole Effluent Toxicity Requirement Definitions

7.1 "Chronic Whole Effluent Toxicity (WET) Test is a static renewal test conducted on an exponentially diluted series of effluent. The purpose is to calculate appropriate biological effect endpoints (NOEC/LOEC or IC25), specified in the referenced chronic manual. A statistical effect level less than or equal to the Receiving Water Concentration (RWC) constitutes a positive test for chronic toxicity. The RWC equals the 10 percent effluent concentration or 9.9 TUc.

7.2 "Chronic toxic unit (TUc)" is the reciprocal of the effluent dilution that causes no unacceptable effect on the test organisms by the end of the chronic exposure period. For example, a TUc equals [7Q10flow (mgd) + effluent average dry weather flow (mgd)]/[effluent average dry weather flow (mgd)].

7.3 "Test" refers to an individual species.

7.4 "Test Battery" consists of WET testing of all test species for the specified test. For chronic WET testing, all test species includes Fathead minnows and ceriodaphnia dubia.

Chapter 5. Pretreatment

1. Pretreatment - Definitions

1.1 For the purposes of these pretreatment requirements, "Significant Industrial User" (SIU) shall mean any industrial user (IU) which:

a. is subject to Categorical Pretreatment Standards, as defined in Minnesota Rules 7049.0120, subpart 5;

b. discharges 25,000 gallons per day or more of process wastewater, excluding sanitary, noncontact cooling or boiler blowdown wastewater, to the POTW;

c. contributes a process wastewater containing five percent or more of the flow or load of any pollutant of concern to the POTW treatment plant; or

d. is designated as significant by the Permittee on the basis that the Industrial User has a reasonable potential for adversely affecting the POTW's operation or for violating any pretreatment standard or requirement.

Chapter 5. Pretreatment

2. Exemption

2.1 Industrial users qualifying as significant solely on the basis of criteria b. or c. above may be exempted from consideration as a SIU if the Permittee finds that they have no reasonable potential to adversely affect the POTW's operation or to violate pretreatment standards or requirements.

2.2 The Permittee must notify the MPCA in writing of any Industrial User so exempted and provide justification for their exemption.

3. Pretreatment - Delegated Authority

3.1 Under the authority of the General Pretreatment Regulations (40 CFR 403), the Permittee's pretreatment program was approved on May 27, 1994. The Permittee has been delegated authority to operate as the Publicly Owned Treatment Works (POTW) control authority under the General Pretreatment Regulations. The Permittee shall fully and effectively implement and operate the approved pretreatment program according to the legal authorities contained therein and the General Pretreatment Regulations.

3.2 In addition to the Prohibitions contained in the General Pretreatment Regulations and the approved program, the Permittee shall prohibit new discharges of non-contact cooling waters to the POTW unless there are no cost-effective alternatives.

3.3 Existing discharges of non-contact cooling water to the wastewater treatment facility shall be eliminated where elimination is cost effective, or where an infiltration/inflow analysis and sewer system evaluation survey indicate the need for such removal.

3.4 Pollutants of concern in the administration of the Permittee's pretreatment program shall be considered in the determination of the Significance of Industrial Users, monitoring of Significant Industrial Users, establishment of limitations on users, and communications with users. A pollutant of concern is a pollutant that is discharged, or may be discharged by an industrial user to the permittees treatment works and that is, or should be, of concern on the basis that it may cause interference or pass through as defined in Minnesota Rules 7049.0120, subparts 10 and 12.

4. Legal Authority

4.1 The Permittee shall maintain the legal authority that allows it to fully implement its approved pretreatment program in conformance with the requirements of the General Pretreatment Regulation.

5. Industrial Users Inventory

5.1 The Permittee shall update its inventory of Industrial Users at least annually and as needed to ensure that all SIUs are properly identified, characterized and categorized. The Permittee shall:

a. identify Industrial Users which may be subject to the POTW pretreatment program;

b. characterize the discharge of pollutants to the POTW by the Industrial User; and

c. determine the applicable categories for industrial users subject to National Categorical Pretreatment Standards.

5.2 Within 30 days of the designation of an Industrial User as significant, the Permittee shall notify the SIU of all applicable pretreatment standards and requirements. The Permittee shall also notify all Industrial Users of all applicable pretreatment standards and requirements, and the Industrial Users' obligation to comply with applicable requirements under Subtitles C and D of the Resource Conservation and Recovery Act (RCRA).

6. Local Limits

6.1 The Permittee shall develop, maintain and enforce specific local limits to implement the prohibitions listed in Minnesota Rules 7049.0140.

Chapter 5. Pretreatment

6. Local Limits

6.2 The Permittee shall evaluate the need to revise local limits to effectively implement these prohibitions at least once during the term of this permit. Prior to the expiration date of this permit, the permittee shall submit, for approval, a report on the evaluation. If the evaluation determines that a more restrictive local limit is needed, the permittee shall submit for approval a suggested schedule for amending the permittee's local limits.

6.3 The evaluation shall include a pollutant mass balance for all pollutants of concern. The mass balance shall attempt to balance the source of the pollutants (Industrial Users and other sources), the measured headworks loading of the pollutants and the fates of the pollutants (discharge, biosolids and others). The mass balance shall make use of all available and appropriate monitoring data.

The permittee shall, for all pollutants of concern, obtain sufficient data to allow the permittee to evaluate the need for local limits and to set local limits if they are needed. Monitoring shall be done at a sensitivity adequate to evaluate the need for local limits and set local limits if needed.

7. Permit Significant Industrial Users

7.1 The Permittee shall issue and reissue permits to all existing SIUs within 180 days of expiration of the existing SIU permit for existing SIUs, or identification of a new SIU. The permit shall contain at least the following:

a. a statement of duration (no longer than five (5) years);

b. a statement of nontransferability without prior approval by the POTW, and provision of a copy of the existing permit to the new owner or operator;

c. discharge limits based on applicable prohibited discharges in Minnesota Wastewater Pretreatment Rules (Minn. R. 7049.0140), National Categorical Pretreatment Standards, and local limits and local discharge prohibitions;

d. self-monitoring, sampling, reporting, notification and record keeping requirements, including an identification of the pollutants to be monitored, sampling location, sampling frequency and sample type; and

e. a statement of applicable civil and criminal penalties for violation of pretreatment standards and requirements, and any applicable compliance schedule.

7.2 The Permittee may not extend the compliance date beyond applicable federal deadlines in any compliance schedule.

8. Compliance Monitoring and Inspections

8.1 The Permittee shall randomly sample and analyze the discharge from Industrial Users and conduct surveillance activities to identify, independent of information supplied by Industrial Users, noncompliance with pretreatment standards. The Permittee shall inspect and sample the discharge from each SIU at least once a year.

8.2 The Permittee shall evaluate whether each SIU needs a plan to control spill and slug discharges as provided in Minnesota Rules 7049.0830 G. Where a control plan is determined to be needed, the Permittee shall require, in the permit issued to the industrial user, that the industrial user develop and implement such a plan.

9. Industrial User Reports

9.1 The Permittee shall receive and analyze self-monitoring reports and other reports and notices submitted by Industrial Users in accordance with requirements contained in permits issued by the Permittee and in accordance with the General Pretreatment Regulation.

Chapter 5. Pretreatment

10. Enforcement Actions

10.1 The Permittee shall investigate instances of noncompliance with pretreatment standards and requirements as indicated by reports submitted by Industrial Users, by information collected by the Permittee or by other means.

10.2 The Permittee shall collect samples, analyze data and compile information in a manner to ensure accuracy and admissibility in enforcement proceedings and judicial actions.

10.3 In instances of noncompliance, the Permittee shall take effective enforcement action in accordance with the approved enforcement response plan.

11. Data Management and Record Keeping

11.1 The Permittee shall maintain records documenting pretreatment activities. These records shall contain an inventory of industrial users, characterization of discharges, compliance status, permit status, and records of enforcement actions.

11.2 The Permittee shall retain all records of monitoring activities and results for at least three (3) years and shall make the records available to EPA and the MPCA upon request.

12. Public Participation

12.1 The Permittee shall comply with public participation requirements of 40 CFR 25 in the enforcement of national pretreatment standards.

12.2 The Permittee shall, once a year, publish the names of Industrial Users that were in significant noncompliance with pretreatment requirements, as defined in Minnesota Rules 7049.0120, subpart 25, any time during the previous twelve (12) months.

12.3 All industrial discharge data shall be made available to the public upon request.

13. Program Resources

13.1 The Permittee shall acquire sufficient resources and qualified personnel to carry out the program implementation procedures described in this permit.

14. Program Modification

14.1 The Permittee shall submit to the MPCA a statement of the basis for desired program modifications and a modified program description for all substantial modifications as defined in Minnesota Rules 7049.0980. The Permittee must await formal approval from the MPCA before implementing substantial program modifications.

14.2 The Permittee shall notify the MPCA of non-substantial modifications to its pretreatment program at least 45 days prior to implementing the modification.

14.3 Non-substantial modifications are deemed approved unless the MPCA notifies the Permittee otherwise within 45 days.

15. Multijurisdictional Agreements

15.1 The Permittee must establish agreements with other political jurisdictions requiring those jurisdictions to develop and adopt legal authority at least as stringent as the Permittee's, and carry out the specific responsibilities listed above in implementing the pretreatment program.

16. Notification Requirements

16.1 The Permittee shall notify the MPCA of planned or actual changes in the discharges from SIUs which will require changes to the user's control document and which may affect the Permittee's effluent.

16.2 The Permittee shall supply the MPCA with information regarding the discharge, compliance status, or enforcement actions taken for any industrial user upon request.

Chapter 5. Pretreatment

17. Pretreatment Annual Report

17.1 The Permittee shall submit the pre-treatment report annually to the following address:

MPCA
Attn: WQ Submittals Center
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

The report shall describe the Permittee's pretreatment activities during the previous calendar year and is due on February 28 of each year and shall contain at least the following information.

17.2 The Pretreatment Annual Report shall describe the pretreatment activities during the previous calendar year and shall contain the following lists:

a. An updated list of the Permittee's significant industrial users including their names, addresses, any applicable federal categorical standards, and a summary total of significant industrial users and categorical industrial users.

b. A separate list of deletions from and additions to previously submitted lists of SIUs, with a brief explanation for each deletion.

c. A list of SIUs with expired permits.

17.3 The Pretreatment Annual Report shall contain the following descriptions:

a. A characterization of the compliance status of each SIU during the reporting year. The compliance characterization shall at least indicate status as follows:

1) no violations noted with discharge limits, and compliance with monitoring and reporting requirements is sufficient to determine compliance with discharge limitations;
2) violations were noted with discharge limits, or violations of monitoring and reporting requirements that may have impaired the Permittee's ability to determine compliance with discharge limitations were noted, but the noncompliance does not meet the definition of significant noncompliance as referenced below;
3) significant noncompliance (as defined by 40 CFR 403.8(f)(2)(vii)); or
4) status unknown.

b. A description of the standards or requirements that were violated for SIUs that are out of compliance with pretreatment standards. For an SIU in significant noncompliance, the characterization shall note the reason for the significant violations (if known) and whether the SIU is on a compliance schedule. If the SIU is on a compliance schedule, the date of final compliance shall be noted in the report.

c. A description of any upsets, interference, or pass through incidents at the POTW which the Permittee knows or suspects were caused by Industrial Users of the POTW system. The description shall include the reasons why the incidents occurred, the corrective actions taken, and the Industrial Users responsible, if known.

17.4 The permittee shall, for all pollutants of concern, obtain sufficient data to allow the permittee to evaluate the need for local limits, and shall set local limits it they are needed. Monitoring shall be done at a sensitivity adequate to evaluate the need for local limits and set local limits if they are needed.

Chapter 5. Pretreatment

17. Pretreatment Annual Report

17.5 The Pretreatment Annual Report shall contain the following summaries:

a. A summary of the discharge monitoring data for each SIU for the reporting year. This summary shall include all available data and shall accurately represent the discharge by the user.

b. A summary of the inspection and sampling activities conducted by the POTW during the reporting year to gather information and data regarding Industrial Users. The summary shall include identification of the Industrial Users subject to surveillance by the POTW and an indication of the type (inspection or sampling) and the number of surveillance activities performed.

c. A summary of the enforcement actions by the POTW during the reporting year. The summary shall include the names and addresses of the Industrial Users that were the subject of enforcement action, the enforcement action taken, and whether the Industrial User has returned to compliance.

d. A summary of the Permittee's pretreatment budget for the reporting year, including the cost of personnel, equipment and services employed in the pretreatment program.

e. A summary of public participation activities to involve and inform the public. This shall include a copy of the annual publication of significant noncompliance, if such publication was needed to comply with 40 CFR 403.8(f)(2)(vii).

17.6 The Permittee shall monitor the treatment plant influent, effluent and sludge concurrently at least two times per year for:

Arsenic
Chromium
Cyanide
Mercury
Silver
Cadmium
Copper
Lead
Nickel
Zinc

This monitoring may be combined with any other monitoring. The results of this monitoring shall be reported in the pretreatment annual report, as well as on the application for permit reissuance. The results of this monitoring shall also be used in the evaluation of local limits as required in this Chapter.

Chapter 6. Domestic Wastewater -- Mechanical System

1. Bypass Structures

1.1 All structures capable of bypassing the treatment system shall be manually controlled and kept locked at all times.

2. Sanitary Sewer Extension Permit

2.1 The Permittee may be required to obtain a Sanitary Sewer Extension Permit from the MPCA prior to the start of construction of any addition, extension or replacement to the sanitary sewer. If a sewer extension permit is required, no construction of any part of the system may begin until that permit has been issued.

Chapter 6. Domestic Wastewater -- Mechanical System

3. Operator Certification

3.1 The Permittee shall provide a Class A state certified operator who is in direct responsible charge of the operation, maintenance and testing functions required to ensure compliance with the terms and conditions of this permit.

3.2 The Permittee shall provide the appropriate number of operators with a Type IV certification to be responsible for the land application of biosolids or semisolids from commercial or industrial operations.

3.3 If the Permittee chooses to meet operator certification requirements through a contractual agreement, the Permittee shall provide a copy of the contract to the MPCA, WQ Submittals Center. The contract shall include the certified operator's name, certificate number, company name if appropriate, the period covered by the contract and provisions for renewal; the duties and responsibilities of the certified operator; the duties and responsibilities of the permittee; and provisions for notifying the MPCA 30 days in advance of termination if the contract is terminated prior to the expiration date.

3.4 The Permittee shall notify the MPCA within 30 days of a change in operator certification or contract status.

Chapter 7. Biosolids Land Application

1. Authorization

1.1 This permit authorizes the Permittee to store and land apply domestic wastewater treatment biosolids in accordance with the provisions in this chapter and Minnesota Rules, ch. 7041.

1.2 Permittees who prepare bulk biosolids must obtain approval of the sites on which bulk biosolids are applied before they are applied unless they are exceptional quality biosolids. Site application procedures are set forth in Minnesota Rules, pt. 7041.0800.

2. Compliance Responsibility

2.1 The Permittee is responsible for ensuring that the applicable requirements in this chapter and Minnesota Rules ch. 7041 are met when biosolids are prepared, distributed, or applied to the land.

3. Notification Requirements

3.1 The Permittee shall provide information needed to comply with the biosolids requirements of Minnesota Rules, ch. 7041 to others who prepare or use the biosolids.

Chapter 7. Biosolids Land Application

4. Pollutant Limits

4.1 Biosolids which are applied to the land must not exceed the ceiling concentrations in Table 1 and must not be applied so that the cumulative amounts of pollutant in Table 2 are exceeded.

Table 1 Ceiling Concentrations (dry weight basis)

Parameter in units mg/kg
Arsenic 75
Cadmium 85
Copper 4300
Lead 840
Mercury 57
Molybdenum 75
Nickel 420
Selenium 100
Zinc 7500

Table 2 Cumulative Loading Limits

Parameter in units lbs/acre
Arsenic 37
Cadmium 35
Copper 1339
Lead 268
Mercury 15
Molybdenum not established*
Nickel 375
Selenium 89
Zinc 2500

*The cumulative limit for molybdenum has not been established at the time of permit issuance

5. Pathogen and Vector Attraction Reduction

5.1 Biosolids shall be processed, treated, or be incorporated or injected into the soil to meet one of the vector attraction reduction requirements in Minnesota Rules, pt. 7041.1400.

5.2 Biosolids shall be processed or treated by one of the alternatives in Minnesota Rules, pt. 7041.1300 to meet the Class A or Class B standards for the reduction of pathogens. When Class B biosolids are applied to the land, the site restrictions in Minnesota Rules, pt. 7041.1300 must also be met.

Chapter 7. Biosolids Land Application

5. Pathogen and Vector Attraction Reduction

5.3 The minimum duration between application and harvest, grazing or public access to areas where Class B biosolids have been applied to the land is as follows:

a. 14 months for food crops whose harvested parts may touch the soil/biosolids mixture (such as melons, squash, tomatoes, etc.), when biosolids are surface applied, incorporated or injected.

b. 20 months or 38 months depending on the application method for food crops whose harvested parts grow in the soil (such as potatoes, carrots, onions, etc.). The 20 month time period is required when biosolids are surface applied or surface applied and incorporated after they have been on the soil surface for at least four (4) months. The 38 month time period is required when the biosolids are injected or surface applied and incorporated within four (4) months of application.

c. 30 days for feed crops, other food crops (such as field corn, sweet corn, etc.), hay or fiber crops when biosolids are surface applied, incorporated or injected.

d. 30 days for grazing of animals when biosolids are surface applied, incorporated or injected.

e. One year where there is a high potential for public contact with the site, (such as a reclamation site located in populated areas, a construction site located in a city, turf farms, plant nurseries, etc.) and 30 days where there is low potential for public contact (such as agricultural land, forest, a reclamation site located in an unpopulated area, etc.) when biosolids are surface applied, incorporated, or injected.

6. Management Practices

6.1 The management practices for the land application of biosolids are described in detail in Minnesota Rules, pt. 7041.1200 and must be followed unless specified otherwise in a site approval letter or a permit issued by the MPCA.

6.2 Overall management requirements:

a. Biosolids must not be applied to the land if it is likely to adversely affect a threatened or endangered species listed under Section 4 of the Endangered Species Act or its designated critical habitat.

b. Biosolids must not be applied to flooded, frozen or snow covered ground so that the biosolids enter wetlands or other waters of the state.

c. Biosolids must be applied at an agronomic rate unless specified otherwise by the MPCA in a permit.

d. Biosolids shall not be applied within 33 feet of a wetland or waters of the state unless specified otherwise by the MPCA in a permit.

7. Monitoring Requirements

7.1 Representative samples of biosolids applied to the land must be analyzed by methods specified in Minnesota Rule pt. 7041.3200 for the following parameters: arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, Kjeldahl nitrogen, ammonia nitrogen, total solids, volatile solids, phosphorus, potassium and pH.

Chapter 7. Biosolids Land Application

7. Monitoring Requirements

7.2 At a minimum, biosolids must be monitored at the frequencies specified in Table 3 for the parameters listed above, and any pathogen or vector attraction reduction requirements in Minnesota Rules, pts. 7041.1300 and 7041.1400 if used to determine compliance with those parts.

Table 3 Minimum Sampling Frequencies

Biosolids Applied* (metric tons/365-day period)	Biosolids Applied* (tons/365-day period)	Frequency (times/365-day period)
>0 but <290	>0 but <320	1
>=290 but <1,500	>=320 but <1,650	4
>=1,500 but <15,000	>=1,650 but <16,500	6
>=15,000	>=16,500	12

* Either the amount of bulk biosolids applied to the land or the amount of biosolids received by a person who prepares biosolids that are sold or given away in a bag or other container for application to the land (dry weight basis).

7.3 Representative samples of biosolids that are transferred to storage units and are stored for more than two years shall be analyzed by methods specified in Minnesota Rule pt. 7041.3200 for each cropping year they are stored for the following parameters: arsenic, cadmium, copper, lead, molybdenum, nickel, selenium, and zinc. Mercury is specifically NOT included in the stored biosolids analysis because of the short holding time [28 days] required between sampling and analysis.

7.4 Increased sampling frequencies are specified for the parameters listed in Table 4. Sampling at a frequency at twice the minimum frequencies in Table 3 is required if concentrations listed in Table 4 are exceeded (based on the average of all analyses made during the previous cropping year).

Table 4 Increased Frequency of Sampling

Parameter (mg/kg dry weight basis)
Arsenic 38
Cadmium 43
Copper 2150
Lead 420
Mercury 28
Molybdenum 38
Nickel 210
Selenium 50
Zinc 3750

8. Records

8.1 The Permittee shall keep records of the information necessary to show compliance with pollutant concentrations and loadings, pathogen reduction requirements, vector attraction reduction requirements and management practices as specified in Minnesota Rules, pt. 7041.1600, as applicable to the quality of biosolids produced.

9. Reporting Requirements

9.1 By December 31 following the end of each cropping year, the Permittee shall submit a Biosolids Annual Report for the land application of biosolids on a form provided by or approved by the MPCA. The report shall include the requirements in Minnesota Rules, part 7041.1700.

Chapter 7. Biosolids Land Application

9. Reporting Requirements

9.2 If, during any cropping year, biosolids were transferred, or not land applied, the Permittee shall submit a Biosolids Annual Report by December 31 following the end of the cropping year. The report shall state that biosolids were not land applied, how much was generated, and where they were transferred to.

9.3 For biosolids that are stored for more than two years, the Biosolids Annual Report must also include the analytical data from the representative sample of the biosolids generated during the cropping year.

9.4 The Permittee shall submit the Biosolids Annual Report to:

Biosolids Coordinator
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

9.5 The Permittee must notify the MPCA in writing when 90 percent or more of any of the cumulative pollutant loading rates listed for any Land Application Sites has been reached for a site.

Chapter 8. Waste Stream Stations

1. Requirements for Specific Stations

1.1 WS 001: Submit a monthly DMR by 21 days after the end of each calendar month following permit issuance.

1.2 WS 002: Submit a monthly DMR by 21 days after the end of each calendar month following permit issuance.

1.3 WS 003: Submit a monthly DMR by 21 days after the end of each calendar month following permit issuance.

1.4 WS 004: Submit a monthly DMR by 21 days after the end of each calendar month following permit issuance.

1.5 WS 005: Submit a monthly DMR by 21 days after the end of each calendar month following permit issuance.

1.6 WS 006: Submit a monthly DMR by 21 days after the end of each calendar month following permit issuance.

1.7 WS 007: Submit a monthly DMR by 21 days after the end of each calendar month following permit issuance.

2. General Requirements

2.1 The City of Mankato and Mankato Energy Center, LLC have entered into a cooperative agreement to construct, operate, and maintain a water reclamation project adjacent to the City's existing treatment plant.

The water reclamation project will provide phosphorus removal for all the treatment plant's flow and will provide additional filtration and chlorination to a portion of that water (up to 6.2 mgd) in such a way that it is suitable for cooling and process use at the Mankato Energy Center.

Chapter 8. Waste Stream Stations

2. General Requirements

2.2 The use of effluent obtained from the WWTP at the Mankato Energy Center will result in a reduced discharge volume to the Minnesota River due to evaporative losses in the Mankato Energy Center's cooling towers. Evaporative loss is expected to result in an increase in the phosphorus concentration of the water returned from the Mankato Energy Center to the WWTP (as compared to the phosphorus concentration of the effluent directed to the Mankato Energy Center), but no change in phosphorus mass. Water from the cooling water system will be routed back to the wastewater treatment plant upstream of the final dechlorination process.

Per the limits and monitoring section of this permit, the Permittee shall meet a 0.9 mg/L total phosphorus limit at the alternate compliance point to be located directly downstreatm from the phosphorus treatment system.

Additionally, the Permittee shall achieve a no mass loading increase of phosphorus when water is being routed to the Mankato Energy Center. The Permittee shall ensure that the mass discharged from the final effluent discharge point is less than or equal to the mass calculated at the alternate compliance point at a 1 mg/L phosphorus concentration. This limitation takes into account a small phosphorus addition expected at the Mankato Energy Center for control of pH in the facility's boiler operation so as to ensure that the mass of phosphorus discharged to the river will always be less than or equal to the mass discharge associated with the WWTP meeting a 1 mg/L concentration limit.

2.3 "Disinfected tertiary recycled water" has been determined to be protective of public health in used that include: food crops where the water comes in contact with the edible portion of the crop; parks and playgrounds; school yards; residential landscaping; and unrestricted golf courses. The same level of treatment is required where the recycled water is used in cooling systems that involve a cooling tower.

Sampling Location

2.4 Samples for Station WS 001 shall be collected at point representative of influent flow.

2.5 Samples for Station WS 002 shall be collected at the internal compliance point for phosphorus located directly downstream from the phosphorus treatment system and prior to the flow splitting point for effluent going to Mankato Energy Center.

2.6 Samples for Station WS 003 shall be collected directly downstream from the filtration system.

2.7 Samples for Station WS 004 shall be collected directly downstream from the chlorine disinfection process (in the water reclamation system) prior to flow to the Mankato Energy Center.

2.8 Samples for Station WS 005 shall be collected at the return point for reclaimed water from the Mankato Energy Center, prior to final dechlorination and prior to combining with the flow from the treatment plant.

2.9 If conditions are such that no sample for stations WS002 - WS005 could be reasonably taken during a monitoring period, check the "No Flow" box on the DMR forms.

Discharge Monitoring Reports

2.10 The Permittee shall submit monitoring results in accordance with the limits and monitoring requirements for this station. If flow conditions are such that no sample could be acquired, the Permittee shall check the "No Flow" box and note the conditions on the Discharge Monitoring Report (DMR).

Chapter 9. Surface Discharge Stations

1. Priority Pollutants - Monitoring Requirements

1.1 The Permittee shall monitor the effluent three times in the life of the permit for the following specified priority pollutants. Sampling events shall not be less than one year apart.

Monitoring shall be for the organic priority pollutants identified under the volatile, acid, base/neutral, and pesticide fractions using EPA methods 624, 625 and 608 (40 CFR Part 136, October 25, 1984) as listed in Table II of 40 CFR Part 122, Appendix D.

The following priority pollutant total metals shall also be monitored using either EPA method 200.8 or their corresponding graphite furnace method found in Table IB of 40 CFR Part 136: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc. In addition, the Permittee shall monitor for Total Cyanide (EPA method 335), Total Phenolic Compounds (EPA method 420), and Hardness (total as $CaCO_3$) (EPA method 130). Total Mercury shall be monitored by EPA method 1631, if not already required by the permit.

The sampling results shall be submitted to the MPCA within 30 days of completion of the analysis.

1.2 Submit the results of the first sampling event no later than three years prior to the expiration date of this permit.

1.3 Submit the results of the second sampling event no later than two years prior to the expiration date of this permit.

1.4 Submit the results of the third or final sampling event no later than one year prior to the expiration date of this permit.

2. Requirements for Specific Stations

2.1 SD 001: Submit a monthly DMR by 21 days after the end of each calendar month following permit issuance.

3. Sampling Location

3.1 Samples and measurements required by this permit shall be representative of the monitored activity.

3.2 All samples for this station shall be collected after mixing of all waste streams and dechlorination of the combined waste stream.

4. Surface Discharges

4.1 Floating solids or visible foam shall not be discharged in other than trace amounts.

4.2 Oil or other substances shall not be discharged in amounts that create a visible color film.

4.3 The Permittee shall install and maintain outlet protection measures at the discharge stations to prevent erosion.

5. Discharge Monitoring Reports

5.1 The Permittee shall submit monitoring results for discharges in accordance with the limits and monitoring requirements for this station. If no discharge occurred during the reporting period, the Permittee shall check the "No Discharge" box on the Discharge Monitoring Report (DMR).

Chapter 10. Total Facility Requirements

1. General Requirements

General Requirements

Chapter 10. Total Facility Requirements

1. General Requirements

1.1 Incorporation by Reference. The following applicable federal and state laws are incorporated by reference in this permit, are applicable to the Permittee, and are enforceable parts of this permit: 40 CFR pts. 122.41, 122.42, 136, 403 and 503; Minn. R. pts. 7001, 7041, 7045, 7050, 7052, 7053, 7060, and 7080; and Minn. Stat. Sec. 115 and 116.

1.2 Permittee Responsibility. The Permittee shall perform the actions or conduct the activity authorized by the permit in compliance with the conditions of the permit and, if required, in accordance with the plans and specifications approved by the Agency. (Minn. R. 7001.0150, subp. 3, item E)

1.3 Toxic Discharges Prohibited. Whether or not this permit includes effluent limitations for toxic pollutants, the Permittee shall not discharge a toxic pollutant except according to Code of Federal Regulations, Title 40, sections 400 to 460 and Minnesota Rules 7050, 7052, 7053 and any other applicable MPCA rules. (Minn. R. 7001.1090, subp.1, item A)

1.4 Nuisance Conditions Prohibited. The Permittee's discharge shall not cause any nuisance conditions including, but not limited to: floating solids, scum and visible oil film, acutely toxic conditions to aquatic life, or other adverse impact on the receiving water. (Minn. R. 7050.0210 subp. 2)

1.5 Property Rights. This permit does not convey a property right or an exclusive privilege. (Minn. R. 7001.0150, subp. 3, item C)

1.6 Liability Exemption. In issuing this permit, the state and the MPCA assume no responsibility for damage to persons, property, or the environment caused by the activities of the Permittee in the conduct of its actions, including those activities authorized, directed, or undertaken under this permit. To the extent the state and the MPCA may be liable for the activities of its employees, that liability is explicitly limited to that provided in the Tort Claims Act. (Minn. R. 7001.0150, subp. 3, item O)

1.7 The MPCA's issuance of this permit does not obligate the MPCA to enforce local laws, rules, or plans beyond what is authorized by Minnesota Statutes. (Minn. R. 7001.0150, subp.3, item D)

1.8 Liabilities. The MPCA's issuance of this permit does not release the Permittee from any liability, penalty or duty imposed by Minnesota or federal statutes or rules or local ordinances, except the obligation to obtain the permit. (Minn. R. 7001.0150, subp.3, item A)

1.9 The issuance of this permit does not prevent the future adoption by the MPCA of pollution control rules, standards, or orders more stringent than those now in existence and does not prevent the enforcement of these rules, standards, or orders against the Permittee. (Minn. R. 7001.0150, subp.3, item B)

1.10 Severability. The provisions of this permit are severable, and if any provisions of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances and the remainder of this permit shall not be affected thereby.

1.11 Compliance with Other Rules and Statutes. The Permittee shall comply with all applicable air quality, solid waste, and hazardous waste statutes and rules in the operation and maintenance of the facility.

1.12 Inspection and Entry. When authorized by Minn. Stat. Sec. 115.04; 115B.17, subd. 4; and 116.091, and upon presentation of proper credentials, the agency, or an authorized employee or agent of the agency, shall be allowed by the Permittee to enter at reasonable times upon the property of the Permittee to examine and copy books, papers, records, or memoranda pertaining to the construction, modification, or operation of the facility covered by the permit or pertaining to the activity covered by the permit; and to conduct surveys and investigations, including sampling or monitoring, pertaining to the construction, modification, or operation of the facility covered by the permit or pertaining to the activity covered by the permit. (Minn. R. 7001.0150, subp.3, item I)

Chapter 10. Total Facility Requirements

1. General Requirements

1.13 Control Users. The Permittee shall regulate the users of its wastewater treatment facility so as to prevent the introduction of pollutants or materials that may result in the inhibition or disruption of the conveyance system, treatment facility or processes, or disposal system that would contribute to the violation of the conditions of this permit or any federal, state or local law or regulation.

Sampling

1.14 Representative Sampling. Samples and measurements required by this permit shall be conducted as specified in this permit and shall be representative of the discharge or monitored activity. (40 CFR 122.41 (j)(1))

1.15 Additional Sampling. If the Permittee monitors more frequently than required, the results and the frequency of monitoring shall be reported on the Discharge Monitoring Report (DMR) or another MPCA-approved form for that reporting period. (Minn. R. 7001.1090, subp. 1, item E)

1.16 Certified Laboratory. A laboratory certified by the Minnesota Department of Health shall conduct analyses required by this permit. Analyses of dissolved oxygen, pH, temperature and total residual oxidants (chlorine, bromine) do not need to be completed by a certified laboratory but shall comply with manufacturers specifications for equipment calibration and use. (Minn. Stat. Sec. 144.97 through 144.98 and Minn. R. 4740.2010 and 4740.2050 through 4740.2120) (Minn. R. 4740.2010 and 4740.2050 through 2120)

1.17 The list of analytes that do not need to be performed by a certified laboratory shall also include turbidity.

1.18 Sample Preservation and Procedure. Sample preservation and test procedures for the analysis of pollutants shall conform to 40 CFR Part 136 and Minn. R. 7041.3200.

1.19 Equipment Calibration: Flow meters, pumps, flumes, lift stations or other flow monitoring equipment used for purposes of determining compliance with permit shall be checked and/or calibrated for accuracy at least twice annually. (Minn. R. 7001.0150, subp. 2, items B and C)

1.20 Maintain Records. The Permittee shall keep the records required by this permit for at least three years, including any calculations, original recordings from automatic monitoring instruments, and laboratory sheets. The Permittee shall extend these record retention periods upon request of the MPCA. The Permittee shall maintain records for each sample and measurement. The records shall include the following information (Minn. R. 7001.0150, subp. 2, item C):

a. The exact place, date, and time of the sample or measurement;

b. The date of analysis;

c. The name of the person who performed the sample collection, measurement, analysis, or calculation; and

d. The analytical techniques, procedures and methods used; and

e. The results of the analysis.

Chapter 10. Total Facility Requirements

1. General Requirements

1.21 Completing Reports. The Permittee shall submit the results of the required sampling and monitoring activities on the forms provided, specified, or approved by the MPCA. The information shall be recorded in the specified areas on those forms and in the units specified. (Minn. R. 7001.1090, subp. 1, item D; Minn. R. 7001.0150, subp. 2, item B)

Required forms may include:

DMR Supplemental Form
Individual values for each sample and measurement must be recorded on the DMR Supplemental Form which, if required, will be provided by the MPCA. DMR Supplemental Forms shall be submitted with the appropriate DMRs. You may design and use your own supplemental form; however it must be approved by the MPCA. Note: Required summary information MUST also be recorded on the DMR. Summary information that is submitted ONLY on the DMR Supplemental Form does not comply with the reporting requirements.

1.22 Submitting Reports. DMRs and DMR Supplemental Forms shall be submitted to:

MPCA
Attn: Discharge Monitoring Reports
520 Lafayette Road North
St. Paul, Minnesota 55155-4194.

DMRs and DMR Supplemental Forms shall be postmarked by the 21st day of the month following the sampling period or as otherwise specified in this permit. A DMR shall be submitted for each required station even if no discharge occurred during the reporting period. (Minn. R. 7001.0150, subps. 2.B and 3.H)

Other reports required by this permit shall be postmarked by the date specified in the permit to:

MPCA
Attn: WQ Submittals Center
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

1.23 Incomplete or Incorrect Reports. The Permittee shall immediately submit an amended report or DMR to the MPCA upon discovery by the Permittee or notification by the MPCA that it has submitted an incomplete or incorrect report or DMR. The amended report or DMR shall contain the missing or corrected data along with a cover letter explaining the circumstances of the incomplete or incorrect report. (Minn. R. 7001.0150 subp. 3, item G)

Chapter 10. Total Facility Requirements

1. General Requirements

1.24 Required Signatures. All DMRs, forms, reports, and other documents submitted to the MPCA shall be signed by the Permittee or the duly authorized representative of the Permittee. Minn. R. 7001.0150, subp. 2, item D. The person or persons that sign the DMRs, forms, reports or other documents must certify that he or she understands and complies with the certification requirements of Minn. R. 7001.0070 and 7001.0540, including the penalties for submitting false information. Technical documents, such as design drawings and specifications and engineering studies required to be submitted as part of a permit application or by permit conditions, must be certified by a registered professional engineer. (Minn. R. 7001.0540)

Chapter 10. Total Facility Requirements

1. General Requirements

1.25 Detection Level. The Permittee shall report monitoring results below the reporting limit (RL) of a particular instrument as "<" the value of the RL. For example, if an instrument has a RL of 0.1 mg/L and a parameter is not detected at a value of 0.1 mg/L or greater, the concentration shall be reported as "<0.1 mg/L." "Non-detected," "undetected," "below detection limit," and "zero" are unacceptable reporting results, and are permit reporting violations. (Minn. R. 7001.0150, subp. 2, item B)

Where sample values are less than the level of detection and the permit requires reporting of an average, the Permittee shall calculate the average as follows:

a. If one or more values are greater than the level of detection, substitute zero for all nondetectable values to use in the average calculation.

b. If all values are below the level of detection, report the averages as "<" the corresponding level of detection.

c. Where one or more sample values are less than the level of detection, and the permit requires reporting of a mass, usually expressed as kg/day, the Permittee shall substitute zero for all nondetectable values. (Minn. R. 7001.0150, subp. 2, item B)

1.26 Records. The Permittee shall, when requested by the Agency, submit within a reasonable time the information and reports that are relevant to the control of pollution regarding the construction, modification, or operation of the facility covered by the permit or regarding the conduct of the activity covered by the permit. (Minn. R. 7001.0150, subp. 3, item H)

1.27 Confidential Information. Except for data determined to be confidential according to Minn. Stat. Sec. 116.075, subd. 2, all reports required by this permit shall be available for public inspection. Effluent data shall not be considered confidential. To request the Agency maintain data as confidential, the Permittee must follow Minn. R. 7000.1300.

Noncompliance and Enforcement

1.28 Subject to Enforcement Action and Penalties. Noncompliance with a term or condition of this permit subjects the Permittee to penalties provided by federal and state law set forth in section 309 of the Clean Water Act; United States Code, title 33, section 1319, as amended; and in Minn. Stat. Sec. 115.071 and 116.072, including monetary penalties, imprisonment, or both. (Minn. R. 7001.1090, subp. 1, item B)

1.29 Criminal Activity. The Permittee may not knowingly make a false statement, representation, or certification in a record or other document submitted to the Agency. A person who falsifies a report or document submitted to the Agency, or tampers with, or knowingly renders inaccurate a monitoring device or method required to be maintained under this permit is subject to criminal and civil penalties provided by federal and state law. (Minn. R. 7001.0150, subp.3, item G., 7001.1090, subps. 1, items G and H and Minn. Stat. Sec. 609.671)

1.30 Noncompliance Defense. It shall not be a defense for the Permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit. (40 CFR 122.41(c))

1.31 Effluent Violations. If sampling by the Permittee indicates a violation of any discharge limitation specified in this permit, the Permittee shall immediately make every effort to verify the violation by collecting additional samples, if appropriate, investigate the cause of the violation, and take action to prevent future violations. Violations that are determined to pose a threat to human health or a drinking water supply, or represent a significant risk to the environment shall be immediately reported to the Minnesota Department of Public Safety Duty Officer at 1(800)422-0798 (toll free) or (651)649-5451 (metro area). In addition, you may also contact the MPCA during business hours. Otherwise the violations and the results of any additional sampling shall be recorded on the next appropriate DMR or report.

Chapter 10. Total Facility Requirements

1. General Requirements

1.32 Unauthorized Releases of Wastewater Prohibited. Except for conditions specifically described in Minn. R. 7001.1090, subp. 1, items J and K, all unauthorized bypasses, overflows, discharges, spills, or other releases of wastewater or materials to the environment, whether intentional or not, are prohibited. However, the MPCA will consider the Permittee's compliance with permit requirements, frequency of release, quantity, type, location, and other relevant factors when determining appropriate action. (40 CFR 122.41 and Minn. Stat. Sec 115.061)

1.33 Discovery of a release. Upon discovery of a release, the Permittee shall:

a. Take all reasonable steps to immediately end the release.

b. Notify the Minnesota Department of Public Safety Duty Officer at 1(800)422-0798 (toll free) or (651)649-5451 (metro area) immediately upon discovery of the release. In addition, you may also contact the MPCA during business hours at 1(800) 657-3864.

c. Recover as rapidly and as thoroughly as possible all substances and materials released or immediately take other action as may be reasonably possible to minimize or abate pollution to waters of the state or potential impacts to human health caused thereby. If the released materials or substances cannot be immediately or completely recovered, the Permittee shall contact the MPCA. If directed by the MPCA, the Permittee shall consult with other local, state or federal agencies (such as the Minnesota Department of Natural Resources and/or the Wetland Conservation Act authority) for implementation of additional clean-up or remediation activities in wetland or other sensitive areas.

d. Collect representative samples of the release. The Permittee shall sample the release for parameters of concern immediately following discovery of the release. The Permittee may contact the MPCA during business hours to discuss the sampling parameters and protocol. In addition, Fecal Coliform Bacteria samples shall be collected where it is determined by the Permittee that the release contains or may contain sewage. If the release cannot be immediately stopped, the Permittee shall consult with MPCA regarding additional sampling requirements. Samples shall be collected at least, but not limited to, two times per week for as long as the release continues.

e. Submit the sampling results as directed by the MPCA. At a minimum, the results shall be submitted to the MPCA with the next DMR.

1.34 Upset Defense. In the event of temporary noncompliance by the Permittee with an applicable effluent limitation resulting from an upset at the Permittee's facility due to factors beyond the control of the Permittee, the Permittee has an affirmative defense to an enforcement action brought by the Agency as a result of the noncompliance if the Permittee demonstrates by a preponderance of competent evidence:

a. The specific cause of the upset;

b. That the upset was unintentional;

c. That the upset resulted from factors beyond the reasonable control of the Permittee and did not result from operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventative maintenance, or increases in production which are beyond the design capability of the treatment facilities;

d. That at the time of the upset the facility was being properly operated;

e. That the Permittee properly notified the Commissioner of the upset in accordance with Minn. R. 7001.1090, subp. 1, item I; and

f. That the Permittee implemented the remedial measures required by Minn. R. 7001.0150, subp. 3, item J.

Chapter 10. Total Facility Requirements

1. General Requirements

Operation and Maintenance

1.35 The Permittee shall at all times properly operate and maintain the facilities and systems of treatment and control, and the appurtenances related to them which are installed or used by the Permittee to achieve compliance with the conditions of the permit. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training, and adequate laboratory and process controls, including appropriate quality assurance procedures. The Permittee shall install and maintain appropriate backup or auxiliary facilities if they are necessary to achieve compliance with the conditions of the permit and, for all permits other than hazardous waste facility permits, if these backup or auxiliary facilities are technically and economically feasible Minn. R. 7001.0150. subp. 3, item F.

1.36 In the event of a reduction or loss of effective treatment of wastewater at the facility, the Permittee shall control production or curtail its discharges to the extent necessary to maintain compliance with the terms and conditions of this permit. The Permittee shall continue this control or curtailment until the wastewater treatment facility has been restored or until an alternative method of treatment is provided. (Minn. R. 7001.1090, subp. 1, item C)

1.37 Solids Management. The Permittee shall properly store, transport, and dispose of biosolids, septage, sediments, residual solids, filter backwash, screenings, oil, grease, and other substances so that pollutants do not enter surface waters or ground waters of the state. Solids should be disposed of in accordance with local, state and federal requirements. (40 CFR 503 and Minn. R. 7041 and applicable federal and state solid waste rules)

1.38 Scheduled Maintenance. The Permittee shall schedule maintenance of the treatment works during non-critical water quality periods to prevent degradation of water quality, except where emergency maintenance is required to prevent a condition that would be detrimental to water quality or human health. (Minn. R. 7001.0150. subp. 3, item F and Minn. R. 7001.0150. subp. 2, item B)

1.39 Control Tests. In-plant control tests shall be conducted at a frequency adequate to ensure compliance with the conditions of this permit. (Minn. R. 7001.0150. subp. 3, item F and Minn. R. 7001.0150. subp. 2, item B)

Changes to the Facility or Permit

1.40 Permit Modifications. No person required by statute or rule to obtain a permit may construct, install, modify, or operate the facility to be permitted, nor shall a person commence an activity for which a permit is required by statute or rule until the Agency has issued a written permit for the facility or activity. (Minn. R. 7001.0030)

Permittees that propose to make a change to the facility or discharge that requires a permit modification must follow Minn. R. 7001.0190. If the Permittee cannot determine whether a permit modification is needed, the Permittee must contact the MPCA prior to any action. It is recommended that the application for permit modification be submitted to the MPCA at least 180 days prior to the planned change.

1.41 Construction. No construction shall begin until the Permittee receives written approval of plans and specifications from the MPCA (Minn. Stat. Sec. 115.03(f)).

Plans, specifications and MPCA approval are not necessary when maintenance dictates the need for installation of new equipment, provided the equipment is the same design size and has the same design intent. For instance, a broken pipe, lift station pump, aerator, or blower can be replaced with the same design-sized equipment without MPCA approval.

If the proposed construction is not expressly authorized by this permit, it may require a permit modification. If the construction project requires an Environmental Assessment Worksheet under Minn. R. 4410, no construction shall begin until a negative declaration is issued and all approvals are received or implemented.

Chapter 10. Total Facility Requirements

1. General Requirements

1.42 Report Changes. The Permittee shall give advance notice as soon as possible to the MPCA of any substantial changes in operational procedures, activities that may alter the nature or frequency of the discharge, and/or material factors that may affect compliance with the conditions of this permit. (Minn. R. 7001.0150, subp. 3, item M)

1.43 Chemical Additives. The Permittee shall receive prior written approval from the MPCA before increasing the use of a chemical additive authorized by this permit, or using a chemical additive not authorized by this permit, in quantities or concentrations that have the potential to change the characteristics, nature and/or quality of the discharge.

The Permittee shall request approval for an increased or new use of a chemical additive at least 60 days, or as soon as possible, before the proposed increased or new use.

This written request shall include at least the following information for the proposed additive:

a. The process for which the additive will be used;
b. Material Safety Data Sheet (MSDS) which shall include aquatic toxicity, human health, and environmental fate information for the proposed additive;
c. A complete product use and instruction label;
d. The commercial and chemical names and Chemical Abstract Survey (CAS) number for all ingredients in the additive (If the MSDS does not include information on chemical composition, including percentages for each ingredient totaling to 100%, the Permittee shall contact the supplier to have this information provided); and
e. The proposed method of application, application frequency, concentration, and daily average and maximum rates of use.

Upon review of the information submitted regarding the proposed chemical additive, the MPCA may require additional information be submitted for consideration. This permit may be modified to restrict the use or discharge of a chemical additive and include additional influent and effluent monitoring requirements.

Approval for the use of an additive shall not justify the exceedance of any effluent limitation nor shall it be used as a defense against pollutant levels in the discharge causing or contributing to the violation of a water quality standard. (Minn. R. 7001.0170)

1.44 MPCA Initiated Permit Modification, Suspension, or Revocation. The MPCA may modify or revoke and reissue this permit pursuant to Minn. R. 7001.0170. The MPCA may revoke without reissuance this permit pursuant to Minn. R. 7001.0180.

1.45 TMDL Impacts. Facilities that discharge to an impaired surface water, watershed or drainage basin may be required to comply with additional permits or permit requirements, including additional restriction or relaxation of limits and monitoring as authorized by the CWA 303(d)(4)(A) and 40 CFR 122.44.l.2.i., necessary to ensure consistency with the assumptions and requirements of any applicable US EPA approved wasteload allocations resulting from Total Maximum Daily Load (TMDL) studies.

1.46 Permit Transfer. The permit is not transferable to any person without the express written approval of the Agency after compliance with the requirements of Minn. R. 7001.0190. A person to whom the permit has been transferred shall comply with the conditions of the permit. (Minn. R., 7001.0150, subp. 3, item N)

Chapter 10. Total Facility Requirements

1. General Requirements

1.47 Facility Closure. The Permittee is responsible for closure and postclosure care of the facility. The Permittee shall notify the MPCA of a significant reduction or cessation of the activities described in this permit at least 180 days before the reduction or cessation. The MPCA may require the Permittee to provide to the MPCA a facility Closure Plan for approval.

Facility closure that could result in a potential long-term water quality concern, such as the ongoing discharge of wastewater to surface or ground water, may require a permit modification or reissuance.

The MPCA may require the Permittee to establish and maintain financial assurance to ensure performance of certain obligations under this permit, including closure, postclosure care and remedial action at the facility. If financial assurance is required, the amount and type of financial assurance, and proposed modifications to previously MPCA-approved financial assurance, shall be approved by the MPCA. (Minn. Stat. Sec. 116.07, subd. 4)

1.48 Permit Reissuance. If the Permittee desires to continue permit coverage beyond the date of permit expiration, the Permittee shall submit an application for reissuance at least 180 days before permit expiration. If the Permittee does not intend to continue the activities authorized by this permit after the expiration date of this permit, the Permittee shall notify the MPCA in writing at least 180 days before permit expiration.

If the Permittee has submitted a timely application for permit reissuance, the Permittee may continue to conduct the activities authorized by this permit, in compliance with the requirements of this permit, until the MPCA takes final action on the application, unless the MPCA determines any of the following (Minn. R. 7001.0040 and 7001.0160):

a. The Permittee is not in substantial compliance with the requirements of this permit, or with a stipulation agreement or compliance schedule designed to bring the Permittee into compliance with this permit;

b. The MPCA, as a result of an action or failure to act by the Permittee, has been unable to take final action on the application on or before the expiration date of the permit;

c. The Permittee has submitted an application with major deficiencies or has failed to properly supplement the application in a timely manner after being informed of deficiencies.

APPENDIX B

Wigen Water Technologies – Ultrafiltration Pilot Study Report & Cost Estimate

UF Filter Pilot Study Report
Performed at Mankato, MN
For Bolton & Menk, Inc.

Report # 3370

January 27, 2016

Prepared for:
Mr. Jake Pichelmann
Bolton & Menk, Inc.
1960 Premier Drive
Mankato, MN 56001-5900
Email: jakepi@bolton-menk.com
Tel: (507) 625-4171 ext. 2867

UF System Manufacturer:
Wigen Water Technologies
Mr. Joseph Kelly
Email: Joe.Kelly@wigen.com
Tel: 952-448-4884, 315-415-2620

TABLE OF CONTENTS

ATTACHMENTS

1. TORAY UF Module Technical Specifications
2. DOW UF Module Technical Specifications
3. Inge UF Module Technical Specifications

1.0 INTRODUCTION

January 27, 2016

Wigen Water Technologies (WWT) is pleased to submit this Pilot Report to Bolton & Menk, Inc. summarizing performance data taken during the duration of UF Pilot Study performed at Mankato, MN. The data and results presented herein have been taken from August 10, 2015 through November 7, 2015.

The UF pilot system evaluated the performance of three UF membranes each from different suppliers.

- TORAY HFU-2020N
- DOW SFD-2880 XP
- Inge dizzer® XL 0.9 MB 60W

The UF pilot utilized full scale membrane modules and was configured with the same instrumentation and operating procedures as a full-scale ultrafiltration system.

We are grateful for the assistance provided by Mr. Josh Gad of the City of Mankato and his staff whose combined efforts helped to ensure a successful UF pilot study.

Please review the content and our design recommendations in this report.

Sincerely,

Joseph Kelly
Pilot Program Manager
Wigen Water Technologies

2.0 PILOT STUDY OBJECTIVES

Evaluate the effectiveness of ultrafiltration as a tertiary step for phosphorus removal providing an efflunet phosphorus concentration of 0.1 mg/L TP or less with a target value of 0.06 mg/L TP.

3.0 PILOT SYSTEM DESCRIPTION

3.1 TORAY Ultrafiltration Membrane Information

The TORAY HFU-2020N Ultrafiltration module was one of three UF filters evaluated at the Mankato, MN pilot study. The UF filter module consists of a pressurized vessel which contains hollow fiber polyvinylidene difluoride (PVDF) membranes that operate in a dead-end filtration mode. Specific membrane details are summarized in Table 3.1.1 with additional product literature provided in Attachment 1.

Table 3.1.1: TORAY HFU-2020N UF Membrane Module Specifications

Parameter		Description
Nominal Pore Size		**0.01 micrometers**
Active Membrane Surface Area		**775 sq ft (72 m^2)**
Flow Direction		**Outside-in**
Approx. Dimensions	Dia. x Length	**8.5” x 96”**
Weight	Full of Water	**243 lb (110 kg)**
	Empty	**148 lb (67 kg)**
Material	Membrane	**PVDF**
	Casing	**PVC**
	Potting	**Epoxy Resin**
Membrane Fiber Dimensions		**ID: 0.9 mm OD: 1.4 mm**
Design Operating Pressure		**0 to 44 psi**
Operating Temperature		**1 – 40 deg C**
Operating pH Range		**1-10 filtration (0-12 CIP)**
Oxidation Resistance		**3,000 mg/L NaOCl**
Maximum Instantaneous Flux		**100 GFD @ 20 ^{o}C**

3.2 DOW Ultrafiltration Membrane Information

The DOW SFD-2880 XP Ultrafiltration module was one of three UF filters evaluated at the Mankato, MN pilot study. The UF filter module consists of a pressurized vessel which contains hollow fiber PVDF membranes that operate in a dead-end filtration mode. Specific membrane details are summarized in Table 3.2.1 with additional product literature provided in Attachment 2.

Table 3.2.1: DOW SFD-2880 XP UF Membrane Module Specifications

Parameter		Description
Nominal Pore Size		0.03 micrometers
Active Membrane Surface Area		829 sq ft
Flow Direction		Outside-in
Approx. Dimensions	Dia. x Length	8.9” x 93”
Weight	Full of Water	220 lb
	Empty	135 lb
Material	Membrane	PVDF
	Casing	PVC
	Potting	Epoxy Resin
Membrane Fiber Dimensions		ID: 0.7 mm OD: 1.3 mm
Design Operating Pressure		0 to 45 psi
Operating Temperature		1 – 40 deg C
Operating pH Range		2-11
Oxidation Resistance		2,000 mg/L NaOCl
Maximum Recommended Flux		65 GFD @ 24 °C

3.3 Inge Ultrafiltration Membrane Information

The Inge dizzer® XL 0.9 MB 60W Ultrafiltration module was one of three UF filters evaluated at the Mankato, MN pilot study. The UF filter module consists of a pressurized vessel which contains hollow fiber PESM membranes that operate in a dead-end filtration mode. Specific membrane details are summarized in Table 3.3.1 with additional product literature provided in Attachment 3.

Table 3.3.1: Inge dizzer® XL 0.9 MB 60W UF Membrane Module Specifications

Parameter		Description
Nominal Pore Size		**0.02 micrometers**
Active Membrane Surface Area		**645 sq ft**
Flow Direction		**Inside-Out**
Approx. Dimensions	Dia. x Length	**9.9" x 66"**
Weight	Wet	**120 lb (55 kg)**
Material	Membrane	**PESM**
	Casing	**PVC**
	Potting	**Epoxy Resin**
Capillaries per Fiber		**7**
Membrane Fiber Dimensions		**ID: 0.9 mm** **OD: 4 mm**
Design Operating Pressure		**0 to 70 psi**
Operating Temperature		**1 – 40 deg C**
Operating pH Range		**1-13**
Oxidation Resistance		**2,000 mg/L NaOCl**
Flux Range		**35-105 GFD (60 – 180 l/(m^2h))**

3.4 Pilot Plant Description

Figure 3.4.1: UF Pilot Skid utilized at the Mankato, MN Pilot study

The UF pilot plant used for this pilot study consisted of the following components:

Ultrafiltration Pilot System:

- (3) 50 GPM @ 47 psi, 3 HP Feed/CIP pumps with VFD.
- (3) Amiad TAF750 300 micron automatic backwashing feed strainers.
- (1) 90 GPM @ 30 psi, 3 HP backwash pumps.
- (1) 105 gal HDPE CIP tank.
- (1) Allen Bradley PLC and HMI for system operation and data recording.
- (1) Hach Turbidimeters (feed)
- (3) Hach Turbidimeters (filtrate)
- (4) 10 gal PVC Chemical storage tanks and peristaltic dosing pumps with calibration columns. Can be used for CEB/CIP chemicals and coagulant.
- Skid Dimensions: 200” L x 54” W x 120” H Skid Weight: 5000 lbs Approx.

A summary of the instrumentation provided on the pilot plant is shown below in Table 2.

Table 3.4.1: UF Pilot Plant Instrument Matrix

Instrument	Location
Flow Meters	Feed & Backwash
Turbidimeter	Feed and Filtrate
Pressure Transmitter	Feed and Filtrate
Pressure Gauges	Feed and Filtrate
Temperature & pH	Feed

3.5 Description of Pilot Plant Location

The UF pilot trial was conducted at a Waste Water Treatment Plant (WWTP) located in Mankato, MN. The influent water sample location for the UF evaluation was initially located prior to the Disc Filter System immediately Downstream of the Actiflo System.

The influent water to the pilot unit first enters a Feed Tank which is used to maintain a constant influent flow to the pilot. An accumulation of sand in the Feed Tank as well as in the backwash stream confirmed that there was sand carry over from the Actiflo System. The continued exposure to silica sand has potential to cause abrasion on the UF filter membranes.

To mitigate this risk, tighter strainer backwash screens were installed on the Amaid backwash strainers. The tighter screen did capture the iron and sand; however, it also quickly blinded the screen. The short operation time between strainer backwashes and incomplete removal of the solids prevented the use of the tighter screens on the strainer.

It was decided to move the influent water sample point to Downstream of the Disc Filter System. The new sample point was operational on August 26th 2015.

4.0 RESULTS AND DISCUSSION

Operational Interruptions

Equipment failures periodically interfered with the ability to operate the UF pilot autonomously during the duration of the pilot study. The cause and timing of the equipment failures which lead to the interruption in operation are illustrated in Figure 4.0.1.

Pilot Study Operational Parameters

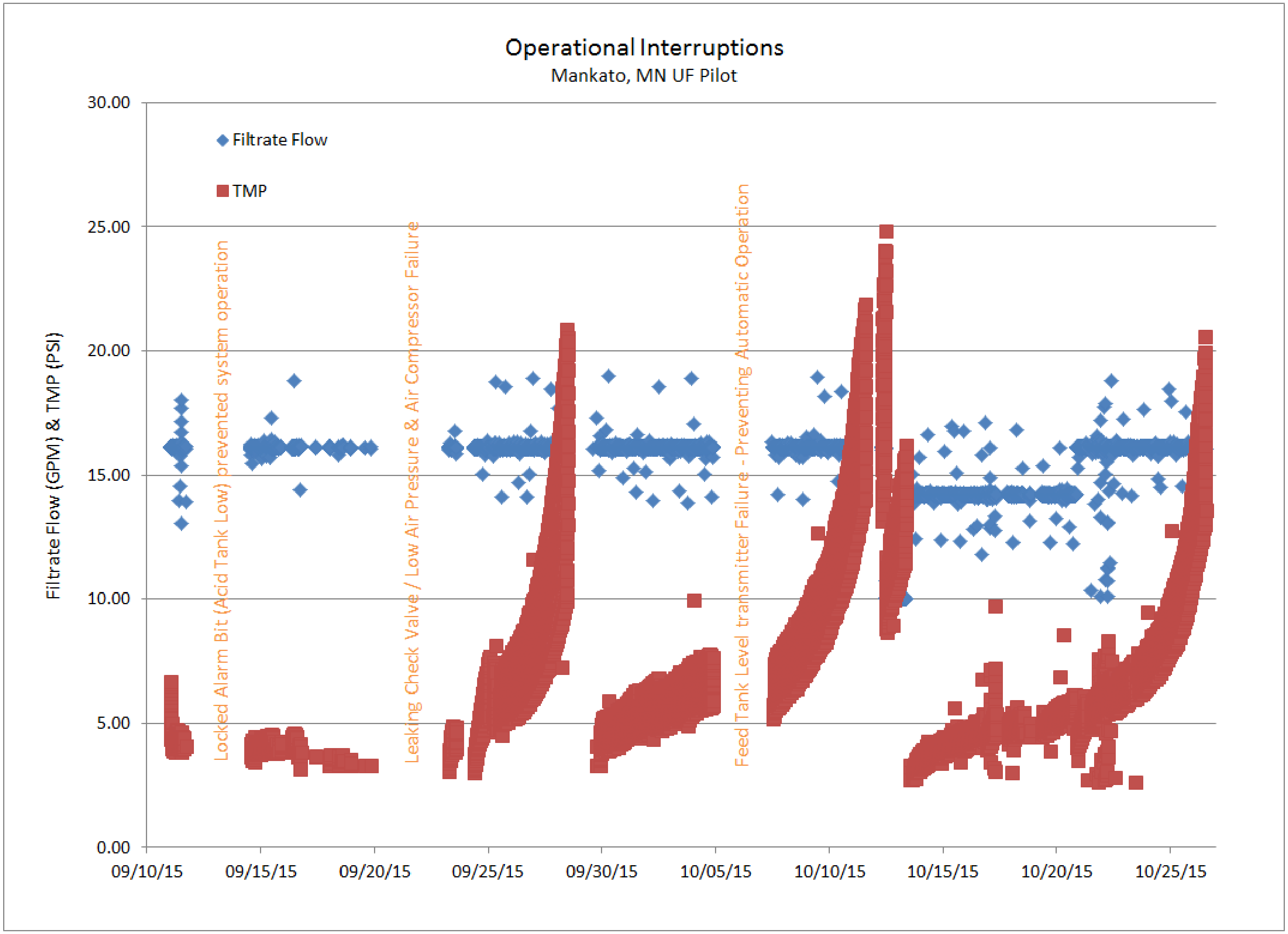
The table below summarizes the system's operational parameters for the Pilot Study.

Table 4.0.1: Operational Parameters

		TORAY HFU-2020N		DOW SFD-2880 XP		Inge dizzer® XL 0.9 MB 60W	
Function	**Parameter**		**Units**		**Units**		**Units**
Filtration	Flow	16.1	GPM	17.8	GPM	15.9	GPM
	Flux	30	GFD	31	GFD	35	GFD
	Filter Time	30	min	30	min	30	min
	Recovery	95	%	95	%	92	%
Backwash	Backwash Flow	18.4	GPM	33	GPM	60	GPM
	Backwash Flux	34	GFD	57	GFD	133	GFD
	Backwash Duration	30	sec	30	sec	40	sec
	Air Scour Flow	3.8	scfm	3.8	scfm	0	scfm
	Air Scour Duration	30	sec	30	sec	0	sec
	Forward Flush Flow	15	GPM	15	GPM	15	GPM
	Forward Flush Duration	30	sec	30	sec	30	sec

Water.
Process.
Solutions.

Figure 4.0.1



4.1 TORAY HFU-2020N Ultrafiltration Module

Figure 4.1.1 is a data plot of the filtrate flow rate and transmembrane pressure (TMP) over time. The TORAY UF filter was challenged @ 30 GFD, which for the TORAY HFU-2020N module equates to a filtrate flow of 16 GPM. This flux produced a hockey stick profile for the rise in TMP. The hockey stick profile refers to when the rate in change of the TMP abruptly increases. This phenomenon is clearly shown in the three curves illustrated in the data plot.

The data plot also illustrates the effectiveness of the clean in place (CIP) sequence. The CIP effectively returned the TMP back to the initial value of the previous run.

Note that the filtrate flow rate was lowered from 16.1 GPM to 14.2 GPM between 10/13/15 and 10/20/15. The drop in flow was initially lowered to allow the TORAY filter to remain below the high TMP set-point and continue to produce filtrate while in the queue to receive a CIP. After the CIP was completed the lower flow rate was maintained and then raised back to the 16.1 GPM filtrate flow rate at 9 AM on 10/20/15.

Figure 4.1.2 & Figure 4.1.3 provide a comparison between the two flux rates. Figure 4.1.2 illustrates the data set for the higher filtrate flow rate of 16.1 GPM which produces a 2 psi increase in TMP over the 30 minute filtrate interval. Figure 4.1.3 illustrates the data set for the lower filtrate flow rate of 14.2 GPM which produces a 0.9 psi increase in TMP over the 30 minute filtrate interval.

It is difficult to predict the rate of TMP rise from viewing this 24 hour data sets, however, referring back to Figure 4.1.1 the trend is evident. It is clear that a reduction in the flux rate would extend the filtrate duration prior to reaching the inflection in the TMP/time slope.

Figure 4.1.4 is a plot of the filtrate turbidity and total phosphorus results of the TORAY UF filtrate. The rise in filtrate turbidity readings correspond with the increase in TMP. The flow rate to the filtrate turbidity meter is dependent on the pressure in the filtrate piping. This change in sample flow rate is a potential reason for the change in the effluent turbidity readings. The actual change in the value is very small as these are mNTU measurements.

Figure 4.1.5 is a plot of the total phosphorus results at three locations; Downstream of the Actiflo System, Downstream of the Disc Filter System, and Downstream of the TORAY UF filter. The overall trend indicates that the effluent of the UF filter further decreases the total phosphorus level. The first half of the plot indicates a 0.03 reduction between the Disc Filter effluent and the TORAY UF filter effluent. The second half of the plot illustrates a larger delta, however, I suspect this is due to something with the Disc Filter operation or sampling as the Actiflo results are lower than the Disc Filter.

