CITY OF WINNIPEG

PILOT TESTING AN ALTERNATIVE COAGULANT FOR THE WINNIPEG WATER TREATMENT PLANT

FINAL REPORT

OCTOBER 30, 2018
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PROJECT NO.: 161-06111-00
DATE: OCTOBER 30, 2018

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October 30, 2018

City of Winnipeg
Water and Waste Department
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Attn: Heather Buhler, P.Eng.
Project Manager

Dear Heather,

Subject: Pilot Testing of an Alternative Coagulant at the City of Winnipeg Water Treatment Plant

WSP Canada Inc. (WSP) is pleased to submit our Final Report regarding pilot testing of an alternative coagulant for the Winnipeg water treatment plant. Over 80 benchtop jar tests were completed to recommend a coagulant for piloting during five subsequent piloting sessions. The report provides our evaluation and recommendation of a selected alternative coagulant.

Once again thank you for providing WSP the opportunity to work with the City of Winnipeg. As always, do not hesitate to contact the undersigned should you have any further consulting engineering needs.

Yours sincerely,

Ian McKinnon, P. Eng.

Encl.
cc:
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QUALITY MANAGEMENT

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WSP

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Technical Direction	Dr. Robert Andrews Dr. Ronald Hofmann
Technician	Michael McKie

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ACRONYMS AND ABBREVIATIONS

AACEI
American Association of Cost Engineers International
Al
aluminum
alum
aluminum sulphate
ANSI
American National Standards Institute
AO
aesthetic objective
ATP
adenosine triphosphate
AWWA
American Water Works Association
BAC
biologically active carbon
CCC
Canada Colors and Chemicals Ltd.
CDW
Committee on Drinking Water
City
City of Winnipeg
CSMR
chloride-sulphate mass ratio
CT
contact time
Cu
copper
d
day
DAF
dissolved air flotation
DBP
disinfection by-product
DO
dissolved oxygen
DOC
dissolved organic carbon
Eh
activity of electrons
EPA
Environmental Protection Agency (US)
EPDM
ethylene propylene diene monomer
Fe
iron
FKM
fluoroelastomer
FRP
fiberglass reinforced plastic
g/mol
grams per mole
GAC
granular activated carbon
GCDWQ
Guidelines for Canadian Drinking Water Quality
HAA
haloacetic acids
HAAFP
haloacetic acid formation potential
Hach
Hach spectrophotometer
ICP-MS
Inductively Coupled Plasma-Mass Spectrometer
kg
kilogram
kg/h
kilogram per hour
kPa
kilopascal
L
litre
L/h
litre per hour
Lab
City of Winnipeg Analytical Services Branch
LaI
Larson Skold Index
LOD
limit of detection
LSI
Langelier Saturation Index
LT1ESWTR
Long Term 1 Enhanced Surface Water Treatment Rule
MAC
maximum acceptable concentration
mg/L
miligram per litre
min
minutes
MLD
megalitres per day
Mn
manganese
m^2
square metre

m^3/d
cubic metres per day
m^3/year
cubic metres per year
N/D
non detect
NPV
net present value
NSF
National Science Foundation
NTU
nephelometric turbidity unit
ODW
Office of Drinking Water
O&M
operating and maintenace
Pb
lead
PE
polyethylene
pH
power of hydrogen
PP
polypropylene
PTFE
polytetrafluoroethylene
PVC
polyvinyl chloride
rpm
rotations per minute
RSI
Ryznar Index
SCADA
supervisory control and data acquisition
sec
seconds
SOP
standard operating procedure
TCU
true colour unit
TDS
total dissolved solids
THM
trihalomethanes
THMFP
trihalomethane formation potential
TM
technical memorandum
TOC
total organic carbon
ton
tonne
TON
threshold odour number
TS
total solids
TSS
total suspended solids
UFRV
unit filter run volume
UV
ultraviolet
UVT
UV-transmittance
UV_{254nm}
UV absorbance at 245 nm
WTP
Water Treatment Plant
Zn
zinc

EXECUTIVE SUMMARY

In December 2009, the City of Winnipeg (City) implemented its first water treatment plant (WTP) to address increasingly stringent drinking water quality regulations, particularly with regards to the formation of disinfection by-products, namely trihalomethanes (THMs). Since the WTP (hereon referred to as the full-scale system) went online, the City has experienced an increased number of customer complaints related to discoloured water at the tap. Studies conducted in 2011, 2013, and 2015 alluded to elevated levels of manganese in the distribution system, which was believed to be a significant contributor to the discoloured water reported by customers. Furthermore, previous studies into the cause of the discoloured water indicated that the current coagulant, ferric chloride, had high levels of manganese which was believed to be contributing to the elevated manganese concentrations measured in the distribution system. The previous studies recommended that an investigation be conducted to identify an alternative coagulant to ferric chloride which had lower, or no manganese content, to reduce the amount of manganese entering the distribution system. It was believed that a decrease in manganese entering the distribution system would reduce the occurrence of discoloured water and, in turn, the number of customer complaints.

In 2016, WSP Canada Inc. was retained by the City to select and test alternative coagulants and/or coagulant-aids with less, or preferably no, manganese content to reduce the discoloured water complaints. The approach to selecting an alternative coagulant was conducted in four phases. The following outlines the major components of each project phase:

Phase 1: Background Review, Benchmarking and Selection of Appropriate Coagulant to Pilot

- ➔ Conduct a review of background information and benchmarking of the full-scale system.
- ➔ Identify candidate alternative coagulants to ferric chloride, and candidate coagulant-aids.
  - o Identification of ideal coagulants for bench testing.
  - o Identification of ideal coagulant-aids for bench testing.
  - o Development of a standard operating procedure (SOP) for bench testing.
- ➔ Conduct bench-scale jar-testing of candidate coagulants and coagulant-aids to establish the most appropriate coagulant(s) and coagulant-aid(s) to be piloted based on key water treatment targets (e.g. turbidity, UV-Transmittance (UVT), absorbance, and manganese).
  - o Determine optimal conditions for candidate alternative coagulants, i.e. coagulant dose and operating pH.
  - o Determine optimal conditions for coagulant-aid, i.e. coagulant-aid dose.
- ➔ Identify the most appropriate alternative coagulant and coagulant-aid to undergo seasonal piloting.
- ➔ Evaluate the impacts of the selected coagulants on the full-scale system.

Phase 2: Development of a Coagulant Piloting Work Program

- ➔ Develop piloting testing protocols.
- ➔ Develop operational goals for the pilot-scale system.

Phase 3: Coagulant Piloting

- ➔ Evaluate the performance of the pilot-scale system against the full-scale system. Confirm the differences in operation when the same chemicals are used and dosed at equivalent quantities.

- Conduct a seasonal pilot-scale system study of the most appropriate alternative coagulant and coagulant-aid identified in Phase 1.
    - Pilot the alternative coagulant and coagulant-aid in four seasons, i.e. Spring, Summer, Fall, and Winter, to evaluate the limitations of the chemicals in different raw water conditions.
    - Determine the optimal chemical dose and operating pH for the alternative coagulant and coagulant-aid under different water conditions.

Phase 4: Meetings and Reporting

- Report the findings including:
    - The optimal coagulant and coagulant-aid dose, as well as the optimal operating pH, for each season based on the results of key water quality parameters, i.e. pH, turbidity, UVT, absorbance, and manganese when compared to the operation of the pilot-scale system using the current coagulant.
- Identify areas of concern following a transition from the current coagulant, ferric chloride, to the proposed alternative coagulant and/or coagulant-aid, including:
    - Potential impacts to the existing full-scale system and operations such as:
        - Bulk chemical storage;
        - Chemical delivery systems;
        - Existing water treatment processes, i.e. dissolved air floatation (DAF) system, ozonation, and filtration;
        - Structural components of the full-scale system, such as concrete buildings and tanks, piping, and the distribution system;
        - Finished water quality objectives related to the City's Operating Licence; and
        - Associated changes to current operating costs.
- Finally, report the most appropriate alternative coagulant and/or coagulant-aid conditions that would meet the objective of reducing the manganese concentration in the treated water entering the distribution system, while still meeting the Operating Licence and effluent water quality guidelines according to the Manitoba Drinking Water Safety Act and the Guidelines for Canadian Drinking Water Quality (GCDWQ).

The project was conducted over an approximately 22-month period. The major results obtained from each phase of the project are summarized below:

Phase 1 Results:

- Review of background information provided by the City identified that elevated manganese in the treated water was likely the cause for discoloured water reported by customers.
- The City would struggle to meet the future GCDWQ aesthetic objective (AO) of <0.02 mg/L for manganese in the finished water with the current coagulant.
- The elevated manganese in the treated water was a result of both the high manganese content in the current coagulant in use, ferric chloride, as well as seasonal increases in manganese in the raw water source (Shoal Lake). It is believed that the primary contributor to elevated manganese in the treated

water is from the residual manganese found in the ferric chloride.

- ➔ Four alternative coagulants were identified as meeting the criteria of lower residual manganese, and potentially meeting the current treated water targets while having a minimal impact to the full-scale system following a transition from ferric chloride. These four alternative coagulants are as follows:
  - o Ferric chloride/ferric sulphate blend (50/50)
  - o Ferric sulphate
  - o Aluminum/ferric sulphate blend (Blend 1: 50/50)
  - o Aluminum/ferric sulphate blend (Blend 2: 70/30)
- ➔ Three coagulant-aids that would complement the alternative coagulant objectives were identified as follows:
  - o Magnafloc LT-22S
  - o Prosedim ASP-20
  - o Prosedim CSP-640
- ➔ Jar testing results identified ferric sulphate as the most appropriate alternative coagulant candidate to be used for seasonal piloting, with an optimal dose of 41 mg/L and an optimal pH of 5.3.
- ➔ Jar testing results identified LT-22S as the most appropriate coagulant-aid to complement ferric sulphate during the seasonal piloting, with an optimal dose of 0.5 mg/L.

Phase 2 Results:

- ➔ Coagulant piloting protocol was elaborated for the benchmarking period with the current coagulant and for the transition periods and piloting sessions with the selected coagulant for piloting.

Phase 3 Results:

- ➔ Jar testing results from Phase 1 were used as the starting point for determining optimization during piloting. While jar testing of ferric sulphate had determined an optimal pH of 5.3, this pH was not used during piloting at the City’s direction. Due to the City’s concern over the condition of the concrete structures no tests were run at a pH below 5.7.
- ➔ Benchmark testing was conducted and confirmed that the pilot-scale system operations were reflective of the full-scale system and any differences were noted.
- ➔ Seasonal piloting sessions identified the optimal ferric sulphate dose, coagulant-aid dose, and pH, which are summarized as follows:

SEASON	COAGULANT DOSE (mg/L)	COAGULANT-AID DOSE (mg/L)	pH
Winter #1	46	0.02	Not Tested
Spring	42	0.20	6.1
Summer	38	0.10	5.8
Fall	42	0.07	5.7
Winter #2	41	Not Tested	5.8

Phase 4 Results:

- ➔ The current project involved the preparation of eight Technical Memoranda (TM) and this Final Report.
- ➔ Coagulation using ferric sulphate met the City's Operating Licence requirements, as well as lowering the final effluent manganese concentration below the proposed Health Canada aesthetic objective of <0.02 mg/L. Furthermore, the manganese concentration in the final effluent was below the City's operational target of <0.015 mg/L in all seasonal piloting sessions, apart from the Summer piloting session where a final effluent manganese concentration of 0.017 mg/L was measured. The elevated raw water manganese during the Summer piloting session was believed to have contributed to the elevated manganese in the final effluent.
- ➔ It was determined that the coagulant-aid marginally improved treated water quality; however, the improvements were not significant enough to warrant the added cost associated with its use. Furthermore, the addition of coagulant-aid caused a significant increase in the need for cleaning and maintenance of the pilot-scale system, particularly the DAF system. Likewise, the addition of coagulant-aid negatively impacted the filter operations with regards to unit filter run volume (UFRV).
- ➔ Evaluation of any potential impacts to the full-scale system following a change to ferric sulphate were believed to be minimal and may in fact produce slightly more stable water with regards to corrosive indices, in particular the chloride to sulphate mass ratio (CSMR).

Overall, the project was successful in identifying an alternative coagulant for ferric chloride which would meet the project objective of minimizing the concentration of manganese entering the distribution system, while still meeting all target treatment objectives. It is believed that a transition to ferric sulphate would have minimal impacts to the current operations in the full-scale system, while reducing the manganese entering the distribution system, which may reduce the frequency and duration of discoloured water events reported by customers.

Nevertheless, it should be noted that any change in the treated water chemistry could have impacts in a distribution system that may last a few seasons, due to the acclimation of the protective biofilm and reaction with existing deposits in the distribution system.

1 INTRODUCTION

1.1 OUTLINE OF THE PROJECT

Since 2010, only a year after the Winnipeg WTP was commissioned, the City received customer inquiries and service requests regarding discoloured water. From previous studies carried out, it was established that the manganese content in the treated water was the main reason for the discoloured water complaints. The sources of manganese were attributed to the raw water and the current coagulant chemical used (ferric chloride). The WTP treatment train cannot remove manganese to levels below 0.02 mg/L, the level at which water discoloration is detectable through visual observation.

In 2016, WSP Canada was retained by the City to select and test an alternative coagulant, with or without a coagulant-aid, for the Winnipeg WTP that reduces the concentration of manganese in the treated water. The reduction of manganese is believed to decrease the accumulation of manganese in the distribution system, and prevent, or eliminate, discoloured water events. The proactive approach taken by the City in reducing manganese in the treated water is in accordance with the newly proposed Health Canada AO for manganese of 0.02 mg/L, and a health based maximum acceptable concentration (MAC) of 0.1 mg/L. A secondary requirement for selecting an appropriate alternative coagulant, and/or coagulant-aid, is that it should meet all water quality treatment objectives and water quality targets required by the City. Lastly, the project aimed to evaluate the impacts of an alternative coagulant, and/or coagulant-aid, to the water treatment processes, chemical supply and delivery systems, residual production and management, and impacts to the distribution system.

The approach was to select an alternative coagulant by performing a series of bench-scale tests, followed by pilot-scale tests and analyses to obtain reliable results.

The current project was divided into four phases: (1) review of background information, (2) developing the coagulant piloting work program, (3) piloting an alternative coagulant and (4) reporting, which involved the preparation of eight TMs and this Final Report:

- TM No. 1 - Background Review, Benchmarking and Selection of Appropriate Coagulant to Pilot – Appendix A
- TM No. 2 – Development of Coagulant Piloting Work Program – Appendix B
- TM No. 3 – Winter Piloting Session #1 (March 15 – April 5, 2017) – Appendix C
- TM No. 4 – Spring Piloting Session (May 11 – May 31, 2017) – Appendix D
- TM No. 5 – Summer Piloting Session (July 24 – August 17, 2017) – Appendix E
- TM No. 6 – Fall Piloting Session (October 16 – October 31, 2017) – Appendix F
- TM No. 7 – Winter Piloting Session # 2 (November 17 – December 7, 2017) – Appendix G
- TM No. 8 – Review and Update of Front End Chemical Dose Procedure – Appendix H
- Final Report

Each of the TM documents can be found in Appendices A-H and are discussed within this Final Report. The objectives of this Final Report are to discuss the key findings of the overall project and to provide a recommended alternative coagulant, and coagulant-aid (if required), including operational conditions, such as chemical dose and pH, that will meet water quality objectives in all four seasons. The Final Report will also present recommendations regarding the expected impacts to current operations at the WTP following a transition to the alternative coagulant.

1.2 BACKGROUND REVIEW

A complete review of the background information provided by the City was conducted by WSP, which included various WTP reports, previous piloting studies, drawings, review of water quality data, and current operational parameters in the WTP and the distribution system. The detailed background review is presented TM No.1 which can be found in Appendix A.

The Winnipeg WTP was commissioned in 2009. Figure 1-1 illustrates the process flow diagram of the WTP including all chemicals used throughout the treatment train and their injection points.

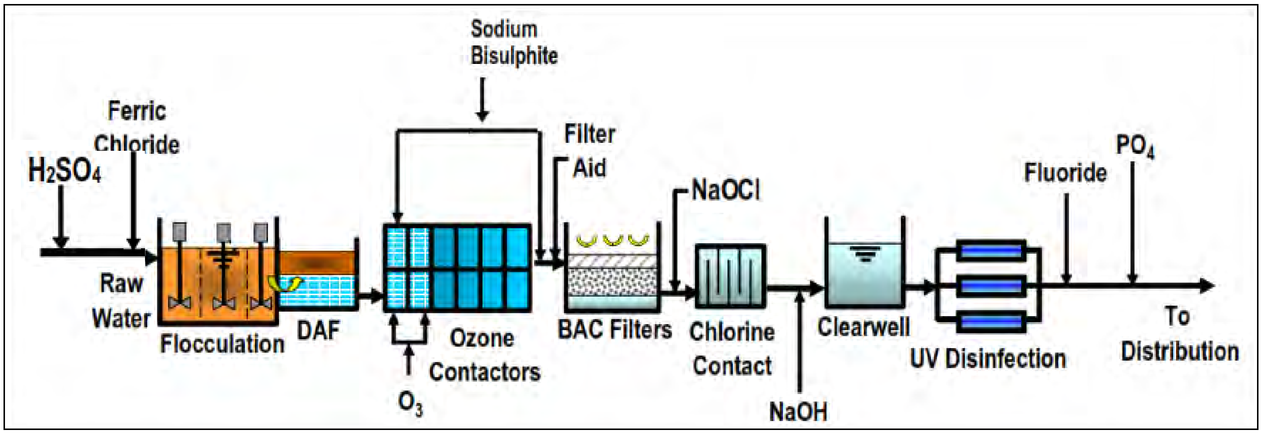

Figure 1-1: Winnipeg WTP - process flow diagram (adapted from CH2M Hill, June 2013).

Ferric chloride was selected based on extensive pilot studies at the pilot-scale system, which were concluded in September 1997, and is known as the Phase 2 pilot program. During this pilot program, ferric chloride outperformed aluminium sulphate (alum) in total organic carbon (TOC) removal, filtered particle counts, filter ripening, as well as odour removal; however, alum still met performance targets. Additionally, from an operational standpoint, when ferric chloride was used, the filter runs were more stable and not affected by changes in raw water quality to the same extent as alum. Therefore, ferric chloride was recommended as the primary coagulant.

Since 2010, the City has received a considerable number of customer complaints regarding discoloured water. In 2013, the City changed its ferric chloride supplier which resulted in even higher concentrations of manganese in the coagulant (CH2M Hill, December 2013).

Previous studies at the WTP concluded that the main reason for the discoloured water was due to elevated manganese concentration in the treated water, even though an aesthetic objective of 0.05 mg/L for manganese in drinking water was met most of the time (Health Canada, 2014). From the evaluation of previous study data, the concentration of manganese in treated water leaving the WTP and water throughout the distribution system was consistently higher than the raw water influent to the WTP, suggesting that the WTP treatment train itself was increasing the manganese content of water through an external source. Manganese content in Shoal Lake and the raw water (Deacon Reservoir) has been increasing with time. Figure 1-2 presents total manganese historical trends throughout the WTP.

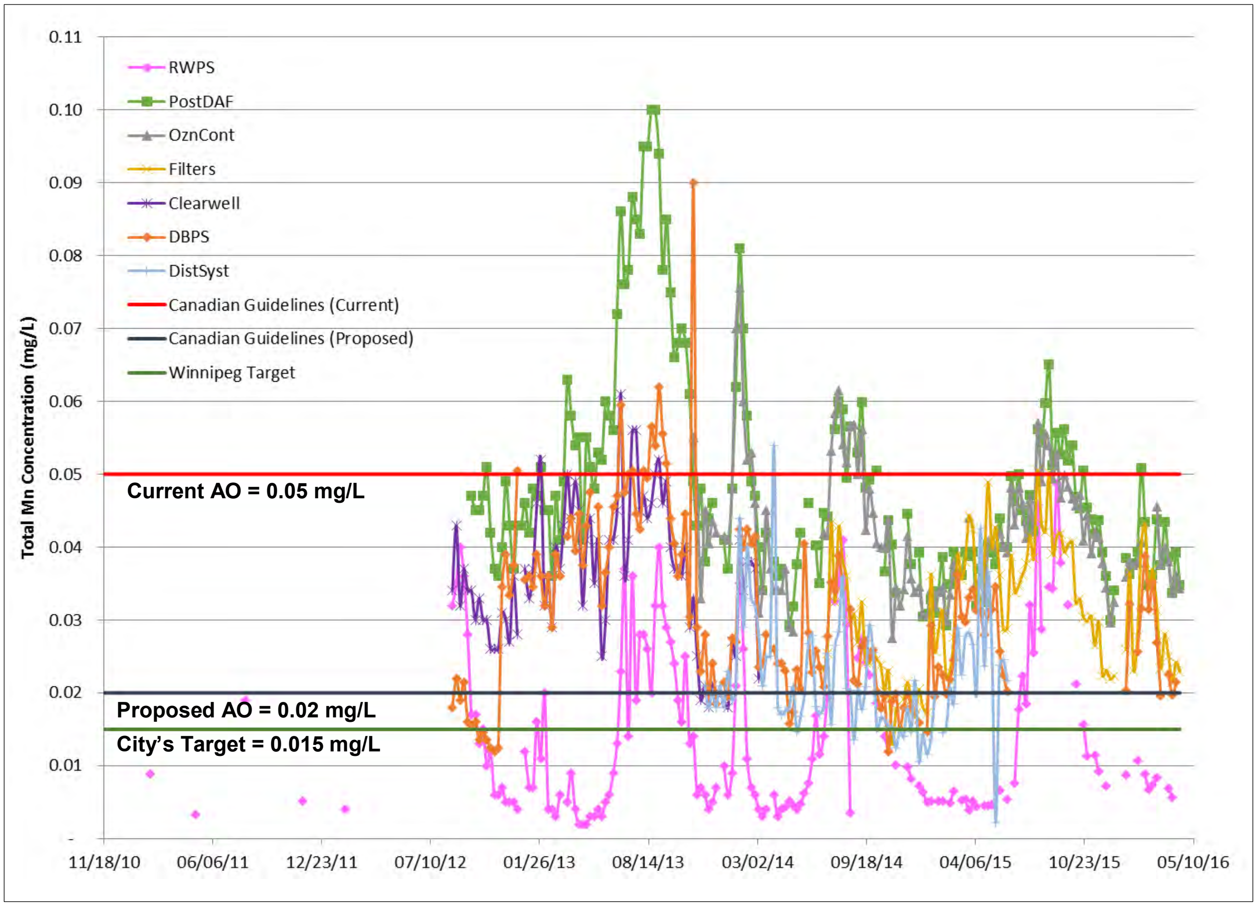

Figure 1-2: Historical trend, total manganese levels in the WTP.

Since previous studies lacked evidence indicating a source of manganese in the distribution system, and manganese concentrations in treated water leaving the WTP were higher than raw water concentrations, the increase in manganese concentration was attributed to chemical addition at the WTP.

Recently, Health Canada (and the Federal-Provincial-Territorial Committee on Drinking Water, referred to as CDW) proposed to lower the AO of total manganese from 0.05 mg/L to 0.02 mg/L, while adding a MAC for total manganese of 0.1 mg/L to the existing drinking water guidelines (Health Canada, 2016). Moreover, in 2006 the US Environmental Protection Agency (EPA) suggested a target level of 0.02 mg/L for manganese to reduce manganese deposition. As a result, some utilities are now targeting 0.015 mg/L total manganese in the treated water to prevent customer complaints. Due to the continuous water discolouration concerns in the City, and to regain customer confidence, in 2013 the City decided to set a future objective level of 0.015 mg/L for total manganese content in the treated water (CH2M Hill, 2013).

The previous studies to date made two main recommendations to assist in resolving the high manganese concentrations. The first recommendation was to change the ferric chloride specifications to receive a ferric chloride product with less manganese. In 2014, the City changed its coagulant specification to limit the manganese content to <600 mg/kg, which resulted in lower manganese entering the distribution system (Associated Engineering, 2015). The second recommendation was to ultimately investigate an alternative coagulant to ferric chloride, which has led to the current project.

In order to better understand possible manganese sources, a thorough mass balance analysis was conducted by WSP around the DAF process and throughout the WTP, as presented in Figure 1-3 and Figure 1-4, respectively. It should also be noted that limited data was available with regards to different residuals at the WTP and downstream of some processes. The blue area in Figure 1-3 illustrates raw water total manganese mass in kilograms per day, whereas the yellow area demonstrates the additional total manganese mass due to the addition of ferric chloride. It was assumed all manganese is in soluble form. Based on the results obtained from the mass balance analysis, the current ferric chloride used at the WTP was confirmed to be the primary reason for high manganese concentration in the treated water.

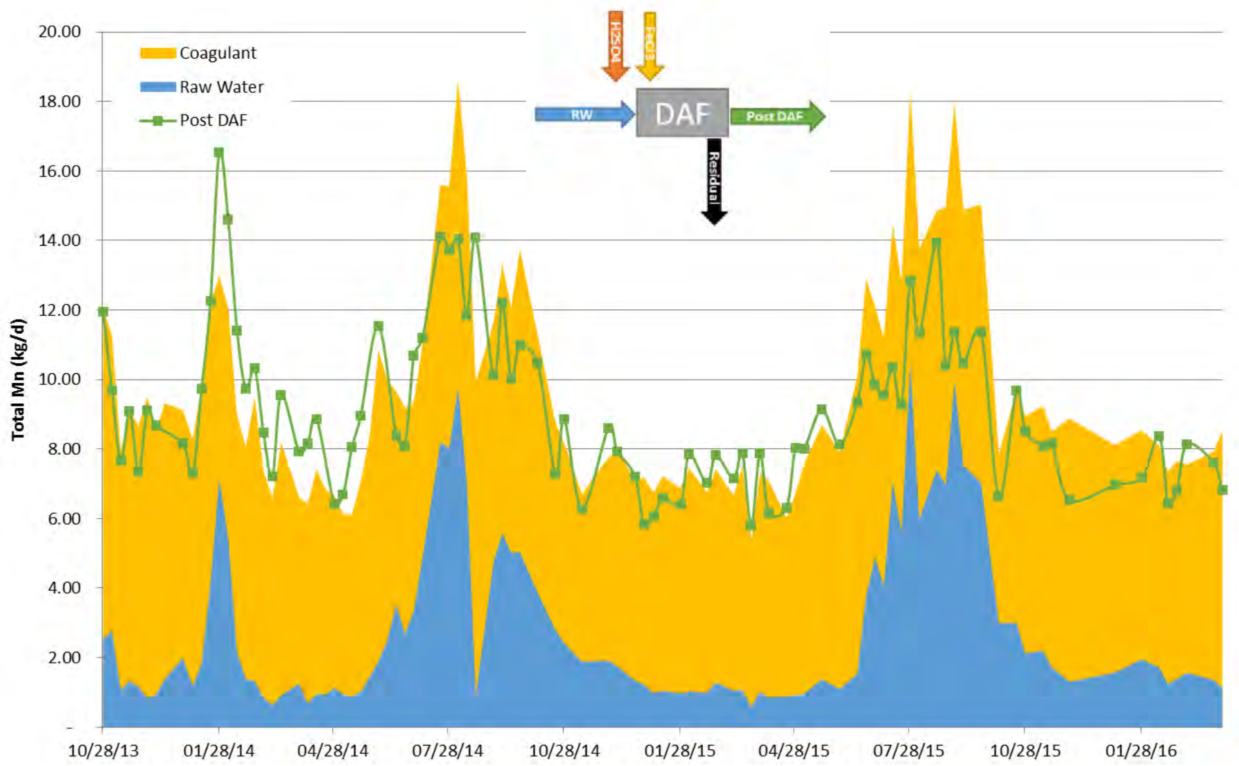

Figure 1-3: Total manganese mass balance, DAF process

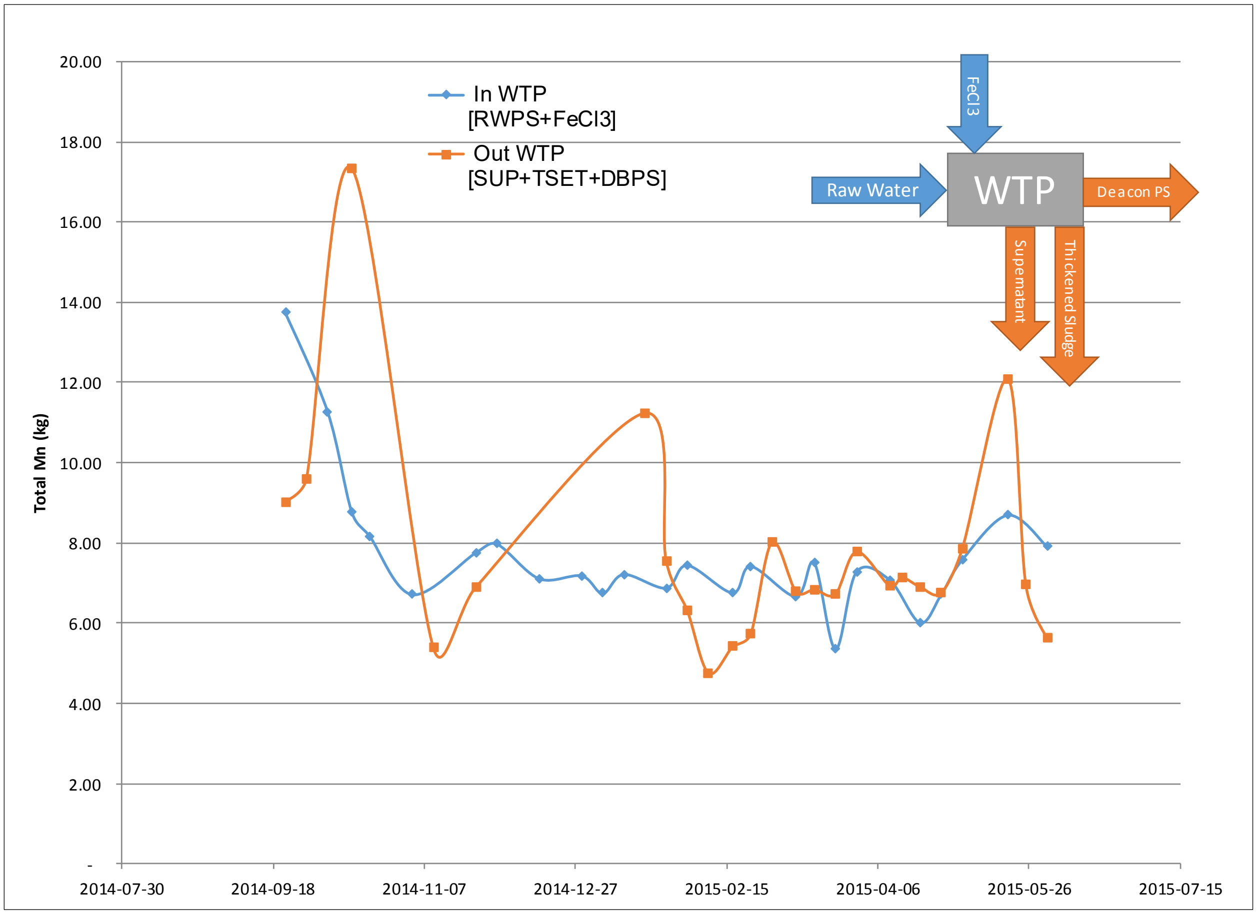

Figure 1-4: Total manganese mass balance for the full-scale system (input streams are in blue; output streams are in orange).

1.3 BENCHMARKING OF FULL-SCALE SYSTEM PERFORMANCE

Between 2010 and the beginning of 2016, raw and treated water quality, upstream and downstream water quality of each treatment process, and the quality of residuals and the filter operational parameters, were analysed. During this period, the average water production was 210 MLD. The full-scale system performance was benchmarked to establish a baseline for the evaluation of the alternative coagulant in each of the four seasons.

Table 1-1 tabulates the results of the water quality analysis throughout the full-scale system for this period.

Table 1-1: Benchmarking of full-scale system, water quality.

SAMPLE		TEMPERATURE	pH	TURBIDITY	TRUE COLOUR	APPARENT COLOUR	UVT FILTERED	UVT UNFILTERED	DOC	TOC	DO	ORP	ALKALINITY	CONDUCTIVITY	TDS	TS	THRESHOLD ODOUR NUMBER	IRON TOTAL	IRON SOLUBLE	MANGANESE TOTAL	MANGANESE SOLUBLE	SODIUM TOTAL	SODIUM SOLUBLE	SULPHATE	CHLORIDE	CSMR	TOTAL THM	TOTAL HAA
		°C	-	NTU	units	units	%	%	mg/L	mg/L	mg/L	mV	mg/L	µS/cm	mg/L	mg/L	TON	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	µg/L	µg/L
Raw Water Pumping Station	**Average**	**10.0**	**7.99**	**1.12**	**5.2**	**15.2**	**77.6**	**75.4**	**9.6**	**10.0**	**10.6**	**372**	**75**	**163**	**98**	**110**	**110**	**0.051**	**0.019**	**0.016**	**0.0045**	**2.25**	**2.19**	**2**	**2.7**	**1.00**	**9.8**	**6.5**
	Minimum	*<0.2*	*7.07*	*0.17*	*0.5*	*1.0*	*71.0*	*61.8*	*4.0*	*3.0*	*7.15*	*237*	*63*	*122*	*60*	*66*	*40*	*<0.008*	*<0.008*	*<0.001*	*<0.0003*	*1.65*	*1.56*	*<2*	*1.0*	*0.40*	*<0.5*	*<1*
	Maximum	*24.5*	*8.82*	*5.78*	*15.0*	*35.0*	*94.8*	*94.3*	*26.0*	*27.0*	*14.0*	*553*	*89*	*196*	*150*	*284*	*200*	*0.540*	*0.129*	*0.104*	*0.1000*	*4.70*	*3.54*	*8*	*6.2*	*3.00*	*95*	*50*
Post-DAF	**Average**		**5.57**	**0.53**	**1.9**	**8.5**	**92.7**	**86.1**	**4.1**	**4.2**	**10.9**	**395**	**8.1**					**0.570**	**0.201**	**0.0521**	**0.048**	**2.24**	**2.24**	**48**	**18**	**0.41**	**<3**	**<3**
	Minimum		*4.64*	*0.06*	*1.0*	*6.5*	*82.5*	*64.9*	*2.0*	*1.7*	*7.46*	*240*	*<2*					*0.042*	*0.004*	*0.0250*	*0.012*	*1.60*	*1.66*	*28*	*11*	*0.28*	*<3*	*<3*
	Maximum		*7.36*	*3.70*	*2.5*	*11.0*	*95.9*	*97.6*	*7.0*	*11.8*	*14.3*	*574*	*24*					*1.79*	*0.954*	*0.4690*	*0.099*	*4.70*	*2.88*	*68*	*29*	*1.04*	*<3*	*<3*
Post-Ozone Contactor	**Average**	**11.6**	**5.58**	**1.03**	**1.5**				**4.6**	**5.0**	**11.9**	**493**						**424**	**0.732**	**0.253**	**0.0748**	**2.14**	**2.08**				**0.3**	**4**
	Minimum	*0.80*	*4.99*	*0.26*	*1.5*				*3.0*	*4.0*	*10.1*	*281*						*0.290*	*<0.010*	*0.024*	*0.0140*	*1.85*	*1.80*				*<0.5*	*<3*
	Maximum	*24.3*	*5.94*	*12.0*	*1.5*				*13.0*	*12.0*	*13.6*	*610*						*23700*	*39.5*	*10.35*	*1.97*	*2.54*	*2.50*				*1.0*	*15*
Post-Carbon Filters	**Average**		**6.10**	**0.12**	**0.8**			**92.7**	**3.8**	**3.8**	**12.1**	**380**	**9**				**10**	**0.062**	**0.023**	**0.0295**	**0.0279**						**<0.5**	**2.1**
	Minimum		*4.37*	*<0.05*	*0.5*			*92.3*	*1.3*	*<1.0*	*8.35*	*262*	*6*				*5*	*<0.008*	*<0.008*	*0.0086*	*0.0077*						*<0.5*	*<3*
	Maximum		*7.78*	*0.53*	*2.5*			*93.1*	*7.0*	*10.0*	*16.4*	*623*	*12*				*30*	*0.308*	*0.124*	*0.0510*	*0.0476*						*<0.5*	*3.0*
Clear Well	**Average**	**11.0**	**7.84**	**0.17**	**1.4**	**5.8**	**95.0**	**93.9**	**4**	**4**	**9.42**	**417**	**70**	**316**	**175**	**190**	**26**	**0.043**	**0.010**	**0.038**	**0.023**	**33.0**	**30.6**	**48**	**20**	**0.44**	**12**	**13**
	Minimum	*<0.2*	*6.47*	*0.06*	*0.5*	*0.5*	*90.2*	*84.4*	*<1*	*<1*	*6.18*	*267*	*57*	*271*	*116*	*146*	*12*	*<0.010*	*<0.010*	*0.018*	*0.010*	*23.4*	*27.4*	*23*	*13*	*0.20*	*<0.5*	*<5*
	Maximum	*25.0*	*9.74*	*1.52*	*7.5*	*18.0*	*98.7*	*97.5*	*19*	*19*	*13.4*	*665*	*89*	*368*	*230*	*258*	*75*	*0.240*	*0.060*	*0.068*	*0.040*	*67.1*	*34.7*	*70*	*31*	*1.04*	*81*	*40*
Deacon Booster Pumping Station	**Average**	**9.9**	**7.77**	**0.17**	**1.18**	**6.14**	**95.4**	**94.2**	**4.1**	**4.1**	**11.9**	**393**	**69**	**318**	**178**	**191**	**24**	**0.041**	**0.015**	**0.031**	**0.0130**	**32.0**	**30.2**	**50**	**21**	**0.43**	**14**	**16**
	Minimum	*<0.2*	*7.23*	*0.07*	*0.5*	*0.5*	*79.4*	*78*	*0.5*	*0.5*	*8.3*	*275*	*54*	*275*	*131*	*144*	*5*	*<0.008*	*<0.008*	*0.012*	*0.0007*	*24.0*	*23.7*	*19*	*13*	*0.21*	*<0.5*	*<5*
	Maximum	*24.5*	*9.27*	*1.08*	*7.5*	*30*	*99.1*	*97.8*	*19.0*	*20.0*	*16.2*	*582*	*87*	*368*	*229*	*246*	*70*	*0.380*	*0.120*	*0.144*	*0.0450*	*42.8*	*39.0*	*71*	*31*	*1.37*	*81*	*40*
Distribution System	**Average**	**11.0**	**7.52**	**0.30**	**1.3**	**7.3**					**11.2**	**390**	**67**		**180**		**26**	**0.054**	**0.017**	**0.0243**	**0.0073**	**31.5**	**30.7**	**50**	**21**	**0.44**	**31**	**29**
	Minimum	*0.2*	*6.42*	*0.06*	*<0.5*	*0.5*					*6.30*	*278*	*57*		*71*		*8*	*<0.008*	*<0.008*	*0.0086*	*<0.0003*	*23.4*	*23.5*	*29*	*13*	*0.20*	*5*	*5*
	Maximum	*27.2*	*8.35*	*164*	*10.0*	*70.0*					*15.4*	*567*	*86*		*248*		*100*	*2.04*	*0.090*	*0.1925*	*0.0534*	*47.2*	*46.5*	*69*	*30*	*0.86*	*97*	*61*

Note: This table is an updated version of the corresponding table presented in TM No. 1.

Blank cells indicate that no data was available.

Table 1-2 presents water quality targets or regulations that are relevant to benchmarking and piloting of an alternative coagulant to ferric chloride. It should be noted Table 1-2 does not include all water quality objectives the City is expected to comply with, or aims to meet.

Table 1-2: City of Winnipeg select treated water quality targets.

PARAMETER	REGULATORY AGENCY	TARGET GUIDELINE OR REGULATION
Turbidity	Office of Drinking Water (ODW) - Operating Licence	No more than 0.3 NTU in 95% of the measurements per month; never >1.0 NTU Operating Guideline <0.1 NTU
Chlorine Residual	ODW - Operating Licence	At least 0.5 mg/L free chlorine entering the distribution system after 20 minutes of contact time and a free chlorine residual of >0.1 mg/L at any point in the distribution system
Iron	GCDWQ - Aesthetic Objective	≤0.3 mg/L
Manganese	GCDWQ - Aesthetic Objective	≤0.05 mg/L Operating Guideline <0.015 mg/L
Aluminum	GCDWQ - Operational Guideline	< 0.1 mg/L
Total Trihalomethanes	ODW - Operating Licence	No more than 100 µg/L on a locational running average of quarterly samples
Total Haloacetic Acids	ODW - Operating Licence	No more than 80 µg/L on a locational running average of quarterly samples
True Colour	GCDWQ -Aesthetic Objective	< 15 True Colour Units
Odour	GCDWQ -Aesthetic Objective	Inoffensive
pH	GCDWQ - Operational Guideline	7.0 - 10.5
Total Dissolved Solids	GCDWQ - Aesthetic Objective	≤500 mg/L
Chloride	GCDWQ - Aesthetic Objective	≤250 mg/L
Sulphate	GCDWQ - Aesthetic Objective	≤500 mg/L

Based on full-scale system historical data, it was observed that the average total manganese concentration increases from 0.016 mg/L to 0.052 mg/L following DAF treatment. Some removal is observed via filtration; however, manganese in the treated water at the clearwell remains higher than the raw water with an average concentration of 0.038 mg/L, which is below the current AO limit of 0.05 mg/L, but higher than the new recommended treatment objective set by the City of 0.015 mg/L.

Table 1-3 presents the filters and the filter backwash performance for the full-scale system between 2010 and 2015. These values will be used as a baseline for the evaluation of the alternative coagulant in each of the four seasons.

Table 1-3: Benchmarking of full-scale system - filters operational parameters.

	RUN TIME	UNIT FILTER RUN VOLUME	HYDRAULIC FLOW RATE	CONTACT TIME	DIFFERENTIAL HEAD LOSS	BACKWASH FREQUENCY
	hours	m^3/m^2	m/h	min	kPa	Number per day
Average	**28.9**	**495**	**15.9**	**7.93**	**48.9**	**5.3**
Minimum	20.0	319	11.9	10.6	23.7	4.1
Maximum	40.9	630	20.9	6.2	70.6	7.1

2 SELECTION OF APPROPRIATE COAGULANT AND COAGULANT-AID

2.1 OVERVIEW

As discussed in Section 1, it is understood that the majority of manganese in the treated water was attributed to ferric chloride. The strategy was to reduce the manganese level and maintain the current full-scale system performance by identifying an alternative coagulant that contains the lowest possible levels of manganese. Therefore, the selected coagulants should:

- Reduce the potential for discoloured water in the distribution system, while complying with regulatory requirements and operational objectives;
- Contain the minimum levels of impurities that may pass through the treatment processes;
- Be compatible with the existing materials, chemicals and processes at the full-scale system, where possible;
- Maintain or improve current full-scale system performance, with regards to DAF and filter operation, and the treated water stability; and
- Minimize disturbance to the distribution system.

The bench testing program was developed during July and August of 2016, to test the candidate coagulants and coagulant-aids. The first-round of bench testing was performed in September and October of 2016. A second bench test was performed in January 2017, for confirmatory purposes.

Based on the bench testing results, the impacts of coagulant changeover were evaluated for the best two combinations of coagulant and coagulant-aid, in order to select the alternative coagulant and coagulant-aid for pilot studies. The best coagulant that meets the project objectives was determined to be ferric sulphate, while the best coagulant-aid was Magnafloc LT-22S.

Additional information about the candidate coagulants and coagulant-aids, the bench testing details and results, and the evaluation of the impacts of switching coagulants are presented in TM No.1 which can be found in Appendix A.

2.2 IDENTIFICATION OF CANDIDATE COAGULANTS AND COAGULANT-AIDS

2.2.1 COAGULANT

Among all the commercial coagulants, aluminum-based and iron-based coagulants are widely available and are the most commonly used products for coagulation in WTPs. However, the performance of each coagulant varies according to the characteristics of the water that is being treated.

In order to identify candidate coagulants that could be used as a replacement for the current coagulant, ferric chloride, several coagulant producers and distributors were contacted to discuss their product availability and characteristics (PVS Fanchem, Univar, Brenntag, Cleartech, Canadian Colors and

Chemicals Ltd. (CCC), Kemira, Azelis America, Border Chemicals). Several Canadian water treatment utilities were also contacted to discuss their experience and overall satisfaction level with the performance of their coagulant (Repentigny WTP, Pierrefonds WTP and Saskatoon WTP).

Initially, complex aluminum-based coagulants, i.e. poly-aluminum chloride, were considered as one of the coagulant candidates. These coagulants consume less alkalinity and are effective throughout a wide pH range. The coagulation/flocculation process is operated at a higher pH, allowing for partial precipitation of available manganese ions and formation of manganese species which could be removed through the DAF process. Furthermore, aluminum-based coagulants are known to contain less metallurgical impurities/contaminants compared to ferric based coagulants.

After completing an extensive background review of the available reports and water quality data, it was believed that the Phase 2 pilot program report presented a very compelling argument for the use of ferric based coagulants (as outlined in Section 4 of TM No. 1 – Appendix A). Bench-scale testing does not consider seasonal water quality variations, and therefore is not as comprehensive, nor as accurate as pilot-scale testing. Consequently, it is assumed that the results that can be obtained with bench-scale tests would not reverse the previous pilot results, and suggests the superiority of ferric chloride in relation to alum.

Thus, the selected coagulants for bench-scale testing were ferric chloride, a blend of ferric chloride and ferric sulphate, ferric sulphate, and two blends of aluminum/ferric sulphate. Table 2-1 presents the short-listed coagulants, their main characteristics, and other impurities found in the coagulants. In order to attain the future operational objective of <0.015 mg/L in total manganese in the treated water, the manganese content in the coagulant should be limited to approximately 140 mg/kg for a coagulant dose of 30 mg/L or 100 mg/kg for a dose of 40 mg/L. This also takes into consideration the average manganese in the raw water and the average removal of manganese during the water treatment process. Among the identified coagulants, ferric sulphate and the blends of aluminum/ferric sulphate could achieve these targets based on their manganese concentrations.

Table 2-1: Identified coagulants characteristics.

COAGULANT[1]	**FERRIC CHLORIDE**	**FERRIC CHLORIDE / FERRIC SULPHATE BLEND**	**FERRIC SULPHATE**	**ALUMINUM/FERRIC SULPHATE BLEND 1**	**ALUMINUM/FERRIC SULPHATE BLEND 2**	**ALUM (ALUMINUM SULPHATE)**[5]
CONSTITUENT	$FeCl_3$	50% $FeCl_3$ 50% $Fe_2(SO_4)_3$	$Fe_2(SO_4)_3$	50% $Al_2(SO_4)_3.18H_2O$ 50% $Fe_2(SO_4)_3$	70% $Al_2(SO_4)_3.18H_2O$ 30% $Fe_2(SO_4)_3$	$Al_2(SO_4)_3.18H_2O$
Concentration (%)	37% - 42%	40% - 42%	43%	45% - 46%	46% - 47%	48%
Specific gravity	1.38 - 1.45	1.45 – 1.50	1.55	1.44	1.38	1.3
Iron Content (%w/w)	12.7 -14.1%	12% - 13.5%	11.5-13%	6.0 %	3.28%	< 0.01%
Aluminum Content (%w/w)	-	-	-	2.2%	3.0%	4.3%
Manganese Content (mg/kg)[2]	< 600	< 300	< 100	< 55	< 37	< 10
% Free acid as HCl_3	< 1.0	0.21	0.01	0.01	0.01	0.01
Insoluble Solids (mg/kg) [3]	< 80	567	27	606	388	299
Lead (mg/kg)	< 1.3 [3]	0	0	0	0	0
Magnesium (mg/kg) [3]	< 35	60	142	24	6	0
Optimal pH range	< 6	< 6	< 6	5.5 – 6.5	5.5 – 6.5	5.8 - 6.5
Suppliers	Kemira, PVS Fanchem	Kemira[4]	Kemira, CCC	Kemira[4]	Kemira[4]	Kemira Brenntag Border Chemicals
References	-	-	Repentigny, QC Saskatoon, SK	Pierrefonds, QC	-	Most widely used North America

1 All coagulants meet the AWWA standards and are ANSI/NSF Standard 60 certified.

2 The manganese content is expressed in mg/kg in a wet weight basis. The manganese content of the blends is variable, and were calculated according to blend ratio.

3 Ferric chloride information based on Winnipeg WTP historical analysis. Other coagulants based on certificate of analysis provided by Kemira.

4 Even though Kemira is the only vendor that market these coagulant blends, these are not proprietary blends and other vendors that commercialize the main products (like Brenntag and Univar) are able to supply these products.

5 Due to the limited number of trials available, alum was not selected as a potential coagulant for bench-scale tests, however its characteristics are shown, since it was used as a source for the proposed blends.

2.2.2 COAGULANT-AID

A coagulant-aid, when used in conjunction with a coagulant, can provide benefits such as reducing the amount of coagulant needed, reducing head loss in filtration processes, and even reducing sludge volume. Consequently, careful selection of a coagulant-aid is warranted.

In order to identify candidate coagulant-aids, several polymer producers and distributors (BASF, Nalco and ERPAC) were contacted to discuss their product availability and characteristics. Each polymer supplier provided a recommendation of a polymer to act as a coagulant-aid, based on the Winnipeg full-scale system characteristics and water quality. Dry polymers with complete solubility were specified, considering the possible amount required at the Winnipeg full-scale system.

The recommended coagulant-aids, along with their characteristics and rationale for the selection, are presented in Table 2-2.

Table 2-2: Identified coagulant-aids characteristics.

COAGULANT-AID[1]	MAGNAFLOC LT-22S	PROSEDIM ASP-20	PROSEDIM CSP-640
CONSTITUENT	Acrylamide co-polymer and quaternized cationic monomer	Acrylamide co-polymer	Acrylamide co-polymer
Charge	Low cationic	Non-ionic	Very low cationic
Molecular weight	High	Very high	High
Type	Dry Powder	Dry Powder	Dry Powder
Usage	Coagulant-aid or filter aid	Coagulant-aid or filter-aid	Coagulant-aid or filter-aid
Maximum concentration	1.0 mg/L	1.0 mg/L	1.0 mg/L
Supplier	BASF	ERPAC	ERPAC
Reference[2]	Windsor PUC, On Mannheim WTP, Waterloo, On Chatham WTP, On Rossdale WTP, Calgary, On Bearspaw WTP, Calgary, On	Pierrefonds, QC Repentigny, QC	Contrecoeur, QC (DAF) Gatineau, QC Régie de l'eau d'Ile-Perrot, QC L'Assomption, QC St-Georges-de-Beauce, QC Québec, QC St-Jérôme, QC
Rational for selection	Current filter-aid in use	Different charge	Very successful in DAF installations

1 All coagulant-aids meet the AWWA standards and are ANSI/NSF Standard 60 certified.

2 The references are not extensive.

2.3 SUMMARY OF BENCH TESTING RESULTS

The DAF jar-testing program was completed to compare the alternative coagulants to the current coagulant at a bench-scale level, with the aim of achieving Post-DAF manganese concentrations less than the manganese concentrations noted with the current coagulant, and to satisfy the 0.015 mg/L objective set by the City. The results of the numerous bench-scale trials performed were used to determine the best coagulant, coagulant-aid and pH to be further tested at the pilot-scale system.

2.3.1 BENCH TEST 1

The bench testing program was performed between September 12th, 2016 and October 21st, 2016. The bench testing experiments spanned approximately six weeks and it was noted that there was considerable variation in raw water temperature during this period. During the beginning of the experiments (setup and baselining) the temperature ranged between 17.7°C and 20.9°C. At the end of the jar testing, the water temperature was approximately 8.9°C. Historical data shows that the manganese issues were most prevalent in the warm water conditions, which is likely associated with increased coagulant doses and higher seasonal manganese in the raw water during the summer. As such, a reduction in temperature during the test may have affected the results.

Due to the compressed bench testing schedule, and the turnaround time for analytical results from the City's Analytical Services Branch (hereafter referred as the Lab), an initial investigation was carried out to determine if data collected using a Hach spectrophotometer (Hach) and Method 8149 (low range manganese by 1-(2-pyridylazo)-2-naphthol) available at the full-scale system, would be an acceptable representative value of the actual manganese concentration. The manganese results from the Hach instrument were deemed not to be an acceptable quantitative screening value for the actual manganese concentration. This was due to the manganese concentration being at, or near, the limit of detection (LOD) of the Hach instrument. Although the Hach manganese method was found to be unsuitable for accurately quantifying the manganese concentrations, the method was still valuable in indicating general increases or decreases in manganese concentration. As such, it was used to guide optimal dose decisions.

Prior to the commencement of jar testing, operational parameters were established to be used during testing. This setup included testing the functionality of the jar tester, testing the benchtop equipment and calibrating the benchtop probes, i.e. the pH probe, and adjusting the saturation pressure to match the full-scale system. During the initial setup, tests were conducted using ferric chloride with no coagulant-aid. Following the completion of the initial setup and evaluation of the jar testing equipment, seven trials were conducted each with a distinct objective. Full results obtained during Bench Test #1 are presented in Section 7 of TM No. 1 – Appendix A.

2.3.1.1 BENCH TEST 1 – TRIAL #1: CONFIRMING JAR TESTING PROCEDURE

During Trial #1, the jar testing procedure was evaluated including mirroring the full-scale system conditions, for example flash mixing energy, coagulation/flocculation time, and air saturation pressure. Confirmation of the jar testing procedures was carried out using ferric chloride and no coagulant-aid. The dose of ferric chloride used for evaluating the jar testing procedure was varied by 75% and 125% of the full-scale system coagulant dose at the time of the trial (25 mg/L) and pH was not controlled. The jar testing parameters which were tested, and the subsequent parameter changes to jar testing parameters based on the turbidity, UVT, total manganese and TOC results are presented in Table 2-3.

Table 2-3: Bench Test 1 - Trial #1 jar testing parameters and changes based on key parameter results.

PARAMETERS	INITIAL PARAMETERS VALUES	PARAMETER VALUES AFTER TESTING
Ferric Chloride Dose (mg/L)	25	18.75
Flash Mixing Speed (RPM)	200	200
Flash Mix Time (sec)	30	30
Flocculation Speed (RPM)	45	45
Flocculation Time (min)	20	15
Saturation Pressure (kPa)	500	500
DAF Time Before Sample Collection (min)	10	10

2.3.1.2 BENCH TEST 1 – TRIAL #2: OPTIMIZE COAGULANT DOSE

The initial bench testing was conducted on five shortlisted coagulant candidates: the current coagulant used in the full-scale system (ferric chloride), ferric sulphate, a ferric chloride/ferric sulphate blend, an aluminum/ferric sulphate Blend 1 (50/50), and an aluminum/ferric sulphate Blend 2 (70/30). All coagulants were tested between 15 mg/L and 45 mg/L for the best dose based on turbidity, UVT, total manganese, and TOC results. The best dose determined for each coagulant was then further refined to determine the optimal dose for each coagulant. Following the coagulant screening, a choice was required between Blend 1 and Blend 2 as to which would be carried forward for bench testing. Since aluminum/ferric sulphate Blend 2 consistently exhibited lower manganese concentrations than Blend 1 at all doses, it was selected as the coagulant to be tested further during bench testing. The optimal dose and refined optimal dose for each coagulant, determined based on turbidity, UVT, total manganese and TOC results, are presented in Table 2-4. There was no coagulant-aid added and the pH was adjusted to 5.30 for all tests.

Table 2-4: The optimal coagulant dose and refined coagulant dose determined during Bench Test 1 - Trial #2

COAGULANT	OPTIMAL DOSE SELECTED (mg/L)	REFINED OPTIMAL DOSE SELECTED (mg/L)
Ferric chloride	15	15
Ferric sulphate	45	41
Ferric Chloride/Ferric Sulphate	40	41
Aluminum/ferric sulphate Blend 2	45	43

The rationale for selection of optimal dose for the coagulants are summarized below:

- Ferric chloride: The optimal dose ranged between 11 mg/L and 19 mg/L, so an intermediate dose of 15 mg/L was selected.
- Ferric sulphate: The optimal dose in all trials was 41 mg/L (except for a dose of 43 mg/L in one of the duplicate Lab total manganese data), so 41 mg/L was selected as the optimal dose.
- Ferric chloride/ferric sulphate: The best dose varied between 37 mg/L and 43 mg/L; therefore, an intermediate dose of 41 mg/L was selected.
- Aluminum/ferric sulphate Blend 2: Results from the key parameters during dose refinement testing identified an optimal dose of 43 mg/L, which was selected as the dose to be carried forward.

2.3.1.3 BENCH TEST 1 – TRIAL #3: pH OPTIMIZATION

Bench tests were performed to evaluate the optimal pH for each coagulant. Based on the protocol, pH ranges of 5.0 to 6.0 were investigated for the ferric based coagulants, while pH ranges of 5.5 - 6.5 were investigated for the aluminum based coagulant. The pH was altered by the addition of sulphuric acid. The optimal pH was determined for each coagulant at the optimal dose determined in Trial #2. The optimal pH was determined based on turbidity, total manganese (Hach and Lab results), and UVT (Table 2-5).

Table 2-5: Optimal coagulant pH determined in Bench Test 1 - Trial #3 based on total manganese, turbidity and UVT.

COAGULANT	OPTIMAL pH RESULTING FROM TEST:				OPTIMAL pH SELECTED
	BASED ON HACH MANGANESE	BASED ON LAB TOTAL MANGANESE	BASED ON TURBIDITY	BASED ON UVT	
Ferric chloride	5.0 to 6.0	6.0	6.0	5.3	5.3
Ferric sulphate	5.0	6.0	5.3	5.3	5.3
Ferric Chloride/Ferric Sulphate	5.6	5.6	5.6	5.6	5.6
Aluminum/ferric sulphate Blend 2	5.5	5.5	6.5	6.5	6.5

The rationale for selection of optimal pH for the coagulants are presented below:

- ➔ Ferric chloride: The optimal pH based on Hach manganese and Lab total manganese ranged between 5.0 and 6.0. Turbidity and UVT suggested an optimal pH of 5.3 or 6.0. Considering the results, a value of 5.3 was selected.

- ➔ Ferric sulphate: The optimal pH based on Hach manganese and Lab total manganese was between 5.0 and 6.0. Turbidity and UVT both yielded an optimal pH of 5.3 so this was selected for further testing.

- ➔ Ferric chloride/Ferric sulphate: pH of 5.6 was the best pH considering Hach manganese, Lab Total manganese, turbidity and UVT and was hence deemed as the optimal pH.

- ➔ Aluminum/ferric sulphate Blend 2: The optimal pH considering Hach manganese and Lab total manganese was 5.5, while the optimal pH considering turbidity and UVT was 6.5. The higher pH of 6.5 was selected for further testing.

2.3.1.4 BENCH TEST 1 – TRIAL #4: COAGULANT-AID OPTIMIZATION

Each coagulant was tested with the three-selected coagulant-aids identified in Table 2-2 at the optimal coagulant dose determined in Trial #2, and the optimal pH determined in Trial #3. The optimal coagulant-aid was determined for each coagulant, as well as the optimal coagulant-aid dose. The optimal coagulant-aid dose was selected based on the turbidity and manganese (Hach and Lab) results (Table 2-6).

Table 2-6: Optimal coagulant-aid dose determined in Bench Test 1 - Trial #4 based on total manganese and turbidity.

COAGULANT	OPTIMAL COAGULANT-AID BASED ON LAB TOTAL MANGANESE	CORRESPONDING OPTIMAL CONC. OF COAGULANT-AID (mg/L)	OPTIMAL COAGULANT-AID BASED ON TURBIDITY	OPTIMAL COAGULANT-AID SELECTED
Ferric chloride	CSP-640	0.5	ASP-20	CSP-640
Ferric sulphate	LT-22S	0.5	LT-22S	LT-22S
Ferric Chloride/Ferric Sulphate	LT-22S	0.5	LT-22S	LT-22S
Aluminum/ferric sulphate Blend 2	LT-22S	0.5	CSP-640	CSP-640

The rationale for selection of the optimal coagulant-aid is presented below:

- ➔ Ferric chloride: The best coagulant-aid relating to total manganese removal was CSP-640, and it was noted to have an optimal removal at a concentration of 0.5 mg/L. At this concentration, ASP-20 was observed to be the best coagulant-aid when turbidity was considered. However, since ASP-20 had a rather high manganese concentration (0.0064 mg/L) at a coagulant-aid concentration of 0.5 mg/L, the optimal coagulant-aid selected was CSP-640.

➔ Ferric sulphate: When manganese removal was evaluated, LT-22S was the coagulant-aid with the highest removal at a concentration of 0.5 mg/L. Turbidity was also lowest with LT-22S at 0.5 mg/L, confirming the choice of coagulant-aid.

➔ Ferric chloride/ferric sulphate: LT-22S yielded the lowest manganese concentration. A coagulant-aid concentration of 0.5 mg/L was selected as optimal, though lower concentrations could also be considered with similar manganese removal. At a concentration of 0.5 mg/L, LT-22S was also the best coagulant-aid in reducing turbidity.

➔ Aluminum/ferric sulphate Blend 2: The best performing coagulant-aid in lowering manganese concentration was LT-22S. At the selected concentration of 0.5 mg/L; however, CSP-640 lowered turbidity 0.6 NTU lower than LT-22S. At the same time, CSP-640 was noted to yield a manganese concentration of only 0.0011 mg/L more than the manganese concentration with LT-22S at a dose of 0.5 mg/L of coagulant-aid. Consequently, CSP-640 was selected as the coagulant-aid of choice.

2.3.1.5 BENCH TEST 1 – TRIAL #5: EFFECT OF pH WITH NO COAGULANT

Bench Trial #5 evaluated the effect of pH on the removal of total manganese and TOC without the addition of coagulant or coagulant-aid. The pH range tested was 5.0 - 6.5. The results found the concentration of total manganese decreased with increasing pH, likely due to the greater degree of precipitation of metals at higher pH, i.e. formation of metal-hydroxides. The TOC results were found to be minimally affected by changing pH, ranging from 9.5 – 10.6 mg/L.

2.3.1.6 BENCH TEST 1 – TRIAL #6: OPTIMAL CONDITIONS

The four coagulants were tested under optimal conditions (coagulant dose, coagulant-aid dose, and pH) to compare the alternative coagulants under the same water conditions. The tests were performed in triplicate to ensure a greater degree of statistical analysis could be applied in determining the optimal combination to be carried forward for piloting. The optimal coagulant combination was determined based on total manganese (Hach and Lab) and TOC results. Metal analysis was also conducted to determine the residual aluminum and iron remaining following coagulation. Lastly, the total manganese results using the Hach method were compared to the total manganese results provided by the Lab to establish the degree of variability between the two methods.

The following conclusions were made based on the results obtained in Trial #6.

- ➔ Ferric sulphate yielded the best removal of TOC.
- ➔ The total manganese with ferric sulphate and aluminum/ferric sulphate Blend 2 were lower than corresponding manganese values with ferric chloride and ferric chloride/ferric sulphate for all trials performed.
- ➔ The Hach manganese method was not found to be as quantitatively accurate as the method used by the Lab. However, the Hach method yielded the same conclusions and was determined to be valuable for screening.

- As expected, there was an increase in aluminum content in the water with aluminum/ferric sulphate Blend 2, while elevated iron was measured with the three ferric based coagulants.

2.3.1.7 BENCH TEST 1 – TRIAL #7: OPTIMIZED MIXING TIME AND APPLIED ENERGY

A series of jar tests were performed to evaluate the impact of changes to mixing durations and intensities on one chemical combination. Changes of –50% to +50% from the previously utilized values for rapid mix and coagulation mixing time and intensity were evaluated. This test was aimed at determining whether process changes may be appropriate to improve the efficiency of the alternative coagulant.

Mixing time and applied energy was investigated using only the following coagulant, coagulant-aid and pH combination: aluminum/ferric sulphate Blend 2 (43 mg/L), CSP 640 (0.5 mg/L), pH 6.5. The coagulant aluminum/ferric sulphate Blend 2 was selected for these tests because it had produced the best results in the bench tests. Previous tests were all carried out using the following baselined parameters which represent the full-scale system:

- Flash Speed: 200 rpm
- Flash Time: 30 s
- Coagulation Speed: 45 rpm
- Coagulation Time: 15 min
- Saturation Pressure: 500 kPa
- DAF clarification time: 10 min

The mixing time and applied energy were evaluated based on total manganese (Hach and Lab), turbidity, TOC, and UVT results. The results indicated that there were only minor changes in turbidity, total manganese, and UVT when compared to the results obtained in Trial #1 indicating that there were no significant improvements when energy and mixing time were altered.

2.3.1.8 RECOMMENDATIONS FROM BENCH TEST 1 RESULTS

The recommendations from the Bench Test 1 results are:

- From the five initial coagulants short listed for bench testing, four were selected for further tests based on total manganese, turbidity, TOC and UVT results from the screening jar tests.
- The optimal combinations of coagulant, coagulant-aid and pH for the four coagulants were then tested together to compare performance. Based on the optimal conditions jar test results (Trial 6), the two coagulants which emerged as the coagulants of choice for manganese reduction were ferric sulphate and aluminum/ferric sulphate Blend 2.
- Regarding the coagulant-aids, it was evident that the addition of a coagulant-aid reduced the manganese content. However, the bench-scale test results were not conclusive about the choice of coagulant and the optimal dose. The coagulant-aids selected for optimal condition testing were all candidate coagulant-aids, though others may equally be considered.
- Additional jar tests were recommended to select the coagulant and coagulant-aid to be pilot tested.

2.3.2 BENCH TEST 2

Results of the first DAF-jar testing program were not conclusive in identifying a single coagulant that would be carried forward for pilot testing. The ferric sulphate and aluminum/ferric sulphate Blend 2 emerged as the two most promising coagulants. Since the results were not definitive enough to choose one over the other, it was recommended that a second round of DAF-jar tests be completed with the aim of selecting the best of the two coagulants for pilot testing. Ferric chloride was bench tested as well, to allow comparisons to the current coagulant used in the full-scale system. Additionally, based on the results of the first DAF-jar testing, two of the coagulant-aids, Magnafloc LT-22S and Prosedim CSP-640, were selected for further jar testing.

The Bench Test #1 program was performed between September 12th, 2016 and October 21st, 2016. This was then followed up with an additional bench testing, Bench Test #2, which was performed between January 24th, 2017 and January 31st, 2017.

During Bench Test #2 the raw water temperature did not change significantly, and ranged between 2.5 °C and 2.7 °C. Baseline parameters previously established in original bench scale testing were used.

Full results obtained during Bench Test #2 are presented in Section 8 of TM No. 1 – Appendix A.

2.3.2.1 BENCH TEST 2 – TRIAL #1: CONFIRMING JAR TESTING PROCEDURE

There was no adjustment to the baseline parameters previously established in Bench Test #1 due to time and resources limitations.

2.3.2.2 BENCH TEST 2 – TRIAL #2: OPTIMIZED COAGULANT DOSE

The coagulant screening jar tests aimed to identify the coagulant dose between 15 and 45 mg/L which yielded the lowest manganese concentrations, while achieving acceptable turbidity and TOC removal. The optimal coagulant dose identified was then carried forward for dose refinement (Table 2-7). During tests to identify optimal coagulant dose, the pH was adjusted to 5.70 and no coagulant-aid was added.

Table 2-7: The optimal coagulant dose and refined optimal coagulant dose determined during Bench Test 2 - Trial #2.

COAGULANT	OPTIMAL DOSE SELECTED (mg/L)	REFINED OPTIMAL DOSE SELECTED (mg/L)
Ferric chloride	45	45
Ferric sulphate	45	53
Aluminum/ferric sulphate Blend 2	45	41

2.3.2.3 BENCH TEST 2 – TRIAL #3.0: pH OPTIMIZATION

Bench tests were performed to evaluate the optimal pH for each coagulant. Based on the initial protocol, pH ranges of 5.0 to 6.0 were investigated for the ferric based coagulants, while a pH range of 5.5 to 6.5 was investigated for the aluminum/ferric sulphate Blend 2. The pH was altered by the addition of sulphuric acid. The refined coagulant dose determined in Bench Test 2 -Trial #2 (Table 2-7) was used for pH optimization, and coagulant-aid was added. The optimal pH was determined based on total manganese

(Lab), turbidity, and TOC removal (Table 2-8). Full results obtained during Bench Test 2 – Trial #3.0 are presented in Appendix A.

Table 2-8: Optimal coagulant pH determined in Bench Test 2 - Trial #3.0 based on manganese, turbidity and TOC.

COAGULANT	OPTIMAL pH RESULTING FROM TEST (UNITLESS)			OPTIMAL pH SELECTED
	BASED ON LAB TOTAL MANGANESE	BASED ON TURBIDITY	BASED ON TOC	
Ferric chloride	Inconclusive	5.6	5.3	5.6
Ferric sulphate	Inconclusive	5.6	5.3	5.6
Aluminum/ferric sulphate Blend 2	Inconclusive	6.5	6.2	6.5

The following conclusions can be made from Bench Test 2 – Trial #3.0:

- The results found only minimal changes in manganese as pH increased in all three coagulants; therefore, the total manganese results were inconclusive at determining an optimal pH.
- Turbidity improved in the ferric based coagulants up to a pH of 5.6, where subsequent increases in pH did not improve turbidity. For the aluminum/ferric sulphate Blend 2, the lowest turbidity occurred at a pH of 6.5
- The lowest measured TOC concentration was observed at a pH of 5.3 for both ferric coagulants, while the lowest TOC was observed at a pH of 6.2 for the aluminum/ferric sulphate Blend 2.

2.3.2.4 BENCH TEST 2 – TRIAL #3.1: DOSE REFINEMENT AT THE OPTIMAL pH

The dose for each alternative coagulant was further refined at the optimal pH determined in Trial #3.0. Coagulant doses were tested ±2 mg/L and ±4 mg/L from the optimal dose found in Trial #2 (Table 2-7). The refined coagulant dose was determined based on turbidity, total manganese (Lab), TOC and alkalinity results (Table 2-9). No coagulant-aid was added during the dose refinement at optimal pH.

Table 2-9: Optimal refined coagulant dose determined at optimal pH

COAGULANT	REFINED COAGULANT DOSE RESULTING FROM TEST (mg/L)				OPTIMAL REFINED DOSE (mg/L)
	BASED ON LAB TOTAL MANGANESE	BASED ON TURBIDITY	BASED ON TOC	BASED ON ALKALINITY	
Ferric chloride	Inconclusive	43	49	Inconclusive	45
Ferric sulphate	Inconclusive	55	57	Inconclusive	55
Aluminum/ferric sulphate Blend 2	Inconclusive	45	43	Inconclusive	43

The following conclusions can be made from Bench Test 2 – Trial #3.1:

- Manganese and alkalinity did not significantly change during optimal coagulant refinement and was inconclusive at determining an optimal pH.
- Turbidity and TOC results indicated the optimal refined dose for ferric chloride, ferric sulphate and the aluminum/ferric sulphate Blend 2 was 45 mg/L, 55 mg/L and 43 mg/L, respectively.

2.3.2.5 BENCH TEST 2 – TRIAL #4: OPTIMIZED COAGULANT-AID DOSE

Each of the three coagulants was tested with the two best coagulant-aids (CSP-640 and LT-22S) selected from the first DAF-jar testing. The coagulant-aid concentrations tested were: 0.05, 0.1, 0.25 and 0.5 mg/L. The coagulants were tested at their optimal dose and optimal pH as follows:

- Ferric chloride dose: 45 mg/L, pH: 5.6
- Ferric sulphate dose: 55 mg/L, pH: 5.6
- Aluminum/ferric sulphate Blend 2 dose: 43 mg/L, pH: 6.5

The optimal dose for each coagulant-aid was determined based on total manganese (Lab), turbidity, TOC, alkalinity, and dissolved aluminum and iron concentrations (Table 2-10).

Table 2-10: Results from Bench Test 2 - Trial #4 for the determination of the optimal coagulant-aid and coagulant-aid dose.

COAGULANT	NO COAGULANT-AID (Trial 3.1)	CSP-640 (Trial 4)	LT-22S (Trial 4)
	Average Manganese Concentration (mg/L)		
Ferric Chloride	0.029	0.032	0.030
Aluminum/Ferric Sulphate Blend 2	0.009	0.010	0.009
Ferric Sulphate	0.011	0.011	0.011
	Average Turbidity Concentration (NTU)		
Ferric Chloride	2.81	4.63	1.99
Aluminum/Ferric Sulphate Blend 2	1.52	1.29	1.37
Ferric Sulphate	2.07	7.47	2.07
	Average TOC Concentration (mg/L)		
Ferric Chloride	4.70	4.18	5.07
Aluminum/Ferric Sulphate Blend 2	7.00	6.82	6.60
Ferric Sulphate	4.81	4.07	4.64
	Average Alkalinity Concentration (mg $CaCO_3$/L)		
Ferric Chloride	4.53	<1.0	5.38
Aluminum/Ferric Sulphate Blend 2	43.1	40.6	49.8
Ferric Sulphate	4.79	1.4	4.10
	Average Dissolved Aluminum Concentration (mg/L)		
Ferric Chloride	0	0.023	<0.02
Aluminum/Ferric Sulphate Blend 2	0.212	0.071	0.091
Ferric Sulphate	0	0.027	<0.02
	Average Dissolved Iron Concentration (mg/L)		
Ferric Chloride	0.382	0.133	0.188
Aluminum/Ferric Sulphate Blend 2	<0.1	<0.1	<0.1
Ferric Sulphate	0.212	0.173	0.118

The following conclusions can be made from Bench Test 2 – Trial #4:

- Manganese did not increase from the addition of coagulant-aid.
- Neither coagulant-aid was better at reducing manganese.
- Ferric chloride and Blend 2 had improved turbidity removal with the addition of LT-22S, compared to when no coagulant-aid was added. Turbidity increased when CSP-640 was used with either ferric coagulants, while a minor reduction in turbidity was measured for Blend 2 and CSP-640.

- There was not a significant difference in TOC with the addition of either coagulant-aids.
- For ferric chloride there was lower iron content with CSP-640, while with ferric sulphate there was lower iron when LT-22S was added.
- There was less depression of alkalinity with LT-22S compared to CSP-640.
- Based on the results, the optimal coagulant-aid for aluminum/ferric sulphate Blend 2 was CSP-640 at a dose of 0.25 mg/L.
- Based on the results, the optimal coagulant-aid, for both ferric based coagulants, was LT-22S at a dose of 0.25 mg/L.

The recommendations from the Bench Test 2 trials are:

- Ferric sulphate at 42 mg/L, pH: 5.6, LT-22S at 0.25 mg/L.
- Aluminum/ferric sulphate Blend 2 at 43 mg/L, pH: 6.5, CSP-640 at 0.25 mg/L.

The ultimate choice on which coagulant should be selected for pilot studies was not solely based on the empirical results obtained during jar testing, considerations such as the effect of the new coagulant to the distribution system and other parts of the treatment process were also considered, which is further discussed in Section 2.4.

2.4 RECOMMENDATION OF SELECTED CANDIDATE COAGULANT FOR PILOTING

2.4.1 EVALUATION OF POTENTIAL IMPACTS

On the basis of over 80 bench tests completed, two possible coagulants for the primary reduction of manganese were identified. These coagulants were: ferric sulphate and aluminum/ferric sulphate Blend 2, as well as identification of the preferred coagulant-aids being LT-22S and CSP-640, respectively.

The findings of these tests were used to evaluate the potential impact of each preferred coagulant on the full-scale system, based on the full-scale system historical data. It should be noted that due to the limitations of the bench test, and unavailability of some full-scale system data, not all parameters could be quantified. However, the main barriers and limitations have been identified and discussed. Although finding the right balance between multiple water quality objectives is very challenging, it is important to prioritize the objectives of the City while complying with regulatory requirements.

To facilitate the selection of the appropriate coagulant for pilot study, the expected potential impacts of each coagulant were compared against each other and categorised as tabulated below.

- **Equivalent**: the potential impact on the full-scale system from the coagulant changeover is expected to be equivalent for both preferred coagulants;
- **Lower**: the potential impact on the full-scale system from the coagulant changeover is expected to be lower in comparison with the other alternative coagulant;
- **Higher**: the potential impact on the full-scale system from the coagulant changeover is expected to be higher in comparison with the other alternative coagulant.

Table 2-11 presents a summary of the comparative analysis of the potential impacts for ferric sulphate and aluminum/ferric sulphate Blend 2, indicating the potential impacts category of each preferred coagulant and outlines the motives supporting the analysis.

Table 2-11: Comparative analysis of potential impacts for ferric sulphate and aluminum/ferric sulphate Blend 2 on the full-scale system

PARAMETER	FERRIC SULPHATE	ALUMINUM/FERRIC SULPHATE BLEND 2
	Expected Potential Impact	**Expected Potential Impact**
Full-Scale System Process		
Material compatibility of the existing chemical storage and feed system	**Equivalent** Compatible	**Equivalent** Compatible
Addition of equipment for coagulant-aid	**Equivalent** Additional preparation system and dosing pumps required	**Equivalent** Additional preparation system and dosing pumps required
Formation of precipitates in the recycling system	**Higher** Higher formation of Fe and Cu residuals in comparison to aluminum/ferric Sulphate Blend 2	**Lower** Higher Al residual in comparison to ferric sulphate
Filter run and backwash	**Lower**	**Higher** Higher operating pH may result in shorter filter runs and increased backwashing
Chlorine contact time and dose (for Virus only)	**Lower** Lower operating pH increases disinfection efficiency	**Higher** Higher operating pH compared to ferric sulphate results in lower disinfection efficiency TOC removal efficiency increases chlorine instantaneous chemical demand
Chemical Supply and Water Chemistry in the Full-Scale System		
Local availability and price	**Higher** 7% higher cost in comparison with aluminum/ ferric sulphate Blend 2	**Lower**
pH operating range for optimal performance	**Higher** Higher alkalinity consumption Higher acid and base consumption due to lower pH operating range 49% higher annual cost in comparison with aluminum/ferric sulphate Blend 2	**Lower** Lower alkalinity consumption Lower acid and base consumption due to higher pH operating range
Alkalinity consumption	**Lower**	**Higher** Potential higher impact on the biological activity due to higher operating pH (it could not be quantified or qualified at that stage)
Method of delivery/frequency of delivery/storage	**Higher** Less autonomy and higher delivery frequency for acid and base in comparison with aluminum/ferric sulphate Blend 2 Equivalent delivery frequency for coagulant Higher specific gravity (1.55) which affects existing coagulant storage tank volume	**Lower** Lower specific gravity (1.38), no impact on existing coagulant storage tank volume

PARAMETER	FERRIC SULPHATE	ALUMINUM/FERRIC SULPHATE BLEND 2
	Expected Potential Impact	**Expected Potential Impact**
Finished Water Quality		
Aluminum	**Lower**	**Higher** Higher Al, most in particulate form, in comparison with ferric sulphate
Iron	**Higher** Higher Fe, most in particulate form in comparison with aluminum/ferric sulphate Blend 2	**Lower**
Manganese	**Higher** Higher Mn content in comparison with aluminum/ferric sulphate Blend 2	**Lower**
TOC and Disinfection By-products (DBPs)	**Lower**	**Higher** Lower TOC removal, higher risks of DBP formation (Could not be quantified or qualified at that stage)
UVT	Could not be quantified or qualified at that stage	Could not be quantified or qualified at that stage
Full-Scale System Residuals Production and Management		
Sludge Production	**Higher** 62% higher sludge production in comparison with aluminum/ ferric sulphate Blend 2 (theoretical calculations)	**Lower**
Sludge Composition	**Lower**	**Higher** Different sludge composition (aluminium hydroxides)
Distribution System		
Aesthetic concerns	Could not be quantified or qualified at that stage	Could not be quantified or qualified at that stage
Corrosion by products	**Higher**	**Lower** Equivalent CSMR and Zn, Pb, Cu corrosion Higher operating pH improves buffering capacity and water stability
Hydraulic Impacts	**Equivalent** Low to moderately aggressive water	**Equivalent** Low to moderately aggressive water

2.4.2 SELECTED ALTERNATIVE COAGULANT FOR PILOTING

Based on the results presented in Table 2-11, the main outcomes of this analysis were:

- ➔ Ferric sulphate would potentially have lower impacts on the operational parameters of the current treatment train and the biological filtration process (similar pH), produce a finished water quality similar to the current one, and lower potential manganese release from the filter media following the coagulant switch. On the other hand, the chemical costs would increase and the treated water could present lower stability than with the Aluminum/ferric sulphate Blend 2 (a hypothesized perspective given Blend 2 was not further investigated).
- ➔ Aluminum/ferric sulphate Blend 2 has a higher potential for improvements in terms of operation costs and treated water stability and would be able to produce a finished water quality that complies with the

standards. However, impacts on the biological activity could not be assessed during the bench tests and subsequent potential impacts on the full-scale system operation and the distribution system cannot be determined at this point. Given the unknowns with regards to the impact of the aluminum/sulphate blend on the full-scale system operations and distribution system, the aluminum/ferric sulphate blend was considered a higher risk to the full-scale system operation and the distribution system.

Although, piloting both coagulants through seasonal variations was originally recommended, due to the tight schedule and technical considerations presented above, the recommended coagulant for the pilot study was ferric sulphate. Ferric sulphate would be able to meet the main objective of the study by providing an alternate coagulant with a lower manganese content, while also minimizing disruptions to the full-scale system operations and distribution system, and meeting all full-scale system Operating Licence requirements. The ferric sulphate contribution to the manganese content of the finished water, and its potential impacts on the discussed parameters above, was the lowest among the ferric coagulants.

A comparative summary of the potential impacts between the selected coagulant, ferric sulphate, and the existing coagulant, ferric chloride, have been tabulated in Table 2-12. The following comparisons are based on the expected changes which would come about from the replacement of ferric chloride with ferric sulphate.

Table 2-12: Comparative analysis of potential impacts for ferric sulphate vs ferric chloride on the full-scale system

PARAMETER	FERRIC SULPHATE vs FERRIC CHLORIDE
	Expected Potential Impact
Full-Scale System Process	
Material compatibility of the existing chemical storage and feed system	**Equivalent** Compatible, no changes expected
Addition of equipment for coagulant-aid	**Higher** Additional preparation system and dosing pumps required for use of coagulant-aid
Formation of precipitates in the recycling system	**Equivalent** Overall formation of precipitates cannot be quantified or qualified at this stage Higher total iron and lower dissolved iron compared to ferric chloride Lower dissolved and total manganese compared to ferric chloride
Filter run and backwash	Cannot be quantified or qualified at this stage
Chlorine contact time and dose (for Virus only)	**Equivalent** Similar operating pH ranges for both coagulants
Chemical Supply and Water Chemistry in the Full-Scale System	
Local availability and price	**Higher** 14% higher cost compared to ferric chloride
pH operating range for optimal performance and Alkalinity consumed	**Higher** Equivalent optimum pH range Lower acid consumption due to higher coagulant dose required Higher base consumption due to higher coagulant dose required 10% cost increase in the annual supply of chemicals
Method of delivery/frequency of delivery/storage	**Higher** Less autonomy and higher delivery frequency for coagulant and base Higher autonomy and lower delivery frequency for acid Affects coagulant storage volume due to higher specific gravity (1.55)

PARAMETER	FERRIC SULPHATE vs FERRIC CHLORIDE
	Expected Potential Impact
Finished Water Quality	
Aluminum	**Equivalent** No major concerns identified
Iron	**Higher** Higher Fe (1.02 mg/L as total iron), most in particulate form, compared to ferric chloride (0.59 mg/L as total iron)
Manganese	**Lower** Improvement expected Lower total manganese (0.011 mg/L) compared to ferric chloride (0.049 mg/L) Lower dissolved manganese (0.011 mg/L) compared to ferric chloride (0.045 mg/L)
TOC and DBP	**Equivalent** Similar TOC removal expected
UVT	Cannot be quantified or qualified at this stage
Full-Scale System Residuals Production and Management	
Sludge Production	**Higher** 24% increase of sludge production (theoretical calculations)
Sludge Composition	**Equivalent** Similar sludge composition expected
Distribution System	
Aesthetic concerns	**Lower** Lower Mn content is expected to reduce water discolouration concerns that are the attributed to the Mn content. Odour concerns cannot be quantified or qualified at this stage
Corrosion by products	**Lower** Improvement expected Lower CSMR Less Zn, Pb, Cu corrosion
Hydraulic Impacts	**Lower** Improvement expected Lower CSMR Similar Larson Skold Index (LaI) and Langelier Saturation Index (LSI) No additional depositions expected

Given the potential for impacts to be exacerbated in the full-scale operation, ferric sulphate remains the closest in chemical composition and activity to the exiting ferric chloride. Being both iron based coagulants, ferric sulphate provides the least amount of expected impact at both pilot-scale and full-scale systems. As such, ferric sulphate was recommended for the pilot study. Nevertheless, the potential impacts on the chemical supply, sludge production, and operation costs on the full-scale system were re-evaluated once the results of the pilot study were available.

3 PILOTING SESSION RESULTS

3.1 OVERVIEW

The pilot-scale system was fabricated and installed within the full-scale system by the City's Water and Waste Department to select and test an alternative coagulant that contains less manganese than the current ferric chloride coagulant.

Following commissioning, the pilot-scale system was operated by the City during the benchmarking and transitioning periods and by WSP during the piloting sessions over an approximate 12-month period through four different water quality seasons. The intent was to evaluate seasonal effects and demonstrate confidence in subsequent recommendations to the City regarding the potential adoption of a suitable alternative coagulant for the full-scale system and determine operation guidelines for the coagulant in the different seasons.

The piloting program operated from February 4th, 2017 to January 19th, 2018, piloting the ferric sulphate coagulant during four water quality seasons: cold water (Winter #1 and Winter #2), cool water (Spring), warm water (Summer), and cool water (Fall). These phases are further defined by their temperature ranges, specifically cold water is less than 4°C, cool water temperature range is 4 to 14°C, and warm water is above 14°C.

Table 3-1 summarizes the seasonal piloting schedule and the associated phase durations.

Table 3-1: Seasonal piloting schedule.

SEASON	PHASE	START	END	DURATION (DAYS)
Winter #1 (<4°C)	Benchmarking Period (with $FeCl_3$)	04-Feb-17	17-Feb-17	14
	Transition to $Fe_2(SO_4)_3$	24-Feb-17		1
	Transition Period (with $Fe_2(SO_4)_3$)	25-Feb-17	14-Mar-17	17
	Piloting Session (with $Fe_2(SO_4)_3$)	15-Mar-17	05-Apr-17	21
Spring (4 to14°C)	Benchmarking Period (with $FeCl_3$)	10-Apr-17	03-May-17	24
	Transition to $Fe_2(SO_4)_3$	06-May-17		1
	Transition Period (with $Fe_2(SO_4)_3$)	06-May-17	10-May-17	4
	Piloting Session (with $Fe_2(SO_4)_3$)	11-May-17	31-May-17	20
Summer (>14°C)	Benchmarking Period (with $FeCl_3$)	23-Jun-17	10-Jul-17	17
	Transition to $Fe_2(SO_4)_3$	11-Jul-17		1
	Transition Period (with $Fe_2(SO_4)_3$)	12-Jul-17	23-Jul-17	11
	Piloting Session (with $Fe_2(SO_4)_3$)	24-Jul-17	17-Aug-17	24
Fall (4 to 14°C)	Extended Pilot Operation (with $Fe_2(SO_4)_3$)	21-Aug-17	09-Oct-17	49
	Transition Period (with $Fe_2(SO_4)_3$)	10-Oct-17	15-Oct-17	5
	Piloting Session (with $Fe_2(SO_4)_3$)	16-Oct-17	31-Oct-17	15
Winter #2 (<4°C)	Pilot Transition Period (with $Fe_2(SO_4)_3$)	09-Nov-17	16-Nov-17	7
	Piloting Session (with $Fe_2(SO_4)_3$)	17-Nov-17	07-Dec-17	20
	Transition to $FeCl_3$	07-Dec-17		1
	Benchmarking Period (with $FeCl_3$)	12-Dec-17	19-Jan-18	38

The raw water being fed into the full-scale system from the Deacon reservoirs experience a great deal of change throughout the seasons, primarily identifiable by the increases or decreases in raw water temperature which defines the seasons, and subsequently brings about observable changes in water quality, (i.e. turbidity, etc.). Table 3-2 identifies the temperatures during piloting sessions.

Table 3-2: Average full-scale system train 1 and train 2 raw water temperatures, averaged by day.

WATER QUALITY SEASON	WINTER #1	SPRING	SUMMER	FALL	WINTER #2
Observed Temperature Range (°C)	2.9 to 4.1	11.1 to 13.5	21.2 to 23.0	11.3 to 4.0	1.9 to 1.7
Average Temperature (°C)	3.5	12.6	22.1	8.6	2.0
Minimum Temperature (°C)	2.8	11.0	21.1	4.0	1.3
Maximum Temperature (°C)	4.2	14.0	23.1	11.4	2.4

This section of the report provides an overview of the experimental plan used to complete the pilot study objectives. The detailed experimental plan (i.e., Type I and Type II testing) can be found in TM No.2 included in Appendix B. The overall pilot program was subdivided into a total of 3 stages as follows:

Generally, each piloting phase consisted of the following subdivisions:

1 **Benchmarking -** A comparison between the full-scale and the pilot-scale system. During benchmarking periods, the pilot-scale system was operated to mimic the full-scale systems operation in terms of coagulant type, dose and target pH. During this time, the pilot-scale system was operated by the City.

2 **Transition -** This period provides an evaluation of the stability of the pilot-scale system following the change of a coagulant. The intent is to minimize the potential for process upset, and acclimatize the pilot-scale system operating under a new coagulant prior to the piloting session. During this time, the pilot-scale system was operated by the City.

3 **Piloting -** Throughout the seasonal piloting sessions, the pilot-scale system was operated by WSP under differing chemical doses (sulphuric acid, coagulant, and coagulant-aid) affecting the pH and coagulation, differing individual filters and filter bank flows, as well as differing backwash procedures.

3.2 BENCHMARKING PERIODS

Benchmarking periods, during different seasonal raw water temperatures, serve to provide a comparison between the full-scale and pilot-scale systems and to determine the relative difference between the two systems performances. As such, the intent of this period is for the pilot-scale system to operate in the same manner as the full-scale system, particularly with respect to the chemical dosing, flow rate, DAF processes, ozonation, and filtration.

During the benchmarking periods, daily samples were collected by the City at the locations identified in Table 3-3 for analysis by the Lab.

Table 3-3: Full-scale and pilot-scale system benchmarking sample locations.

	RAW WATER	POST-DAF	POST-OZONE	INDIVIDUAL FILTER EFFLUENT	COMBINED FILTER EFFLUENT
Full-Scale System	Sampled from entry into full scale system during benchmarking.	Sampled from Post-DAF location	Combined ozone manually mixed from both ozone tanks.	Filters 1 through 8, note that at any point two of the eight filters were offline.	Sampled from the below grade combined filter tank using a dip container.
Pilot-Scale System	Not sampled during benchmarking.	Sampled from DAF overflow piping	Sampled from combined ozone piping feeding the ozone contact tank.	Filters 1 through 8	Not sampled during benchmarking.

In addition to Table 3-3, notable piloting protocol modifications between each period were as follows:

➔ Prior to the seasonal benchmarking periods, the pilot-scale system was shut down for any necessary maintenance and cleaning which was performed by the City.

➔ Post-Ozone samples from the pilot-scale system were not collected during the Winter #1 benchmarking period because the ozone generator was offline in both the full-scale and pilot-scale systems.

➔ Following the Winter #1 piloting session, it was determined that raw water would only be sampled from the full-scale system during the benchmarking periods. The previous analytical session found nominal significant quantitative differences between the raw water for both the full-scale and pilot-scale systems. This excludes a temperature increase of approximately 1°C to 2°C occurring from the estimated 600 ft (180 m) of pipe which conveys raw water from the raw water piping to the pilot-scale system.

➔ The Fall piloting session did not include a benchmarking period. In its place, the City operated the pilot-scale system using ferric sulphate for an extended period from August 21st to October 9th, 2017 to observe any long-term effects. As such, the Fall does not include a benchmarking period using ferric chloride.

➔ The Winter #2 benchmarking period occurred after the completion of the final day of the Winter #2 piloting session due to scheduling and maintenance concerns. A hard transition from ferric sulphate to ferric chloride was used, specifically no shutdown or cleaning occurred prior to coagulant switching at this transition point. Following this hard transition, the pilot-scale system was shut-down for cleaning and maintenance prior to the Winter #2 benchmarking period.

A comparison of the results for pH, turbidity, TOC, and total manganese from both the full-scale and pilot-scale systems for the Post-DAF and combined filtrate processes have been tabulated in the following sections. Section 3.2.1 to Section 3.2.4 provide a summary of these parameters.

All data collected during the benchmarking periods were analyzed by the Lab. To facilitate evaluation of the full-scale system combined filtrate sample, results from the individual filter effluents of the pilot-scale system have been averaged to reflect a combined filter effluent for comparison purposes.

3.2.1 pH

The average pH for the full-scale and pilot-scale systems during the seasonal benchmarking periods did not exhibit significant differences. The numerical comparison in Table 3-4 between Post-DAF and filter effluent highlights the average and associated seasonal standard deviation, while a seasonal day to day illustration is provided in Figure 3-1. Pilot-scale system filters are presented as an average of Filters 1-8.

Table 3-4: Average pH in the full-scale and pilot-scale systems during seasonal benchmarking periods.

BENCHMARKING PERIOD	PARAMETER (Avg±St.Dev)	POST-DAF pH		COMBINED FILTRATE pH	
		PILOT	FULL	PILOT*	FULL
Winter #1	pH	6.01±0.15	5.94±0.06	6.20±0.14	6.05±0.12
Spring	pH	5.35±0.18	5.38±0.13	5.41±0.21	5.28±0.11
Summer	pH	5.60±0.12	5.51±0.07	5.72±0.16	5.43±0.07
Winter #2	pH	5.83±0.10	5.83±0.08	5.91±0.12	5.79±0.08

*Combined filter from the pilot-scale system is an average of filter effluent
Note: No benchmarking period was held in the Fall session

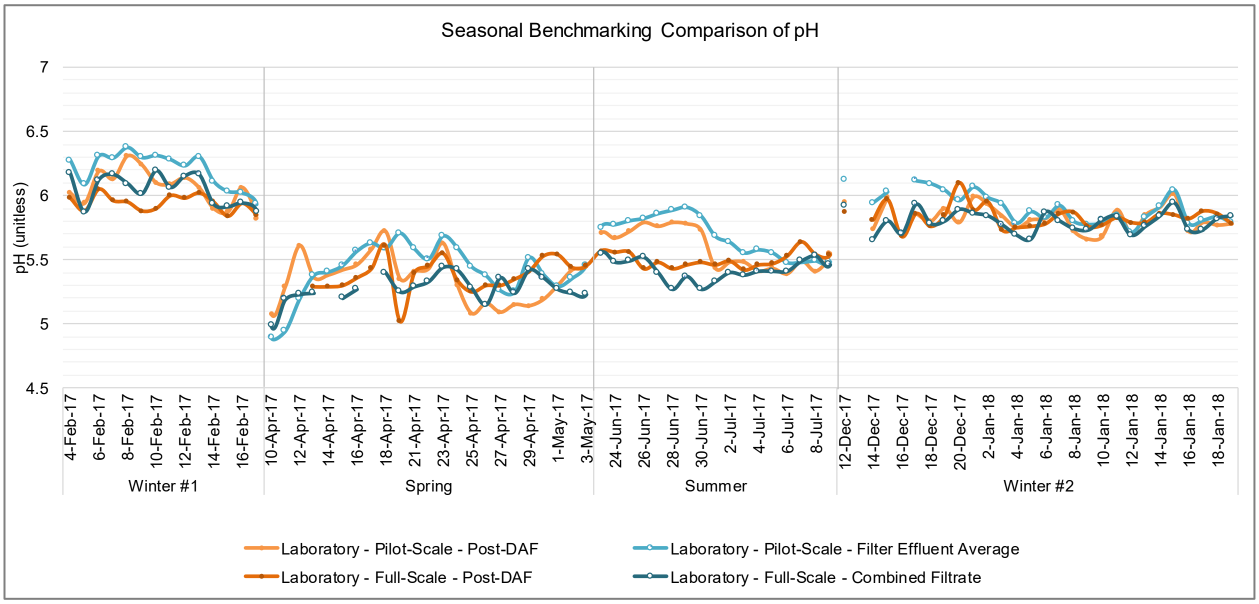

Figure 3-1: Comparison of pH levels in the full-scale and pilot-scale systems during the seasonal benchmarking periods.

Seasonally, a comparison of the average Post-DAF pH results between the full-scale and pilot-scale systems yielded the largest difference (0.09 pH unit) during the Summer benchmarking period, while the Winter #2 benchmarking period had the same average between the two systems. A difference of 0.09 pH units is considered marginally significant.

When seasonally evaluating the filter effluent from both the pilot-scale and full-scale systems, on average there were greater variances in the pH when compared to the Post-DAF samples. Similarly, the largest difference in the seasonal average pH arising from the pilot-scale system's filter averages and full-scale combined filtrate was observed in the Summer benchmarking period (0.29 pH units), while the Winter #2 benchmarking period had the smallest difference between the full-scale and pilot-scale systems (0.12 pH units).

A possible contributor to the discrepancy in filter effluent pH between the two systems could be the difference in biological activity of the filter media. Prior to the commencement of piloting, the filter media (granular activated carbon, GAC) from the full-scale and pilot-scale systems were sampled and analyzed for the presence of adenosine triphosphate (ATP). ATP generation has been shown to be well correlated to the bacterial cell count per gram of media (Magic-Knezev and Kooij, 2004). As such, when there is more ATP generated, the media is more biologically activity, which can affect pH. As bacteria uptake molecular oxygen, they in turn respire carbon dioxide, which will subsequently reduce the pH (Zhang et al., 2017).

When evaluating the ATP generation from the filter media collected from the full-scale and pilot-scale systems, the results indicated that all filters were operating biologically, but the one filter sampled in the full-scale system had slightly higher ATP generation (i.e. more bacteria) compared to the eight filters in the pilot-scale system (Figure 3-2). It is unknown if all filters in the full-scale system contained equally high ATP results. However, based on the data available, the higher concentration of bacteria in the full-scale system filter media would generate more carbon dioxide which would account for the lower post-effluent pH compared to the pilot-scale system. It should be noted that the ATP testing was only conducted once and therefore it is unknown if the microbial population difference between the two systems was consistent across all piloting sessions.

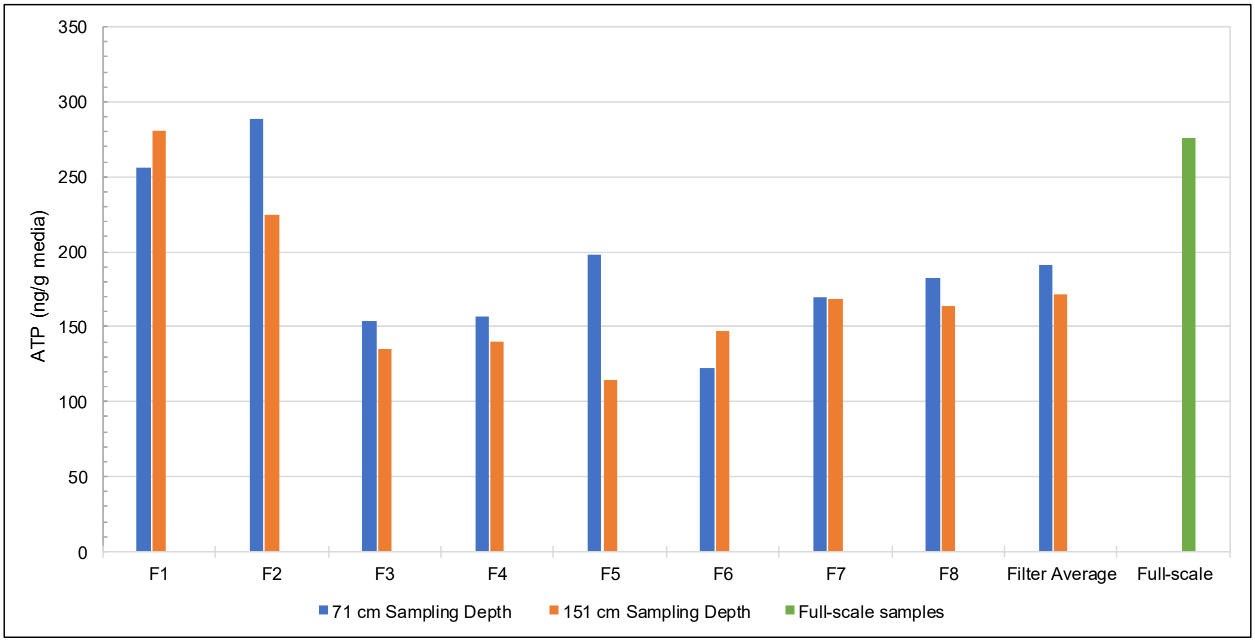

Figure 3-2: ATP testing results from GAC media collected from the full-scale and pilot-scale systems. The full-scale (green) is the average of two samples collected at approximately 155 cm depth from Filter 5 of full-scale system.

Other potential causes for the discrepancy in filter effluent pH between the two systems could be the difference in reaction time of the degradation of ozone to hydroxide (OH^-) and oxygen (O_2) or nitrogen cycling within the filter. However, it is not possible to conclude cause, or combination of causes, which are contributing to the pH discrepancy without further examination.

The slight pH difference in filter effluent from the full-scale and pilot-scale systems can influence the biological oxidation of manganese and the removal of metals by the filters. Furthermore, the pH of the solution will affect the surface charge of the GAC, which will either increase or decrease the electrostatic attractions between the media and the sorbate (Moreno-Castilla and van der Kooij, 2004). In this context, the net influence that either the pH or surface change has with respect to oxidation or removal processes is the product of metastable charge interactions and biological kinetics, respectively. As such, a qualitative impact is described above rather than a quantitative impact due to inherent complexities.

When considering the pH between the full-scale and pilot-scale systems, it is believed that the pH during coagulation would influence more the manganese levels than the filter effluent pH, since chemical coagulation efficiency is directly related to pH, due to the formation of metal hydroxides (i.e. $Fe(OH)_3$). Since the difference in Post-DAF pH between the two systems is negligible for all benchmarking periods, the full-scale and pilot-scale systems appeared to be well benchmarked with regards to pH.

3.2.2 TURBIDITY

The average turbidity for the full-scale and pilot-scale systems during the benchmarking periods throughout the seasons exhibited significant differences between the full-scale and pilot-scale systems for measurements taken of the Post-DAF samples. However, this difference was not observed in the filter effluents. The numerical comparison in Table 3-5 between Post-DAF and filter effluent highlights this average and associated seasonal standard deviation, while a seasonal day to day illustration is provided in Figure 3-3.

Table 3-5: Comparison between full-scale and pilot-scale systems Post-DAF turbidity during seasonal benchmarking periods.

BENCHMARKING SEASON	RAW TURBIDITY (NTU)	POST-DAF TURBIDITY (NTU)		COMBINED FILTER EFFLUENT TURBIDITY (NTU)	
		PILOT	FULL	PILOT	FULL
Winter #1	0.62±0.08	1.67±0.63	0.69±0.21	0.11±0.19	0.23±0.28
Spring	0.78±0.17	1.18±0.15	0.46±0.07	0.07±0.01	0.13±0.05
Summer	0.92±0.19	0.67±0.42	0.28±0.04	0.07±0.01	0.12±0.06
Winter #2	0.64±0.08	1.20±0.47	0.66±0.11	0.10±0.05	0.11±0.04

*Combined filter from the pilot-scale system is an average of filter effluent
Note: No benchmarking period was held in the Fall session

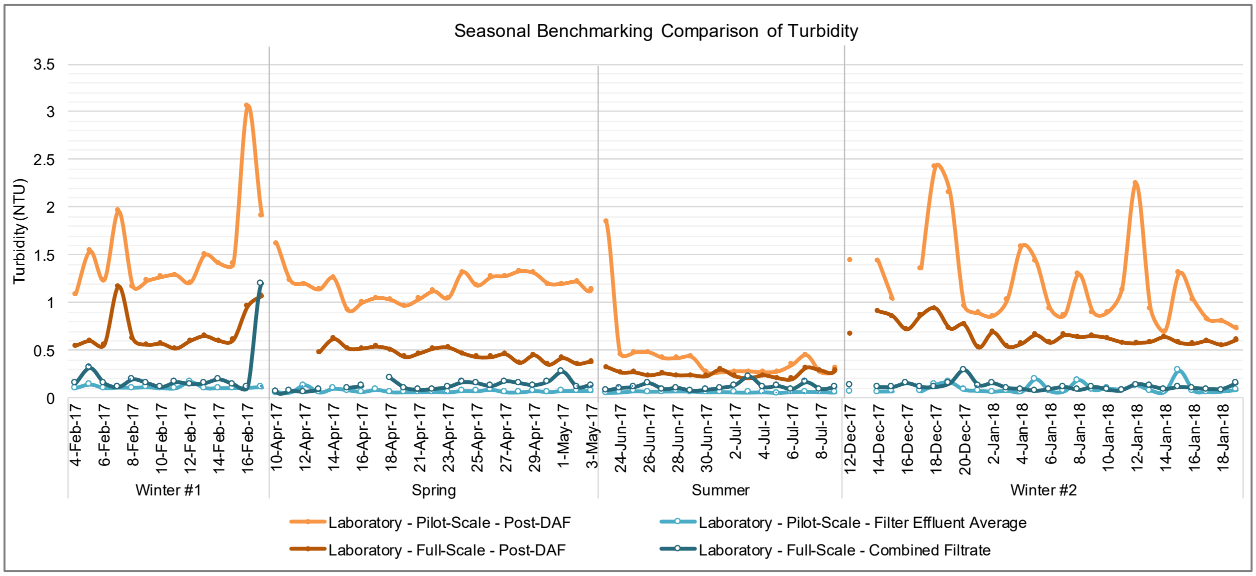

Figure 3-3: Comparison of turbidity results in the full-scale and pilot-scale systems during the seasonal benchmarking periods.

Comparing the seasonal average Post-DAF turbidity results between the full-scale and pilot-scale systems yielded the largest seasonal average difference between scales (0.98 NTU) during the Winter #1 benchmarking period, while the Summer benchmarking period had the smallest seasonal average difference between scales (0.39 NTU). More so, the pilot-scale system exhibited higher Post-DAF turbidity seasonal variance in its average turbidity when compared to the full-scale system. With the Spring freshet came the largest change in raw water quality. As a result, both the pilot-scale and full-scale systems required frequent adjustments and subsequent process equalization in their response to changing raw water quality conditions.

A significant contributing factor to the elevated turbidity measured in the pilot-scale Post-DAF samples is the flow rate through the DAF. The full-scale system, operating at an average 210 MLD, has an approximate retention time in the DAF tank of 27.9 minutes, while the pilot-scale system, operating at 3 L/s, has an approximate retention time in the DAF tank of 8.3 minutes. The difference in the retention time between the full-scale and pilot-scale systems can significantly impact the DAF effluent turbidity. A longer retention time will allow more time for the coagulation process to take place, which will equate to better a floc formation. Furthermore, the longer the retention time, the increased time for the floc to move to the surface of the DAF (i.e. increasing the float, thereby, reducing the turbidity). This impact is amplified in cold or cool-water conditions as colder water temperatures decrease the overall effectiveness of the coagulation kinetics.

In the Winter #1 and Spring benchmarking periods, the full-scale system Post-DAF average turbidity was 0.69 NTU and 0.46 NTU, while the pilot-scale system Post-DAF average turbidity was 1.67 NTU and 1.18 NTU, respectively. During these two benchmarking periods, the pilot-scale system operated at a higher proportional flow compared to the full-scale system, equating to a shorter retention time in the pilot-scale system DAF and, in turn, higher turbidity. When comparing the cold-water conditions (i.e., Winter #1 and Winter #2), there was less difference in average turbidity between the full-scale and pilot-scale systems in Winter #2, compared to Winter #1. This was due to the reduced flow rate in the pilot-scale system during the Winter #2 benchmarking period (flow rate of approximately 2.50 L/s). Although the pilot-scale system operated at a lower flow rate in the Winter #2, the flow still exceeded that of the full-scale system; however, there was less difference in the Post-DAF turbidity between the two systems in Winter #2 compared to Winter #1.

These results indicate a need to better match the retention time in the DAF systems to have more comparable Post-DAF turbidity between the full-scale and pilot-scale systems. Although the turbidity in the filter effluent between the full-scale and pilot-scale systems is comparable, the elevated Post-DAF turbidity in the pilot-scale system suggests there is greater loading on the pilot-scale filters. The greater loading rate on the pilot-scale filters could impact filter run times and UFRV values, as it is expected that a higher load on the filters will cause them to reach retention capacity faster, compared to the full-scale system.

The effect of temperature can be seen when comparing the Post-DAF average turbidity results for both the full-scale and pilot-scale systems. In the full-scale system, the raw water flow rates were lowest in the Winter, followed by the Spring and highest in the Summer. This equates to DAF retention times that are the highest in Winter, followed by the Spring and lowest in the Summer. Post-DAF turbidity, however, is the highest in the Winter, followed by the Spring and lowest in the Summer. The same Post-DAF turbidity trend was observed in the pilot-scale system.

3.2.3 TOTAL ORGANIC CARBON

Prefacing a discussion on TOC, it is important to note that during the Spring and Fall piloting seasons, including the benchmarking periods, the City indicated an instrumental error in the Lab's TOC analyzer. Specifically, the TOC analyzer was measuring TOC concentrations approximately two to three times higher than the actual concentration. Fortunately, the full-scale and pilot-scale system samples collected during Spring and Fall seasons all contained the same instrumental error, as such, comparisons drawn between each system for a given piloting session are valid. However, because the error was not observed in all piloting seasons comparisons between seasons are not possible.

The average seasonal benchmarking TOC data presented in Table 3-6 and Figure 3-4 found the TOC concentration in the Post-DAF and combined filter effluent were not statistically different between the full-scale and pilot-scale systems. The raw water TOC was reduced by 56% to 75% and 52% to 75% following DAF treatment in the full-scale and pilot-scale systems, respectively. The pilot-scale system filters reduced the Post-DAF TOC by 14% to 28%, while the full-scale system filters only removed the Post-DAF TOC by 9% to 14%.

Table 3-6: Average TOC measured during seasonal benchmarking periods for the full-scale and pilot-scale systems.

BENCHMARKING PERIOD	RAW TOC (mg/L)	POST-DAF TOC (mg/L)		COMBINED FILTER EFFLUENT TOC (mg/L)	
		PILOT	FULL	PILOT [1]	FULL
Winter #1	8.52±0.15	4.07±0.52	3.52±0.15	3.00±0.11	3.20±0.15
Spring[2]	22.10±2.96	5.58±1.58	5.56±1.33	4.34±0.96	4.79±1.17
Summer	8.73±1.25	3.35±0.79	3.41±0.65	2.88±0.54	3.04±0.64
Winter #2	8.51±0.61	4.06±0.37	3.82±0.38	2.94±0.88	3.40±0.42

[1] Combined filter from the pilot-scale system is an average of filter effluent.

[2] Concentrations are artificially elevated by approximately 2-3 times the actual TOC concentration due instrumental error.

Note: No benchmarking period was undertaken during the Fall session.

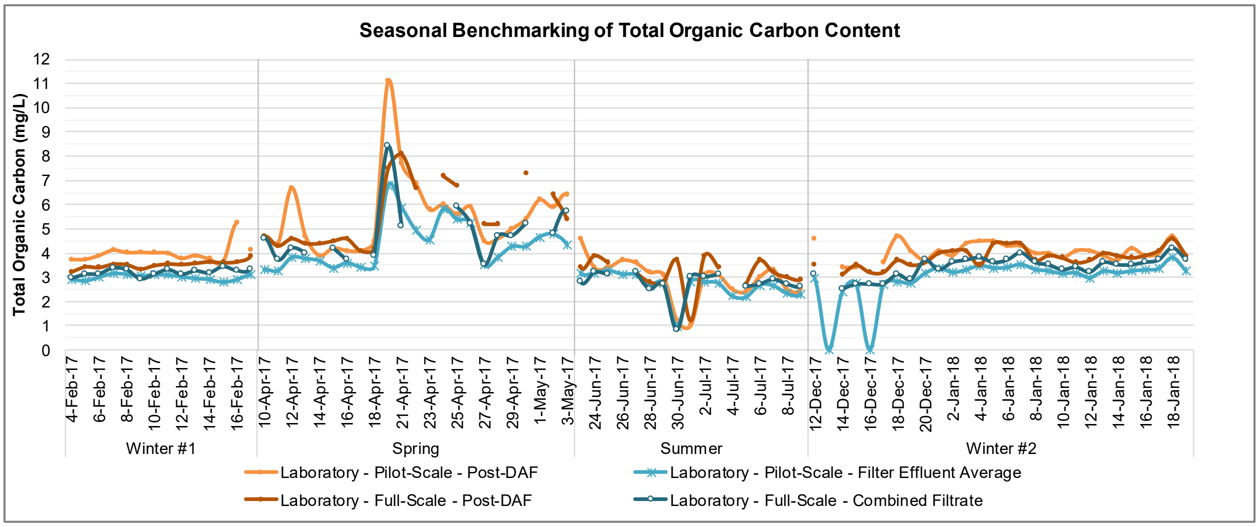

Figure 3-4: Comparison of TOC results in the full-scale and pilot-scale systems during the seasonal benchmarking periods.

Biologically active carbon (BAC) filters are better at removing low molecular weight organic compounds, as microbes are able to transport these compounds across the cellular membranes more easily (Lohwacharin et al. 2011). Since the filters in both the full-scale and pilot-scale system come after ozonation the resulting organic matter composition should be comprised of lower molecular weight compounds which would be more amendable with filtration. However, studies have shown that when BAC filters are operated for extended periods of time, i.e. years, there is an overall reduction in pore size due to the accumulation of organic and inorganic substances, dead microbial cells, and microbial by-products (Kototta-Gamage and Sathasivan, 2017). The reduction in pore size results in lower removal of organic matter, regardless of molecular weight.

On the other hand, the BAC filters are expected to remove organic matter by adsorption in a smaller extent than biologically. Also, some limitations in organic removal by adsorption should be considered. Studies conducted by Matilainen et al. (2006) and Świetlik et al. (2002 & 2004) investigated the removal of organic matter by GAC media following oxidative treatments, such as ozone or chlorine dioxide. The three studies found that low molecular weight organic matter (<500 g/mol) is generally poorly removed by GAC media. This is due to low molecular weight organic matter being generally more polar, and thus hydrophilic, making this fraction less prone to transfer from the aqueous phase and adsorb on to the GAC media (Świetlik et al., 2002). Furthermore, the studies found that the addition of an oxidant prior to GAC filtration breaks intermediate (1,000 – 4,000 g/mol) and high molecular weight (>5,000 g/mol) compounds into low molecular weight compounds, again decreasing the organic removal efficiency by GAC filtration (Matilainen et al. 2006; Świetlik et al., 2002 & 2004).

The removal of TOC by the City's full-scale and pilot-scale systems may indicate that the organic matter composition may be comprised largely of lower molecular weight organic compounds, considering that minimal organic removal was measured in the Winter #1 and Winter #2 Benchmarking periods when no ozone was added. However, it was found that the BAC filters were performing within the expectation of an average of 15% removal of TOC for ozonated biofilters (Terry and Summers, 2018).

However, since neither the organic matter composition nor the media pore size, or adsorptive capacity, was investigated in this study, the explanations provided are purely speculative. Furthermore, the biological activity for the filters was measured only once (Figure 3-2) and it is unclear how, or if, the biological activity in the filters changed during seasonal piloting. Fortunately, the City is currently meeting disinfection by-product regulations indicating there is no need to further investigate the cause for reduced organic removal; however, it is recommended that if the City begins to experience elevated THMs or HAAs in the treated water that an organic matter composition study, as well as a study investigating the reduction in media pore size, be conducted to determine the best approach to control THM or HAA formation.

Overall, the seasonal benchmarking results indicate that the full-scale and pilot-scale systems were closely matched with regards to TOC removal.

3.2.4 TOTAL MANGANESE

It has been previously established that the use of the ferric chloride coagulant appreciably contributes to the total manganese of the DAF effluent water (raw water manganese in addition to the coagulant). As such, raw water analysis of manganese has been included as part of this benchmarking parameter evaluation. It should be noted that total manganese was measured using two instruments, a benchtop Hach spectrophotometer and an Inductively Coupled Plasma-Mass Spectrometer (ICP-MS). ICP-MS is more accurate and has a lower detection limit compared to the Hach spectrophotometer. Therefore, results obtained from the Hach instrument were intended to be used as a qualitative screening method for total manganese, whereas results obtained from the Lab, using ICP-MS, represent accurate quantitative measurements for manganese. A detailed discussion of the limitations and differences in measuring manganese with the Hach spectrophotometer and ICP-MS can be found in Tech Memo No.1 (Appendix A).

Manganese in the raw water was analyzed from both the pilot-scale and full-scale systems during the initial the Winter #1 benchmarking period. This is presented in Figure 3-5, and demonstrates sufficient similarity in water quality between the two raw water sources that only a single sampling location was warranted during future benchmarking periods (this location being from the full-scale system during the benchmarking periods). Furthermore, it was observed that the raw water manganese content followed its expectant historic peaks and lows during the benchmarking periods, with annual low periods occurring in March, April, May and annual peaks occurring in July, August, and September. This is attributed to typically freshwater lake thermocline inversion patterns.

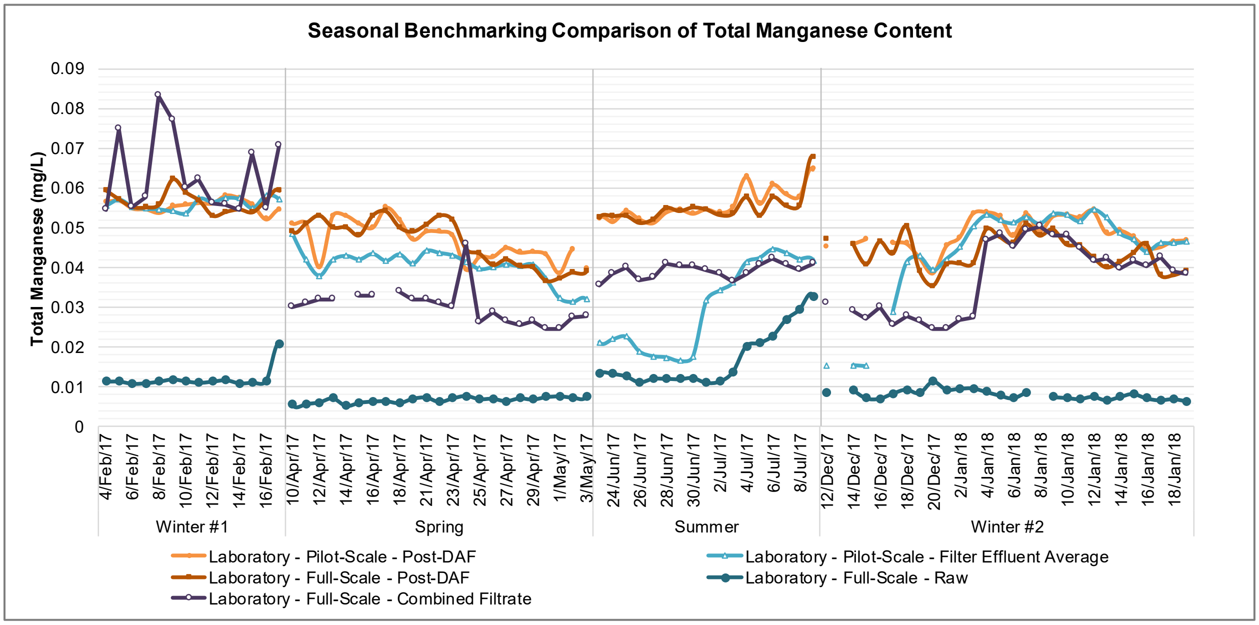

Figure 3-5: Seasonal benchmarking of total manganese.

The average total manganese concentration for the full-scale and pilot-scale systems measured during the seasonal benchmarking periods are presented in Table 3-7. The data shows that for both the full-scale and pilot-scale systems were very similar in terms of the increase in total manganese following the addition of ferric chloride (reported as Post-DAF; Table 3-7). The pilot-scale system filters removed an additional 10% to 43% of the Post-DAF manganese in Summer, Fall and Winter #2, while the full-scale system filters removed 15% to 35% of the Post-DAF manganese. However, during the Winter #1 benchmarking period, there was a slight increase in total manganese of 12% and 1%, following filtration for the full-scale and pilot-scale systems, respectively. It is unclear why both the full-scale and pilot-scale system filters were unable to remove manganese during the Winter #1 benchmarking period; however, the results show that the full-scale and pilot-scale systems were well benchmarked with regards to total manganese.

Table 3-7: Average total manganese during seasonal benchmarking for the full-scale and pilot-scale systems.

BENCHMARKING PERIOD	RAW TOTAL MANGANESE (mg/L)	POST-DAF TOTAL MANGANESE (mg/L)		COMBINED FILTER EFFLUENT TOTAL MANGANESE (mg/L)	
		PILOT	FULL	PILOT	FULL
Winter #1	0.011±0.001	0.055±0.002	0.057±0.003	0.056±0.002	0.063±0.010
Spring	0.007±0.001	0.047±0.005	0.046±0.006	0.040±0.004	0.030±0.005
Summer	0.015±0.006	0.054±0.004	0.052±0.003	0.031±0.003	0.039±0.005
Winter #2	0.008±0.001	0.048±0.004	0.044±0.004	0.044±0.012	0.037±0.009

*Combined filter from the pilot-scale system is an average of filter effluent
Note: No benchmarking period was held in the Fall session

3.2.5 FILTER OPERATION

Both filter banks of the pilot-scale system were operated at an average flow of 0.3 L/s during the seasonal benchmarking periods to represent the full-scale system average flow rate. The differential pressure transmitter data obtained from the pilot-scale system supervisory control and data acquisition (SCADA) system during the seasonal benchmarking periods was evaluated on an average hourly basis to determine:

- the filter run times (observed and forecasted),
- the UFRV values (observed and forecasted),
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter, and
- the rate of head loss increases of each filter.

The calculations were performed as outlined in Section 2.4 of TM No. 3 – Appendix C. The observed filter run times and UFRV values were calculated using data which originated from the pilot-scale system SCADA, between the filtration start time and the filter overflow or the start of the subsequent backwash (whichever occurred first). For filters which did not reach the maximum head loss, the forecasted filter run times and UFRV values were calculated based on linear two-point extrapolations. Filter operation data was compared against filter effluent turbidity measured by the Lab to verify if the filters failed based on exceeding 0.1 NTU effluent turbidity. Table 3-8 presents the average observed filter run times, average observed UFRV values and average forecasted UFRV values for each benchmarking period.

Table 3-8: Summary of filter run times and UFRV values for benchmarking periods.