Figure 4.1.1

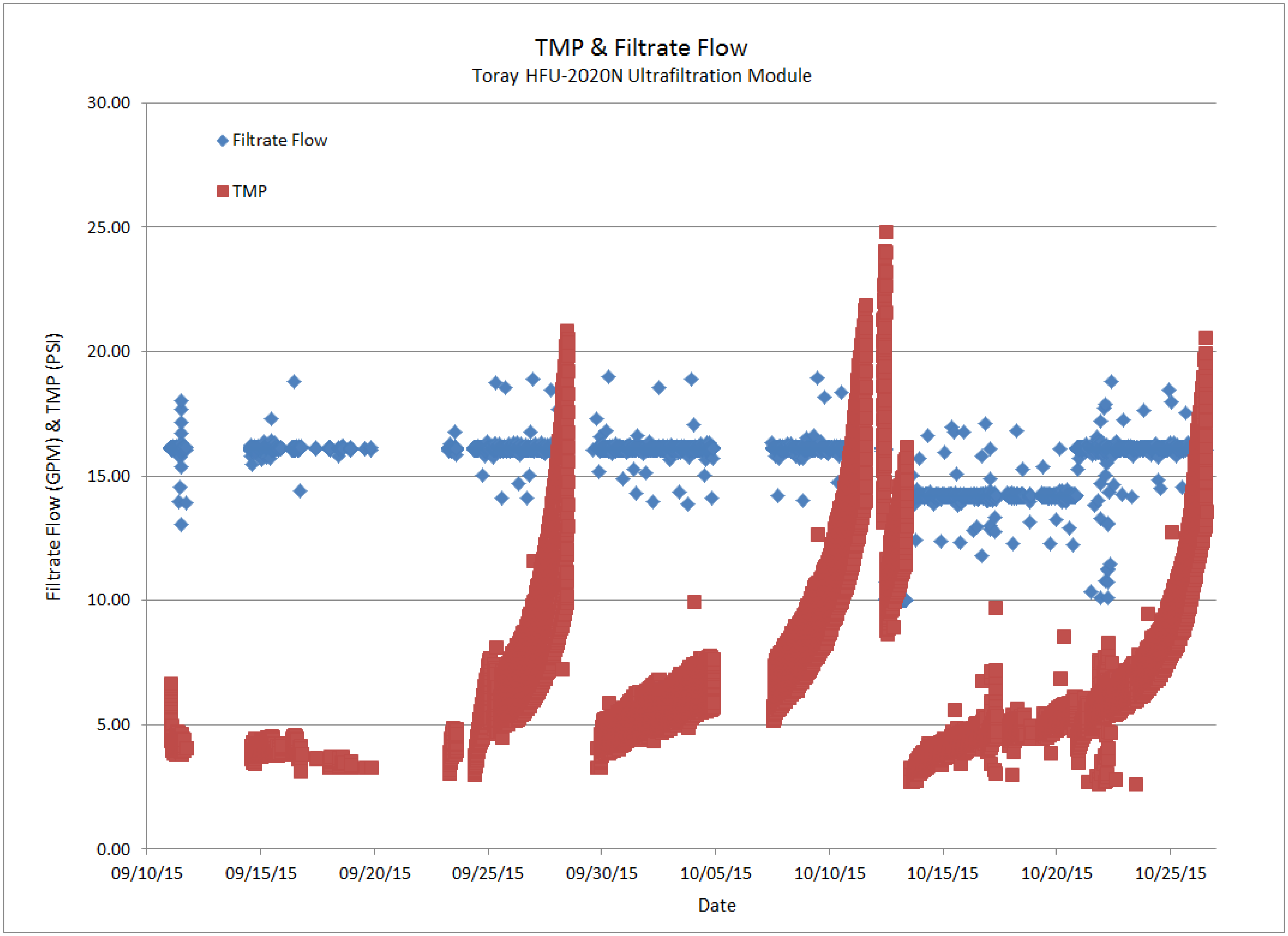

TMP & Filtrate Flow
Toray HFU-2020N Ultrafiltration Module
Filtrate Flow
TMP
Filtrate Flow (GPM) & TMP (PSI)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
09/10/15
09/15/15
09/20/15
09/25/15
09/30/15
10/05/15
10/10/15
10/15/15
10/20/15
10/25/15
Date

Figure 4.1.2

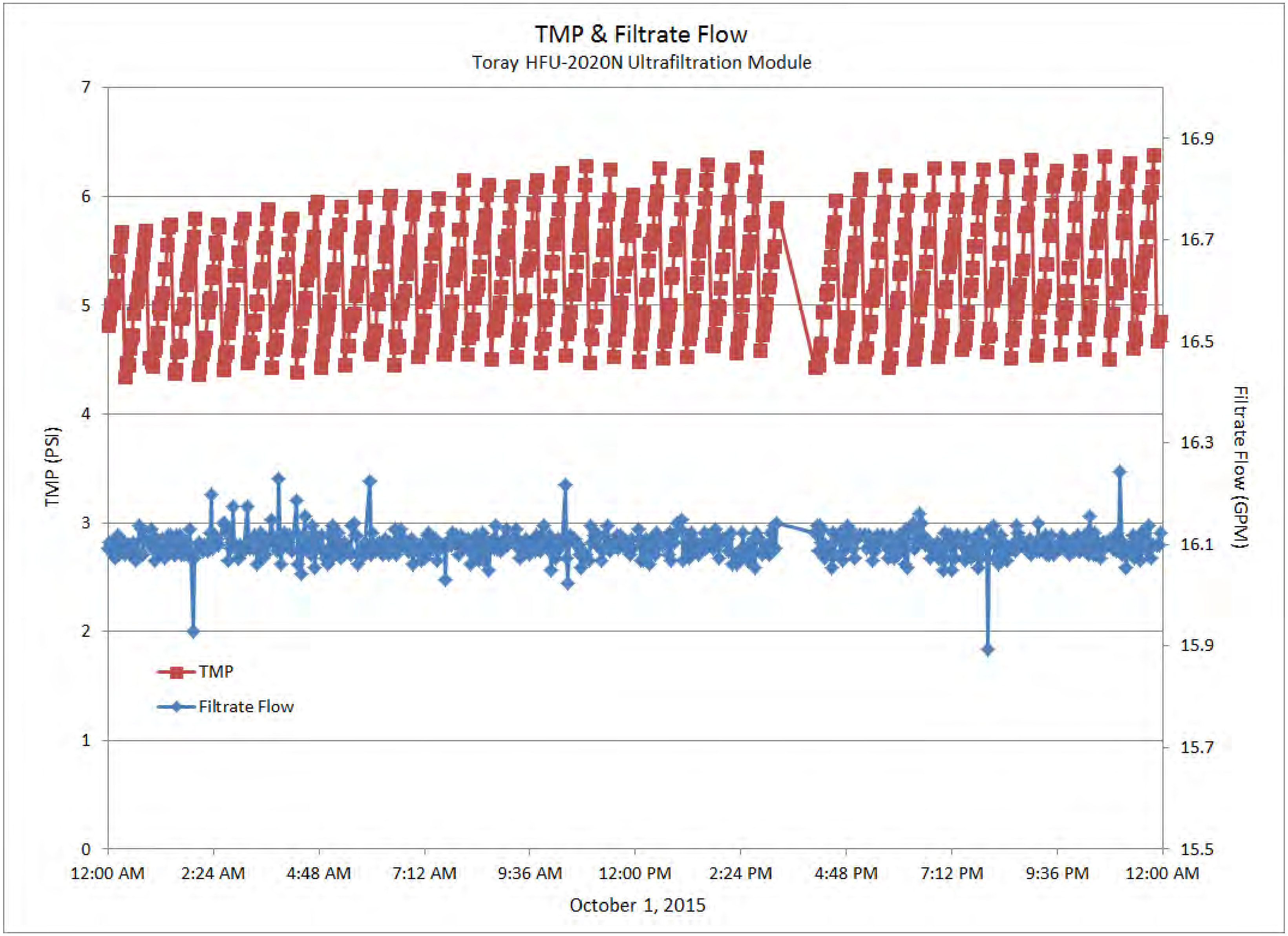

TMP & Filtrate Flow
Toray HFU-2020N Ultrafiltration Module
TMP (PSI)
Filtrate Flow (GPM)
0
1
2
3
4
5
6
7
15.5
15.7
15.9
16.1
16.3
16.5
16.7
16.9
12:00 AM
2:24 AM
4:48 AM
7:12 AM
9:36 AM
12:00 PM
2:24 PM
4:48 PM
7:12 PM
9:36 PM
12:00 AM
October 1, 2015
TMP
Filtrate Flow

Figure 4.1.3

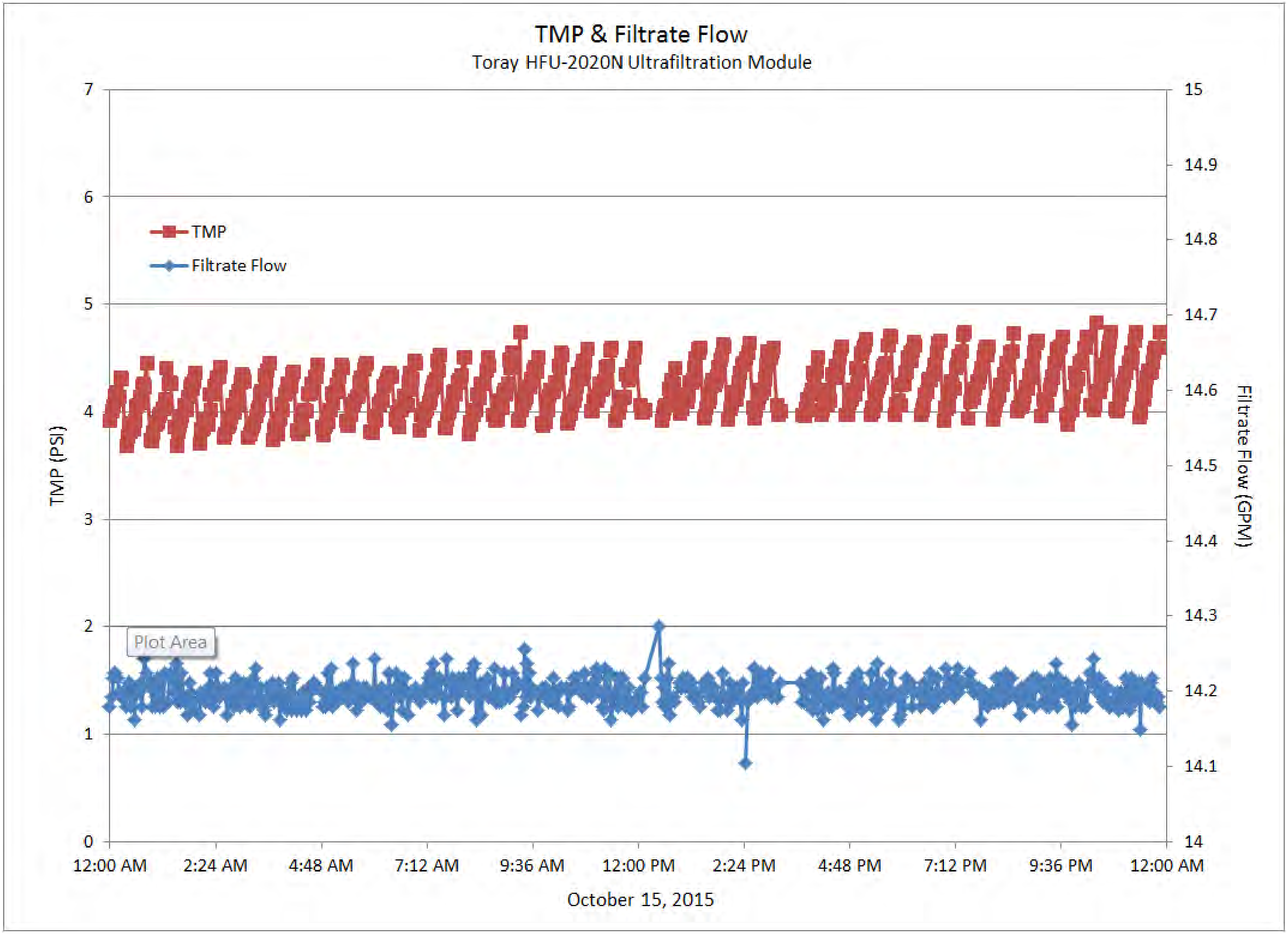

TMP & Filtrate Flow
Toray HFU-2020N Ultrafiltration Module
TMP
Filtrate Flow
Plot Area
TMP (PSI)
Filtrate Flow (GPM)
0
1
2
3
4
5
6
7
14
14.1
14.2
14.3
14.4
14.5
14.6
14.7
14.8
14.9
15
12:00 AM
2:24 AM
4:48 AM
7:12 AM
9:36 AM
12:00 PM
2:24 PM
4:48 PM
7:12 PM
9:36 PM
12:00 AM
October 15, 2015

Figure 4.1.4

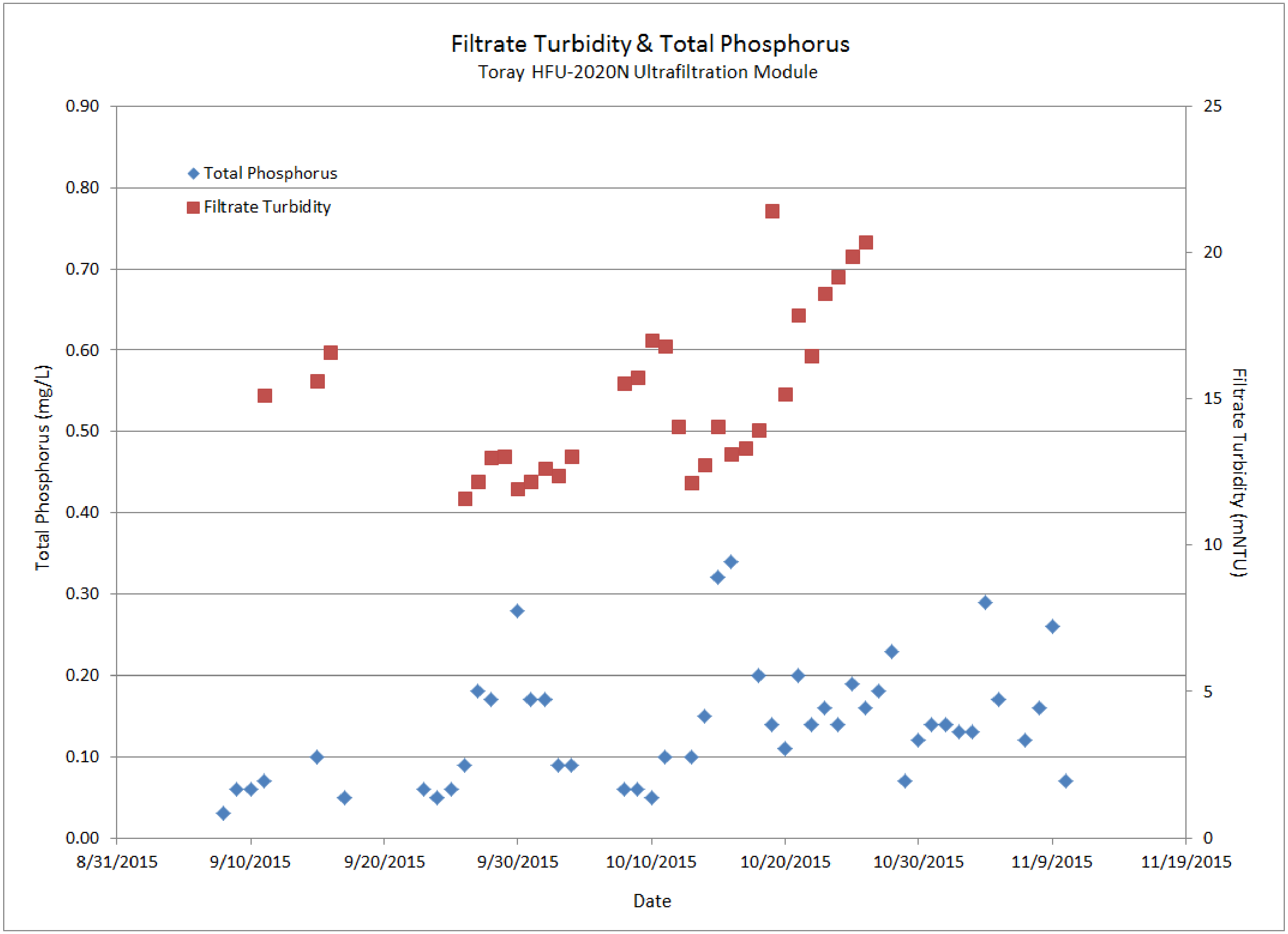
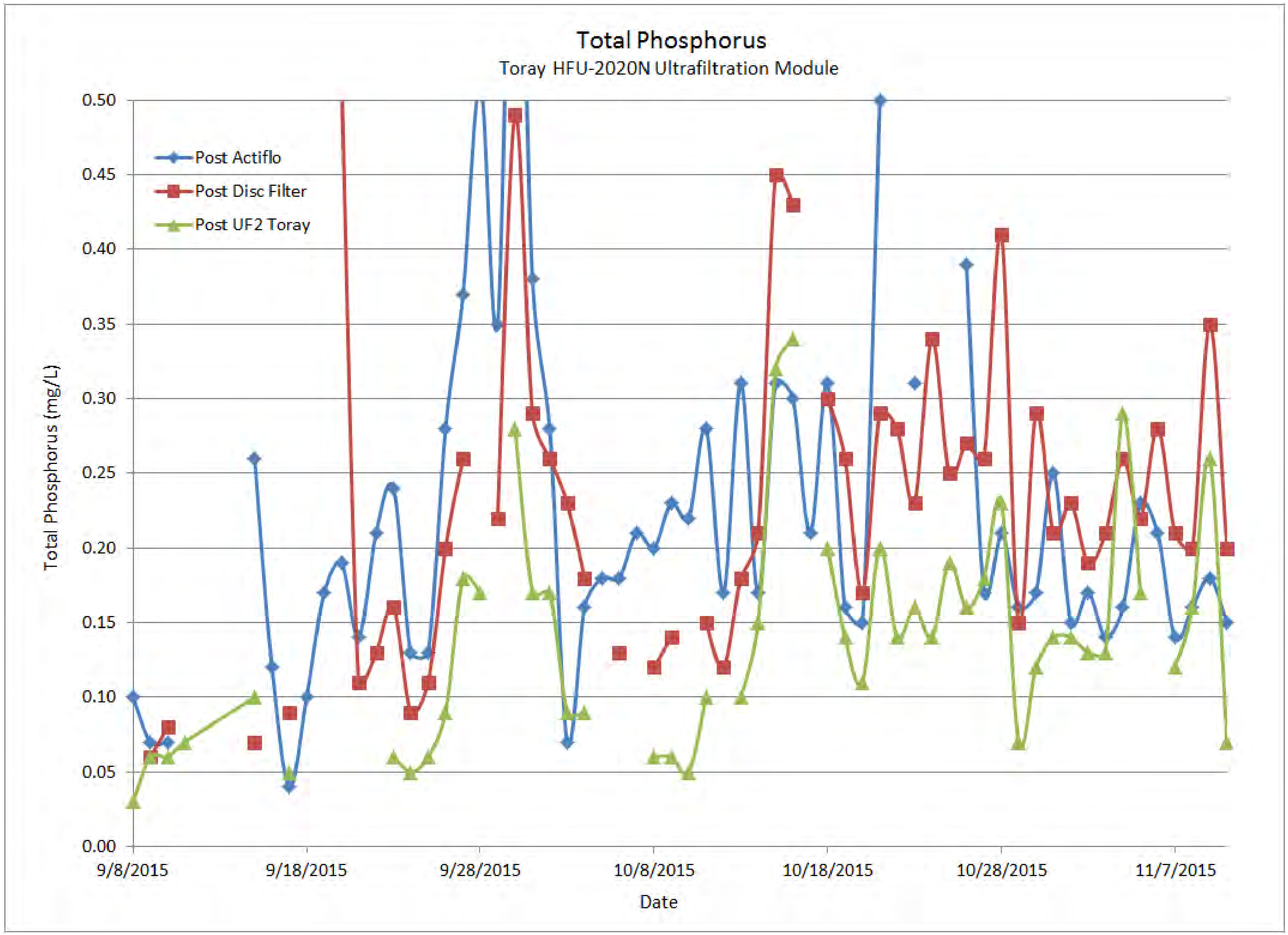

Filtrate Turbidity & Total Phosphorus
Toray HFU-2020N Ultrafiltration Module
Total Phosphorus
Filtrate Turbidity
Total Phosphorus (mg/L)
Filtrate Turbidity (mNTU)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
25
20
15
10
5
0
8/31/2015
9/10/2015
9/20/2015
9/30/2015
10/10/2015
10/20/2015
10/30/2015
11/9/2015
11/19/2015
Date

Figure 4.1.5


Total Phosphorus
Toray HFU-2020N Ultrafiltration Module
Post Actiflo
Post Disc Filter
Post UF2 Toray
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
9/8/2015
9/18/2015
9/28/2015
10/8/2015
10/18/2015
10/28/2015
11/7/2015
Date

4.2 DOW SFD-2880 XP Ultrafiltration Module

Figure 4.2.1 is a data plot of the filtrate flow rate and transmembrane pressure (TMP) over time. The DOW UF filter was challenged @ 31 GFD, which for the DOW SFD-2880 XP module equates to a filtrate flow of 17.8 GPM. The rate of TMP rise observed is constant with a fouled filter surface.

The CIP effectively returned the TMP back to the initial value of the previous run. However, the rate of TMP increase was rapid despite the initially low TMP.

Note that the filtrate flow rate was lowered from 16.1 GPM to 14.2 GPM between 10/2/15 and 10/16/15. The drop in flow did not seem to alter the rapid increase in TMP experienced by the DOW SFD-2880 XP module.

Figure 4.2.2 is a plot of the filtrate turbidity and total phosphorus results of the DOW UF filtrate. The filtrate turbidity readings remained remarkable consistent with a result of 15 mNTU.

Figure 4.2.3 is a plot of the total phosphorus results at three locations; Downstream of the Actiflo System, Downstream of the Disc Filter System, and Downstream of the DOW UF filter. The overall trend indicates that the effluent of the UF filter further decreases the total phosphorus level. The first half of the plot indicates a modest reduction between the Disc Filter effluent and the DOW UF filter effluent. The second half of the plot illustrates a larger delta, however, I suspect this is due to something with the Disc Filter operation or sampling as the Actiflo results are lower than the Disc Filter.

Figure 4.2.1

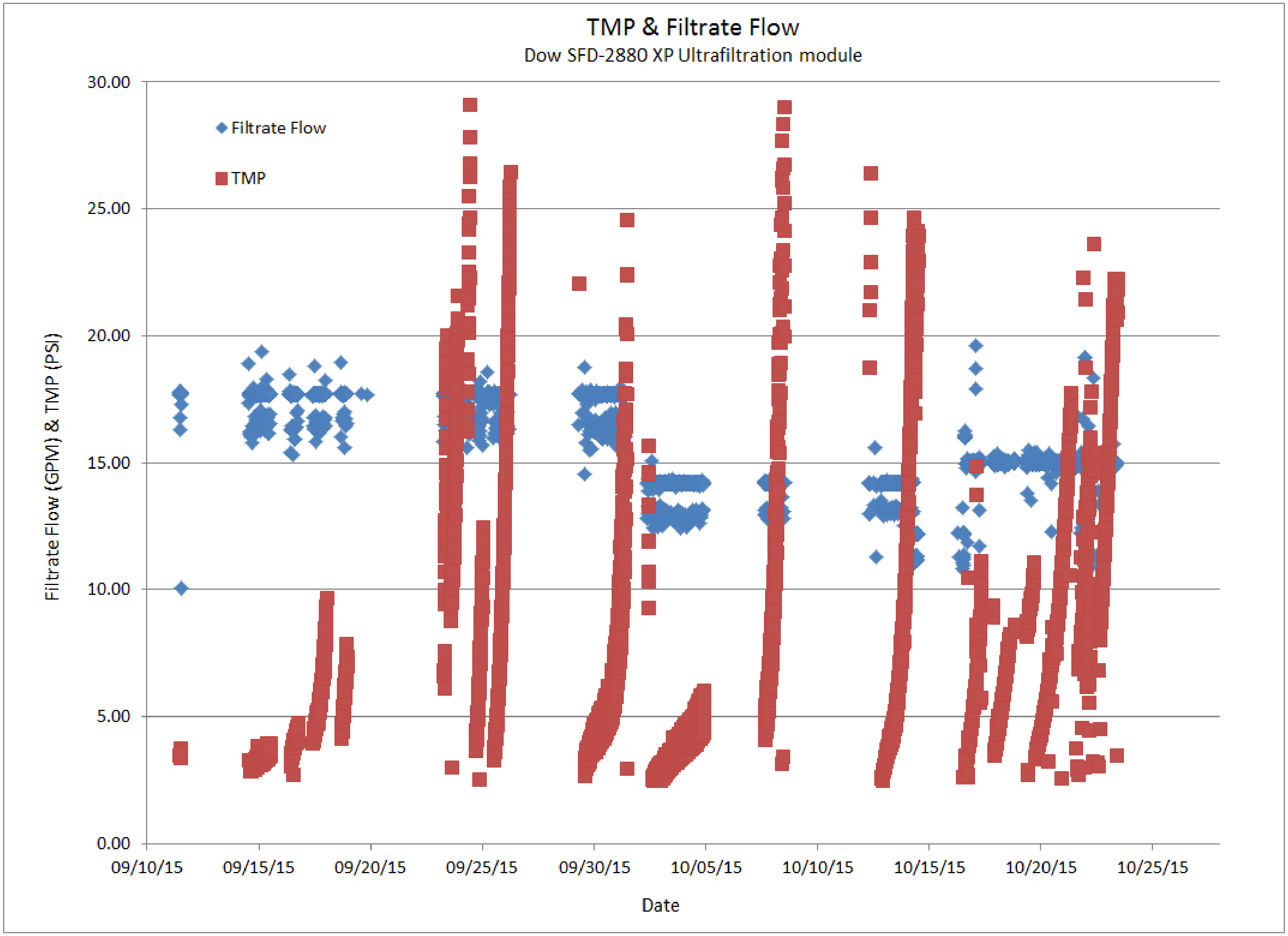

TMP & Filtrate Flow
Dow SFD-2880 XP Ultrafiltration module
Filtrate Flow
TMP
Filtrate Flow (GPM) & TMP (PSI)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
09/10/15
09/15/15
09/20/15
09/25/15
09/30/15
10/05/15
10/10/15
10/15/15
10/20/15
10/25/15
Date

Figure 4.2.2

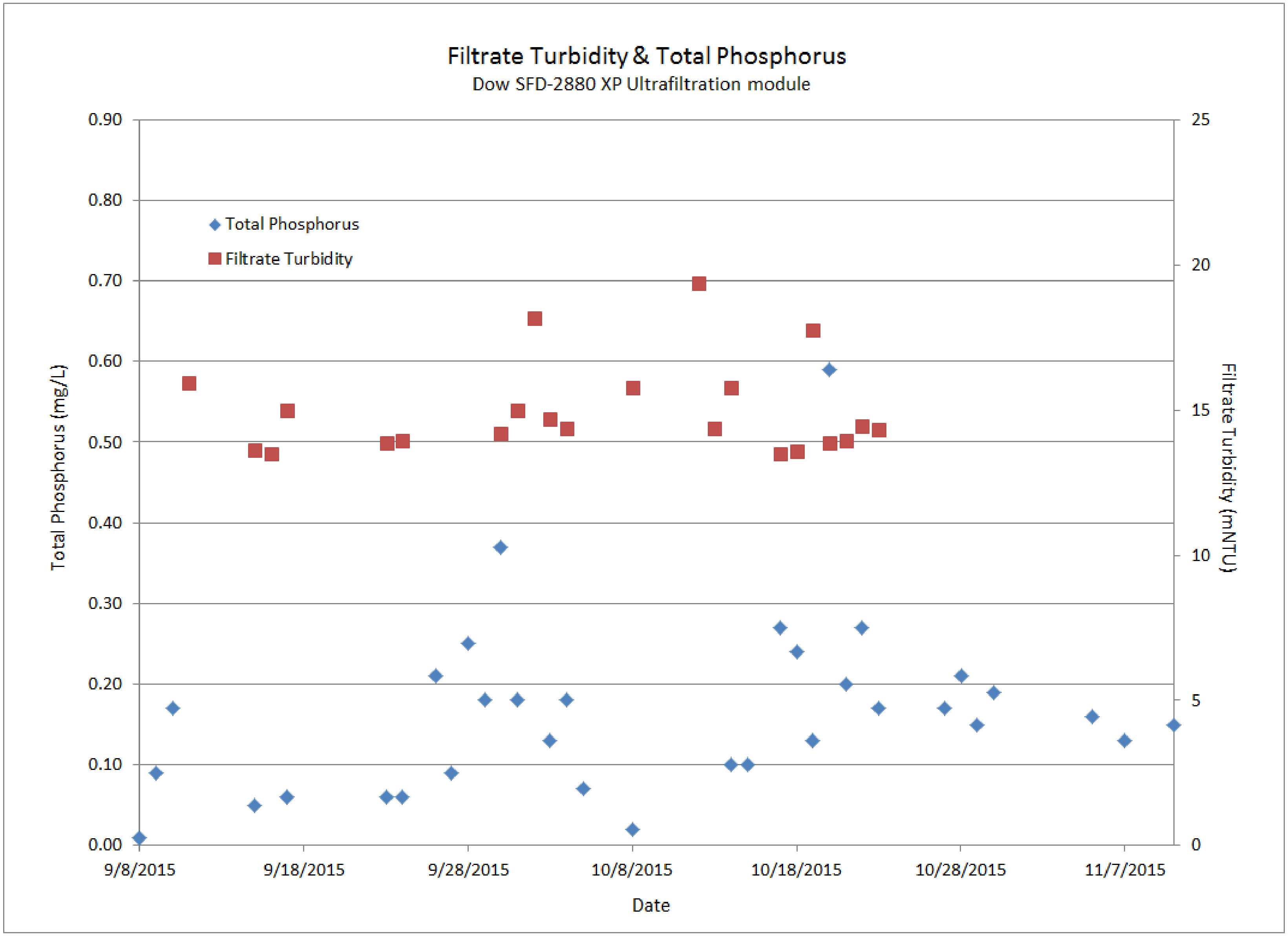
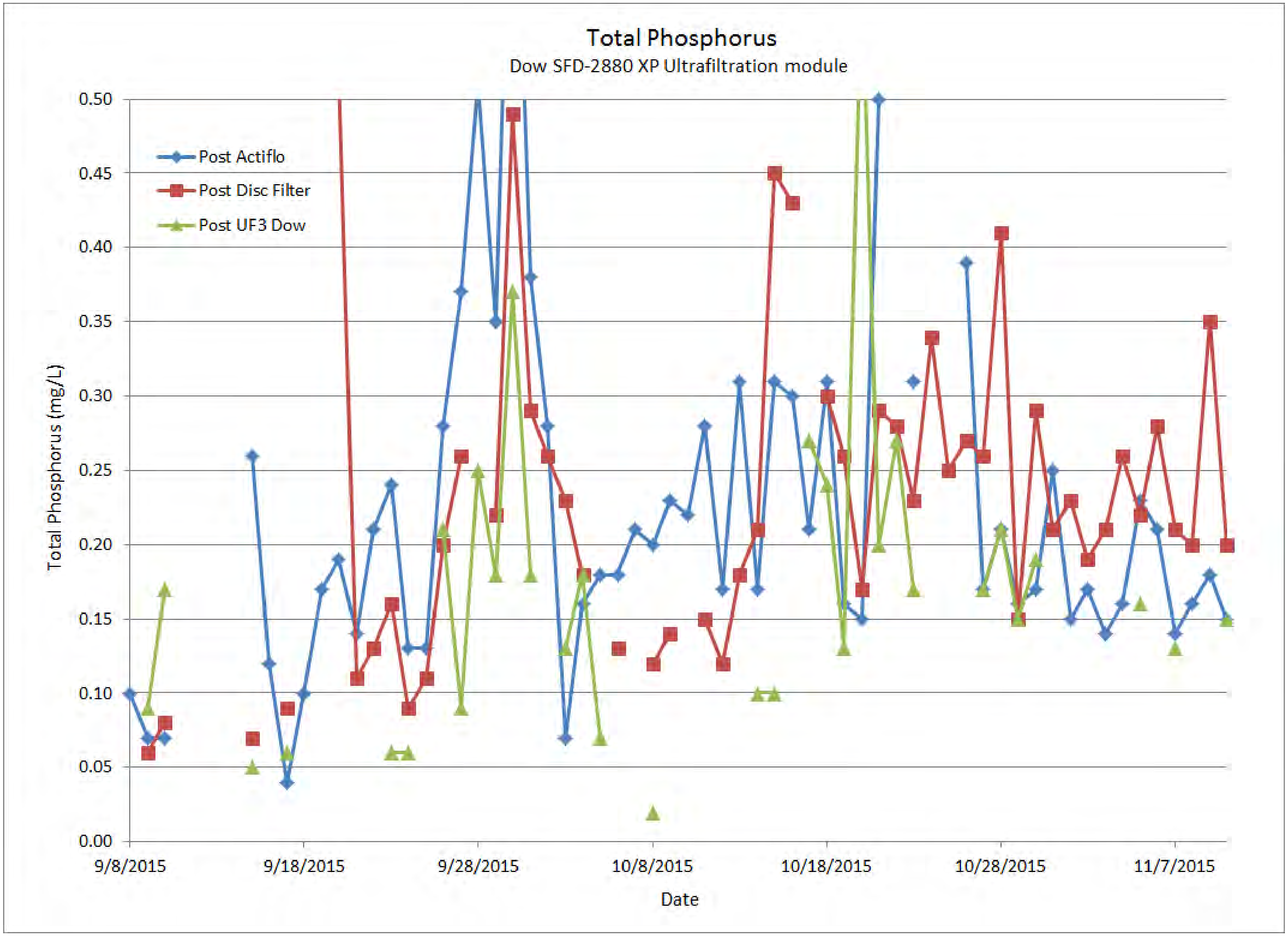

Filtrate Turbidity & Total Phosphorus
Dow SFD-2880 XP Ultrafiltration module
Total Phosphorus
Filtrate Turbidity
Total Phosphorus (mg/L)
Filtrate Turbidity (mNTU)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
0
5
10
15
20
25
9/8/2015
9/18/2015
9/28/2015
10/8/2015
10/18/2015
10/28/2015
11/7/2015
Date

Figure 4.2.3


Total Phosphorus
Dow SFD-2880 XP Ultrafiltration module
Post Actiflo
Post Disc Filter
Post UF3 Dow
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
9/8/2015
9/18/2015
9/28/2015
10/8/2015
10/18/2015
10/28/2015
11/7/2015
Date

4.3 Inge dizzer® XL 0.9 MB 60W Ultrafiltration Module

Figure 4.3.1 is a data plot of the filtrate flow rate and transmembrane pressure (TMP) over time. The Inge UF filter was challenged @ 35 GFD, which for the Inge dizzer® XL 0.9 MB 60W module equates to a filtrate flow of 15.9 GPM. The Inge filter demonstrated a good resistance to fouling.

The CIP effectively returned the TMP back to the initial value of the previous run.

Figure 4.3.2 is a plot of the filtrate turbidity and total phosphorus results of the Inge UF filtrate. The filtrate turbidity readings for the Inge module were higher than the other filters evaluated. The effluent turbidity readings remained between 25 and 70 mNTU.

Figure 4.3.3 is a plot of the total phosphorus results at three locations; Downstream of the Actiflo System, Downstream of the Disc Filter System, and Downstream of the Inge UF filter. The overall trend indicates that the effluent of the UF filter further decreases the total phosphorus level. The first half of the plot indicates a modest reduction between the Disc Filter effluent and the Inge UF filter effluent. The second half of the plot illustrates a larger delta, however, I suspect this is due to something with the Disc Filter operation or sampling as the Actiflo results are lower than the Disc Filter.

Figure 4.3.1

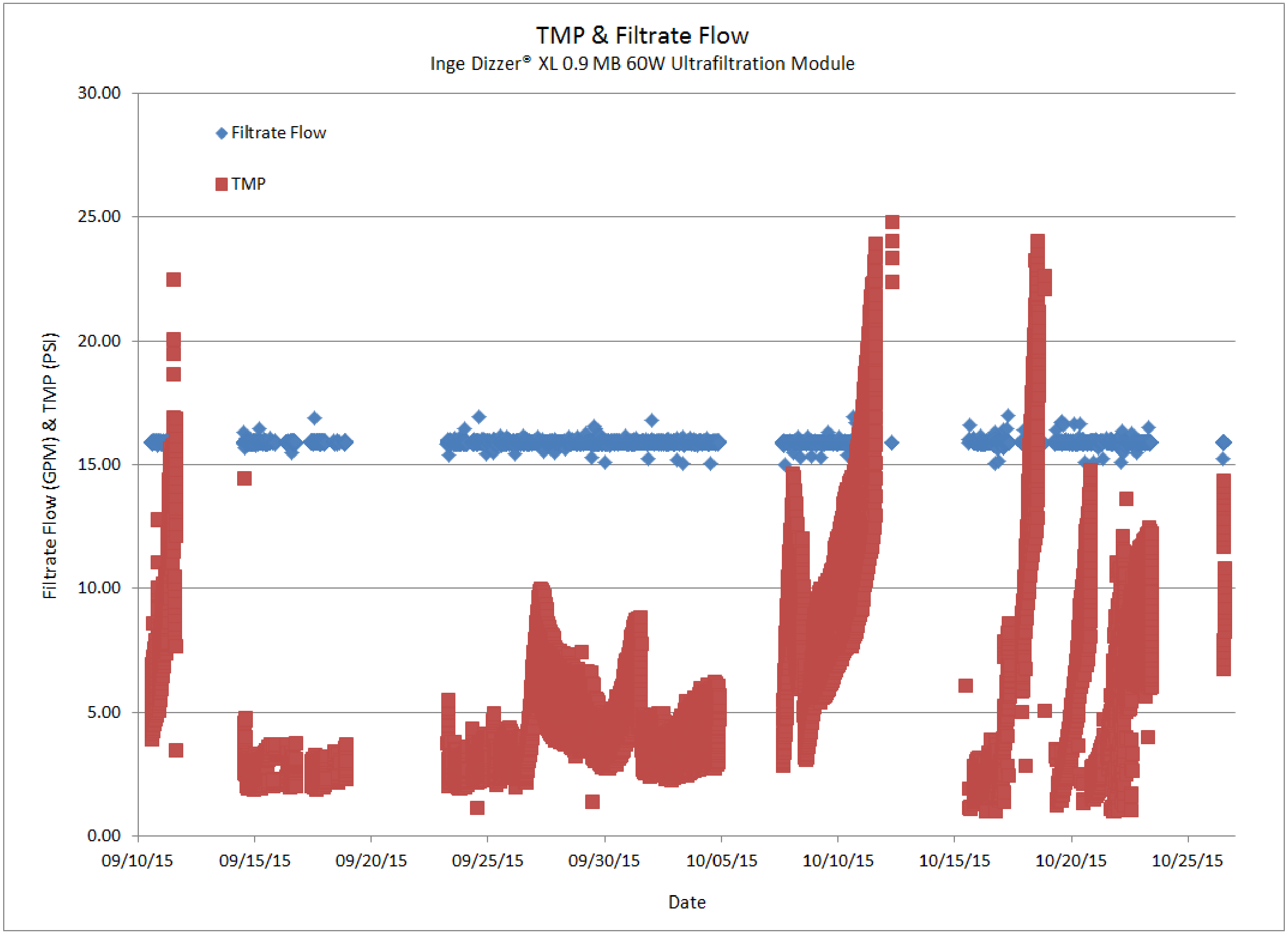

TMP & Filtrate Flow
Inge Dizzer® XL 0.9 MB 60W Ultrafiltration Module
Filtrate Flow
TMP
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Filtrate Flow (GPM) & TMP (PSI)
09/10/15
09/15/15
09/20/15
09/25/15
09/30/15
10/05/15
10/10/15
10/15/15
10/20/15
10/25/15
Date

Figure 4.3.2

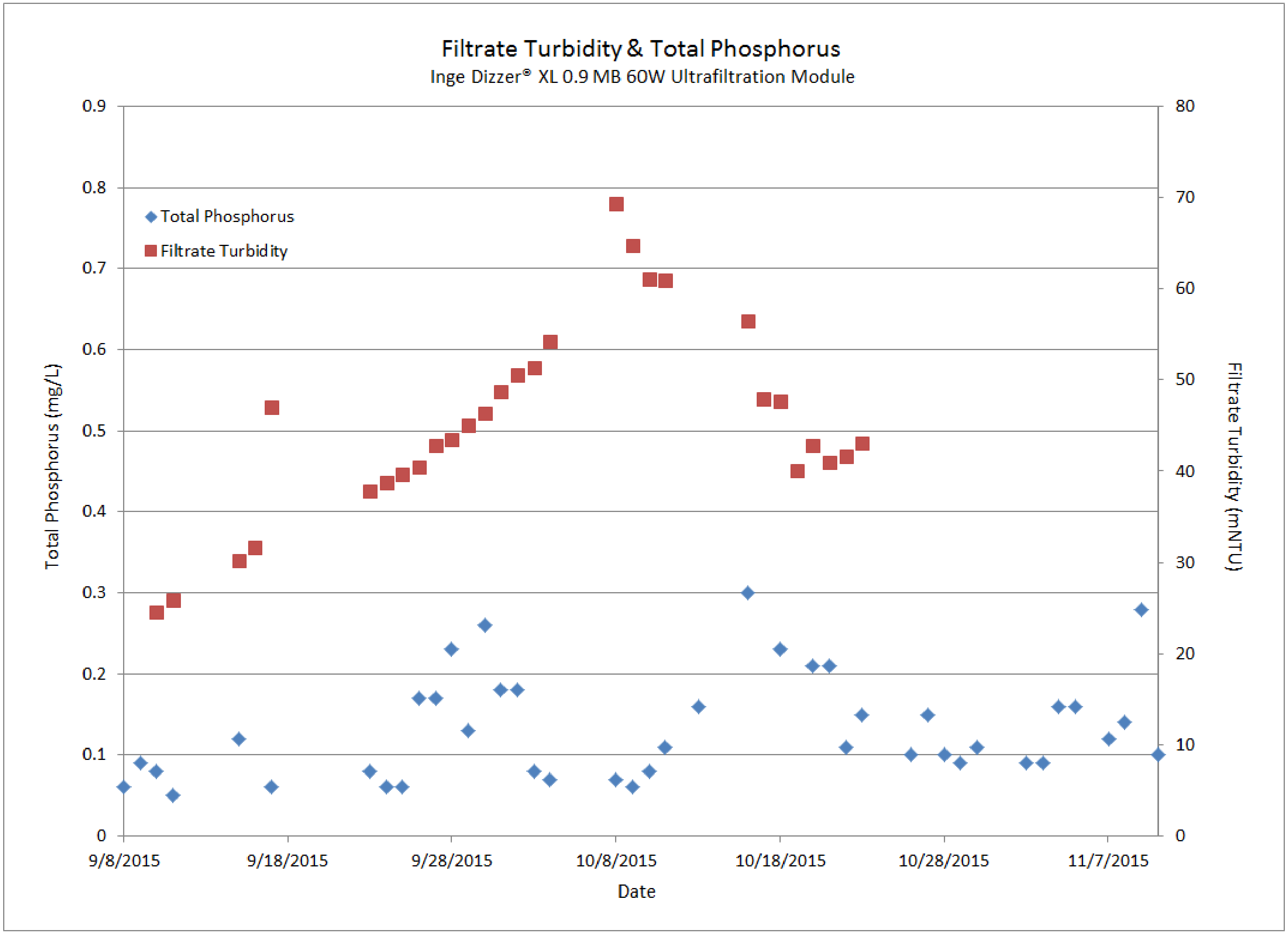
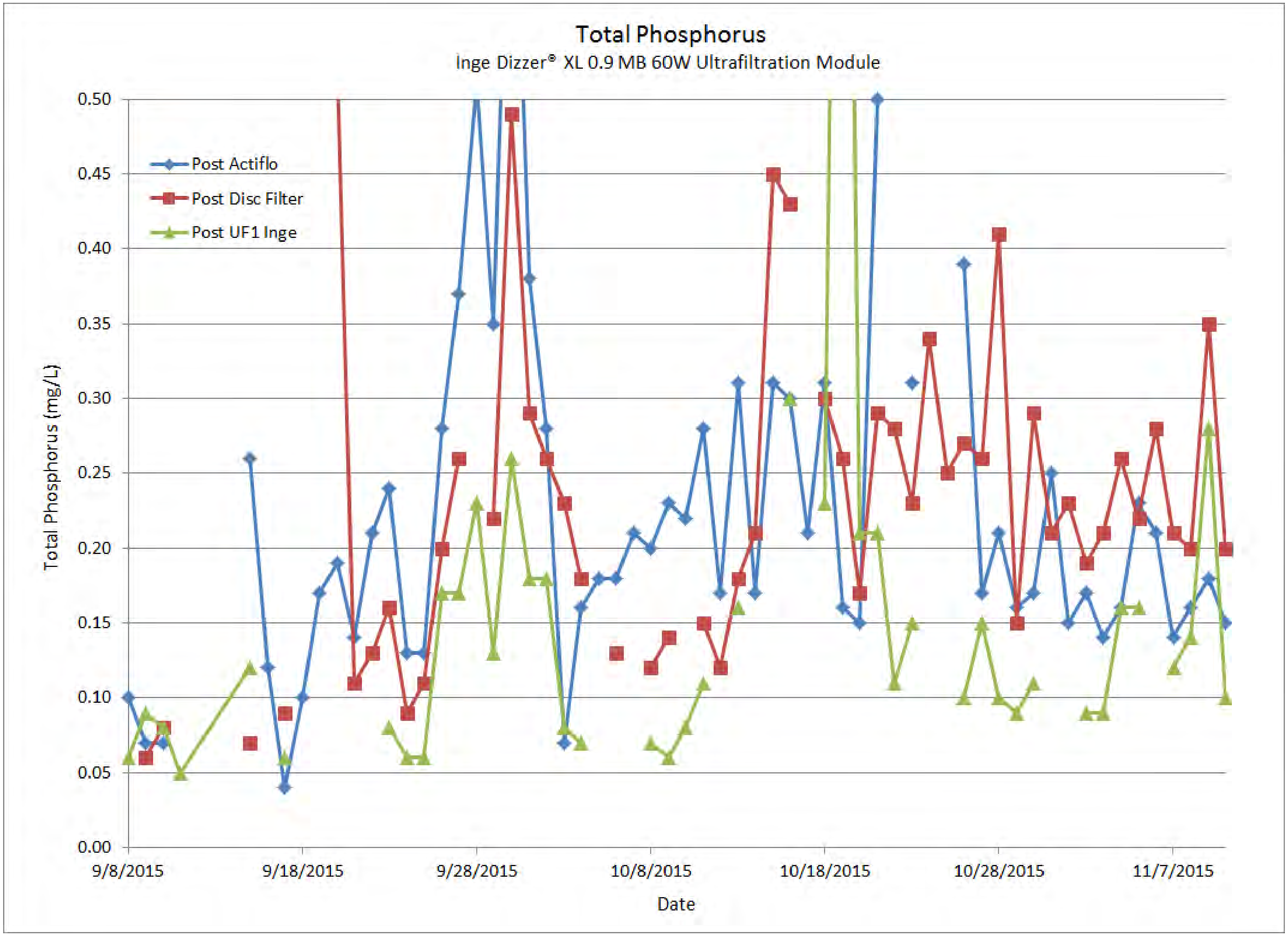

Filtrate Turbidity & Total Phosphorus
Inge Dizzer® XL 0.9 MB 60W Ultrafiltration Module
Total Phosphorus
Filtrate Turbidity
Total Phosphorus (mg/L)
Filtrate Turbidity (mNTU)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
80
70
60
50
40
30
20
10
0
9/8/2015
9/18/2015
9/28/2015
10/8/2015
10/18/2015
10/28/2015
11/7/2015
Date

Figure 4.3.3


Total Phosphorus
Inge Dizzer® XL 0.9 MB 60W Ultrafiltration Module
Post Actiflo
Post Disc Filter
Post UF1 Inge
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
9/8/2015
9/18/2015
9/28/2015
10/8/2015
10/18/2015
10/28/2015
11/7/2015
Date

5.0 SUMMARY

The pilot trial at the Mankato, MN WWTP experienced its share of operational difficulties, but the data collected confirmed that UF filtration will reduce the total phosphorus concentration in the tertiary effluent.

The total phosphorus concentration in the UF filtrate was consistently lower than effluent from both the Actiflo and disc filter systems. However, as Figures 4.1.5, 4.2.3, and 4.3.3 display, that concentration was variable and followed the general effluent concentration trends of the Actiflo and disc filter systems. The UF filtration system was unable to consistently provide filtrate that met the total phosphorus concentration goals. More exploration is needed to fine tune the system so that tertiary effluent water quality goals are met.

The secondary effluent feeding the tertiary treatment system has a high fouling potential which can be observed by the rapid rise in TMP displayed in Figures 4.1.1, 4.2.1, and 4.3.1. Both the Toray and Inge UF modules demonstrated adequate fouling resistances which can be observed in the above mentioned Figures as the “blade” in the hockey stick analogy or as the longer filter run times at a TMP centered at 5 psi. The CIP sequences were effective at removing any accumulated foulant, and allowed the modules to return to their baseline TMP of 5 psi.

Due to the high fouling potential of the secondary effluent, careful attention to the design of the CIP system is recommended. The CIP system should be designed to provide daily, “mini” CIPs as well as monthly full CIPs to each filter rack.

6.0 RECOMMENDATIONS FOR FULL SCALE IMPLIMENTATION

Silica sand will need to be effectively removed from the influent water prior to the UF filter system. The abrasive character of the silica sand will alter the surface properties of the UF membranes. The result will lead to permanent fouling on the affected area of the membrane. The reduction of high permeability membrane area will cause the filter system to perform below expectations. A robust strainer system such as an Amiad Grooved Disc Filter will be required upstream of the UF system.

A multiple train UF system utilizing universal filter racks will provide flexibility in design. A system with a quantity of eight 8" diameter filter piping assemblies is recommended. The system is intended to operate within a flux range of 20 to 30 GFD an average influent flow of 9.4 MGD. The eight rack design will operate within a flux range of 25 to 35 GFD for a maximum design flow of 11.25 MGD.

A three tank CIP system capable of completing one full CIP within an eight hour day would be incorporated into the system design. A multi tank CIP system will allow daily "mini" CIPs as well as monthly full CIPs to each filter rack.

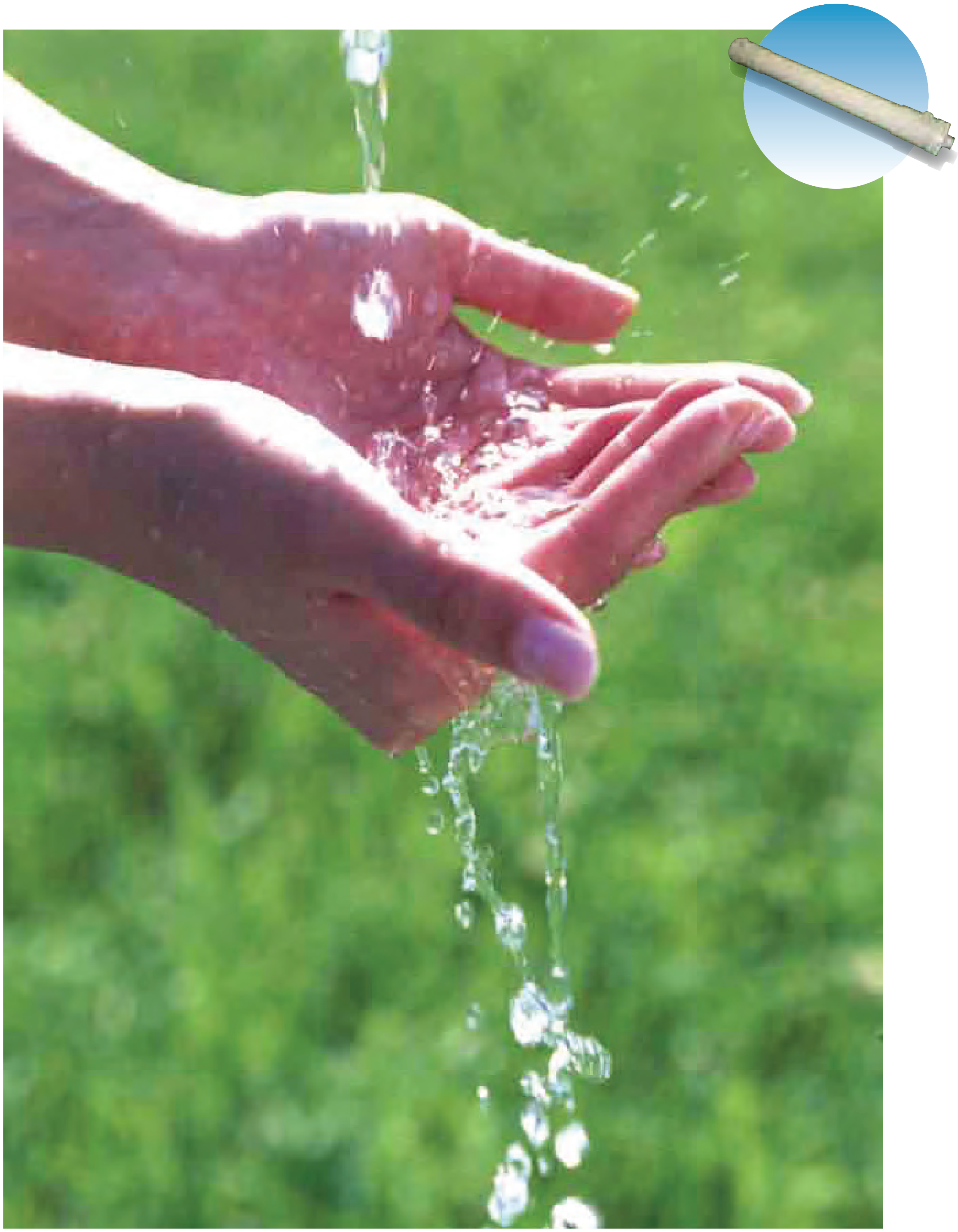
ATTACHMENTS

1. TORAY UF Module Technical Specifications
2. DOW UF Module Technical Specifications
3. Inge UF Module Technical Specifications

TORAY
Innovation by Chemistry

TORAYFIL® HFU/HFS Series

PVDF Hollow Fiber UF Membrane
Pressured Type Module



Toray Industries, Inc.

Pressured Type Module Specifications

Series		HFU Series		HFS Series	
Module Type		HFU-2020	HFU-1020	HFS-2020	HFS-1020
MWCO or Pore Size		150,000 Da		0.02 micrometer	
Membrane Surface Area [Outer Surface]		72 m^2 (775 ft^2)	29 m^2 (312 ft^2)	72 m^2 (775 ft^2)	29 m^2 (312 ft^2)
Design Flux (m^3/hour)		8.0 - 2.6	3.2 - 1.1	11.0 - 2.4	4.3 - 1.0
Dimensions	Diameter	216 mm (8.50 inches)	216 mm (8.50 inches)	216 mm (8.50 inches)	216 mm (8.50 inches)
	Length	2,160 mm (7.087 ft.)	1,120 mm (3.675 ft.)	2,160 mm (7.087 ft.)	1,120 mm (3.675 ft.)
Weight	Full of water	110 kg	60 kg	110 kg	60 kg
	After draining	67 kg	40 kg	67 kg	40 kg
Material	Membrane	PVDF (Polyvinylidene fluoride)			
	Casing	Polyvinylchloride			
	Potting	Epoxy Resin or equivalent			
Max. Inlet Pressure		300 kPa (44 psi)			
Operating Temperature Range		0 – 40 degree C			
pH Range		1 – 10 at Filtration, 0 – 12 at Chemical Cleaning			

• Other modules with smaller membrane areas are also available upon request.
• Specifications subject to change without notice.

Note:
Product exports may need security control and government regulatory clearances.
Exporters are required to obtain such clearances.

TORAY satisfies global water treatment needs.

Global Website: http://www.toraywater.com/

ASIA (JAPAN)
Toray Industries, Inc. Head Office
MF & UF Membrane Products Dept., Water Treatment Division
1-1, Nihonbashi-muromachi 2-chome, Chuo-ku,
Tokyo 103-8666, JAPAN
TEL: +81-3-3245-4557 FAX: +81-3-3245-4913
URL: http://www.toray.com/

NORTH AMERICA
Toray Membrane USA, Inc.
13435 Danielson Street, Poway, CA 92064, U.S.A.
Tel: +1-858-218-2390 Fax: +1-858-486-3063

EUROPE
Toray Membrane Europe AG
Grabenackerstrasse 8b, CH-4142 Munchenstein 1, Switzerland
Tel: +41-61-415-8710 Fax: +41-61-415-8720

MIDDLE EAST
Toray Membrane Europe (Middle East Branch)
Armada Tower P2 – Suite 1206 Jumeirah Lakes Towers
P.O. Box 17978, Dubai, United Arab Emirates
Tel: +971-4-392-8811 Fax: +971-395-8639

ASIA (SINGAPORE)
Toray Asia Pte. Ltd.
111 Somerset Road, #14-01 Devonshire Wing,
Singapore Power Building, Singapore 238164
Tel: +65-6226-0525 Fax: +65-6226-0509

ASIA (CHINA)
Toray Membrane (Beijing) Co., Ltd.
Room 918, Beijing Fortune Building, 5 Dongsanhuan Beilu,
Chao Yang District, Beijing 100004, China
Tel: +86-10-6590-8365 Fax: +86-10-6590-8611

ASIA (KOREA)
Toray International (Korea), Inc.
10F, LG Mapo Bldg. 275, Gongdeok-dong, Mapo-gu,
Seoul, 121-721, Republic of Korea
Tel: +82-2-3273-8974 Fax: +82-2-3273-8360

About Toray

Established in 1926, Toray is a worldwide leader in chemical manufacturing and related products. Leveraging decades of experience in synthetic fibers and textiles, Toray has expanded into many other fields such as carbon fiber and its composites, plastics, fine chemicals and innovative water treatment technologies.

Toray is committed to achieving sustainable growth and environmental preservation, while meeting the diverse needs of its customers worldwide. Toray constantly strives to contribute to the countries and communities in which it operates, not only through superior products and services, but by acting as a concerned corporate citizen. In this way, Toray seeks to play its part in building a better society for all the people of the world.

Advantages of Toray PVDF Hollow Fiber Membrane Modules

Safe Water Provided

Toray membrane modules are made of reliable materials and manufactured under our rigorous quality control.

Model HFS-2020 is certified for drinking water production.

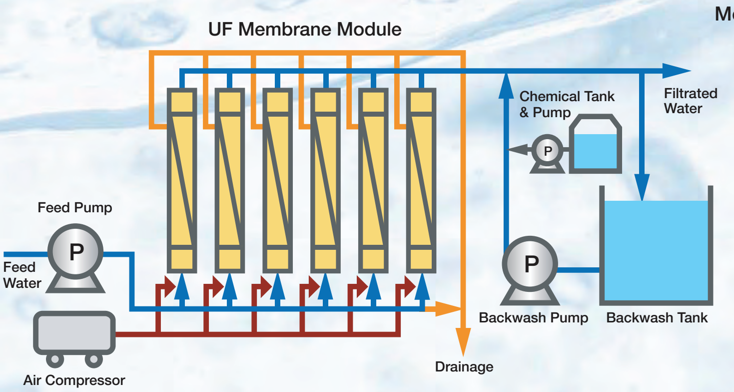
- ANSI/NSF 61
- AMST (Association of Membrane Separation Technology of Japan)
- CDPH (California Department of Public Health)

CLASSIFIED UL WATER QUALITY

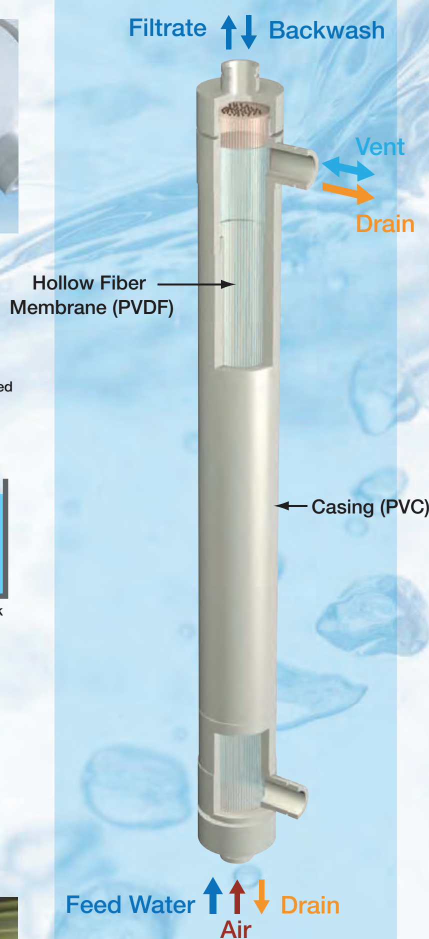
Large Size Module with Large Membrane Area

Module Type 2020 has 72m² of membrane area that provides large amount of filtration flow continuously. Such a large size module is suitable for large-scale water treatment plants.

Cutaway View



Filtration Process Flow



Module Figure

Examples of Actual Plants

Toray's membrane modules provide high-quality water on a daily basis for drinking, RO pretreatment, water reuse and other applications.

Drinking Water Production
Capacity: 44,000m³/d x 2 plants
Location: Tokyo, Japan
Operation start: Mar. 2007

Seawater Desalination (for RO pretreatment)
Capacity: 2,700m³/d
Location: Ehime, Japan
Operation start: Sept. 2003

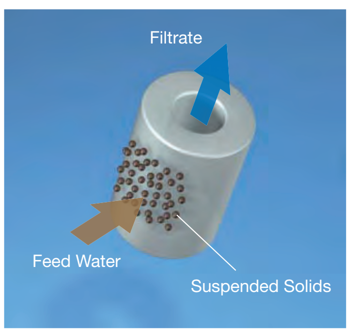
Toray's Innovative Separation Technology Offers Competitive Solutions.

Toray's PVDF hollow fiber membrane module, a pressured type hollow fiber UF (ultra filtration) membrane module, effectively removes suspended solids and microorganisms such as pathogens, when used for various types of water treatment. This innovative membrane module was developed with polymer science and the membrane fabrication technologies accumulated in Toray Industries, Inc. for more than 30 years.

Toray PVDF Hollow Fiber Membrane

Outside-to-Inside Flow Direction

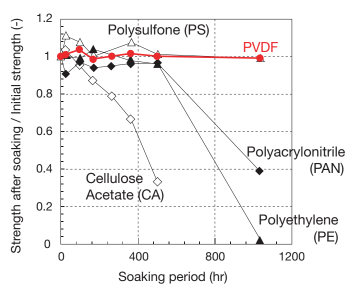
The flow direction is outside-to-inside, which is suitable for high turbidity water treatment, because an air-scrubbing method can be adopted to remove suspended solids effectively.



Flow Direction

High Chemical Resistance with Polyvinylidene Fluoride (PVDF)

PVDF is one of the best membrane materials that allows using chlorine and strong acid for chemical cleaning of the membrane, resulting in better cleaning effect and longer sustainable flux rates.

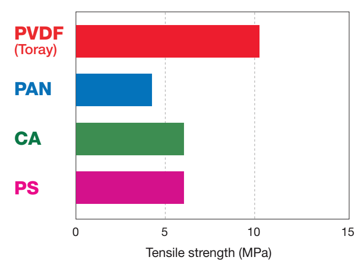


Test Conditions
Sodium hypochlorite 1,000 ppm, pH=10

Soaking Test Results in Chlorine

High Mechanical Strength with High Filtration Flux

Toray's special spinning method with PVDF enables high mechanical strength without reinforcement and high filtration flux at the same time. Additionally, the spinning method achieves high-precision small pore size control with uniform diameter distribution, providing high fouling resistance.



Test Conditions
Sample Length: 50mm
Pulling Speed: 50mm/min, Temp.: 25?

Tensile Strength Test Results

Two Membrane Types for Various Applications

Toray provides two types of PVDF hollow fiber membranes to meet the requirements on various applications with many kinds of untreated water.

✔✔ : Recommended ✔ : Suitable

Membrane Module Type		HFU series	HFS series
MWCO or Nominal Pore Size		150,000 Da (UF)	0.02 micrometer (UF)
Pure Water Flux [m/h at 100 kPa]		0.8	1.6
Recommended Applications	Drinking Water Production	✔	✔✔
	Industrial Water Treatment	✔✔	✔
	Seawater Desalination (for RO pretreatment)	✔✔	✔
	Wastewater Tertiary Treatment	✔✔	✔

Product Data Sheet

DOW IntegraFlux™ Ultrafiltration Modules

Model SFP-2860XP, SFD-2860XP, SFP-2880XP and SFD-2880XP

Features

DOW IntegraFlux™ Ultrafiltration (UF) modules with XP fiber are made from high permeability, high mechanical strength, hollow fiber PVDF membranes. The modules provide excellent performance, industry leading membrane area with low energy and chemical consumption. IntegraFlux modules have the following general properties and characteristics:

- Up to 35% higher permeability than previous generation modules helping to improve operating efficiencies and productivity
- 0.03 µm nominal pore diameter for removal of bacteria, viruses, and particulates including colloids to protect downstream processes such as RO
- PVDF polymeric hollow fibers for high mechanical strength with excellent chemical resistance providing long membrane life and reliable operation
- Outside-In flow configuration allowing a wide range of solids in the feed water minimizing the need for pretreatment processes and reducing the backwash volume compared to Inside-Out configurations

These modules are an excellent choice for systems with capacities greater than 50 m^3/hr (220 gpm). The shorter SFP-2860XP or SFD-2860XP modules are well suited for installations with limited height. Larger and longer, 8 inch diameter and 80 inch in length, the SFP-2880XP or SFD-2880XP modules offer a high effective membrane area combined with high permeability that provides the most economical and efficient membrane system design.

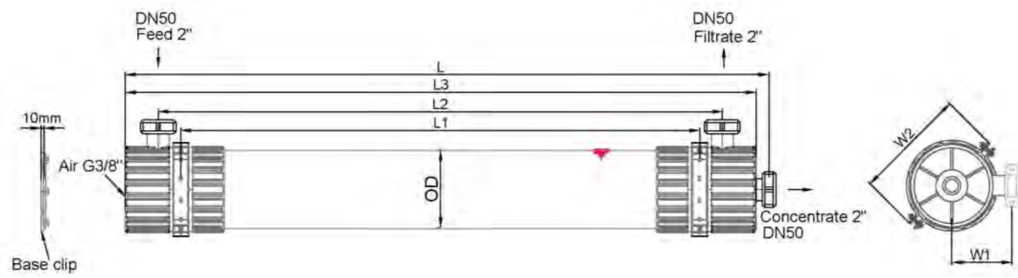
DOW IntegraFlux Ultrafiltration Modules can be used for a wide variety of treatment applications such as industrial and municipal wastewaters, surface water, and seawater.

Product Specifications

Product	Type	Part Number	Membrane Area		Volume		Weight (empty/water filled)	
			m^2	ft^2	liters	gallons	kg/lbs	kg/lbs
SFP-2860XP	Industrial	11127351	51	549	35	9.3	48/83	106/183
SFD-2860XP	NSF/ANSI 61	11127353	51	549	35	9.3	48/83	106/183
SFP-2880XP	Industrial	11127349	77	829	39	10.3	61/100	135/220
SFD-2880XP	NSF/ANSI 61	11123432	77	829	39	10.3	61/100	135/220

Form No. 795-50222-0615, Rev 0

Figure 1 SFP-2860XP, SFD-2860XP, SFP-2880XP, and SFD-2880XP (8-inch diameter)



Product	Units	Length				Diameter	Width	
		L	L1	L2	L3	D	W1	W2
SFP-2860XP and SFD-2860XP	SI (mm)	1860±3	1500	1630±3	1820±3	225	180	342
	US (inch)	73.2±0.1	59.1	64.2±0.1	71.7±0.1	8.9	7.1	13.5
SFP-2880XP and SFD-2880XP	SI (mm)	2360±3	2000	2130±3	2320±3	225	180	342
	US (inch)	92.9±0.1	78.7	83.9±0.1	91.3±0.1	8.9	7.1	13.5

Operating Limits

	SI Units	US Units
Filtrate Flux (25ºC)	40-110 l/m²/hr	24-65 gfd
Flow Range	3.1-8.5 m³/hr	13.6 – 37.4 gpm
Temperature	1-40ºC	34-104ºF
Maximum Inlet Module Pressure (20ºC)	6.25 bar	90.65 psi
Maximum Operating TMP	2.1 bar	30.5 psi
Maximum Operating Air Scour Flow	12 Nm³/hr	7.1 scfm
Maximum Backwash Pressure	2.5 bar	36 psi
Operating pH	2 – 11	
Maximum NaOCl	2,000 mg/L	
Maximum Particle Size	300 µm	
Flow Configuration	Outside in, dead end flow	
Expected Filtrate Turbidity	≤ 0.1 NTU	
Expected Filtrate SDI	≤ 2.5	

Important Information

Proper start-up of an ultrafiltration system is essential to prepare the membranes for operating service and to prevent membrane damage. Following the proper start-up sequence also helps ensure that system operating parameters conform to design specifications so that system water quality and productivity goals can be achieved.

Before initiating system start-up procedures, membrane pretreatment, installation of the membrane modules, instrument calibration and other system checks should be completed.

Please refer to the DOW™ UF Product Manual.

Operation Guidelines

Avoid any abrupt pressure variations during start-up, shutdown, cleaning or other sequences to prevent possible membrane damage. Flush the ultrafiltration system to remove shipping solution prior to start-up. Remove residual air from the system prior to start-up. Manually start the equipment. Depending on the application, filtrate obtained from initial operations should be discarded.

Please refer to the DOW™ UF Product Manual.

General Information

- If operating limits and guidelines given in this bulletin are not strictly followed, the limited warranty will be null and void.
- To control biological growth during extended system shutdowns, it is recommended that storage solution be injected into the membrane modules.

Please refer to the DOW UF Product Manual and Technical Service Bulletins.

Regulatory Note

NSF/ANSI 61 certified drinking water modules require specific conditioning procedures prior to producing potable water. Please refer to the product technical manual flushing section for specific procedures. Drinking water modules may be subjected to additional regulatory restrictions in some countries. Please check local regulatory guidelines and application status before use and sales.

Product Stewardship

Dow has a fundamental concern for all who make, distribute, and use its products, and for the environment in which we live. This concern is the basis for our product stewardship philosophy by which we assess the safety, health, and environmental information on our products and then take appropriate steps to protect employee and public health and our environment. The success of our product stewardship program rests with each and every individual involved with Dow products - from the initial concept and research, to manufacture, use, sale, disposal, and recycle of each product.

Customer Notice

Dow strongly encourages its customers to review both their manufacturing processes and their applications of Dow products from the standpoint of human health and environmental quality to ensure that Dow products are not used in ways for which they are not intended or tested. Dow personnel are available to answer your questions and to provide reasonable technical support. Dow product literature, including safety data sheets, should be consulted prior to use of Dow products. Current safety data sheets are available from Dow.

DOW™ Ultrafiltration
For more information, call the Dow Water & Process Solutions business:
North America: 1-800-447-4369
Latin America: (+55) 11-5188-9222
Europe: +800-3-694-6367
Italy: +800-783-825
South Africa: +0800 99 5078
Pacific: +800 7776 7776
China: +400 889-0789
www.dowwaterandprocess.com

Notice: The use of this product in and of itself does not necessarily guarantee the removal of cysts and pathogens from water. Effective cyst and pathogen reduction is dependent on the complete system design and on the operation and maintenance of the system.

Form No. 795-50222-0615, Rev 0

inge® heart of pure water

dizzer® XL

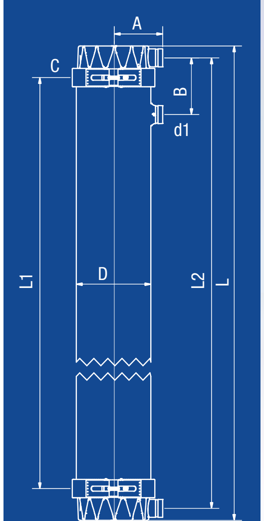
Ultrafiltration modules

BASF

The Chemical Company

dizzer® XL - Ultrafiltration modules

- Excellent efficiency and high output
- Easy installation, plug-and-play operation
- Compact design
- Low operating costs



Modules for large scale application

Module designation:

dizzer® XL 0.9 MB 60 W

- Active membrane area
- Multibore® membrane
- Capillary diameter
- Modules for large scale application

dizzer® modules with Multibore® 0.9 membrane

Module data			dizzer® XL 0.9 MB 60 W		dizzer® XL 0.9 MB 38 W	
Part number			VK-0068		VK-0070	
Membrane area	m^2	sq.ft.	60	645	38	410
Length with end cap (L)	mm	inch	1680 ± 3	66 1/8	1180 ± 3	46 1/2
Length without end cap (L1)	mm	inch	1486 ± 1.5	58 1/2	986 ± 1.5	38 3/4
Distance feed connectors (L2)	mm	inch	1600 ± 3	63	1100 ± 3	43 1/2
Distance feed – module center axis (A)	mm	inch	165	6 1/2	165	6 1/2
Distance feed – filtrate connector (B)	mm	inch	190 ± 1.5	7 1/2	190 ± 1.5	7 1/2
Outer diameter end cap coupling max. (C)	mm	inch	295	11 5/8	295	11 5/8
Outer diameter module (D)	mm	inch	250	9 7/8	250	9 7/8
Connector flexible victaulic (d1)		inch	2			
Weight* (wet)	kg	lbs.	55	120	40	90

dizzer® modules with Multibore® 1.5 membrane

Module data			dizzer® XL 1.5 MB 40 W		dizzer® XL 1.5 MB 25 W	
Part number			VK-0069		VK-0071	
Membrane area	m^2	sq.ft.	40	430	25	270
Length with end cap (L)	mm	inch	1680 ± 3	66 1/8	1180 ± 3	46 1/2
Length without end cap (L1)	mm	inch	1486 ± 1.5	58 1/2	986 ± 1.5	38 3/4
Distance feed connectors (L2)	mm	inch	1600 ± 3	63	1100 ± 3	43 1/3
Distance feed – module center axis (A)	mm	inch	165	6 1/2	165	6 1/2
Distance feed – filtrate connector (B)	mm	inch	190 ± 1.5	7 1/2	190 ± 1.5	7 1/2
Outer diameter end cap coupling max. (C)	mm	inch	295	11 5/8	295	11 5/8
Outer diameter module (D)	mm	inch	250	9 7/8	250	9 7/8
Connector flexible victaulic (d1)		inch	2			
Weight* (wet)	kg	lbs.	55	120	40	90

Technical information

Material				
Housing			PVC-U, white	
End cap			PVC-U, grey	
End cap coupling			SS (sealing EPDM)	
Operation parameters				
Pressure max.	bar	psi	5	70
Temperature range	°C	°F	1 – 40	34 – 104

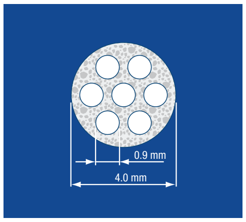
* shipping weight

® = Registered trademark of BASF

Multibore® 0.9 and 1.5 membranes

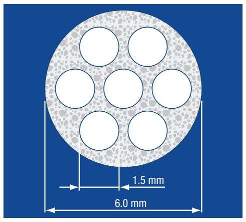
Multibore® 0.9 membrane

Membrane data		
Capillaries per fibre		7
Inner diameter	mm	0.9
Outer diameter	mm	4.0
Pore size	µm	approx. 0.02
Material		PESM



Multibore® 1.5 membrane

Membrane data		
Capillaries per fibre		7
Inner diameter	mm	1.5
Outer diameter	mm	6.0
Pore size	µm	approx. 0.02
Material		PESM



Technical information

Cleaning/disinfection chemicals			Multibore® 0.9 and 1.5 membrane	
Free chlorine	ppm ppm x h		max. 200 max. 200,000 (at pH ≥ 9.5)	
H_2O_2 (Hydrogenperoxide)	ppm		max. 500	
Caustic Soda pH			max. 13	
Acid pH			min. 1	
Flux rate				
Filtration*	l/(m²h)	gfd	60 – 180	35 – 105
Backwash standard	l/(m²h)	gfd	230	135
Backwash range	l/(m²h)	gfd	230 – 300	135 – 175
Transmembrane pressure (TMP)				
Filtration*	bar	psi	0.1 – 1.5	1.5 – 20
Backwash standard*	bar	psi	0.3 – 3.0	5 – 40
Burst pressure membrane	bar	psi	> 10	> 150

* Specifications apply to common operating conditions.

Subject to technical modifications and errors. Modules are to be operated in accordance with the relevant “Installation, Operation and Maintenance Guidelines“. Customized configurations are available on request. Please contact the inge GmbH team if you require any further information.

Note

The descriptions, designs, data and information („Product Information“) contained herein are presented in good faith and are based on inge GmbH’s current knowledge and experience. inge GmbH cannot accept any liability for the accuracy of this Product Information, which is provided at no charge and for guidance only.

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inge GmbH
Flurstraße 27
86926 Greifenberg, Germany
Phone +49 8192 997-700
Fax +49 8192 997-999
info@inge.ag

www.inge.ag

Corporate Headquarters

302 Lake Hazeltine Drive
Chaska, MN 55318 USA

Phone 800-240-3330
Phone 952-448-4884
Fax 952-448-4886
Web WIGEN.COM

PROJECT:

CITY OF MANKATO WWTP, MN

EQUIPMENT:

11.25 MGD ULTRAFILTRATION SYSTEM

PREPARED FOR:

BOLTON AND MENK

WWT BUDGET PROPOSAL No. 050616-200A

DATE: 5/6/16

Revision 0.0

Prepared By:
Michael Bourke
Wigen Water Technologies
Tel: (303) 350 3086
Email: Michael.Bourke@wigen.com

2.0 EQUIPMENT SCOPE OF SUPPLY

11.25 MGD 8-Skid UF System

- (8) UF Skids, each to include the following:
    - Skids designed for an operating flux range of 20-30 gfd with 78 UF module spaces.
    - (72) Toray HFU-2020N UF Modules,
    - PVC piping headers connecting feed, backwash and filtrate piping.
    - Isolation valves for each module, allowing the skid to remain in operation while maintenance is performed on any one module.
    - Turbidity meter, analyzing filtrate water quality.
    - Electromagnetic flow meter on Membrane feed piping to monitor and control flow rate to skid assembly.
    - Pressure transmitters on feed and filtrate sides of the membranes, for monitoring TMP and testing during membrane integrity tests.
    - NEMA 4/12 Local Control Panel Enclosure to be wired to Master PLC Control Panel.
    - Skid constructed of carbon steel, with epoxy paint.
- ARCAL Backwash Disk Pre-filter
- (1) Backwash pump/RO Feed pump Skid with the following:
    - (2) UF Backwash pumps and VFDs (duty/standby)
    - (1) Local control panel to be wired to Master PLC Control Panel.
    - Powder coated carbon steel skid.
- (1) HDPE UF Backwash Feed Tank with level transmitter.
- (1) UF CIP Pump Skid with the following:
    - (2) CIP recirculation pumps
    - Instruments and valves for CIP control (UF CIP automated).
    - (1) Local control panel to be wired to Master PLC Control Panel.
    - Powder coated carbon steel skid.
- (2) 2000 gal HDPE cone bottom CIP tanks with epoxy coated carbon steel stands.
    - (2) 48 kW CIP heaters.
    - (3) Level transmitters.
- Chemical Feed Equipment provided loose for contractor installation as follows:
    - CIP Chemical Dosing pumps.

   - o Calibration columns and all valves and accessories for each pump to provide complete chemical metering systems.

- (1) Master Control Panel with Allan Bradley CompactLogix PLC and 15” PVP7 HMI, supplied loose for installation in the building.
- (2) 10 HP Rotary Screw Air Compressor system with 400 Gal receiver for UF air scour and UF instrument air.
- Start-up Services, including 10-days onsite plus travel expenses and per diem.

EXCLUSIONS

The following would be required **by others:**

- Installation of skid and loose components.
- All interconnecting piping between skids and tanks.
- Power drops to control panels and wiring between UF and pump skids and Master PLC panel. Hard wiring from chemical pumps to PLC panel.
- CIP waste neutralization system (can be added if needed).
- Loading of UF membranes (under Wigen supervision).
- All chemicals.
- Disinfection of equipment prior to start-up.

3.0 BUDGET PRICING

The budget price for the equipment and services outlined above is as follows:

Equipment	Budget Price
(8) UF Skid System and ancillary equipment, including start-up services as described in this scope of supply.	**$4,400,000.00**

Budget Price is in US dollars FOB Mankato, Minnesota exclusive of any applicable taxes.

Customer understands that this proposal has been issued based upon the information provided by customer, and currently available to WWT at the time of issuing this proposal. Any changes or discrepancies in site conditions, including but not limited to system influent water characteristics, changes in environmental health and safety conditions, Customer financial standing, Customer requirements, or any other relevant change, or discrepancy in, the factual basis upon which this proposal was created, may lead to changes in the offering, including but not limited to changes in pricing, warranties, quoted specifications, or terms and conditions.

WIGEN Since 1965 WATER TECHNOLOGIES
Water. Process. Solutions.

SYSTEM INFORMATION

TOTAL UF FILTRATE FLOW RATE (GPM)	7813
UF PERCENT RECOVERY (%)	95.0%
FILTER SURFACE AREA (FT2)	775
# FILTER TRAINS TOTAL	8
# INSTALLED FILTERS PER TRAIN	72
ELECTRICITY COST ($/KWH)	$0.08
UF FILTRATE FLUX RATE (GFD)	25.2
TOTAL UF FILTRATE FLOW RATE (MGD)	11.25

UF FEED PUMP ELECTRICITY COST

AVERAGE UF FEED PRESSURE (PSI)	30
PUMP EFFICIENCY AT SPECIFIED RECOVERY (%)	72.0%
MOTOR EFFICIENCY AT SPECIFIED RECOVERY (%)	92.0%
VFD EFFICIENCY (%)	98.5%
HP PUMP(S) BRAKE HORSEPOWER (HP)	220.58
HP PUMP(S) DAILY POWER CONSUMPTION (KWH/DAY)	3,948
HP PUMP(S) MONTHLY POWER CONSUMPTION (KWH/MONTH)	118,433
HP PUMP(S) YEARLY POWER CONSUMPTION (KWH/YEAR)	1,440,934
HP PUMP(S) DAILY OPERATING COST ($/DAY)	$315.82
HP PUMP(S) MONTHLY OPERATING COST ($/MONTH)	$9,474.63
HP PUMP(S) YEARLY OPERATING COST ($/YEAR)	$115,274.69

CONTROL PANEL/CIP PUMP/CIP HEATER ELECTRICITY COST

120VAC CONTROL POWER AVERAGE AMP DRAW (A)	5
CIP HEATER SIZE (KW)	48
CIP PUMP MOTOR SIZE (HP)	20
CLEANING FREQUENCY (CLEANINGS/YEAR)	96
CONTROL PANEL YEARLY POWER CONSUMPTION (KWH)	5,256.00
CIP HEATER YEARLY POWER CONSUMPTION (KWH)	294,912.00
CIP PUMP YEARLY POWER CONSUMPTION (KWH)	67,737.60
CONTROL PANEL YEARLY OPERATING COST ($/YEAR)	$420.48
CIP HEATER YEARLY POWER CONSUMPTION ($/YEAR)	$23,592.96
CIP PUMP YEARLY POWER CONSUMPTION ($/YEAR)	$5,419.01

TOTAL ANNUAL ELECTRICITY COST

TOTAL ANNUAL ELECTRICITY COST	$144,707.13

CIP CHEMICAL COST

CITRIC ACID CHEMICAL REQUIRED PER CIP (gal)	30.25
Cl CHEMICAL REQUIRED PER CIP (gal)	18.5
CITRIC ACID CHEMICAL REQUIRED PER MINICIP (gal)	0
Cl CHEMICAL REQUIRED PER MINICIP (gal)	1.8
ACID CHEMICAL COST ($/gal)	$0.79
Cl CHEMICAL COST ($/gal)	$2.05
CIP FREQUENCY (TIMES/YEAR)	12
ACID MINICIP FREQUENCY (TIMES/YEAR)	0
Cl MINICIP FREQUENCY (TIMES/YEAR)	182.5
TOTAL ACID CHEMICAL REQUIRED (gal/YEAR)	2904
TOTAL Cl CHEMICAL REQUIRED (gal/YEAR)	4404
ACID CHEMICAL COST ($/YEAR)	$2,294.16
Cl CHEMICAL COST ($/YEAR)	$9,028.20
YEARLY CIP CHEMICAL COST ($/YEAR)	$11,322.36

MEMBRANE REPLACEMENT COST

# OF MEMBRANES IN SYSTEM	576
MEMBRANE COST ($/MEMBRANE)	$1,850.00
CHANGEOUT FREQUENCY (YEARS)	8
COST PER MEMBRANE CHANGEOUT ($/CHANGEOUT)	$1,065,600.00
YEARLY MEMBRANE REPLACEMENT COST ($/YEAR)	$133,200.00

OPERATING COST SUMMARY

TOTAL ANNUAL ELECTRICAL COST	$144,707.13
TOTAL ANNUAL CHEMICAL COST	$11,322.36
YEARLY MEMBRANE REPLACEMENT COST ($/YEAR)	$133,200.00
TOTAL YEARLY OPERATING COST	$289,229.49
COST PER 1000 GALLONS TREATED WATER	**$0.070**

Corporate Headquarters:
302 Lake Hazeltine Drive
Chaska, MN 55318 USA

Phone 800-240-3330
Phone 952-448-4884
Fax 952-448-4886
Web WIGEN.COM

Proposal for a 2-Train UF Pilot Study for the City of Mankato, MN

WWT Proposal No. 031315-200A

Prepared for:

March 13, 2015

Prepared for:
Mr. Kris Swanson
Bolton & Menk

UF/RO System Manufacturer:
Wigen Water Technologies
Mr. Michael Bourke
Email: michael.bourke@wigen.com
Tel: 303-350-3086, 800-240-3330

TABLE OF CONTENTS

ATTACHMENTS

1. UF and RO Pilot P&IDs and GA Drawings
2. Wigen Pilot Equipment Rental Agreement

Water.
Process.
Solutions.

1.0 INTRODUCTION

Wigen Water Technologies (WWT) is pleased to submit this proposal for a 2-train ultrafiltration and pilot plant study for the City of Mankato, MN

This proposal provides the scope of supply for equipment and services for a 2 to 3-month pilot study, including proposed responsibilities between WWT, Bolton & Menk and the City of Mankato.

The UF pilot plant proposed for this pilot study is configured with the same instrumentation and operating procedures as a full-scale system. The scope of supply for this pilot study incudes the supply of full-scale UF modules from Toray, Dow and Inge so that each can be evaluated for this project.

We look forward to conducting this pilot study and if there are any questions or required changes regarding our proposed scope of supply, please do not hesitate to contact me.

Sincerely,

Michael Bourke

Michael Bourke
VP Business Development
Wigen Water Technologies

2.0 PILOT STUDY SCOPE OF SUPPLY

Wigen's scope of supply for the UF pilot equipment will be as follows:

- Provide skid mounted 2-Train UF pilot unit and associated equipment and services as described in Section 3. This includes all necessary chemical feed pumps and intermediate storage tanks.
- Provide (1) Dow IntegraFlo DW102-1100 UF module (1103 ft2), one (1) Toray HFU-2020 module and one (1) Inge Dizzer module for UF pilot plant.
- CEB and CIP chemicals for duration of pilot study.
- Ship equipment to project site and direct city staff regarding utility connections.
- Start-up equipment & ensure proper operation.
- Train operators in operation of equipment and completing log sheet for data collection.
- Receive and interpret log data from Bolton & Menk as requested.
- Assist with pack-up of equipment for return shipment to our facility.
- Prepare a final pilot study report at the conclusion of the study that includes recommendations on full-scale design for UF system equipment including an O&M analysis.

Table 1: Proposed Field Service Schedule

Task	Duration
Check installation of equipment. Start-up pilot equipment, and train operators on equipment operation.	Up to 2-weeks
Additional visit during trial period to conduct UF CIP.	2 days on-site
Assist with pack up of equipment for return to Wigen at end of study.	2 days on-site

The following would be required by the City/Bolton & Menk:

- Unloading and placement of the equipment.
  - The UF pilot requires a 30A 460/3/60 electrical drop to the UF skid panel and a 15A 120/1/60 outlet for the air compressor.
  - Run signal wires from pump relays to UF panel to turn UF on and off.
  - Tank overflows, backwash, permeate and concentrate lines will need to be piped to drain.
- Shelter for the pilot plant for protection from weather.
- Feed water flow of up to 50 gpm to UF pilot.
- Loading the equipment onto the truck for return to our facility (WWT rep will be present to assist).

3.0 UF EQUIPMENT SPECIFICATIONS

UF UNIT

SYSTEM OVERVIEW

This pilot plant is designed to replicate the performance of a full-scale system with fully automated backwashing, integrity tests and chemically enhanced backwashes. The settings for these processes will be optimized by a WWT technician during the first few days of operation after start-up. CIPs are conducted manually and will be performed by a WWT technician when required. The pilot plant can also be monitored and controlled remotely if there is Ethernet or phone access at the site. Full-scale UF modules will be used on the pilot plant so that fluxes, backwash rates and overall performance will be exactly the same as a full-scale system.

Figure 1: UF Pilot Skid Proposed for Study (Feed and backwash tanks at rear).

3.0 UF EQUIPMENT SPECIFICATIONS

UF SYSTEM COMPONENTS

The UF pilot skid consists of two independent treatment trains. Components of the train are as follows:

Ultrafiltration Pilot Skid:

- (2) 50 gpm @ 47 psi, 3 HP Feed/CIP pumps with VFDs.
- (2) Amiad 2" 300 micron automatic backwashing feed strainers.
- (1) 3 HP, 90 gpm @30 psi backwash pump.
- (1) 105 gal HDPE CIP tank.
- (1) Allen Bradley CompactLogix PLC and HMI for system operation and data recording.
- Instrumentation as shown on P&ID in Attachment 1.
- (5) 5 gal HDPE Chemical storage tanks and peristaltic dosing pumps with calibration columns. Can be used for CEB/CIP chemicals and coagulant.
- Skid Dimensions: 158" L x 54" W x 120" H – Note that this is the height with the module installed. This skid will be shipped without the module and header piping and the shipping height will be 78".
- Skid Weight: 3000 lbs Approx.

Components Shipped Loose:

- (1) 300 gal HDPE Feed Tank (36" dia. x 72" Tall)
- (1) 300 gal HDPE Backwash Tank (36" dia. x 72" Tall)
- (1) Dow, (1) Toray and (1) Inge UF Module.
- (1) 1.5 HP Compressor and 30 gal storage for air scour and instrument air.
- Interconnecting piping between UF skid, Feed and Backwash tanks.
- CIP and CEB Chemicals

INSTRUMENT MATRIX

Instrument	Location
Flow Meters	Feed and Filtrate
Turbidimeters	Feed and Filtrate
Pressure Transmitters	Feed, Filtrate, Backwash
Pressure Gauges	Feed, Filtrate, Backwash
Temperature	Feed
pH	Feed, CIP, and Neutralization
Tank Level Switches	Filtrate, CIP, and Neutralization Tanks

3.0 UF EQUIPMENT SPECIFICATIONS

UTILITY REQUIREMENTS & CONNECTIONS

Feed Tank Inlet	3.0” Flange
Feed Tank Outlet	3.0” Flange (piping to UF skid by Wigen)
UF Skid Inlet	3.0” Flange (piping to feed tank by Wigen)
UF Skid Filtrate Outlet	3.0” Flange (piping to filtrate/backwash tank by Wigen)
Filtrate/Backwash Tank Inlet	3.0” Flange (piping to filtrate/backwash tank by Wigen)
Backwash Tank Feed to UF Skid	3.0” Flange (piping to UF skid by Wigen)
UF Skid Backwash Inlet	3.0” Flange (piping to filtrate/backwash tank by Wigen)
UF Filtrate/Backwash Tank Outlet (to RO Pilot)	2.0” Flange
Backwash Outlet	3.0” Flange (this must drain to gravity)
Power Feed to UF Skid	460 V / 3 Phase / 60 HZ / 30 Amps
Power Feed to Compressor	120 V / 1 Phase / 60 HZ / 15 Amps
Feed Water Supply	Up to 50 gpm @ 40 psi

ITEMS TO BE FURNISHED BY OTHERS

- Unloading of the equipment and placement at pilot site.
- Power, water and drain utilities.
- Raw water, filtrate and backwash drain piping to 3” flanges on UF skid and tanks.
- Pilot unit must by undercover for protection from weather.
- Loading of pilot equipment after pilot study.

4.0 SUPPORT SERVICES

DAYS INCLUDED	SERVICES PROVIDED
10	**Equipment Start-up:** Includes preparing the equipment to operate, testing control sequences and fully operating the system to achieve performance objectives. **Operator Training:** This includes training that typically during and after the equipment has been started up.
2	**Visit During 6-Month Study:** Conduct CIP on UF pilot(s) and conduct preventative maintenance, system checks and process optimization if required.
2	**Decommissioning:** Pack up equipment at end of pilot. Collect membranes for autopsy and conduct CIPs if needed.

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5.0 RENTAL PRICING

UF PILOT EQUIPMENT RENTAL PRICING

Item	Deliverable	Unit Cost	Extension
Pilot Set-up and Breakdown	Shipping to and from site, UF modules, CIP and CEB chemicals, start-up services and pack up assistance at end of pilot study and final pilot study report.	$15,000	$15,000
Monthly Rental Price	Monthly Equipment Rental including additional chemicals as required, conducting CIPs as required, review of data.	$5,000	$5,000 per month or part thereof.

Payment Terms

Pilot Set-up and Breakdown charge will be invoiced upon delivery of pilot equipment.
Monthly Rental charge will be invoiced at the end of each month of rental.

Payment due 30 days from invoice.

**Prices do not include any applicable taxes.*

Water.
Process.
Solutions.

6.0 NOTES & CLARIFICATIONS

1. Wigen is not responsible for damage to the UF pilot equipment due to negligence or operator error. Owner shall reimburse Wigen for any repairs which may be necessary due to damage. It will be necessary to sign a pilot agreement covering responsibilities for any damages that may occur during the pilot study.

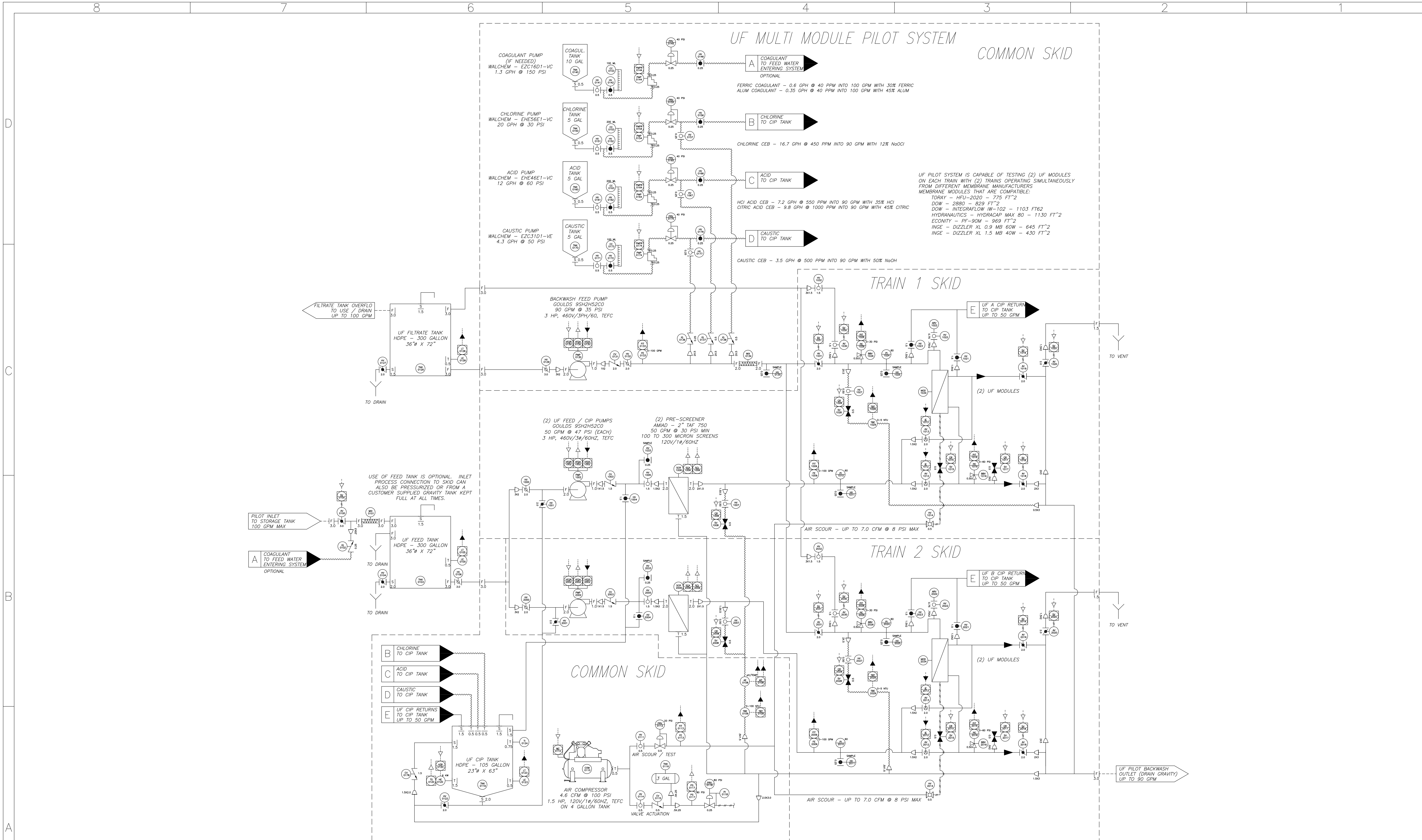
2. Availability: Notice of 4 weeks of pilot start-date is required to ensure the pilot equipment is prepared and membranes are available and to schedule a Field Engineer for start-up. The pilot equipment described in this proposal is currently available from July 2015. It will be held for 30 days from the date of this proposal but cannot be guaranteed to remain available if the proposal is not accepted after 30 days.

Water.
Process.
Solutions.

ATTACHMENTS

1. UF Pilot P&ID and GA Drawings

2. Wigen Pilot Equipment Agreement



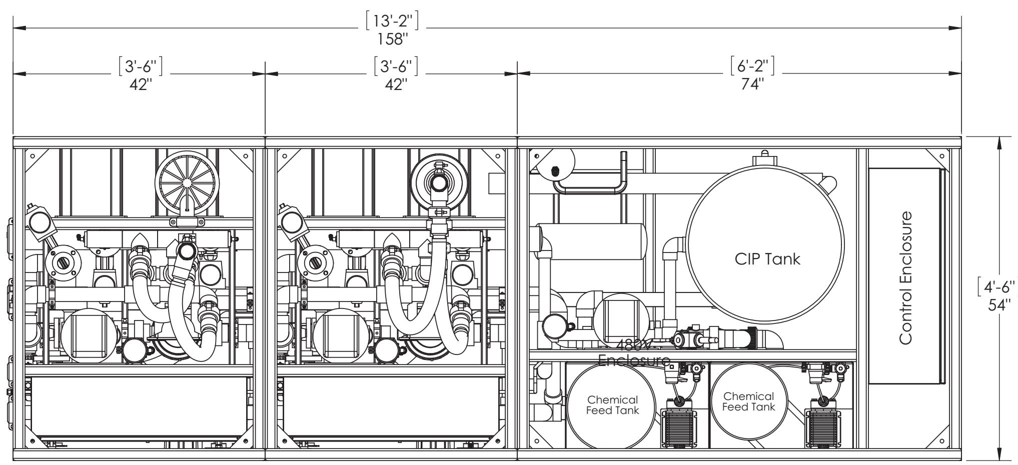
UL NUMBER #	DRAWING NOTES: NOTE 1. NOTE 2. NOTE 3. NOTE 4. NOTE 5. NOTE 6.				
REV	DATE	DWN	APVD	DESCRIPTION	
B	11/25/14	SMN	EIP	AS-BUILT	

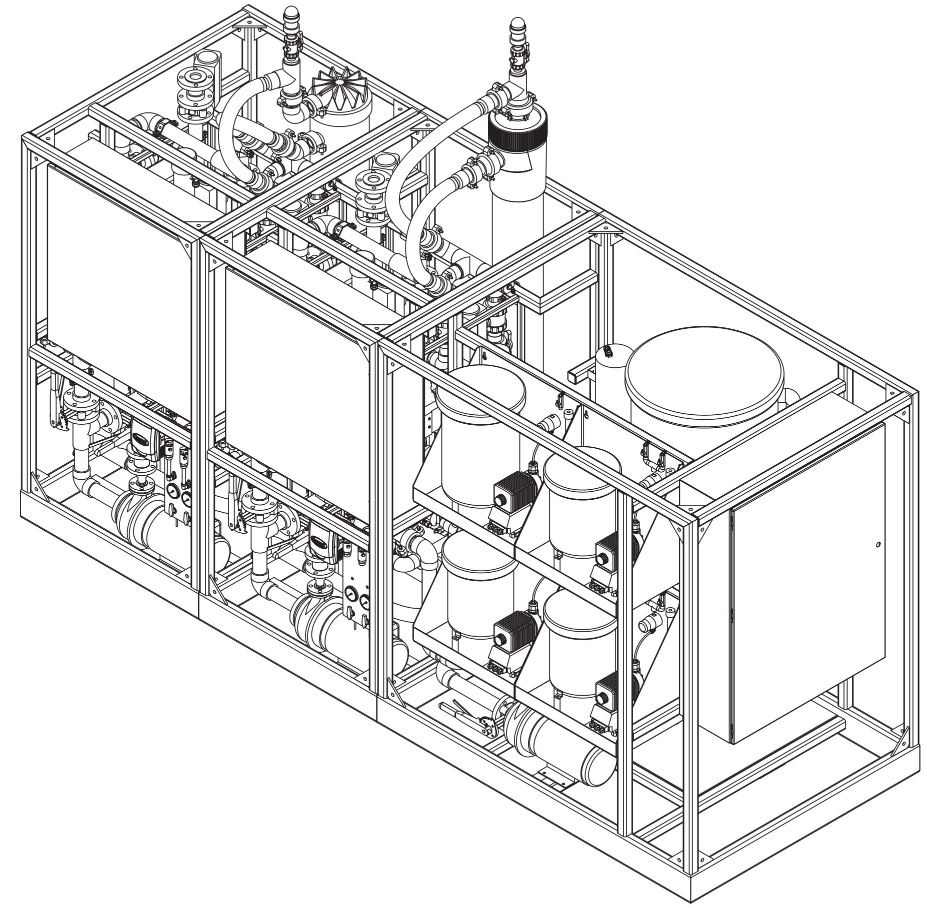
NOTICE ON REPRODUCTIONS

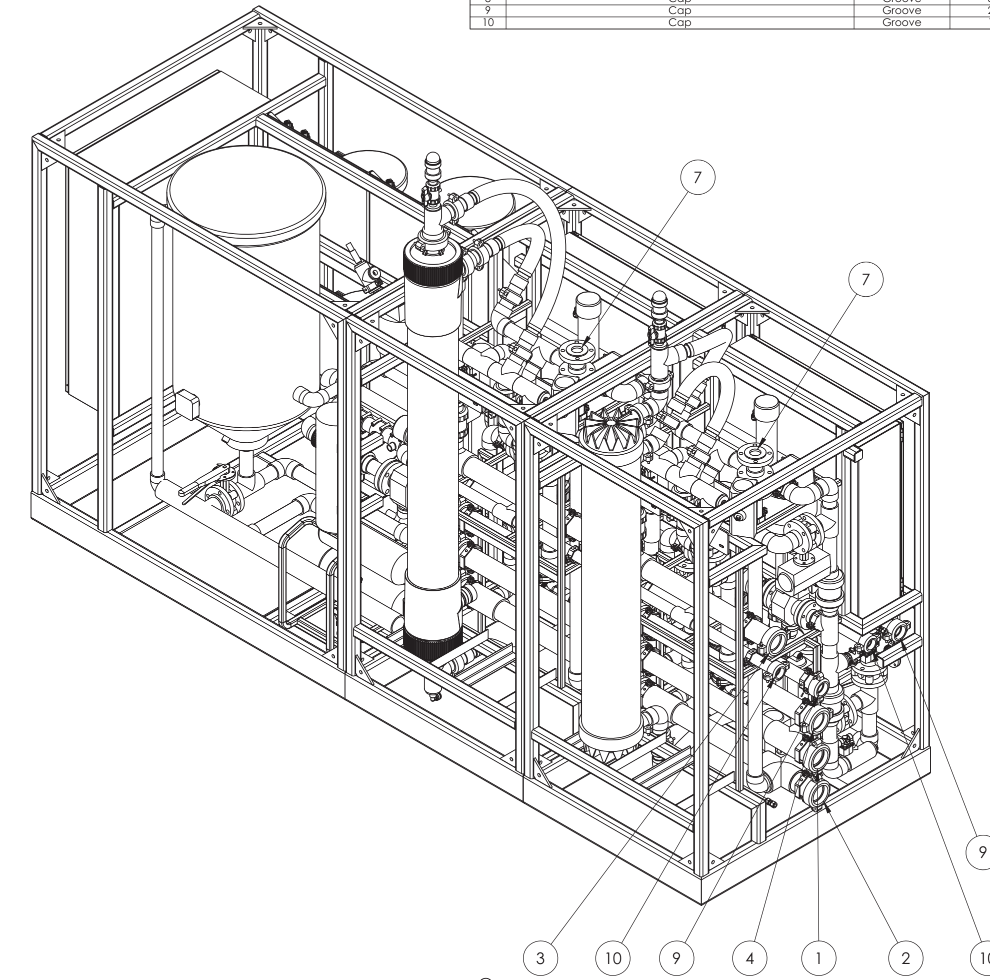
DRAWN BY: EIP	DATE: 7/2/14	TITLE: PROCESS AND INSTRUMENTATION DIAGRAM UF PILOT #2 (2) TRAIN FULL SCALE MODULES PILOT
CHK'D BY: SAB	DATE: 7/3/14	CLIENT NAME: WIGEN WATER TECHNOLOGIES
SIZE: D	SCALE: NONE	
CAD FILE NUMBER: ACAD	PROJECT NUMBER: C-3327-0814	DRAWING NUMBER: C-3327-200 · SHEET: 1 OF 1 · REV: B

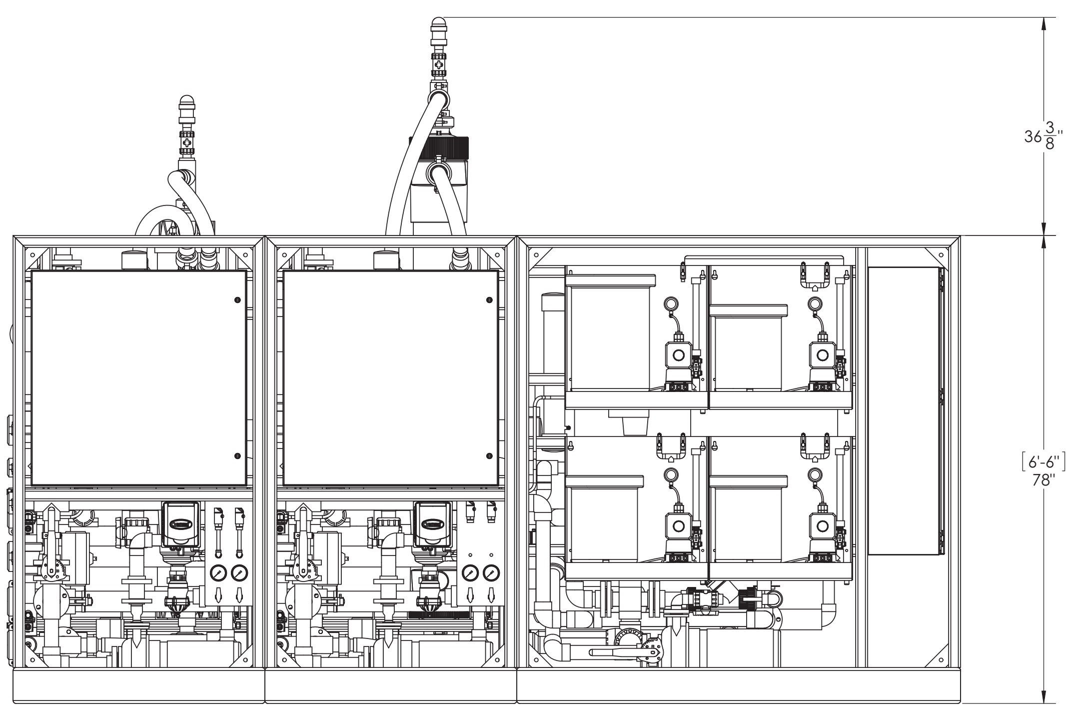
WIGEN SINCE 1965
WATER TECHNOLOGIES
302 LAKE HAZELTINE DRIVE
CHASKA, MN 55318 USA
952-448-4884
WWW.WIGEN.COM

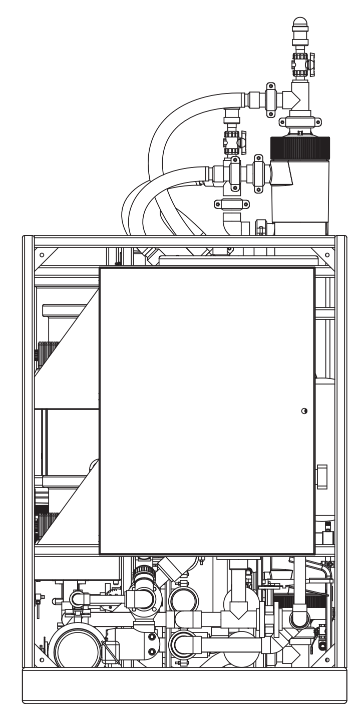
CONNECTION SCHEDULE			
#	DESCRIPTION	TYPE	SIZE
1	UF System Inlet from Water Source or Feed Tank	150# R.F. FLG.	3.00
2	UF System Drain	150# R.F. FLG.	2.00
3	Filtrate Outlet To UF Backwash Tank	150# R.F. FLG.	3.00
4	Backwash Inlet (From B/W Tank)	150# R.F. FLG.	3.00
7	Vent (To Drain)	150# R.F. FLG.	2.00
8	Cap	Groove	3.00
9	Cap	Groove	2.00
10	Cap	Groove	1.50

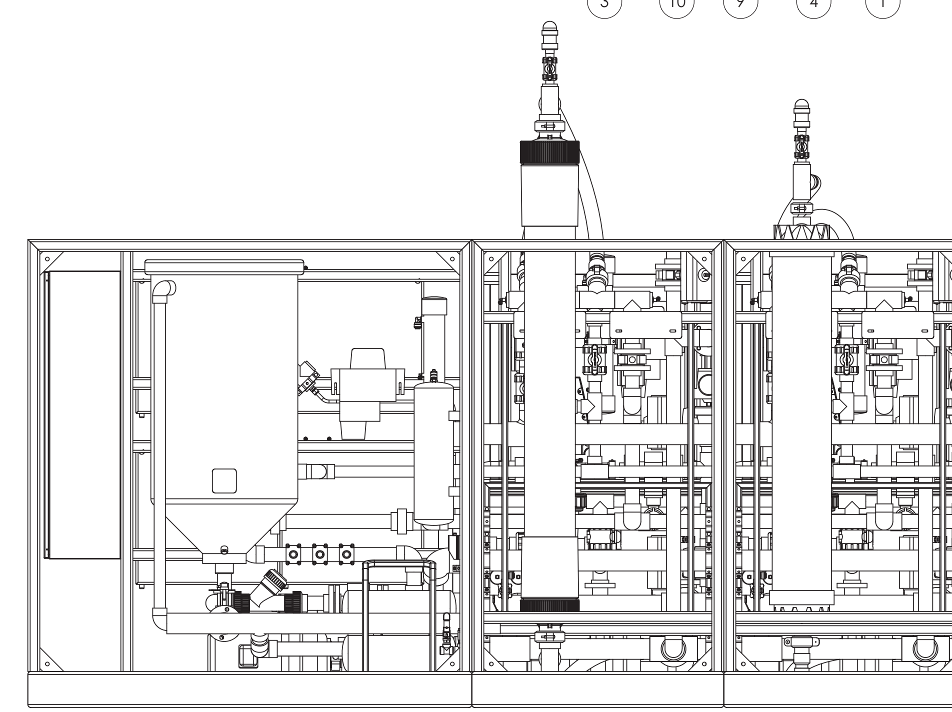












NOTE 1: Varies By Module Manufacturer, Maximum Shown
NOTE 2:
NOTE 3:
NOTE 4:
NOTE 5:
NOTE 6:

DRAWING NOTES

REV.	DATE	DWN	APVD	DESCRIPTION
A	7/31/2014	SMN		Initial Release - Preliminary

NOTICE ON REPRODUCTIONS

DRAWN BY: SMN	DATE: 9/10/14	TITLE: UF Pilot (UFDT - 2)
CHK'D BY:	DATE:	CLIENT NAME: Wigen Water Technologies
SIZE: D	SCALE: 1:16	
FILE TYPE: SLDDRW		PROJECT NUMBER: C-3327-0814

DRAWING NUMBER	SHEET	REV
Modular UF Pilot-2 GA	1 of 8	A

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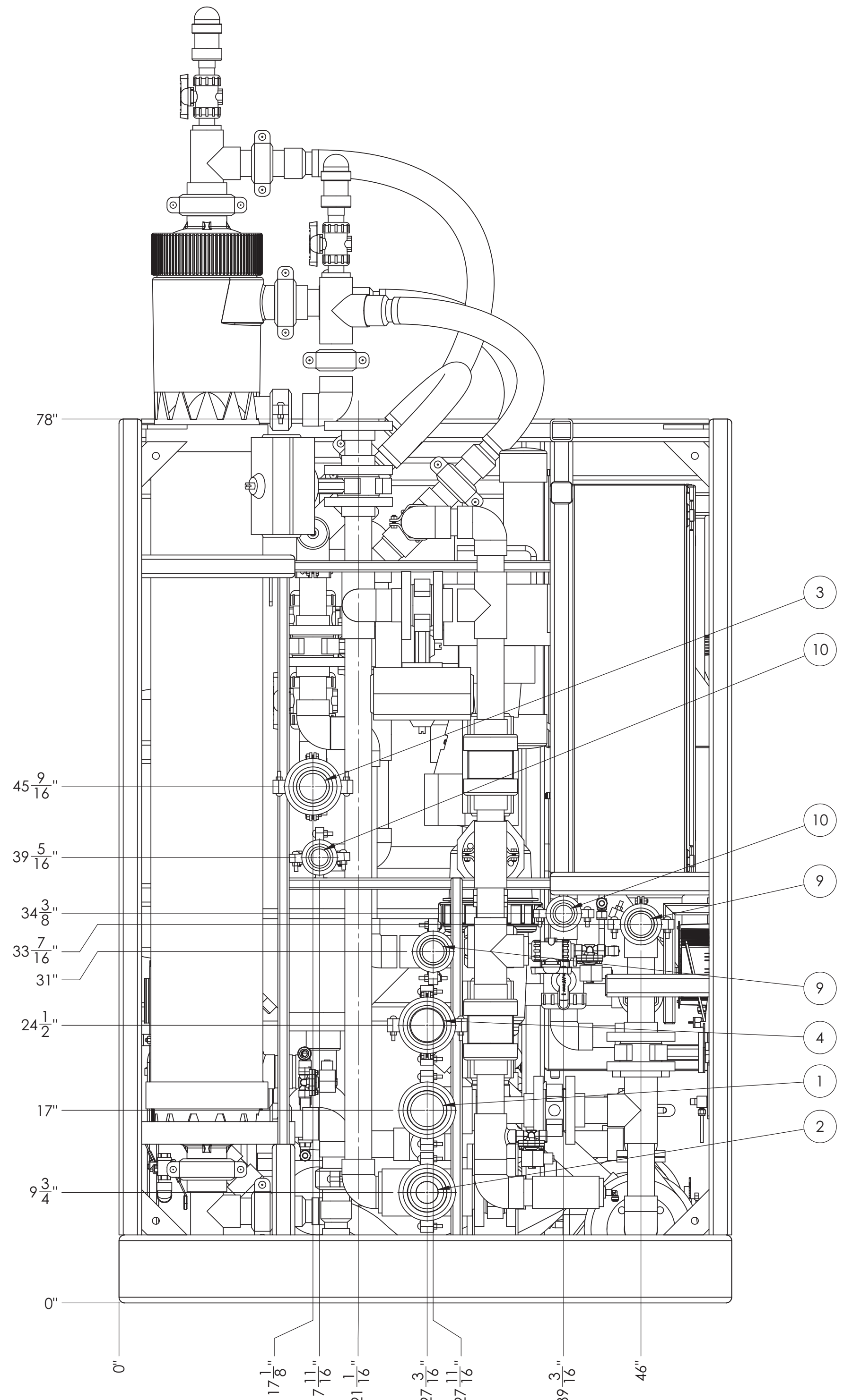
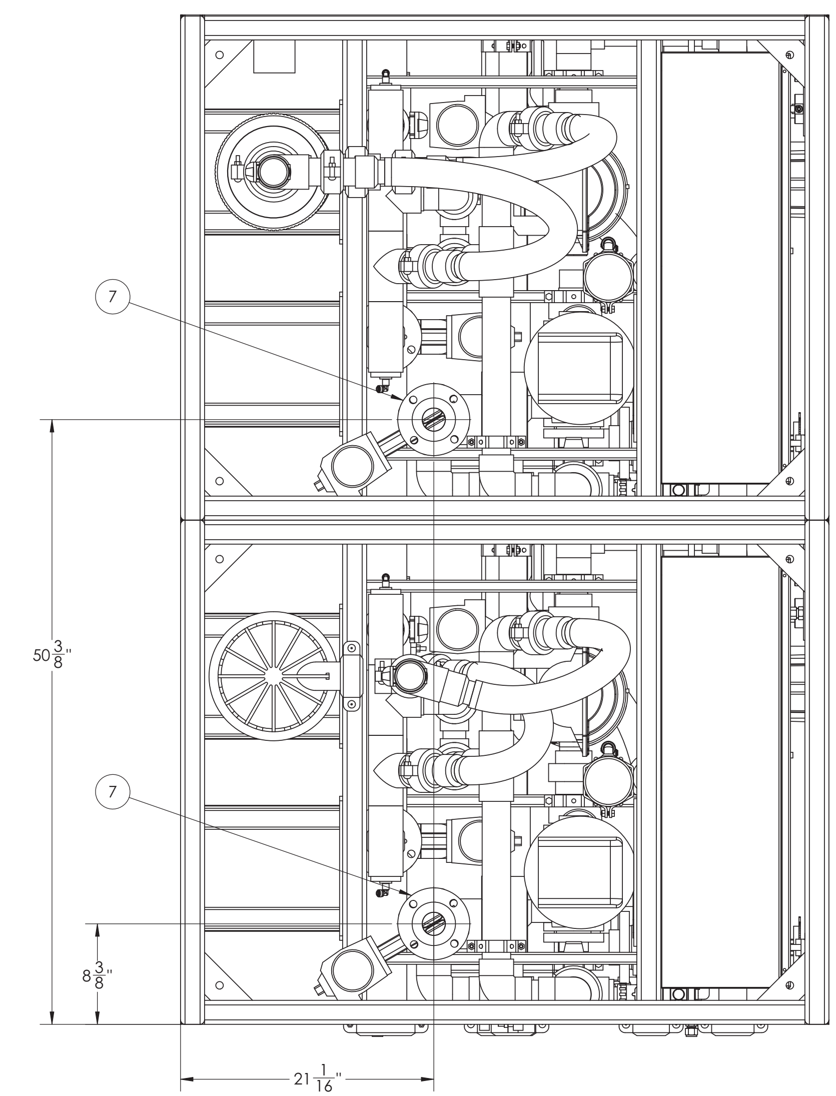
WATER TECHNOLOGIES
302 LAKE HAZELTINE DRIVE
CHASKA, MN 55318 USA
952-448-4884
WWW.WIGEN.COM

CONNECTION SCHEDULE			
#	DESCRIPTION	TYPE	SIZE
1	UF System Inlet from Water Source or Feed Tank	150# R.F. FLG.	3.00
2	UF System Drain	150# R.F. FLG.	2.00
3	Filtrate Outlet To UF Backwash Tank	150# R.F. FLG.	3.00
4	Backwash Inlet (From B/W Tank)	150# R.F. FLG.	3.00
7	Vent (To Drain)	150# R.F. FLG.	2.00
8	Cap	Groove	3.00
9	Cap	Groove	2.00
10	Cap	Groove	1.50



LEFT VIEW



TOP VIEW

NOTE 1: Varies By Module Manufacturer, Maximum Shown
NOTE 2:
NOTE 3:
NOTE 4:
NOTE 5:
NOTE 6:

DRAWING NOTES

REV.	DATE	DWN	APVD	DESCRIPTION
A	7/31/2014	SMN		Initial Release - Preliminary

NOTICE ON REPRODUCTIONS

DRAWN BY	DATE
SMN	9/10/14
CHK'D BY	DATE
SIZE D	SCALE 1:16
FILE TYPE SLDDRW	

TITLE: UF Pilot (UFDT - 2)

CLIENT NAME: Wigen Water Technologies

PROJECT NUMBER	DRAWING NUMBER	SHEET	REV
C-3327-0814	Modular UF Pilot-2 GA	2 of 8	A

WIGEN Since 1965
WATER TECHNOLOGIES
302 LAKE HAZELTINE DRIVE
CHASKA, MN 55318 USA
952-448-4884
WWW.WIGEN.COM

Corporate Office:
302 Lake Hazeltine Drive
Chaska, MN 55318 USA

Phone 800-240-3330
Phone 952-448-4884
Fax 952-448-4886
Web WIGEN.COM

PILOT EQUIPMENT RENTAL AGREEMENT

These terms and conditions form the rental contract (the "Pilot Contract") between _________________ ("Client") and Wigen Companies, Inc. ("Wigen"), and apply to the equipment rented by Client in accordance with Wigen's quote in RFQ# 031315-200A .

TERMS AND CONDITIONS

1. "Equipment" means all types of water treatment equipment or other supplies rented to Client under the Pilot Contract. Client will have an opportunity to test and examine the Equipment to determine that the Equipment is in good working order. Any Issues regarding condition of Equipment shall be reported to Wigen immediately.

2. Client agrees to defend, indemnify and hold Wigen free and harmless from and against any and all claims liabilities, losses, costs and out of pocket expenses (including attorneys' fees) arising out of, or in connection with the Equipment rented, its use, or out of operations conducted by Client, but not limited to, active and/or passive negligence.

3. Client is considered to have taken delivery of the Equipment from the time the Equipment is delivered to Client's designated location. From the time Client takes delivery of the Equipment, until the Equipment is returned to Wigen, Client assumes all risks of loss while in Client's possession. Client will examine equipment on receipt and verify it is in good condition, notifying Wigen of any defects or non-functioning item(s) immediately. Client will return equipment in the same condition as when received, ordinary wear and tear expected. Client will pay promptly when due all charges which accrue because of this rental, including damage or loss of said item(s).

4. Client will take all necessary precautions in regard to the use of the Equipment rented to protect all persons and property from injury or damage. The Equipment rented shall be used only by Client's employees or agents qualified to use such equipment.

5. Client shall, at its own expense, maintain at all times during the pilot period all risk perils insurance covering the Equipment rented from Wigen for full replacement cost of the Equipment. Coverage shall begin from the time Client takes delivery of the Equipment and continue until the time the Equipment is returned to and accepted by Wigen. Such insurance shall name Wigen as the loss payee for loss or damage to the rented Equipment and cover all risks of loss of, or damage to the Equipment.

6. Before obtaining possession of the Equipment, Client shall provide to Wigen a certificate of insurance.

7. Client warrants and represents that it is fully aware of any and all dangers and risks, patent as well as latent, involved in the use and handling of the Equipment.

8. Client shall be responsible to Wigen for the full replacement costs, without depreciation, or repair costs of all Equipment rented which is lost, stolen or damaged. In such event, the rental fees for the subject Equipment shall continue to accrue until the Client has paid for the lost, damaged or stolen Equipment or until repairs are completed. Wigens determination whether the damaged Equipment shall be replaced or repaired shall be conclusive.

9. Invoices per the fee schedule outlined herein, shall be payable upon receipt, unless a different payment schedule is mutually agreed upon in writing. Payments not paid within agreed terms shall be considered past due and a late charge in the amount of 5% of the invoice amount may be assessed. Client agrees to pay attorneys' fees and collection costs in the event it is deemed necessary by Wigen to pursue collection of past due accounts through a collection agency or by an attorney.

10. Wigen is entitled to compensation, not to exceed the amount due for the proposed rental period, in the event of cancellation of all or part of an order unless Wigen agrees otherwise.

11. Client must return the Equipment on the date specified or be subject to additional charges.

12. This agreement shall be governed by the laws of the State of Minnesota. Client agrees to jurisdiction over any dispute in the courts of the State of Minnesota and to venue in Carver County, Minnesota. Client is authorized to enter into this agreement. If for any reason Client does not have insurance coverage adequate to cover any damages to the Equipment and lost profits to Wigen, Client agrees to be liable for such damages.

________________________ ________________________

Projected Rental Start Date Projected Rental Finish Date

Client Name

Printed Contact Name Title

Signature of Authorized Representative of Client Date

PILOT EQUIPMENT RENTAL AGREEMENT

FEE SCHEDULE

Pilot Equipment Rental Prices

Item	Deliverable	Unit Cost	Extension
Pilot Set-up and Breakdown	Shipping to and from site, UF modules, CIP and CEB chemicals, start-up services and pack up assistance at end of pilot study and final pilot study report.	$15,000	$15,000
Monthly Rental Price	Monthly Equipment Rental including additional chemicals as required, conducting CIPs as required, review of data.	$5,000	$5,000 per month or part thereof.

The above pricing does not include any applicable taxes.

Payment Schedule

Payment No.	Billing Period	Amount
1	At time of equipment delivery.	$15,000.00
2,3,4	Following each month after delivery.	$5,000.00

Prices do not include any applicable taxes.

Billing & Shipping Information

Billing Address & Phone No.

____
____
____
____
____

Attn: __________________________

Phone: _________________________

Shipping Address & Phone No.

____
____
____
____
____

Attn: __________________________

Phone: _________________________

Barb Anderson

From: Kris Swanson
Sent: Thursday, March 26, 2015 1:36 PM
To: Barb Anderson
Subject: FW: UF Pilot Study
Attachments: Mankato 2 Train UF Pilot Proposal.pdf

Kris Swanson, PE
Bolton & Menk, Inc.
P: (507) 625.4171 ext. 1263
M: (507) 380.3206
email: krissw@bolton-menk.com

On Mar 13, 2015, at 12:39 PM, Michael Bourke <michael.bourke@wigen.com<mailto:michael.bourke@wigen.com>> wrote:

Kris,

Please find attached a proposal for a 2-3 month pilot study using our 2-train UF Pilot. The scope of supply includes providing 3 full scale UF modules Dow, Toray and Inge (one from each).
Jeff wanted to give you a good rental price here, so our pricing is less than what we normally charge for a single train UF pilot.

If you have any questions on the proposal or need any additional information at this stage, let me know.

Regards,
Michael

Michael Bourke
VP Business Development
Wigen Water Technologies

<image002.png>

6500 S Quebec St, Suite 300 * Centennial, CO 80111 USA
P: (303) 350-3086 * T: (800) 240-3330
F: (303) 220-9134 * W: WIGEN.COM<http://www.wigen.com/>

Denver * Los Angeles * Minneapolis * Phoenix * New York

From: Kris Swanson [mailto:krissw@bolton-menk.com]
Sent: Wednesday, March 11, 2015 8:06 PM
To: Michael Bourke
Subject: RE: UF Pilot Study

Michael,

I am looking for wastewater reuse. I have spoken to Jeff and Eric and Stacy regarding this and need a price from Wigen by March 15th per my discussion with Jeff. We are going to run for about 2-3 months and try out 2 or 3 membranes. Looking to rent a unit for this purpose. We could start as early as June or as late as September depending on availability. Preference would be a later summer or fall start time.

Pilot is to optimize phos. removal. Looking to reach 0.1 mg/L or less consistently and compare results against the City's current disc filters.

Please call on my cell phone with additional questions

Thanks,
Kris

Kris Swanson, PE
Bolton & Menk, Inc.
P: (507) 625.4171 ext. 1263
M: (507) 380.3206
email: krissw@bolton-menk.com<mailto:krissw@bolton-menk.com>

From: Michael Bourke [mailto:michael.bourke@wigen.com]
Sent: Tuesday, March 10, 2015 2:17 PM
To: Kris Swanson
Subject: UF Pilot Study

Hi Kris,

Jeff Wigen asked me to call you regarding the UF pilot proposal you would like from us in the next few weeks. I was wanting to get a feel for when you were planning on doing the pilot and how long you would need it for. Also, Jeff indicated you are interested in using out 2-train pilot that can pilot 2 different UF modules at the same time. We have a fair bit of demand for that pilot, so the sooner we can get that reserved the better. I am not sure if the application you are looking at is drinking water or reuse and what the pilot objectives will be.

Can you give me a call or email more details on the pilot and I will then start pulling together a proposal for you.

Regards,
Michael

Michael Bourke
VP Business Development
Wigen Water Technologies

<image003.png>

6500 S Quebec St, Suite 300 * Centennial, CO 80111 USA
P: (303) 350-3086 * T: (800) 240-3330
F: (303) 220-9134 * W: WIGEN.COM<http://www.wigen.com/>

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APPENDIX C

Meiden America, Inc. – Ceramic Flat-Sheet Membrane Pilot Study Report & Cost Estimate

CFM Pilot Results	Mankato WWTP
Ceramic Filtration Membrane	Mankato Treatment Plant
	Filtration Report

1. Purpose

Bench-scale filtration testing using Meiden flat-sheet ceramic membrane (CFM) for filtration was conducted at the Mankato Waste Recovery Center from November 9 to December 17, 2015. Influent to the unit included tertiary wastewater that was both before and after the Actiflo microsand unit(s).

Initial Summary

1. Pre-Actiflo water could be filtered by the Meiden CFM unit at a higher flux than Post-Actiflo. The membranes fouled less quickly using pre-Actiflo influent.
   Souring air could be applied to the membranes when using pre-Actiflo influent.
2. Post-Actiflo influent could be filtered by ceramic membranes. However, scouring air was not effective to minimize membrane fouling.
3. Standard Meiden CFM membrane cleaning chemical procedures were sufficient to recover the membrane. Both 0.1% NaClO and 1.0% Citric acid could recover the membrane with minimal drop in performance. Citric acid visibly dissolved the foulant layer on the membranes.

2. Experiment Parameters

A. Location and date

Location: Mankato Waste Water Treatment Facility, 701 Pine, Mankato, MN

Experimenters:	Bill Pagels	Meiden
	Jake Pichelmann	Bolton-Menk
	Josh Gad	City of Mankato

Mankato Operators and Chemist: Josh Gad, Bobby, Darryl, Troy, Jim Archer

B. Raw water for filtration test of CFM

1. Pre-Actiflo
   Filtrate was taken from the first injection basin, where $FeCl_3$ was added to the wastewater. The water characteristic was always dynamic, based on the system influent and the mixing proportions. Polymer and micro-sand are added downstream from this sampling point.
2. Post-Actiflo
   Filtrate for this testing was taken from the Actiflo effluent. It included the $FeCl_3$, polymer and micosand. This sample point was prior to disk filters which are used for iron chloride removal. A 150gallon poly tank was filled from the source piping. Water sample for testing was then drawn from center of the tank, not from settled materials near bottom. The poly tank was not stirred during sampling.

C. Setup

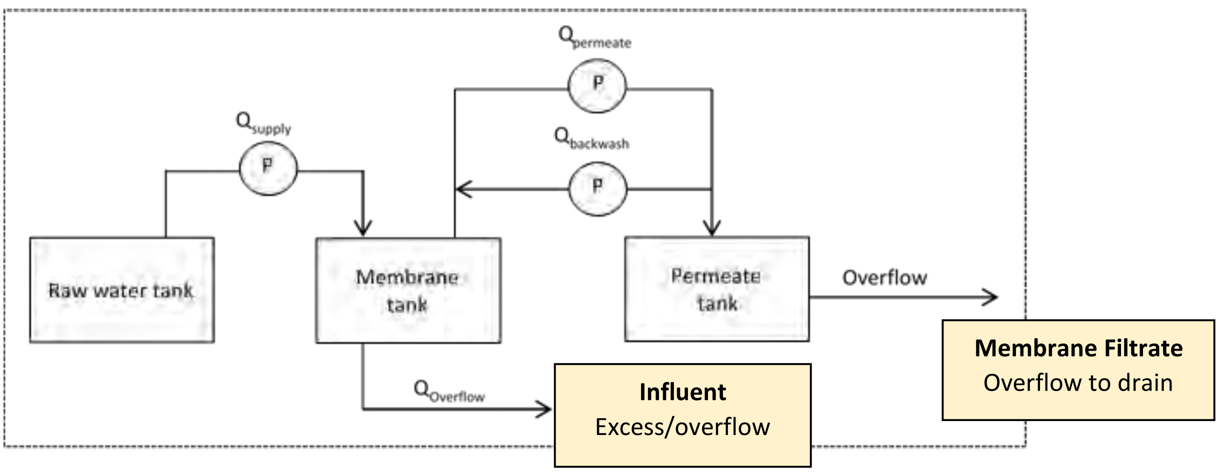
1. Two locations were used for the Meiden pilot unit, with each location close to each of the two influent sources within the Mankato facility. The pilot unit was placed on a workbench also near the source piping, drain and 120VAC power.

2. The pilot feed pump was set to supply sufficient influent to the membrane tank to maintain a slight membrane tank overflow throughout the testing.
3. The Filtrate pump was set to achieve the initial set-point of flux at the beginning of each test. The pump system was not provided with a closed loop control, so the the flux level decreased as the TMP/membrane fouling increased in each test run.
4. The Backwash pump was set to achieve a flow rate approximately twice the filtration rate, 2Q. This pump also was not controlled, so backwash volume also decreased with increasing TMP. However, this parameter was not measured by the pilot unit. Individual inspection showed that the backwash flow decrease was not as significant in operation as the filtration flow decrease.
5. Air scour was monitored by manometers. During some testing modes there was no air scour used because it appeared to work in conjunction with the $FeCl_3$, creating a thicker fouling layer, and at a faster rate of fouling.

D. Apparatus

A small, transportable, system for filtration testing was used for testing. The summary sketch of the system is shown below.

Summary Diagram of Test System



Specification and Conditions of CFM System

	Specifications and Conditions
Membrane	CFM from Meiden Material: Alumina ceramic core, and membrane layer Pore size: 0.1 μm Membrane area: $0.431 ft^2$ ($0.040 m^2$)
Membrane tank	Volume: 0.79g (3 L)
Pumps	Peristaltic pump for influent and filtrate/backwash

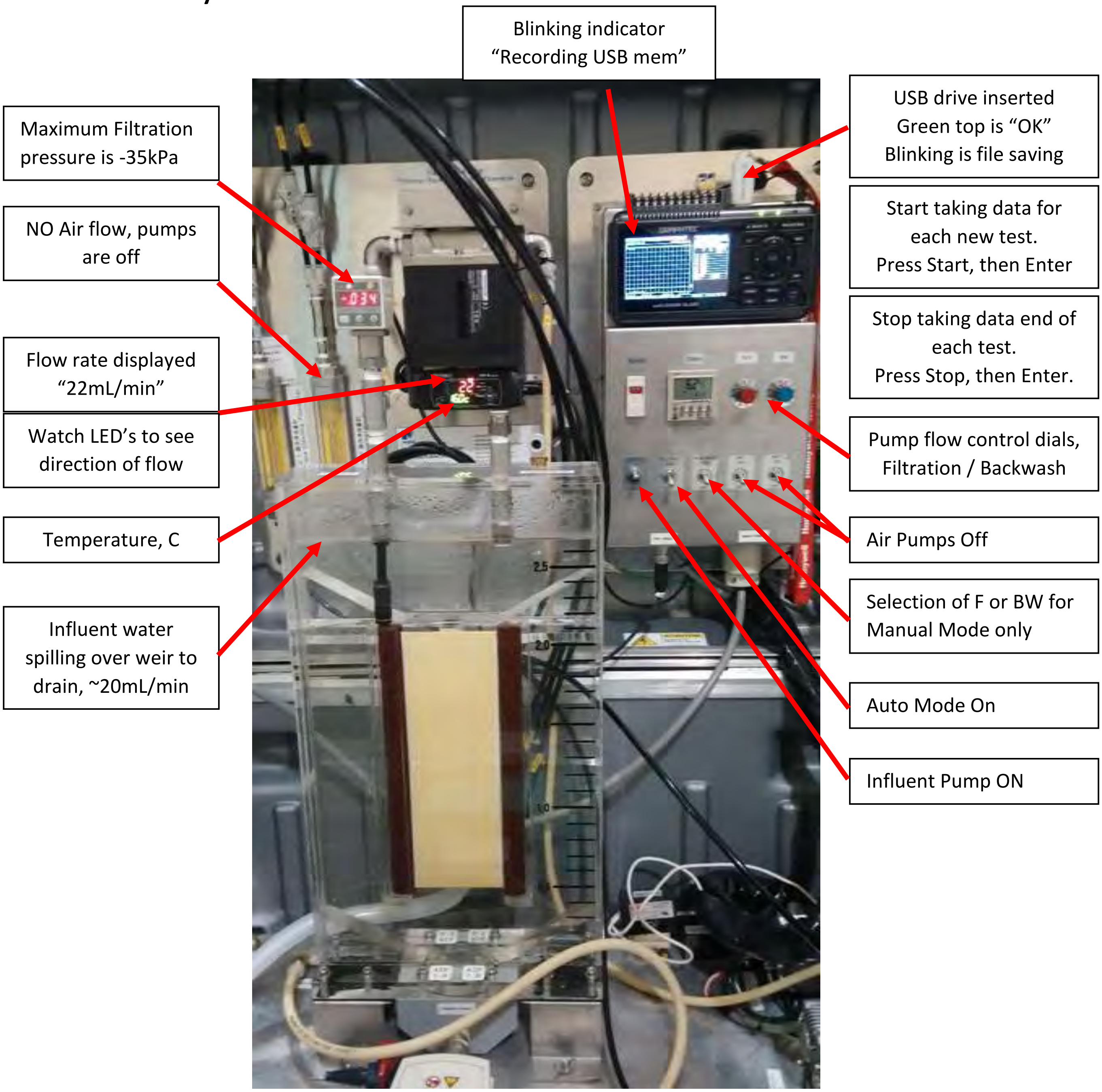
Test Setup at 790 Pine Street

Wastewater Treatment Facility

(Disc Filter Systems for Ferric removal located in this room)

Location of Meiden Ceramic Membrane Pilot Unit for Post Actiflo water testing

Pilot Unit Summary Controls



3. Testing Sequence

1. Prepare membrane sheet

a. Clean membrane (next page) or be sure that it has been soaking for ~4 hours in clean water to be sure that pore are sufficiently in contact with water.
b. Confirm designation of membrane, and condition of its surface.

2. Install membrane into tank

a. Connect 8mm tube between pressure sensor and membrane port
b. Slide membrane into membrane tank slot, lid covers tank.
c. Connect hose #1 to pressure sensor piping.
d. Confirm electrical cable is installed to control box (pressure sensor light is on).

3. Start Test Run

a. Confirm USB thumb drive is installed.
b. Start the data acquisition, press “Start” on control panel, confirm with “Enter”.
c. Confirm that text on data recorder blinking “Recording USB mem” (not internal memory).

4. Initialize Pump units (assuming no pumps currently operating)

a. Set Feed Pump switch to ON.
b. Set MAN MODE switch to BW (backwash)
c. Set FILT/BW switch to MAN and leave on for about 1.5 minutes (~100ml). Now BW pump will operate and push clean filtrate water into the membrane. Confirm direction and quantity (~60ml/min) from flow meter.