BENCHMARKING PERIOD	AVERAGE OBSERVED FILTER RUN TIMES (h)		AVERAGE OBSERVED UFRV VALUES (m^3/m^2)		AVERAGE FORECASTED UFRV VALUES (m^3/m^2)	
	BANK A	BANK B	BANK A	BANK B	BANK A	BANK B
Winter #1 [1]	9.4	9.8	136	141	136	143
Spring [2]	17.4	13.1	263	201	321	222
Summer [3]	21.2	20.7	322	322	806	833
Fall [4]	N/A	N/A	N/A	N/A	N/A	N/A
Winter #2 [5]	19.5	18.6	295	287	395	320

[1] Out of the 13 days during the Winter #1 benchmarking period, all filters overflowed, except Filters 4, 5 and 7 which did no overflow, and the filter effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU only 15% of the time.

[2] Out of the 23 days during the Spring benchmarking period, Bank A filters did not overflow 8 cycles, while Bank B did not overflow 4 cycles, and filter effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU only 11% of the time.

[3] During the 17 days of Summer benchmarking period, all of the filters did not overflow, and the filters' effluent turbidity levels never exceeded the City's operational guideline of 0.1 NTU.

[4] No benchmarking was conducted during the Fall session.

[5] During the 38 days of Winter #2 benchmarking period, Bank A filters did not overflow 24 cycles, while Bank B did not overflow 26 cycles, and the filters' effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU only 14% of the time.

When considering the pilot-scale system filter banks (Bank A and B), it would be expected that both banks would exhibit similar observed filter run times and UFRV values, as both banks were operated at an average flow of 0.3 L/s during the benchmarking periods. This assumption was observed in all benchmarking periods, except during the Spring benchmarking period where Bank A had an average observed UFRV of 263 m^3/m^2, while Bank B had average observed UFRV of 201 m^3/m^2. When evaluating the daily UFRV and filter run times measured during Spring benchmarking period (TM No. 4 Figure 2-53 – Appendix D), there are days where the UFRV results between Bank A and B are similar (<20% difference); however, there are also days where Bank A UFRV results exceed Bank B by 75% to 272%. It is unclear what the cause for the deviation in UFRV results between Bank A and B is; however, one possible difference could be inconsistent addition of filter-aid to each bank. The City has indicated that the filter-aid pumps were operating at the low-end of their range which has contributed to periodic inconsistent dosing of the filter-aid to each bank.

The Summer benchmarking period presented the highest average filter run time and highest average UFRV value when compared to the other benchmarking periods. During the 17-day Summer benchmarking period, no filters overflowed, or exceed, the City's operational criteria of <0.1 NTU for filter effluent. The improved filter operation during the Summer benchmarking period is a result of a significant reduction in turbidity by the DAF system during the Summer benchmarking period, which in turn reduced the loading on the filters. Another factor that likely improved filter operation was the warmer water temperature during the Summer benchmarking period. The viscosity of water is a function of temperature, where warmer water has a lower viscosity than cool or cold water. For example, water at 25°C has a dynamic viscosity of 0.8900 mPa.s, while water at 4°C has a dynamic viscosity of 1.567 mPa.s. This results in a lower head during the warm water period compared to cool or cold-water periods, when comparing clean filter beds. It should be noted, forecasted UFRV values seem substantially higher for the Summer benchmarking period. It would be expected that these filters cycle may be terminated earlier based on running time or effluent turbidity above 0.1 NTU, thus, these high UFRV values may never be reached.

The Winter #1 benchmarking period had the lowest filter run times and lowest UFRV (observed and forecasted) for all benchmarking periods. The cause for the poor filter performance during Winter #1 benchmarking is likely due to the elevated Post-DAF turbidity, 1.67±0.63 NTU, measured during this period. The elevated Post-DAF turbidity, as mentioned, was a likely the result of a higher flow rate through the DAF. During the Winter #2 benchmarking period, the flow rate was reduced, increasing the removal of turbidity, and lowering the load to the filters. This significantly improved the filter operation during the Winter #2 benchmarking period, compared to the Winter #1 benchmarking period.

Based on the full-scale historical benchmarking, the five-year average UFRV was 495 m^3/m^2, with an average rate of head loss increase of 1.7 kPa/h, and an average Post-Ozone turbidity of 0.79 NTU (See Table 1-1 and Table 1-3). The overall average observed UFRV values for the pilot-scale system during all the benchmarking periods was 246 m^3/m^2, with an average head loss rate of 1.3 kPa/h. As explained in detail in Section 2.4 of TM No. 3 – Appendix C, the full-scale and pilot-scale system UFRV values cannot be directly compared since the head loss available at the pilot-scale system (23.9 kPa) is half that of the average full-scale system head loss (48.9 kPa). This would result in the pilot-scale system UFRV being approximately half of the full-scale system values, at the same rate of increasing head loss and filter run time. This translates to an overall average observed UFRV of 246 m^3/m^2 at the pilot-scale system filters that could be approximately 492 m^3/m^2 if similar head loss to the full-scale system was available (which closely matches full-scale UFRV results for the past 5-years).

In the light of the rate of increasing head loss, the pilot-scale system presented an average head loss rate 23% lower (1.3 kPa/h) than the historical full-scale system (1.7 kPa/h). This difference is indicative that the pilot-scale system filters may have outperformed the full-scale system filters. It should be noted that this is strictly a high-level comparison, since the pilot-scale system and the full-scale system filters are operated with different backwash procedures and present different available head losses.

As such, it is considered that the benchmarking results indicate that comparable filter performance between full-scale and pilot-scale system filters was observed, with exception of the Winter #1 benchmarking period.

3.3 TRANSITION PERIOD

In light of the previous results for pH, turbidity, TOC and manganese content, the benchmarking periods provided sufficient results to proceed to transitioning the pilot-scale system from ferric chloride to ferric sulphate. The transition periods aimed to evaluate the stability of the pilot-scale system prior to the start of the next piloting session. Stability for the transition period was achieved following a minimum of 5 days (schedule permitting) of operations where turbidity fluctuations in the pilot-scale system Post-DAF samples were within ±0.2 NTU, and pilot-scale system filter effluent turbidity fluctuations were within ±0.05 NTU, as identified in TM No. 2 – Appendix B. The Winter #1, Spring and Summer transition periods were designed specifically to observe the pilot-scale system adjustment and climatization (as needed) resulting from the transition from ferric chloride to ferric sulphate.

During the Summer transition period the pilot-scale system was operated at two separate concentrations of coagulant and coagulant-aid. From July 12th to 18th, ferric sulphate was dosed at 35 mg/L with 0.2 mg/L of coagulant-aid; however, at the request of WSP, the ferric sulphate dose was reduced to 25 mg/L with no coagulant-aid, from July 19th to 23rd, in preparation for the Summer piloting session. Since the Summer transition period tested two different chemical doses (referred to as Summer transition period #1 and #2, respectively) for coagulant and coagulant-aid, the stability criteria were evaluated for each of the two periods independently.

Following the Summer piloting session, it was decided to continue operation of the pilot-scale system for an extended period of time using ferric sulphate. As a result, no transition between ferric chloride and ferric sulphate occurred prior to the Fall piloting session. The “Fall transition period” discussed in this section represents a short stabilization period prior to the start of the Fall piloting session to confirm stability and operation of the pilot-scale system.

To maintain the project schedule, the Winter #2 transition period consisted of only a three-day stabilization period to verify ferric sulphate coagulant dose and to evaluate pilot-scale system operation and performance, based on Post-DAF turbidity only. The deviation from the standard transition period procedure during the Winter #2 transition period was due to the occurrence of discoloured water at the end of the Fall piloting session. As a result, the Winter #2 transition period evaluated the stability of the pilot-scale system, based on Post-DAF turbidity only, with increasing ferric sulphate doses from 34 mg/L to 48 mg/L. No samples were collected from the filters, or the combined filter effluent, during the Winter #2 transition period.

Tabulated in Table 3-9 are the turbidity results from the transition periods of the piloting program. Additional details relating to the use of coagulant-aid and results pertaining to pH, TOC, and manganese content can be found in the appropriate seasonal technical memorandum included in Appendices A-G.

Table 3-9: Pilot-scale average turbidity levels for the transition periods.

	POST-DAF	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6	FILTER 7	FILTER 8
Stability criteria	*±0.2 NTU*	*±0.05 NTU*							
Winter #1 (March 10th to 14th) 42 mg/L $Fe_2(SO_4)_3$	1.41±0.07	0.15±0.03	0.14±0.04	0.14±0.03	0.13±0.03	0.12±0.02	0.11±0.01	0.11±0.01	0.11±0.02
Spring (May 6th to May 10th) 42 mg/L $Fe_2(SO_4)_3$	1.86±0.36	0.07±0.01	0.07±0.02	0.07±0.018	0.06±0.02	0.06±0.01	0.06±0.01	0.06±0.02	0.06±0.01
Summer (2-periods) (July 12th to 18th) 35 mg/L $Fe_2(SO_4)_3$	0.58±0.06	0.16±0.02	0.15±0.02	0.15±0.02	0.15±0.02	0.14±0.01	0.14±0.016	0.14±0.02	0.14±0.01
(July 19th to 23th) 25 mg/L $Fe_2(SO_4)_3$	1.52±0.19	0.59±0.08	0.59±0.08	0.59±0.08	0.59±0.08	0.58±0.07	0.58±0.07	0.59±0.08	0.59±0.09
Fall (October 10th to 15th) 38 mg/L $Fe_2(SO_4)_3$	0.96±0.12	0.21±0.07	0.22±0.07	0.21±0.07	0.22±0.12	0.22±0.09	0.20±0.07	0.22±0.10	0.20±0.08
Winter #2 (November 13th to 15th) 34 – 48 mg/L $Fe_2(SO_4)_3$	1.90 – 2.02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note: Winter #2 transition period only evaluated the Post-DAF turbidity at increasing coagulant doses to ensure the pilot-scale system was operating in a stable manner following an increase in coagulant dose.

The pilot-scale system Post-DAF turbidity criteria of ±0.2 NTU was met for all transition periods, except in the Spring transition period where the average Post-DAF turbidity was 1.86±0.36 NTU. The increased variability in Post-DAF turbidity measured during the Spring transition period is due to the turbidity measured on May 10th (Post-DAF turbidity = 2.40 NTU). This elevated Post-DAF turbidity on May 10th coincides with a coagulant dose change from 42 mg/L to 46 mg/L, in preparation for the Spring piloting session. The increase in coagulant dose may have caused a carry-over in coagulant, as the dose of 46 mg/L was not the optimal coagulant dose for this period, increasing the Post-DAF turbidity. If the May 10th Post-DAF turbidity is excluded from this data set the resulting average turbidity from May 6th to 8th is 1.68±0.04 NTU, which would meet the criteria for Post-DAF turbidity.

When evaluating the pilot-scale system's stability with regards to filter effluent, the stability criteria of ±0.05 NTU was met in the Winter #1, Spring, Summer period #1, and Winter #2 transition periods. During the Summer transition period #2 and Fall transition period, the deviation in the filter effluent turbidity exceeded the criteria for stability. During the Summer transition period #2, there was elevated Post-DAF turbidities of 1.59 NTU and 1.83 NTU, on July 22nd and 23rd, which equated to post-filter effluent turbidities of 0.62±0.01NTU and 0.70±0.01 NTU, respectively. The effluent turbidity measured on these two dates caused the overall deviation to increase beyond the 0.05 NTU criteria; however, the deviation between each individual filter during the Summer transition period #2 was <0.01 NTU. Although the filter effluent turbidity criterium was not met for the period from July 19th to 23rd, the data indicated the filters were operating in a stable manner on a day-to-day basis. During the Fall transition period, the variance in turbidity measured in the average combined filter effluent over the 6-day period was the result of elevated raw water turbidity of 1.19 NTU on October 13th. If the results from October 13th are omitted from the data set, the average combined filter turbidity is 0.18±0.04 NTU, meeting the criteria for stable pilot-scale system operation for 5 out of 6 days.

During the Winter #2 transition period, only Post-DAF turbidity and pH were measured, with the sulphuric dosage remained constant at 42 mg/L, and the raw water flow was reduced from 3.0 L/s to 2.75 L/s. During these three days, the coagulant dose was increased in increments of 2 mg/L (34 – 48 mg/L), while monitoring changes in Post-DAF turbidity. At a ferric sulphate dose of 42 mg/L, the lowest Post-DAF turbidity was observed at 1.68 NTU. These efforts were not intended to optimize the system, but rather were intended to test operational performance of the pilot-scale system following maintenance. It was reported that this transition period did not exhibit discoloured water and that the pilot-scale system was operating under normal conditions. Lastly, it was observed during the Winter #2 transition period that a slower raw water flow increases DAF hydraulic retention time, a favourable performance aspect when considering that cold water conditions reduce chemical kinetics and increase the solubility of dissolved gases.

The evaluation of the aforementioned transition periods provided sufficient confidence that the pilot-scale system generally met the turbidity objective and deviations exceeding the stability criteria were based on isolated incidences. Therefore, seasonal transition periods results indicated the pilot-scale system was operating in a stable manner and could begin seasonal piloting sessions.

3.4 PILOTING SESSION RESULTS

3.4.1 RAW WATER TEMPERATURE AND FLOW

The raw water temperature and flow were continuously recorded by the online full-scale system SCADA during all periods of the project. Figure 3-6 reports the average raw water temperature measured from the online temperature sensors for each of the two treatment trains (Trains 1 and 2) of the full-scale system, and the daily average raw water flow to the pilot-scale system, recorded by the pilot-scale system mag meter. Grab samples were collected daily from the raw water line in the pilot-scale system and measured using a hand-held digital thermometer. Grab samples taken in the pilot-scale system were slightly elevated (~1-2°C) compared to the temperature recorded by the two online temperature sensors for the full-scale system. This increase in temperature is attributed to the transfer of raw water within the full-scale system (~180 m) to the pilot-scale system. The increase in temperature was not expected to significantly impact raw water quality, as confirmed from detailed water quality testing completed during the Winter #1 benchmarking period.

Temperatures during the Spring and Summer piloting sessions ranged from approximately 3.9°C to 22.7°C. Likewise, a steady decline in raw water temperature was measured during the Fall piloting session, where the temperature fell from approximately 10.0°C to 4.4°C. During both the Winter piloting sessions (Winter #1 and Winter #2), the temperature remained more stable with average temperatures of 3.30±0.24°C and 1.86±0.38°C, respectively. During the project, each season had a temperature requirement for testing under specific water conditions, i.e. Winter – cold water <4°C; Spring and Fall – cool water 4-14°C; Summer – warm water >14°C. The criteria for piloting under specific temperatures were met for all days during the Spring, Summer, Fall, and Winter #2 piloting sessions. The only time the raw water temperature criterion was not met was during the Winter #1 piloting session, where the average raw water temperature exceeded 4°C on April 4th by 0.14°C.

The raw water flow was maintained at approximately 3.0 L/s during the Winter #1, Spring, Summer, and Fall piloting sessions. However, during the Winter #2 piloting session, the flow was maintained below 2.75 L/s as higher flow rates were found to cause an increase in Post-DAF turbidity. Deviations in flow rates seen in Figure 3-6 are typically attributed to maintenance or cleaning of the pilot-scale system, the possible buildup of coagulant in the raw water line, or raw water flow changes in the full-scale system which can affect raw water flow rates in the pilot-scale system. Generally, the desired raw water flow rates were well maintained during the entirety of the project.

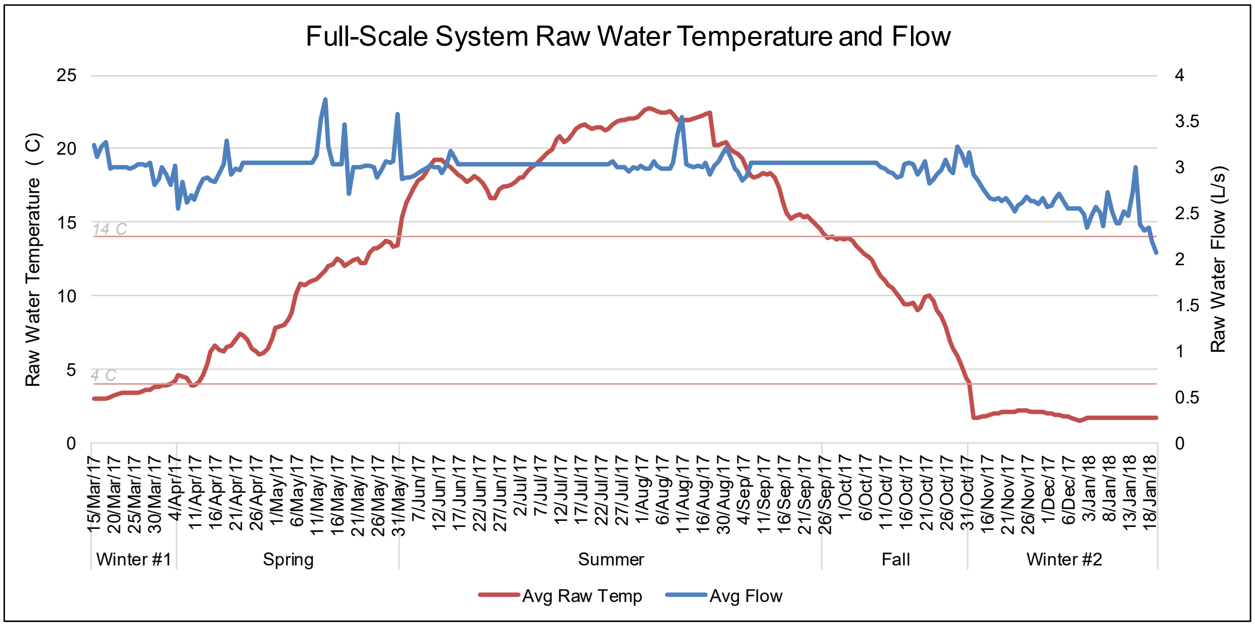

Figure 3-6: Raw water temperature presented as the average from the full-scale system online temperature sensors for Train 1 and 2 (red) and raw water flow (blue) in the pilot-scale system taken during the entirety of the project.

3.4.2 OPTIMIZATION OF FERRIC SULPHATE

The optimal dose for ferric sulphate was determined for each season in the piloting sessions by measuring the change in key parameters, i.e. pH, turbidity, UVT, absorbance, and total manganese, over a desired dose range of ferric sulphate. It should be noted that filter performance was not included as a daily parameter to determine optimal chemical dose. Filter performance, under optimal and non-optimal conditions, has been evaluated and are discussed in the following sections related to filter performance.

Figure 3-10 presents the range of ferric sulphate doses tested during each piloting session, the optimal dose found for ferric sulphate during that piloting session, and the key parameter results for the filter effluent at the optimal ferric sulphate dose.

Table 3-10: Pilot-scale system filter effluent water quality results for key parameters at the optimal dose of ferric sulphate determined during seasonal piloting.

PILOTING SESSION	FERRIC SULPHATE DOSE RANGE TESTED (mg/L)	COAGULANT-AID DOSE (mg/L)	TARGET POST-DAF pH	OPTIMAL FERRIC SULPHATE DOSE (mg/L)	FILTER EFFLUENT WATER QUALITY
Winter #1[2]	34 - 50	0.01	N/A[1]	46	Turbidity (NTU) - 0.10 UVT (%) - 94.6 Absorbance (cm^{-1}) - 0.025 Manganese (mg/L) - 0.014
Spring	32 - 52	0.01	5.65	42	Turbidity (NTU) - 0.10 UVT (%) - 95.2 Absorbance (cm^{-1}) - 0.021 Manganese (mg/L) - 0.013
Summer	25 - 42	0.00	6.00	38	Turbidity (NTU) - 0.23 UVT (%) - 92.3 Absorbance (cm^{-1}) - 0.035 Manganese (mg/L) - 0.012
Fall	36 - 44	0.00	5.80	42	Turbidity (NTU) - 0.12 UVT (%) - 94.2 Absorbance (cm^{-1}) - 0.026 Manganese (mg/L) - 0.015
Winter #2	40 – 44	0.00	5.80	41	Turbidity (NTU) - 0.13 UVT (%) - 95.2 Absorbance (cm^{-1}) - 0.021 Manganese (mg/L) - 0.017

[1] No target Post-DAF pH was used for the Winter #1 piloting session. During this session the addition of sulphuric acid to the raw water remained constant at 42 mg/L.

[2] The combined filter effluent was not collected during the Winter #1 piloting session. The results presented for Winter #1 piloting session are an average of the filter effluent from filters 1-8.

For the Winter #1 piloting session, the ferric sulphate dose range tested was 34 mg/L to 50 mg/L, with a constant coagulant-aid (LT-22S) dose of 0.01 mg/L, and 42 mg/L of sulphuric acid. It should be noted that during the Winter #1 piloting session, the pilot-scale system DAF pH controller had not yet been installed and therefore, pH was not maintained at a desired endpoint and the addition of sulphuric acid remained constant throughout the optimization of ferric sulphate. The optimal ferric sulphate dose was determined to be 46 mg/L based on the results of the four key parameters. The Post-DAF pH measured at the optimal dose of 46 mg/L was 5.70.

The ferric sulphate dose range tested during the Spring piloting session was similar to the range evaluated during Winter #1 piloting session. The key parameters tested during Spring piloting session indicated the optimal dose for ferric sulphate was 42 mg/L. The same optimal dose of 42 mg/L was found for the Fall piloting session which was expected considering both piloting sessions tested cool water conditions.

The lowest optimal dose for ferric sulphate determined was 38 mg/L, which occurred during the Summer piloting session. The efficiency of lower ferric sulphate dosage is mainly attributed to improved coagulation kinetics and DAF operation in warmer water. Under warm water conditions, the floc forms more rapidly compared to cool or cold water. Furthermore, in warm water, microbubbles in the DAF tank would move to the surface more quickly, which would increase sludge blanket formation.

The Winter #2 piloting session tested the smallest range of ferric sulphate dose for all piloting sessions. The small range tested was determined based on preliminary results obtained by the City just prior to the commencement of the Winter #2 piloting session which suggested the optimal dose for ferric sulphate would lie within the range of 40 mg/L to 44 mg/L. The optimal dose for ferric sulphate during the Winter #2 piloting session was determined to be 41 mg/L. When comparing Winter #1 and Winter #2 piloting sessions, the optimal dose for ferric sulphate was lower in the Winter #2 piloting session. This is mainly due to the improvements in pilot-scale system operations between the two periods, i.e. the addition of the pH controller in the DAF, operating the DAF at a reduced flow rate <2.75 L/s, and the increased experience by the onsite WSP personnel operating the pilot-scale system. The results for the two Winter piloting sessions show that improvements in the operation of the pilot-scale system can reduce the optimal dose for ferric sulphate while still achieving the desired finished water quality.

3.4.3 OPTIMIZATION OF pH

The optimal pH for coagulation using ferric sulphate was determined for the Spring, Summer, Fall, and Winter #2 piloting sessions and the results for the key parameters tested are presented in Table 3-11. It should be noted that the optimal pH for coagulation was not established during the Winter #1 piloting session. A sulphuric acid dose of 42 mg/L was maintained throughout the Winter #1 piloting session and did not control the pH to any set point. The reason for not optimizing the pH during the Winter #1 piloting was due to WSP's limited experience in operating the pilot-scale system at the time. It was believed that a minimal number of parameters should be evaluated during the initial piloting session, i.e. Winter #1 piloting, and that optimizing the chemical dosages for coagulant and coagulant-aid were of greater importance.

Table 3-11: Results for key parameters tested at the optimal pH determined during seasonal piloting.

PILOTING SESSION	pH RANGE TESTED	FERRIC SULPHATE DOSE (mg/L)	COAGULANT-AID DOSE (mg/L)	OPTIMAL pH	FILTER EFFLUENT WATER QUALITY
Winter #1	pH optimization not conducted				No Results Available
Spring	5.65 - 6.85	42	0.02	6.01	Turbidity (NTU) - 0.300 UVT (%) - 94.5 Absorbance (cm^{-1}) - 0.024 Manganese (mg/L) - 0.004
Summer	5.65 - 6.25	38	0.00	5.80	Turbidity (NTU) - 0.16 UVT (%) - 94.6 Absorbance (cm^{-1}) - 0.024 Manganese (mg/L) - 0.019
Fall	5.70 - 6.00	42	0.00	5.70	Turbidity (NTU) - 0.15 UVT (%) - 93.2 Absorbance (cm^{-1}) - 0.031 Manganese (mg/L) - 0.018
Winter #2	5.70 - 6.00	41	0.00	5.80	Turbidity (NTU) - 0.10 UVT (%) - 95.2 Absorbance (cm^{-1}) - 0.021 Manganese (mg/L) - 0.008

The Spring piloting session tested the widest range of pH of all piloting sessions to account for the wide range of optimal pH conditions for coagulation using ferric sulphate reported in the literature (Pernitsky, 2003). A tighter test range for pH was utilized in subsequent piloting sessions as it was evident that a significant decrease in water quality occurred at a pH exceeding 6.2. The optimal pH established during the Spring piloting session, under cool water conditions, was 6.01, which was the highest optimal pH found during the project. It should be noted that the Spring piloting session was also the only period that determined the optimal pH with both coagulant and coagulant-aid added. Therefore, the optimal pH of 6.01 determined during the Spring piloting session is for ferric sulphate with the addition of coagulant-aid, LT-22S. However, because it was undetermined if the City would transition to both ferric sulphate and coagulant-aid, or just ferric sulphate alone, the City requested that subsequent pH optimization testing be conducted on ferric sulphate without the addition of coagulant-aid.

The optimal pH established during the Summer, Fall and Winter #2 piloting sessions was approximately 5.70 to 5.80. This result suggests that water temperature does not significantly affect the determination of the optimal pH for coagulation using ferric sulphate provided the optimal coagulant dose is applied. The results presented in TM No. 5 to 7 (Appendix E to G) report only minor decreases in the water quality, according to the key parameters tested, for pH up to 6.0. This implies that the City could operate the full-scale system with ferric sulphate at slightly higher pH, i.e. approaching a pH of 6.0, while still meeting treatment objectives.

3.4.4 OPTIMIZATION OF COAGULANT-AID (LT-22S)

The optimal dose for coagulant-aid was determined during the Winter #1, Spring, Summer, and Fall piloting sessions. It should be noted that during the Summer, Fall and Winter #2 piloting sessions the pH was optimized prior to the optimization of coagulant-aid. The coagulant-aid dose range was limited during cold water testing in the Winter #1 piloting session due to the rapid formation of large floc on the surface, or mud-balling, resulting from the addition of coagulant-aid to the top of pilot-scale system DAF Tank #3. Following the recommendation from WSP, the City relocated the dosing point for coagulant-aid in DAF Tank #3, eliminating the formation of large floc, significantly improving the coagulation process when the coagulant-aid is applied. As a result, piloting during the Spring, Summer and Fall piloting sessions evaluated a wider range of coagulant-aid doses compared to the Winter #1 piloting session.

Spring and Summer piloting sessions tested coagulant-aid doses up to 0.20 mg/L and 0.25 mg/L, respectively (Table 3-12); however, it was observed that coagulant-aid concentrations in this range caused a significant buildup of coagulant/coagulant-aid within the system which increased the need for cleaning and maintenance, particularly within the DAF. With maintenance issues in mind, it was determined that the Fall piloting session should test an upper limit of coagulant-aid of 0.13 mg/L. Again, the coagulant-aid dose of 0.13 mg/L caused an observable buildup of coagulant/coagulant-aid within the pilot-scale system, which increased the need for cleaning and maintenance of the DAF system. Due to the perceived maintenance concerns following the addition of coagulant-aid the City requested that the Winter #2 piloting session be conducted without the addition of coagulant-aid. The optimal dose for coagulant-aid established for the Spring, Summer and Fall piloting sessions was 0.20 mg/L, 0.10 mg/L and 0.07 mg/L, respectively. Although there was some improvement in the finished water quality when coagulant-aid was used, it is not believed that the minimal improvement would justify both the added capital costs, chemical costs, potential increased need for cleaning and maintenance, and decreased UFRVs if the coagulant-aid were to be applied in full-scale system operation.

Table 3-12: Results for key parameters tested at the optimal dose of coagulant-aid (LT-22S) determined during seasonal piloting.

PILOTING SESSION	COAGULANT-AID DOSE RANGE TESTED (mg/L)	OPTIMAL FERRIC SULPHATE DOSE (mg/L)	TARGET POST-DAF pH	OPTIMAL COAGULANT-AID DOSE (mg/L)	FILTER EFFLULENT WATER QUALITY
Winter #1	0.01 - 0.03	46	N/A[1]	0.02	Turbidity (NTU) - 0.14 UVT (%) - 92.4 Absorbance (cm^{-1}) - 0.035 Manganese (mg/L) - 0.013
Spring	0.01 - 0.20	42	5.65[2]	0.20	Turbidity (NTU) - 0.10 UVT (%) - 95.5 Absorbance (cm^{-1}) - 0.020 Manganese (mg/L) - 0.014
Summer	0.05 - 0.25	38	6.00	0.10	Turbidity (NTU) - 0.15 UVT (%) - 95.1 Absorbance (cm^{-1}) - 0.022 Manganese (mg/L) - 0.019
Fall	0.05 - 0.13	42	5.80	0.07	Turbidity (NTU) - 0.10 UVT (%) - 94.3 Absorbance (cm^{-1}) - 0.026 Manganese (mg/L) - 0.014
Winter #2	No Coagulant-aid tested				No Results Available

[1] No target Post-DAF pH was use for the Winter #1 piloting session. During this session the addition of sulphuric acid to the raw water remained constant at 42 mg/L.

[2] It should be noted the optimization of coagulant-aid dose was determined before pH in the Spring piloting session. Thus, the target pH of Table 3-11 and Table 3-12 are not the same.

3.4.5 METAL ANALYSIS

Table 3-13 outlines changes in various metals measured in the raw water, Post-DAF, Post-Ozone, and combined filter effluent during seasonal piloting with ferric sulphate. The results presented in Table 3-13 are not inclusive of all metals measure by the Lab, and is limited to metals that were measured in appreciable amounts, or deemed important indicators of the treatment process. Full metal analysis results can be found for each piloting season in Appendix C-G.

Table 3-13: Results for key metals (total) measured during seasonal piloting of ferric sulphate.

PILOTING SESSION	ALUMINUM (mg/L)	ARSENIC (mg/L)	CALCIUM (mg/L)	CHLORIDE (mg/L)	IRON (mg/L)	POTASSIUM (mg/L)	MAGNESIUM (mg/L)	MANGANESE (mg/L)	NICKEL (mg/L)	SODIUM (mg/L)
Winter #1										
Raw	BDL	0.0008	22.5	1.85	0.07	1.20	6.54	0.004	BDL	2.49
Post-DAF	0.02	BDL	22.1	N/T	1.72	1.18	6.34	0.009	0.006	2.46
Post-Ozone	0.02	BDL	21.8	N/T	1.71	1.16	6.21	0.009	0.005	2.52
Combined Filtrate[1]	0.04	BDL	22.2	2.23	0.06	1.19	6.28	0.008	0.008	2.80
Spring										
Raw	BDL	0.0007	21.8	2.0	0.04	1.21	6.19	0.011	BDL	2.31
Post-DAF	0.02	BDL	21.3	N/T	1.46	1.15	6.06	0.014	0.004	2.22
Post-Ozone	0.01	BDL	21.0	N/T	1.07	1.13	6.03	0.014	0.004	2.73
Combined Filtrate	0.01	BDL	21.9	2.1	0.08	1.19	6.19	0.004	0.003	2.60
Summer										
Raw	BDL	0.0013	19.7	3.0	0.05	1.14	5.61	0.031	BDL	2.28
Post-DAF	BDL	0.0008	19.6	N/T	0.77	1.10	5.40	0.026	0.004	2.23
Post-Ozone	BDL	0.0008	19.3	N/T	0.62	1.11	5.50	0.026	0.004	2.17
Combined Filtrate	BDL	BDL	20.2	3.4	0.02	1.13	5.59	0.017	0.003	5.33
Fall										
Raw	0.003	BDL	20.0	2.6	0.03	1.15	5.93	0.011	BDL	2.23
Post-DAF	0.010	BDL	19.7	N/T	1.83	1.13	5.91	0.012	0.002	2.23
Post-Ozone	0.011	BDL	19.8	N/T	1.89	1.12	5.94	0.012	0.002	2.25
Combined Filtrate	0.004	BDL	19.7	2.4	0.18	1.16	5.95	0.011	0.003	2.28
Winter #2										
Raw	BDL	BDL	21.1	2.7	0.05	1.17	6.12	0.009	BDL	2.38
Post-DAF	0.014	BDL	20.8	N/T	1.59	1.18	6.13	0.013	0.003	2.34
Post-Ozone	0.013	BDL	20.3	N/T	1.54	1.15	6.09	0.012	0.003	2.32
Combined Filtrate	0.010	BDL	20.8	2.5	0.09	1.19	6.18	0.008	0.002	2.51

[1] Combined filtrate not tested, results presented as the average of Filters 1-8
N/T = Not tested
BDL = Below Detection Limit. Note: results that are below detection limits are excluded from empirical averaging.

The iron concentration significantly increased in the Post-DAF samples for all piloting sessions, resulting from the addition of ferric sulphate. Ozonation did not affect iron, except during the Spring piloting session where iron was reduced from 1.43 mg/L to 0.52 mg/L. This reduction in iron can be attributed to a higher operational pH (pH > 6.0) which would have reduced the iron solubility and increased the formation of iron hydroxides which would precipitated out of solution.

The total manganese concentration increased in the Post-DAF samples in all piloting sessions, resulting from the addition of ferric sulphate, except in the Summer piloting session. Although there was an elevated raw water manganese concentration measured in the raw water during the Summer piloting session, the improved coagulation kinetics in warm water conditions allowed for better removal of manganese by the DAF system. Ozone did not affect manganese concentrations and only minimal reductions in manganese following filtration were observed.

Aluminum was only detected in the Post-DAF, Post-Ozone, and combined filter effluent samples during cool or cold-water piloting sessions.

Arsenic was measured in low concentration in the raw water in cool and cold-water piloting sessions, and was effectively removed by coagulation. In warm water, arsenic was partially removed by coagulation and was not detected in the combined filter effluent. The concentrations of calcium, potassium, magnesium and sodium were not significantly affected during the treatment process.

3.4.6 FILTER OPERATION

The differential pressure transmitter data obtained from the pilot-scale system SCADA for the optimal conditions of each piloting sessions were evaluated on an average hourly basis to determine:

- the filter run times (observed and forecasted),
- the UFRV values (observed and forecasted),
- if individual filters overflowed prior to the subsequent backwash cycle based on the typical overflow pressures of each individual filter, and
- the rate of increasing head loss of each filter.

The calculations were performed as described in Section 2.4 of TM No. 3 – Appendix C and filter operation data was compared against filter effluent turbidity measured by benchtop analysis to verify the filters turbidity had, or had not, failed on turbidity (approximately 4 hours after starting the filter operation). Table 3-14 tabulates the average filter run times, average observed UFRV values and average projected UFRV values for each the optimal conditions determined during each seasonal piloting period, while also considering the overall operation cycle and those which have not failed based upon sampled turbidity (>0.1 NTU). Additional specific filter performance detail can be found in Appendix J.

Table 3-14: Summary of filter bank flow rates, filter run times and UFRV values (overall cycles and cycles with sampled turbidity ≤0.1 NTU) for optimal conditions of each piloting session.

PILOTING SESSION	COAGULANT DOSE	OPTIMUM pH	COAGULANT-AID DOSE	FILTER BANK FLOW RATE (L/s)		OBSERVED FILTER RUN TIMES (h)		OVERALL AVERAGE OBSERVED UFRV VALUES (m^3/m^2)		AVERAGE OBSERVED UFRV VALUES OF CYCLES WITH SAMPLED TURBIDITY ≤ 0.1 NTU(m^3/m^2)		AVERAGE FORECASTED UFRV VALUES OF CYCLES WITH SAMPLED TURBIDITY ≤ 0.1 NTU (m^3/m^2)	
	mg/L	Unitless	mg/L	BANK A	BANK B	BANK A	BANK B	BANK A	BANK B	BANK A	BANK B	BANK A	BANK B
Winter #1 [1]	46	N/A	0.02	0.3	0.6	22.5	5.3	326	155	N/R	152	N/R	152
Spring [2]	42	6.01 - 6.16	0.20	0.6	0.3	3.0	7.8	92	118	N/R	137	N/R	137
Summer [3]	38	5.8	0.10	0.6	0.3	10.5	21.7	333	335	N/R	N/R	N/R	N/R
Fall (Without coagulant-aid)[4]	42	5.7	Not added	0.6	0.3	8.2	17.5	252	258	355	262	355	275
Fall (With coagulant-aid)[5]	42	5.7	0.07	0.6	0.3	6.3	9.8	193	150	N/R	N/R	N/R	N/R
Winter #2 [6]	41	5.8	Not added	0.6	0.3	6.6	19.1	273	355	204	394	204	394

[1] Out of the 2 optimal days during the Winter #1 piloting session, all Bank A filters overflowed and none of Bank B overflowed, and filter effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU 71% of the time.

[2] Out of the 2 optimal days during the Spring piloting session, all individual filters overflowed, except Bank B filters did not overflow 1 cycles, and filter effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU 83% of the time.

[3] Out of the 4 optimal days during the Summer piloting session, all individual filters overflowed 50% of the time, and filter effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU 100% of the time.

[4] Out of the 3 optimal days during the Fall piloting session without coagulant-aid, all individual filters overflowed, except Bank B filters didn't overflow 1 cycles, and filter effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU 50% of the time.

[5] At the optimal day during the Fall piloting session with coagulant-aid, all individual filters overflowed, and filter effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU 100% of the time.

[6] Out of the 4 optimal days during the Winter #2 piloting session without coagulant-aid, all Bank A filters overflowed and Bank B overflowed 50% of the time, and filter effluent turbidity levels exceeded the City's operational guideline of 0.1 NTU 81% of the time.

N/R: No results since sampled turbidity levels were above 0.1 NTU for all individual filters.

The overall average observed UFRV was 237 m^3/m^2 considering all piloting sessions at optimal conditions. When discarding the operation cycles where turbidity levels exceeded 0.1 NTU when sampled, the average observed UFRV value increased to 251 m^3/m^2. No substantial difference was observed when comparing the observed UFRV values with the forecasted UFRV values for cycles with sampled turbidity ≤ 0.1 NTU, except for the optimal conditions without coagulant-aid during the Fall piloting session. It should be noted the overall average observed UFRV values may be overestimated as the filter effluent turbidity may have exceed the City's operational guideline turbidity level of 0.1 NTU. Thus, average observed UFRV values of cycles with a sampled turbidity of less than or equal to 0.1 NTU for the optimal conditions of piloting session are favoured in this analysis. However, this has substantially decreased the quantity of data being analyzed, especially for Bank A.

Considering the pilot filter banks (Bank A and B), it would be expected that both banks would exhibit similar UFRV values, while the filter bank operating at 0.3 L/s would have a filter run time double that of the bank operating at 0.6 L/s. In all piloting sessions, the filter bank operating at the lower flow rate had the approximately 36-76% longer filter run times, with the longest filter run times occurring in the Summer piloting session. The largest difference (76%) in filter run times between Banks A and B occurred in the Winter #1 piloting session. During this period, coagulant-aid was added to the top of Tank #3 of the DAF unit (see TM. No. 3; Figures 5-18 to 5-20 – Appendix C) causing the surface aggregation of coagulant/coagulant-aid, i.e. mud-balling, due to poor mixing conditions. This likely resulted in carry-over of coagulant-aid which would have clogged the filter bank operating at the higher flow rate more rapidly. The change in coagulant-aid addition during the Winter #1 piloting session resulted in the bank operating at low flow to have filter run times approximately double that of the bank operating at high flow. As mentioned, another potential cause for deviations in filter run times could be due to the inconsistent addition of filter-aid to each bank. However, it is unclear to what extent this inconsistent addition of filter-aid impacted the filter operation. It is recommended that future piloting studies investigate the impact of filter-aid on filter operations, as well as optimize the filter-aid dose. The discrepancies between Bank A and Bank B operation and their possible causes are discussed further in Section 3.4.7.

When comparing the observed UFRV results of Bank A and Bank B during seasonal piloting, the two banks closely matched (<2.5% difference) during the Summer piloting session and Fall piloting session without coagulant. On the other hand, the Winter #1, Spring, and Winter #2 piloting sessions, the UFRV difference between the two banks ranged between 22-52%. The Summer piloting session had the highest average UFRV of both filter banks; however, the turbidity levels exceeded the operational guideline for filter operation of <0.1 NTU 100% of the time. This discrepancy between UFRV and failure on filter effluent turbidity during the Summer piloting session may be related to the density and viscosity difference of the water in cold and warm conditions. In warm water conditions, there is a lower viscosity and density which would allow water to more easily flow through the filters, increasing UFRV values; however, this also results in less turbidity removal by the filters. The City provided typical filter overflow pressure differentials for each filter (TM No.3; Table 2-1 – Appendix C), which are assumed to be averaged over different water temperature conditions. The results imply that it may be prudent to determine differential filter pressure limits for varying water temperatures to better determine UFRV results under different seasonal conditions.

In order to achieve a recovery (ratio between the net and total quantity of filtered water) greater than 95%, the filters should present a minimum UFRV value of 200 m^3/m^2 (Crittenden *et al.*, 2012). Considering the average observed UFRV values of cycles with a sampled turbidity ≤ 0.1 NTU under the optimal conditions reported in Table 3-14, the minimum UFRV value of 200 m^3/m^2 was exceeded only during the Fall piloting session without coagulant-aid and during the Winter #2 piloting session at both filter bank flow rates. Since the head loss available at the pilot-scale system is half that of the average full-scale system head loss, the pilot-scale system UFRV values would likely be half of the full-scale system UFRV values at the same rate of head loss increase and filter run time. It is expected that the minimum UFRV value of 200 m^3/m^2 would also be achieved for ferric sulphate in the full-scale system and average filter flow rate. This notion is supported based on the results of the Winter #1 piloting session and the Spring piloting session (152 and 137 m^3/m^2, respectively). However, it is not possible to conclude if the minimum UFRV value of 200 m^3/m^2 would be achieved by the filters at warm water conditions (Summer) while meeting the City's operational guideline for turbidity (≤0.1 NTU).

With the objective to better understand the relationship between filter effluent turbidity, the UFRV values and the filter performance during the piloting sessions, the filter effluent turbidity measured by the Lab was plotted against the differential pressure at 4 hours after start of filter cycle (or approximate sampling time) of each individual filter for the piloting days at optimal conditions, as shown on Figure 3-7. This illustration also highlights the City's operational filter turbidity limit of 0.1 NTU, the full-scale system operating licence limit of 0.3 NTU, and the expected differential pressures at the sampling time per flow rate to match the full-scale system performance. The expected differential pressures of 6.8 kPa for filters at average flow rate and 12.4 kPa for filters at high flow rate are based on the historical benchmarking values of the full-scale system filters presented in Table 1-3 (average head loss of 48.9 kPa and average filter run of 28.9 h).

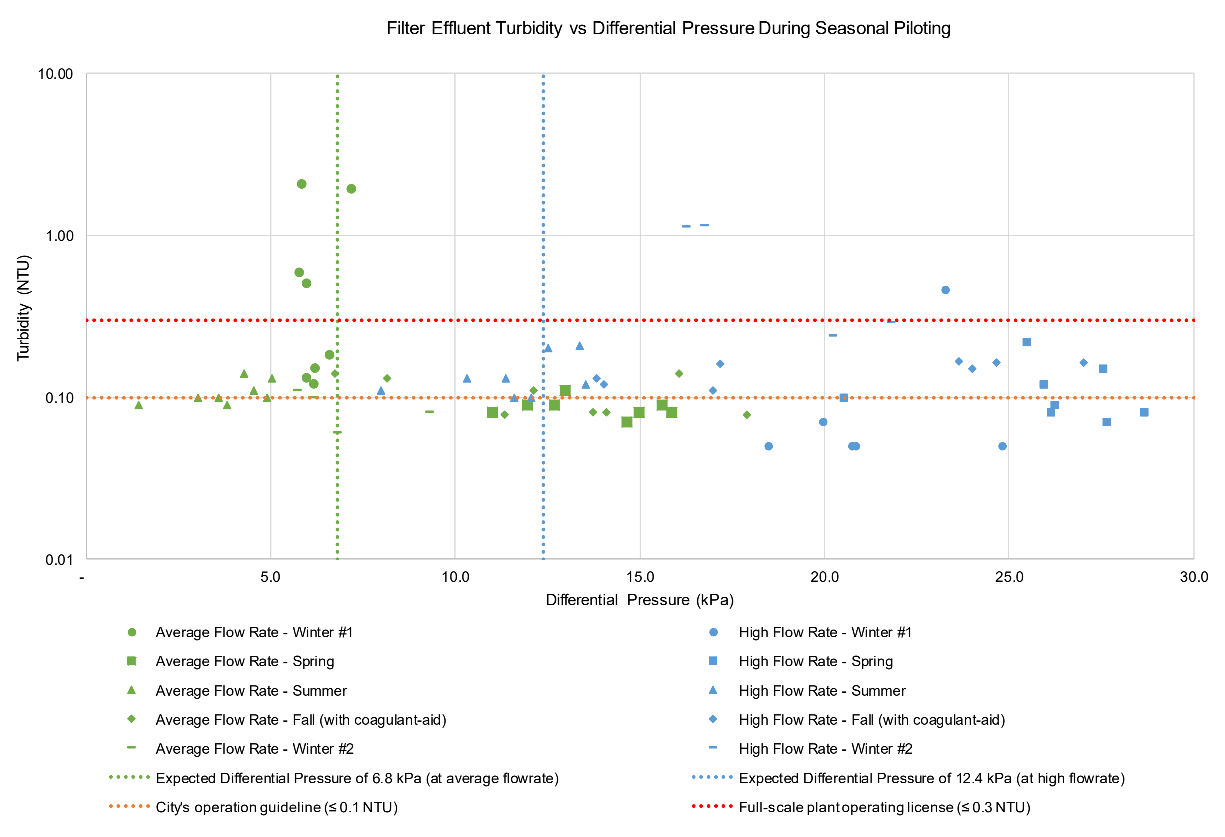

Figure 3-7: Filter effluent turbidity versus differential pressure at sampling time for each individual pilot-scale system filter for optimal conditions of piloting sessions. Note the turbidity levels (y-axis) are displayed in a logarithmic scale to improve visualization.

In Figure 3-7, filters with acceptable performance in terms of effluent turbidity levels and UFRV values are represented below 0.1 NTU and having a differential pressure at sampling time less than, or close to, the expected differential pressures at the filter bank's given flow rate.

It was observed that only a few filters met these conditions during the Summer piloting session (with coagulant-aid) and the Winter #2 piloting session (without coagulant-aid). Although most of the filters met the full-scale system operating licence requirements of ≤0.3 NTU, they did not meet the City's internal operational limit of ≤0.1 NTU. Filters operating at a higher flow rate presented poorer performance in terms of effluent turbidity levels and UFRV values than the filters operating at the average flow rate.

Table 3-15 provides for a comparison of the average observed UFRV values for the benchmarking periods (using ferric chloride) and optimal conditions piloting days (using ferric sulphate) during the piloting session. The average observed UFRV values are calculated from those filters which did not exceed the City's operational filter effluent turbidity guideline of ≤0.1 NTU. As a result, the average observed UFRV values represent only select filters which met this guideline, whereas those filters with effluent which exceeded 0.1 NTU were excluded.

Table 3-15: Average observed UFRV values for the benchmarking periods and optimal conditions of the piloting sessions.

PILOTING SESSION	BENCHMARKING PERIOD WITH FERRIC CHLORIDE	OPTIMAL CONDITIONS OF PILOTING SESSION WITH FERRIC SULPHATE			
	AVERAGE OBSERVED UFRV VALUES OF CYCLES WITH SAMPLED TURBIDITY ≤ 0.1 NTU (m^3/m^2)	OVERALL AVERAGE OBSERVED UFRV VALUES (m^3/m^2)		AVERAGE OBSERVED UFRV VALUES OF CYCLES WITH SAMPLED TURBIDITY ≤ 0.1 NTU (m^3/m^2)	
	ALL FILTERS	BANK A	BANK B	BANK A	BANK B
Winter #1	139	326	155	N/R	152
Spring	224	92	118	N/R	137
Summer	322	333	335	N/R	N/R
Fall (Without coagulant-aid)	N/A[1]	252	258	355	262
Fall With coagulant-aid)	N/A[1]	193	150	N/R	N/R
Winter #2	290	273	355	204	394

[1] Fall benchmarking period was not performed.

N/R: No results since sampled turbidity levels were above 0.1 NTU for all individual filters.

Similar results were observed between the Winter #1 benchmarking period (139 m^3/m^2) and the Winter #1 piloting session Bank B (152 m^3/m^2 at 0.6 L/s), indicative that the use of ferric sulphate is not expected to significantly impact filter performance with respect to the UFRV. However, it should be noted that Bank A filter effluent, operating at 0.3 L/s, was not able to meet the operational guideline of ≤0.1NTU for all samples.

When comparing the UFRV results which occurred in the Spring between the Spring benchmarking period (224 m^3/m^2) and Spring piloting session Bank B (137 m^3/m^2 at 0.3 L/s), smaller UFRV values (estimated to be approximately 60%) were observed for cool water conditions. Bank A filter effluent, operating at 0.6 L/s, was not able to meet the operational guideline of ≤0.1NTU for all samples. The Spring piloting session was also the piloting session with the highest dose of coagulant-aid used (0.20 mg/L) which empathizes the notion that this elevated coagulant-aid significantly impacted filter operations.

A relatively small difference of 4% was observed between the Summer benchmarking period UFRV (322 m^3/m^2) and the Summer piloting session UFRV of all filters (334 m^3/m^2 being the average for both filter banks). During the Summer piloting session, it is understood that the warm water provided for ideal coagulation conditions, i.e., improving chemical kinetics, reducing water viscosity, and density. As such, the filters longer filter run times were observed during the Summer, even with the addition of coagulant-aid. However, the impacts of the use of coagulant-aid to the filter effluent turbidity remained, as all filters continued to not meet the operational guideline of ≤0.1NTU for all samples.

In a comparison of the results of the Winter #2 benchmarking period (290 m^3/m^2) and the Winter #2 piloting session (301 m^3/m^2 in average for both filter banks), where no coagulant-aid was added, similar UFRV results were observed indicating that the use of ferric sulphate without coagulant-aid may not significantly impact filter performance.

Furthermore, when evaluating the Fall piloting session with and without coagulant-aid addition, there is an observed significant reduction in both the filter run times and UFRV values when coagulant-aid is employed. This difference continues to highlight that the use of coagulant-aid not only significantly impacted the filter capacity to produce sufficient treated water, but also filtration performance. It is hypothesized that this impact is due to the nature of the polymerization mechanism (dimers, trimers, longer oligomers, etc.) and its interaction with the filtration media, in particular when considering cool and cold-water conditions.

Although the pilot-scale system filters were not able to produce filter effluent with turbidity levels that did not exceed the City's operational guideline of ≤0.1 NTU at all piloting sessions, it is believed that the primary loss of performance was attributed to the use of coagulant-aid, inferring that the coagulant type had a smaller, less prominent impact to filter operations. In light of this, to confirm that the filter performance is not affected by the ferric sulphate, it is recommended that the City perform additional long-term piloting testing with ferric sulphate as a coagulant.

When comparing the pilot-scale system UFRV values presented in Table 3-15 with the historical full-scale system data, the full-scale system historical average UFRV value (495 m^3/m^2) is up to three times higher than the range of observed UFRV values of cycles with a sampled filter effluent turbidity of ≤ 0.1 NTU during the optimal conditions of the piloting sessions (ranging from 137 m^3/m^2 to 394 m^3/m^2). As described in detail in Section 2.4 of TM No. 3 – Appendix C, UFRV values from the full-scale and pilot-scale systems cannot be directly compared since the head loss available at the pilot-scale system is half that of the average full-scale system. Accordingly, the pilot UFRV values would likely be half of the full-scale system values at the same rate of head loss increase and filter run time. Continuing this notion, the observed UFRV values for the Fall piloting session without coagulant-aid (309 m^3/m^2 being the combined average for both filter banks) and the Winter #2 piloting session (301 m^3/m^2 being the average for both filter banks) at the pilot-scale system filters indicate the full-scale system historical average could be achieved with no coagulant-aid if similar head loss to the full-scale system was available.

3.4.7 INDIVIDUAL FILTER PERFORMANCE TESTING

There were noted differences in filter effluent water quality and filter operation by the pilot-scale system filter Bank A and Bank B during the entirety of the piloting sessions. The filter bank operating at the average flow rate of 0.3 L/s generally outperformed the filter bank operating at the high flow rate of 0.6 L/s in terms of effluent water quality.

On December 5th, 2017, a test was conducted to attempt to establish difference between filter banks. During the test, both filter banks were operated at 0.45 L/s, and Filters 1, 2, 5, and 6 flow rates were set manually at 0.15 L/s, while Filters 3, 4, 7, and 8 flow rates were set manually at 0.075 L/s. The UFRV values obtained for Filters 1 to 8 are presented in Figure 3-8. Note that UFRV results could not be calculated for Filter 3 due to an error in the data recorded by the pilot SCADA system.

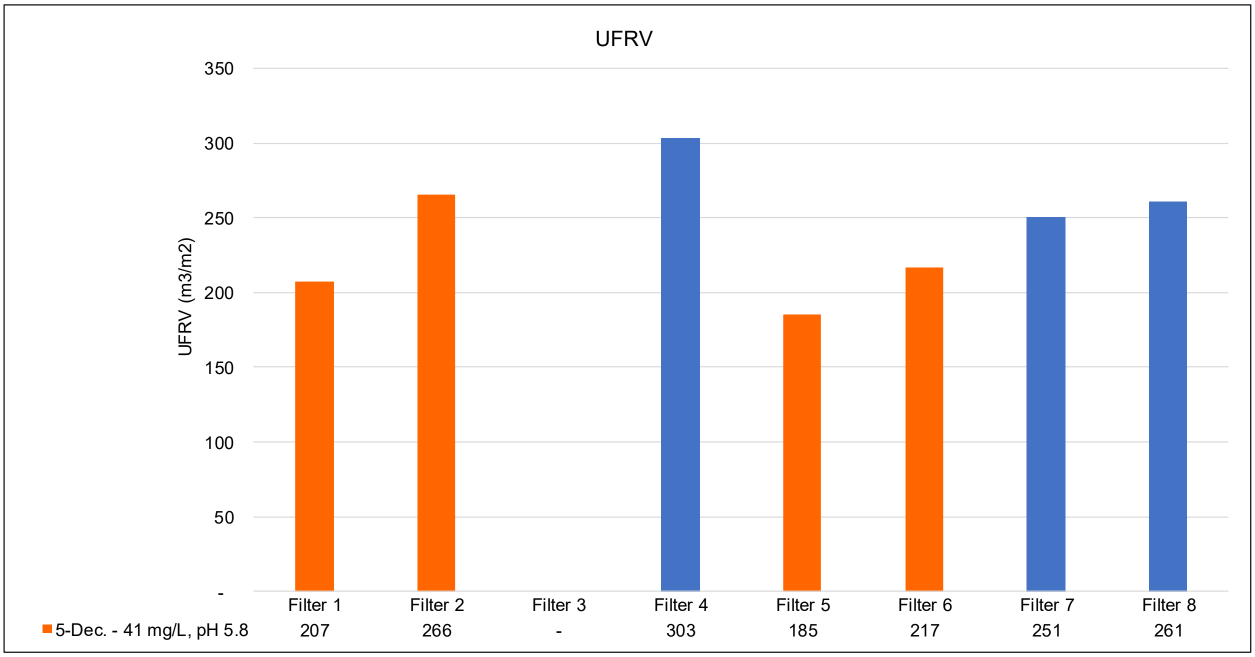

Figure 3-8: UFRV results for the individual filter performance testing at high flow rate (high flow rate = 0.15 L/s; orange) and low flow rate (low flow rate = 0.075 L/s; blue) during the Winter #2 piloting session. Data originates from the pilot-scale system's SCADA dataset. Note that no data was available for Filter 3.

In terms of the rate of head loss increase, higher variability was observed among filters of the same bank operating at the high flow rate in the same day. When comparing UFRV results, the filters in either bank that were operating at the lower flow rate had better UFRV values. However, when comparing filters in Bank A and B, there are better UFRV results for Bank A compared to Bank B. These discrepancies may be due to physical and mechanical differences in the filter banks (pipe length, pipe orientation, etc.) and their operation (flow rate, filter-aid dose, filter media compaction, etc.), or inconsistent filter-aid dosing (note it is possible the filter-aid dosing pump PX505 feeding Bank A was not operating consistently). Additional details and results about the test performed are further discussed in Section 4.7 of TM No. 7- Appendix G.

3.4.8 BACKWASH PROCEDURES

Alternative backwash conditions were explored for the first ten days of the Winter #1 piloting session, including increasing and/or decreasing the air scour and water backflush durations to determine if these changes affected filter performance. For the modified backwash procedure, Filters 1, 2, 5, 6 backwashes followed the standard backwash procedures, Filters 3 and 7 followed a shortened backwash procedure (less 25% in time), and Filters 4 and 8 followed an extended backwash (additional 25% in time). A detailed discussion on the modified backwashing procedures are included in TM No.3 – Appendix C.

Little variation between filters was found with regards to filter effluent turbidity, UVT, absorbance, and total manganese. UFRV values did not indicate that the shortened or the extended backwashes affected filter performance, compared to the standard backwash procedure. This implies changes to the backwash procedures had little effect on the filter performance in the pilot scale-system. Thus, the original backwashing procedures were maintained throughout the remainder of the piloting sessions, mainly because they mimicked the full-scale systems backwashing procedures as closely as possible with the pilot-scale system's.

3.4.9 DAF SLUDGE PRODUCTION

Table 3-16 presents the average total suspended solids (TSS) during the optimal conditions of each piloting session.

Table 3-16: Comparison of DAF sludge production for all piloting sessions

PILOTING SESSION	COAGULANT DOSE (mg/L)	OPTIMAL pH	COAGULANT-AID DOSE (mg/L)	AVERAGE TSS (mg/L)
Winter #1	46	-	0.02	5,550
Spring	42	6.1	0.20	7,575
Summer	38	5.8	0.10	5,433
Fall	42	5.7	0.07	4,850
Winter #2	41	5.8	0	3,875

It was observed during the Winter #1 piloting session that the TSS concentration increased with the increase of coagulant dose. It was further observed that the TSS concentration increases with the pH increase in acidity in the Spring, Summer and Winter #2 piloting sessions. The results of TSS concentration from Fall piloting session suggested an opposing relationship with pH and coagulant-aid.

At the same time, a coagulant–aid decrease correlates to a decrease in TSS concentration between the Spring, Summer and Winter #2 piloting sessions. No relationship was inferred from the coagulant-aid dose within the Winter #1 piloting sessions. However, there was a lower TSS measured at the optimal coagulant dose used in the Winter #2 piloting session, compared to the Winter #1 piloting session, which was attributed to the higher coagulant dose and the addition of coagulant-aid during the Winter #1 piloting session. This indicates the likelihood of increased sludge TSS concentration if coagulant-aid is used along with ferric sulphate as an alternative chemical scheme to the current coagulant applied in the full-scale system, ferric chloride.

Additional support material and explanation can be found in TM No. 3-7 (Appendix C-G). It should be noted that the sludge sampling from the DAF is via float collection from the DAF beach, and therefore, is subject to incomplete scrapper collection and/or variances in the scrapper level affecting the sludge blanket movement.

3.4.10 COMPARISON BETWEEN BENCHMARKING AND SEASONAL PILOTING OF THE PILOT-SCALE SYSTEM

Figures 3-9 to 3-11 presents the key parameter data for the seasonal benchmarking periods, when the pilot-scale system operated with ferric chloride, and the optimal seasonal piloting session results when the pilot-scale system operated with ferric sulphate. It should be noted that there was no benchmarking period during the Fall session and therefore not included in the comparison between benchmarking and seasonal piloting. The pilot-scale system operated under different conditions during the benchmarking periods and piloting sessions, such as coagulant type, coagulant dose, pH, water temperature, filter operation, the addition of coagulant-aid, and the duration of testing (i.e. benchmarking data was collected over an approximate 2 to 3-week period, whereas the optimal days during the seasonal piloting sessions was collected on 1 or 2 days of a particular session). As a result, it is difficult to directly compare the results between each period. However, the results indicate how the pilot-scale system operated using either ferric chloride or ferric sulphate during each season and provide insight as to how the full-scale system would operate if transitioned to ferric sulphate. Insight into the expected full-scale operation following the transition to ferric sulphate is based on the close comparison between the pilot-scale system data and the full-scale system data obtained during the benchmarking periods.

When comparing the turbidity results (Figure 3-9) for the pilot-scale system, operating with either ferric chloride or ferric sulphate, there was generally an increase in turbidity following DAF treatment with either coagulant, except during the Summer where there was a reduction in turbidity measured in the Post-DAF samples with both ferric chloride and ferric sulphate, and during the Spring piloting session using ferric sulphate only. However, when comparing the full-scale and pilot-scale systems during the benchmarking periods (Table 3-5 in Section 3.2.2), the increase in Post-DAF turbidity is only evident in the pilot-scale system. This implies that the increase in Post-DAF turbidity is isolated to the pilot-scale system, and therefore, an increase in Post-DAF turbidity is not expected in the full-scale system following a transition to ferric sulphate. There was similar combined filter effluent turbidity, except during Winter #1, during the benchmarking and piloting phases. This suggests that there is little concern with regards to the final effluent turbidity following a transition from ferric chloride to ferric sulphate. The higher turbidity in Winter #1 maybe a result of the addition of polymer-aid during the piloting session.

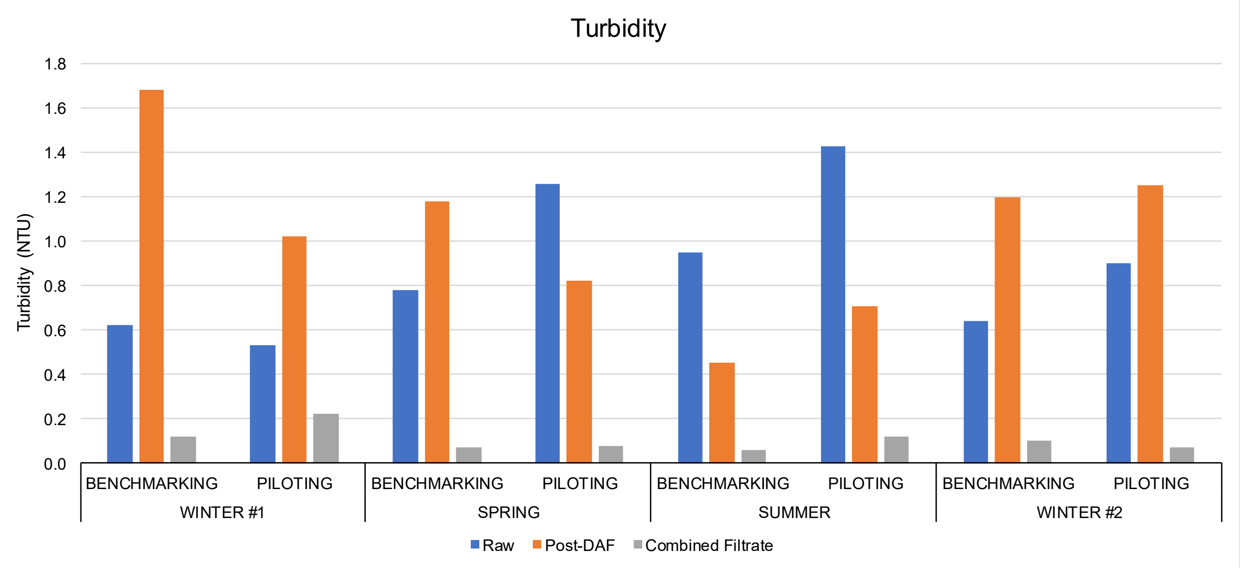

Figure 3-9: Seasonal comparison of turbidity removal during benchmarking periods with ferric chloride and piloting sessions with ferric sulphate. Note: benchmarking data is presented as the average results of each seasonal benchmarking period and piloting data is presented as the average results of the optimal conditions during each seasonal piloting session.

The total manganese concentration in the pilot-scale system Post-DAF samples were significantly lower when operating with ferric sulphate, compared to ferric chloride (Figure 3-10). This is expected considering the lower residual manganese concentration in ferric sulphate. Comparing the full-scale and pilot-scale systems during the seasonal benchmarking periods (Table 3-7 in Section 3.2.4) shows that the two systems had very similar manganese removals when operating with ferric chloride. Therefore, it is anticipated that if the full-scale system were transitioned to ferric sulphate there would be a substantial reduction in total manganese similar to that which was observed in the pilot-scale system operating with ferric sulphate.

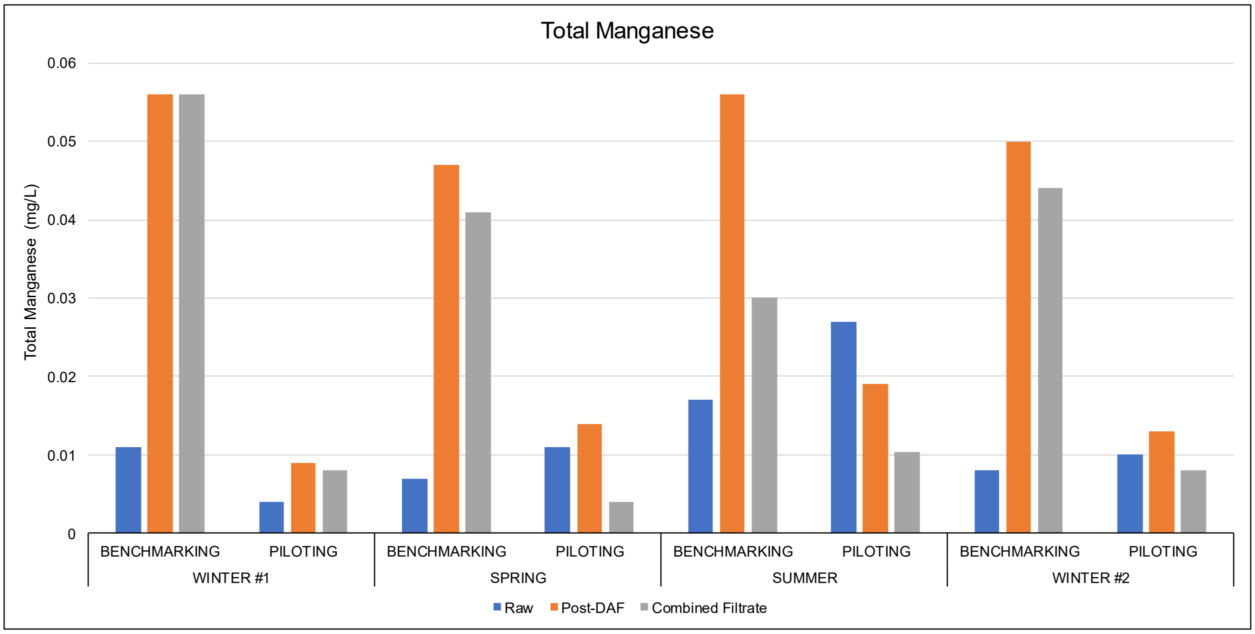

Figure 3-10: Seasonal comparison of total manganese removal during benchmarking periods with ferric chloride and piloting sessions with ferric sulphate. Note: benchmarking data is presented as the average results of each seasonal benchmarking period and piloting data is presented as the average results of the optimal conditions during each seasonal piloting session.

The TOC results presented in Figure 3-11 show similar removals by the pilot-scale system operating with either ferric chloride or ferric sulphate. Considering the full-scale system and pilot-scale system were very closely matched during the seasonal benchmarking periods with ferric chloride (Table 3-6 in Section 3.2.3), there is no expected impact to TOC removal if the full-scale system were transitioned to ferric sulphate.

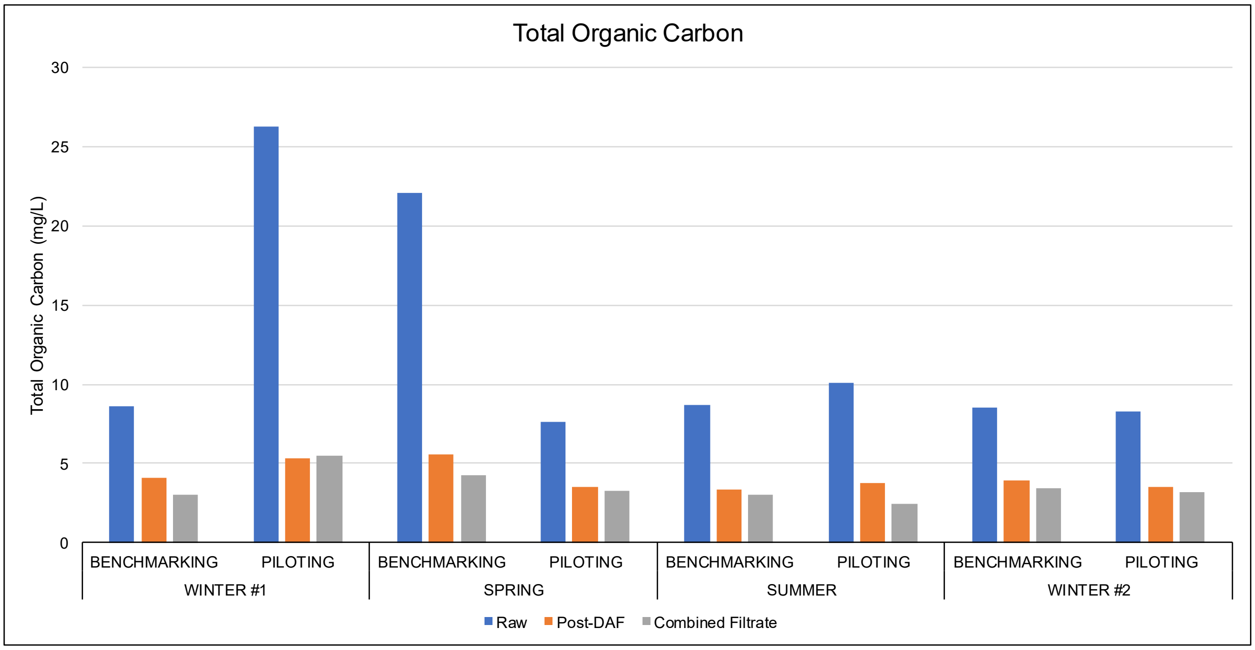

Figure 3-11: Seasonal comparison of total organic carbon removal during benchmarking periods with ferric chloride and piloting sessions with ferric sulphate. Note: benchmarking data is presented as the average results of each seasonal benchmarking period and piloting data is presented as the average results of the optimal conditions during each seasonal piloting session. TOC concentration in the Winter #1 piloting session and the Spring benchmarking period is believed to be elevated by 2-3 times the actual TOC concentration.

3.4.11 COMPARISON BETWEEN SEASONAL PILOTING AND FULL-SCALE SYSTEM HISTORICAL DATA

The following section compares the historical data for the full-scale system, operating with ferric chloride, and the optimal results obtained during the seasonal piloting sessions using ferric sulphate. The objective of this section is to outline any observable differences in raw water quality between the historical average and during the optimal conditions of the seasonal piloting sessions which may have impacted the seasonal piloting session results. Furthermore, this section will compare the historical data of the full-scale system Post-DAF and combined filter effluent with the results obtained during the optimal conditions of the seasonal piloting sessions to evaluate differences in water quality when coagulating with ferric chloride (full-scale system) or ferric sulphate (pilot-scale system).

When comparing the historical raw water quality to the raw water quality obtained during the seasonal piloting sessions (Table 3-17) there appears to be little difference between the two data sets with regards to the key parameters. Higher raw water turbidity was observed in the pilot-scale system during the Spring piloting session; however, the opposite trend was observed in the Fall piloting session with lower turbidity measured in the pilot-scale system when compared to the historical trend. Another noted difference when comparing the historical data to the seasonal piloting sessions data is the raw water temperature, which is consistently 1-2°C warmer in the pilot-scale system, compared to the historical data. This is due to the locations at which the temperature is measured. In the historical data, the temperature is obtained from two temperature sensors located on the full-scale system raw water intake feeding Trains 1&2. However, the seasonal piloting sessions' temperature presented in Table 3-18 was obtained from grab samples collected from the raw water intake feeding the pilot-scale system. The raw water feeding the pilot-scale system travels approximately 180 m within the full-scale system which raises the pilot-scale system raw water temperature. It is not suspected that the slight increase in temperature significantly impacted the pilot-scale system raw water quality.

Table 3-17: Results for key parameters measured during the optimal conditions of the seasonal piloting sessions using ferric sulphate with the historical data collected from the full-scale system from 2010-2015 using ferric chloride.

SAMPLE LOCATION	WINTER (DEC - FEB)		SPRING (MAR - MAY)		SUMMER (JUN - AUG)		FALL (SEPT - NOV)	
	HISTORICAL[1]	PILOTING[2, 3]	HISTORICAL[1]	PILOTING[2]	HISTORICAL[1]	PILOTING[2]	HISTORICAL[1]	PILOTING[2]
Raw								
pH	7.72	7.86	7.96	8.04	8.25	7.98	8.11	7.80
Turbidity (NTU)	0.60	0.72	0.66	1.26	1.42	1.42	1.84	0.79
Temperature (ºC)	2.0	3.7	7.0	14.3	20.2	22.5	11.2	6.6
Post-DAF								
pH	5.64	5.74	5.64	6.31	5.58	6.09	5.51	5.97
Turbidity (NTU)	0.72	1.31	0.62	0.82	0.36	0.71	0.41	1.40
Manganese, Total (mg/L)	0.040	0.009	0.040	0.014	0.067	0.025	0.050	0.012
Combined Filtrate								
pH	7.35[4]	5.86	7.47[4]	6.36	7.54[4]	6.26	7.52[4]	5.84
Turbidity (NTU)	0.17	0.15	0.15	0.08	0.21	0.12	0.18	0.06
Manganese, Total (mg/L)	0.028	0.008	0.035	0.004	0.030	0.046	0.023	0.011
Temperature (ºC)	3.2	4.6	8.0	14.0	20.5	22.9	12.2	6.9

[1] Data presented as the average seasonal data collected from the full-scale system from 2010-2015

[2] Data presented as the average results obtained during the optimal seasonal piloting sessions.

[3] Data for WINTER (DEC – FEB) piloting is presented as the average of the results obtained during optimal piloting conditions in Winter #1 and Winter #2 piloting sessions.

[4] Data presented for historical combined filter pH is reported after pH adjustment with sodium hydroxide.

When evaluating the differences between the Post-DAF water quality measured during optimal conditions of the seasonal piloting sessions with the historical trend, for all seasons, there was significantly lower total manganese in the pilot-scale system Post-DAF samples compared to the full-scale system historical data. This was expected considering ferric sulphate has a lower residual manganese concentration compared to ferric chloride. Another difference between Post-DAF water quality was that the turbidity measured during optimal conditions of the seasonal piloting sessions was consistently higher than the historical average. Elevated turbidity in the pilot-scale system Post-DAF effluent was observed throughout the piloting project. This elevated turbidity in the pilot-scale system has been attributed to minor differences between the full-scale and pilot-scale DAF systems, i.e. flow rates, surface area, and aeration or microbubble formation. Considering the elevated Post-DAF turbidity is only observed in the pilot-scale system, operating with either coagulant, it is believed that the full-scale system operating with ferric sulphate, once transitioned, would not produce Post-DAF water with elevated turbidity.

Similar comparisons can be made for the pilot-scale system combined filter effluent quality, with regards to total manganese. The total manganese measured in the combined filter effluent during optimal conditions of the seasonal piloting sessions was significantly lower compared to the historical trend. Again, this is due to the lower residual manganese concentration in ferric sulphate, compared to ferric chloride. Another observable difference in the combined filter effluent between optimal conditions of the seasonal piloting session results and the historical data was that turbidity was lower in the pilot-scale system, compared to the historical trend. The combined filter effluent results obtained during optimal conditions of the seasonal piloting sessions suggest that if the full-scale system were transitioned to ferric sulphate there would be a significant reduction in total manganese entering the distribution system, compared to the total manganese entering the distribution system historically. Furthermore, the results suggest that similar, or even possibly slightly lower, filter effluent turbidity will be achieved by the full-scale system operating with ferric sulphate.

3.4.12 DISINFECTION BY-PRODUCT FORMATION POTENTIAL

The trihalomethane formation potential (THMFP) and haloacetic acid formation potential (HAAFP) analyses were completed during the optimal coagulation conditions determined for the Spring, Summer, Fall, and Winter #2 piloting sessions (note such analyses were not completed as part of benchmarking). Formation potential tests were conducted to establish if ferric sulphate would effectively reduce organic precursors, i.e. dissolved organic carbon (DOC), prior to the disinfection phase.

Table 3-18 tabulates the overall reduction of DOC by the pilot-scale system along with the associated THMFP and HAAFP for the raw and combined filter effluent water from the pilot-scale system. The total reduction of DOC by the pilot-scale system ranged from 58 – 71% for all seasons tested. The reduction in DOC resulted in reductions of THMFP and HAAFP ranging from 7 – 64% and 4 – 45%, respectively. Although there was only a minor reduction in THMFP of 7% in the Fall piloting session and HAAFP of 4% in the Summer piloting session, the total THMs or HAAs did not exceed provincial regulations. Therefore, the results indicate that coagulation using ferric sulphate should be effective in reducing disinfection by-product precursors and controlling the formation of THMs and HAAs.

Table 3-18: Seasonal THM and HAA formation potentials

PILOTING SESSION	OPTIMAL FERRIC SULPHATE DOSE (mg/L)	OPTIMAL COAGULANT-AID DOSE (mg/L)	OPTIMAL pH	DOC$_{RAW}$ (mg/L)	DOC$_{FINAL}$ (mg/L)	REDUCTION OF DOC (%)	THMFP$_{RAW}$ (µg/L)	THMFP$_{FINAL}$ (µg/L)	REDUCTION OF THMFP (%)	HAAFP$_{RAW}$ (µg/L)	HAAFP$_{FINAL}$ (µg/L)	REDUCTION OF HAAFP (%)
Spring	42	0.20	6.10	7.4	3.1	58	41	21	49	54	40	26
Summer	38	0.10	5.80	9.0	2.6	71	64	54	16	49	47	4
Fall	42	0.07	5.70	26.6*	11.0*	59	30	28	7	20	14	30
Winter #2	41	0.00	5.80	8.3	3.2	61	55	20	64	40	22	45

*DOC was confirmed to be artificially elevated by 2-3 times the actual DOC concentration
Note: THMFP and HAAFP are reported as total THMs or HAAs measured in a sample.

3.4.13 CORROSIVE INDICES

Internal corrosion can impact water quality, infrastructure performance, scaling, and re-equilibrium issues, inclusive of discolouration and taste and odour concerns. These problems are typically the result of corrosion of metal pipe surfaces, pipe solder, and plumbing fixtures or dissolution of existing pipe scales.

The degree of corrosion is determined primarily by the characteristics of various metals and water, and nature and duration in which the two are in contact with each other. Table 3-19Table 3-19 highlights some factors that can influence the corrosiveness of drinking water and select full-scale distribution system historical results.

Table 3-19: Factors affecting corrosiveness.

CORROSION VECTOR	GENERAL EFFECTS	DISTRIBUTION SYSTEM HISTORICAL AVERAGES (2010-2016)	POTENTIAL IMPACTS OF HISTORICAL AVERAGES
pH	Lowering the pH generally accelerates corrosion.	7.5	Varies on water quality, although maintaining consistency is often best practise.
Dissolved Oxygen	Higher rates of DO typically induces corrosion, particularly in ferrous and copper materials.	11.2 mg/L	A high DO can impact solubility of iron, manganese, lead and copper.
Low Buffering Capacity	Low or insufficient alkalinity reduce the ability to buffer corrosion activities.	67.0 mg/L $CaCO_3$	GCDWQ notes that between 80 to 100 mg/L $CaCO_3$ provide an acceptable balance between corrosion and incrustation.
High Halogen and Sulphate-Alkalinity	With a molar ratio greater than 0.5 of halogen (i.e. chloride) to sulphate, the conditions become favourable for corrosion (pitting in ferrous and copper materials).	0.43 (Cl^-/SO_4^{2-}) (2010 to April 2016)	With a molar ratio below 0.5, yet above 0.4, conditions may become prone corrosion.
Total Dissolved Solids and Conductivity	High concentrations of dissolved salts often increase conductivity and subsequently can stimulate corrosive tendencies.	180.0 mg/L TDS 316.47 µS/cm Conductivity (Feb 2010 to 2014)	GCDWQ note that a TDS above 500 mg/L results in excessive scaling.
Various Metals	The types of corrosion products present depends on the metals availability and their oxidation state. For example, copper can aggravate corrosion of downstream materials within distribution networks	0.054 mg/L Total Fe 0.0243 mg/L Total Mn 31.5 mg/L Total Na	Varies on factors such as pH, hardness, alkalinity, $CaCO_2$ saturation, etc.

Table 3-20 tabulates the calculated corrosive indices of the combined filtrate product from the pilot-scale system on the days that were considered optimum results based upon water quality.

Table 3-20: Indicators of corrosivity based on average filter effluent.

PILOTING SESSION	WINTER #1	SPRING	SUMMER	FALL	WINTER #2
WATER QUALITY PARAMETERS	AVERAGE APRIL 4 & 5, 2017	MAY 31, 2017	AUGUST 14, 2017	OCTOBER 31, 2017	DECEMBER 6, 2017
pH	5.84	6.34	6.15	5.78	5.95
EC (µS/cm at 25ºC)	212.44	200.25	192.13	188.50	194.13
Calcium (mg/L)	21.89	21.78	19.68	19.60	21.74
Alkalinity (mg $CaCO_3$/L)	7.44	17.63	10.25	9.13	10.86
Bicarbonate* (mg/L)	9.10	21.50	12.50	11.10	13.2
Carbonate* (mg/L)	0.00	0.00	0.00	0.00	0.00
Sample Temperature (°C)	6.93	15.03	23.38	7.70	4.25
Chloride (mg/L)	2.23	2.20	3.70	2.50	2.50
Sulphate (mg/L)	80.19	70.00	99.00	77.00	78.00
Magnesium (mg/L)	6.20	5.95	5.11	6.33	6.40
Indicators of Corrosivity					
Hardness (mg $CaCO_3$/L)	80.11	78.81	70.11	74.93	80.56
Alkalinity (mg $CaCO_3$/L)	7.44	17.63	10.25	9.13	10.86
LSI	-3.80	-2.76	-3.07	-3.80	-3.58
Ryznar Index (RSI)	13.43	11.86	12.28	13.38	13.11
LaI	11.6	4.3	10.6	9.2	7.8
CSMR	0.028	0.031	0.037	0.032	0.032

Considering Table 3-20, the data tabulated represents the average from the pilot-scale system's individual filter effluents, as opposed to a single combined filter effluent sample. Specifically, water quality parameters tested represent individual filter results averaged, with the exception of chloride and sulphate parameters which came from combined filter effluent samples. This is a result of the differing sampling suites identified and discussed in detail in TM No. 2, Appendix B (Type I vs Type II testing). All data originates from the Lab, while sample temperatures were recorded at the time of sampling.

When considering the impacts of coagulant-aid between piloting sessions, marginal numerical differences were observed with its use. Given these small differences, the use of coagulant-aid is expected to provide minimal impact to the corrosive indices.

3.4.13.1 HARDNESS AND ALKALINITY

Literature suggests that to benefit from corrosively buffering by alkalinity, a total alkalinity and calcium concentration should be at least 50 to 100 mg/L $CaCO_3$ (Hill and Cantor, 2011). In general, an elevated concentration of alkalinity and calcium improve the water's capacity for corrosion retardation; however, excessive concentrations of alkalinity and calcium can promote scale formation. Publicly available City distribution water quality test results indicated a 2017 hardness of 81 mg/L $CaCO_3$, with a range between 74 to 90 mg/L $CaCO_3$ and a total alkalinity of 67 mg/L $CaCO_3$ with a range between 51 to 78 mg/L $CaCO_3$. This is within the acceptable range for publicly available distribution system water.

Pilot-scale system results using ferric sulphate indicate minimal seasonal variation in the hardness values (70.11 to 80.56 mg/L $CaCO_3$), which are within the expectant range. However, the filter effluent alkalinity is low (7.44 to17.63 mg/L $CaCO_3$), in concurrence with similar conditions to that of the full-scale system prior to the addition of sodium hydroxide (a historical range between 6 and 12 mg/L $CaCO_3$). These low values are due to ferric coagulants consuming alkalinity, for example ferric sulphate forms the floc particle ferric hydroxide ($Fe(OH)_3$) per the stochiometric equation below:

(Reaction 1) $Fe_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 2Fe(OH)_3 + 3CaSO_4 + 6CO_2$

As a result, the full-scale system adds sodium hydroxide to their filter effluent to the clearwell to raise the finished water alkalinity (a historical range between 57 to 89 mg/L $CaCO_3$). Therefore, if the current process continues with the addition of sodium hydroxide, the finished water alkalinity would continue to match the historical results. A specific comparison of alkalinity between full-scale and pilot-scale systems is tabulated in Table 3-21. It should be noted that benchmarking periods did not include alkalinity measurements.

Table 3-21: Alkalinity on optimum days between the full-scale and pilot-scale systems.

PILOTING SESSION	WINTER #1	SPRING	SUMMER	FALL	WINTER #2
ALKALINITY BY LAB ANALYSIS (mg $CaCO_3$/L)	**AVERAGE APRIL 4 & 5, 2017**	**MAY 31, 2017**	**AUGUST 14, 2017**	**OCTOBER 31, 2017**	**DECEMBER 6, 2017**
Pilot-Scale System	7.44	17.63	10.25	9.13	10.86
Full-Scale System	7.67	6.00	6.00	8.00	11.00
Clear Well Full-Scale System Historical	Between 6.3 and 15.4 mg/L $CaCO_3$ and an average of 11.2 mg/L $CaCO_3$				

One factor that may be valuable to consider in future piloting sessions is the turbidity removal efficiency following the addition of alkalinity prior to coagulation. As mentioned, the raw water turbidity is low, on average 75 mg/L $CaCO_3$, and following coagulation the alkalinity is reduced to < 20 mg/L $CaCO_3$. Studies have shown that there is a reduction in turbidity removal efficiency when alkalinity is <30 mg/L $CaCO_3$ during coagulation (Tseng *et al.*, 2000). This is due to incomplete formation of iron hydroxides, according to Reaction 1, and therefore, reducing the amount of turbidity removed. Tseng *et al.* (2000) found that increasing the alkalinity prior to coagulation improved the removal of turbidity, at the optimal coagulant dose. The disadvantage to this is the addition of alkalinity prior to coagulation increases the pH, which Tseng *et al.* (2000) reported, decreased the removal of organics by coagulation. The reduction of organic matter removal can be overcome by increasing the coagulant dose.

Post filtration alkalinity results remain comparable between the full-scale and pilot scale systems; however, elevated alkalinity values were observed during the Spring and Summer piloting sessions. These results coincide with the two highest operating pH's of the piloting program. Alkalinity results in these seasons may be higher due to the increased potential for the higher pH to impact the formation of iron hydroxides which consume alkalinity. Nonetheless, results emphasize that an additional source of alkalinity is needed post filtration to stabilize the filter effluent (through an increase in alkalinity) for ferric based coagulants.

3.4.13.2 LANGELIER SATURATION INDEX

The LSI indicates scale or corrosion forming tendencies based on the hardness, alkalinity, dissolved solids, and pH of the water. The ideal LSI value is zero, indicative of a minimal tendency to form scale or be corrosive, whereas when greater than zero the LSI suggests that scale will form and less than zero indicates the water to be corrosive.

Seasonally, LSI values calculated during the seasonal piloting sessions remain between -2.76 and -3.80 (Table 3-22). With all LSI values below zero, the pilot-scale system filter effluent represents water that is undersaturated with respect to $CaCO_3$ and would subsequently have a tendency to corrode. Observations emphasize that the LSI is highly influenced by the low alkalinity in the filter effluent, a concern resolved through the addition of sodium hydroxide at the full-scale system. Full-scale LSI results, collected from the combined filter location prior to pH adjustment and sampled on the same day, were analogously calculated and tabulated below. Results remain indicative of the filtrate's tendency to corrode and justify the need to increase alkalinity.

Table 3-22: LSI comparisons between the full-scale and pilot-scale systems.

PILOTING SESSION	WINTER #1	SPRING	SUMMER	FALL	WINTER #2
LSI	**AVERAGE APRIL 4 & 5, 2017**	**MAY 31, 2017**	**AUGUST 14, 2017**	**OCTOBER 31, 2017**	**DECEMBER 6, 2017**
Pilot-Scale System	-3.80	-2.76	-3.07	-3.80	-3.58
Full-Scale System	-4.01	-4.16	-4.50	-4.24	-3.82

Note that in order to calculate LSI, it is necessary to know alkalinity, hardness, TDS, pH and temperature of the water, as such, a historical comparison to the full-scale system or the pilot-scale system benchmarking is not possible as data is not collected post-filtration and prior pH adjustment in either the full-scale system or during the benchmarking period to compute similarly comparable (i.e. post filtration but prior to alkalinity adjustment) piloting LSI values. A comparison between the full-scale system and the pilot-scale system is made under the provision that samples taken from their respective sources on the same day share identical raw water quality. Furthermore, as these indices are of a strict predicative nature (the development of a general index is inherently difficult due to the multiple roles of chemical species in potable water), and do not necessarily correlate between theoretical and actual conditions, only a relative comparison is made.

3.4.13.3 RYZNAR INDEX

The RSI is used to consider pitting corrosion depth, as it is a measure of the amount of calcium carbonate in saturation compared to the actual amount present. Like the LSI, it is used to calculate scale and corrosion tendencies in water and distribution networks. If the index is above 6, the indices suggest there is a tendency for pitting to occur.

With a RSI value ranging between 11.86 and 13.43 (Table 3-23) on optimum days of the seasonal piloting sessions, the expectant filter effluent is considered highly corrosive. Like similar corrosive indices which are calculated based upon aspects of alkalinity (specifically the carbonate equilibrium), the RSI is impacted by the imbalance in carbonate speciation of the filter effluent. RSI values are adjusted with the addition of sodium hydroxide after filtration and prior to distribution.

Full-scale RSI results, collected from the combined filter location prior to pH adjustment and sampled on the same day, were analogously calculated and tabulated below. Results remain indicative of the corrosivity of the filtrate and justify the need to increase alkalinity.

Table 3-23: RSI comparisons between the full-scale and pilot-scale systems

PILOTING SESSION	WINTER #1	SPRING	SUMMER	FALL	WINTER #2
RSI	AVERAGE APRIL 4 & 5, 2017	MAY 31, 2017	AUGUST 14, 2017	OCTOBER 31, 2017	DECEMBER 6, 2017
Pilot-Scale System	13.43	11.86	12.28	13.38	13.11
Full-Scale System	13.65	13.75	14.43	14.03	13.44

Note that the RSI only provides an indication of the aggressiveness of the water and is considered a semi-empirical method. Thus, it is best practise to use the saturation index as part of the calculation to provide reliable results. In this, it is necessary to know parameters such as alkalinity, hardness, TDS, pH and temperature of the water. As such, a historical comparison to the full-scale system or the pilot-scale system benchmarking period is not possible as the data required to compute similarly comparable piloting RSI values was not collected post-filtration (i.e. post filtration and prior to alkalinity adjustment).

3.4.13.4 LARSON SKOLD INDEX

The LaI was developed to empirically evaluate the degree of corrosiveness of water relative to mild steel metal surfaces. This index is used to reference the in-situ corrosion of mild steel pipelines conveying naturally occurring water from lakes and other freshwater sources.

The LaI range calculated throughout the optimum water quality days during the seasonal piloting sessions ranged from 4.3 to 11.6 (Table 3-24). Under ideal conditions, the LaI would range between 0 and 1 with anything greater than 1 indicative of a high tendency for corrosion. As the LaI is calculated as the ratio of sulphate and chloride to bicarbonate and carbonate, this index is highly sensitive to the total alkalinity of the finished water.

Full-scale LaI results, collected from the combined filter location prior to pH adjustment and sampled on the same day, were analogously calculated and tabulated below. Results remain indicative of in situ corrosion and justify the need to increase alkalinity.

Table 3-24: Larson Skold Index comparisons between the full-scale and pilot-scale systems

PILOTING SESSION	WINTER #1	SPRING	SUMMER	FALL	WINTER #2
LaI	AVERAGE APRIL 4 & 5, 2017	MAY 31, 2017	AUGUST 14, 2017	OCTOBER 31, 2017	DECEMBER 6, 2017
Pilot-Scale System	11.6	4.3	10.6	9.2	7.8
Full-Scale System	N/R (Cl^- and SO_4^{2-})	13.2	12.4	9.6	7.1

N/R = no result

Note that the theory of LaI is based upon evaluation of in situ corrosion of mild steel lines transporting Great Lakes water. It is relevant to waters having similar composition to the Great Lakes and to its usefulness as in indicator of aggressiveness in reviewing the applicability of corrosion inhibition treatment programs that rely on the natural alkalinity and film forming capabilities.

A historical comparison to the full-scale system or the pilot-scale system benchmarking period is not possible as the data required to compute similarly comparable piloting LaI values was not collected post-filtration.

3.4.13.5 CHLORIDE TO SULPHATE MASS RATIO

Based on the CSMR values for the pilot-scale and full-scale systems (Table 3-25), the observed water quality from the pilot-scale system is not expected to increase the galvanic corrosion of lead solder connected to copper pipes. When compared to the full-scale system, and the historical data, ferric sulphate is anticipated to further reduce the CSMR (due to a reduction in chloride and increase in sulphate content from the use of ferric sulphate). However beneficial, the observed low alkalinity in the pilot-scale and full-scale systems provides minimal potential to impede previously discussed corrosive tendencies as LSI, RSI, and LaI.

Table 3-25: CSMR comparisons between the full-scale and pilot-scale systems

PILOTING SESSION	WINTER #1	SPRING	SUMMER	FALL	WINTER #2
CSMR	AVERAGE APRIL 4 & 5, 2017	MAY 31, 2017	AUGUST 14, 2017	OCTOBER 31, 2017	DECEMBER 6, 2017
Pilot-Scale System	0.028	0.031	0.037	0.032	0.032
Full-Scale System	N/R (Cl^- and SO_4^{2-})	0.478	0.383	0.360	0.489
Clear Well Full-Scale System Historical	Between 0.443 and 0.565 and an average of 0.420				

Of potential concern is the increase in sulphate concentration of the finished water, potentially impacting concrete structures. This concept is further discussed in Section 4.7.2.

Full-scale system CSMR results, collected from the combined filter location prior to pH adjustment and sampled on the same day, were analogously calculated and tabulated above, along with historical minimum, maximum, and average from the full-scale system. As results remain below a CSMR 0.5 for both the pilot-scale and full-scales systems, an increase in galvanic corrosion is not anticipated.

3.5 RECOMMENDATION FOR FUTURE PILOTING ACTIVITIES

The following are recommendations which could improve future piloting projects. The recommendations are related to, but not limited to, the reduction of manganese in the finished water, and within the distribution system to reduce or prevent the occurrence of discoloured water at the tap.

1 The benchmarking period undertaken in this project identified that the water produced by the pilot-scale system closely matched the full-scale system, when operating under the same conditions, i.e. coagulant and chemical dose, pH, etc. However, there are differences noted between the two systems, particularly related to the pilot-scale system DAF effluent, which generally produced effluent water with higher turbidity than what was measured in the full-scale system DAF effluent. It is recommended that a study be conducted to better identify the cause for variances in Post-DAF turbidity between the full-scale and pilot-scale systems. Differences identified in the pilot-scale system DAF causing unexpected increases in Post-DAF turbidity, for example tank size and orientation, should be mitigated to allow for a better comparison between the two systems. This would further improve the predictability of the full-scale system following changes based on pilot-scale system operations.

2 Identify the cause for differences observed in the pilot-scale system filter effluent water quality both with regards to Bank A (Filters 1-4) and Bank B (Filters 5-8), as well as within a particular bank, i.e. Filters

1 and 2 generally underperformed compared to Filters 3 and 4. Although the current project attempted to investigate the differences between Banks A and B by varying backwashing procedures and alternating flow rates both between the two banks, as well as within the banks themselves, no discernible cause for the observed differences could be determined. It is believed that flow rates, along with mechanical and possible chemical differences i.e. filter-aid addition to each bank, may be impacting the filter operations causing the differences observed between the two banks. It would be beneficial for both filter banks in the pilot-scale system to be operated more similarly, in order to obtain more reliable piloting results which are needed to better predict filter operations in the full-scale system.

3 For this study the filter-aid system was set to match the dosing rate used in the full-scale system. No further changes or optimization was made to this chemical system during the seasonal piloting session of the ferric sulphate. It is recommended that further investigate into the filter-aid dosing system and optimal dosages with the use of coagulant ferric sulphate be completed to determine if filter performance can be improved.

4 Given the already low raw water alkalinity, the addition of sulphuric acid and ferric sulphate to the raw water reduces the available alkalinity required for coagulation. It is recommended that future piloting sessions evaluate if the coagulation process improves following the addition of carbonate or bicarbonate alkalinity to the raw water, prior to DAF treatment.

5 Implement processes to the pilot-scale system to better mimic full-scale system operations taking place following filtration. Currently, the pilot-scale system mimics full-scale operations up to, and including, filtration. However, the full-scale system further adds chlorine for primary disinfection, sodium hydroxide to increase pH and add alkalinity to the water, UV contactors for secondary disinfection, fluoride to prevent tooth decay, and phosphoric acid for corrosion controls. Since these processes will impact the quality of treated water, it would be helpful to be able to assess these processes with the pilot-scale system to allow for more accurate predictions to full-scale system operations and the quality of water entering the distribution system.

6 The objective of the current study was to reduce the overall manganese concentration entering the distribution system to prevent or reduce the occurrence of discoloured water at the tap. The results collected during the current project indicate that a transition to ferric sulphate would reduce the manganese entering the distribution system; however, the current undertaking does not address the potential contribution of discoloured water from the distribution system itself. To address the possible impact of corrosive water to the distribution system WSP recommends conducting a pipe-loop study utilizing treated water from the pilot-scale system. The study would require extracting a water main from an area with high rates of service call, which would be used to mimic the current distribution system in the City. This main would be incorporated into the pipe-loop system, along with both chemical injection and sample collection points, which would be used to adjust the water quality with regards to factors affecting corrosive indices. It is also recommended that the impact of flow rates also be investigated using the pipe-loop system. Utilizing a pipe-loop system within the pilot-scale systems would allow for better control of conditions and water quality, without impacting the treated water quality entering the distribution system. Conclusions from the pipe-loop study could identify strategies and water quality targets that would reduce, or prevent, the formation of discoloured water in the distribution system.

7 During benchmarking, corrosivity parameters (i.e. chloride, sulphate, alkalinity, carbonate and bicarbonate) were not measured making it difficult to compare corrosivity indices between the pilot-scale system operating with ferric chloride (benchmarking period) and ferric sulphate (piloting session). It is

recommended that water quality parameters required to calculate the corrosive indices be measured so that appropriate comparisons between coagulants can be made.

8 During the seasonal piloting sessions, UFRV was not considered as a primary factor for determining optimal chemical dose and operating conditions. Although WSP does not feel that water production should take precedence over water quality treatment objectives or health-based regulations, it is believed that UFRV should be given more consideration when determining optimal chemical dose and operating conditions during piloting of alternative chemicals or chemical doses.

4 EXPECTED IMPACTS FROM SWITCHING TO FERRIC SULPHATE

4.1 OVERVIEW

In addition to the potential impact on the finished water quality at the full-scale system, different coagulants may have different effects on the performance of rapid mixing, flocculation, clarification, filtration, treatment and disposal of residuals and on the physical components of the full-scale system such as piping, pumps and valves. The potential impacts of coagulant changeover on the full-scale system should be evaluated in detail prior to the implementation stage. The findings from the piloting sessions were used to quantify and qualify the anticipated impacts on the full-scale system operation from switching to ferric sulphate. These anticipated outcomes are evaluated and discussed in this section. Costs and financial impacts are discussed in Section 5.

4.2 COMPARISON OF FERRIC CHLORIDE AND FERRIC SULPHATE

Table 4-1 summarizes the main characteristics of ferric chloride and ferric sulphate, which can affect the coagulant changeover.

Table 4-1: Main characteristics of ferric chloride and ferric sulphate.

COAGULANT	FERRIC CHLORIDE	FERRIC SULPHATE
Molecular Formula	$FeCl_3$	$Fe_2(SO_4)_3$
Concentration (%)	37% - 42%	43%
Ferric Content (%w/w)	12.7 -14.1%	11.5-13.0%
Ferrous Content (%w/w)	< 0.5	< 0.3
Appearance/Odour	Liquid, dark brown colour, slightly acidic odour	Liquid, red/brown colour, acidic odour
Specific gravity	1.38 - 1.45	1.55
Absolute Viscosity	10 mPa·s @ 20°C	50 mPa·s @ 21°C
Alkalinity Consumed	0.93 $mgCaCO_3$ / mg $FeCl_3$/L	0.75 $mgCaCO_3$ / mg $Fe(SO_4)_3$/L
Optimal pH range	< 6	< 6
Manganese Content (mg/kg)	< 600	< 100
% Free acid as HCl	< 1.0	< 0.5
Insoluble Solids (mg/kg)	< 80	27
Lead (mg/kg)	< 1.3	0
Magnesium (mg/kg)	< 35	142
pH	< 1	< 2
Boiling Point (°C)	100 – 105	105 – 110
Flash Point (°C)	Does not flash	Does not flash
Freezing Point (°C)	-25	-50
Effects of Dilution	Completely soluble at 20°C	Completely soluble
Stability/Reactivity	Under normal conditions, ferric chloride is generally stable, but it decomposes to yield hydrochloric acid on exposure to light. Not combustible. Reaction with some alkaline metals may evolve flammable hydrogen gas. Heating above the decomposition temperature can cause formation of hydrogen chloride. Thermal decomposition into corrosive vapours.	Under normal conditions, ferric sulphate is generally stable. Not combustible. No hazardous polymerization. Thermal decomposition into toxic products like sulphur oxides, hydrogen sulphide and irritating gases. Reaction with some alkaline metals may evolve flammable hydrogen gas.
Storage Conditions	Max. 12 months Store in a clean, cool well-ventilated area, away from organic chemicals, strong bases, strong acids, metal powders, carbides, sulphides, and any readily oxidizable material. Protect from direct sunlight.	Max. 12 months (10 – 30°C). Mixture can stratify. Store in a clean, cool well-ventilated area, away from organic chemicals, strong bases, strong acids, metal powders, carbides, sulphides, and any readily oxidizable material. Protect from direct sunlight.
Materials Compatibility	Highly corrosive Preferable: plastic (PE, PP, PVC), polyester with fiberglass reinforcement, rubber-coated steel, titanium. Avoid: Metals, bases, stainless steel, non-acid proof metals (as aluminum, copper and iron)	Corrosive Preferable: plastic (PE, PP, PVC), polyester with fiberglass reinforcement, rubber-coated steel, stainless steel, titanium, glass. Avoid: Metals, bases, non-acid proof metals (as aluminum, copper and iron)
Suppliers	Brenntag, Kemira, PVS Fanchem	Brenntag, Kemira, CCC

Ferric chloride and ferric sulphate are very similar chemicals; however, there are some slight differences between them. On a per mass basis, ferric chloride has a higher iron content, 1-1.5% more than ferric sulphate. While comparatively, ferric sulphate shows improved purity and alkalinity consumption when comparing equal doses of ferric chloride to ferric sulphate.

It is important to note the operational requirement when using iron based coagulants. Either coagulant, reacts readily with different species in natural water. These reactions include ligand substitution with natural occurring phosphates and sulphates, which will impact the overall success of coagulation. This is a reason why it is important to use the right coagulant dose and why the dose varies with different natural waters. Also, as denoted below, the addition of metal coagulants to water will subsequently lower the pH through the consumption of carbonate bearing species and the subsequent formation for hydroxide precipitates. The reactions that metal coagulants participate in (e.g. hydration and stepwise substitution) are very rapid, which makes initial mixing of coagulant in raw water very important as destabilization of hydroxide complexes can occur in <1 second.

Differences in trace metals impurities and contamination of the end-product are highly dependent on the available iron sources and their manufacturing process. The majority of ferric sulphate coagulants, suitable for potable water treatment purposes, are produced by direct reaction of iron ore with sulphuric acid. On the other hand, ferric chloride, suitable for potable water treatment purposes, is commonly produced either as a by-product of titanium dioxide (TiO_2) manufacturing or by ferrous iron oxidation in a solution of a strong acid (similar to the ferric chloride currently in at the full-scale system). These two manufacturing processes lead to lower purity.

4.3 IMPACT ON CHEMICAL SUPPLY

Table 4-2 presents the minimal, intermediate and maximal operating conditions for the optimal conditions of the seasonal piloting sessions with ferric sulphate as coagulant, which are used to evaluated chemical consumption. The limits of these operational parameters are further evaluated in terms of the financial impacts in Section 5. These values represent the anticipated potential operating ranges for the coagulant adoption, based on the piloting findings.

Table 4-2: Expected operating conditions for ferric sulphate as coagulant.

PARAMETER	MINIMAL	INTERMEDIATE	MAXIMAL
Ferric sulphate dose (mg/L)	38	40	42
Optimal pH	5.7	5.8	6.1

4.3.1 COAGULANT

Table 4-3 tabulates the expected coagulant annual consumption of coagulant arising from the historical average production of 210 MLD. The full-scale system historical average between 2010 and beginning of 2016 were used for ferric chloride consumption, while the three operating conditions presented in Table 4-2 were considered for the evaluation of ferric sulphate consumption.

Table 4-3: Anticipated coagulant consumption rates when utilizing ferric sulphate vs. historical consumption rates utilizing ferric chloride as coagulant.

COAGULANT	FERRIC CHLORIDE[1]	FERRIC SULPHATE (MINIMAL)	FERRIC SULPHATE (INTERMEDIATE)	FERRIC SULPHATE (MAXIMAL)
Coagulant Dose (mg/L)	27.6	38	40	42
Coagulant Dose (mg Fe/L)	9.8	10.6	11.2	11.7
Coagulant Annual Consumption (kg Fe/year)[2]	749,000	813,000	856,000	899,000
Coagulant Annual Consumption (kg/year) [2]	5,428,000	6,774,000	7,130,000	7,488,000
Coagulant Annual Consumption (m^3/year) [2]	3,750	4,370	4,600	4,830

[1] As per full-scale system historical average between 2010 and beginning of 2016.

[2] Based on historical data average flow of 210 MLD.

4.3.1.1 FERRIC SULPHATE LOCAL AVAILABILITY

One of the most important factors in selecting the coagulant is to investigate its local availability. Location of the full-scale system and the suppliers can affect availability and subsequently the purchasing price of the coagulant. In this, ferric sulphate is a commonly used coagulant in the water and wastewater treatment industry. With multiple suppliers available and rail accessibility at the full-scale system, availability and volume are not considered impediments to adoption. The ferric sulphate suppliers listed in Table 4-4 were identified as being capable of delivering to the Winnipeg full-scale system via rail car.

Table 4-4: Ferric sulphate suppliers and its origin.

SUPPLIER NAME	REPORTED FERRIC SULPHATE ORIGIN
Kemira	Bulk storage is in Varennes, Quebec or St-Louis, Missouri (USA)
Brenntag	Bulk storage is in Ontario
CCC	Bulk storage is in Brampton, Ontario

With at least three suppliers identified for ferric sulphate, ferric sulphate and ferric chloride are deemed comparable in terms of local availability.

4.3.1.2 COMPATIBILITY OF THE EXISTING COAGULANT STORAGE AND FEED SYSTEM

Table 4-5 summarizes the existing coagulant handling system components and their materials in direct contact with the chemical prior to its injection into the treatment system and the compatibility of the system with ferric sulphate. The existing chemical feed system has been specifically designed for storage and dosing of ferric chloride, which is more corrosive than ferric sulphate. Table 4-5 presents the existing and alternative coagulants' chemical resistances noted above and their compatibility with select handling materials.

Table 4-5: Existing coagulant handling system components, their materials and compatibility with ferric sulphate.

COMPONENT	EXISTING MATERIAL	FERRIC SULPHATE
Piping	PVC (SCH 80)	Existing is excellent[2]. Conveyance materials should be rubber-lined steel or plastics.
Valves	Bodies: PVC Seats/Seals/Balls: Viton/FKM, EPDM, PTFE Bodies: Polypropylene Seats/Seals: EPDM	
Chemical Pump Skid	Polypropylene[1]	
Chemical Storage Tank	Bisphenol- A Epoxy Vinyl Ester Resin Dissolved in Styrene Liner: F010-CNM-00 Gaskets: EPDM	Existing is excellent[2]. Tankage may be constructed of fiberglass reinforced plastic (FRP), rubber-lined steel, or plastic-lined steel. Resin impregnated carbon or graphite are also suitable materials for storage. Long term storage in heated areas recommended to prevent crystallization. Tanks should have a free vent or vacuum-relief valve. May be constructed of fiberglass reinforced plastic (FRP), rubber-lined steel, or plastic-lined steel.
Injection Nozzle	Titanium	Excellent[2]

[1] All PVC components of the coagulant pump skid were recently replaced to polypropylene.

[2] Based on Cole-Parmer Scientific Experts Online Chemical Compatibility Database.

Based on the above table, the existing system is expected to be fully compatible with ferric sulphate.

The ferric sulphate has a specific gravity (1.55) 7% higher than the ferric chloride (1.45). This will affect the pressure drop in the unloading piping and in the dosing piping, as well as the possible storage capacity of the existing coagulant tanks.

The Darcy-Weisbach equation for pressure drop calculation shows a linear correlation between head losses and specific gravity. Thus, the head losses in the unloading piping and in the dosing piping are expected to increase 7% as well, which is considered very small. Since the filling systems is designed for higher pressures than required for the coagulant (based on sulphuric acid with specific gravity of 1.835) and since the dosing pumps have a design head usually several times higher than the operating pressures, no modifications are anticipated, besides possible adjustments to the pressure regulators.

In case the coagulant storage tanks are not able to structurally support the same volume of ferric sulphate, due to the higher specify gravity of ferric sulphate, the four coagulant storage tanks with storage volume of 94 m^3 for ferric chloride would have their capacity reduced to 88 m^3, when storing ferric sulphate. Since the potential loss is only 6.5%, no additional tanks are proposed at this stage; however, the coagulant storage autonomy would be reduced and the coagulant frequency of delivery impacted, as further discussed in Section 4.3.4.

The current coagulant dosing pumps (Seepex MD 05-6LT/B4-T4-T4-F0-GA-X) are design to dose ferric chloride at 39% concentration from 15 to 50 mg/L and process flow from 102 MLD to 409 MLD, which would represent a maximum pump flow of 1,500 L/h at maximum full-scale system flow and maximum coagulant dosage. Applying the same ranges of full-scale system flow and coagulant dosage for ferric sulphate at 43% concentration, the dosing pumps should be able to pump between 90 to 1,300 L/h of ferric sulphate. Based on minimal and maximal operation conditions for the seasonal piloting sessions with ferric sulphate (Table 4-2), the ferric sulphate flow rate would be between 500 to 550 L/h. The material of construction is also compatible for both chemicals.

Therefore, no physical changes in the chemical feed system are anticipated, except for the replacement of existing labels to identify the new coagulant. However, it is recommended that the City performs a detailed analysis of each component of the filling system and dosing system (such as storage tank, valves, pumps, piping) in terms of pressure and flow ratings to confirm these findings. The re-rating of their operating parameters or adjustments of the overflow levels may be required.

4.3.2 SULPHURIC ACID AND CAUSTIC SODA

Table 4-6 presents the optimal pH ranges, the sulphuric acid consumption and the sodium hydroxide consumption associated with each coagulant for anticipated pH and alkalinity adjustment.

Table 4-6: Anticipated sulphuric acid and sodium hydroxide consumption utilizing ferric sulphate vs. historical consumption rates utilizing ferric chloride.

COAGULANT	FERRIC CHLORIDE[1]	FERRIC SULPHATE (MINMUM) [3]	FERRIC SULPHATE (INTERMEDIATE) [3]	FERRIC SULPHATE (MAXIMUM)[3]
Optimal pH	5.6	6.1[3]	5.8[3]	5.7[3]
Dose of Sulphuric acid required (mg/L)	41.7	30.0	38.8	40.2
Acid Annual Consumption (ton/year)[2]	3,400	2,470	3,190	3,300
Acid Annual Consumption (m^3/year) [2]	1,870	1,340	1,740	1,800
Dose of sodium hydroxide (base) required (mg/L)	49.6	39.9[4]	47.9[4]	49.9[4]
Base Annual Consumption (ton/year)[2]	7,600	6,100	7,350	7,650
Base Annual Consumption (m^3/year)[2]	4,970	4,000	4,800	5,000

[1] As per full-scale system historical average between 2010 and beginning of 2016.
[2] Based on historical data average flow of 210 MLD.
[3] Minimum, intermediate and maximum optimal pH values identified from optimal conditions determined during seasonal piloting sessions with ferric sulphate as coagulant.
[4] Based on theoretical calculations to adjust to the full-scale system historical average pH of 7.84 at the clearwell (Table 1-1).

Based on the above table, less sulphuric acid is required with ferric sulphate to reach the minimum, intermediate or maximum optimal pH for coagulation determined during seasonal piloting sessions due to the fact that ferric sulphate is operating at a higher pH. Furthermore, less or equal sodium hydroxide is required with ferric sulphate to adjust the pH from optimal pH for coagulation to reach the historical average clear well pH of 7.84 than for ferric chloride. It should be noted these findings are based on an operating pH of 5.6 for ferric chloride, which is below the optimal pH yielded from the seasonal piloting sessions using ferric sulphate. At the same operating pH and same coagulant dose, ferric sulphate would require more acid than ferric chloride to achieve the same pH.

The current acid metering pumps are designed to dose sulphuric acid from 5 to 45 mg/L for a process flow of 102 MLD to 409 MLD. The current base metering pumps are designed to dose sodium hydroxide from 20 to 50 mg/L for a process flow from 102 MLD to 409 MLD. The same full-scale system flows and dosing ranges can be considered when used for ferric sulphate as the coagulant. Therefore, no physical changes in the chemical feed system are anticipated. It should be noted the historical average dose of sodium hydroxide for ferric chloride (49.6 mg/L) and the maximal anticipated dose for ferric sulphate (49.9 mg/L) are very close to the maximum dose of 50 L/h used for the dosing pump design, the additional pumping capacity may be required if the full-scale system is operated at flowrate near the its capacity.

4.3.3 COAGULANT-AID

Table 4-7 presents the expected coagulant-aid consumption associated with each coagulant for an historical average production of 210 MLD.

Table 4-7: Anticipated coagulant-aid consumption rates utilizing ferric sulphate vs. historical consumption rates utilizing ferric chloride.

COAGULANT	FERRIC CHLORIDE	FERRIC SULPHATE (MINIMUM) [2]	FERRIC SULPHATE (INTERMEDIATE) [2]	FERRIC SULPHATE (MAXIMUM) [2]
Dose of Coagulant-Aid Required (mg/L)	None	0	0.07	0.1
Coagulant-Aid Annual Consumption (kg of dry polymer/year)[1]	None	0	5,370	7,670
Coagulant-Aid Daily Consumption at 0.5% concentration (m^3/d)[1]	None	0	5.9	8.4

[1] Based on historical data average flow of 210 MLD.

[2] Minimum, intermediate and maximum coagulant dosages identified from optimal conditions determined during seasonal piloting sessions with ferric sulphate as coagulant.

Currently, the full-scale system doesn't incorporate any coagulant-aid into its process; however, it uses Magnafloc LT-22S polymer as a filter-aid prior to the filtration process. A complete polymer preparation system and dosing system (storage area for the dry bags, chemical storage area, and associated feed system) is required specifically for the preparation of the Magnafloc LT-22S for coagulant-aid use. Although the current polymer make-up system is operated with Magnafloc LT-22S, the existing system does not have capacity for coagulation-aid purposes.

Considering a maximum coagulant-aid dose of 0.1 mg/L and maximum process flow of 409 MLD, an automated polymer make-up system with capacity of 2 kg per hour (kg/h) at a 0.5% stock solution concentration with 60 minutes of maturing time in a mixing tank volume of 500 L and a 500 L dosing tank is conceptualized.

Coagulant-aid would be pumped to the flocculation basins from the polymer make-up room. It is estimated that 16 progressive cavity dosing pumps would be required with capacity to dose up to 100 L/h to the 16 applications points (in the second and the third flocculation chamber of each DAF). The clean water consumption for primary and secondary dilution is approximately 400 L/h. It is estimated that an area of 80 m^2 would be required to accommodate the new polymer preparation system and dosing system for coagulant-aid. At this point, the existing polymer make-up room is considered to have sufficient space for a new coagulant-aid system and that no building extension would be required.

4.3.4 METHOD OF DELIVERY AND FREQUENCY OF DELIVERY

With the implementation of an alternative coagulant, the method of delivery and frequency of delivery of coagulant, sulphuric acid and sodium hydroxide should be assessed to investigate the impact of the alternative coagulant (ferric sulphate) on the daily operation of Winnipeg full-scale system.

Currently, ferric chloride is delivered to the full-scale system via rail cars every five to six days. Each rail car has an approximate capacity of 80 to 90 tonnes. The vendors for ferric sulphate have confirmed the possibility of applying the same delivery method for the proposed coagulant.

Table 4-8 provides a summary of the autonomy and frequency of delivery for the existing (ferric chloride) and proposed coagulant (ferric sulphate), as well as their associated acid and base requirements.

Table 4-8: Anticipated storage autonomy and frequency of chemical delivery utilizing ferric sulphate vs. historical autonomy and frequency of chemical delivery utilizing ferric chloride.

COAGULANT	FERRIC CHLORIDE[1]	FERRIC SULPHATE (MINIMUM)[4]	FERRIC SULPHATE (INTERMEDIATE)[4]	FERRIC SULPHATE (MAXIMUM)[4]
Coagulant Frequency of Delivery (days)[2,3]	6.1	4.5	4.2	4.0
Coagulant Storage Autonomy (days)[2,3]	37	29	28	27
Acid Frequency of Delivery (days)[2]	3.2	4.4	3.4	3.3
Acid Storage Autonomy (days)[2]	37	51	40	38
Base Frequency of Delivery (days)[2]	4.3	5.4	4.5	4.3
Base Storage Autonomy (days)[2]	28	34	29	27

[1] As per full-scale system historical average between 2010 and beginning of 2016.
[2] Based on historical data average flow of 210 MLD.
[3] The tank volume was reduced by 6.5% to account for the higher specific gravity of ferric sulphate (1.55) in comparison with ferric chloride (1.45).
[4] Minimum, intermediate and maximum coagulant, acid, and base consumption identified from optimal conditions determined during seasonal piloting sessions with ferric sulphate as coagulant.

As noted in Table 4-8, the delivery frequency of coagulant chemical will increase and the autonomy will be decreased by 20% when utilising ferric sulphate when compared with ferric chloride. However, the minimum chemical storage requirements of 14 days based on the maximum process flow and average chemical dose condition are still met. On the other hand, utilizing ferric sulphate slightly decreases the delivery frequency of the acid (sulphuric acid) and base (sodium hydroxide). Therefore, no physical changes in the chemical storage system are anticipated.

It should be noted that the higher ferric sulphate dose expected (38 to 42 mg/L in comparison with the historical average of 27.6 mg/L for ferric chloride) has much more impact on the reduction of coagulant storage autonomy (14 to 22%) than the loss of storage tank capacity due to the higher specific gravity of ferric sulphate (6.5%).

4.4 IMPACT ON FULL-SCALE SYSTEM PROCESSES

4.4.1 RAPID MIXING AND FLOCCULATION

The rapid mix facility is intended to provide an appropriate amount of mixing energy to the raw water for the mixing of two chemicals, specifically sulphuric acid for pH adjustment, and ferric chloride, the primary coagulant. Iron coagulants, inclusive of ferric chloride and ferric sulphate, work by reacting with the water's alkalinity to form jelly-like particles of iron hydroxide (floc). Sufficient amounts of mixing and alkalinity must be present for this to occur.

Regarding ferric sulphate, sufficient mixing can be achieved by jet flash mixing the coagulant into the raw water. The use of the existing flash mix injectors installed in each of the raw water headers feeding each train are expected to meet mixing requirements. Furthermore, the existing 40 mm diam. Schedule 80 PVC ferric chloride solution line is deemed to have sufficient capacity and can be repurposed for the conveyance of ferric sulphate to each mixing nozzle.

No impacts are anticipated on the sulphuric acid feed system if the coagulant is switched from ferric chloride to ferric sulphide, as pumping capacities and dosages remain within the existing scales used. In this, existing control methodologies are also not expected to require adjustment.

Flocculation practises promote the agglomeration of small floc particles generated during coagulation into larger, more easily removed particles. As such, the formation of floc particles is a function of the relative turbulence of the DAF process, through the use of moderately high mixing energy to generate a small, tough floc. Given this relationship and the fact that there is a different concentration of active component ferric iron in ferric chloride and ferric sulphide, minor adjustments to mixing strategies is anticipated when switching the active coagulant to ferric sulphate.

4.4.2 FORMATION OF PRECIPITATES IN THE RECYCLING STREAM

Precipitation of soluble metals in water is highly dependent on the activity of hydrogen ions (pH) and the activity of electrons (Eh). Consequently, the precipitation reactions commonly illustrated on Eh–pH diagrams involve either proton transfer (i.e. hydrolysis) or electron transfer (i.e. oxidation or reduction) or both. Among all metals in solution, iron, aluminium, and copper have the highest tendency to precipitate downstream of the DAF process and potentially be present in the DAF recycle stream.

Table 4-9 summarizes of results obtained during the seasonal piloting sessions for total and dissolved concentrations of iron, aluminum, and manganese for the clarified water of ferric chloride and ferric sulphate, as well as the total solids (TS) and calculated TSS. Although higher iron concentrations were found in the pilot-scale system Post-DAF samples with ferric sulphate, lower manganese concentrations and similar aluminum, total solids and TSS concentrations were observed. Accordingly, it cannot be concluded that ferric sulphate would generate more precipitates than ferric chloride. Further investigation by a laboratory analysis of the recycle stream to identify the dissolved metal content, carbonate speciation concentrations, pH, conductivity, etc., combined with a software analysis using MINEQL+ or equivalent, could identify the thermodynamic precipitation reactions, products, and their associated concentrations. However, such calculations remain theoretical in nature and requires inspection prior to adoption.

Table 4-9: Anticipated metals and solids contents in the recycle stream utilizing ferric sulphate vs. utilizing ferric chloride.