5. Start Test

a. Set FILT/BW switch to Auto. Now unit will automatically switch from Filtration for 9:30 minutes and Backwash for 30 seconds. Durations typically have been already set on the timer unit.
b. During the first cycle of Filtration, the trapped air in the membrane will be pulled out and will be seen going into the Filtrate tank as some bubbles for the few minutes. After this air is flushed out, then the flow rate will become constant.
c. Record Filtration and Backwash flows and pressures. This will confirm the initial operating condition of the fresh filter.
d. Change the dial settings for FILT and/or BW to be sure that actual flow matches the target flow now at the start of the test. Each filter will vary slightly.
e. As possible, check every two hours and record pressures and flows and confirm operation is normal.

6. End Test

a. Record time and final pressures and flows.
b. Press Stop button on data recorder, confirm with Enter. USB drive cap will blink several times (depending on model used) and then stop within ~30 seconds as final data is recorded. Now USB drive can be removed and data copied to PC. Files are identified by date. Return USB drive to the pilot unit before next test.
c. Set FILT/BW switch to OFF.
d. If no more testing will follow, turn off the Feed Pump switch.
e. Disconnect tube #1 to membrane tank lid.
f. Pull membrane from tank and disconnect tube from 8mm port.
g. Note color and condition of membrane.
h. Move membrane to cleaning tub and clean appropriately.

Cleaning Summary for Flat Sheet Ceramic Membrane at Mankato Facility

Sodium Hypohlorite Soak with 0.1% Solution NaClO

1. Fill the tub (3/4 full) with potable water (approximately 3 liters).
2. Add ~**25mL** of 12% sodium hypochlorite to the tub.
    a. For example; 3000mL x 0.001 {0.1%} = 0.12 {12%} x volume Z. Z = 25mL
3. Mix solution.
4. Place membrane in tub. Cover tub with lid.
5. Wait for 1 hour (or ~8 hours for additional cleaning)
6. Dispose of soak solution
7. Rinse membrane for a few moments in potable water, allow to drain.
8. Return membrane to the Pilot Membrane tank and reconnect 8mm hose fitting.

Citric Acid Soak with 1% Solution

1. Fill the tub (3/4 full) with potable water (approximately 3 liters).
2. Add ~**60mL** of 50% citric acid to the tub.
    a. For example; 3000mL x 0.01 {1%} = 0.50 {50%} x volume Y. Y = 60mL.
3. Mix solution.
4. Place membrane in tub. Cover tub with lid.
5. Wait for 2 hour (or ~8 hours for additional cleaning)
6. Dispose of soak solution
7. Rinse membrane for a few moments in potable water, allow to drain.
8. Return membrane to the Pilot Membrane tank and reconnect 8mm hose fitting.

Preparation to use Dry Membrane (new)

1. Fill the tub with potable water, enough to cover membrane.
2. Soak membrane for 4 hours to completely wet all pores.

Drain/Transport the Membrane

1. Rinse membrane from previous use if needed.
2. Pour out water from interior channels of membrane (takes a little shaking/sloshing and then most of the liquid in the interior channels will pour through the port.
3. Wrap with paper towel, and protect with bubble wrap.

Proposed procedure for chemical soaking of membrane using the Membrane tank (instead of removal of membrane for each soak)

1. Stop feed pump. Keep scouring air ON
2. Turn mode switch from AUTO to OFF
3. Add 20ml of 12% NaClO to the full membrane tank that contains sample water. 2.5liter membrane tank x 0.1% target concentration = 12% stock solution x Y liters. Y = 20ml.
4. Pour solution slowly into membrane tank and allow scouring air bubbles to mix it.
5. Allow chemical to clean in membrane tank for 15 minutes, with scouring air ON, Filtration OFF, Backwash OFF.
6. Drain membrane tank.
7. No additional potable water flush after the drain.
8. Refill membrane tank with sample water.
9. Turn pump switch to BW Mode, turn mode switch from OFF to Manual for about one minute, then turn mode switch to OFF.
10. Turn mode switch to Auto for the next 16 hours and continue data acquisition.

Operating notes from first testing phase

The first phase of bench-scale testing using Meiden flat-sheet ceramic membrane (CFM) for filtration of wastewater was conducted in Mankato waste recover center from November 9 to November 13, 2015.

Run One 29.4gfd (50lmh) November 9, 2015 Membrane 1

Backwash dial setting set at 5.3 to provide 80ml/min at 10kPa.

Start of test: 1640 with 500ms sampling rate, temperature 19.2C

End of test: 0745, temperature 17.6C. Followed by training to operators.

Test could not continue due to the high TMP level during filtration.

12% bleach solution provided to MAI. Approximate 0.1% solution prepared and used for membrane soak of one hour in a separate container. 3000ml x 0.001solution = Z x 0.12 solution. Z= 25ml.

Membrane rinsed of bleach in warm potable water. Light red film remained attached to membrane surface. Film was lightly brushed off with wet paper towel. One half of back side of membrane surface (~25%) was not wiped clean to more easily see change. See pictures.

Filtrate tank and membrane tank were drained, not rinsed. Then membrane tank refilled with same (not freshened) sample water from 150 gallon tank. Sample water taken from approximate center of tank.

Run Two 29.4gfd (50lmh) November 10, 2015 Membrane 1

Start of test: 1028 with 500ms sampling rate, temperature of 17.9C.

Additional testing attempted at 1300:

How much will TMP increase if filtrate pump increased for 38ml/min flow?

Increase from 35 to 37 resulted in no measureable change in TMP.

Will a longer backwash with higher back pressure improve situation?

Increased from backwash from 31 to 40kPa for 90 seconds; -103ml/min flow.

Result, no change in filtration.

Attempted 50kPa backpressure for 90 seconds.

Increased backwash from 31 to 49kPa for 90 seconds; 123ml/min flow.

Result, no change in filtration.

Samples of membrane permeate and influent taken by Jake Pichelmann.

End of test 1400. Test could continue but evidence of fast TMP rise was evident.

50% citric acid solution provided to MAI. Approximate 1% solution prepared and used for membrane soak of two hours in a separate container. 3000ml x 0.01solution = Z x 0.50 solution. Z= 60ml.

Membrane rinsed of citric acid in warm potable water. Light red film was no longer visible.

Filtrate tank and membrane tank were drained, not rinsed. Then membrane tank refilled with same (not freshened) sample water from 150 gallon tank. Sample water taken from approximate center of tank.

Run Three 29.4gfd (50lmh) November 10, 2015 Membrane 1

Start of test: 1655 with 500ms sampling rate, temperature of 18.5C

Samples of membrane permeate and influent taken by university staff.

Test could not continue due to filtration TMP

End of test: 0723 November 11.

Preparation for Run Four

Drained 150 gallon sample tank (~80 gallons)

Filled sample tank with fresh water, same water source as for Runs 1 to 3.

Drained membrane and filtrate tanks.

Rinsed membrane and filtrate tanks with tap water.

Installed new membrane (#2) that was soaked in tap water 16 hours.

Began 0.1% bleach soak of Membrane 1.

Run Four 23.5gfd (40lmh) November 11, 2015 Membrane 2

Flow settings modified for 40lmh flux, to identify a more stable operating point.

H20I considered that air scour may be causing an anhydrous iron particulate, so they suggested that the test be run without the air scour.

Start of test 9:33am

Test started and ran for 1.5 hour without air. TMP rose 3kPa. So total lack of mixed air is not perfect.

1150 No orange coloration noticed on membrane and no color transferred to wet paper towel.

1151 Air scour was turned on (recorder notes 1:29 minutes; “9:52”).

1219 Measurements taken, was found that TMP rose 7kPa in two hours, perhaps air scour is not effective with respect to iron particulates.

1230 Drained membrane tank, filled with fresh sample water, turned off air scour for remainder of test.

1422 Found that TMP rose 2kPa in two hours; seems to be an improvement.

1528 TMP increase still appears to be under control.

1600 Measured again, similar result.

November 12, 2015

0816 21ml/min at -34kPa Filtration, -61ml/min at 41kPa. Stopped test and retrieved data.

Membrane has orange coloration.

After rinsing Membrane 1 with tap water after the 8 hour bleach soak, the orange film did wash off easily. This membrane then soaked in 1% citric acid overnight and is now placed in a tap water container ready for potential use on Monday.

Run Five 23.5gfd (40lmh) November 12, 2015 Membrane 2

This is an attempt to optimize previous results and obtain a 24 hour run resulting in less than 35kPa TMP.

Preparation:

Soaked Membrane 2 for one hour in 0.1% bleach. No physical scouring. A light rinse in tap water and travel from sink (in tap water filled container) to pilot did wash some of the orange film from membrane surface. Some of the film rolled off the surface in small bits of thin film.

Installed membrane and backwashed with 100mL of permeate (about 1.5 minutes at current setting). This was to approximate chemically enhanced backwash of full system.

No membrane scour air was used during the 24hour test.

Ran test until Friday morning.

After Run 5 completion; removed Membrane 2 and cleaned in 0.1% hypo for one hour and then tested recovery.

Recovery was good and shown in the chart above.

Drained membrane and filtrate tanks, flushed with potable water.

Drained sample tank.

Labeled tubs that contained Membranes 2 and 3.

Left equipment for the weekend.

End of Notes from first phase

Pictures of Membrane During Stages of Testing. Business Card used for white comparison

Result After Run 1 and 1 hour 0.1% NaClO soak.

Orange Film stayed on membrane after cleaning. Only wet towel wiped on membrane removed a streak of ferric/polymer film.


Result After Run 2 (untouched, no chemicals added yet). Additional color to the white areas of membrane


Result After Run 2 and 2 hour 1% Citric Acid soak

All visible trace of film has been removed and is not seen in the chemical tub, bright white membrane as original in color.

Result After Run 3

After testing, this membrane below was soaked in 0.1% NaClO for 8 hours, then 1% Citric Acid for 24 hours, then assumed READY for later testing. No pictures taken after cleaning, but it was white color as original membrane after the cleaning process.

Result After Run 4

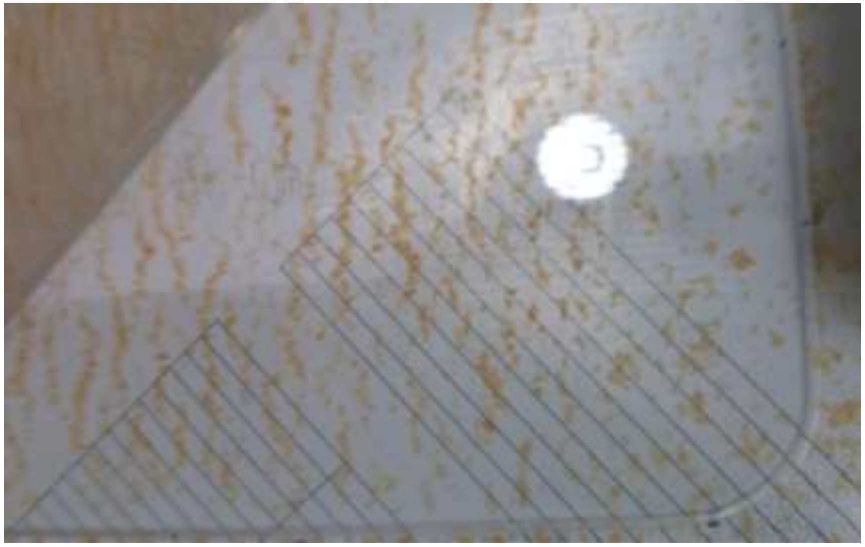
Result after Run 4 with 1 hour soak in 0.1% NAClO

Film was nearly washing off in a light rinse of water.

By the time that this membrane was installed in the membrane tank, more of the film had already been washed away.

Result After Run 5 and 1 hour 0.1% NaClO soak

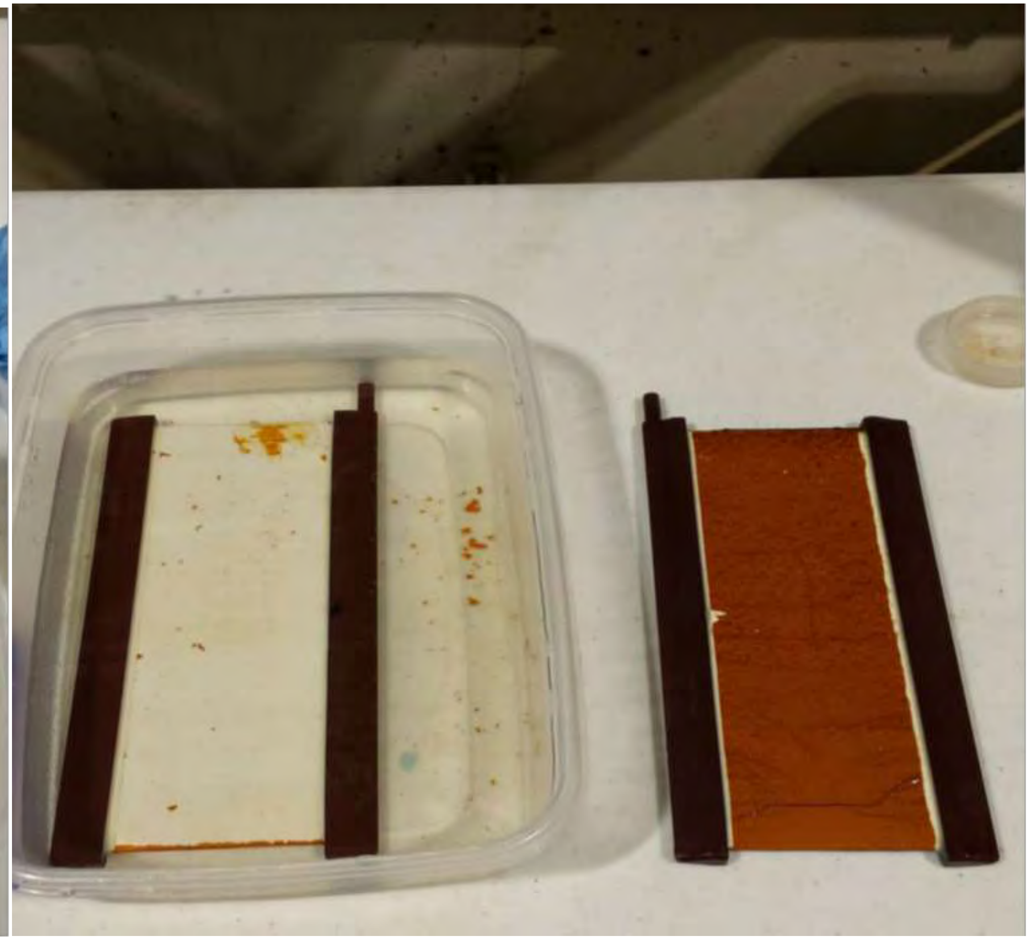
This film is lighter and easier to remove than after Run 4. Run 5 did not use membrane air scouring.



Film particles left in the chemical cleaning tub after walking from the sink to the pilot unit.

Study Continuation

Example of film collected during Pre-Actiflo testing



This foulant film washed from membrane in NaClO   Result After 24 hour NaClO soak   Filter after 24 hours of test, Dec 8

Test Procedure by City of Mankato during Pre-Actiflo Testing

Mankato Transportable Pilot, CFM Study Continuation

Day	Sample (still TBD)	Flux lmh	Filt flow / BW flow set	mL/min Initial Filtration	ML/min Final Filtration	Initial TMP kPa	Final TMP kPa	Operation	Air Scour	Cleaning time	Chemical Clean	Influent Total Phosphorus	Effluent Total Phosphorus	Note
12/7/2015	Pre Actiflo	52	42/-71	42	23	-7	-46	24 on	No	24 hour	0.1% NaClO	0.08mg/L	0.05	Thick foulant film
12/8/2015	Pre Actiflo	37	28/-55	29	21	-9	-34	24 on	No	1hr	0.1% NaClO	0.11	0.05	Thick foulant film
12/9/2015	Pre Actiflo	37	28/-55	29	24	-7	-22	23 on	N2hr/ Y21hr	1hr	0.1% NaClO	0.28	0.06	Sand blocked influent backflow preventer, cleaned
12/10/2015	Pre Actiflo	37	28/-55	29	---	-7	---	24	Only one pump on due to ground fault	1hr	0.1% NaClO	0.42	0.06	Removed influent backflow preventer, GFCI faults from pump
12/11/2015	Pre Actiflo	37	28/-55	---	---	---	---	---	Both units on	---	0.1% NaClO	---	---	Trial run with 8/16, see procedure below for in-tank soak.
12/11 after 8 hours filt	Pre Actiflo	37	28/-55	29	28	-7	-8	8 hours	Yes	Soak in hypo for 15min; BW at 71mL/min for one min, rinse tank	0.1% NaClO	---	---	
12/12/2015 morning, after 16 hours filt	Pre Actiflo	45	35/-71	35	33	-8	-10	16 hours	Yes	Soak in hypo for 15 min; BW at 71mL/min for one min, rinse tank	0.2% NaClO	---	---	Baseline for 45lmh
12/13/2015	Pre Actiflo	45	35/-71	35	33	-8	-9	24	Yes	Soak in hypo for 7min; BW at 71mL/min for one min, rinse tank	0.2% NaClO	---	---	Baseline for 45lmh
12/14/2015	Pre Actiflo	45	35/-71	33	32	-9	-9	24hrs	Yes	No initial cleaning	-	0.84	0.04	increase P; 1.5 to 2mg/L phosphorus. No cleaning on Monday morning.
12/15/2015	Pre Actiflo	64	50/-100	49	45	-11	-20	5 hrs	Yes	Soak in hypo for 15 min; BW at 100 mL/min for one min, rinse tank	0.05% NaClO	0.34	0.02	
12/15/2015	Pre Actiflo	66	50/-100	52	44	-11	-27	8 hrs	Yes	Soak in hypo for 15 min; BW at 100 mL/min for one min, rinse tank	0.2% NaClO	0.34	0.02	
12/15/2015	Pre Actiflo	73	50/-100	58	48	-11	-63	10 hrs	Yes	Soak in hypo for 15 min; BW at 100 mL/min for one min, rinse tank	0.2% NaClO	0.34	0.02	Feed pump had not provided enough flow, thus the filter was only half submerged when found in the morning. Moved to another new section of hose, and increased pumping to 60 rpms.
12/16/2015	Pre Actiflo	73	58/-100	57	53	-8	-21	4 hrs	Yes	Changed filter with filter # 3, began 24 hour soak on filter #2.	0.1% NaClO	0.4	0.02	
12/16/2015	Pre Actiflo	52	42/-80	42	32	-12	-40	8 hr or 24 hr depending on TMP	Yes	Soak in hypo for 15 min; BW at 100 mL/min for one min, rinse tank	0.05% NaClO	0.4	0.02	
12/17/2015	Post Actiflo?	52	41	41	40	-9	-14	8 hours	Yes	Soak in hypo for 15 min; BW at 100 mL/min for one min, rinse tank	0.05% NaClO	0.45	0.03	

DRAFT Phosphorus Levels as of December 18, 2015, from City of Mankato

MSU Sampling and Analysis

Influent/ Effluent	Sample Date	Sample Name	Total Phosphorus (mg/L)
Influent	11/11/2015	MFINF1111	0.32
Influent	11/11/2015	MFEFF1111#1	0.07
Effluent	11/11/2015	MFINF1111#2	0.23
Effluent	11/11/2015	MFEFF1111#2	0.08
Influent	11/12/2015	MFINF1112	0.22
Effluent	11/12/2015	MFEFF1112	0.06
Influent	11/13/2015	MFINF1113	0.20
Effluent	11/13/2015	MFINF1113	0.10
Influent	11/18/2015	MFINF1118	0.11
Effluent	11/18/2015	MFEFF1118	0.06
Influent	11/20/2015	MFINF1120	0.12
Influent	11/20/2015	MFINF1120#2	0.09
Effluent	11/20/2015	MFEFF1120#1	0.05
Effluent	11/20/2015	MFEFF1120#2	0.04
Effluent	11/20/2015	MFEFF1120#3	0.03
Influent	11/21/2015	MFINF1121	0.08
Effluent	11/21/2015	MFEFF1121	0.03
Influent	11/22/2015	MFINF1122	0.20
Effluent	11/22/2015	MFEFF1122	0.06
Influent	11/23/2015	MFINF1123	0.10
Effluent	11/23/2015	MFEFF1123#1	0.04

Red is assuming the numbers reported were inverted.

Reported values are in mg/L units - Results are DRAFT

Mankato WWTP Sampling and Analysis

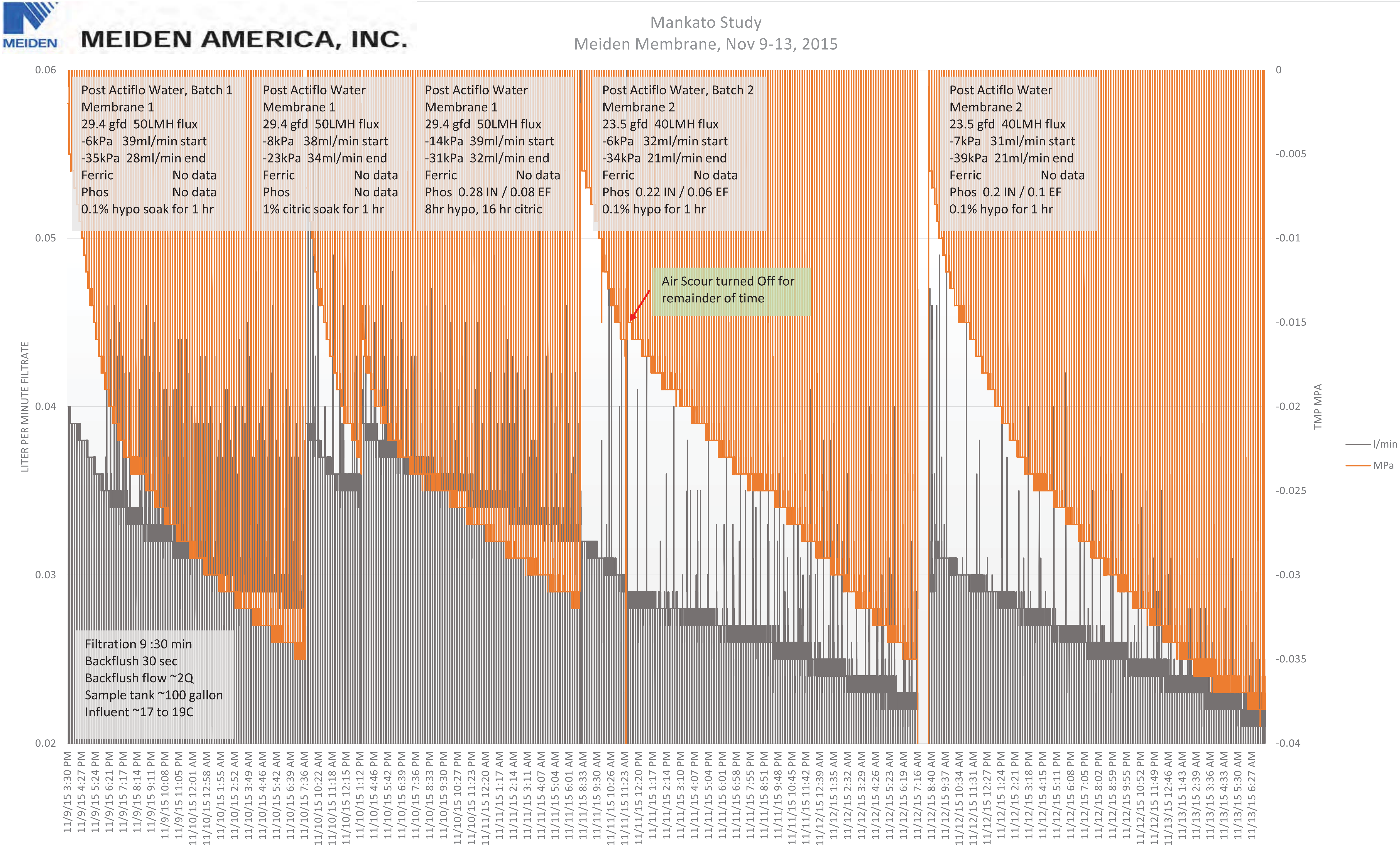
Influent/ Effluent	Sample Date	Sample Name	Total Phosphorus (mg/L)
Influent	11/23/2015	MFEFF1123#2	0.02
Effluent	11/24/2015	MFINF1124	0.07
Influent	11/24/2015	MFEFF1124	0.03
Effluent	11/24/2015	MFEFF1124#2	0.04
Influent	11/25/2015	MFINF1125	0.05
Effluent	11/25/2015	MFEFF1125	0.03
Effluent	11/25/2015	MFEFF1125#2	0.02
Influent	11/30/2015	MFINF1130	0.06
Effluent	11/30/2015	MFEFF1130#1	0.03
Effluent	11/30/2015	MFEFF1130#2	0.05
Influent	12/1/2015	MFINF1201	0.08
Effluent	12/1/2015	MFEFF1201#1	0.02
Effluent	12/1/2015	MFEFF1201#2	0.05
Influent	12/7/2015	MFINF1207 PM	0.08
Effluent	12/7/2015	MFEFF1207 PM	0.05
Influent	12/8/2015	MFINF1208	0.11
Effluent	12/8/2015	MFEFF1208#1	0.05
Effluent	12/8/2015	MFEFF1208#2	0.06
Influent	12/9/2015	MFINF1209 #1	0.26
Effluent	12/9/2015	MFEFF1209#1	0.05
Influent	12/9/2015	MFINF1209 #2	0.29
Effluent	12/9/2015	MFEFF1209 #2	0.06
Influent	12/10/2015	MFINF1210	0.42
Effluent	12/10/2015	MFEFF1210	0.06

Reported values are in mg/L units - Results are DRAFT

Mankato WWTP Sampling and Analysis

Influent/ Effluent	Sample Date	Sample Name	Total Phosphorus (mg/L)
Influent	12/14/2015	MFINF1214-1	1.15
Effluent	12/14/2015	MFEFF1214-1	0.05
Influent	12/14/2015	MFINF1214-2	0.52
Effluent	12/14/2015	MFEFF1214-2	0.03
Influent	12/15/2015	MFINF1215-1	0.57
Effluent	12/15/2015	MFEFF1215-1	0.03
Influent	12/15/2015	MFINF1215-2	0.11
Effluent	12/15/2015	MFEFF1215-2	0.02
Influent	12/16/2015	MFINF1216-1	0.13
Effluent	12/16/2015	MFEFF1216-1	0.04
Influent	12/16/2015	MFINF1216-2	0.66
Effluent	12/16/2015	MFEFF1216-2	0.00
Influent	12/17/2015	MFINF1217-1	0.46
Effluent	12/17/2015	MFEFF1217-1	0.03
Influent	12/17/2015	MFINF1217-2	0.45
Effluent	12/17/2015	MFEFF1217-2	0.03
Influent	12/18/2015	MFINF1218	0.62
Effluent	12/18/2015	MFEFF1218	0.03

Reported values are in mg/L units - Results are DRAFT


MEIDEN
MEIDEN AMERICA, INC.
Mankato Study
Meiden Membrane, Nov 9-13, 2015
Post Actiflo Water, Batch 1
Membrane 1
29.4 gfd 50LMH flux
-6kPa 39ml/min start
-35kPa 28ml/min end
Ferric No data
Phos No data
0.1% hypo soak for 1 hr
Post Actiflo Water
Membrane 1
29.4 gfd 50LMH flux
-8kPa 38ml/min start
-23kPa 34ml/min end
Ferric No data
Phos No data
1% citric soak for 1 hr
Post Actiflo Water
Membrane 1
29.4 gfd 50LMH flux
-14kPa 39ml/min start
-31kPa 32ml/min end
Ferric No data
Phos 0.28 IN / 0.08 EF
8hr hypo, 16 hr citric
Post Actiflo Water, Batch 2
Membrane 2
23.5 gfd 40LMH flux
-6kPa 32ml/min start
-34kPa 21ml/min end
Ferric No data
Phos 0.22 IN / 0.06 EF
0.1% hypo for 1 hr
Post Actiflo Water
Membrane 2
23.5 gfd 40LMH flux
-7kPa 31ml/min start
-39kPa 21ml/min end
Ferric No data
Phos 0.2 IN / 0.1 EF
0.1% hypo for 1 hr
Air Scour turned Off for
remainder of time
Filtration 9 :30 min
Backflush 30 sec
Backflush flow ~2Q
Sample tank ~100 gallon
Influent ~17 to 19C
LITER PER MINUTE FILTRATE
0.06
0.05
0.04
0.03
0.02
TMP MPA
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
-0.035
-0.04
l/min
MPa
11/9/15 3:30 PM
11/9/15 4:27 PM
11/9/15 5:24 PM
11/9/15 6:21 PM
11/9/15 7:17 PM
11/9/15 8:14 PM
11/9/15 9:11 PM
11/9/15 10:08 PM
11/9/15 11:05 PM
11/10/15 12:01 AM
11/10/15 12:58 AM
11/10/15 1:55 AM
11/10/15 2:52 AM
11/10/15 3:49 AM
11/10/15 4:46 AM
11/10/15 5:42 AM
11/10/15 6:39 AM
11/10/15 7:36 AM
11/10/15 10:22 AM
11/10/15 11:18 AM
11/10/15 12:15 PM
11/10/15 1:12 PM
11/10/15 4:46 PM
11/10/15 5:42 PM
11/10/15 6:39 PM
11/10/15 7:36 PM
11/10/15 8:33 PM
11/10/15 9:30 PM
11/10/15 10:27 PM
11/10/15 11:23 PM
11/11/15 12:20 AM
11/11/15 1:17 AM
11/11/15 2:14 AM
11/11/15 3:11 AM
11/11/15 4:07 AM
11/11/15 5:04 AM
11/11/15 6:01 AM
11/11/15 8:33 AM
11/11/15 9:30 AM
11/11/15 10:26 AM
11/11/15 11:23 AM
11/11/15 12:20 PM
11/11/15 1:17 PM
11/11/15 2:14 PM
11/11/15 3:10 PM
11/11/15 4:07 PM
11/11/15 5:04 PM
11/11/15 6:01 PM
11/11/15 6:58 PM
11/11/15 7:55 PM
11/11/15 8:51 PM
11/11/15 9:48 PM
11/11/15 10:45 PM
11/11/15 11:42 PM
11/12/15 12:39 AM
11/12/15 1:35 AM
11/12/15 2:32 AM
11/12/15 3:29 AM
11/12/15 4:26 AM
11/12/15 5:23 AM
11/12/15 6:19 AM
11/12/15 7:16 AM
11/12/15 8:40 AM
11/12/15 9:37 AM
11/12/15 10:34 AM
11/12/15 11:31 AM
11/12/15 12:27 PM
11/12/15 1:24 PM
11/12/15 2:21 PM
11/12/15 3:18 PM
11/12/15 4:15 PM
11/12/15 5:11 PM
11/12/15 6:08 PM
11/12/15 7:05 PM
11/12/15 8:02 PM
11/12/15 8:59 PM
11/12/15 9:55 PM
11/12/15 10:52 PM
11/12/15 11:49 PM
11/13/15 12:46 AM
11/13/15 1:43 AM
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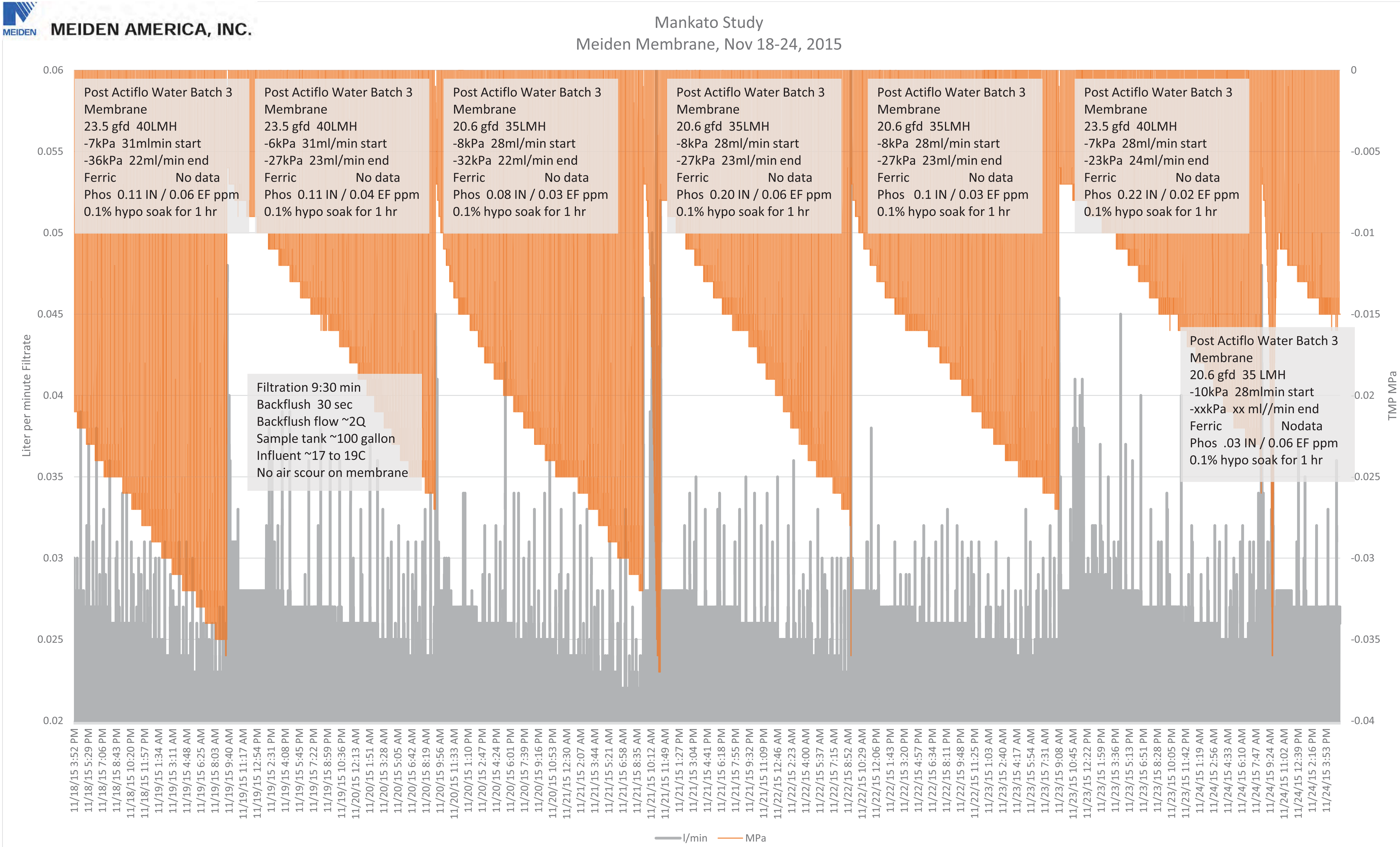
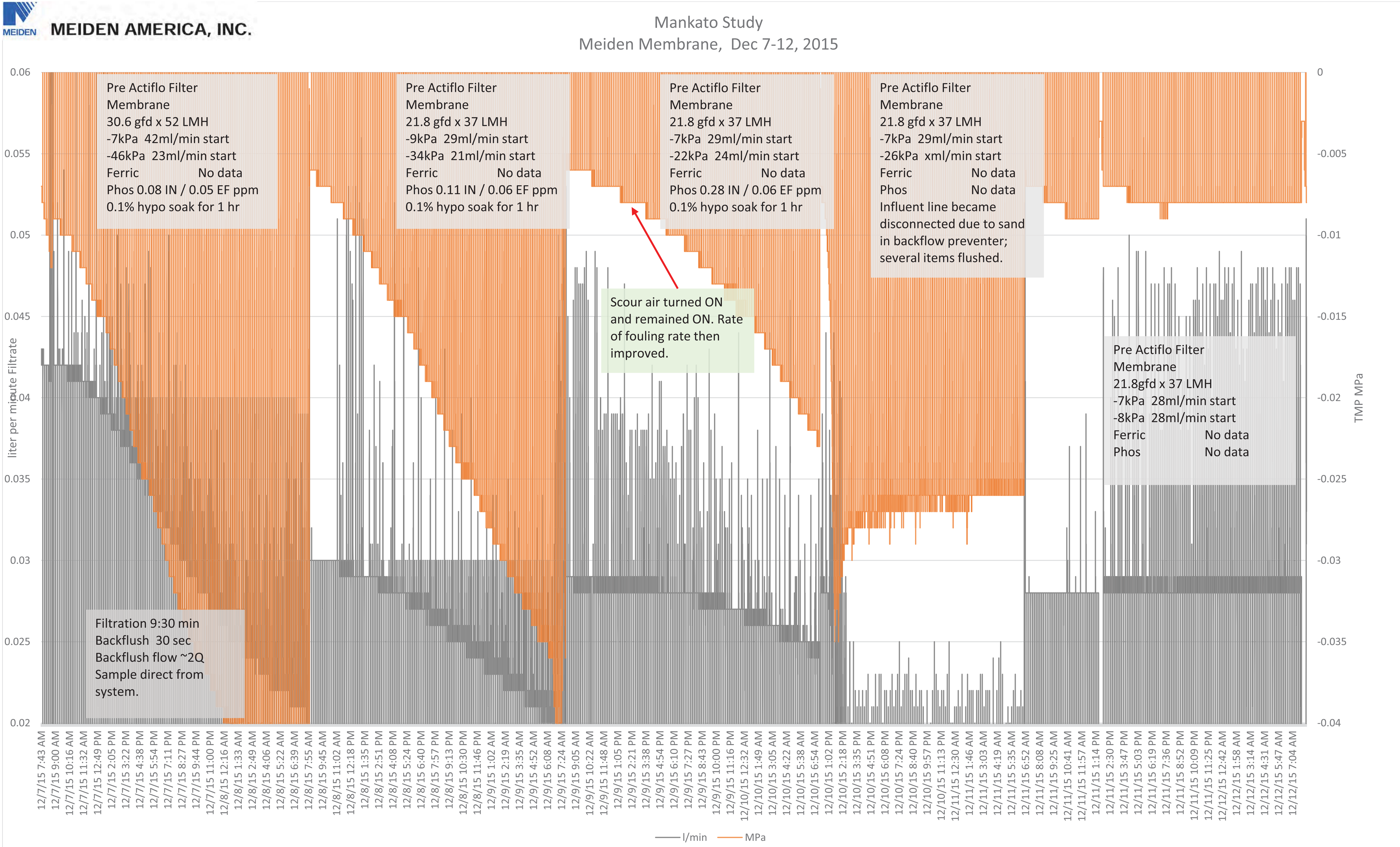
11/13/15 5:30 AM
11/13/15 6:27 AM


MEIDEN AMERICA, INC.
Mankato Study
Meiden Membrane, Nov 18-24, 2015
Post Actiflo Water Batch 3 Membrane 23.5 gfd 40LMH -7kPa 31mlmin start -36kPa 22ml/min end Ferric No data Phos 0.11 IN / 0.06 EF ppm 0.1% hypo soak for 1 hr
Post Actiflo Water Batch 3 Membrane 23.5 gfd 40LMH -6kPa 31ml/min start -27kPa 23ml/min end Ferric No data Phos 0.11 IN / 0.04 EF ppm 0.1% hypo soak for 1 hr
Post Actiflo Water Batch 3 Membrane 20.6 gfd 35LMH -8kPa 28ml/min start -32kPa 22ml/min end Ferric No data Phos 0.08 IN / 0.03 EF ppm 0.1% hypo soak for 1 hr
Post Actiflo Water Batch 3 Membrane 20.6 gfd 35LMH -8kPa 28ml/min start -27kPa 23ml/min end Ferric No data Phos 0.20 IN / 0.06 EF ppm 0.1% hypo soak for 1 hr
Post Actiflo Water Batch 3 Membrane 20.6 gfd 35LMH -8kPa 28ml/min start -27kPa 23ml/min end Ferric No data Phos 0.1 IN / 0.03 EF ppm 0.1% hypo soak for 1 hr
Post Actiflo Water Batch 3 Membrane 23.5 gfd 40LMH -7kPa 28ml/min start -23kPa 24ml/min end Ferric No data Phos 0.22 IN / 0.02 EF ppm 0.1% hypo soak for 1 hr
Filtration 9:30 min Backflush 30 sec Backflush flow ~2Q Sample tank ~100 gallon Influent ~17 to 19C No air scour on membrane
Post Actiflo Water Batch 3 Membrane 20.6 gfd 35 LMH -10kPa 28mlmin start -xxkPa xx ml//min end Ferric Nodata Phos .03 IN / 0.06 EF ppm 0.1% hypo soak for 1 hr
Liter per minute Filtrate
0.06 0.055 0.05 0.045 0.04 0.035 0.03 0.025 0.02
TMP MPa
0 -0.005 -0.01 -0.015 -0.02 -0.025 -0.03 -0.035 -0.04
l/min
MPa


MEIDEN
MEIDEN AMERICA, INC.
Mankato Study
Meiden Membrane, Dec 7-12, 2015
Pre Actiflo Filter
Membrane
30.6 gfd x 52 LMH
-7kPa 42ml/min start
-46kPa 23ml/min start
Ferric No data
Phos 0.08 IN / 0.05 EF ppm
0.1% hypo soak for 1 hr
Pre Actiflo Filter
Membrane
21.8 gfd x 37 LMH
-9kPa 29ml/min start
-34kPa 21ml/min start
Ferric No data
Phos 0.11 IN / 0.06 EF ppm
0.1% hypo soak for 1 hr
Pre Actiflo Filter
Membrane
21.8 gfd x 37 LMH
-7kPa 29ml/min start
-22kPa 24ml/min start
Ferric No data
Phos 0.28 IN / 0.06 EF ppm
0.1% hypo soak for 1 hr
Pre Actiflo Filter
Membrane
21.8 gfd x 37 LMH
-7kPa 29ml/min start
-26kPa xml/min start
Ferric No data
Phos No data
Influent line became disconnected due to sand in backflow preventer; several items flushed.
Scour air turned ON and remained ON. Rate of fouling rate then improved.
Pre Actiflo Filter
Membrane
21.8gfd x 37 LMH
-7kPa 28ml/min start
-8kPa 28ml/min start
Ferric No data
Phos No data
Filtration 9:30 min
Backflush 30 sec
Backflush flow ~2Q
Sample direct from system.
liter per minute Filtrate
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
TMP MPa
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
-0.035
-0.04
12/7/15 7:43 AM
12/7/15 9:00 AM
12/7/15 10:16 AM
12/7/15 11:32 AM
12/7/15 12:49 PM
12/7/15 2:05 PM
12/7/15 3:22 PM
12/7/15 4:38 PM
12/7/15 5:54 PM
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12/8/15 5:22 AM
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12/8/15 9:45 AM
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12/8/15 12:18 PM
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12/8/15 6:40 PM
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12/8/15 9:13 PM
12/8/15 10:30 PM
12/8/15 11:46 PM
12/9/15 1:02 AM
12/9/15 2:19 AM
12/9/15 3:35 AM
12/9/15 4:52 AM
12/9/15 6:08 AM
12/9/15 7:24 AM
12/9/15 9:05 AM
12/9/15 10:22 AM
12/9/15 11:48 AM
12/9/15 1:05 PM
12/9/15 2:21 PM
12/9/15 3:38 PM
12/9/15 4:54 PM
12/9/15 6:10 PM
12/9/15 7:27 PM
12/9/15 8:43 PM
12/9/15 10:00 PM
12/9/15 11:16 PM
12/10/15 12:32 AM
12/10/15 1:49 AM
12/10/15 3:05 AM
12/10/15 4:22 AM
12/10/15 5:38 AM
12/10/15 6:54 AM
12/10/15 1:02 PM
12/10/15 2:18 PM
12/10/15 3:35 PM
12/10/15 4:51 PM
12/10/15 6:08 PM
12/10/15 7:24 PM
12/10/15 8:40 PM
12/10/15 9:57 PM
12/10/15 11:13 PM
12/11/15 12:30 AM
12/11/15 1:46 AM
12/11/15 3:03 AM
12/11/15 4:19 AM
12/11/15 5:35 AM
12/11/15 6:52 AM
12/11/15 8:08 AM
12/11/15 9:25 AM
12/11/15 10:41 AM
12/11/15 11:57 AM
12/11/15 1:14 PM
12/11/15 2:30 PM
12/11/15 3:47 PM
12/11/15 5:03 PM
12/11/15 6:19 PM
12/11/15 7:36 PM
12/11/15 8:52 PM
12/11/15 10:09 PM
12/11/15 11:25 PM
12/12/15 12:42 AM
12/12/15 1:58 AM
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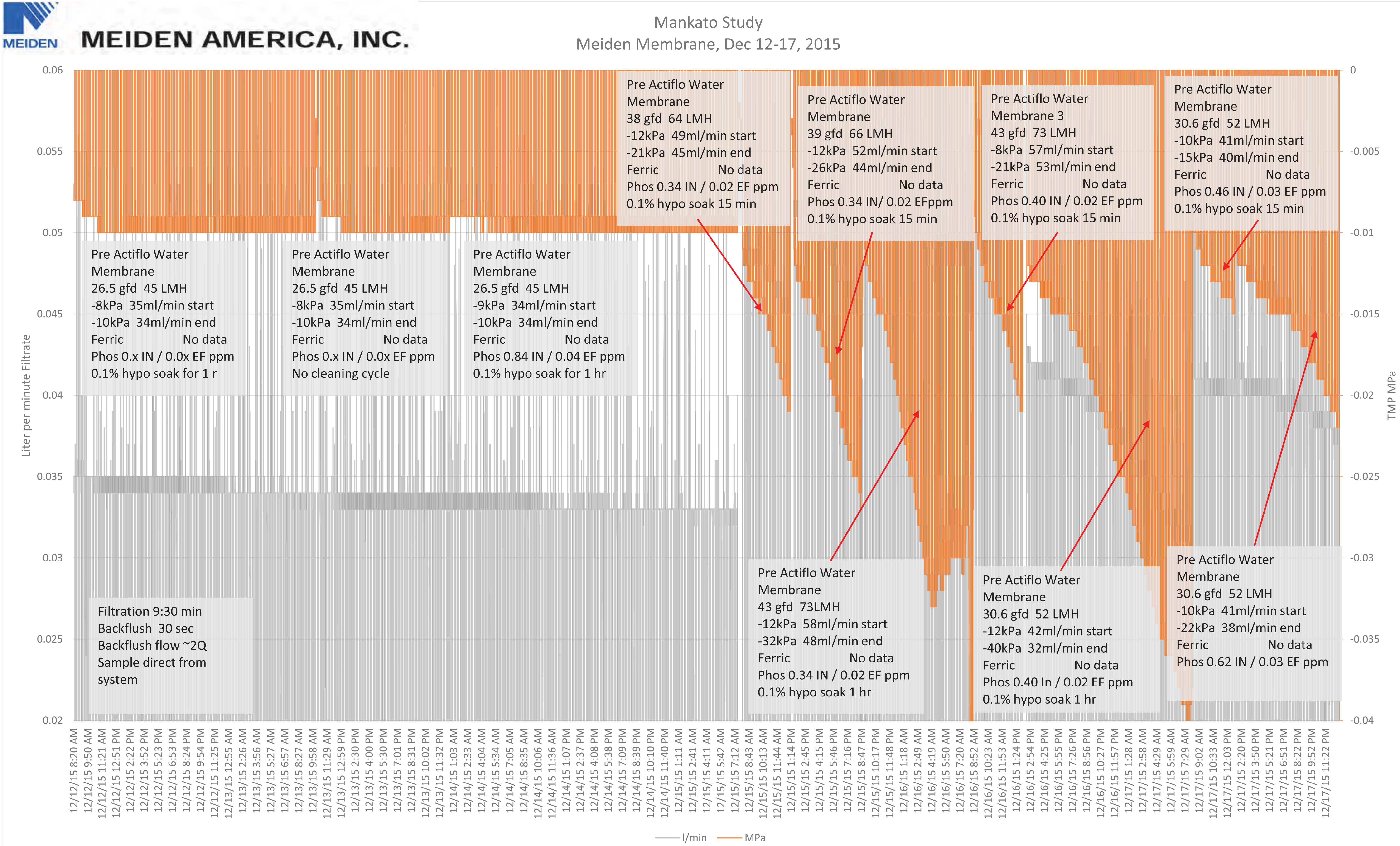
12/12/15 7:04 AM
l/min
MPa


MEIDEN
MEIDEN AMERICA, INC.
Mankato Study
Meiden Membrane, Dec 12-17, 2015
Liter per minute Filtrate
TMP MPa
Pre Actiflo Water Membrane 26.5 gfd 45 LMH -8kPa 35ml/min start -10kPa 34ml/min end Ferric No data Phos 0.x IN / 0.0x EF ppm 0.1% hypo soak for 1 r
Pre Actiflo Water Membrane 26.5 gfd 45 LMH -8kPa 35ml/min start -10kPa 34ml/min end Ferric No data Phos 0.x IN / 0.0x EF ppm No cleaning cycle
Pre Actiflo Water Membrane 26.5 gfd 45 LMH -9kPa 34ml/min start -10kPa 34ml/min end Ferric No data Phos 0.84 IN / 0.04 EF ppm 0.1% hypo soak for 1 hr
Pre Actiflo Water Membrane 38 gfd 64 LMH -12kPa 49ml/min start -21kPa 45ml/min end Ferric No data Phos 0.34 IN / 0.02 EF ppm 0.1% hypo soak 15 min
Pre Actiflo Water Membrane 39 gfd 66 LMH -12kPa 52ml/min start -26kPa 44ml/min end Ferric No data Phos 0.34 IN/ 0.02 EFppm 0.1% hypo soak 15 min
Pre Actiflo Water Membrane 3 43 gfd 73 LMH -8kPa 57ml/min start -21kPa 53ml/min end Ferric No data Phos 0.40 IN / 0.02 EF ppm 0.1% hypo soak 15 min
Pre Actiflo Water Membrane 30.6 gfd 52 LMH -10kPa 41ml/min start -15kPa 40ml/min end Ferric No data Phos 0.46 IN / 0.03 EF ppm 0.1% hypo soak 15 min
Filtration 9:30 min Backflush 30 sec Backflush flow ~2Q Sample direct from system
Pre Actiflo Water Membrane 43 gfd 73LMH -12kPa 58ml/min start -32kPa 48ml/min end Ferric No data Phos 0.34 IN / 0.02 EF ppm 0.1% hypo soak 1 hr
Pre Actiflo Water Membrane 30.6 gfd 52 LMH -12kPa 42ml/min start -40kPa 32ml/min end Ferric No data Phos 0.40 In / 0.02 EF ppm 0.1% hypo soak 1 hr
Pre Actiflo Water Membrane 30.6 gfd 52 LMH -10kPa 41ml/min start -22kPa 38ml/min end Ferric No data Phos 0.62 IN / 0.03 EF ppm
l/min
MPa

Barb Anderson

From: Bill Pagels <bill.pagels@meidenamerica.com>
Sent: Monday, May 16, 2016 1:42 PM
To: Jake Pichelmann
Subject: MANKATO Budget for filtration system

Hello Jake,

I am not sure what format is best for your report, but I do have the following summary information regarding the cost estimate for this filtration system.

This price is not low, although we do hope to have the future opportunity to operate a more detailed pilot study. A scalable pilot would allow us to better consider process improvements and find a stable and optimized flux. At this time we have a few concepts for improving the flux, but without a scalable pilot it is difficult to make a very definitive statement(s), and process improvements would likely cover a larger scope than just the single pilot interface. We are currently working with similarly challenging influent water on a different certification project; I will be working with our engineering group even this week as we test alternative membrane cleaning methods and chemicals to optimize our operation.

This budget result has been coordinated between Meiden and H20I Engineering as we have been sharing data and reviewing the initial pilot progress over the last year. The supply of the system assumes the combination of H2OI value-added engineering and materials, with the supply of Meiden ceramic systems.

> We are assuming that a total of ten immersed membrane process trains are required (9 duty and 1 standby) for a net permeate production capacity of 9.38 MGD. Further, it is assumed a total of 20 membrane units/cassettes would be installed in each train, utilizing Meiden's ceramic membrane unit CH250-1000TM100-U2DJ-EKFPA0. This is a double stacked membrane unit, which includes 400 sheet, and is 200m^2 in membrane area.
>
> Here is the recommended scope of supply:
>
> - Membrane units (200), mounting brackets and hardware
> - Membrane elements (200x400)
> - Permeate pump skid (one per membrane train)
> - Valves, fittings and pipework between membrane process trains and respective permeation skids (loose shipped)
> - Backwash system (loose shipped)
> - CIP system (loose shipped)
> - Blower system
> - Compressed air system
> - Instrumentation and controls
> - Main control panel, remote I/O panels and required junction boxes for supplied equipment
>
> Items not included:
>
> - Supply and installation of membrane process tanks, as well as associated access stairs, platforms and accessories (if required)
> - Supply and installation of inter-connective pipework and wiring
> - Shipping is Ex-Works, H2OI manufacturing facility
> - Commissioning and startup
> - Applicable taxes, permits, etc.

With these assumptions and exclusions, the budgetary price for a 9.38 MGD immersed ceramic membrane system is $9,331,000.

Please let me know how well this information is meeting your needs, and what we can do to assist you further.

Regards,

William Pagels
Senior Product Manager
Ceramic Flat Sheet Membrane

MEIDEN AMERICA INC
15800 Centennial Drive
Northville, MI 48168-9629
Phone 734-927-6032
Fax 734-459-1863
Cell 248-860-6188
http://www.meidensha.com/products/water/prod_06/prod_06_01/index.html

MEIDEN AMERICA, INC.

15800 Centennial Drive
Northville, MI 48168
Phone:
Fax:

Date: 21-Oct-15

Offer : CM0011

MAI Proposal

Customer **The City of Mankato**
10 Civic Center Plaza
Mankato, MN 56001 USA

Project **Meiden CFM lab test unit leasing**

Item No.	Quantity	Description	Unit Price	Extended Price
1	1	**Meiden CFM lab test unit leasing fee** ※Leasing period : 2 weeks for lab test operation at nominated facility by the City of Mankato. ※Meiden engineer with its partner will do lab test with the unit. ※Need to discuss about detail lab test plan with the parties related to this project and then it will be finalized.	$1,000.00	$1,000.00
		TOTAL PRICE ※Sales Tax is not included		**US$1,000.00**

Terms of Sale:

Ship to: TBA by the City of Mankato

Payment: Net 30 days after receipt of invoice, by T/T remittance.

Validity: Valid until November 20th, 2015.

Contact information for Meiden America is as follows:
Nobunari Onishi
Phone: 858-263-3333
Fax: 734-459-1863
Email: nobunari.onishi@meidenamerica.com

Nobunari Onishi
Meiden America Inc.

APPENDIX D

Precision Evaluation and Calibration of Total Phosphorus Analysis (MSU)

Precision Evaluation and Calibration
of
Total Phosphorous Analysis

Prepared For:

Jim Archer
Industrial Chemist
City of Mankato Wastewater Treatment Plant

Prepared By:

Stephen J. Druschel, PhD, PE
Environmental Engineering Laboratory
Department of Mechanical & Civil Engineering
Minnesota State University, Mankato

August 30, 2015

Abstract

The analysis of total phosphorus in water by persulfate and acid digestion followed by molybdate-ascorbic in acid combination for colorimetric analysis was evaluated. Specific evaluations included: response of blank samples; responses from two deionized water sources; analytical drift, contaminant drag-through after acid wash and triple deionized water rinse; precision; and calibration. Samples above 2.00 ppm-P are recommended for ten-fold in-tube dilution to bring results onto linear calibration range. A minimum detection level of 0.04 ppm-P was determined. Analytical method steps and quality control procedures were established and systematized.

1.0 Introduction

The City of Mankato (Minnesota), in conjunction with Bolton & Menk, Inc. and Minnesota State University (MSU), Mankato, received a grant from the Minnesota Pollution Control Agency (MPCA) for the evaluation of phosphorous reduction in the Wastewater Treatment Plant (WWTP) effluent. The City proposed using ultra filtration and ferric chloride optimization, both singly and in combination. Ultra filtration will be evaluated using a pilot plant approach with three different vendor approaches in parallel, while the ferric chloride optimization will be evaluated using full plant flow with four different injection locations. Phosphorous evaluation is proposed for locations at: the pilot plant at the sample ports at the effluent of each of the three vendor filtration system,; and six different sample locations along the full plant wastewater flow.

As part of the grant, MSU will perform the bulk of the phosphorous testing. This report documents the method, materials, procedures, evaluation of precision, and calibration of MSU's phosphorous analysis. These analyses are being done in the Environmental Engineering Laboratory, 382 Trafton Science Center North, under the direction of Stephen Druschel, PhD, PE, Associate Professor of Civil Engineering. Analysts performing work evaluated in this report were Bridget Anderson and Thu (Amy) Nguyen, civil engineering undergraduates. Analytical guidance and demonstration was provided by Jim Archer, Industrial Chemist, City of Mankato Wastewater Treatment Plant.

2.0 Method

The analysis of phosphorous in water samples was done using persulfate and acid digestion and colorimetric analysis according to Method 4500-P, Sections A, B and C of Standard Methods (Rice, et al, 2012), with modifications proposed by Hach (2015a and 2015b) (modifications listed below). Summarizing from Standard Methods:

- Phosphorous can stimulate the growth of algae and other aquatic microorganisms in nuisance quantities, when discharged into receiving waters where phosphate is a growth limiting nutrient;
- Phosphorous occurs in natural waters and wastewaters as orthophosphates, condensed (poly) phosphates and organically bound phosphates. Organically bound phosphates are typically presented as within the structure of organic cells, tissue or detritus.

- Colorimetric analysis responds primarily to orthophosphate, but not to condensed phosphates and organically bound phosphates.
- Digestion releases and converts condensed phosphates and organically bound phosphates to orthophosphate where it can measured using colorimetric analyses and termed “total phosphorus”.
- Colorimetric analysis of non-digested samples measures the phosphate fraction termed “reactive phosphorus”, largely a measure of orthophosphate but likely with a small fraction of condensed phosphate.

Selected for this study are digestion by persulfate and sulfuric acid at 150° C for 30 minutes, neutralization with sodium hydroxide, then molybdate-ascorbic acid colorization followed by colorimetric measurement at 880 nm wavelength. Colorimetric measurement was done using a Hach DR 6000 spectrophotometer.

The modifications proposed by Hach include:

- The combination of the persulfate with sulfuric acid for digestion rather than either method individually (Hach 2015a);
- The molybdate-ascorbic acid combination for colorization, rather than alternative colorization agents (Hach 2015b); and,
- The use of spectrophotometric measurement at 880 nm, rather than an alternative wavelength corresponding to the response of the alternative colorization agents (Hach 2015b).

Glassware used in this study were dedicated for these analyses and removed from general laboratory practice. Analysis vials, 60 mL beakers, 25 mL graduated flasks, gas-tight glass syringes in 5 mL and 10 mL volume, and syringe pipet needles were all taken from previously unused stocks. 100 mL graduated flasks were acid washed with extended acidification to discourage any prior phosphate contamination.

Analysis vials were obtained from Hach as part of a phosphorus analysis kit. Vials came pre cleaned and preloaded with sulfuric acid.

Glassware was cleaned prior to use (including new syringes, needles, flasks and beakers but not vials) using acid wash technique suggested in Standard Methods: 6.0 N hydrochloric (HCl) acid was flushed over all glass surfaces likely to touch liquid to be analyzed, followed by triple rinsing with MSU laboratory deionized (DI) water. Analysis vials were capped for acid flushing and inverted to confirm acid flushing of cap interior surfaces; inversion was done for at least 1 full minute. Acid washed glassware was allowed to air dry then capped or covered with aluminum foil for protection against dust or other contaminates.

Auto pipets were used for measuring 500 and 1000 uL volumes. Auto pipets were checked prior to use measuring DI water (1.00 g/mL) onto a 0.0001 g laboratory balance, returning a mean of five measurements within ±0.3% of proposed mass per measurement. Pipet tips were single use, supplied pre cleaned by the vendor (Fisher Scientific Company LLC, Pittsburgh, PA).

Acid wastes were containerized for MSU Environmental Health and Safety (EHS) for hazardous waste disposal. Approximately 200 analytical samples prepared for this report, neutralized during the analysis procedure, were disposed in the MSU laboratory sewer system, though logged as directed by MSU EHS. However, upon preparation of this report it was noted that

Hach (2015) recommends containerizing analytical samples for consideration of hazardous waste disposal due to the potential for molybdenum release. Procedures going forward will containerize all waste from analytical samples.

3.0 Materials

Deionized water for cleaning was obtained from the MSU laboratory DI system. Deionized water for dilutions and mixing was supplied by the City of Mankato from their wastewater treatment plant laboratory DI system. Sulfuric acid was supplied by Hach preloaded in analysis vials used for the first time; sulfuric acid (1.54 N, phosphate free) was thereafter obtained from NC Labs of Birnamwood, WI. Sodium hydroxide was supplied by Hach in combination with the analysis vials used for the first time; sodium hydroxide (1.54 N, phosphate free) was thereafter obtained from NC Labs. Potassium persulfate was obtained from Hach in "powder pillow" form consisting of premeasured individual analytical doses contained in sealed foil packets.

Phosphate standard was obtained from NC Labs in the following concentrations:

- 1 ppm as P (1.00 mL = 1 ug P)
- 5 ppm as P (1.00 mL = 5 ug P)
- 50 ppm as P (1.00 mL = 50 ug P)
- 1000 ppm as P (1.00 mL = 1 mg P)

Note that all chemical supplies and analysis vials were supplied by the vendors (Hach or NC Labs) through the City of Mankato, as part of the City's cost share responsibilities under the MPCA grant.

4.0 Analyses

The method steps for the analysis of total phosphorus included:

1. Acid wash glassware, including analysis vials and caps, syringes, and 60 mL beakers if used for transfer.
2. Load 2.00 mL of 1.54 N sulfuric acid into analysis vials using auto pipet (two 1 mL aliquots).
3. Pipet 5.00 mL of sample liquid into vial using glass syringe. Record vial number with tabulation of sample. Sample may be stored in this condition for up to 28 days according to Standard Methods. Acid wash glass syringe in preparation for next sample measurement.
4. Add contents of potassium persulfate powder pillow and cap; shake vial vigorously for 20 to 30 seconds.
5. Load vials (up to 12) into heater block prewarmed to 150° C. Set timer to 30 minutes.
6. Upon completion of 30 minute period, remove vial and cool. Check vial for "boil off" of more than 1 mL (about 1 cm level drop); if so, note on vial tabulation.
7. Load 2.00 mL of 1.54 N sodium hydroxide into analysis vials using auto pipet (two 1 mL aliquots).
8. Clean and dry vial exterior with kim wipe.
9. Place vial into spectrophotometer and press read (zero).

10. Add contents of PhosVer® 3 powder pillow and cap; shake vial vigorously for 20 to 30 seconds. Sample may exhibit blue tint.
11. Place vial into spectrophotometer and press read. Timer will count down 2:00 minutes then beep when reading will be displayed in ppm-P. Record reading on vial tabulation.
12. Dispose of vial contents into dedicated waste container. Return glassware for acid washing.

Note that should reactive phosphorus be required for measurement rather than total phosphorus, steps 2 through 7 are omitted.

5.0 Results

A total of 193 analyses were done for this report, all with a "clear water" or very low turbidity matrix (Appendix A – All Results). Quality control (QC) checks removed 52 analyses for reasons including: "boil down" or volume reduction during digestion in excess of 1 mL (about 10% of the specimen volume); analyst error, primarily relating addition of inadequate digestion chemicals; lack of vigorous reagent shaking, resulting in incomplete mixing and substantial portion of reagent as debris; or insufficient specimen volume during preparation (e.g., 19 specimens at 5 mL could be taken from a 100 mL mixture, but the 20th specimen could not be fulfilled, though the analysis vial was typically prepared). Useable results are presented in the Appendix B as Trimmed by Quality Control Results.

6.0 Evaluation

6.1 Evaluation of Blanks

Table 1 presents the results of all blanks analyzed, plus results of subdivision populations according to DI water source (Mankato WWTP or MSU Environmental Engineering Laboratory) and sulfuric acid source (NC Labs or Hach). Results are given as mean ± standard deviation, with relative standard deviation (RSD) included as a percentage. The Table 1 results were developed in JMP® software, Version 8.02, 2009, SAS Institute, Inc., Cary, NC (Appendix C).

Mean concentration measured for all blanks was under 0.02 ppm-P, with analytical variability for all blanks less than 0.01 ppm-P. Blanks were evaluated by run order (Figure 1) to assess tendency for drift. Statistical analysis of run order as a factor was done in JMP® as a model (Appendix C); results suggested that run order was a slight but significant factor ($p < 0.0001$) at a 95% confidence interval (i.e., $\alpha = 0.05$), with measured concentration of blanks trending downward at 0.001 ppm-P per run. This result is interpreted as a sign that analyst skill improves with repetition, as the downward trend means that blanks are measured as more blank with repeated analyses.

Results of blanks made with each of the two DI sources were compared in JMP® using a One-Way Analysis of Variance (ANOVA). The DI sources were not significantly different (NSD) ($p = 0.1206$) at a 95% confidence interval, and continued to be NSD when the analysis was widened to a 90% confidence interval. Therefore, DI may be incorporated without concern for experimental compromise from either DI source.

Table 1. Results for analysis of blanks.		
Population Characteristic	**Concentrations Measured x ± SD (RSD, %), ppm-P**	**Count**
All blanks	0.017 ± 0.008 (48%)	27
Blanks made with DI water sourced from the Mankato WWTP	0.019 ± 0.009 (47%)	20
Blanks made with DI water sourced from the MSU Environmental Engineering Laboratory	0.013 ± 0.005 (38%)	7
Blanks made with sulfuric acid sourced from Hach	0.028 ± 0.010 (35%)	4
Blanks made with sulfuric acid sourced from NC Labs	0.015 ± 0.007 (44%)	23
Notes: x: mean. SD: Standard Deviation. RSD: Relative Standard Deviation, equal to the standard deviation divided by the mean, given as a percentage. ppm-P: part per million as phosphorus, equivalent to one milligram of phosphorus per liter.		

Similarly results of blanks made with each of the two sulfuric acid sources were compared in JMP® using a One-Way ANOVA. The sulfuric acid sources were not significantly different (NSD) (p = 0.0036) at a 95% confidence interval, and continued to be not significantly different when the analysis was widened to a 90% confidence interval. However, a general trend of difference was noted in the results with Hach sulfuric acid returning a slightly higher measurement for blanks than the NC Labs sulfuric acid. This observed effect may be related to the previously observed run order effect, as blanks with NC Labs sulfuric acid were analyzed later in the run order than the blanks with Hach sulfuric acid. Sulfuric acid therefore is deemed without significant effect on measurement and may be incorporated without concern for experimental compromise from either sulfuric acid source.

Blanks constructed immediately after standards were constructed were compared to blanks constructed in a sequence of blanks, as a means to evaluate any “drag through” of contamination using a single syringe to pipet sample aliquots into the analysis vials. The two populations of results were compared in JMP® using a One-Way ANOVA and found to be not significantly different (p = 0.9694) at a 95% confidence interval. The high p value of this result strongly suggests no drag through is occurring with the acid washing procedure in place (described in Section 2.0), manifested for the syringe as a full barrel uptake of the acid then a return to the acid stock, followed by the full barrel uptake of DI water and a return to the DI stock for each of three separate DI stocks.

Two additional blanks were evaluated as samples: tap water from a faucet, and DI that had rinsed through a beaker from the normal-classroom use supplies that had been washed with Alconox detergent and triple DI rinsed, both of the Environmental Engineering Laboratory at MSU. Measurements were 0.38 and 0.02 ppm-P, respectively. While single analyses are not definitive, these results suggest that: (a) tap water should be scrupulously avoided for laboratory operations related to phosphorus analysis; and (b) that an exposure to Alconox-washed glassware does not mean the result should be automatically rejected. However, good practice suggests such exposure to Alconox-washed glassware should be avoided.

6.2 Precision Evaluation

Precision was evaluated using sequences of the same concentration constructed and analyzed in order. Three series were evaluated: 0.05 ppm-P, to represent low concentration measurements; 1.00 ppm-P made from pure standard, to represent medium concentration measurements; and 1.00 ppm-P made from 50 ppm-P standard and diluted externally in a 100 mL volumetric flask, to represent medium concentration measurements using standards prepared by the analyst. Results of each sequence are provided in Table 2, developed in JMP® (Appendix D).

Precision was found to be 32% and 3%, as measured by relative standard deviation, for the low (0.05 ppm-P) and the medium (1.00 ppm-P, of both pure standard and externally diluted standard) concentration sequences, respectively. The medium concentration value compares similarly to the precision identified by Hach (2015a) for the persulfate-acid digestion coupled with the molybdate-ascorbic acid colorization analysis of a 95% confidence interval equal to 2.93 – 3.07 ppm-P for a 3.00 ppm-P standard, or an equivalent RSD of 0.07/3.00 = 2.33%.

Table 2. Results for precision analysis using common standard source.

Population Characteristic	**Concentrations Measured** **x ± SD (RSD, %), ppm-P**	**Count**
0.05 ppm-P made from 5 mL of 1 ppm as P standard diluted to 100 mL	0.053 ± 0.017 (32%)	19
1.00 ppm-P (100 mL pure standard)	1.02 ± 0.032 (3%)	16
1.00 ppm-P made from 2 mL of 50 ppm as P standard diluted to 100 mL	1.05 ± 0.032 (3%)	13

Additionally, the precisions found in this study were better than though similar in form to the precisions presented by Standard Methods (2012) in which RSDs of 55.8%, 23.9% and 6.5% were found for concentrations of 0.2, 0.99 and 10.23 ppm-P, respectively, in results of 31 to 32 laboratories using three different mixtures of phosphates. These results are interpreted as the overall precision of this study is equivalent to precision of ideal conditions, and may be better than precision of typical conditions. It should be cautioned that results could be different when matrix effects are considered; evaluation beyond the limits of this study are suggested.

Comparison of the pure standard and the standard prepared by the analyst was done in JMP® using a One-Way ANOVA and found to be statistically significant ($p = 0.0231$) at a 95% confidence interval, as the two populations were found to differ slightly (by 0.03 ppm-P). This result is interpreted as suggesting standards should be used pure when possible, and not subject to an intermediary dilution step by the analyst if possible.

The minimum detection limit (MDL) may be determined using the recommendations of the United States Environmental Protection Agency (USEPA) for good practice in chemical analysis of water samples, as summarized by Childress, et al (1999):

> Using a concentration of about twice the limit of quantification (LOQ), calculate the MDL as equal to the standard deviation multiplied by the Student's t statistic for a 99% confidence interval in a one-tailed distribution

The population of 0.05 ppm-P results was used with a standard deviation of 0.017 ppm-P and a count of 19. The t statistic was obtained from Box, Hunter and Hunter (2005) for n = 19 as 2.552. Therefore, the MDL was calculated as 0.04 ppm-P.

It should be noted that the limit of quantification (LOQ) is typically defined as 3 times the MDL (Childress, et al, 1999). If considered so here, the LOQ would be 0.13 ppm-P. However, as previously noted the precision broadens with lower concentration analyses, and the level used for the MDL and LOQ evaluation is below the LOQ concentration. Therefore, determination of the LOQ should be redone using a level low but clearly above the LOQ – perhaps 0.20 ppm-P. A minimum of 7 replicates should be used for statistical strength (Childress, et al, 1999).

6.3 Calibration

Calibration was done using a series of mixtures with generally at least three replicates through a range of concentrations reported by Hach (2015a) as providing a linear response in the colorimetric measurement. Eight concentration levels from 0.05 to 5.00 ppm-P were measured (Table 3) plus five additional concentration levels from 2.00 to 20.0 ppm-P were measured although incorporating an in-tube, 10-fold dilution step (500 uL of specimen and 4.50 mL of DI to an analysis vial rather than the typical 5.00 mL of specimen) (Table 4). Concentrations of 2.00 and 5.00 ppm-P were analyzed in form both as whole and in-tube diluted. Note that the analyses used for the precision evaluation were including in the calibration. Eighty six analyses in total were considered for calibration, and are graphed in Figure 2 as measured concentration by calculated (constructed) concentration.

Because neither persulfate-acid digestion nor molybdate-ascorbic acid colorization analysis make direct contact with any sensor with chemical compounds but merely turn both the digester and the spectrophotometer on and off in the physical space outside the analysis vial, it was considered unnecessary to vary the order of the concentration levels as response would be unaffected by the concentration of a previous analysis. No randomization of order or concentration level was therefore done. Blanks were evaluated in-between concentration levels as an evaluation of syringe wash/prevention of drag-through, as previously discussed in Section 5.1.

Comparing the results of the two concentrations, 2.00 and 5.00 ppm-P, analyzed both as whole specimen and in-tube diluted specimen, substantial discrepancy is noted at the 5.00 ppm-P level, while strong agreement is noted at the 2.00 ppm-P level. The measurement of the undiluted 5.00 ppm-P concentration returned a mean result of 3.60 ppm-P, a level about three fourths the actual concentration. This discrepancy is interpreted as meaning the concentration of 5.00 ppm-P is beyond the linear range of the colorization, a result in agreement with the recommendations of Hach (2015a). In comparison, the results of the in-tube diluted 2.00 ppm-P level, the undiluted 2.00 ppm-P results, and the in-tube diluted 20.0 ppm-P results all had means in substantial agreement and with very low RSD values. The data points for 5.00 ppm-P may clearly be seen to not be in linear agreement with the rest of the data points (Figure 2).

Table 3. Results for analysis of normal range concentration samples (no dilution required).		
Population Characteristic	**Concentrations Measured x ± SD (RSD, %), ppm-P**	**Count**
0.05 ppm-P made from 1 ppm as P standard as 1.25 mL diluted to 25 mL (n=3) or 5 mL diluted to 100 mL (n=19)	0.060 ± 0.024 (40%)	22
0.10 ppm-P made from 2.5 mL of 1 ppm as P standard diluted to 25 mL	0.123 ± 0.012 (9%)	3
0.20 ppm-P made from 5 mL of 1 ppm as P standard diluted to 25 mL	0.23 ± 0.01 (3%)	3
0.50 ppm-P made from 12.5 mL of 1 ppm as P standard diluted to 25 mL	0.51 ± 0.02 (3%)	3
0.80 ppm-P made from 20 mL of 1 ppm as P standard diluted to 25 mL	0.88 ± 0.10 (12%)	3
1 ppm-P pure standard as 25 mL (n=3) or 100 mL (n=16), or 2 mL of 50 ppm as P standard diluted to 100 mL (n=13)	1.03 ± 0.03 (4%)	32
2 ppm-P made from 10 mL of 5 ppm as P standard diluted to 25 mL	2.01 ± 0.01 (1%)	3
5 ppm-P (25 mL pure standard)	3.60 ± 0.52 (14%)	3
Note: 5.00 ppm-P sample analyses were not used for calibration.		

Table 4. Results for analysis of high range concentration samples using in-tube 10-fold dilution.		
Population Characteristic	**Concentrations Measured x ± SD (RSD, %), ppm-P**	**Count**
2 ppm-P made from 10 mL of 5 ppm as P standard diluted to 25 mL	0.21 ± 0.01 (3%)	3
5 ppm-P (25 mL pure standard)	0.50 ± 0.01 (1%)	3
8 ppm-P made from 4 mL of 50 ppm as P standard diluted to 25 mL	0.73 ± 0.01 (1%)	3
10 ppm-P made from 5 mL of 50 ppm as P standard diluted to 25 mL	0.97 ± 0.01 (1%)	2
20 ppm-P made from 10 mL of 50 ppm as P standard diluted to 25 mL	1.91 ± 0.04 (2%)	3

Analytical variation of concentrations from 0.05 to 2.00 ppm-P has the general trend of a wide variation at low concentrations (e.g., RSD of 40% at 0.05 ppm-P) to a tight variation at higher concentrations (e.g., RSD of 1 to 4% at 0.5 to 2.00 ppm-P), excepting the variation associated with 0.80 ppm-P that suffers from a single anomalous value of 1.00 ppm-P (though not screened out by quality control). Tight variation of 3% is reached by two separate groupings of analyses at 0.20 ppm-P. These behaviors are interpreted as the analytical method and procedure studied herein has a high level of measurement accuracy in the range of 0.20 – 2.00 ppm-P, with lesser but still acceptable accuracy down to 0.05 ppm-P. As discussed previously, matrix effects are not evaluated here. Additionally, an accuracy challenge is recommended for a future time period as this method becomes fully established with the analysts, as insufficient testing has been done in this study to support a broadly-applicable evaluation.

Sixty-nine analytical specimens, each prepared from a known concentration stock without in-tube dilution and ranging in level from 0.05 to 2.00 ppm-P, were incorporated into a Least Squares Analysis (LSA) to develop a linear regression calibration equation (Appendix E). Triplicate specimens were analyzed for each of five levels, with 22 and 32 specimens analyzed for 0.05 and 1.00 ppm-P concentrations, respectively, which includes the incorporation of the analytical results for the precision evaluation. Based on these measurements, the LSA returned a relationship for the measured concentration based on the tested (calculated) concentration of:

Measured Concentration = 1.012 (Tested Concentration) + 0.02 (Equation 1)

For evaluation of samples with unknown concentrations, Equation 1 may be rewritten to provide a calibration relationship of:

Sample Concentration = 0.988 (Measured Concentration) - 0.02 (Equation 1)

This linear regression relationship has a r^2 value of 0.9953, and is statistically significant at a 95% confidence interval ($p < 0.0001$). It should be noted that this calibration equation will return values that are within 2% of the spectrophotometer readout value for higher (1 to 2 ppm-P) values of the linear range, but are within about 20% of the spectrophotometer readout value for lower (0.1 to 0.5 ppm-P) values of the linear range. It is therefore interpreted that the calibration equation should consistently be used when reporting results from this analysis.

7.0 Conclusions and Recommendations

The analysis of total phosphorus in water by persulfate and acid digestion followed by molybdate-ascorbic in acid combination for colorimetric analysis was evaluated and found to be statistically significant in the range of 0.04 ppm-P, the MDL, to 2.00 ppm-P. Samples above 2.00 ppm-P are recommended for ten-fold in-tube dilution to bring results onto linear calibration range. Analytical method steps and quality control procedures were established and systematized.

Acid washing with 6.0 N hydrochloric acid followed by triple rinsing with deionized water was found to be adequate to prevent the drag-through of previously contacted or contained phosphorus. Deionized water from both the Mankato Wastewater Treatment Plant and the Minnesota State University Environmental Engineering Laboratory were both determined to be without analytical impact on phosphorous determination in both dilution and cleaning procedures. However, dedicated glassware is recommended for the containing and transferring of sample or specimen fluids.

Quality control procedures were defined related to checks on the reagent addition, reagent mixing, and prevention of "boil down" during digestion. When volumes within an analytical vial are reduced by more than 10% or about 1 mL during digestion, it is recommended that the analysis not be accepted without qualification as the likely measurement will be high due to condensation.

Matrix effects should be evaluated as samples are collected and analyzed. It is recommended that two matrix spikes be run per every sampling sequence, with 1 ppm-P and 2 ppm-P final concentration spikes being added as 50 uL aliquots, an adjustment of 1% of the specimen volume (10 mL of 1000 ppm-P diluted to 100 mL and 20 mL of 1000 ppm-P diluted to 100 mL, respectively, used as 50 uL spikes into 5 mL samples) The difference between the spike levels may be evaluated as a recovery and analyzed for matrix effects, adjusting for the dilution caused by the spike volume.

Additional quality control samples should include a blank and a 1.00 ppm-P standard in every digestion sequence (12 total vials per digestion heating cycle). Calibration check standards of 0.20, 0.50, 0.80 and 2.00 ppm-P should also be included for analysis with every sampling sequence, or weekly, if daily/frequent sampling is being done. Therefore:

- For 1 – 8 samples, randomly include 4 QC samples: a blank, a 1.00 ppm-P standard (5 mL pure standard), a sample with a 1 ppm-P spike, and a sample with a 2 ppm-P spike (same source for both spike samples). Digest up to 12 analysis vials per cycle.
- For additional samples, include a blank and a 1.00 ppm-P standard per digestion cycle.
- Include four check standards per week minimum, or more frequently within sample sequences.

Wastes from analysis vials should be containerized separately and prepared for hazardous waste disposal.

Level of quantification should be revisited using 19 analyses of 0.20 ppm-P specimens, to see if the level could be driven lower. For the current period, the level of quantification is set at 0.13 ppm-P.

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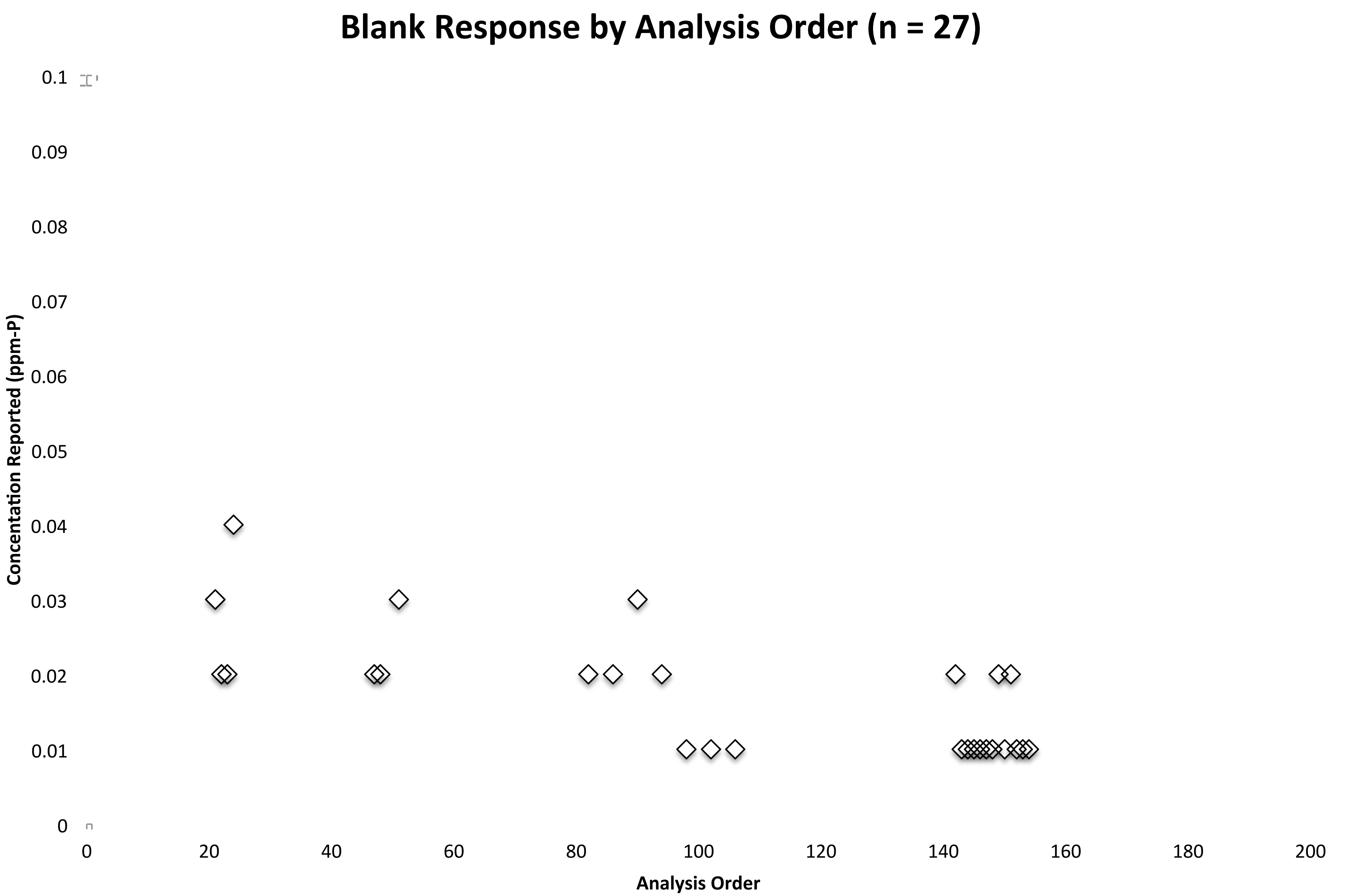


Figure 1. Blank response by analysis order.

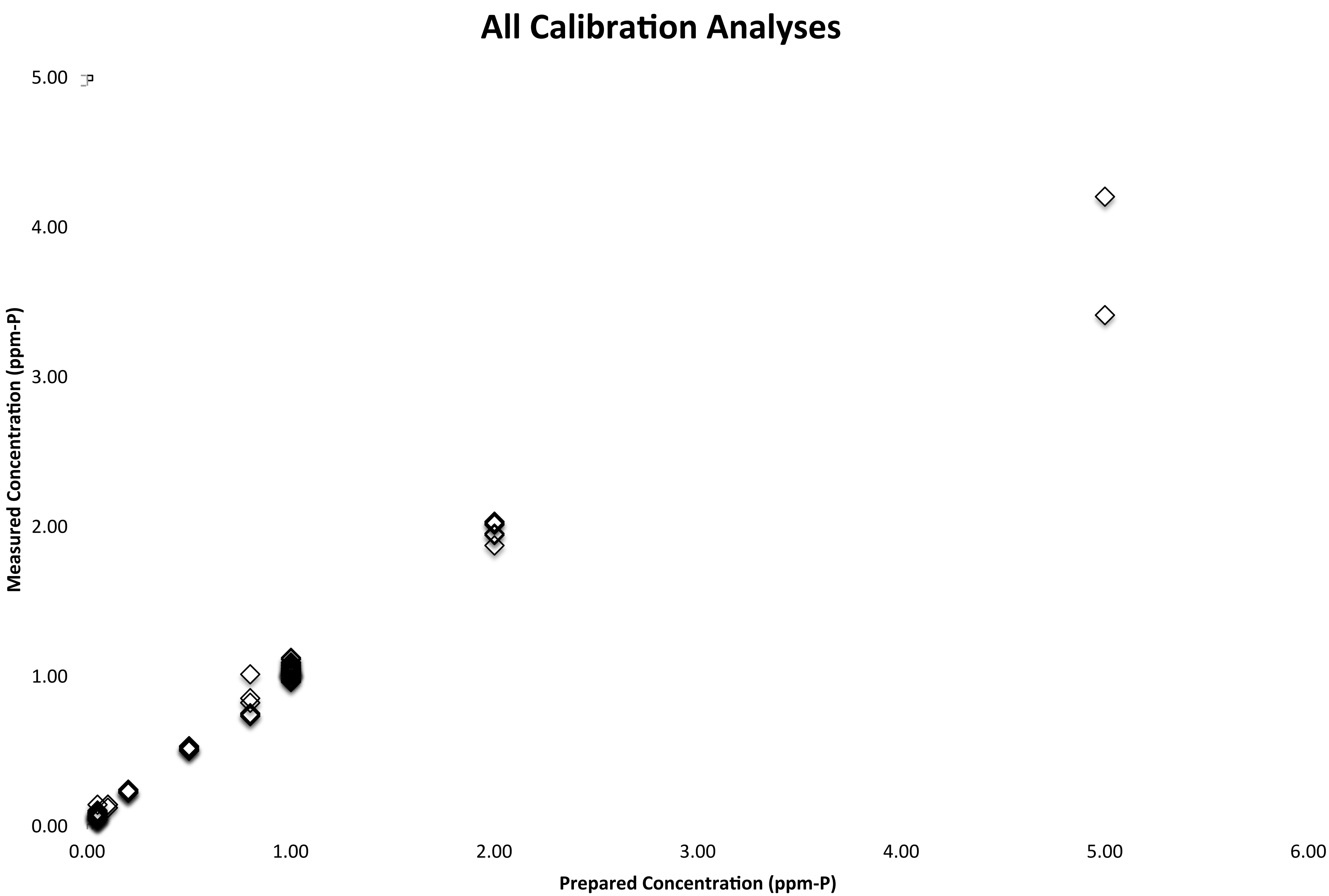


Figure 2. Results of all calibration analyses.

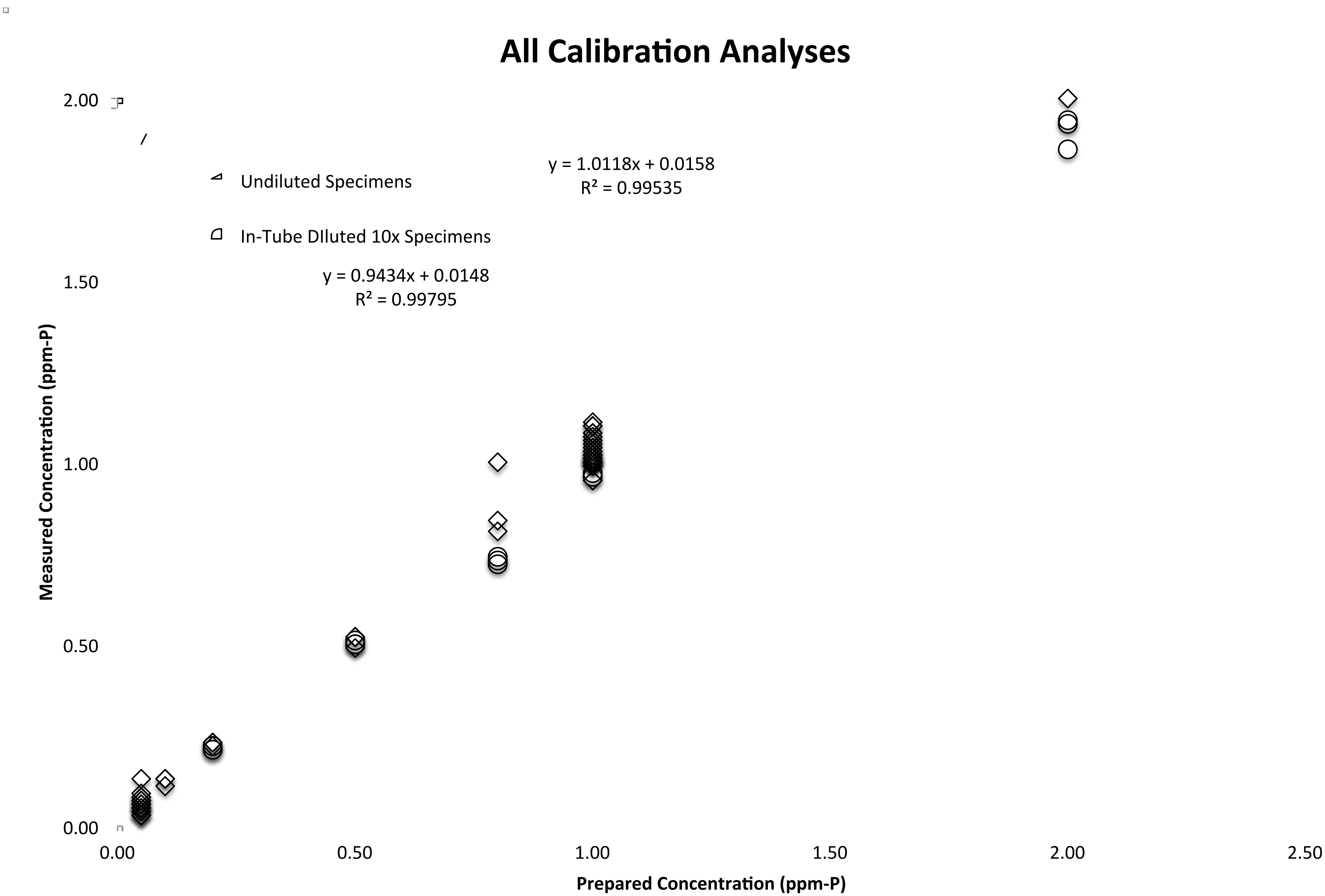


Figure 3. Comparison of undiluted and in-tube diluted specimens for calibration analysis.

Appendix A

All Results

Sequence	Vial	Date/Time Made	H_2SO_4 Source	Standard (ppm-P) or Sample	Volume (mL)	DI Source (if added)	DI Volume (mL)	Spike Conc (ppm-P)	Spike Volume (mL)	Potassium Persulfate	Bake 30 min	NaOH 2 mL	PhosVer3	Analysis By Whom	Conc Calc (ppm-P)	Conc Measured (ppm-P)	Notes	original file name	Analysis order
Calib Precis	11	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.00		081215 UltP	1
Calib Precis	12	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.00		081215 UltP	2
Calib Precis	13	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	3
Calib Precis	14	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.10		081215 UltP	4
Calib Precis	15	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00		Did not test	081215 UltP	5
Calib Precis	16	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.08		081215 UltP	6
Calib Precis	17	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	7
Calib Precis	18	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00		Did not test	081215 UltP	8
Calib Precis	19	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.02		081215 UltP	9
Calib Precis	20	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	10
Calib Precis	21	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	11
Calib Precis	22	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	12
Calib Precis	23	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00		Did not test	081215 UltP	13
Calib Precis	24	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	14
Calib Precis	25	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.00		081215 UltP	15
Calib Precis	26	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	0.99		081215 UltP	16
Calib Precis	27	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.02		081215 UltP	17
Calib Precis	28	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.07		081215 UltP	18
Calib Precis	29	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00		Did not test	081215 UltP	19
Calib Precis	30	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.00		081215 UltP	20
Calib Precis	31	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.03		081215 UltP	21
Calib Precis	32	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.02		081215 UltP	22
Calib Precis	33	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.02		081215 UltP	23
Calib Precis	34	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.04		081215 UltP	24
Calib Precis	35	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.16	Inadeq mix?	081215 UltP	25
Calib Precis	36	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.24	Inadeq mix?	081215 UltP	26
Calib Precis	37	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.14	Inadeq mix?	081215 UltP	27
Calib Precis	41	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	NA	Did not test	081415 UltP	28
Calib Precis	42	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.05		081415 UltP	29
Calib Precis	43	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.08		081415 UltP	30
Calib Precis	44	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.36	Low Liquid	081415 UltP	31
Calib Precis	45	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	NA	Did not test	081415 UltP	32
Calib Precis	46	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.06		081415 UltP	33
Calib Precis	47	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.11		081415 UltP	34
Calib Precis	48	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	NA	Did not test	081415 UltP	35
Calib Precis	49	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	NA	Did not test	081415 UltP	36
Calib Precis	50	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.00		081415 UltP	37
Calib Precis	52	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.04		081415 UltP	38
Calib Precis	53	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	NA	Did not test	081415 UltP	39
Calib Precis	54	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.03		081415 UltP	40
Calib Precis	55	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.06		081415 UltP	41
Calib Precis	56	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.02		081415 UltP	42
Calib Precis	57	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.03		081415 UltP	43
Calib Precis	58	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.10		081415 UltP	44
Calib Precis	59	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.04		081415 UltP	45
Calib Precis	60	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.03		081415 UltP	46
Calib Precis	1	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.02		081415 UltP	47
Calib Precis	2	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.02		081415 UltP	48
Calib Precis	3	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.03	Low Liquid	081415 UltP	49
Calib Precis	4	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.03	Low Liquid	081415 UltP	50
Calib Precis	5	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.03		081415 UltP	51
Calib Precis	6	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.03	Low Liquid	081415 UltP	52
Calib Precis	7	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.29	Inadeq mix?	081415 UltP	53
Calib Precis	82	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	54
Calib Precis	83	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	55
Calib Precis	84	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	56
Calib Precis	85	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.04		0814a15 UltP	57
Calib Precis	86	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.06		0814a15 UltP	58
Calib Precis	87	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	59
Calib Precis	88	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	60
Calib Precis	89	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	61
Calib Precis	90	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.06		0814a15 UltP	62
Calib Precis	91	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.08		0814a15 UltP	63
Calib Precis	92	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.04		0814a15 UltP	64
Calib Precis	93	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	65
Calib Precis	94	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	66
Calib Precis	95	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	67
Calib Precis	96	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.06		0814a15 UltP	68
Calib Precis	97	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.06		0814a15 UltP	69
Calib Precis	98	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.00		0814a15 UltP	70
Calib Precis	99	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.09		0814a15 UltP	71
Calib Precis	11	SD 081315	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA 081715	0.00	NA	Did not test	0814a15 UltP	72
Calib Precis	12	SD 081315	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA 081715	0.00	0.25	Inadeq mix?	0814a15 UltP	73
Calib Precis	13	SD 081315	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA 081715	0.00	0.36	Inadeq mix?	0814a15 UltP	74
Calib Precis	14	SD 081315	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA 081715	0.00	NA	Did not test	0814a15 UltP	75
Calib Precis	15	SD 081315	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA 081715	0.00	NA	Did not test	0814a15 UltP	76
Calib Precis	16	SD 081315	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA 081715	0.00	0.40	Inadeq mix?	0814a15 UltP	77
Calib Precis	17	SD 081315	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA 081715	0.00	0.32	Inadeq mix?	0814a15 UltP	78
Calib Precis	9	AN 081815	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.05	0.13		081815 UltP	79
Calib Precis	45	AN 081815	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.05	0.08		081815 UltP	80

Sequence	Vial	Date/Time Made	H_2SO_4 Source	Standard (ppm-P) or Sample	Volume (mL)	DI Source (if added)	DI Volume (mL)	Spike Conc (ppm-P)	Spike Volume (mL)	Potassium Persulfate	Bake 30 min	NaOH 2 mL	PhosVer3	Analysis By Whom	Conc Calc (ppm-P)	Conc Measured (ppm-P)	Notes	original file name	Analysis order
Calib Precis	1	AN 081815	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.05	0.08		081815 UltP	81
Calib Precis	5	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.02		081815 UltP	82
Calib Precis	46	AN 081815	lab	0.10	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.10	0.13		081815 UltP	83
Calib Precis	52	AN 081815	lab	0.10	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.10	0.13		081815 UltP	84
Calib Precis	2	AN 081815	lab	0.10	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.10	0.11		081815 UltP	85
Calib Precis	53	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.02		081815 UltP	86
Calib Precis	55	AN 081815	lab	0.20	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.20	0.22		081815 UltP	87
Calib Precis	54	AN 081815	lab	0.20	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.20	0.23		081815 UltP	88
Calib Precis	50	AN 081815	lab	0.20	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.20	0.23		081815 UltP	89
Calib Precis	43	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.03		081815 UltP	90
Calib Precis	4	AN 081815	lab	0.50	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.50	0.49		081815 UltP	91
Calib Precis	3	AN 081815	lab	0.50	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.50	0.52		081815 UltP	92
Calib Precis	49	AN 081815	lab	0.50	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.50	0.52		081815 UltP	93
Calib Precis	6	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.02		081815 UltP	94
Calib Precis	8	AN 081815	lab	0.80	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.80	0.81		081815 UltP	95
Calib Precis	41	AN 081815	lab	0.80	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.80	1.00		081815 UltP	96
Calib Precis	48	AN 081815	lab	0.80	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.80	0.84		081815 UltP	97
Calib Precis	47	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.01		081815 UltP	98
Calib Precis	37	AN 081815	lab	1.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	1.00	0.95		081815 UltP	99
Calib Precis	35	AN 081815	lab	1.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	1.00	1.00		081815 UltP	100
Calib Precis	34	AN 081815	lab	1.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	1.00	1.00		081815 UltP	101
Calib Precis	18	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.01		081815 UltP	102
Calib Precis	19	AN 081815	lab	2.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	2.00	2.00		081815 UltP	103
Calib Precis	22	AN 081815	lab	2.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	2.00	2.02		081815 UltP	104
Calib Precis	44	AN 081815	lab	2.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	2.00	2.01		081815 UltP	105
Calib Precis	42	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.01		081815 UltP	106
Calib Precis	21	AN 081815	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	5.00	3.37	Rem w Series	081815a UltP	107
Calib Precis	10	AN 081815	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	5.00	3.44	Rem w Series	081815a UltP	108
Calib Precis	24	AN 081815	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	5.00	3.50	Low Liquid	081815a UltP	109
Calib Precis	25	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.01	Rem w Series	081815a UltP	110
Calib Precis	26	AN 081815	lab	8.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	8.00	3.65	Rem w Series	081815a UltP	111
Calib Precis	27	AN 081815	lab	8.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	8.00	4.48	Low Liquid	081815a UltP	112
Calib Precis	28	AN 081815	lab	8.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	8.00	3.65	Rem w Series	081815a UltP	113
Calib Precis	29	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.01	Low Liquid	081815a UltP	114
Calib Precis	30	AN 081815	lab	10.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	10.00	4.52	Low Liquid	081815a UltP	115
Calib Precis	33	AN 081815	lab	10.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	10.00	3.99	Rem w Series	081815a UltP	116
Calib Precis	23	AN 081815	lab	10.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	10.00	2.94	Rem w Series	081815a UltP	117
Calib Precis	20	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.02	Low Liquid	081815a UltP	118
Calib Precis	31	AN 081815	lab	20.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	20.00	4.01	Low Liquid	081815a UltP	119
Calib Precis	32	AN 081815	lab	20.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	20.00	4.54	Low Liquid	081815a UltP	120
Calib Precis	36	AN 081815	lab	20.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	20.00	3.62	Low Liquid	081815a UltP	121
Calib Precis	60	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.06	low; 1mL NaOH	081915 UltP	122
Calib Precis	59	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.06	mL NaOH. Zer	081915 UltP	123
Calib Precis	58	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.00	1 mL NaOH	081915 UltP	124
Calib Precis	57	AN 081915	lab	0.02	0.00	no DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01	L NaOH; zero w	081915 UltP	125
Calib Precis	56	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02		low; 1mL NaOH	081915 UltP	126
Calib Precis	95	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.01	1 mL NaOH	081915 UltP	127
Calib Precis	94	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.01	1 mL NaOH	081915 UltP	128
Calib Precis	45	AN 081915	lab	0.02	0.00	no DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.00	1 mL NaOH	081915 UltP	129
Calib Precis	43	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.02	low; 1mL NaOH	081915 UltP	130
Calib Precis	6	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02		Rem w Series	081915 UltP	131
Calib Precis	8	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.01	Rem w Series	081915 UltP	132
Calib Precis	21	AN 081915	lab	0.02	0.00	no DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.06	Rem w Series	081915 UltP	133
Calib Precis	44	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.01	1 mL NaOH	081915 UltP	134
Calib Precis	10	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.01	L NaOH, zero w	081915 UltP	135
Calib Precis	54	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.02	Rem w Series	081915 UltP	136
Calib Precis	55	AN 081915	lab	0.02	0.00	no DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02	Rem w Series	081915 UltP	137
Calib Precis	1	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.02	zero w 3	081915 UltP	138
Calib Precis	9	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.03	Rem w Series	081915 UltP	139
Calib Precis	50	AN 081915	lab	0.02	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.02	0.02	Rem w Series	081915 UltP	140
Calib Precis	47	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00		Did not test	081915 UltP	141
Calib Precis	5	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02		081915 UltP	142
Calib Precis	3	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	143
Calib Precis	4	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	144
Calib Precis	48	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	145
Calib Precis	49	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	146
Calib Precis	9	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	147
Calib Precis	46	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	148
Calib Precis	37	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02		081915 UltP	149
Calib Precis	53	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	150
Calib Precis	52	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02		081915 UltP	151
Calib Precis	41	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	152
Calib Precis	91	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	153
Calib Precis	98	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	154
Calib Precis	15	AN 081915	lab	0.00	0.00	tap water	5.00	0.00	0.00					BA/AN 082715	0.00	0.38	tap water	081915 UltP	155
Calib Precis	7	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02	alcnx washed	081915 UltP	156
Calib Precis	82	AN 081915	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	5.00	4.19		081915a UltP	157
Calib Precis	83	AN 081915	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	5.00	3.40		081915a UltP	158
Calib Precis	84	AN 081915	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	5.00	3.22		081915a UltP	159
Calib Precis	85	AN 081915	lab	5.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.50	0.50	10x	081915a UltP	160
Calib Precis	86	AN 081915	lab	5.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.50	0.50	10x	081915a UltP	161
Calib Precis	11	AN 081915	lab	5.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.50	0.51	10x	081915a UltP	162
Calib Precis	96	AN 081915	lab	2.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.20	0.21	10x	081915a UltP	163
Calib Precis	97	AN 081915	lab	2.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.20	0.22	10x	081915a UltP	164

Sequence	Vial	Date/Time Made	H_2SO_4 Source	Standard (ppm-P) or Sample	Volume (mL)	DI Source (if added)	DI Volume (mL)	Spike Conc (ppm-P)	Spike Volume (mL)	Potassium Persulfate	Bake 30 min	NaOH 2 mL	PhosVer3	Analysis By Whom	Conc Calc (ppm-P)	Conc Measured (ppm-P)	Notes	original file name	Analysis order
Calib Precis	99	AN 081915	lab	2.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.20	0.21	10x	081915a UltP	165
Calib Precis	90	AN 081915	lab	8.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.80	0.74	10x	081915a UltP	166
Calib Precis	15	AN 081915	lab	8.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.80	0.72	10x	081915a UltP	167
Calib Precis	14	AN 081915	lab	8.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.80	0.73	10x	081915a UltP	168
Calib Precis	91	AN 081915	lab	10.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	1.00	0.96	10x	081915a UltP	169
Calib Precis	92	AN 081915	lab	10.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	1.00	0.97	10x	081915a UltP	170
Calib Precis	93	AN 081915	lab	10.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	1.00	**0.06**	Spurious Res	081915a UltP	171
Calib Precis	87	AN 081915	lab	20.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	2.00	1.86	10x	081915a UltP	172
Calib Precis	88	AN 081915	lab	20.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	2.00	1.94	10x	081915a UltP	173
Calib Precis	89	AN 081915	lab	20.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	2.00	1.93	10x	081915a UltP	174
Calib Precis	12	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.07		082715 UltP	175
Calib Precis	13	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.07		082715 UltP	176
Calib Precis	14	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.06		082715 UltP	177
Calib Precis	17	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	178
Calib Precis	18	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.06		082715 UltP	179
Calib Precis	19	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.04		082715 UltP	180
Calib Precis	30	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.07		082715 UltP	181
Calib Precis	16	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	182
Calib Precis	31	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.03		082715 UltP	183
Calib Precis	32	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	184
Calib Precis	33	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.03		082715 UltP	185
Calib Precis	34	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	186
Calib Precis	35	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.03		082715 UltP	187
Calib Precis	36	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.08		082715 UltP	188
Calib Precis	90	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	189
Calib Precis	92	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.03		082715 UltP	190
Calib Precis	93	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.09		082715 UltP	191
Calib Precis	96	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.06		082715 UltP	192
Calib Precis	97	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	193

Appendix B

Results Trimmed by Quality Control

Sequence	Vial	Date/Time Made	H_2SO_4 Source	Standard (ppm-P) or Sample	Volume (mL)	DI Source (if added)	DI Volume (mL)	Spike Conc (ppm-P)	Spike Volume (mL)	Potassium Persulfate	Bake 30 min	NaOH 2 mL	PhosVer3	Analysis By Whom	Conc Calc (ppm-P)	Conc Measured (ppm-P)	Notes	Original File Name	Analysis order
Calib Precis	11	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.00		081215 UltP	1
Calib Precis	12	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.00		081215 UltP	2
Calib Precis	13	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	3
Calib Precis	14	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.10		081215 UltP	4
Calib Precis	16	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.08		081215 UltP	6
Calib Precis	17	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	7
Calib Precis	19	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.02		081215 UltP	9
Calib Precis	20	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	10
Calib Precis	21	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	11
Calib Precis	22	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	12
Calib Precis	24	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.01		081215 UltP	14
Calib Precis	25	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.00		081215 UltP	15
Calib Precis	26	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	0.99		081215 UltP	16
Calib Precis	27	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.02		081215 UltP	17
Calib Precis	28	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.07		081215 UltP	18
Calib Precis	30	BA/SD 081215	Hach	1.00	5.00	no DI	0.00	0.00	0.00					BA 081315	1.00	1.00		081215 UltP	20
Calib Precis	31	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.03		081215 UltP	21
Calib Precis	32	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.02		081215 UltP	22
Calib Precis	33	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.02		081215 UltP	23
Calib Precis	34	BA/SD 081215	Hach	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081315	0.00	0.04		081215 UltP	24
Calib Precis	42	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.05		081415 UltP	29
Calib Precis	43	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.08		081415 UltP	30
Calib Precis	46	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.06		081415 UltP	33
Calib Precis	47	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.11		081415 UltP	34
Calib Precis	50	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.00		081415 UltP	37
Calib Precis	52	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.04		081415 UltP	38
Calib Precis	54	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.03		081415 UltP	40
Calib Precis	55	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.06		081415 UltP	41
Calib Precis	56	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.02		081415 UltP	42
Calib Precis	57	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.03		081415 UltP	43
Calib Precis	58	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.10		081415 UltP	44
Calib Precis	59	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.04		081415 UltP	45
Calib Precis	60	SD 081315	Hach	1.00	5.00	no DI	0.00	0.00	0.00	100mL vol flsk				BA 081715	1.00	1.03		081415 UltP	46
Calib Precis	1	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.02		081415 UltP	47
Calib Precis	2	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.02		081415 UltP	48
Calib Precis	5	SD 081315	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA 081715	0.00	0.03		081415 UltP	51
Calib Precis	82	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	54
Calib Precis	83	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	55
Calib Precis	84	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	56
Calib Precis	85	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.04		0814a15 UltP	57
Calib Precis	86	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.06		0814a15 UltP	58
Calib Precis	87	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	59
Calib Precis	88	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	60
Calib Precis	89	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	61
Calib Precis	90	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.06		0814a15 UltP	62
Calib Precis	91	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.08		0814a15 UltP	63
Calib Precis	92	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.04		0814a15 UltP	64
Calib Precis	93	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	65
Calib Precis	94	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	66
Calib Precis	95	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.05		0814a15 UltP	67
Calib Precis	96	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.06		0814a15 UltP	68
Calib Precis	97	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.06		0814a15 UltP	69
Calib Precis	98	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.00		0814a15 UltP	70
Calib Precis	99	SD 081315	Hach	0.02	5.00	no DI	0.00	0.00	0.00					BA 081715	0.02	0.09		0814a15 UltP	71
Calib Precis	9	AN 081815	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.05	0.13		081815 UltP	79
Calib Precis	45	AN 081815	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.05	0.08		081815 UltP	80
Calib Precis	1	AN 081815	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.05	0.08		081815 UltP	81
Calib Precis	5	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.02		081815 UltP	82
Calib Precis	46	AN 081815	lab	0.10	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.10	0.13		081815 UltP	83
Calib Precis	52	AN 081815	lab	0.10	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.10	0.13		081815 UltP	84
Calib Precis	2	AN 081815	lab	0.10	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.10	0.11		081815 UltP	85
Calib Precis	53	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.02		081815 UltP	86
Calib Precis	55	AN 081815	lab	0.20	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.20	0.22		081815 UltP	87
Calib Precis	54	AN 081815	lab	0.20	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.20	0.23		081815 UltP	88
Calib Precis	50	AN 081815	lab	0.20	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.20	0.23		081815 UltP	89
Calib Precis	43	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.03		081815 UltP	90
Calib Precis	4	AN 081815	lab	0.50	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.50	0.49		081815 UltP	91
Calib Precis	3	AN 081815	lab	0.50	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.50	0.52		081815 UltP	92
Calib Precis	49	AN 081815	lab	0.50	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.50	0.52		081815 UltP	93
Calib Precis	6	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.02		081815 UltP	94
Calib Precis	8	AN 081815	lab	0.80	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.80	0.81		081815 UltP	95
Calib Precis	41	AN 081815	lab	0.80	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.80	1.00		081815 UltP	96
Calib Precis	48	AN 081815	lab	0.80	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	0.80	0.84		081815 UltP	97
Calib Precis	47	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.01		081815 UltP	98
Calib Precis	37	AN 081815	lab	1.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	1.00	0.95		081815 UltP	99
Calib Precis	35	AN 081815	lab	1.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	1.00	1.00		081815 UltP	100
Calib Precis	34	AN 081815	lab	1.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	1.00	1.00		081815 UltP	101
Calib Precis	18	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.01		081815 UltP	102
Calib Precis	19	AN 081815	lab	2.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	2.00	2.00		081815 UltP	103
Calib Precis	22	AN 081815	lab	2.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	2.00	2.02		081815 UltP	104

Sequence	Vial	Date/Time Made	H_2SO_4 Source	Standard (ppm-P) or Sample	Volume (mL)	DI Source (if added)	DI Volume (mL)	Spike Conc (ppm-P)	Spike Volume (mL)	Potassium Persulfate	Bake 30 min	NaOH 2 mL	PhosVer3	Analysis By Whom	Conc Calc (ppm-P)	Conc Measured (ppm-P)	Notes	Original File Name	Analysis order
Calib Precis	44	AN 081815	lab	2.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082515	2.00	2.01		081815 UltP	105
Calib Precis	42	AN 081815	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082515	0.00	0.01		081815 UltP	106
Calib Precis	5	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02		081915 UltP	142
Calib Precis	3	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	143
Calib Precis	4	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	144
Calib Precis	48	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	145
Calib Precis	49	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	146
Calib Precis	9	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	147
Calib Precis	46	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	148
Calib Precis	37	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02		081915 UltP	149
Calib Precis	53	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	150
Calib Precis	52	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02		081915 UltP	151
Calib Precis	41	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	152
Calib Precis	91	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	153
Calib Precis	98	AN 081915	lab	0.00	0.00	lab DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.01		081915 UltP	154
Calib Precis	15	AN 081915	lab	0.00	0.00	tap water	5.00	0.00	0.00					BA/AN 082715	0.00	0.38	tap water	081915 UltP	155
Calib Precis	7	AN 081915	lab	0.00	0.00	WWTP DI	5.00	0.00	0.00					BA/AN 082715	0.00	0.02	alcnx washed	081915 UltP	156
Calib Precis	82	AN 081915	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	5.00	4.19		081915a UltP	157
Calib Precis	83	AN 081915	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	5.00	3.40		081915a UltP	158
Calib Precis	84	AN 081915	lab	5.00	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	5.00	3.22		081915a UltP	159
Calib Precis	85	AN 081915	lab	5.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.50	0.50	10x	081915a UltP	160
Calib Precis	86	AN 081915	lab	5.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.50	0.50	10x	081915a UltP	161
Calib Precis	11	AN 081915	lab	5.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.50	0.51	10x	081915a UltP	162
Calib Precis	96	AN 081915	lab	2.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.20	0.21	10x	081915a UltP	163
Calib Precis	97	AN 081915	lab	2.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.20	0.22	10x	081915a UltP	164
Calib Precis	99	AN 081915	lab	2.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.20	0.21	10x	081915a UltP	165
Calib Precis	90	AN 081915	lab	8.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.80	0.74	10x	081915a UltP	166
Calib Precis	15	AN 081915	lab	8.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.80	0.72	10x	081915a UltP	167
Calib Precis	14	AN 081915	lab	8.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	0.80	0.73	10x	081915a UltP	168
Calib Precis	91	AN 081915	lab	10.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	1.00	0.96	10x	081915a UltP	169
Calib Precis	92	AN 081915	lab	10.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	1.00	0.97	10x	081915a UltP	170
Calib Precis	87	AN 081915	lab	20.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	2.00	1.86	10x	081915a UltP	172
Calib Precis	88	AN 081915	lab	20.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	2.00	1.94	10x	081915a UltP	173
Calib Precis	89	AN 081915	lab	20.00	0.50	WWTP DI	4.50	0.00	0.00					BA/AN 082715	2.00	1.93	10x	081915a UltP	174
Calib Precis	12	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.07		082715 UltP	175
Calib Precis	13	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.07		082715 UltP	176
Calib Precis	14	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.06		082715 UltP	177
Calib Precis	17	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	178
Calib Precis	18	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.06		082715 UltP	179
Calib Precis	19	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.04		082715 UltP	180
Calib Precis	30	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.07		082715 UltP	181
Calib Precis	16	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	182
Calib Precis	31	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.03		082715 UltP	183
Calib Precis	32	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	184
Calib Precis	33	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.03		082715 UltP	185
Calib Precis	34	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	186
Calib Precis	35	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.03		082715 UltP	187
Calib Precis	36	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.08		082715 UltP	188
Calib Precis	90	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	**0.05**		082715 UltP	189
Calib Precis	92	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.03		082715 UltP	190
Calib Precis	93	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.09		082715 UltP	191
Calib Precis	96	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.06		082715 UltP	192
Calib Precis	97	AN 082515	lab	0.05	5.00	no DI	0.00	0.00	0.00					BA/AN 082715	0.05	0.05		082715 UltP	193

Appendix C

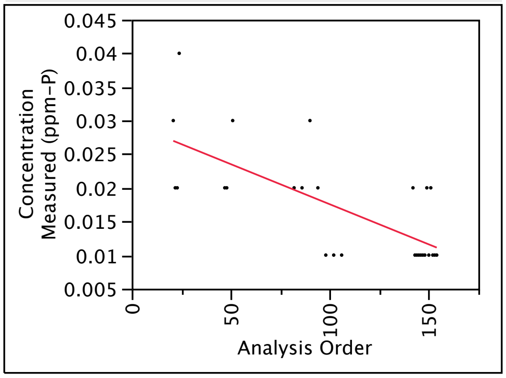
Evaluation of Blanks

Blanks

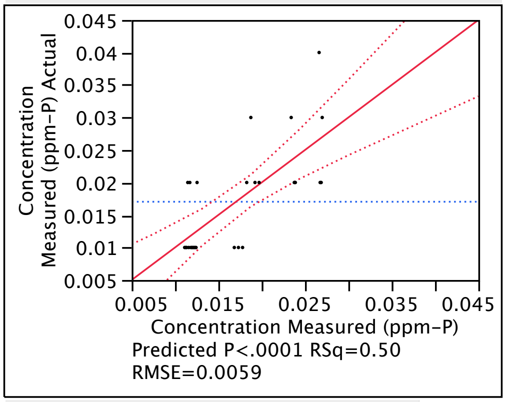
	H2SO4 Source	DI Source	Concentration Calculated (ppm-P)	Concentration Measured (ppm-P)	Analysis Order	Blank Following Standard
1	Hach	WWTP DI	0	0.03	21	Blanks in Sequence
2	Hach	WWTP DI	0	0.02	22	Blanks in Sequence
3	Hach	WWTP DI	0	0.02	23	Blanks in Sequence
4	Hach	WWTP DI	0	0.04	24	Blanks in Sequence
5	lab	WWTP DI	0	0.02	47	Blanks in Sequence
6	lab	WWTP DI	0	0.02	48	Blanks in Sequence
7	lab	WWTP DI	0	0.03	51	Blanks in Sequence
8	lab	WWTP DI	0	0.02	82	Following Standard
9	lab	WWTP DI	0	0.02	86	Following Standard
10	lab	WWTP DI	0	0.03	90	Following Standard
11	lab	WWTP DI	0	0.02	94	Following Standard
12	lab	WWTP DI	0	0.01	98	Following Standard
13	lab	WWTP DI	0	0.01	102	Following Standard
14	lab	WWTP DI	0	0.01	106	Following Standard
15	lab	WWTP DI	0	0.02	142	Blanks in Sequence
16	lab	WWTP DI	0	0.01	143	Blanks in Sequence
17	lab	WWTP DI	0	0.01	144	Blanks in Sequence
18	lab	WWTP DI	0	0.01	145	Blanks in Sequence
19	lab	WWTP DI	0	0.01	146	Blanks in Sequence
20	lab	WWTP DI	0	0.01	147	Blanks in Sequence
21	lab	lab DI	0	0.01	148	Blanks in Sequence
22	lab	lab DI	0	0.02	149	Blanks in Sequence
23	lab	lab DI	0	0.01	150	Blanks in Sequence
24	lab	lab DI	0	0.02	151	Blanks in Sequence
25	lab	lab DI	0	0.01	152	Blanks in Sequence
26	lab	lab DI	0	0.01	153	Blanks in Sequence
27	lab	lab DI	0	0.01	154	Blanks in Sequence

Response Concentration Measured (ppm-P)

Regression Plot



Actual by Predicted Plot



Summary of Fit

RSquare	0.502982
RSquare Adj	0.483101
Root Mean Square Error	0.00592
Mean of Response	0.017037
Observations (or Sum Wgts)	27

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.00088674	0.000887	25.3000
Error	25	0.00087622	0.000035	**Prob > F**
C. Total	26	0.00176296		<.0001*

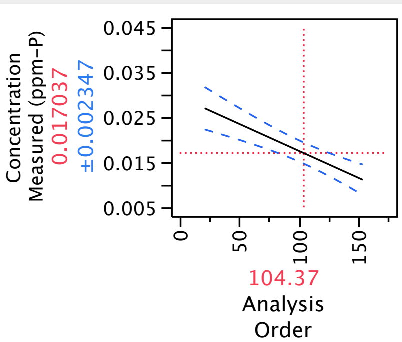
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0294926	0.002726	10.82	<.0001*
Analysis Order	-0.000119	2.373e-5	-5.03	<.0001*

Sorted Parameter Estimates

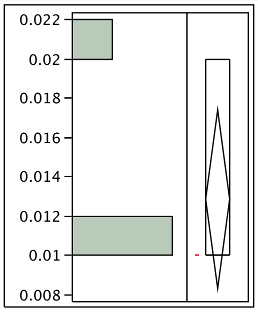
Term	Estimate	Std Error	t Ratio	Prob>|t|
Analysis Order	-0.000119	2.373e-5	-5.03	<.0001*

Prediction Profiler



Distributions DI Source=lab DI

Concentration Measured (ppm–P)



Quantiles

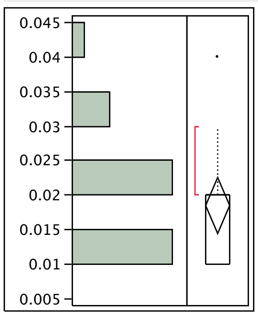
100.0%	maximum	0.02
99.5%		0.02
97.5%		0.02
90.0%		0.02
75.0%	quartile	0.02
50.0%	median	0.01
25.0%	quartile	0.01
10.0%		0.01
2.5%		0.01
0.5%		0.01
0.0%	minimum	0.01

Moments

Mean	0.0128571
Std Dev	0.0048795
Std Err Mean	0.0018443
Upper 95% Mean	0.0173699
Lower 95% Mean	0.0083444
N	7

Distributions DI Source=WWTP DI

Concentration Measured (ppm–P)



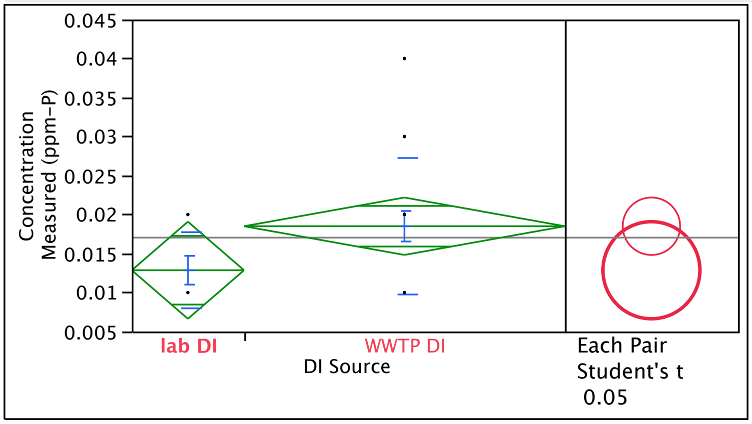
Quantiles

100.0%	maximum	0.04
99.5%		0.04
97.5%		0.04
90.0%		0.03
75.0%	quartile	0.02
50.0%	median	0.02
25.0%	quartile	0.01
10.0%		0.01
2.5%		0.01
0.5%		0.01
0.0%	minimum	0.01

Moments

Mean	0.0185
Std Dev	0.0087509
Std Err Mean	0.0019568
Upper 95% Mean	0.0225956
Lower 95% Mean	0.0144044
N	20

Oneway Analysis of Concentration Measured (ppm-P) By DI Source



Oneway Anova

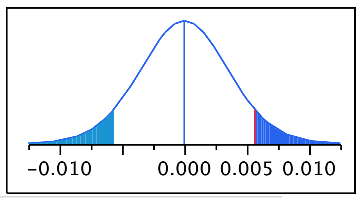
Summary of Fit

Rsquare	0.093652
Adj Rsquare	0.057399
Root Mean Square Error	0.007995
Mean of Response	0.017037
Observations (or Sum Wgts)	27

t Test

WWTP DI-lab DI
Assuming equal variances

Difference	0.00564	t Ratio	1.607246
Std Err Dif	0.00351	DF	25
Upper CL Dif	0.01287	Prob > |t|	0.1206
Lower CL Dif	-0.00159	Prob > t	0.0603
Confidence	0.95	Prob < t	0.9397



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
DI Source	1	0.00016511	0.000165	2.5832	0.1206
Error	25	0.00159786	0.000064		
C. Total	26	0.00176296			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
lab DI	7	0.012857	0.00302	0.00663	0.01908
WWTP DI	20	0.018500	0.00179	0.01482	0.02218

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
lab DI	7	0.012857	0.004880	0.00184	0.00834	0.01737
WWTP DI	20	0.018500	0.008751	0.00196	0.01440	0.02260

Means Comparisons

Comparisons for each pair using Student's t

t	Alpha
2.05954	0.05

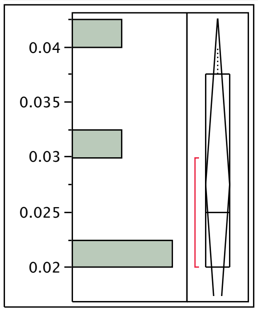
Abs(Dif)-LSD

	WWTP DI	lab DI
WWTP DI	-0.00521	-0.00159
lab DI	-0.00159	-0.0088

Positive values show pairs of means that are significantly different.

Distributions H2SO4 Source=Hach

Concentration Measured (ppm-P)



Quantiles

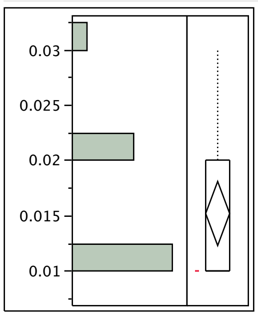
100.0%	maximum	0.04
99.5%		0.04
97.5%		0.04
90.0%		0.04
75.0%	quartile	0.0375
50.0%	median	0.025
25.0%	quartile	0.02
10.0%		0.02
2.5%		0.02
0.5%		0.02
0.0%	minimum	0.02

Moments

Mean	0.0275
Std Dev	0.0095743
Std Err Mean	0.0047871
Upper 95% Mean	0.0427348
Lower 95% Mean	0.0122652
N	4

Distributions H2SO4 Source=lab

Concentration Measured (ppm-P)



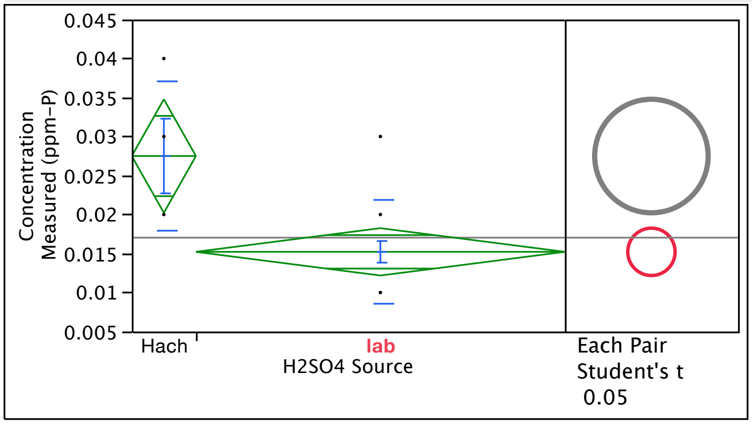
Quantiles

100.0%	maximum	0.03
99.5%		0.03
97.5%		0.03
90.0%		0.026
75.0%	quartile	0.02
50.0%	median	0.01
25.0%	quartile	0.01
10.0%		0.01
2.5%		0.01
0.5%		0.01
0.0%	minimum	0.01

Moments

Mean	0.0152174
Std Dev	0.0066535
Std Err Mean	0.0013873
Upper 95% Mean	0.0180946
Lower 95% Mean	0.0123402
N	23

Oneway Analysis of Concentration Measured (ppm-P) By H2SO4 Source



Oneway Anova

Summary of Fit

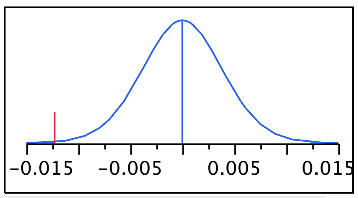
Rsquare	0.291583
Adj Rsquare	0.263246
Root Mean Square Error	0.007068
Mean of Response	0.017037
Observations (or Sum Wgts)	27

t Test

lab-Hach

Assuming equal variances

Difference	-0.01228	t Ratio	-3.20779
Std Err Dif	0.00383	DF	25
Upper CL Dif	-0.00440	Prob > |t|	0.0036*
Lower CL Dif	-0.02017	Prob > t	0.9982
Confidence	0.95	Prob < t	0.0018*



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
H2SO4 Source	1	0.00051405	0.000514	10.2899	0.0036*
Error	25	0.00124891	0.000050		
C. Total	26	0.00176296			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hach	4	0.027500	0.00353	0.02022	0.03478
lab	23	0.015217	0.00147	0.01218	0.01825

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Hach	4	0.027500	0.009574	0.00479	0.01227	0.04273
lab	23	0.015217	0.006653	0.00139	0.01234	0.01809

Means Comparisons

Comparisons for each pair using Student's t

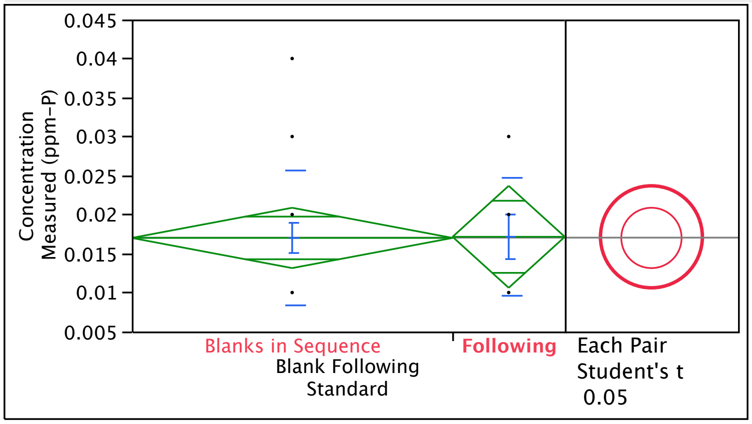
t	Alpha
2.05954	0.05

Abs(Dif)-LSD

	Hach	lab
Hach	-0.01029	0.004397
lab	0.004397	-0.00429

Positive values show pairs of means that are significantly different.

Oneway Analysis of Concentration Measured (ppm-P) By Blank Following Standard



Oneway Anova

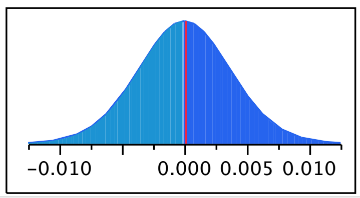
Summary of Fit

Rsquare	0.00006
Adj Rsquare	-0.03994
Root Mean Square Error	0.008397
Mean of Response	0.017037
Observations (or Sum Wgts)	27

t Test

Following Standard-Blanks in Sequence
Assuming equal variances

Difference	0.00014	t Ratio	0.038739
Std Err Dif	0.00369	DF	25
Upper CL Dif	0.00774	Prob > |t|	0.9694
Lower CL Dif	-0.00745	Prob > t	0.4847
Confidence	0.95	Prob < t	0.5153



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Blank Following Standard	1	0.00000011	1.058e-7	0.0015	0.9694
Error	25	0.00176286	0.000071		
C. Total	26	0.00176296			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Blanks in Sequence	20	0.017000	0.00188	0.01313	0.02087
Following Standard	7	0.017143	0.00317	0.01061	0.02368

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Blanks in Sequence	20	0.017000	0.008645	0.00193	0.01295	0.02105
Following Standard	7	0.017143	0.007559	0.00286	0.01015	0.02413

Means Comparisons

Comparisons for each pair using Student's t

t	Alpha
2.05954	0.05

Abs(Dif)-LSD

	Following Standard	Blanks in Sequence
Following Standard	-0.00924	-0.00745
Blanks in Sequence	-0.00745	-0.00547

Positive values show pairs of means that are significantly different.

Appendix D

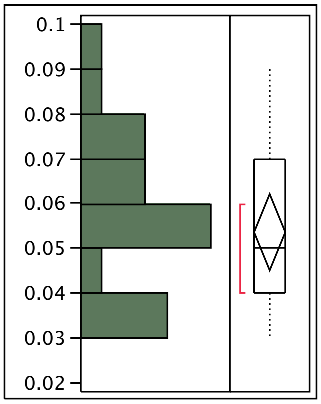
Precision Evaluation

Precision

	Calculated Concentration (ppm-P)	Measured Concentration (ppm-P)	Preparation
1	1	1	pure standard
2	1	1	pure standard
3	1	1.01	pure standard
4	1	1.1	pure standard
5	1	1.08	pure standard
6	1	1.01	pure standard
7	1	1.02	pure standard
8	1	1.01	pure standard
9	1	1.01	pure standard
10	1	1.01	pure standard
11	1	1.01	pure standard
12	1	1	pure standard
13	1	0.99	pure standard
14	1	1.02	pure standard
15	1	1.07	pure standard
16	1	1	pure standard
17	1	1.05	std mixture
18	1	1.08	std mixture
19	1	1.06	std mixture
20	1	1.11	std mixture
21	1	1	std mixture
22	1	1.04	std mixture
23	1	1.03	std mixture
24	1	1.06	std mixture
25	1	1.02	std mixture
26	1	1.03	std mixture
27	1	1.1	std mixture
28	1	1.04	std mixture
29	1	1.03	std mixture
30	0.05	0.07	std mixture
31	0.05	0.07	std mixture
32	0.05	0.06	std mixture
33	0.05	0.05	std mixture
34	0.05	0.06	std mixture
35	0.05	0.04	std mixture
36	0.05	0.07	std mixture
37	0.05	0.05	std mixture
38	0.05	0.03	std mixture
39	0.05	0.05	std mixture
40	0.05	0.03	std mixture
41	0.05	0.05	std mixture
42	0.05	0.03	std mixture
43	0.05	0.08	std mixture
44	0.05	0.05	std mixture
45	0.05	0.03	std mixture
46	0.05	0.09	std mixture
47	0.05	0.06	std mixture
48	0.05	0.05	std mixture

Distributions Calculated Concentration (ppm−P)=0.05, Preparation=std mixture

Measured Concentration (ppm−P)



Quantiles

100.0%	maximum	0.09
99.5%		0.09
97.5%		0.09
90.0%		0.08
75.0%	quartile	0.07
50.0%	median	0.05
25.0%	quartile	0.04
10.0%		0.03
2.5%		0.03
0.5%		0.03
0.0%	minimum	0.03

Moments

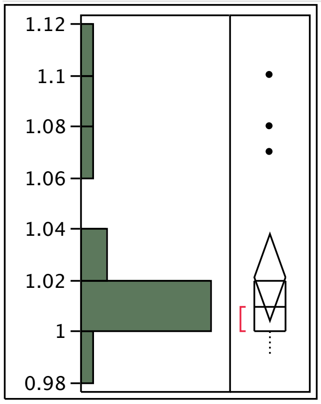
Mean	0.0536842
Std Dev	0.0173879
Std Err Mean	0.0039891
Upper 95% Mean	0.0620649
Lower 95% Mean	0.0453035
N	19

Distributions Calculated Concentration (ppm−P)=1, Preparation=pure standard

Measured Concentration (ppm−P)

Distributions Calculated Concentration (ppm−P)=1, Preparation=pure standard

Measured Concentration (ppm−P)



Quantiles

100.0%	maximum	1.1
99.5%		1.1
97.5%		1.1
90.0%		1.086
75.0%	quartile	1.02
50.0%	median	1.01
25.0%	quartile	1
10.0%		0.997
2.5%		0.99
0.5%		0.99
0.0%	minimum	0.99

Moments

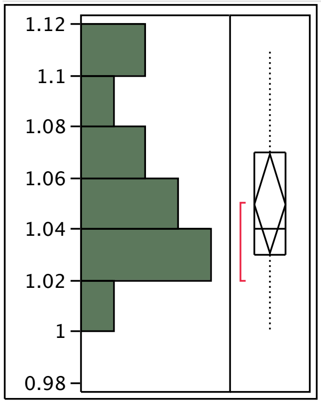
Mean	1.02125
Std Dev	0.0322232
Std Err Mean	0.0080558
Upper 95% Mean	1.0384205
Lower 95% Mean	1.0040795
N	16

Distributions Calculated Concentration (ppm−P)=1, Preparation=std mixture

Measured Concentration (ppm−P)

Distributions Calculated Concentration (ppm−P)=1, Preparation=std mixture

Measured Concentration (ppm−P)



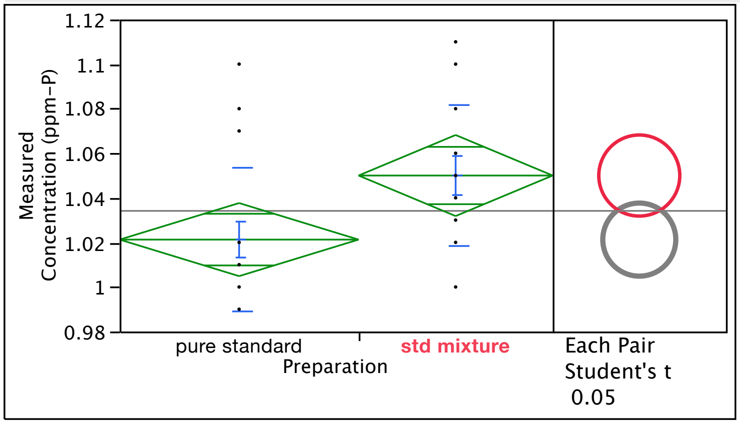
Quantiles

100.0%	maximum	1.11
99.5%		1.11
97.5%		1.11
90.0%		1.106
75.0%	quartile	1.07
50.0%	median	1.04
25.0%	quartile	1.03
10.0%		1.008
2.5%		1
0.5%		1
0.0%	minimum	1

Moments

Mean	1.05
Std Dev	0.0316228
Std Err Mean	0.0087706
Upper 95% Mean	1.0691095
Lower 95% Mean	1.0308905
N	13

Oneway Analysis of Measured Concentration (ppm-P) By Preparation



Oneway Anova

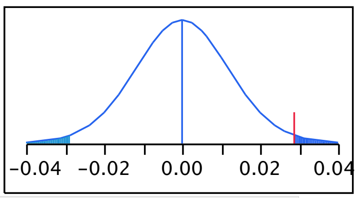
Summary of Fit

Rsquare	0.17695
Adj Rsquare	0.146467
Root Mean Square Error	0.031958
Mean of Response	1.034138
Observations (or Sum Wgts)	29

t Test

std mixture-pure standard
Assuming equal variances

Difference	0.028750	t Ratio	2.409321
Std Err Dif	0.011933	DF	27
Upper CL Dif	0.053234	Prob > |t|	0.0231*
Lower CL Dif	0.004266	Prob > t	0.0115*
Confidence	0.95	Prob < t	0.9885



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Preparation	1	0.00592845	0.005928	5.8048	0.0231*
Error	27	0.02757500	0.001021		
C. Total	28	0.03350345			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
pure standard	16	1.02125	0.00799	1.0049	1.0376
std mixture	13	1.05000	0.00886	1.0318	1.0682

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
pure standard	16	1.02125	0.032223	0.00806	1.0041	1.0384
std mixture	13	1.05000	0.031623	0.00877	1.0309	1.0691

Means Comparisons

Comparisons for each pair using Student's t

t	Alpha
2.05183	0.05

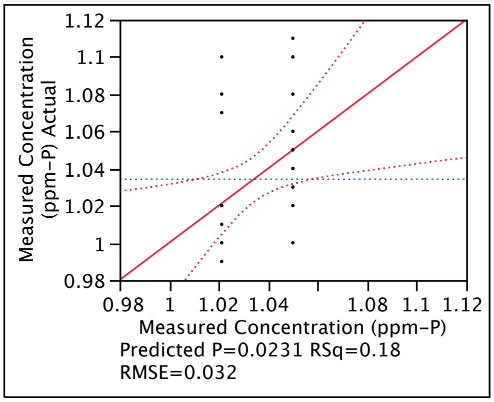
Abs(Dif)-LSD

	std mixture	pure standard
std mixture	-0.02572	0.004266
pure standard	0.004266	-0.02318

Positive values show pairs of means that are significantly different.