COAGULANT	FERRIC CHLORIDE[1]	FERRIC SULPHATE[2]
Total iron (mg/L)	0.0387 - 0.647	0.817 - 1.95
Dissolved iron (mg/L)	0.117 - 0.239	0.141 - 0.474
Total aluminum (mg/L)	< 0.01 - 0.020	< 0.01 - 0.020
Dissolved aluminum (mg/L)	0.004 - 0.012	0.002 - 0.010
Total manganese (mg/L)	0.040 - 0.065	0.009 - 0.050
Dissolved manganese (mg/L)	0.039 - 0.062	0.011 - 0.020
Total Solids (mg/L)	132 - 180	116 - 162
Total Suspended Solids, calculated (mg/L)	17 - 48	11 - 40

[1] Concentration ranges of full-scale system Post-DAF, during the piloting sessions.
[2] Concentration ranges of pilot-scale system Post-DAF, during the piloting sessions.

4.4.3 FILTER OPERATIONAL PERFORMANCE

Filter run time and frequency of filter backwashes are dependent on the concentration of suspended solids in the water upstream of the filtration process. Furthermore, suspended solids not removed in the DAF process, and some of the dissolved metals present would be oxidized through the ozonation process prior to entering the filtration step. In this context, suspended solids are mainly precipitates of iron, aluminium, copper and manganese, as well as other colloidal material which will be retained by the filters. Higher TSS concentrations would result in shorter filter run times and UFRV and an increase in the backwash frequency. Furthermore, an increase in backwash duration may be required as a result of this, consequently resulting in higher water losses during backwashing and increased residual processing requirements. However, it is not expected that ferric sulphate will generate more precipitates than ferric chloride as indicated in Section 4.4.2.

There has been some concern presented regarding legacy manganese held within the filter media. Specifically, it has been reported that WTPs using ferric chloride as a coagulant have observed the release of legacy manganese in elevated concentrations following the changing of coagulant to ferric sulphate (Gabelich et al., 2006). The release is suspected to be the result of metal-metal ligand displacement within the filter media arising from the increase of competing metals due to a switch in coagulant. The result is oxidation of the newly released manganese into solution from the filter media. With no empirical identification of the manganese oxides present in the filter media available, the filter effluent potentially remains subject to a short-term increase in manganese following the changing coagulant.

Comparing the pilot-scale system operational performance with ferric sulphate and with ferric chloride, the overall average observed UFRV was 246 m^3/m^2 for the benchmarking periods (ferric chloride), it is believed that the primary loss of performance was attributed to the use of coagulant-aid, specially for the Summer and Fall sessions. This infers that the use of coagulant-aid had a greater impact on the filter operation than the coagulant type.

Without the addition of coagulant-aid during the Fall and Winter #2 piloting sessions, it is conceptualized that similar UFRV values to the historical full-scale system benchmarking could be obtained with ferric sulphate at the full-scale system, should these piloting sessions have had similar and comparable head losses to the full-scale system.

Nonetheless, the pilot-scale system filters were not able to produce filter effluent turbidity results that did not exceed the City's operational guideline of ≤0.1 NTU for all seasonal piloting sessions. These filter effluent turbidity results imply that the use of coagulant-aid in conjunction of ferric sulphate not only significantly impacted the filter's capacity to produce sufficiently treated water, but also the filtration performance, a result likely due to the nature of polymerization and its interaction with the filtration media, especially in cool and cold-water conditions. In light of this, to confirm that the filter performance is not affected by the ferric sulphate year-round, it is recommended that the City perform additional long-term pilot-scale system testing with ferric sulphate as a coagulant.

4.4.4 CHLORINE CONTACT TIME AND DOSE

As part of a multi-barrier approach to provide safe potable water, the full-scale system utilizes chlorine for primary disinfection purposes, for the inactivation of viruses. It should be noted that the required contact time (CT) for inactivation of viruses by free chlorine is largely dependent upon the required log inactivation and water temperature, and is not a function of the pH of the water under normal circumstances (specifically, a pH below 6 for giardia cysts and viruses).

Specific licence requirements set by the ODW for the City regarding chlorine residual require a minimum of 0.5 mg/L leaving the full-scale system and a minimum contact time of 20 minutes. In this, the CT is defined as the product of the disinfectant residual and the effective disinfectant contact time. Specific impacts to these parameters arising from use switch coagulants from ferric chloride to ferric sulphate anticipated are tabulated in Table 4-10.

Table 4-10: Consideration for chlorine contact time calculation variables.

CHLORINE CONTACT TIME VARIABLE	DESCRIPTION AND ANTICIPATED IMPACT
Disinfectant Residual	The remaining chlorine residual after chlorine demand is accounted as the disinfectant available to inactivate disease-causing organisms. The chlorine demand may change with dosage, time, temperature, pH and the nature the overall quality of the water. Switching coagulants is not anticipated to impact water quality as the full-scale system will adjust the chlorine dose in order to attain the required disinfectant residual of 0.5 mg/L free chlorine.
Effective Disinfectant Contact Time	Switching coagulants will not impact the effective disinfectant contact time, as it is a function of operating and design conditions (peak flows, temperature, a maximum pH to be less than 6, baffling factor, etc.).

In light of the CT, the pH is an important factor in coagulation. The optimum pH range corresponds to that over which the minimum solubility of the hydrolysed coagulant products occurs and maximum turbidity and colour removal is achieved. Typically for ferric salts, the coagulation pH is between 5.0 and 6.0. As a result of the similarities in operating pH's between ferric chloride and ferric sulphate, impacts to CT due to pH resulting from switching coagulants are considered minimal. Per the EPA Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) guidance document, giardia cysts and virus inactivation using free chlorine at a pH less than 6.0 subsequently does not impact CT requirements (USEPA, 2013).

Furthermore, when considering the amount of hypochlorous acid to be added to reach a disinfectant residual of 0.5 mg/L, under theoretical conditions, differences in pH as a result of the specific coagulant used will subsequently affect the dissociation between hypochlorous acid (HOCl) and the hypochlorite ion (OCl^-).

When sodium hypochlorite is added to water, it dissociates to hypochlorous acid and hypochlorite ion. Among the two, literature considers hypochlorous acid to be the stronger disinfectant; however, both species provide disinfection capabilities.

In this, it is conceivable that a minor adjustment in chlorine dose may be needed to offset this potential observation to maintain a free chlorine of 0.5 mg/L. However, an empirical value cannot be calculated as the disinfection efficiencies of either hypochlorous acid and hypochlorite ion are a function of the water quality and microbiological quality of the water guiding the initial sodium hypochlorite dosage.

4.5 IMPACT ON FINISHED WATER QUALITY

Each coagulant produces a specific finished water quality which is unique to that coagulant and is based on its characteristics and its reaction with raw water. Notable impacts in the comparison of ferric chloride to ferric sulphate are as follows.

4.5.1 FILTER EFFLUENT TURBIDITY AND PARTICLE COUNTS

Table 4-11 presents the average turbidity data collected from the pilot-scale system during seasonal benchmarking periods, as well as the average turbidity data collected on the optimal days from the pilot-scale system during the seasonal piloting sessions. It should be noted that there was no Fall benchmarking period, instead the pilot-scale system was evaluated for long-term operation with ferric sulphate. As such, no comparison can be made between the benchmarking period and the piloting session for the Fall period.

Table 4-11: The average turbidity results from each benchmarking period ($FeCl_3$) compared against the average optimal days turbidity for each piloting session ($Fe_2(SO_4)_3$).

LABORATORY SAMPLE TURBIDITY (NTU)	WINTER #1		SPRING		SUMMER		WINTER #2	
	$FeCl_3$	$Fe_2(SO_4)_3$	$FeCl_3$	$Fe_2(SO_4)_3$	$FeCl_3$	$Fe_2(SO_4)_3$	$FeCl_3$	$Fe_2(SO_4)_3$
Raw	0.62	0.53	0.78	1.26	0.95	1.28	0.64	0.90
Post-DAF	1.67	1.36	1.18	0.82	0.45	0.71	1.20	1.25
Post-Ozone	1.45	1.56	1.13	0.93	0.65	1.16	1.44	1.37
Combined Filtrate	0.12	0.22	0.07	0.08	0.06	0.12	0.10	0.07

The results in Table 4-11 show that there is an increase in turbidity following DAF treatment in the pilot-scale system when operated with either ferric chloride or ferric sulphate. This implies that the increase in Post-DAF turbidity is irrespective of coagulant and is therefore attributed to the pilot-scale system itself. Ozonation did not appear to improve turbidity removal when either ferric chloride or ferric sulphate was applied. There is a lower combined filter effluent turbidity when the pilot-scale system was operated with ferric chloride in Winter #1 and Summer; however, in Winter #2 the turbidity was lower in the combined filter effluent when the pilot-scale system was operated with ferric sulphate. The highest combined effluent turbidity was measured in the Winter #1 session for both ferric chloride and ferric sulphate at 0.12 NTU and 0.22 NTU, respectively. The elevated turbidity in the combined filter effluent during the Winter #1 benchmarking period and the Winter #1 piloting session is likely attributed to a higher flow rate (~3.0 L/s) through the DAF causing a significant increase in Post-DAF turbidity, and subsequently higher combined filtrate turbidity. During the Winter #2 benchmarking period and the Winter #2 piloting session, lower flow rates were used which improved both Post-DAF turbidity, and in turn, produced a lower combined filtrate turbidity for both ferric chloride and ferric sulphate.

When comparing the difference in combined filtrate turbidity using ferric chloride and ferric sulphate, the results are very comparable, aside from the Winter #1 results. Furthermore, when ferric sulphate is used the turbidity meets the Operating Licence requirements of ≤0.3 NTU. Therefore, the results indicate that there is no concern in meeting the Operating Licence combined filter effluent turbidity following a transition to ferric sulphate.

Particle count data was continuously monitored in the pilot-scale system by the online particle counters. However, upon review of this data the results were found to be highly irregular. After conferring with the City, it was determined that the pilot-scale system SCADA was not recording the correct particle count data from the online instrumentation. As such, a comparison cannot be evaluated and the data available does not warrant additional analysis.

4.5.2 OPERATING pH RANGE AND ALKALINITY

The optimal operating pH for coagulation determined during the seasonal piloting sessions for ferric sulphate ranged between 5.7 to 6.0 (Table 4-12), which is comparable to the optimal pH for ferric coagulants reported in the literature.

Table 4-12: Full-scale and pilot-scale systems pH at optimal conditions during the seasonal piloting sessions.

SAMPLE LOCATION pH (unitless)	WINTER #1		SPRING		SUMMER		FALL		WINTER #2	
	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT
Raw pH	7.99	7.89	7.97		7.71		7.49		7.82	
Post-DAF pH	5.63	5.67	5.42	6.20	5.50	5.98	5.59	5.79	5.83	5.80
Post-Ozone pH	5.73	5.67	5.59	6.19	5.68	5.98	5.72	5.76	5.92	5.80
Combined Filtrate pH	5.65	5.82	5.44	6.20	5.40	6.08	5.51	5.77	5.74	5.89

Since the primary component for coagulation in both ferric chloride and ferric sulphate is iron(III), both coagulants should theoretically have the same optimal operating pH range. However, both coagulants will affect the alkalinity in the water differently, which can impact the pH of treated water. Based on stoichiometry, ferric chloride consumes more alkalinity compared to ferric sulphate (Reaction 2 & 3). As such, it is important to take into account the alkalinity in the water following coagulation, as low alkalinity water can become corrosive and damage piping and concrete structures within the full-scale system or the distribution system.

(Reaction 2) $2FeCl_3 + 3Ca(HCO_3)_2 \rightarrow 2Fe(OH)_3 + 3CaCl_2 + 6CO_2$

(Reaction 3) $Fe_2(SO_4)_3 \bullet 9H_2O + 3Ca(HCO_3)_2 \rightarrow 2Fe(OH)_3 + 3CaSO_4 + 6CO_2 + 9H_2O$

The alkalinity results (Table 4-13) indicate that the natural alkalinity in the source water is low, ranging from 73.0-87.5 mg/L $CaCO_3$ during the seasonal piloting sessions. It should be noted that the alkalinity was not measured during the benchmarking periods and therefore comparisons cannot be made between the pilot-scale system operating with ferric chloride (benchmarking period) and piloting sessions with ferric sulphate. The lowest raw water alkalinity occurred during the summer months where there are warmer water conditions. The seasonal change in raw water alkalinity is related to several factors such as the change in flux of carbon dioxide (CO_2), metabolic processes in the water body (i.e. photosynthesis by aquatic plants and respiration from aquatic species), as well as the influence of carbonate rocks, for example limestone, all of which contain a varying degree of temperature dependence (Talling, 2010). In general, the raise in temperature, and subsequent decrease in pH and alkalinity indicates that the raw water would be more subject to changes in pH, due to the loss of carbonate buffering capacity. As a result, less acid would be required to depress the pH to the desired optimal operating range in warm water conditions, compared to cool, or cold-water conditions.

Table 4-13: Full-scale and pilot-scale systems alkalinity at optimal conditions during the seasonal piloting sessions. Alkalinity results are reported in mg/L $CaCO_3$.

SAMPLE LOCATION pH (unitless)	WINTER #1		SPRING		SUMMER		FALL		WINTER #2	
	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT
Raw	87.5	81.0	78.0		73.0		75.0		75.7	
Post-DAF	7.5	7.5	6.0	18.5	7.8	14.5	8.0	10.0	13.0	10.0
Post-Ozone	8.5	7.5	6.0	18.0	8.5	14.5	10.0	10.0	14.7	9.3
Combined Filtrate	7.9	7.4	6.0	20.5	6.0	13.3	8.0	9.0	12.0	11.0

When evaluating the effect of ferric chloride and ferric sulphate on the alkalinity, there are two important factors to consider. First is the addition of sulphuric acid to depress the pH to the desired operating pH for the coagulant. The seasonal piloting session results found the optimal operating pH range for ferric sulphate ranged between 5.7 and 6.0. The optimal pH range determined for ferric sulphate is within the optimal range for ferric coagulants reported in literature (Letterman and Yiacoumi, 2011). The second important consideration is the consumption of alkalinity by each of the coagulants presented in Reactions

2 & 3, which is directly related to the dose of the coagulant. When evaluating the change in alkalinity in the full-scale and pilot-scale systems, there is a significant reduction in alkalinity following coagulation, as expected. Since Reactions 2 & 3 indicate that there should be more alkalinity consumed by ferric chloride, one would expect lower alkalinity in the Post-DAF samples collected from the full-scale system. However, when evaluating the reduction of alkalinity in situations where Post-DAF pH is similar between the two systems, i.e. Winter #1, there is lower alkalinity in the pilot-scale system (7.4 mg/L $CaCO_3$), using ferric sulphate, compared to the full-scale system (7.9 mg/L $CaCO_3$), using ferric chloride. The reason for this discrepancy is likely the result of a higher optimal coagulant dose for ferric sulphate, compared to ferric chloride. Since more ferric sulphate is added during coagulation in the pilot-scale system, there is more alkalinity consumed than ferric chloride, when the pH for coagulation is the same between each system. However, in situations where there is a higher operating pH for coagulation using ferric sulphate, compared to ferric chloride (measured as Post-DAF; Table 4-12), for example the Spring and Summer piloting sessions, the resulting alkalinity in the combined filter effluent is significantly higher in the pilot-scale system (Spring = 20.5 mg/L $CaCO_3$ and Summer = 13.3 mg/L $CaCO_3$), compared to the full-scale system where the combined filtrate alkalinity for both Spring and Summer was 6.0 mg/L $CaCO_3$.

Since the combined filter effluent alkalinity is low in both the full-scale and pilot-scale systems, there is a need to increase the alkalinity to prevent corrosive water. The results shown here imply that if the full-scale system were transitioned to ferric sulphate the resulting alkalinity of the final combined filter effluent would be similar to operating with ferric chloride, provided the higher optimal dose of ferric sulphate and similar coagulation pH is used. However, since the optimal coagulation pH determined for ferric sulphate is slightly higher (5.8-6.0) than the current pH range applied in full-scale operation (5.5-5.8), the result would be a slightly higher finished water alkalinity and therefore would require less sodium hydroxide to increase the alkalinity and pH to the operating conditions used by the City. The slightly higher alkalinity and operating pH range for ferric sulphate could reduce the impact of acidic water on concrete structures. However, it is important to keep in mind the impact of sulphates on concrete structures when exceeding 150 mg/L, and that the existing infrastructure was not constructed to be sulphate resistant. This is discussed further in Section 4.7.2.

4.5.3 ALUMINUM, IRON AND MANGANESE

Aluminum, iron, and manganese concentrations measured in the full-scale and pilot-scale systems during seasonal testing can be found in Table 4-14 to Table 4-16.

The aluminum results presented in Table 4-14 show an increase in aluminum following coagulation with ferric chloride (full-scale system) and ferric sulphate (pilot-scale system); however, there is a greater increase in both total and dissolved aluminum with ferric chloride compared to ferric sulphate. This is due to the high residual aluminum content found in ferric chloride (440 mg/kg), compared to ferric sulphate. Ozonation and filtration did not reduce the aluminum concentration in either system. The total and dissolved aluminum concentration in the final effluent collected from the full-scale system was higher compared to the pilot-scale system for all seasons, except for the Winter #2 piloting session. The aluminum results in the full-scale system filter effluent samples collected during the Winter #2 piloting session are suspect as the dissolved aluminum concentration (0.010 mg/L) exceeds the total aluminum concentration (0.007 mg/L). The cause for this discrepancy is unclear but can be related to either sampling or sample preparation.

Table 4-14: Average total and dissolved aluminum concentrations in the full-scale and pilot-scale systems during the seasonal piloting sessions at optimal conditions. The data originates from the Laboratory.

PILOTING SESSION	RAW	POST-DAF	POST-OZONE	COMBINED FILTRATE
Winter #1				
Full-scale				
Total Aluminum (mg/L)	<0.01	0.020	0.020	0.020
Dissolved Aluminum (mg/L)	N/A	N/A	N/A	N/A
Pilot-scale				
Total Aluminum (mg/L)	<0.01	0.020	0.020	0.010
Dissolved Aluminum (mg/L)	N/A	N/A	N/A	N/A
Spring				
Full-scale				
Total Aluminum (mg/L)	<0.01	<0.01	<0.01	<0.01
Dissolved Aluminum (mg/L)	0.002	0.011	0.010	0.011
Pilot-scale				
Total Aluminum (mg/L)	<0.01	<0.01	<0.01	<0.01
Dissolved Aluminum (mg/L)	0.002	0.002	0.003	0.002
Summer				
Full-scale				
Total Aluminum (mg/L)	<0.01	0.020	0.010	0.010
Dissolved Aluminum (mg/L)	<0.003	0.012	0.010	0.011
Pilot-scale				
Total Aluminum (mg/L)	<0.01	<0.01	<0.01	<0.01
Dissolved Aluminum (mg/L)	<0.003	0.003	0.003	0.003
Fall				
Full-scale				
Total Aluminum (mg/L)	<0.003	0.004	0.004	0.010
Dissolved Aluminum (mg/L)	<0.003	0.004	0.004	0.006
Pilot-scale				
Total Aluminum (mg/L)	<0.003	0.010	0.011	0.004
Dissolved Aluminum (mg/L)	<0.003	0.010	0.010	0.005
Winter #2				
Full-scale				
Total Aluminum (mg/L)	<0.003	0.008	0.009	0.007
Dissolved Aluminum (mg/L)	<0.003	0.007	0.006	0.010
Pilot-scale				
Total Aluminum (mg/L)	<0.003	0.014	0.013	0.010
Dissolved Aluminum (mg/L)	<0.003	0.010	0.011	0.007

N/A = not tested

The results show there is little concern with regards to the presence of aluminum in the finished water when using either of the ferric coagulants as there is no MAC for aluminum in drinking water and the concentrations measured in the pilot-scale system during seasonal piloting are well below Heath Canada’s operation guidelines of <0.1 mg/L in finished water. Therefore, there is little concern with regards to elevated aluminum concentrations entering the distribution system following a transition to ferric sulphate.

The total and dissolved iron measured during seasonal piloting on optimal days is presented in Table 4-15. An increase in iron was observed in both the full-scale and pilot-scale system Post-DAF samples for all seasonal piloting sessions due to the addition of a ferric-based coagulant. There was a higher total iron concentration in the Post-DAF samples collected from the pilot-scale system, which is more evident in cool or cold-water conditions. The higher iron concentrations in the pilot-scale system are likely due to the additional iron added at the optimal ferric sulphate dose (seasonal average dose of approximately 40 mg/L) compared to the optimal dose of ferric chloride used in the full-scale system, which typically ranges from approximately 25-35 mg/L. For example, an optimal ferric chloride dose of 30 mg/L would equate to an equivalent ferric sulphate dose of 37 mg/L. However, the optimal ferric sulphate dose determined during seasonal piloting exceeded the equivalent ferric sulphate dose based on ferric chloride, which equates to unreacted iron remaining following coagulation (measured in Post-DAF). The major contributing factor to the elevated iron levels in the Post-DAF samples collected from the pilot-scale system would be the higher flow rates and lower residence time through the pilot-scale system DAF compared to the full-scale system. The lower residence time in the pilot-scale system would reduce the time for coagulation to occur, allowing some of the iron in ferric sulphate to go unreacted, and increasing the Post-DAF iron concentration. This may indicate that a lower optimal ferric sulphate dose may be used if transitioned to the full-scale system, where the DAF has a longer residence time. This, in turn, would also reduce the unreacted residual iron content following DAF treatment, lowering the iron content in the filter effluent.

Table 4-15: Average total and dissolved iron concentrations in the full-scale and pilot-scale systems during the seasonal piloting sessions at optimal conditions. The data originates from the Laboratory

PILOTING SESSION	RAW	POST-DAF	POST-OZONE	COMBINED FILTRATE
Winter #1				
Full-scale				
Total Iron (mg/L)	0.06	0.55	0.57	0.02
Dissolved Iron (mg/L)	N/A	N/A	N/A	N/A
Pilot-scale				
Total Iron (mg/L)	0.07	1.72	1.71	0.06
Dissolved Iron (mg/L)	N/A	N/A	N/A	N/A
Spring				
Full-scale				
Total Iron (mg/L)	0.05	0.39	0.40	0.03
Dissolved Iron (mg/L)	0.02	0.15	0.05	0.03
Pilot-scale				
Total Iron (mg/L)	0.05	1.46	1.07	0.08
Dissolved Iron (mg/L)	0.02	0.14	0.11	0.03
Summer				
Full-scale				
Total Iron (mg/L)	0.05	0.44	0.63	0.06
Dissolved Iron (mg/L)	0.03	0.24	0.35	0.05
Pilot-scale				
Total Iron (mg/L)	0.05	0.77	0.62	0.02
Dissolved Iron (mg/L)	0.03	0.23	0.10	0.01
Fall				
Full-scale				
Total Iron (mg/L)	0.03	0.52	0.59	0.06
Dissolved Iron (mg/L)	0.01	0.12	0.02	0.02
Pilot-scale				
Total Iron (mg/L)	0.03	1.83	1.89	0.18
Dissolved Iron (mg/L)	0.01	0.47	0.14	0.004
Winter #2				
Full-scale				
Total Iron (mg/L)	0.05	0.65	0.70	0.07
Dissolved Iron (mg/L)	0.02	0.22	0.22	0.01
Pilot-scale				
Total Iron (mg/L)	0.05	1.59	1.54	0.09
Dissolved Iron (mg/L)	0.02	0.22	0.20	0.01

The low alkalinity found in the raw water may act as the limiting reagent in the coagulation reaction (Reaction 1), which may allow a portion of the iron to go unreacted leading to increased iron in the Post-DAF effluent. Increasing the alkalinity in the raw water, prior to coagulation, may improve the formation of iron hydroxide and reduce the concentration of iron following coagulation.

There are no anticipated negative impacts with regards to iron concentrations in the finished water following a transition from ferric chloride to ferric sulphate, provided optimal conditions are maintained, as both total and dissolved iron concentrations during all the seasonal piloting sessions were well below the Health Canada aesthetic objective limits of ≤0.3 mg/L.

A major objective of the project aimed to establish the expected impact on manganese concentrations following a transition from ferric chloride to ferric sulphate. As expected, the lower residual manganese concentration in ferric sulphate (Manganese = 54.8±2.4 mg/kg) equates to a lower overall manganese concentration in the Post-DAF samples collected from the pilot-scale system during the seasonal piloting sessions, compared to the Post-DAF samples collected from the full-scale system operating with ferric chloride, which has a residual manganese concentration of 511±47 mg/kg (Table 4-16).

Table 4-16: Average total and dissolved manganese measured in the full-scale and pilot-scale systems during the seasonal piloting sessions at optimal conditions. The data originates from the Laboratory

PILOTING SESSION	RAW	POST-DAF	POST-OZONE	COMBINED FILTRATE
Winter #1				
Full-scale				
Total Manganese (mg/L)	0.006	0.049	0.047	0.033
Dissolved Manganese (mg/L)	N/A	N/A	N/A	N/A
Pilot-scale				
Total Manganese (mg/L)	0.004	0.009	0.009	0.008
Dissolved Manganese (mg/L)	N/A	N/A	N/A	N/A
Spring				
Full-scale				
Total Manganese (mg/L)	0.011	0.050	0.046	0.034
Dissolved Manganese (mg/L)	0.002	0.050	0.021	0.042
Pilot-scale				
Total Manganese (mg/L)	0.011	0.014	0.014	0.004
Dissolved Manganese (mg/L)	0.002	0.013	0.012	0.004
Summer				
Full-scale				
Total Manganese (mg/L)	0.033	0.065	0.059	0.047
Dissolved Manganese (mg/L)	0.012	0.062	0.038	0.042
Pilot-scale				
Total Manganese (mg/L)	0.031	0.026	0.026	0.017
Dissolved Manganese (mg/L)	0.012	0.020	0.026	0.017
Fall				
Full-scale				
Total Manganese (mg/L)	0.011	0.040	0.036	0.027
Dissolved Manganese (mg/L)	0.002	0.039	0.019	0.024
Pilot-scale				
Total Manganese (mg/L)	0.011	0.012	0.012	0.011
Dissolved Manganese (mg/L)	0.002	0.011	0.011	0.011
Winter #2				
Full-scale				
Total Manganese (mg/L)	0.009	0.044	0.043	0.031
Dissolved Manganese (mg/L)	0.003	0.045	0.024	0.027
Pilot-scale				
Total Manganese (mg/L)	0.009	0.013	0.012	0.008
Dissolved Manganese (mg/L)	0.003	0.012	0.007	0.008

The raw water total manganese increased by 3-times, from 0.011 mg/L to 0.033 mg/L, during the Summer piloting session, while the dissolved manganese increased by 6-times, from 0.002 mg/L to 0.012 mg/L. The increase in total and dissolved manganese during Summer (i.e., warm water conditions) is typical for the source water, according to historical data. This increase in manganese during the Summer months is related to the increased solubility for metals in warmer water. The elevated manganese in the raw water in the Summer caused higher Post-DAF manganese (total and dissolved) in both the full-scale and pilot-scale systems, in comparison to the manganese results obtained during the seasonal piloting sessions in cold and cool-water conditions. The concentration of manganese measured by the Lab exceeded the future target for manganese (0.015 mg/L) in the filter effluent from the pilot-scale system by 0.002 mg/L during the Summer piloting session, indicating that the full-scale system may not meet the future target for manganese in Summer. However, the manganese concentration in the filter effluent from the pilot-scale system during the Summer was still below the proposed AO for manganese of <0.020 mg/L. Ozonation did not alter the total manganese concentration; however, ozone treatment in the full-scale system did reduce the dissolved manganese measured in the Post-DAF by 39 – 58%. When comparing the total and dissolved manganese in the combined filter effluent from the full-scale and pilot-scale systems, there is approximately 52-81% less total manganese, and 54-89% less dissolved manganese, when ferric sulphate is used as the coagulant. The pilot-scale system results show that coagulation with ferric sulphate would reduce the total manganese concentration below the proposed AO for manganese of <0.02 mg/L, and will likely meet the City's internal target of <0.015 mg/L for manganese in the finished water most of the time. Exceedance of the <0.015 mg/L target would be minimal.

4.5.4 TRUE COLOUR

The comparative seasonal results for true colour are presented in Table 4-17. The results show a significant reduction in true colour following DAF treatment in both the full-scale and pilot-scale systems. Ozonation was found to further reduce colour; however, the reduction was minimal. The true colour measured in the combined filter effluent collected from the full-scale system ranged from 0.50 TCU to 2.13 TCU, while the pilot-scale system filters reduced the true colour to between 0.50 TCU to 2.00 TCU. Therefore, there is no anticipated concern with regards to colour removal following a transition to ferric sulphate in the full-scale system.

Table 4-17: Average true colour results for the full-scale and pilot-scale systems during the seasonal piloting sessions at optimal conditions.

PILOTING SESSION	WINTER #1		SPRING		SUMMER		FALL		WINTER #2	
TRUE COLOUR (TCU)	**FULL**	**PILOT**	**FULL**	**PILOT**	**FULL**	**PILOT**	**FULL**	**PILOT**	**FULL**	**PILOT**
Raw	13.00	13.50	12.00		11.25		13.00		12.00	
Post-DAF	1.25	1.75	1.25	2.00	4.25	3.50	2.00	2.00	2.00	2.83
Post-Ozone	1.00	1.00	0.50	1.25	2.25	2.50	2.00	2.00	1.17	1.50
Combined Filtrate	0.63	0.78	0.50	0.75	2.13	1.88	1.50	2.00	1.17	0.67

4.5.5 TOTAL SOLIDS AND TOTAL DISSOLVED SOLIDS

The seasonal piloting sessions results at optimal condition for TS and TDS for the full-scale system, operating with ferric chloride, and the pilot-scale system, operating with ferric sulphate, are presented in Table 4-18. The results show an increase in both TS and TDS following the addition of coagulant in both systems for all seasonal piloting sessions, which is expected when using inorganic coagulants. When comparing ferric chloride to ferric sulphate, the results show that generally the TS and TDS are the same as, or slightly lower, when ferric sulphate is used. Therefore, there is not anticipated concern with TS or TDS should the full-scale system be transitioned to ferric sulphate.

Table 4-18: Average TS and TDS results for the full-scale and pilot-scale systems during the seasonal piloting sessions at optimal conditions.

PILOTING SESSION	WINTER #1		SPRING		SUMMER		FALL		WINTER #2	
LOCATION	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT
Raw										
TS (mg/L)	133	126	105	105	135	135	110	110	107	107
TDS (mg/L)	116	110	81	81	104	104	98	98	98	98
Post-DAF										
TS (mg/L)	180	160	165	119	176	162	132	116	135	139
TDS (mg/L)	143	120	136	108	128	129	112	120	118	121
Post-Ozone										
TS (mg/L)	162	155	133	132	185	166	124	132	134	134
TDS (mg/L)	152	120	123	118	141	129	104	115	119	121
Combined Filtrate										
TS (mg/L)	173	157	158	140	197	176	120	130	133	127
TDS (mg/L)	149	135	109	117	132	129	117	117	123	120

4.5.6 ORGANIC CARBON REMOVAL

Table 4-19 compares the TOC removal by the full-scale system and pilot-scale system during the seasonal benchmarking periods with ferric chloride. The results show similar TOC removals by the full-scale and pilot-scale DAF systems, except during the Winter #1 benchmarking period where there was an approximately 12% difference in TOC removal between the full-scale and pilot-scale DAF systems. Ozone did not appear to significantly reduce TOC in either system. When comparing the combined filter effluent, the results show strong similarity with the difference between the two systems ranged from 0 – 12%. The results indicate that both systems show similar TOC removal using ferric chloride.

Table 4-19: TOC removal (average) by the full-scale and pilot-scale systems during the seasonal benchmarking periods.

BENCHMARKING PERIOD	WINTER #1		SPRING[1]		SUMMER		WINTER #2	
SAMPLE LOCATION	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT
Raw DOC (mg/L)	8.5	8.6	22.1		8.7		8.5	
Post-DAF DOC (mg/L)	3.5	4.0	5.6	5.6	3.4	3.3	3.8	4.1
Post-Ozone DOC (mg/L)	N/A	3.9	4.9	5.3	3.3	3.3	3.5	3.9
Combined Filtrate DOC (mg/L)	3.2	3.0	4.8	4.3	3.0	2.9	3.4	2.9

[1] Results are believed to artificially exceed the actual TOC concentration by 2-3 times.

Table 4-20 compares the removal of organic matter, typically measured as TOC or DOC, by the full-scale and pilot-scale systems during optimal conditions of the seasonal piloting sessions. The results show that the coagulation and DAF process, with either ferric chloride or ferric sulphate, significantly reduces organic matter. On the other hand, the ozonation and filtration processes are not effective at reducing DOC in either the full-scale or pilot-scale systems. There are similar concentrations of DOC in the combined filter effluent in both the full-scale and pilot-scale systems suggesting there would be little concern for controlling DOC if the full-scale system were transitioned to ferric sulphate.

Table 4-20: Average organic carbon results (reported as DOC) for the full-scale and pilot-scale systems during the seasonal piloting sessions at optimal conditions.

PILOTING SESSION	WINTER #1[1]		SPRING		SUMMER		FALL[1]		WINTER #2	
SAMPLE LOCATION	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT	FULL	PILOT
Raw DOC (mg/L)	28.00	26.30	7.40		11.90		26.60		8.37	
Post-DAF DOC (mg/L)	6.40	5.30	2.65	2.95	4.03	4.10	N/A	8.30	3.87	3.50
Post-Ozone DOC (mg/L)	6.20	5.30	2.65	3.05	3.95	3.95	N/A	8.30	3.93	3.30
Combined Filtrate DOC (mg/L)	6.95	5.53	2.65	2.80	3.15	4.43	N/A	11.00	3.43	3.20

[1] DOC results are assumed to be artificially elevated by 2-3 times the actual DOC value. Data is consistent for samples taken in both the pilot-scale and full-scale systems.

4.5.7 THRESHOLD ODOUR NUMBER AND ALGAL TOXINS

Table 4-21 provides the threshold odour number and algal toxins for the raw water, and full-scale and pilot-scale system combined filtrate collected during the Summer piloting session.

Table 4-21: Average threshold odour number and algal toxins results for the full-scale and pilot-scale systems during the Summer piloting session at optimal conditions. All empirical results are reported in ng/L.

SOURCE (reported as ng/L)	2-ISOPROPYL-3-METHOXYPYRAZINE	2-ISOBUTYL-3-METHOXYPYRAZINE	2-METHYL ISOBORNEOL	2,4,6-TRICHLOROANISOLE	2,3,6-TRICHLOROANISOLE	GEOSMIN	3,4,5-TRICHLOROVERATROLE	ODOUR (QUALITATIVE ANALYSIS)
Raw Water	<0.19	<0.19	<9.7	<0.49	<0.49	12.7	<0.19	Grassy
Combined Filter (Full-scale system)	<0.19	<0.19	<9.7	<0.49	<0.49	5.47	<0.19	Musty
Filter Effluent (Pilot-scale system)	<0.20	<0.20	<9.8	<0.49	<0.49	1.18	<0.20	No Odour

Taste and odour problems can stem from microbiological or chemical causes, and are prompted by conditions in the raw water source, as part of the treatment process, or in the distribution system. The primary sources of these taste and odour compounds are largely the result of algae and bacteria, which are more present during Summer months. The only compound of concern according to the results presented in Table 4-21 is geosmin, which is 4-5 times greater in the full-scale system combined filter effluent, compared to the pilot-scale system combined filtrate. The presence of geosmin in the combined filter effluent in the full-scale system causes a presence of a musty odour.

4.5.8 DISINFECTION AND DISINFECTION BY-PRODUCT FORMATION

From the seasonal piloting sessions, it was determined that the optimal operating pH for ferric chloride is slightly lower than for ferric sulphate, i.e. the optimal pH for ferric chloride is 5.6 and the optimal pH range for ferric sulphate is 5.7-6.0. Therefore, it is important to consider any potential impacts to disinfection as disinfecting with sodium hypochlorite is both temperature and pH dependant. As mentioned, HOCl is a better disinfectant than OCl^-, and the ratio between these two species in water is governed by the concentration of hydroxide ions and the acid ionization constant (K_a) (Equation 1), which is a function of temperature.

$$K_a = \frac{[H^+][OCl^-]}{[HOCl]} \qquad \text{(Equation 1)}$$

Table 4-22 provides the percentage of hypochlorous acid as a function of pH and temperature according to Equation 1. As seen in Table 4-22, there is only a minor reduction in the percent of hypochlorous acid present in water between the optimal pH for ferric chloride (pH = 5.6) and the upper limit of the optimal pH range for ferric sulphate (pH = 6.0) across the operating temperatures experienced by the City. Therefore, it is not anticipated that a transition to ferric sulphate would significantly impact the chlorine demand for disinfection, or the disinfection process.

Table 4-22: The percent of hypochlorous acid as a function of pH and temperature (White, 2010).

TEMPERATURE (°C)	% HOCl	
	pH = 5.5	pH = 6.0
0	99.53	98.53
10	99.45	98.27
20	99.18	97.45

The concentration of disinfection by-products, namely THMs and HAAs, formed following chlorine disinfection is strongly related to the concentration and composition of natural organic matter (measured as TOC or DOC). It is therefore important to consider the removal efficiency of THM and HAA precursors by ferric chloride and ferric sulphate, prior to the disinfection phase. Table 4-23 presents the concentration of organic matter, reported as either TOC or DOC, in the combined filter effluent for both ferric chloride (full-scale system) and ferric sulphate (pilot-scale system) during the seasonal piloting sessions.

Table 4-23: Organic matter (reported as either TOC or DOC) and THM and HAA formation potential results for the full-scale and pilot-scale systems during seasonal piloting at optimal conditions.

PILOTING PERIOD	TOC (or DOC) (mg/L)		TOTAL THMs (µg/L)		TOTAL HAAs (µg/L)	
	FULL	PILOT	FULL	PILOT	FULL	PILOT
Winter #1	7.95	5.53	N/A	N/A	N/A	N/A
Spring	2.65	2.80	13	21	33	44
Summer	3.10	3.70	80	64	54	46
Fall	6.20	6.10	19	28	11	14
Winter #2	3.60	3.20	19	20	18	22

The results show that in cold water conditions (Winter #1 and Winter #2 piloting sessions) ferric sulphate appears to be better at removing organic matter compared to ferric chloride. On the other hand, ferric chloride appears to outperform ferric sulphate, with regards to organic matter removal, in cool and warm water conditions. Although there appears to be some differences in the organic matter removal efficiency between ferric chloride and ferric sulphate, both coagulants appear to reduce the THMFP and HAAFP in the combined filter effluent in both the full-scale and pilot-scale systems below the provincial guidelines. Therefore, there would be little concern with regards to organic matter removal and disinfection by-product formation following a transition to ferric sulphate.

4.6 IMPACT ON COAGULATED WASTE RESIDUAL PRODUCTION AND MANAGEMENT

It is rather difficult to estimate DAF sludge production rates as there are no empirical methods for predicting turbidity spikes and the chemical dosages required to treat them. Furthermore, there is limited data available on the residual characteristics from the full-scale system, therefore determining a baseline to compare the pilot-scale results with full-scale system is not feasible. Although the potential impact of coagulant change over on solid characteristics is not evident, chemical sludge generation rate was considered for evaluation and comparison. Table 4-24 presents the expected DAF sludge production associated with ferric chloride and ferric sulphate for an historical average production of 210 MLD, based on stoichiometry of coagulation process.

Table 4-24: Expected DAF sludge production for ferric chloride and ferric sulphate.

SLUDGE PRODUCTION	FERRIC CHLORIDE	FERRIC SULPHATE (MINIMUM)	FERRIC SULPHATE (INTERMEDIATE)	FERRIC SULPHATE (MAXIMUM)
Sludge Production (ton/y)[1]	1,400,000	1,570,000	1,660,000	1,740,000

[1] Based on historical data average flow of 210 MLD.

Considering the current average dose applied in the full-scale system and the intermediate optimum dose for ferric sulphate, DAF sludge production rate is anticipated to increase by 18% with ferric sulphate as coagulant. It should be noted that these values do not consider the removal of other constituents in the raw water such as TSS, TOC, etc., which are common for both coagulants.

Since the sludge from the full-scale system is drained by gravity to the thickened sludge equalization tanks, the sludge composition (TSS concentration) is also important. The sludge formed by ferric sulphate is expected to be similar to the current sludge formed by ferric chloride, since both coagulants would form iron hydroxides. However, no data is available from the full-scale system or the pilot-scale system benchmarking with ferric chloride to be compared with the results from the seasonal piloting sessions with ferric sulphate to support this statement. On the other hand, the seasonal piloting session results have indicated the possibility that the addition of coagulant-aid increases the sludge TSS concentration.

4.7 IMPACT ON DISTRIBUTION SYSTEM

Due to the complexity of the distribution system, the potential impact of coagulant changeover on the distribution network may take years to be revealed. Potential concerns are mainly aesthetic which includes colour, odour and taste, impact on corrosion by-products levels and their formation, and hydraulic impacts due to possible corrosion and/or deposition inside the distribution network.

4.7.1 AESTHETIC CONCERNS (COLOUR, TASTE AND ODOUR)

The seasonal piloting sessions with ferric sulphate did not indicate concerns with colour, taste or odour in the combined filter effluent. Furthermore, there was a significant reduction in total manganese in the finished water when piloting with ferric sulphate. It is believed that a reduction in manganese in the treated effluent entering the distribution system could result in fewer occurrences of discoloured water at the tap. However, previous studies conducted at the full-scale system, i.e. AECOM (2011), C2HM Hill (2013) and Associated Engineering (2015), suggest aspects of the distribution system may be contributing to elevated levels of iron and manganese, thereby increasing the formation of discoloured water in the distribution system. Until there is a subsequent study that better identifies the impact of the distribution system on the formation of discoloured water, it is believed the distributions system may still contribute appreciable levels of iron and/or manganese to the water, increasing colour. The reduction in manganese entering the distribution system may reduce the frequency and duration of discoloured water events associated with the presence of elevated levels of manganese.

Taste and odour concerns largely result from microbiological or chemical sources. The seasonal piloting sessions with ferric sulphate indicated a reduction in threshold odour number and algal toxins, compared to ferric chloride. Previous studies by AECOM (2011) and C2HM Hill (2013) identified the presence of old diatoms in the distribution system that were found to slough off the interior of the distribution system piping, which can impact taste at the tap. However, it is believed that the reduction in nutrients to the distribution system following the inclusion of the WTP would limit the concerns with taste and/or odour from microbial communities forming in the distribution system. It is not expected that transitioning to ferric sulphate will cause increased taste and odour problems associated with microbes present in the distribution system.

4.7.2 CORROSION BY-PRODUCTS AND EXISTING CORROSION CONTROL MEASURES

Corrosion of metal pipe surfaces, pipe solder, plumbing fixtures, or dissolution of existing pipe scales can impact colour, taste and odour in the distribution system. The corrosion indices results from the seasonal piloting sessions show that there is a potential for the water treated with ferric sulphate to produce similar LaI, RSI and LSI results as water treated with ferric chloride. This assumes that a similar target pH, alkalinity and the addition of a corrosion inhibitor to the finished water is maintained following a transition to ferric sulphate. Alkalinity greatly impacts corrosion indices results and it is expected that low alkalinity will reduce the stability of the treated water leading to possible corrosion of the piping and dissolution of the scale, thereby, causing discoloured water at the tap. The CSMR, on the other hand, is lower when treating with ferric sulphate (season piloting session results observed a ratio between 0.028 to 0.032), when compared to ferric chloride (ranging from 0.360 to 0.489 on full-scale system sampling days during the season piloting sessions), suggesting the treated water entering the distribution system would be more stable. However, the CSMR does not consider alkalinity and therefore it is difficult to determine if the water treated with ferric sulphate will reduce the corrosiveness of the water and prevent the formation of discoloured water at the tap.

The sulphate levels are expected to increase in the treated water with the use of ferric sulphate (from 50 mg/L to up to 99 mg/L); however, the sulphate levels would still be below 150 mg/L as indicated in Table 3-21. The increase in sulphate levels concentrate is not significant to change the degree of exposure to sulphate attack to the concrete. Below a sulphate concentration of 150 mg/L, the degree of exposure to sulphate attack is considered low (CSA. A23.1-14/A23.2-14, 2015). However, it is recommended to verify the original concrete mixes of the distribution piping where available as a precaution and to identify their exposure class. Since very often older structures have used Type GU (General Use) or previously called Type I concrete, it may be prudent to protect the concrete to avoid premature deterioration with the use of a coating.

4.7.3 HYDRAULIC IMPACTS

There are several factors that can impact the hydraulic integrity of the distribution system including leaks and breaks in the pipes, rapid changes in flow and pressure, maintenance activities and emergencies, improper operations, and tuberculation or scale buildup within the pipes. Events such as breaks, maintenance, emergencies, changes in flow, and improper operations are unrelated to the coagulant used during treatment. Tuberculation and the buildup of scale can be related to the type of coagulant used; however, the finished water is expected to be moderately corrosive with the use of ferric sulphate. Therefore, changes to the degree of tuberculation and/or scaling are not expected to drastically change the pipe diameter in the short-term following a transition to ferric sulphate; therefore, there is no anticipated impacts to hydraulics in the distribution system.

4.8 SUMMARY OF REGULATORY OVERVIEW

Table 4-25 presents a comprehensive summary of the filter effluent water quality measured on optimal piloting days for each seasonal piloting session for both the full-scale system, operating with ferric chloride, and the pilot-scale system, operating with ferric sulphate. Table 4-25 also compares the filter effluent quality from each system with the water quality objectives set in the City's Operating Licence, the GCDWQ, or the City's operational guidelines.

When comparing the finished water quality from each system, it can be seen that both ferric chloride (full-scale system) and ferric sulphate (pilot-scale system) are able to meet all water quality objectives except manganese. With regards to filter effluent turbidity, both the full-scale and pilot-scale systems met the City's Operating Licence limit of <0.3 NTU during all seasons; however, both the full-scale and pilot-scale systems struggled to meet the City's operation guideline of <0.1 NTU in the filter effluent. The full-scale system only met the criteria during the Winter #1 piloting session (0.09 NTU), and the pilot-scale system only met the criteria during the Spring (0.08 NTU) and Winter #2 (0.07 NTU) piloting sessions. Overall, the results indicate similar effluent turbidity when using either ferric chloride or ferric sulphate, therefore there should be no concern with meeting the Operating Licence requirements for turbidity should the full-scale system be transition to ferric sulphate.

Regarding manganese in the filter effluent from each system, there is significantly higher manganese in the effluent from the full-scale system compared to the pilot-scale system. This is expected given the higher residual manganese concentration in ferric chloride. In all seasonal piloting sessions, the full-scale system failed to meet proposed future AO for manganese in treated water of 0.02 mg/L. On the other hand, the pilot-scale system, utilizing ferric sulphate, was able to meet the proposed aesthetic objective in all seasonal piloting sessions, as well as the City's operating guideline of <0.015 mg/L in all seasons, except during the Summer piloting session where manganese exceeded the City's operational guideline of <0.015 mg/L by 0.002 mg/L. It is important to note that the highest raw water manganese occurred during the Summer piloting session which would contribute to the elevated manganese concentration in the finished water during this period. It should also be noted that the manganese concentration in the pilot-scale system effluent during the Summer piloting session reported in Table 4-25 excludes August 14th data due to extremely elevated manganese concentrations measured in Bank A, which were 5-10 times the manganese measured from Bank B. Although the manganese in the final effluent from the pilot-scale system exceeded the 0.015 mg/L operation target, it was below the proposed AO from Health Canada of 0.02 mg/L.

Overall, the seasonal piloting session results indicate that ferric sulphate is good replacement for ferric chloride, producing similar water quality, as well as reducing manganese in the filter effluent.

Table 4-25: Summary of finished water quality from full-scale and pilot-scale systems at optimal conditions during seasonal piloting sessions.

COMBINED FILTER EFFLUENT	TEMPERATURE	ALKALINITY	HARDNESS	CHLORIDE	SULPHATE	pH	TRUE COLOUR	CONDUCTIVITY	TOC	DOC	TOTAL HAA	TOTAL THM	THRESHOLD ODOUR NUMBER	TSS	TDS	TS	TURBIDITY	UVT FILTERED	ALUMINIUM TOTAL	ANTIMONY TOTAL	ARSENIC TOTAL	CADMIUM TOTAL	CALCIUM TOTAL	CHROMIUM TOTAL	COPPER TOTAL	IRON TOTAL	POTASSIUM TOTAL	LEAD TOTAL	MAGNESIUM TOTAL	MANGANESE TOTAL[7]	NICKEL TOTAL	SODIUM TOTAL	URANIUM TOTAL	ZINC TOTAL
	°C	mg/L	mg/L	mg/L	mg/L	-	units	µS/cm	mg/L	mg/L	µg/L	µg/L	TON	mg/L	mg/L	mg/L	NTU	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Full-Scale Winter #1[2]	5.8	7				5.67	0.5	220		7.0	<3	<3	10	32	128	159	0.09	95.0	0.018	<0.0005	<0.0007	<0.0001	21.6	<0.001	<0.005	0.020	1.15	<0.0004	6.15	0.0375	0.003	2.93	<0.0004	<0.005
Pilot-Scale Winter #1[2]	7.0	7	80.2	2.2	80	5.84	0.8	212		5.5	<3	<3		21	136	157	0.22	95.0	0.040	<0.0005	<0.0008	<0.0001	21.9	<0.0010	<0.005	0.060	1.16	<0.0004	6.20	0.0083	0.008	2.80	<0.0004	<0.005
CDWQ Guideline	15[1]	-	-	250[1]	500[1]	7.0-10.5	15[1]	-	-	-	80	100	inoffensive[1]	-	500[1]	-	-	-	-	0.006	0.010	0.005	-	0.05	1.0[1]	0.3[1]	-	0.01	-	0.02[3]	-	200[1]	0.02	5.0[1]
Operating Licence	-	-	-	-	-	-	-	-	-	-	0.08	0.10	-	-	-	-	<0.3	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-
City Operating Guidelines	-	-	-	-	-	5.5-5.8[4]	-	-	-	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.015	-	-	-	-
Full-Scale Spring	14.6	7	77.0	21.0	46	5.50	0.5	205	2.55	2.8	30	19		38	119	157	0.11	94.6	<0.010	<0.0005	<0.0007	<0.0001	21.0	<0.0010	<0.005	0.036	1.17	<0.0004	5.97	0.0321	0.003	2.24	<0.0004	<0.005
Pilot-Scale Spring	14.4	15	79.7	2.1	74	6.06	0.8	201	2.85	2.8	35	19.5	5	28	130	157	0.08	93.2	<0.010	<0.0005	<0.0007	<0.0001	21.6	<0.0010	<0.005	0.080	1.18	<0.0004	6.25	0.0040	0.003	2.60	<0.0004	<0.005
CDWQ Guideline	15[1]	-	-	250[1]	500[1]	7.0-10.5	15[1]	-	-	-	80	100	inoffensive[1]	-	500[1]	-	-	-	-	0.006	0.010	0.005	-	0.05	1.0[1]	0.3[1]	-	0.01	-	0.02[3]	-	200[1]	0.02	5.0[1]
Operating Licence	-	-	-	-	-	-	-	-	-	-	0.08	0.10	-	-	-	-	<0.3	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-
City Operating Guidelines	-	-	-	-	-	5.5-5.8[4]	-	-	-	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.015	-	-	-	-
Full-Scale Summer	22.6	6	72.5	21.0	43	5.51	2.5	196	21.5[6]	2.4	45	64.5	6	44	136	179	0.17	94.5	<0.010	<0.0005	<0.0007	<0.0001	19.7	<0.0010	<0.005	0.042	1.12	<0.0004	5.37	0.0449	0.003	2.35	<0.0004	<0.005
Pilot-Scale Summer	23.1	11	73.2	3.4	86	6.24	2.5	220	3.4	3.6	42	54	6	21	156	177	0.12	92.8	<0.010	<0.0005	<0.0007	<0.0001	20.6	<0.0010	<0.005	0.020	1.12	<0.0004	5.45	0.017	0.003	5.33	<0.0004	<0.005
CDWQ Guideline	15[1]	-	-	250[1]	500[1]	7.0-10.5	15[1]	-	-	-	80	100	inoffensive[1]	-	500[1]	-	-	-	-	0.006	0.010	0.005	-	0.05	1.0[1]	0.3[1]	-	0.01	-	0.02[3]	-	200[1]	0.02	5.0[1]
Operating Licence	-	-	-	-	-	-	-	-	-	-	0.08	0.10	-	-	-	-	<0.3	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-
City Operating Guidelines	-	-	-	-	-	5.5-5.8[4]	-	-	-	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.015	-	-	-	-
Full-Scale Fall	7.3	9	74.1	17.5	49	5.66	1.8	196		5.0	14	23		19	119	138	0.15	95.3	0.009	<0.0005	<0.0010	<0.0006	19.6	<0.0006	0.002	0.060	1.14	<0.0006	6.15	0.0263	0.002	2.57	<0.0006	0.0011
Pilot-Scale Fall	7.7	10	73.6	2.4	75	5.90	2.3	189		7.8	22	34.5		18	121	139	0.12	94.0	0.004	<0.0005	<0.0010	<0.0006	19.5	<0.0006	<0.001	0.180	1.13	<0.0006	6.07	0.0118	0.003	2.28	<0.0006	<0.0009
CDWQ Guideline	15[1]	-	-	250[1]	500[1]	7.0-10.5	15[1]	-	-	-	80	100	inoffensive[1]	-	500[1]	-	-	-	-	0.006	0.010	0.005	-	0.05	1.0[1]	0.3[1]	-	0.01	-	0.02[3]	-	200[1]	0.02	5.0[1]
Operating Licence	-	-	-	-	-	-	-	-	-	-	0.08	0.10	-	-	-	-	<0.3	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-
City Operating Guidelines	-	-	-	-	-	5.5-5.8[4]	-	-	-	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.015	-	-	-	-
Full-Scale Winter #2	2.6	11	77.2	22.0	45	5.84	2.0	201		3.6	18	19		6	126	132	0.12	94.8	0.006	<0.0005	<0.0010	<0.0006	21.0	<0.0006	0.002	0.050	1.22	<0.0006	5.98	0.0301	0.002	2.61	<0.0006	0.0018
Pilot-Scale Winter #2	3.7	10	82.0	2.5	78	5.95	0.5	195		3.2	22	20		<3	124	126	0.07	94.7	0.010	<0.0005	<0.0010	<0.0006	22.1	<0.0006	<0.001	0.090	1.25	<0.0006	6.49	0.0082	0.002	2.51	<0.0006	<0.0009
CDWQ Guideline	15[1]	-	-	250[1]	500[1]	7.0-10.5	15*	-	-	-	80	100	inoffensive[1]	-	500[1]	-	-	-	-	0.006	0.010	0.005	-	0.05	1.0[1]	0.3[1]	-	0.01	-	0.02[3]	-	200[1]	0.02	5.0[1]
Operating Licence	-	-	-	-	-	-	-	-	-	-	0.08	0.10	-	-	-	-	<0.3	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-
City Operating Guidelines	-	-	-	-	-	5.5-5.8*[4]	-	-	-	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.015	-	-	-	-

[1] Aesthetic Objective
[2] Average of Individual Filters
[3] Pending Aesthetic Objective
[4] Post-DAF
[5] Excludes August 14th, 2017 due to elevated concentrations in Bank A only
[6] TOC concentration is believed to be elevated by 2-3 times above the actual concentration
[7] Total manganese concentration was measured by the Lab using ICP-MS

5 FINANCIAL IMPACTS FROM SWITCHING TO FERRIC SULPHATE

5.1 OVERVIEW

This section summarizes the methodology, resources, and assumptions used to develop the life cycle cost estimates and the financial impact from switching to ferric sulphate. It should be noted all costs are based on 2018 prices.

5.2 CAPITAL COSTS ESTIMATE

Based on the findings regarding the potential for operational impacts evaluated in Section 4, capital cost considerations have been estimated. As such, capital construction cost estimates encompass anticipated and expected works associated with the required changes to the full-scale system, specifically accommodating a rated production capacity of 400 MLD. The following systems and components have been identified:

1 Coagulant Storage and Feed System

   i. Cleaning of the system and disposal of remaining ferric chloride.

   ii. Upgrade of metering system (set-points adjustment and labelling).

2 Coagulant-Aid System

   i. New coagulant-aid preparation system, including 2 automatic polymer make-up system of 2 kg/h at 0.5% stock solution, each of them consisting of powder hopper, wetting cone and mixing, 500 L mixing tank, 500 L dosing tank and control panel.

   ii. New dosing system, including 16 progressive cavity dosing pumps (8 in operation and 8 in stand-by), valves and accessories.

   iii. New feeding piping from the existing polymer room to the DAF and injection system to the 16 dosing points, including valves and accessories.

   iv. Minor building mechanical, structural, architectural and electrical works.

   v. Instrumentation and control.

   vi. Upgrade of existing SCADA system.

3 Start-up, commissioning, training, operating and maintenance (O&M) manual and SOP updates.

In addition, the capital construction costs also include the following allowance components:

   i. Provisional and cash allowances (10%) for additional minor works that cannot be developed at this phase;

   ii. General requirements (10%) and contractor profit (10%);

   iii. Manitoba retail sales tax (MRST) (8%);

iv. Engineering and design (15%);

v. City's overhead (3.25% of total project construction cost without engineering and design);

vi. Construction and design contingencies to account for unknowns (30%).

The construction cost estimates were completed based on WSP's financial database consisting of previous projects. All cost estimates presented within this conceptual design are calculated in 2018 Canadian dollars. Capital costs with and without coagulant-aid have been provided to evaluate the cost-benefit of potentially utilizing a coagulant-aid system.

Table 5-1 presents an estimation of the capital costs associated with replacing the full-scale system's coagulant with ferric sulphate with the addition of coagulant-aid.

Table 5-1: Estimated capital costs for switching to ferric sulphate, including addition of a coagulant-aid system.

WORKS TO BE PERFORMED	ADDITIONAL DETAILS	QUANTITY	UNIT COST (CAD)	ESTIMATED COSTS (CAD)
General Requirements and Profit	20% of capital construction costs	1	$ 360,000	$ 360,000
Coagulant Storage and Feed System				
Cleaning of the system and disposal of remaining ferric chloride		1	$ 50,000	$ 50,000
Upgrade of metering system	Set-points adjustments and labelling	3	$ 5,000	$ 15,000
Coagulant-Aid System				
New coagulant-aid preparation	2 systems of 2 kg/h at 0.5% stock solution	2	$ 300,000	$ 600,000
New dosing system	16 pumping systems of 100 L/h	16	$ 40,000	$ 640,000
New feeding piping and injection system	800 m of piping, up to DAF units and 16 injection systems	1	$ 80,000	$ 80,000
Minor building mechanical, structural, architectural and electrical works		1	$ 70,000	$ 70,000
Instrumentation and Control		1	$ 100,000	$ 100,000
Upgrade of existing SCADA system		1	$ 30,000	$ 30,000
Start-up, Commissioning, Training, O&M Manual and SOP updates		1	$ 50,000	$ 50,000
Provisional and Cash Allowances 10%	10% of capital construction costs	1	$ 164,000	$ 164,000
Total Construction Cost				**$ 2,159,000**
MRST	8%	1	$173,000	$173,000
Engineering and design	15% of total construction costs	1	$324,000	$324,000
City's overhead	3.25% of total construction costs	1	$70,000	$70,000
Contingency	30% of total cost	1	$ 818,000	$ 818,000
TOTAL ESTIMATED CAPITAL COSTS				**$ 3,544,000**

Table 5-2 presents the capital costs estimated to switch to ferric sulphate as coagulant, without the addition of a coagulant-aid system, but with the same assumptions presented above.

Table 5-2: Estimated capital costs for switching to ferric sulphate, without the addition of a coagulant-aid system.

WORKS TO BE PERFORMED	ADDITIONAL DETAILS	QUANTITY	UNIT COST (CAD)	ESTIMATED COSTS (CAD)
General Requirements and Profit	20% of capital construction costs	1	$ 21,000	$ 21,000
Coagulant Storage and Feed System				
Cleaning of the system and disposal of remaining ferric chloride		1	$ 50,000	$ 50,000
Upgrade of metering system	Set-points adjustment and labelling	3	$ 5,000	$ 15,000
Start-up, Commissioning, Training, O&M Manual and SOP updates		1	$ 30,000	$ 30,000
Provisional and Cash Allowances 10%	10% of capital construction costs	1	$ 10,000	$ 10,000
Total Construction Cost				**$ 126,000**
MRST	8%	1	$ 10,000	$ 10,000
Engineering and design	15% of total construction costs	1	$ 19,000	$ 19,000
City's overhead	3.25% of total construction costs	1	$ 4,000	$ 4,000
Contingency	30% of total costs	1	$ 47,000	$ 47,000
TOTAL ESTIMATED CAPITAL COSTS				**$ 206,000**

In consideration of the above estimates, the following costs are excluded:

- Additional bulk storage tank required for adoption of ferric sulphate, inclusive of sulphuric acid and caustic soda addition, since it is considered not required at this time.
- Re-lining of existing coagulant storage tanks and replacement of coagulant metering systems as part of the changeover, since it is considered not required at this time.
- Building extension, major electrical upgrades or site works, since it is considered not required at this time.
- Any land, legal, and other owner administrative expenses.
- Regulatory and permit processing fees.

As the above has been prepared using very limited information, with no engineering work completed, this is considered a Class 5 – Concept Screening cost estimate as defined by the American Association of Cost Engineers International (AACEI). This AACEI Class 5 estimate has an expected accuracy range of -30% to +50%. This estimate serves to establish an order of magnitude to assess the initial viability of switching to ferric sulphate.

5.3 OPERATION AND MAINTENANCE COSTS ESTIMATE

Table 5-3 presents the comparative O&M expenses associated with ferric chloride and ferric sulphate as a coagulant, which includes recurring costs for chemicals and maintenance based upon a historical average production of 210 MLD.

Chemical consumption valuations were based upon the historical averages between 2010 and the beginning of 2018 for ferric chloride, sulphuric acid, and sodium hydroxide, when the full-scale system benchmarking was developed. In contrast, chemical consumption valuations utilizing ferric sulphate, the coagulant of choice, are based upon theoretical consumptions rates inferred from the results of the seasonal piloting sessions, as indicated in Table 4-1.

Chemical unit costs are based on 2016 prices provided by the City and Kemira, which were corrected to 2018 value using 2% as an inflation rate. For each coagulant, unit prices used are based on the iron content of the coagulant. Maintenance costs for the new coagulant-aid feed system were estimated at 1% percent of capital costs for the system described in Table 5-1 which includes a coagulant-aid system. Additional power required for the potential use of a coagulant-aid feed system is considered relatively insignificant; however, it is suspected that labour costs would increase with its use (as observed from the pilot-scale system). Lastly, it should be noted that the common O&M costs between the two coagulants are not included in this analysis.

Table 5-3: Estimated annual operational costs for ferric chloride and ferric sulphate as coagulant.

COAGULANT	FERRIC CHLORIDE[1]	FERRIC SULPHATE (MINIMUM)[2]	FERRIC SULPHATE (INTERMEDIATE)[2]		FERRIC SULPHATE (MAXIMUM)[2]
		NO COAGULANT-AID	NO COAGULANT-AID	WITH COAGULANT-AID	WITH COAGULANT-AID
Coagulant					
Coagulant Price ($/kg of iron)[3]	$ 1.82	$ 1.73			
Coagulant Annual Consumption (kg iron per year)[4]	749,000	813,000	856,000		899,000
Coagulant Annual Cost[5]	$ 1,364,000	$1,406,000	$1,480,000		$1,554,000
Sulphuric Acid					
Acid Annual Consumption (ton/year)[4]	3,400	2,470	3,190		3,300
Acid Total Annual Costs[5]	$ 495,600	$356,600	$461,000		$478,000
Coagulant-Aid (Magnafloc LT-22S)					
Coagulant-Aid Annual Consumption (kg/y)[4]	N/A	0	N/A	5,370	7,670
Coagulant-Aid Annual Costs[5]	N/A	$ 0	N/A	$30,000	$42,700
Coagulant-Aid System Annual Maintenance	N/A	$ 15,200	N/A	$ 15,200	$ 15,200
Coagulant-Aid Annual Costs (Chemical and Maintenance)	N/A	$ 15,200	N/A	$ 45,200	$ 57,900
Sodium Hydroxide					
Base Annual Consumption (ton/y)[4]	7,600	6,120	7,340		7,650
Base Total Annual Costs[5]	$ 3,806,000	$3,065,000	$3,679,300		$3,833,000
TOTAL ANNUAL COSTS	**$ 5,665,600**	**$4,842,800**	**$ 5,620,300**	**$ 5,665,500**	**$5,922,900**
COST DIFFERENCE		- 14.5%	- 0.8%	+ 0.0%	+ 4.5%

[1] As per full-scale system historical average between 2010 and beginning of 2016.

[2] Minimum, intermediate and maximum coagulant, acid, and base consumption identified from optimal conditions determined during seasonal piloting sessions with ferric sulphate as coagulant.

[3] Based on the 2018 price of ferric chloride and cost relation between coagulants provided by Kemira. Note: Costs of ferric chloride were provided by the City. Costs of ferric sulphate were provided by Kemira (proportional to the % of iron of each chemical).

[4] Based on historical data average flow of 210 MLD.

[5] Based on 2018 prices of sulphuric acid ($144.7/ton), sodium hydroxide ($501.1/ton) and Magnafloc LT-22S ($5.58/kg).

Based on the above estimated O&M costs for both coagulants, a reduction of 14.5% up to an increase of 4.5% in chemical costs can be expected in changing the existing coagulant (ferric chloride) to the alternative coagulant (ferric sulphate).

5.4 LIFE-CYCLE COST ESTIMATE

Table 5-4 provides for a life cycle cost estimate, including capital cost and O&M costs for both ferric chloride and ferric sulphate as coagulants. This analysis was estimated based upon the net present value (NPV) methodology. The NPV utilized a 20-year operating period, an interest rate of 5% and an inflation rate of 2%. The ferric chloride and ferric sulphate (intermediate) O&M costs tabulated in Table 5-3 were used as the basis of the NPV calculation.

Table 5-3: Estimated life-cycle cost estimate for ferric chloride and ferric sulphate as coagulant.

COSTS[1]	FERRIC CHLORIDE	FERRIC SULPHATE (INTERMEDIATE)	
		WITH COAGULANT-AID	NO COAGULANT-AID
Total Annual Operational Costs	$ 5,665,600	$ 5,665,500	$ 5,620,300
Present Value of Total Annual Operational Costs (20 years)	$ 84,300,000	$ 84,300,000	$ 83,616,000
Capital Costs	$ 0	$ 3,544,000	$ 206,000
NET PRESENT VALUE (20 YEARS)	**$ 84,300,000**	**$ 87,844,000**	**$ 83,822,000**

[1] Prices are 2018 based.

Based on the life-cycle cost estimate for both coagulants, an increase of 4.2% in costs can be expected for replacing the existing coagulant of ferric chloride, to the alternative, ferric sulphate in the case where a coagulant-aid system is implemented. Marginal costs savings of 0.6% are expected for changing the coagulant over from ferric chloride to ferric sulphate, in the case where no coagulant-aid system is implemented.

6 CONCLUSION AND RECOMMENDATIONS

The following section highlights the conclusions for the major project objectives for Phases 1-4 of the project. The conclusions and recommendations made regarding specific piloting sessions can be found in the Conclusions and Recommendations sections of the individual seasonal piloting sessions reported in TM No. 3-7 (Appendix C-G).

➔ A review of historical documentation and previous studies conducted on the Winnipeg full-scale system and distribution system indicated that elevated levels of manganese entering the distribution system was likely contributing to the occurrence and frequency of discoloured water reported by customers.

➔ A review of the full-scale system processes and chemicals identified the main cause of elevated levels of manganese was due to the high manganese contamination in the coagulant, ferric chloride.

➔ A review of alternative coagulants identified five possible candidates to replace ferric chloride that could meet the objective of lowering the residual manganese entering the distribution system while still meeting target treatment objectives. The five-alternative coagulants were: 50/50 blend ferric chloride/ferric sulphate blend, ferric sulphate, 50/50 aluminum/ferric sulphate blend, 70/30 aluminum/ferric sulphate blend, and alum. It should be noted that alum was not carried forward for jar-testing.

➔ Three coagulant-aids (Magnafloc LT-22S, Prosedim ASP-20, and Prosedim CSP-640) were selected for testing because of their potential to complement the alternative coagulants selects.

➔ Jar-testing was conducted to compare the selected alternative coagulants, and the proposed coagulant-aids, to ferric chloride, at optimal conditions, i.e. chemical dose and pH. Results from the jar-tests identified ferric sulphate as the lead candidate to undergo seasonal piloting. The coagulant-aid, LT-22S, was identified as the most effective polymer to complement seasonal piloting with ferric sulphate.

➔ The seasonal piloting sessions with the alternative coagulant, ferric sulphate, and coagulant-aid, LT-22S, identified the following optimal doses and operating pH:

- Winter #1 piloting session: Coagulant = 46 mg/L; Coagulant-aid = 0.02 mg/L; pH = not controlled
- Spring piloting session: Coagulant = 42 mg/L; Coagulant-aid = 0.20 mg/L; pH = 6.1
- Summer piloting session: Coagulant = 38 mg/L; Coagulant-aid = 0.10 mg/L; pH = 5.8
- Fall piloting session: Coagulant = 42 mg/L; Coagulant-aid = 0.07 mg/L; pH = 5.7
- Winter #2 piloting session: Coagulant = 41 mg/L; Coagulant-aid = not tested; pH = 5.8

➔ Seasonal piloting sessions with ferric sulphate consistently produced lower manganese concentrations in all processes with the final effluent concentrations in all seasonal piloting sessions being below the proposed AO from Health Canada of 0.02 mg/L. The City's operating guideline of <0.015 mg/L for total manganese was met in all of the seasonal piloting sessions with the exception of the Summer piloting session. The Summer piloting session final effluent manganese exceeded the City's operational guideline of <0.015 mg/L by 0.002 mg/L. It should be noted, however, that for 3 out of the 4 seasonal benchmarking periods, the pilot-scale system filters outperformed the full-scale system filters for manganese removal. This indicates that the full-scale results for filter effluent manganese for ferric sulphate may be slightly higher than what was predicted in the pilot-scale system.

➔ The seasonal piloting turbidity results found that ferric sulphate would meet the Operational Licence requirement of <0.3 NTU for all seasons. The City's internal operating limit of <0.1 NTU was met only during the Spring and Winter #2 piloting sessions.

➔ Seasonal piloting UVT and absorbance results found that the pilot plant operating with ferric sulphate, at optimal operating conditions, produced final filter effluent water with UVT ranging from 92.3-95.2%, and absorbance ranging from 0.035-0.021 cm^{-1}, respectively. UVT and absorbance values in this range are considered acceptable with regards to finished water quality.

➔ Seasonal piloting sessions of ferric sulphate with the addition of the coagulant-aid, LT-22S, produced finished water quality that was only marginally better than treating without coagulant-aid under the same conditions. When coagulant-aid was applied there was a rapid build-up of residual coagulant/coagulant-aid within the pilot-scale system which increased the frequency and extent of cleaning and maintenance, particularly to the DAF system. Additionally, the estimated capital costs associated with adding coagulant-aid to the full-scale system operations is approximately $3.3M. Given the increased cleaning and maintenance requirements, decreased filter run times, and estimated capital costs required, adding coagulant-aid is not recommended.

➔ UFRVs could not be calculated from all the seasonal piloting sessions with ferric chloride as most filters did not meet the City's internal operational limit of 0.1 NTU. The UFRV achieved in the Fall (without coagulant aid) and Winter #2 piloting sessions with ferric sulphate were comparable to the UFRV values measured during the seasonal benchmarking periods and the historical full-scale system operating with ferric chloride. It is believed that the primary loss of performance was attributed to the use of coagulant-aid, specifically for the Summer and Fall sessions. This infers that the use of coagulant-aid had a greater impact on the filter operation than coagulant type. In light of this, it is recommended that a future study be undertaken to validate the impacts to the UFRVs with ferric sulphate, and no coagulant-aid, under an extended period of operation to confirm that the filter performance is not impacted by the ferric sulphate.

Post Study Note: After the competition of the Winter #2 benchmarking period, the City of Winnipeg continued to operate the pilot-scale system to confirm and optimize filter performance with the alternative coagulant, ferric sulphate, refer to Appendix K for detailed findings of this trial. Based on the UFRV and filter pressure data collected in the pilot-scale system from May 10 to June 26, 2018, it has been confirmed that the pilot-scale system while dosing ferric sulphate is capable of achieving UFRVs averaging 436-452 m^3/m^2 during spring temperature conditions which is in line with what has historically been seen from the full-scale system (495 m^3/m^2). The rise of filter pressure in the pilot-scale system over this period was consistently lower than seen in the full-scale system historically. This indicates that the pilot-scale system filters are capable of building up pressure slower with ferric sulphate then the full-scale system filters when dosing ferric chloride. It is anticipated, based on this data, that the full-scale system should be able to achieve comparable, filter performance after the transition to coagulation with ferric sulphate.

➔ UFRVs were not considered in the determination of optimal chemical conditions. For future piloting activities, UFRVs should be given more consideration when determining the optimal chemical conditions.

➔ For this study the filter-aid system was set to match the dosing rate used in the full-scale system. No further changes or optimization was made to this chemical system during the seasonal piloting sessions for ferric sulphate. It is recommended that further investigation into the optimization of the filter-aid dose utilizing ferric sulphate as a coagulant be completed to determine if filter performance can be further improved.

Post Study Note: After the competition of the Winter #2 benchmarking period, the City of Winnipeg continued to operate the pilot-scale system to further test the operation of the filter-aid dosing system. Through several tests, it was confirmed that the filter-aid pump dosing Bank A was not capable of dosing a comparable chemical volume as the filter-aid pump dosing Bank B, either due to difference in piping or due to the pumps operating at the very bottom of their pump curve. The pump on Bank A was required to be set to a rate two times greater than the rate of pump B in order to achieve the same volume of filter-aid.

➔ It is not anticipated that significant alterations to the existing chemical storage and dosing systems of the full-scale system would be required to facilitate a transition to ferric sulphate. Furthermore, capital costs for the transition are estimated to be approximately $200,000, which is largely due to requirements for cleaning and flushing of the chemical delivery systems, and changes in chemical storage for ferric sulphate.

➔ Throughout the seasonal piloting sessions, differences were observed with respect to filter operation and performance between Banks A (Filters 1-4) and Bank B (Filters 5-8). Although the current project attempted to identify the cause for deviations between the two banks, no discernible cause could be determined. It is recommended that a future study be undertaken to evaluate pilot-scale system filter bank operations to identify the cause for the variance observed between Banks A and B.

➔ It is recommended that a study be conducted to better identify the cause for variances in Post-DAF turbidity between the full-scale and pilot-scale systems. Differences identified in the pilot-scale DAF system causing unexpected increases in Post-DAF turbidity, for example tank size and orientation, should be mitigated to allow for better comparisons between the two systems, improving the predictability of the full-scale system following changes based on pilot-scale system operations.

➔ When calculating the corrosivity results from the seasonal piloting sessions, comparison between the seasonal benchmarking periods could not be performed as the appropriate data was not collected during the seasonal benchmarking periods. This info should be collected during future benchmarking periods to allow for a proper comparison to be completed

➔ The treated water entering the distribution system should be evaluated for corrosion indicators, and factors affecting corrosiveness, i.e. alkalinity, pH, chloride and sulphate, to better understand the impact of corrosive water on the occurrence of discoloured water. It is recommended that the study be conducted using a pipe-loop system, where a section of the pipe-loop system includes a portion of a water main that was extracted from a location in the City where there is a high occurrence of discoloured water. Factors affecting water stability could be manipulated to establish what factors could be causing rapid dissolution of manganese from the scale into the distribution system, thereby controlling, or reducing the occurrence of discoloured water at the tap.

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APPENDIX

A

TM NO. 1

BACKGROUND REVIEW, BENCHMARKING AND SELECTION OF APPROPRIATE COAGULANT TO PILOT

TECHNICAL MEMORANDUM NO.1

Project: Pilot Testing an Alternative Coagulant for the Winnipeg Water Treatment
Date: May 29th, 2018
To: Heather Buhler, City of Winnipeg
From: Maika Pellegrino (WSP), Justin Rak-Banville (WSP), Robert Andrews (AHA), Ron Hofmann (AHA)
Project No.: 161-06111-00
Location: Winnipeg Water Treatment Plant
Subject: Background Review, Benchmarking and Selection of Appropriate Coagulant to Pilot - Identification of Candidate Coagulants – FINAL (Rev.04)

1. Introduction

The Winnipeg Water Treatment Plant (WTP) was commissioned in 2009. Figure 1-1 illustrates the process flow diagram of the WTP including all chemicals used throughout the treatment train and their injection points (the plant also has infrastructure in place to dose hydrogen peroxide, but it has never been utilized).

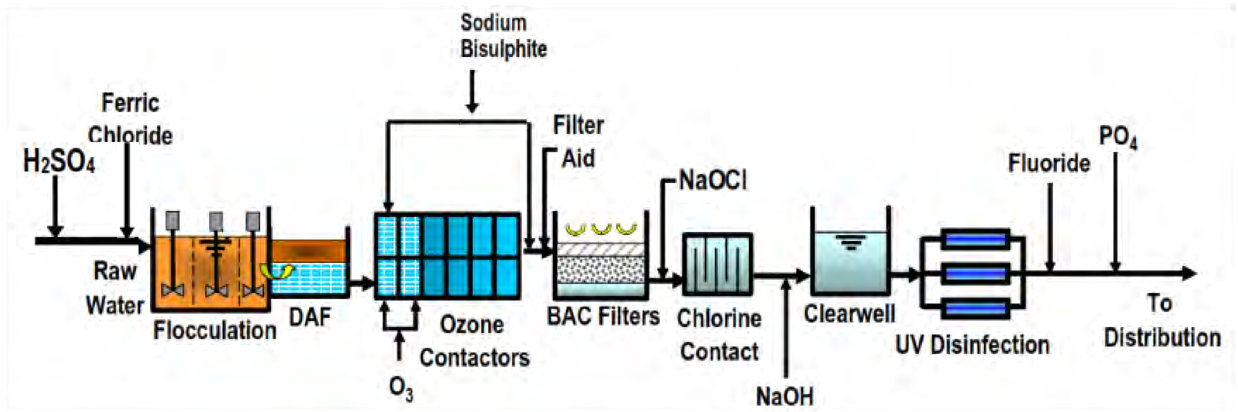


Figure 1-1 Winnipeg WTP - Process Flow Diagram (CH2M Hill, June 2013)

Since 2010, the City of Winnipeg (the City) has received customer complaints regarding discoloured water. In order to regain customer confidence, considerable efforts have been made by the City to alleviate this aesthetic concern. Previous studies at the WTP concluded that the main reason for the discoloured water has been the manganese (Mn) concentration of the treated water. The identified Mn sources are the raw water and the current coagulant chemical used (ferric chloride). Recently, several full-scale operational improvements were tested and some were implemented by the City to increase the efficiency of Mn removal at the WTP. Some of these improvements include:

- Optimization of ozone dosage,
- Changing the specification of ferric chloride, and
- Stabilization of the treated water.

In 2016, WSP was retained by the City to select, test and implement an alternative coagulant and/or coagulant aid with less or preferably no Mn content to resolve the discoloured water complaints issue in the treated water. The approach would be to select an alternative coagulant by performing a series of bench-scale tests, followed by pilot-scale tests and analyses to obtain reliable results.

Guidelines for Canadian Drinking Water Quality (GCDWQ) suggest an Aesthetic Objective (AO) of 0.05 mg/L for Mn (Mn) in drinking water with the possible occurrence of coating formation within distribution piping at concentrations below 0.05 mg/L (Health Canada, 2014). It is established that this coating can slough off as black precipitates. However, recently Health Canada (and the Federal-Provincial-Territorial Committee on Drinking Water, referred to as CDW) established a public consultation on lowering the AO of total Mn from 0.05 mg/L to 0.02 mg/L and adding a maximum acceptable concentration (MAC) of 0.1 mg/L of Mn to the existing drinking water guidelines (Health Canada, 2016). The proposed new lower AO for Mn will be implemented to address the recent trends towards using higher chlorine residuals in the distribution system. In the past, maintaining residuals was not a concern, so chlorine levels were lower. However, higher residuals lead to more Mn oxidation, hence colour problems even at lower Mn concentrations. Moreover, in 2006 the Environmental Protection Agency (EPA) suggested a target level of 0.02 mg/L for Mn and since then based on their survey, the current standard of 0.05 mg/L Mn was not sufficiently low to ensure minimal customer complaints. Some utilities are now targeting 0.015 mg/L Mn as the concentration at which minimal customer complaints will develop and are maintaining distribution Mn concentrations below that level.

Due to the continuous water discolouration concerns in the City and to regain customer confidence, in 2013 the City decided to set a future objective level of 0.015 mg/L for total Mn content in the treated water (CH2M Hill, 2013).

The objective of this Technical Memorandum (TM) is to present the findings of Phase 1 of this project as outlined below:

- Background review and benchmarking of full-scale plant
- Selection of candidate coagulant
    - Identification of candidate coagulants for bench testing
    - Identification of candidate coagulant-aids for bench testing
    - Development of bench testing standard operation procedures
    - Presentation of bench tests results
- Evaluation of the impacts of selected coagulants on full-scale plant
- Recommendation of selected coagulant for pilot testing

2. Background Review and Benchmarking Full-scale Performance of Current Coagulant

A complete review of the background information provided by the City was conducted. From the evaluation of previous study data, the concentrations of Mn in treated water leaving the WTP and water throughout the distribution system were consistently higher than the raw water influent to the plant suggesting that the WTP treatment train itself was increasing the Mn content of water through an external source. Some Mn reduction was observed within the WTP filtration process but the treatment train was not designed to achieve reduction of Mn to below the new treatment objective of 0.015 mg/L. From 2010 to 2013, the Mn content has not been increasing in Shoal Lake, ranging on average from 0.008 – 0.018 mg/L, and the raw water (Deacon Reservoir), ranging from 0.009 – 0.017 mg/L, respectively. Since previous studies lacked evidence indicating a source of Mn in the distribution system and Mn concentrations in treated water leaving the WTP were higher than raw water concentrations, the increase in Mn concentration is attributed to chemical addition at the WTP.

After studying the effectiveness of each treatment process, it was concluded that the main source of Mn is the coagulant (ferric chloride, $FeCl_3$). Ferric chloride was selected based on extensive pilot studies at the WTP pilot system which concluded in September 1997 (please refer to Sections 3 and 4 for more details).

In 2013, the City changed its ferric chloride supplier and this resulted in even higher concentrations of Mn in the coagulant (CH2M Hill, December 2013). The studies made two recommendations to deal with the high Mn concentrations. The first recommendation was to change the ferric chloride specifications to get a ferric chloride product with less Mn. In 2014, the City changed its coagulant specification to limit the Mn content to < 600 mg/kg, which resulted in lower Mn concentration entering the distribution system (Associated Engineering, 2015). The second recommendation was to ultimately consider changing coagulant type. It was suggested that the ferric chloride coagulant be replaced with an alternative product which contains less Mn. This could be another ferric based coagulant, or an aluminum-based coagulant which would contain significantly lower amounts of Mn. Additional recommendations were for year-round ozonation to minimize the duration of offline maintenance activities on the ozonation system, adjustment of the pH by raising it prior to filtration, and filter aid optimization for Mn removal. All of these options would require testing at pilot-scale and/or full scale.

To establish a baseline for evaluation of the alternative coagulant in each of the four seasons, starting in 2010 and concluding in 2016, upstream and downstream water quality of each treatment process were analyzed. This included raw and treated water quality, the quality of residuals, and the filter operational parameters.

Table 2-1 tabulates results of the water quality analysis throughout the WTP.

Table 2-1 Benchmarking of Full-Scale WTP for Identification of Candidate Coagulants, Water Quality

Sample		Temperature	pH	Turbidity	True Colour	Apparent Colour	UVT Filtered	UVT Unfiltered	Threshold Odor Number	DOC	TOC	DO	ORP	Alkalinity	Conductivity	TDS	TS	Fe Total	Fe Soluble	Mn Total	Mn Soluble	Sodium	Sulphate	Chloride	CSMR	Total THM	Total HAA
		°C	-	NTU	units	units	%	%	TON	mg/L	mg/L	mg/L	mV	mg/L	**µS/cm**	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	**µg/L**	**µg/L**
Raw Water Pumping Station	Average	9.51	7.98	1.11	5.37	11.27	77.01	74.88	123.17	9.51	9.72	10.85	352.2	75.3	168.2	105.2	115.7	0.05	0.02	0.014	0.004	2.3	1.7	3.0	1.00		
	Minimum	*0.50*	*7.27*	*0.26*	*2.50*	*5.00*	*73.46*	*71.74*	*75.0*	*7.00*	*6.00*	*7.15*	*237.0*	*68.0*	*149.0*	*61.0*	*92.0*	*0.01*	*0.01*	*0.002*	*0.000*	*1.9*	*0.0*	*1.4*	*0.40*		
	Maximum	*24.14*	*8.69*	*4.91*	*8.50*	*18.00*	*80.70*	*78.60*	*200.0*	*21.00*	*20.00*	*14.00*	*553.0*	*85.0*	*190.0*	*166.0*	*225.0*	*0.54*	*0.04*	*0.049*	*0.024*	*3.5*	*5.0*	*6.2*	*3.00*		
Post-DAF	Average		5.59	0.54			92.94	86.10		4.19	4.33	11.31	361.3	8.7				0.59	0.24	0.049	0.045		50.3	20.2	0.41		
	Minimum		*4.92*	*0.21*			*90.30*	*78.10*		*3.00*	*2.80*	*7.46*	*258.0*	*5.0*				*0.05*	*0.09*	*0.029*	*0.029*		*40.0*	*14.0*	*0.28*		
	Maximum		*6.41*	*1.45*			*94.40*	*91.60*		*7.00*	*7.00*	*14.30*	*544.0*	*16.0*				*1.79*	*0.65*	*0.100*	*0.097*		*62.0*	*48.0*	*1.04*		
Post-Ozone Contactor	Average		5.58	0.79	0.79						4.17	12.58	350.3					0.65	0.18	0.042	0.033						3.50
	Minimum		*5.31*	*0.37*	*0.50*						*1.00*	*8.78*	*258.0*					*0.04*	*0.04*	*0.028*	*0.015*						*3.00*
	Maximum		*6.09*	*1.42*	*2.50*						*8.00*	*16.10*	*508.0*					*1.31*	*0.49*	*0.076*	*0.059*						*4.00*
Post- Carbon Filters	Average		5.58	0.12	0.65				10.0		3.67							0.07		0.031	0.032						3.00
	Minimum		*5.30*	*0.06*	*0.50*				*6.00*		*2.00*							*0.01*		*0.013*	*0.016*						*3.00*
	Maximum		*7.61*	*0.27*	*1.00*				*15.0*		*6.00*							*0.31*		*0.051*	*0.048*						*3.00*
Clear Well	Average	10.46	7.84	0.18	1.40	5.88	94.97	93.84	24.1	4.21	4.19	9.57	396.0	70.5	316.5	176.0	190.8	0.05		0.036	0.022	33.1	48.4	20.3	0.44		
	Minimum	*0.90*	*7.38*	*0.08*	*0.50*	*2.50*	*92.34*	*90.33*	*12.0*	*1.00*	*1.00*	*6.36*	*267.0*	*57.0*	*271.0*	*116.0*	*146.0*	*0.01*		*0.018*	*0.010*	*23.4*	*23.0*	*13.0*	*0.20*		
	Maximum	*24.58*	*8.30*	*0.47*	*7.50*	*11.00*	*97.13*	*95.82*	*75.0*	*19.00*	*19.00*	*12.00*	*665.0*	*89.0*	*368.0*	*310.0*	*336.0*	*0.24*		*0.061*	*0.038*	*67.1*	*70.0*	*29.0*	*1.04*		
Deacon Booster Pumping Station	Average	9.58	7.78	0.17	1.47	5.99	95.40	94.12	23.0	4.05	4.08	11.91	374.7	69.4	318.1	178.1	191.1	0.05		0.031	0.017	32.5	49.5	20.6	0.43	9.33	14.40
	Minimum	*0.48*	*7.39*	*0.10*	*0.50*	*0.50*	*92.98*	*91.10*	*12.0*	*1.50*	*1.00*	*3.50*	*275.0*	*54.0*	*273.0*	*97.0*	*135.0*	*0.00*		*0.012*	*0.004*	*23.9*	*19.0*	*13.5*	*0.21*	*0.00*	*5.00*
	Maximum	*24.14*	*8.28*	*0.45*	*7.50*	*18.50*	*97.88*	*96.20*	*70.0*	*19.00*	*20.00*	*16.10*	*578.0*	*84.0*	*367.5*	*229.0*	*264.0*	*0.23*		*0.090*	*0.052*	*64.5*	*69.5*	*29.0*	*1.37*	*43.40*	*37.00*
Distribution System	Average	9.58	7.62			5.95							371.8	68.1		179.8		0.06		0.024			49.1	20.8	0.44		
	Minimum	*0.48*	*7.26*			*0.50*							*278.0*	*57.0*		*158.0*		*0.01*		*0.002*			*29.0*	*13.0*	*0.20*		
	Maximum	*24.14*	*8.35*			*20.00*							*549.0*	*86.0*		*248.0*		*0.17*		*0.179*			*69.0*	*30.0*	*0.86*		

Note. No data is available for algae toxins removal, TSS, aluminium and copper. The extensive water quality data and historical trends are presented in Appendix A.

Based on historical data, it was observed that the average Mn concentration in the raw water increases from 0.014 mg/L to 0.049 mg/L downstream of the DAF process. Figure 2-1 presents total Mn historical trends throughout the WTP, as well as Mn targets. Some removal is observed via filtration; however, Mn in the treated water remains higher than the raw water with an average concentration of 0.031 mg/L which is below the current AO limit of 0.05 mg/L, but higher than the new recommended treatment objective set by the City of 0.015 mg/L. Figure 1-1 indicates that the only chemicals added to the water prior to the DAF process are sulphuric acid and ferric chloride. Sulphuric acid is used to lower the pH of the raw water to approximately 5.5 to enhance the coagulation process and has no Mn content (as the manufacturing of bulk sulphuric acid is generally from the sublimation of gaseous sulphur trioxide). On the other hand, ferric chloride, used for coagulation, contains Mn arising from its manufacturing process.

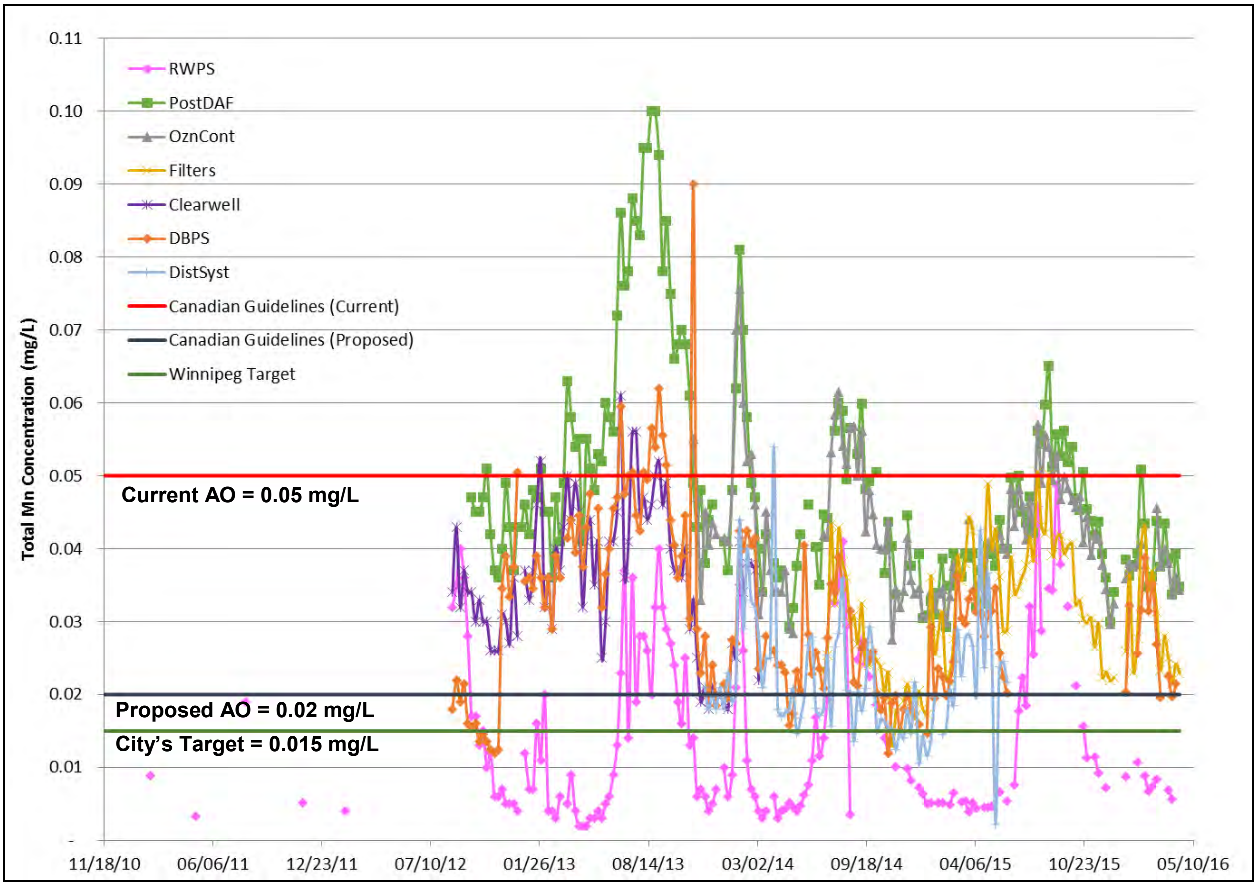


Figure 2-1 Total Manganese Level Historical Trend in the WTP

In order to better understand possible Mn sources, a thorough mass balance analysis was conducted around the DAF process and throughout the WTP. A mass balance for Mn was not provided in any of the previous reports. A mass balance provides information regarding Mn loading on a process basis and clarifies if the Mn issue is due entirely to the ferric chloride. By accounting for materials entering and leaving a system, mass flows can be identified which might have been unknown, or difficult to measure without this technique.

It should also be noted that limited data was available with regards to different residuals at the WTP and downstream of some processes. It was assumed all Mn is in soluble form (pH of raw water prior to DAF~ 5.5) and no Mn is present in the residuals of the DAF process. Figure 2-1 demonstrates the mass balance between the raw water (after the additional of coagulant) and post-DAF water for the total Mn mass per day.

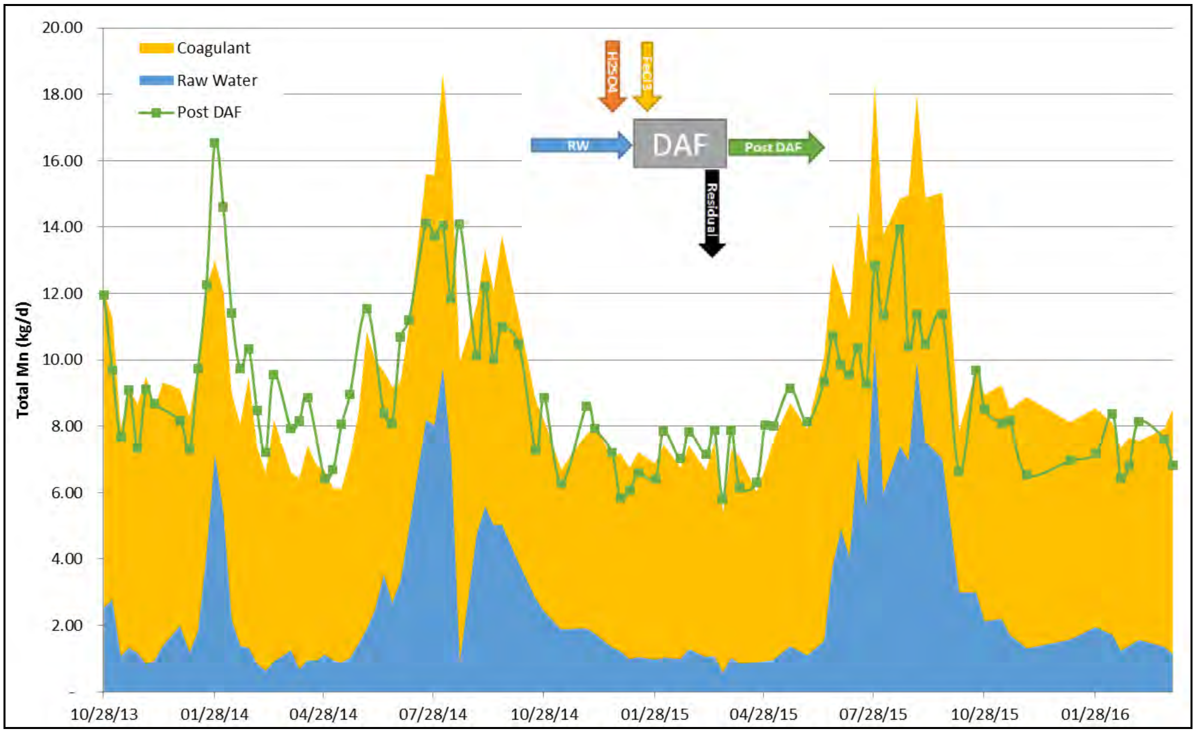


Figure 2-1 Total Manganese Mass Balance – Post DAF

The blue area in the graph illustrates raw water total Mn mass in kilograms per day, whereas the yellow area demonstrates the additional total Mn mass due to the addition of ferric chloride. From the figure, it can be observed that the Mn mass per day in the post-DAF stream correlates with pre-DAF stream. This not only suggests that the sudden increase in Mn mass is due to ferric chloride but also illustrates no or negligible Mn removal during the DAF process. As stated previously, sulphuric acid is added prior to DAF to lower the pH to 5.5. At this pH, Mn mainly present in solution in its ionic form (Mn^{+2}) and therefore no Mn in solid form is expected. The DAF process only removes flocculated solids and therefore soluble Mn would leave the DAF system without any removal.

The mass balance around the WTP is depicted in Figure 2-2. Although the amount of Mn entering the plant seems to be different to the amount of Mn leaving the WTP on a daily basis, the overall raw data shows that there is a fair correlation between the inlet and outlet amounts to the plant and no accumulation is taking place in the WTP. The difference shown in the graph is possibly because sampling days and times are different for raw water, post DAF, treated water, residuals and supernatant. The possible discrepancy between the data hence does not allow the mass balance to be visually observed.

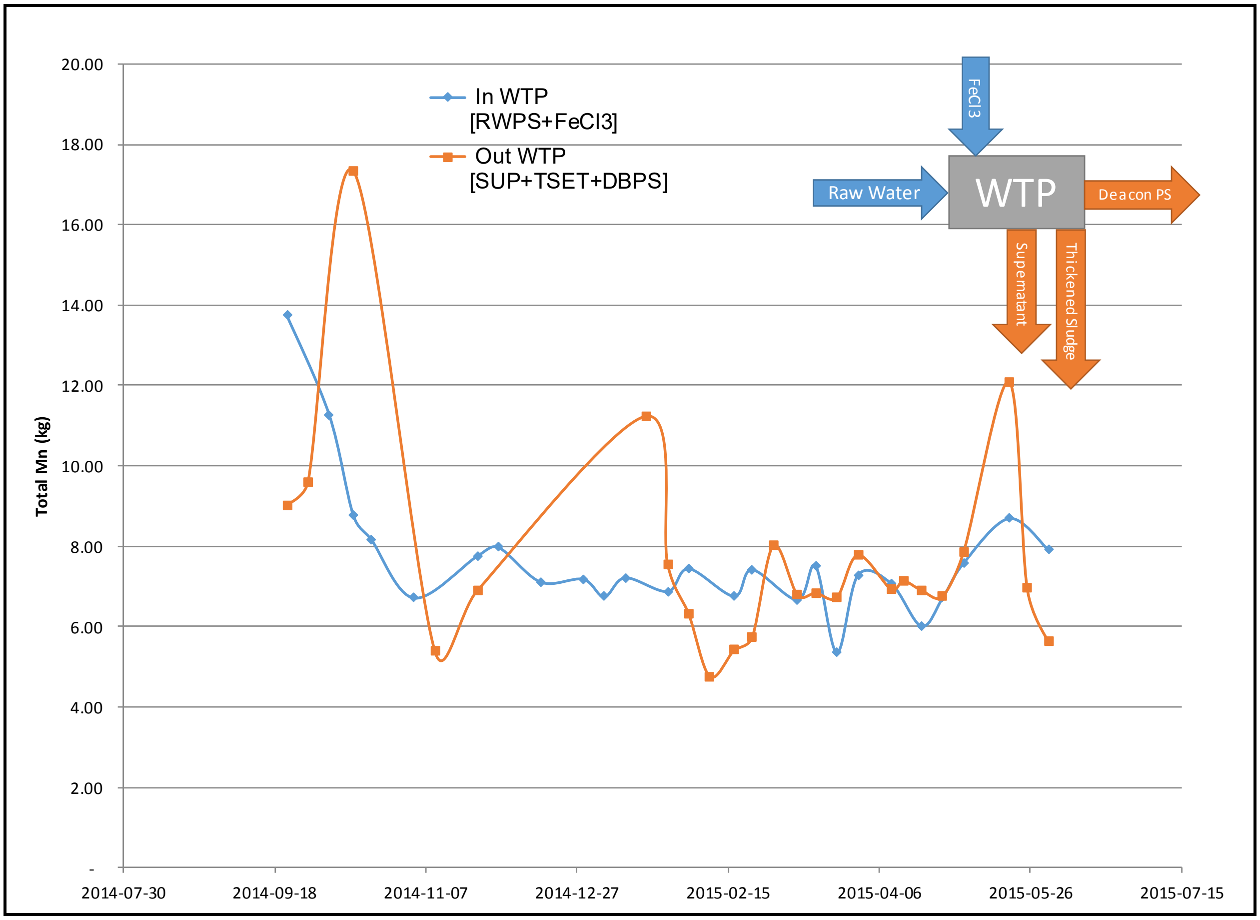


Figure 2-2 Total Manganese Mass Balance - WTP

Based on the results obtained from historical data, the current ferric chloride used at the WTP is the primary reason for high Mn concentration in the treated water.

A detailed pilot study was performed in 1996 for the selection of the appropriate coagulant at the Winnipeg WTP. Several coagulants and polymers were tested at different pH levels and dosages to optimise the efficiency of the treatment train. Section 3 is a summary of the 1996 pilot study.

Table 2-2 presents the filters and the filter backwash performance for the full-scale WTP between 2010 and 2015. These values will be used as a baseline for the evaluation of the alternative coagulant in each of the four seasons.

Table 2-2 Benchmarking of Full-Scale WTP, Filters Operational Parameters

	Filter Run Time	Unit Filter Run Volume	Hydraulic Flowrate	Contact Time	Differential Head loss	Backwash Frequency
	h	m^3/m^2	m/h	min	kPa	Number per day
Average	28.9	495	15.9	7.93	48.9	5.3
Minimum	20.0	319	11.9	10.6	23.7	4.1
Maximum	40.9	630	20.9	6.2	70.6	7.1

3. Phase 2 Pilot Program

As part of the Phase 2 Pilot Program, the City commissioned the construction of a permanent pilot plant in the Deacon pumping station, adjacent to Deacon Reservoir (CH2M Hill, 1998). The City's Phase 2 Pilot Plant was commissioned in June 1996 and the testing program was completed in September 1997. The information gathered from the Phase 2 Pilot Program was used to define the water treatment process train that was to become the basis of a conceptual design for a full-scale facility.

Phase 2 concentrated on identifying solutions to all outstanding water quality and treatability issues, and developing design parameters for use in the conceptual design phase of this project. It is believed that the results of the Phase 2 Pilot Program project, as presented in the document: “City of Winnipeg Water Treatment Plant Phase 2 Pilot Program (Final Report)” provided guidance to the City in selecting ferric chloride as the coagulant of choice.

The water in the Deacon Reservoir was characterized by low turbidity (0.3 to 5.3 NTU) and moderate to high total organic carbon (TOC) (5 to 17 mg/L). As a result of chlorination at the Shoal Lake headworks, Deacon Reservoir water also contained significant background levels of disinfection by-products (DBPs).

The Phase 2 Pilot Plant included two base types of water treatment: direct filtration with ozone and DAF with and without ozone. The three process configurations evaluated during Phase 2 are summarized as follows:

- Direct filtration plus ozone: O_3 + rapid mix + floculation + filtration
- DAF treatment: Rapid mix + flocculation + DAF + filtration
- DAF treatment plus ozone: Rapid mix + flocculation + DAF + O_3 + filtration

Also, different filter media were used for the filtration process: granular activated carbon (GAC) or anthracite. Figure 3-1 is a schematic of this pilot study. Two different polymers (LT22 and LT20) at two different dosages were tested. The ozone dose was constant during the pilot test at 0.35 mg/L aluminum sulphate (alum), ferric chloride and polyaluminum chloride (PACl) were evaluated as primary coagulants during the pilot program.

Testing for both the direct filtration and DAF treatment processes was divided into two major tasks. Initial tests concentrated on determining the best coagulation chemicals and filter media based on turbidity and particle removal, as well as water production. These baseline conditions were then fine-tuned to maximize particle removal and water production to test DAF and filter loading rates. Once results were acceptable and performance had been established, the most promising process configurations were tested for the removal efficiency of TOC, chlorination DBPs, DBP precursors, and odour.

Three water quality periods were investigated: ***warm water, cool water and cold water***. During each water quality period, each coagulant was tested by itself, then with a polymer and/or filter aid polymer. To minimize the concentration of dissolved metallic species, coagulation was conducted as near as practicable to the pH corresponding to minimum aluminum or iron solubility. The pilot program set-up and configuration is illustrated in Figure 3-1.

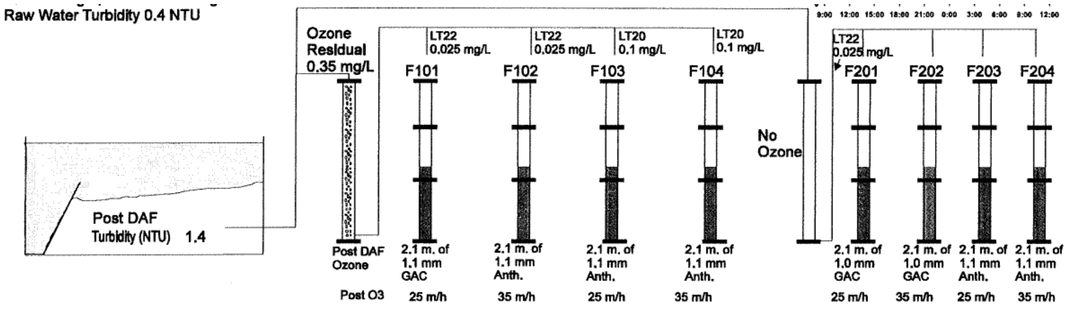


Figure 3-1 Schematic of 1996 Pilot Study

3.1 Results

3.1.1 Particle Reduction

Despite turbidity analysis being the pre-dominantly used standard in water quality monitoring, it is a relative measure of water clarity that does not directly relate to physical parameters. This resulted in the pilot program using particle counts instead. Particle counters extended the sensitivity of particle detection beyond that achievable by turbidimeters.

In general, both alum and ferric chloride produced acceptable results. During some seasons, several combinations of coagulants, polymers and acids demonstrated potential success. In general, the treated water targets could be met with the primary coagulant and the addition of either a cationic coagulant-aid polymer or a filter-aid polymer. However, the Cold-Winter season was an exception where the targets were met with the addition of filter-aid polymer, but not with addition of coagulant-aid polymer. The correct coagulation pH could be achieved by higher coagulant doses, or lower coagulant doses with supplementary acid addition.

Preliminary testing of PACl found that it was not successful in meeting the filtered water particle target of less than 20 counts/mL, with the polymers and filter aids tested. PACl doses were similar to alum doses, and because PACl was significantly more expensive than alum, it was not evaluated as extensively as alum or ferric chloride. Overall, under different water temperature conditions (warm, cool and cold water) and with and without ozone, ferric chloride achieved better removal of particles than alum.

Considering ozonated stream filters during the Cold-Winter period, it was observed that the DAF process alone was less effective for particle removal when using alum coagulation. Ferric coagulation provided approximately 1-log removal while alum coagulation provided about 0.3-log removal as demonstrated in Figure 3-2 below.

Ferric coagulation was more effective for particle removal with an overall removal (DAF and filtration) of approximately 4-log. Alum achieved an overall removal of approximately 2.7- to 3.6-log depending on the filter media. Results for the non-ozonated stream yielded similar conclusions as the ozonated stream.

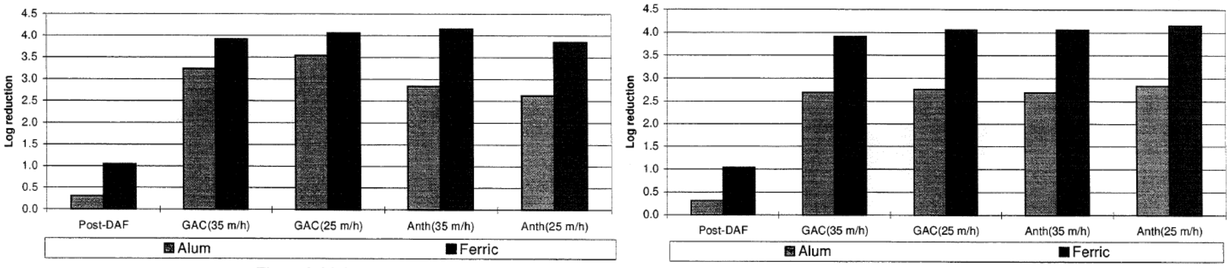


Figure 3.6.2-2
Cold Water Particle Log Removal - Ozonated Stream

Figure 3.6.2-4
Cold Water Particle Log Removal - Non-Ozonated Stream

Figure 3-2 Particle Log Removal for Ozonated & Non-Ozonated streams

Similar investigations carried out with cool water and warm water also resulted in superior performance of ferric chloride for particle reduction.

3.1.2 TOC Reduction

Enhanced coagulation proposed by USEPA differs from conventional coagulation in that it is based on reduction of organic levels and not turbidity reduction. The TOC removal outlined by the enhanced coagulation strategy for a raw water TOC level of 4-17 mg/L (Deacon raw water 1989-1994) results in a 40% reduction in TOC. This was hence set as the reduction target for TOC, though the goal was to reduce TOC as much as possible. During the cold-water period, TOC reduction with ferric chloride was 69-74%, while TOC reduction with alum was 43-54%. During the warm water period, TOC reduction with ferric chloride was 51-61% while TOC reduction with alum was 44-47% as noted in Table 3-1 below.

Table 3-1 Seasonal TOC Reduction with Alum and Ferric Chloride during the Pilot Study

Season	Ferric Chloride	Alum
Cold Water	69-74%	43-54%
Warm Water	51-61%	44-47%

TOC reduction was hence noted to be between 10-20% higher when ferric chloride was used compared to alum. Although both coagulants met the target of 40% of TOC reduction, ferric chloride was the preferred option because of the lower potential to form DBPs.

3.1.3 TOC reduction vs. DBPs

The pilot program short term target levels for DBPs were 100 μg/L for total trihalomethanes (TTHM) and no short-term target for haloacetic acid (HAA). The long-term target levels were 40 μg/L for TTHM and 30 μg/L for HAA. The tests have shown a good correlation between TOC reduction and simulated distribution system trihalomethanes (SDS-THM) reduction indicating a proportional reduction in DBP precursors other than for one of the precursors: F-103, as shown in Figure 3-3 below.

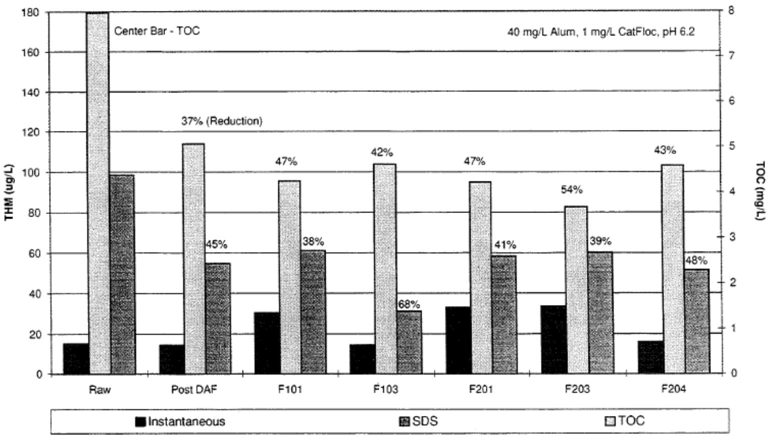


Figure 3.3.4-1
TOC Reduction Vs. SDS-THM Reduction

Figure 3-3 TOC Reduction *versus* SDS-THM Reduction

3.1.4 Threshold Odour Number (TON)

Alum and ferric chloride were tested during a cool water quality period with a relatively low raw water TON of 60, and also during a warm water quality period with a relatively high raw water TON of 150 as shown in Figure 3-4 below. At relatively low raw water TON values, there was little difference in TON reduction performance between alum and ferric chloride coagulation. However, at higher raw water TON values, there was a significant improvement in TON reduction using ferric chloride coagulation over alum. This improvement in TON reduction using ferric chloride was seen through the DAF, ozone, and filtration processes.

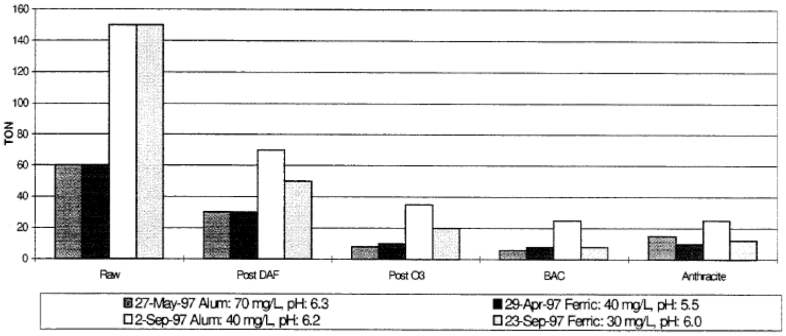


Figure 3.4.2-7
TON Data - Alum Vs. Ferric Coagulation - Ozonated Stream

Figure 3-4 TON Data for Ozonated Stream and Different Coagulants

3.2 Conclusions

Ferric chloride outperformed alum in TOC, filtered particle counts, filter performance, as well as in odour removal. Additionally, from an operational standpoint, when ferric chloride was used, the filter runs were more stable and not affected by changes in raw water quality to the same extent as alum. However, alum still met the performance targets. Ferric chloride was hence recommended as the primary coagulant. A number of successful ferric chloride doses were determined and proposed. It was also recommended that the pH be decreased to 5.5 prior to the DAF process.

4. Comparison of Full-scale performance with Phase 2 Pilot Program

As stated in the previous chapter, the Phase 2 pilot program recommended ferric chloride to be used as the primary coagulant at the full-scale plant. In order to verify the accuracy of the Phase 2 pilot testing, a comparison between the projected results of the Phase 2 pilot program and the existing full-scale performance was performed. Key water quality parameters were selected for this comparison based on available data, such as water turbidity, TOC, particle counts, unit filter run volume (UFRV). Post WTP construction water quality data collected from 2010 to the beginning of 2016 was used for full-scale analysis. The importance of this comparison is to confirm the accuracy of the pilot program due to the fact that future recommendations will be guided based on the previous studies performed. For this comparison, only the pilot-scale runs that had a similar configuration to the full-scale were selected i.e. addition of ferric chloride with doses ranging between 20-40 mg/L, LT22 as polymer (same product is currently being used under a different name LT22S), with ozonation and GAC filter media.

Due to the lack of data, the performance of the pilot study and full-scale is only comparable during the Cool-Spring and Warm seasons as indicated in Table 4-1. The available data was arranged in a seasonal manner and results were compared between the averages per season for each parameter between the two scales.

Table 4-1 Full *versus* Pilot-Scale Seasonal Comparison

Season	Duration	Pilot- Scale $FeCl_3$	Full-Scale $FeCl_3$
		mg/L	mg/L
Cool-Spring	*April - May*	37.90	26.82
Warm	*June - August*	30.00	29.41
Cool - Fall	*Sept - Oct*	-	28.20
Cold	*Nov - March*	-	26.18

4.1 Results

The results of this comparison are indicated in Figure 4-1 to Figure 4-4.

4.1.1 Total Organic Carbon

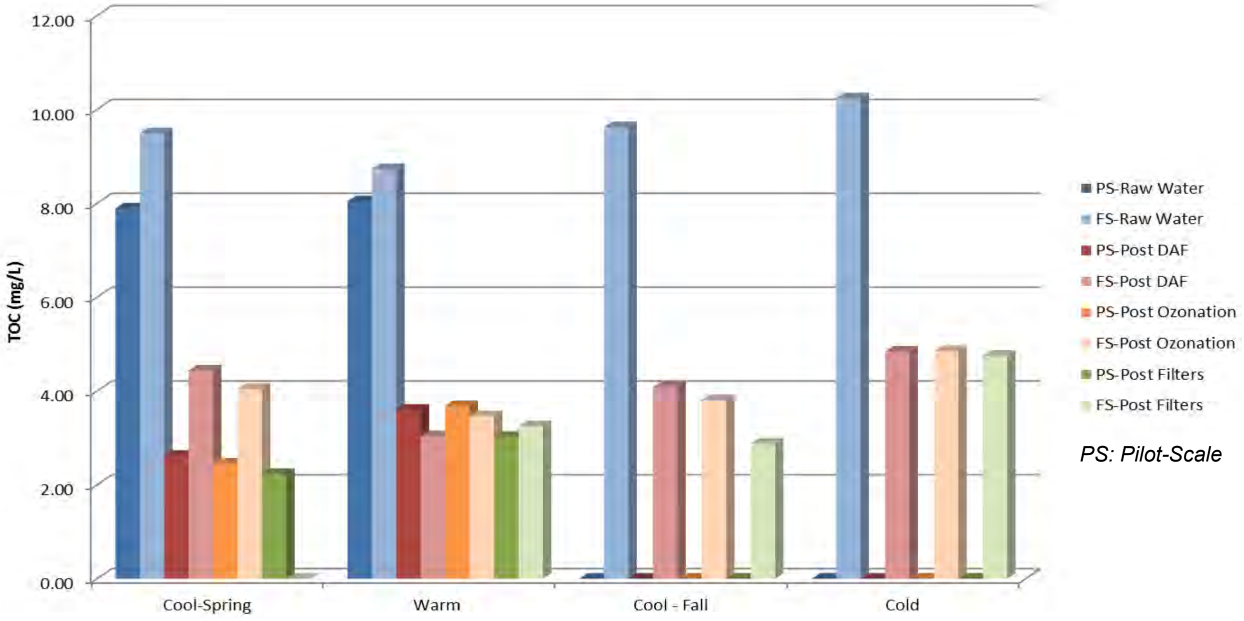


Figure 4-1 Seasonal TOC Concentration

As presented in Figure 4-1, the performance between pilot and full scales is fairly similar for TOC concentration. Results indicate a slightly higher TOC concentration at full *versus* pilot-scale; however, the results are comparable.

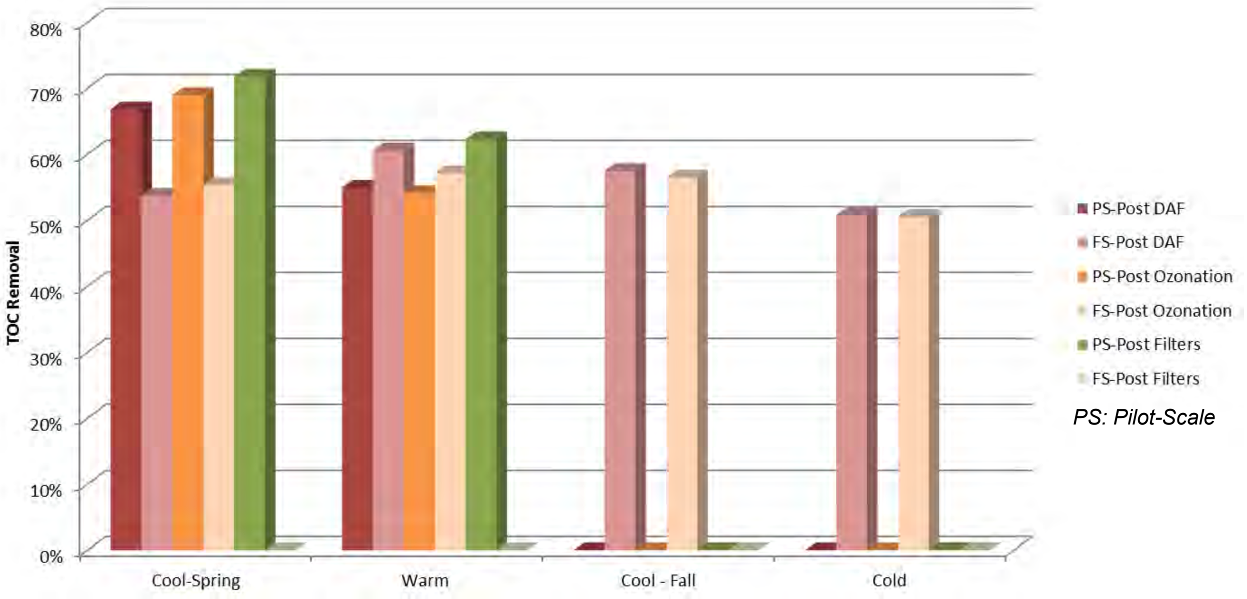


Figure 4-2 Seasonal TOC Removal (%)

Pilot-scale TOC removal efficiency is slightly higher (5 to 15%) than the full-scale plant. But overall the results are fairly similar, as shown in Figure 4-2.

TOC concentration and removal efficiency is highly dependent on the raw water TOC content which might be different between current data and 1996 when the pilot program was conducted. Concurrent with recent literature, both spatial and temporal variations are expected to affect organic carbon characterisation. Table 4-2 and Table 4-3 summarize the results between the full and pilot-scales:

Table 4-2 TOC concentration and removal efficiency at Full-Scale

Season	TOC Raw Water	TOC Post DAF	TOC Post Ozonation	TOC Post Filter	TOC Removal Post DAF	TOC Removal Post Ozonation	TOC Removal Post Filter
	mg/L	mg/L	mg/L	mg/L	%	%	%
Cool-Spring	9.49	4.43	4.04	-	54%	55%	-
Warm	8.73	3.04	3.46	3.25	61%	57%	-
Cool - Fall	9.62	4.08	3.81	2.88	57%	56%	-
Cold	10.24	4.84	4.85	4.75	51%	51%	-

Table 4-3 TOC concentration and removal efficiency at Pilot-Scale

Season	TOC Raw Water	TOC Post DAF	TOC Post Ozonation	TOC Post Filter	TOC Removal Post DAF	TOC Removal Post Ozonation	TOC Removal Post Filter
	mg/L	mg/L	mg/L	mg/L	%	%	%
Cool-Spring	7.89	2.62	2.45	2.23	67%	69%	72%
Warm	8.04	3.60	3.68	3.02	55%	54%	62%

4.1.2 Turbidity

Figure 4-3 indicates that pilot-scale post-DAF average turbidity levels are slightly higher than the full scale, 0.73 NTU *versus* 0.63 NTU for Cool-Spring and 0.43 NTU *versus* 0.37 NTU for Warm seasons.