Response Measured Concentration (ppm-P)

Actual by Predicted Plot



Summary of Fit

RSquare	0.17695
RSquare Adj	0.146467
Root Mean Square Error	0.031958
Mean of Response	1.034138
Observations (or Sum Wgts)	29

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.00592845	0.005928	5.8048
Error	27	0.02757500	0.001021	**Prob > F**
C. Total	28	0.03350345		0.0231*

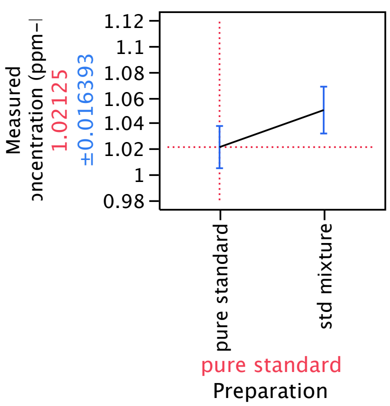
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.035625	0.005966	173.58	<.0001*
Preparation[pure standard]	-0.014375	0.005966	-2.41	0.0231*

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
Preparation[pure standard]	-0.014375	0.005966	-2.41		0.0231*

Prediction Profiler



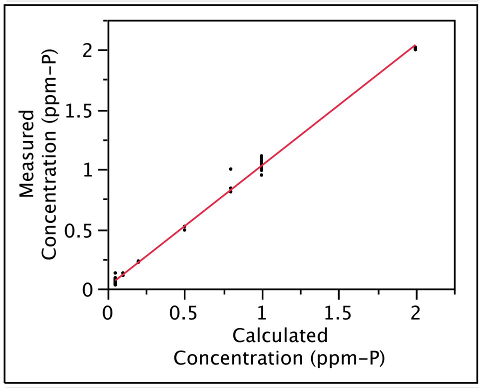
Appendix E

Calibration

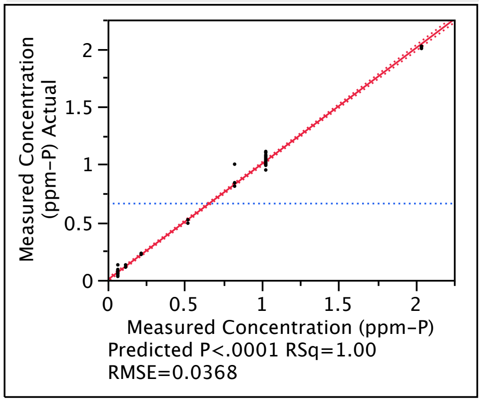
Response Measured Concentration (ppm–P)

Whole Model

Regression Plot



Actual by Predicted Plot



Summary of Fit

RSquare	0.995346
RSquare Adj	0.995277
Root Mean Square Error	0.036789
Mean of Response	0.659565
Observations (or Sum Wgts)	69

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	19.395406	19.3954	14330.40
Error	67	0.090681	0.0014	**Prob > F**
C. Total	68	19.486087		<.0001*

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
				2.3792
Lack Of Fit	5	0.01459785	0.002920	**Prob > F**
Pure Error	62	0.07608295	0.001227	0.0487*
Total Error	67	0.09068080		**Max RSq**
				0.9961

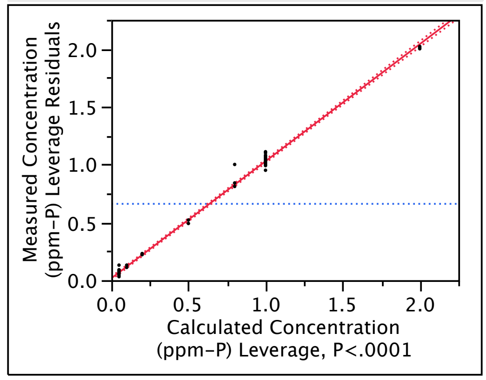
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0158049	0.006967	2.27	0.0265*
Calculated Concentration (ppm–P)	1.0118329	0.008452	119.71	<.0001*

Residual by Predicted Plot

Calculated Concentration (ppm–P)

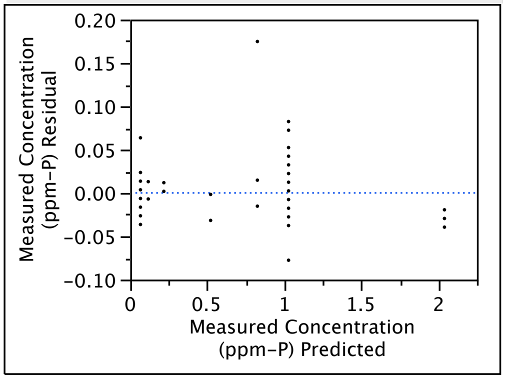
Leverage Plot



Response Measured Concentration (ppm-P)

Whole Model

Residual by Predicted Plot



APPENDIX E

Experimental Data, Figures, and Tables

Final Results (ordered by Sample Location)

Vial	Date/Time Made	H_2SO_4 Source	Standard (ppm-P) or Sample	Volume (mL)	DI Source (if added)	DI Volume (mL)	Spike Conc (ppm-P)	Spike Volume (mL)	Analysis By Whom	Conc Rpt (ppm-P)	Calibrated	Conc Less Spike (ppm-P)	Notes	Days Since Start of Evaluation	DATE	TIME	SAMPLER STAFF
18	9/9/2015	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA	0.03	0.01	0.01		2	9/9/2015		
19	9/9/2015	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA	0.02	0.00	0.00		2	9/9/2015		
52	9/10/15 13:55	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.01	-0.01	-0.01	USED 53 TO ZERO	3	9/10/2015	13:55	
82	9/11/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.02	0.00	0.00		4	9/11/2015	13:00	
94	9/15/15 18:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.02	0.00	0.00		8	9/15/2015	18:30	
6	9/16/15 18:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.02	0.00	0.00		9	9/16/2015	18:00	
66	AN 9/18/15 8:15	HACH	BLANK	5.00	LAB	0.00	0.00	0.00	MA	0.04	0.02	0.02		11	9/18/2015	8:15	AN
76	BA 9/19/15 10:55	HACH	BLANK	5.00	LAB	0.00	0.00	0.00	MA	0.02	0.00	0.00		12	9/19/2015	10:55	BA
37	AN 9/20/15 10:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/26/15	0.02	0.00	0.00		13	9/20/2015	10:30	AN
49	AN 9/21/15 10:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/26/15	0.02	0.00	0.00		14	9/21/2015	10:30	AN
59	AN 9/22/15 9:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/26/15	0.02	0.00	0.00		15	9/22/2015	9:30	AN
83	BA 9/23/15 18:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/26/15	0.01	-0.01	-0.01		16	9/23/2015	18:00	BA
96	AN 9/24/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 9/28/15	0.01	-0.01	-0.01		17	9/24/2015	11:00	AN
7	BA 9/25/15 13:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 9/28/15	0.01	-0.01	-0.01		18	9/25/2015	13:20	BA
19	AN 9/26/15 15:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/29/15	0.02	0.00	0.00		19	9/26/2015	15:30	AN
76	BA 9/27/15 15:25	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.01	-0.01	-0.01		20	9/27/2015	15:25	BA
84	AN 9/28/15	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.02	0.00	0.00		21	9/28/2015		AN
34	BA 9/30/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.01	-0.01	-0.01		22	9/30/2015	8:30	BA
46	BA 9/30/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.03	0.01	0.01		23	9/30/2015	8:30	BA
11	AN 10/1/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.04	0.02	0.02		24	10/1/2015	13:00	AN
24	BA 10/2/15 10:40	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/4/15	0.01	-0.01	-0.01		25	10/2/2015	10:40	BA
58	BA 10/3/15 11:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/4/15	0.01	-0.01	-0.01		26	10/3/2015	11:20	BA
91	AN 10/4/15 19:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/5/15	0.02	0.00	0.00		27	10/4/2015	19:00	AN
35	BA 10/5/15 20:35	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/5/15	0.01	-0.01	-0.01		28	10/5/2015	20:35	BA
8	BA 10/6/15 14:11	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/6/15	0.02	0.00	0.00		29	10/6/2015	14:11	BA
18	BA 10/7/15 14:11	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/9/15	0.01	-0.01	-0.01		30	10/7/2015	14:11	BA
40	AN 10/8/15 14:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/10/15	0.01	-0.01	-0.01		31	10/8/2015	14:20	AN
23	BA 10/9/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/11/17	0.01	-0.01	-0.01		32	10/9/2015	8:30	BA
1	AN 10/10/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	AN 10/13/15	0.01	-0.01	-0.01		33	10/10/2015	11:00	AN
31	AN 10/11/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	AN 10/13/15	0.04	0.02	0.02		34	10/11/2015	11:00	AN
67	BA 10/12/15 17:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/13/15	0.04	0.02	0.02		35	10/12/2015	17:20	BA
60	AN 10/13/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/14/15	0.03	0.01	0.01		36	10/13/2015	8:30	AN
80	AN 10/14/15 16:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/16/15	0.02	0.00	0.00		37	10/14/2015	16:00	AN
92	AN 10/15/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/16/15	0.01	-0.01	-0.01		38	10/15/2015	8:30	AN
13	BA 10/16/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.05	MA 10/18/15	0.01	-0.01	-0.01		39	10/16/2015	8:00	BA
5	BA 10/17/15 14:50	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/18/15	0.01	-0.01	-0.01		40	10/17/2015	14:50	BA
27	BA 10/18/15 9:40	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/20/15	0.02	0.00	0.00		41	10/18/2015	9:40	BA
52	BA 10/19/15 19:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/22/15	0.02	0.00	0.00		42	10/19/2015	19:00	BA
36	AN 10/20/15 9:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/22/15	0.02	0.00	0.00		43	10/20/2015	9:00	AN
64	BA 10/21/15 19:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/22/15	0.01	-0.01	-0.01		44	10/21/2015	19:00	BA
1	AN 10/22/15 10:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/27/15	0.02	0.00	0.00		45	10/22/2015	10:00	AN
97	BA 10/23/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/27/15	0.02	0.00	0.00		46	10/23/2015	8:30	BA
13	AN 10/24/15 10:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/27/15	0.02	0.00	0.00		47	10/24/2015	10:00	AN
21	AN 10/24/15 10:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/27/15	0.02	0.00	0.00		48	10/24/2015	10:00	AN
31	BA 10/26/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/27/15	0.01	-0.01	-0.01		49	10/26/2015	8:30	BA
38	AN 10/27/15 9:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/27/15	0.01	-0.01	-0.01		50	10/27/2015	9:00	AN
54	BA 10/28/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/28/15	0.01	-0.01	-0.01		51	10/28/2015	8:00	BA
1	AN 10/29/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/31/15	0.01	-0.01	-0.01		52	10/29/2015	8:00	AN
19	BA 10/30/15 8:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/4/15	0.01	-0.01	-0.01		53	10/30/2015	8:20	BA
31	BA 10/31/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/4/15	0.01	-0.01	-0.01		54	10/31/2015	11:00	BA

1	AN 11/1/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 11/5/15	0.01	-0.01	-0.01		55	11/1/2015	11:00	AN
49	BA 11/2/15 8:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 11/5/15	0.01	-0.01	-0.01		56	11/2/2015	8:20	BA
56	AN 11/3/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/7/15	0.02	0.00	0.00		57	11/3/2015	8:00	AN
70	BA 11/4/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/7/15	0.03	0.01	0.01		58	11/4/2015	8:00	BA
80	AN 11/5/15 9:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/7/15	0.02	0.00	0.00		59	11/5/2015	9:00	AN
96	BA 11/6/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/7/15	0.01	-0.01	-0.01		60	11/6/2015	8:00	BA
5	BA 11/7/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/9/15	0.01	-0.01	-0.01		61	11/7/2015	11:00	BA
21	AN 11/8/15 12:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/9/15	0.01	-0.01	-0.01		62	11/8/2015	12:00	AN
36	BA 11/9/15 9:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/10/15	0.02	0.00	0.00		63	11/9/2015	9:00	BA
1	AN 11/10/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/11/15	0.01	-0.01	-0.01		64	11/10/2015	13:00	AN
97	BA 11/11/15 16:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/12/15	0.02	0.00	0.00		65	11/11/2015	16:00	BA
2	AN 11/12/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/13/15	0.01	-0.01	-0.01		66	11/12/2015	8:00	AN
77	BA 11/13/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/16/15	0.01	-0.01	-0.01		67	11/13/2015	13:00	BA
62	AN 11/14/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/16/15	0.03	0.01	0.01		68	11/14/2015	11:00	AN
1	AN 11/15/15 10:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/16/15	0.02	0.00	0.00		69	11/15/2015	10:00	AN
9	AN 11/16/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/16/15	0.01	-0.01	-0.01		70	11/16/2015	13:00	AN
27	AN 11/17/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/20/15	0.01	-0.01	-0.01		71	11/17/2015	13:00	AN
38	BA 11/18/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/20/15	0.01	-0.01	-0.01		72	11/18/2015	8:00	BA
46	BA 11/18/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 11/22/15	0.02	0.00	0.00	FROM BAGGY	72	11/18/2015	8:00	BA
47	AN 11/19/15 9:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 11/22/15	0.01	-0.01	-0.01		73	11/19/2015	9:30	AN
59	BA 11/20/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/23/15	0.01	-0.01	-0.01		74	11/20/2015	8:00	BA
70	AN 11/21/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/24/15	0.01	-0.01	-0.01		75	11/21/2015	11:00	AN
83	AN 11/22/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/24/15	0.01	-0.01	-0.01		76	11/22/2015	13:00	AN
96	BA 11/23/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/24/15	0.01	-0.01	-0.01		77	11/23/2015	8:00	BA
5	BA 11/23/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/24/15	0.02	0.00	0.00	FROM BAGGY	77	11/23/2015	8:00	BA
15	9/8/2015	LAB	INF	5.00	-	0.00	0.00	0.00	MA	0.02	0.00	0.00		1	9/8/2015	7:10	AN
16	9/8/2015	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA	0.11	0.09	0.89		1	9/8/2015	7:10	AN
26	9/9/2015	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA	0.61	0.58	5.83		2	9/9/2015	7:10	JA
27	9/9/2015	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA	0.64	0.61	6.12		2	9/9/2015	7:10	JA
45	9/10/15 13:55	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA	0.45	0.42	4.25		3	9/10/2015	7:10	TN
58	9/11/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ	0.64	0.61	6.12		4	9/11/2015	7:30	BA
91	9/15/15 18:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ	0.71	0.68	6.81		8	9/15/2015	9:30	TN
11	9/16/15 18:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ	0.38	0.36	3.55		9	9/16/2015	7:50	JA/BA
51	AN 9/18/15 8:15	HACH	INF	0.50	LAB	4.50	0.00	0.00	MA	0.33	0.31	3.06		11	9/18/2015	7:18	JA/BA
70	BA 9/19/15 10:55	HACH	INF	0.50	LAB	4.50	0.00	0.00	MA	0.31	0.29	2.86		12	9/19/2015	8:41	BA
30	AN 9/20/15 10:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 9/26/15	0.27	0.25	2.47		13	9/20/2015	8:35	TN
42	AN 9/21/15 10:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 9/26/15	0.35	0.33	3.26		14	9/21/2015	7:55	JA/BA
26	AN 9/22/15 9:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 9/26/15	0.42	0.39	3.95		15	9/22/2015	10:00	JA
69	BA 9/23/15 18:00	HACH	INF	0.50	LAB	4.50	0.00	0.00	MA 9/26/15	0.34	0.32	3.16		16	9/23/2015	7:55	BA
89	AN 9/24/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 9/28/15	0.30	0.28	2.76		17	9/24/2015	9:30	JA
1	BA 9/25/15 13:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 9/28/15	0.65	0.62	6.22		18	9/25/2015	8:15	JA
12	AN 9/26/15 15:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 9/29/15	0.32	0.30	2.96		19	9/26/2015	9:15	BA
70	BA 9/27/15 15:25	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.41	0.39	3.85		20	9/27/2015	8:31	BA
68	AN 9/28/15	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.36	0.34	3.36		21	9/28/2015	7:49	JA/BA
25	BA 9/30/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.40	0.38	3.75		22	9/29/2015	8:30	JA
36	BA 9/30/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.01	-0.01	-0.10		23	9/30/2015	7:43	BA
1	AN 10/1/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.41	0.39	3.85		24	10/1/2015	9:30	JA
14	BA 10/2/15 10:40	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/4/15	1.02	0.99	9.88		25	10/2/2015	7:45	BA
60	AN 10/4/15 19:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/5/15	0.38	0.36	3.55		27	10/4/2015	8:50	BA
31	BA 10/5/15 20:35	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/5/15	0.44	0.41	4.15		28	10/5/2015	7:55	BA
1	BA 10/6/15 14:11	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/6/15	0.59	0.56	5.63		29	10/6/2015	7:20	JA
11	BA 10/7/15 14:11	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/9/15	0.63	0.60	6.02		30	10/7/2015	7:44	BA
43	AN 10/8/15 14:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/10/15	0.6	0.57	5.73		31	10/8/2015	8:40	JA
20	BA 10/9/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/11/15	0.46	0.43	4.34		32	10/9/2015	7:30	BA
3	AN 10/10/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	AN 10/13/15	0.47	0.44	4.44		33	10/10/2015	9:50	TN
33	AN 10/11/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	AN 10/13/15	0.10	0.08	0.79		34	10/11/2015	8:35	AN
61	BA 10/12/15 17:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/13/15	0.51	0.48	4.84		35	10/12/2015	7:40	BA
70	AN 10/13/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/14/15	0.52	0.49	4.94		36	10/13/2015	7:30	TN
82	AN 10/14/15 16:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/16/15	0.51	0.48	4.84		37	10/14/2015	7:40	BA

94	AN 10/15/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/16/15	0.45	0.42	4.25		38	10/15/2015	7:30	JA
11	BA 10/16/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/18/15	0.73	0.70	7.01		39	10/16/2015	7:15	BA
1	BA 10/17/15 14:50	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/18/15	0.34	0.32	3.16		40	10/17/2015	9:45	TN
24	BA 10/18/15 9:40	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/20/15	0.59	0.56	5.63		41	10/18/2015	8:45	BA
41	BA 10/19/15 19:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/22/15	1.01	0.98	9.78		42	10/19/2015	7:38	BA
37	AN 10/20/15 9:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/22/15	0.39	0.37	3.65		43	10/20/2015	8:30	JA
61	BA 10/21/15 19:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/22/15	0.32	0.30	2.96		44	10/21/2015	7:15	BA
2	AN 10/22/15 10:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/27/15	0.37	0.35	3.46		45	10/22/2015	8:15	JA
100	BA 10/23/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/27/15	0.41	0.39	3.85		46	10/23/2015	8:07	JA
14	AN 10/24/15 10:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/27/15	0.33	0.31	3.06		47	10/24/2015	8:20	TN
22	AN 10/24/15 10:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/27/15	0.30	0.28	2.76		48	10/25/2015	8:45	TN
28	BA 10/26/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/27/15	0.79	0.76	7.61		49	10/26/2015	7:35	BA
39	AN 10/27/15 9:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/27/15	0.28	0.26	2.57		50	10/27/2015	7:40	JA
51	BA 10/28/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/28/15	0.70	0.67	6.72		51	10/28/2015	7:10	BA
2	AN 10/29/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/3/15	0.35	0.33	3.26		52	10/29/2015	8:50	BA
16	BA 10/30/15 8:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/4/15	0.65	0.62	6.22		53	10/30/2015	7:25	BA
28	BA 10/31/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/4/15	0.57	0.54	5.43		54	10/31/2015	9:35	BA
9	AN 11/1/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 11/5/15	0.28	0.26	2.57		55	11/1/2015	9:10	TN
38	BA 11/2/15 8:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 11/5/15	0.70	0.67	6.72		56	11/2/2015	7:35	BA
57	AN 11/3/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.27	0.25	2.47		57	11/3/2015	7:35	TN
67	BA 11/4/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.46	0.43	4.34		58	11/4/2015	11:37	BA
82	AN 11/5/15 9:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.45	0.42	4.25		59	11/5/2015	8:10	TN
93	BA 11/6/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.33	0.31	3.06		60	11/6/2015	7:18	BA
2	BA 11/7/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.52	0.49	4.94		61	11/7/2015	8:47	BA
22	AN 11/8/15 12:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/9/15	0.33	0.31	3.06		62	11/8/2015	11:00	TN
33	BA 11/9/15 9:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/10/15	0.35	0.33	3.26		63	11/9/2015	7:45	BA
46	AN 11/10/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/11/15	0.36	0.34	3.36		64	11/10/2015	9:10	TN
100	BA 11/11/15 16:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/12/15	0.51	0.48	4.84		65	11/11/2015	7:50	BA
3	AN 11/12/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/13/15	0.53	0.50	5.04		66	11/12/2015	9:30	TN
84	BA 11/13/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/16/15	0.17	0.15	1.48		67	11/13/2015	7:10	JA
63	AN 11/14/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/16/15	0.23	0.21	2.07		68	11/14/2015	10:10	TN
2	AN 11/15/15 10:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/16/15	0.23	0.21	2.07		69	11/15/2015	9:40	TN
10	AN 11/16/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/16/15	0.38	0.36	3.55		70	11/16/2015	7:42	BA
28	AN 11/17/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/20/15	0.17	0.15	1.48		71	11/17/2015	9:20	TN
35	BA 11/18/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/20/15	0.32	0.30	2.96		72	11/18/2015	7:15	BA
48	AN 11/19/15 9:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 11/22/15	0.28	0.26	2.57		73	11/19/2015	8:40	TN
71	AN 11/21/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/24/15	0.21	0.19	1.87		75	11/21/2015	10:10	TN
84	AN 11/22/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/24/15	0.18	0.16	1.58		76	11/22/2015	11:10	TN
94	BA 11/23/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/24/15	0.34	0.32	3.16		77	11/23/2015	7:20	BA
86	AN 11/11/15 16:00	LAB	ME EFF	5.00		0.00	0.00	0.00	MA 11/12/15	0.08	0.06	0.06		65	11/11/2015	7:45	BA
87	AN 11/11/15 16:00	LAB	MF INF	5.00		0.00	0.00	0.00	MA 11/12/15	0.23	0.21	0.21		65	11/11/2015	7:45	BA
89	AN 11/11/15 16:00	LAB	MF INF	5.00		0.00	0.00	0.00	MA 11/12/15	0.32	0.30	0.30		65	11/11/2015	7:45	BA
88	AN 11/11/15 16:00	LAB	MF EFF	5.00		0.00	0.00	0.00	MA 11/12/15	0.07	0.05	0.05		65	11/11/2015	7:45	BA
13	AN 11/12/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/13/15	0.06	0.04	0.04		66	11/12/2015	10:00	AN
12	AN 11/12/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/13/15	0.22	0.20	0.20		66	11/12/2015	10:00	AN
72	BA 11/13/15 13:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.10	0.08	0.08		67	11/13/2015	7:25	BA
73	BA 11/13/15 13:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.20	0.18	0.18		67	11/13/2015	7:25	BA
67	BA 11/20/15 8:00	LAB	ME EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.04	0.02	0.02		72	11/18/2020	7:18	BA
44	BA 11/18/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	MA 11/20/15	0.06	0.04	0.04		72	11/18/2015	7:31	BA
43	BA 11/18/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	MA 11/20/15	0.11	0.09	0.09		72	11/18/2015	7:31	BA
69	BA 11/20/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.05	0.03	0.03		73	11/20/2015	7:18	BA
68	BA 11/20/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.12	0.10	0.10		73	11/19/2015	7:17	BA
65	BA 11/20/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	MA 11/23/15	0.03	0.01	0.01		74	11/19/2015	7:18	BA
64	BA 11/20/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	MA 11/23/15	0.09	0.07	0.07		74	11/20/2015	7:17	BA
80	AN 11/21/15 11:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.03	0.01	0.01		75	11/21/2015	10:30	AN
79	AN 11/21/15 11:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.08	0.06	0.06		75	11/21/2015	10:30	AN
93	AN 11/22/15 13:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.06	0.04	0.04		76	11/22/2015	11:50	AN
92	AN 11/22/15 13:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.20	0.18	0.18		76	11/22/2015	11:50	AN
3	BA 11/23/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.04	0.02	0.02		77	11/23/2015	7:24	BA

2	BA 11/23/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.10	0.08	0.08		77	11/23/2015	7:23	BA
			MF EFF	5.00		0.00	0.00	0.00		0.02	0.00	0.00			11/23/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.07	0.05	0.05			11/24/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.03	0.01	0.01			11/24/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.04	0.02	0.02			11/24/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.05	0.03	0.03			11/25/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.03	0.01	0.01			11/25/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.02	0.00	0.00			11/25/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.06	0.04	0.04			11/30/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.03	0.01	0.01			11/30/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.05	0.03	0.03			11/30/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.08	0.06	0.06			12/1/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.02	0.00	0.00			12/1/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.05	0.03	0.03			12/1/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.08	0.06	0.06			12/7/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.05	0.03	0.03			12/7/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.11	0.09	0.09			12/8/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.05	0.03	0.03			12/8/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.06	0.04	0.04			12/8/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.26	0.24	0.24			12/9/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.05	0.03	0.03			12/9/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.29	0.27	0.27			12/9/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.06	0.04	0.04			12/9/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.42	0.39	0.39			12/10/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.06	0.04	0.04			12/10/2015		JA
			MF INF	5.00		0.00	0.00	0.00		1.15	1.12	1.12			12/14/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.05	0.03	0.03			12/14/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.52	0.49	0.49			12/14/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.03	0.01	0.01			12/14/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.57	0.54	0.54			12/15/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.03	0.01	0.01			12/15/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.11	0.09	0.09			12/15/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.02	0.00	0.00			12/15/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.13	0.11	0.11			12/16/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.04	0.02	0.02			12/16/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.66	0.63	0.63			12/16/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.00	0.00	0.00			12/16/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.46	0.43	0.43			12/17/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.03	0.01	0.01			12/17/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.45	0.42	0.42			12/17/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.03	0.01	0.01			12/17/2015		JA
			MF INF	5.00		0.00	0.00	0.00		0.62	0.59	0.59			12/18/2015		JA
			MF EFF	5.00		0.00	0.00	0.00		0.03	0.01	0.01			12/18/2015		JA
7	9/8/2015	LAB	PA	5.00	-	0.00	0.00	0.00	MA	0.10	0.08	0.08		1	9/8/2015	7:30	JA
8	9/8/2015	LAB	PA	0.50	LAB	4.50	0.00	0.00	MA	0.03	0.01	0.10		1	9/8/2015	7:30	JA
30	9/9/2015	LAB	PA	5.00	-	0.00	0.00	0.00	MA	0.07	0.05	0.05		2	9/8/2015	7:30	JA
31	9/9/2015	LAB	PA	5.00	-	0.00	0.00	0.00	MA	0.01	-0.01	-0.01		2	9/9/2015	7:30	JA
48	9/10/15 13:55	LAB	PA	5.00	-	0.00	0.00	0.00	KZ	0.07	0.05	0.05		3	9/10/2015	7:30	TN
83	9/11/15 13:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA	0.01	-0.01	-0.01		4	9/11/2015	7:30	BA
95	9/15/15 18:30	LAB	PA	5.00	-	0.00	0.00	0.00	KZ	0.26	0.24	0.24		8	9/15/2015	7:30	JA
7	9/16/15 18:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ	0.12	0.10	0.10		9	9/16/2015	8:00	BA
63	AN 9/18/15 8:15	HACH	PA	5.00	-	0.00	0.00	0.00	MA	0.10	0.08	0.08		11	9/18/2015	7:30	BA
73	BA 9/19/15 10:55	HACH	PA	5.00	-	0.00	0.00	0.00	MA	0.17	0.15	0.15		12	9/19/2015	8:49	BA
33	AN 9/20/15 10:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.19	0.17	0.17		13	9/20/2015	8:50	TN
45	AN 9/21/15 10:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.14	0.12	0.12		14	9/21/2015	8:05	BA
27	AN 9/22/15 9:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.21	0.19	0.19		15	9/22/2015	10:05	TN
80	BA 9/23/15 18:00	HACH	PA	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.24	0.22	0.22		16	9/23/2015	8:09	BA
92	AN 9/24/15 11:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.13	0.11	0.11		17	9/24/2015	9:43	TN
4	BA 9/25/15 13:20	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.13	0.11	0.11		18	9/25/2015	8:29	TN

22	AN 9/26/15 15:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.28	0.26	0.26		19	9/26/2015	9:35	BA
73	BA 9/27/15 15:25	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.37	0.35	0.35		20	9/27/2015	8:46	BA
81	AN 9/28/15	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.51	0.48	0.48		21	9/28/2015	8:06	BA
28	BA 9/30/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.35	0.33	0.33		22	9/29/2015	8:50	TA
39	BA 9/30/15 8:30	LAB	PA	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.73	0.70	0.21		23	9/30/2015	7:50	BA
4	AN 10/1/15 13:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.38	0.36	0.36		24	10/1/2015	9:40	JA
18	BA 10/2/15 10:40	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.28	0.26	0.26		25	10/2/2015	7:55	BA
51	BA 10/3/15 11:20	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.07	0.05	0.05		26	10/3/2015	8:59	BA
68	AN 10/4/15 19:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.16	0.14	0.14		27	10/4/2015	9:02	BA
36	BA 10/5/15 20:35	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.18	0.16	0.16		28	10/5/2015	8:04	BA
4	BA 10/6/15 14:11	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/6/15	0.18	0.16	0.16		29	10/6/2015	7:38	BA
14	BA 10/7/15 14:11	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/9/15	0.21	0.19	0.19		30	10/7/2015	7:53	BA
45	AN 10/8/15 14:20	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.20	0.18	0.18		31	10/8/2015	8:48	JA
24	BA 10/9/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/11/18	0.23	0.21	0.21		32	10/9/2015	7:45	BA
5	AN 10/10/15 11:00	LAB	PA	5.00	-	0.00	0.00	0.00	AN 10/13/15	0.22	0.20	0.20		33	10/10/2015	9:45	TN
36	AN 10/11/15 11:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.28	0.26	0.26		34	10/11/2015	9:00	AN
64	BA 10/12/15 17:20	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.17	0.15	0.15		35	10/12/2015	7:45	BA
73	AN 10/13/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.31	0.29	0.29		36	10/13/2015	7:40	TN
85	AN 10/14/15 16:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.17	0.15	0.15		37	10/14/2015	7:50	JA
96	AN 10/15/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.31	0.29	0.29		38	10/15/2015	7:30	JA
14	BA 10/16/15 8:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.30	0.28	0.28		39	10/16/2015	7:23	BA
6	BA 10/17/15 14:50	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.21	0.19	0.19		40	10/17/2015	10:10	TN
28	BA 10/18/15 9:40	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/20/15	0.31	0.29	0.29		41	10/18/2015	8:55	BA
44	BA 10/19/15 19:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.16	0.14	0.14		42	10/19/2015	7:49	BA
40	AN 10/20/15 9:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.15	0.13	0.13		43	10/20/2015	9:00	JA
65	BA 10/21/15 19:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.50	0.47	0.47		44	10/21/2015	7:30	JA
96	BA 10/23/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.31	0.29	0.29		46	10/23/2015	8:30	BA
32	BA 10/26/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.39	0.37	0.37		49	10/26/2015	7:45	JA
47	AN 10/27/15 9:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.17	0.15	0.15		50	10/27/2015	8:02	TN
55	BA 10/28/15 8:00	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.21	0.19	0.19		51	10/28/2015	7:21	JA
10	AN 10/29/15 8:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.16	0.14	0.14		52	10/29/2015	9:12	MA
20	BA 10/30/15 8:20	LAB	PA	5.00		0.00	0.00	0.00	MA 11/4/15	0.17	0.15	0.15		53	10/30/2015	7:51	JA
32	BA 10/31/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/4/15	0.25	0.23	0.23		54	10/31/2015	9:43	BA
43	AN 11/1/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	BA 11/5/15	0.15	0.13	0.13		55	11/1/2015	9:30	TN
50	BA 11/2/15 8:20	LAB	PA	5.00		0.00	0.00	0.00	BA 11/5/15	0.17	0.15	0.15		56	11/2/2015	7:48	BA
60	AN 11/3/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/7/15	0.14	0.12	0.12		57	11/3/2015	7:45	JA
71	BA 11/4/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/7/15	0.16	0.14	0.14		58	11/4/2015	7:44	BA
85	AN 11/5/15 9:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/7/15	0.23	0.21	0.21		59	11/5/2015	8:21	TN
97	BA 11/6/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/7/15	0.21	0.19	0.19		60	11/6/2015	7:25	BA
6	BA 11/7/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/9/15	0.14	0.12	0.12		61	11/7/2015	8:54	BA
25	AN 11/8/15 12:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/9/15	0.16	0.14	0.14		62	11/8/2015	11:30	TN
37	BA 11/9/15 9:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/10/15	0.18	0.16	0.16		63	11/9/2015	7:56	BA
48	AN 11/10/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/11/15	0.15	0.13	0.13		64	11/10/2015	9:20	TN
96	BA 11/11/15 16:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/12/15	0.17	0.15	0.15		65	11/11/2015	7:37	BA
6	AN 11/12/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/13/15	0.18	0.16	0.16		66	11/12/2015	9:40	TN
80	BA 11/13/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/16/15	0.35	0.33	0.33		67	11/13/2015	7:39	BA
65	AN 11/14/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/16/15	0.21	0.19	0.19		68	11/14/2015	10:40	TN
4	AN 11/15/15 10:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/16/15	0.10	0.08	0.08		69	11/15/2015	10:05	AN
13	AN 11/16/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		70	11/16/2015	7:54	BA
30	AN 11/17/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/20/15	0.07	0.05	0.05		71	11/17/2015	9:50	TN
39	BA 11/18/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/20/15	0.08	0.06	0.06		72	11/18/2015	7:36	BA
55	AN 11/19/15 9:30	LAB	PA	5.00		0.00	0.00	0.00	BA 11/22/15	0.06	0.04	0.04		73	11/19/2015	9:10	TN
60	BA 11/20/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/23/15	0.05	0.03	0.03		74	11/20/2015	7:19	BA
74	AN 11/21/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/24/15	0.09	0.07	0.07		75	11/21/2015	10:40	TN
87	AN 11/22/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/24/15	0.06	0.04	0.04		76	11/22/2015	11:40	TN
98	BA 11/23/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/24/15	0.06	0.04	0.04		77	11/23/2015	7:24	BA
49	9/10/15 13:55	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ	0.53	0.50	0.01		3	9/10/2015	7:30	TN
84	9/11/15 13:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA	0.59	0.56	0.07		4	9/11/2015	8:10	BA
96	9/15/15 18:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ	0.66	0.63	0.14		8	9/15/2015	7:30	JA

8	9/16/15 18:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ	0.60	0.57	0.08		9	9/16/2015	10:10	JA
64	AN 9/18/15 8:15	HACH	PA SP 1	5.00	-	0.00	50.00	0.05	MA	0.50	0.47	-0.02		11	9/18/2015	7:30	BA
74	BA 9/19/15 10:55	HACH	PA SP 1	5.00	-	0.00	50.00	0.05	MA	0.64	0.61	0.12		12	9/19/2015	8:49	BA
34	AN 9/20/15 10:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/26/15	0.74	0.71	0.22		13	9/20/2015	8:50	TN
46	AN 9/21/15 10:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/26/15	0.61	0.58	0.09		14	9/21/2015	8:05	BA
56	AN 9/22/15 9:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/26/15	0.69	0.66	0.17		15	9/22/2015	10:05	TN
81	BA 9/23/15 18:00	HACH	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/26/15	0.75	0.72	0.23		16	9/23/2015	8:08	BA
5	BA 9/25/15 13:20	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 9/28/15	0.68	0.65	0.16		18	9/25/2015	8:29	TN
15	AN 9/26/15 15:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/29/15	0.91	0.88	0.39		19	9/26/2015	9:35	BA
74	BA 9/27/15 15:25	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.81	0.78	0.29		20	9/27/2015	8:46	BA
82	AN 9/28/15	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.96	0.93	0.44		21	9/28/2015	8:06	BA
29	BA 9/30/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.55	0.52	0.03		22	9/29/2015	7:50	BA
40	BA 9/30/15 8:30	LAB	PA SP 1	5.00	-	0.00	100.00	0.05	MA 10/3/15	1.13	1.10	0.11		23	9/30/2015	7:50	BA
5	AN 10/1/15 13:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.93	0.90	0.41		24	10/1/2015	9:40	JA
19	BA 10/2/15 10:40	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/4/15	0.77	0.74	0.25		25	10/2/2015	7:55	BA
52	BA 10/3/15 11:20	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/4/15	0.75	0.72	0.23		26	10/3/2015	8:59	BA
69	AN 10/4/15 19:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/5/15	0.80	0.77	0.28		27	10/4/2015	9:02	BA
37	BA 10/5/15 20:35	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/5/15	0.72	0.69	0.20		28	10/5/2015	8:04	BA
5	BA 10/6/15 14:11	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/6/15	0.71	0.68	0.19		29	10/6/2015	7:38	JA
46	AN 10/8/15 14:20	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/10/15	0.76	0.73	0.24		31	10/8/2015	8:48	JA
25	BA 10/9/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/11/19	0.92	0.89	0.40		32	10/9/2015	7:45	BA
6	AN 10/10/15 11:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	AN 10/13/15	0.72	0.69	0.20		33	10/10/2015	9:45	TN
37	AN 10/11/15 11:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/13/15	1.02	0.99	0.50		34	10/11/2015	9:00	AN
65	BA 10/12/15 17:20	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/13/15	0.74	0.71	0.22		35	10/12/2015	7:45	BA
74	AN 10/13/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/14/15	0.95	0.92	0.43		36	10/13/2015	7:40	TN
86	AN 10/14/15 16:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/16/15	0.96	0.93	0.44		37	10/14/2015	7:50	JA
97	AN 10/15/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/16/15	1.05	1.02	0.53		38	10/15/2015	7:50	JA
15	BA 10/16/15 8:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.00	MA 10/18/15	0.89	0.86	0.86		39	10/16/2015	7:23	BA
7	BA 10/17/15 14:50	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/18/15	0.94	0.91	0.42		40	10/17/2015	10:10	TN
29	BA 10/18/15 9:40	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/22/15	0.96	0.93	0.44		41	10/18/2015	8:55	BA
45	BA 10/19/15 19:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/22/15	0.80	0.77	0.28		42	10/19/2015	7:49	BA
53	AN 10/20/15 9:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/22/15	0.85	0.82	0.33		43	10/20/2015	9:00	JA
66	BA 10/21/15 19:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/22/15	1.01	0.98	0.49		44	10/21/2015	7:30	JA
6	AN 10/22/15 10:00	LAB	PA SP 1	5.00	-	0.00	0.00	0.00	MA 10/27/15	1.08	1.05	1.05		45	10/22/2015	8:00	JA
95	BA 10/23/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/27/15	0.96	0.93	0.44		46	10/23/2015	8:30	BA
33	BA 10/26/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/27/15	1.02	0.99	0.50		49	10/26/2015	7:45	JA
48	AN 10/27/15 9:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/28/15	0.04	0.02	-0.48		50	10/27/2015	8:02	TN
56	BA 10/28/15 8:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/28/15	0.76	0.73	0.24		51	10/28/2015	7:21	JA
11	AN 10/29/15 8:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 11/3/15	0.74	0.71	0.22		52	10/29/2015	9:12	MA
21	BA 10/30/15 8:20	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/4/15	0.74	0.71	0.22		53	10/30/2015	7:51	JA
33	BA 10/31/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/4/15	0.82	0.79	0.30		54	10/31/2015	9:43	BA
44	AN 11/1/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	BA 11/5/15	0.70	0.67	0.18		55	11/1/2015	9:30	TN
51	BA 11/2/15 8:20	LAB	PA SP 1	5.00		0.00	50.00	0.05	BA 11/5/15	0.74	0.71	0.22		56	11/2/2015	7:48	BA
61	AN 11/3/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/7/15	0.71	0.68	0.19		57	11/3/2015	7:45	JA
72	BA 11/4/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/7/15	0.73	0.70	0.21		58	11/4/2015	7:44	BA
86	AN 11/5/15 9:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/7/15	0.79	0.76	0.27		59	11/5/2015	8:21	TN
98	BA 11/6/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/7/15	0.79	0.76	0.27		60	11/6/2015	7:25	BA
8	BA 11/7/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/9/15	0.75	0.72	0.23		61	11/7/2015	8:54	BA
26	AN 11/8/15 12:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/9/15	0.78	0.75	0.26		62	11/8/2015	11:30	TN
38	BA 11/9/15 9:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/10/15	0.79	0.76	0.27		63	11/9/2015	7:56	BA
49	AN 11/10/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/11/15	0.77	0.74	0.25		64	11/10/2015	9:20	TN
95	BA 11/11/15 16:00	LAB	PA SP 1	5.00		0.00	50.00	0.00	MA 11/12/15	0.83	0.80	0.80		65	11/11/2015	7:37	BA
8	AN 11/12/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.00	KZ 11/13/15	0.82	0.79	0.79		66	11/12/2015	9:40	TN
79	BA 11/13/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/16/15	1.03	1.00	0.51		67	11/13/2015	7:39	BA
66	AN 11/14/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/16/15	0.90	0.87	0.38		68	11/14/2015	10:40	TN
5	AN 11/15/15 10:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/16/15	1.18	1.15	0.66		69	11/15/2015	10:05	AN
14	AN 11/16/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/16/15	0.79	0.76	0.27		70	11/16/2015	7:54	BA
31	AN 11/17/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/20/15	0.80	0.77	0.28		71	11/17/2015	9:10	TN
40	BA 11/18/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/20/15	0.82	0.79	0.30		72	11/18/2015	7:36	BA

51	AN 11/19/15 9:30	LAB	PA SP 1	5.00		0.00	50.00	0.05	BA 11/22/15	0.84	0.81	0.32		73	11/19/2015	9:10	TN
61	BA 11/20/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/23/15	0.86	0.83	0.34		74	11/20/2015	7:19	BA
75	AN 11/21/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/24/15	0.90	0.87	0.38		75	11/21/2015	10:40	TN/JA
88	AN 11/22/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/24/15	0.9	0.87	0.38		76	11/22/2015	11:40	TN
99	BA 11/23/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/24/15	0.9	0.87	0.38		77	11/23/2015	7:24	BA
50	9/10/15 13:55	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ	0.96	0.93	-0.06		3	9/10/2015	7:50	TN
85	9/11/15 13:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA	0.43	0.40	-0.59		4	9/11/2015	8:10	BA
97	9/15/15 18:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ	1.12	1.09	0.10		8	9/15/2015	7:30	JA
9	9/16/15 18:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ	1.10	1.07	0.08		9	9/16/2015	8:00	BA
65	AN 9/18/15 8:15	HACH	PA SP 2	5.00	-	0.00	100.00	0.05	MA	1.12	1.09	0.10		11	9/18/2015	7:30	BA
75	BA 9/19/15 10:55	HACH	PA SP 2	5.00	-	0.00	100.00	0.05	MA	1.17	1.14	0.15		12	9/19/2015	8:49	BA
35	AN 9/20/15 10:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/26/15	1.19	1.16	0.17		13	9/20/2015	8:50	TN
47	AN 9/21/15 10:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/26/15	1.11	1.08	0.09		14	9/21/2015	8:05	BA
57	AN 9/22/15 9:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/26/15	1.21	1.18	0.19		15	9/22/2015	10:05	TN
82	BA 9/23/15 18:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/26/15	1.23	1.20	0.21		16	9/23/2015	8:08	BA
94	AN 9/24/15 11:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 9/28/15	1.28	1.24	0.26		17	9/24/2015	9:43	TN
6	BA 9/25/15 13:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 9/28/15	1.22	1.19	0.20		18	9/25/2015	8:29	TN
16	AN 9/26/15 15:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/29/15	1.29	1.25	0.27		19	9/26/2015	9:35	BA
75	BA 9/27/15 15:25	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/3/15	1.33	1.29	0.31		20	9/27/2015	8:46	BA
83	AN 9/28/15	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/3/15	1.47	1.43	0.45		21	9/28/2015	8:06	BA
41	BA 9/30/15 8:30	LAB	PA SP 2	5.00	-	0.00	0.00	0.00	MA 10/3/15	1.87	1.83	1.83		23	9/30/2015	7:50	BA
6	AN 10/1/15 13:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/3/15	0.49	0.46	-0.53		24	10/1/2015	9:40	JA
20	BA 10/2/15 10:40	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/4/15	1.31	1.27	0.29		25	10/2/2015	7:55	BA
53	BA 10/3/15 11:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/4/15	1.26	1.22	0.24		26	10/3/2015	8:59	BA
70	AN 10/4/15 19:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/5/15	1.55	1.51	0.53		27	10/4/2015	9:02	BA
38	BA 10/5/15 20:35	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/5/15	1.32	1.28	0.30		28	10/5/2015	8:04	BA
6	BA 10/6/15 14:11	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/6/15	1.28	1.24	0.26		29	10/6/2015	7:38	JA
47	AN 10/8/15 14:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/10/15	1.34	1.30	0.32		31	10/8/2015	8:48	JA
26	BA 10/9/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/11/20	1.45	1.41	0.43		32	10/9/2015	7:45	BA
7	AN 10/10/15 11:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	AN 10/13/15	1.45	1.41	0.43		33	10/10/2015	9:45	TN
38	AN 10/11/15 11:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/13/15	1.62	1.58	0.60		34	10/11/2015	9:00	AN
66	BA 10/12/15 17:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/13/15	1.39	1.35	0.37		35	10/12/2015	7:45	BA
75	AN 10/13/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/14/15	1.57	1.53	0.55		36	10/13/2015	7:40	TN
87	AN 10/14/15 16:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/18/15	1.74	1.70	0.72		37	10/14/2015	7:50	JA
98	AN 10/15/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/16/15	1.61	1.57	0.59		38	10/15/2015	7:50	JA
16	BA 10/16/15 8:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.00	MA 10/18/15	1.62	1.58	1.58		39	10/16/2015	7:23	BA
8	BA 10/17/15 14:50	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/18/15	1.59	1.55	0.57		40	10/17/2015	10:10	TN
30	BA 10/18/15 9:40	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/22/15	1.65	1.61	0.63		41	10/18/2015	8:55	BA
46	BA 10/19/15 19:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/22/15	1.5	1.46	0.48		42	10/19/2015	7:49	BA
54	AN 10/20/15 9:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/22/15	1.50	1.46	0.48		43	10/20/2015	9:00	JA
67	BA 10/21/15 19:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/22/15	0.86	0.83	-0.16		44	10/21/2015	7:30	JA
7	AN 10/22/15 10:00	LAB	PA SP 2	5.00	-	0.00	0.00	0.00	MA 10/27/15	1.76	1.72	1.72		45	10/22/2015	8:00	JA
94	BA 10/23/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/27/15	1.74	1.70	0.72		46	10/23/2015	8:30	BA
34	BA 10/26/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/27/15	1.86	1.82	0.84		49	10/26/2015	7:45	JA
49	AN 10/27/15 9:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/28/15	1.68	1.64	0.66		50	10/27/2015	8:02	TN
57	BA 10/28/15 8:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/28/15	1.37	1.33	0.35		51	10/28/2015	7:21	JA
12	AN 10/29/15 8:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 11/3/15	1.24	1.21	0.22		52	10/29/2015	9:12	MA
22	BA 10/30/15 8:20	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/4/15	1.29	1.25	0.27		53	10/30/2015	7:51	JA
34	BA 10/31/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/4/15	1.37	1.33	0.35		54	10/31/2015	9:43	BA
45	AN 11/1/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	BA 11/5/15	1.26	1.22	0.24		55	11/1/2015	9:30	TN
52	BA 11/2/15 8:20	LAB	PA SP 2	5.00		0.00	100.00	0.05	BA 11/5/15	1.11	1.08	0.09		56	11/2/2015	7:48	BA
62	AN 11/3/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/7/15	1.62	1.58	0.60		57	11/3/2015	7:45	JA
73	BA 11/4/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/7/15	1.10	1.07	0.08		58	11/4/2015	7:44	BA
87	AN 11/5/15 9:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/7/15	1.18	1.15	0.16		59	11/5/2015	8:21	TN
99	BA 11/6/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/7/15	1.18	1.15	0.16		60	11/6/2015	7:25	BA
10	BA 11/7/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/9/15	1.13	1.10	0.11		61	11/7/2015	8:54	BA
27	AN 11/8/15 12:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/9/15	1.15	1.12	0.13		62	11/8/2015	11:30	TN
39	BA 11/9/15 9:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/10/15	1.12	1.09	0.10		63	11/9/2015	7:56	BA
50	AN 11/10/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/11/15	1.20	1.17	0.18		64	11/10/2015	9:20	TN

94	BA 11/11/15 16:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/12/15	1.23	1.20	0.21		65	11/11/2015	7:37	BA
9	AN 11/12/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/13/15	1.26	1.22	0.24		66	11/12/2015	9:40	TN
78	BA 11/13/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/16/15	1.62	1.58	0.60		67	11/13/2015	7:39	BA
67	AN 11/14/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/16/15	1.33	1.29	0.31		68	11/14/2015	10:40	TN
6	AN 11/15/15 10:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/16/15	1.21	1.18	0.19		69	11/15/2015	10:05	TN
15	AN 11/16/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/16/15	1.24	1.21	0.22		70	11/16/2015	7:54	BA
32	AN 11/17/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/20/15	1.25	1.22	0.23		71	11/17/2015	9:40	TN
41	BA 11/18/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/20/15	1.24	1.21	0.22		72	11/18/2015	7:36	BA
52	AN 11/19/15 9:30	LAB	PA SP 2	5.00		0.00	100.00	0.05	BA 11/22/15	1.34	1.30	0.32		73	11/19/2015	9:10	TN
62	BA 11/20/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/23/15	1.45	1.41	0.43		74	11/20/2015	7:19	BA
76	AN 11/21/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/24/15	1.45	1.41	0.43		75	11/21/2015	10:40	TN/JA
89	AN 11/22/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/24/15	1.51	1.47	0.49		76	11/22/2015	11:40	TN
100	BA 11/23/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/24/15	1.53	1.49	0.51		77	11/23/2015	7:24	BA
5	9/8/2015	LAB	PDF	5.00	-	0.00	0.00	0.00	MA	0.20	0.18	0.18		1	9/8/2015	9:10	TN
6	9/8/2015	LAB	PDF	0.50	LAB	4.50	0.00	0.00	MA	0.30	0.28	2.76		1	9/8/2015	9:10	TN
32	9/9/2015	LAB	PDF	5.00	-	0.00	0.00	0.00	MA	0.06	0.04	0.04		2	9/9/2015	8:12	BA
33	9/9/2015	LAB	PDF	5.00	-	0.00	0.00	0.00	MA	0.05	0.03	0.03		2	9/9/2015	8:12	BA
54	9/10/15 13:55	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.08	0.06	0.06		3	9/10/2015	9:50	TN
87	9/11/15 13:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.07	0.05	0.05		4	9/11/2015	8:10	BA
88	9/11/15 13:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.09	0.07	0.07		4	9/11/2015	8:10	BA
99	9/15/15 18:30	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.07	0.05	0.05		8	9/15/2015	9:50	TN
12	9/17/15 17:23	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.09	0.07	0.07		9	9/16/2015	13:40	JA
78	BA 9/19/15 10:55	HACH	PDF	5.00	-	0.00	0.00	0.00	MA	0.04	0.02	0.02		12	9/19/2015	8:50	BA
36	AN 9/20/15 10:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.52	0.49	0.49		13	9/20/2015	8:30	TN
48	AN 9/21/15 10:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.11	0.09	0.09		14	9/21/2015	8:06	BA
58	AN 9/22/15 9:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.13	0.11	0.11		15	9/22/2015	10:10	TN
85	BA 9/23/15 18:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.16	0.14	0.14		16	9/23/2015	8:09	BA
97	AN 9/24/15 11:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.09	0.07	0.07		17	9/24/2015	9:47	TN
9	BA 9/25/15 13:20	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.11	0.09	0.09		18	9/25/2015	8:33	TN
20	AN 9/26/15 15:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.2	0.18	0.18		19	9/26/2015	9:45	BA
78	BA 9/27/15 15:25	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.26	0.24	0.24		20	9/27/2015	8:56	BA
31	BA 9/30/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.22	0.20	0.20		22	9/29/2015	7:45	BA
7	AN 10/1/15 13:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.29	0.27	0.27		24	10/1/2015	9:41	JA
21	BA 10/2/15 10:40	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.26	0.24	0.24		25	10/2/2015	7:57	BA
54	BA 10/3/15 11:20	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.23	0.21	0.21		26	10/3/2015	9:00	BA
71	AN 10/4/15 19:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.18	0.16	0.16		27	10/4/2015	9:04	BA
10	BA 10/6/15 14:11	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/6/15	0.10	0.08	0.08		28	10/5/2015	13:28	BA
9	BA 10/6/15 14:11	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/6/15	0.13	0.11	0.11		29	10/6/2015	13:28	BA
56	AN 10/8/15 14:20	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.12	0.10	0.10		30	10/7/2015	8:48	JA
49	AN 10/8/15 14:20	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.12	0.10	0.10		31	10/8/2015	8:48	JA
28	BA 10/9/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/11/22	0.14	0.12	0.12		32	10/9/2015	7:50	BA
91	AN 10/14/15 16:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.21	0.19	0.19		33	10/14/2015	7:55	AN
35	AN 10/11/15 11:00	LAB	PDF	5.00	-	0.00	0.00	0.00	AN 10/13/15	0.15	0.13	0.13		34	10/11/2015	9:15	AN
69	BA 10/12/15 17:20	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.12	0.10	0.10		35	10/12/2015	7:50	JA
76	AN 10/13/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.18	0.16	0.16		36	10/13/2015	7:40	TN
100	AN 10/15/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.45	0.42	0.42		38	10/15/2015	7:50	TN
19	BA 10/16/15 8:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.43	0.40	0.40		39	10/16/2015	7:27	BA
31	BA 10/18/15 9:40	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.30	0.28	0.28		41	10/18/2015	8:59	BA
47	BA 10/19/15 19:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.26	0.24	0.24		42	10/19/2015	7:51	JA
55	AN 10/20/15 9:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.17	0.15	0.15		43	10/20/2015	9:00	TN
68	BA 10/21/15 19:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.29	0.27	0.27		44	10/21/2015	7:27	BA
8	AN 10/22/15 10:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.28	0.26	0.26		45	10/22/2015	8:10	JA
93	BA 10/23/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.23	0.21	0.21		46	10/23/2015	8:30	BA
20	AN 10/24/15 10:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.34	0.32	0.32		47	10/24/2015	9:10	TN
27	AN 10/24/15 10:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.25	0.23	0.23		48	10/24/2015	9:10	TN
35	BA 10/26/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.27	0.25	0.25		49	10/26/2015	7:47	BA
42	AN 10/27/15 9:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.26	0.24	0.24		50	10/27/2015	8:05	TN
58	BA 10/28/15 8:00	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.41	0.39	0.39		51	10/28/2015	7:27	BA
5	AN 10/29/15 8:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.15	0.13	0.13		52	10/29/2015	9:14	BA

23	BA 10/30/15 8:20	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/4/15	0.29	0.27	0.27		53	10/30/2015	7:53	BA
35	BA 10/31/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/4/15	0.21	0.19	0.19		54	10/31/2015	9:42	BA
46	AN 11/1/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	BA 11/5/15	0.23	0.21	0.21		55	11/1/2015	9:30	TN
53	BA 11/2/15 8:20	LAB	PDF	5.00		0.00	0.00	0.00	BA 11/5/15	0.19	0.17	0.17		56	11/2/2015	7:50	BA
66	AN 11/3/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/7/15	0.21	0.19	0.19		57	11/3/2015	7:45	TN
74	BA 11/4/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/7/15	0.26	0.24	0.24		58	11/4/2015	7:42	BA
89	AN 11/5/15 9:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/7/15	0.22	0.20	0.20		59	11/5/2015	8:23	TN
100	BA 11/6/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/7/15	0.28	0.26	0.26		60	11/6/2015	7:30	BA
11	BA 11/7/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/9/15	0.21	0.19	0.19		61	11/7/2015	9:00	BA
28	AN 11/8/15 12:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/9/15	0.20	0.18	0.18		62	11/8/2015	11:40	TN
40	BA 11/9/15 9:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/10/15	0.35	0.33	0.33		63	11/9/2015	8:00	BA
20	AN 11/10/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/11/15	0.20	0.18	0.18		64	11/10/2015	9:30	TN
85	AN 11/11/15 16:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/12/15	0.31	0.29	0.29		65	11/11/2015	7:42	BA
10	AN 11/12/15 8:00	LAB	PDF	5.00		0.00	0.00	0.05	KZ 11/13/15	0.09	0.07	0.07		66	11/12/2015	9:50	TN
75	BA 11/13/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.59	0.56	0.56		67	11/13/2015	7:40	BA
69	AN 11/14/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.06	0.04	0.04		68	11/14/2015	10:50	TN
7	AN 11/15/15 10:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		69	11/15/2015	10:10	AN
16	AN 11/16/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		70	11/16/2015	8:00	BA
33	AN 11/17/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/20/15	0.09	0.07	0.07		71	11/17/2015	9:50	TN
42	BA 11/18/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/20/15	0.07	0.05	0.05		72	11/18/2015	7:56	BA
53	AN 11/19/15 9:30	LAB	PDF	5.00		0.00	0.00	0.00	BA 11/22/15	0.04	0.02	0.02		73	11/19/2015	9:15	TN
63	BA 11/20/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/23/15	0.07	0.05	0.05		74	11/20/2015	7:20	BA
77	AN 11/21/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.07	0.05	0.05		75	11/21/2015	10:40	TN
90	AN 11/22/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.07	0.05	0.05		76	11/22/2015	11:40	TN
1	BA 11/23/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.06	0.04	0.04		77	11/23/2015	7:26	BA
28	9/9/2015	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA	0.2	0.18	0.89		2	9/9/2015	8:00	BA
29	9/9/2015	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA	0.14	0.12	0.59		2	9/9/2015	8:00	BA
46	9/10/15 13:55	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.17	0.15	0.74		3	9/10/2015	7:30	TN
59	9/11/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.36	0.34	1.68		4	9/11/2015	7:55	BA
92	9/15/15 18:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.37	0.35	1.73		8	9/15/2015	9:30	TN
4	9/16/15 18:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.71	0.68	3.41		9	9/16/2015	7:30	JA
61	AN 9/18/15 8:15	HACH	PE	1.00	LAB	4.00	0.00	0.00	MA	0.37	0.35	1.73		11	9/18/2015	7:20	JA/BA
31	AN 9/20/15 10:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 9/26/15	0.35	0.33	1.63		13	9/20/2015	8:00	TN
43	AN 9/21/15 10:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 9/26/15	0.46	0.43	2.17		14	9/21/2015	7:55	JA
53	AN 9/22/15 9:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 9/26/15	0.58	0.55	2.77	Used vial 68 from 9/32 to zero	15	9/22/2015	10:00	JA
68	BA 9/23/15 18:00	HACH	PE	1.00	LAB	4.00	0.00	0.00	MA 9/26/15	0.42	0.39	1.97		16	9/23/2015	7:45	JA
90	AN 9/24/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 9/28/15	0.56	0.53	2.67		17	9/24/2015	9:35	JA
2	BA 9/25/15 13:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 9/28/15	0.49	0.46	2.32		18	9/25/2015	8:15	JA
13	AN 9/26/15 15:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 9/29/15	0.53	0.50	2.52		19	9/26/2015	9:21	BA
71	BA 9/27/15 15:25	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.71	0.68	3.41		20	9/27/2015	8:36	BA
69	AN 9/28/15	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.69	0.66	3.31		21	9/28/2015	7:57	BA
26	BA 9/30/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.81	0.78	3.90		22	9/29/2015	7:40	JA
37	BA 9/30/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.40	0.38	1.88		23	9/30/2015	7:40	JA
12	AN 10/1/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.76	0.73	3.65		24	10/1/2015	9:35	JA
15	BA 10/2/15 10:40	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/4/15	0.72	0.69	3.46		25	10/2/2015	7:45	JA
49	BA 10/3/15 11:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/4/15	0.43	0.40	2.02		26	10/3/2015	8:34	BA
61	AN 10/4/15 19:00	LAB	PE	1.00	LAB	1.00	0.00	0.00	KZ 10/5/15	0.45	0.42	0.85		27	10/4/2015	8:42	BA
32	BA 10/5/15 20:35	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/5/15	0.45	0.42	2.12		28	10/5/2015	7:55	JA
2	BA 10/6/15 14:11	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/6/15	0.44	0.41	2.07		29	10/6/2015	7:55	JA
12	BA 10/7/15 14:11	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/9/15	1.08	1.05	5.24		30	10/7/2015	7:44	JA
42	AN 10/8/15 14:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/10/15	0.4	0.38	1.88		31	10/8/2015	8:40	JA
21	BA 10/9/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/11/15	0.42	0.39	1.97		32	10/9/2015	7:37	BA
59	AN 10/11/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	AN 10/13/15	0.95	0.92	4.59		34	10/11/2015	8:30	AN
71	AN 10/13/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/14/15	0.91	0.88	4.40		36	10/13/2015	7:30	JA
83	AN 10/14/15 16:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/16/15	0.82	0.79	3.95		37	10/14/2015	7:40	JA
93	AN 10/15/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/16/15	0.83	0.80	4.00		38	10/15/2015	7:35	JA
3	BA 10/17/15 14:50	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/18/15	0.71	0.68	3.41		40	10/17/2015	9:30	TN
22	BA 10/17/15 14:50	LAB	PE	1.00	-	0.00	0.00	0.00	MA 10/18/15	0.78	0.75	0.75		40	10/17/2015	9:30	TN
25	BA 10/18/15 9:40	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/20/15	0.86	0.83	4.15		41	10/18/2015	8:40	BA