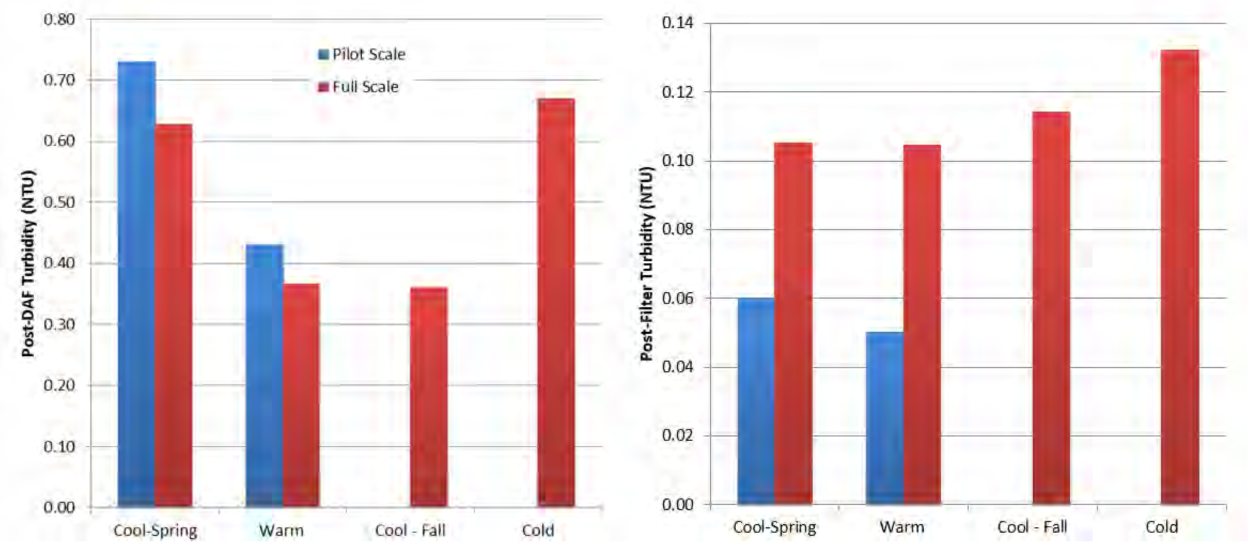


Figure 4-3 Seasonal Post-DAF and Post-Filtration Turbidity

4.1.3 Particle Count and UFRV

Figure 4-4 indicates the seasonal particles count and UFRV. A comparison of particle counts suggests a large difference between the pilot and full- scales. Cool-Spring season average particle count for the full-scale is 22.3 particles/mL whereas the pilot test shows only 2.3 particles/mL for the same season. Similar results are observed for the Warm season.

On the other hand, UFRV results indicate comparable values between the two scales. Full-scale presented a better performance for Cool-Spring season, but lower performance for Warm season.

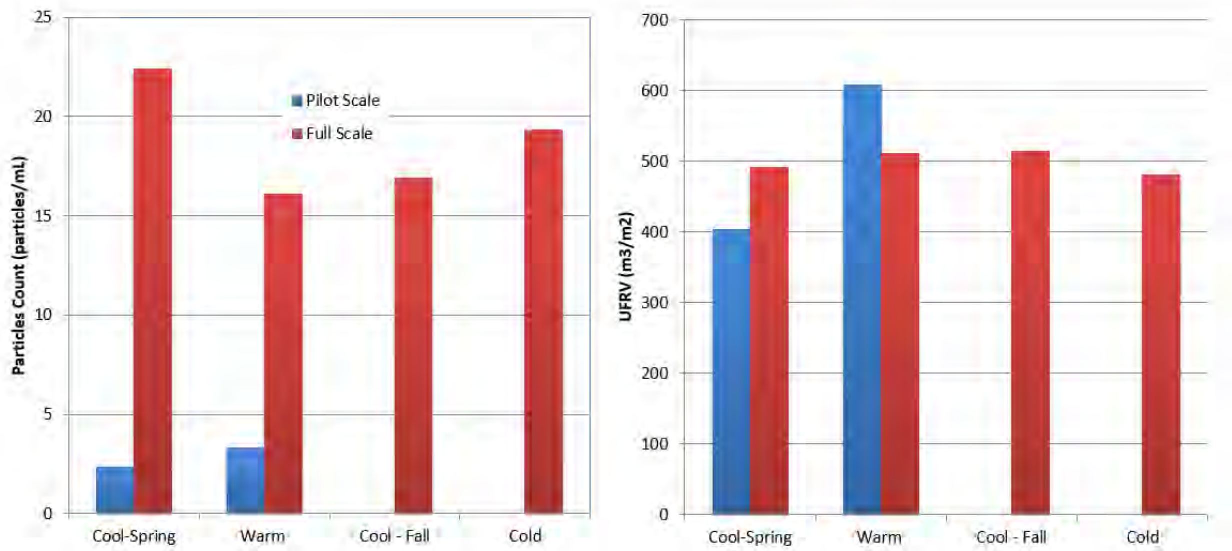


Figure 4-4 Seasonal Particles Count and UFRV

4.2 Results

The similarity between treatment performance at pilot *versus* full-scale is usually very close within the expected bounds of variability. The only large difference is in filtered water particle counts. However, particle counters are notoriously difficult to calibrate and maintain in calibration, therefore these results were not considered. All other parameters matched quite closely between the pilot and full-scale.

Since the pilot results and the subsequent full-scale performance seem to match quite well, it provides confidence that the pilot testing which began in 1996 was a very accurate estimation of full-scale treatment. As such, the conclusion from the pilot testing that ferric chloride was a superior coagulant compared to the other coagulants, such as alum is likely upheld as being valid.

It was also noticed that the ferric chloride doses during pilot testing in the Cold-Spring season were higher than the existing doses used at the full-scale plant. This could explain the subsequent full-scale results (e.g. TOC) showing poorer Cold-Spring season performance than were observed during pilot testing.

5. Identification of Candidate Coagulants for Bench Testing

The selected coagulants should:

- Reduce the potential for discoloured water in the distribution system, while complying with the criteria set out in the WTP Operating Licence;
- Contain minimum levels of impurities that may pass through the treatment processes;
- Be compatible with the existing materials, chemicals and processes at the WTP, where possible;
- Maintain or improve current plant performance and the treated water stability;
- Minimize disturbance of the distribution system.

Among all the commercial coagulants, aluminum-based and iron-based coagulants are widely available and are the most commonly used products for coagulation in water treatment plants. The performance of each coagulant varies according to the quality of the water that is being treated.

5.1 Aluminum-based Coagulants

The most common aluminum-based coagulants are: alum, aluminum chloride and complex forms of alum. Complex forms include: polyaluminum Sulphate (PAS), polyaluminum silicate sulphate (PASS), PACl and aluminum chlorohydrate (ACH). Alum is the most widely used coagulant chemical used for water treatment. In Canada, the complex forms are mostly used during winter conditions due to their better performance at slower chemical reaction rates. Aluminum-based coagulants are produced from purified aluminum tri-hydrate and therefore no or minimum metal impurities/contamination are expected in the end product. Aluminum-based coagulant production sources are widely available (such as bauxite and sulphuric acid) which makes them the most commonly used coagulant in the market.

5.2 Iron-based Coagulants

The most common iron-based coagulants are ferric sulphate and ferric chloride. Their complex forms are not commonly used in North America. The purity of iron-based coagulants is highly dependent on the available iron sources and their manufacturing process. The majority of ferric sulphate coagulants, suitable for potable water treatment purposes, are produced by direct reaction of iron ore with sulphuric acid. On the other hand, in North America, there are limited manufacturers that produce ferric chloride coagulants through direct reaction with iron ore and their production is for small scale applications (not for water treatment). Ferric chloride, suitable for potable water treatment purposes, is commonly produced either as a by-product of titanium dioxide (TiO_2) manufacturing or by ferrous iron oxidation in a solution of a strong acid. These two manufacturing processes lead to higher trace metal impurities and contamination in the end product, either of which does not impact iron coagulant compliance with NSF potable water standards. The cost of iron-based coagulants depends on their availability, cost of transportation, and the actual fabrication process.

The ferric chloride currently in use at the Winnipeg WTP is fabricated by the oxidation of ferrous iron in steel pickle liquor (a solution of mixed strong acids). Manganese is only one of the trace contaminants introduced into the raw water by ferric chloride at a higher contribution than by ferric sulphate.

5.3 Discussion with Vendors and Other Utilities

In order to identify the candidate coagulants as a replacement for the current coagulant in use, several coagulant producers and distributors were contacted to discuss their product availability and characteristics. Table 5-1 lists the vendors that have been contacted along with their products. Each coagulant supplier provided the chemical properties of their product including Mn concentration and other trace contaminants.

Table 5-1 Available coagulants

Vendors	Coagulants
PVS Fanchem	Ferric chloride, Enhanced ferric chloride
Univar	Ferric Sulphate, alum, Polyaluminum Chloride, Polyaluminum Silicate Sulphate
Brenntag	Ferric Sulphate, alum, Polyaluminum Chloride, Polyaluminum Silicate Sulphate
Cleartech	Aluminum chlorohydrate, Polyaluminum chloride, Polyaluminum Silicate Sulphate
CCC Chemicals	Ferric Sulphate
Kemira	Ferric Chloride, ferric sulphate, alum, Polyaluminum Chloride, Polyaluminum Silicate Sulphate (PASS10), Polyferric sulphate (PFS), blends of ferric chloride and ferric sulphate, blends of aluminum/ferric sulphate[1]
Azelis Americas	Polyaluminum chloride
Border Chemical	Alum, Polyaluminum Chloride

[1] Even though Kemira is the only vendor that market these coagulant blends, these are not proprietary blends and other vendors that commercialize the main products (like Brenntag and Univar) are able to supply these products.

Several Canadian water treatment utilities were contacted to discuss their experience and overall satisfaction level with the performance of their coagulant. As an example, they were asked to share their experience if they had conducted any coagulant selection tests and if any they have encountered potential problems. It should be noted that there are very few utilities in Canada that use iron-based coagulants such as ferric sulphate and aluminum/ferric sulphate. Most utilities use alum as their coagulant of choice.

In Quebec, Repentigny WTP has recently changed their coagulant, for cool and warm season, from aluminum sulphate to ferric sulphate, in order to improve their settling performance. Following this change, they have encountered an increase in Mn concentration in the treated water, which currently is controlled through chlorination prior to a filtration step. Since the source water has low alkalinity during the winter time, they use PASS10 as their coagulant.

In Montreal, Pierrefonds WTP is currently using an aluminum/ferric sulphate blend during the winter season. WSP contacted Pierrefonds WTP operation staff, however they were not willing to share any information.

Saskatoon WTP also changed its coagulant from aluminum-based coagulant to ferric sulphate which was triggered by high aluminum residual in their treated water. This change was implemented after a thorough bench-scale and pilot-scale program. The results of the bench-test identified two coagulants based on their turbidity and taste removal performances: ferric chloride (ranked first), followed by ferric sulphate. These two coagulants were further tested during the pilot program. Although the overall pilot-scale performance of ferric chloride was superior, ferric sulphate was selected as the coagulant of choice due to its similarity in terms of treated water quality with the full-scale results.

5.4 Identification of Coagulants Rationale

At first, complex aluminum-based coagulants were considered as one of the coagulant candidates. These coagulants consume less alkalinity and are effective in a wide pH range. The coagulation/flocculation process is operated at a higher pH, allowing partial precipitation of present Mn ions and formation of Mn species which could be removed through the DAF process. Aluminum-based coagulants contain less metallurgical impurities/contaminants as well.

After completing an extensive background review of the available reports and water quality data, it was believed that the Phase 2 pilot testing report presented a very compelling argument for the use of ferric based coagulants, (as outlined in Section 4). Bench scale testing does not consider seasonal water quality variations, and therefore is not as comprehensive and accurate as pilot-scale testing.

Consequently, it is assumed that the results that can be obtained with bench tests would not reverse the previous pilot results, and suggest the superiority of ferric chloride in relation to alum.

On the other hand, as presented above it is believed that the majority of the Mn content in the treated water is attributed to ferric chloride. The strategy to reduce the Mn level and maintain current plant performance is to find an alternative iron-based coagulant that contains as low Mn contamination as possible.

Thus, the selected coagulants for Bench Scale tests are ferric chloride, a blend of ferric chloride and ferric sulphate, ferric sulphate and a blend of aluminum/ferric sulphate with a higher aluminum concentration (Blend 2). Table 5-2 presents the short-listed coagulants, their main characteristics and other impurities found in the coagulants. Due to the limited number of trials available, alum and the aluminum/ferric sulphate blend with low concentration of aluminum (Blend 1) were not selected as potential coagulants for Bench Scale tests, however their characteristics are shown, since they were used as a source for the proposed blends. Aluminum/ferric sulphate Blend 2 was selected over aluminum/ferric sulphate Blend 1 for bench tests since it had a higher aluminum content and hence differed more from ferric sulphate (which was selected for bench testing).

Table 5-2 also presents other impurities found on the City’s current specification for Coagulants. For the coagulants containing alum, insoluble solids is the only parameter that exceeds the current standard (< 80 mg/kg) set by the City. Considering the average Mn in the raw water and the average removal of Mn along the water treatment process, the Mn content in the coagulant should be limited to approximately 140 mg/kg for a coagulant dose of 30 mg/L or 100 mg/kg for a dose of 40 mg/L, in order to attain the objective of 0.015 mg Mn/L in the treated water. Between the identified coagulants, ferric sulphate and the blends of aluminum/ferric sulphate could achieve these targets based on their Mn concentrations.

Table 5-2 Identified Coagulants Characteristics

Coagulant	Ferric Chloride	Ferric Chloride / ferric sulphate Blend	Ferric Sulphate	Aluminum/Ferric Sulphate Blend 1	Aluminum/Ferric Sulphate Blend 2	Alum (Aluminum Sulphate)
Constituent	$FeCl_3$	50% $FeCl_3$ 50% $Fe_2(SO_4)_3$	$Fe_2(SO_4)_3$	50% $Al_2(SO_4)_3.18H_2O$ 50% $Fe_2(SO_4)_3$	70% $Al_2(SO_4)_3.18H_2O$ 30% $Fe_2(SO_4)_3$	$Al_2(SO_4)_3.18H_2O$
Concentration (%)	37% - 42%	40% - 42%	43%	45% - 46%	46% - 47%	48%
Specific gravity	1.38 - 1.45	1.45 – 1.50	1.55	1.44	1.38	1.3
Iron Content ($\%_{w/w}$)	12.7 -14.1%	12% - 13.5%	11.5-13%	6.0 %	3.28%	< 0.01%
Aluminum Content ($\%_{w/w}$)	-	-	-	2.2%	3.0%	4.3%
Manganese Content (mg/kg) [2]	< 600	< 300	< 100	< 55	< 37	< 10
% Free acid as HCl[3]	< 1.0	0.21	0.01	0.01	0.01	0.01
Insoluble Solids (mg/kg) [3]	< 80	567	27	606	388	299
Lead (mg/kg) [3]	< 1.3	0	0	0	0	0
Magnesium (mg/kg) [3]	< 35	60	142	24	6	0
Optimal pH range	< 6	< 6	< 6	5.5 – 6.5	5.5 – 6.5	5.8 - 6.5
Suppliers	Kemira, PVS Fanchem	Kemira[4]	Kemira, CCC Chemicals	Kemira[4]	Kemira[4]	Kemira Brenntag Border Chemical
References	-	-	Repentigny, QC Saskatoon, SK	Pierrefonds, QC	-	Most widely used North America

1 All coagulants meet the AWWA standards and are ANSI/NSF Standard 60 certified.
2 The Mn content is expressed in mg/kg in a wet weight basis. The Mn content of the blends is variable, and were calculated according to blend ratio.
3 Ferric chloride information based on Winnipeg WTP historical analysis. Other coagulants based on certificate of analysis provided by Kemira.
4 Even though Kemira is the only vendor that market these coagulant blends, these are not proprietor blends and other vendors that commercialize the main products (like Brenntag and Univar) are able to supply these products.

6. Identification of Candidate Coagulant-Aids for Bench Testing

A coagulant-aid, when used in conjunction with a coagulant, can provide benefits such as reducing the amount of coagulant needed, reducing head-loss at filtration processes, and even reducing sludge production. Consequently, careful selection of a coagulant-aid is warranted.

The aim of the addition of a coagulant-aid is to facilitate bridging between flocculate and solids. This interparticle bridging is most often achieved using a high molecular weight polymer, having either cationic or non-ionic charged sites and used in low dose concentrations (0.1 to 1.0 mg/L). Generally, poly-acrylamide polymers meet these conditions and easily attach to micro-flocs consisting of organic matter, and as a result, are used most for this purpose. A drawback of cationic polymers is often cited to be their sensitivity to pH, although this may be overcome using quaternary monomer derivatives.

In order to identify the candidate coagulant-aids several polymer producers and distributors (BASF, Nalco and ERPAC) were contacted to discuss their product availability and characteristics. Each polymer supplier provided a recommendation of polymer to act as coagulant-aid, based on the Winnipeg WTP characteristics and water quality. Dry polymers with complete solubility were specified, considering the possible amount required at Winnipeg WTP.

The recommended coagulant-aids and their characteristics are presented in the Table 6-1 below.

Table 6-1 Identified Coagulant-Aids Characteristics

Coagulant-aid	Magnafloc LT-22S	Optimer 8110 PULV	Prosedim ASP-20	Prosedim CSP-640
Constituent	Acrylamide co-polymer and quaternized cationic monomer	Acrylamide co-polymer	Acrylamide co-polymer	Acrylamide co-polymer
Charge	Low cationic	Low cationic	Non-ionic	Very low cationic
Molecular weight	High	Medium	Very high	High
Type	Dry Powder	Dry Powder	Dry Powder	Dry Powder
Usage	Coagulant aid or filter aid	Coagulant aid or filter aid	Coagulant aid or filter aid	Coagulant aid or filter aid
Maximum concentration[1]	1.0 mg/L	1.0 mg/L	1.0 mg/L	1.0 mg/L
Supplier	BASF	Nalco	ERPAC	ERPAC
Reference[2]	Windsor PUC, On Mannheim WTP, Waterloo, On Chatham WTP, On Rossdale WTP, Calgary, On Bearspaw WTP, Calgary, On	Several plants in USA (only)	Pierrefonds, QC Repentigny, QC	Contrecoeur, QC (DAF) Gatineau, QC Régie de l'eau d’Ile-Perrot, QC L'Assomption, QC St-Georges-de-Beauce, QC Québec, QC St-Jérôme, QC

1 All coagulants meet the AWWA standards and are ANSI/NSF Standard 60 certified.
2 The references are not extensive.

The coagulant-aids short listed for Bench Scale tests are:

- Magnafloc LT-22S: Cationic with high molecular weight, current filter-aid in use at the Winnipeg WTP
- Prosedim ASP-20: Non-ionic with very high molecular weight
- Prosedim CSP-640: Cationic with high molecular weight, reported to be very successful in DAF installations by the manufacturer

7. Bench Testing of Candidate Coagulants and Coagulant-Aids

7.1 Objective

The DAF-jar testing program was completed to compare alternative coagulants to the current coagulant at a bench-scale level, with the aim of achieving post-DAF Mn concentrations less than the Mn concentrations noted with the current coagulant, and able to satisfy the 0.015 mg/L objective set by the City.

The results of the numerous bench-scale trials performed were used to determine the best coagulant, coagulant-aid and pH to be further tested at pilot-scale.

A summary of the coagulants, coagulant-aids and pH adjustment reagent utilized during the bench scale experiments are summarized in Table 7-1.

Table 7-1 Summary of Coagulants, Coagulant-aids and pH Adjustment reagent tested during bench tests

Coagulants	Coagulant Aids	pH Adjustment
Ferric Chloride (Kemira) Ferric Sulphate (Kemira) Ferric Chloride/Ferric Sulphate (Kemira) Aluminum/Ferric Sulphate Blend 1 (Kemira) Aluminum/Ferric Sulphate (Hi [Al]) Blend 2 (Kemira)	Magnafloc LT-22S Prosedim ASP-20 Prosedim CSP-640	Analytical Grade Sulphuric Acid

7.2 Bench Testing Details

The bench testing program was performed between September 12, 2016 and October 21, 2016. The bench testing experiments spanned about 6 weeks and it was noted that there was some variation in raw water temperature during this period. During the beginning of the experiments (setup and baselining) the temperature ranged between 17.7 ^{0}C and 20.9 ^{0}C. At the end of the jar testing, the water temperature was significantly lower and around 8.9^{0}C. This may have affected results.

Initially, several tests were performed to evaluate jar test functionality. These were followed by seven trials each with a distinct objective. The trials all used raw water coming into the WTP. Table 7-2 summarizes the various trials carried out.

Table 7-2 Jar Tests Carried out During Bench testing

Trial Number	Purpose	Bench Test Details
0	Establish operating parameters (Setup)	- Parameters were established to be used during testing - The jar tester functionality was evaluated - Benchtop probes were tested - Saturation pressure was adjusted to match treatment plant - Tests carried out with ferric chloride, no coagulant aid
1	Confirm jar-test procedure (Baseline)	- Full-scale conditions baselined. The full-scale rapid mix and coagulation energy and duration were simulated - Different Jars were evaluated to determine if similar results were noted - Operational parameters were adjusted by varying coagulation time and coagulant dose (each from 75% to 125% compared to full-scale parameters) to optimize performance and match treatment plant water quality - Test carried out with ferric chloride, no coagulant-aid and no pH control. - The optimal coagulation dose and time were determined to be: 75% Flocculation time & 75% coagulant dose of the full scale based upon jar testing results (Hach Mn, turbidity, UVT)
2	Optimize coagulant dose (Coagulant Screening)	- All the shortlisted coagulants were screened for initial performance. pH was reduced to match full-scale coagulation pH, no coagulant-aid was added. - 4 chemical doses were tested for each coagulant: 15, 25, 35 and 45 mg/L - All five coagulants were tested - The best dose for each coagulant was determined by evaluating the following key field parameters: Hach Mn, turbidity, UVT
	Refine Coagulant Dose (Dose Refinement)	- Dose of each coagulant was refined by dosing ± 2 mg/L and ± 4 mg/L from the “best dose” determined during coagulant screening. No coagulant-aid was added. - The following four coagulants were selected for further jar testing: • Ferric Chloride • Ferric Sulphate • Ferric Chloride/Ferric Sulphate • Aluminum/Ferric Sulphate Blend 2
3	Optimize coagulation pH	- pH was altered using Sulphuric Acid to examine optimal coagulation pH. The 3 Ferric coagulants were tested at the following pH: 5, 5.3, 5.6 and 6. The aluminum based coagulant was tested at the following pH: 5.5, 5.9, 6.2 and 6.5. No further pH refinement was carried out. - The pH optimization as carried out with no coagulant-aid added and at the optimal coagulant dose determined from Trial 2 above.
4	Optimize coagulant-aid addition	- 3 different coagulant-aids were tested - Coagulant-aids of the following concentrations: 0.05, 0.1, 0.25 and 0.5 mg/L (based on dry mass) were tested. The coagulants were tested at the optimal dose (determined in Trial 2) and at the Optimal pH (determined in Trial 3) - The best coagulant-aid concentration for each coagulant was determined by evaluating the following key field parameters: Mn, turbidity, UVT
5	No coagulant	- The DAF process was tested without coagulation or pH adjustment to evaluate potential benefits and cost savings
6	Optimal conditions	- The optimal combination of each coagulant, coagulant-aid, pH combination was re-evaluated again in triplicate.
7	Optimize mixing time and applied energy	- The mixing speed and mixing duration of both the rapid mix and flocculation processes were altered using the best combination of coagulant, coagulant-aid and pH.

The bench testing protocol can be found in Appendix B, including details of each trial and schedule. The complete bench test results are presented in Appendix C.

7.3 Manganese Baseline Test

Due to the compressed bench testing schedule and the lengthy turnaround time for samples from the City of Winnipeg laboratory (City Lab), an initial investigation was carried out to determine if data collected using a Hach spectrophotometer and method 8149 (low range Mn by 1-(2-pyridylazo)-2-naphthol) available at the plant would be an acceptable representative of the actual Mn concentration.

The test was carried out by preparing a 10 mg/L stock solution of Mn and using this to prepare various dilutions with concentrations ranging from 0.005 mg/L to 0.05 mg/L. The bench top Hach DR6000 spectrophotometer was then used to obtain a Mn concentration (henceforth referred to as Hach Mn). This method is noted by Hach to be intended for the detection of Total Mn concentrations ranging from 0.006 to 0.7 mg/L. A sample was also sent to the City Lab for Mn determination. The results of this experiment are presented in Figure 7-1.

The City Lab Total Mn results (henceforth referred to as Lab Total Mn) were noted to be closer to the expected concentrations; however, the magnitude of corresponding samples was noted to be similar between the Hach Mn results and the Lab Total Mn results as seen in Figure 7-1. In terms of magnitude hence, a larger Lab Total Mn concentration corresponded to higher Hach Mn concentration.

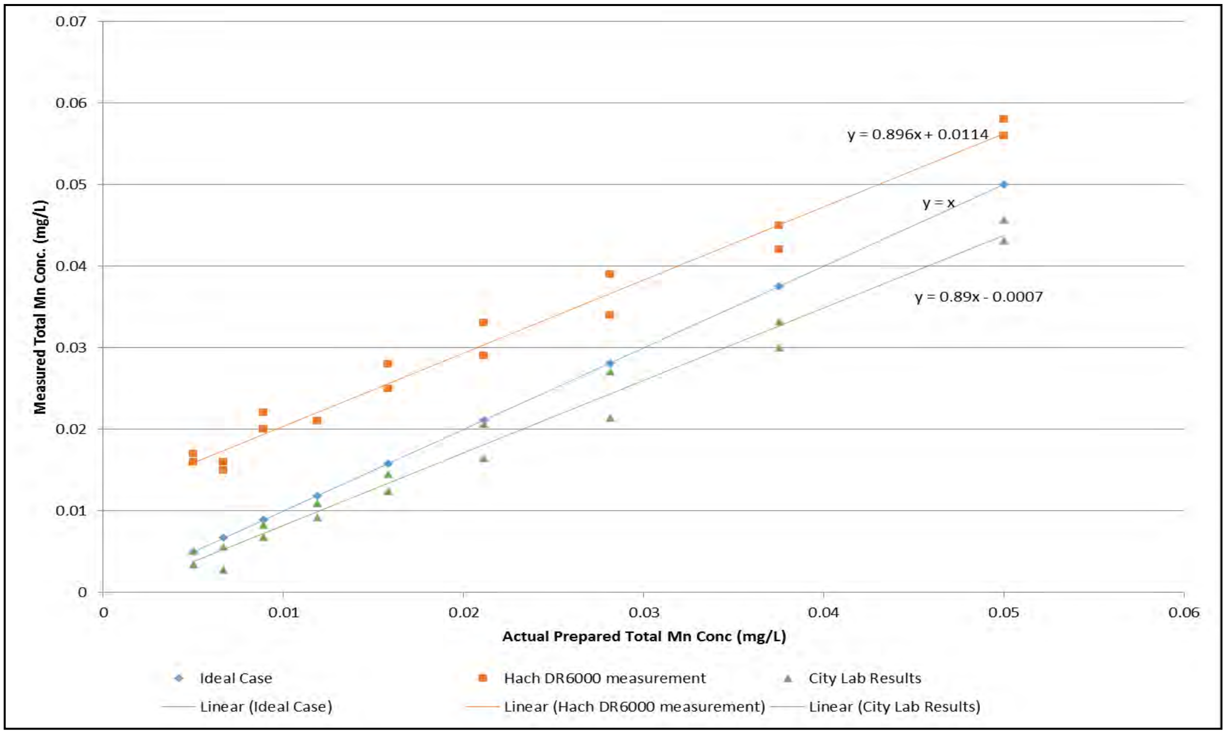


Figure 7-1 Comparison between Hach Mn and City Lab Total Mn

It was noted however that quantitatively, the Total Mn concentrations differed between the Hach Mn and the Lab Total Mn. At higher concentrations of 0.0375 mg/L and above, the differences between the Hach Total Mn and Lab Total Mn were less than 10%. At concentrations below 0.0089 mg/L however, the difference in concentration increases to more than 100%.

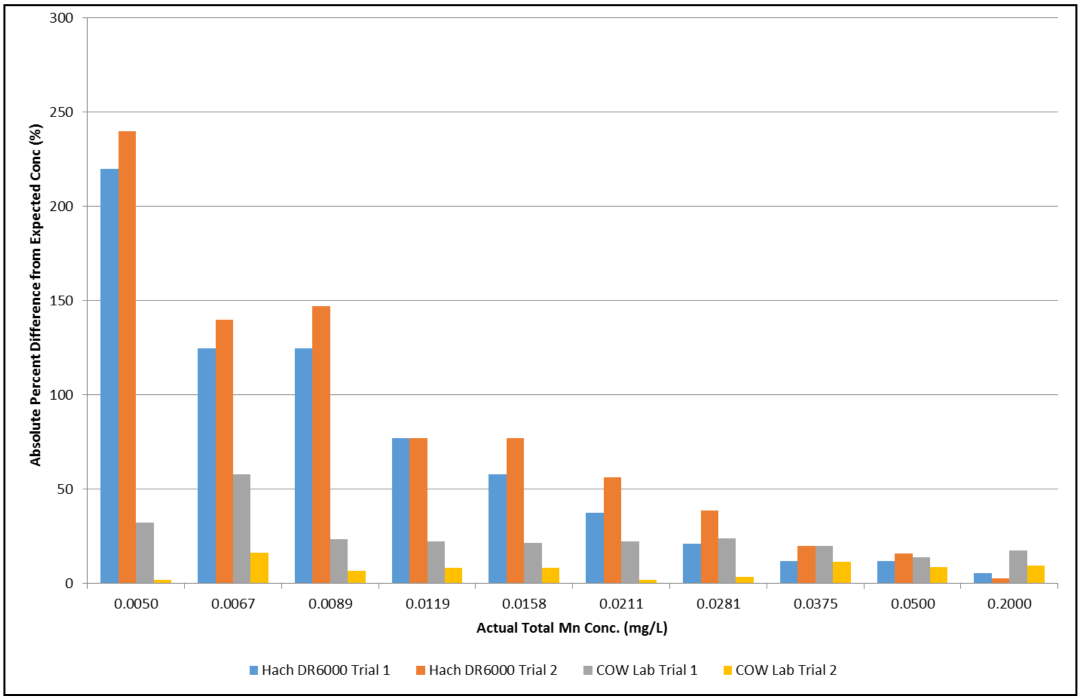


Figure 7-2 Percent Difference: Hach Mn & Lab Total Mn with Expected Concentration

Based on the above assessment, as shown in Figure 7-2, the Mn results from the Hach instrument (Hach Mn) were deemed to be an acceptable qualitative screening value for the actual Mn concentration due to the observed trends noted regarding magnitude. The Hach Mn however was shown not to be an accurate representation of the quantitative Mn concentrations, likely in part due to the nature of such a comparative method employing the dilution, and utilizing the reaction flask as the analytical optical glassware.

7.4 Bench Test Results

7.4.1 Trial 1: Baseline

A summary of the base parameters tested during Trial 1 are summarized in Table 7-3 and are discussed in Sections 7.4.1.1 through 7.4.1.5. The results of the tests are discussed in Section 7.4.1.6.

Table 7-3 Initial Parameters Tested during Trial 1

Parameters	Value
Coagulant Dose	25 mg/L
Flash Speed	200 RPM
Flash Time	30 s
Flocculation Speed	45 RPM
Flocculation Time	20 min
Saturation Pressure	500 kPa
DAF wait time (prior to subnatent sampling)	10 min

7.4.1.1 Flash Mixing

To achieve flash mixing of the coagulant in the plant, jet flash mixing is used to mix ferric chloride into the raw water. The flash mix injector installed in the raw water header consists of a full cone style spray nozzle of titanium construction mounted within a tee. The injector is served by a flash mix pump, which draws a side-stream flow of 3% of the flow to each train. A 50 mm ferric chloride solution line delivers coagulant to the throat of the nozzle so that the turbulence generated by the nozzle will flash mix the ferric chloride across the diameter of the pipe.

The flash mixing procedure employed at the full-scale plant is rather complex and difficult to reproduce at the bench scale. For this reason, the jar testing equipment manufacturer's recommendation of 200 RPM mixing speed for 30 s was utilized for flash mixing intended to thoroughly and completely mix the coagulant into solution.

7.4.1.2 Ferric Chloride Dosing

The following information was provided by the City regarding the ferric chloride dosing:

$FeCl_{3\ Flow}$ = 3.2 L/min
Water Production $_{Flow}$: 10^8 L/day
$FeCl_{3\ \%}$ = 39%
$FeCl_{3\ SG}$ (Specific Gravity) = 1420 mg/mL = 1.42 mg/L

The ferric chloride dose is calculated as follows:

$$Ferric\ Chloride_{Dose} = \frac{\mathrm{FeCl_3}_{\%}\ \mathrm{FeCl_3}_{SG}\mathrm{FeCl_3}_{Flow}}{\mathrm{Production}_{Flow}} = 25.5\ mg/L$$

Ferric chloride is dosed in the full-scale plant at 25.5 mg/L, and the initial dose selected for testing was hence 25 mg/L.

7.4.1.3 Flocculation

The flocculation basins in the plant are laid out in two discrete, parallel trains, each of four basins. Each flocculation basin is directly coupled to the respective DAF basin, to ensure good flow distribution across the full width of the DAF basin and to minimize short circuiting. Each basin is designed to provide a nominal 16 minutes of flocculation time at the water treatment plant design capacity of 409 ML/day, and is sub-divided into three sub-cells in series, of equal size. Each of the three sub-cells in the flocculation basin includes two vertical, axial flow, hydrofoil style flocculators in parallel (for a total of six per basin). Each flocculator is fitted with a variable frequency drive (VFD) to allow operations staff to individually tailor flocculation mixing energy for each of the three cells in series. The flocculator has a maximum design G-value of 100 s^{-1}. Figure 7-3 is a schematic of the flocculation and DAF Processes.

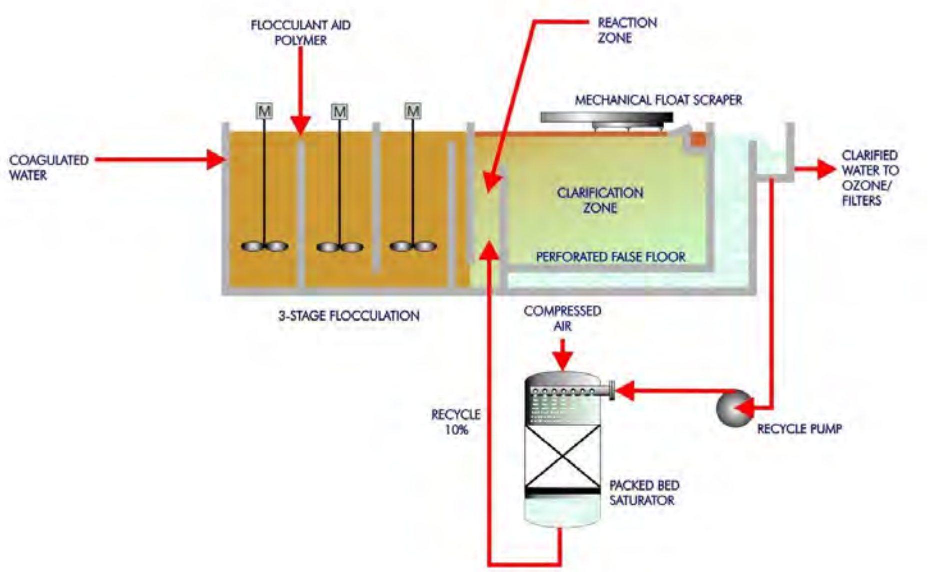


Figure 7-3 Schematic of Flocculation and DAF Process (CH2M Hill, July 2005)

Each DAF mixing motor in the flocculation basins is rated for 1765 RPM, with two gearbox speed reducers. The first reducer has a turn down ratio of 6.41:1, followed by a second reducer for a total turn down ratio of 90.14:1. The maximum rated mixer speed with a 1765 rpm motor is hence calculated as follows:

$$Motor_{\max RPM} = \frac{1765\ RPM}{90.14} = 19.6\ RPM$$

The City described the three flocculation basins operating at different RPMs as follows: 75%, 65%, and 55% of the maximum speed. The maximum G-value for flocculation was calculated as follow:

$$G = \sqrt{\frac{P}{\mu . V}}$$

Where:

- Dynamic Viscosity at 20C (μ)= 1.002 X 10^{-3} N s/m^2
- Volume (V) = 11 m x 10.5 m x 5.3 m = 612.15 m^3
- Power (P) = 1 HP with 90% efficiency (670W) @ 75%, 65% and 55% and 2 flocculators per cell = 2,615 W

$$G = \sqrt{\frac{2 \times 670W * (0.75 + 0.65 + 0.55)}{1.002 \times 10^{-3} N \frac{s}{m^2} \times 612.5\ m^3}} = 65\ s^{-1}$$

Using the 2 L reaction flask volume and the 80 x 35 mm paddle at 20 ^{0}C, the Platypus Jar Tester manufacturer recommends between a speed of 40 RPM and a corresponding G-value of 48.1 s^{-1}, and a speed of 50 RPM and a corresponding G-value of 67.3 s^{-1}. Given the bench tester allows for speed increments of 5 RPM, hence to best approximate the G-value of 65 s^{-1} in the plant, a speed of 45 RPM was selected. A flocculation time of 20 min was selected.

7.4.1.4 Recycle Volume

In the full-scale plant, a recycle pump draws clarified water and passes it through a packed bed saturator fed with compressed air. The recycled water is fed into a DAF channel where water transitions from the 3-stage flocculation tank to the DAF basin. The DAF channel is fed at a rate between 280 and 300 L/s. The DAF saturators recycle at a flow of approximately 70 L/s, for the two DAF channels. The recycle rate for the plant was hence calculated to be:

$$DAF_{recycle,plant} = \frac{\frac{70}{2}\ L/s}{290\ L/s + \frac{70}{2} L/s} = 10.8\%$$

The jar test was performed with 2 L of sample and a recycle rate of 10% was targeted. A 10% recycle rate was achieved by decanting 200 mL from the sample port of each jar following flocculation. The volume decanted equals the volume of air saturated water to be transferred during the DAF step. The recycled water was made up with 200 mL of air saturated deionized water due to the formation of precipitates and subsequent blockages when using raw water for the recycle.

$$DAF_{recycle,bench} = \frac{200\ mL}{(2L - 200\ mL) + 200\ mL} = 10\%$$

Transfer of the saturated air was accomplished by completely opening the saturator valve into the previously primed distribution manifold. Although some larger bubbles were often observed, the jar tester manufacturer notes that this is normal and expected, as the bubbles quickly dissipated white and cloudy air saturated water into each jar at relatively equal fill rates. When unequal fill rates were observed, it was necessary to disassemble the apparatus and thoroughly clean all ports and the manifold.

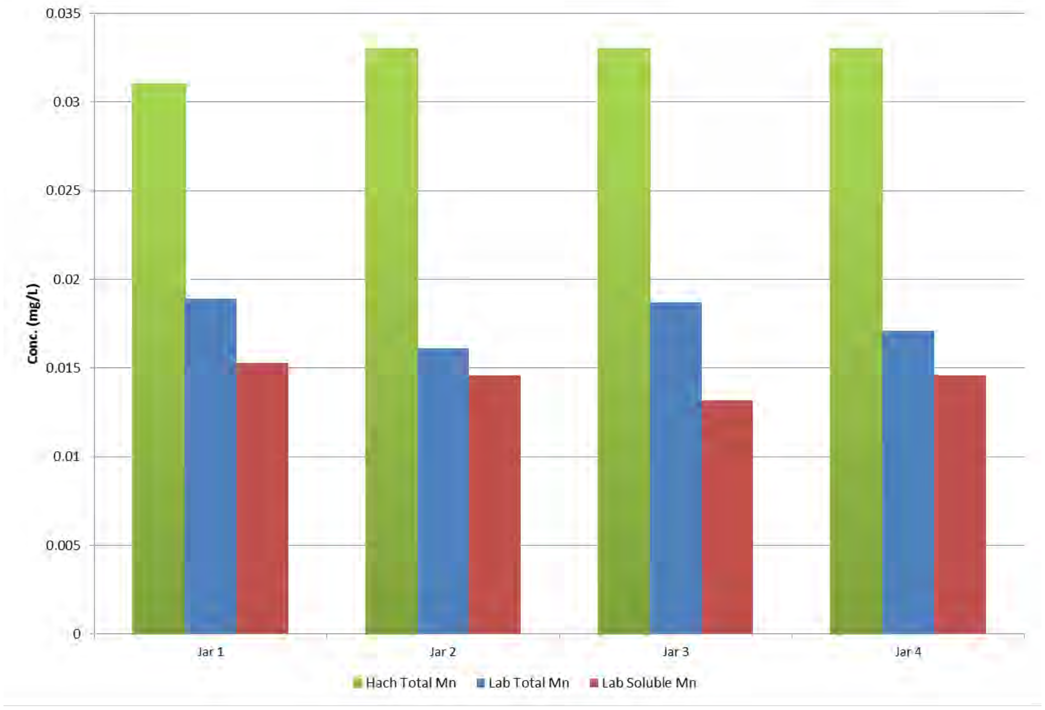
7.4.1.5 *Saturation Pressure*

In the plant, saturated air is injected inline in the DAF reaction zone to the scraper channel between 475 and 550 kPa. Initial benchtop testing was carried out at 600 kPa, matching the previous City's settings used during bench testing carried out at the plant. To more accurately match the current conditions however, a saturation pressure of 500 kPa was used for baselining and for all further trials.

7.4.1.6 Baseline Test Description and Results

The baseline test was carried out to investigate the effect of varying the coagulation dose and the flocculation time. Based on discussions with City staff, it was established from previous jar tests performed by the City that finished jar test water with turbidity levels of approximately 2 NTU and UVT of 64% was representative of the full scale. With this target in mind, WSP varied the coagulant dose and flocculation time to ±10% and ±25% of the selected dose (25 mg/L) and selected flocculation time (20 min). When the coagulant dose was 75% of the selected dose (18.75 mg/L), and the flocculation time was 75% of the selected time (15 min), the turbidity and UVT were noted to be 2.48 NTU and 63.5% respectively. Based on these values for turbidity and UVT, the 75% coagulation time and 75% coagulant dose condition was considered the most representative of the full-scale.

A jar test (4 jars) with the 75% coagulant dose and 75% flocculation time condition was repeated to determine uniformity between the jars and reproducibility. The different jars were noted to produce very similar water quality. The Mn levels in the different jars were very similar with 3% percentage standard deviation between jars for Hach Mn, and 6% between jars for Lab Total Mn and Lab Soluble Mn (Figure 7-4). The percentage standard deviation was 10% between jars for turbidity and 0.8% between jars for UVT, both as measured with bench instruments (Figure 7-5).



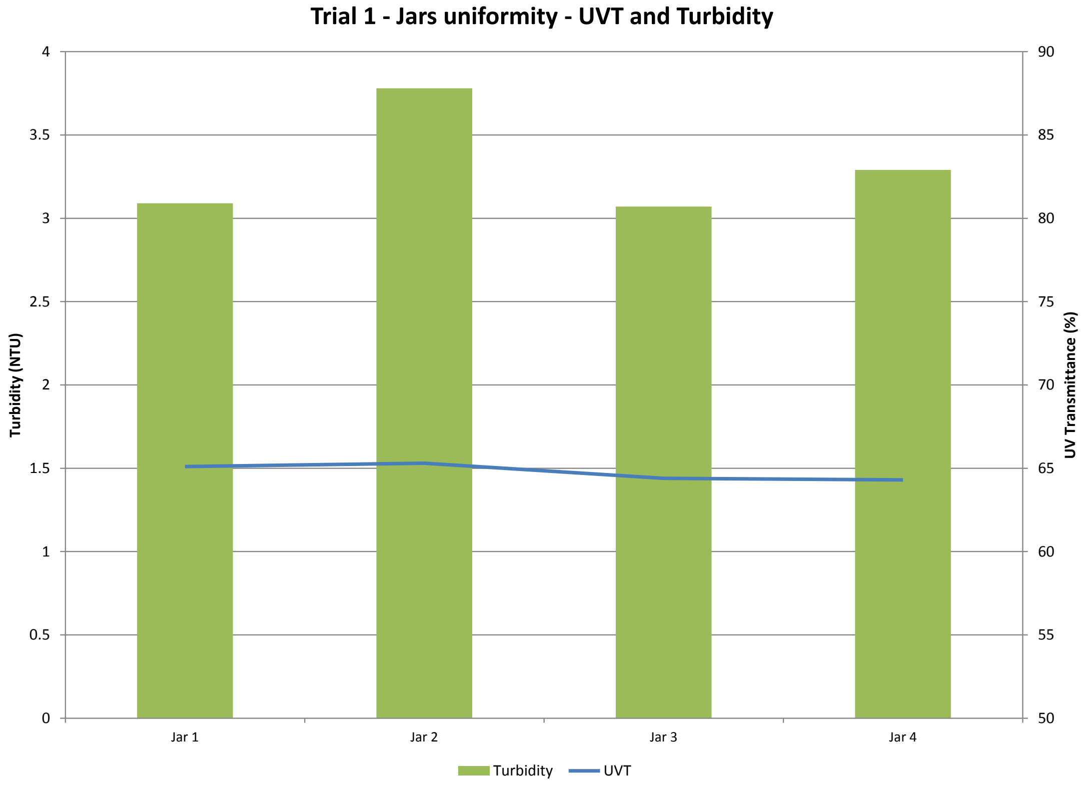


Figure 7-5 Uniformity between Jars - Turbidity, UVT

Following the baselining test, the parameters carried forward for the remaining trails are as summarized in Table 7-4.

Table 7-4 Baseline Parameters Used for All Remaining Trials

Parameters	Value
Coagulant Dose	18.75 mg/L
Flash Speed	200 RPM
Flash Time	30 s
Flocculation Speed	45 RPM
Flocculation Time	15 min
Saturation Pressure	500 kPa
DAF wait time (prior to subnatent sampling)	10 min

7.4.2 Trial 2: Optimize Coagulant Dose

7.4.2.1 Coagulant Screening

Initial bench testing was carried out with the five shortlisted coagulants. The ferric chloride is currently the coagulant used in the plant. The four other coagulants to be tested during the bench-scale testing were: ferric sulphate, a blend of ferric chloride and ferric sulphate, alum and ferric sulphate [Blend 1]; and alum and ferric sulphate [Blend 2]. Since two blends of the aluminum/ferric sulphate mix were available, the initial screening aimed to select the better performing coagulant in relation to Mn removal. For all the coagulants, the initial screening also aimed to identify the coagulant dose between 15 and 45 mg/L which yielded the lowest Mn concentrations, turbidity and highest TOC removal. The dose identified was then carried forward for dose refinement.

Initial coagulant dose screening was carried out when the raw water temperature was between 14.6 ^{0}C and 16.3 ^{0}C. The pH during the initial coagulant screening tests were maintained at the full-scale pre-DAF pH of 5.3. Results of the initial coagulant screening are presented for various parameters in Figure 7-6 to Figure 7-9.

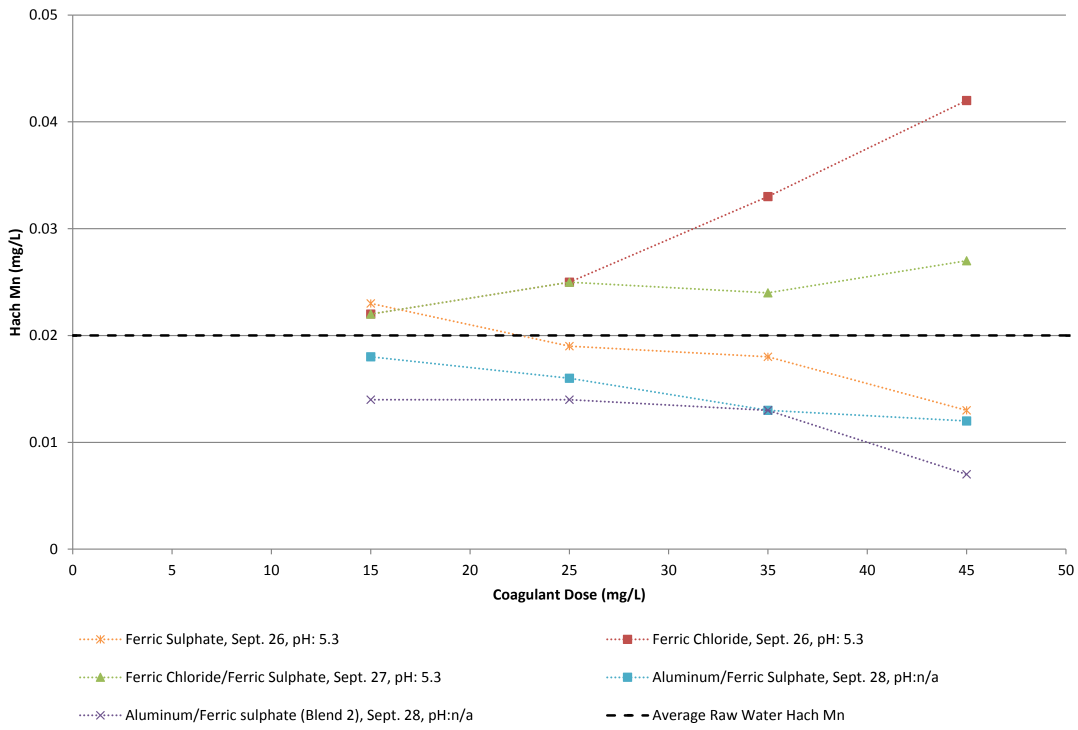


Figure 7-6 Initial Coagulant Screening - Hach Mn (No Coagulant Aid, pH full scale)

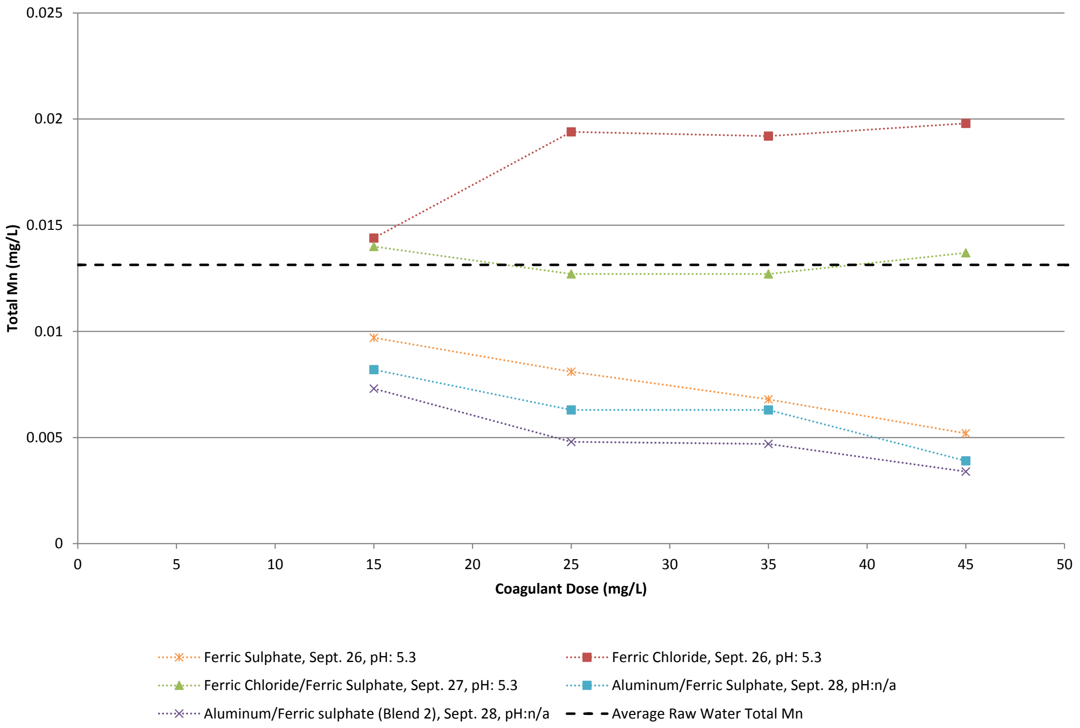


Figure 7-7 Initial Coagulant Screening - Lab Total Mn (No Coagulant Aid, pH full scale)
Note: pH data was not available for aluminium/ferric sulphate blend.

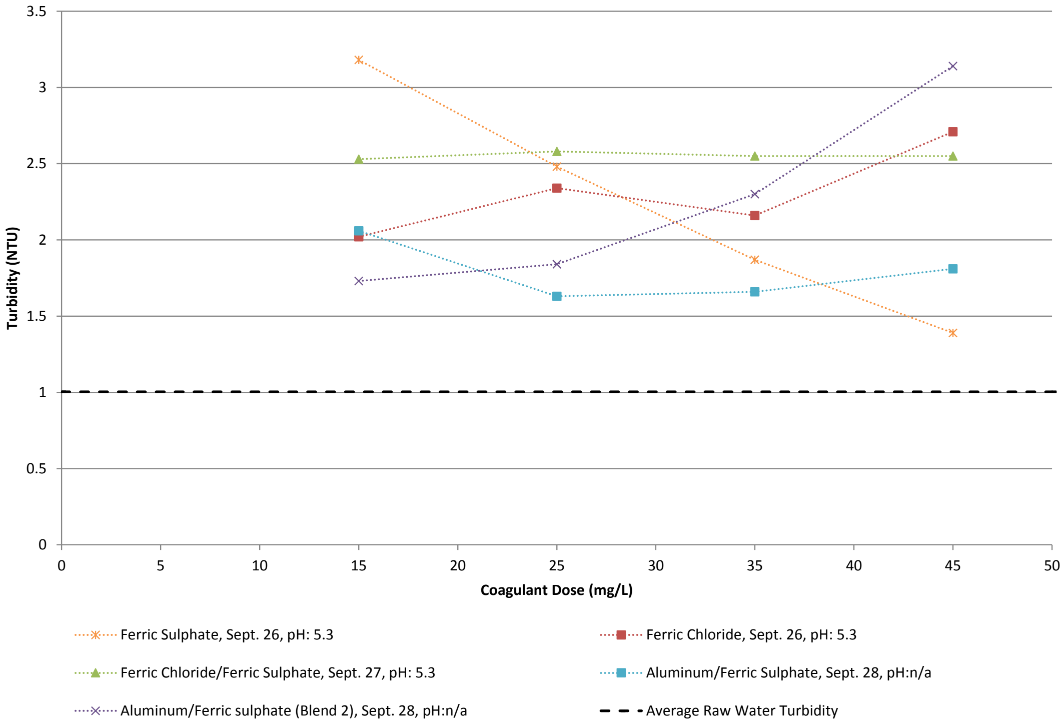


Figure 7-8 Initial Coagulant Screening - Turbidity (No Coagulant Aid, pH full scale)

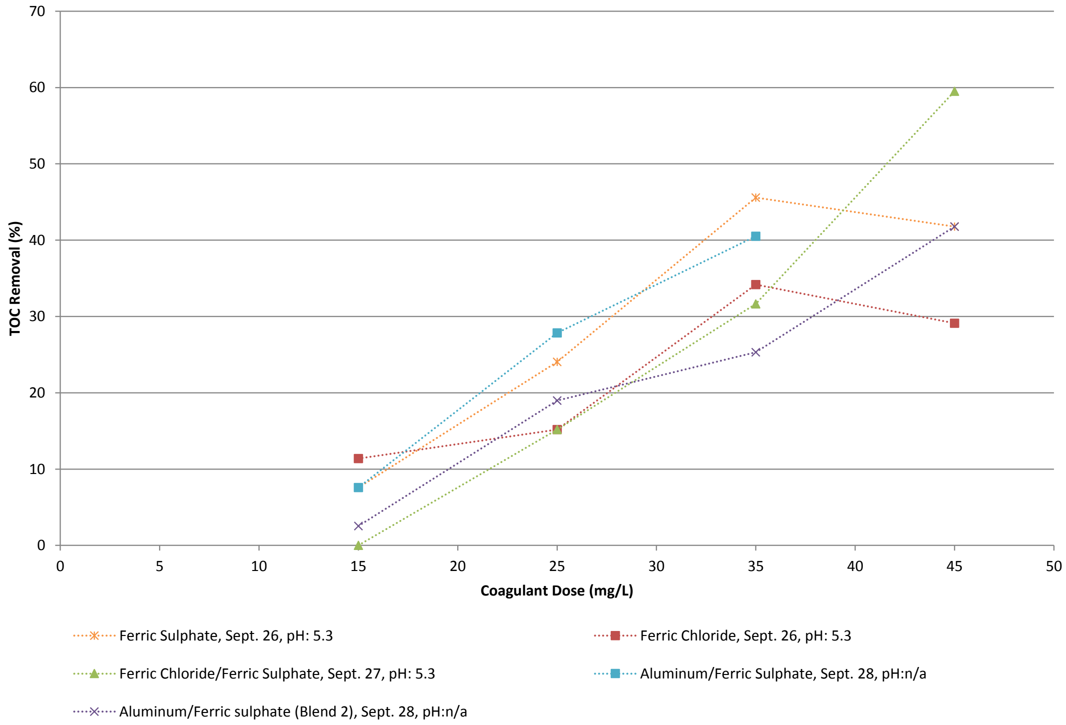


Figure 7-9 Initial Coagulant Screening - TOC Removal (No Coagulant Aid, pH full scale)
Note: A sample was reported missing for aluminum/ferric sulphate Blend 1 on Sept 28. pH data was not available for aluminium/ferric sulphate blend.

Manganese contribution from ferric chloride

When both Hach Mn and Lab Total Mn values for the initial screening were considered, it was noted that both coagulants containing ferric chloride exhibited an increase in Mn concentration with higher dose, reinforcing the theory that there is an introduction of Mn into the treatment process when coagulants containing ferric chloride are used.

Choice of aluminum/ferric sulphate compound to be tested

Following the coagulant screening, a choice was required between aluminum/ferric sulphate Blend 1 and aluminum/ferric sulphate Blend 2 as to which would be carried forward for bench testing. The aluminum/ferric sulphate Blend 2 was noted to yield lower Mn levels when both Hach Mn and Lab Total Mn values were considered. This was true for all coagulant doses. The opposite was true for TOC and turbidity, with aluminum/ferric sulphate Blend 1 yielding lower turbidity and higher TOC removal than aluminum/ferric sulphate Blend 2.

Since aluminum/ferric sulphate Blend 2 consistently exhibited lower Mn concentrations at all doses, and hence differed more from ferric sulphate (which was selected for bench testing), it was selected as the coagulant to be tested further during bench testing.

Optimal Dose Selection

The optimal dose for the coagulants was determined as the dose yielding the best combination of lowest Hach Mn, lowest Lab Total Mn, lowest turbidity and highest TOC removal. Table 7-5 summarizes the best dose concentrations as determined from the different parameters tested. Where three (3) parameters yielded a particular dose as the best concentration, that dose was selected as the optimal concentration for the dose. In cases, where a single concentration could not be determined by these parameters, UVT values were also assessed to aid the choice of concentration.

Table 7-5 Coagulant Screening: Optimizing Dose Selection

Coagulant	Best Concentration (mg/L) Resulting from Test:				Optimal Conc. Selected (mg/L)
	Based on Hach Mn	Based on Lab Total Mn	Based on Turbidity	Based on TOC	
Ferric Chloride	15	15	15	35	15
Ferric Sulphate	45	45	45	35	45
Ferric Chloride/Ferric Sulphate	15	25	15	45	40
Aluminum/Ferric Sulphate Blend 2	45	45	15	45	45

- The optimal concentration for ferric chloride, ferric sulphate and aluminum/ferric sulphate Blend 2 were easily selected as the common concentration that emerged as optimal from three of the tests.
- From 2013 to 2016, the plant's ferric chloride dosage has ranged between 25 and 35 mg/L. It is hence acknowledged that the plant cannot operate at a ferric chloride dosage of 15 mg/L. However, since the results of the jar tests determined this dosage as optimal, it was carried forward for subsequent trials.
- In the case of ferric chloride/ferric sulphate, the best concentration ranged between 15 and 45 mg/L when the three parameters above were considered, therefore UVT values were evaluated as well. The maximum UVT value was obtained at a dose of 45 mg/L, so an intermediate value of 40 mg/L was selected for refinement.

7.4.2.2 Dose Refinement

At the determined optimal dose, additional bench tests were carried out to further refine the optimal dose. Table 7-6 presents results of Mn concentrations at ±2 mg/L and ±4 mg/L of the optimal dose determined in Trial 1.

Table 7-6 Optimal dose selection

Coagulant	Best Concentration (mg/L) Resulting from Test:			Optimal Conc. Selected (mg/L)
	Based on Hach Mn	Based on Lab Total Mn	Based on Turbidity	
Ferric Chloride	13	11 / 19	13	15
Ferric Sulphate	41	41 / 43	41	41
Ferric Chloride/Ferric Sulphate	37	37 / 43	41	41
Aluminum/Ferric Sulphate Blend 2	43	43 / 49	43 / 47	43

The dose refinement jar tests were carried out on October 11, 2016 and October 13, 2016. The temperature on these two dates was 11.6 ^{0}C and 10.4 ^{0}C respectively. It was noticed that the Mn concentrations of the finished water for the same coagulant tested on the two dates varied largely (roughly 0.09 mg/L higher Mn concentrations on October 13, as noted for ferric sulphate and aluminum/ferric sulphate Blend 2 in Figure 7-10).

The raw water source which was used on October 11, 2016 for the bench testing was obtained from the feed to the pilot plant. On October 13, 2016 changes were made to the pilot plant which required shutting down this source, and the raw water source was hence replaced with one closer to the raw water entry into the plant. Since the pilot plant raw feed line is taken off of the influent raw water piping coming into the WTP, this was determined to be an acceptable alternative on site.

Since they were no changes to the bench testing procedure between these two dates, and no changes to the coagulants, it was concluded that the spike in Mn concentration resulted from higher raw water Mn concentrations. Since the raw water Mn concentration was not available for October 13, 2016, this could not be verified quantitatively.

The raw water pH on both dates (October 11 and 13) was 8.13. The pH of the finished water following the jar tests ranged between 4.3 and 5.3 during these two dates, indicating significant pH depression by all the coagulants. Finished water pH values observed for the different coagulant jar tests are noted in the legend of shown in Figure 7-10 to Figure 7-12 below.

Figure 7-10 to Figure 7-12 below show the optimal doses for the selected coagulants based on Hach Mn, Lab Total Mn, and turbidity.

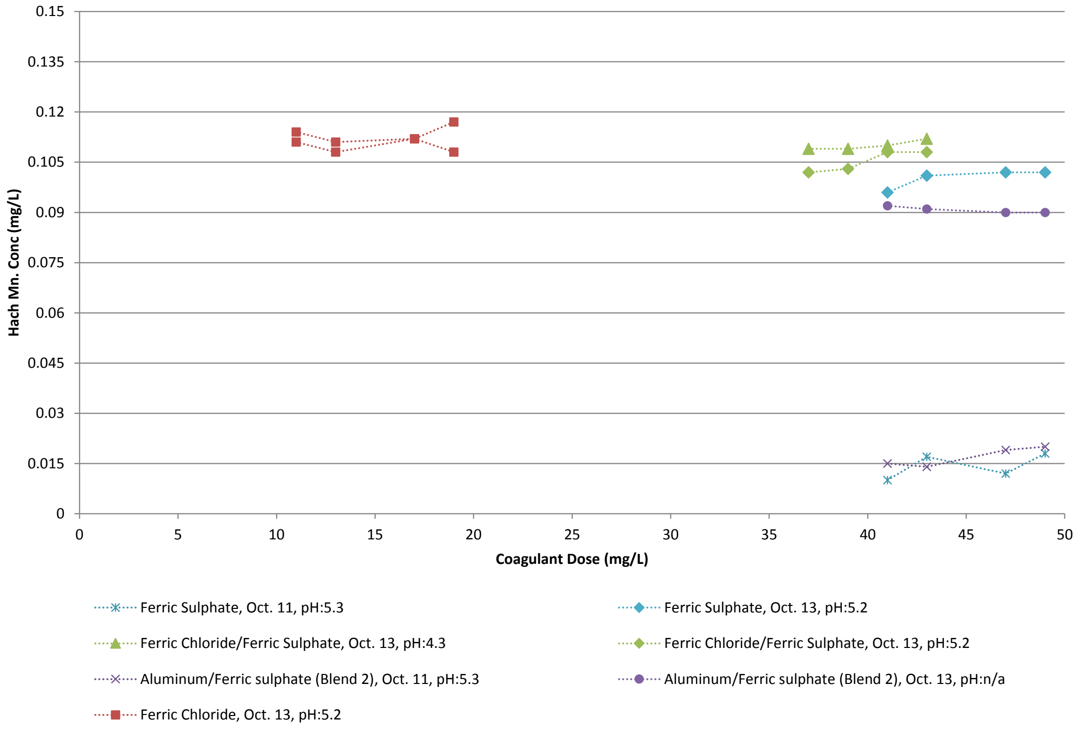


Figure 7-10 Optimal Dose Refinement (No Coagulant Aid, pH full scale) - Hach Mn

Note: A duplicate of ferric chloride and ferric chloride/Ferric Sulphate was performed on Oct 13, hence two sets of results are shown in the gr

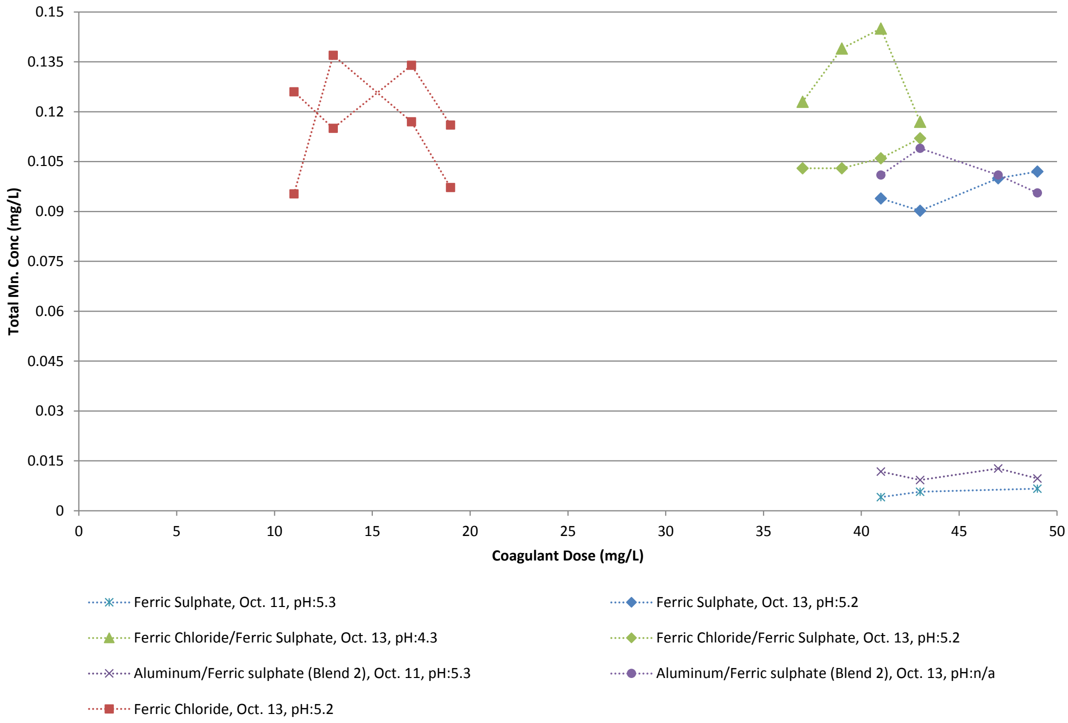


Figure 7-11 Optimal Dose Refinement (No Coagulant Aid, pH full scale) – Lab Total Mn
Note: pH data was not available for aluminium/ferric sulphate blends.

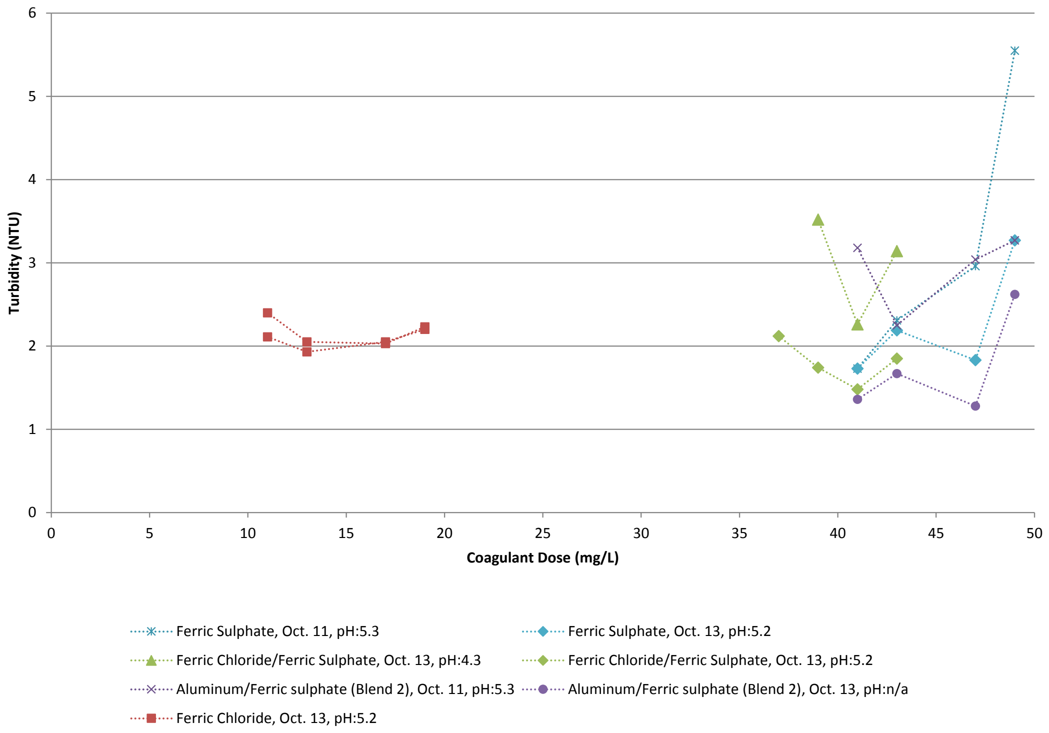


Figure 7-12 Optimal Dose Refinement (No Coagulant Aid, pH full scale) – Turbidity
Note: pH data was not available for aluminium/ferric sulphate blends.

The optimal doses for the selected coagulants based on Hach Mn, Lab Total Mn, and turbidity are summarized in Table 7-6 above.

The rationale for selection of optimal dose for the coagulants are summarized below:

- Ferric Chloride: The optimal dose ranged between 11 mg/L and 19 mg/L, so an intermediate dose of 15 mg/L was selected.
- Ferric Sulphate: The optimal dose in all trials was 41 mg/L (except for a dose of 43 mg/L in one of the duplicate Lab Total Mn data), so 41 mg/L was selected as the optimal dose.
- Ferric Chloride/Ferric Sulphate: The best dose varied between 37 mg/L and 43 mg/L so an intermediate dose of 41 mg/L was selected
- Aluminum/Ferric Sulphate Blend 2: In each trial at least one of the doses which emerged as optimal was 43 mg/L so this was selected as the dose to be carried forward.

7.4.3 Trial 3: pH Optimization

Bench tests were performed to evaluate the optimal pH for each coagulant. Based on the protocol identifying typical pH ranges for these coagulants, pH ranges of 5 to 6 were investigated for the Ferric based coagulants, while pH ranges of 5.5 - 6.5 were investigated for the aluminum based coagulant. The pH was altered by addition of sulphuric acid.

Results for changes observed in Hach Mn concentrations, Lab Total Mn concentrations, turbidity and UVT are presented in Figure 7-13 to Figure 7-16.

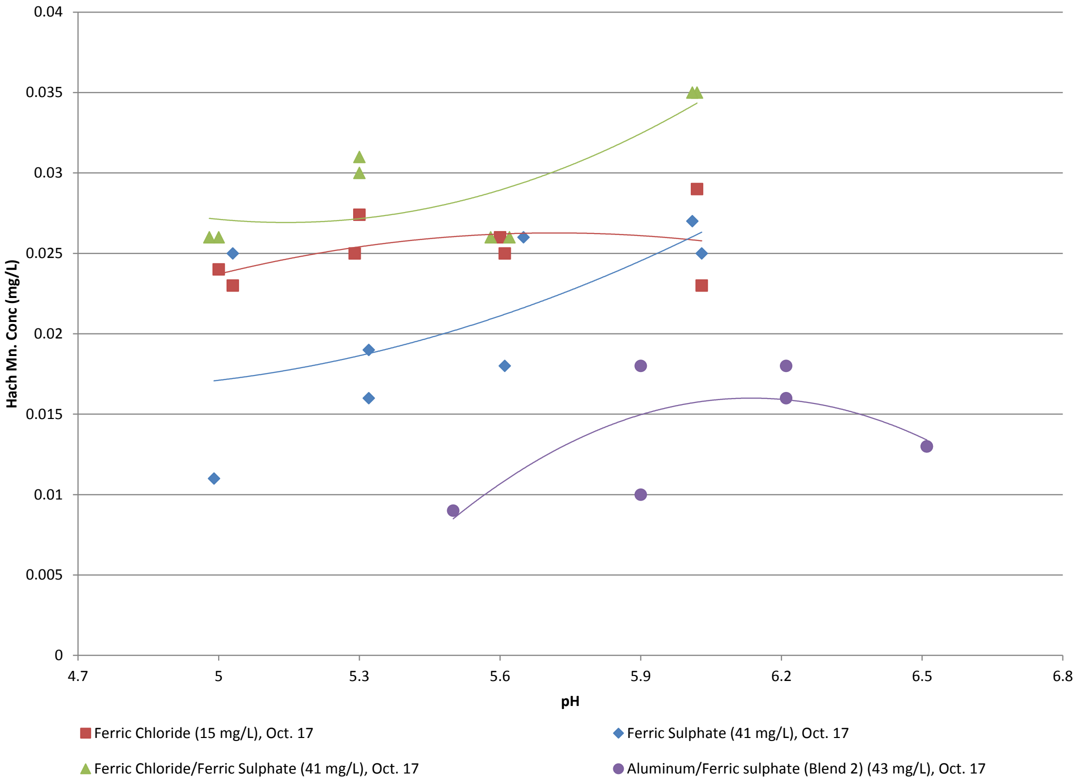


Figure 7-13 Trial 3 - pH Optimization (No Coagulant Aid) – Hach Mn

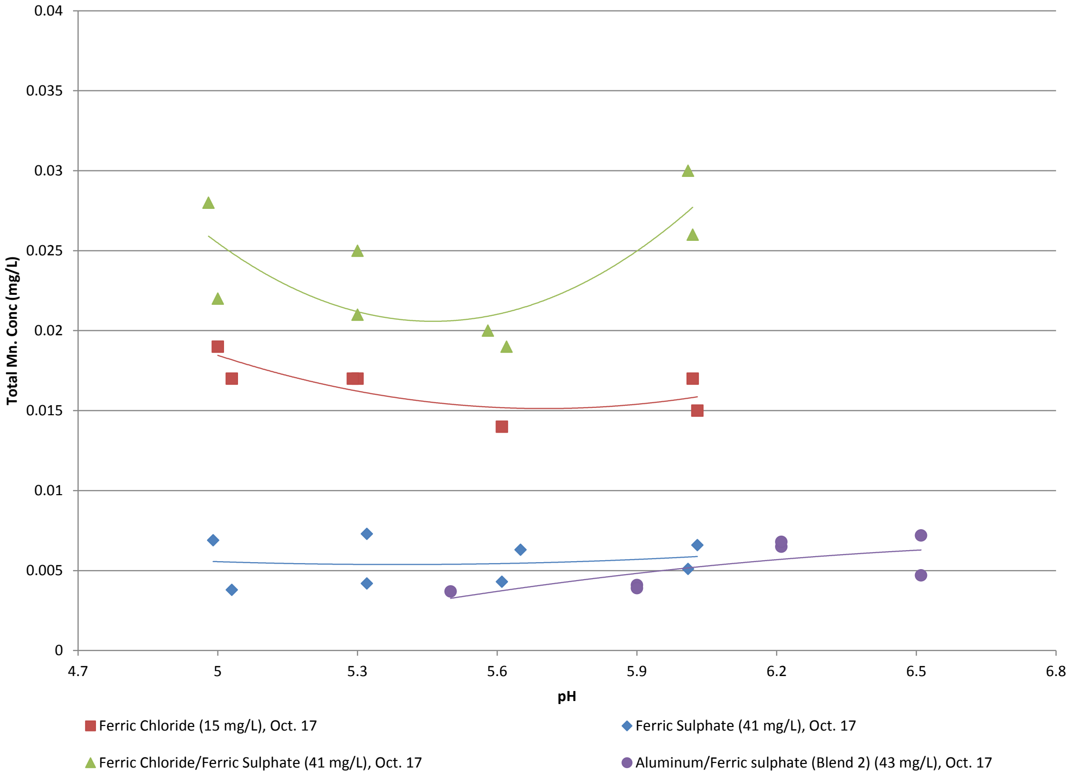


Figure 7-14 Trial 3 - pH Optimization (No Coagulant Aid) – Lab Total Mn

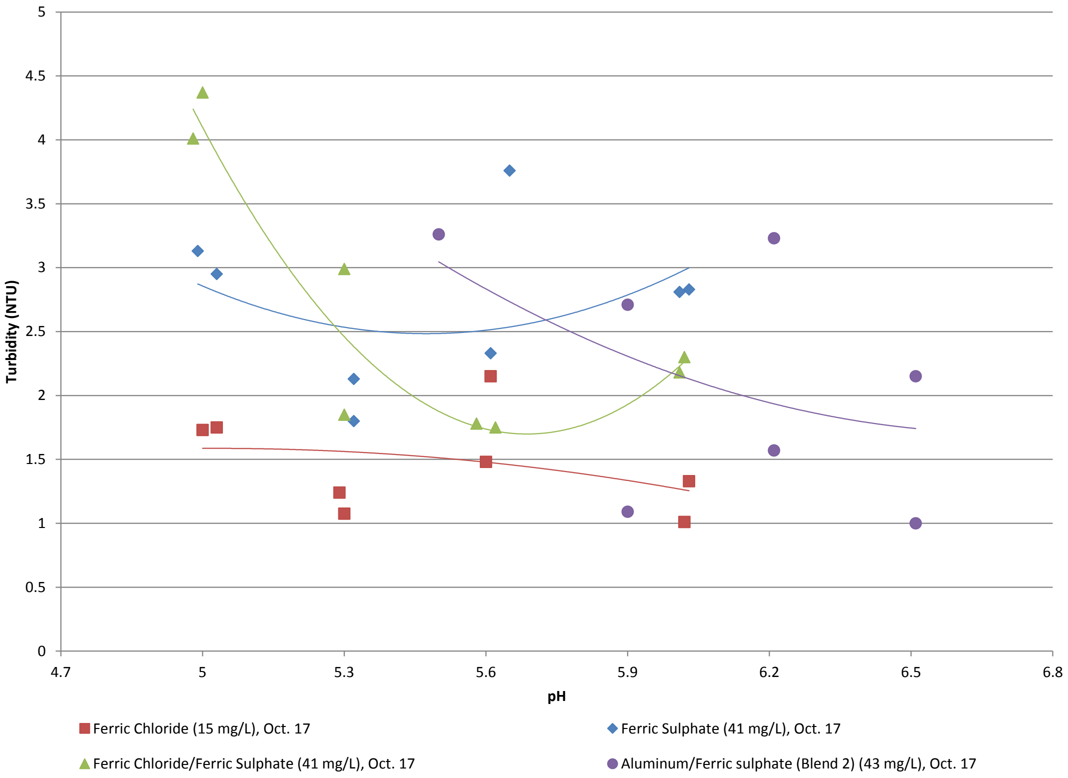


Figure 7-15 pH Optimization (No Coagulant Aid) – Turbidity

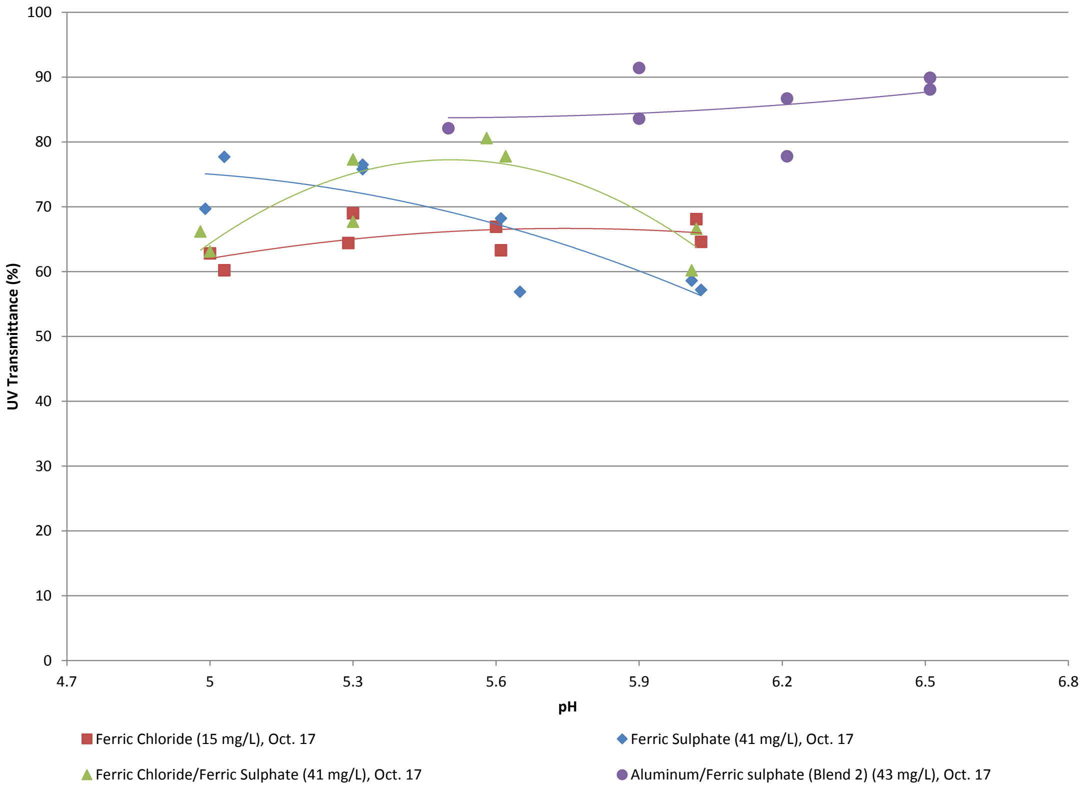


Figure 7-16 pH Optimization (No Coagulant Aid) – UVT

The optimal pH based on the four parameters: Hach Mn, Lab Total Mn, turbidity and UVT were selected as follows: the pH yielding the lowest Mn concentration or turbidity was shortlisted as the pH of choice. pH ranges tested above the pH of choice were evaluated. If the difference in Mn concentration/turbidity between the pH of choice and a higher pH was less than 10%, the higher pH was chosen. With this rational, the optimal pH yielding best Mn/turbidity or a higher pH yielding similar results was selected. The decision to explore higher pH values with similar results, accounted for inherent variances in the pH observed, and favored conditions where less acid and subsequent buffering would be required.

The best pH value bases on these three parameters are presented in Table 7-7.

Table 7-7 Optimal pH selection

Coagulant	Best pH Resulting from Test:				Optimal pH Selected
	Based on Hach Mn	Based on Lab Total Mn	Based on Turbidity	Based on UVT	
Ferric Chloride	5 / 6	6	6	5.3	5.3
Ferric Sulphate	5	6	5.3	5.3	5.3
Ferric Chloride/Ferric Sulphate	5.6	5.6	5.6	5.6	5.6
Aluminum/Ferric Sulphate Blend 2	5.5	5.5	6.5	6.5	6.5

The rationale for selection of optimal pH for the coagulants are presented below:

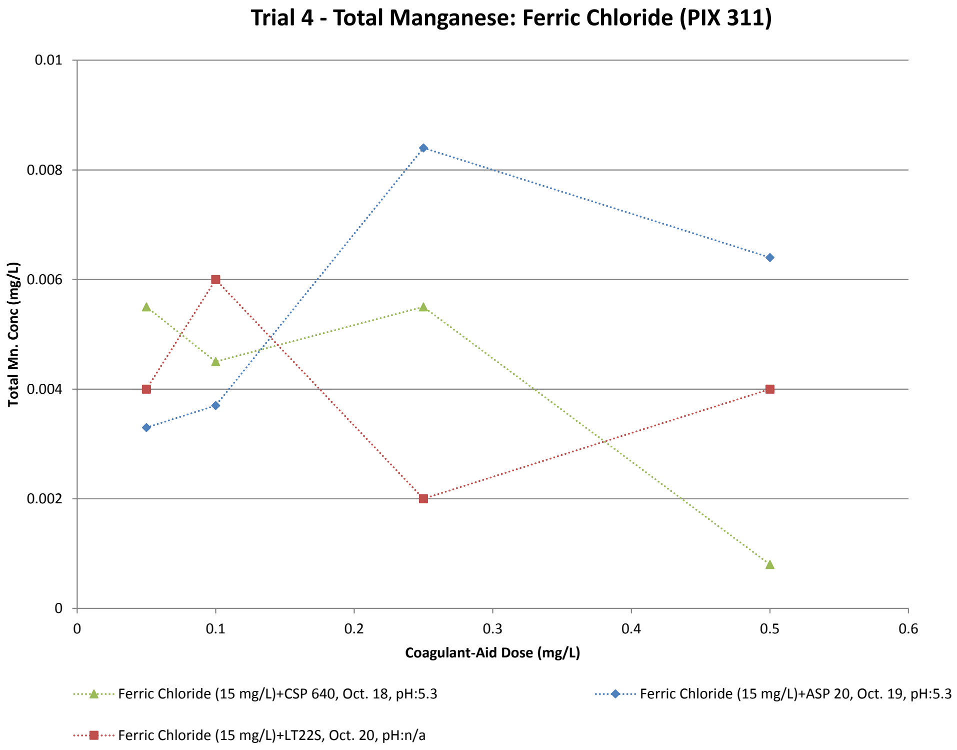
- Ferric Chloride: The optimal pH based on Hach Mn and Lab Total Mn ranged between 5 and 6. Turbidity and UVT suggested an optimal pH of 5.3 or 6. An intermediate value of 5.3 was selected.
- Ferric Sulphate: The optimal pH based on Hach Mn and Lab Total Mn was between 5 and 6. Turbidity and UVT both yielded an optimal pH of 5.3 so this was selected for further testing.
- Ferric Chloride/Ferric Sulphate: pH of 5.6 was the best pH considering Hach Mn, Lab Total Mn Turbidity and UVT and was hence deemed as the optimal pH.
- Aluminum/Ferric Sulphate Blend 2: The optimal pH considering Hach Mn and Lab Total Mn was 5.5, while the optimal pH considering Turbidity and UVT was 6.5. The higher pH of 6.5 was selected for further testing.

No further pH refinement was carried out, and the optimal pH identified for each coagulant in this trial was carried forward for subsequent investigations.

7.4.4 Trial 4: Coagulant-Aid Optimization

Each coagulant was tested with the three selected coagulant-aids identified in Table 7-1 at the optimal coagulant dose determined in Trial 2, and the optimal pH determined in Trial 3. The coagulant-aid optimization tests were carried out on October 19, 2016 and October 20, 2016. During these two days, the raw water Mn concentrations (Lab Total Mn) were noted to vary significantly from 0.0056 mg/L on October 19, 2016 to almost double this concentration (0.01 mg/L) on October 20, 2016. All Mn concentrations were hence corrected to the raw water concentration by subtracting the measured raw water Mn concentration from the jar test concentration. Turbidity was also considered and raw water corrected.

Figure 7-17 to Figure 7-24 present the Lab Total Mn concentrations and turbidity values for the tested coagulants as the dose of the coagulant-aids were altered.



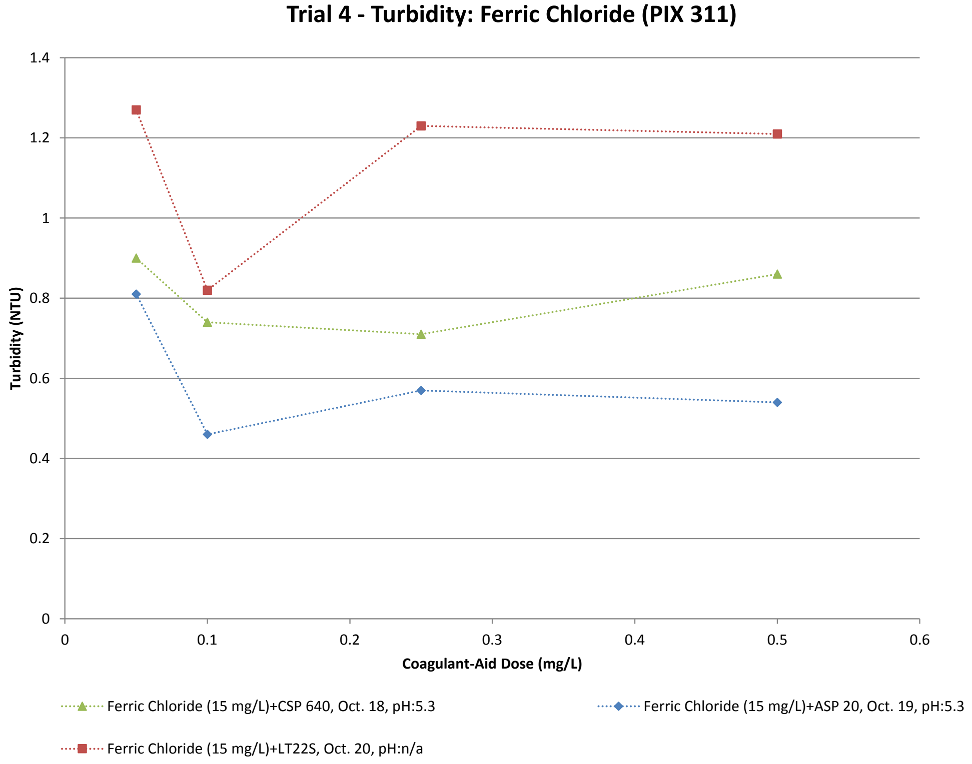


Figure 7-18 Coagulant Aid Optimization: ferric chloride – Turbidity

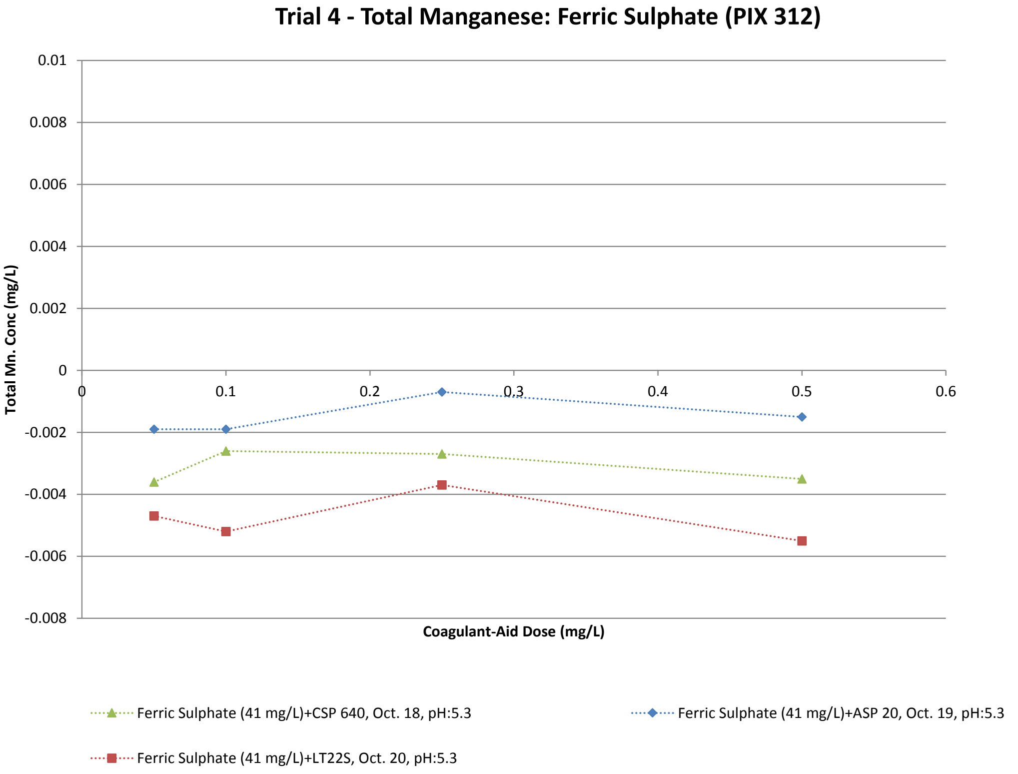


Figure 7-19 Coagulant Aid Optimization: ferric sulphate –Δ Total Mn (Final - Raw Water Mn)

Note: Negative values of ΔTotal Mn indicate that the Final Mn < Raw Mn due to removal by the coagulant & coagulant-aid.

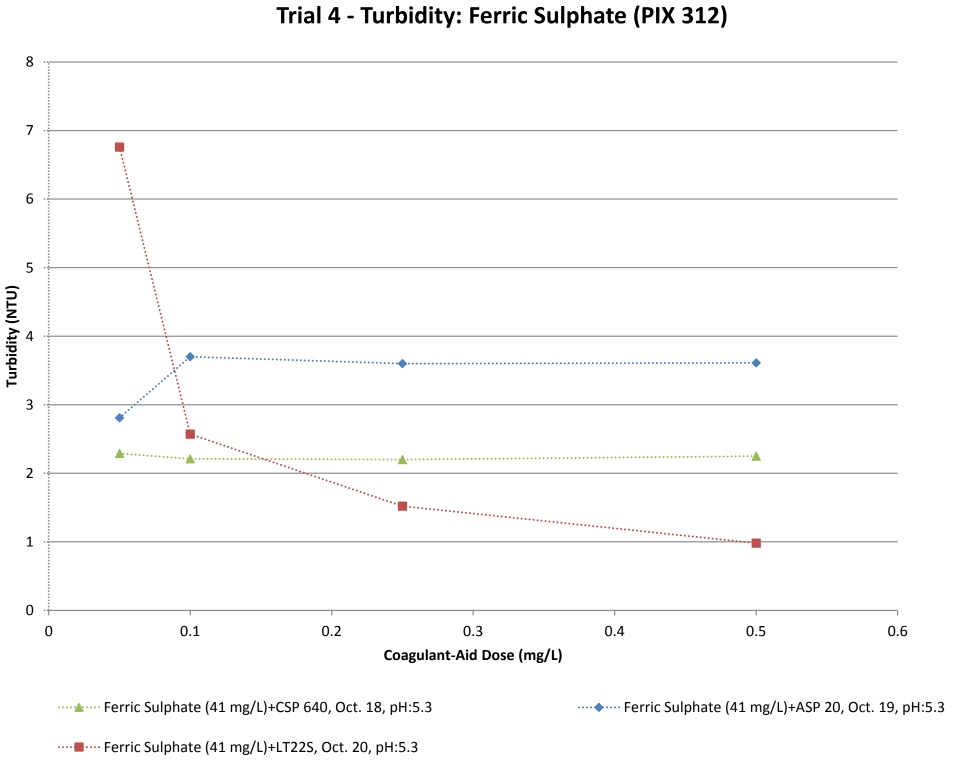
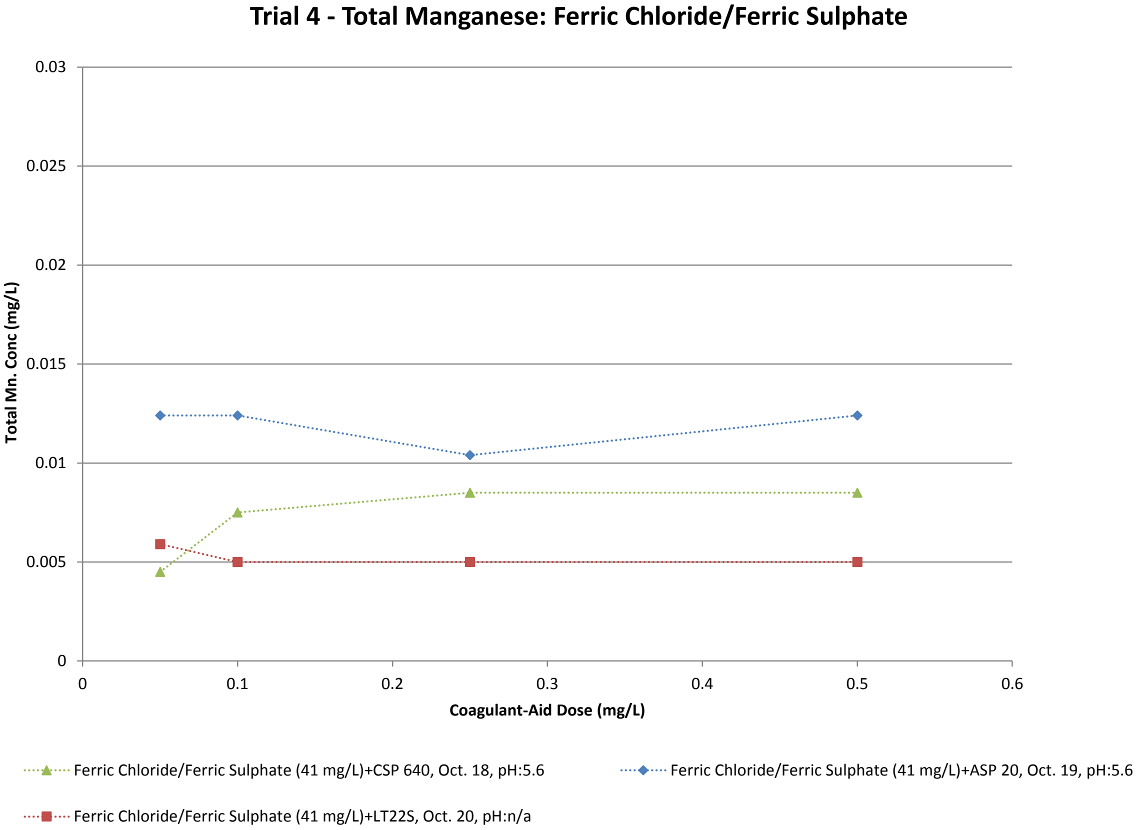


Figure 7-20 Coagulant Aid Optimization: ferric sulphate – Turbidity



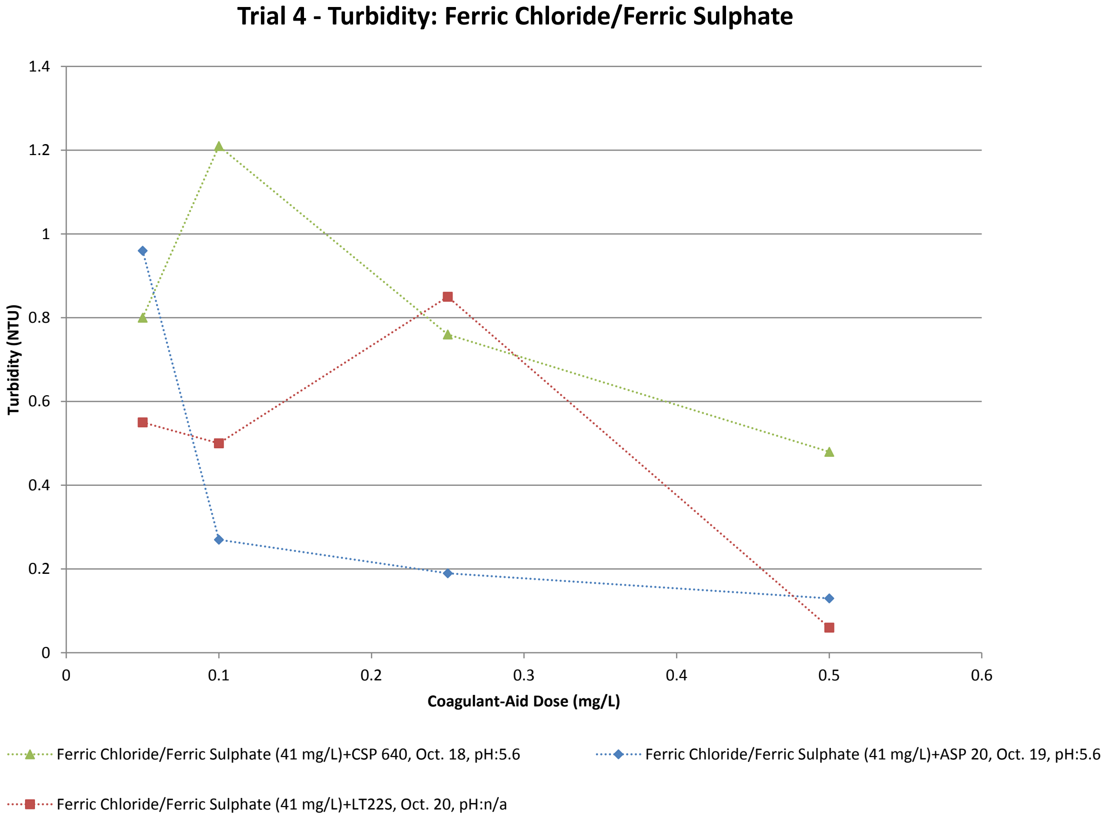


Figure 7-22 Coagulant Aid Optimization: ferric chloride/Ferric Sulphate – Turbidity

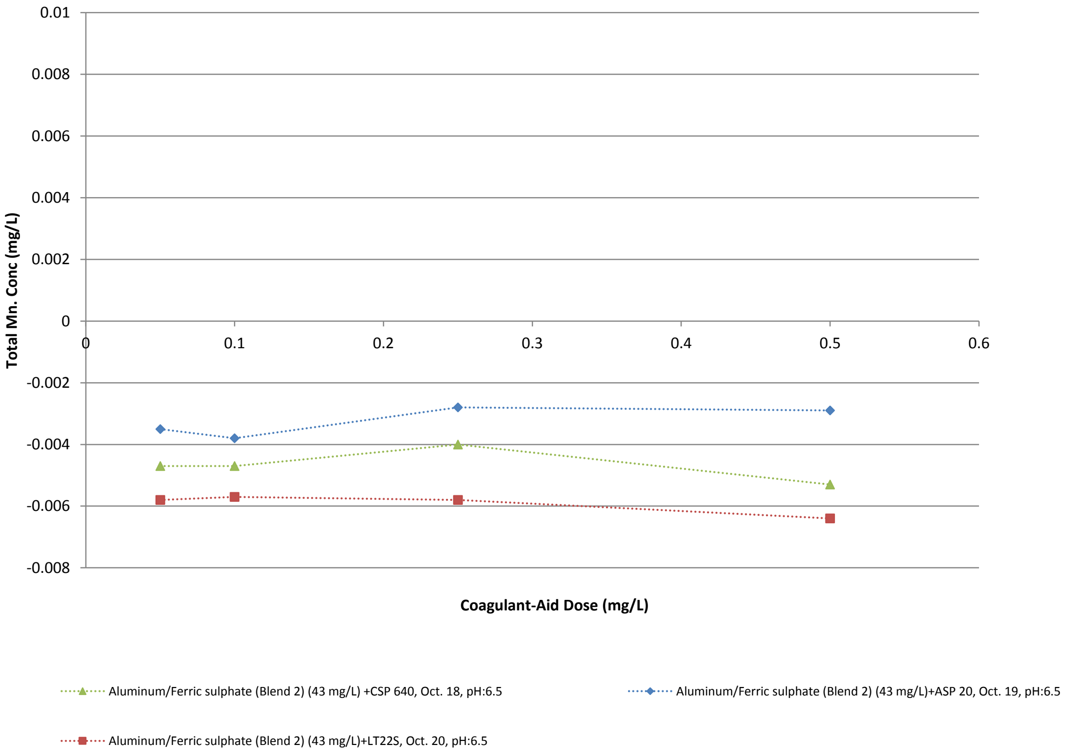


Figure 7-23 Coagulant Aid Optimization: aluminum/ferric sulphate Blend 2 – Δ Total Mn (Final-Raw Water Mn)

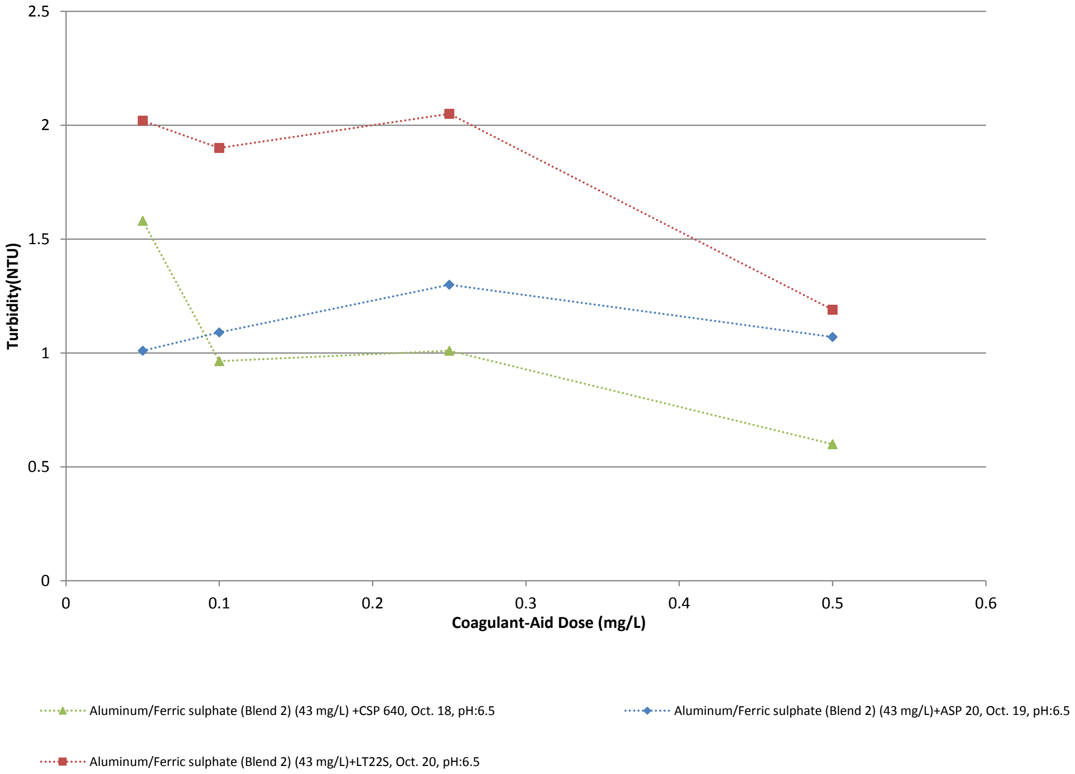


Figure 7-24 Coagulant Aid Optimization: aluminum/ferric sulphate Blend 2– Turbidity

The best coagulant-aids and their optimal dosages corresponding to each coagulant based on Lab Total Mn and turbidity are summarized in Table 7-8:

Table 7-8 Optimal Coagulant-aid Selection

Coagulant	Optimal Coagulant-aid based on Lab Total Mn	Corresponding Optimal Conc. of Coagulant-aid (mg/L)	Optimal Coagulant-aid based on Turbidity	Optimal Coagulant-Aid Selected
Ferric Chloride	CSP-640	0.5	ASP-20	CSP-640
Ferric Sulphate	LT-22S	0.5	LT-22S	LT-22S
Ferric Chloride/Ferric Sulphate	LT-22S	0.5	LT-22S	LT-22S
Aluminum/Ferric Sulphate Blend 2	LT-22S	0.5	CSP-640	CSP-640

**With the exception of ferric chloride, the corresponding optimal coagulant-aid dose when turbidity was considered was 0.5 mg/L. For ferric chloride, the ASP-20 optimal concentration was 0.1 mg/L.*

The rationale for selection of the optimal coagulant-aid is presented below:

- Ferric chloride: The best coagulant-aid relating to Mn removal was CSP-640, and it was noted to have an optimal removal at a concentration of 0.5 mg/L. At this concentration, ASP-20 was observed to be the best coagulant when turbidity was considered. However, since ASP-20 had a rather high Mn concentration (0.0064 mg/L) at a coagulant-aid concentration of 0.5 mg/L, the optimal coagulant-aid selected was CSP-640.
- Ferric Sulphate: When Mn removal was evaluated, LT-22S was the coagulant-aid with highest removal at a concentration of 0.5 mg/L. Turbidity was also lowest with LT-22S at 0.5 mg/L, confirming the choice of coagulant-aid.
- Ferric Chloride/Ferric Sulphate: LT-22S yielded the lowest Mn concentration. A coagulant-aid concentration of 0.5 mg/L was selected as optimal, though lower concentrations could also be considered with similar Mn removal. At a concentration of 0.5 mg/L, LT-22S was also the best coagulant-aid in reducing turbidity.
- Aluminum/Ferric Sulphate Blend 2: The best performing coagulant-aid in lowering Mn concentration was LT-22S. At the selected concentration of 0.5 mg/L however, CSP-640 lowered turbidity 0.6 NTU lower than LT-22S. At the same time, CSP-640 was noted to yield a Mn concentration of only 0.0011 mg/L more than the Mn concentration with LT-22S at a dose of 0.5 mg/L of coagulant-aid. Consequently CSP-640 was selected as the coagulant-aid of choice.

7.4.5 Trial 5: No Coagulant

Under no coagulant, no coagulant-aid conditions, jar tests were undertaken to evaluate the effect of pH variations on Mn concentrations and on TOC. Trial 5 was carried out on October 19, 2019 when the raw water temperature was 9.5 ^{0}C. The pH was varied between 5 and 6.5 and Mn concentrations and TOC were monitored.

It was noticed that both Hach Mn and Lab Total Mn decreased with an increase in pH suggesting higher pH values favored Mn precipitation. TOC changed slightly between the jars ranging between 9.5 and 10.6 mg/L as illustrated in Figure 7-25.

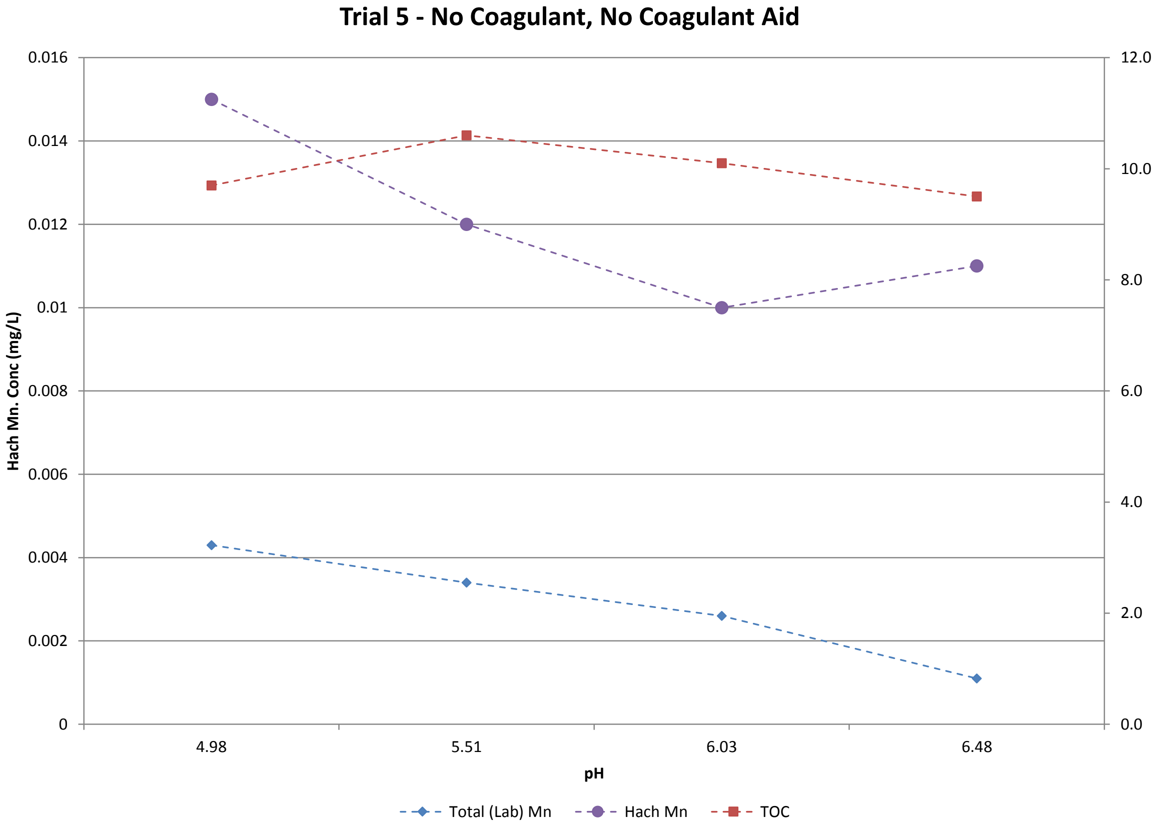


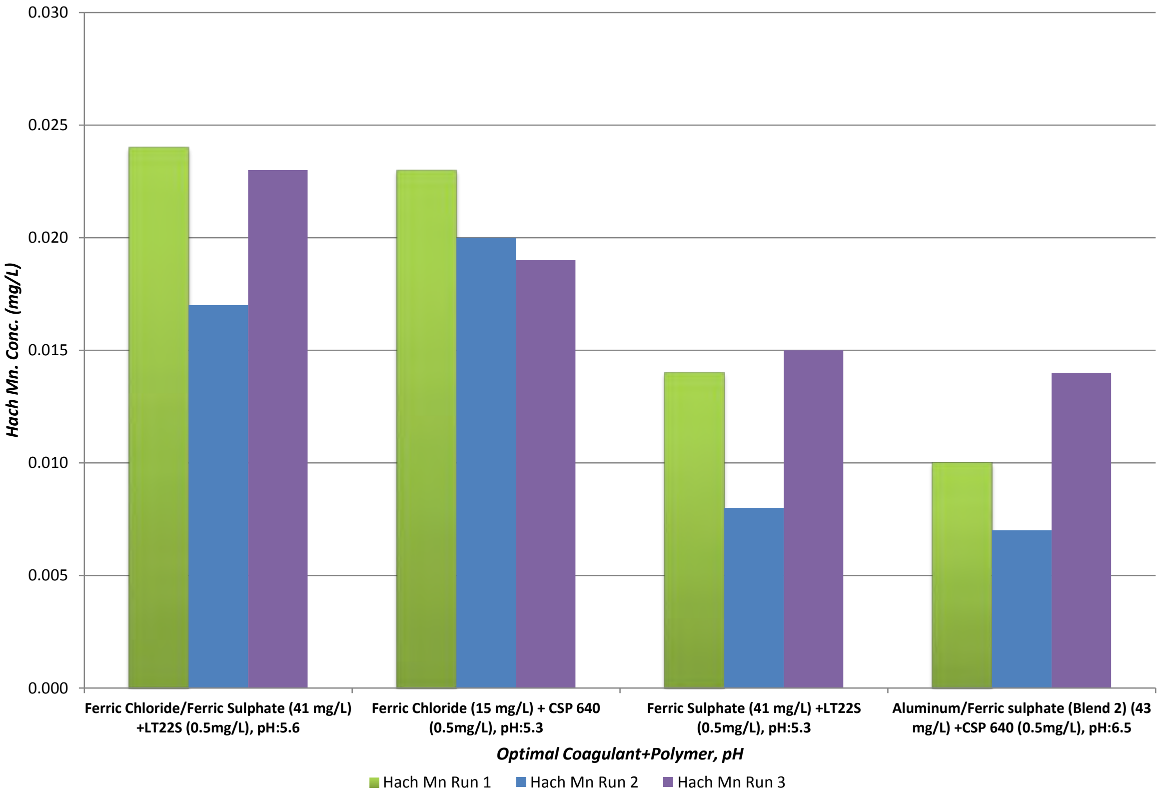
Figure 7-25 Trial 5: No Coagulant, No Coagulant-Aid

7.4.6 Trial 6: Optimal Conditions

Upon identifying the best combination of: coagulant and coagulant-aid (at the respective optimal concentrations), and the best pH at which the coagulant operated, the four best combinations were tested again side by side. This test ensured that each of the alternatives was tested on the same raw water and was reproducible (conducted in triplicate) with the aim of identifying the combination that would be pilot tested.

The results from Hach Mn and Lab Total Mn for each of the four alternatives tested are plotted in Figure 7-26 and Figure 7-27. Since the initial Manganese Baseline test suggested that the Hach Mn values were only good for screening, the Lab Total Mn values in this case are relied on more. The following observations are made:

- Good precision is obtained with the Lab Total Mn values indicating good replicability.
- The Mn values with ferric sulphate and aluminum/ferric sulphate Blend 2 are lower than corresponding Mn values with ferric chloride and ferric chloride/ferric sulphate for all trials performed.
- The Hach Mn, though not very accurate quantitatively, yield the same conclusions.



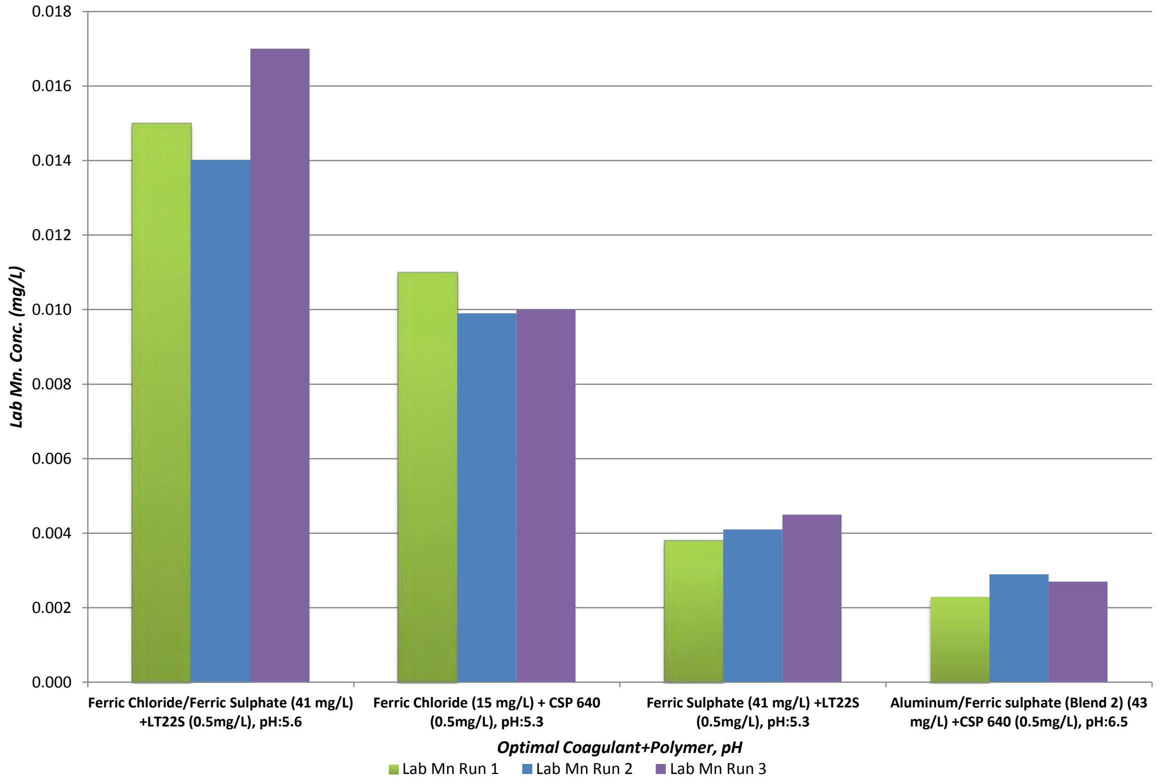


Figure 7-27 Optimal Conditions: Lab Total Mn

TOC values were also compared between the different combinations. The data is presented in Figure 7-2

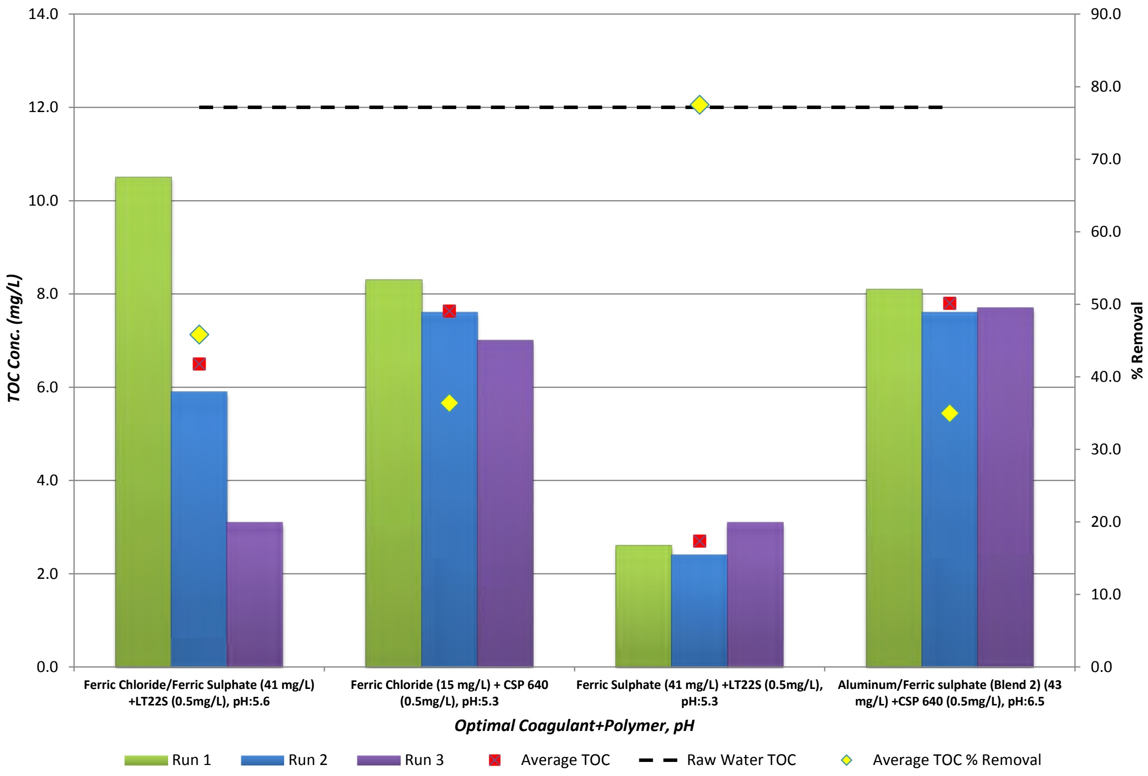
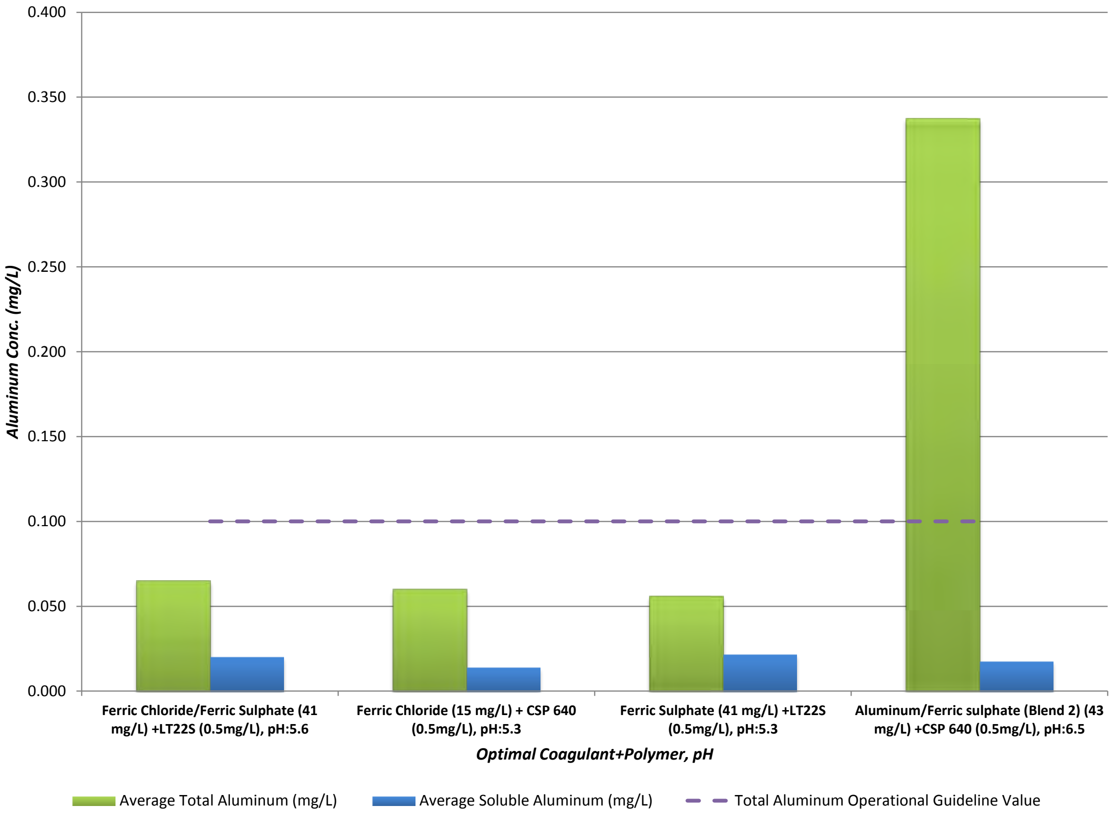


Figure 7-28 Optimal Conditions: TOC Data

Considering the TOC data, it is observed that from all the coagulants, ferric sulphate yields the lowest TOC (and consequently highest TOC removal) with a final average TOC of 2.7 mg/L. The average TOC value for aluminum/ferric sulphate Blend 2 which also yielded low Mn concentration, was much higher at 7.8 mg/L.

Data for the aluminum and iron concentrations following the jar tests are presented in Figure 7-29 and Figure 7-30.



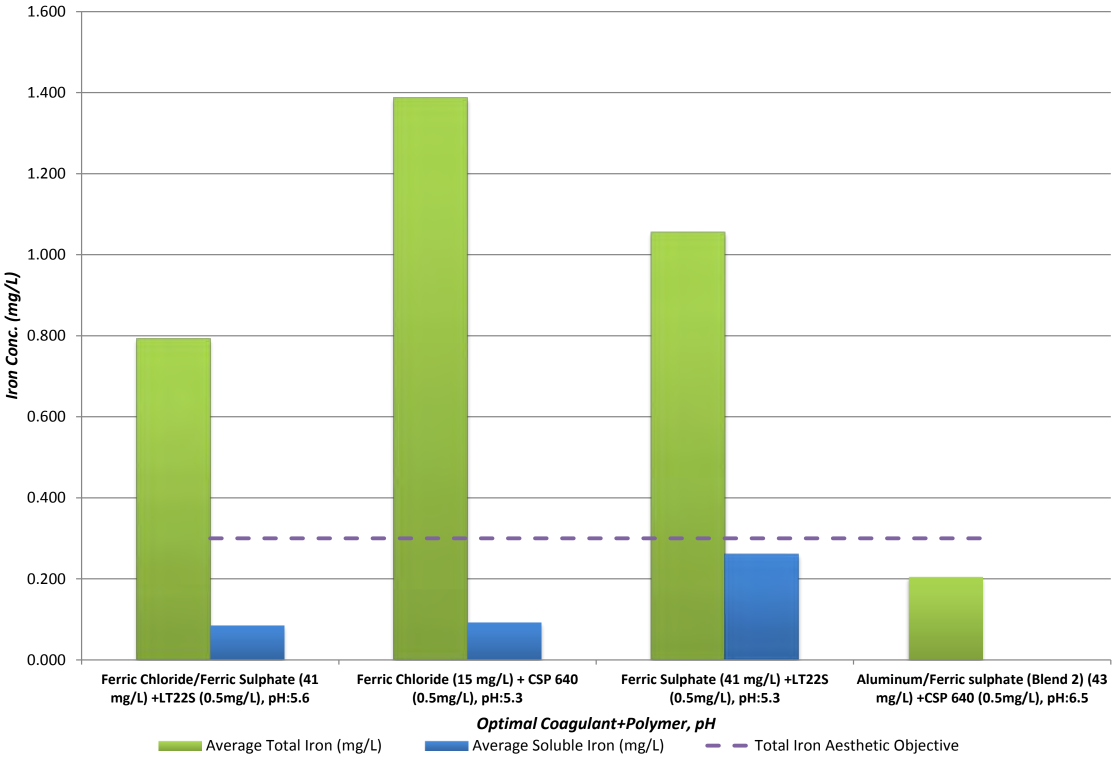


Figure 7-30 Optimal Conditions: Iron

As expected, there is significant aluminum content added to the water when the aluminum/ferric sulphate Blend 2 coagulant is used, and the aluminum concentration exceeds the Operational Guidance Value of 0.1 mg/L. Similarly, the iron concentrations exceed the Aesthetic Objective of 0.3 mg/L when the three Ferric based coagulants are used. Note that results reflect total metal content (i.e. samples were not filtered prior to analysis).

In both cases however, most of the aluminum and iron were in the particulate form which should be retained by the filters. It should be noted however that the additional particulates can impact the filter run and the backwash water quality. No results of Total Suspended Solids (TSS) were available to quantify the overall impact of particles.

7.4.7 Trial 7: Optimizing Mixing Time and Applied Energy

A series of jar tests were performed to evaluate the impact of changes to mixing durations and intensities, on one chemical combination. Changes of –50% to +50% from the previously utilized values for rapid mix and coagulation mixing time and intensity were evaluated. This test was aimed at determining whether process changes may be appropriate to improve the efficiency of the alternative coagulant.

Mixing time and applied energy was investigated using only the following coagulant, coagulant-aid and pH combination: aluminum/ferric sulphate Blend 2 (43 mg/L) + CSP 640 (0.5 mg/L), pH 6.5. The coagulant aluminum/ferric sulphate Blend 2 Blend 2 was selected for these tests because it had produced the best results in the bench tests. Previous tests were all carried out using the following baselined parameters which represent the full-scale plant:

- Flash Speed: 200 rpm
- Flash Time: 30 s
- Coagulation Speed: 45 rpm
- Coagulation Time: 15 min
- Saturation Pressure: 500 kPa
- DAF clarification time: 10 min

During the mixing time and applied energy tests, the saturation pressure and DAF clarification time were not altered. The applied energy and mixing time parameters investigated are summarized in Table 7-9.

Table 7-9 Applied Energy and Mixing Time Parameters

	Mixing Energy Designation	Flash Speed	Flash Time	Flocculation Speed	Flocculation Time
Jar 1	-50%	100 rpm	15 s	25 rpm	7.5 min
Jar 2	-25%	150 rpm	25 s	35 rpm	12 min
Jar 3	+25%	200 rpm	40 s	55 rpm	18.75 min
Jar 4	+50%	200 rpm	45 s	70 rpm	22.5 min

The Hach Mn, Lab Total Mn, TOC, turbidity and UVT data obtained during the four tests are presented in Figure 7-31 to Figure 7-35.

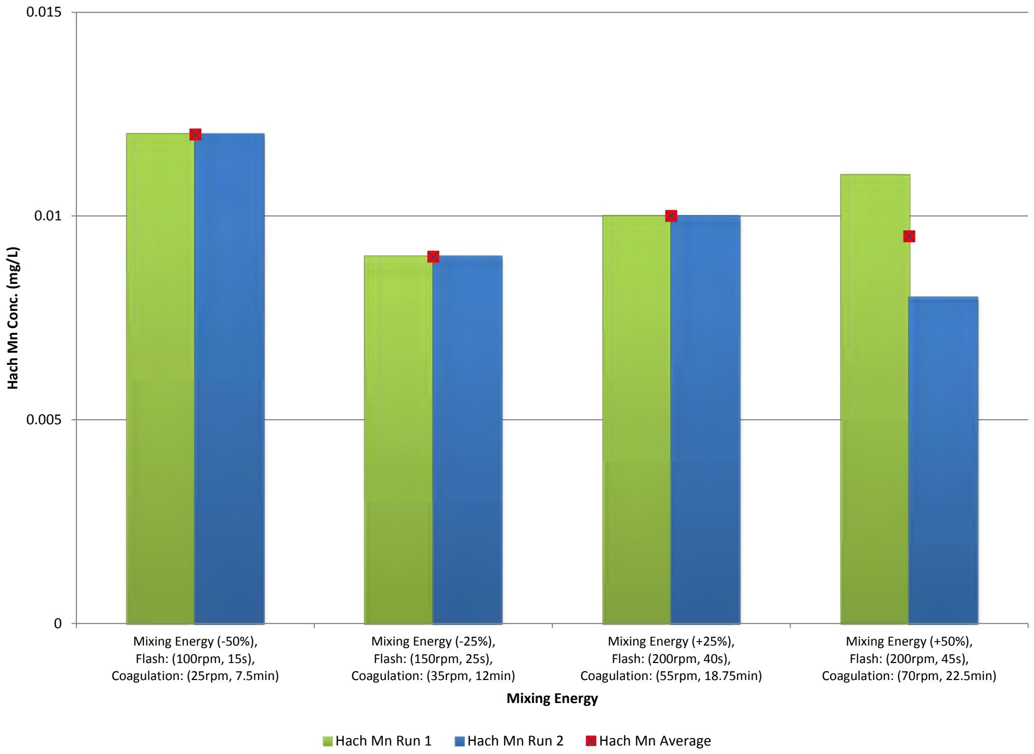


Figure 7-31 Applied Energy and Mixing Time - Hach Mn

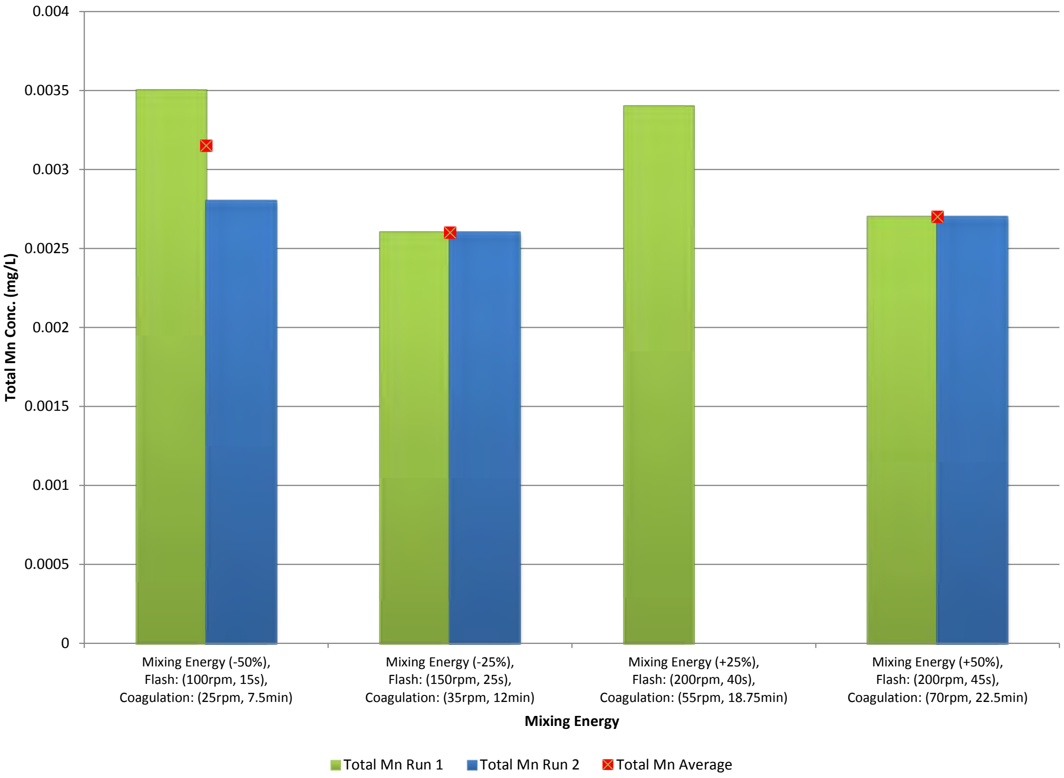


Figure 7-32 Applied Energy and Mixing Time – Lab Total Mn

Note: A value of 0.92 mg/L Total Mn was recorded for Mixing Energy (+25%) Run 2. This was considered an outlier and is not shown on the graph.

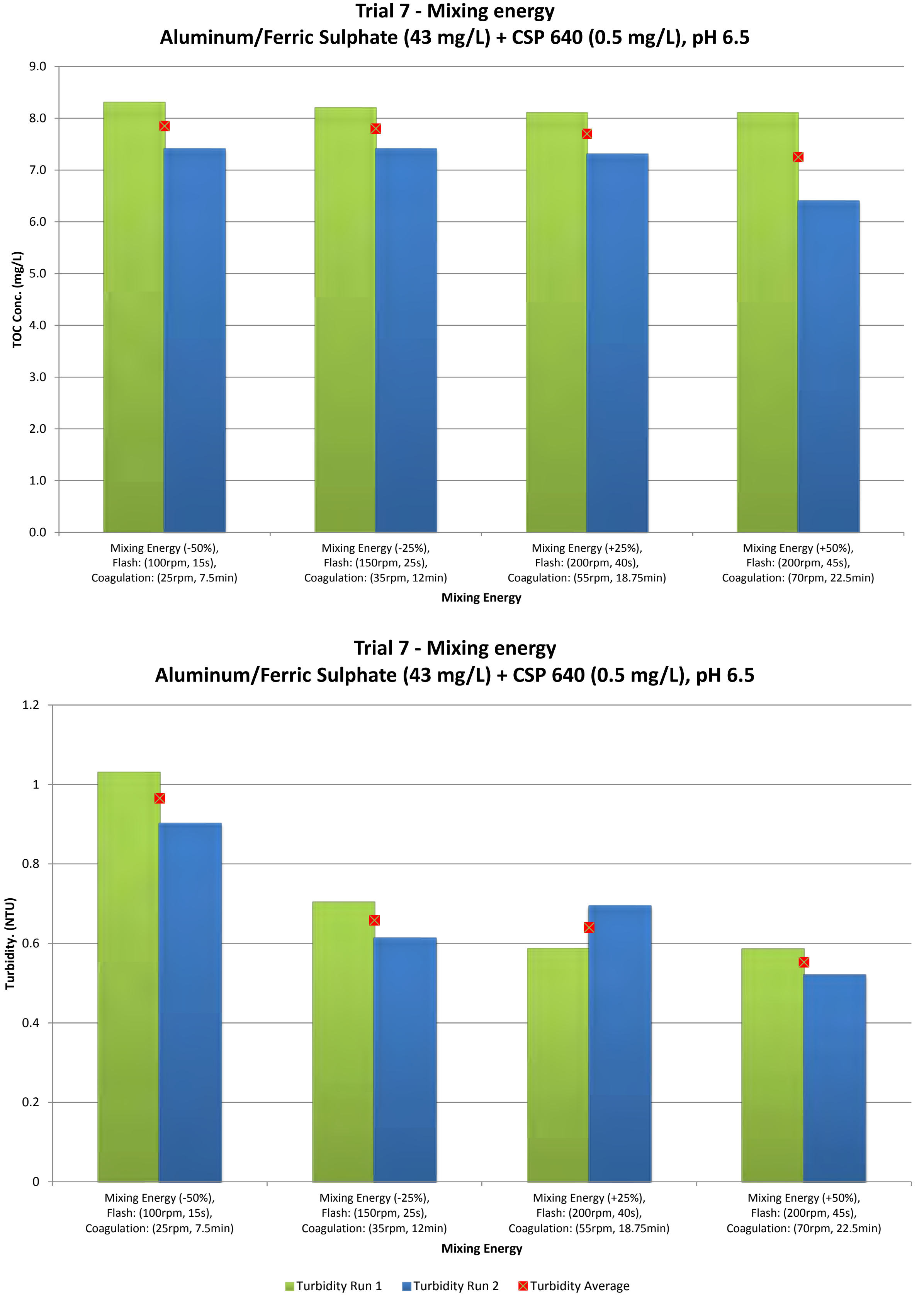


Figure 7-34 Applied Energy and Mixing Time - Turbidity

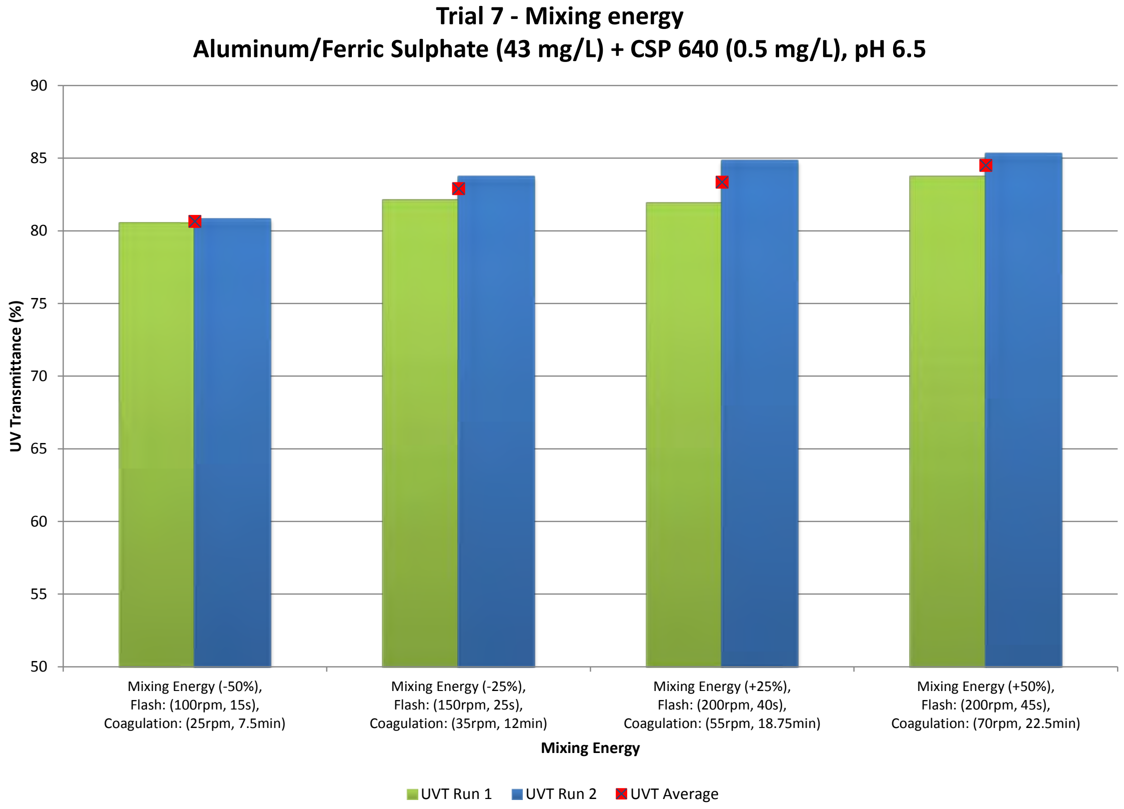


Figure 7-35 Applied Energy and Mixing Time - UVT

G-Value

Mixing is used in flocculation to promote contact between particles. The particles get in contact with each other after coagulation has been used to neutralize their natural repulsion for each other. The speed of flocculation is directly proportional to the root mean square velocity gradient (G-Value). The G-Value is a standard used to characterize energy inputs in mixing processes.

The Platypus Jar Test Equipment provided two G-values corresponding to paddle velocity as follows:

- Paddle Velocity: 40 RPM, G-Value: 48.1 s^{-1}
- Paddle Velocity: 50 RPM, G-Value: 67.3 s^{-1}

In order to estimate the G-values for other paddle velocities, the following expression was used:

$$P = \frac{C_D A_P \rho v^3}{2}$$

Where:

- P = Power
- C_D = Drag Coefficient on paddle
- A_P = Projected Area of Paddle
- ρ = fluid density
- v = velocity of paddle

Hence the Velocity Gradient, G:

$$G = \sqrt{\frac{P}{\mu . V}} = \sqrt{\frac{C_D A_P \rho v^3}{2 . \mu . V}}$$

The linear velocity is related to the angular velocity as follows:

$$v = r.\omega$$

Where:

- R = radius
- ω = angular velocity

So:

$$G = \sqrt{\frac{C_D A_P \rho v^3}{2.\mu.V}} = \sqrt{\frac{C_D A_P \rho r^3 \omega^3}{2.\mu.V}}$$

Since C_D, A_P and r are functions of the paddle, ρ and μ are functions of the fluid, and V is a function of the container, none of which change between trials, these are constant.

$$G = \sqrt{k\omega^3}$$

$$k = \frac{G^2}{\omega^3}$$

For the pair of angular velocity and G-values provided by the Platypus jar-test manufacturer, the k is calculated to be:

$$k = \frac{48.1^2}{40^3} = 0.0362$$

$$k = \frac{67.3^2}{50^3} = 0.0362$$

So, the constant value k is confirmed to be 0.0362. G-values for the four conditions tested are calculated as follows:

$$G = \sqrt{k\omega^3} = \sqrt{0.0362\,.(\omega)^3}$$

Discussion

By varying the applied energy and mixing time from -50% to +50%, the G-values tested ranged from 24 s $^{-1}$ to 111 s^{-1} as indicated in Table 7-10. The Mn, turbidity and UVT results obtained from Trial 7 were compared to the best case applied energy and mixing time obtained in Trial 1, to evaluate if this change in G-value resulted in better flocculation conditions.

Table 7-10 G-Values as Applied Energy and Mixing Time were varied

Parameter	Flocculation Velocity/RPM	G-Value **(s^{-1})**
Mixing Energy -50%	25	24
Mixing Energy -25%	35	39
Mixing Energy +25%	55	78
Mixing Energy +50%	70	111

It was noted that only minor changes were observed as the applied energy and mixing time were varied. The average turbidity differed by 12%, the average Hach Mn differed by 9%, the average Lab Total Mn varied by 3%, while the average UVT varied by 6%. The difference in TOC values could not be calculated since no TOC values were available for Trial 1. Based on these minor differences, these results do not indicate better flocculation conditions when the energy and time of mixing are altered.

7.5 Recommendation Based on Bench Testing Results

From the five initial coagulants short listed for bench testing, four were selected for further tests based on Mn, turbidity and UVT results from the screening jar tests. A more in-depth investigation was undertaken with these four to identify the optimal coagulant dose, select the optimal coagulant-aid and dosage, and to select the optimal pH.

The optimal combination of coagulant, coagulant-aid and pH for the four coagulants were then tested together to compare performance. Based on the Optimal Conditions jar test results (Trial 6), the two coagulants which emerge as the coagulants of choice for Mn reduction are ferric sulphate and aluminum/ferric sulphate Blend 2. The ultimate choice on which coagulant should be selected for pilot studies should be based on other considerations such as the effect of the new coagulant to the distribution system and other parts of the treatment process (inclusive of operational costs based on estimated dosages and similar financial considerations).

Regarding the coagulant-aids, it was evident that the addition of a coagulant-aid reduced the Mn content. However, the bench test results were not conclusive about the choice and best dose. The coagulant-aids selected for optimal condition testing were good candidate coagulant-aids, though others may equally be considered.

Additional jar tests were recommended to select the coagulant and coagulant-aid to be pilot tested. A second round of bench testing was hence undertaken (Section 8) with this aim.

8. Bench Testing of Candidate Coagulants and Coagulant-Aids (Second Round)

8.1 Objective

Results of the first DAF-jar testing program were not conclusive in identifying a single coagulant that would be carried forward for pilot testing. The ferric sulphate and aluminum/ferric sulphate Blend 2 emerged as the two most promising coagulants. Since the results were not definitive enough to choose one over the other, it was recommended that a second round of DAF-jar testing be completed with the aim of selecting the better of the two coagulants to be piloted. Ferric chloride would be bench tested as well, to allow comparisons to the current coagulant used in the full-scale plant.

Additionally, based on the results of the first DAF-jar testing, two of the coagulant-aids: Magnafloc LT-22S and Prosedim CSP-640 were selected for further jar testing.

A summary of the coagulants, coagulant-aids and pH adjustment reagent utilized during the second DAF-jar testing bench scale experiments are summarized in Table 8-1.

Table 8-1 Summary of Coagulants, Coagulant-aids and pH Adjustment Reagent Tested during second DAF-jar testing

Coagulants	Coagulant Aids	pH Adjustment
Ferric Chloride (Kemira) Ferric Sulphate (Kemira) Aluminum/Ferric Sulphate Blend 2 (Kemira)	Magnafloc LT-22S Prosedim CSP-640	Analytical Grade Sulphuric Acid

8.2 Second Round Bench Testing Details

The bench testing program was performed between January 24, 2017 and January 31, 2017. The raw water temperature did not change significantly during this time period and ranged between 2.5 ^{0}C and 2.7 ^{0}C. During most of the jar tests, water temperature was recorded at the beginning of the test and again at the end of the test. The water temperature at the beginning of the test ranged between 5.2 ^{0}C and 14.6 ^{0}C, while the temperature at the end of the tests ranged between 8.6 ^{0}C and 16.7 ^{0}C. The increase in initial temperature from the raw water temperature is due to the effect of higher ambient temperature in the laboratory. The water temperature also increases during bench testing due to mixing and continued exposure to higher ambient room temperature.

Initially, the baseline parameters previously established in the first bench scaling test were tested (Trial 1). Due to limitations in time and resources, no adjustment to these parameters was considered. These were followed by additional trials each with a distinct objective. Table 8-2 summarizes the various trials carried out.

Table 8-2 Jar Tests Carried out during the second DAF-jar testing

Trial Number	Purpose	Bench Test Details
1	Establish operating parameters (Setup)	- Used baseline parameters previously established in original bench scale testing. Due to time and resources available, no adjustment to these parameters was considered.
2	Optimize coagulant dose (Coagulant Screening)	- The three coagulants were screened for initial performance. - pH was kept constant at 5.7 - No coagulant-aid - 4 chemical doses were tested for each coagulant: 15, 25, 35 and 45 mg/L - The best dose for each coagulant was determined by evaluating reduction of the following key field parameters: Mn, turbidity and UVT. If the UVT results were within relative error among the samples, the turbidity results were relied upon over the UVT for guidance.
2.1	Refine Coagulant Dose (Dose Refinement)	- Dose of each coagulant was refined by dosing ± 4 mg/L and ± 8 mg/L from the “best dose” determined during coagulant screening. - No coagulant-aid was added. - pH was kept constant at 5.7
3	Optimize coagulation pH	- pH was altered using Sulphuric Acid to refine the optimal coagulation pH. - As carried out during the first round of jar testing, the ferric coagulants (Ferric Chloride and ferric sulphate) were tested at a pH of: 5, 5.3, 5.6 and 6. Aluminum/ferric sulphate Blend 2 was tested at a pH of: 5.5, 5.9, 6.2 and 6.5. - No coagulant-aid was added. - Coagulant aid dose tested was the optimal dose determined from Trial 2.1 as follows: ferric chloride: 45 mg/L, ferric sulphate: 53 mg/L and aluminum/ferric sulphate Blend 2: 41 mg/L - The optimal pH was selected based on the following parameters: turbidity and UVT. If the results were within relative error, the turbidity results were relied upon over the UVT.
3.1	Dose Refinement at the Optimal pH	- Once the optimal pH for each coagulant was determined, the dose refinement was repeated at the optimal pH. - Doses tested were ± 2 mg/L and ± 4 mg/L from the “best dose” determined during Trial 2.1 as follows: ferric chloride: 45 mg/L, ferric sulphate: 53 mg/L and aluminum/ferric sulphate Blend 2: 41 mg/L - No coagulant-aid was added. - The best dose for each coagulant was determined by evaluating reduction of the following key field parameters: turbidity and UVT. In the event that the results were within relative error, the turbidity results were relied more than the UVT.
4	Coagulant-aid dose Selection	- Once the optimal coagulant dose and optimal pH were determined for each of the coagulants, the two coagulant-aids: CP-640 and LT-22S were tested with each of the coagulants - Coagulant-aid doses tested were: 0.05, 0,1, 0.25 and 0.5 mg/L - Coagulant dose and pH tested were as follows: • ferric chloride dose: 45 mg/L, pH: 5.6 • ferric sulphate dose: 55 mg/L, pH: 5.6 • aluminum/ferric sulphate Blend 2 dose: 43 mg/L, pH: 6.5

The Bench Test Protocol can be found in Appendix D, including the details of each trial. The complete bench test results are presented in Appendix E.

8.3 Second Round Bench Test Results

8.3.1 Trial 2: Optimize Coagulant Dose

8.3.1.1 Coagulant Screening

The second DAF-jar testing was carried out with three coagulants. Ferric sulphate and aluminum/ferric sulphate Blend 2 were the most promising coagulants from the first round of jar testing, and this jar-testing was aimed at determining which of the two would be recommended for pilot testing. Ferric chloride which is the coagulant currently used in the WTP, was tested as a control.

The coagulant screening jar tests aimed to identify the coagulant dose between 15 and 45 mg/L which yielded the lowest Mn concentrations, turbidity and highest TOC removal. The dose identified was then carried forward for dose refinement. No coagulant-aid was added, and the pH was kept constant at 5.7. The coagulant dose screening was carried out when the initial water temperature was between 8.5 ^{0}C and 10.5 ^{0}C.

Results of the coagulant screening jar test are presented in Figure 8-1 to Figure 8-4

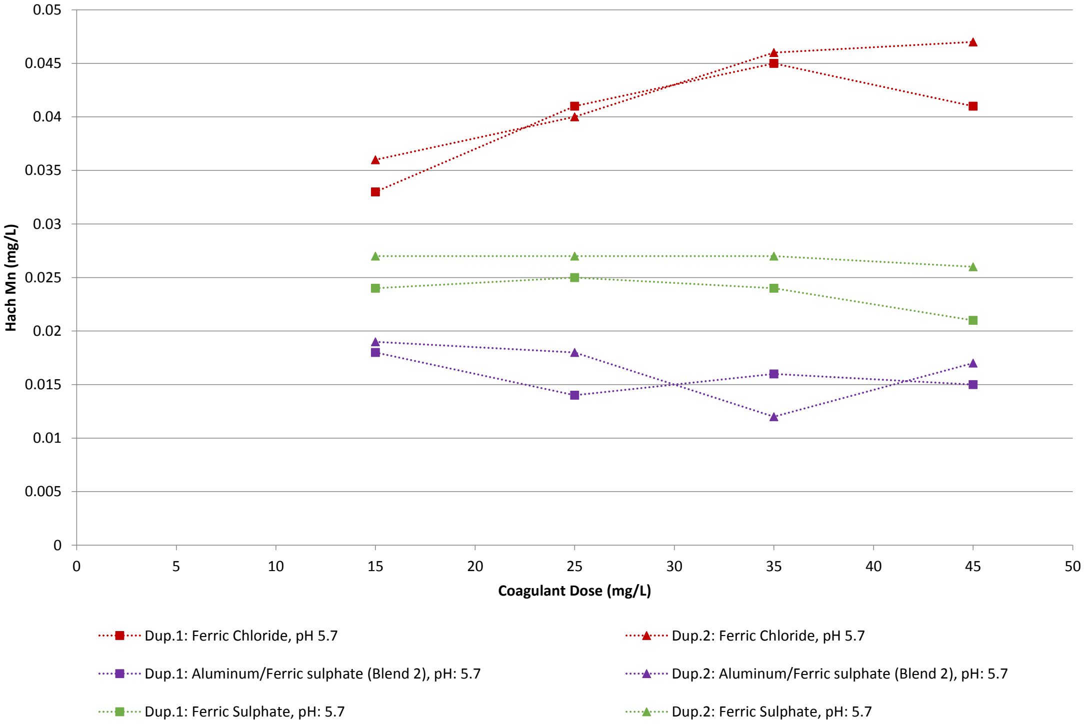
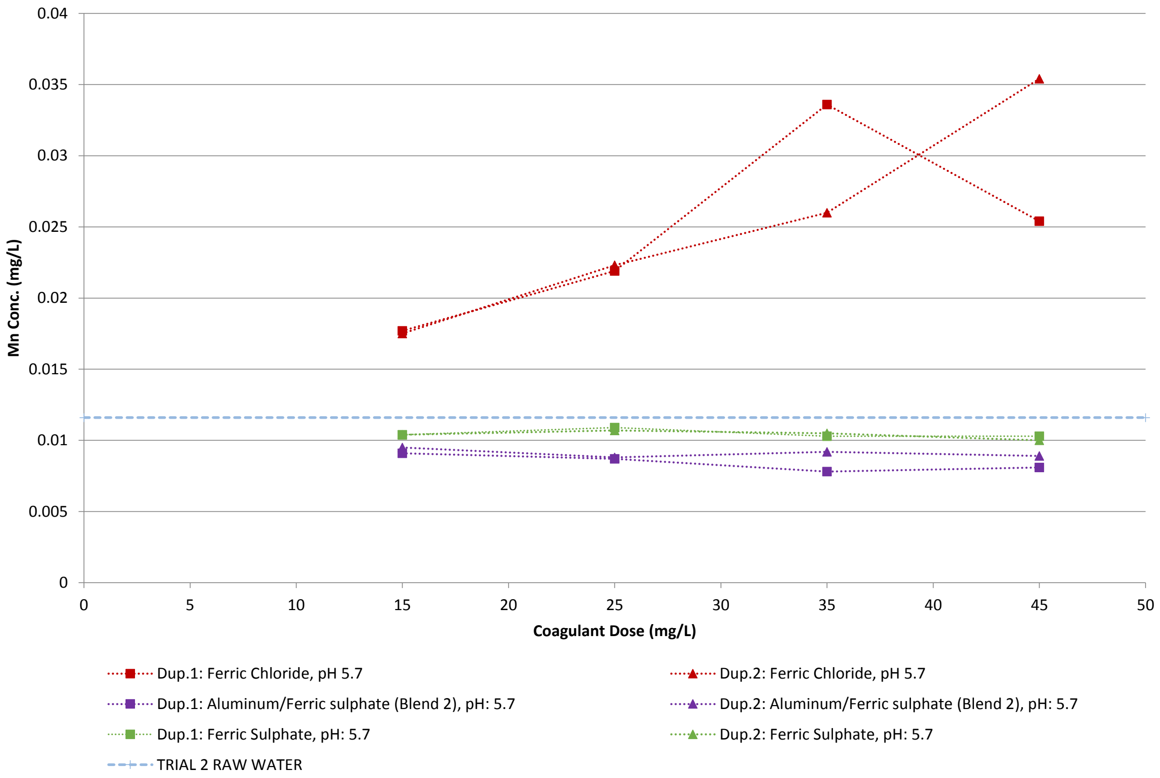


Figure 8-1 Initial Coagulant Screening - Hach Mn (No Coagulant Aid, pH 5.7)



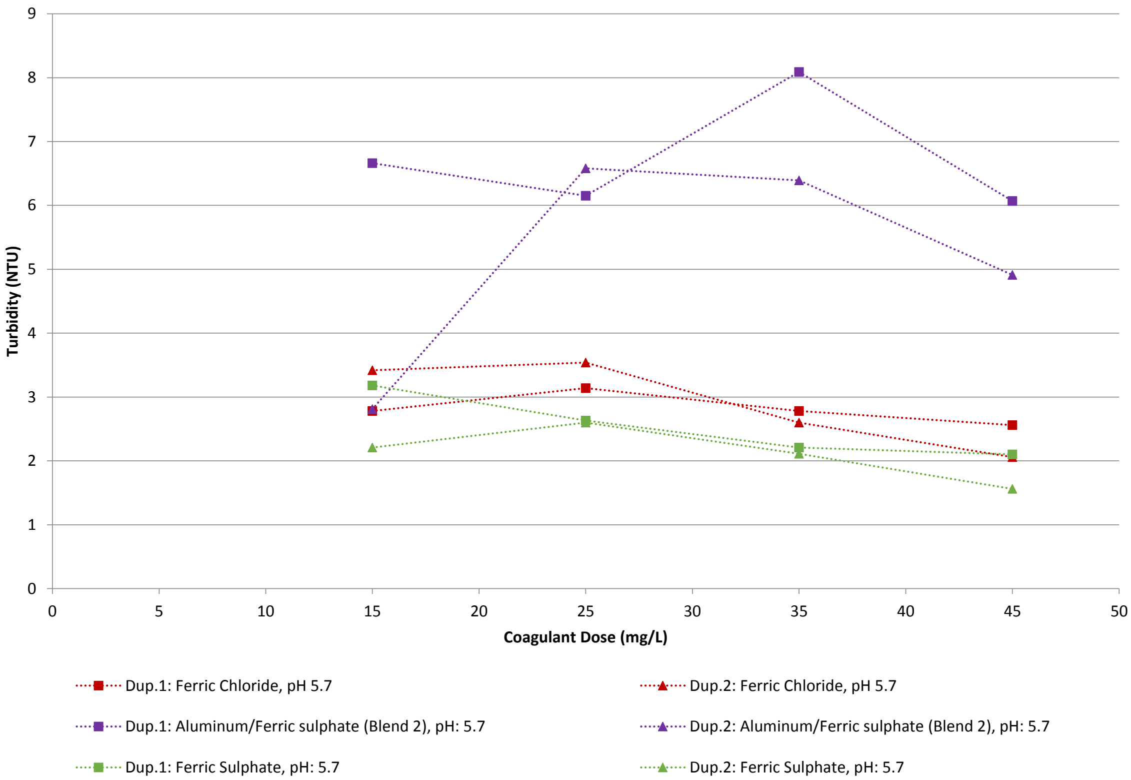


Figure 8-3 Initial Coagulant Screening - Turbidity (No Coagulant Aid, pH 5.7)

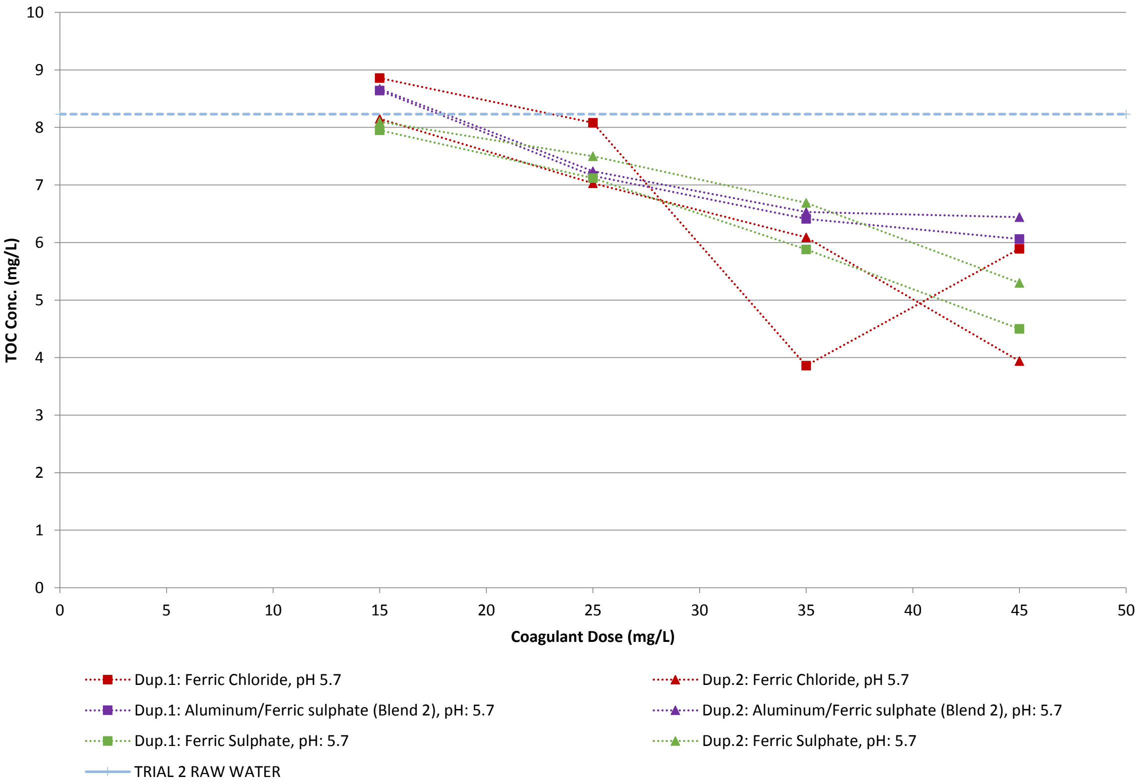


Figure 8-4 Initial Coagulant Screening - TOC Removal (No Coagulant Aid, pH 5.7)

The main focus of this jar testing was to screen for the optimal dose for ferric sulphate and aluminum/ferric sulphate Blend 2 particularly regarding Mn removal, while also considering other important parameters like TOC and turbidity. When both Hach Mn and Lab Total Mn values for the initial screening were considered, it was verified that the ferric chloride was contributing Mn into the water, with higher Mn concentrations noted at higher ferric chloride doses. For ferric sulphate, the Hach Mn and Lab Total Mn did not change significantly as dose changed between 15 mg/L to 45 mg/L varying between 0.021 and 0.027 mg/L (Hach Mn) and 0.010 and 0.011 mg/L (Lab Total Mn) respectively. Similarly, for aluminum/ferric sulphate Blend 2, there was only a small variance in Hach Mn and Lab Total Mn as the coagulant dose was changed varying between 0.019 and 0.012 mg/L (Hach Mn) and 0.01 and 0.009 mg/L (Lab Total Mn) respectively.

At higher doses of the ferric compounds (ferric chloride and ferric sulphate), the turbidity was observed to decrease with a maximum of 40% (ferric sulphate) and 41% (ferric chloride) noted percent reduction. As expected, the final turbidity with the ferric coagulants was lower than the alum based compound, with an average of 2.86 NTU for ferric chloride and 2.33 NTU for ferric sulphate compared to 5.96 NTU for aluminum/ferric sulphate Blend 2.

When TOC was considered, it was noted that TOC decreased with increasing dose of all three coagulants. The largest difference in TOC attenuation between the ferric coagulants and the aluminum/ferric sulphate Blend 2 was noted at the largest dose of 45 mg/L where the average TOC noted with ferric chloride was 4.92 mg/L, ferric sulphate was 4.9 mg/L and aluminum/ferric sulphate Blend 2 was 6.25 mg/L (the TOC concentration with ferric chloride at a dose of 35 mg/L (duplicate 1) was considered an outlier).

Based on the above results, a coagulant dose of 45 mg/L was selected for all coagulants to be further examined during the next jar testing for dose refinement.

8.3.2 Trial 2.1: Coagulant Dose Refinement

At the determined best dose of 45 mg/L for all coagulants, additional bench tests were carried out to further refine this dose. Coagulant doses of ± 4 mg/L and ± 8 mg/L were tested. No coagulant-aid was added and the pH was kept constant at 5.7, while the 53 mg/L result from the Hach Mn remains suspect. Re

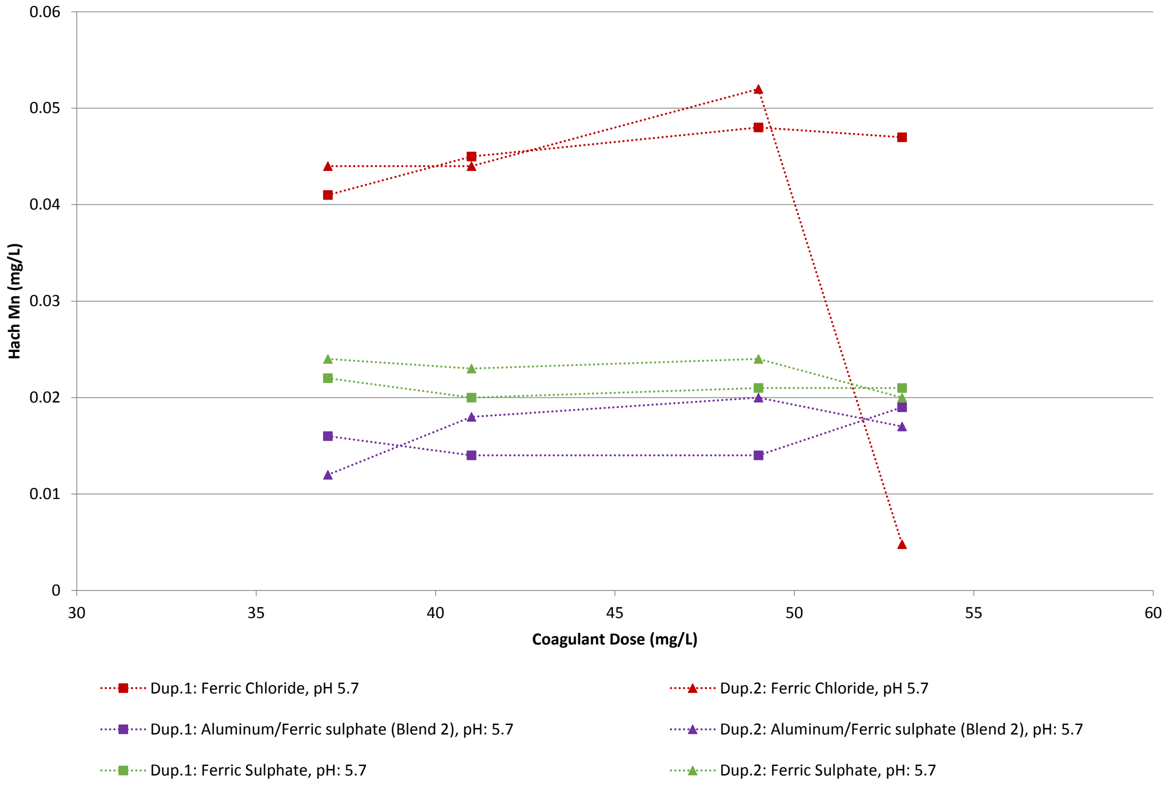


Figure 8-5 Optimal Dose Refinement (No Coagulant Aid, pH 5.7) - Hach Mn

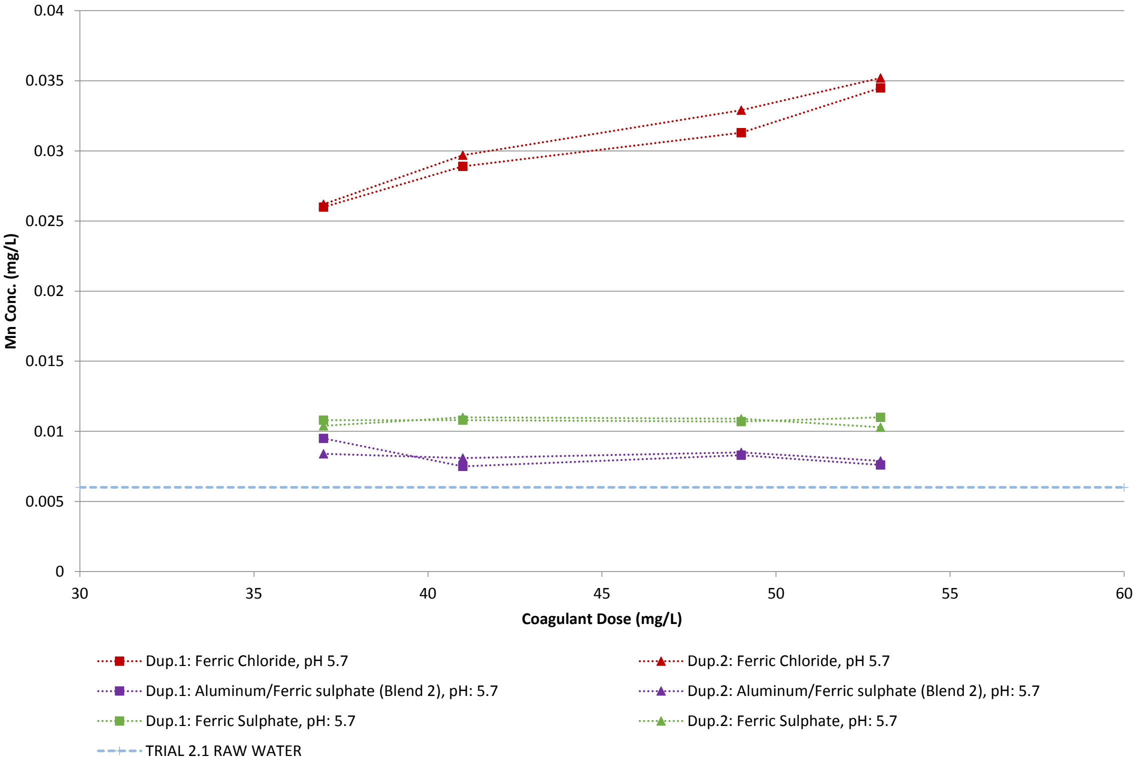


Figure 8-6 Optimal Dose Refinement (No Coagulant Aid, pH 5.7) - Lab Total Mn

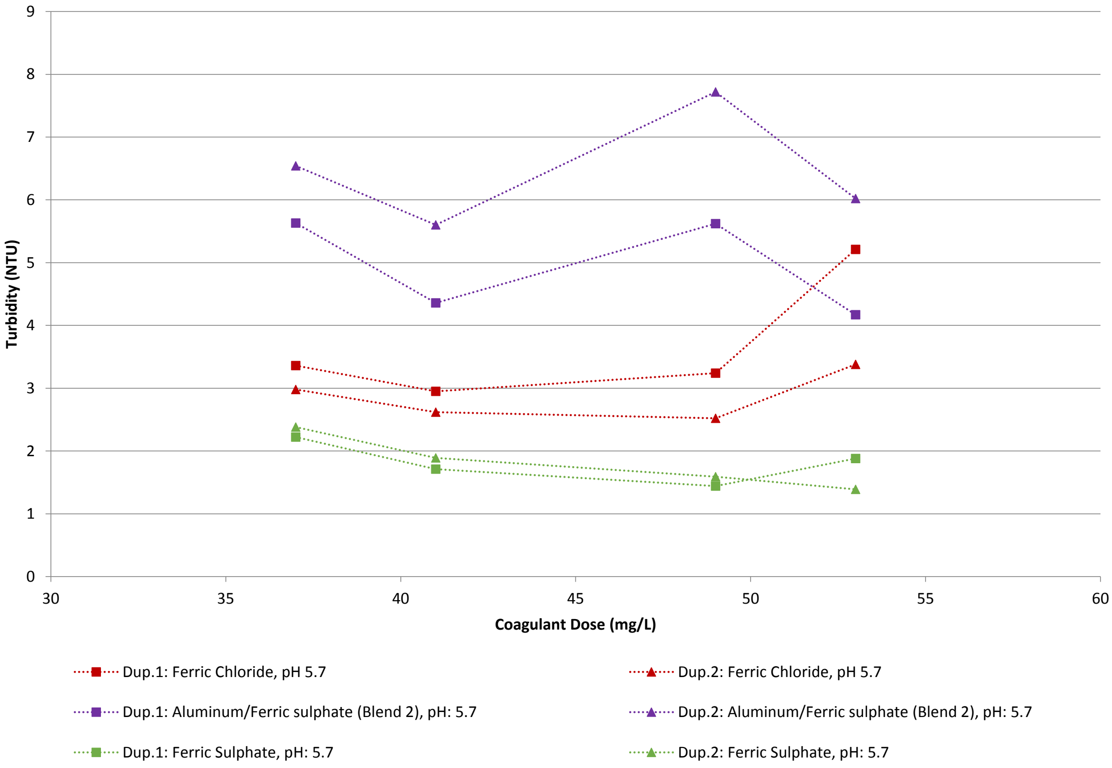


Figure 8-7 Optimal Dose Refinement (No Coagulant Aid, pH 5.7) - Turbidity

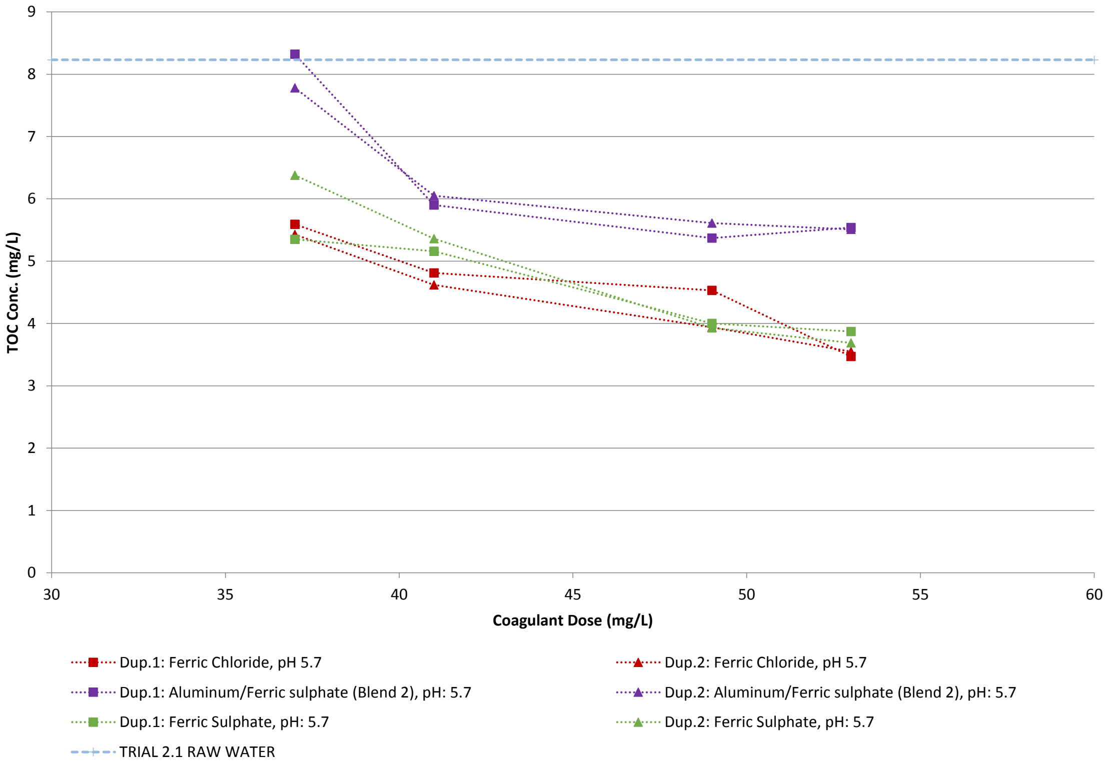


Figure 8-8 Optimal Dose Refinement (No Coagulant Aid, pH 5.7) - TOC

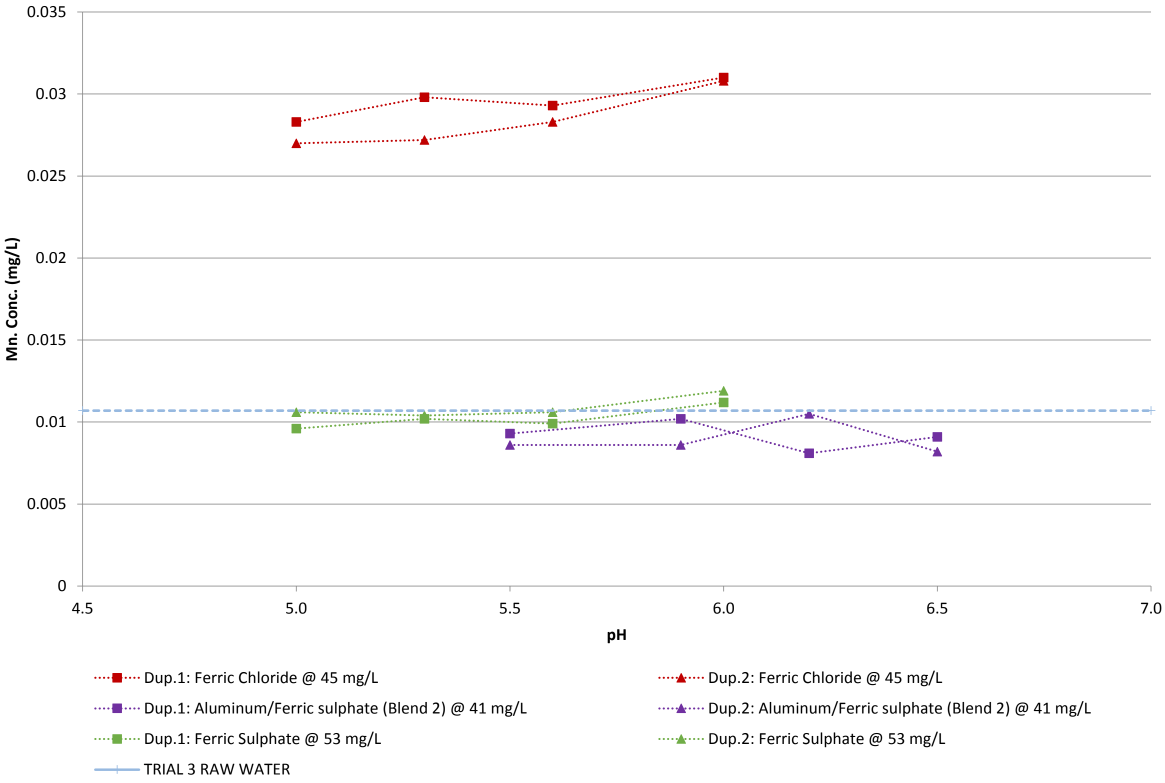
Based on the results presented above, the rationale for selection of the optimal dose for the three coagulants is as follows:

- Ferric Chloride: The turbidity decreased when the coagulant dose was increased from 37 mg/L to 41 mg/L but increased when the dose was increased further to 49 mg/L. The intermediate dose of 45 mg/L was hence selected as the optimal dose.
- Ferric Sulphate: The Hach Mn values at the highest dose tested were lowest, so 53 mg/L was selected as the optimal dose.
- Aluminum/Ferric Sulphate Blend 2: The turbidity decreased between 37 mg/L and 41 mg/L, then increased as the dose was increased to 49 mg/L. Additionally, no decrease in Mn was noted as the dose was increased from 41 mg/L to 49 mg/L. An optimal coagulant dose of 41 mg/L, was hence selected.

8.3.3 Trial 3: pH Optimization

Bench tests were performed to evaluate the optimal pH for each coagulant. Based on the initial protocol, pH ranges of 5 to 6 were investigated for the ferric based coagulants, while a pH range of 5.5 to 6.5 was investigated for the aluminum-based coagulant. The pH was altered by addition of sulphuric acid. No coagulant-aid was added.

Results for changes observed in Hach Mn concentrations, Lab Total Mn concentrations, turbidity and UVT are presented in Figure 8-9 to Figure 8-11 below.



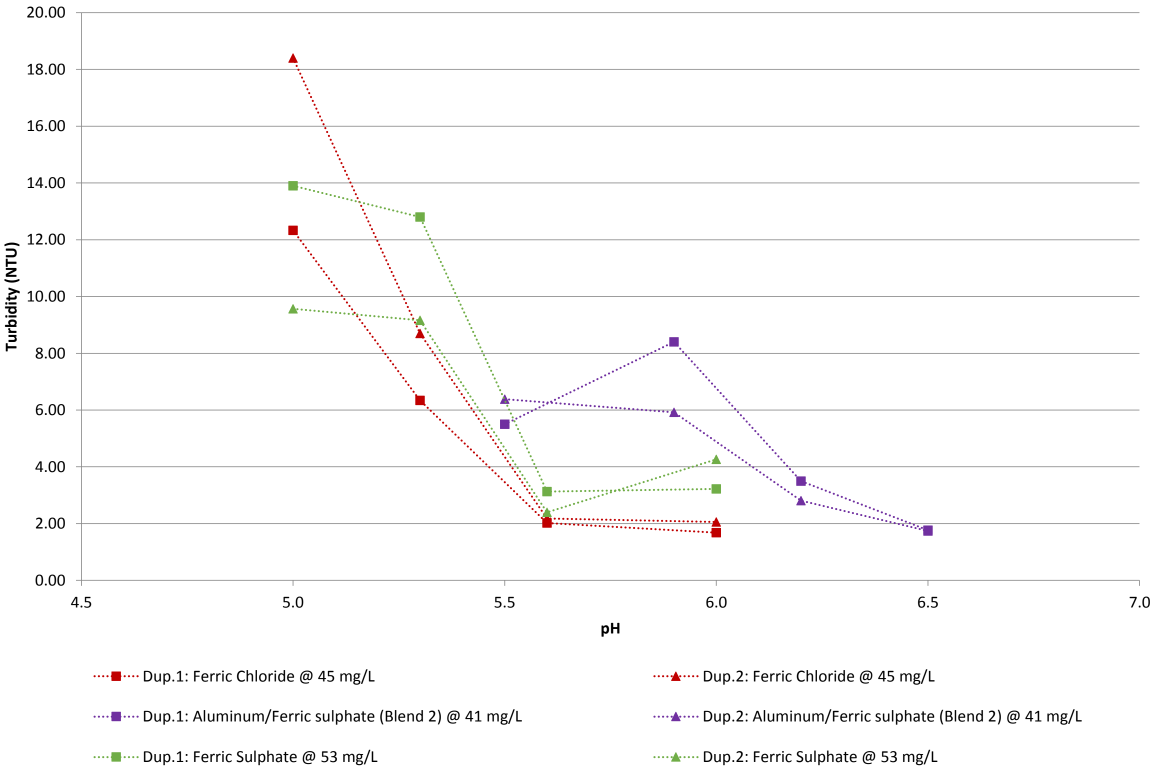


Figure 8-10 pH Optimization (No Coagulant Aid) – Turbidity

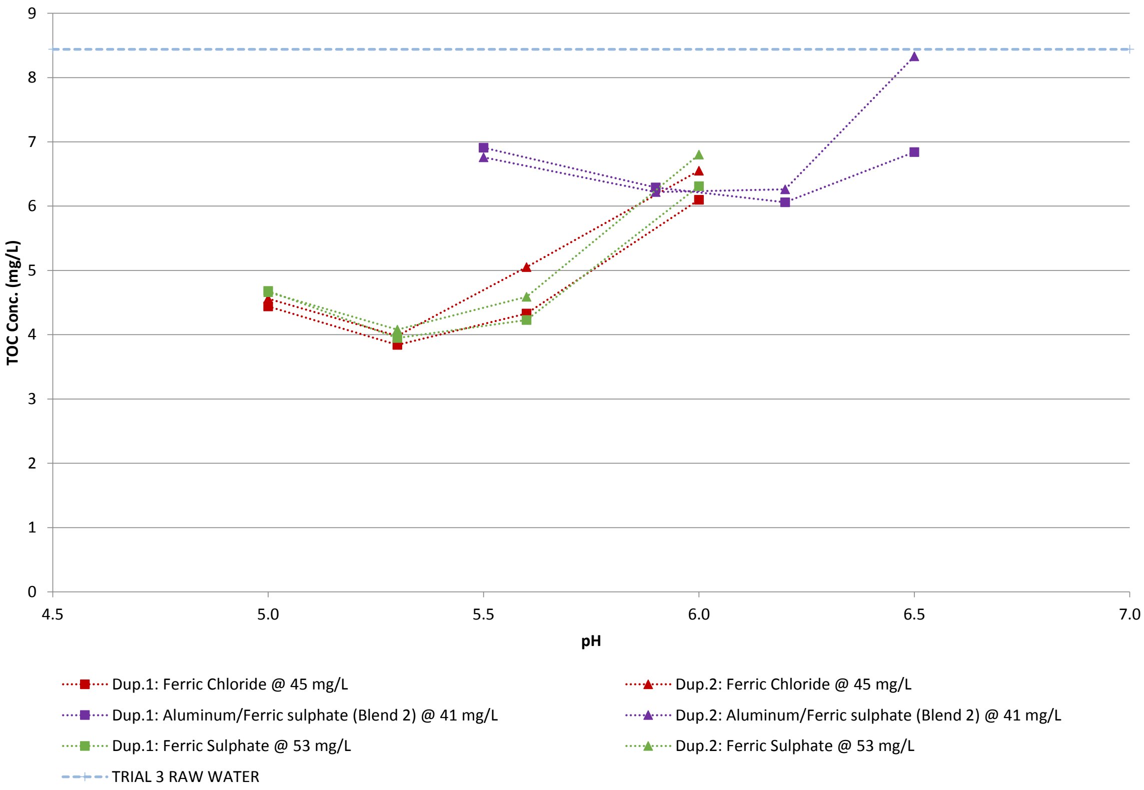


Figure 8-11 pH Optimization (No Coagulant Aid) – TOC

Only slight changes in Mn concentrations were noted for each of the coagulants as the pH was altered with the maximum difference between the lowest and highest Mn concentrations ranging between 9 and 22% for the three coagulants from the raw concentration. The lowest TOC concentrations for the ferric coagulants were noted at a pH of 5.3, while for aluminum/ferric sulphate Blend 2 was noted at a pH of 6.2.

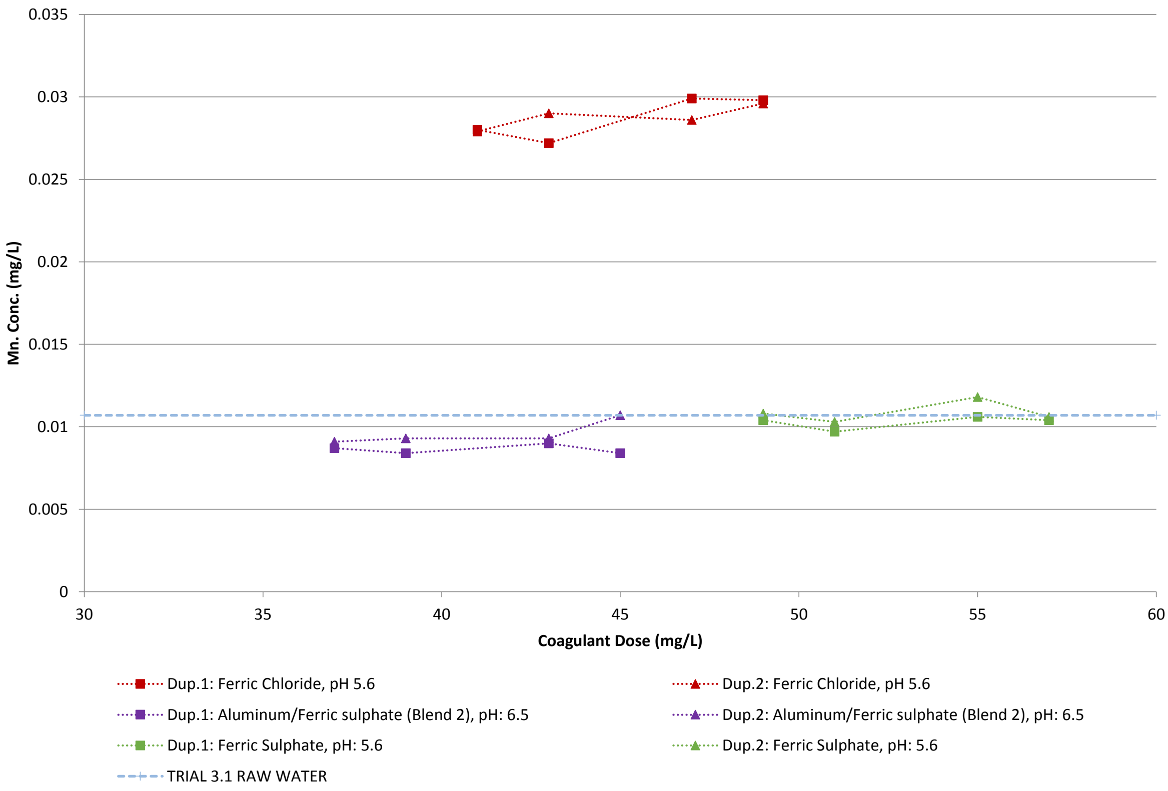
The turbidity for the ferric coagulants was noted to drop greatly from 18.4 NTU to 2.18 NTU (Ferric Chloride) and 13.9 NTU to 2.9 NTU (ferric sulphate) when the pH was increased from 5 to 5.6. There was only a marginal decrease further to 1.68 NTU for ferric chloride as the pH was increased further to 6. For aluminum/ferric sulphate Blend 2 there was a decrease in turbidity from 3.13 NTU to 1.74 NTU as the pH was increased from 5.5 to 6.5.

Since the decrease in turbidity beyond a pH of 5.6 was minimal for the ferric compounds, the optimal pH selected for ferric chloride and ferric sulphate was 5.6. The lowest turbidity noted for aluminum/ferric sulphate Blend 2 was at a pH of 6.5 and this was hence selected as the optimal pH value.

8.3.4 Trial 3.1: Dose Refinement at the Optimal pH

Following completion of Trial 3, the optimal pH selected for each of the coagulants was noted to be different from the pH at which the dose refinement jar test (Trial 2.1) was performed. Trial 3.1 hence repeated the dose refinement jar test at the optimal pH of each coagulant.

Results of the Mn, TOC, turbidity, and alkalinity (note that an alkalinity of 20 mg/L is usually considered the minimum after coagulation) are presented in Figure 8-12 to Figure 8-15 below.



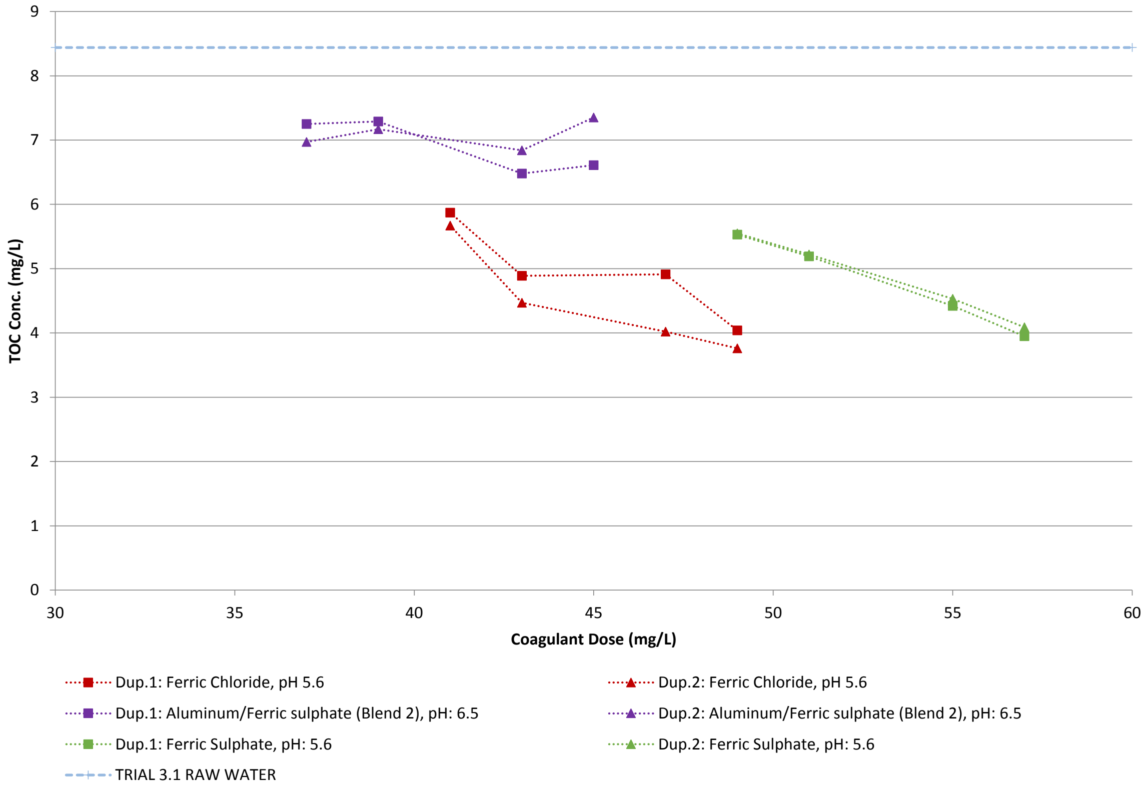
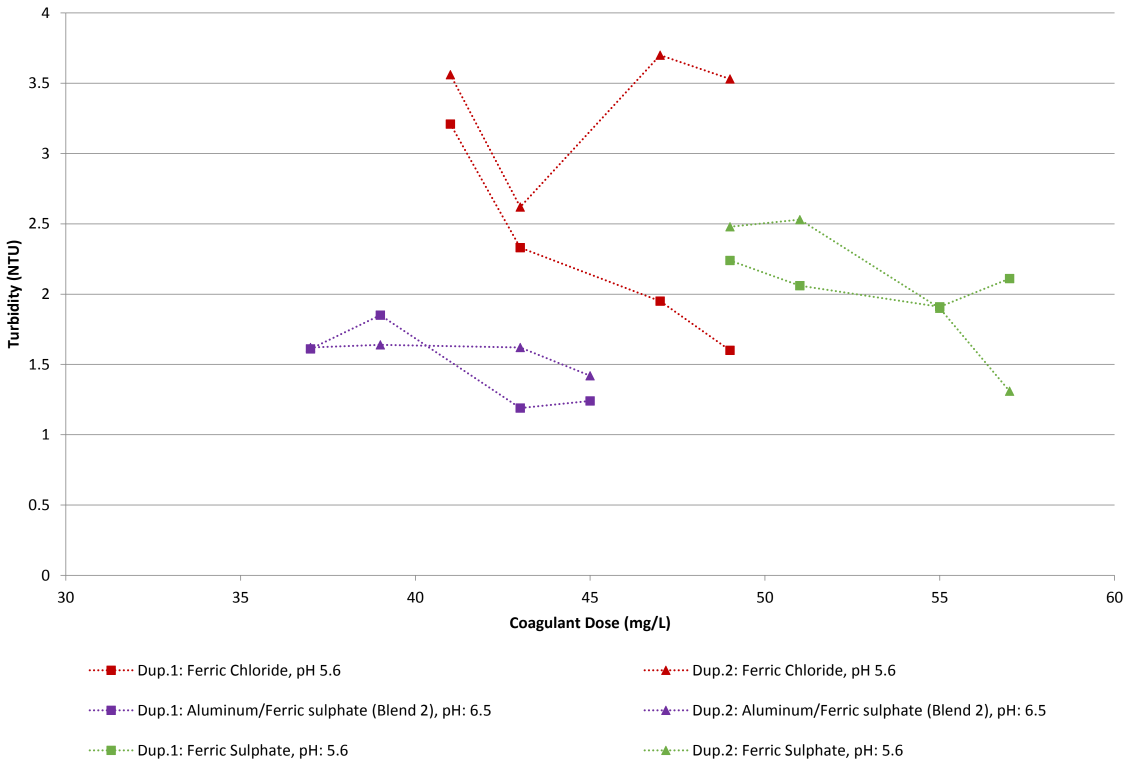


Figure 8-13 Optimal Dose Refinement (No Coagulant Aid, Optimal pH) – TOC



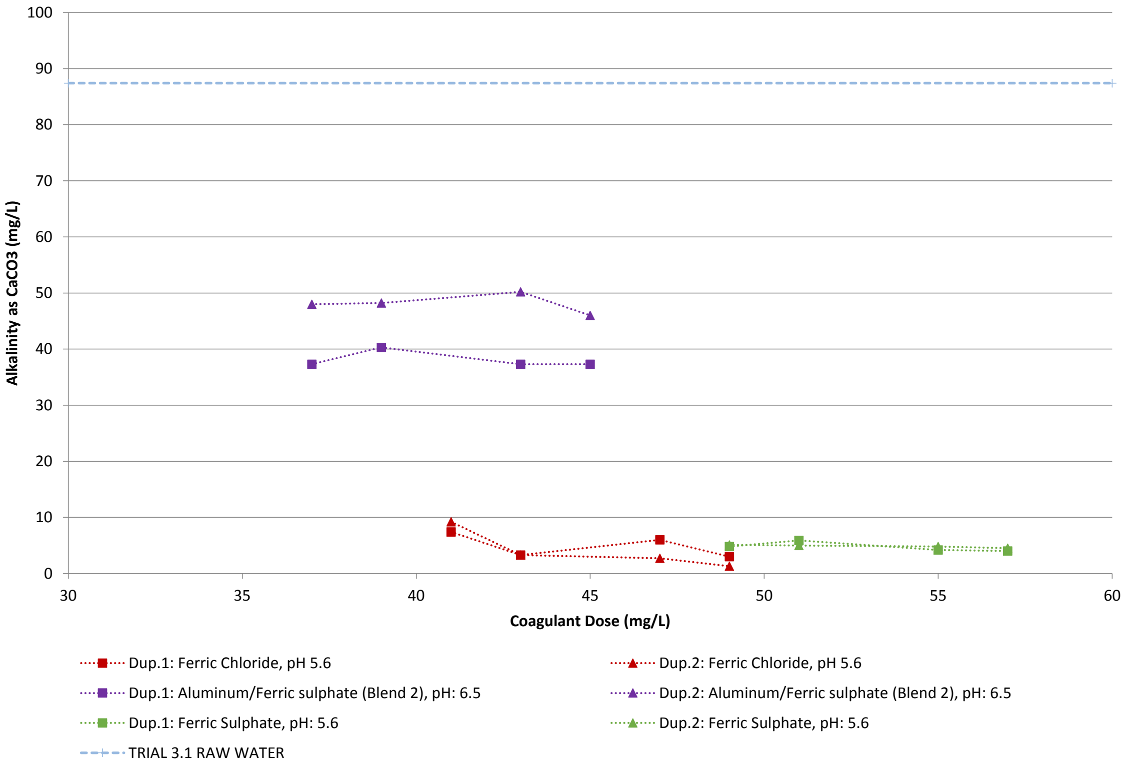


Figure 8-15 Optimal Dose Refinement (No Coagulant Aid, Optimal pH) - Alkalinity

When the dose refinement was repeated at the optimal pH identified for each coagulant, it was noted that the Mn concentration in ferric chloride was still much more elevated than the Mn concentrations in ferric sulphate and aluminum/ferric sulphate Blend 2. When all coagulant doses tested were considered, the average Mn concentration when ferric chloride was considered was 0.029 mg/L, the average Mn concentration when aluminum/ferric sulphate Blend 2 was considered was 0.009 mg/L, while the average Mn concentration when ferric sulphate was used as the coagulant was 0.01 mg/L. Compared to the Mn concentration noted when ferric chloride was used, the aluminum/ferric sulphate Blend 2 Mn concentration was only 69% lower, and the ferric sulphate Mn concentration was 65% lower.

With such large differences in Mn concentration, the benefit of switching to either of these coagulants from the current ferric chloride is evident. Furthermore, the difference in Mn removal of 4% between aluminum/ferric sulphate Blend 2 and ferric sulphate is not deemed significant and the two coagulants are expected to perform in a similar manner for Mn removal.

When TOC is considered, the aluminum/ferric sulphate Blend 2 was noted to exhibit the lowest average TOC removal of 17%. Ferric chloride and ferric sulphate exhibited higher TOC removals of 44%, and 43% respectively.

The average turbidity on the other hand was noted to be lowest with aluminum/ferric sulphate Blend 2 (1.5 NTU) and highest with ferric chloride (2.8 NTU), though the turbidity was noted to drop from 3.2 NTU to 1.6 NTU during one of the ferric chloride duplicate jar test.

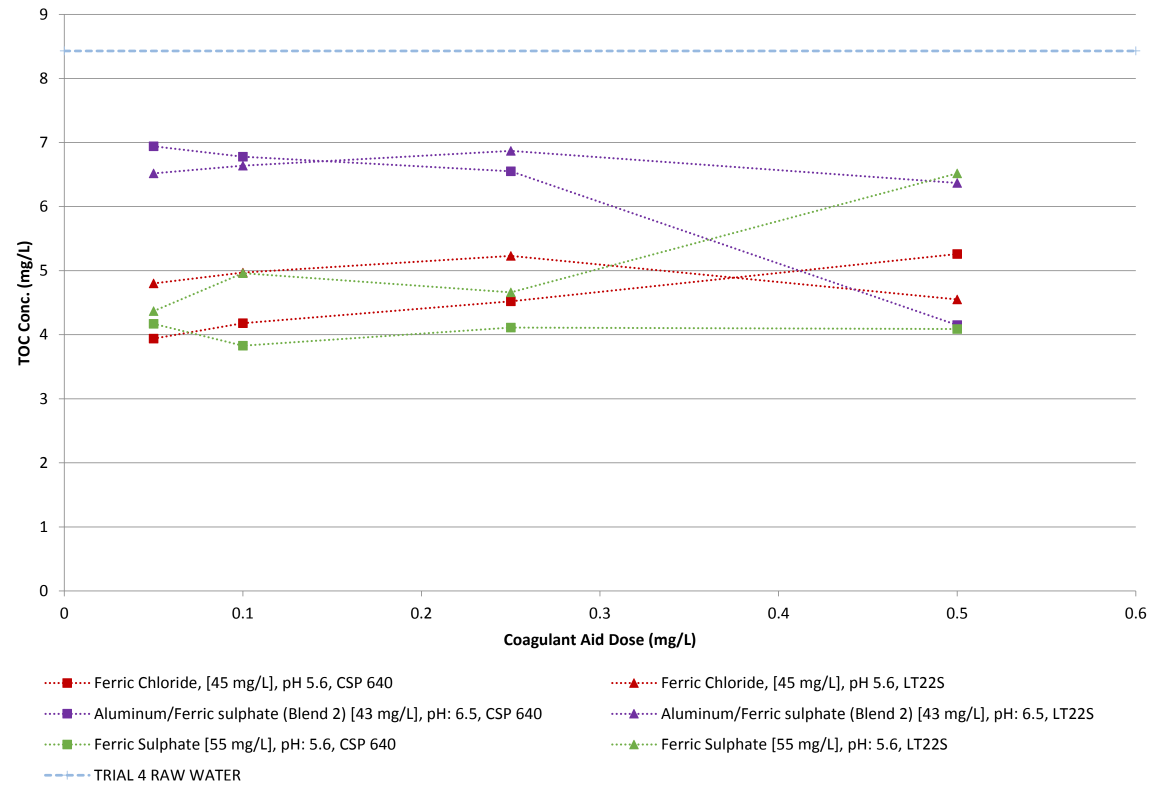
The average alkalinity within the jars when aluminum/ferric sulphate Blend 2 was used was much higher with an average of 43 mg/L (as $CaCO_3$) compared to lower average alkalinity values of 4.5 mg/L (as $CaCO_3$) with ferric chloride and 4.79 mg/L (as $CaCO_3$) with ferric sulphate. This suggests that the chemistry within the plant and distribution system is likely to be similar if a switch to ferric sulphate is made. With such a large difference in alkalinity however, a switch to aluminum/ferric sulphate Blend 2 is likely to have a larger impact on the plant and distribution system chemistry, which would need to be considered.

8.3.5 Trial 4: Coagulant-Aid Optimization

Each of the three coagulants was tested with the two best coagulant-aids (CSP-640 and LT-22S) selected from the first DAF-jar testing. The coagulant-aid concentrations tested were: 0.05, 0.1, 0.25 and 0.5 mg/L. The coagulants were tested at their optimal dose and optimal pH as follows:

- Ferric Chloride dose: 45 mg/L, pH: 5.6
- Ferric Sulphate dose: 55 mg/L, pH: 5.6
- Aluminum/Ferric Sulphate Blend 2 dose: 43 mg/L, pH: 6.5

Results for Mn, turbidity, TOC, alkalinity, aluminum and iron are presented in Figure 8-16 to Figure 8-22 below.



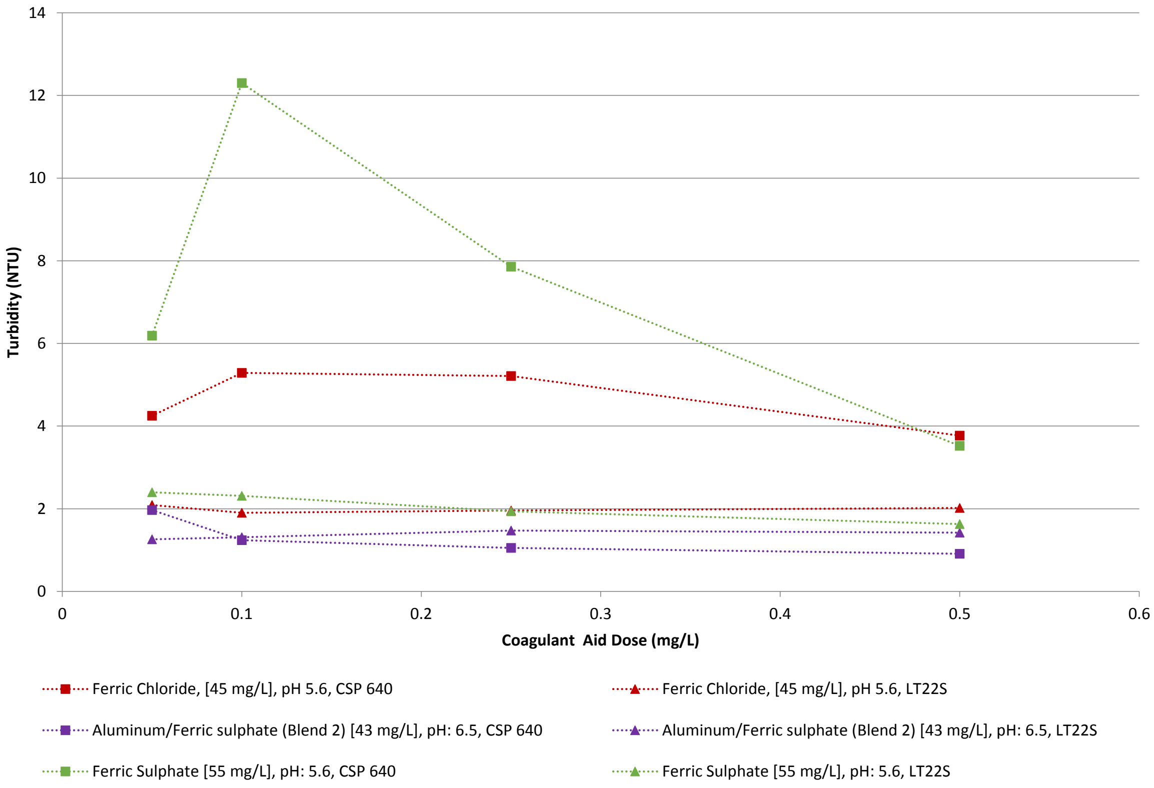


Figure 8-17 Coagulant Aid Optimization – Turbidity

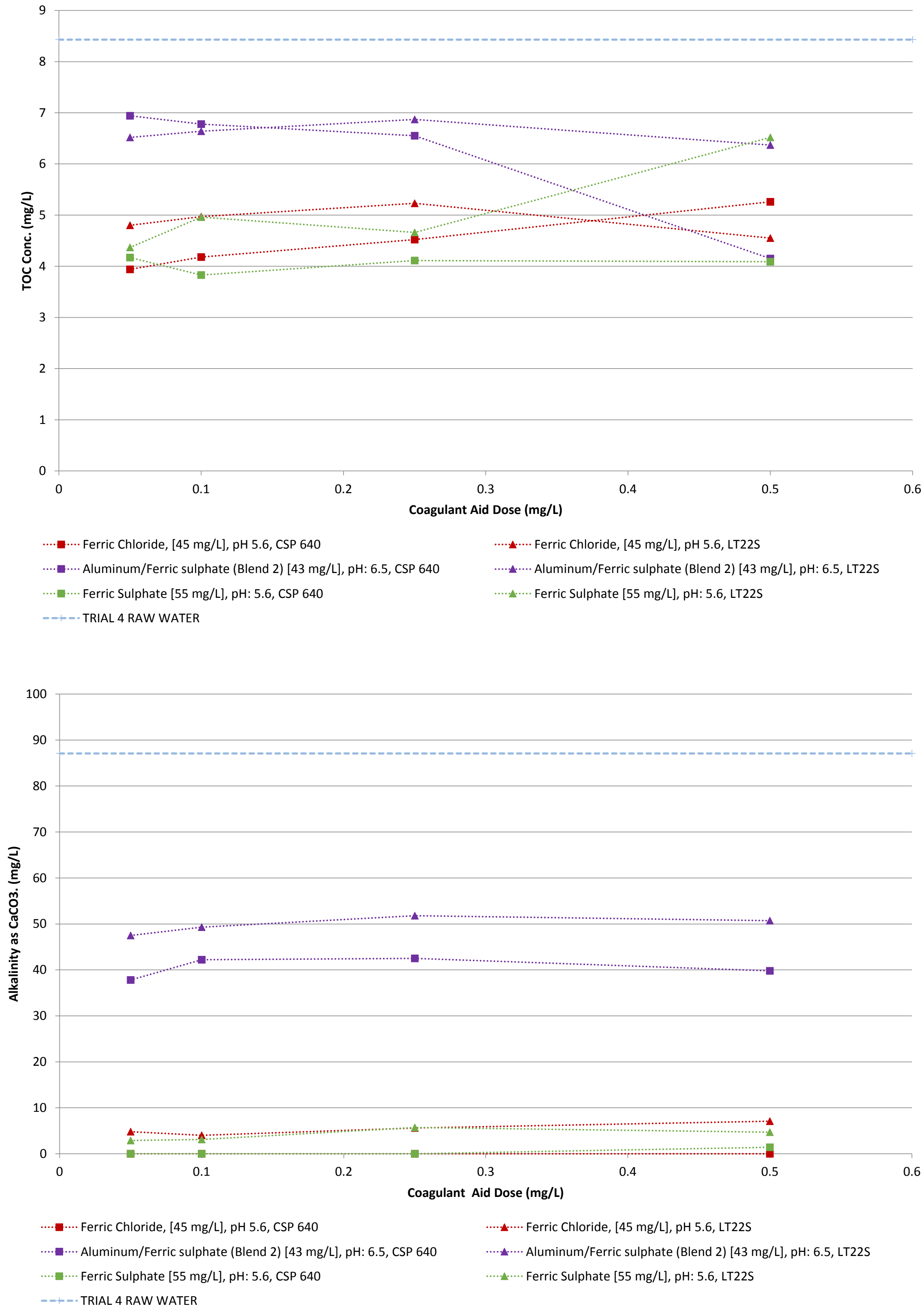
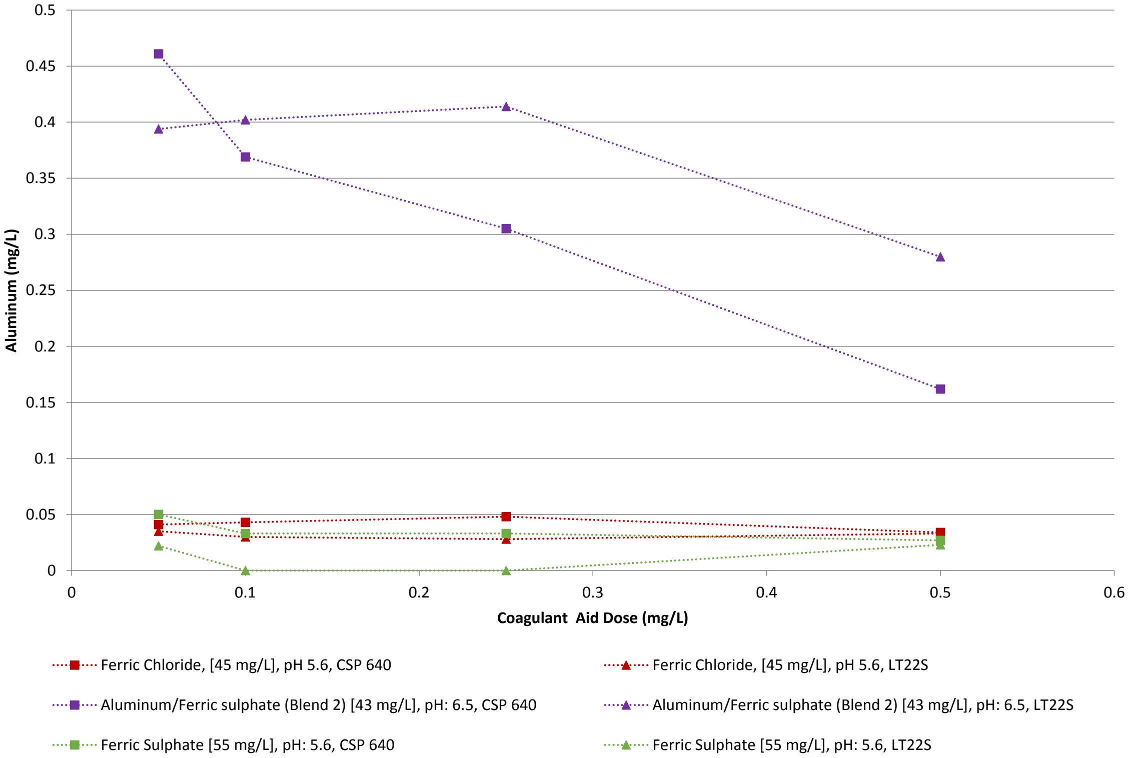


Figure 8-19 Coagulant Aid Optimization – Alkalinity



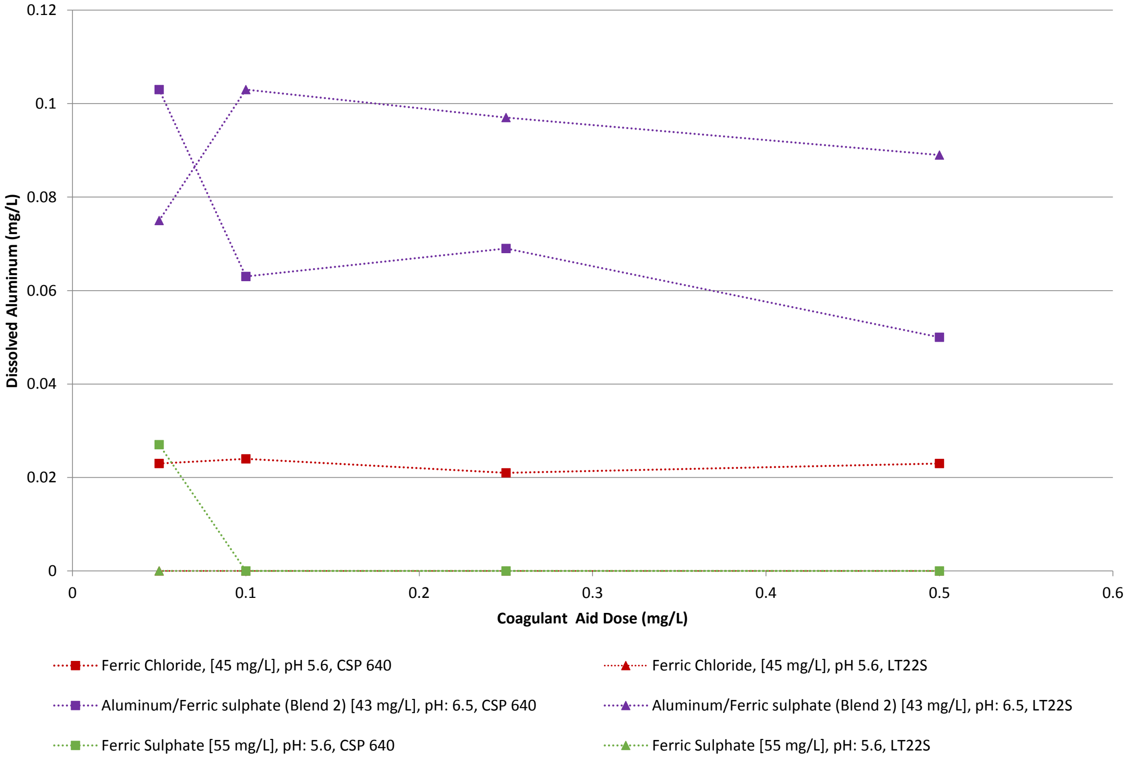


Figure 8-21 Coagulant Aid Optimization – Dissolved aluminum

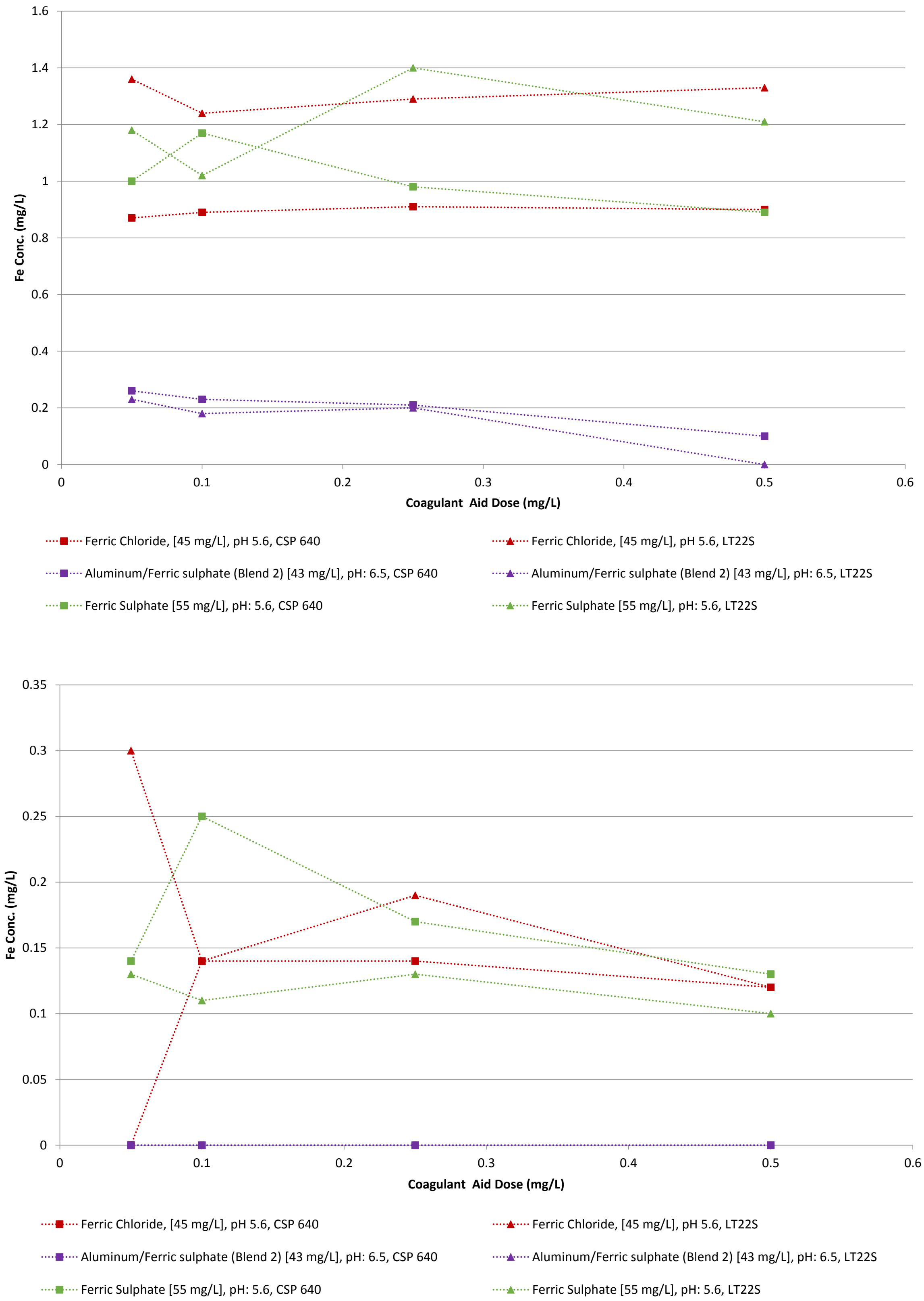


Figure 8-23 Coagulant Aid Optimization – Dissolved Iron

Comparison between CSP-640 and LT-22S

Concentrations of various parameters measured when the two coagulant-aids (CSP-640 and LT-22S) were considered as well as when no coagulant-aid was added are presented in Table 8-3.

Table 8-3 Coagulant Aid - Average Concentrations of Measured parameters

Coagulant	No Coagulant-Aid (Trial 3.1)	CSP-640 (Trial 4)	LT-22S (Trial 4)
	Average Mn Concentration (mg/L)		
Ferric Chloride	0.029	0.032	0.030
Aluminum/Ferric Sulphate Blend 2	0.009	0.010	0.009
Ferric Sulphate	0.011	0.011	0.011
	Average Turbidity Concentration (NTU)		
Ferric Chloride	2.81	4.63	1.99
Aluminum/Ferric Sulphate Blend 2	1.52	1.29	1.37
Ferric Sulphate	2.07	7.47	2.07
	Average TOC Concentration (mg/L)		
Ferric Chloride	4.70	4.18	5.07
Aluminum/Ferric Sulphate Blend 2	7.00	6.82	6.6
Ferric Sulphate	4.81	4.07	4.64
	Average Alkalinity Concentration (mg $CaCO_3$/L)		
Ferric Chloride	4.53	<1.0	5.38
Aluminum/Ferric Sulphate Blend 2	43.1	40.6	49.8
Ferric Sulphate	4.79	1.4	4.1
	Average Dissolved Aluminum Concentration (mg/L)		
Ferric Chloride	0	0.023	<0.02
Aluminum/Ferric Sulphate Blend 2	0.212	0.071	0.091
Ferric Sulphate	0	0.027	<0.02
	Average Dissolved Iron Concentration (mg/L)		
Ferric Chloride	0.382	0.133	0.188
Aluminum/Ferric Sulphate Blend 2	<0.1	<0.1	<0.1
Ferric Sulphate	0.212	0.173	0.118

The results above indicate that the coagulant-aid did not increase Mn removal. Furthermore, neither of the coagulant-aids performed better than the other for Mn removal, contrary to what was observed on the first bench test. Similarly, when turbidity is considered the coagulant-aid did not increase turbidity removal compared to when there was no coagulant-aid added. In fact, turbidity seemed to have increased when CSP-640 was used in conjunction with ferric sulphate.

The average dissolved aluminum concentration when no coagulant-aid was used was 0.212 mg/L (Trial 3.1) above the Operational Guidance Value of 0.1 mg/L. Both coagulants CSP-640 and LT-22S were able to reduce the average dissolved aluminum concentration to below the 0.1 mg/L threshold. The CSP-640 removed more aluminum achieving a final concentration of 0.071 mg/L dissolved aluminum compared to 0.091 mg/L with LT-22S.

When no coagulant aid was used, the average dissolved iron concentration was 0.382 mg/L for ferric chloride and 0.212 mg/L for ferric sulphate. Both coagulant-aids lowered these concentrations staying below the aesthetic objective of 0.3 mg/L at all doses. CSP-640 reduced the iron concentration more than LT-22S for ferric chloride. The opposite was true for ferric sulphate, where the LT-22S lowered iron concentrations more than CSP-640.

Use of CSP-640 caused more pH depression when compared to LT-22S. The initial average pH of 5.89 when CSP-640 was being tested was depressed to a pH of 5.25 after the test. On the other hand, the initial average pH of 5.84 did not change significantly when LT-22S was used as the coagulant aid and the final pH was noted to be 5.83.

Similarly, the use of CSP-640 caused a larger drop in alkalinity compared to LT-22S. The final alkalinity with the CSP-640 averaged 40.6 mg $CaCO_3$/L for the aluminum/ferric sulphate Blend 2 and 1.4 mg $CaCO_3$/L for ferric sulphate (alkalinity for ferric chloride was <0.1 mg $CaCO_3$/L). The alkalinity was higher when LT-22S was used at 49.8 mg $CaCO_3$/L for aluminum/ferric sulphate Blend 2, 5.38 mg $CaCO_3$/L for ferric chloride and 4.1 mg $CaCO_3$/L for ferric sulphate.

Though the coagulant-aids did not affect the Mn concentrations, they were useful in bringing the aluminum and iron concentrations below their operational guidance and aesthetic objective values respectively.

In achieving these goals, CSP-640 would be recommended for use if aluminum/ferric sulphate Blend 2 was selected as the coagulant to be piloted, while LT-22S would be recommended if the ferric sulphate Blend 2 was selected as the coagulant to be piloted. The optimal CSP-640 concentration that achieved the lowest aluminum concentration when aluminum/ferric sulphate Blend 2 was considered was 0.25 mg/L. Similarly, the optimal LT-22S concentration that achieved the lowest iron concentration when ferric sulphate was considered was also 0.25 mg/L. These concentrations were hence selected as the optimal concentrations recommended for the respective coagulant-aids.

8.4 Recommendation Based on the Second Round Bench Test Results

In the second run of bench-scale tests, a more in-depth investigation was undertaken with ferric chloride and two of the candidate coagulants, ferric sulphate and aluminum/ferric sulphate Blend 2, in order to identify the optimal coagulant dose and to select the optimal pH. The optimum coagulant doses resulting from the bench tests were 45 mg/L for ferric chloride, 55 mg/L for ferric sulphate and 43 mg/L for aluminum/ferric sulphate Blend 2.

The ferric chloride dose obtained at bench scale (45 mg/L) was much higher than the full-scale dose. During the January 2017 bench testing, the ferric chloride dose at the full-scale was 32.7 mg/L. By comparison, it is not expected that the ferric sulphate dose at the full-scale would be as high as the optimal dose determined during the second round of bench tests, and the impacts of ferric sulphate would be much smaller than presented above.

Considering that the ferric chloride optimum dose was 45 mg/L (15.9 mg Fe/L) and the Ferric Sulphide optimum dose was 55 mg/L (15.3 mg Fe/L) at the bench tests to produce similar water quality, Table 8-4 presents the expected full-scale dose for ferric sulphate based on iron-equivalent content.

Table 8-4 Expected Full-Scale Dose for ferric sulphate

Coagulant Dose	Bench Test	Full Scale
Ferric Chloride	45 mg/L 15.9 mg Fe/L	32.7 mg/L 11.6 mg Fe/L
Ferric Sulphate	55 mg/L 15.3 mg Fe/L	42 mg/L 11.7 mg Fe/L (expected)

Regarding the impacts of two coagulant-aids retested: LT-22S and CSP-640, it was evident that the addition of a coagulant-aid lowered the metals concentrations in the clarified water, aluminum and iron contents. Overall, the CSP-640 would be recommended for use if aluminum/ferric sulphate Blend 2 was selected as the coagulant to be piloted, while LT-22S would be recommended if the ferric sulphate was selected as the coagulant to be piloted. The optimum dose obtained was 0.25 mg/L for both coagulant-aids.

The ultimate choice on which coagulant should be selected for pilot studies should be based on other considerations such as the effect of the new coagulant to the distribution system and other parts of the treatment process, which is discussed in the next chapter. The following initial conditions are recommended for the pilot-scale and the evaluation of impacts from switching coagulant:

- Ferric Sulphate at 42 mg/L, pH: 5.6, LT-22S at 0.25 mg/L
- Aluminum/Ferric Sulphate Blend 2 at 43 mg/L, pH: 6.5, CSP-640 at 0.25 mg/L

9. Evaluation of Impacts from Switching Coagulant

The potential impacts of coagulant changeover on the existing WTP should be evaluated in detail prior to the implementation stage. In this section, the selected doses for the two preferred coagulants from the bench test were used to quantify and qualify the anticipated results on the full scale, based on the WTP historical data. It should be noted that, due to the limitations of the bench test and unavailability of some full-scale data, not all parameters could be quantified. However, the main barriers and limitations have been identified and discussed.

9.1 On WTP process

9.1.1 Compatibility of the Existing Chemical Storage and Feed System

A well designed and engineered chemical feed system is an integral part of an effective water treatment process. If the feed system is not designed properly for the specific chemical in use, high corrosion rates and resultant equipment maintenance and replacement is expected. Also, there is a risk to damage the process equipment. Therefore, it is important to verify the compatibility of the existing chemical feed system with the new selected coagulant.

The existing coagulant handling system is comprised of the components listed in Table 9-1 below.

Table 9-1 Existing coagulant handling system

Parameter	Material
Existing Coagulant (Chemical)	Ferric Chloride ($FeCl_3$)
Piping & Valves	PVC (SCH 80)
Chemical Pump Skid	PVC & Polypropylene[1]
Chemical Storage Tank	Bisphenol- A Epoxy Vinyl Ester Resin Dissolved in Styrene Liner: F010-CNM-00

[1] Currently in the process of replacing all the PVC components to of the chemical pump skid to polypropylene

The above table lists all the components of the existing chemical feed system that are in direct contact with the chemical prior to its injection into the treatment system. Among all the chemicals, ferric chloride is known to be one of the most corrosive ones. The existing chemical feed system has been specifically designed for storage and dosing of this chemical. Table 9-2 presents the existing and proposed coagulants' chemical resistances and their compatibility with the materials noted above.

Table 9-2 PVC and Polypropylene Compatibility

Parameter	Material and Compatibility	
	PVC	Polypropylene
Ferric Chloride *(Existing Coagulant)*	Excellent	Excellent
Ferric Sulphate	Excellent	Excellent
Aluminum/Ferric Sulphate Blend 2	Aluminum Sulphate: Excellent Ferric Sulphate: Excellent	Aluminum Sulphate: Excellent Ferric Sulphate: Excellent

[1] Used Cole-Parmer Scientific Experts Online Chemical Compatibility Database

Based on the above table, the existing system is expected to be fully compatible with both proposed coagulants. Therefore, no physical changes in the chemical feed system is required except replacing all the existing labels to identify the new coagulant.

9.1.2 Addition of Equipment for Coagulant-aid

Coagulation is used to promote formation of large floc sizes and to increase the settling rate of the solids and therefore, achieve higher contaminant removal efficiency. However, in some waters, even high doses of primary coagulant will not produce the desired effluent quality. A polymeric coagulant aid added after the primary coagulant, may reduce the amount of coagulant required and enhance coagulation performance by developing larger flocs.

Currently Winnipeg WTP does not use any coagulant aid, however, it uses Magnafloc LT22S polymer as filter aid prior to filtration process. During the bench testing, three coagulant aid polymer types were tested. Results indicated that Prosedim CSP-640 is recommended for use with aluminum/ferric sulphate Blend 2, while LT-22S is recommended for use with ferric sulphate.

A complete polymer preparation system and dosing system (storage area for the bags and chemical storage and feed system) is required specifically for coagulation purposes for both coagulant-aids, Magnafloc LT-22S or Prosedim CSP-640. Even though the current polymer preparation system is operated with Magnafloc LT-22S, the system does not have capacity for coagulation and filter-aid purposes.

9.1.3 Formation of Precipitates in the Recycling System

Precipitation of soluble metals in water are highly dependent on the pH of water. Among all metals, iron, aluminium, and copper have the highest tendency to precipitate downstream of the DAF process and potentially be present in the DAF recycling stream. Table 9-3 is a summary of results obtained during the bench test for total and dissolved concentrations of iron, aluminum, copper and manganese for the clarified water of each coagulant. As shown below, coagulation with ferric sulphate produces higher metal residuals than the aluminum/ferric sulphate Blend 2. Since there are no full-scale data available for aluminum and copper concentrations, a baseline could not be developed for comparison purposes and therefore it cannot be concluded that ferric sulphate might generate more precipitates.

Table 9-3 Iron, Aluminum, Copper, and Manganese Contents in Clarified Water

Coagulant	Ferric Chloride (current coagulant)[1]	Ferric Sulphate + LT22S[2]	Aluminum/Ferric Sulphate Blend 2 +CSP-640[2]
Constituent	$FeCl_3$	$Fe_2(SO_4)_3$	70% $Al_2(SO_4)_3.18H_2O$ 30% $Fe_2(SO_4)_3$
Total Iron (mg/L)	0.59	1.02	0.23
Dissolved Iron (mg/L)	0.24	0.13	<0.1
Total aluminum (mg/L)	N/A	<0.02	0.37
Dissolved aluminum (mg/L)	N/A	<0.02	0.07
Total Copper (mg/L)	N/A	0.025	<0.005
Dissolved Copper (mg/L)	N/A	0.02	<0.003
Total Manganese (mg/L)	0.049	0.011	0.010
Dissolved Manganese (mg/L)	0.045	0.011	0.011

1 Average values as per Full scale.
2 Average values from Lab analysis as per Bench Test results from January 2017.
3 N/A – Not applicable

9.1.4 Filter run and backwash

Filter run time and frequency of filter backwashes are dependent on the concentration of suspended solids in water upstream of the filtration step. Suspended solids, not removed in DAF process, and some of the present dissolved metals would be oxidized through ozonation process prior to entering the filtration step. The suspended solids are mainly precipitates of iron, aluminium, copper and Mn, as well as other colloidal material which will be retained by the filters. Higher TSS concentration would result in shorter filter run times and UFRV and increase the backwash frequency. Furthermore, longer backwash times might be required resulting in higher water losses during backwash stage.

As discussed in section 9.1.3, ferric sulphate produces higher metal residuals than the aluminum/ferric sulphate Blend 2, mainly due to iron precipitation. However, since there is no full-scale data available for aluminum and copper concentrations, a baseline could not be developed for comparison purposes and therefore it cannot be concluded that ferric sulphate might generate more precipitates.

On the other hand, the optimum pH (6.3) for the aluminum/ferric sulphate Blend 2 is considerably higher than the current optimum pH (5.6). Higher operation pH prior filtration may be linked to shortened filter runs due to Mn precipitation or alteration of the biological activity within the filters. Therefore, it could be possible that the aluminum/ferric sulphate Blend 2 would result in shorter filter runs and higher backwash frequency.

9.1.5 Chlorine Contact Time and Dose

Current Winnipeg WTP disinfection processes are as follows:

- Chlorination: Inactivation of viruses only.
- Ultraviolet (UV) system: Inactivation of Giardia and Cryptosporidium

It should be noted that the required contact time (CT) for inactivation of viruses by free chlorine is only dependent on the required log inactivation and water temperature and is not dependent on the pH of water (for pH between 6 to 9)[1].

When sodium hypochlorite is added to water, it dissociates to hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). Among the two, HOCl is the stronger disinfectant. As pH decreases, HOCl presence becomes more dominant and therefore higher disinfection efficiency is achieved.

Higher disinfection efficiency is expected from ferric sulphate since it decreases the pH to a lower value than the other candidate coagulants. On the other hand, coagulant changeover to aluminum/ferric sulphate Blend 2 is expected to decrease disinfection efficiency due to higher required pH ranges and increase chlorine instantaneous chemical demand, due to lower TOC removal efficiency. Higher chlorine doses could increase the potential for disinfection by-products formation.

9.2 On Chemical Supply and Water Chemistry

9.2.1 Local Availability and Price

One of the most important factors in selecting the coagulant is to investigate their local availability. Location of the WTP and the suppliers can affect availability and price of the coagulant. The proposed coagulants are the two most commonly used coagulants in the water treatment industry and therefore are easily available throughout Canada and can be shipped to the Winnipeg WTP. Therefore, they are comparable in terms of local availability.

In order to calculate the price of each coagulant, the optimal average dose of ferric chloride in the full-scale and the optimal average doses of ferric sulphate and aluminum/ferric sulphate Blend 2 in the bench test were used. The unit prices used for each coagulant are based on iron content of the coagulant.

A summary of the expected coagulant annual consumption and associated costs are presented in Table 9-4.

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[1] MOE (Ministry of Environment, Ontario). Procedure for Disinfection of Drinking Water in Ontario, June 1, 2003

Table 9-4 Coagulant Consumption and Costs

Coagulant	Ferric Chloride (current coagulant)	Ferric Sulphate	Aluminum/Ferric Sulphate Blend 2
Constituent	$FeCl_3$	$Fe_2(SO_4)_3$	70% $Al_2(SO_4)_3.18H_2O$ 30% $Fe_2(SO_4)_3$
Price ($/kgFe)	$ 1.75	$ 1.66	$ 1.96
Optimal Dose (mg/L)	27.6[1]	42[2]	43[3]
Optimal Dose (mgFe/L)	9.8	11.7	9.3[4]
Annual Consumption (kgFe/y)	749,000	900,000	709,000
Annual Consumption (kg/y)	5,428,000	7,487,000	7,165,000
Annual Consumption (m^3/y)	3,750	4,830	5,190
Total Annual Cost[5]	$ 1,300,000	$ 1,490000	$ 1,390,000

1 As per Full scale.
2 As per equivalent iron dose of Full scale
3 As per Bench Test from January 2017.
4 Based on aluminum and iron atomic weight of 56 g/mol and 27g/mol respectively.
5 Based on the actual price of ferric chloride and cost relation between coagulants provided by Kemira. Note: Costs of ferric chloride were provided by the City. Costs of ferric sulphate and aluminum/ferric sulphate Blend 2 were provided by Kemira (proportional to the % of iron of each chemical).

When coagulant costs alone are considered (Table 9-4), coagulant change over from ferric chloride to ferric sulphate and aluminum/ferric sulphate Blend 2 would result in 14% and 6% increase in the annual chemical costs respectively.

9.2.2 pH Operating Range for Optimal Performance and Alkalinity Consumed

Addition of either iron based or alum coagulants will lower the pH of water because these agents are acidic and alkalinity is consumed during the coagulation processes. The extent of the pH reduction is dependent principally on the initial alkalinity concentration of the raw water. The higher the alkalinity, the lower the reduction of pH for a given chemical dosage. All iron based coagulants contain substantial amounts of free sulphuric acid or hydrochloric acid, which will additionally consume alkalinity and suppress the pH of the water. Aluminum sulphate addition consumes alkalinity at a rate of 0.51 mg (as $CaCO_3$) per mg of alum which corresponds to a need for 0.41 mg of caustic (NaOH). On the other hand, ferric chloride addition consumes alkalinity at a rate of 0.92 mg (as $CaCO_3$), which corresponds to a need for 0.74 mg of caustic (NaOH), and ferric sulphate addition consumes alkalinity at a rate of 0.75 mg (as $CaCO_3$), which corresponds to a need for 0.60 mg of caustic (NaOH).

Therefore, ferric chloride and ferric sulphate consume more alkalinity than aluminum sulphate, and hence have a higher tendency to depress the pH of the water even more. Between the two ferric based coagulants, ferric sulphate consumes less alkalinity than ferric chloride. Table 9-5 presents the optimal pH ranges for all three coagulants, the post-DAF water pH based either on the full-scale or bench test results.

Table 9-5 pH Ranges and Alkalinity Consumed for aluminum and Iron Based Coagulants

Coagulant	Ferric Chloride (current coagulant)	Ferric Sulphate	Aluminum/Ferric Sulphate Blend 2
Constituent	$FeCl_3$	$Fe_2(SO_4)_3$	70% $Al_2(SO_4)_3.18H_2O$ 30% $Fe_2(SO_4)_3$
Iron Content ($\%_{w/w}$)	12.7 -14.1%	11.5-13%	3.28%
Aluminum Content ($\%_{w/w}$)	-	-	3.0%
Optimal pH range	< 6	< 6	5.5 – 6.5
Optimal pH	N/A	5.6^2	6.5^2
pH depression	N/A	-0.2^2	-0.2^2
Post-DAF pH	5.6^1	5.4^2	6.3^2

1 As per Full scale.
2 As per Bench Test from January 2017.

Based on the above table, sulphuric acid is required to reach optimal pH for coagulation. However, less sulphuric acid is required for aluminum/ferric sulphate Blend 2 than the other two coagulants.

Furthermore, for all coagulants, additional alkalinity will have to be added to maintain an acceptable treated water pH range. However, less caustic soda is required for aluminum/ferric sulphate Blend 2 than the other two coagulants.

Between the two proposed coagulants, the overall alkalinity consumption is higher for ferric sulphate than for the aluminum/ferric sulphate Blend 2 which is mainly due to the lower required optimum pH range. As such, there may be the need to improve alkalinity prior to coagulation. The average alkalinity consumption for ferric chloride is 68 as mg$CaCO_3$ at full scale. A comparison between the full-scale and expected doses of the candidate coagulants indicates no major change in the alkalinity consumption for ferric sulphate and a 27% decrease in the calculated alkalinity consumption for aluminum/ferric sulphate Blend 2. However, since the optimal pH for ferric sulphate is relative low, ferric sulphate presents a higher risk of low buffer capacity than aluminum/ferric sulphate Blend 2. At this stage, no alkalinity results are available from the bench tests to corroborate the above statement. This could be confirmed during the piloting stage.

Table 9-6 presents the chemical costs associated with each coagulant and their requirement for pH and alkalinity adjustment.

Table 9-6 Acid and Base Consumption and Costs

Coagulant	Ferric Chloride (current coagulant)	Ferric Sulphate	Aluminum/Ferric Sulphate Blend 2
Dose of acid required (mg/L)	41.7[1]	36[2]	15[2]
Acid Annual Consumption (ton/y)	3,400	2,960	1,230
Acid Annual Consumption (m^3/y)	1,870	1,600	700
Acid Total Annual Costs[4]	$480,000	$415,000	$175,000
Dose of base required (mg/L)	49.6[1]	55[3]	33[3]
Base Annual Consumption (ton/y)	7,600	8,500	5,060
Base Annual Consumption (m^3/y)	4,970	5,500	3,300
Base Total Annual Costs[4]	$3,660,000	$4,060,000	$2,440,000
TOTAL ANNUAL COSTS	$5,440,000	$5,965,000	$4,005,000

1 As per Full scale.
2 Based on theoretical calculations to adjust to the optimum pH established in the Bench tests.
3 Based on theoretical calculations to adjust to the full-scale average clearwell pH of 7.84 (as presented in Table 2-1).
4 Based on the actual prices of sulphuric acid and caustic soda.

Based on the above costs associated with supplementary acid and base requirement for pH and alkalinity adjustment for of the three coagulants, a 10% increase and a 27% decrease in chemical costs is expected for changing the coagulant over from ferric chloride to ferric sulphate and aluminum/ferric sulphate Blend 2 respectively.

In addition, the pH of operation would impact the biological activity in the filters, which could lead to other changes to the water chemistry. The previous trials tests performed at the WTP when the pH was raised prior filtration are not conclusive in terms of TOC removal or other parameters. Hence, the impact of the operation pH change on the biological filters with aluminum/ferric sulphate Blend 2 with cannot be quantified or qualified at this stage.

9.2.3 Method of Delivery/Frequency of Delivery

With the implementation of a new coagulant, the method of delivery and frequency of delivery should be assessed to investigate the impact on the new coagulant on the daily operation of Winnipeg WTP. Currently, ferric chloride is delivered to the site via rail cars every 5 to 6 days. Each rail car has a capacity of 80 to 90 tons. The vendors for both ferric sulphate and aluminum/ferric sulphate Blend 2 coagulants have confirmed the possibility of applying the same delivery method for the proposed coagulants. Table 9-7 is a summary of the autonomy and frequency of delivery for the existing and proposed coagulants and their associated acid and base requirements.