42	BA 10/19/15 19:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/22/15	0.62	0.59	2.96		42	10/19/2015	7:34	BA
38	AN 10/20/15 9:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/22/15	0.68	0.65	3.26		43	10/20/2015	8:30	JA
62	BA 10/21/15 19:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/22/15	0.72	0.69	3.46		44	10/21/2015	7:12	BA
3	AN 10/22/15 10:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/27/15	0.65	0.62	3.11		45	10/22/2015	8:15	JA
99	BA 10/23/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/27/15	0.60	0.57	2.86		46	10/23/2015	8:19	BA
15	AN 10/24/15 10:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/27/15	0.59	0.56	2.81		47	10/24/2015	8:30	TN
23	AN 10/24/15 10:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/27/15	0.50	0.47	2.37		48	10/24/2015	8:30	TN
29	BA 10/26/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/27/15	0.65	0.62	3.11		49	10/26/2015	7:35	JA
40	AN 10/27/15 9:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/27/15	0.52	0.49	2.47		50	10/27/2015	7:45	JA
52	BA 10/28/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/28/15	0.82	0.79	3.95		51	10/28/2015	7:06	JA
3	AN 10/29/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/3/15	0.48	0.45	2.27		52	10/29/2015	8:55	BA
15	BA 10/30/15 8:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/4/15	0.94	0.91	4.54		53	10/30/2015	7:29	JA
29	BA 10/31/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/4/15	0.52	0.49	2.47		54	10/31/2015	9:32	BA
41	AN 11/1/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 11/5/15	0.53	0.50	2.52		55	11/1/2015	9:00	TN
39	BA 11/2/15 8:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 11/5/15	0.51	0.48	2.42		56	11/2/2015	7:35	JA
58	AN 11/3/15 8:00	LAB	PE	1.20	LAB	4.00	0.00	0.00	MA 11/7/15	0.58	0.55	2.40		57	11/3/2015	7:40	JA
68	BA 11/4/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/7/15	0.88	0.85	4.25		58	11/4/2015	11:37	JA
83	AN 11/5/15 9:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/7/15	0.61	0.58	2.91		59	11/5/2015	8:50	TN
94	BA 11/6/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/7/15	0.65	0.62	3.11		60	11/6/2015	7:19	BA
3	BA 11/7/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/7/15	0.36	0.34	1.68		61	11/7/2015	8:40	BA
32	AN 11/8/15 12:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/9/15	0.53	0.50	2.52		62	11/8/2015	10:50	TN
34	BA 11/9/15 9:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/10/15	1.04	1.01	5.04		63	11/9/2015	7:49	BA
47	AN 11/10/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/11/15	0.64	0.61	3.06		64	11/10/2015	9:15	TN
99	BA 11/11/15 16:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/12/15	0.96	0.93	4.64		65	11/11/2015	7:20	BA
4	AN 11/12/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/13/15	0.59	0.56	2.81		66	11/12/2015	9:30	TN
83	BA 11/13/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/16/15	0.28	0.26	1.28		67	11/13/2015	7:20	BA
11	AN 11/16/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/16/15	0.41	0.39	1.93		70	11/16/2015	7:45	BA
36	BA 11/18/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/20/15	0.32	0.30	1.48		72	11/18/2015	7:27	BA
49	AN 11/19/15 9:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 11/22/15	0.30	0.28	1.38		73	11/19/2015	8:50	TN
82	AN 11/21/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/24/15	0.45	0.42	2.12		75	11/21/2015	10:20	TN
85	AN 11/22/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/24/15	0.40	0.38	1.88		76	11/22/2015	11:20	TN
95	BA 11/23/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/24/15	0.23	0.21	1.04		77	11/23/2015	7:15	BA
11	9/8/2015	LAB	PFC	5.00	-	0.00	0.00	0.00	MA	0.53	0.50	0.50		1	9/8/2015	9:05	TN
12	9/8/2015	LAB	PFC	0.50	LAB	4.50	0.00	0.00	MA	0.80	0.77	7.70		1	9/8/2015	9:05	TN
13	9/8/2015	LAB	PFC	5.00	-	0.00	0.00	0.00	MA	0.42	0.39	0.39		1	9/8/2015	9:05	TN
14	9/8/2015	LAB	PFC	0.50	LAB	4.50	0.00	0.00	MA	0.06	0.04	0.39		1	9/8/2015	9:05	TN
20	9/9/2015	LAB	PFC	5.00	-	0.00	0.00	0.00	MA	0.41	0.39	0.39		2	9/9/2015	8:10	BA
21	9/9/2015	LAB	PFC	5.00	-	0.00	0.00	0.00	MA	0.41	0.39	0.39		2	9/9/2015	8:10	BA
47	9/10/15 13:55	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ	0.24	0.22	0.43		3	9/10/2015	9:50	TN
60	9/11/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ	0.27	0.25	0.49		4	9/11/2015	8:05	BA
93	9/15/15 18:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ	0.21	0.19	0.37		8	9/15/2015	9:40	TN
5	9/16/15 18:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ	0.30	0.28	0.55		9	9/16/2015	8:00	BA
62	AN 9/18/15 8:15	HACH	PFC	2.50	LAB	2.50	0.00	0.00	MA	0.27	0.25	0.49		11	9/18/2015	7:30	BA
72	BA 9/19/15 10:55	HACH	PFC	2.50	LAB	2.50	0.00	0.00	MA	0.24	0.22	0.43		12	9/19/2015	8:47	BA
32	AN 9/20/15 10:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/26/15	0.06	0.04	0.08		13	9/20/2015	8:45	TN
44	AN 9/21/15 10:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/26/15	0.33	0.31	0.61		14	9/21/2015	8:04	BA
54	AN 9/22/15 9:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/26/15	0.47	0.44	0.89		15	9/22/2015	10:05	TN
79	BA 9/23/15 18:00	HACH	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/26/15	0.55	0.52	1.05		16	9/23/2015	8:07	BA
3	BA 9/25/15 13:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 9/28/15	0.46	0.43	0.87		18	9/25/2015	8:31	TN
14	AN 9/26/15 15:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/29/15	0.59	0.56	1.13		19	9/26/2015	9:40	BA
72	BA 9/27/15 15:25	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.66	0.63	1.26		20	9/27/2015	8:45	BA
80	AN 9/28/15	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.75	0.72	1.44		21	9/28/2015	8:05	BA
27	BA 9/30/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.74	0.71	1.42		22	9/29/2015	7:51	BA
38	BA 9/30/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.78	0.75	1.50		23	9/30/2015	7:51	BA
3	AN 10/1/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.83	0.80	1.60		24	10/1/2015	9:39	JA
16	BA 10/2/15 10:40	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/4/15	0.74	0.71	1.42		25	10/2/2015	7:53	BA
50	BA 10/3/15 11:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/4/15	0.65	0.62	1.24		26	10/3/2015	8:57	BA
62	AN 10/4/15 19:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/5/15	0.57	0.54	1.09		27	10/4/2015	9:00	BA
33	BA 10/5/15 20:35	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/5/15	0.5	0.47	0.95		28	10/5/2015	8:02	BA

3	BA 10/6/15 14:11	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/6/15	0.47	0.44	0.89		29	10/6/2015	7:40	JA
13	BA 10/7/15 14:11	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/9/15	0.45	0.42	0.85		30	10/7/2015	7:55	BA
44	AN 10/8/15 14:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/10/15	0.37	0.35	0.69		31	10/8/2015	8:49	JA
22	BA 10/9/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/11/16	0.46	0.43	0.87		32	10/9/2015	7:40	BA
4	AN 10/10/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	AN 10/13/15	0.53	0.50	1.01		33	10/10/2015	9:05	TN
34	AN 10/11/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	AN 10/13/15	0.81	0.78	1.56		34	10/11/2015	9:10	AN
63	BA 10/12/15 17:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/13/15	0.74	0.71	1.42		35	10/12/2015	7:50	BA
72	AN 10/13/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/14/15	0.88	0.85	1.70		36	10/13/2015	7:39	TN
84	AN 10/14/15 16:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/16/15	0.72	0.69	1.38		37	10/14/2015	7:51	JA
95	AN 10/15/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/16/15	0.83	0.80	1.60		38	10/15/2015	7:50	JA
12	BA 10/16/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.05	MA 10/18/15	0.89	0.86	1.74		39	10/16/2015	7:22	BA
4	BA 10/17/15 14:50	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/18/15	0.79	0.76	1.52		40	10/17/2015	10:00	TN
26	BA 10/18/15 9:40	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/20/15	0.85	0.82	1.64		41	10/18/2015	8:54	BA
43	BA 10/19/15 19:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/22/15	0.74	0.71	1.42		42	10/19/2015	7:45	BA
39	AN 10/20/15 9:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/22/15	0.67	0.64	1.28		43	10/20/2015	9:00	JA
63	BA 10/21/15 19:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/22/15	0.73	0.70	1.40		44	10/21/2015	7:29	JA
98	BA 10/23/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/27/15	0.69	0.66	1.32		46	10/23/2015	8:29	BA
16	AN 10/24/15 10:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/27/15	0.66	0.63	1.26		47	10/24/2015	9:10	TN
24	AN 10/24/15 10:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/27/15	0.69	0.66	1.32		48	10/24/2015	9:10	TN
30	BA 10/26/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/27/15	0.64	0.61	1.22		49	10/26/2015	7:43	JA
41	AN 10/27/15 9:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/28/15	0.62	0.59	1.19		50	10/27/2015	8:00	TN
53	BA 10/28/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/28/15	0.67	0.64	1.28		51	10/28/2015	7:20	JA
4	AN 10/29/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/3/15	0.63	0.60	1.20		52	10/29/2015	9:08	MA
18	BA 10/30/15 8:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/4/15	0.59	0.56	1.13		53	10/30/2015	7:50	JA
30	BA 10/31/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/4/15	0.61	0.58	1.17		54	10/31/2015	9:45	BA
42	AN 11/1/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 11/5/15	0.58	0.55	1.11		55	11/1/2015	9:30	TN
40	BA 11/2/15 8:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 11/5/15	0.54	0.51	1.03		56	11/2/2015	7:46	BA
59	AN 11/3/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/7/15	0.54	0.51	1.03		57	11/3/2015	7:40	JA
69	BA 11/4/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/7/15	0.59	0.56	1.13		58	11/4/2015	7:42	BA
84	AN 11/5/15 9:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/7/15	0.57	0.54	1.09		59	11/5/2015	8:20	TN
95	BA 11/6/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/7/15	0.56	0.53	1.07		60	11/6/2015	7:23	BA
4	BA 11/7/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/9/15	0.59	0.56	1.13		61	11/7/2015	8:53	BA
24	AN 11/8/15 12:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/9/15	0.55	0.52	1.05		62	11/8/2015	11:20	TN
35	BA 11/9/15 9:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/10/15	0.58	0.55	1.11		63	11/9/2015	7:54	BA
7	AN 11/10/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/11/15	0.70	0.67	1.34		64	11/10/2015	9:20	TN
98	BA 11/11/15 16:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/12/15	0.60	0.57	1.15		65	11/11/2015	7:35	BA
5	AN 11/12/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/13/15	0.61	0.58	1.17		66	11/12/2015	9:40	TN
82	BA 11/13/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/16/15	0.36	0.34	0.67		67	11/13/2015	7:38	BA
64	AN 11/14/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/16/15	0.29	0.27	0.53		68	11/14/2015	10:30	TN
3	AN 11/15/15 10:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/16/15	0.29	0.27	0.53		69	11/15/2015	10:00	AN
12	AN 11/16/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/16/15	0.26	0.24	0.47		70	11/16/2015	7:50	BA
29	AN 11/17/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/20/15	0.22	0.20	0.39		71	11/17/2015	9:30	TN
37	BA 11/18/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/20/15	0.23	0.21	0.41		72	11/18/2015	7:35	BA
50	AN 11/19/15 9:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 11/22/15	0.18	0.16	0.32		73	11/19/2015	9:00	TN
73	AN 11/21/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/24/15	0.14	0.12	0.24		75	11/21/2015	10:40	TN/JA
86	AN 11/22/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/24/15	0.17	0.15	0.30		76	11/22/2015	11:30	TN
97	BA 11/23/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/24/15	0.15	0.13	0.26		77	11/23/2015	7:23	BA
22	9/9/2015	LAB	PFC SP 1	5.00	-	0.00	50.00	0.05	MA	1.23	1.20	0.71		2	9/9/2015	8:10	BA
23	9/9/2015	LAB	PFC SP 1	5.00	-	0.00	50.00	0.05	MA	0.47	0.44	-0.05		2	9/9/2015	8:10	BA
24	9/9/2015	LAB	PFC SP 2	5.00	-	0.00	100.00	0.05	MA	1.41	1.37	0.39		2	9/9/2015	8:10	BA
25	9/9/2015	LAB	PFC SP 2	5.00	-	0.00	100.00	0.05	MA	1.40	1.36	0.38		2	9/9/2015	8:10	BA
86	9/11/15 13:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA	0.20	0.18	0.18		4	9/11/2015	13:00	BA
98	9/15/15 18:30	LAB	STD	5.00	-	0.00	0.00	0.00	KZ	0.20	0.18	0.18		8	9/15/2015	18:30	BA
10	9/16/15 18:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ	0.19	0.17	0.17		9	9/16/2015	18:00	TN
67	AN 9/18/15 8:15	HACH	STD	5.00	-	0.00	0.00	0.00	MA	0.23	0.21	0.21		11	9/18/2015	8:15	TN
77	BA 9/19/15 10:55	HACH	STD	5.00	-	0.00	0.00	0.00	MA	0.20	0.18	0.18		12	9/19/2015	10:55	BA
41	AN 9/20/15 10:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.19	0.17	0.17		13	9/20/2015	10:30	TN
50	AN 9/21/15 10:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.23	0.21	0.21		14	9/21/2015	10:30	TN
60	AN 9/22/15 9:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.18	0.16	0.16		15	9/22/2015	9:30	TN

84	BA 9/23/15 18:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.21	0.19	0.19		16	9/23/2015	18:00	BA
95	AN 9/24/15 11:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.19	0.17	0.17		17	9/24/2015	11:00	TN
8	BA 9/25/15 13:20	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.19	0.17	0.17		18	9/25/2015	13:20	BA
18	AN 9/26/15 15:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.20	0.18	0.18		19	9/26/2015	15:30	TN
77	BA 9/27/15 15:25	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.20	0.18	0.18		20	9/27/2015	15:25	BA
85	AN 9/28/15	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.21	0.19	0.19		21	9/28/2015	9:00	TN
35	BA 9/30/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.2	0.18	0.18		22	9/29/2015	8:30	BA
47	BA 9/30/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.20	0.18	0.18		23	9/30/2015	8:30	BA
10	AN 10/1/15 13:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.21	0.19	0.19		24	10/1/2015	13:00	TN
48	BA 10/2/15 10:40	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.21	0.19	0.19		25	10/2/2015	10:40	BA
59	BA 10/3/15 11:20	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.19	0.17	0.17		26	10/3/2015	11:20	BA
63	AN 10/4/15 19:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.19	0.17	0.17		27	10/4/2015	19:00	TN
34	BA 10/5/15 20:35	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.19	0.17	0.17		28	10/5/2015	20:35	BA
7	BA 10/6/15 14:11	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/6/15	0.19	0.17	0.17		29	10/6/2015	14:11	BA
19	BA 10/7/15 14:11	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/9/15	0.21	0.19	0.19		30	10/7/2015	14:11	BA
48	AN 10/8/15 14:20	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.20	0.18	0.18		31	10/8/2015	14:20	TN
27	BA 10/9/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/11/21	0.19	0.17	0.17		32	10/9/2015	8:30	BA
39	AN 10/11/15 11:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.21	0.19	0.19		34	10/11/2015	11:00	TN
68	BA 10/12/15 17:20	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.20	0.18	0.18		35	10/12/2015	17:20	BA
77	AN 10/13/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.19	0.17	0.17		36	10/13/2015	8:30	TN
88	AN 10/14/15 16:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.21	0.19	0.19		37	10/14/2015	16:00	TN
99	AN 10/15/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.20	0.18	0.18		38	10/15/2015	8:30	TN
18	BA 10/16/15 8:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.20	0.18	0.18		39	10/16/2015	8:00	BA
10	BA 10/17/15 14:50	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.20	0.18	0.18		40	10/17/2015	14:50	BA
35	BA 10/18/15 9:40	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.20	0.18	0.18		41	10/18/2015	9:40	BA
51	BA 10/19/15 19:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.20	0.18	0.18		42	10/19/2015	19:00	BA
59	AN 10/20/15 9:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.20	0.18	0.18		43	10/20/2015	9:00	TN
71	BA 10/21/15 19:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/23/15	0.20	0.18	0.18		44	10/21/2015	19:00	BA
90	BA 10/23/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.17	0.15	0.15		46	10/23/2015	8:30	BA
19	AN 10/24/15 10:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.20	0.18	0.18		47	10/24/2015	10:00	TN
26	AN 10/24/15 10:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.20	0.18	0.18		48	10/24/2015	10:00	TN
37	BA 10/26/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.19	0.17	0.17		49	10/26/2015	8:30	BA
43	AN 10/27/15 9:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.21	0.19	0.19		50	10/27/2015	9:00	TN
61	BA 10/28/15 8:00	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.19	0.17	0.17		51	10/28/2015	8:00	BA
6	AN 10/29/15 8:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.19	0.17	0.17		52	10/29/2015	8:00	TN
27	BA 10/30/15 8:20	LAB	STD	5.00		0.00	0.00	0.00	MA 11/4/15	0.19	0.17	0.17		53	10/30/2015	8:20	BA
37	BA 10/31/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/4/15	0.19	0.17	0.17		54	10/31/2015	11:00	BA
47	AN 11/1/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	BA 11/5/15	0.19	0.17	0.17		55	11/1/2015	11:00	TN
55	BA 11/2/15 8:20	LAB	STD	5.00		0.00	0.00	0.00	BA 11/5/15	0.20	0.18	0.18		56	11/2/2015	8:20	BA
64	AN 11/3/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/7/15	0.19	0.17	0.17		57	11/3/2015	8:00	TN
77	BA 11/4/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/7/15	0.19	0.17	0.17		58	11/4/2015	8:00	BA
88	AN 11/5/15 9:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/7/15	0.19	0.17	0.17		59	11/5/2015	9:00	TN
1	BA 11/6/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/7/15	0.19	0.17	0.17		60	11/6/2015	8:00	BA
15	BA 11/7/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/9/15	0.23	0.21	0.21		61	11/7/2015	11:00	BA
29	AN 11/8/15 12:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/9/15	0.20	0.18	0.18		62	11/8/2015	12:00	TN
43	BA 11/9/15 9:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/10/15	0.19	0.17	0.17		63	11/9/2015	9:00	BA
19	AN 11/10/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/11/15	0.20	0.18	0.18		64	11/10/2015	13:00	TN
93	BA 11/11/15 16:00	LAB	STD	5.00		0.00	0.00	0.05	MA 11/12/15	0.19	0.17	0.17		65	11/11/2015	16:00	BA
11	AN 11/12/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/13/15	0.19	0.17	0.17		66	11/12/2015	8:00	TN
76	BA 11/13/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/16/15	0.19	0.17	0.17		67	11/13/2015	13:00	BA
68	AN 11/14/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/16/15	0.20	0.18	0.18		68	11/14/2015	11:00	TN
8	AN 11/15/15 10:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/16/15	0.20	0.18	0.18		69	11/15/2015	10:00	TN
18	AN 11/16/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/16/15	0.19	0.17	0.17		70	11/16/2015	13:00	TN
34	AN 11/17/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/20/15	0.15	0.13	0.13		71	11/17/2015	13:00	TN
45	BA 11/18/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/20/15	0.2	0.18	0.18		72	11/18/2015	8:00	BA
54	AN 11/19/15 9:30	LAB	STD	5.00		0.00	0.00	0.00	BA 11/22/15	0.21	0.19	0.19		73	11/19/2015	9:30	TN
66	BA 11/20/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/23/15	0.20	0.18	0.18		74	11/20/2015	8:00	BA
78	AN 11/21/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/24/15	0.23	0.21	0.21		75	11/21/2015	11:00	TN
91	AN 11/22/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/24/15	0.20	0.18	0.18		76	11/22/2015	13:00	TN

4	BA 11/23/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/24/15	0.19	0.17	0.17		77	11/23/2015	8:00	BA
9	9/8/2015	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA	0.06	0.04	0.04		1	9/8/2015	9:19	TN
10	9/8/2015	LAB	UF 1	0.50	LAB	4.50	0.00	0.00	MA	0.04	0.02	0.20		1	9/8/2015	9:19	TN
36	9/9/2015	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA	0.09	0.07	0.07		2	9/9/2015	8:06	BA
37	9/9/2015	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA	0.1	0.08	0.08		2	9/9/2015	8:06	BA
55	9/10/15 13:55	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ	0.08	0.06	0.06		3	9/10/2015	9:42	TN
89	9/11/15 13:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA	0.05	0.03	0.03		4	9/11/2015	8:00	BA
100	9/15/15 18:30	HACH	UF 1	5.00	-	0.00	0.00	0.00	KZ	0.12	0.10	0.10		8	9/15/2015	9:50	TN
13	9/17/15 17:23	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ	0.06	0.04	0.04		9	9/16/2015	13:40	JA
86	BA 9/23/15 18:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.08	0.06	0.06		16	9/23/2015	8:00	BA
98	AN 9/24/15 11:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.06	0.04	0.04		17	9/24/2015	9:41	TN
10	BA 9/25/15 13:20	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.06	0.04	0.04		18	9/25/2015	8:34	TN
21	AN 9/26/15 15:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.17	0.15	0.15		19	9/26/2015	9:30	BA
63	BA 9/27/15 15:25	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.17	0.15	0.15		20	9/27/2015	8:50	BA
86	AN 9/28/15	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.23	0.21	0.21		21	9/28/2015	8:00	BA
32	BA 9/30/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.13	0.11	0.11		22	9/29/2015	7:53	BA
43	BA 9/30/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.26	0.24	0.24		23	9/30/2015	7:53	BA
8	AN 10/1/15 13:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.18	0.16	0.16		24	10/1/1930	9:37	JA
22	BA 10/2/15 10:40	LAB	UF 1	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.18	0.16	0.16		25	10/2/1930	7:53	BA
55	BA 10/3/15 11:20	LAB	UF 1	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.08	0.06	0.06		26	10/3/1930	9:03	BA
64	AN 10/4/15 19:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.07	0.05	0.05		27	10/4/1930	8:55	BA
53	AN 10/8/15 14:20	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.03	0.01	0.01		30	10/7/2015	8:45	JA
50	AN 10/8/15 14:20	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.07	0.05	0.05		31	10/8/2015	8:45	JA
29	BA 10/9/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/11/23	0.06	0.04	0.04		32	10/9/2015	7:38	BA
10	AN 10/10/15 11:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	AN 10/13/15	0.08	0.06	0.06		33	10/10/2015	9:30	TN
57	AN 10/11/15 11:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.11	0.09	0.09		34	10/11/2015	9:15	TN
20	BA 10/16/15 8:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.30	0.28	0.28		39	10/16/2015	7:23	BA
32	BA 10/18/15 9:40	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.23	0.21	0.21		41	10/18/2015	8:50	BA
48	BA 10/19/15 19:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/22/15	1.16	1.13	1.13		42	10/19/2015	7:49	TN
56	AN 10/20/15 9:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.21	0.19	0.19		43	10/20/2015	9:00	TN
69	BA 10/21/15 19:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.21	0.19	0.19		44	10/21/2015	7:25	BA
10	BA 10/23/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.11	0.09	0.09		45	10/22/2015	8:33	BA
92	BA 10/23/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.15	0.13	0.13		46	10/23/2015	8:33	BA
50	AN 10/27/15 9:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.10	0.08	0.08		49	10/26/2015	7:50	TN
44	AN 10/27/15 9:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.15	0.13	0.13		50	10/27/2015	7:50	TN
79	BA 11/4/15 8:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/7/15	0.10	0.08	0.08		51	10/28/2015	7:42	BA
14	AN 10/29/15 8:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.09	0.07	0.07		52	10/29/2015	9:16	BA
24	BA 10/30/15 8:20	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/4/15	0.11	0.09	0.09		53	10/30/2015	7:55	JA
78	BA 11/4/15 8:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/7/15	0.09	0.07	0.07		57	11/3/2015	7:42	BA
75	BA 11/4/15 8:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/7/15	0.16	0.14	0.14		58	11/4/2015	7:42	BA
90	AN 11/5/15 9:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/7/15	0.16	0.14	0.14		59	11/5/2015	8:20	TN
12	BA 11/7/15 11:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/9/15	0.12	0.10	0.10		61	11/7/2015	8:51	BA
30	AN 11/8/15 12:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/9/15	0.14	0.12	0.12		62	11/8/2015	11:10	TN
41	BA 11/9/15 9:00	LAB	UF 1	5.00		0.00	0.00	0.00	KZ 11/10/15	0.28	0.26	0.26		63	11/9/2015	7:52	BA
23	AN 11/10/15 13:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/11/15	0.10	0.08	0.08		64	11/10/2015	9:35	TN
92	AN 11/11/15 16:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/12/15	0.27	0.25	0.25		65	11/11/2015	7:32	BA
74	BA 11/13/15 13:00	LAB	UF 1	5.00		0.00	0.00	0.00	KZ 11/16/15	0.53	0.50	0.50		67	11/13/2015	7:42	BA
70	AN 11/14/15 11:00	LAB	UF 1	5.00		0.00	0.00	0.00	KZ 11/16/15	0.05	0.03	0.03		68	11/14/2015		TN
4	9/8/2015	LAB	UF 2	0.50	LAB	4.50	0.00	0.00	MA	0.08	0.06	0.59		1	9/8/2015	9:18	TN
41	9/9/2015	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA	0.06	0.04	0.04		2	9/9/2015	8:05	JA/BA
42	9/9/2015	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA	0.05	0.03	0.03		2	9/9/2015	8:05	JA/BA
56	9/10/15 13:55	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ	0.06	0.04	0.04		3	9/10/2015	9:45	TN
90	9/11/15 13:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA	0.07	0.05	0.05		4	9/11/2015	8:02	BA
1	9/15/15 18:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ	0.10	0.08	0.08		8	9/15/2015	9:55	TN
14	9/17/15 17:23	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ	0.05	0.03	0.03		9	9/16/2015	11:45	JA
87	BA 9/23/15 18:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.06	0.04	0.04		16	9/23/2015	8:05	BA
99	AN 9/24/15 11:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.05	0.03	0.03		17	9/24/2015	9:49	TN
11	BA 9/25/15 13:20	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.06	0.04	0.04		18	9/25/2015	8:36	TN
23	AN 9/26/15 15:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.09	0.07	0.07		19	9/26/2015	9:32	BA

64	BA 9/27/15 15:25	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.18	0.16	0.16		20	9/27/2015	8:54	BA
87	AN 9/28/15	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.17	0.15	0.15		21	9/28/2015	8:02	BA
13	BA 10/2/15 10:40	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.17	0.15	0.15		24	10/1/2015	7:54	BA
23	BA 10/2/15 10:40	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.17	0.15	0.15		25	10/2/2015	7:54	BA
56	BA 10/3/15 11:20	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.09	0.07	0.07		26	10/3/2015	8:56	BA
65	AN 10/4/15 19:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.09	0.07	0.07		27	10/4/2015	9:08	BA
54	AN 10/8/15 14:20	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.05	0.03	0.03		30	10/7/2015	8:44	JA
51	AN 10/8/15 14:20	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.06	0.04	0.04		31	10/8/2015	8:44	JA
30	BA 10/9/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/11/24	0.06	0.04	0.04		32	10/9/2015	7:39	BA
58	AN 10/11/15 11:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.10	0.08	0.08		34	10/11/2015		AN
78	AN 10/13/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.16	0.14	0.14		36	10/13/2015	7:35	TN
79	AN 10/13/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.10	0.08	0.08		36	10/13/2015	7:35	TN
89	AN 10/14/15 16:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.15	0.13	0.13		37	10/14/2015	7:50	BA
2	AN 10/15/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.32	0.30	0.30		38	10/15/2015	7:50	TN
21	BA 10/16/15 8:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.34	0.32	0.32		39	10/16/2015	7:25	BA
33	BA 10/18/15 9:40	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.2	0.18	0.18		41	10/18/2015	8:52	BA
49	BA 10/19/15 19:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.14	0.12	0.12		42	10/19/2015	7:48	JA
57	AN 10/20/15 9:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.11	0.09	0.09		43	10/20/2015	9:00	TN
70	BA 10/21/15 19:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/23/15	0.20	0.18	0.18		44	10/21/2015	7:29	BA
11	BA 10/23/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.14	0.12	0.12		45	10/22/2015	8:28	BA
91	BA 10/23/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.16	0.14	0.14		46	10/23/2015	8:28	BA
18	AN 10/24/15 10:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.14	0.12	0.12		47	10/24/2015	9:15	TN
25	AN 10/24/15 10:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.19	0.17	0.17		48	10/24/2015	9:15	TN
36	BA 10/26/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.16	0.14	0.14		49	10/26/2015	7:49	BA
45	AN 10/27/15 9:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.18	0.16	0.16		50	10/27/2015	7:51	TN
59	BA 10/28/15 8:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.23	0.21	0.21		51	10/28/2015	7:20	BA
8	AN 10/29/15 8:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.07	0.05	0.05		52	10/29/2015	9:21	MA
25	BA 10/30/15 8:20	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/4/15	0.12	0.10	0.10		53	10/30/2015	7:32	BA
36	BA 10/31/15 11:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/4/15	0.14	0.12	0.12		54	10/31/2015	9:40	BA
48	AN 11/1/15 11:00	LAB	UF 2	5.00		0.00	0.00	0.00	BA 11/5/15	0.14	0.12	0.12		55	11/1/2015	9:35	TN
54	BA 11/2/15 8:20	LAB	UF 2	5.00		0.00	0.00	0.00	BA 11/5/15	0.13	0.11	0.11		56	11/2/2015	7:52	BA
65	AN 11/3/15 8:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/7/15	0.13	0.11	0.11		57	11/3/2015	7:50	TN
76	BA 11/4/15 8:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/7/15	0.29	0.27	0.27		58	11/4/2015	7:46	BA
91	AN 11/5/15 9:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/7/15	0.17	0.15	0.15		59	11/5/2015	8:21	TN
13	BA 11/7/15 11:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/9/15	0.12	0.10	0.10		61	11/7/2015	8:49	BA
31	AN 11/8/15 12:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/9/15	0.16	0.14	0.14		62	11/8/2015	11:05	TN
42	BA 11/9/15 9:00	LAB	UF 2	5.00		0.00	0.00	0.00	KZ 11/10/15	0.26	0.24	0.24		63	11/9/2015	7:53	BA
44	AN 11/10/15 13:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/11/15	0.07	0.05	0.05		64	11/10/2015	9:35	TN
91	AN 11/11/15 16:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/12/15	0.20	0.18	0.18		65	11/11/2015	7:33	BA
71	AN 11/14/15 11:00	LAB	UF 2	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		68	11/14/2015		AN
3	9/8/2015	LAB	UF 3	0.50	LAB	4.50	0.00	0.00	MA	0.03	0.01	0.10		1	9/8/2015	9:20	TN
43	9/9/2015	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA	0.09	0.07	0.07		2	9/9/2015	8:07	BA
44	9/9/2015	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA	0.07	0.05	0.05		2	9/9/2015	8:07	BA
2	9/15/15 18:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ	0.05	0.03	0.03		8	9/15/2015	9:55	TN
15	9/17/15 17:23	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ	0.06	0.04	0.04		10	9/16/2015	11:12	JA
88	BA 9/23/15 18:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.06	0.04	0.04		16	9/23/2015	8:10	JA
100	AN 9/24/15 11:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.06	0.04	0.04		17	9/24/2015	9:39	TN
24	AN 9/26/15 15:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.21	0.19	0.19		19	9/25/2015	11:45	AN
65	BA 9/27/15 15:25	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.09	0.07	0.07		20	9/27/2015	8:52	BA
88	AN 9/28/15	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.25	0.23	0.23		21	9/28/2015		
33	BA 9/30/15 8:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.18	0.16	0.16		22	9/29/2015	7:50	BA
9	AN 10/1/15 13:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.18	0.16	0.16		24	10/1/2015	9:42	JA
57	BA 10/3/15 11:20	LAB	UF 3	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.13	0.11	0.11		26	10/3/2015	8:55	BA
67	AN 10/4/15 19:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.18	0.16	0.16		27	10/4/2015	8:58	BA
39	BA 10/5/15 20:35	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.07	0.05	0.05		28	10/5/2015		
55	AN 10/8/15 14:20	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.06	0.04	0.04		30	10/8/2015	8:53	JA
52	AN 10/8/15 14:20	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.02	0.00	0.00		31	10/8/2015	8:53	JA
90	AN 10/14/15 16:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.1	0.08	0.08		37	10/13/2015		
9	AN 10/15/15 8:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.10	0.08	0.08		38	10/14/2015		

23	BA 10/17/15 14:50	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.27	0.25	0.25		40	10/17/2015		
34	BA 10/18/15 9:40	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.24	0.22	0.22		41	10/18/2015	8:49	BA
50	BA 10/19/15 19:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.13	0.11	0.11		42	10/19/2015	7:50	JA
58	AN 10/20/15 9:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.59	0.56	0.56		43	10/20/2015	9:00	TN
12	BA 10/23/15 8:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.27	0.25	0.25		45	10/22/2015		
46	AN 10/27/15 9:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.17	0.15	0.15		50	10/27/2015	7:52	TN
60	BA 10/28/15 8:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.21	0.19	0.19		51	10/28/2015	7:21	BA
13	AN 10/29/15 8:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.15	0.13	0.13		52	10/29/2015	9:20	MA
26	BA 10/30/15 8:20	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/4/15	0.19	0.17	0.17		53	10/30/2015	7:49	BA
92	AN 11/5/15 9:00	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/7/15	0.16	0.14	0.14		59	11/5/2015	8:22	TN
14	BA 11/7/15 11:00	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/9/15	0.13	0.11	0.11		61	11/7/2015	8:50	BA
45	AN 11/10/15 13:00	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/11/15	0.15	0.13	0.13		64	11/10/2015	8:35	TN
90	AN 11/11/15 16:00	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/12/15	0.22	0.20	0.20		65	11/11/2015	7:34	BA
61	AN 11/14/15 11:00	LAB	UF 3	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		68	11/14/2015		

All Data (Chronological Order)

Vial	Date/Time Made	H_2SO_4 Source	Standard (ppm-P) or Sample	Volume (mL)	DI Source (if added)	DI Volume (mL)	Spike Conc (ppm-P)	Spike Volume (mL)	Analysis By Whom	Conc Rpt (ppm-P)	Calibrated	Conc Less Spike (ppm-P)	Notes	
34	9/9/2015	LAB	0.2	5.00	-	0.00	0.00	0.00	MA	0.19	0.17	0.17		2
35	9/9/2015	LAB	0.2	5.00	-	0.00	0.00	0.00	MA	0.2	0.18	0.18		2
~~17~~	~~9/9/2015~~	~~LAB~~	~~BLANK~~	~~5.00~~	~~LAB~~	~~5.00~~	-	-	MA	-		~~BROKE~~	~~BROKE~~	
18	9/9/2015	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA	0.03	0.01	0.01		2
19	9/9/2015	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA	0.02	0.00	0.00		2
52	9/10/15 13:55	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.01	-0.01	-0.01	USED 53 TO ZERO	3
82	9/11/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.02	0.00	0.00		4
94	9/15/15 18:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.02	0.00	0.00		8
6	9/16/15 18:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.02	0.00	0.00		9
20	9/17/15 17:23	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ	0.02	0.00	0.00	DOUBLE COOKED	10
66	AN 9/18/15 8:15	HACH	BLANK	5.00	LAB	0.00	0.00	0.00	MA	0.04	0.02	0.02		11
76	BA 9/19/15 10:55	HACH	BLANK	5.00	LAB	0.00	0.00	0.00	MA	0.02	0.00	0.00		12
37	AN 9/20/15 10:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/26/15	0.02	0.00	0.00		13
49	AN 9/21/15 10:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/26/15	0.02	0.00	0.00		14
59	AN 9/22/15 9:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/26/15	0.02	0.00	0.00		15
83	BA 9/23/15 18:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/26/15	0.01	-0.01	-0.01		16
96	AN 9/24/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 9/28/15	0.01	-0.01	-0.01		17
7	BA 9/25/15 13:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 9/28/15	0.01	-0.01	-0.01		18
19	AN 9/26/15 15:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 9/29/15	0.02	0.00	0.00		19
76	BA 9/27/15 15:25	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.01	-0.01	-0.01		20
84	AN 9/28/15	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.02	0.00	0.00		21
34	BA 9/30/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.01	-0.01	-0.01		22
46	BA 9/30/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.03	0.01	0.01		23
11	AN 10/1/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/3/15	0.04	0.02	0.02		24
24	BA 10/2/15 10:40	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/4/15	0.01	-0.01	-0.01		25
58	BA 10/3/15 11:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/4/15	0.01	-0.01	-0.01		26
91	AN 10/4/15 19:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/5/15	0.02	0.00	0.00		27
35	BA 10/5/15 20:35	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/5/15	0.01	-0.01	-0.01		28
8	BA 10/6/15 14:11	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/6/15	0.02	0.00	0.00		29
18	BA 10/7/15 14:11	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/9/15	0.01	-0.01	-0.01		30
40	AN 10/8/15 14:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/10/15	0.01	-0.01	-0.01		31
23	BA 10/9/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/11/17	0.01	-0.01	-0.01		32
1	AN 10/10/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	AN 10/13/15	0.01	-0.01	-0.01		33
31	AN 10/11/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	AN 10/13/15	0.04	0.02	0.02		34
67	BA 10/12/15 17:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/13/15	0.04	0.02	0.02		35
60	AN 10/13/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/14/15	0.03	0.01	0.01		36
80	AN 10/14/15 16:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/16/15	0.02	0.00	0.00		37
92	AN 10/15/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/16/15	0.01	-0.01	-0.01		38
13	BA 10/16/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.05	MA 10/18/15	0.01	-0.01	-0.01		39
5	BA 10/17/15 14:50	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/18/15	0.01	-0.01	-0.01		40
27	BA 10/18/15 9:40	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/20/15	0.02	0.00	0.00		41

52	BA 10/19/15 19:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/22/15	0.02	0.00	0.00		42
36	AN 10/20/15 9:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/22/15	0.02	0.00	0.00		43
64	BA 10/21/15 19:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/22/15	0.01	-0.01	-0.01		44
1	AN 10/22/15 10:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/27/15	0.02	0.00	0.00		45
97	BA 10/23/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/27/15	0.02	0.00	0.00		46
13	AN 10/24/15 10:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/27/15	0.02	0.00	0.00		47
21	AN 10/24/15 10:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 10/27/15	0.02	0.00	0.00		48
31	BA 10/26/15 8:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/27/15	0.01	-0.01	-0.01		49
38	AN 10/27/15 9:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 10/27/15	0.01	-0.01	-0.01		50
54	BA 10/28/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/28/15	0.01	-0.01	-0.01		51
1	AN 10/29/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 10/31/15	0.01	-0.01	-0.01	STRESS TEST DAY	52
19	BA 10/30/15 8:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/4/15	0.01	-0.01	-0.01		53
31	BA 10/31/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/4/15	0.01	-0.01	-0.01		54
1	AN 11/1/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 11/5/15	0.01	-0.01	-0.01		55
49	BA 11/2/15 8:20	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 11/5/15	0.01	-0.01	-0.01		56
56	AN 11/3/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/7/15	0.02	0.00	0.00		57
70	BA 11/4/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/7/15	0.03	0.01	0.01		58
80	AN 11/5/15 9:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/7/15	0.02	0.00	0.00		59
96	BA 11/6/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/7/15	0.01	-0.01	-0.01		60
5	BA 11/7/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/9/15	0.01	-0.01	-0.01		61
21	AN 11/8/15 12:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/9/15	0.01	-0.01	-0.01		62
36	BA 11/9/15 9:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/10/15	0.02	0.00	0.00		63
1	AN 11/10/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/11/15	0.01	-0.01	-0.01		64
97	BA 11/11/15 16:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/12/15	0.02	0.00	0.00		65
2	AN 11/12/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/13/15	0.01	-0.01	-0.01		66
77	BA 11/13/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/16/15	0.01	-0.01	-0.01		67
62	AN 11/14/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/16/15	0.03	0.01	0.01		68
1	AN 11/15/15 10:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/16/15	0.02	0.00	0.00		69
9	AN 11/16/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/16/15	0.01	-0.01	-0.01		70
19	AN 11/17/15 9:50	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/17/15	0.01	-0.01	-0.01	OVER COOKED	71
27	AN 11/17/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/20/15	0.01	-0.01	-0.01		71
38	BA 11/18/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/20/15	0.01	-0.01	-0.01		72
46	BA 11/18/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 11/22/15	0.02	0.00	0.00	FROM BAGGY	72
47	AN 11/19/15 9:30	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	BA 11/22/15	0.01	-0.01	-0.01		73
59	BA 11/20/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	MA 11/23/15	0.01	-0.01	-0.01		74
70	AN 11/21/15 11:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/24/15	0.01	-0.01	-0.01		75
83	AN 11/22/15 13:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/24/15	0.01	-0.01	-0.01		76
96	BA 11/23/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/24/15	0.01	-0.01	-0.01		77
5	BA 11/23/15 8:00	LAB	BLANK	5.00	LAB	0.00	0.00	0.00	KZ 11/24/15	0.02	0.00	0.00	FROM BAGGY	77
15	9/8/2015	LAB	INF	5.00	-	0.00	0.00	0.00	MA	0.02	0.00	0.00		1
16	9/8/2015	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA	0.11	0.09	0.89		1
26	9/9/2015	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA	0.61	0.58	5.83		2
27	9/9/2015	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA	0.64	0.61	6.12		2
45	9/10/15 13:55	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA	0.45	0.42	4.25		3
58	9/11/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ	0.64	0.61	6.12		4
91	9/15/15 18:30	LAB	INF	0.05	LAB	4.50	0.00	0.00	KZ	0.71	0.68	62.01		8
11	9/16/15 18:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ	0.38	0.36	3.55		9

16	9/17/15 17:23	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ	0.18	0.16	1.58	DOUBLE COOKED	10
51	AN 9/18/15 8:15	HACH	INF	0.50	LAB	4.50	0.00	0.00	MA	0.33	0.31	3.06		11
70	BA 9/19/15 10:55	HACH	INF	0.50	LAB	4.50	0.00	0.00	MA	0.31	0.29	2.86		12
30	AN 9/20/15 10:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 9/26/15	0.27	0.25	2.47		13
42	AN 9/21/15 10:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 9/26/15	0.35	0.33	3.26		14
26	AN 9/22/15 9:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 9/26/15	0.42	0.39	3.95		15
69	BA 9/23/15 18:00	HACH	INF	0.50	LAB	4.50	0.00	0.00	MA 9/26/15	0.34	0.32	3.16		16
89	AN 9/24/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 9/28/15	0.30	0.28	2.76		17
1	BA 9/25/15 13:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 9/28/15	0.65	0.62	6.22		18
12	AN 9/26/15 15:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 9/29/15	0.32	0.30	2.96		19
70	BA 9/27/15 15:25	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.41	0.39	3.85		20
68	AN 9/28/15	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.36	0.34	3.36		21
25	BA 9/30/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.40	0.38	3.75		22
36	BA 9/30/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.01	-0.01	-0.10		23
1	AN 10/1/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/3/15	0.41	0.39	3.85		24
14	BA 10/2/15 10:40	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/4/15	1.02	0.99	9.88		25
60	AN 10/4/15 19:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/5/15	0.38	0.36	3.55		27
31	BA 10/5/15 20:35	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/5/15	0.44	0.41	4.15		28
1	BA 10/6/15 14:11	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/6/15	0.59	0.56	5.63		29
11	BA 10/7/15 14:11	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/9/15	0.63	0.60	6.02		30
43	AN 10/8/15 14:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/10/15	0.6	0.57	5.73		31
20	BA 10/9/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/11/15	0.46	0.43	4.34		32
3	AN 10/10/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	AN 10/13/15	0.47	0.44	4.44		33
33	AN 10/11/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	AN 10/13/15	0.10	0.08	0.79		34
61	BA 10/12/15 17:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/13/15	0.51	0.48	4.84		35
70	AN 10/13/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/14/15	0.52	0.49	4.94		36
82	AN 10/14/15 16:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/16/15	0.51	0.48	4.84		37
94	AN 10/15/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/16/15	0.45	0.42	4.25		38
11	BA 10/16/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/18/15	0.73	0.70	7.01		39
1	BA 10/17/15 14:50	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/18/15	0.34	0.32	3.16		40
24	BA 10/18/15 9:40	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/20/15	0.59	0.56	5.63		41
41	BA 10/19/15 19:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/22/15	1.01	0.98	9.78		42
37	AN 10/20/15 9:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/22/15	0.39	0.37	3.65		43
61	BA 10/21/15 19:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/22/15	0.32	0.30	2.96		44
2	AN 10/22/15 10:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/27/15	0.37	0.35	3.46		45
100	BA 10/23/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/27/15	0.41	0.39	3.85		46
14	AN 10/24/15 10:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/27/15	0.33	0.31	3.06		47
22	AN 10/24/15 10:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 10/27/15	0.30	0.28	2.76		48
28	BA 10/26/15 8:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/27/15	0.79	0.76	7.61		49
39	AN 10/27/15 9:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 10/27/15	0.28	0.26	2.57		50
51	BA 10/28/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 10/28/15	0.70	0.67	6.72		51
2	AN 10/29/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/3/15	0.35	0.33	3.26	STRESS TEST DAY	52
16	BA 10/30/15 8:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/4/15	0.65	0.62	6.22		53
28	BA 10/31/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/4/15	0.57	0.54	5.43		54
9	AN 11/1/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 11/5/15	0.28	0.26	2.57		55
38	BA 11/2/15 8:20	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 11/5/15	0.70	0.67	6.72		56
57	AN 11/3/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.27	0.25	2.47		57

67	BA 11/4/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.46	0.43	4.34		58
82	AN 11/5/15 9:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.45	0.42	4.25		59
93	BA 11/6/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.33	0.31	3.06		60
2	BA 11/7/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/7/15	0.52	0.49	4.94		61
22	AN 11/8/15 12:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/9/15	0.33	0.31	3.06		62
33	BA 11/9/15 9:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/10/15	0.35	0.33	3.26		63
46	AN 11/10/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/11/15	0.36	0.34	3.36		64
100	BA 11/11/15 16:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/12/15	0.51	0.48	4.84		65
3	AN 11/12/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/13/15	0.53	0.50	5.04		66
84	BA 11/13/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/16/15	0.17	0.15	1.48		67
63	AN 11/14/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/16/15	0.23	0.21	2.07		68
2	AN 11/15/15 10:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/16/15	0.23	0.21	2.07		69
10	AN 11/16/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/16/15	0.38	0.36	3.55		70
20	AN 11/17/15 9:50	LAB	INF	0.50	LAB	4.50	0.00	0.00	MA 11/17/15	0.01	-0.01	-0.10	OVER COOKED	71
28	AN 11/17/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/20/15	0.17	0.15	1.48		71
35	BA 11/18/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/20/15	0.32	0.30	2.96		72
48	AN 11/19/15 9:30	LAB	INF	0.50	LAB	4.50	0.00	0.00	BA 11/22/15	0.28	0.26	2.57		73
[redacted]												-0.10	[redacted]	74
71	AN 11/21/15 11:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/24/15	0.21	0.19	1.87		75
84	AN 11/22/15 13:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/24/15	0.18	0.16	1.58		76
94	BA 11/23/15 8:00	LAB	INF	0.50	LAB	4.50	0.00	0.00	KZ 11/24/15	0.34	0.32	3.16		77
~~3~~	~~9/16/15 18:00~~	~~LAB~~	~~INF~~	~~0.50~~	~~LAB~~	~~4.50~~	~~0.00~~	~~0.00~~	KZ	~~0.71~~	0.68	6.81	~~? Not sure~~	
86	AN 11/11/15 16:00	LAB	ME EFF	5.00		0.00	0.00	0.00	MA 11/12/15	0.08	0.06	0.06		65
87	AN 11/11/15 16:00	LAB	MF EFF	5.00		0.00	0.00	0.00	MA 11/12/15	0.23	0.21	0.21		65
89	AN 11/11/15 16:00	LAB	MF INF	5.00		0.00	0.00	0.00	MA 11/12/15	0.32	0.30	0.30		65
88	AN 11/11/15 16:00	LAB	MF INF	5.00		0.00	0.00	0.00	MA 11/12/15	0.07	0.05	0.05		65
13	AN 11/12/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/13/15	0.06	0.04	0.04		66
12	AN 11/12/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/13/15	0.22	0.20	0.20		66
72	BA 11/13/15 13:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.10	0.08	0.08		67
73	BA 11/13/15 13:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.20	0.18	0.18		67
67	BA 11/20/15 8:00	LAB	ME EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.04	0.02	0.02		72
44	BA 11/18/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	MA 11/20/15	0.06	0.04	0.04		72
43	BA 11/18/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	MA 11/20/15	0.11	0.09	0.09		72
69	BA 11/20/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.05	0.03	0.03		73
68	BA 11/20/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.12	0.10	0.10		73
65	BA 11/20/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	MA 11/23/15	0.03	0.01	0.01		74
64	BA 11/20/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	MA 11/23/15	0.09	0.07	0.07		74
80	AN 11/21/15 11:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.03	0.01	0.01		75
79	AN 11/21/15 11:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.08	0.06	0.06		75
93	AN 11/22/15 13:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.06	0.04	0.04		76
92	AN 11/22/15 13:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.20	0.18	0.18		76
3	BA 11/23/15 8:00	LAB	MF EFF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.04	0.02	0.02		77
2	BA 11/23/15 8:00	LAB	MF INF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.10	0.08	0.08		77
7	9/8/2015	LAB	PA	5.00	-	0.00	0.00	0.00	MA	0.10	0.08	0.08		1
8	9/8/2015	LAB	PA	0.50	LAB	4.50	0.00	0.00	MA	0.03	0.01	0.10		1
30	9/9/2015	LAB	PA	5.00	-	0.00	0.00	0.00	MA	0.07	0.05	0.05		2
31	9/9/2015	LAB	PA	5.00	-	0.00	0.00	0.00	MA	0.01	-0.01	-0.01		2

48	9/10/15 13:55	LAB	PA	5.00	-	0.00	0.00	0.00	KZ	0.07	0.05	0.05		3
83	9/11/15 13:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA	0.01	-0.01	-0.01		4
95	9/15/15 18:30	LAB	PA	5.00	-	0.00	0.00	0.00	KZ	0.26	0.24	0.24		8
7	9/16/15 18:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ	0.12	0.10	0.10		9
21	9/17/15 17:23	LAB	PA	5.00	-	0.00	0.00	0.00	KZ	0.04	0.02	0.02	DOUBLE COOKED	10
63	AN 9/18/15 8:15	HACH	PA	5.00	-	0.00	0.00	0.00	MA	0.10	0.08	0.08		11
73	BA 9/19/15 10:55	HACH	PA	5.00	-	0.00	0.00	0.00	MA	0.17	0.15	0.15		12
33	AN 9/20/15 10:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.19	0.17	0.17		13
45	AN 9/21/15 10:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.14	0.12	0.12		14
27	AN 9/22/15 9:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.21	0.19	0.19		15
80	BA 9/23/15 18:00	HACH	PA	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.24	0.22	0.22		16
92	AN 9/24/15 11:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.13	0.11	0.11		17
4	BA 9/25/15 13:20	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.13	0.11	0.11		18
22	AN 9/26/15 15:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.28	0.26	0.26		19
73	BA 9/27/15 15:25	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.37	0.35	0.35		20
81	AN 9/28/15	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.51	0.48	0.48		21
28	BA 9/30/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.35	0.33	0.33		22
39	BA 9/30/15 8:30	LAB	PA	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.73	0.70	0.21		23
4	AN 10/1/15 13:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.38	0.36	0.36		24
18	BA 10/2/15 10:40	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.28	0.26	0.26		25
51	BA 10/3/15 11:20	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.07	0.05	0.05		26
68	AN 10/4/15 19:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.16	0.14	0.14		27
36	BA 10/5/15 20:35	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.18	0.16	0.16		28
4	BA 10/6/15 14:11	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/6/15	0.18	0.16	0.16		29
14	BA 10/7/15 14:11	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/9/15	0.21	0.19	0.19		30
45	AN 10/8/15 14:20	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.20	0.18	0.18		31
24	BA 10/9/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/11/18	0.23	0.21	0.21		32
5	AN 10/10/15 11:00	LAB	PA	5.00	-	0.00	0.00	0.00	AN 10/13/15	0.22	0.20	0.20		33
36	AN 10/11/15 11:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.28	0.26	0.26		34
64	BA 10/12/15 17:20	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.17	0.15	0.15		35
73	AN 10/13/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.31	0.29	0.29		36
85	AN 10/14/15 16:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.17	0.15	0.15		37
96	AN 10/15/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.31	0.29	0.29		38
14	BA 10/16/15 8:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.30	0.28	0.28		39
6	BA 10/17/15 14:50	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.21	0.19	0.19		40
28	BA 10/18/15 9:40	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/20/15	0.31	0.29	0.29		41
44	BA 10/19/15 19:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.16	0.14	0.14		42
40	AN 10/20/15 9:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.15	0.13	0.13		43
65	BA 10/21/15 19:00	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.50	0.47	0.47		44
5	AN 10/22/15 10:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.52	0.49	0.49	LOW AFTER COOKING	45
96	BA 10/23/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.31	0.29	0.29		46
32	BA 10/26/15 8:30	LAB	PA	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.39	0.37	0.37		49
47	AN 10/27/15 9:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.17	0.15	0.15		50
55	BA 10/28/15 8:00	LAB	PA	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.21	0.19	0.19		51
10	AN 10/29/15 8:00	LAB	PA	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.16	0.14	0.14	STRESS TEST DAY	52
20	BA 10/30/15 8:20	LAB	PA	5.00		0.00	0.00	0.00	MA 11/4/15	0.17	0.15	0.15		53
32	BA 10/31/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/4/15	0.25	0.23	0.23		54

43	AN 11/1/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	BA 11/5/15	0.15	0.13	0.13		55
50	BA 11/2/15 8:20	LAB	PA	5.00		0.00	0.00	0.00	BA 11/5/15	0.17	0.15	0.15		56
60	AN 11/3/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/7/15	0.14	0.12	0.12		57
71	BA 11/4/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/7/15	0.16	0.14	0.14		58
85	AN 11/5/15 9:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/7/15	0.23	0.21	0.21		59
97	BA 11/6/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/7/15	0.21	0.19	0.19		60
6	BA 11/7/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/9/15	0.14	0.12	0.12		61
25	AN 11/8/15 12:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/9/15	0.16	0.14	0.14		62
37	BA 11/9/15 9:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/10/15	0.18	0.16	0.16		63
48	AN 11/10/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/11/15	0.15	0.13	0.13		64
96	BA 11/11/15 16:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/12/15	0.17	0.15	0.15		65
6	AN 11/12/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/13/15	0.18	0.16	0.16		66
80	BA 11/13/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/16/15	0.35	0.33	0.33		67
65	AN 11/14/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/16/15	0.21	0.19	0.19		68
4	AN 11/15/15 10:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/16/15	0.10	0.08	0.08		69
13	AN 11/16/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		70
22	AN 11/17/15 9:50	LAB	PA	5.00		0.00	0.00	0.00	MA 11/17/15	0.01	-0.01	-0.01	OVER COOKED	71
30	AN 11/17/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/20/15	0.07	0.05	0.05		71
39	BA 11/18/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/20/15	0.08	0.06	0.06		72
55	AN 11/19/15 9:30	LAB	PA	5.00		0.00	0.00	0.00	BA 11/22/15	0.06	0.04	0.04		73
60	BA 11/20/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	MA 11/23/15	0.05	0.03	0.03		74
74	AN 11/21/15 11:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/24/15	0.09	0.07	0.07		75
87	AN 11/22/15 13:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/24/15	0.06	0.04	0.04		76
98	BA 11/23/15 8:00	LAB	PA	5.00		0.00	0.00	0.00	KZ 11/24/15	0.06	0.04	0.04		77
49	9/10/15 13:55	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ	0.53	0.50	0.01		3
84	9/11/15 13:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA	0.59	0.56	0.07		4
96	9/15/15 18:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ	0.66	0.63	0.14		8
8	9/16/15 18:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ	0.60	0.57	0.08	cant read number, water damage	9
22	9/17/15 17:23	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ	0.54	0.51	0.02	DOUBLE COOKED	10
64	AN 9/18/15 8:15	HACH	PA SP 1	5.00	-	0.00	50.00	0.05	MA	0.50	0.47	-0.02		11
74	BA 9/19/15 10:55	HACH	PA SP 1	5.00	-	0.00	50.00	0.05	MA	0.64	0.61	0.12		12
34	AN 9/20/15 10:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/26/15	0.74	0.71	0.22		13
46	AN 9/21/15 10:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/26/15	0.61	0.58	0.09		14
56	AN 9/22/15 9:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/26/15	0.69	0.66	0.17		15
81	BA 9/23/15 18:00	HACH	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/26/15	0.75	0.72	0.23		16
93	AN 9/24/15 11:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 9/28/15	0.73	0.70	0.21	LOW AFTER COOKING	17
5	BA 9/25/15 13:20	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 9/28/15	0.68	0.65	0.16		18
15	AN 9/26/15 15:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 9/29/15	0.91	0.88	0.39		19
74	BA 9/27/15 15:25	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.81	0.78	0.29		20
82	AN 9/28/15	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.96	0.93	0.44		21
29	BA 9/30/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.55	0.52	0.03		22
40	BA 9/30/15 8:30	LAB	PA SP 1	5.00	-	0.00	100.00	0.05	MA 10/3/15	1.13	1.10	0.11		23
5	AN 10/1/15 13:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/3/15	0.93	0.90	0.41		24
19	BA 10/2/15 10:40	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/4/15	0.77	0.74	0.25		25
52	BA 10/3/15 11:20	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/4/15	0.75	0.72	0.23		26
69	AN 10/4/15 19:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/5/15	0.80	0.77	0.28		27
37	BA 10/5/15 20:35	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/5/15	0.72	0.69	0.20		28

5	BA 10/6/15 14:11	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/6/15	0.71	0.68	0.19		29
15	BA 10/7/15 14:11	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/9/15	0.20	0.18	-0.32	UNCLEAR IF SPIKE ACTUALLY IN	30
46	AN 10/8/15 14:20	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/10/15	0.76	0.73	0.24		31
25	BA 10/9/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/11/19	0.92	0.89	0.40		32
6	AN 10/10/15 11:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	AN 10/13/15	0.72	0.69	0.20		33
37	AN 10/11/15 11:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/13/15	1.02	0.99	0.50		34
65	BA 10/12/15 17:20	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/13/15	0.74	0.71	0.22		35
74	AN 10/13/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/14/15	0.95	0.92	0.43		36
86	AN 10/14/15 16:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/16/15	0.96	0.93	0.44		37
97	AN 10/15/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/16/15	1.05	1.02	0.53		38
15	BA 10/16/15 8:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.00	MA 10/18/15	0.89	0.86	0.86		39
7	BA 10/17/15 14:50	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/18/15	0.94	0.91	0.42		40
29	BA 10/18/15 9:40	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/22/15	0.96	0.93	0.44		41
45	BA 10/19/15 19:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/22/15	0.80	0.77	0.28		42
53	AN 10/20/15 9:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/22/15	0.85	0.82	0.33		43
66	BA 10/21/15 19:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/22/15	1.01	0.98	0.49		44
6	AN 10/22/15 10:00	LAB	PA SP 1	5.00	-	0.00	0.00	0.00	MA 10/27/15	1.08	1.05	1.05		45
95	BA 10/23/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/27/15	0.96	0.93	0.44		46
33	BA 10/26/15 8:30	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	KZ 10/27/15	1.02	0.99	0.50		49
48	AN 10/27/15 9:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 10/28/15	0.04	0.02	-0.48		50
56	BA 10/28/15 8:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	BA 10/28/15	0.76	0.73	0.24		51
11	AN 10/29/15 8:00	LAB	PA SP 1	5.00	-	0.00	50.00	0.05	MA 11/3/15	0.74	0.71	0.22	STRESS TEST DAY	52
21	BA 10/30/15 8:20	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/4/15	0.74	0.71	0.22		53
33	BA 10/31/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/4/15	0.82	0.79	0.30		54
44	AN 11/1/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	BA 11/5/15	0.70	0.67	0.18		55
51	BA 11/2/15 8:20	LAB	PA SP 1	5.00		0.00	50.00	0.05	BA 11/5/15	0.74	0.71	0.22		56
61	AN 11/3/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/7/15	0.71	0.68	0.19		57
72	BA 11/4/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/7/15	0.73	0.70	0.21		58
86	AN 11/5/15 9:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/7/15	0.79	0.76	0.27		59
98	BA 11/6/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/7/15	0.79	0.76	0.27		60
8	BA 11/7/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/9/15	0.75	0.72	0.23		61
26	AN 11/8/15 12:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/9/15	0.78	0.75	0.26		62
38	BA 11/9/15 9:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/10/15	0.79	0.76	0.27		63
49	AN 11/10/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/11/15	0.77	0.74	0.25		64
95	BA 11/11/15 16:00	LAB	PA SP 1	5.00		0.00	50.00	0.00	MA 11/12/15	0.83	0.80	0.80		65
8	AN 11/12/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.00	KZ 11/13/15	0.82	0.79	0.79		66
79	BA 11/13/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/16/15	1.03	1.00	0.51		67
66	AN 11/14/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/16/15	0.90	0.87	0.38		68
5	AN 11/15/15 10:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/16/15	1.18	1.15	0.66		69
14	AN 11/16/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/16/15	0.79	0.76	0.27		70
23	AN 11/17/15 9:50	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/17/15	0.00	-0.02	-0.52	OVER COOKED	71
31	AN 11/17/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/20/15	0.80	0.77	0.28		71
40	BA 11/18/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/20/15	0.82	0.79	0.30		72
51	AN 11/19/15 9:30	LAB	PA SP 1	5.00		0.00	50.00	0.05	BA 11/22/15	0.84	0.81	0.32		73
61	BA 11/20/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	MA 11/23/15	0.86	0.83	0.34		74
75	AN 11/21/15 11:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/24/15	0.90	0.87	0.38		75
88	AN 11/22/15 13:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/24/15	0.9	0.87	0.38		76

99	BA 11/23/15 8:00	LAB	PA SP 1	5.00		0.00	50.00	0.05	KZ 11/24/15	0.9	0.87	0.38		77
50	9/10/15 13:55	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ	0.96	0.93	-0.06		3
85	9/11/15 13:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA	0.43	0.40	-0.59		4
97	9/15/15 18:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ	1.12	1.09	0.10		8
9	9/16/15 18:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ	1.10	1.07	0.08		9
23	9/17/15 17:23	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ	1.08	1.05	0.06	DOUBLE COOKED	10
65	AN 9/18/15 8:15	HACH	PA SP 2	5.00	-	0.00	100.00	0.05	MA	1.12	1.09	0.10		11
75	BA 9/19/15 10:55	HACH	PA SP 2	5.00	-	0.00	100.00	0.05	MA	1.17	1.14	0.15		12
35	AN 9/20/15 10:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/26/15	1.19	1.16	0.17		13
47	AN 9/21/15 10:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/26/15	1.11	1.08	0.09		14
57	AN 9/22/15 9:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/26/15	1.21	1.18	0.19		15
82	BA 9/23/15 18:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/26/15	1.23	1.20	0.21		16
94	AN 9/24/15 11:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 9/28/15	1.28	1.24	0.26		17
6	BA 9/25/15 13:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 9/28/15	1.22	1.19	0.20		18
16	AN 9/26/15 15:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 9/29/15	1.29	1.25	0.27		19
75	BA 9/27/15 15:25	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/3/15	1.33	1.29	0.31		20
83	AN 9/28/15	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/3/15	1.47	1.43	0.45		21
30	BA 9/30/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/3/15	1.85	1.81	0.83	LOW AFTER COOKING	22
41	BA 9/30/15 8:30	LAB	PA SP 2	5.00	-	0.00	0.00	0.00	MA 10/3/15	1.87	1.83	1.83		23
6	AN 10/1/15 13:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/3/15	0.49	0.46	-0.53		24
20	BA 10/2/15 10:40	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/4/15	1.31	1.27	0.29		25
53	BA 10/3/15 11:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/4/15	1.26	1.22	0.24		26
70	AN 10/4/15 19:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/5/15	1.55	1.51	0.53		27
38	BA 10/5/15 20:35	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/5/15	1.32	1.28	0.30		28
6	BA 10/6/15 14:11	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/6/15	1.28	1.24	0.26		29
16	BA 10/7/15 14:11	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/9/15	0.20	0.18	-0.82	UNCLEAR IF SPIKE ACTUALLY IN	30
47	AN 10/8/15 14:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/10/15	1.34	1.30	0.32		31
26	BA 10/9/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/11/20	1.45	1.41	0.43		32
7	AN 10/10/15 11:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	AN 10/13/15	1.45	1.41	0.43		33
38	AN 10/11/15 11:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/13/15	1.62	1.58	0.60		34
66	BA 10/12/15 17:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/13/15	1.39	1.35	0.37		35
75	AN 10/13/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/14/15	1.57	1.53	0.55		36
87	AN 10/14/15 16:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/18/15	1.74	1.70	0.72		37
98	AN 10/15/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/16/15	1.61	1.57	0.59		38
16	BA 10/16/15 8:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.00	MA 10/18/15	1.62	1.58	1.58		39
8	BA 10/17/15 14:50	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/18/15	1.59	1.55	0.57		40
30	BA 10/18/15 9:40	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/22/15	1.65	1.61	0.63		41
46	BA 10/19/15 19:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/22/15	1.5	1.46	0.48		42
54	AN 10/20/15 9:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/22/15	1.50	1.46	0.48		43
67	BA 10/21/15 19:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/22/15	0.86	0.83	-0.16		44
7	AN 10/22/15 10:00	LAB	PA SP 2	5.00	-	0.00	0.00	0.00	MA 10/27/15	1.76	1.72	1.72		45
94	BA 10/23/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/27/15	1.74	1.70	0.72		46
34	BA 10/26/15 8:30	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	KZ 10/27/15	1.86	1.82	0.84		49
49	AN 10/27/15 9:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 10/28/15	1.68	1.64	0.66		50
57	BA 10/28/15 8:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	BA 10/28/15	1.37	1.33	0.35		51
12	AN 10/29/15 8:00	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 11/3/15	1.24	1.21	0.22	STRESS TEST DAY	52
22	BA 10/30/15 8:20	LAB	PA SP 2	5.00	-	0.00	100.00	0.05	MA 11/4/15	1.29	1.25	0.27		53

34	BA 10/31/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/4/15	1.37	1.33	0.35		54
45	AN 11/1/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	BA 11/5/15	1.26	1.22	0.24		55
52	BA 11/2/15 8:20	LAB	PA SP 2	5.00		0.00	100.00	0.05	BA 11/5/15	1.11	1.08	0.09		56
62	AN 11/3/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/7/15	1.62	1.58	0.60		57
73	BA 11/4/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/7/15	1.10	1.07	0.08		58
87	AN 11/5/15 9:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/7/15	1.18	1.15	0.16		59
99	BA 11/6/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/7/15	1.18	1.15	0.16		60
10	BA 11/7/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/9/15	1.13	1.10	0.11		61
27	AN 11/8/15 12:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/9/15	1.15	1.12	0.13		62
39	BA 11/9/15 9:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/10/15	1.12	1.09	0.10		63
50	AN 11/10/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/11/15	1.20	1.17	0.18		64
94	BA 11/11/15 16:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/12/15	1.23	1.20	0.21		65
9	AN 11/12/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/13/15	1.26	1.22	0.24		66
78	BA 11/13/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/16/15	1.62	1.58	0.60		67
67	AN 11/14/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/16/15	1.33	1.29	0.31		68
6	AN 11/15/15 10:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/16/15	1.21	1.18	0.19		69
15	AN 11/16/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/16/15	1.24	1.21	0.22		70
24	AN 11/17/15 9:50	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/17/15	0.01	-0.01	-1.01	OVER COOKED	71
32	AN 11/17/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/20/15	1.25	1.22	0.23		71
41	BA 11/18/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/20/15	1.24	1.21	0.22		72
52	AN 11/19/15 9:30	LAB	PA SP 2	5.00		0.00	100.00	0.05	BA 11/22/15	1.34	1.30	0.32		73
62	BA 11/20/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	MA 11/23/15	1.45	1.41	0.43		74
76	AN 11/21/15 11:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/24/15	1.45	1.41	0.43		75
89	AN 11/22/15 13:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/24/15	1.51	1.47	0.49		76
100	BA 11/23/15 8:00	LAB	PA SP 2	5.00		0.00	100.00	0.05	KZ 11/24/15	1.53	1.49	0.51		77

5	9/8/2015	LAB	PDF	5.00	-	0.00	0.00	0.00	MA	0.20	0.18	0.18		1
6	9/8/2015	LAB	PDF	0.50	LAB	4.50	0.00	0.00	MA	0.30	0.28	2.76		1
32	9/9/2015	LAB	PDF	5.00	-	0.00	0.00	0.00	MA	0.06	0.04	0.04		2
33	9/9/2015	LAB	PDF	5.00	-	0.00	0.00	0.00	MA	0.05	0.03	0.03		2
54	9/10/15 13:55	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.08	0.06	0.06		3
87	9/11/15 13:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.07	0.05	0.05		4
88	9/11/15 13:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.09	0.07	0.07		4
99	9/15/15 18:30	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.07	0.05	0.05		8
12	9/17/15 17:23	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ	0.09	0.07	0.07		9
38	AN 9/18/15 8:15	HACH	PDF	5.00	-	0.00	0.00	0.00	MA	0.02	0.00	0.00	DOUBLE COOKED	10
78	BA 9/19/15 10:55	HACH	PDF	5.00	-	0.00	0.00	0.00	MA	0.04	0.02	0.02		12
36	AN 9/20/15 10:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.52	0.49	0.49		13
48	AN 9/21/15 10:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.11	0.09	0.09		14
58	AN 9/22/15 9:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.13	0.11	0.11		15
85	BA 9/23/15 18:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.16	0.14	0.14		16
97	AN 9/24/15 11:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.09	0.07	0.07		17
9	BA 9/25/15 13:20	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.11	0.09	0.09		18
20	AN 9/26/15 15:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.2	0.18	0.18		19
78	BA 9/27/15 15:25	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.26	0.24	0.24		20
31	BA 9/30/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.22	0.20	0.20		22
42	BA 9/30/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.49	0.46	0.46	LOW AFTER COOKING	23
7	AN 10/1/15 13:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.29	0.27	0.27		24