Table 9-7 Autonomy and Frequency of Delivery

Coagulant	Ferric Chloride (current coagulant) [1]	Ferric Sulphate [2, 3]	Aluminum/Ferric Sulphate Blend 2[2]
Coagulant Frequency of Delivery (days)	5 - 6	3.5 – 4.5	3.5 – 4.5
Coagulant Storage Autonomy (days)	36	26	26
Acid Frequency of delivery (days)	2.8 – 3	3 - 4	7 - 9
Acid Storage Autonomy (days)	37	43	> 100
Base Frequency of delivery (days)	3.5 – 4.5	3 - 4	5 - 7
Base Storage Autonomy (days)	28	25	42

1 As per full-scale historical data.
2 Based on historical data average flow.
3 Considering the tank volume was reduced by 6.5% to account for the higher specific gravity of ferric sulphate (1.55) in comparison with ferric chloride (1.45).

As shown in Table 9-7 above, both proposed coagulants increase the delivery frequency of coagulant chemical when compared with ferric chloride (current coagulant). Ferric sulphate and aluminum/ferric sulphate Blend 2 would be delivered to the site every 3.5 to 4.5 days. Ferric chloride is currently being delivered to the site every 5 to 6 days. On the other hand, both proposed coagulants decrease the delivery frequency of acid. Among the two, since aluminum/ferric sulphate Blend 2 has the lowest requirements for acid due to a higher operating pH, the acid delivery frequency is reduced in half when compared with the acid requirement for the existing coagulant. The frequency of delivery of base would be similar between the current coagulant and ferric sulphate, but is reduced by 40% with aluminum/ferric sulphate Blend 2.

The daily consumptions of aluminum/ferric sulphate Blend 2 as coagulant, acid and base result in a storage autonomy of 26, 100 and 42 days respectively, whereas the storage autonomy for the existing coagulant, acid and base are 36, 37 and 28 days respectively. The daily consumptions of ferric sulphate, acid and base result in a storage autonomy of 26, 43 and 25 days respectively.

9.3 Finished Water Quality

Each coagulant produces a specific finished water quality which is unique to that coagulant and is based on its characteristics and its reaction with raw water. Following the detailed bench test performed, it was revealed that the main differences between the existing and bench tested clarified water quality are related to:

- Aluminum

  Water treated with aluminum salts contains forms of soluble aluminum, which is a prevalent bioavailable source ingested by humans. It has been hypothesized that aluminum exposure is a risk factor for neurological diseases such as the onset of Alzheimers. A health-based guideline for the presence of aluminum in drinking water has not been established. However, based on the GCDWQ, the Operational Guidelines (OG) for residual aluminum in the treated water, due to using an aluminum-based coagulant, is 0.1 mg/L. High residual aluminum can cause coating of the pipes in the distribution system and therefore higher energy requirement for pumps and flocculation in the distribution system. Based the bench test results presented in Table 9-3, changeover to aluminum/ferric sulphate Blend 2 resulted in six (6) times more total aluminum content than ferric sulphate (0.37 mg/L and <0.02mg/L as total aluminum, respectively) with over 95% in particulate form. However, the particulate form is expected to be removed through the filtration process and therefore, no major concerns are expected at this moment.

- Iron, Manganese & TOC

  Finished water colour could be affected by the presence of iron and Mn compounds. The current GCDWQ AO for iron and Mn in drinking water are 0.3 and 0.05 mg/L respectively. Iron and Mn can stain laundry and fixtures brown and black respectively and cause undesirable tastes in drinking water. Iron can promote the growth of iron bacteria in water mains and service pipes.

  Natural organic matter (usually measured as TOC) is not a regulated parameter, however, it’s directly related to the formation of disinfection by products, as trihalomethanes (THM) and HAA. GCDWQ guidelines has a maximum acceptable concentrations (MAC) of 0.1 mg/L for THM, based on annual average of quarterly samples and AO of 5 mg/L for dissolved organic carbon. HAA is not currently regulated in Canada, except in Quebec. EPA’s and Quebec’s maximum accepted concentration for THM and HAA are 0.08 mg/L and 0.06 mg/l respectively.

  According to Table 2-1, the iron, Mn and TOC historical average contents are 0.57 mg/L as total iron, 0.049 mg/L as total Mn and 4.33 mg/L as TOC in the clarified water (Post-DAF) with ferric chloride as coagulant.

  Based on Table 9-3 and as expected, the results of bench test indicated that aluminum/ferric sulphate Blend 2 produces a clarified water quality with lower iron (0.23 mg/L as total iron) and Mn (0.01 mg/L as total Mn) content in comparison with the other two coagulants. On the other hand, lower TOC removal (6.82 mg/L) and higher residual aluminum content (0.37 mg/L) is observed in the clarified water.

Since TOC does not have a linear relationship with THM or HAA, it is not feasible to quantify how much the aluminum/ferric sulphate Blend 2 may impact the formation of THM or HAA due to its lower TOC removal capability. However, based on the full-scale historical data, the treated water THM concentration has always been considerably below the MAC (0.043 mg/L) with a maximum historical concentration of 0.037 mg/L for HAA. Therefore, it is not expected that THM or HAA would exceed the current GCDWQ or EPA guidelines.

Furthermore, as shown in Table 9-3 and as expected, the results of bench test indicated that ferric sulphate produces a clarified water quality with lower Mn (0.011 mg/L as total Mn) but higher iron (1.02 mg/L as total iron) contents in comparison with the other two coagulants. On the other hand, higher or similar TOC removal (4.64 mg/L) was observed when compared with the current coagulant. In summary, it is expected that ferric sulphate finished water has higher quality in terms of Mn and TOC content. However, the iron content is also higher, but the majority of the iron content in the finished water are in particulate form and is expected to be removed downstream of the water treatment plant through the filtration process and therefore, no major concerns are expected at this moment.

- UV transmittance (UVT)

One of the other water quality parameters that should be studied in the UVT of finished water. UVT is directly impacted by the amount of pi-bonding often present as TOC, turbidity and other dissolved substitutes found in the colour of water. The impact of coagulant change over to the proposed one on UVT values will be further investigated during the pilot-scale tests.

- Alkalinity

Refer to section 9.2.2.

9.4 On WTP Residuals Production and Management

There is limited data available for residual characteristics at the Winnipeg WTP, therefore determining a baseline to compare bench scale results with full-scale is not feasible. Although the potential impact of coagulant change over on solid characteristics is not evident, chemical sludge generation rate was considered for evaluation and comparison.

The addition of coagulant for removal of impurities from water through precipitation results in large amounts of chemical sludge. The sludge production rate is a function of various variables such as removal efficiency of TSS, capability of coagulant to form metal hydroxides, formation of metal phosphates, and precipitation of colloidal particles in water.

Stoichiometry of coagulation process was applied to each of the coagulants to estimate the amount of produced chemical sludge and the results are presented in Table 9-8. The reactions involve removal of impurities through the formation of insoluble, positively charged aluminum or iron hydroxide (or polymericaluminum- or iron-hydroxo complexes) that efficiently attracts negatively charged colloidal particles, including microbes.

Table 9-8 Estimated Sludge Production

Coagulant	Ferric Chloride (current coagulant) [1]	Ferric Sulphate [2]	Aluminum/Ferric Sulphate Blend 2[2]
Sludge Production (ton/y)	1,400,000	1,740,000	1,074,000

1 As per full-scale historical data.
2 Based on historical data average flow.

Among the existing and the two proposed coagulants, aluminum/ferric sulphate Blend 2 has the lowest sludge production rate, followed by ferric chloride and then ferric sulphate. Considering the current average dose applied in the full-scale and the expected optimum doses, aluminum/ferric sulphate Blend 2 will reduce sludge production rate by 23%, while ferric sulphate will increase it by 24%. The aforementioned percentages do not consider the removal of other constituents in the raw water such as TSS, TOC, etc.

Since the sludge from the WTP is drained by gravity to the thickened sludge equalization tanks, the sludge composition is also important. The sludge formed by ferric sulphate would be similar to the current sludge formed by ferric chloride. On other hand, the sludge composition of the sludge formed by aluminum/ferric sulphate Blend 2 could be different and the sludge may not flow as well as the current sludge. Additional evaluation must be performed to determine if additional conditioning pf the sludge is required prior to disposal.

9.5 On Distribution System

Due to the complexity of the distribution system, the potential impact of coagulant changeover on the distribution network may take years to be revealed. Potential concerns are mainly aesthetic which includes colour, odour and taste, impact on corrosion by products levels and their formation, and hydraulic impacts due to possible corrosion and/or deposition inside the distribution network.

9.5.1 Aesthetic Concerns

Aesthetic concerns are mainly colour, odour and taste. Based on the results obtained from the bench test, water coagulated with aluminum/ferric sulphate Blend 2 has lower Mn and iron content which not only reduces the potential for their precipitation in the distribution system, but also reduces water discolouration and taste concerns. Results presented in Table 9-3 presents significant residual aluminum content in the water coagulated with aluminum/ferric sulphate Blend 2, however the residuals are expected to be removed downstream through filtration process and therefore, no aesthetic concern is expected.

Similarly, the bench test results indicated that water coagulated with ferric sulphate has low Mn content which not only reduces the potential for its precipitation in the distribution system, it also reduces water discolouration and taste concerns caused by Mn. However, iron and its potential precipitation is still an aesthetic concern.

Due to laboratory limitations, no analysis for colour or Threshold Odour Number (TON) could be conducted during the bench tests to quantify the impact of different coagulants on these parameters. Also, there is no full-scale data available for the aforementioned parameters for downstream of the DAF process, therefore a baseline could not be developed. However, one of the parameters that could have a direct impact on colour and TON values is TOC removal from the raw water. The bench test results indicated that the removal efficiency of ferric sulphate is two times higher than the aluminum/ferric sulphate Blend 2. Therefore, these parameters should be analyzed during the pilot-scale testing to assess the impact of coagulant changeover on colour.

9.5.2 Corrosion by Products

One of the major possible impacts of coagulant changeover is on the corrosion control program. The changes are due to electrochemical changes in the finished water quality which could result in a higher or lower water corrosivity. The major corrosion by-products are zinc, copper and lead. Zinc corrosion is mostly dependent on pH, alkalinity, hardness and chloride. Lead corrosion is strongly influenced by pH, dissolved oxygen, ammonia and chloride-to-sulphate mass ratio, and copper corrosion is influenced by pH, alkalinity, sulphate, and dissolved oxygen. The current corrosion control program at Winnipeg WTP includes pH adjustment and Orthophosphate dosing prior to distributing water to the network.

Although corrosivity is very difficult to assess in either bench or pilot-scale, it is still possible to predict the main changes in the electrochemical characteristics of the finished water for both proposed coagulants. The differences between ferric sulphate and aluminum/ferric sulphate Blend 2 when compared to ferric chloride are the coagulant counter ion, presence of sulphate instead of chloride, and the raw water buffer capacity.

It is expected that changing the coagulant ion to sulphate would reduce the chloride ion concentration and increase the concentration of sulphate ion in water, which would significantly reduce the Chloride-to-Sulphate Mass Ratio (CMSR). Based on coagulant and acids doses presented in Table 9-4 and Table 9-6, respectively, the expected CSMR would be below 0.1 for both coagulants. This improvement applicable for both candidate coagulants leads to corrosion inhibition and reduction of corrosion by products formed by zinc, lead and coper.

Stability of water is governed by pH, alkalinity, carbon dioxide and the water’s ionic strength. Water with low buffer capacity would control the pH adjustment of the finished water and the finished water stability. Therefore, since the coagulation with aluminum/ferric sulphate Blend 2 is optimal at higher optimal pH than the current coagulant, aluminum/ferric sulphate Blend 2 would improve the buffer capacity and the finished water stability.

Long-term monitoring of distribution system impacts is of paramount importance. Following coagulant changeover at full scale, the facility’s corrosion control program should be reassessed to analyze the corrosivity of the treated water prior to leaving the WTP and fine-tuned. For aluminum/ferric sulphate Blend 2, no major changes to the current corrosion control strategies are expected, however for ferric sulphate, treated water pH should be continuously monitored and pH should be adjusted accordingly.

9.5.3 Hydraulic Impacts

Based on full-scale historical data, the current treated water has an average:

- CSMR: 0.43,
- Larson Skold Index (LI): 1.17,
- Langelier Saturation Index (LSI): -0.68.

The above values present a moderately aggressive treated water, therefore there could be some concerns with possible corrosion in the distribution system, inclusive of the potential for associated colour issues.

As noted in section 9.5.2, sulphate-based coagulants would improve the CSMR. Aluminum/ferric sulphate Blend 2 would possibly reduce the LI and increase the LSI which results in a less corrosive water. Ferric sulphate would present similar LI and LSI as ferric chloride. However, it is not possible to assess its impact on the water corrosivity, without having both alkalinity and calcium concentrations.

Nevertheless, it is expected that the finished water would still present low or moderate aggressiveness for both proposed candidate coagulants. Therefore, coagulant changeover is not expected to cause any additional depositions in the distribution system.

10. Recommendation of Selected Candidate Coagulant

Despite the challenge associated with evaluating and balancing multiple interrelated water quality parameters, prioritizing the regulatory objectives of the City, while also complying with the regulatory requirements of their license, remains fundamental to defining our recommendation.

On the basis of over 80 bench tests completed, two possible coagulants for the primary reduction of Mn were identified. These coagulants were: ferric sulphate and aluminum/ferric sulphate Blend 2, as well as identification of the preferred coagulant-aids being LT-22S and CSP-640, respectively.

In Chapter 9, the findings of these tests were used to evaluate the potential impact of each preferred coagulant on the existing WTP. To facilitate the selection of the appropriate coagulant for pilot study, the expected potential impacts of each coagulant were compared against each other and categorised as tabulated below.

- **Equivalent**: the potential impact on the existing WTP from the coagulant changeover is expected to be equivalent for both preferred coagulants;
- **Lower**: the potential impact on the existing WTP from the coagulant changeover is expected to be lower in comparison with the other alternative coagulant;
- **Higher**: the potential impact on the existing WTP from the coagulant changeover is expected to be higher in comparison with the other alternative coagulant.

This comparative analysis has been presented as Table 10-1. For each parameter, Table 10-1 indicates the potential impacts category of each preferred coagulant and outlines the motives supporting the analysis.

Table 10-1 Comparative Analysis of Potential Impacts for Ferric Sulphate and Aluminum/Ferric Sulphate Blend 2 on the existing WTP

Parameter	Ferric Sulphate vs.	Aluminum/Ferric Sulphate Blend 2
WTP Process	Expected Potential Impact	Expected Potential Impact
Material compatibility of the existing chemical storage and feed system	Equivalent Compatible	Equivalent Compatible
Addition of equipment for coagulant-aid (Section 9.1.2)	Equivalent Additional preparation system and dosing pumps required	Equivalent Additional preparation system and dosing pumps required
Formation of precipitates in the recycling system (Section 9.1.3)	Higher Higher formation of Fe and Cu residuals in comparison to aluminum/ferric Sulphate Blend 2	Lower Higher Al residual in comparison to ferric sulphate
Filter run and backwash (Section 9.1.4)	Lower	Higher Higher operating pH may result in shorter filter runs and increased backwashing
Chlorine contact time and dose (for Virus only) (Section 9.1.5)	Lower Lower operating pH increases disinfection efficiency	Higher Higher operating pH compared to ferric sulphate results in lower disinfection efficiency TOC removal efficiency increases chlorine instantaneous chemical demand

Parameter	Ferric Sulphate vs.	Aluminum/Ferric Sulphate Blend 2
Chemical Supply and Water Chemistry in the WTP		
Local availability and price (Section 9.2.1)	Higher 7% higher cost in comparison with aluminum/ ferric sulphate Blend 2	Lower
pH operating range for optimal performance and Alkalinity consumed (Section 9.2.2)	Higher Higher alkalinity consumption Higher acid and base consumption due to lower pH operating range 49% higher annual cost in comparison with aluminum/ferric sulphate Blend 2	Lower Lower alkalinity consumption Lower acid and base consumption due to higher pH operating range
	Lower	Higher Potential higher impact on the biological activity due to higher operating pH (Cannot be quantified or qualified at this stage)
Method of delivery/frequency of delivery/storage (Section 9.2.3)	Higher Less autonomy and higher delivery frequency for acid and base in comparison with aluminum/ferric sulphate Blend 2 Equivalent delivery frequency for coagulant Higher specific gravity (1.55) which affect existing coagulant storage tank volume	Lower Lower specific gravity (1.38), no impact on existing coagulant storage tank volume
Finished Water Quality (Section 9.3)		
Aluminum	Lower	Higher Higher Al, most in particulate form, in comparison with ferric sulphate
Iron	Higher Higher Fe, most in particulate form in comparison with aluminum/ferric sulphate Blend 2	Lower
Manganese	Equivalent Improvement expected	Equivalent Improvement expected
TOC and DBPs	Lower	Higher Lower TOC removal, higher risks of DBP formation (Cannot be quantified or qualified at this stage)
UV transmittance (UVT)	Cannot be quantified or qualified at this stage	Cannot be quantified or qualified at this stage
WTP Residuals Production and Management (Section 9.4)		
Sludge Production	Higher 62% higher sludge production in comparison with aluminum/ ferric sulphate Blend 2 (theoretical calculations)	Lower
Sludge Composition	Lower	Higher Different sludge composition (aluminium hydroxides)

Parameter	Ferric Sulphate vs.	Aluminum/Ferric Sulphate Blend 2
Distribution System		
Aesthetic concerns (Section 9.5.1)	Cannot be quantified or qualified at this stage	Cannot be quantified or qualified at this stage
Corrosion by products (Section 9.5.2)	Higher	Lower Equivalent CSMR and Zn, Pb, Cu corrosion Higher operating pH improves buffering capacity and water stability
Hydraulic Impacts (Section 9.5.3)	Equivalent Low to moderately aggressive water	Equivalent Low to moderately aggressive water

Based on the results presented in the evaluation table, the main outcomes of this comparative analysis are:

- Ferric sulphate would potentially have lower impacts on the operational parameters of the current treatment line and the biological filtration process (similar pH), produce a finished water quality similar to the current one, and lower potential Mn release from the filter media. On the other hand, the chemical costs would increase and the treated water could present lower stability.
- Aluminum/ferric sulphate Blend 2 has a higher potential for improvements in terms of operation costs and treated water stability and would be able to produce a finished water quality that complies with the standards. However, impacts on the biological activity cannot be assessed during the bench tests and subsequent potential impacts on plant operation, finished water quality and distribution system cannot be calculated at this point. As a result, the Aluminum/ferric sulphate Blend 2 was considered a higher risk to the plant operation and the distribution system.

Although piloting both coagulants through seasonal variations is recommended, due to the tight schedule and technical considerations presented above, the recommended coagulant for pilot study is ferric sulphate. Keeping in mind that the main objective of the study is to provide an alternate coagulant with lower Mn content while also minimizing disruptions to the existing plant operations and distribution system and meeting all WTP Operating Licence requirements. The ferric sulphate's contribution to the Mn content in the finished water and its potential impacts on the parameters discussed in Table 10-1 are the lowest among the other candidate coagulants.

During this project, the City has mentioned serious concerns with concrete corrosion throughout the plant, caused by the lower pH of current operation. Considering the Mn issue and the possible improvements brought by aluminum/ferric sulphate Blend 2 with a higher operation pH, this coagulant is also a strong alternative. However, further piloting efforts would be required prior to implementation due to its dissimilarity to the existing coagulant.

In light of this discussion and the findings presented in Chapter 9, a comparative summary of the potential impacts between the selected coagulant, ferric sulphate, and the existing coagulant, ferric chloride, have been tabulated in Table 10-2. The following comparisons are based on the expected changes which would come about from the replacement of ferric chloride with ferric sulphate.

Table 10-2 Comparative Analysis of Potential Impacts for Ferric Sulphate vs Ferric Chloride on the existing WTP

Parameter	Ferric Sulphate vs Ferric Chloride
WTP Process	Expected Potential Impact
Material compatibility of the existing chemical storage and feed system	Compatible, no changes expected
Addition of equipment for coagulant-aid (Section 9.1.2)	Additional preparation system and dosing pumps required for use of coagulant-aid
Formation of precipitates in the recycling system (Section 9.1.3)	Overall formation of precipitates cannot be quantified or qualified at this stage Higher total iron and lower dissolved iron compared to ferric chloride Lower dissolved and total manganese compared to ferric chloride
Filter run and backwash (Section 9.1.4)	Cannot be quantified or qualified at this stage
Chlorine contact time and dose (for Virus only) (Section 9.1.5)	Higher disinfection efficiency due to lower pH operating range
Chemical Supply and Water Chemistry in the WTP	
Local availability and price (Section 9.2.1)	14% higher cost compared to ferric chloride
pH operating range for optimal performance and Alkalinity consumed (Section 9.2.2)	Equivalent optimum pH range Lower acid consumption due to higher coagulant dose required Higher base consumption due to higher coagulant dose required 10% cost increase in the annual supply of chemicals
Method of delivery/frequency of delivery/storage (Section 9.2.3)	Less autonomy and higher delivery frequency for coagulant and base Higher autonomy and lower delivery frequency for acid Affects coagulant storage volume due to higher specific gravity (1.55)
Finished Water Quality (Section 9.3)	
Aluminum	No major concerns at this stage
Iron	Higher Fe (1.02 mg/L as total iron), most in particulate form, compared to ferric chloride (0.59 mg/L as total iron)
Manganese	Improvement expected Lower total manganese (0.011 mg/L) compared to ferric chloride (0.049 mg/L) Lower dissolved manganese (0.011 mg/L) compared to ferric chloride (0.045 mg/L)
TOC and DBPs	Similar TOC removal expected
UV transmittance (UVT)	Cannot be quantified or qualified at this stage
WTP Residuals Production and Management (Section 9.4)	
Sludge Production	24% increase of sludge production (theoretical calculations)
Sludge Composition	Similar sludge composition expected

Parameter	Ferric Sulphate vs Ferric Chloride
Distribution System	
Aesthetic concerns (Section 9.5.1)	Lower Mn content reduces water discolouration and taste concerns Iron content is still an aesthetic concern Odour concerns cannot be quantified or qualified at this stage
Corrosion by products (Section 9.5.2)	Improvement expected Lower CSMR Less Zn, Pb, Cu corrosion
Hydraulic Impacts (Section 9.5.3)	Improvement expected Lower CSMR Similar LI and LSI No additional depositions expected

Given the potential for impacts to be exacerbated at full-scale operation, ferric sulphate remains the closest in chemical composition and activity to the exiting ferric chloride. Being both iron based coagulants, ferric sulphate provides the least amount of expected impact at both pilot and full-scale systems. As such, ferric sulphate is recommended for the pilot study. Nevertheless, the potential impacts on the chemical supply, sludge production and operation costs on the existing WTP will need to be evaluated once the results of the pilot study are available.

As discussed in Chapter 9, some of the parameters evaluated could not be definitively quantified. In order to better understand these parameters, it is recommended that additional testing be completed to study the impact of the selected coagulant on the following parameters in the finished water:

- Alkalinity, TOC, UVT, Colour, Disinfection By-products, Chlorine Demand, and Corrosivity

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Appendix A – Full-scale Water Quality Data

BENCHMARKING OF FULL SCALE WTP (2010 TO MARCH 2016)

	TEMPERATURE	pH	TURBIDITY	TRUE COLOR	APPARENT COLOR	UVT filt	UVT unfilt	TON	DOC
SAMPLE	°C	-	NTU	units	units	%	%	mg/L	mg/L
IN									
AVERAGE									
MIN									
MAX									
RW									
AVERAGE	9.51	7.98	1.11	5.37	11.27	77.01	74.88	123.17	9.51
MIN	0.50	7.27	0.26	2.50	5.00	73.46	71.74	75.00	7.00
MAX	24.14	8.69	4.91	8.50	18.00	80.70	78.60	200.00	21.00
PD									
AVERAGE		5.59	0.54			92.94	86.10		4.19
MIN		4.92	0.21			90.30	78.10		3.00
MAX		6.41	1.45			94.40	91.60		7.00
OC									
AVERAGE		5.58	0.79	0.79					
MIN		5.31	0.37	0.50					
MAX		6.09	1.42	2.50					
CF									
AVERAGE		5.58	0.12	0.65				9.94	
MIN		5.30	0.06	0.50				6.00	
MAX		7.61	0.27	1.00				15.00	
CW									
AVERAGE	10.46	7.84	0.18	1.40	5.88	94.97	93.84	24.09	4.21
MIN	0.90	7.38	0.08	0.50	2.50	92.34	90.33	12.00	1.00
MAX	24.58	8.30	0.47	7.50	11.00	97.13	95.82	75.00	19.00
BP									
AVERAGE	9.58	7.78	0.17	1.47	5.99	95.40	94.12	23.03	4.05
MIN	0.48	7.39	0.10	0.50	0.50	92.98	91.10	12.00	1.50
MAX	24.14	8.28	0.45	7.50	18.50	97.88	96.20	70.00	19.00
DS									
AVERAGE	9.58	7.62			5.95				
MIN	0.48	7.26			0.50				
MAX	24.14	8.35			20.00				

Legend: IN = intake, RW = raw water pumping station, PD = post-daf, OC = post ozone contactors, CF = combined filtered water, CW = clearwell, BP = Deacon booster pumping station, DS = composite of distribution system

SAMPLE	TOC mg/L	DO mg/L	ORP mV	HARDNESS mg/L	ALKALINITY mg/L	CONDUCTIVITY µS/cm	TDS mg/L	TS mg/L	Fe TOTAL mg/L	Fe SOLUBLE mg/L
IN										
AVERAGE				0.03		0.01				
MIN				0.00		0.00				
MAX				0.13		0.04				
RW										
AVERAGE	9.72	10.85	352.20		75.26	168.2	105.2	115.7	0.05	0.02
MIN	6.00	7.15	237.00		68.00	149.0	61.0	92.0	0.01	0.01
MAX	20.00	14.00	553.00		85.00	190.0	166.0	225.0	0.54	0.04
PD										
AVERAGE	4.33	11.31	361.29		8.83				0.59	0.24
MIN	2.80	7.46	258.00		5.00				0.05	0.09
MAX	7.00	14.30	544.00		16.00				1.79	0.65
OC										
AVERAGE	4.17	12.58	350.33						0.65	0.18
MIN	1.00	8.78	258.00						0.04	0.04
MAX	8.00	16.10	508.00						1.31	0.49
CF										
AVERAGE	3.67								0.07	
MIN	2.00								0.01	
MAX	6.00								0.31	
CW										
AVERAGE	4.19	9.57	396.0	78.80	70.45	316.5	176.0	190.8	0.05	
MIN	1.00	6.36	267.0	68.00	57.00	271.0	116.0	146.0	0.01	
MAX	19.00	12.00	665.0	90.00	89.00	368.0	310.0	336.0	0.24	
BP										
AVERAGE	4.08	11.91	374.7	79.56	69.39	318.1	178.1	191.1	0.05	
MIN	1.00	3.50	275.0	70.00	54.00	273.0	97.0	135.0	0.00	
MAX	20.00	16.10	578.0	94.00	84.00	367.5	229.0	264.0	0.23	
DS										
AVERAGE			371.78		68.08		179.8		0.06	
MIN			278.00		57.00		158.0		0.01	
MAX			549.00		86.00		248.0		0.17	

	Mn TOTAL	Mn SOLUBLE	Mn COLLOIDAL	Na	SO4	Chloride	CSMR	LARSON SKOLD	LANGELIER
SAMPLE	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	-	-
IN									
AVERAGE									
MIN									
MAX									
RW									
AVERAGE	**0.014**	**0.004**		2.3	1.7	3.0	1.00		
MIN	0.002	0.000		1.9	0.0	1.4	0.40		
MAX	0.049	0.024		3.5	5.0	6.2	3.00		
PD									
AVERAGE	**0.049**	**0.045**			50.3	20.2	0.41		
MIN	0.029	0.029			40.0	14.0	0.28		
MAX	0.100	0.097			62.0	48.0	1.04		
OC									
AVERAGE	**0.042**	**0.033**	0.04						
MIN	0.028	0.015	0.03						
MAX	0.076	0.059	0.04						
CF									
AVERAGE	**0.031**	**0.032**	0.04						
MIN	0.013	0.016	0.04						
MAX	0.051	0.048	0.04						
CW									
AVERAGE	**0.036**	**0.022**		33.1	48.4	20.3	0.44		
MIN	0.018	0.010		23.4	23.0	13.0	0.20		
MAX	0.061	0.038		67.1	70.0	29.0	1.04		
BP									
AVERAGE	**0.031**	**0.017**		32.5	49.5	20.6	0.43	1.17	-0.68
MIN	0.012	0.004		23.9	19.0	13.5	0.21	0.83	-1.15
MAX	0.090	0.052		64.5	69.5	29.0	1.37	1.53	-0.07
DS									
AVERAGE	0.024				49.1	20.8	0.44	1.20	-0.86
MIN	0.002				29.0	13.0	0.20	0.88	-1.15
MAX	0.179				69.0	30.0	0.86	1.50	-0.53

			MICROBIOLOGY				
SAMPLE	FREE CHLORINE mg/L	TOTAL CHLORINE mg/L	E.Coli MPNU/100mL	TOTAL COLIFORMS MPNU/100mL	GIARDIA TOTAL cysts/100 L	CRYPTO TOTAL cysts/100 L	HPC cfu/mL
IN							
AVERAGE							
MIN							
MAX							
RW							
AVERAGE			12.48	32.77	1.11	0.47	87.51
MIN			0.00	0.00	0.00	0.00	0.00
MAX			130.00	200.00	5.00	6.00	990.00
PD							
AVERAGE							
MIN							
MAX							
OC							
AVERAGE							10.00
MIN							10.00
MAX							10.00
CF							
AVERAGE				36.25			33.93
MIN				3.00			0.00
MAX				89.00			310.00
CW							
AVERAGE	1.55	1.76					
MIN	0.99	1.17					
MAX	2.42	2.66					
BP							
AVERAGE	1.14	1.32	0.00	0.00			4.00
MIN	0.69	0.83	0.00	0.00			1.00
MAX	1.62	1.83	0.00	0.00			10.00
DS							
AVERAGE			0.00	0.00			1.27
MIN			0.00	0.00			1.00
MAX			0.00	0.00			5.00

	DBPs						
	T-THM	T-HAA	ALDEHYDE	FORMALDEHYDE	ACETALDEHYDE	GLYOXAL	METHYL GLYOXAL
SAMPLE	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
IN							
AVERAGE							
MIN							
MAX							
RW							
AVERAGE							
MIN							
MAX							
PD							
AVERAGE							
MIN							
MAX							
OC							
AVERAGE		3.50					
MIN		3.00					
MAX		4.00					
CF							
AVERAGE		3.00					
MIN		3.00					
MAX		3.00					
CW							
AVERAGE							
MIN							
MAX							
BP							
AVERAGE	9.33	14.40	14.99	8.78	2.84	3.37	2.61
MIN	0.00	5.00	1.75	0.70	0.00	1.00	0.65
MAX	43.40	37.00	29.50	18.50	8.00	11.00	7.00
DS							
AVERAGE							
MIN							
MAX							

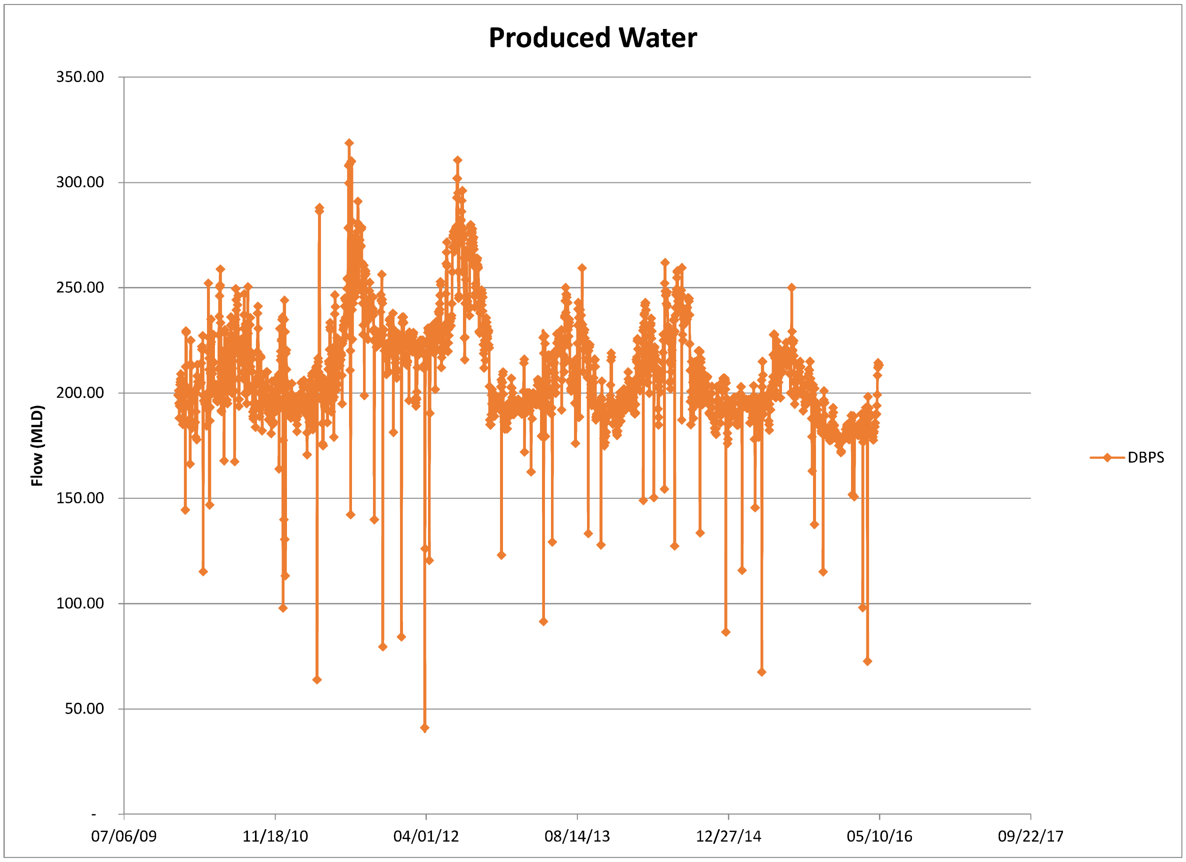
BENCHMARKING OF FULL SCALE WTP (2010 TO MARCH 2016)

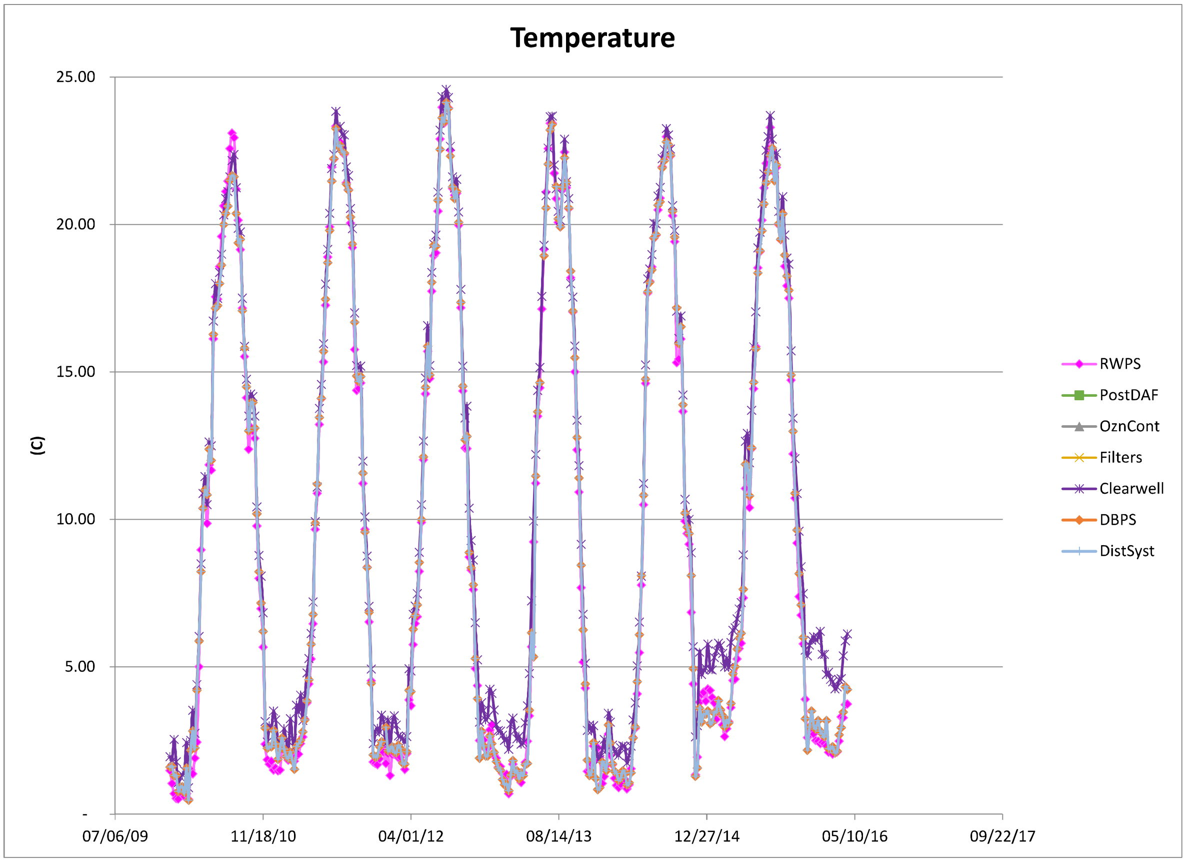
	OZONE CONCENTRATION			
SAMPLE	OZONE CELL 2 CONTACTOR 1 mg/L	OZONE CELL 6 CONTACTOR 2 mg/L	OZONE CELL 2 CONTACTOR 1 mg/L	OZONE CELL 6 CONTACTOR 2 mg/L
AVERAGE	0.20	0.08	0.20	0.08
MIN	0.00	0.00	0.00	0.00
MAX	0.48	0.44	0.54	0.27

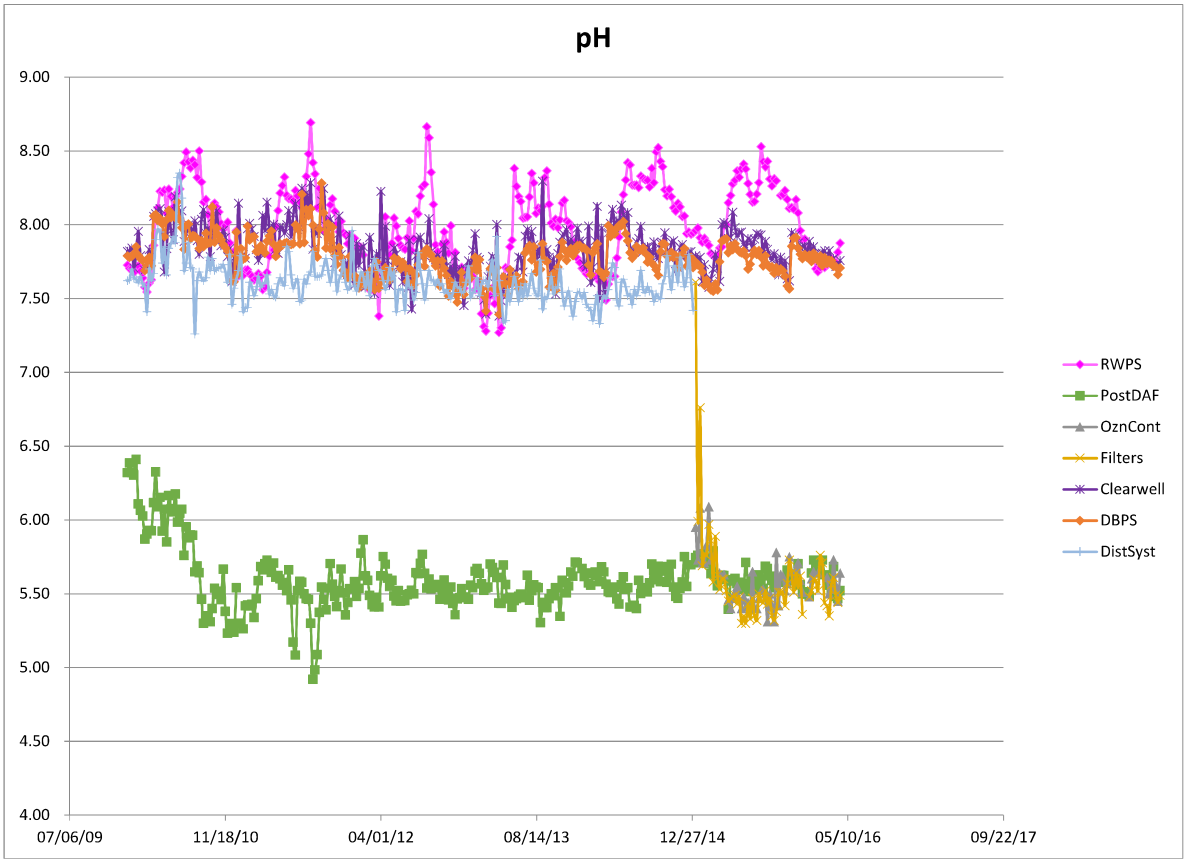
CHEMICAL DOSES	H2SO4 mg/L	FeCl3 mg/L	POLYMER mg/L	O3 mg/L	NaOCl mg/L	NaOH mg/L	H2SiF6 mg/L	H3PO4 mg/L
AVERAGE	41.79	27.65	20.92	0.67	1.64	49.58	0.73	2.00
MIN	21.60	18.50	5.00	-	1.27	35.70	0.70	2.00
MAX	59.44	39.73	51.00	1.50	2.10	66.98	0.85	2.00

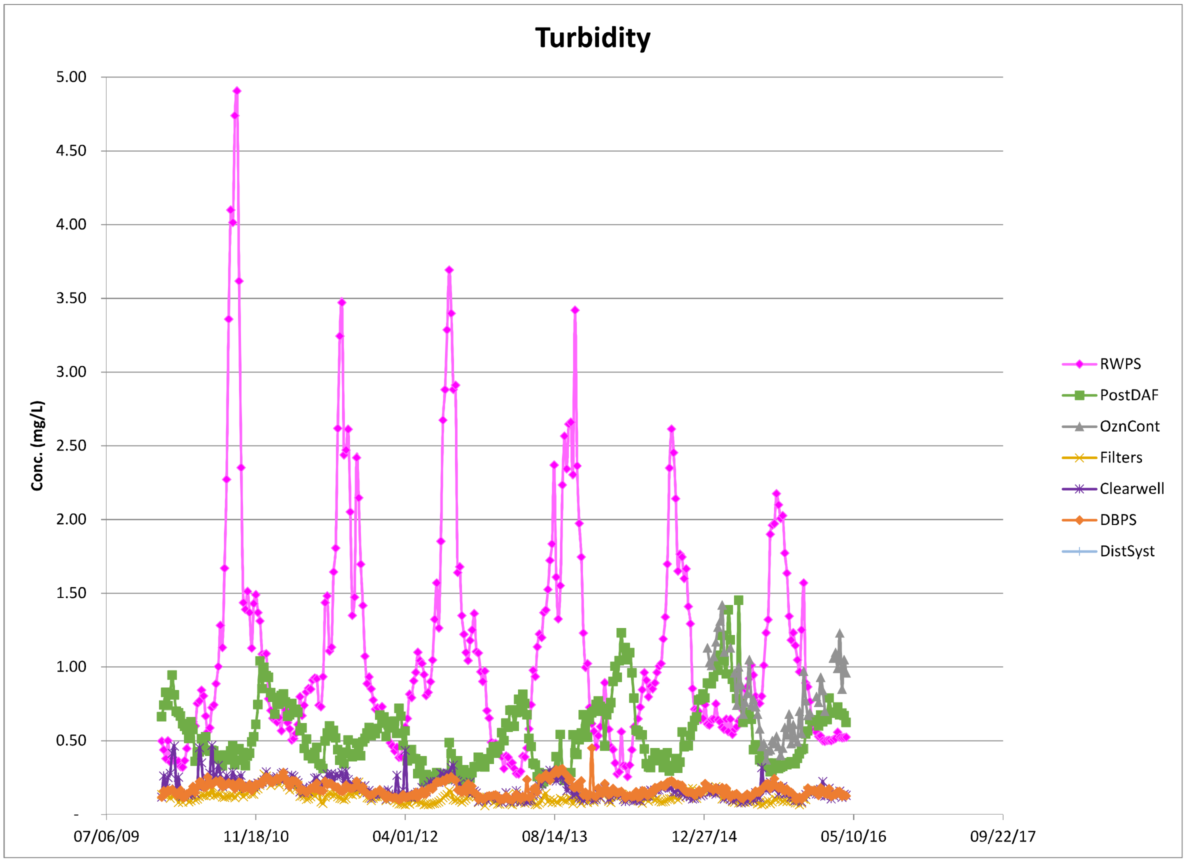
BENCHMARKING OF FULL SCALE WTP (2010 TO MARCH 2016)

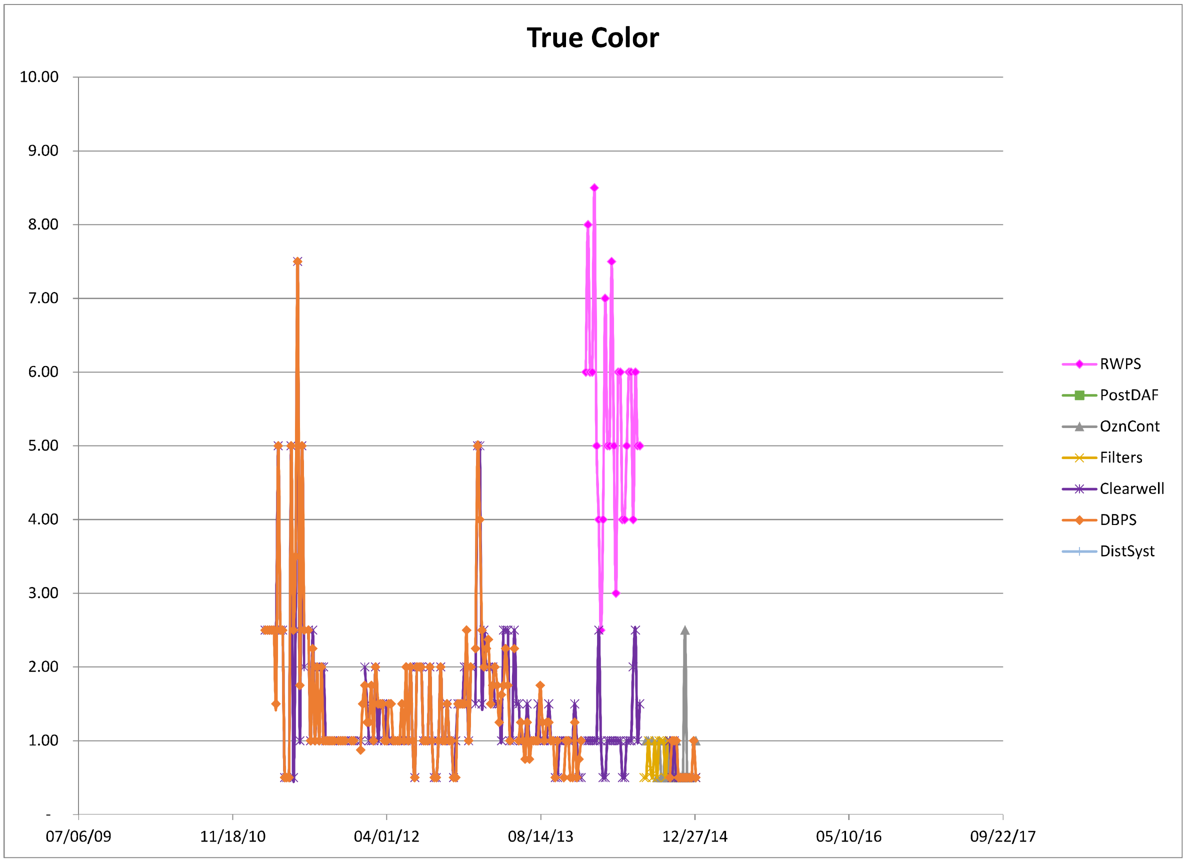
SAMPLE	pH -	TURBIDITY NTU	TRUE COLOR units	Fe TOTAL mg/L	Fe SOLUBLE mg/L	Mn TOTAL mg/L	Mn SOLUBLE mg/L	Mn COLLOIDAL mg/L	**< 2 µ** particles/mL	**2-3 µ** particles/mL	**3-5 µ** particles/mL	**5-7 µ** particles/mL	**7-10 µ** particles/mL	**10-15 µ** particles/mL	**< 15 µ TOTAL** particles/mL
FILTER 1															
AVERAGE	7.02	0.12	0.78	0.06	0.03	0.02	0.02		14.01	10.60	3.53	2.38	1.80	1.04	31.55
MIN	5.44	0.06	0.50	0.01	0.01	0.01	0.01		0.30	2.52	0.78	0.40	0.30	0.15	5.28
MAX	7.76	0.27	2.00	0.16	0.11	0.04	0.04		162.05	96.03	21.03	23.68	9.34	16.27	313.03
FILTER 2															
AVERAGE	7.04	0.12	0.70	0.05	0.03	0.02	0.02		12.22	10.93	3.91	1.99	1.53	0.86	29.70
MIN	5.59	0.06	0.50	0.02	0.01	0.01	0.01		0.23	1.88	0.50	0.28	0.20	0.10	0.00
MAX	7.78	0.34	1.50	0.14	0.05	0.04	0.04		172.80	273.80	124.20	31.37	17.60	6.43	608.40
FILTER 3															
AVERAGE	7.09	0.13	0.65	0.07	0.02	0.03	0.02		17.35	12.72	4.18	2.55	1.67	0.87	37.50
MIN	5.64	0.06	0.50	0.02	0.01	0.02	0.01		0.10	2.00	0.55	0.35	0.20	0.14	4.38
MAX	7.79	0.29	1.00	0.16	0.04	0.04	0.04		159.00	73.14	36.44	16.43	8.60	5.00	270.52
FILTER 4															
AVERAGE	7.23	0.12	0.65	0.07	0.03	0.02	0.02								
MIN	5.49	0.06	0.50	0.02	0.01	0.01	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX	8.12	0.46	1.00	0.19	0.08	0.04	0.04		0.00	0.00	0.00	0.00	0.00	0.00	0.00
FILTER 5															
AVERAGE	7.16	0.11	0.67	0.05	0.02	0.03	0.02								
MIN	5.17	0.06	0.50	0.02	0.01	0.01	0.01		0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX	8.08	0.25	1.00	0.10	0.04	0.05	0.05		0.00	0.00	0.00	0.00	0.00	0.00	0.00
FILTER 6															
AVERAGE	7.04	0.11	0.70	0.05	0.02	0.03	0.03								
MIN	5.20	0.06	0.50	0.01	0.01	0.02	0.01		0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX	7.98	0.24	1.00	0.13	0.05	0.05	0.05		0.00	0.00	0.00	0.00	0.00	0.00	0.00
FILTER 7															
AVERAGE	6.64	0.11	0.67	0.05	0.03	0.03	0.03	0.04							
MIN	5.10	0.06	0.50	0.02	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX	8.01	0.25	1.50	0.12	0.06	0.06	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FILTER 8															
AVERAGE	7.08	0.11	0.62	0.04	0.02	0.03	0.03	0.02							
MIN	5.15	0.05	0.50	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX	8.10	0.24	1.00	0.11	0.04	0.05	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00

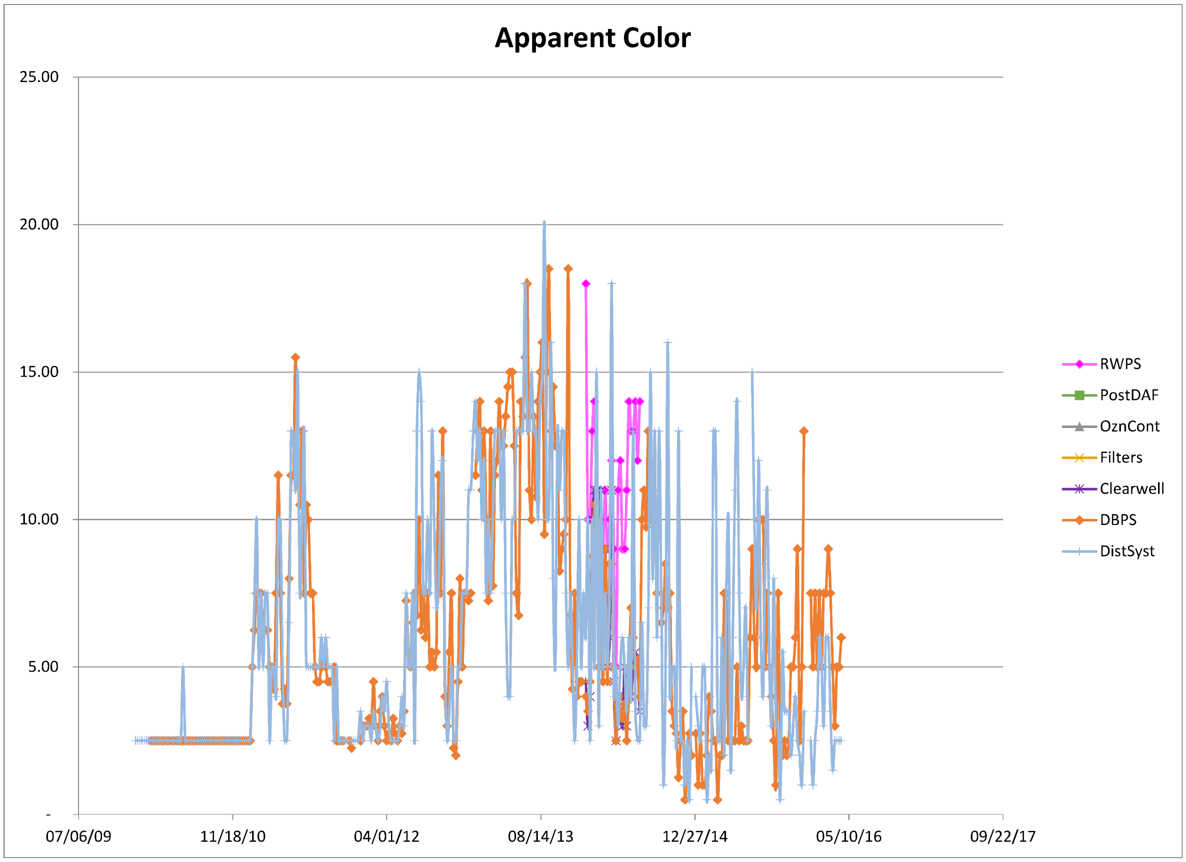

Produced Water
Flow (MLD)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
DBPS

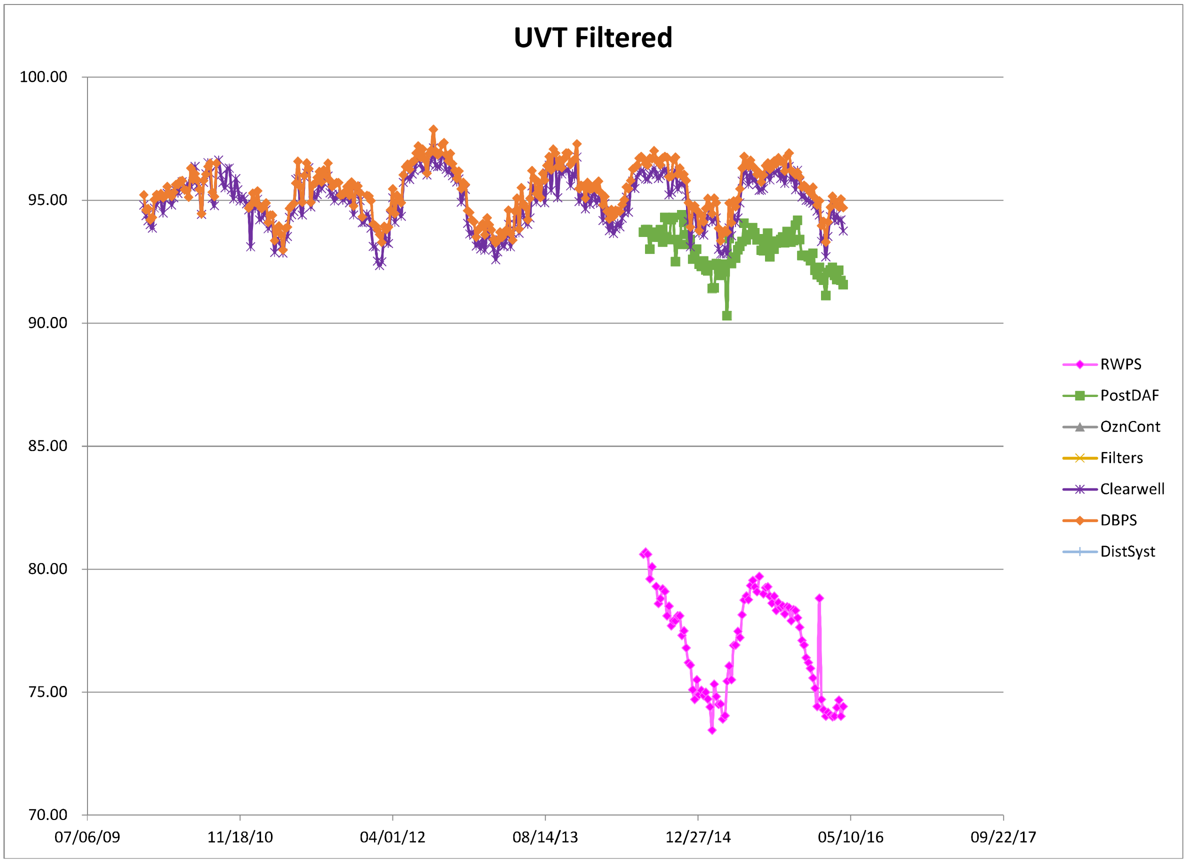

Temperature
(C)
25.00
20.00
15.00
10.00
5.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

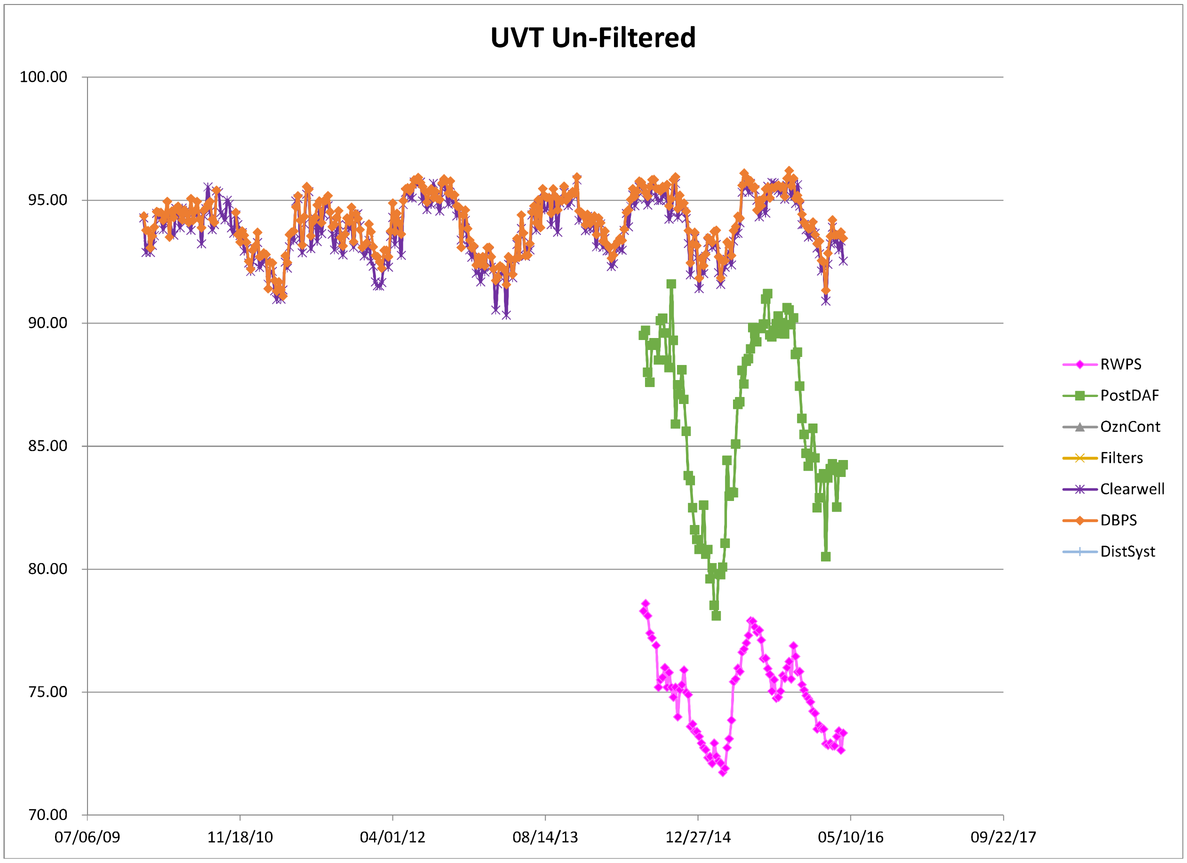

pH
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

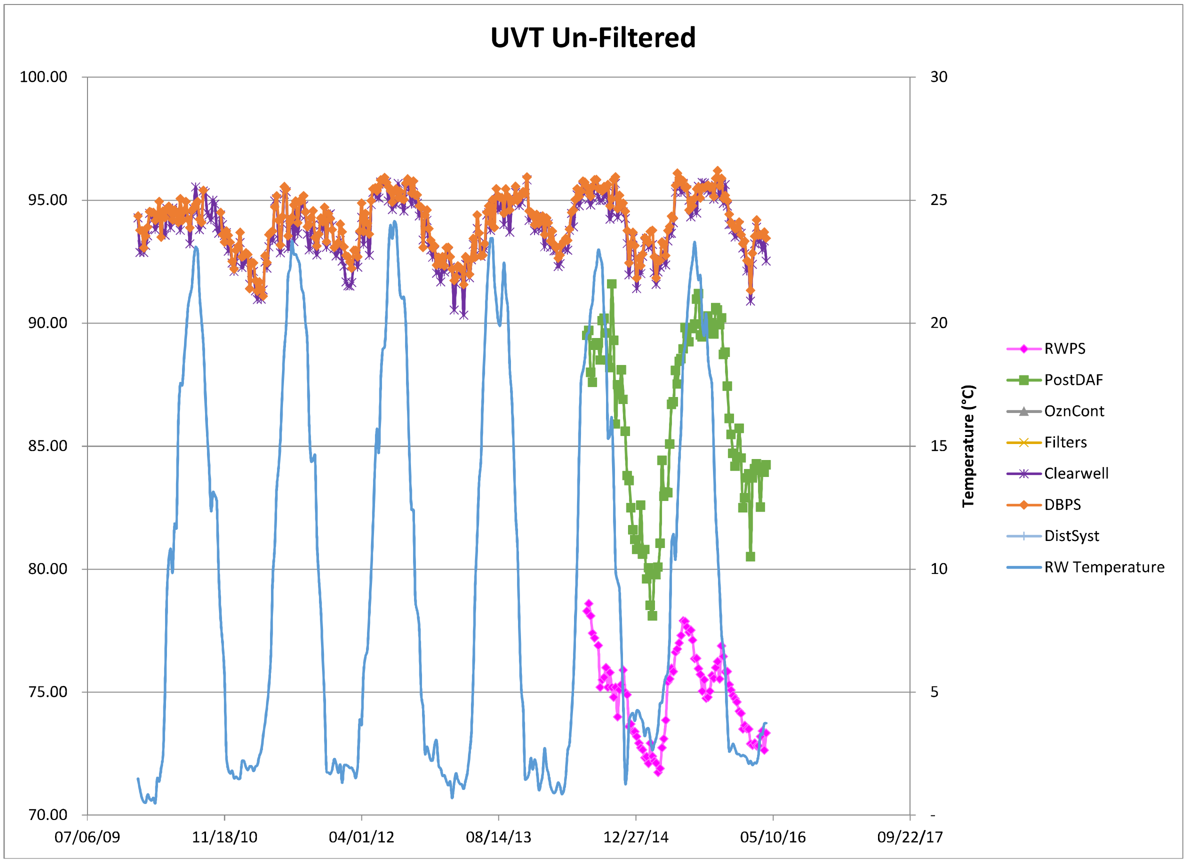

Turbidity
Conc. (mg/L)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

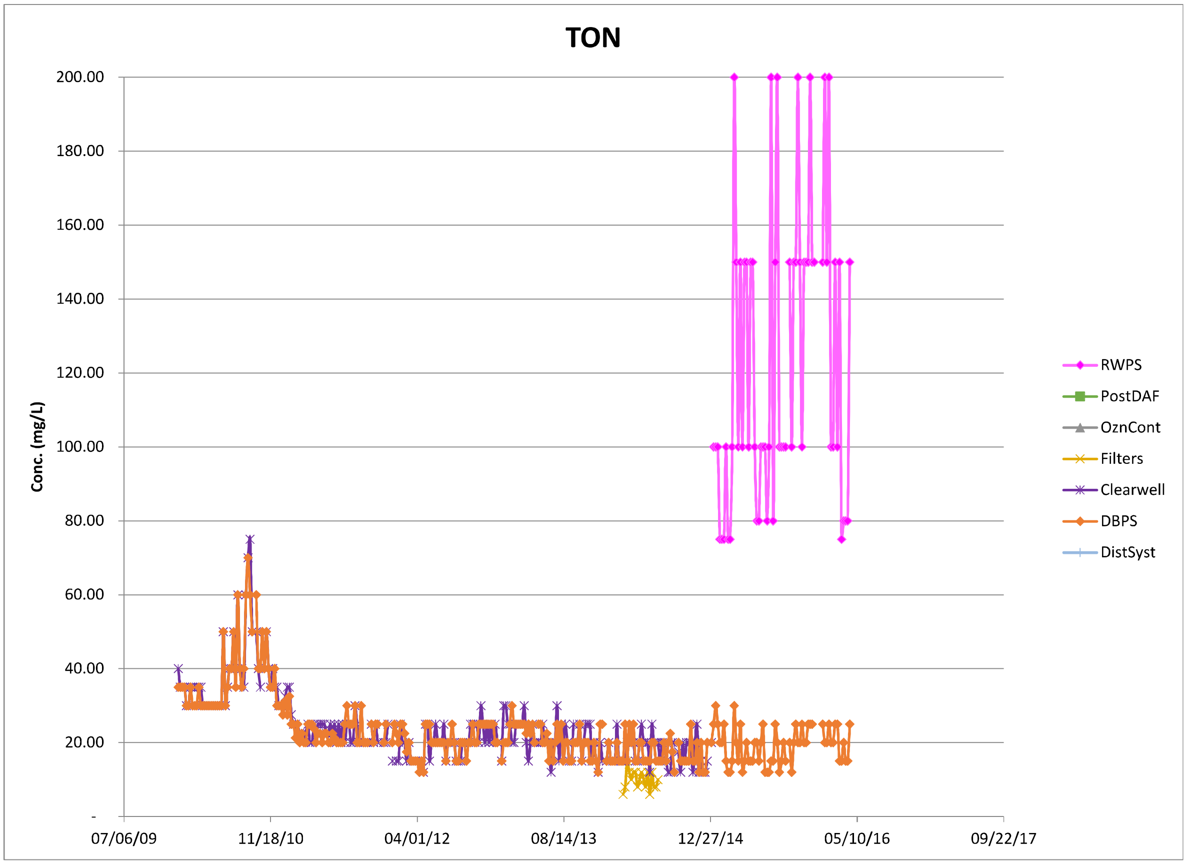

True Color
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

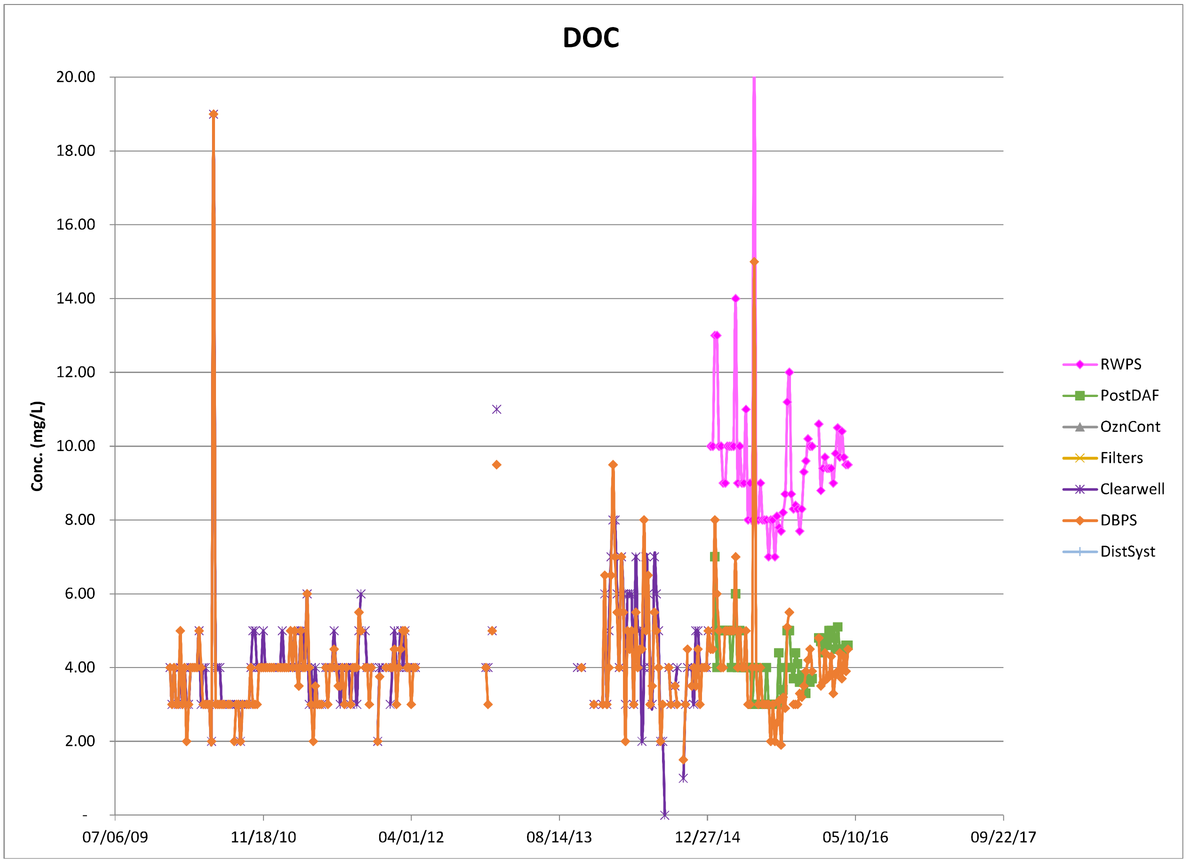

Apparent Color
25.00
20.00
15.00
10.00
5.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

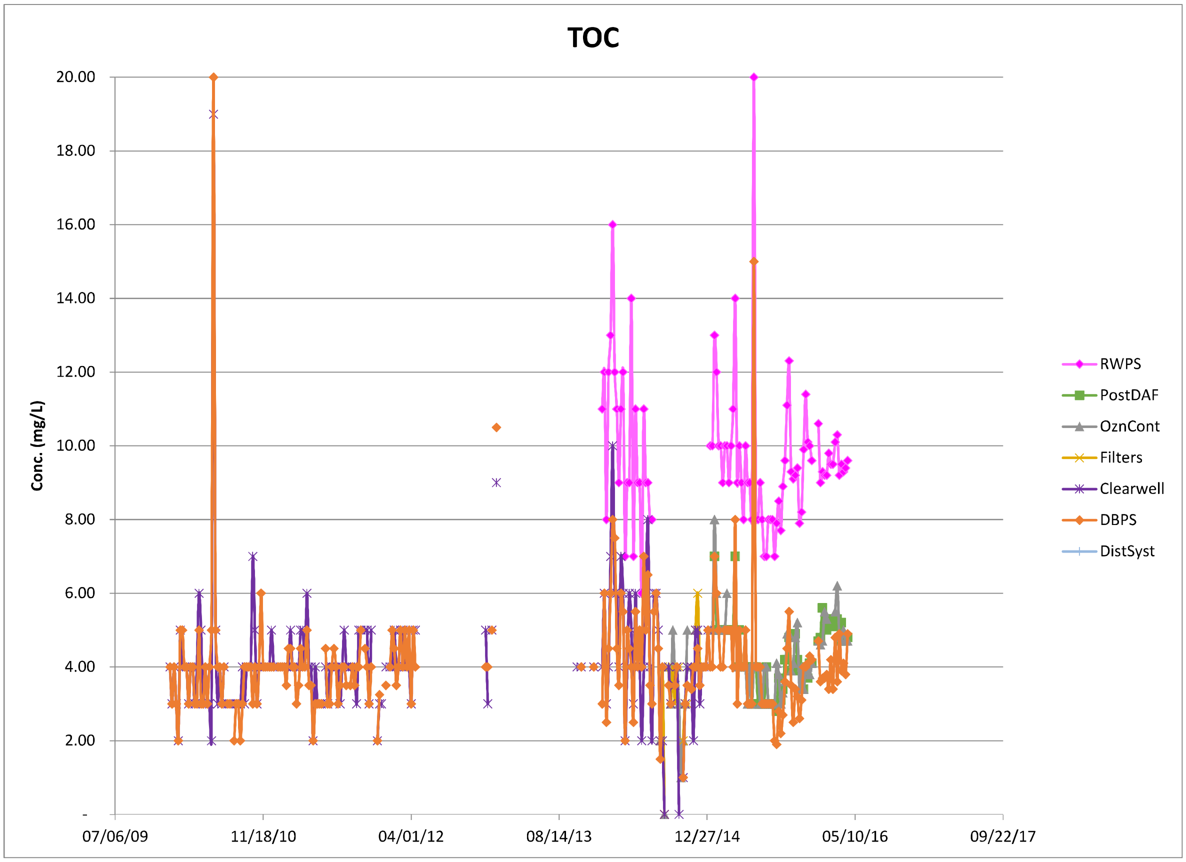

UVT Filtered
100.00
95.00
90.00
85.00
80.00
75.00
70.00
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

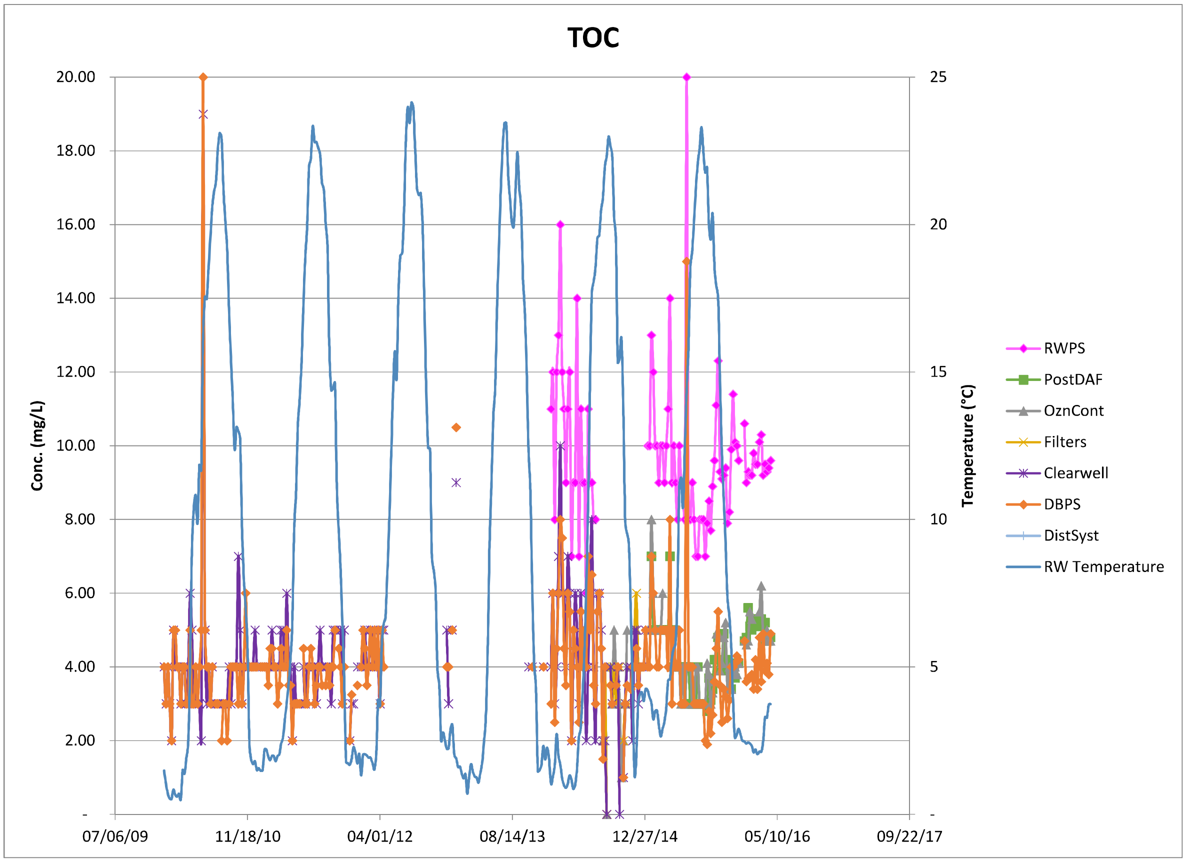

UVT Un-Filtered
100.00
95.00
90.00
85.00
80.00
75.00
70.00
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

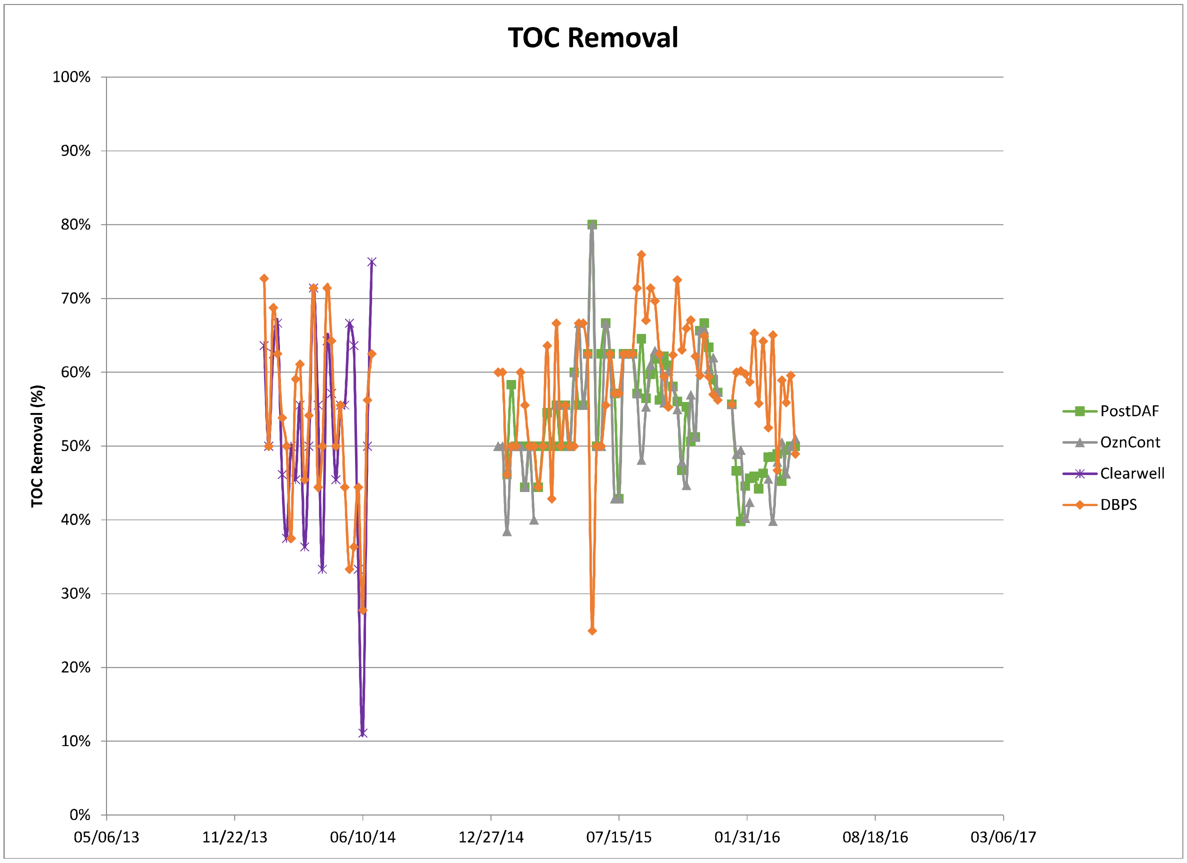

UVT Un-Filtered
100.00
95.00
90.00
85.00
80.00
75.00
70.00
30
25
20
15
10
5
-
Temperature (°C)
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst
RW Temperature

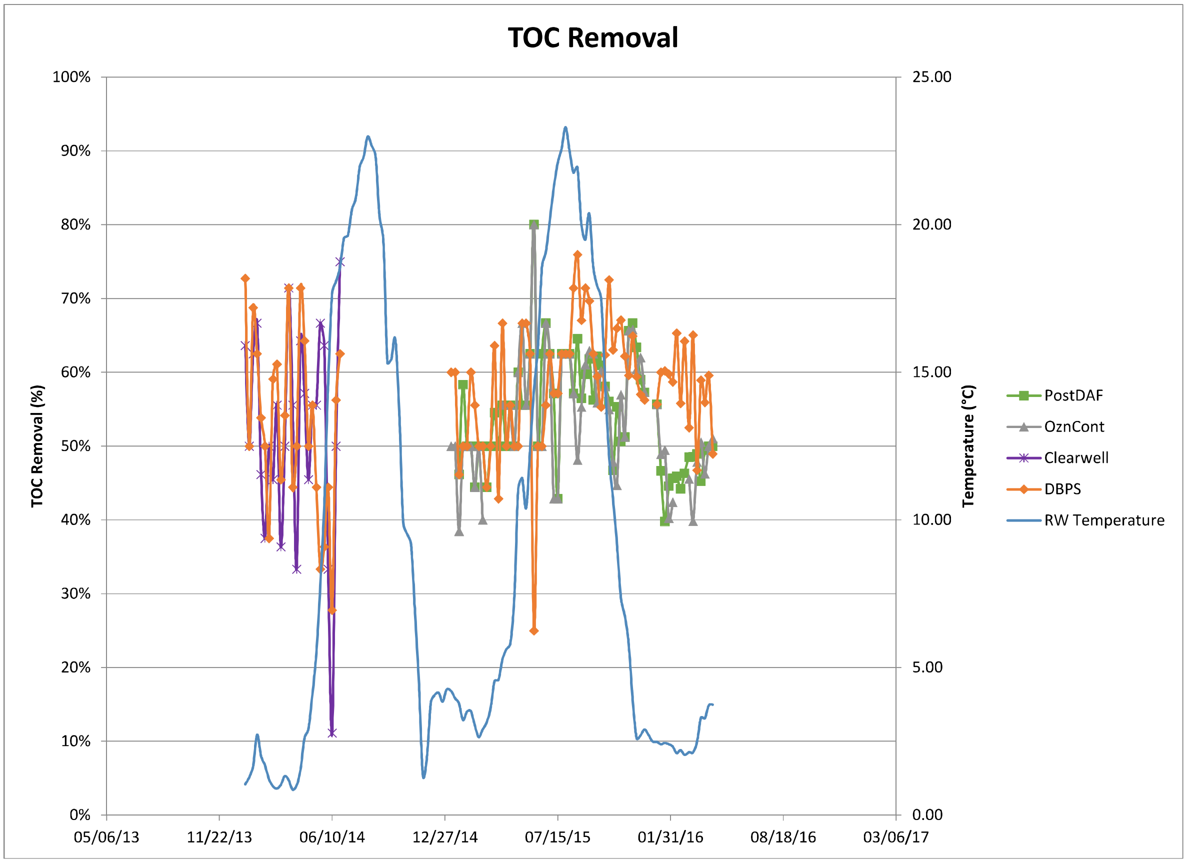

TON
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
-
Conc. (mg/L)
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

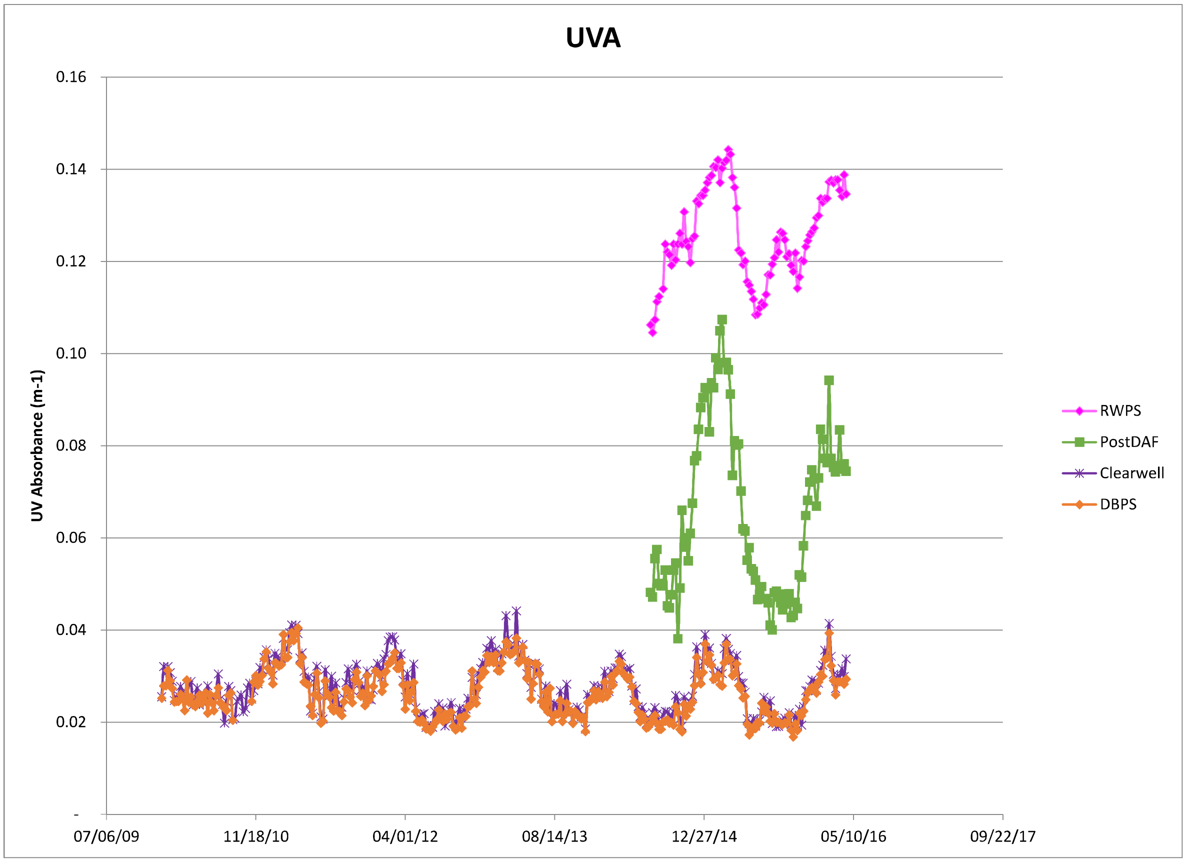

DOC
Conc. (mg/L)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

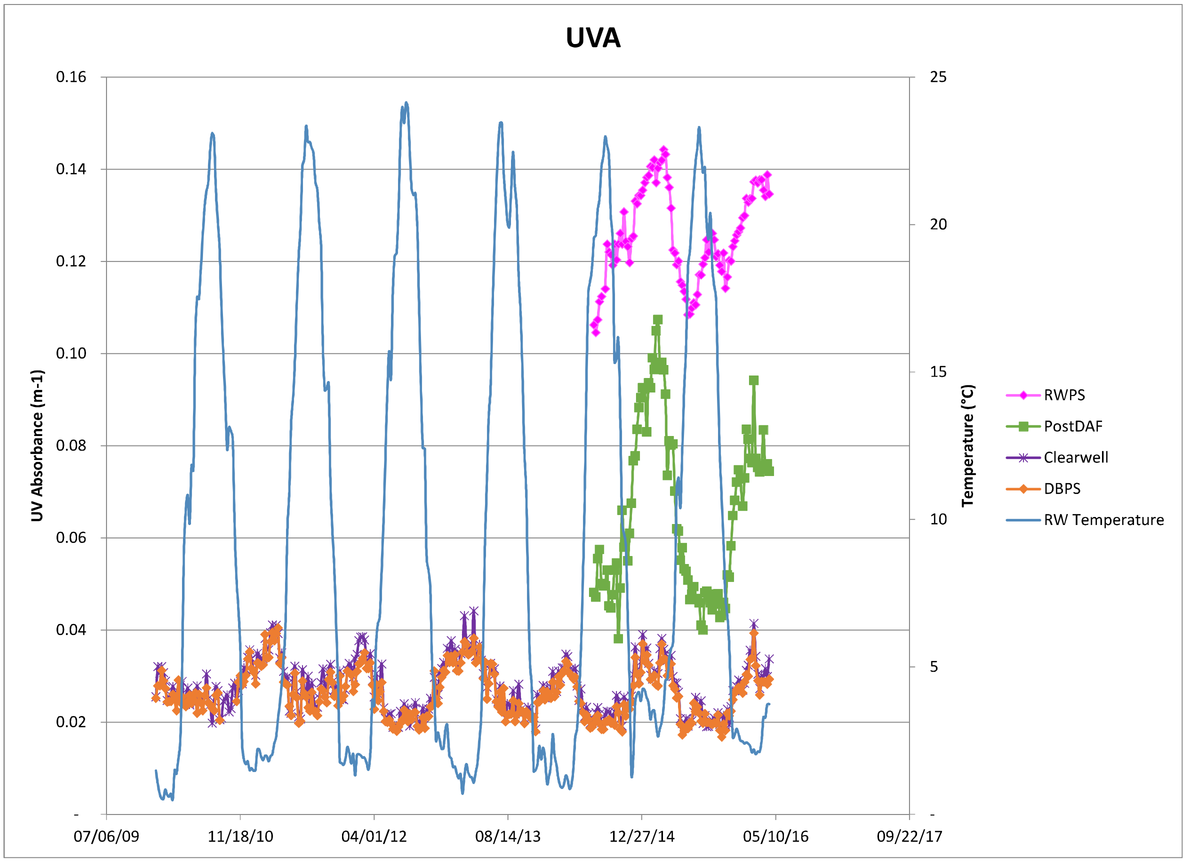

TOC
Conc. (mg/L)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

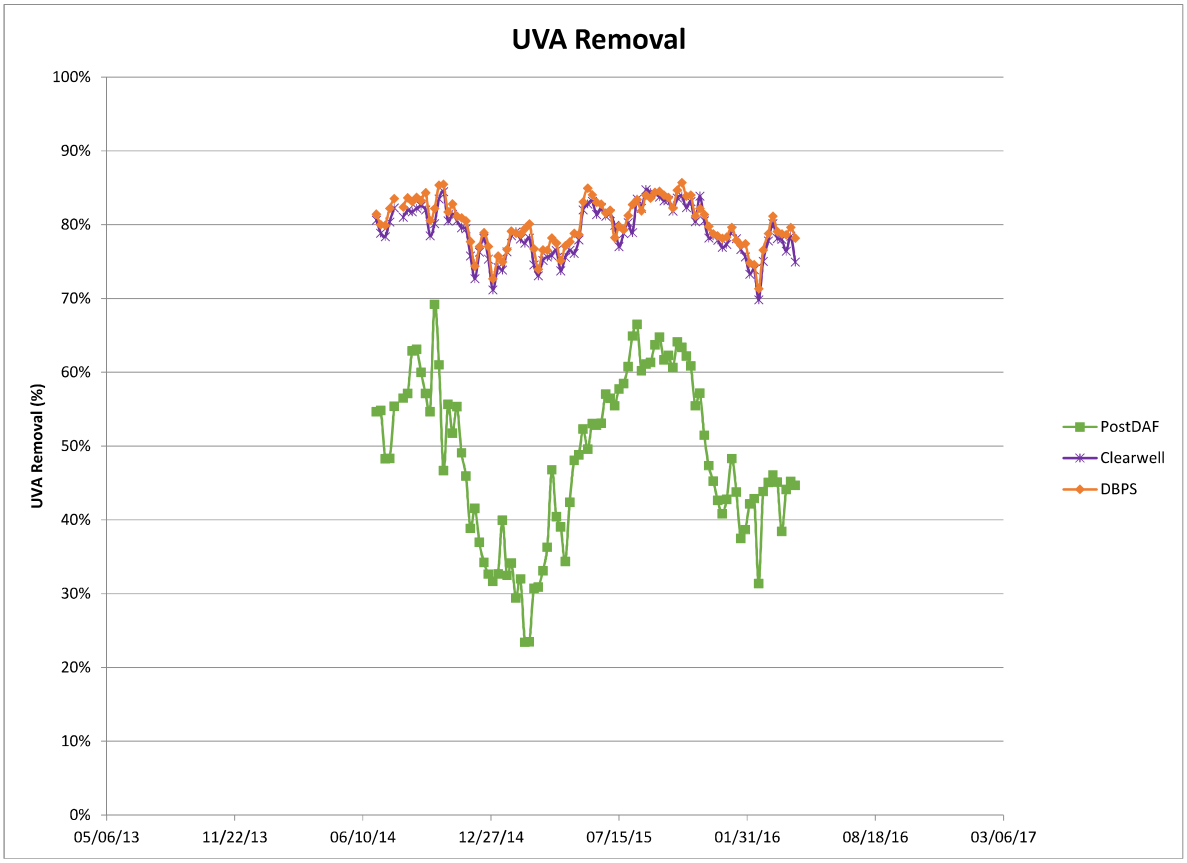

TOC
Conc. (mg/L)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
-
Temperature (°C)
25
20
15
10
5
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst
RW Temperature

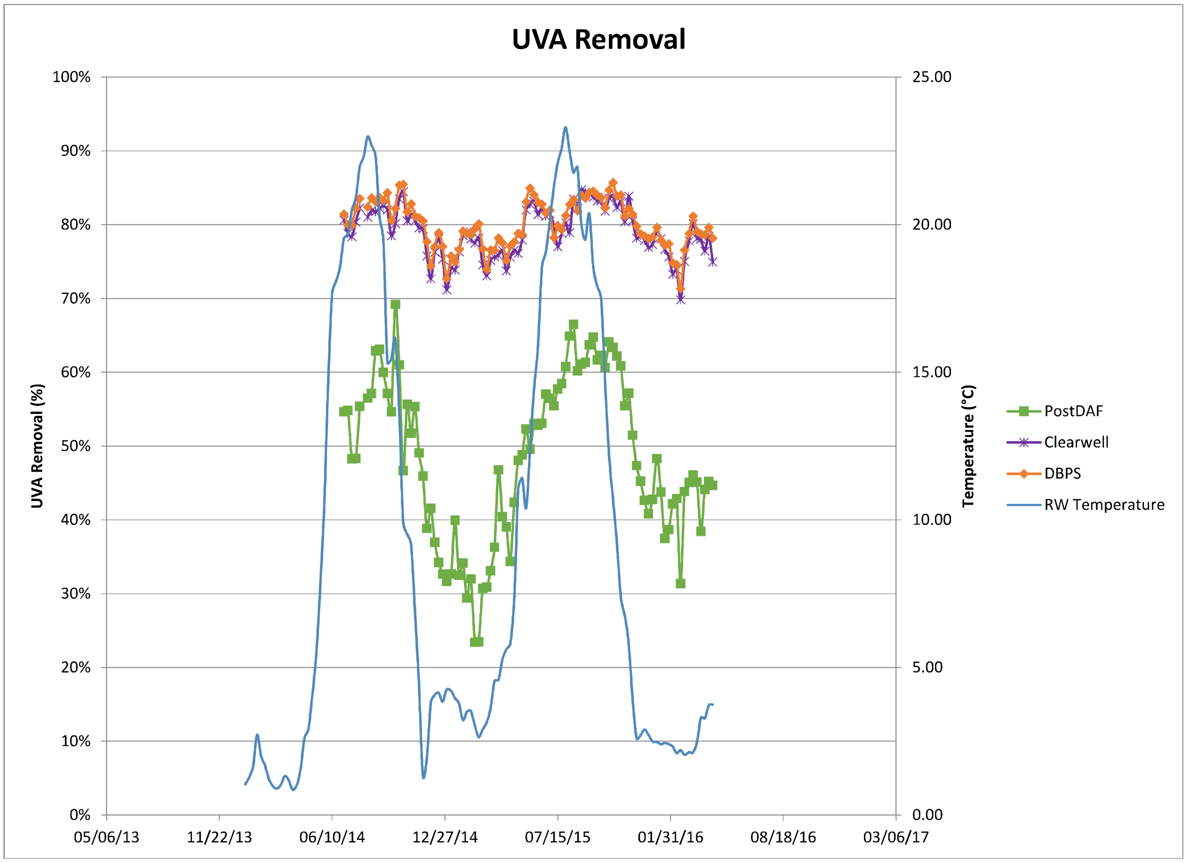

TOC Removal
TOC Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
05/06/13
11/22/13
06/10/14
12/27/14
07/15/15
01/31/16
08/18/16
03/06/17
PostDAF
OznCont
Clearwell
DBPS

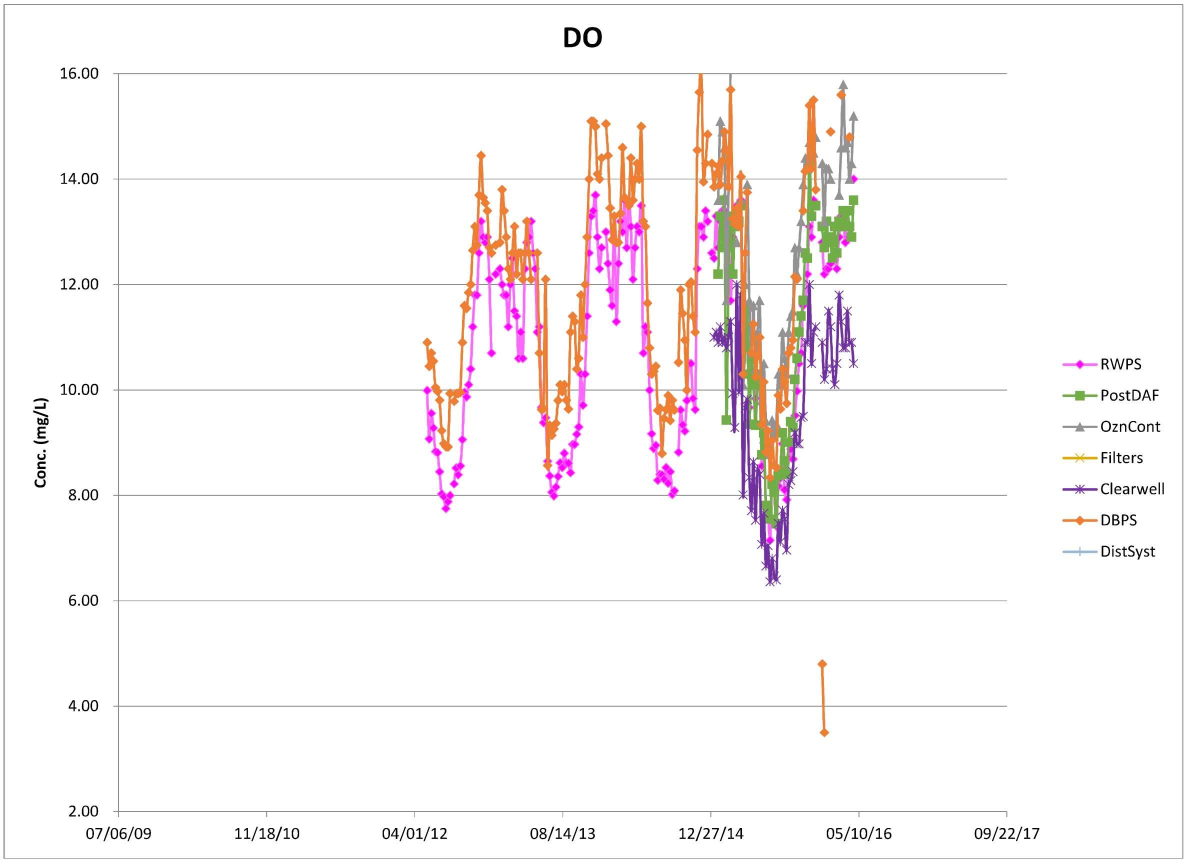

TOC Removal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TOC Removal (%)
25.00
20.00
15.00
10.00
5.00
0.00
Temperature (°C)
05/06/13
11/22/13
06/10/14
12/27/14
07/15/15
01/31/16
08/18/16
03/06/17
PostDAF
OznCont
Clearwell
DBPS
RW Temperature

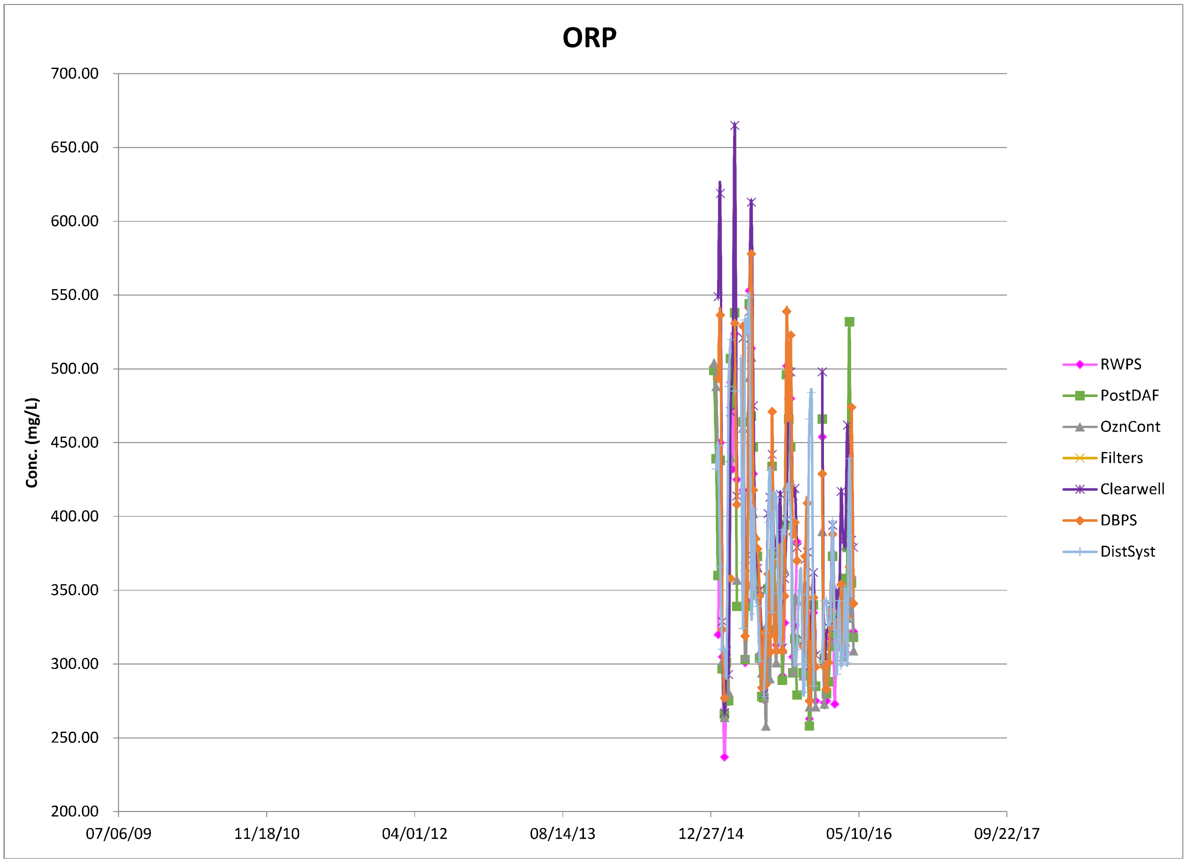

UVA
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-
UV Absorbance (m-1)
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
Clearwell
DBPS

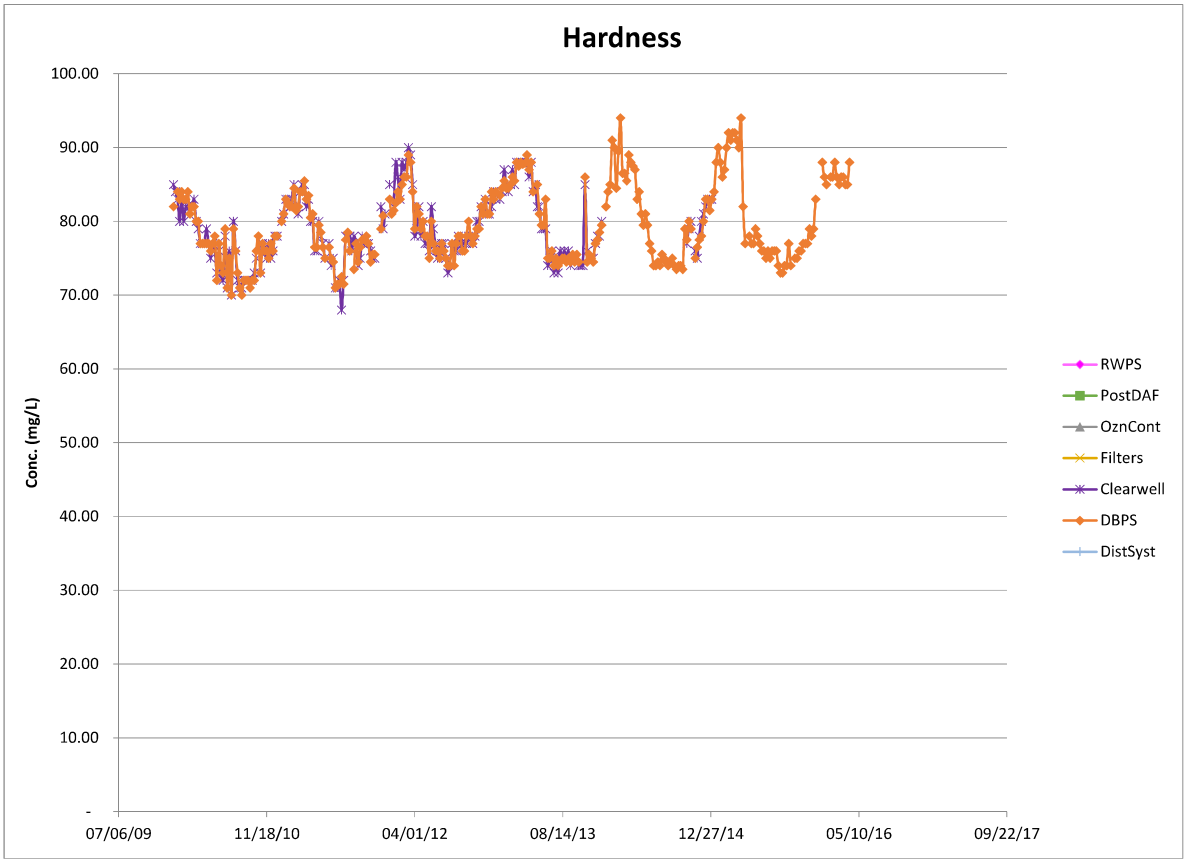

UVA
UV Absorbance (m-1)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-
Temperature (°C)
25
20
15
10
5
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
Clearwell
DBPS
RW Temperature

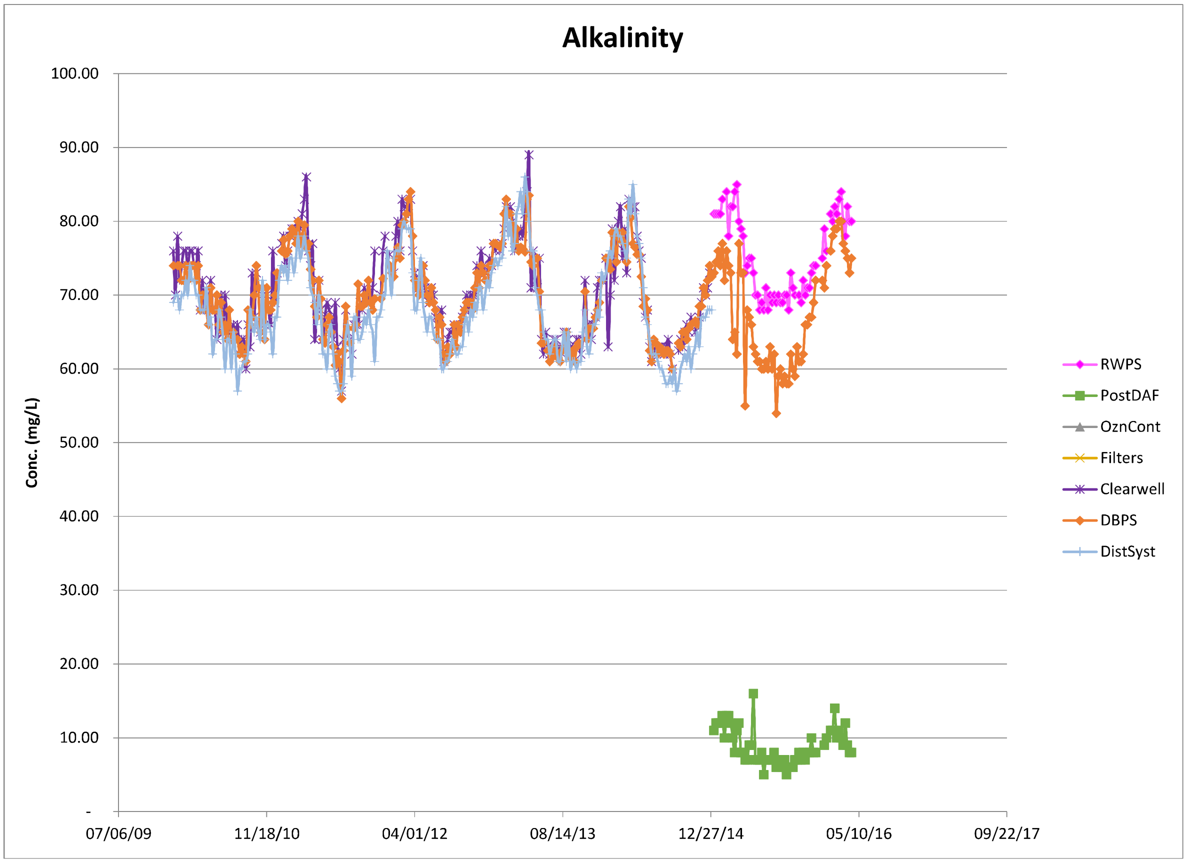

UVA Removal
UVA Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
05/06/13
11/22/13
06/10/14
12/27/14
07/15/15
01/31/16
08/18/16
03/06/17
PostDAF
Clearwell
DBPS

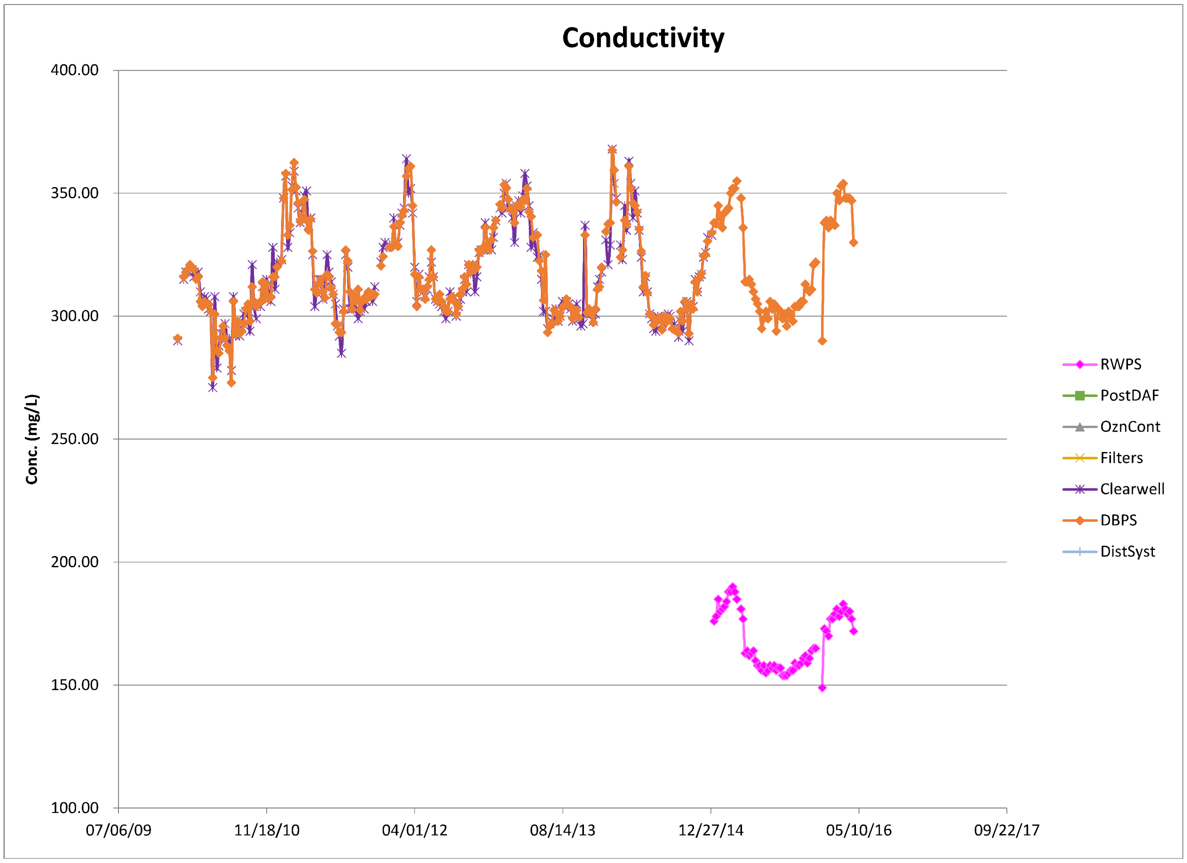

UVA Removal
UVA Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
05/06/13
11/22/13
06/10/14
12/27/14
07/15/15
01/31/16
08/18/16
03/06/17
Temperature (°C)
25.00
20.00
15.00
10.00
5.00
0.00
PostDAF
Clearwell
DBPS
RW Temperature

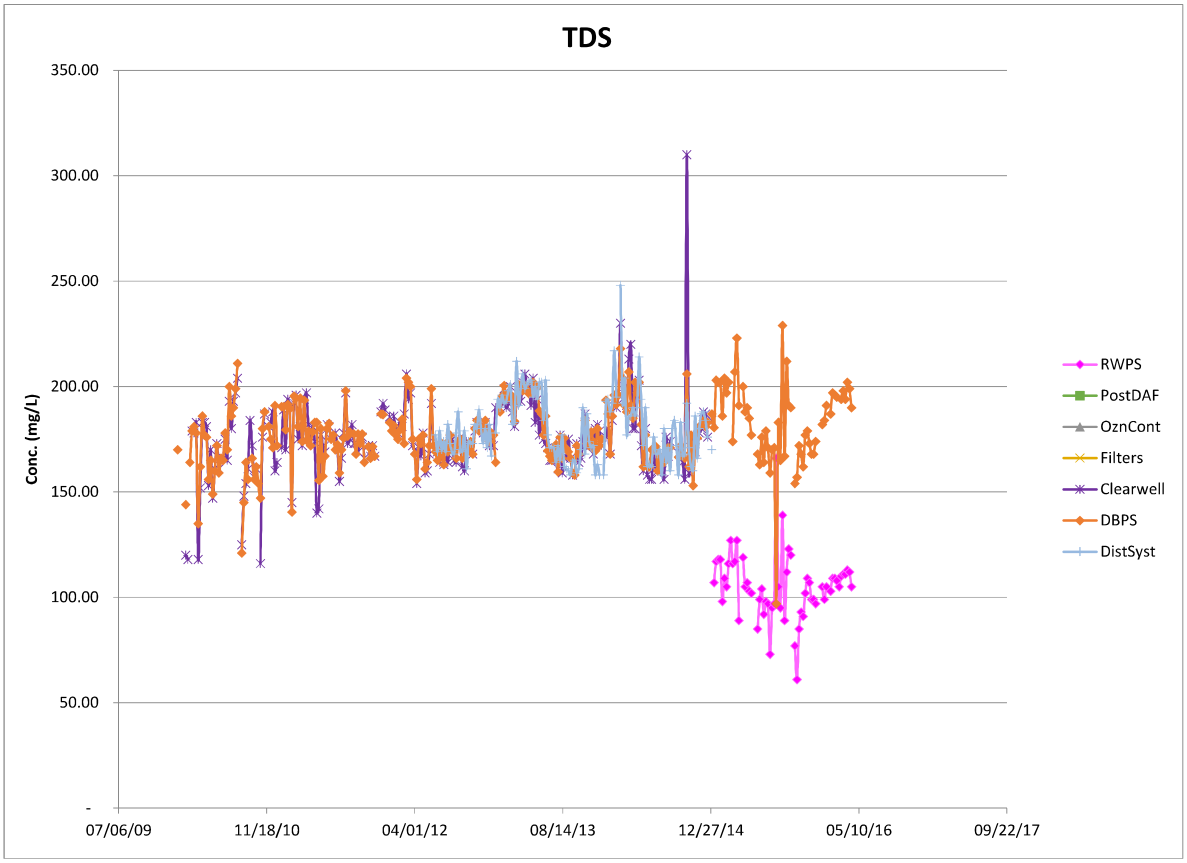

DO
Conc. (mg/L)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

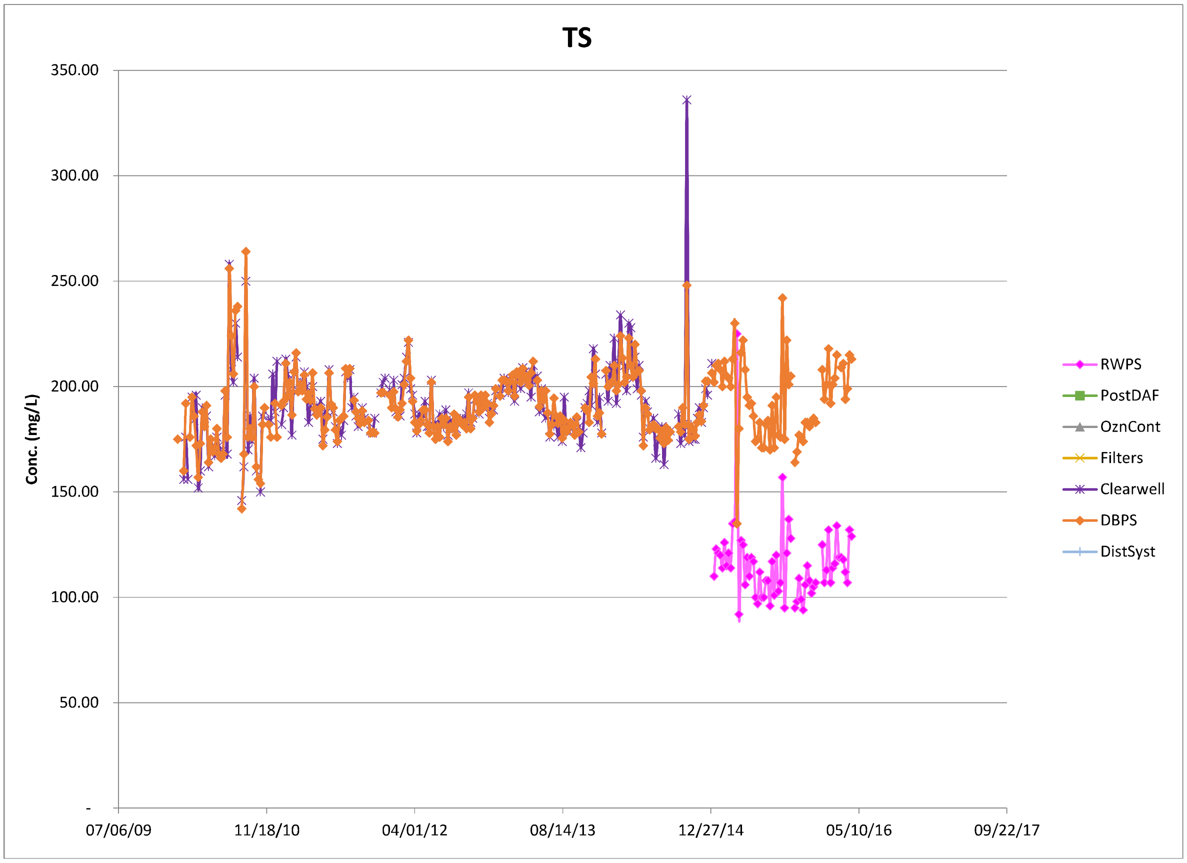

ORP
Conc. (mg/L)
700.00
650.00
600.00
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

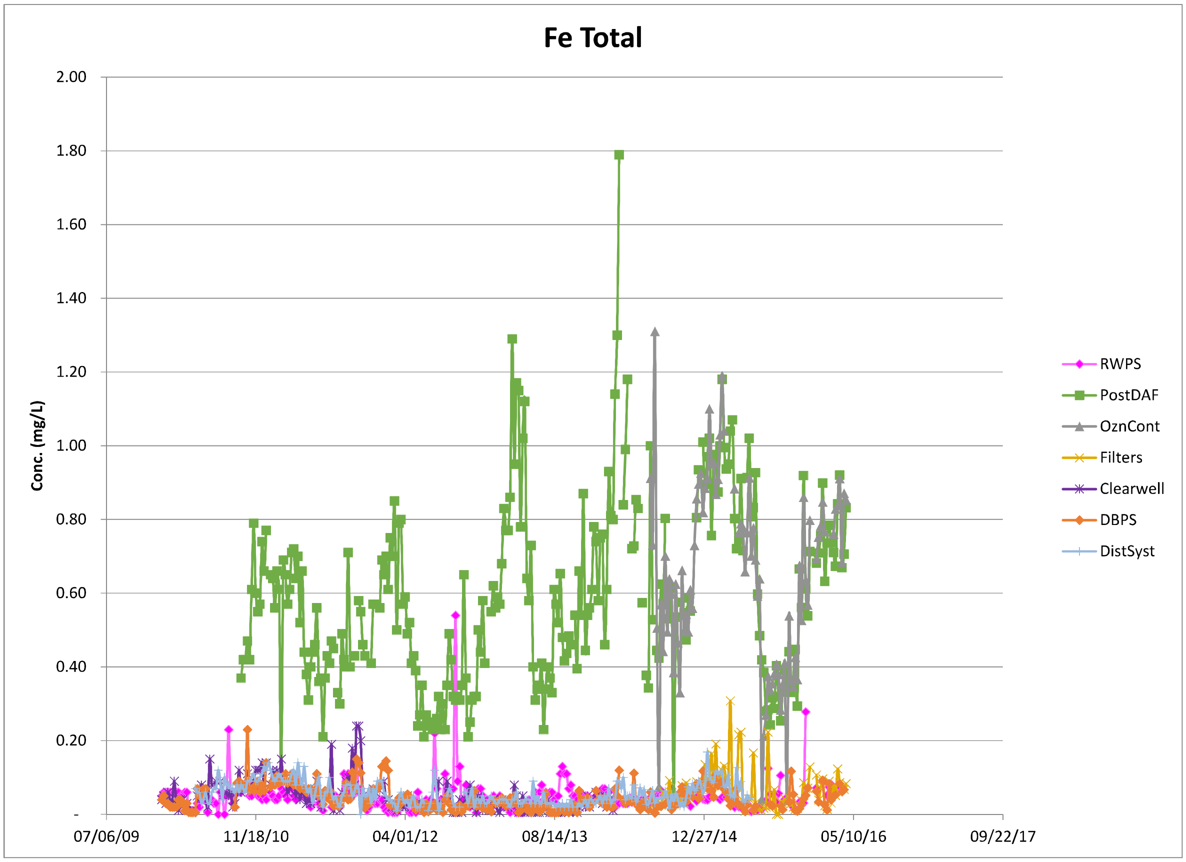

Hardness
Conc. (mg/L)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

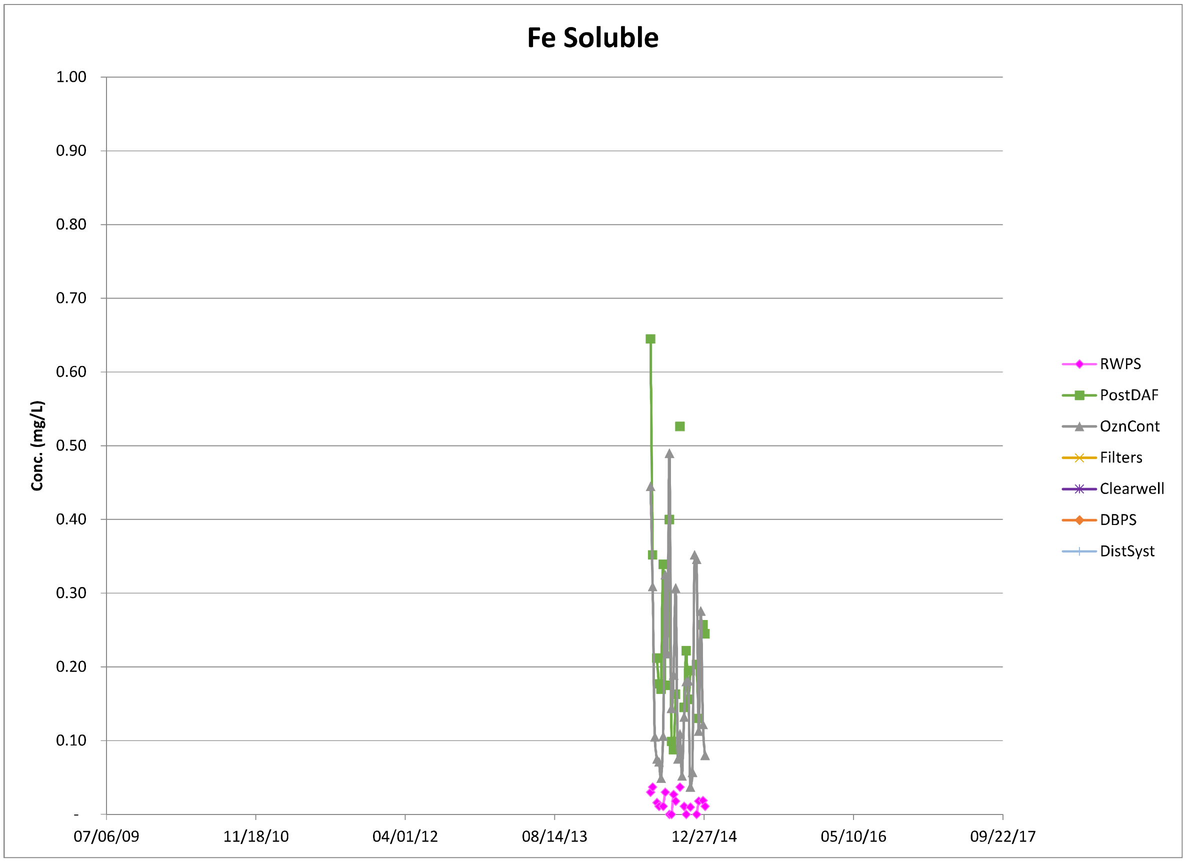

Alkalinity
Conc. (mg/L)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst

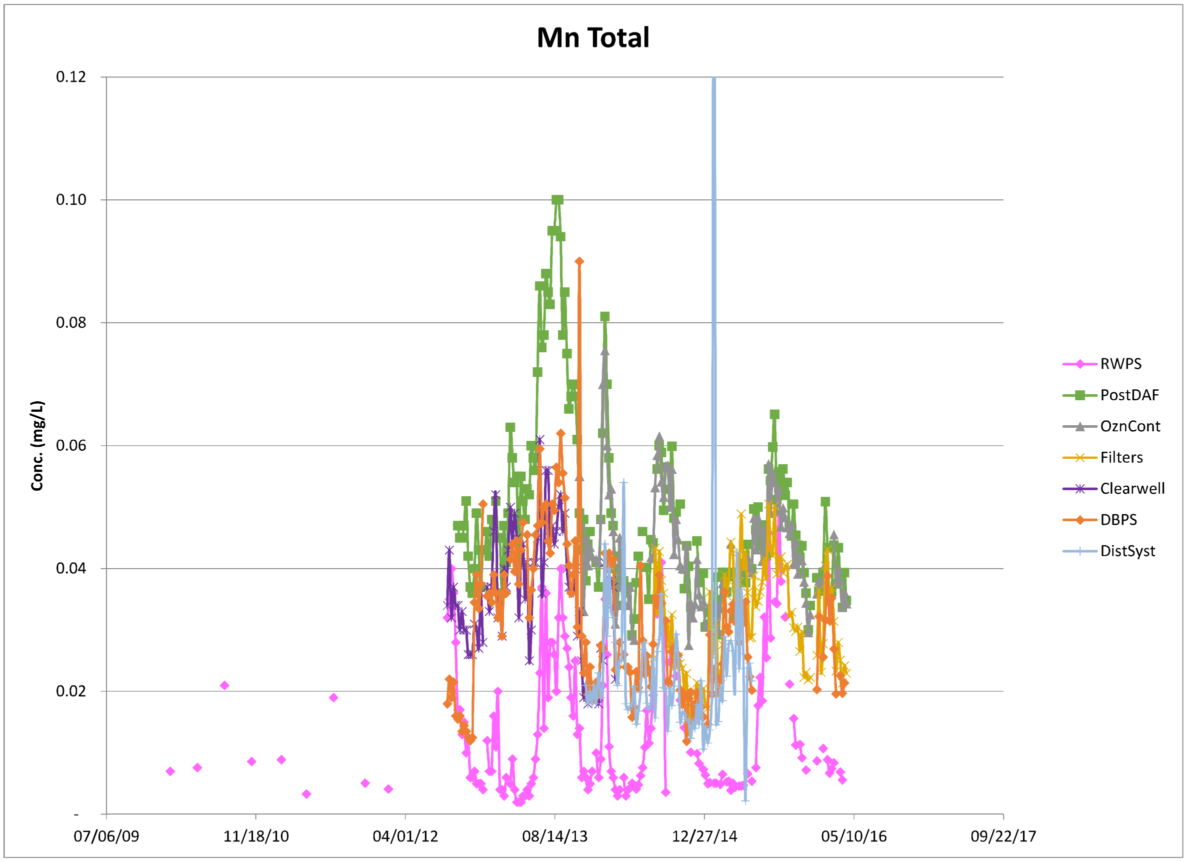

Conductivity
Conc. (mg/L)
400.00
350.00
300.00
250.00
200.00
150.00
100.00
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


TDS
Conc. (mg/L)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


TS
Conc. (mg/L)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


Fe Total
Conc. (mg/L)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


Fe Soluble
Conc. (mg/L)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


Mn Total
Conc. (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
-
07/06/09
11/18/10
04/01/12
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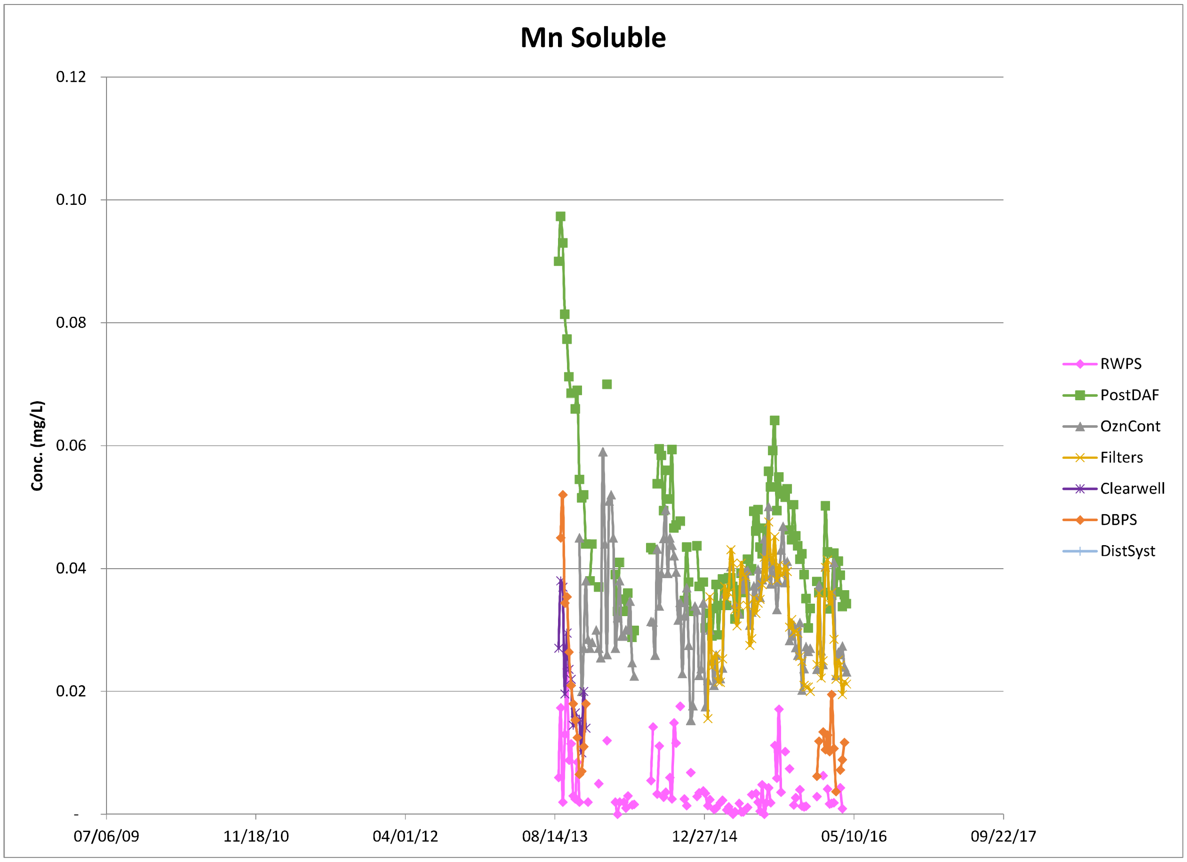
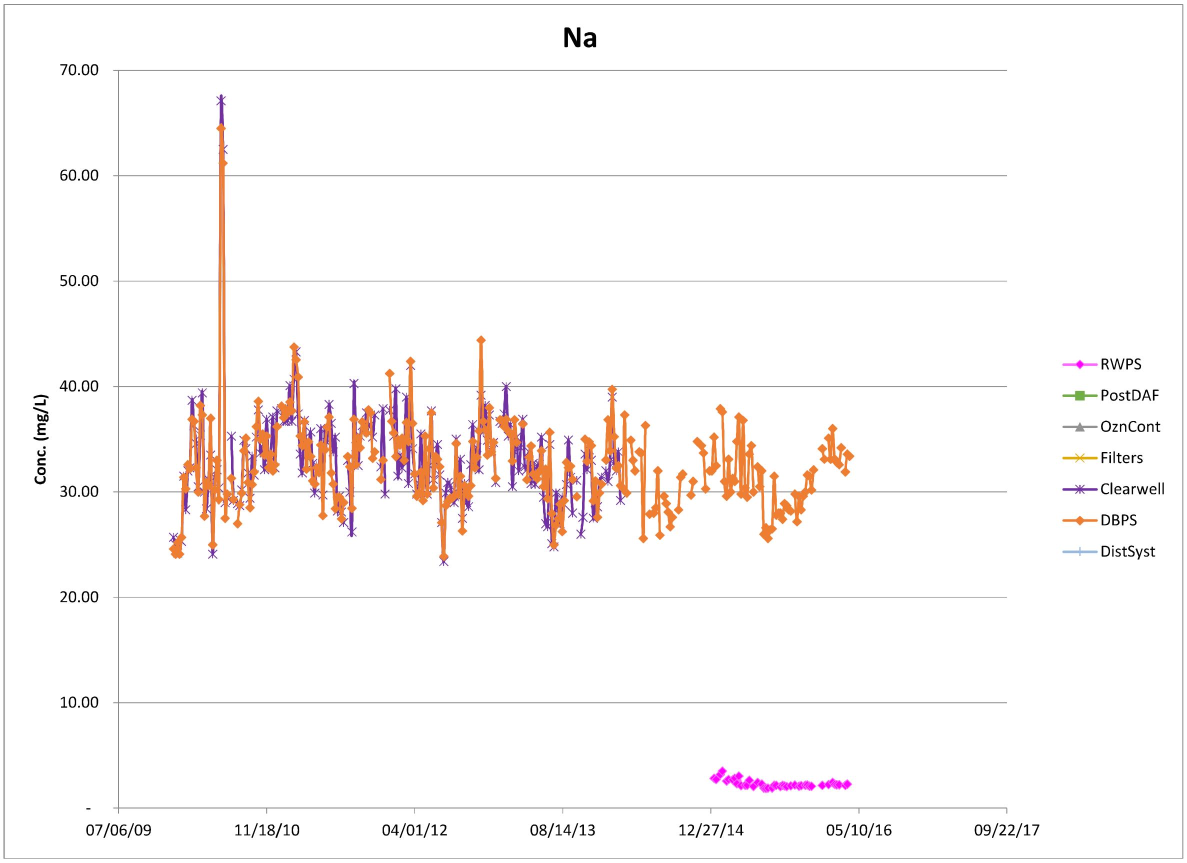
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


Mn Soluble
Conc. (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


Na
Conc. (mg/L)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
-
07/06/09
11/18/10
04/01/12
08/14/13
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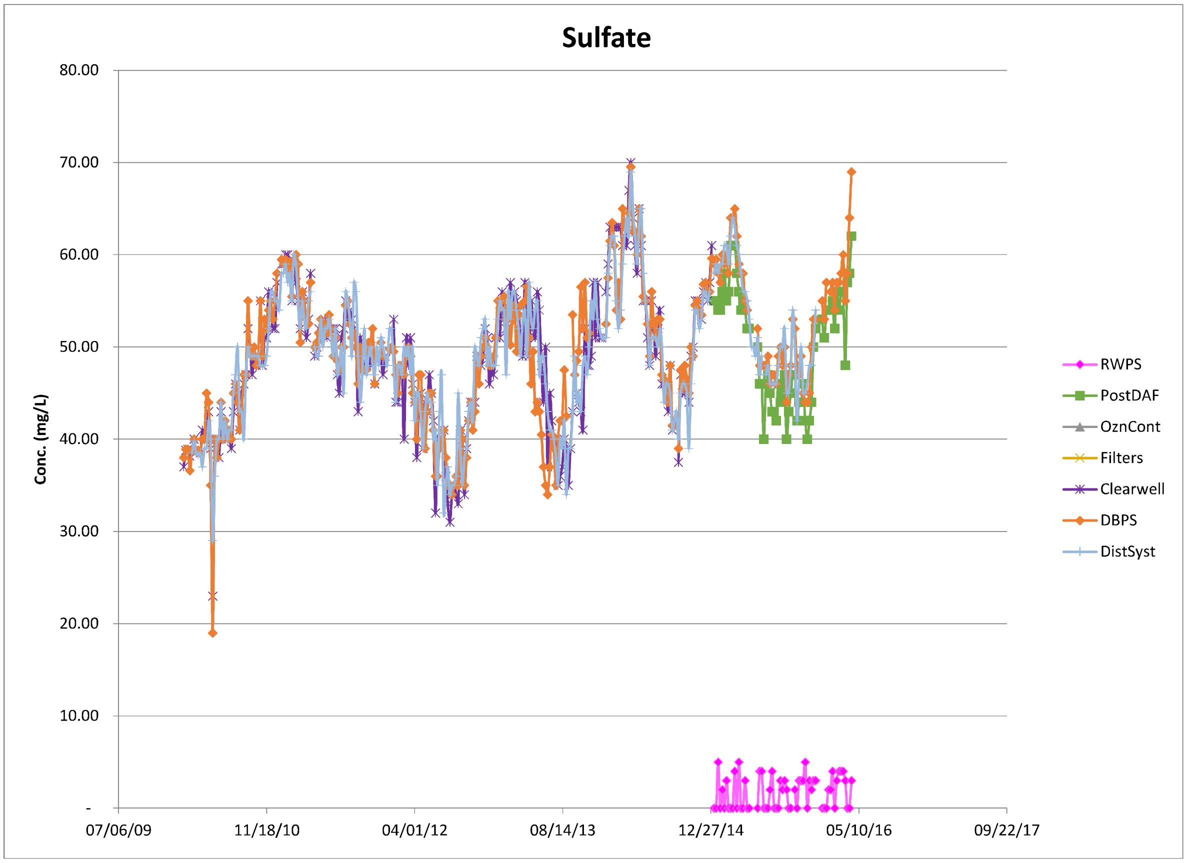
Filters
Clearwell
DBPS
DistSyst


Sulfate
Conc. (mg/L)
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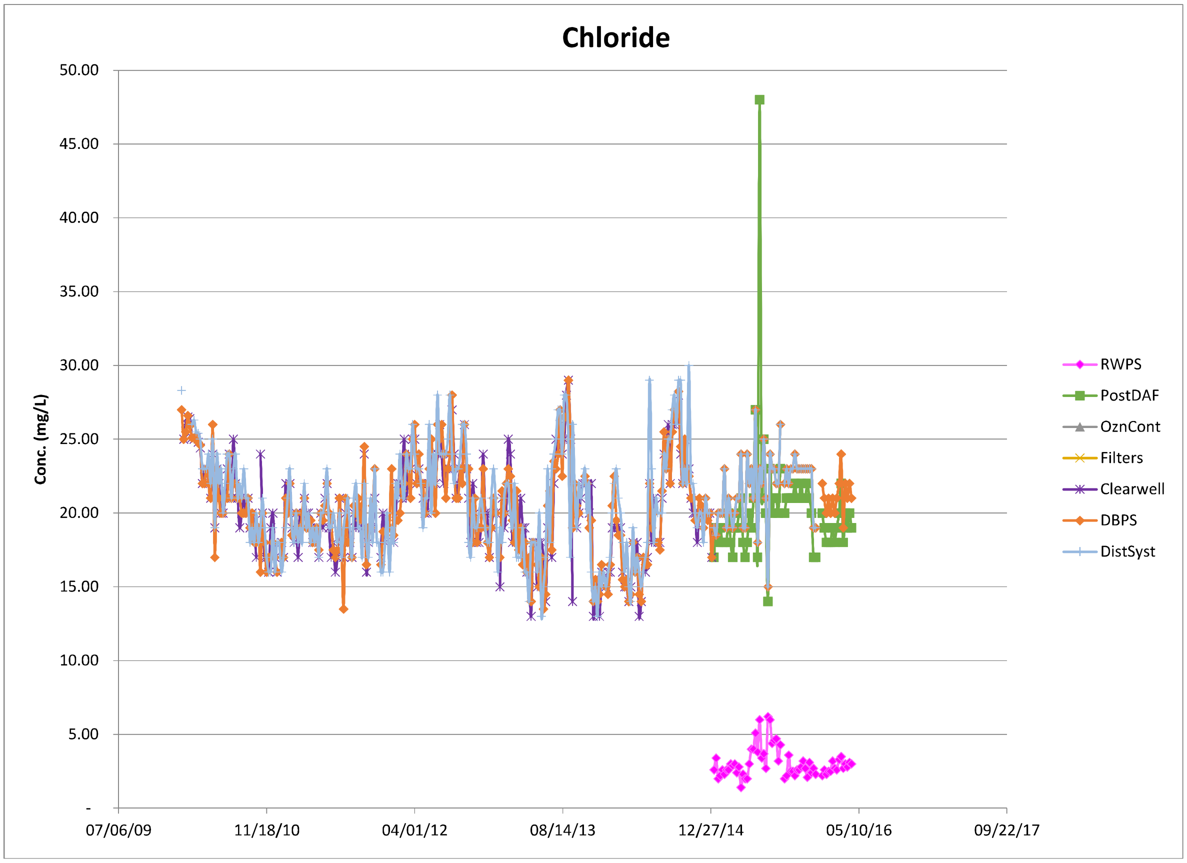
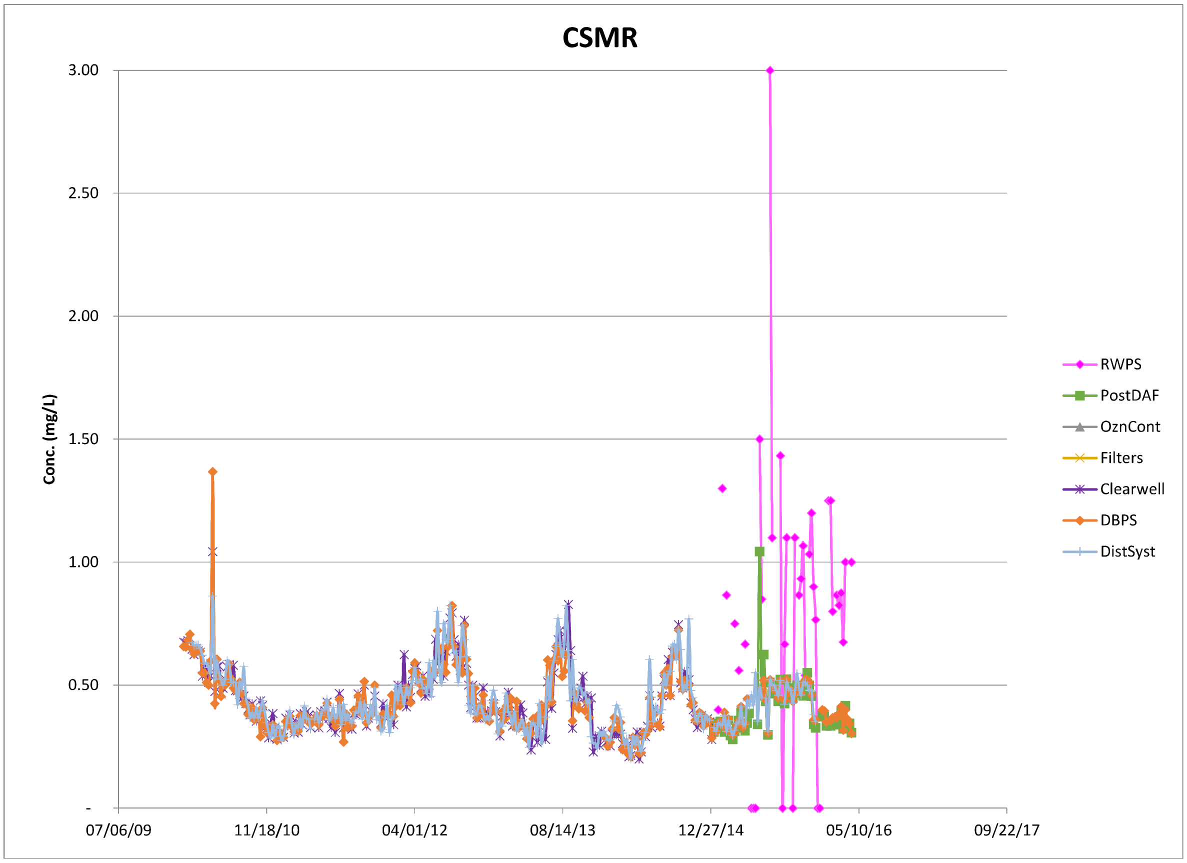
70.00
60.00
50.00
40.00
30.00
20.00
10.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


Chloride
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Conc. (mg/L)
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


CSMR
3.00
2.50
2.00
1.50
1.00
0.50
-
Conc. (mg/L)
07/06/09
11/18/10
04/01/12
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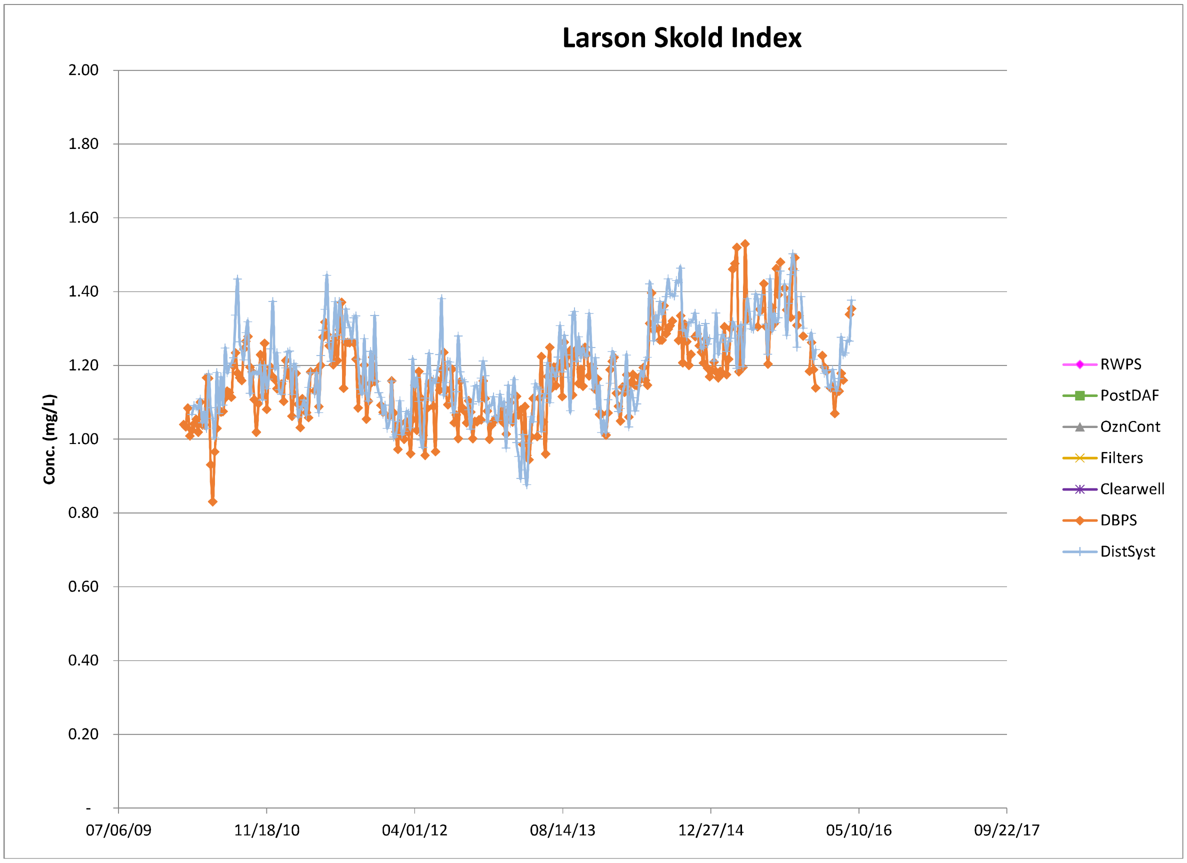
Filters
Clearwell
DBPS
DistSyst


Larson Skold Index
Conc. (mg/L)
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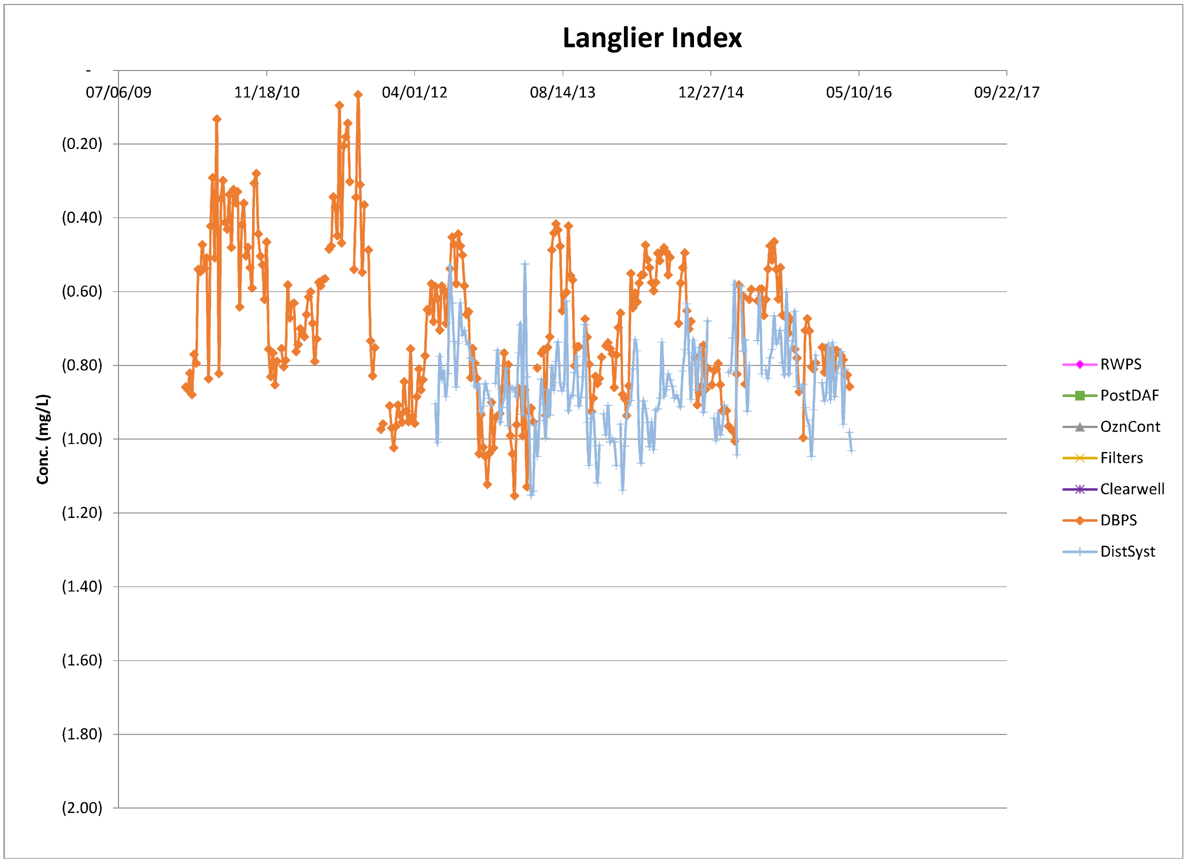
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


Langlier Index
Conc. (mg/L)
-
(0.20)
(0.40)
(0.60)
(0.80)
(1.00)
(1.20)
(1.40)
(1.60)
(1.80)
(2.00)
07/06/09
11/18/10
04/01/12
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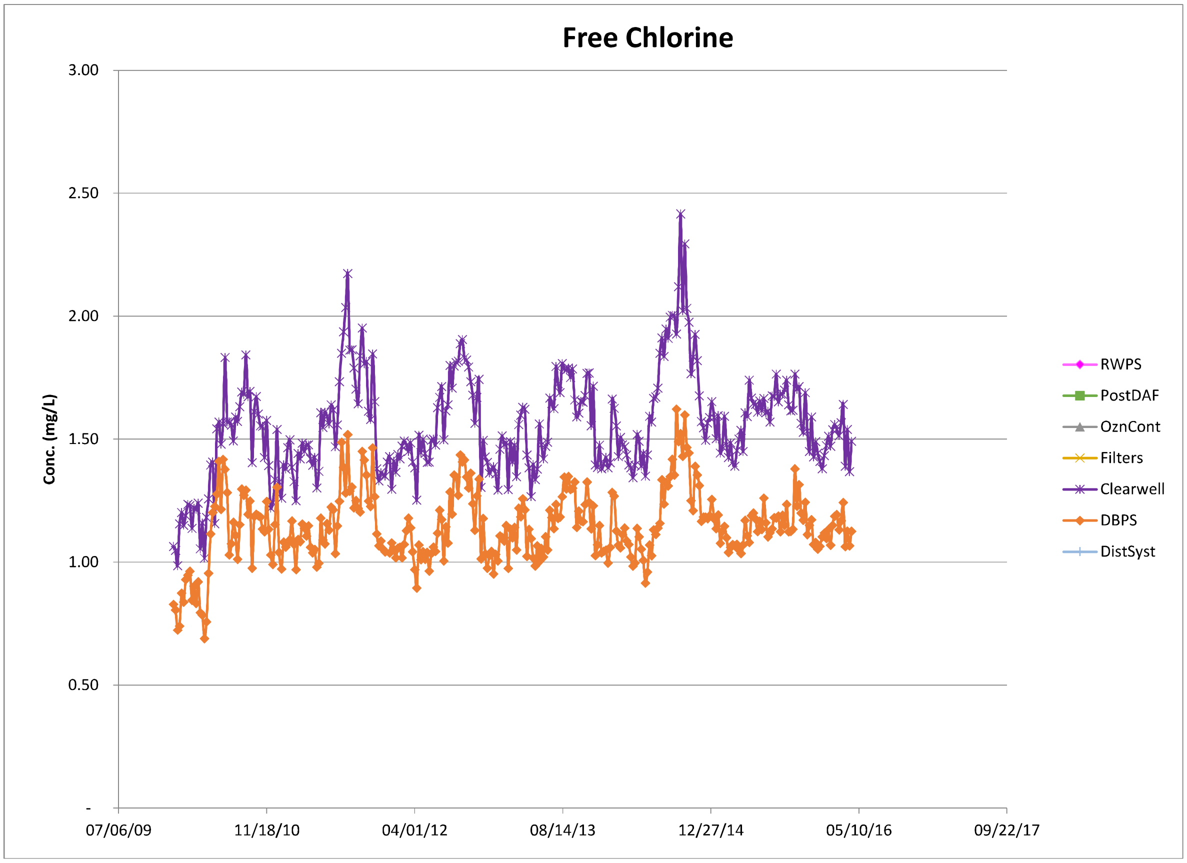
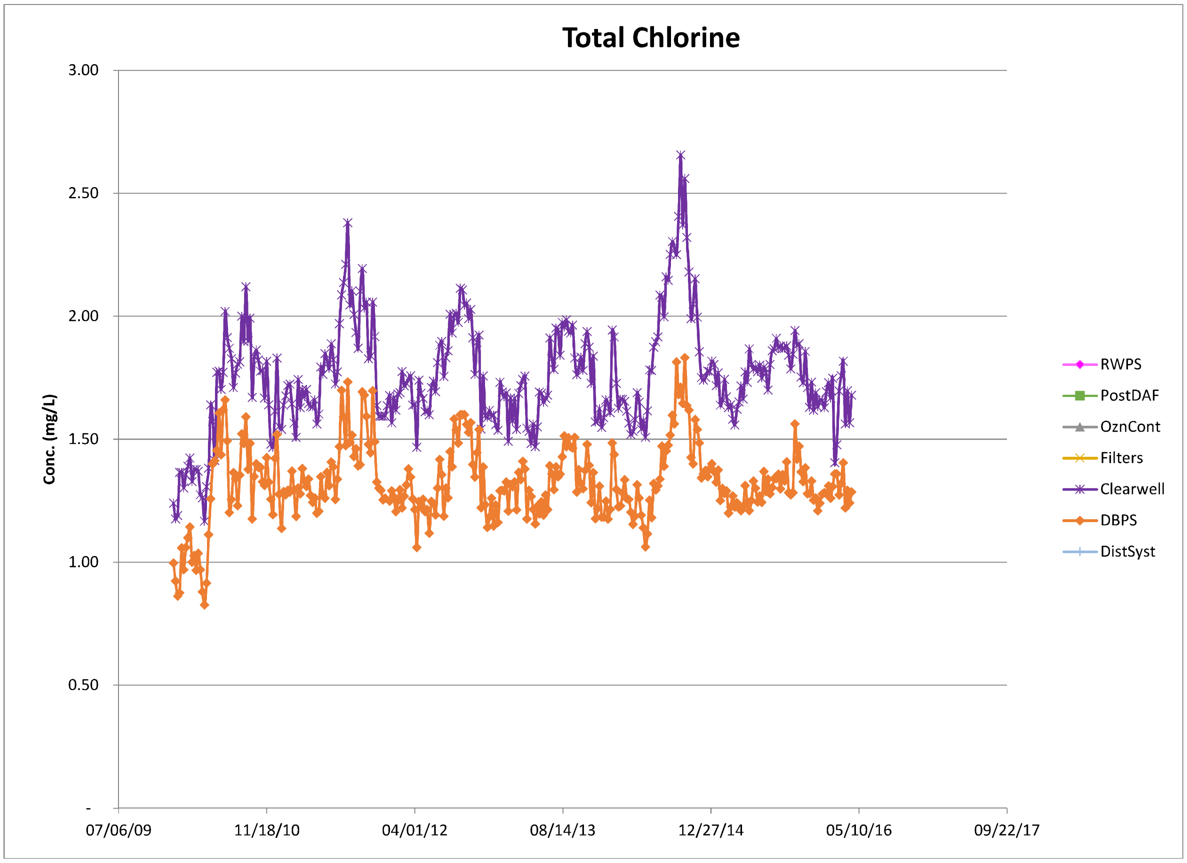
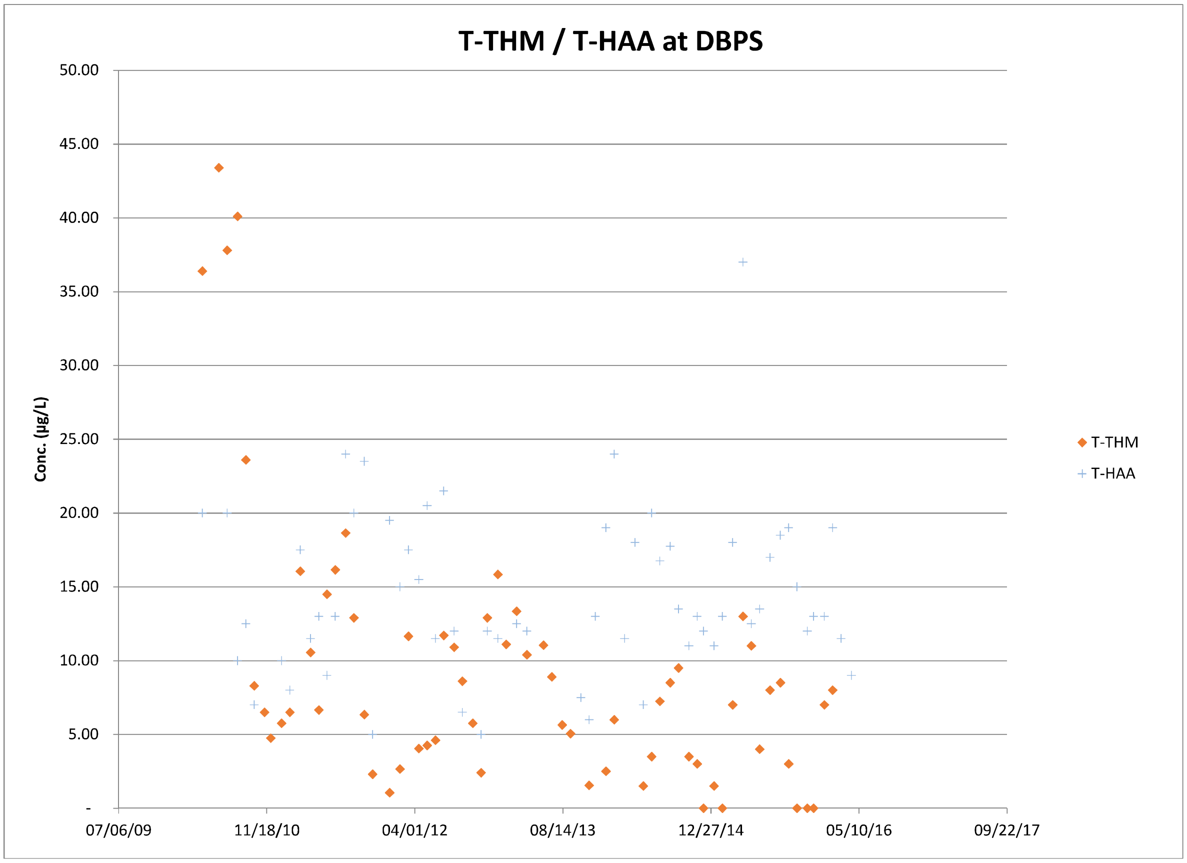
Filters
Clearwell
DBPS
DistSyst


Free Chlorine
Conc. (mg/L)
3.00
2.50
2.00
1.50
1.00
0.50
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


Total Chlorine
Conc. (mg/L)
3.00
2.50
2.00
1.50
1.00
0.50
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
RWPS
PostDAF
OznCont
Filters
Clearwell
DBPS
DistSyst


T-THM / T-HAA at DBPS
Conc. (µg/L)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
T-THM
T-HAA

Appendix B – Bench Testing Protocol

Proposed Jar Testing Protocol

Completed by:
Andrews, Hofmann and Associates

Submitted to:
WSP Canada Inc.

Submitted on:
September 29, 2016
Revised on:
December 14, 2016

Introduction

The City of Winnipeg uses ferric chloride ($FeCl_3$) as a coagulant prior to dissolved air flotation (DAF); however, there are elevated levels of manganese (Mn) in the treated water due to the nature of the coagulant manufacturing process. As such, DAF-jar testing will be completed to compare alternative coagulants to the current coagulant at bench-scale such that the post-DAF Mn concentration is less than the current coagulant, and satisfies the 0.015 mg/L objective set by the City of Winnipeg. Preliminary tests will be completed to evaluate the precision and accuracy of the benchtop Hach DR 6000 low concentration total Mn test method to ensure proper application and data analysis. The results of numerous bench-scale trials will be utilized to determine which alternative is the "best", and should later be tested at pilot-scale. This document describes the process required to achieve applicable results from bench-scale testing.

Jar Test Requirements

Based on the City of Winnipeg request for proposal (RFP) a number of requirements must be satisfied with respect to conducting jar tests. First, a minimum of four different coagulants must be tested. A technical memo prepared by WSP examined the data from previous bench- and pilot-scale studies, and proposed a group of coagulants to be tested. These included ferric chloride (FeCl), a ferric chloride/ferric sulfate blend (FeCl + FeS), ferric sulfate (FeS), and two formulations of aluminum ferric sulfate (AFS1 & AFS2). Sulphuric acid will be applied, similarly to full-scale, to achieve pH reduction for all of the tested coagulants. Additionally, a minimum of three different coagulant aids must be tested. This will involve testing three different polymers to improve floc formation in an effort to further reduce the Mn concentration.

To compare the performance of the coagulants with and without coagulant aids, a number of parameters were identified by the City in the RFP (Table 1). It should be noted, however, that not all of these parameters must be analyzed with every set of trials. Instead, parameters such as DBPs, algae toxins, corrosion indicators and odour will only be evaluated for baseline conditions and optimized trials, instead of all samples. The objective of the bench-scale tests will be to reduce the concentration of dissolved Mn in settled water samples to less than or as close to 0.015 mg/L as possible, while ensuring that none of the other regulated parameters, such as turbidity or DBP formation, exceed the values achieved by using the current FeCl coagulant.

Proposed Jar Tests

The RFP put forth by the City requires the examination of four coagulants, and three filter aids. To ensure that the "optimal" alternative conditions are achieved, the coagulants and coagulation aids will be sequentially optimized. First, coagulation dose for each of the four alternative coagulants will be examined with pH adjustment replicated at bench-scale (using H_2SO_4 for pH reduction) to match the conditions at full-scale, then the ideal coagulation pH for each coagulant will be determined. Finally, the benefits of three different coagulant aids (polymers) will be evaluated. The best combination of chemicals will be later evaluated using pilot-scale tests.

The general procedure for optimizing coagulation through DAF-jar tests will first identify a "best dose". The best dose will be determined by evaluating the results based on the level of importance of each parameter (Table 2). Then pH will be further refined to identify the optimal pH for that particular coagulant, and the optimal dose confirmed at the new pH. Additionally, increasing doses of polymer will be added to identify the concentration required to achieve the best performance, without exceedingly high costs. In addition, a test of the DAF system without any coagulant addition will be completed to determine the potential for particulate removal without chemicals and to determine the non-coagulant baseline. Finally, four of the best combinations of chemicals (ideally one combination including each of the four alternative coagulants) will be tested side-by-side to again compare the results. Further details to these tests are provided in Table 3, and in Appendix A.

Table 1 Summary of DAF-Jar Test Evaluation Parameters Identified by the City of Winnipeg

Parameter #	**Parameter**	**Analysis Location (Bench or City Labs)**
1	Metals (including dissolved and total iron and manganese)	Bench and Lab
2	Total organic carbon (TOC)	Lab
3	Colour	Bench
4	UV transmittance (UVT) @ 254 nm	Bench
5	Post coagulation alkalinity	Lab
6	Total solids; total suspended solids; and total dissolved solids	Lab
7	Conductivity	Bench
8	pH	Bench
9	Turbidity	Bench
10	Dissolved oxygen (DO) and oxidation reduction potential (ORP)	Bench
11	Threshold odour number	Lab
12	Algae toxin removal	Lab
13	Disinfection and disinfection by-product (DBP) formation potential (total trihalomethanes (THM) and total haloacetic acids (HAA))	Lab
14	Corrosion indicators (total sodium, chloride and sulphate)	Lab

Table 2 Analytes Ranked on Their Importance to the Study

Level of Importance	**Analytes**
1 (Most)	Metals (Specifically Mn), Colour,
2	TOC, UVT, DBP Formation Potential, Turbidity
3	Alkalinity, pH, Corrosion indices
4	Total Solids, Suspended Solids, Dissolved Solids
5 (Least)	Odour, Dissolved Oxygen, ORP, Algae Toxins

Table 3 Summary of Proposed Jar Tests

Trial Number	**Description**	**Details**
1	Confirm jar test procedure	-Utilize full-scale conditions (coagulant dose and pH) -Simulate full-scale rapid mix and coagulation energy and duration -Alter DAF time (as required) to match water quality
2	Optimize coagulant dose	-Test 4 alternative coagulants -Reduce pH to match full-scale coagulation pH -Start with chemical doses of 15, 25, 35 and 45 mg/L -Refine by dosing ± 2 mg/L and ± 4 mg/L from the “best dose” as determined by the reduction of key parameters (Mn, turbidity, DOC, etc. as shown in Table 2 below), or, if two dosages generate equal water quality, apply four in-between doses
3	Optimize coagulation pH	-Alter pH using sulphuric acid to examine optimal coagulation pH -FeS containing coagulants tested at pH = 5, 5.3, 5.6 and 6 -AFS coagulants tested at pH = 5.5, 5.9, 6.2 and 6.5 -Refine pH by testing the best identified pH – 0.1 and – 0.2 unit, or four evenly spaced pH levels if two are identified as equal in the first tests -After optimal pH is established, retest the optimal coagulant dose – 2 mg/L and – 4 mg/L to ensure that the best dose has remained the same
4	Optimize polymer addition	-Test 3 different polymer formulations -Add 0.05, 0.1, 0.25 and 0.5 mg/L of polymer (based on dry mass) to optimized coagulant dose and pH -If 0.5 mg/L polymer is found to be the best dose, test increased concentrations (0.55, 0.7, 0.85, 1 mg/L). The maximum dose will be dictated by economic feasibility, as polymer is much more (10x or more) expensive than coagulant. If an optimal dose is not achieved by 1 mg/L, then polymer will be deemed to be unsuitable. -The lowest dose to achieve equivalent water quality will be deemed “optimal” to minimize implementation costs at full-scale
5	No coagulant	-Test the DAF process without coagulation or pH adjustment to evaluate potential benefits and cost savings
6	Optimal conditions	-Re-evaluate the four optimal conditions -Preferably use one condition from each of the alternative coagulants if possible
7	Optimize mixing time and applied energy	-Alter the mixing speed and mixing duration of both the rapid mix and flocculation process -Test on the best identified combination of conditions and chemicals that has been selected to be tested as pilot-scale and is deemed to be the "best" based on Table 2

Trial #1 - Confirmation of Jar Test Procedure

A number of variables dictate the performance of full-scale coagulation and DAF including coagulant dose, rapid mix intensity (G value), rapid mix duration, flocculation intensity (G value), flocculation duration, DAF duration, DAF bubble size, and air:water injection ratio. Based on the limitations of bench-scale testing, coagulant dose, mixing duration, mixing intensity and DAF duration, can be measured or calculated and set equal to full-scale operation. These variables are easily changed at bench-scale and their impact on treated water quality will be evaluated (Trial #1). The mixing intensity (rapid mix and flocculation) at full-scale is a known design parameter, and will be matched at bench-scale by using the appropriate rotation rate. Variation of these parameters will be completed after the best alternatives have been identified (Trial #7). DAF process specifics, such as bubble size and air:water injection ratio are more difficult to measure and adjust at bench-scale, so variation of these parameters will not be considered. Due to this, the bench-scale results may not entirely match the full-scale results, but will be qualitatively comparable to other bench-scale results in an effort to identify the best alternative. Where possible, the bench-scale unit will utilize conditions previously established by the City that best compare to full-scale.

Trial #1 will utilize full-scale chemical doses, as determined on the day of the test, to confirm that the jar testers provide information that is representative of the water quality at full-scale. Initially, the energy applied in rapid mixing and coagulation at full-scale will need to be determined and converted to paddle rotation rate in the jar test unit (likely from past DAF testing at the plant). Once that has been determined the residence time for each stage (rapid mix, coagulation, and DAF) would be calculated such that it could be mimicked in the jar tests. Determination of the residence times requires the volume of each unit process and the operational flow rate, or range of flow rates. After all of the operational parameters have been identified, and converted for application in the jar testers, the Trial #1 can begin.

Although it would be ideal to match all of the water quality parameters listed in Table 1 between the full-scale DAF effluent and the jar test units, due to the analytical time required for many of the parameters, it is not feasible in the time allocated. As such, samples from the jar tests will be immediately analyzed for turbidity, pH, UVT, total dissolved solids, dissolved oxygen, colour, ORP, conductivity and total manganese. After Trial #1 is completed, the operation of the jar test unit will be adjusted according to Figure 1.

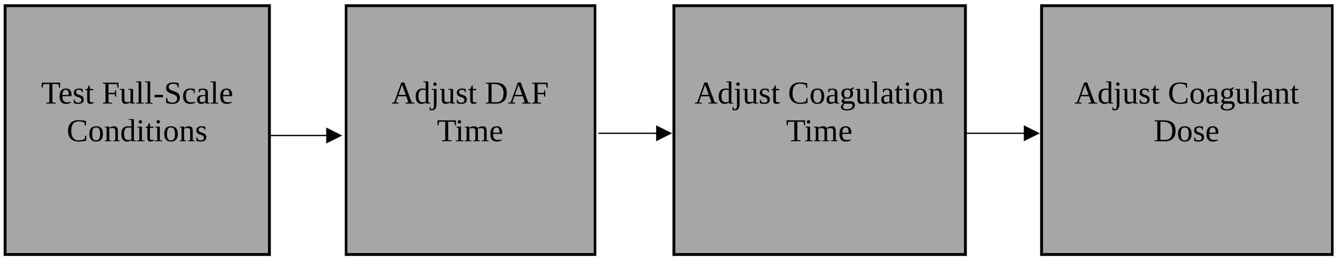


Figure 1 Jar Testing Apparatus Adjustment Procedure

A simple factorial design has been used to evaluate the impact of coagulation time, coagulant dose, and DAF time. Each jar will be sampled after applying dissolved air for periods representing 75%, 90%, 100%, 110% and 125% of the full-scale DAF time. For example, if the residence time of the full-scale DAF process was 10 minutes, jar tests would be sampled at 7.5, 9, 10, 11 and 12.5 minutes. If the volume of water sampled from a jar is greater than 10% of the total volume (~200 mL) the test will need to be repeated to examine the 5 different DAF durations. Based on this procedure, Table 4 is presented to guide in optimizing the operation and adjustment of the jar test apparatus. A total of 100 samples (5 tests x 4 jars x 5 samples/jar) will be collected and analyzed at the plant for the reduction of turbidity, pH, UVT, Mn, and any other parameter that can be measured using benchtop methods and compared to a full-scale, post-DAF sample.

Trial #1 will be used to ensure that the four jars all produce water of the same quality and benchmark the performance of the bench-scale system relative to full-scale operations. The following four tests will attempt to identify if there is any variability in the bench-scale unit compared to the full-scale process. After the operating conditions have been matched to full-scale operation, each of the jars will be used to test the same conditions (referred to as “best” in Table 4) in an effort to ensure that there is no variability in the system. Samples from each jar in Test #6 (Table 4) and a full-scale post-DAF sample will be collected and analyzed for all parameters in Table 1 by the City’s lab (total of 5 samples). Data analysis of the benchtop and lab analyzed data will ensure that each jar performs equally prior to testing the alternative coagulants.

Table 4 Summary of Trial #1 Operational Adjustments (% Relative to Full-Scale Operation)

Test No.	Jar 1		Jar 2		Jar 3		Jar 4	
	Coag Time	Dose	Coag Time	Dose	Coag Time	Dose	Coag Time	Dose
1	100%	100%	100%	100%	100%	100%	100%	100%
2	75%	75%	75%	90%	75%	110%	75%	125%
3	90%	75%	90%	90%	90%	110%	90%	125%
4	110%	75%	110%	90%	110%	110%	110%	125%
5	125%	75%	125%	90%	125%	110%	125%	125%
6	Best	Best	Best	Best	Best	Best	Best	Best

Trial #7 - Impact of Mixing Energy and Duration

As part of the RFP, the City requested that the impact of varying the applied energy and duration for both rapid mixing and coagulation be assessed. In order to fulfill this requirement, it is proposed that these conditions be examined after the optimal chemical combination has been determined using the current operational conditions.

Mixing energy is adjusted by increasing or decreasing the paddle rotation as required. At full-scale it is difficult to adjust the time associated with rapid mixing and coagulation, as it directly impacts plant capacity. If mixing times are increased, the plant capacity decreases, and vice versa. However, to satisfy the RFP and ensure optimal treatment performance, four tests are proposed (Table 5). Similarly to other trials, the first 10 parameters from Table 1 will be analyzed.

Table 5 Summary of Trial #7 – Optimization of Mixing Time and Applied Energy (% Change Relative to Best Condition Results Identified in Previous Trials)

Parameter Adjusted	**Jar 1**	**Jar 2**	**Jar 3**	**Jar 4**
Rapid mix energy	-50%	-25%	+25%	+50%
Coagulation energy	-50%	-25%	+25%	+50%
Rapid mix time	-50%	-25%	+25%	+50%
Coagulation time	-50%	-25%	+25%	+50%

Other Trials and Scheduling

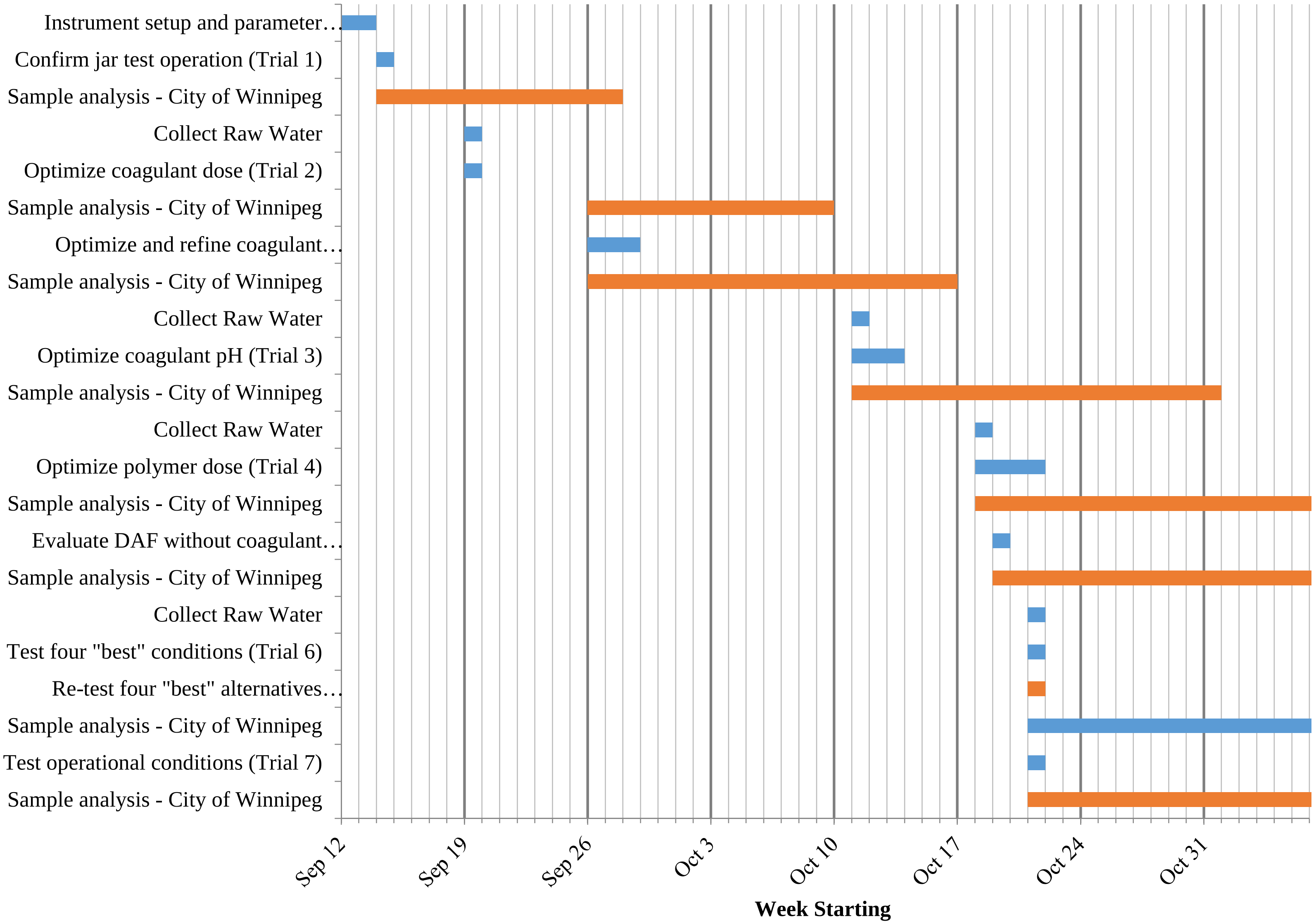
Details pertaining to the remaining trials are presented in Appendix A, and a proposed schedule for the trials that will be completed is presented in 3. This schedule has been developed to aid in determining when the testing will be completed and to aid in planning for samples analysis by the City. It is assumed that it will take approximately one week to receive sampling results back from the City. Based on this assumption it will take around two months to complete the proposed jar tests. If the results can be provided more quickly, this timeline can be accelerated. Details pertaining to each of the proposed Trials can be found in Appendix B.

Comparison to raw water

One potential complication to the jar testing process is changing influent water quality. To overcome this potential issue, raw water data must be collected and analyzed for each of the sampling days. Much of this data may be available from currently installed online monitoring (e.g. pH, turbidity, conductivity, dissolved oxygen, UVT), but other analyses will need to be analyzed by the City’s laboratory (metals, colour, TOC, alkalinity, solids). This data is essential to ensure that the performance of each chemical combination is properly assessed based on the influent water quality.

Another issue that arises is the change in raw water quality due to seasonal effects. Based on plant data provided by The City, the average raw water temperatures in September is 18°C, and by October drops to 11°C. As such, it is recommended that the tests be scheduled to start as soon as possible to take advantage of the relatively stable water temperatures experienced in September and early October. Further temperature control can be achieved by maintaining a constant temperature in the on-site laboratory (using on-site heating), and collecting samples the day before testing to allow for temperature equalization prior to testing.

Figure 2: Proposed Jar Test Schedule (Start Date September 12, 2016)



Note: All blue bars indicate bench-scale testing activities; red bars indicate sample analysis being completed by City of Winnipeg

Statistical Analysis

Data will be evaluated in two ways. In addition to evaluating the post-DAF concentrations for specific parameters, the post-treatment differences will be calculated by subtracting results from the raw water concentration, and then converting to a percent removal. This method would identify which chemical combinations best remove each compound in terms of total mass, and by the percentage of the influent concentration. By assessing the post-treatment concentrations, and the difference between raw and treated water, a more complete understanding of the process can be generated. This approach will allow the results to be compensated for changes in influent water quality, and statistically compared using the Student's t-test. The equation for the two-sample pooled t-test that would be applied is shown below:

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where:

$$s_p^2 = \frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}$$

and: t = the t-test statistic distribution

x_1 = average of sample 1

x_2 = average of sample 2

n_1 = number of data points in sample 1

n_2 = number of data points in sample 2

s_1 = standard deviation of sample 1

s_2 = standard deviation of sample 2

Based on previous studies, and the equations provided, it is suggested that all of the testing be completed in at least duplicate, unless indicated otherwise by the City's staff and laboratory. Based on the estimated time to complete one test, duplicate analysis should be achievable by conducting the first set of tests in the morning and repeating the tests in the afternoon. After the chemical doses have been optimized, it is suggested that the four "best" conditions be tested a minimum of two more times, with triplicate analysis being preferable. This will provide a minimum of two samples on two separate days for the "optimal" conditions (a minimum of four total samples), which will provide a level of certainty to ensure that the best chemical combination is being selected for pilot studies.

Table 6 shows the number of samples required from each Trial of the testing. Samples collected during trials #1 and #6 will be analyzed for all of the parameters listed in Table 1. Samples from trials #2,3,4,5 and 7 will only be analyzed for the first 10 parameters in Table 1. These analyses are required to ensure that any alternative coagulants provide improved treated water effluent Mn concentrations relative to the currently applied chemicals, and do not negatively impact the other water quality parameters. Without collecting all of this data, it will be impossible to fully understand the full spectrum of potential impacts that an alternative combination of chemicals will have on finished water quality, and may result in the incorrect chemicals being tested at pilot in future stages of the project.

Another factor that plays into data analysis is the identification of priority parameters. It is likely that not all water quality parameters will be improved by any one chemical combination. As such, it will be critical to identify which parameters are most important to the client in an effort to identify which chemical should be recommended. Parameters have been divided into 5 categories, based on their presumed level of importance (Table 2).

Table 6 Summary of Sampling Requirements

Trial No.	**Min. Required**	**Max. Required**
1	5	10
2	32	48
3	32	48
4	48	96
5	4	8
6	8	12
7	16	32

Note: Only samples in trial 1 and trial 6 will be evaluated for DBP formation potential, algae toxin, corrosion indicators and threshold odour number.

Application at Pilot-Scale

Following the completion of jar testing, a recommendation will be forthcoming to identify conditions that should be examined at pilot-scale. Currently, the pilot plant consists of a single DAF unit, 8 filters representative of the full-scale filters, and one backwash tank. As such, only one coagulant can be tested at pilot-scale through DAF and filtration.

Based on the existing design of the pilot, it is suggested that the “best” alternative identified by the jar tests be compared to DAF effluent from the full-scale plant. This would require that a post-DAF, or post-ozone feed line be provided to the pilot such that four filters can treat the full-scale DAF supply and four filters can treat the optimal conditions which will be pre-treated at pilot-scale. Although this suggestion is likely unfeasible, but can be considered for future work.

Table 7 Summary of Trials and Analytical Equipment

Trial	Reference	Description	Date	General Requirements[A]	Glassware[B]	Benchtop Analytics[C]	Enviro. Stds. Testing	Sample Generation and Submission[D]
-	*Manganese via benchtop*	Evaluate the accuracy and precision of the Hach DR6000 vs Enviro. Stds. Lab analysis (in duplicate)	17-Aug-16			• Total manganese via DR 6000	• Total manganese via ICPMS	• 2 sets of 10 dilutions. • 20 submissions total.
1	*Confirm and baseline jar test procedure*	Evaluate current full-scale dosing, applied mixing and coagulation rates. Adapt data for jar testing scale. Ensure bench scale equipment functioning, identtify jar variability.	Sept. 19, 2016	• WTP parameters for scaling (coagulant dose, pH, mix energy, DAF time, etc.)	• 1L Beakers (4) • Graduated cylinders (various)	• Total manganese • Absorbance at 254 nm • pH, conductivity, turbidity, DO, ORP, TDS	• ICPMS metals scan • TOC, colour, alkalinity, TSS, threshold odour number • DBP formation potential, HAA • Corrosion indicators (Na^+, Cl^-, SO_4^{2-})	• Minimum 4 samples, 8 if time permits. • Post DAF sample acquisition and submission. • Raw water sample submission and data tracking.
2	*Optimize and evaluate coagulant dosing*	Alternative coagulant tested at varying doses to identify optimal key parameter reduction at existing plant pH	Sept. 26, 2016	• pH/conductivity/TDS calibration standards	• 1L Beakers (8) • Graduated cylinders (various) • Glass buret, stopcock, clamp, and lab stand	• Total manganese • Absorbance at 254 nm • pH, conductivity, turbidity, DO, ORP, TDS	• ICPMS metals scan • TOC, colour, alkalinity, TSS	• 32 Samples generated = 4 jars x 4 coagulants x 2 for duplication. • Only submitting samples near optimal coagulant dose, approx. 4 (8 with duplication).
3	*Optimize and evaluate pH variation*	pH adjustment using H_2SO_4. Identify best pH, followed by pH refinement and coagulant re-testing to reaffirm dose.	Oct. 17, 2016	• Metals-grade H_2SO_4 • pH/conductivity/TDS calibration standards	• 1L Beakers (8) • Graduated cylinders • Glass buret, stopcock, clamp, and lab stand	• Total manganese • Absorbance at 254 nm • pH, conductivity, turbidity, DO, ORP, TDS	• ICPMS metals scan • TOC, colour, alkalinity, TSS	• 32 Samples generated = 4 jars x 4 coagulants x 2 for duplication. • Only submitting samples near optimal pH, approx. 4
4	*Optimize and evaluate polymer addition*	Evaluation of two different polymers for best conditions observed from Trial 2 and 3	Oct. 17, 2016	• 1000 μL micropipette and tips • pH/conductivity/TDS calibration standards	• 1L Beakers (8) • Graduated cylinders Glass buret, stopcock, clamp, and lab stand	• Total manganese • Absorbance at 254 nm • pH, conductivity, turbidity, DO, ORP, TDS	• ICPMS metals scan • TOC, colour, alkalinity, TSS	• 32 samples generated = 4 jars x 4 coagulants x 2 polymers • Only submitting samples near optimal polymer dose, approx. 8
5	*No coagulant*	Using best conditions previously identified in Trials 3, 4, and 5, evaluate no coagulant conditions.	Oct. 17, 2016	• pH/conductivity/TDS calibration standards	• 1L Beakers • Graduated cylinders	• Total manganese • Absorbance at 254 nm • pH, conductivity, turbidity, DO, ORP, TDS	• ICPMS metals scan • TOC, colour, alkalinity, TSS	• Minimum 4 samples generated for submission. • 8 samples for submission if time permits for duplication.
6	*Optimal conditions*	Repeat selected optimum conditions with the selected alternative coagulants	Oct. 24, 2016	• Metals-grade H_2SO_4 • 1000 μL micropipette and tips • pH/conductivity/TDS calibration standards	• 1L Beakers • Graduated cylinders • Glass buret, stopcock, clamp, and lab stand	• Total manganese • Absorbance at 254 nm • pH, conductivity, turbidity, DO, ORP, TDS	• ICPMS metals scan • TOC, colour, alkalinity, TSS, threshold odour number • DBP formation potential, HAA • Corrosion indicators (Na^+, Cl^-, SO_4^{2-})	• Minimum 8 samples = 4 jars x 2 for duplication. • 12 samples for submission if time permits.
7	*Optimize mixing time and evaluate applied energy*	Evaluate best conditions under different mixing speed and duration.	Oct. 24, 2016	• Metals-grade H_2SO_4 • 1000 μL micropipette and tips • pH/conductivity/TDS calibration standards	• 1L Beakers • Graduated cylinders • Glass buret, stopcock, clamp, and lab stand	• Total manganese • Absorbance at 254 nm • pH, conductivity, turbidity, DO, ORP, TDS	• ICPMS metals scan • TOC, colour, alkalinity, TSS	• Minimum 16 samples generated for submission • Duplication to 32 samples if time permits.

[A] General requirements not listed, but required is the Hach DR6000 and two square sample cells, access to an analytical balance, benchtop jar mixer, benchtop DAF air injector, pH probe (temperature calibration capable, ORP and conductivity readout).

[B] Glassware requirements not listed, but required are several 100 mL volumetric flasks, glass pipettes (10 mL, 25 mL, 50 mL, 75 mL, and 100 mL) and a pipette bulb filler (fill/dispense style).

[C] Benchtop analytics refers to analyses which can be conducted without submission the Environmental Standards laboratory, and requires the availability of an analytical pH probe. The pH probe is assumed to provide pH, ORP and conductivity readings. DO and TDS measurements to be provided by a separate probe, also made available.

[D] Each sample submitted will be analyzed for a total of ten different parameters: metals (ICPMS), TOC, colour, alkalinity, TSS, and for Trials 1 and 6: THM, HAA, and corrosion indicators (Na^+, Cl^-, SO_4^{2-}), and threshold odour number.

Appendix A

Trial#1: The first trial serves two purposes: calibrate the jar testing equipment to ensure that it accurately replicates the treatment at full-scale and collected bench-scale data pertaining to Mn concentration, post-DAF turbidity, TOC removal, pH, alkalinity, and solids concentrations when employing the existing coagulant and coagulant aids. Each of the four jars will be dosed with the same concentrations of coagulant and acid to match full-scale conditions, and the results will be compared to samples collected after DAF in the full-scale plant.

The full-scale plant utilizes 8 DAF tanks. A combination of grab samples and online monitoring data will be collected from the effluent of the DAF tanks on the day of the first jar test, if possible. This data will be compared to the samples collected from the jar tests using a t-test at a significance level of 95%. Each of the first 11 parameters presented in Table 1 will be analyzed using this statistical test. If all of the parameters are statistically equal, then the jar test method will be assumed to match the full-scale operation. However, if some of the parameters are not statistically equal, interpretation of the results will be required to determine if the method should be changed, or if the results provided are adequate. Priority should be given to parameters such as metals concentrations, TOC removal, turbidity, solids concentration and pH, whereas parameters such as colour, odour number and alkalinity may be less important. If the data collected at bench-scale are not statistically equal to the full-scale data, then the procedure will be adjusted by changing mixing rate and mixing duration, air injection rates and duration, and settling duration until the bench- and full-scale water quality are the same. Data collected from the bench-scale unit after process adjustments will be used as the comparative data for all other coagulant and coagulant aid combinations. Samples will be analyzed for all parameters presented in Table 1.

Trial #2 (coagulant testing at plant pH – no polymer addition): These tests will be completed to first determine a coagulant dose at the current plant pH (without polymer addition) that produces water which achieves current operational water quality standards, or the highest water quality possible with that particular chemical. Based on provided warm water (May 1st to September 30th) treatment data from 2010 to 2015, the average historical coagulant dose is 29.3 mg/L, ranging from 19.1 to 39.7 mg/L. As such, the first set of trials will be conducted at chemical doses of 15, 25, 35 and 45 mg/L to provide an estimate of the optimal dose. Further refinement will occur by testing doses –2 and –4 mg/L from the current best dose. For example, if 35 mg/L is determined to be the best dose, secondary trials will examine 31, 33, 37 and 39 mg/L. If two doses are found to produce equivalent results the second stage of testing will be evenly spaced between the two best doses. For example, if 25 and 35 mg/L are found to be equivalent, then doses of 27, 29, 31 and 33 mg/L will be evaluated to determine an "optimal" dose. Samples will be analyzed for all parameters in Table 1 except for algae toxins, DBPs, and corrosion indicators.

Trial #3 (coagulant with pH adjustment – no polymer addition): Each coagulant will likely be associated with a pH that provides optimal performance. Ferric chloride and ferric sulfate containing coagulants have an optimal pH <6, while the aluminum ferric sulphate blends have an optimal pH of 5.5 to 6.5. The historical data from the treatment plant shows an average post DAF pH to be 5.6, ranging from 4.9 to 6.4, due to optimization for ferric chloride. Based on this data, test 3 will first evaluate sulphuric acid addition to achieve a pH of 5.0, 5.3, 5.6, and 6. For the AFS blended coagulants, pH levels of 5.5, 5.9, 6.2 and 6.5 will be utilized. Subsequent tests for all coagulants will evaluate – 0.1 and –0.2 units from the identified optimal pH. If two pH are found to perform the same, then the next four jars will be tested at equally spaced intervals between the two best pH levels. Samples will be analyzed for all parameters except for algae toxins, DBPs, and corrosion indicators.

Trial #4 (coagulant with pH adjustment and polymer addition): After an optimal coagulant dose and pH in terms of Mn reduction has been determined, the polymers will be tested. Although the specifics of the polymers have not yet been identified, the process of identifying the optimal polymer dose will be very similar to that used to determine optimal coagulant concentration. First, samples will be spiked with the appropriate amount of coagulant, as identified in Trial 2. Then, polymer will be added to achieve a concentration of 0.05, 0.1, 0.25 and 0.5 mg/L. If the optimal concentration of polymer is found to be less than 0.5 mg/L, then this stage of testing will be complete. However, if 0.5 mg/L is found to be the optimal concentration of the first four, then a second stage of testing will evaluate concentrations of 0.55, 0.7, 0.85 and 1.0 mg/L to determine if higher doses are required. Samples will be analyzed for all parameters except for algae toxins, DBPs, and corrosion indicators. Due to the large number of samples possible by examining 4 alternative coagulants with 3 polymers at 4 different doses (48 samples/replicate), this procedure will likely be completed with one replicate, but may be completed in duplicate, if time permits. An iterative process examining the optimization of coagulant and polymer dose has not been proposed at this time due to the time and analytical demands it would impart, but could be completed in the future at bench- or pilot-scale, if desired.

Trial #5: To determine the impact of the DAF process alone, four samples will be analyzed without any chemical addition. This will determine the benefit of DAF with respect to the identified water quality parameters. However, this test will be used strictly as a comparative tool, since the operating requirements of the plant likely indicate that coagulants must be used at all times. Samples will be analyzed for all parameters except for algae toxins, DBPs, and corrosion indicators.

Trial #6: After evaluating all of the combinations of coagulants and coagulant aids, the four best alternatives will be compared side by side. This test will ensure that each of the alternatives have been tested on the same water with the goal of identifying one or two combinations to test at pilot-scale. These samples will be tested for all of the parameters listed in Table 1 to ensure that the best possible combination of chemicals is pilot tested.

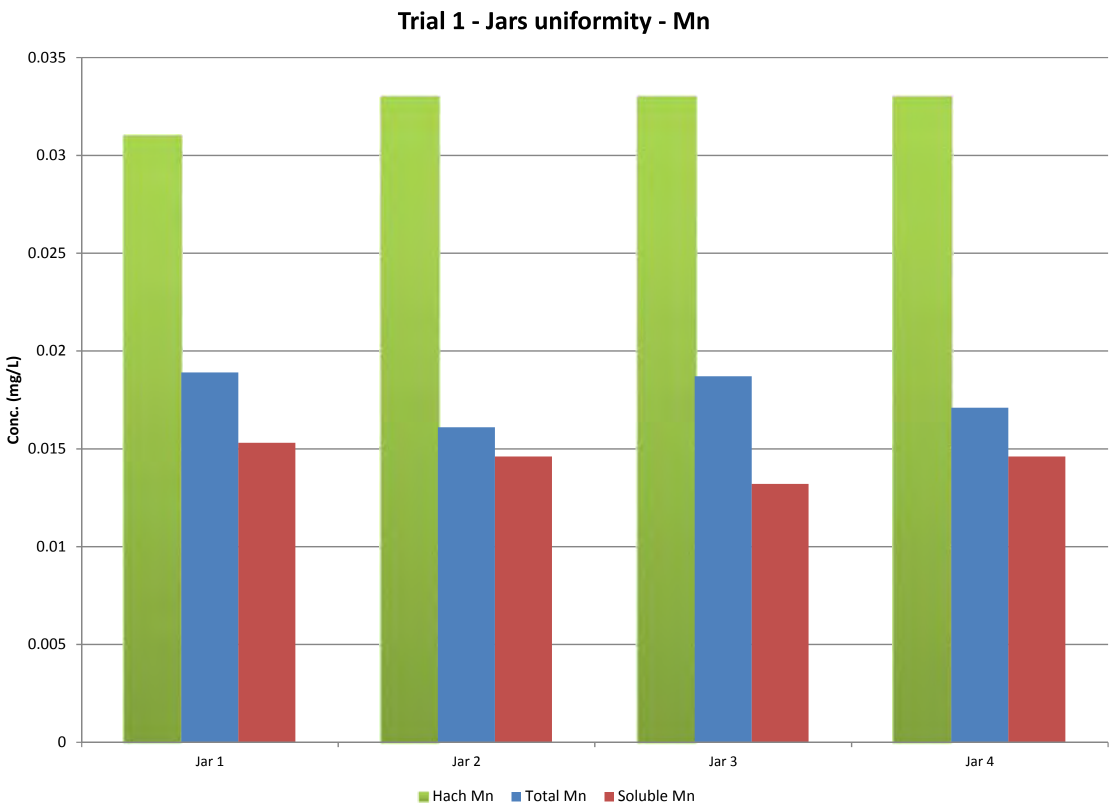
Trial #7: To evaluate the impact of changes to mixing durations and intensities, a series of four jar tests will be completed to evaluate the impact of these parameters on the best alternative chemical combination. Changes of –25% and –50% from the previously utilized values for rapid mix and coagulation mixing time and intensity will be evaluated. Each of the jars will be sampled and analyzed for all of the parameters listed in Table 1, except for DBP formation potential (THM and HAA), algae toxins and corrosion indicators. The results of this test will be used to determine whether process changes may be appropriate to improve the efficiency of the alternative coagulant.

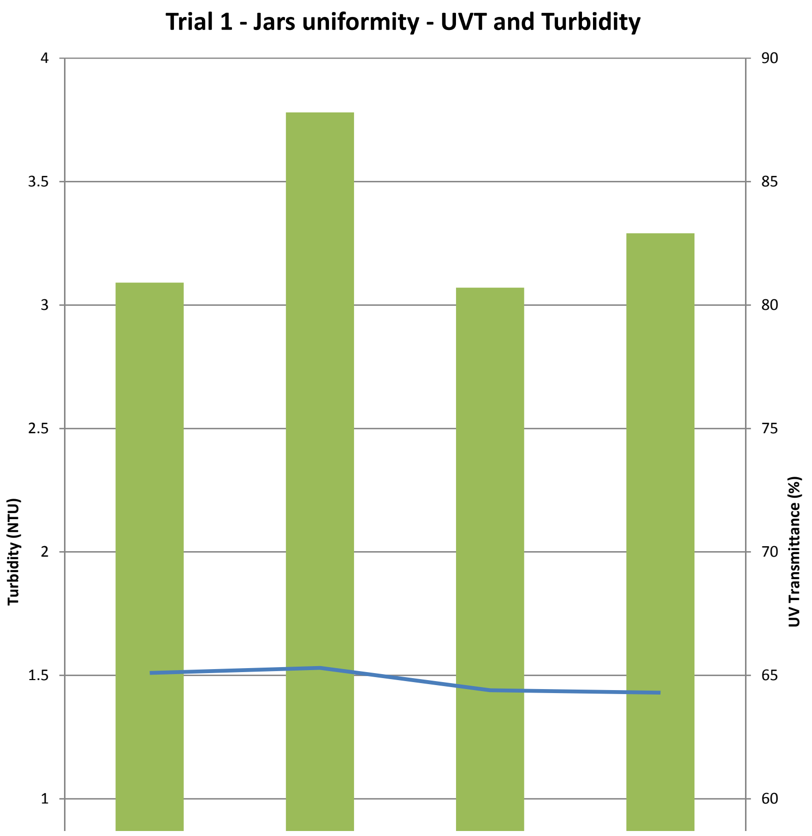
Appendix B

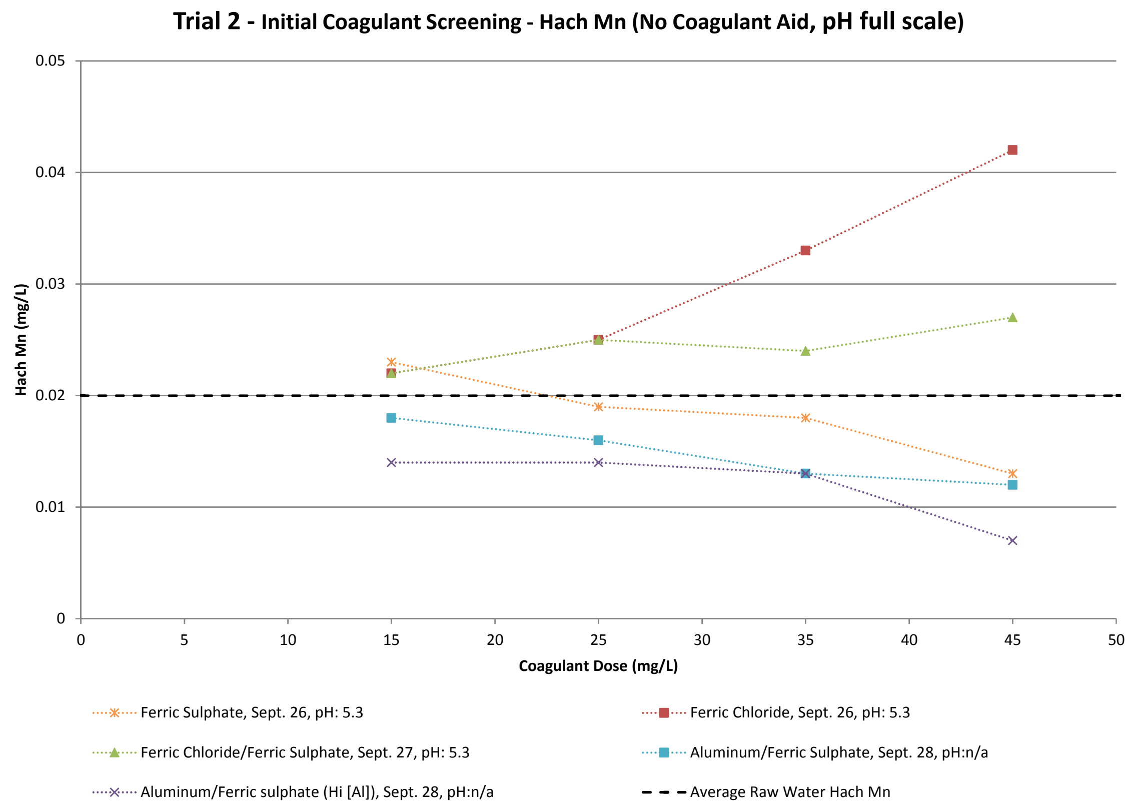
Table 8 Proposed Jar Test Schedule

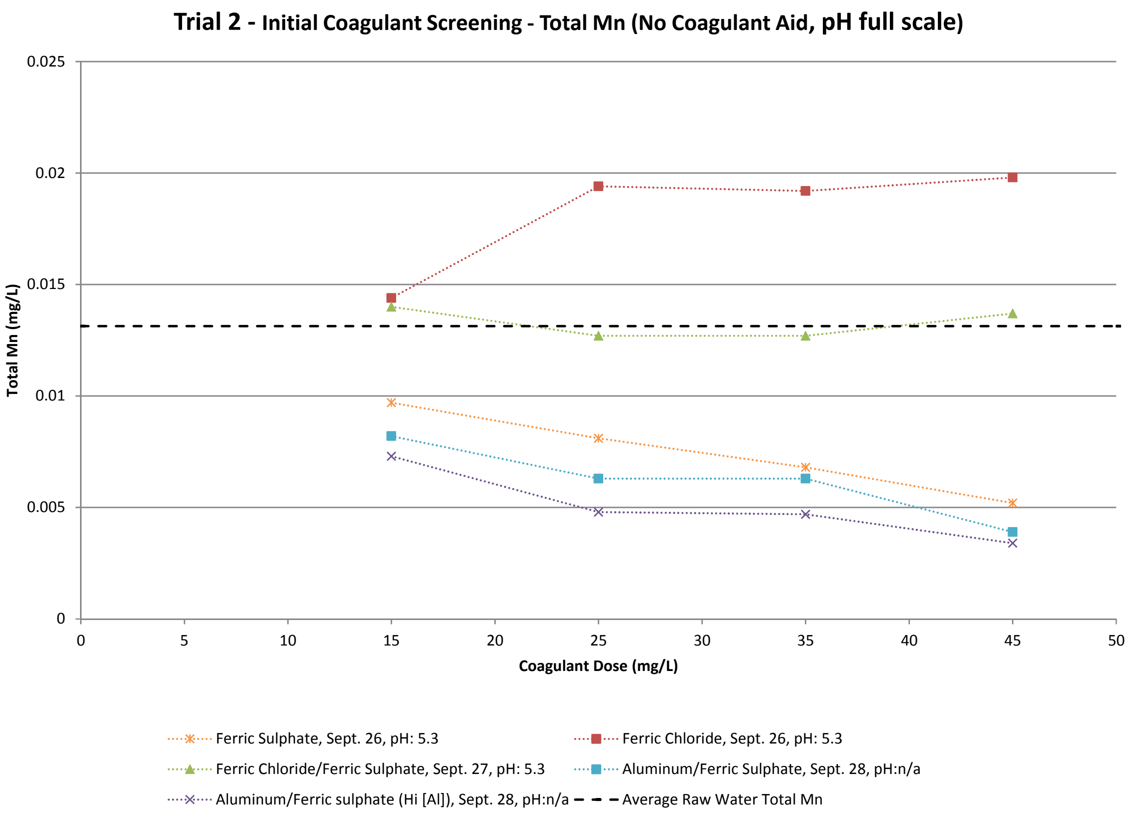
Day(s)	Trials Completed	Details
1, 2	1	Perform a series of jar tests using the full-scale plant operating conditions to fine-tune the equipment operation and ensure the results closely match the water quality achieved at full-scale.
3, 4	2	Complete the first stage of dose optimization for each of the proposed four coagulants. Assuming that each experiment requires approximately 1 hour to complete (15 mins flocculation, and ~ 6 mins of DAF according to pilot design documents)
5, 6	3	Each of the four alternative coagulants will be tested at different pH levels. Each test should be completed twice.
7, 8	4, 5	Evaluation of polymer dose can be completed after the determination of optimal coagulant concentration and coagulation pH. If time permits, a test can be completed to evaluate the impact of DAF if not coagulant is added
9	6	Once all of the test results have been obtained, the optimal conditions for each of the alternative coagulants should be tested alongside the current conditions. Each of the optimal conditions should be tested a minimum of two additional times. All parameters should be evaluated.
10	7	Optimization of mixing energy and duration
11	6	The same procedure as day 9 should be evaluated on a second day, preferably with different influent water quality. At minimum day 9 and 11 should be spaced a couple of weeks apart to ensure that the results measured on day 5 are representative and applicable.

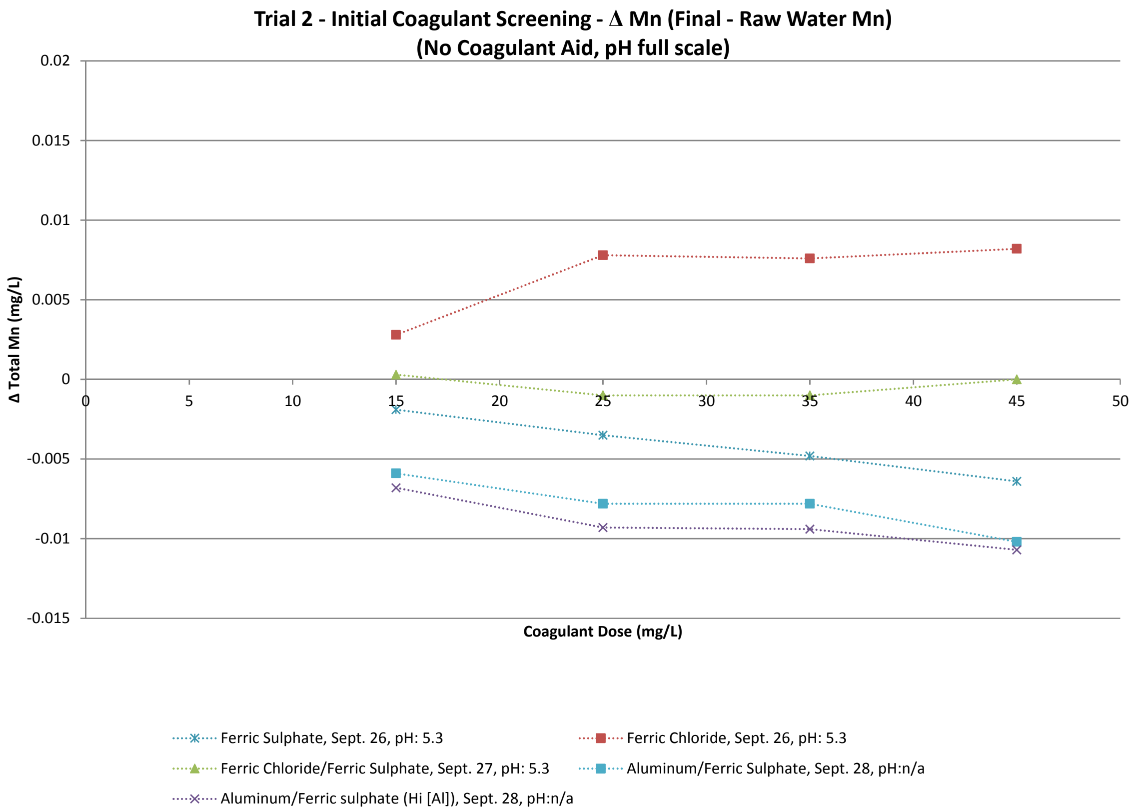
Appendix C – Bench Tests Results

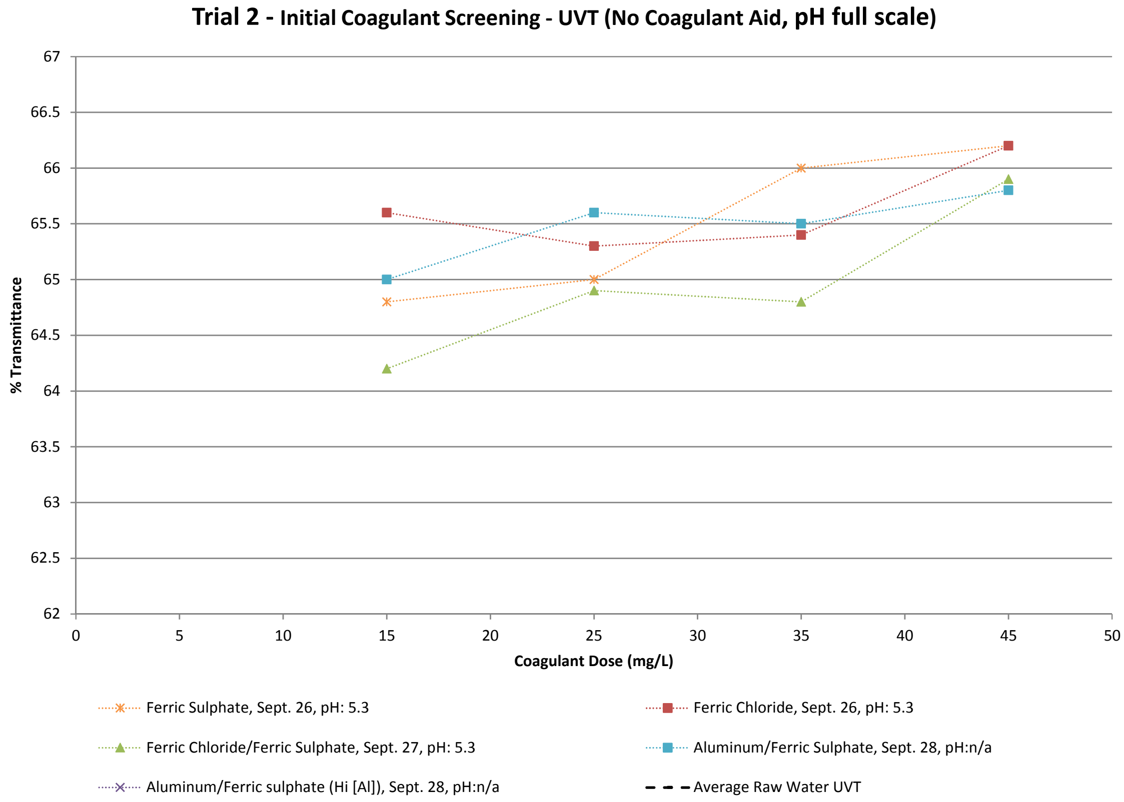

Trial 1 - Jars uniformity - Mn
Conc. (mg/L)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Jar 1
Jar 2
Jar 3
Jar 4
Hach Mn
Total Mn
Soluble Mn

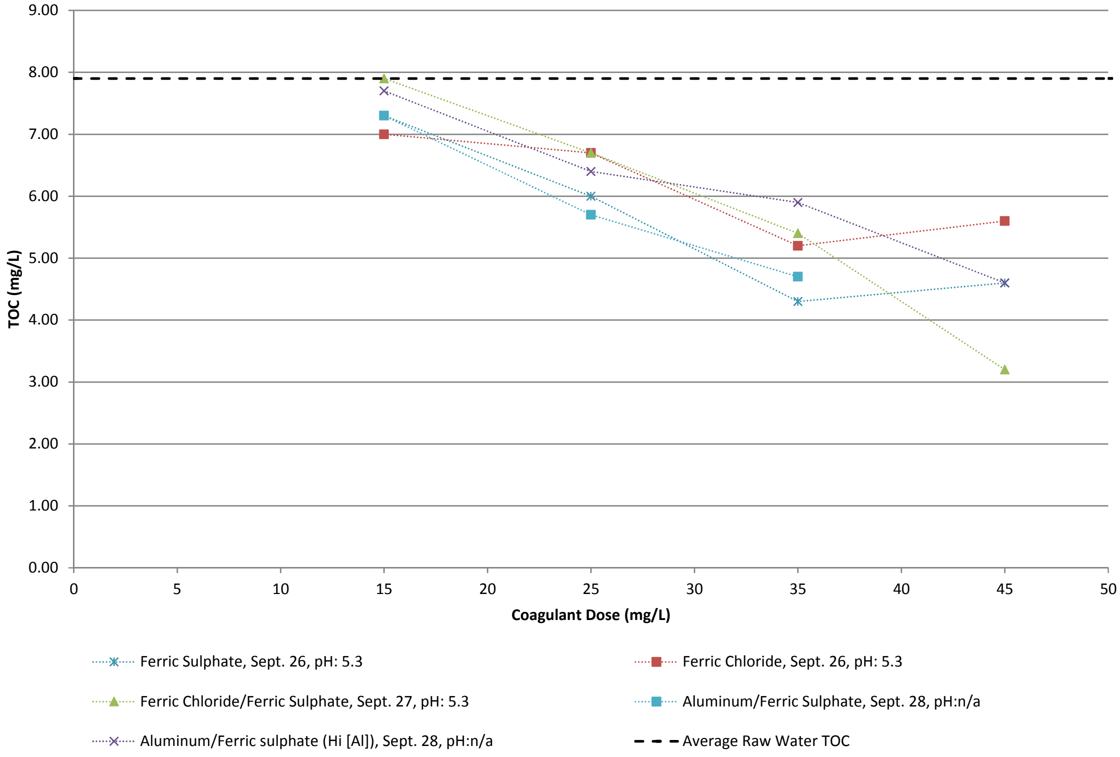

Trial 1 - Jars uniformity - UVT and Turbidity
Turbidity (NTU)
4
3.5
3
2.5
2
1.5
1
UV Transmittance (%)
90
85
80
75
70
65
60


Trial 2 - Initial Coagulant Screening - Hach Mn (No Coagulant Aid, pH full scale)

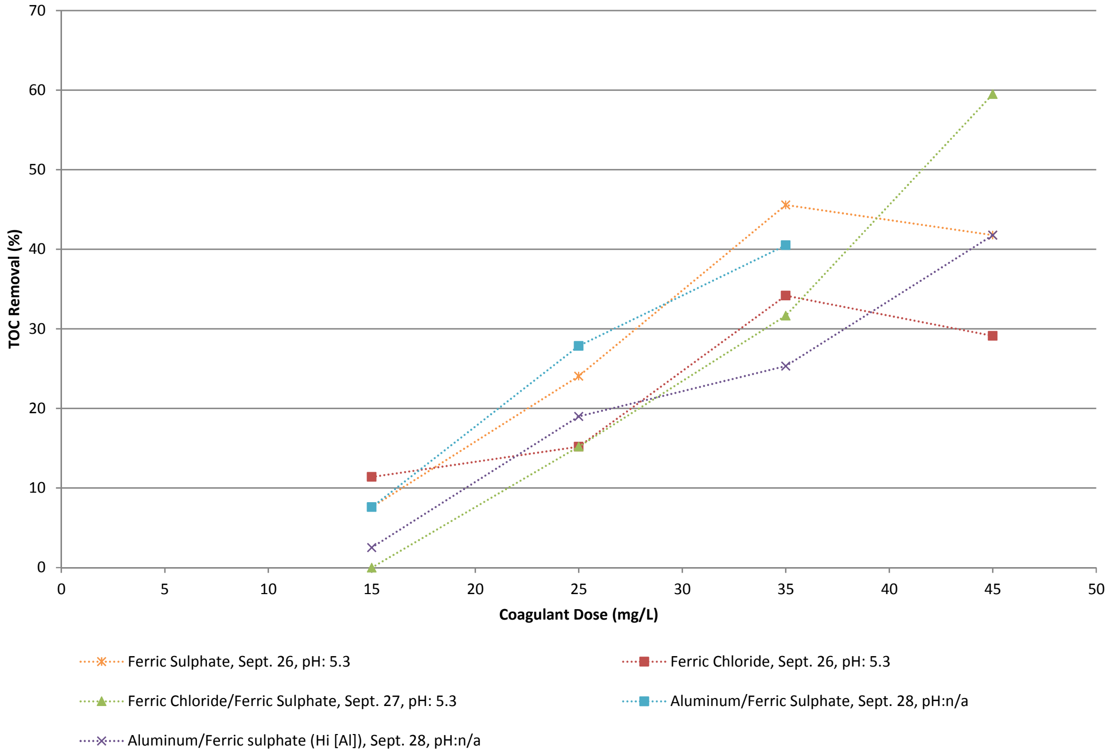

Trial 2 - Initial Coagulant Screening - Total Mn (No Coagulant Aid, pH full scale)


Trial 2 - Initial Coagulant Screening - Δ Mn (Final - Raw Water Mn)
(No Coagulant Aid, pH full scale)
Δ Total Mn (mg/L)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Ferric Sulphate, Sept. 26, pH: 5.3
Ferric Chloride, Sept. 26, pH: 5.3
Ferric Chloride/Ferric Sulphate, Sept. 27, pH: 5.3
Aluminum/Ferric Sulphate, Sept. 28, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]), Sept. 28, pH:n/a

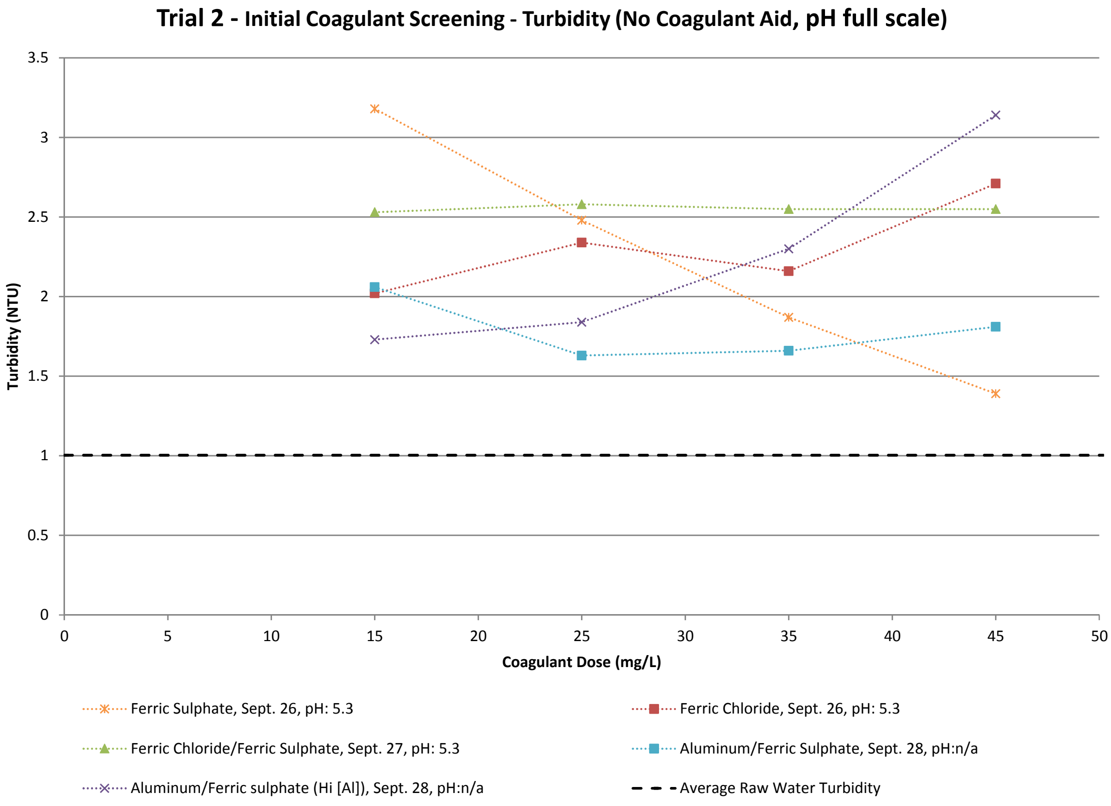

Trial 2 - Initial Coagulant Screening - UVT (No Coagulant Aid, pH full scale)
% Transmittance
67
66.5
66
65.5
65
64.5
64
63.5
63
62.5
62
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Ferric Sulphate, Sept. 26, pH: 5.3
Ferric Chloride, Sept. 26, pH: 5.3
Ferric Chloride/Ferric Sulphate, Sept. 27, pH: 5.3
Aluminum/Ferric Sulphate, Sept. 28, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]), Sept. 28, pH:n/a
Average Raw Water UVT

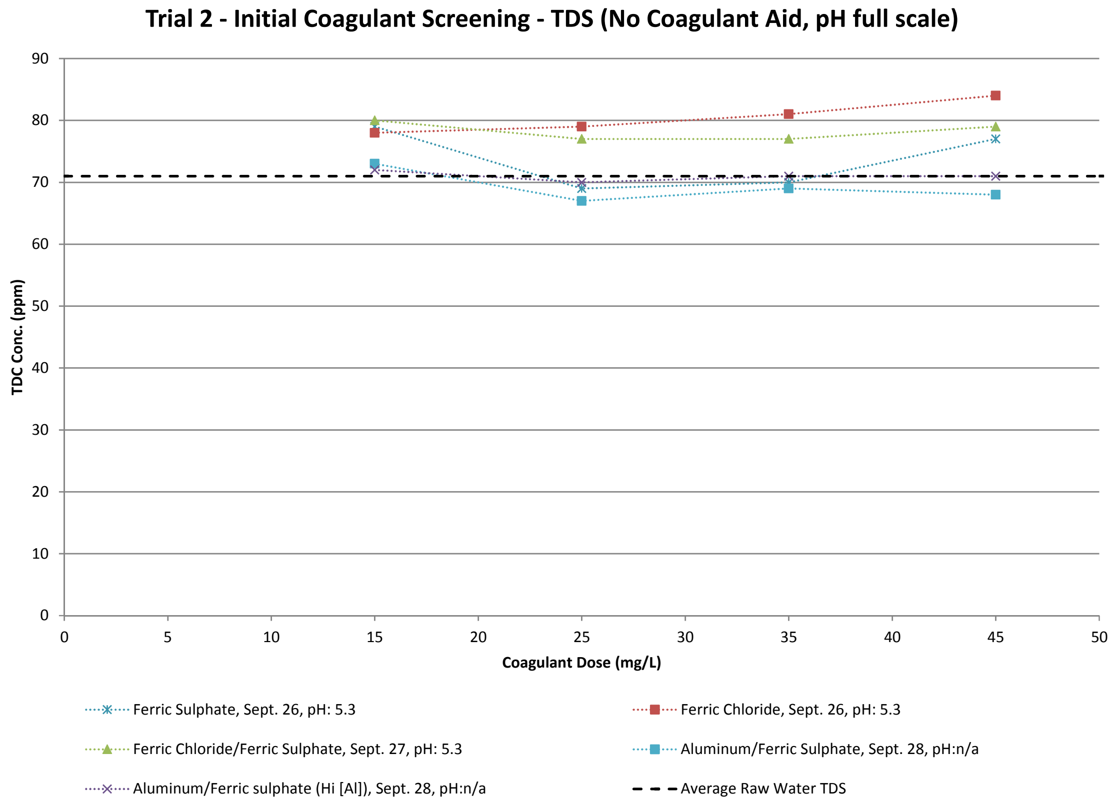


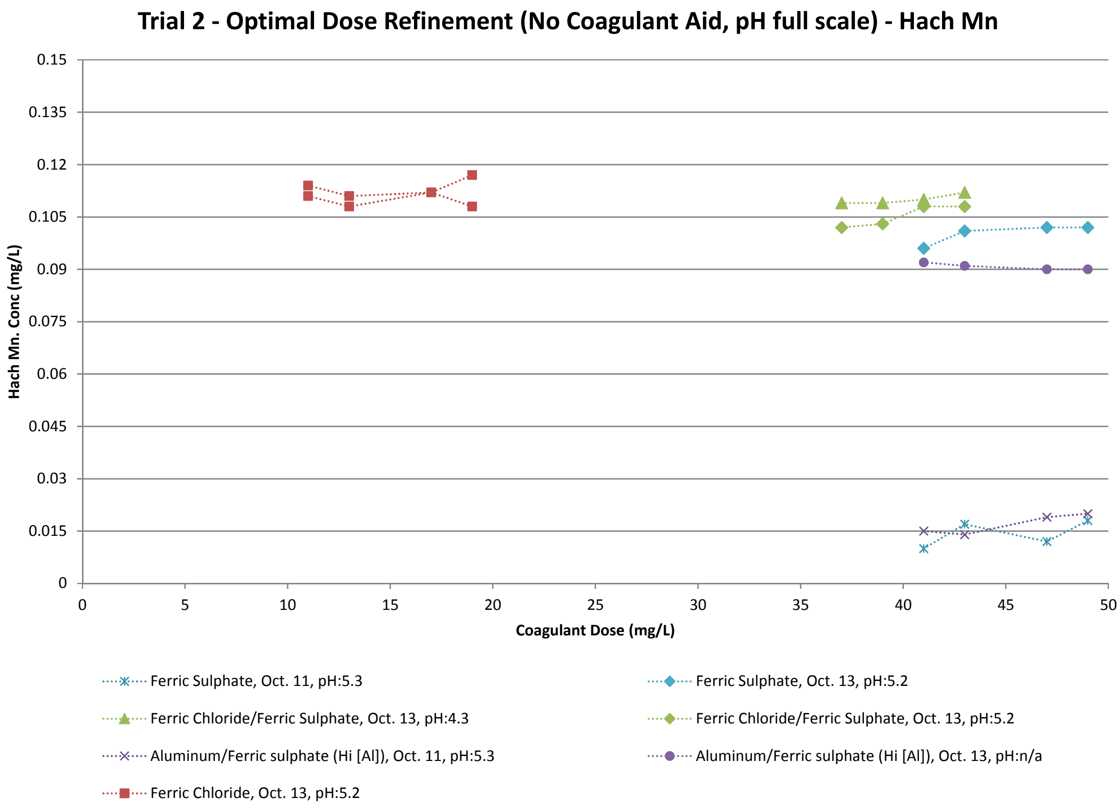
Trial 2 - Initial Coagulant Screening - TOC (No Coagulant Aid, pH full scale)

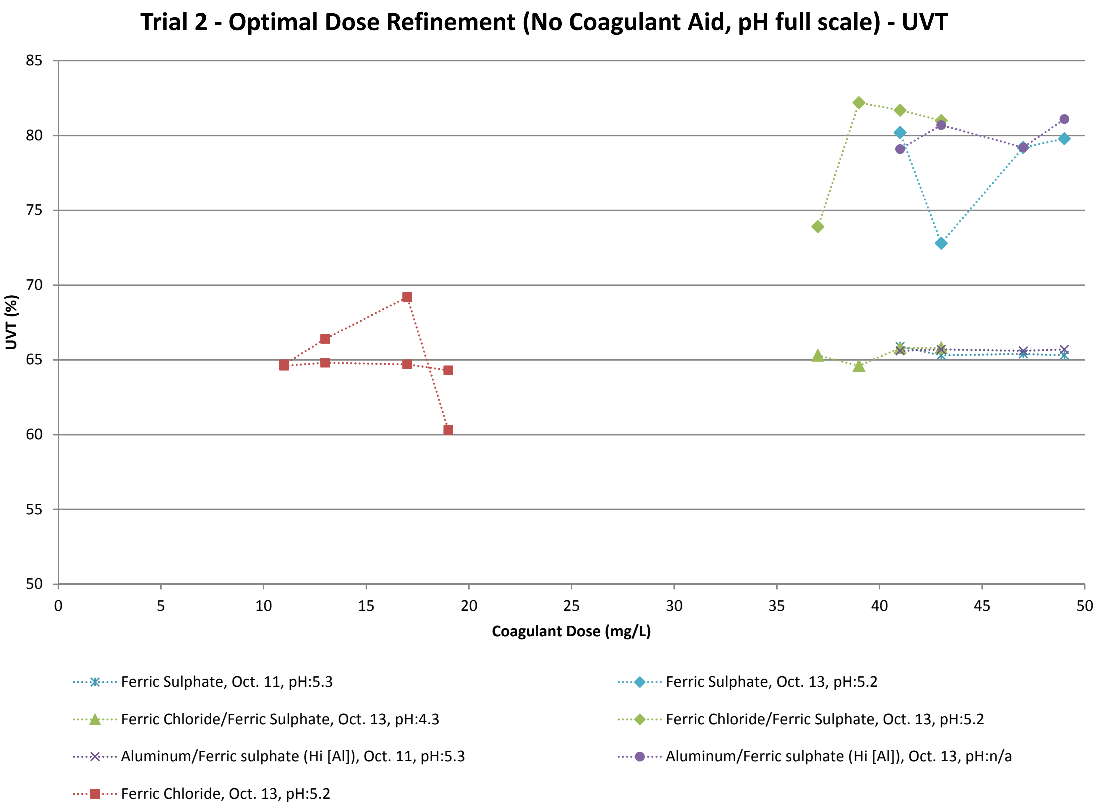


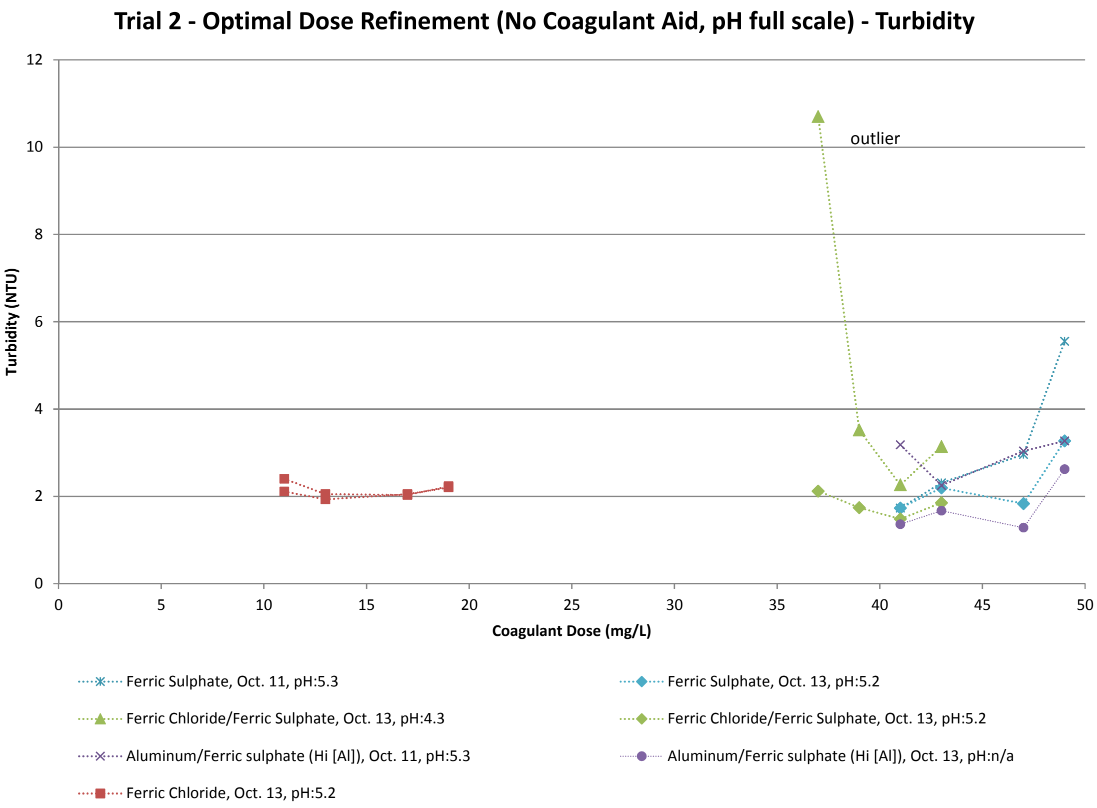
Trial 2 - Initial Coagulant Screening - TOC Removal (No Coagulant Aid, pH full scale)

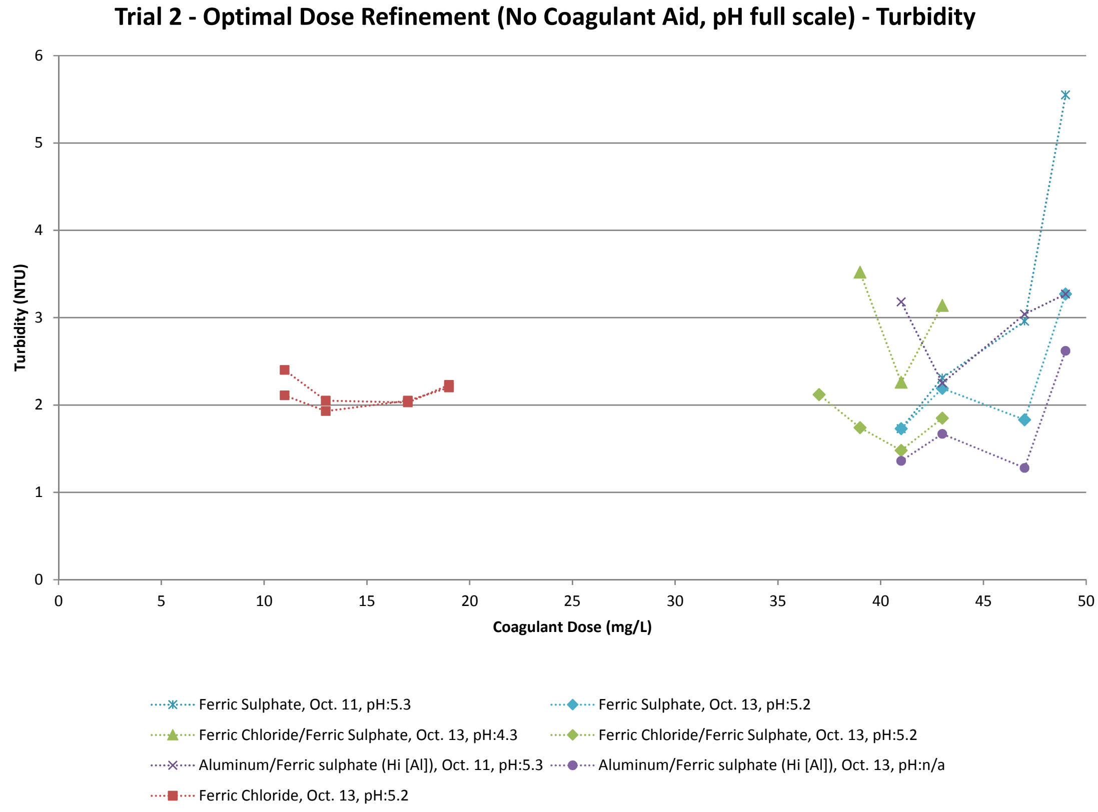

Trial 2 - Initial Coagulant Screening - Turbidity (No Coagulant Aid, pH full scale)
Turbidity (NTU)
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Ferric Sulphate, Sept. 26, pH: 5.3
Ferric Chloride, Sept. 26, pH: 5.3
Ferric Chloride/Ferric Sulphate, Sept. 27, pH: 5.3
Aluminum/Ferric Sulphate, Sept. 28, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]), Sept. 28, pH:n/a
Average Raw Water Turbidity

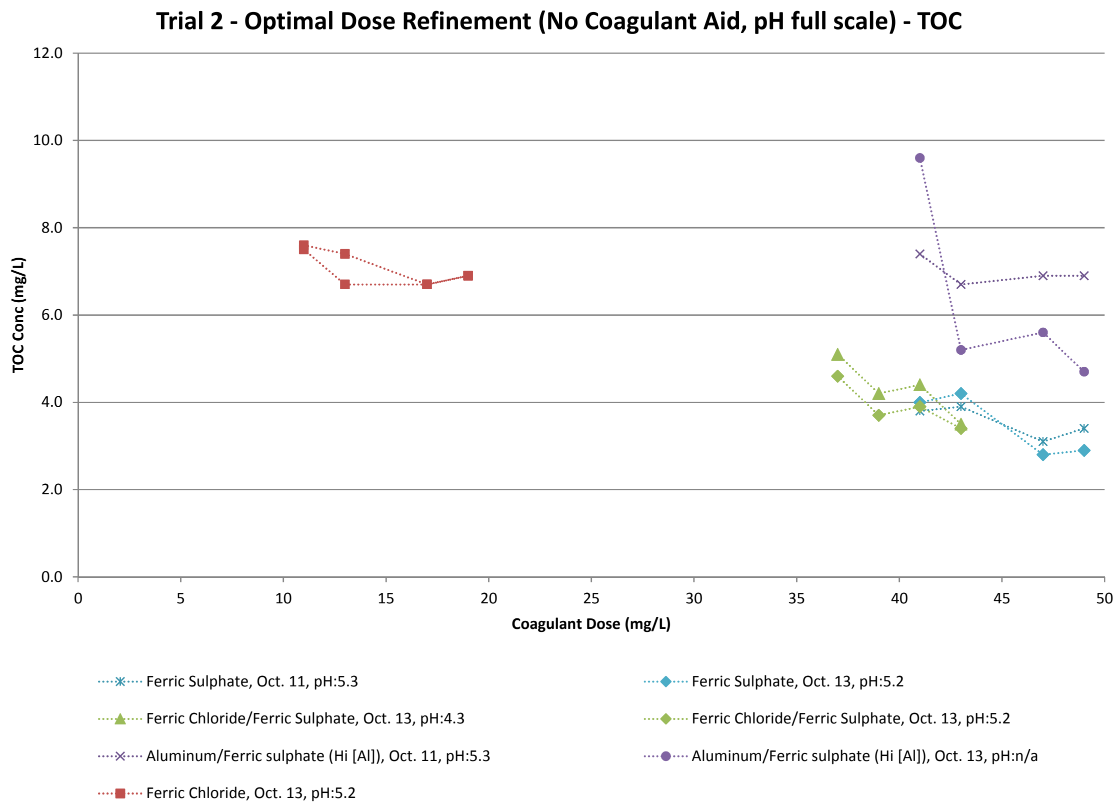

Trial 2 - Initial Coagulant Screening - TDS (No Coagulant Aid, pH full scale)
TDC Conc. (ppm)
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Ferric Sulphate, Sept. 26, pH: 5.3
Ferric Chloride, Sept. 26, pH: 5.3
Ferric Chloride/Ferric Sulphate, Sept. 27, pH: 5.3
Aluminum/Ferric Sulphate, Sept. 28, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]), Sept. 28, pH:n/a
Average Raw Water TDS


Trial 2 - Optimal Dose Refinement (No Coagulant Aid, pH full scale) - Hach Mn

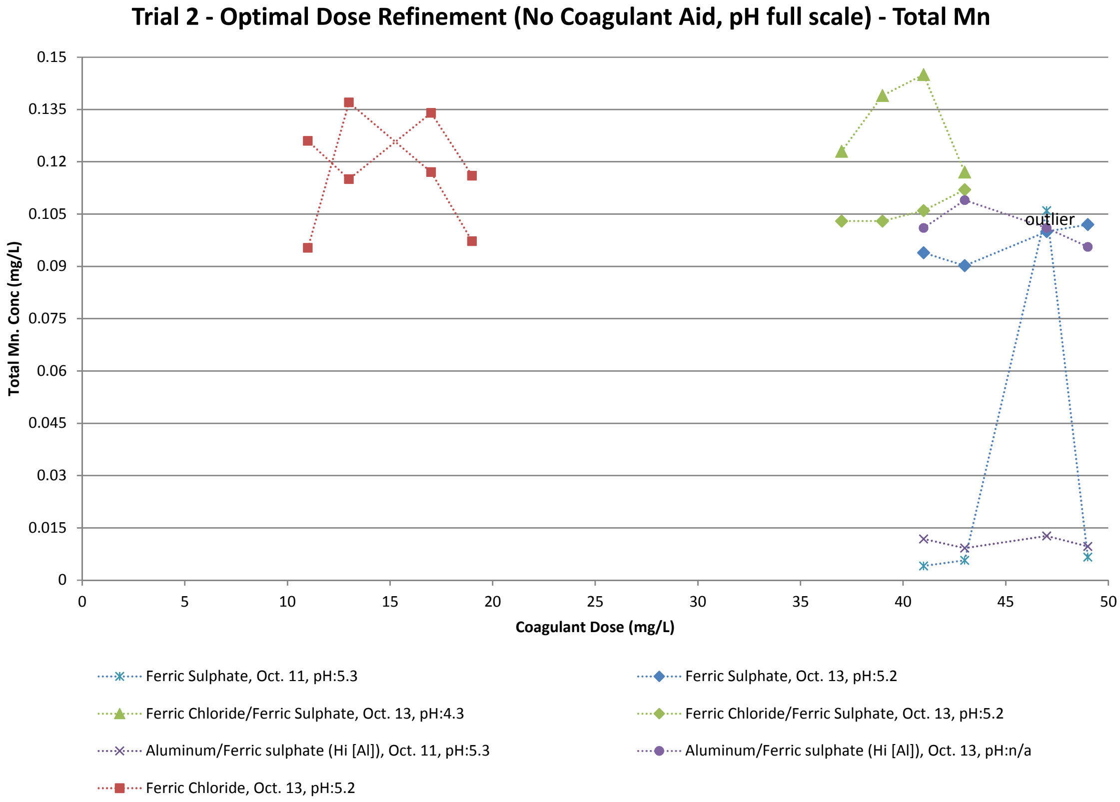

Trial 2 - Optimal Dose Refinement (No Coagulant Aid, pH full scale) - UVT


Trial 2 - Optimal Dose Refinement (No Coagulant Aid, pH full scale) - Turbidity
Turbidity (NTU)
0
2
4
6
8
10
12
outlier
Coagulant Dose (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Ferric Sulphate, Oct. 11, pH:5.3
Ferric Sulphate, Oct. 13, pH:5.2
Ferric Chloride/Ferric Sulphate, Oct. 13, pH:4.3
Ferric Chloride/Ferric Sulphate, Oct. 13, pH:5.2
Aluminum/Ferric sulphate (Hi [Al]), Oct. 11, pH:5.3
Aluminum/Ferric sulphate (Hi [Al]), Oct. 13, pH:n/a
Ferric Chloride, Oct. 13, pH:5.2