21	BA 10/2/15 10:40	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.26	0.24	0.24		25
54	BA 10/3/15 11:20	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.23	0.21	0.21		26
71	AN 10/4/15 19:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.18	0.16	0.16		27
10	BA 10/6/15 14:11	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/6/15	0.10	0.08	0.08		28
9	BA 10/6/15 14:11	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/6/15	0.13	0.11	0.11		29
56	AN 10/8/15 14:20	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.12	0.10	0.10		30
49	AN 10/8/15 14:20	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.12	0.10	0.10		31
28	BA 10/9/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/11/22	0.14	0.12	0.12		32
9	AN 10/10/15 11:00	LAB	PDF	5.00	-	0.00	0.00	0.00	AN 10/13/15		-0.02	-0.02	THROWN AWAY	33
91	AN 10/14/15 16:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.21	0.19	0.19		33
35	AN 10/11/15 11:00	LAB	PDF	5.00	-	0.00	0.00	0.00	AN 10/13/15	0.15	0.13	0.13		34
69	BA 10/12/15 17:20	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.12	0.10	0.10		35
76	AN 10/13/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.18	0.16	0.16		36
100	AN 10/15/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.45	0.42	0.42		38
19	BA 10/16/15 8:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.43	0.40	0.40		39
31	BA 10/18/15 9:40	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.30	0.28	0.28		41
47	BA 10/19/15 19:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.26	0.24	0.24		42
55	AN 10/20/15 9:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.17	0.15	0.15		43
68	BA 10/21/15 19:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.29	0.27	0.27		44
8	AN 10/22/15 10:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.28	0.26	0.26		45
93	BA 10/23/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.23	0.21	0.21		46
20	AN 10/24/15 10:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.34	0.32	0.32		47
27	AN 10/24/15 10:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.25	0.23	0.23		48
35	BA 10/26/15 8:30	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.27	0.25	0.25		49
42	AN 10/27/15 9:00	LAB	PDF	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.26	0.24	0.24		50
58	BA 10/28/15 8:00	LAB	PDF	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.41	0.39	0.39		51
5	AN 10/29/15 8:00	LAB	PDF	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.15	0.13	0.13	STRESS TEST DAY	52
23	BA 10/30/15 8:20	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/4/15	0.29	0.27	0.27		53
35	BA 10/31/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/4/15	0.21	0.19	0.19		54
46	AN 11/1/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	BA 11/5/15	0.23	0.21	0.21		55
53	BA 11/2/15 8:20	LAB	PDF	5.00		0.00	0.00	0.00	BA 11/5/15	0.19	0.17	0.17		56
66	AN 11/3/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/7/15	0.21	0.19	0.19		57
74	BA 11/4/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/7/15	0.26	0.24	0.24		58
89	AN 11/5/15 9:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/7/15	0.22	0.20	0.20		59
100	BA 11/6/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/7/15	0.28	0.26	0.26		60
11	BA 11/7/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/9/15	0.21	0.19	0.19		61
28	AN 11/8/15 12:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/9/15	0.20	0.18	0.18		62
40	BA 11/9/15 9:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/10/15	0.35	0.33	0.33		63
20	AN 11/10/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/11/15	0.20	0.18	0.18		64
85	AN 11/11/15 16:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/12/15	0.31	0.29	0.29		65
10	AN 11/12/15 8:00	LAB	PDF	5.00		0.00	0.00	0.05	KZ 11/13/15	0.09	0.07	0.07		66
75	BA 11/13/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.59	0.56	0.56		67
69	AN 11/14/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.06	0.04	0.04		68
7	AN 11/15/15 10:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		69
16	AN 11/16/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		70
25	AN 11/17/15 9:50	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/17/15	0.01	-0.01	-0.01	OVER COOKED	71
33	AN 11/17/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/20/15	0.09	0.07	0.07		71

42	BA 11/18/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/20/15	0.07	0.05	0.05		72
53	AN 11/19/15 9:30	LAB	PDF	5.00		0.00	0.00	0.00	BA 11/22/15	0.04	0.02	0.02		73
63	BA 11/20/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	MA 11/23/15	0.07	0.05	0.05		74
77	AN 11/21/15 11:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.07	0.05	0.05		75
90	AN 11/22/15 13:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.07	0.05	0.05		76
1	BA 11/23/15 8:00	LAB	PDF	5.00		0.00	0.00	0.00	KZ 11/24/15	0.06	0.04	0.04		77
28	9/9/2015	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA	0.2	0.18	0.89		2
29	9/9/2015	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA	0.14	0.12	0.59		2
46	9/10/15 13:55	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.17	0.15	0.74		3
59	9/11/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.36	0.34	1.68		4
92	9/15/15 18:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.37	0.35	1.73		8
4	9/16/15 18:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.71	0.68	3.41		9
18	9/17/15 17:23	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ	0.18	0.16	0.79	DOUBLE COOKED	10
61	AN 9/18/15 8:15	HACH	PE	1.00	LAB	4.00	0.00	0.00	MA	0.37	0.35	1.73		11
71	BA 9/19/15 10:55	HACH	PE	1.00	LAB	4.00	0.00	0.00	MA	0.42	0.39	1.97	2 PHOSPHOROUS	12
31	AN 9/20/15 10:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 9/26/15	0.35	0.33	1.63		13
43	AN 9/21/15 10:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 9/26/15	0.46	0.43	2.17		14
53	AN 9/22/15 9:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 9/26/15	0.58	0.55	2.77	Used vial 68 from 9/32 to zero	15
68	BA 9/23/15 18:00	HACH	PE	1.00	LAB	4.00	0.00	0.00	MA 9/26/15	0.42	0.39	1.97		16
90	AN 9/24/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 9/28/15	0.56	0.53	2.67		17
2	BA 9/25/15 13:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 9/28/15	0.49	0.46	2.32		18
13	AN 9/26/15 15:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 9/29/15	0.53	0.50	2.52		19
71	BA 9/27/15 15:25	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.71	0.68	3.41		20
69	AN 9/28/15	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.69	0.66	3.31		21
26	BA 9/30/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.81	0.78	3.90		22
37	BA 9/30/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.40	0.38	1.88		23
12	AN 10/1/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/3/15	0.76	0.73	3.65		24
15	BA 10/2/15 10:40	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/4/15	0.72	0.69	3.46		25
49	BA 10/3/15 11:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/4/15	0.43	0.40	2.02		26
61	AN 10/4/15 19:00	LAB	PE	1.00	LAB	1.00	0.00	0.00	KZ 10/5/15	0.45	0.42	0.85		27
32	BA 10/5/15 20:35	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/5/15	0.45	0.42	2.12		28
2	BA 10/6/15 14:11	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/6/15	0.44	0.41	2.07		29
12	BA 10/7/15 14:11	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/9/15	1.08	1.05	5.24		30
42	AN 10/8/15 14:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/10/15	0.4	0.38	1.88		31
21	BA 10/9/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/11/15	0.42	0.39	1.97		32
[illegible]	AN 10/10/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	AN 10/13/15	0.00	0.02	-0.10	THROWN AWAY	33
59	AN 10/11/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	AN 10/13/15	0.95	0.92	4.59		34
62	BA 10/12/15 17:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/13/15		0.02	-0.10	THROWN AWAY	35
71	AN 10/13/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/14/15	0.91	0.88	4.40		36
83	AN 10/14/15 16:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/16/15	0.82	0.79	3.95		37
93	AN 10/15/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/16/15	0.83	0.80	4.00		38
3	BA 10/17/15 14:50	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/18/15	0.71	0.68	3.41		40
22	BA 10/17/15 14:50	LAB	PE	1.00	-	0.00	0.00	0.00	MA 10/18/15	0.78	0.75	0.75		40
25	BA 10/18/15 9:40	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/20/15	0.86	0.83	4.15		41
42	BA 10/19/15 19:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/22/15	0.62	0.59	2.96		42
38	AN 10/20/15 9:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/22/15	0.68	0.65	3.26		43
62	BA 10/21/15 19:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/22/15	0.72	0.69	3.46		44

3	AN 10/22/15 10:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/27/15	0.65	0.62	3.11		45
99	BA 10/23/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/27/15	0.60	0.57	2.86		46
15	AN 10/24/15 10:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/27/15	0.59	0.56	2.81		47
23	AN 10/24/15 10:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 10/27/15	0.50	0.47	2.37		48
29	BA 10/26/15 8:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/27/15	0.65	0.62	3.11		49
40	AN 10/27/15 9:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 10/27/15	0.52	0.49	2.47		50
52	BA 10/28/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 10/28/15	0.82	0.79	3.95		51
3	AN 10/29/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/3/15	0.48	0.45	2.27	STRESS TEST DAY	52
15	BA 10/30/15 8:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/4/15	0.94	0.91	4.54		53
29	BA 10/31/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/4/15	0.52	0.49	2.47		54
41	AN 11/1/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 11/5/15	0.53	0.50	2.52		55
39	BA 11/2/15 8:20	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 11/5/15	0.51	0.48	2.42		56
58	AN 11/3/15 8:00	LAB	PE	1.20	LAB	4.00	0.00	0.00	MA 11/7/15	0.58	0.55	2.40		57
68	BA 11/4/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/7/15	0.88	0.85	4.25		58
83	AN 11/5/15 9:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/7/15	0.61	0.58	2.91		59
94	BA 11/6/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/7/15	0.65	0.62	3.11		60
3	BA 11/7/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/7/15	0.36	0.34	1.68		61
32	AN 11/8/15 12:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/9/15	0.53	0.50	2.52		62
34	BA 11/9/15 9:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/10/15	1.04	1.01	5.04		63
47	AN 11/10/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/11/15	0.64	0.61	3.06		64
99	BA 11/11/15 16:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	MA 11/12/15	0.96	0.93	4.64		65
4	AN 11/12/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/13/15	0.59	0.56	2.81		66
83	BA 11/13/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/16/15	0.28	0.26	1.28		67
11	AN 11/16/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/16/15	0.41	0.39	1.93		70
36	BA 11/18/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/20/15	0.32	0.30	1.48		72
49	AN 11/19/15 9:30	LAB	PE	1.00	LAB	4.00	0.00	0.00	BA 11/22/15	0.30	0.28	1.38		73
57	BA 11/20/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/20/15	0.01	-0.01	-0.05	FORGOT SODIUM	74
82	AN 11/21/15 11:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/24/15	0.45	0.42	2.12		75
85	AN 11/22/15 13:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/24/15	0.40	0.38	1.88		76
95	BA 11/23/15 8:00	LAB	PE	1.00	LAB	4.00	0.00	0.00	KZ 11/24/15	0.23	0.21	1.04		77
11	9/8/2015	LAB	PFC	5.00	-	0.00	0.00	0.00	MA	0.53	0.50	0.50		1
12	9/8/2015	LAB	PFC	0.50	LAB	4.50	0.00	0.00	MA	0.80	0.77	7.70		1
13	9/8/2015	LAB	PFC	5.00	-	0.00	0.00	0.00	MA	0.42	0.39	0.39		1
14	9/8/2015	LAB	PFC	0.50	LAB	4.50	0.00	0.00	MA	0.06	0.04	0.39		1
20	9/9/2015	LAB	PFC	5.00	-	0.00	0.00	0.00	MA	0.41	0.39	0.39		2
21	9/9/2015	LAB	PFC	5.00	-	0.00	0.00	0.00	MA	0.41	0.39	0.39		2
47	9/10/15 13:55	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ	0.24	0.22	0.43		3
60	9/11/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ	0.27	0.25	0.49		4
25	9/17/15 17:23	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA	0.25	0.23	0.45	DOUBLE COOKED	7
93	9/15/15 18:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ	0.21	0.19	0.37		8
5	9/16/15 18:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ	0.30	0.28	0.55		9
19	9/17/15 17:23	LAB	PFC	2.50	LAB	2.40	0.00	0.00	KZ	0.22	0.20	0.39	DOUBLE COOKED	10
62	AN 9/18/15 8:15	HACH	PFC	2.50	LAB	2.50	0.00	0.00	MA	0.27	0.25	0.49		11
72	BA 9/19/15 10:55	HACH	PFC	2.50	LAB	2.50	0.00	0.00	MA	0.24	0.22	0.43		12
32	AN 9/20/15 10:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/26/15	0.06	0.04	0.08		13
44	AN 9/21/15 10:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/26/15	0.33	0.31	0.61		14
54	AN 9/22/15 9:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/26/15	0.47	0.44	0.89		15

79	BA 9/23/15 18:00	HACH	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/26/15	0.55	0.52	1.05		16
91	AN 9/24/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 9/28/15	0.83	0.80	1.60	LOW AFTER COOKING	17
3	BA 9/25/15 13:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 9/28/15	0.46	0.43	0.87		18
14	AN 9/26/15 15:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 9/29/15	0.59	0.56	1.13		19
72	BA 9/27/15 15:25	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.66	0.63	1.26		20
80	AN 9/28/15	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.75	0.72	1.44		21
27	BA 9/30/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.74	0.71	1.42		22
38	BA 9/30/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.78	0.75	1.50		23
3	AN 10/1/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/3/15	0.83	0.80	1.60		24
16	BA 10/2/15 10:40	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/4/15	0.74	0.71	1.42		25
50	BA 10/3/15 11:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/4/15	0.65	0.62	1.24		26
62	AN 10/4/15 19:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/5/15	0.57	0.54	1.09		27
33	BA 10/5/15 20:35	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/5/15	0.5	0.47	0.95		28
3	BA 10/6/15 14:11	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/6/15	0.47	0.44	0.89		29
13	BA 10/7/15 14:11	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/9/15	0.45	0.42	0.85		30
44	AN 10/8/15 14:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/10/15	0.37	0.35	0.69		31
22	BA 10/9/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/11/16	0.46	0.43	0.87		32
4	AN 10/10/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	AN 10/13/15	0.53	0.50	1.01		33
34	AN 10/11/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	AN 10/13/15	0.81	0.78	1.56		34
63	BA 10/12/15 17:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/13/15	0.74	0.71	1.42		35
72	AN 10/13/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/14/15	0.88	0.85	1.70		36
84	AN 10/14/15 16:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/16/15	0.72	0.69	1.38		37
95	AN 10/15/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/16/15	0.83	0.80	1.60		38
12	BA 10/16/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.05	MA 10/18/15	0.89	0.86	1.74		39
4	BA 10/17/15 14:50	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/18/15	0.79	0.76	1.52		40
26	BA 10/18/15 9:40	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/20/15	0.85	0.82	1.64		41
43	BA 10/19/15 19:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/22/15	0.74	0.71	1.42		42
39	AN 10/20/15 9:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/22/15	0.67	0.64	1.28		43
63	BA 10/21/15 19:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/22/15	0.73	0.70	1.40		44
4	AN 10/22/15 10:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/27/15	0.91	0.88	1.76	LOW AFTER COOKING	45
98	BA 10/23/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/27/15	0.69	0.66	1.32		46
16	AN 10/24/15 10:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/27/15	0.66	0.63	1.26		47
24	AN 10/24/15 10:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 10/27/15	0.69	0.66	1.32		48
30	BA 10/26/15 8:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 10/27/15	0.64	0.61	1.22		49
41	AN 10/27/15 9:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/28/15	0.62	0.59	1.19		50
53	BA 10/28/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 10/28/15	0.67	0.64	1.28		51
4	AN 10/29/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/3/15	0.63	0.60	1.20	STRESS TEST DAY	52
18	BA 10/30/15 8:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/4/15	0.59	0.56	1.13		53
30	BA 10/31/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/4/15	0.61	0.58	1.17		54
42	AN 11/1/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 11/5/15	0.58	0.55	1.11		55
40	BA 11/2/15 8:20	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 11/5/15	0.54	0.51	1.03		56
59	AN 11/3/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/7/15	0.54	0.51	1.03		57
69	BA 11/4/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/7/15	0.59	0.56	1.13		58
84	AN 11/5/15 9:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/7/15	0.57	0.54	1.09		59
95	BA 11/6/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/7/15	0.56	0.53	1.07		60
4	BA 11/7/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/9/15	0.59	0.56	1.13		61
24	AN 11/8/15 12:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/9/15	0.55	0.52	1.05		62

35	BA 11/9/15 9:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/10/15	0.58	0.55	1.11		63
7	AN 11/10/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/11/15	0.70	0.67	1.34		64
98	BA 11/11/15 16:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/12/15	0.60	0.57	1.15		65
5	AN 11/12/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/13/15	0.61	0.58	1.17		66
82	BA 11/13/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/16/15	0.36	0.34	0.67		67
64	AN 11/14/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/16/15	0.29	0.27	0.53		68
3	AN 11/15/15 10:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/16/15	0.29	0.27	0.53		69
12	AN 11/16/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/16/15	0.26	0.24	0.47		70
21	AN 11/17/15 9:50	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/17/15	0.01	-0.01	-0.02	OVER COOKED	71
29	AN 11/17/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/20/15	0.22	0.20	0.39		71
37	BA 11/18/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	MA 11/20/15	0.23	0.21	0.41		72
50	AN 11/19/15 9:30	LAB	PFC	2.50	LAB	2.50	0.00	0.00	BA 11/22/15	0.18	0.16	0.32		73
58	BA 11/20/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/20/15	0.01	-0.01	-0.02	FORGOT SODIUM	74
73	AN 11/21/15 11:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/24/15	0.14	0.12	0.24		75
86	AN 11/22/15 13:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/24/15	0.17	0.15	0.30		76
97	BA 11/23/15 8:00	LAB	PFC	2.50	LAB	2.50	0.00	0.00	KZ 11/24/15	0.15	0.13	0.26		77
22	9/9/2015	LAB	PFC SP 1	5.00	-	0.00	50.00	0.05	MA	1.23	1.20	0.71		2
23	9/9/2015	LAB	PFC SP 1	5.00	-	0.00	50.00	0.05	MA	0.47	0.44	-0.05		2
24	9/9/2015	LAB	PFC SP 2	5.00	-	0.00	100.00	0.05	MA	1.41	1.37	0.39		2
25	9/9/2015	LAB	PFC SP 2	5.00	-	0.00	100.00	0.05	MA	1.40	1.36	0.38		2
53	9/10/15 13:55	LAB	STD	5.00	-	0.00	0.00	0.00	KZ	0.26	0.24	0.24	LOW AFTER COOKING	3
86	9/11/15 13:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA	0.20	0.18	0.18		4
98	9/15/15 18:30	LAB	STD	5.00	-	0.00	0.00	0.00	KZ	0.20	0.18	0.18		8
10	9/16/15 18:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ	0.19	0.17	0.17		9
24	9/17/15 17:23	LAB	STD	5.00	-	0.00	0.00	0.00	MA	0.21	0.19	0.19	DOUBLE COOKED	10
67	AN 9/18/15 8:15	HACH	STD	5.00	-	0.00	0.00	0.00	MA	0.23	0.21	0.21		11
77	BA 9/19/15 10:55	HACH	STD	5.00	-	0.00	0.00	0.00	MA	0.20	0.18	0.18		12
41	AN 9/20/15 10:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.19	0.17	0.17		13
50	AN 9/21/15 10:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.23	0.21	0.21		14
60	AN 9/22/15 9:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.18	0.16	0.16		15
84	BA 9/23/15 18:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.21	0.19	0.19		16
95	AN 9/24/15 11:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.19	0.17	0.17		17
8	BA 9/25/15 13:20	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.19	0.17	0.17		18
18	AN 9/26/15 15:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.20	0.18	0.18		19
77	BA 9/27/15 15:25	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.20	0.18	0.18		20
85	AN 9/28/15	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.21	0.19	0.19		21
35	BA 9/30/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.2	0.18	0.18		22
47	BA 9/30/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.20	0.18	0.18		23
10	AN 10/1/15 13:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.21	0.19	0.19		24
48	BA 10/2/15 10:40	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.21	0.19	0.19		25
59	BA 10/3/15 11:20	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.19	0.17	0.17		26
63	AN 10/4/15 19:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.19	0.17	0.17		27
34	BA 10/5/15 20:35	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.19	0.17	0.17		28
7	BA 10/6/15 14:11	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/6/15	0.19	0.17	0.17		29
19	BA 10/7/15 14:11	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/9/15	0.21	0.19	0.19		30
48	AN 10/8/15 14:20	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.20	0.18	0.18		31
27	BA 10/9/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/11/21	0.19	0.17	0.17		32

8	AN 10/10/15 11:00	LAB	STD	5.00	-	0.00	0.00	0.00	AN 10/13/15		-0.02	-0.02	THROWN AWAY	33
39	AN 10/11/15 11:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.21	0.19	0.19		34
68	BA 10/12/15 17:20	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.20	0.18	0.18		35
77	AN 10/13/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.19	0.17	0.17		36
88	AN 10/14/15 16:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.21	0.19	0.19		37
99	AN 10/15/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.20	0.18	0.18		38
18	BA 10/16/15 8:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.20	0.18	0.18		39
10	BA 10/17/15 14:50	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.20	0.18	0.18		40
35	BA 10/18/15 9:40	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.20	0.18	0.18		41
51	BA 10/19/15 19:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.20	0.18	0.18		42
59	AN 10/20/15 9:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.20	0.18	0.18		43
71	BA 10/21/15 19:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/23/15	0.20	0.18	0.18		44
9	AN 10/22/15 10:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.24	0.22	0.22	LOW AFTER COOKING	45
90	BA 10/23/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.17	0.15	0.15		46
19	AN 10/24/15 10:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.20	0.18	0.18		47
26	AN 10/24/15 10:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.20	0.18	0.18		48
37	BA 10/26/15 8:30	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.19	0.17	0.17		49
43	AN 10/27/15 9:00	LAB	STD	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.21	0.19	0.19		50
61	BA 10/28/15 8:00	LAB	STD	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.19	0.17	0.17		51
6	AN 10/29/15 8:00	LAB	STD	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.19	0.17	0.17	STRESS TEST DAY	52
27	BA 10/30/15 8:20	LAB	STD	5.00		0.00	0.00	0.00	MA 11/4/15	0.19	0.17	0.17		53
37	BA 10/31/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/4/15	0.19	0.17	0.17		54
47	AN 11/1/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	BA 11/5/15	0.19	0.17	0.17		55
55	BA 11/2/15 8:20	LAB	STD	5.00		0.00	0.00	0.00	BA 11/5/15	0.20	0.18	0.18		56
64	AN 11/3/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/7/15	0.19	0.17	0.17		57
77	BA 11/4/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/7/15	0.19	0.17	0.17		58
88	AN 11/5/15 9:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/7/15	0.19	0.17	0.17		59
1	BA 11/6/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/7/15	0.19	0.17	0.17		60
15	BA 11/7/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/9/15	0.23	0.21	0.21		61
29	AN 11/8/15 12:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/9/15	0.20	0.18	0.18		62
43	BA 11/9/15 9:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/10/15	0.19	0.17	0.17		63
19	AN 11/10/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/11/15	0.20	0.18	0.18		64
93	BA 11/11/15 16:00	LAB	STD	5.00		0.00	0.00	0.05	MA 11/12/15	0.19	0.17	0.17		65
11	AN 11/12/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/13/15	0.19	0.17	0.17		66
76	BA 11/13/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/16/15	0.19	0.17	0.17		67
68	AN 11/14/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/16/15	0.20	0.18	0.18		68
8	AN 11/15/15 10:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/16/15	0.20	0.18	0.18		69
18	AN 11/16/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/16/15	0.19	0.17	0.17		70
26	AN 11/17/15 9:50	LAB	STD	5.00		0.00	0.00	0.00	MA 11/17/15	0.01	-0.01	-0.01	OVER COOKED	71
34	AN 11/17/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/20/15	0.15	0.13	0.13		71
45	BA 11/18/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/20/15	0.2	0.18	0.18		72
54	AN 11/19/15 9:30	LAB	STD	5.00		0.00	0.00	0.00	BA 11/22/15	0.21	0.19	0.19		73
66	BA 11/20/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	MA 11/23/15	0.20	0.18	0.18		74
78	AN 11/21/15 11:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/24/15	0.23	0.21	0.21		75
91	AN 11/22/15 13:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/24/15	0.20	0.18	0.18		76
4	BA 11/23/15 8:00	LAB	STD	5.00		0.00	0.00	0.00	KZ 11/24/15	0.19	0.17	0.17		77
9	9/8/2015	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA	0.06	0.04	0.04		1

10	9/8/2015	LAB	UF 1	0.50	LAB	4.50	0.00	0.00	MA	0.04	0.02	0.20		1
36	9/9/2015	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA	0.09	0.07	0.07		2
37	9/9/2015	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA	0.1	0.08	0.08		2
55	9/10/15 13:55	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ	0.08	0.06	0.06		3
89	9/11/15 13:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA	0.05	0.03	0.03		4
100	9/15/15 18:30	HACH	UF 1	5.00	-	0.00	0.00	0.00	KZ	0.12	0.10	0.10		8
13	9/17/15 17:23	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ	0.06	0.04	0.04		9
39	AN 9/18/15 8:15	HACH	UF 1	5.00	-	0.00	0.00	0.00	MA	0.04	0.02	0.02	DOUBLE COOKED	10
86	BA 9/23/15 18:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.08	0.06	0.06		16
98	AN 9/24/15 11:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.06	0.04	0.04		17
10	BA 9/25/15 13:20	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.06	0.04	0.04		18
21	AN 9/26/15 15:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.17	0.15	0.15		19
63	BA 9/27/15 15:25	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.17	0.15	0.15		20
86	AN 9/28/15	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.23	0.21	0.21		21
32	BA 9/30/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.13	0.11	0.11		22
43	BA 9/30/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.26	0.24	0.24		23
8	AN 10/1/15 13:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.18	0.16	0.16		24
22	BA 10/2/15 10:40	LAB	UF 1	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.18	0.16	0.16		25
55	BA 10/3/15 11:20	LAB	UF 1	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.08	0.06	0.06		26
64	AN 10/4/15 19:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.07	0.05	0.05		27
53	AN 10/8/15 14:20	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.03	0.01	0.01		30
50	AN 10/8/15 14:20	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.07	0.05	0.05		31
29	BA 10/9/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/11/23	0.06	0.04	0.04		32
10	AN 10/10/15 11:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	AN 10/13/15	0.08	0.06	0.06		33
57	AN 10/11/15 11:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.11	0.09	0.09		34
20	BA 10/16/15 8:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.30	0.28	0.28		39
32	BA 10/18/15 9:40	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.23	0.21	0.21		41
48	BA 10/19/15 19:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/22/15	1.16	1.13	1.13		42
56	AN 10/20/15 9:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.21	0.19	0.19		43
69	BA 10/21/15 19:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.21	0.19	0.19		44
10	BA 10/23/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.11	0.09	0.09		45
92	BA 10/23/15 8:30	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.15	0.13	0.13		46
50	AN 10/27/15 9:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.10	0.08	0.08		49
44	AN 10/27/15 9:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.15	0.13	0.13		50
79	BA 11/4/15 8:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/7/15	0.10	0.08	0.08		51
14	AN 10/29/15 8:00	LAB	UF 1	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.09	0.07	0.07	STRESS TEST DAY	52
24	BA 10/30/15 8:20	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/4/15	0.11	0.09	0.09		53
78	BA 11/4/15 8:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/7/15	0.09	0.07	0.07		57
75	BA 11/4/15 8:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/7/15	0.16	0.14	0.14		58
90	AN 11/5/15 9:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/7/15	0.16	0.14	0.14		59
12	BA 11/7/15 11:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/9/15	0.12	0.10	0.10		61
30	AN 11/8/15 12:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/9/15	0.14	0.12	0.12		62
41	BA 11/9/15 9:00	LAB	UF 1	5.00		0.00	0.00	0.00	KZ 11/10/15	0.28	0.26	0.26		63
23	AN 11/10/15 13:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/11/15	0.10	0.08	0.08		64
92	AN 11/11/15 16:00	LAB	UF 1	5.00		0.00	0.00	0.00	MA 11/12/15	0.27	0.25	0.25		65
74	BA 11/13/15 13:00	LAB	UF 1	5.00		0.00	0.00	0.00	KZ 11/16/15	0.53	0.50	0.50		67
70	AN 11/14/15 11:00	LAB	UF 1	5.00		0.00	0.00	0.00	KZ 11/16/15	0.05	0.03	0.03		68

2	9/8/2015	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA	0.03	0.01	0.01	DIDN'T GET NaOH BEFORE READ	1
4	9/8/2015	LAB	UF 2	0.50	LAB	4.50	0.00	0.00	MA	0.08	0.06	0.59		1
41	9/9/2015	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA	0.06	0.04	0.04		2
42	9/9/2015	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA	0.05	0.03	0.03		2
56	9/10/15 13:55	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ	0.06	0.04	0.04		3
90	9/11/15 13:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA	0.07	0.05	0.05		4
1	9/15/15 18:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ	0.10	0.08	0.08		8
14	9/17/15 17:23	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ	0.05	0.03	0.03		9
87	BA 9/23/15 18:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.06	0.04	0.04		16
99	AN 9/24/15 11:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.05	0.03	0.03		17
11	BA 9/25/15 13:20	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.06	0.04	0.04		18
23	AN 9/26/15 15:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.09	0.07	0.07		19
64	BA 9/27/15 15:25	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.18	0.16	0.16		20
87	AN 9/28/15	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.17	0.15	0.15		21
44	BA 9/30/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.28	0.26	0.26	LOW AFTER COOKING	23
13	BA 10/2/15 10:40	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.17	0.15	0.15		24
23	BA 10/2/15 10:40	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.17	0.15	0.15		25
56	BA 10/3/15 11:20	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.09	0.07	0.07		26
65	AN 10/4/15 19:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.09	0.07	0.07		27
54	AN 10/8/15 14:20	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.05	0.03	0.03		30
51	AN 10/8/15 14:20	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.06	0.04	0.04		31
30	BA 10/9/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/11/24	0.06	0.04	0.04		32
41	AN 10/10/15 11:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	AN 10/13/15	0.05	0.03	0.03	LOW AFTER COOKING	33
58	AN 10/11/15 11:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/13/15	0.10	0.08	0.08		34
78	AN 10/13/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.16	0.14	0.14		36
79	AN 10/13/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/14/15	0.10	0.08	0.08		36
89	AN 10/14/15 16:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.15	0.13	0.13		37
2	AN 10/15/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.32	0.30	0.30		38
21	BA 10/16/15 8:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.34	0.32	0.32		39
33	BA 10/18/15 9:40	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.2	0.18	0.18		41
49	BA 10/19/15 19:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.14	0.12	0.12		42
57	AN 10/20/15 9:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.11	0.09	0.09		43
70	BA 10/21/15 19:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/23/15	0.20	0.18	0.18		44
11	BA 10/23/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.14	0.12	0.12		45
91	BA 10/23/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/28/15	0.16	0.14	0.14		46
18	AN 10/24/15 10:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.14	0.12	0.12		47
25	AN 10/24/15 10:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.19	0.17	0.17		48
36	BA 10/26/15 8:30	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.16	0.14	0.14		49
45	AN 10/27/15 9:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.18	0.16	0.16		50
59	BA 10/28/15 8:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.23	0.21	0.21		51
8	AN 10/29/15 8:00	LAB	UF 2	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.07	0.05	0.05	STRESS TEST DAY	52
25	BA 10/30/15 8:20	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/4/15	0.12	0.10	0.10		53
36	BA 10/31/15 11:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/4/15	0.14	0.12	0.12		54
48	AN 11/1/15 11:00	LAB	UF 2	5.00		0.00	0.00	0.00	BA 11/5/15	0.14	0.12	0.12		55
54	BA 11/2/15 8:20	LAB	UF 2	5.00		0.00	0.00	0.00	BA 11/5/15	0.13	0.11	0.11		56
65	AN 11/3/15 8:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/7/15	0.13	0.11	0.11		57
76	BA 11/4/15 8:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/7/15	0.29	0.27	0.27		58

91	AN 11/5/15 9:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/7/15	0.17	0.15	0.15		59
13	BA 11/7/15 11:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/9/15	0.12	0.10	0.10		61
31	AN 11/8/15 12:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/9/15	0.16	0.14	0.14		62
42	BA 11/9/15 9:00	LAB	UF 2	5.00		0.00	0.00	0.00	KZ 11/10/15	0.26	0.24	0.24		63
44	AN 11/10/15 13:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/11/15	0.07	0.05	0.05		64
91	AN 11/11/15 16:00	LAB	UF 2	5.00		0.00	0.00	0.00	MA 11/12/15	0.20	0.18	0.18		65
71	AN 11/14/15 11:00	LAB	UF 2	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		68
1	9/8/2015	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA	0.01	-0.01	-0.01	DIDN'T GET NaOH BEFORE READ	1
3	9/8/2015	LAB	UF 3	0.50	LAB	4.50	0.00	0.00	MA	0.03	0.01	0.10		1
43	9/9/2015	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA	0.09	0.07	0.07		2
44	9/9/2015	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA	0.07	0.05	0.05		2
57	9/10/15 13:55	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ	0.17	0.15	0.15	LOW AFTER COOKING	3
2	9/15/15 18:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ	0.05	0.03	0.03		8
15	9/17/15 17:23	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ	0.06	0.04	0.04		10
40	AN 9/18/15 8:15	HACH	UF 3	5.00	-	0.00	0.00	0.00	MA	0.06	0.04	0.04	DOUBLE COOKED	10
88	BA 9/23/15 18:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 9/26/15	0.06	0.04	0.04		16
100	AN 9/24/15 11:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 9/28/15	0.06	0.04	0.04		17
24	AN 9/26/15 15:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 9/29/15	0.21	0.19	0.19		19
65	BA 9/27/15 15:25	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.09	0.07	0.07		20
88	AN 9/28/15	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.25	0.23	0.23		21
33	BA 9/30/15 8:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.18	0.16	0.16		22
45	BA 9/30/15 8:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.37	0.35	0.35	LOW AFTER COOKING	23
9	AN 10/1/15 13:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/3/15	0.18	0.16	0.16		24
57	BA 10/3/15 11:20	LAB	UF 3	5.00	-	0.00	0.00	0.00	BA 10/4/15	0.13	0.11	0.11		26
67	AN 10/4/15 19:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.18	0.16	0.16		27
39	BA 10/5/15 20:35	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/5/15	0.07	0.05	0.05		28
55	AN 10/8/15 14:20	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.06	0.04	0.04		30
52	AN 10/8/15 14:20	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/10/15	0.02	0.00	0.00		31
90	AN 10/14/15 16:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.1	0.08	0.08		37
9	AN 10/15/15 8:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/16/15	0.10	0.08	0.08		38
23	BA 10/17/15 14:50	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/18/15	0.27	0.25	0.25		40
34	BA 10/18/15 9:40	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.24	0.22	0.22		41
50	BA 10/19/15 19:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.13	0.11	0.11		42
58	AN 10/20/15 9:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/22/15	0.59	0.56	0.56		43
12	BA 10/23/15 8:30	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 10/27/15	0.27	0.25	0.25		45
46	AN 10/27/15 9:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	KZ 10/27/15	0.17	0.15	0.15		50
60	BA 10/28/15 8:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	BA 10/28/15	0.21	0.19	0.19		51
13	AN 10/29/15 8:00	LAB	UF 3	5.00	-	0.00	0.00	0.00	MA 11/3/15	0.15	0.13	0.13	STRESS TEST DAY	52
26	BA 10/30/15 8:20	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/4/15	0.19	0.17	0.17		53
92	AN 11/5/15 9:00	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/7/15	0.16	0.14	0.14		59
14	BA 11/7/15 11:00	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/9/15	0.13	0.11	0.11		61
45	AN 11/10/15 13:00	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/11/15	0.15	0.13	0.13		64
90	AN 11/11/15 16:00	LAB	UF 3	5.00		0.00	0.00	0.00	MA 11/12/15	0.22	0.20	0.20		65
61	AN 11/14/15 11:00	LAB	UF 3	5.00		0.00	0.00	0.00	KZ 11/16/15	0.08	0.06	0.06		68

OPERATING DATA SUMMARY FROM CITY OF MANKATO WWTF

Date	Raw Influent Flow (MGD)	Ferric Feed to WWTF (gpd)	Ferric Feed to WRF (gpd)	Total FeCl3 Usage (gpd)	WRF (mg/L as FeCl3)	Influent Feed (mg/L as FeCl3)	Dose per feed point (mg/L)	Ferric Feed Point Scenarios					Comments
								42-inch Interceptor (FeCl3(1))	Primary Clarifiers (FeCl3(2))	Secondary Clarifiers (FeCl3(3))	# feed points	WRF (FeCl3(4))	
08/01	7.188	65	297.00	362.00	22.03	4.82	4.82	X			1	X	
08/02	7.359	88	364.00	452.00	26.37	6.37	6.37	X			1	X	
08/03	7.383	85	238.00	323.00	17.18	6.14	6.14	X			1	X	
08/04	7.250	76	330.00	406.00	24.26	5.59	5.59	X			1	X	
08/05	7.059	67	356.00	423.00	26.89	5.06	5.06	X			1	X	
08/06	8.691	93	424.00	517.00	26.01	5.70	5.70	X			1	X	
08/07	8.027	89	382.00	471.00	25.37	5.91	5.91	X			1	X	
08/08	7.590	81	364.00	445.00	25.57	5.69	5.69	X			1	X	
08/09	7.461	83	332.00	415.00	23.72	5.93	5.93	X			1	X	
08/10	7.973	88	484.00	572.00	32.36	5.88	5.88	X			1	X	
08/11	7.937	86	364.00	450.00	24.45	5.78	5.78	X			1	X	
08/12	8.770	90	382.00	472.00	23.22	5.47	5.47	X			1	X	
08/13	8.820	100	432.00	532.00	26.11	6.04	6.04	X			1	X	
08/14	8.379	90	314.00	404.00	19.98	5.73	5.73	X			1	X	
08/15	8.621	87	364.00	451.00	22.51	5.38	5.38	X			1	X	
08/16	9.500	125	399.00	524.00	22.39	7.01	7.01	X			1	X	
08/17	9.673	127	359.00	486.00	19.79	7.00	3.50	X	X		2	X	
08/18	15.718	218	407.00	625.00	13.80	7.39	3.70	X	X		2	X	
08/19	10.640	143	331.00	474.00	16.58	7.16	3.58	X	X		2	X	
08/20	10.716	148	356.00	504.00	17.71	7.36	3.68	X	X		2	X	
08/21	9.632	110	364.00	474.00	20.15	6.09	3.04	X	X		2	X	
08/22	8.543	101	280.00	381.00	17.47	6.30	3.15	X	X		2	X	
08/23	8.000	14	305.00	319.00	20.32	0.93	0.47	X	X		2	X	
08/24	8.539	309	323.00	632.00	20.17	19.29	9.65	X	X		2	X	
08/25	7.340	426	347.00	773.00	25.20	30.94	15.47	X	X		2	X	
08/26	8.398	423	297.00	720.00	18.85	26.85	13.43	X	X		2	X	
08/27	8.371	195	305.00	500.00	19.42	12.42	6.21	X	X		2	X	
08/28	8.110	178	339.00	517.00	22.28	11.70	5.85	X	X		2	X	
08/29	7.762	151	314.00	465.00	21.57	10.37	5.19	X	X		2	X	
08/30	8.000	152	305.00	457.00	20.32	10.13	5.06	X	X		2	X	
08/31	8.352	318	318.00	636.00	20.30	20.30	10.15	X	X		2	X	
09/01	10.340	430	246.00	676.00	12.68	22.17	7.39	X	X	X	3	X	
09/02	9.800	516	272.00	788.00	14.80	28.07	9.36	X	X	X	3	X	
09/03	9.559	440	260.00	700.00	14.50	24.54	8.18	X	X	X	3	X	
09/04	9.570	443	212.00	655.00	11.81	24.68	8.23	X	X	X	3	X	
09/05	11.637	555	271.00	826.00	12.41	25.42	8.47	X	X	X	3	X	
09/06	11.863	593	254.00	847.00	11.41	26.65	8.88	X	X	X	3	X	
09/07	11.760	400	280.00	680.00	12.69	18.13	6.04	X	X	X	3	X	Start of MSU Phosphorus Sampling
09/08	11.559	522	271.00	793.00	12.50	24.07	8.02	X	X	X	3	X	
09/09	10.250	451	297.00	748.00	15.45	23.46	7.82	X	X	X	3	X	
09/10	9.949	400	297.00	697.00	15.91	21.43	7.14	X	X	X	3	X	
09/11	8.301	334	220.00	554.00	14.13	21.45	7.15	X	X	X	3	X	
09/12	8.711	328	212.00	540.00	12.97	20.07	6.69	X	X	X	3	X	
09/13	8.480	324	255.00	579.00	16.03	20.37	6.79	X	X	X	3	X	
09/14	8.457	336	322.00	658.00	20.30	21.18	7.06	X	X	X	3	X	
09/15	8.441	346	260.00	606.00	16.42	21.85	7.28	X	X	X	3	X	
09/16	8.403	379	277.00	656.00	17.57	24.04	8.01	X	X	X	3	X	
09/17	9.024	446	278.00	724.00	16.42	26.35	8.78	X	X	X	3	X	
09/18	7.363	356	305.00	661.00	22.08	25.77	8.59	X	X	X	3	X	
09/19	7.550	168	263.00	431.00	18.57	11.86	11.86		X		1	X	
09/20	7.783	165	288.00	453.00	19.73	11.30	11.30		X		1	X	
09/21	7.827	154	289.00	443.00	19.68	10.49	10.49		X		1	X	
09/22	7.820	143	339.00	482.00	23.11	9.75	9.75		X		1	X	
09/23	8.582	120	279.00	399.00	17.33	7.45	7.45		X		1	X	
09/24	8.051	113	270.00	383.00	17.88	7.48	7.48		X		1	X	
09/25	8.000	97	297.00	394.00	19.79	6.46	6.46		X		1	X	
09/26	7.566	83	297.00	380.00	20.93	5.85	5.85		X		1	X	
09/27	7.571	90	288.00	378.00	20.28	6.34	6.34		X		1	X	
09/28	7.781	88	301.00	389.00	20.62	6.03	6.03		X		1	X	
09/29	7.801	80	339.00	419.00	23.17	5.47	5.47		X		1	X	
09/30	7.488	80	272.00	352.00	19.36	5.70	5.70		X		1	X	
10/01	9.512	135	279.00	414.00	15.64	7.57	7.57		X		1	X	
10/02	6.871	225	255.00	480.00	19.78	17.46	17.46		X		1	X	
10/03	6.839	237	280.00	517.00	21.83	18.47	18.47		X		1	X	
10/04	7.079	272	271.00	543.00	20.41	20.48	20.48		X		1	X	
10/05	7.601	228	297.00	525.00	20.83	15.99	15.99		X		1	X	

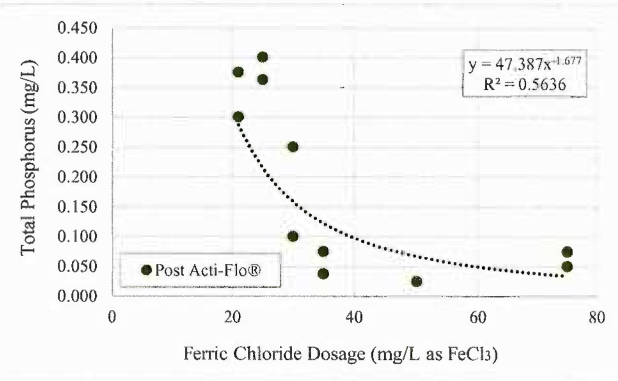
10/06	8.141	197	197.00	394.00	12.90	12.90	12.90		X		1	X	
10/07	6.558	179	289.00	468.00	23.49	14.55	14.55		X		1	X	
10/08	7.016	182	285.00	467.00	21.66	13.83	13.83		X		1	X	
10/09	6.742	192	246.00	438.00	19.45	15.18	15.18		X		1	X	
10/10	6.891	159	272.00	431.00	21.04	12.30	12.30		X		1	X	
10/11	7.652	171	288.00	459.00	20.06	11.91	11.91		X		1	X	
10/12	6.789	189	280.00	469.00	21.99	14.84	14.84		X		1	X	
10/13	6.809	197	322.00	519.00	25.21	15.42	15.42		X		1	X	
10/14	6.652	148	322.00	470.00	25.81	11.86	11.86		X		1	X	
10/15	7.098	200	314.00	514.00	23.58	15.02	15.02		X		1	X	
10/16	6.441	187	288.00	475.00	23.84	15.48	15.48		X		1	X	
10/17	6.051	157	297.00	454.00	26.17	13.83	13.83		X		1	X	
10/18	6.367	159	330.00	489.00	27.63	13.31	13.31		X		1	X	
10/19	7.063	197	373.00	570.00	28.15	14.87	14.87			X	1	X	
10/20	6.898	180	255.00	435.00	19.71	13.91	13.91			X	1	X	
10/21	7.141	215	271.00	486.00	20.23	16.05	16.05			X	1	X	
10/22	7.269	181	407.00	588.00	29.85	13.27	13.27			X	1	X	
10/23	7.242	201	297.00	498.00	21.86	14.80	14.80			X	1	X	
10/24	6.797	202	288.00	490.00	22.59	15.84	15.84			X	1	X	
10/25	6.891	161	347.00	508.00	26.84	12.46	12.46			X	1	X	
10/26	6.910	187	106.00	293.00	8.18	14.43	14.43			X	1	X	
10/27	7.281	159	330.00	489.00	24.16	11.64	11.64			X	1	X	
10/28	8.141	221	373.00	594.00	24.42	14.47	14.47			X	1	X	
10/29	7.758	200	331.00	531.00	22.74	13.74	13.74			X	1	X	
10/30	7.242	190	288.00	478.00	21.20	13.99	13.99			X	1	X	
10/31	8.258	220	322.00	542.00	20.79	14.20	14.20			X	1	X	
11/01	7.652	209	314.00	523.00	21.88	14.56	14.56			X	1	X	
11/02	7.340	200	322.00	522.00	23.39	14.53	14.53			X	1	X	
11/03	8.598	198	322.00	520.00	19.96	12.28	12.28			X	1	X	
11/04	7.402	213	319.00	532.00	22.97	15.34	15.34			X	1	X	
11/05	8.051	230	296.00	526.00	19.60	15.23	15.23			X	1	X	
11/06	7.637	257	272.00	529.00	18.99	17.94	17.94			X	1	X	
11/07	6.921	142	271.00	413.00	20.87	10.94	10.94			X	1	X	
11/08	7.231	180	263.00	443.00	19.39	13.27	13.27			X	1	X	
11/09	8.140	216	305.00	521.00	19.97	14.15	7.07		X	X	2	X	
11/10	7.184	191	271.00	462.00	20.11	14.17	7.09		X	X	2	X	
11/11	10.977	306	433.00	739.00	21.03	14.86	7.43		X	X	2	X	
11/12	10.930	315	271.00	586.00	13.22	15.36	7.68		X	X	2	X	
11/13	8.660	244	356.00	600.00	21.91	15.02	7.51		X	X	2	X	
11/14	8.840	231	339.00	570.00	20.44	13.93	6.97		X	X	2	X	
11/15	9.402	247	365.00	612.00	20.70	14.00	7.00		X	X	2	X	
11/16	9.287	257	347.00	604.00	19.92	14.75	7.38		X	X	2	X	
11/17	11.452	316	475.00	791.00	22.11	14.71	7.35		X	X	2	X	
11/18	9.528	345	425.00	770.00	23.78	19.30	9.65		X	X	2	X	
11/19	10.500	295	441.00	736.00	22.39	14.98	7.49		X	X	2	X	
11/20	9.472	288	432.00	720.00	24.31	16.21	8.10		X	X	2	X	
11/21	8.848	251	356.00	607.00	21.45	15.12	7.56		X	X	2	X	
11/22	9.738	220	370.00	590.00	20.26	12.04	6.02		X	X	2	X	
11/23	9.012	245	407.00	652.00	24.08	14.49	7.25		X	X	2	X	
11/24	10.066	200	305.00	505.00	16.15	10.59	5.30		X	X	2	X	
11/25	10.012	149	475.00	624.00	25.29	7.93	3.97		X	X	2	X	
11/26	9.011	195	253.00	448.00	14.97	11.54	5.77		X	X	2	X	
11/27	7.719	195	205.00	400.00	14.16	13.47	6.73		X	X	2	X	
11/28	7.731	190	200.00	390.00	13.79	13.10	6.55		X	X	2	X	
11/29	7.918	178	210.00	388.00	14.14	11.98	5.99		X	X	2	X	
11/30	8.437	279	217.00	496.00	13.71	17.63	8.81		X	X	2	X	

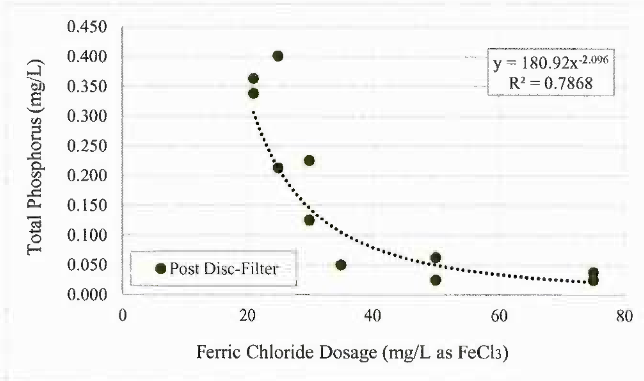
MSU RAW SAMPLING RESULTS - STRESS TEST (OCTOBER 29TH)

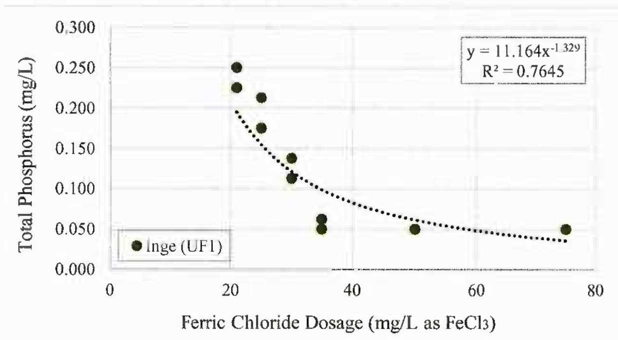
Ferric (mg/L)	SAMPLE	Time of Sample	Ortho Phosphate (mg/L)	Iron (mg/L)	Total P Conversion			Comments
					Lower Limit	Upper Limit	Average	
21	PA ST 1	912	0.24	0.41	0.290	0.312	0.301	
21	PA ST 2	930	0.30	0.49	0.363	0.390	0.376	
25	PA ST 3	945	0.29	0.55	0.351	0.377	0.363	
25	PA ST 4	1000	0.32	0.45	0.387	0.416	0.401	
30	PA ST 5	1015	0.20	0.20	0.242	0.260	0.251	
30	PA ST 6	1030	0.08	0.43	0.097	0.104	0.100	
35	PA ST 7	1045	0.06	0.43	0.073	0.078	0.075	
35	PA ST 8	1100	0.03	0.41	0.036	0.039	0.038	
50	PA ST 9	1115	1.01	0.55	1.221	1.314		Outlier
50	PA ST 10	1130	0.02	0.45	0.024	0.026	0.025	
75	PA ST 11	1145	0.04	0.68	0.048	0.052	0.050	
75	PA ST 12	1200	0.06	0.47	0.073	0.078	0.075	
21	PDF ST 1	913	0.27	0.42	0.327	0.351	0.338	
21	PDF ST 2	931	0.29	0.37	0.351	0.377	0.363	
25	PDF ST 3	946	0.32	0.36	0.387	0.416	0.401	
25	PDF ST 4	1002	0.17	0.40	0.206	0.221	0.213	
30	PDF ST 5	1016	0.18	0.18	0.218	0.234	0.226	
30	PDF ST 6	1032	0.10	0.42	0.121	0.130	0.125	
35	PDF ST 7	1047	0.04	0.42	0.048	0.052	0.050	
35	PDF ST 8	1102	0.04	0.42	0.048	0.052	0.050	
50	PDF ST 9	1116	0.05	0.43	0.060	0.065	0.063	
50	PDF ST 10	1131	0.02	0.45	0.024	0.026	0.025	
75	PDF ST 11	1146	0.03	0.43	0.036	0.039	0.038	
75	PDF ST 12	1201	0.02	0.46	0.024	0.026	0.025	
21	UF 1 ST 1	916	0.18	0.08	0.218	0.234	0.226	
21	UF 1 ST 2	932	0.20	0.06	0.242	0.260	0.251	
25	UF 1 ST 3	947	0.17	0.08	0.206	0.221	0.213	
25	UF 1 ST 4	1004	0.14	0.08	0.169	0.182	0.175	
30	UF 1 ST 5	1017	0.11	0.11	0.133	0.143	0.138	
30	UF 1 ST 6	1034	0.09	0.09	0.109	0.117	0.113	
35	UF 1 ST 7	1048	0.04	0.09	0.048	0.052	0.050	
35	UF 1 ST 8	1106	0.05	0.10	0.060	0.065	0.063	
50	UF 1 ST 9	1117	0.04	0.11	0.048	0.052	0.050	
50	UF 1 ST 10	1133	0.04	0.12	0.048	0.052	0.050	
75	UF 1 ST 11	1153	0.04	0.15	0.048	0.052	0.050	
75	UF 1 ST 12	1202	0.04	0.19	0.048	0.052	0.050	
21	UF 2 ST 1	917	0.14	0.09	0.169	0.182	0.175	
21	UF 2 ST 2	933	0.15	0.09	0.181	0.195	0.188	
25	UF 2 ST 3	949	0.16	0.10	0.194	0.208	0.201	
25	UF 2 ST 4	1005	0.16	0.12	0.194	0.208	0.201	
30	UF 2 ST 5	1018	0.09	0.09	0.109	0.117	0.113	
30	UF 2 ST 6	1035	0.14	0.10	0.169	0.182	0.175	
35	UF 2 ST 7	1049	0.06	0.11	0.073	0.078	0.075	
35	UF 2 ST 8	1107	0.03	0.12	0.036	0.039	0.038	
50	UF 2 ST 9	1118	0.04	0.14	0.048	0.052	0.050	
50	UF 2 ST 10	1134	0.03	0.13	0.036	0.039	0.038	
75	UF 2 ST 11	1154	0.10	0.17	0.121	0.130	0.125	
75	UF 2 ST 12	1203	0.02	0.18	0.024	0.026	0.025	
21	UF 3 ST 1	918	0.59	0.09	0.714	0.767	0.739	
21	UF 3 ST 2	935	0.36	0.06	0.435	0.468	0.451	
25	UF 3 ST 3	954	0.28	0.06	0.339	0.364	0.351	
25	UF 3 ST 4	1006	0.27	0.07	0.327	0.351	0.338	
30	UF 3 ST 5	1020	0.23	0.07	0.278	0.299	0.288	
30	UF 3 ST 6	1036	0.20	0.07	0.242	0.260	0.251	
35	UF 3 ST 7	1051	0.10	0.07	0.121	0.130	0.125	
35	UF 3 ST 8	1108	0.17	0.07	0.206	0.221	0.213	
50	UF 3 ST 9	1119	0.09	0.08	0.109	0.117	0.113	
50	UF 3 ST 10	1136	0.12	0.09	0.145	0.156	0.150	
75	UF 3 ST 11	1150	0.09	0.11	0.109	0.117	0.113	
75	UF 3 ST 12	1204	0.15	0.19	0.181	0.195	0.188	

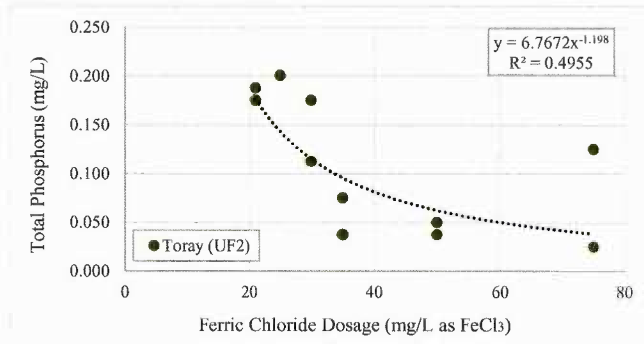
Ortho/Total Ratio Analysis

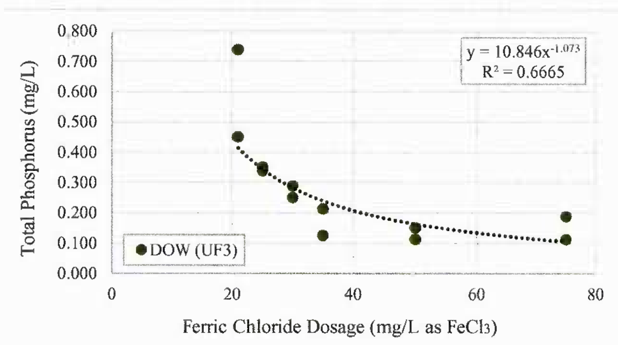
Average	0.798
Standard Deviation	0.130
Standard Error	0.015
95% Lower Limit	0.769
95% Upper Limit	0.827











2015 Effluent Sampling Data for Ortho/Total Phosphorus

Date	Effluent Total Phosphorus (mg/L)	Effluent Ortho Phosphorus (mg/L)	% Ortho of Total
1/6/2015	0.23	0.17	73.9%
1/7/2015	0.2	0.21	105.0%
1/11/2015	0.15	0.11	73.3%
1/12/2015	0.11	0.08	72.7%
1/20/2015	0.38	0.32	84.2%
1/21/2015	0.5	0.43	86.0%
1/25/2015	0.31	0.24	77.4%
1/26/2015	0.31	0.24	77.4%
2/3/2015	0.17	0.13	76.5%
2/4/2015	0.32	0.27	84.4%
2/8/2015	0.3	0.26	86.7%
2/17/2015	0.43	0.37	86.0%
2/18/2015	0.41	0.35	85.4%
2/22/2015	0.25	0.19	76.0%
2/23/2015	0.41	0.35	85.4%
3/3/2015	0.31	0.25	80.6%
3/4/2015	0.33	0.25	75.8%
3/8/2015	0.17	0.09	52.9%
3/9/2015	0.17	0.11	64.7%
3/18/2015	0.41	0.37	90.2%
3/19/2015	0.44	0.35	79.5%
3/22/2015	0.45	0.4	88.9%
3/23/2015	0.5	0.42	84.0%
3/31/2015	0.28	0.21	75.0%
4/1/2015	0.25	0.21	84.0%
4/5/2015	0.26	0.2	76.9%
4/6/2015	0.28	0.22	78.6%
4/12/2015	0.42	0.36	85.7%
4/13/2015	0.43	0.36	83.7%
4/21/2015	0.18	0.17	94.4%
4/22/2015	0.2	0.18	90.0%
4/26/2015	0.27	0.21	77.8%
4/27/2015	0.28	0.22	78.6%
5/5/2015	0.22	0.18	81.8%
5/6/2015	0.28	0.19	67.9%
5/10/2015	0.3	0.22	73.3%
5/11/2015	0.24	0.2	83.3%
5/17/2015	0.23	0.2	87.0%
5/18/2015	0.22	0.17	77.3%
5/25/2015	0.18	0.14	77.8%

5/26/2015	0.2	0.15	75.0%
5/31/2015	0.23	0.18	78.3%
6/1/2015	0.18	0.14	77.8%
6/7/2015	0.28	0.23	82.1%
6/8/2015	0.23	0.18	78.3%
6/16/2015	0.2	0.16	80.0%
6/17/2015	0.18	0.13	72.2%
6/21/2015	0.38	0.32	84.2%
6/22/2015	0.4	0.35	87.5%
6/28/2015	0.22	0.23	104.5%
6/29/2015	0.29	0.25	86.2%
7/5/2015	0.51	0.48	94.1%
7/6/2015	0.46	0.39	84.8%
7/14/2015	0.22	0.09	40.9%
7/15/2015	0.2	0.15	75.0%
7/19/2015	0.46	0.4	87.0%
7/20/2015	0.38	0.33	86.8%
7/27/2015	0.66	0.11	16.7%
7/28/2015	0.34	0.1	29.4%
8/2/2015	0.23	0.2	87.0%
8/3/2015	0.52	0.45	86.5%
8/11/2015	0.38	0.31	81.6%
8/12/2015	0.21	0.16	76.2%
8/16/2015	0.21	0.16	76.2%
8/17/2015	0.31	0.25	80.6%
8/25/2015	0.35	0.26	74.3%
8/26/2015	0.23	0.2	87.0%
8/30/2015	0.48	0.39	81.3%
8/31/2015	0.59	0.48	81.4%
9/8/2015	0.39	0.33	84.6%
9/9/2015	0.26	0.22	84.6%
9/13/2015	0.31	0.26	83.9%
9/14/2015	0.31	0.24	77.4%
9/22/2015	0.4	0.35	87.5%
9/23/2015	0.42	0.38	90.5%
9/27/2015	0.52	0.48	92.3%
9/28/2015	0.78	0.7	89.7%
		Average	**79.8%**
		Standard Deviation	0.1299
		Standard Error	0.0148
		95% Lower Limit	76.9%
		95% Upper Limit	82.7%

APPENDIX F

Capital, Operation, and Maintenance Cost Estimates

Appendix F - Table 1

Capital Cost Opinion - Tertiary Treatment Technologies

Acti-Flo® (alone)

Item	Cost
Mobilization, Bonds, & Insurance	$300,000
Acti-Flo® Process Equipment	
Two (2) Coagulation Tank Mixers	
Two (2) Injection Tank Mixers	
Two (2) Maturation Tank Mixers	
Two (2) Allen Bradley VFDs	
Four (4) Anti-Vortex Baffles	
Settling Tank Equipment	
Two (2) Sludge Scraper Assemblies	
Two (2) VFDs for Scrapers	
Wear Plates / Bottom Hoppers	$2, 000,000
Lamella Tube Settlers	
Effluent Troughs & Supports	
MicroSand Recirculation System	
Four (4) Sand Recirculation Pumps	
Isolation Valves	
Flush Connection Valves	
Discharge Pressure Switch	
Four (4) Hydrocyclones & Associated	
Hydrocyclones Piping	
12 tons of Microsand	
Package Thickener Equipment	
Two (2) Steel Tank Assemblies	
Stairs and Handrails	
Flocculation Tank Mixer & VFD	
Sludge Thickening Tank	
Scraper Mechanism	$500,000
VFD	
Wear Plates for Bottom Hoppers	
Inclined Plates	
Effluent Launders, V-notch Weirs	
Residual Sludge Pump	
Polymer Feed System	$370,000
Ferric Chloride Feed System	$180,000
Equipment Installation	$650,000
General Building Construction	$1,695,000
CIP Concrete Tank Construction	
Acti-Flo® Process Tanks	$350,000
Process Piping (10%)	$650,000

(Cont'd on following page)

Appendix F - Table 1 Capital Cost Opinion - Tertiary Treatment Technologies Acti-Flo® (alone)	
Item	**Cost**
Electrical, Instrumentation, & Controls (12%)	$825,000
General Site Work (2.5%)	$175,000
Generator	$175,000
Subtotal	$7,870,000
Contingencies (10%)	$790,000
Total Construction Costs	$8,660,000
Engineering, Admin., Legal (20%)	$1,730,000
Total Estimated Capital Costs	**$10,390,000**

Appendix F - Table 2

Capital Cost Opinion - Tertiary Treatment Technologies

Acti-Flo® + Disc-Filtration

Item	Cost
Mobilization, Bonds, & Insurance	$350,000
Acti-Flo® Process Equipment	$2,000,000
Two (2) Coagulation Tank Mixers	
Two (2) Injection Tank Mixers	
Two (2) Maturation Tank Mixers	
Two (2) Allen Bradley VFDs	
Four (4) Anti-Vortex Baffles	
Settling Tank Equipment	
Two (2) Sludge Scraper Assemblies	
Two (2) VFDs for Scrapers	
Wear Plates / Bottom Hoppers	
Lamella Tube Settlers	
Effluent Troughs & Supports	
MicroSand Recirculation System	
Four (4) Sand Recirculation Pumps	
Isolation Valves	
Flush Connection Valves	
Discharge Pressure Switch	
Four (4) Hydrocyclones & Associated	
Hydrocyclones Piping	
12 Tons of Microsand	
Package Thickener Equipment	$500,000
Two (2) Steel Tank Assemblies	
Stairs and Handrails	
Flocculation Tank Mixer & VFD	
Sludge Thickening Tank	
Scraper Mechanism	
VFD	
Wear Plates for Bottom Hoppers	
Inclined Plates	
Effluent Launders, V-notch Weirs	
Residual Sludge Pump	
Two (2) Hydrotech Disc-Filtration Systems	$810,000
Polymer Feed System	$370,000
Ferric Chloride Feed System	$180,000
Equipment Installation	$800,000
General Building Construction	$2,575,000

(Cont'd on following page)

Appendix F - Table 2 Capital Cost Opinion - Tertiary Treatment Technologies Acti-Flo® + Disc-Filtration	
Item	**Cost**
CIP Concrete Tank Construction	
Acti-Flo® Process Tanks	$350,000
Disc-Filter Mezzanine	$50,000
Process Piping (10%)	$880,000
Electrical, Instrumentation, & Controls (12%)	$1,000,000
General Site Work (2.5%)	$220,000
Generator	$200,000
Subtotal	$10,285,000
Contingencies (10%)	$1,030,000
Total Construction Costs	$11,315,000
Engineering, Admin., Legal (20%)	$2,260,000
Total Estimated Capital Costs	**$13,575,000**

Appendix F - Table 3

Capital Cost Opinion - Tertiary Treatment Technologies

Acti-Flo® + Ultrafiltration System

Item	Cost
Mobilization, Bonds, & Insurance	$400,000
Acti-Flo® Process Equipment Two (2) Coagulation Tank Mixers Two (2) Injection Tank Mixers Two (2) Maturation Tank Mixers Two (2) Allen Bradley VFDs Four (4) Anti-Vortex Baffles Settling Tank Equipment Two (2) Sludge Scraper Assemblies Two (2) VFDs for Scrapers Wear Plates / Bottom Hoppers Lamella Tube Settlers Effluent Troughs & Supports MicroSand Recirculation System Four (4) Sand Recirculation Pumps Isolation Valves Flush Connection Valves Discharge Pressure Switch Four (4) Hydrocyclones & Associated Hydrocyclones Piping 12 Tons of Microsand	$2,000,000
Package Thickener Equipment Two (2) Steel Tank Assemblies Stairs and Handrails Flocculation Tank Mixer & VFD Sludge Thickening Tank Scraper Mechanism VFD Wear Plates for Bottom Hoppers Inclined Plates Effluent Launders, V-notch Weirs Residual Sludge Pump	$500,000
Polymer Feed System	$370,000
Ferric Chloride Feed System	$180,000

(Cont’d on following page)

Appendix F - Table 3

Capital Cost Opinion - Tertiary Treatment Technologies

Acti-Flo® + Ultrafiltration System

Item	Cost
Ultrafiltration System	
11.25 MGD Ultrafiltration System	
Eight (8) Ultrafiltration Skids (72 modules)	
PVC Piping Feed, Backwash, and Filtrate	
Isolation Valves	
Filtrate Turbidity Meter	
Influent Feed Meter	
TMP Pressure Transmitters	
System Control Panel	
Carbon Steel Skid (painted)	
Backwash Disk Pre-Filter	
Backwash Feed Pump Skid	
Two (2) Backwash Pumps and VFDs	
One (1) Local Control Panel	$4,400,000
Carbon Steel Skid (painted)	
One (1) HDPE UF Backwash Feed Tank and Level Sensor	
One (1) CIP UF Pump Skid	
Two (2) Recirculation Pumps	
CIP Controls and Valves	
One (1) Local Control Panel	
Carbon Steel Skid (painted)	
Two (2) 2,000 Gallon HDPE CIP Tanks	
Two (2) CIP Heaters	
Three (3) Level Transmitters	
CIP Chemical Dosing Pumps & Accessories	
One (1) Master Control Panel	
Two (2) 10 HP Rotary Screw Air Compressors	
Equipment Installation	$1,200,000
General Building Construction	$2,575,000
CIP Concrete Tank Construction	
Acti-Flo® Process Tanks	$350,000
Filtrate/Backwash Tank	$200,000

(Cont’d on following page)

Appendix F - Table 3

Capital Cost Opinion - Tertiary Treatment Technologies

Acti-Flo® + Ultrafiltration System

Item	Cost
Process Piping (10%)	$1,350,000
Electrical, Instrumentation, & Controls (12%)	$1,650,000
General Site Work (2.5%)	$350,000
Generator	$200,000
Subtotal	$15,725,000
Contingencies (10%)	$1,570,000
Total Construction Costs	$17,295,000
Engineering, Admin., Legal (20%)	$3,460,000
Total Estimated Capital Costs	**$20,755,000**

Appendix F - Table 4

Capital Cost Opinion - Tertiary Treatment Technologies

Meiden Ceramic Flat-Sheet Membrane System

Item	Cost
Mobilization, Bonds, & Insurance	$350,000
Ceramic Membrane System	$9,331,000
Nine (9) Immersed Membrane Trains	
Membrane Units (200)	
Membrane Elements (200x400)	
Permeate Pump Skid (one per train)	
Valves, Fittings, and Pipework	
Backwash System	
CIP System	
Blower System	
Compressed Air System	
Local Instrumentation & Controls	
One (1) Main Control Panel	
Equipment Installation	$1,200,000
General Building Construction	$2,575,000
Process Piping (10%)	$1,000,000
Electrical, Instrumentation, & Controls (12%)	$1,200,000
General Site Work (2.5%)	$250,000
Generator	$200,000
Subtotal	$16,106,000
Contingencies (10%)	$1,610,000
Total Construction Costs	$17,716,000
Engineering, Admin., Legal (20%)	$3,540,000
Total Estimated Capital Costs	**$21,256,000**