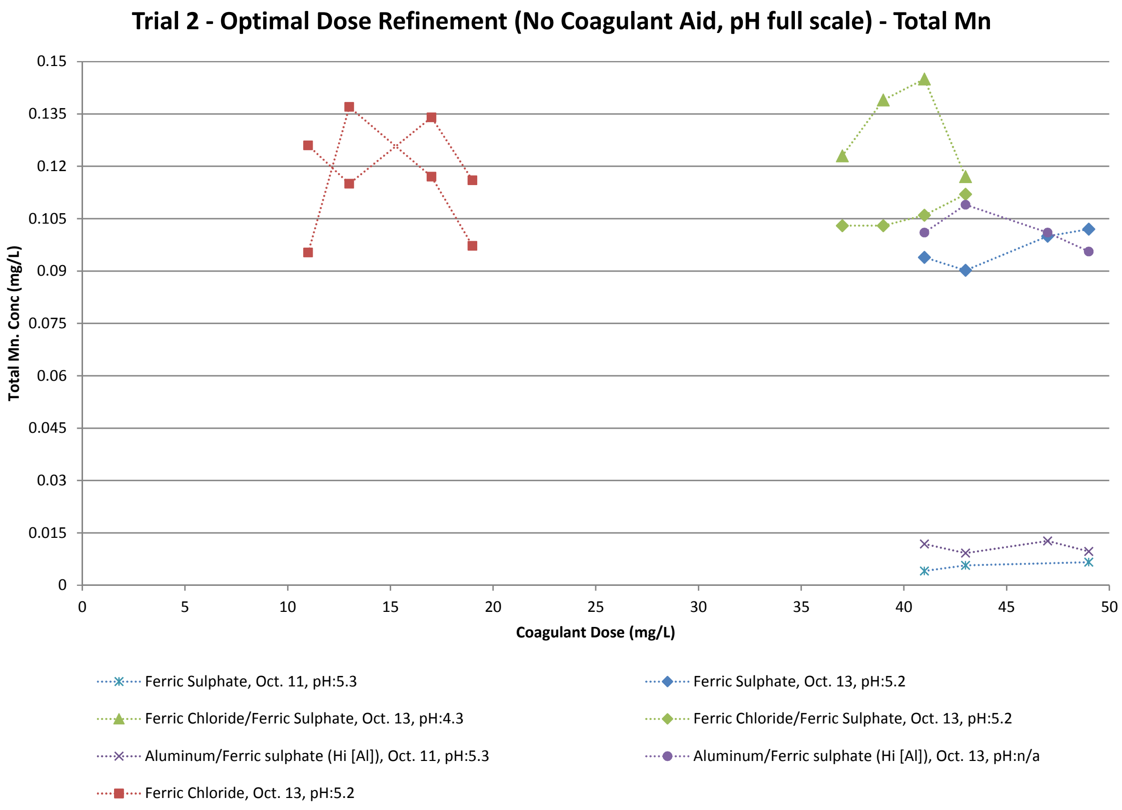

Trial 2 - Optimal Dose Refinement (No Coagulant Aid, pH full scale) - Turbidity
Turbidity (NTU)
0
1
2
3
4
5
6
Coagulant Dose (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Ferric Sulphate, Oct. 11, pH:5.3
Ferric Sulphate, Oct. 13, pH:5.2
Ferric Chloride/Ferric Sulphate, Oct. 13, pH:4.3
Ferric Chloride/Ferric Sulphate, Oct. 13, pH:5.2
Aluminum/Ferric sulphate (Hi [Al]), Oct. 11, pH:5.3
Aluminum/Ferric sulphate (Hi [Al]), Oct. 13, pH:n/a
Ferric Chloride, Oct. 13, pH:5.2

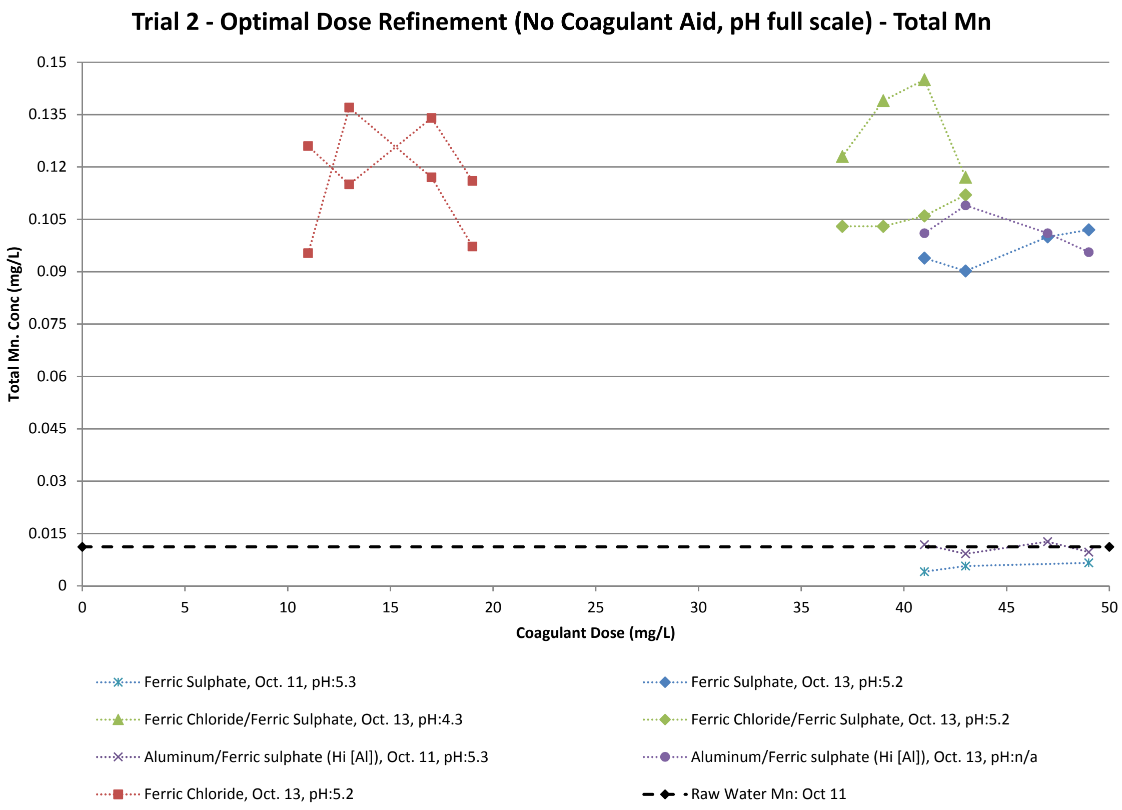


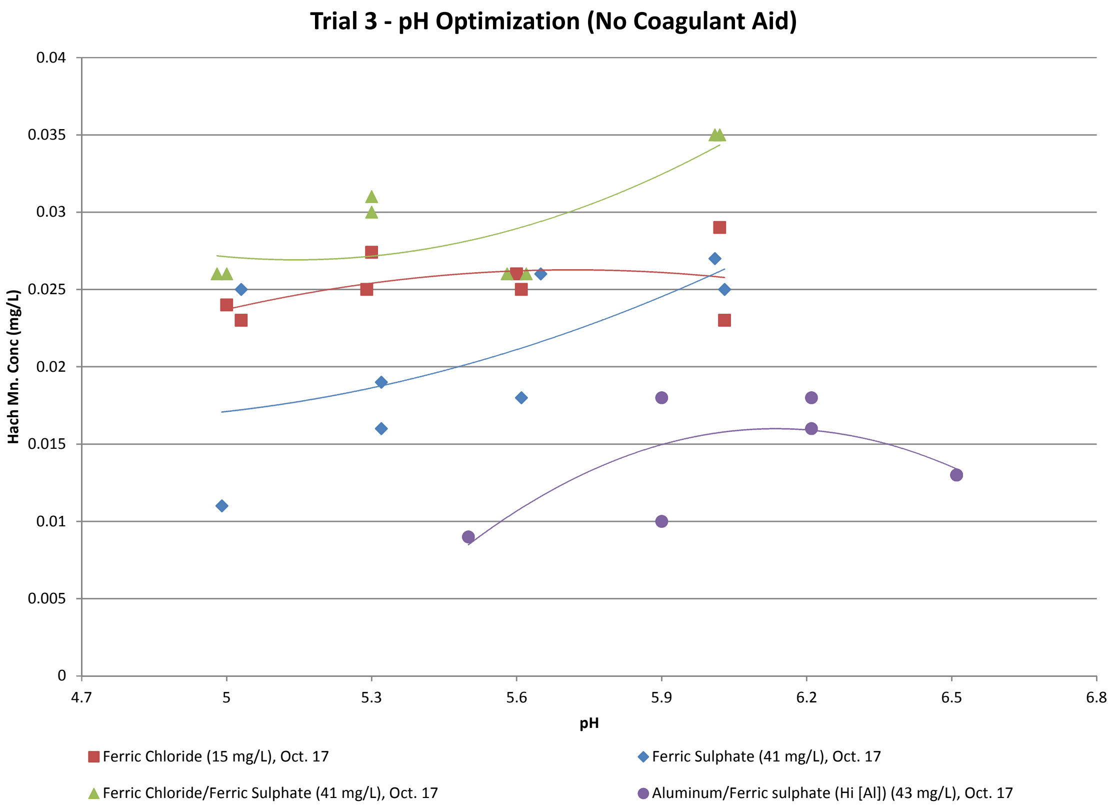
Trial 2 - Optimal Dose Refinement (No Coagulant Aid, pH full scale) - TOC

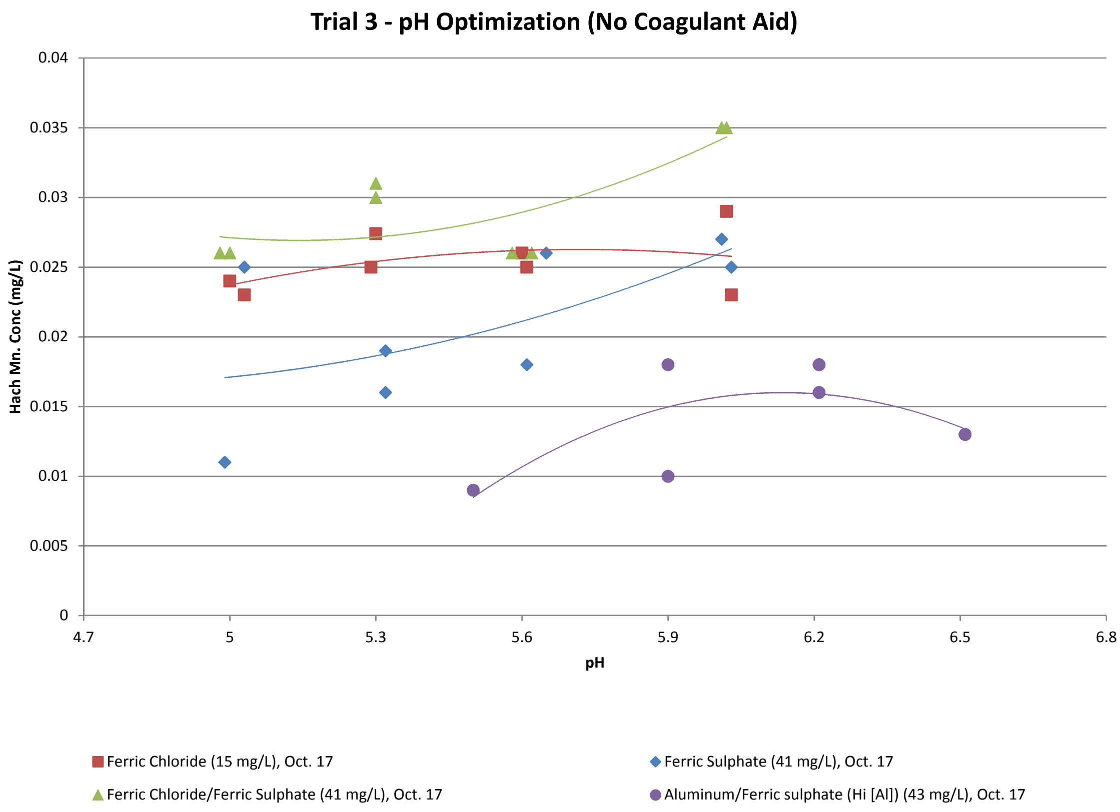


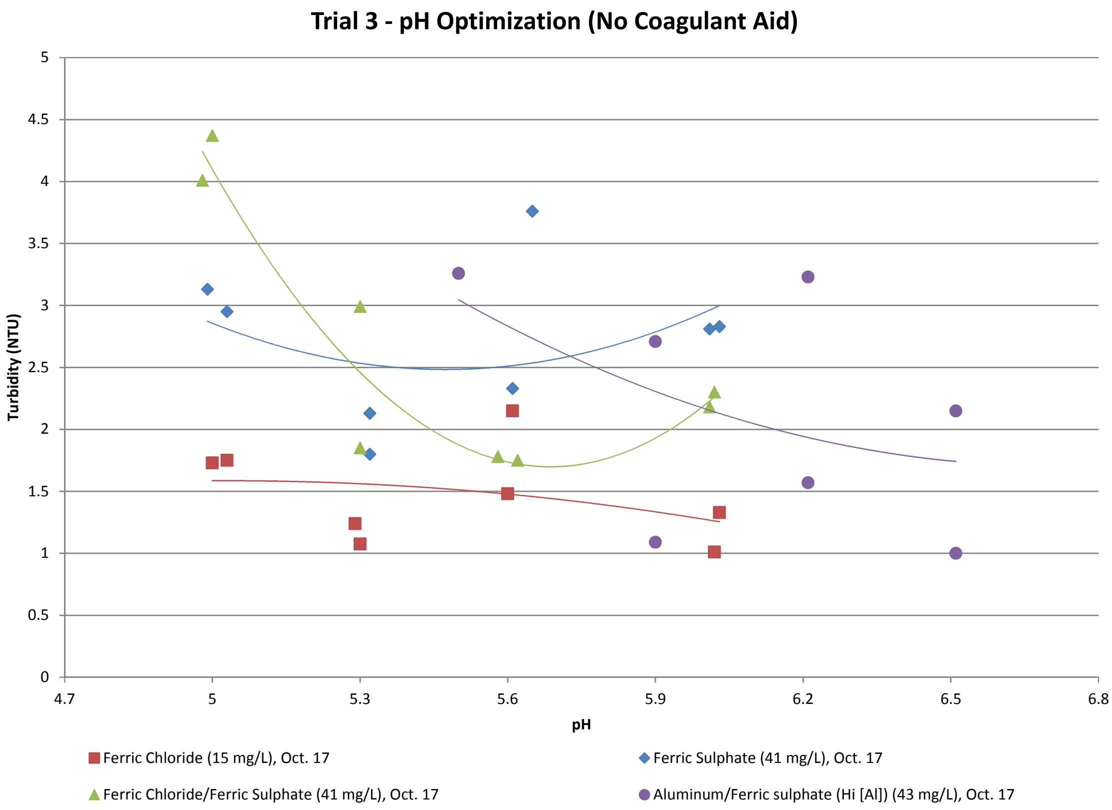
Trial 2 - Optimal Dose Refinement (No Coagulant Aid, pH full scale) - Total Mn

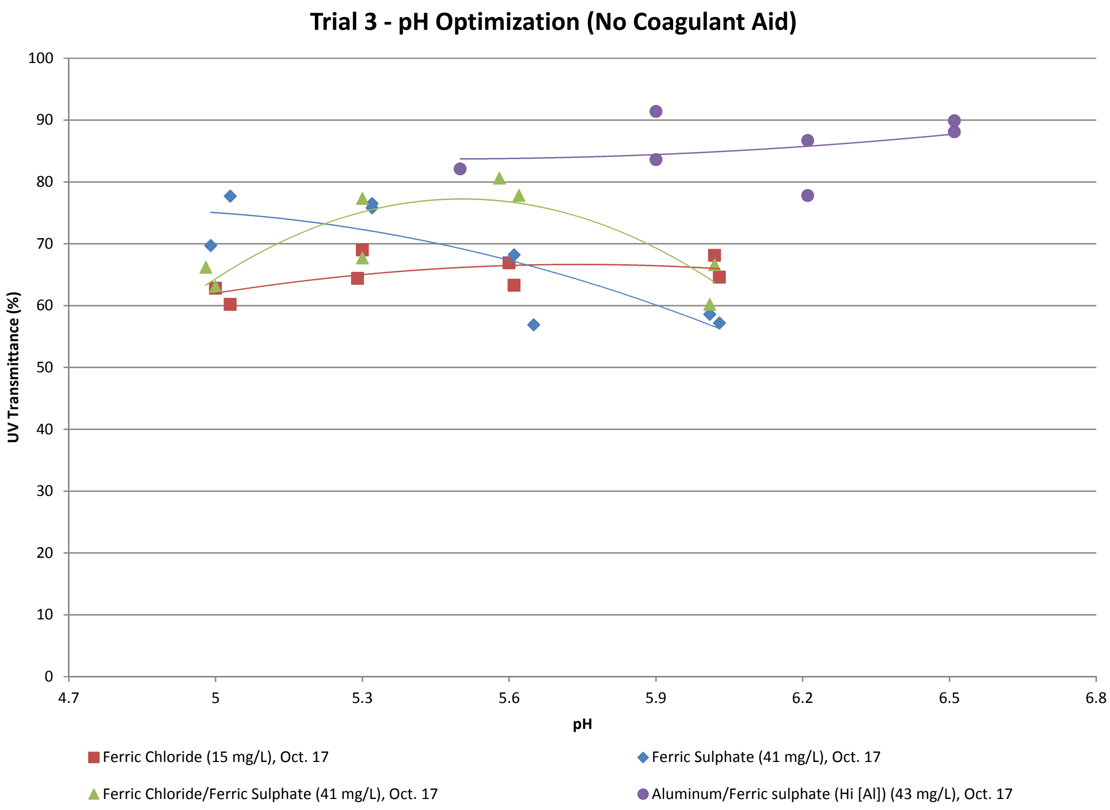

Trial 2 - Optimal Dose Refinement (No Coagulant Aid, pH full scale) - Total Mn
Total Mn. Conc (mg/L)
0.15
0.135
0.12
0.105
0.09
0.075
0.06
0.045
0.03
0.015
0
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Ferric Sulphate, Oct. 11, pH:5.3
Ferric Sulphate, Oct. 13, pH:5.2
Ferric Chloride/Ferric Sulphate, Oct. 13, pH:4.3
Ferric Chloride/Ferric Sulphate, Oct. 13, pH:5.2
Aluminum/Ferric sulphate (Hi [Al]), Oct. 11, pH:5.3
Aluminum/Ferric sulphate (Hi [Al]), Oct. 13, pH:n/a
Ferric Chloride, Oct. 13, pH:5.2

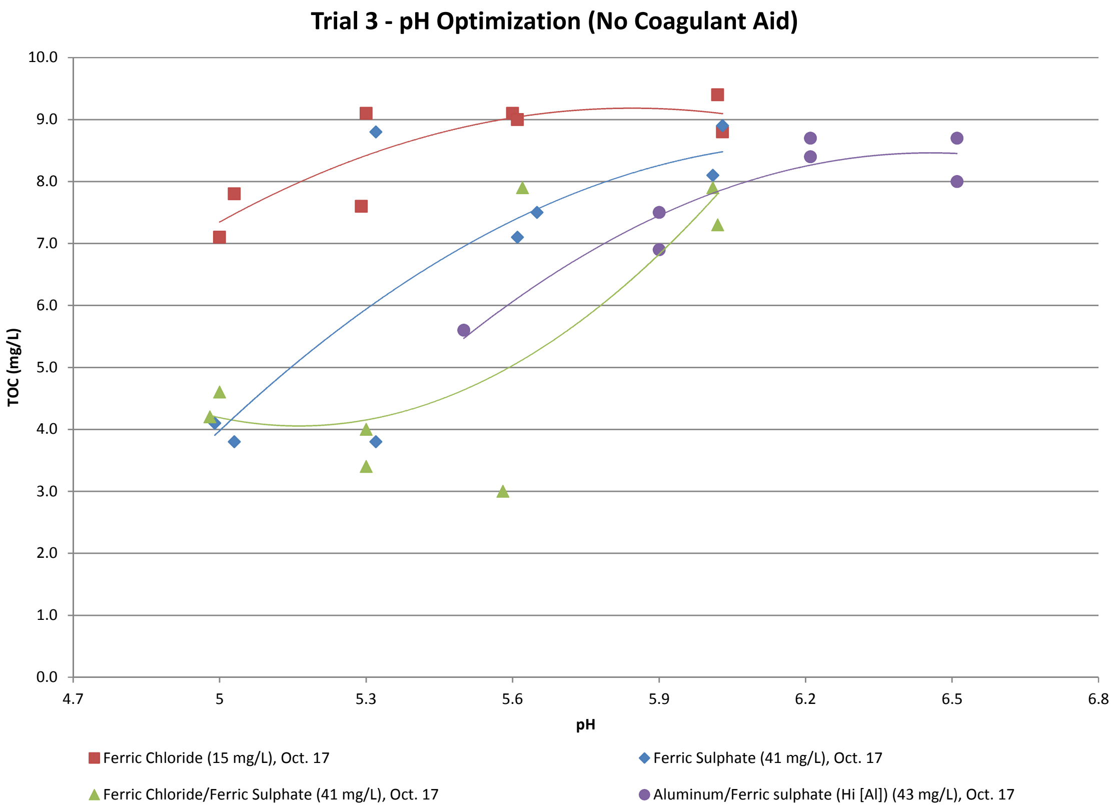

Trial 2 - Optimal Dose Refinement (No Coagulant Aid, pH full scale) - Total Mn
Total Mn. Conc (mg/L)
0.15
0.135
0.12
0.105
0.09
0.075
0.06
0.045
0.03
0.015
0
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Ferric Sulphate, Oct. 11, pH:5.3
Ferric Sulphate, Oct. 13, pH:5.2
Ferric Chloride/Ferric Sulphate, Oct. 13, pH:4.3
Ferric Chloride/Ferric Sulphate, Oct. 13, pH:5.2
Aluminum/Ferric sulphate (Hi [Al]), Oct. 11, pH:5.3
Aluminum/Ferric sulphate (Hi [Al]), Oct. 13, pH:n/a
Ferric Chloride, Oct. 13, pH:5.2
Raw Water Mn: Oct 11

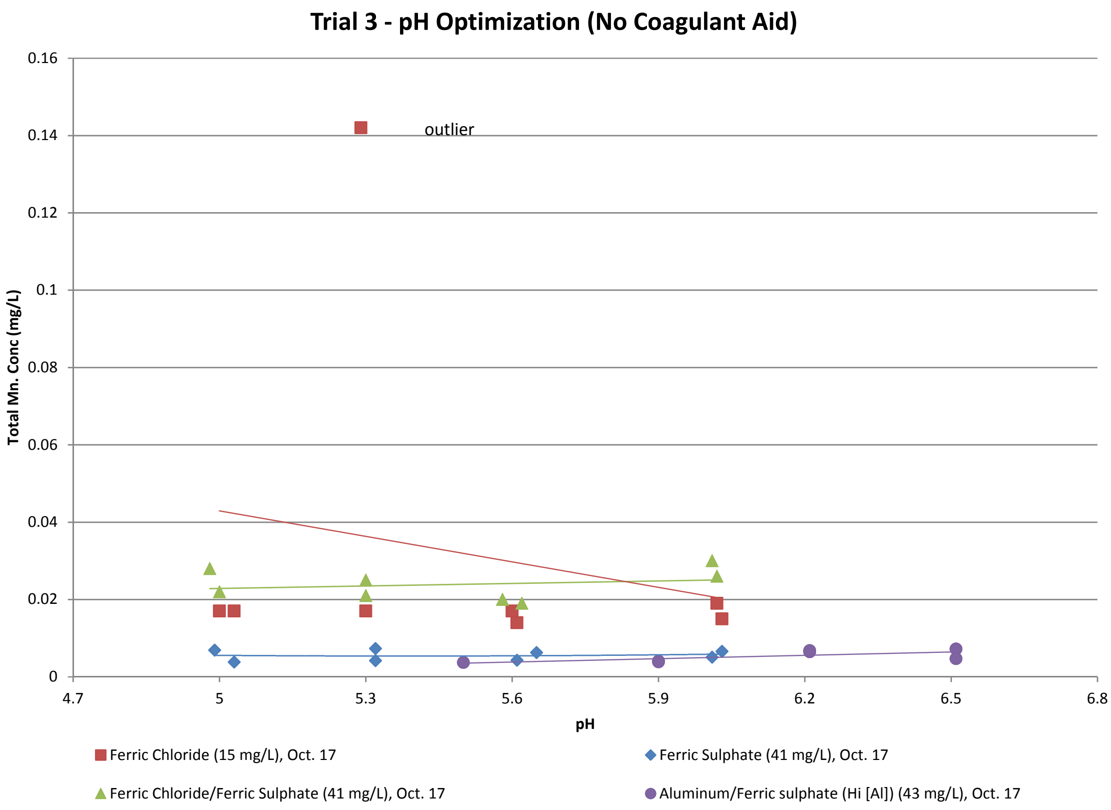

Trial 3 - pH Optimization (No Coagulant Aid)
Hach Mn. Conc (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
4.7
5
5.3
5.6
5.9
6.2
6.5
6.8
pH
■ Ferric Chloride (15 mg/L), Oct. 17
◆ Ferric Sulphate (41 mg/L), Oct. 17
▲ Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
● Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17

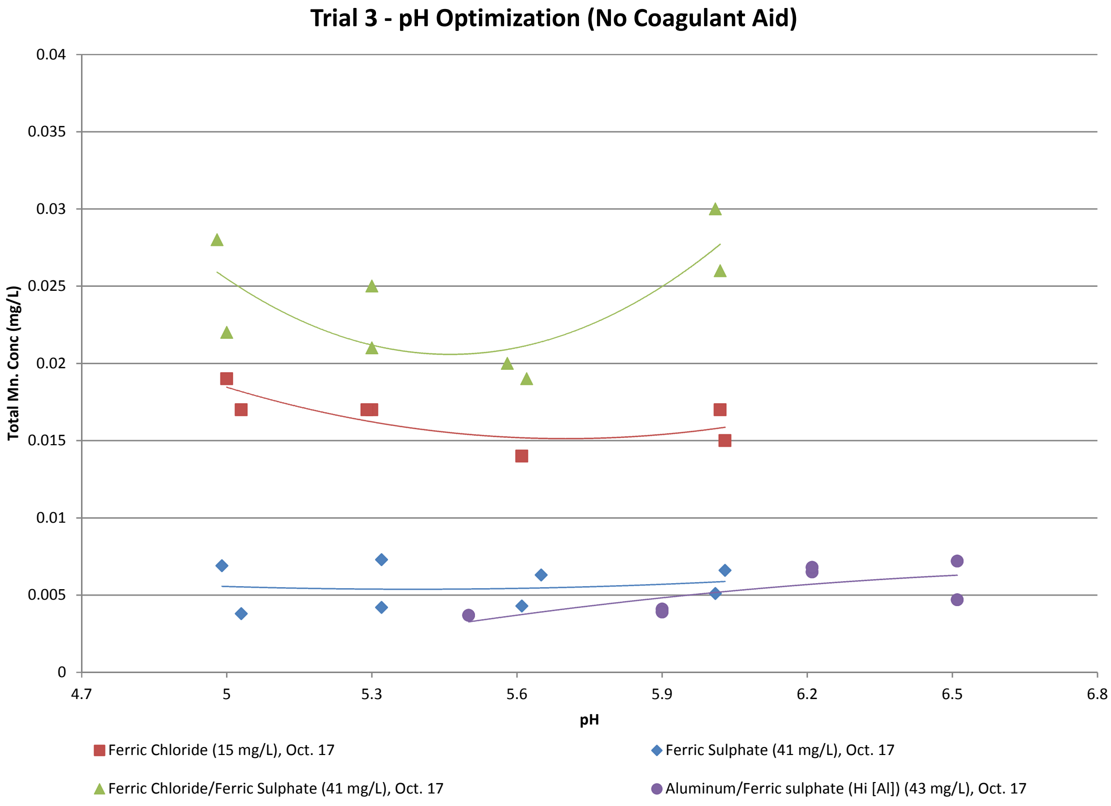

Trial 3 - pH Optimization (No Coagulant Aid)
Hach Mn. Conc (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
4.7
5
5.3
5.6
5.9
6.2
6.5
6.8
pH
■ Ferric Chloride (15 mg/L), Oct. 17
◆ Ferric Sulphate (41 mg/L), Oct. 17
▲ Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
● Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17

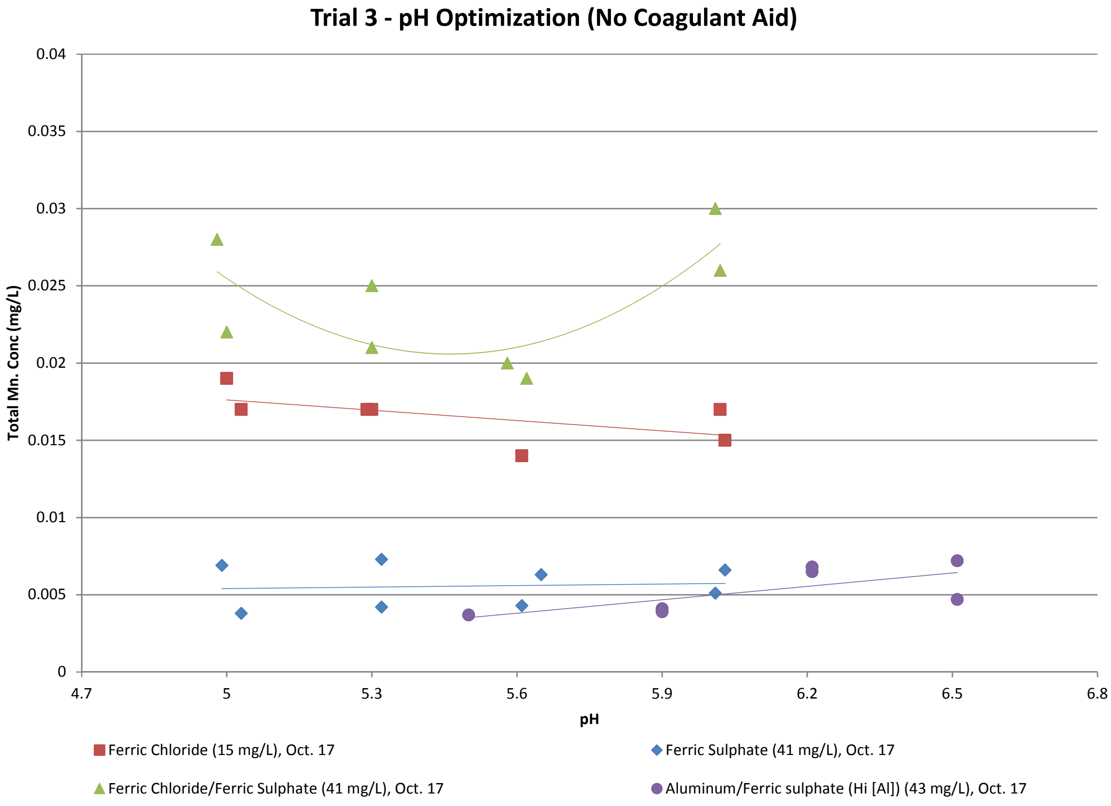

Trial 3 - pH Optimization (No Coagulant Aid)
Turbidity (NTU)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
4.7
5
5.3
5.6
5.9
6.2
6.5
6.8
pH
■ Ferric Chloride (15 mg/L), Oct. 17
◆ Ferric Sulphate (41 mg/L), Oct. 17
▲ Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
● Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17

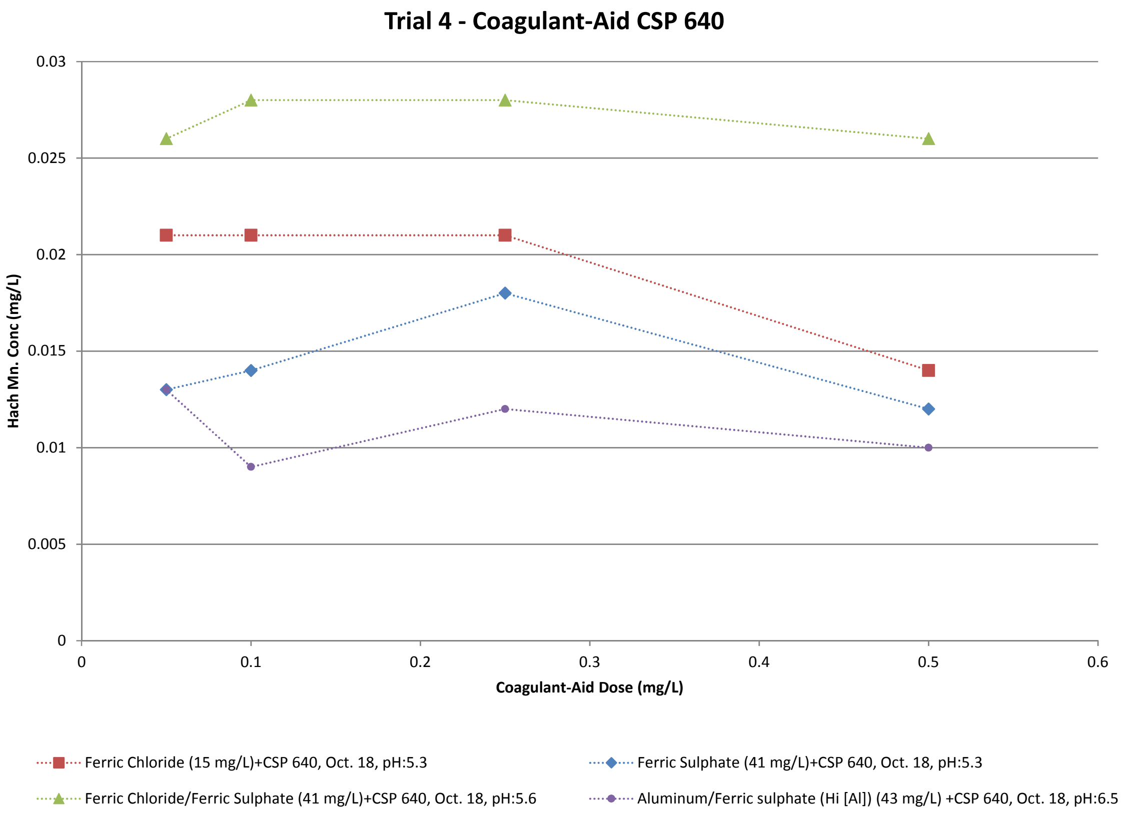

Trial 3 - pH Optimization (No Coagulant Aid)
UV Transmittance (%)
100
90
80
70
60
50
40
30
20
10
0
4.7
5
5.3
5.6
5.9
6.2
6.5
6.8
pH
■ Ferric Chloride (15 mg/L), Oct. 17
◆ Ferric Sulphate (41 mg/L), Oct. 17
▲ Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
● Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17

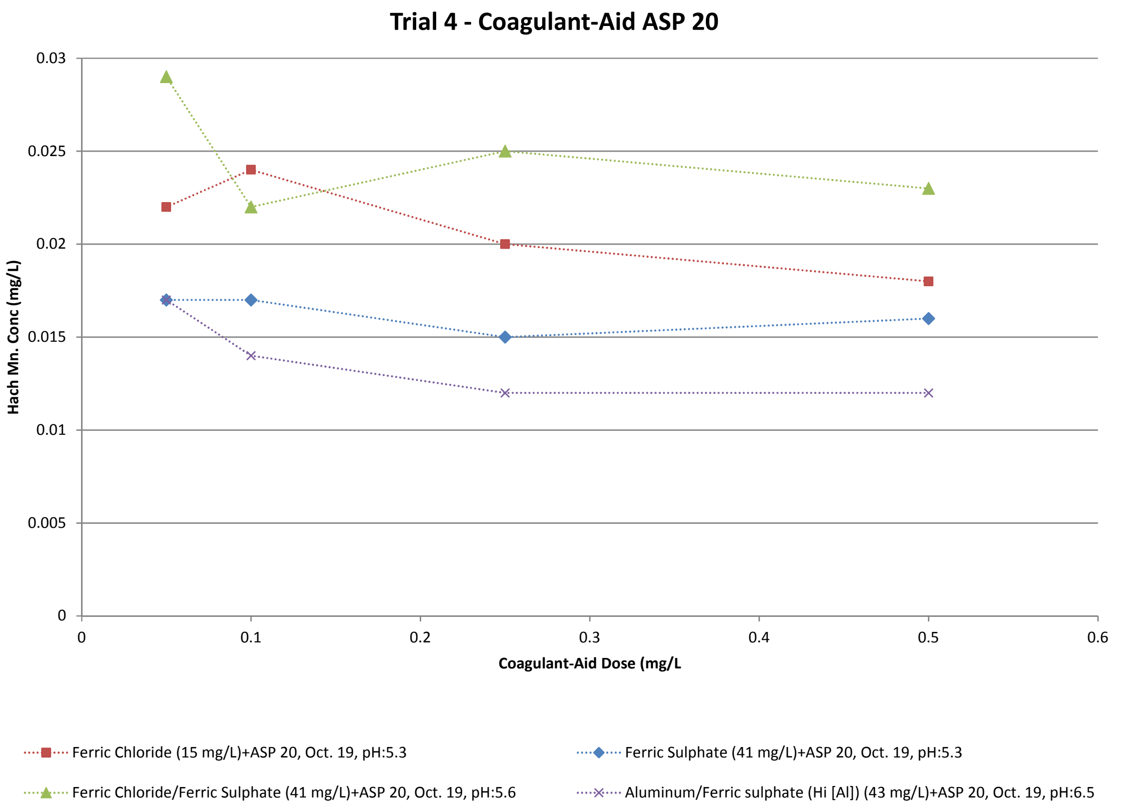

Trial 3 - pH Optimization (No Coagulant Aid)
TOC (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
4.7
5
5.3
5.6
5.9
6.2
6.5
6.8
pH
Ferric Chloride (15 mg/L), Oct. 17
Ferric Sulphate (41 mg/L), Oct. 17
Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17


Trial 3 - pH Optimization (No Coagulant Aid)
Total Mn. Conc (mg/L)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
outlier
4.7
5
5.3
5.6
5.9
6.2
6.5
6.8
pH
Ferric Chloride (15 mg/L), Oct. 17
Ferric Sulphate (41 mg/L), Oct. 17
Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17

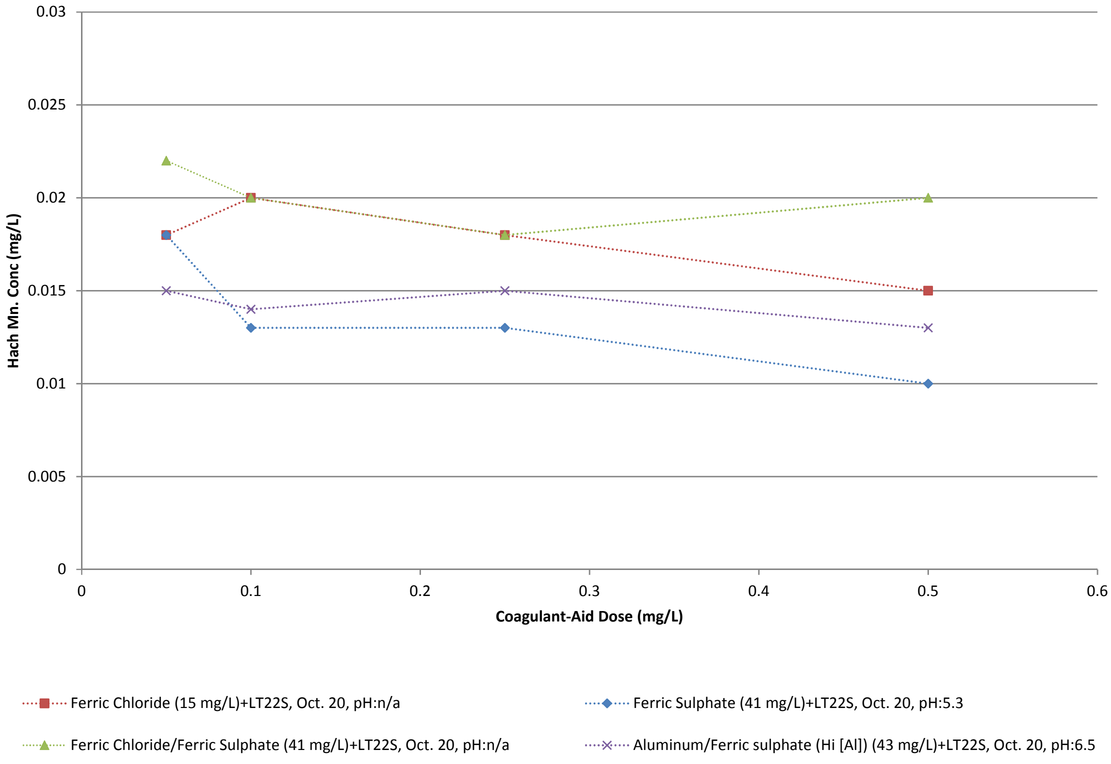

Trial 3 - pH Optimization (No Coagulant Aid)
Total Mn. Conc (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
4.7
5
5.3
5.6
5.9
6.2
6.5
6.8
pH
■ Ferric Chloride (15 mg/L), Oct. 17
◆ Ferric Sulphate (41 mg/L), Oct. 17
▲ Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
● Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17


Trial 3 - pH Optimization (No Coagulant Aid)
Total Mn. Conc (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
4.7
5
5.3
5.6
5.9
6.2
6.5
6.8
pH
■ Ferric Chloride (15 mg/L), Oct. 17
◆ Ferric Sulphate (41 mg/L), Oct. 17
▲ Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
● Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17

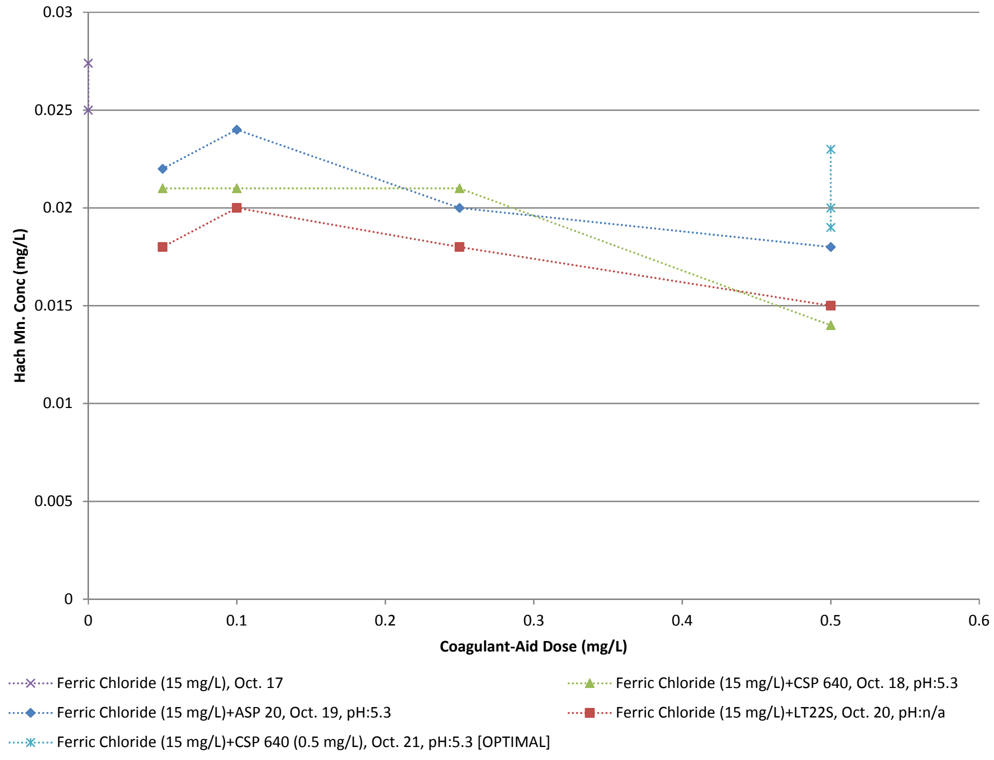

Trial 4 - Coagulant-Aid CSP 640
Hach Mn. Conc (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Chloride/Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.6
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5

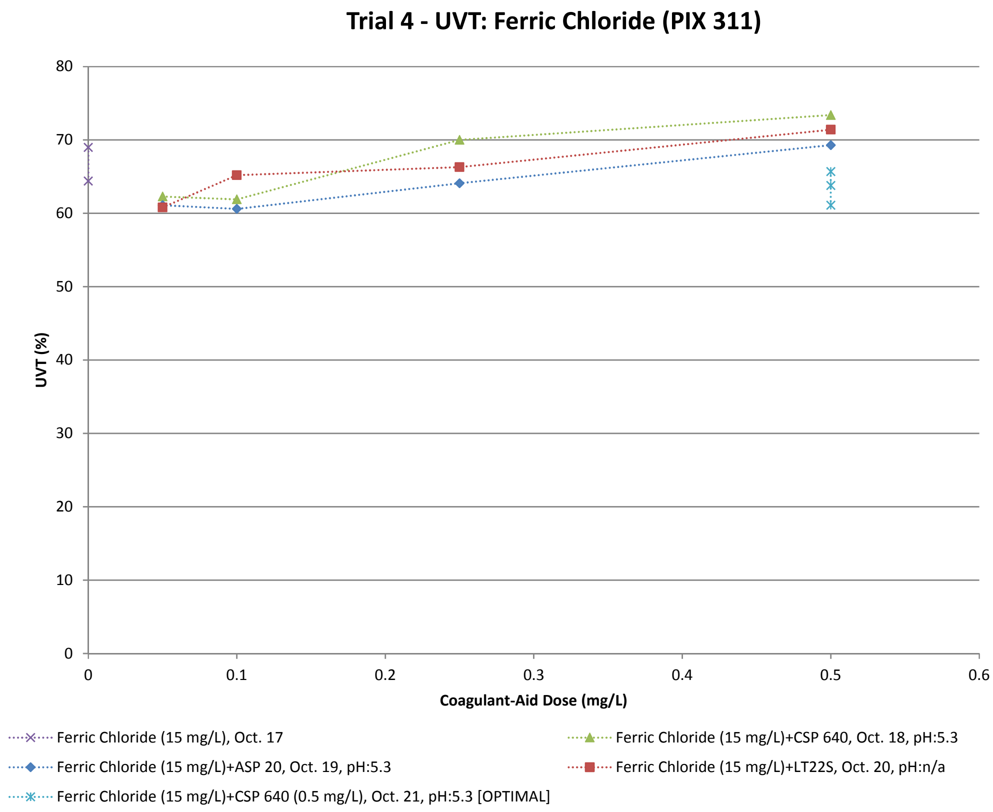

Trial 4 - Coagulant-Aid ASP 20
Hach Mn. Conc (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L
Ferric Chloride (15 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Chloride/Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.6
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+ASP 20, Oct. 19, pH:6.5

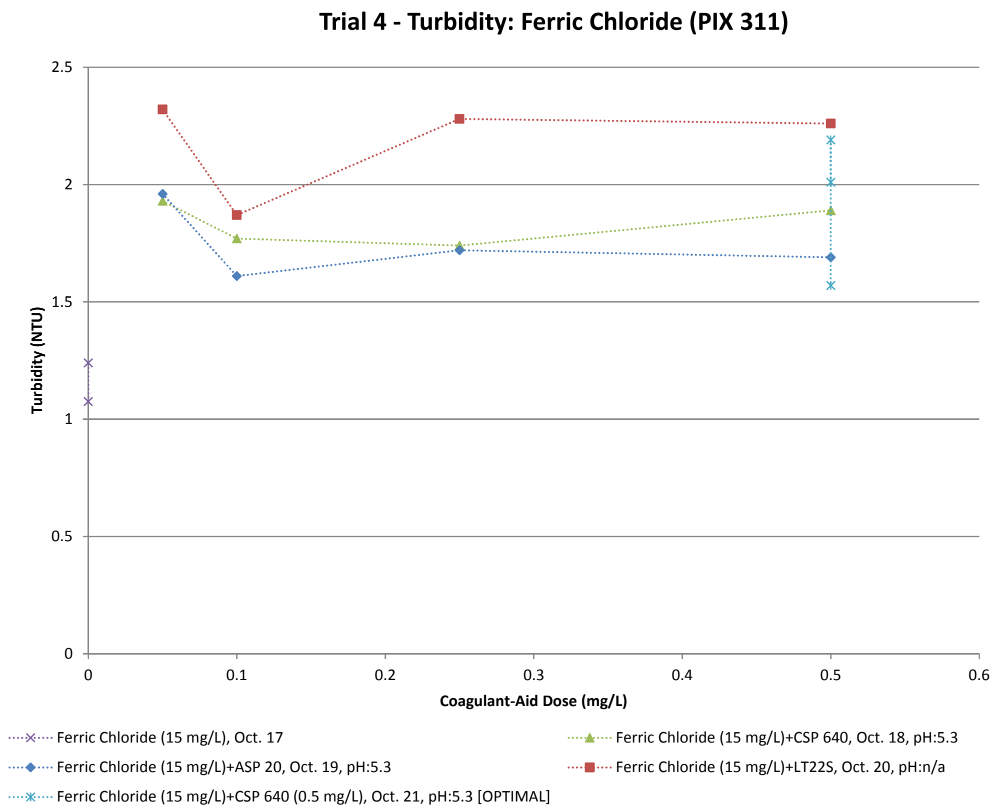
Trial 4 - Coagulant-Aid LT22S

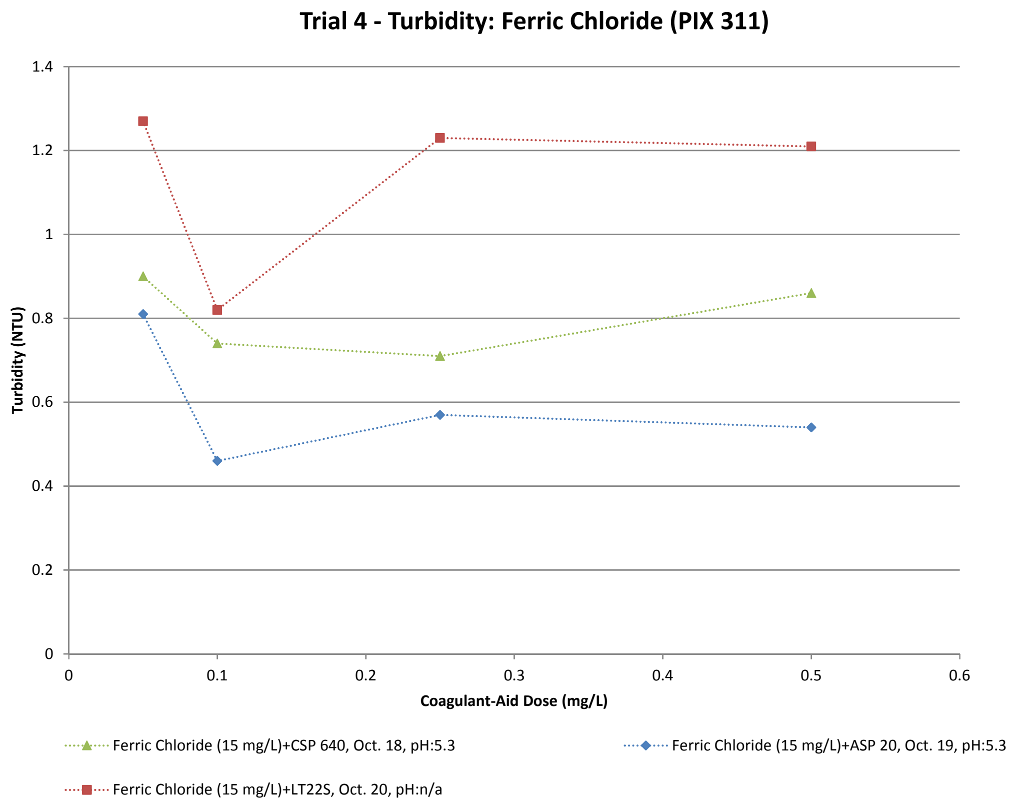


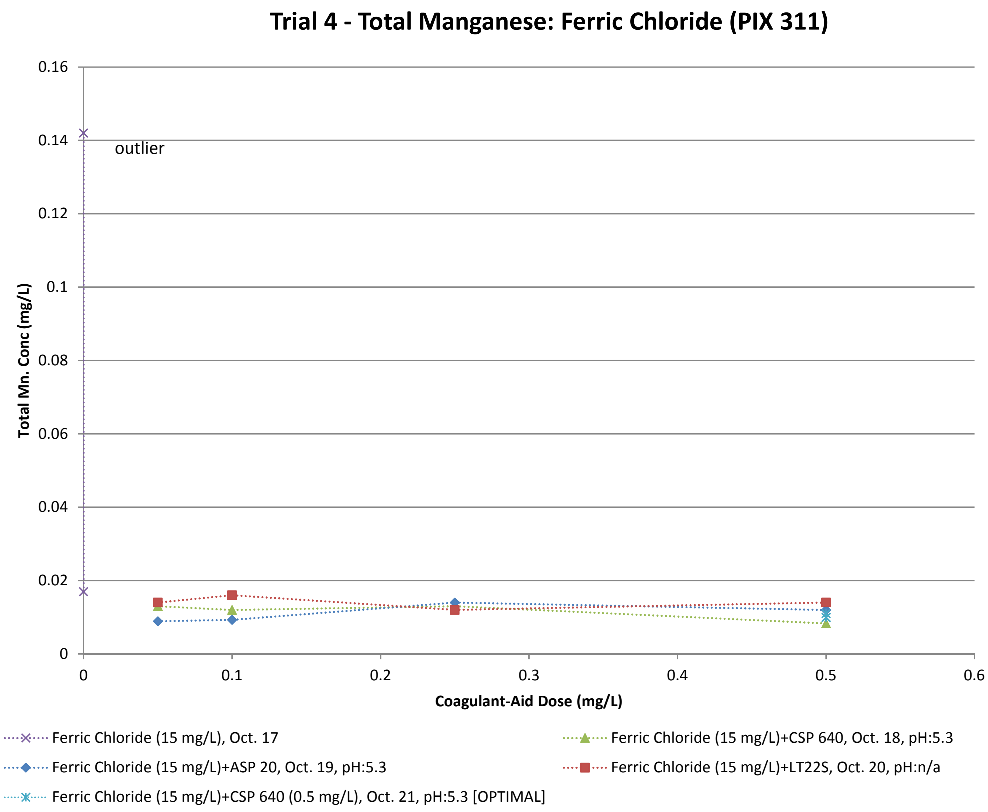
Trial 4 - Hach Manganese: Ferric Chloride (PIX 311)

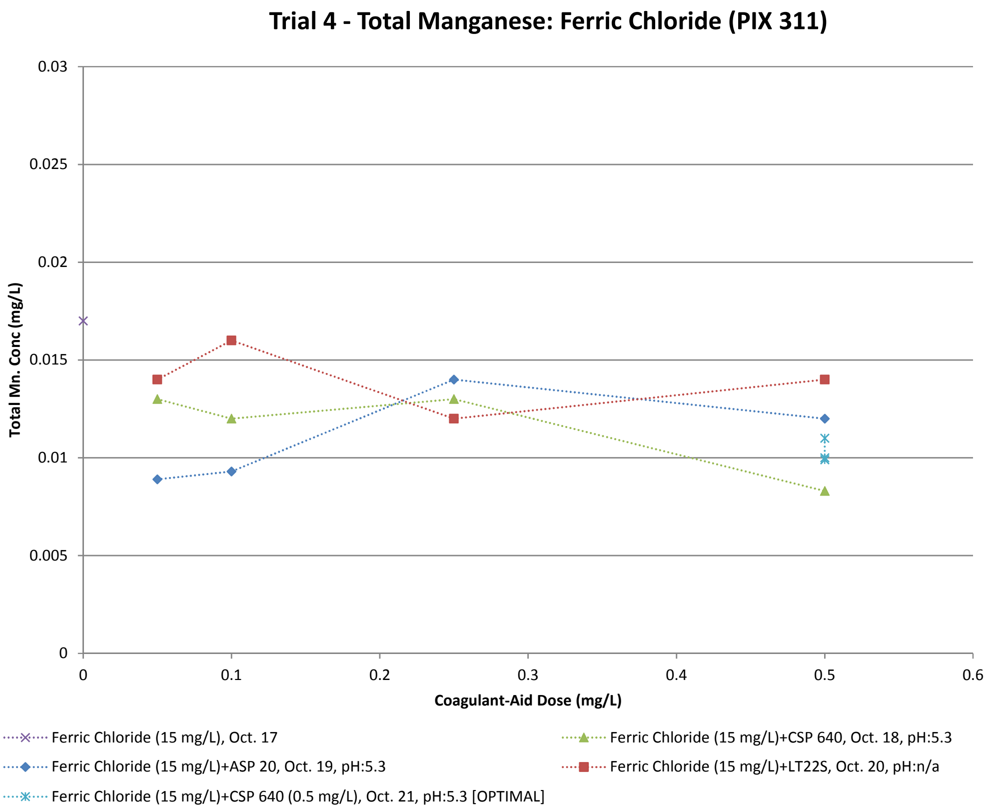


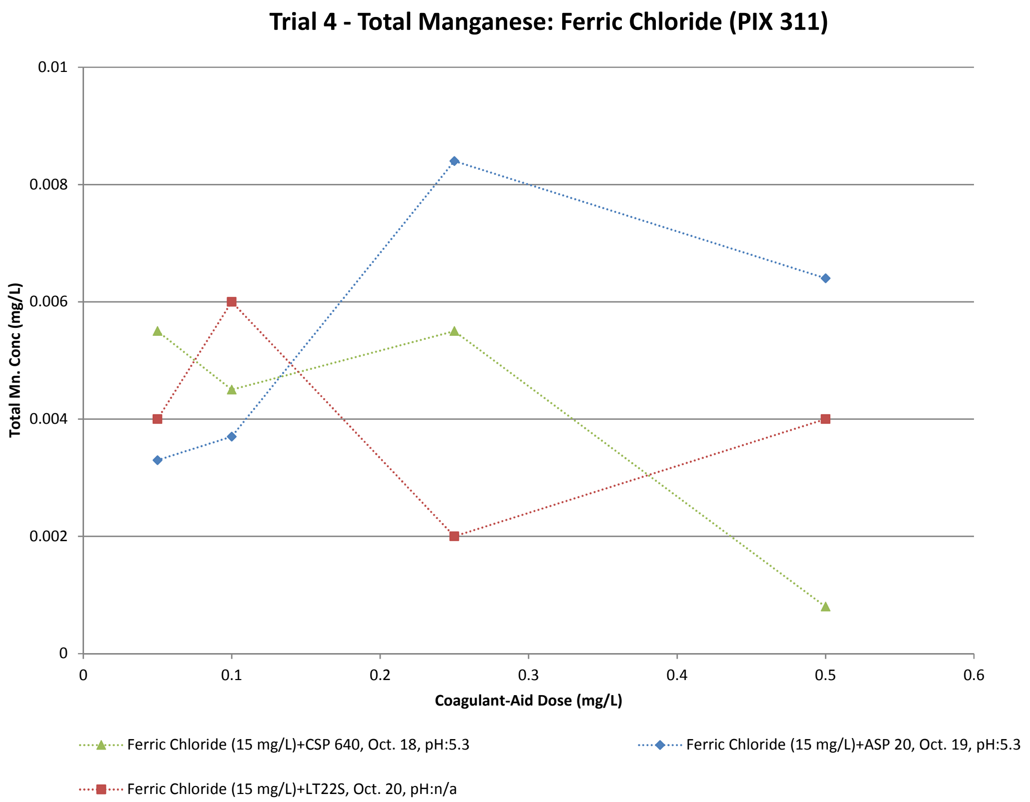

Trial 4 - UVT: Ferric Chloride (PIX 311)
UVT (%)
80
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L), Oct. 17
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Chloride (15 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Chloride (15 mg/L)+LT22S, Oct. 20, pH:n/a
Ferric Chloride (15 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:5.3 [OPTIMAL]

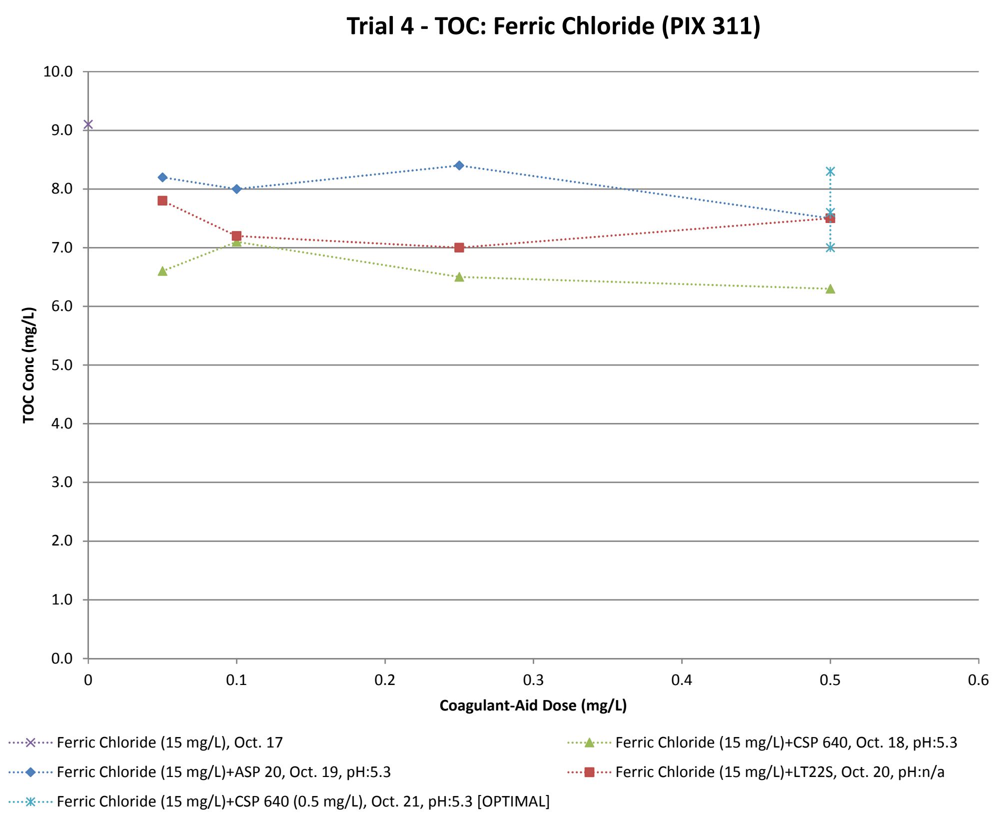

Trial 4 - Turbidity: Ferric Chloride (PIX 311)
Turbidity (NTU)
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L), Oct. 17
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Chloride (15 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Chloride (15 mg/L)+LT22S, Oct. 20, pH:n/a
Ferric Chloride (15 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:5.3 [OPTIMAL]

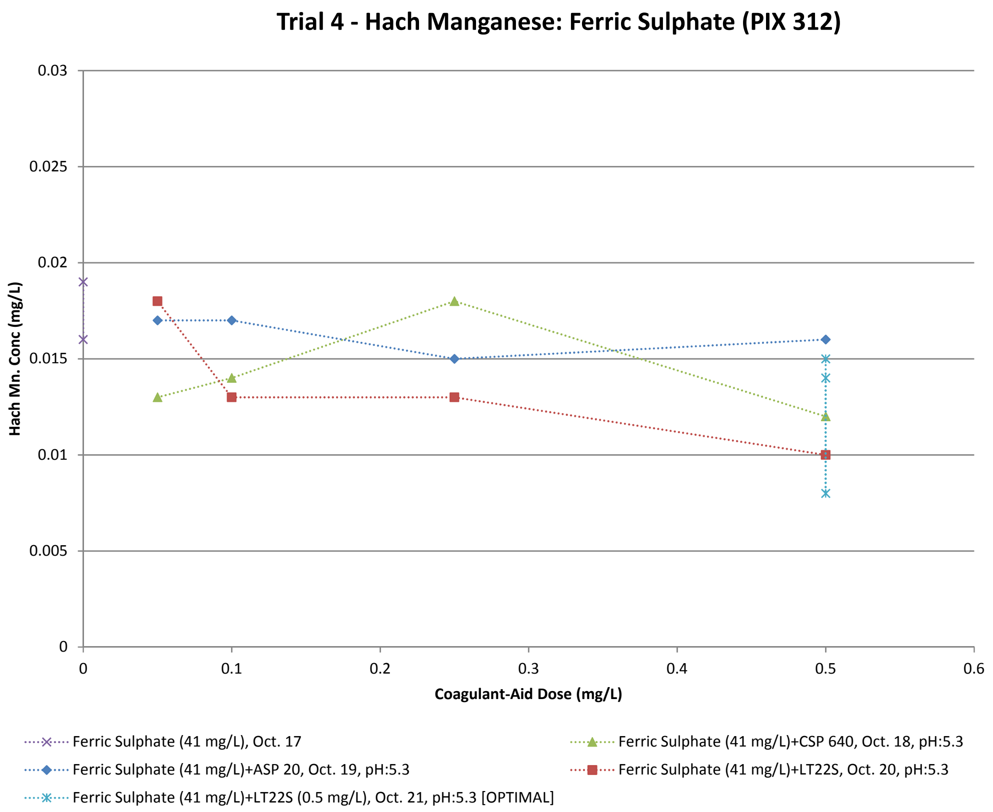

Trial 4 - Turbidity: Ferric Chloride (PIX 311)
Turbidity (NTU)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Chloride (15 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Chloride (15 mg/L)+LT22S, Oct. 20, pH:n/a

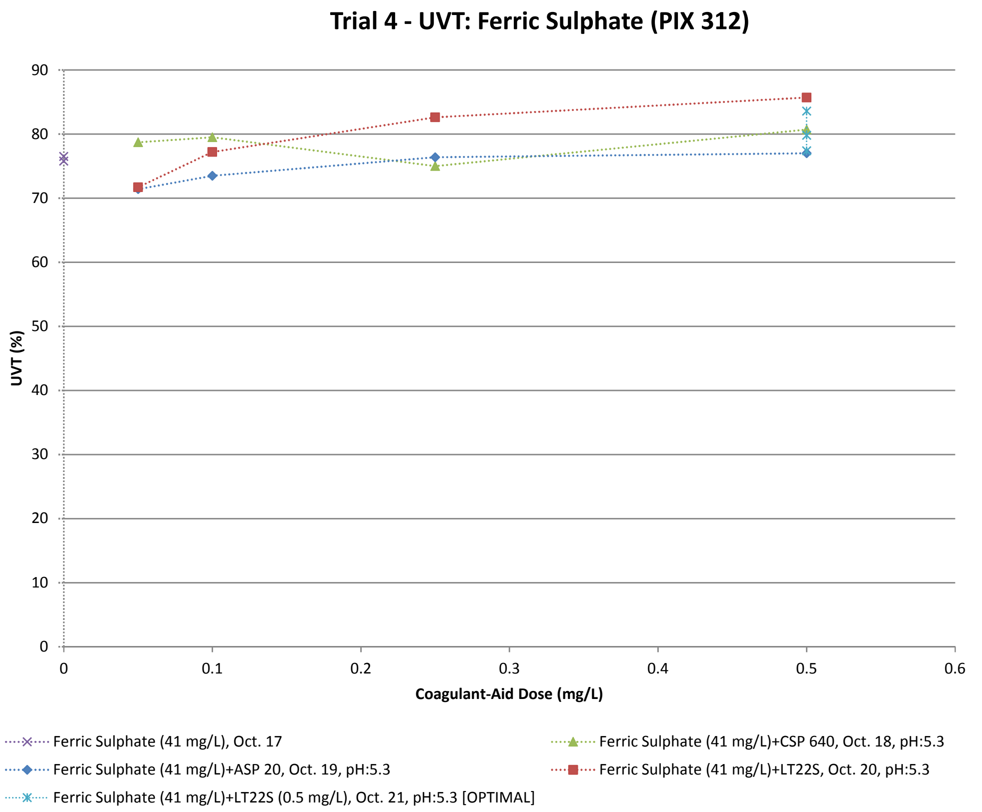

Trial 4 - Total Manganese: Ferric Chloride (PIX 311)
Total Mn. Conc (mg/L)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
outlier
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L), Oct. 17
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Chloride (15 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Chloride (15 mg/L)+LT22S, Oct. 20, pH:n/a
Ferric Chloride (15 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:5.3 [OPTIMAL]

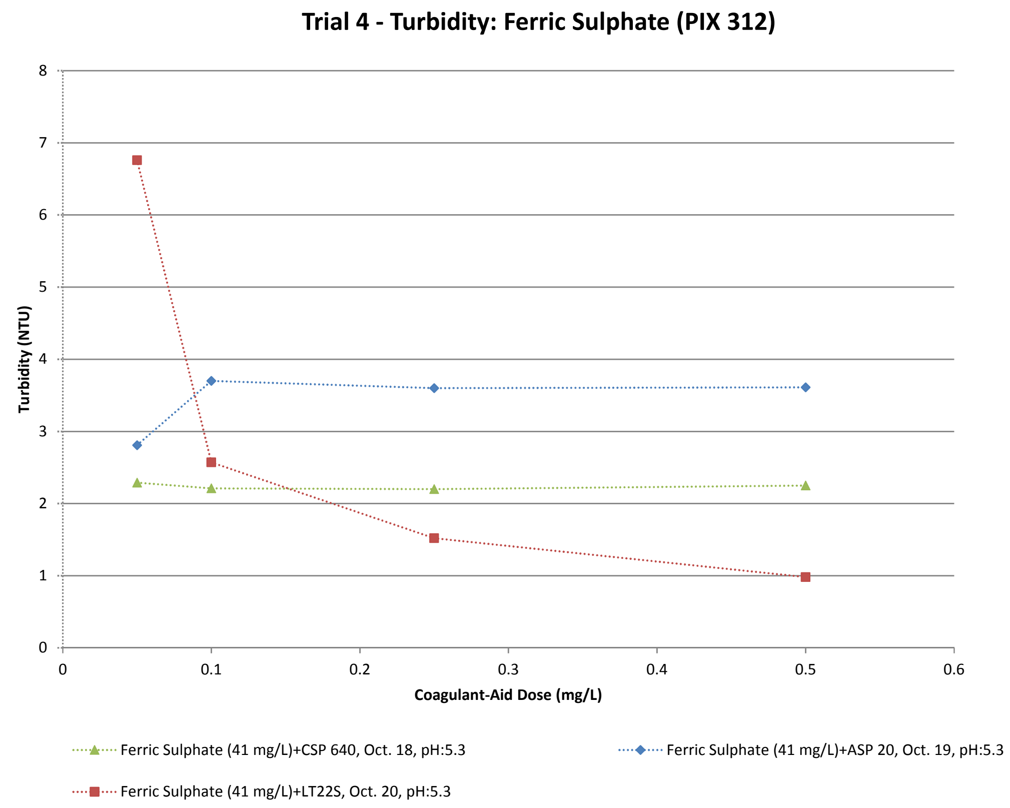

Trial 4 - Total Manganese: Ferric Chloride (PIX 311)
Total Mn. Conc (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L), Oct. 17
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Chloride (15 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Chloride (15 mg/L)+LT22S, Oct. 20, pH:n/a
Ferric Chloride (15 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:5.3 [OPTIMAL]

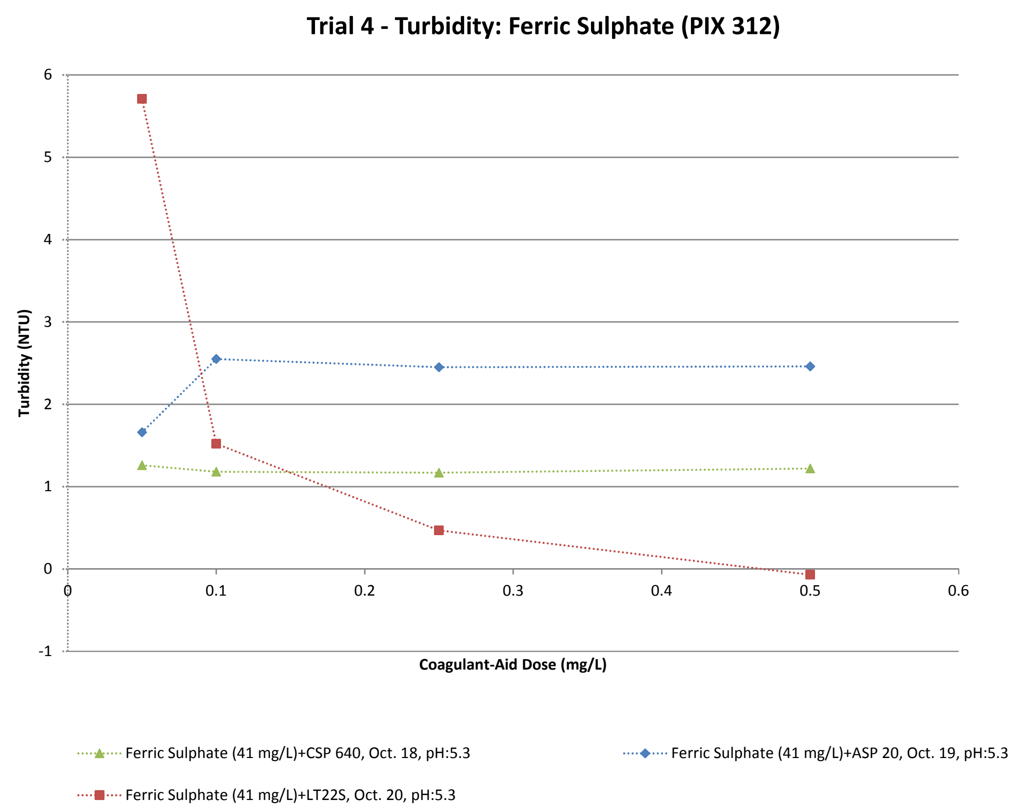

Trial 4 - Total Manganese: Ferric Chloride (PIX 311)
Total Mn. Conc (mg/L)
0.01
0.008
0.006
0.004
0.002
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Chloride (15 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Chloride (15 mg/L)+LT22S, Oct. 20, pH:n/a

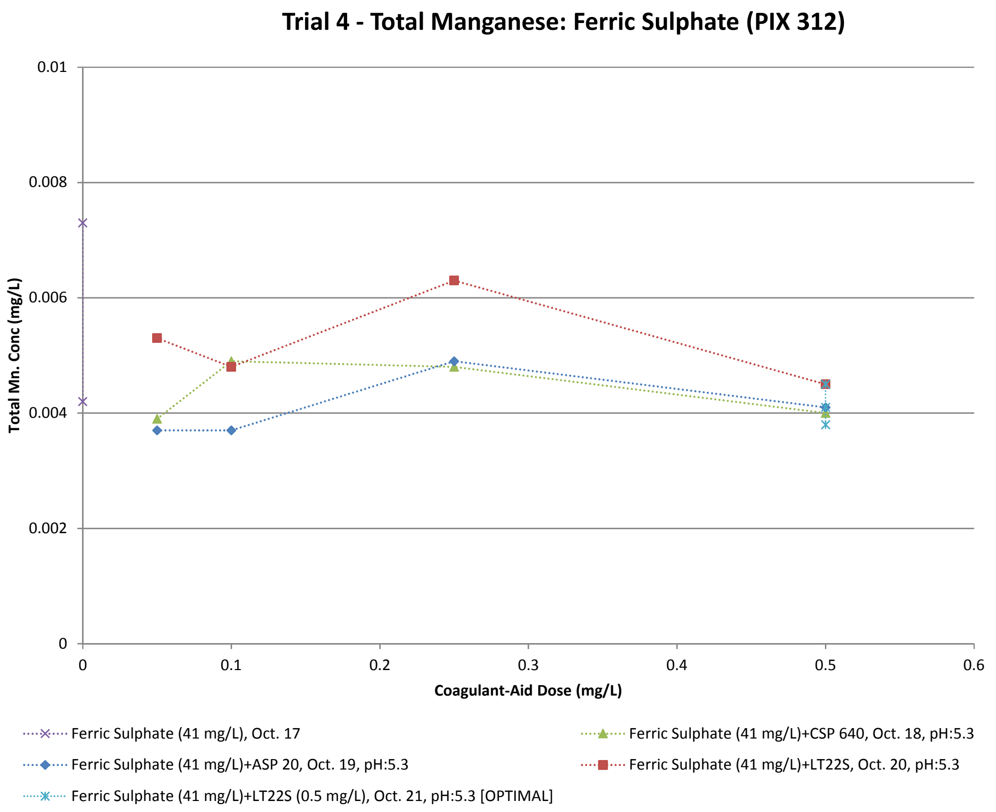

Trial 4 - TOC: Ferric Chloride (PIX 311)
TOC Conc (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L), Oct. 17
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Chloride (15 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Chloride (15 mg/L)+LT22S, Oct. 20, pH:n/a
Ferric Chloride (15 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:5.3 [OPTIMAL]

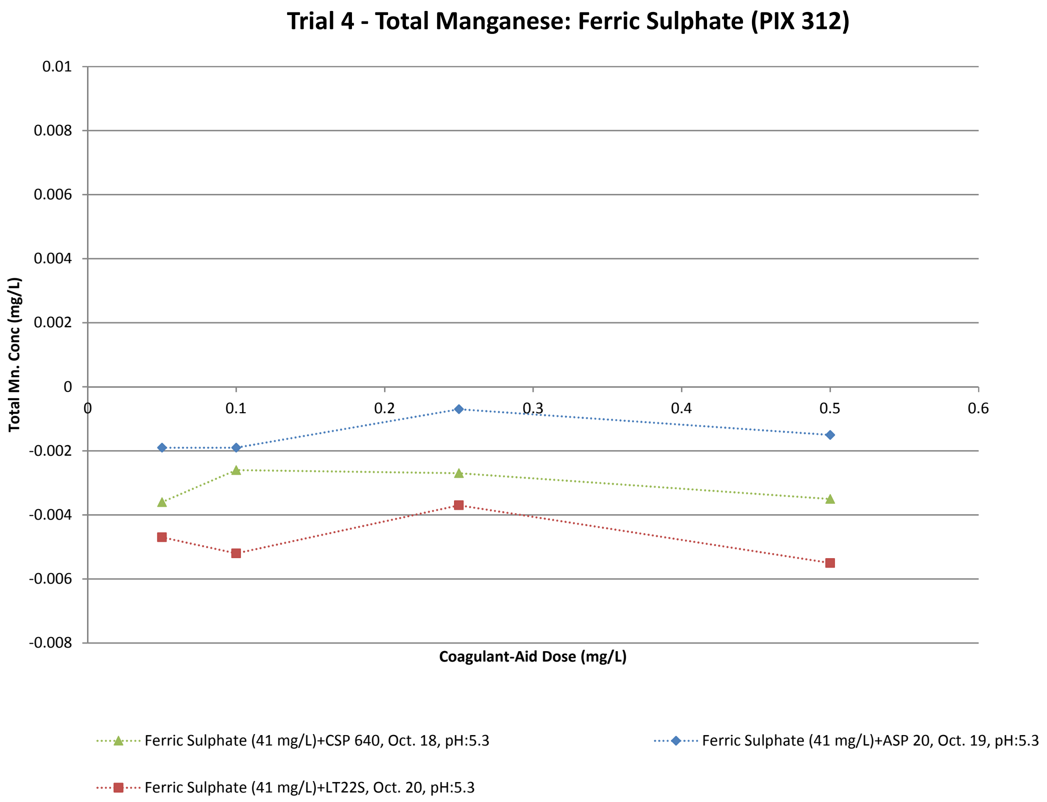

Trial 4 - Hach Manganese: Ferric Sulphate (PIX 312)
Hach Mn. Conc (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Sulphate (41 mg/L), Oct. 17
Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S (0.5 mg/L), Oct. 21, pH:5.3 [OPTIMAL]

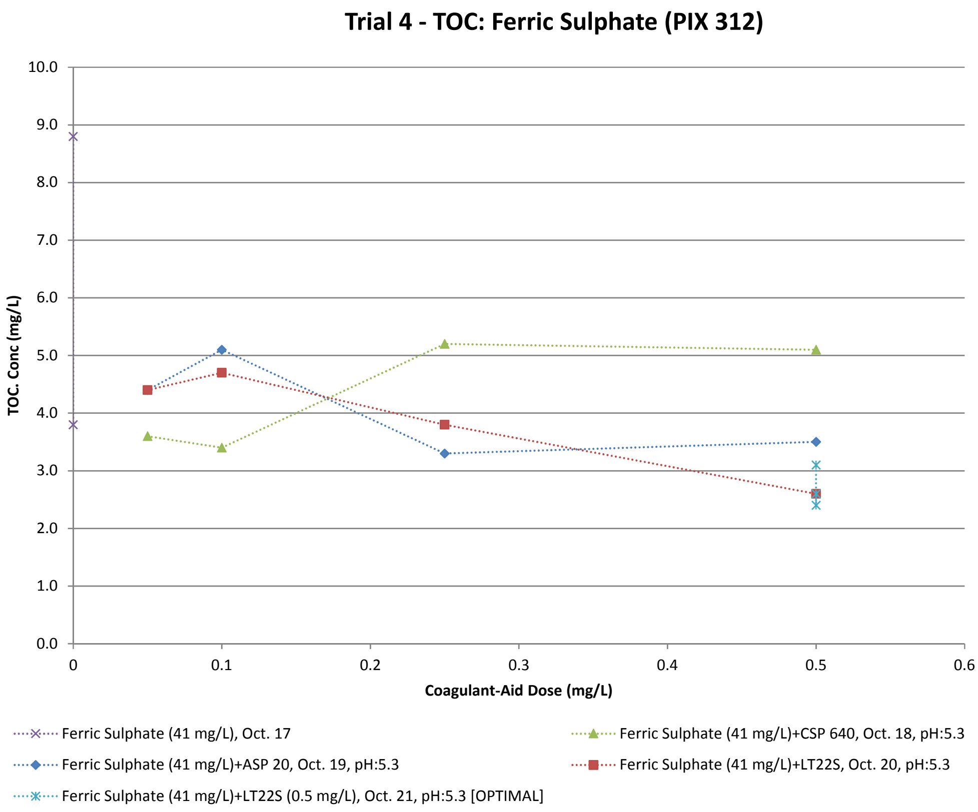

Trial 4 - UVT: Ferric Sulphate (PIX 312)
UVT (%)
0
10
20
30
40
50
60
70
80
90
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Sulphate (41 mg/L), Oct. 17
Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S (0.5 mg/L), Oct. 21, pH:5.3 [OPTIMAL]

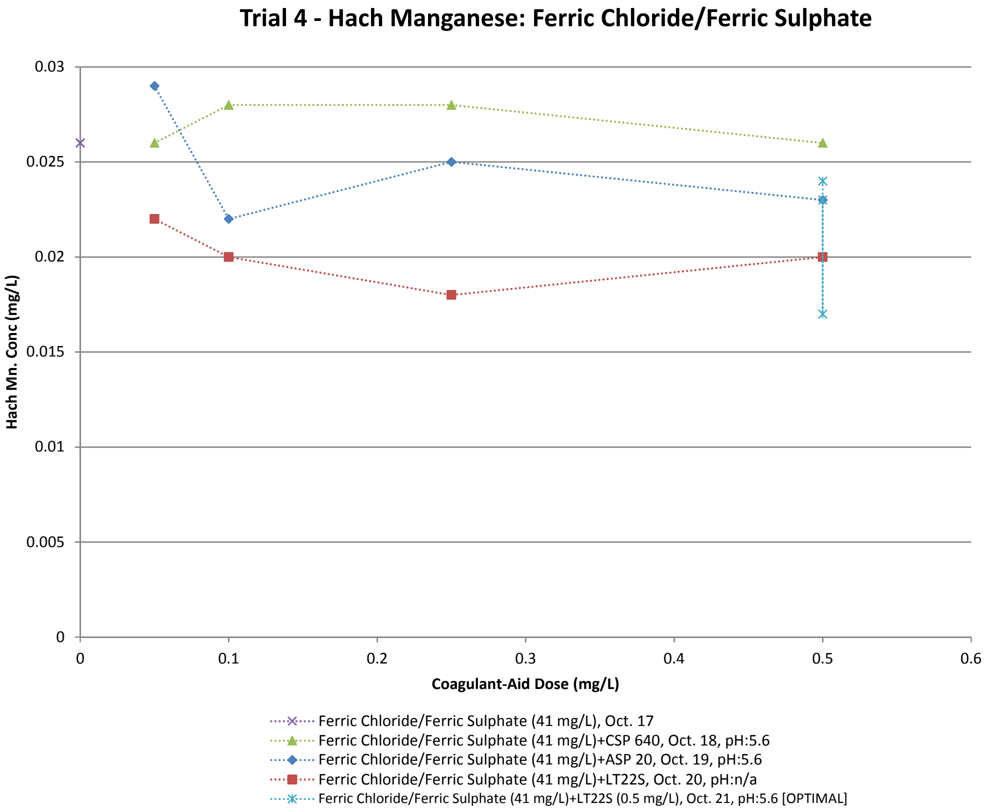

Trial 4 - Turbidity: Ferric Sulphate (PIX 312)
Turbidity (NTU)
0
1
2
3
4
5
6
7
8
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3

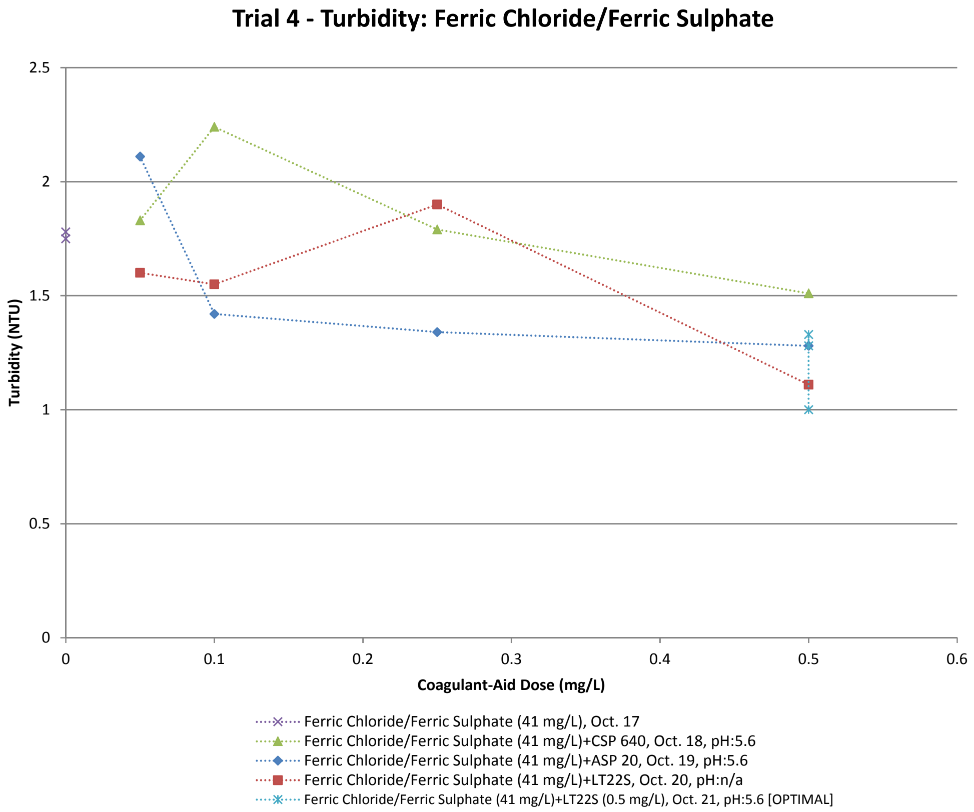

Trial 4 - Turbidity: Ferric Sulphate (PIX 312)

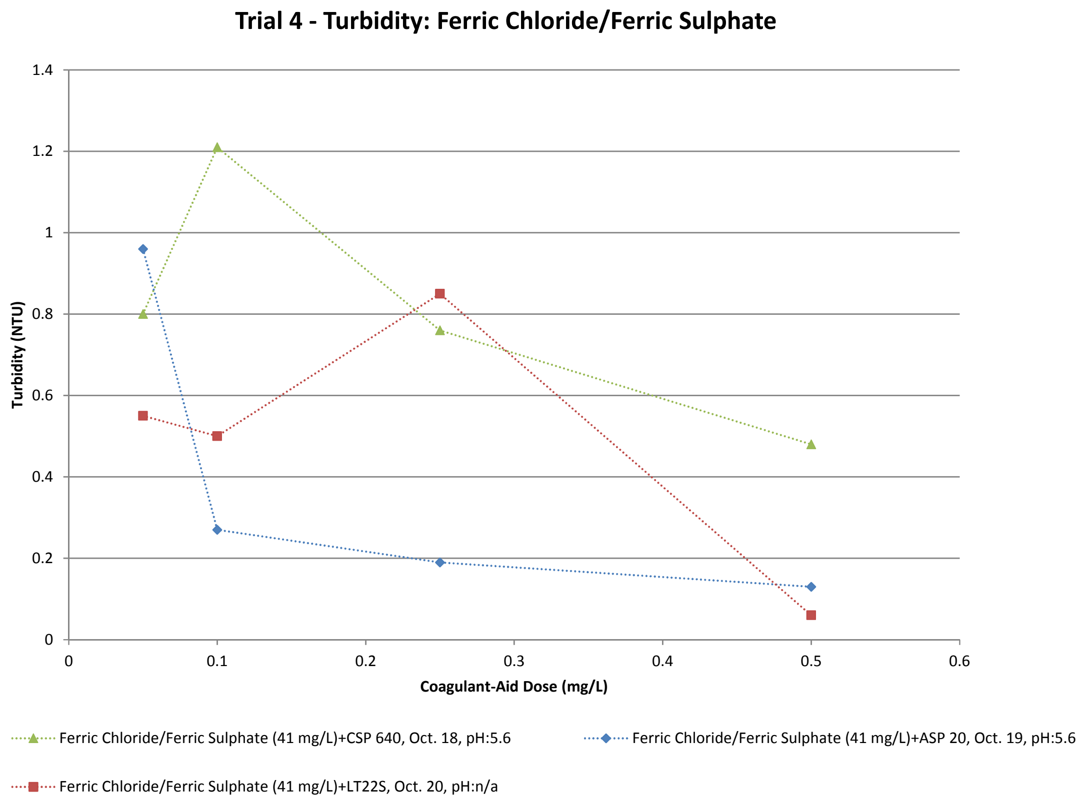

Trial 4 - Total Manganese: Ferric Sulphate (PIX 312)

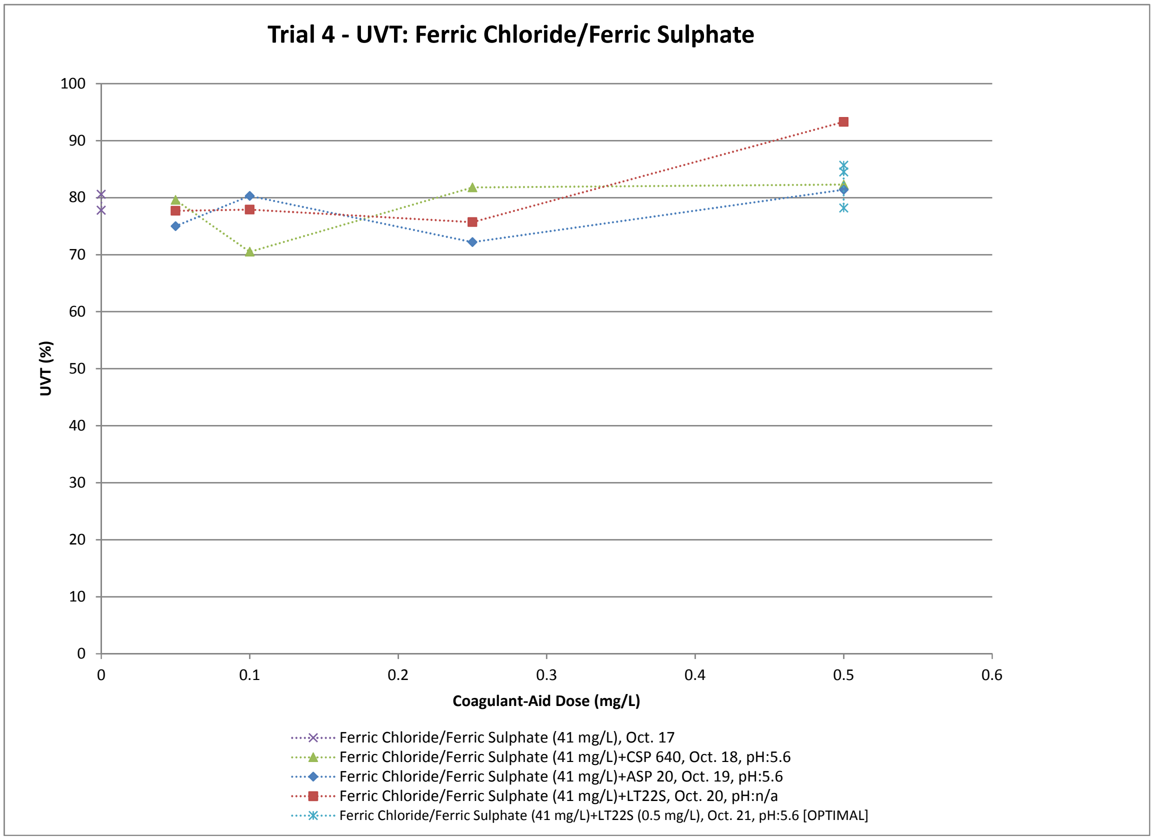

Trial 4 - Total Manganese: Ferric Sulphate (PIX 312)
Total Mn. Conc (mg/L)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3

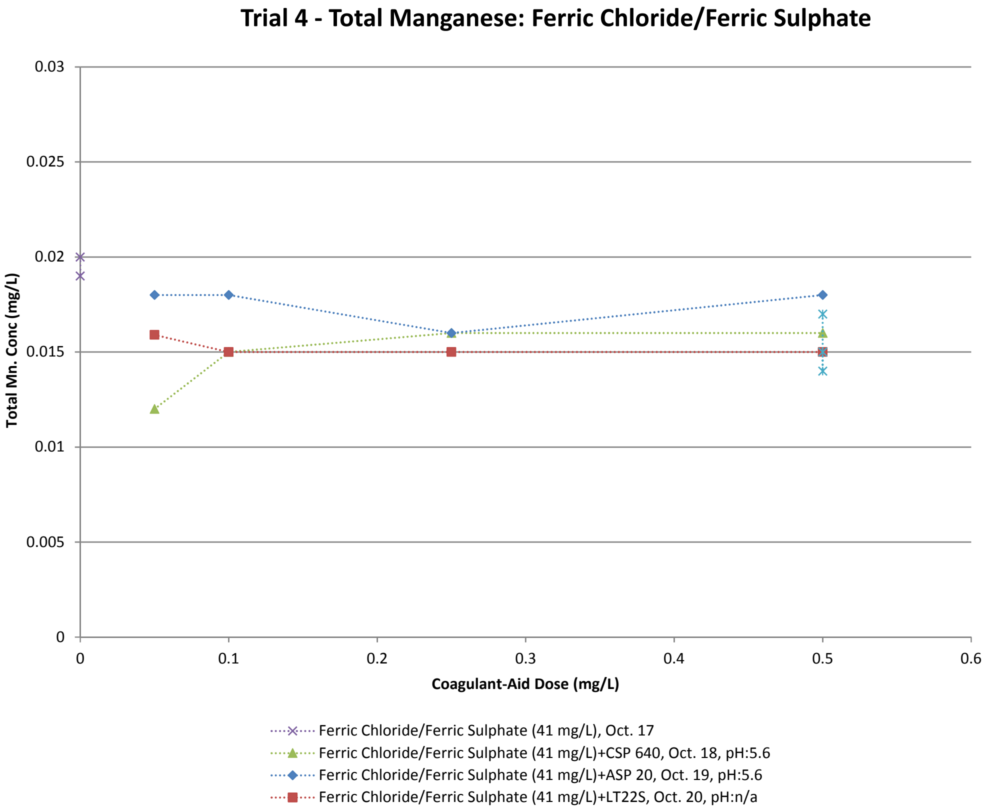

Trial 4 - TOC: Ferric Sulphate (PIX 312)
TOC. Conc (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Sulphate (41 mg/L), Oct. 17
Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S (0.5 mg/L), Oct. 21, pH:5.3 [OPTIMAL]

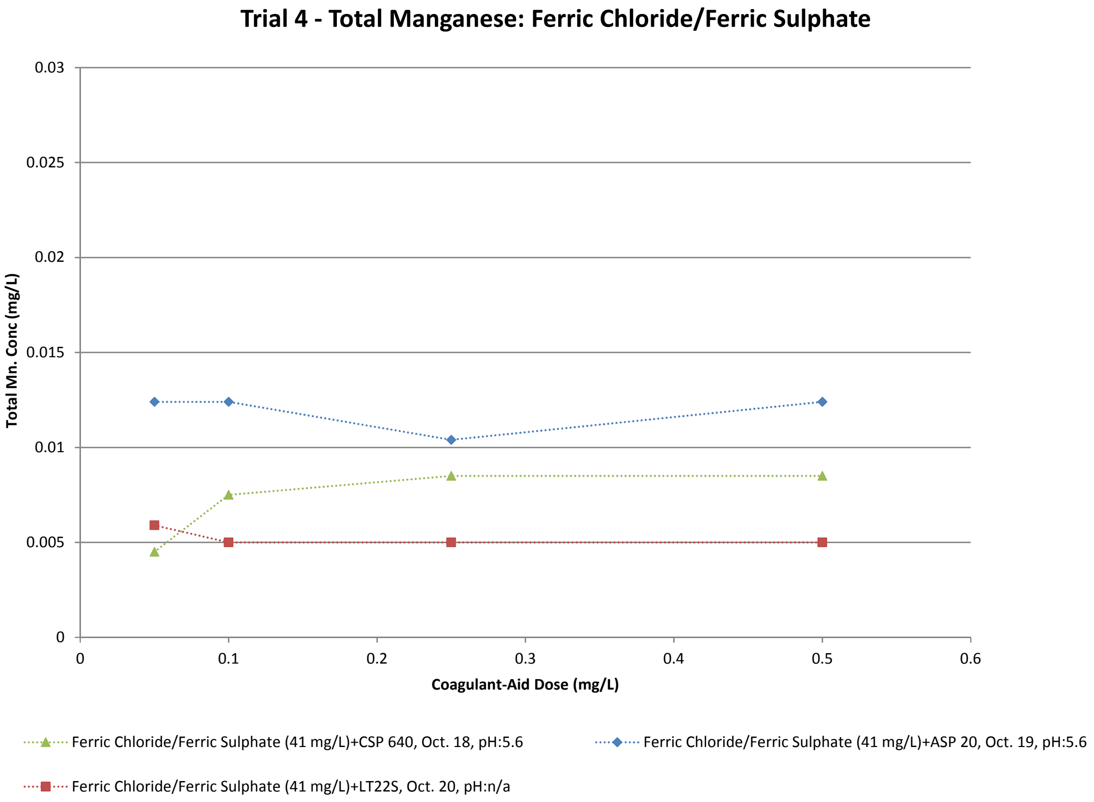

Trial 4 - Hach Manganese: Ferric Chloride/Ferric Sulphate
Hach Mn. Conc (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
Ferric Chloride/Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.6
Ferric Chloride/Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.6
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S (0.5 mg/L), Oct. 21, pH:5.6 [OPTIMAL]


Trial 4 - Turbidity: Ferric Chloride/Ferric Sulphate
Turbidity (NTU)
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
Ferric Chloride/Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.6
Ferric Chloride/Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.6
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S (0.5 mg/L), Oct. 21, pH:5.6 [OPTIMAL]

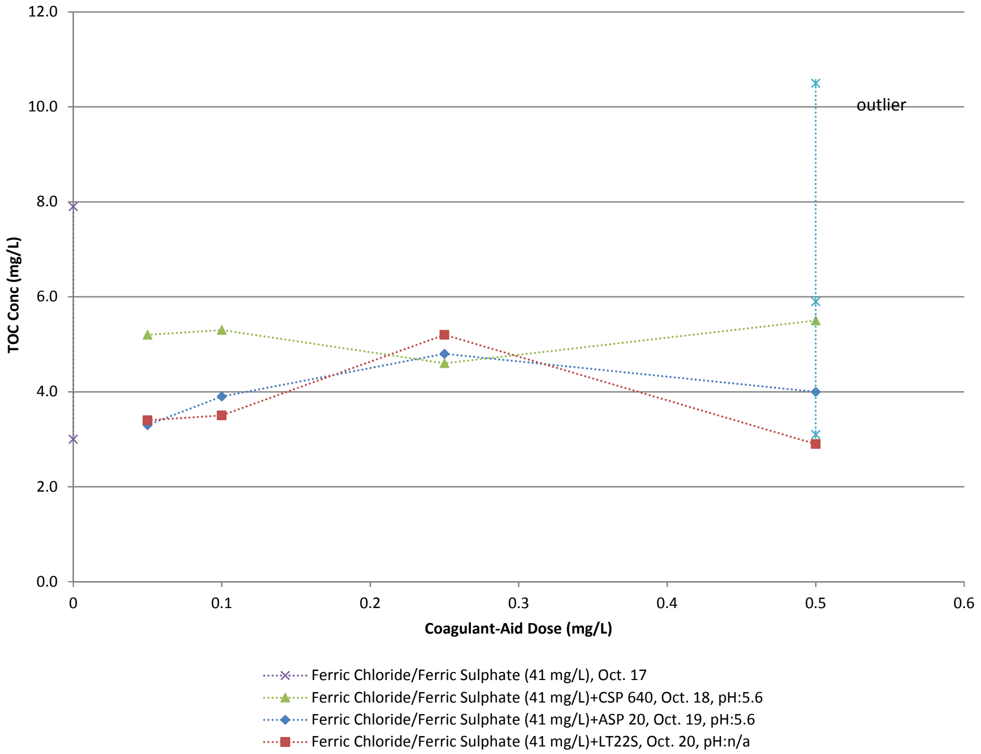

Trial 4 - Turbidity: Ferric Chloride/Ferric Sulphate


Trial 4 - UVT: Ferric Chloride/Ferric Sulphate

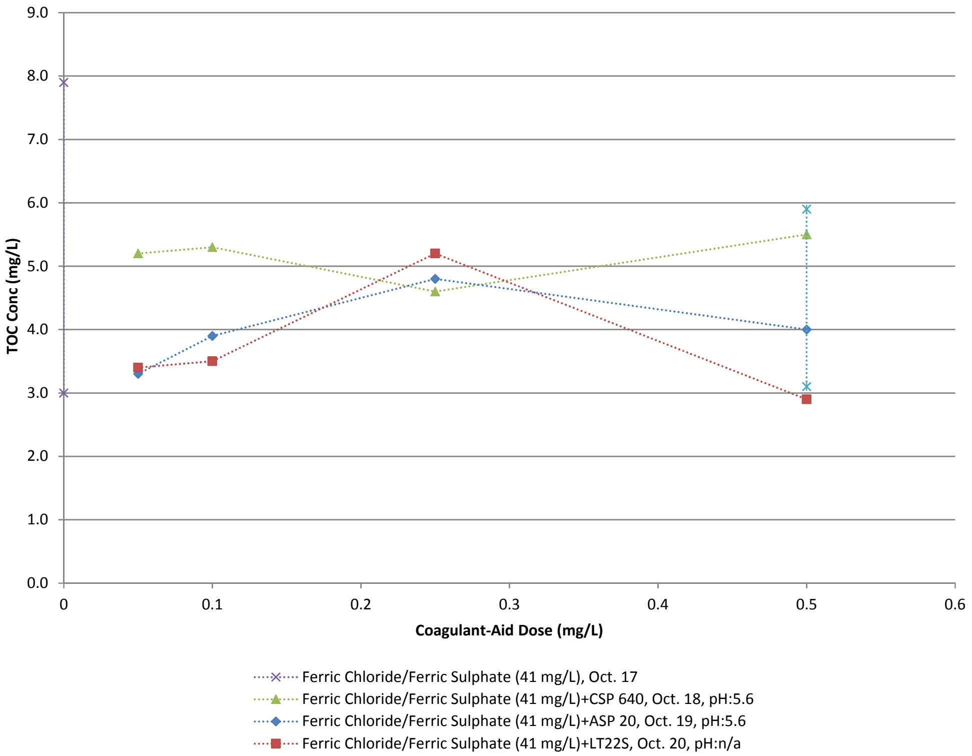

Trial 4 - Total Manganese: Ferric Chloride/Ferric Sulphate
Total Mn. Conc (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L), Oct. 17
Ferric Chloride/Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.6
Ferric Chloride/Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.6
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a

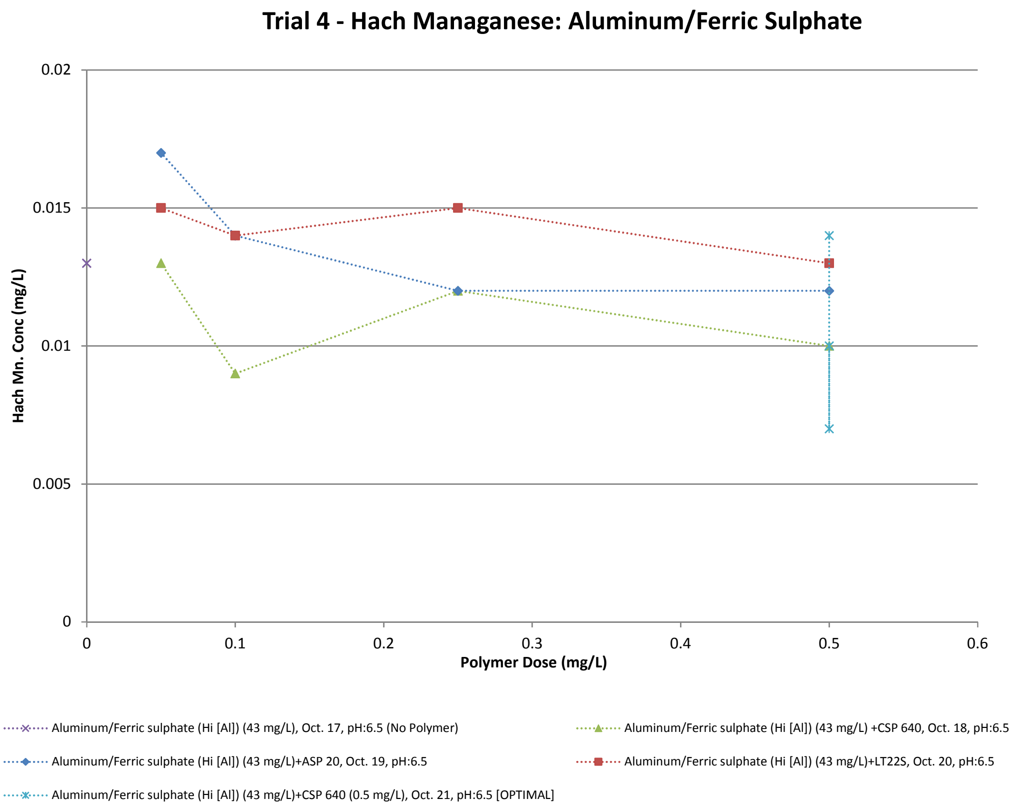

Trial 4 - Total Manganese: Ferric Chloride/Ferric Sulphate
Total Mn. Conc (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L)+CSP 640, Oct. 18, pH:5.6
Ferric Chloride/Ferric Sulphate (41 mg/L)+ASP 20, Oct. 19, pH:5.6
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a

Trial 4 - TOC: Ferric Chloride/Ferric Sulphate

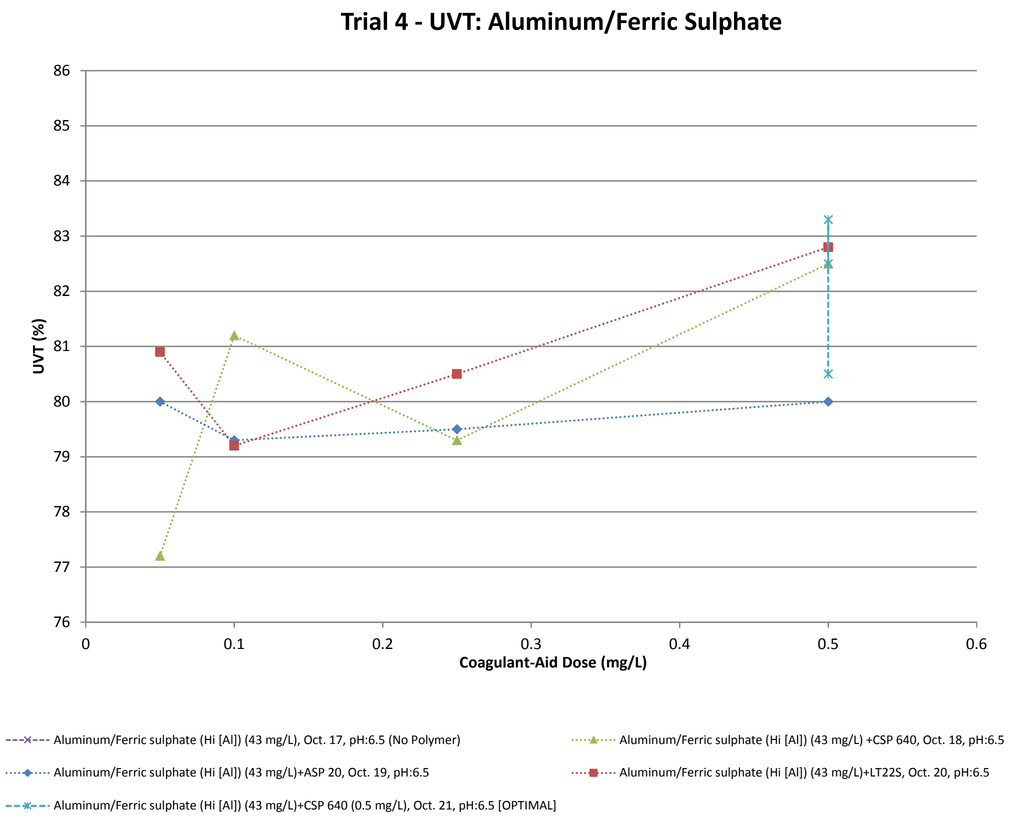


Trial 4 - TOC: Ferric Chloride/Ferric Sulphate



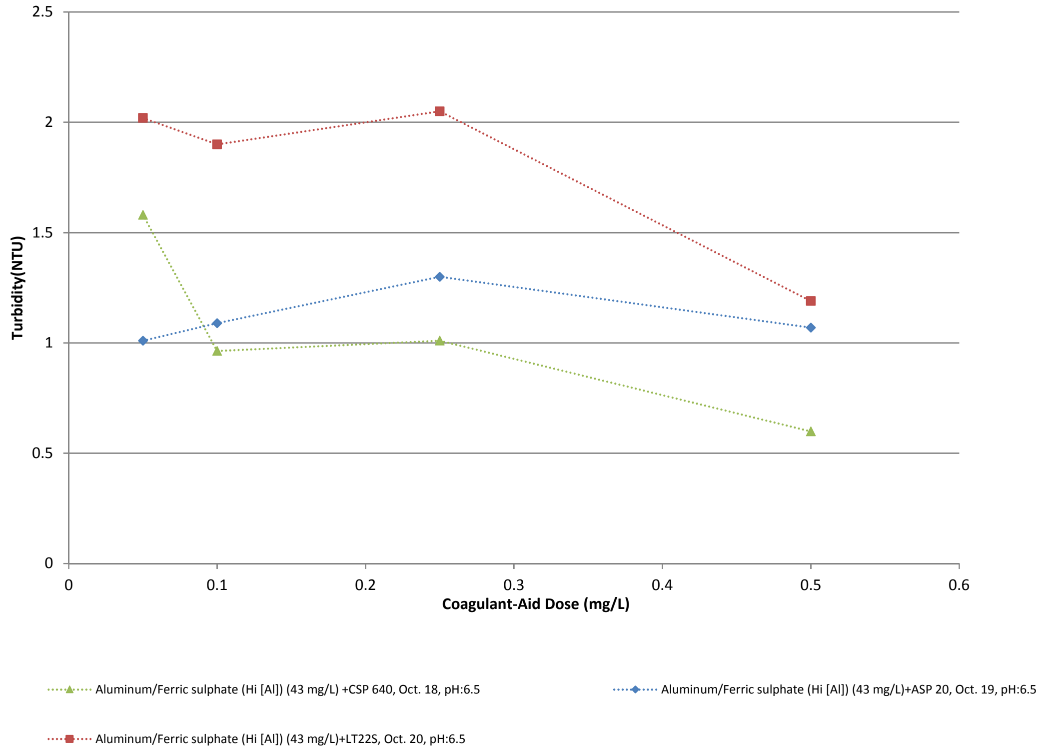


Trial 4 - Hach Managanese: Aluminum/Ferric Sulphate
Hach Mn. Conc (mg/L)
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Polymer Dose (mg/L)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17, pH:6.5 (No Polymer)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+ASP 20, Oct. 19, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+LT22S, Oct. 20, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:6.5 [OPTIMAL]

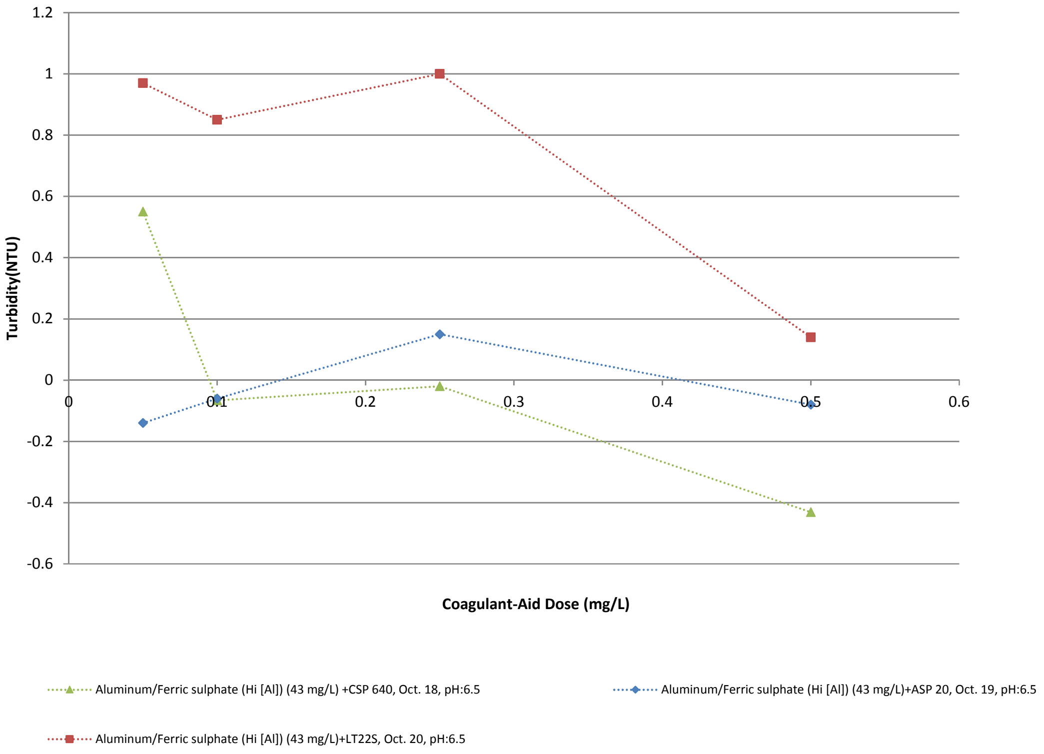


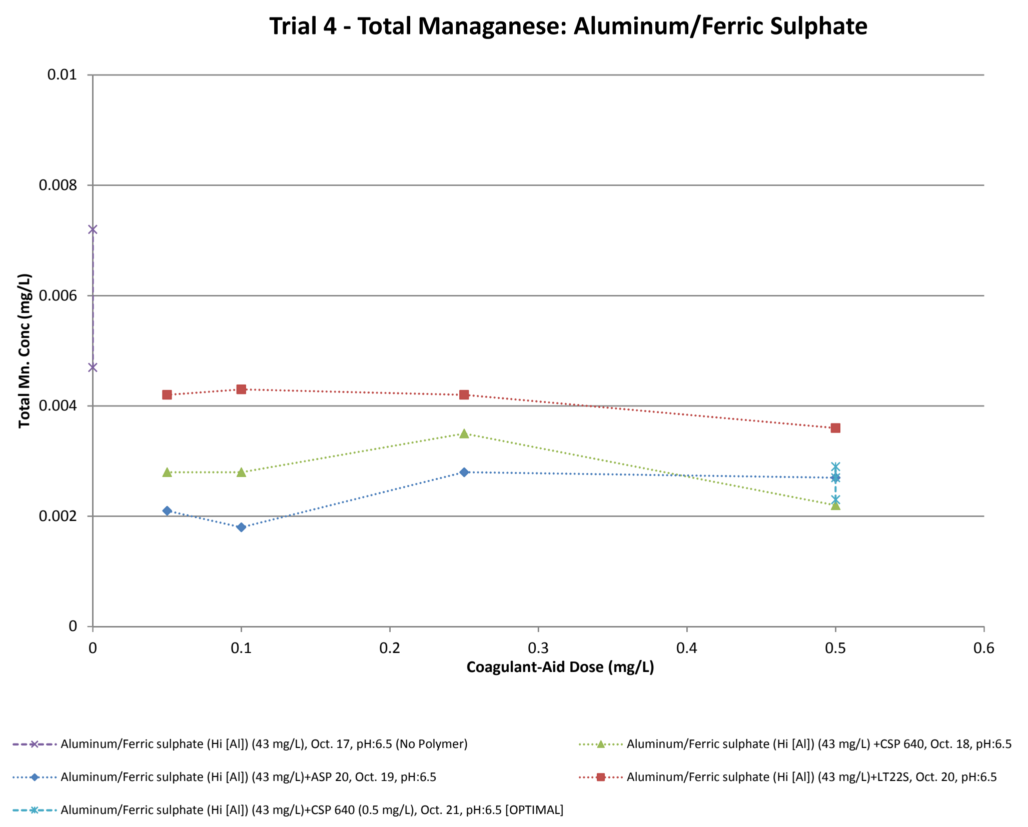
Trial 4 - UVT: Aluminum/Ferric Sulphate
UVT (%)
86
85
84
83
82
81
80
79
78
77
76
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17, pH:6.5 (No Polymer)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+ASP 20, Oct. 19, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+LT22S, Oct. 20, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:6.5 [OPTIMAL]

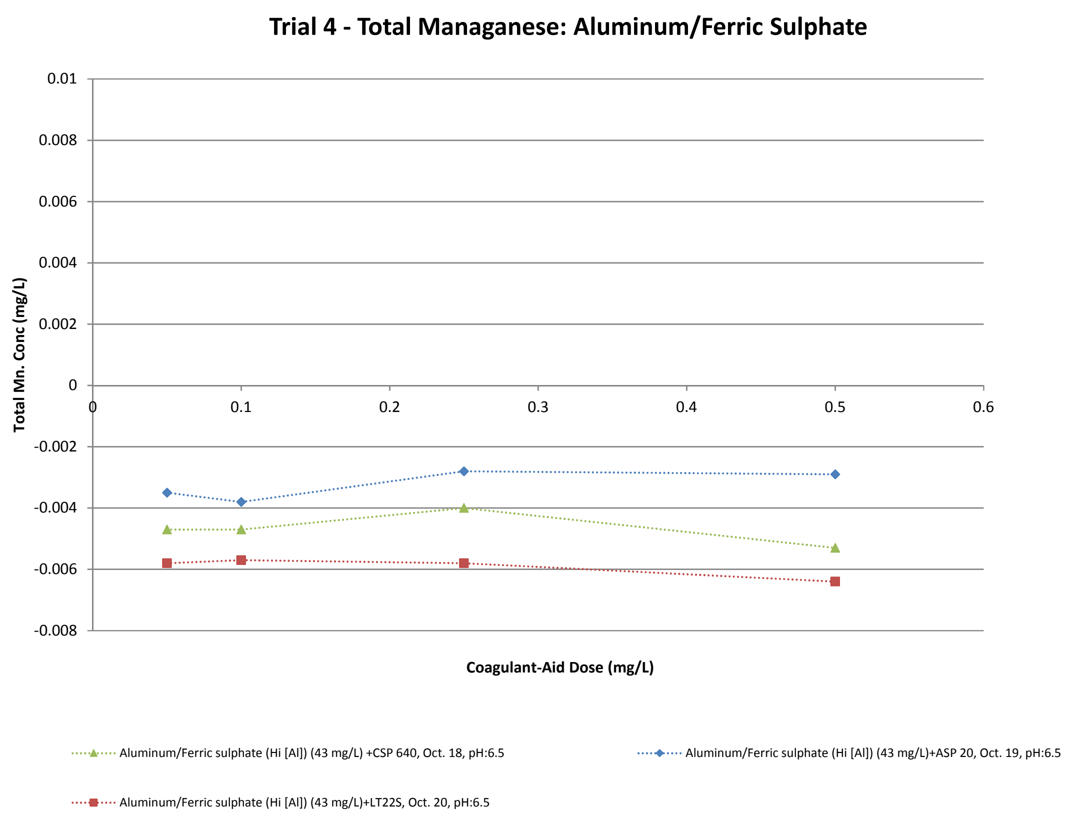
Trial 4 - Turbidity: Aluminum/Ferric Sulphate

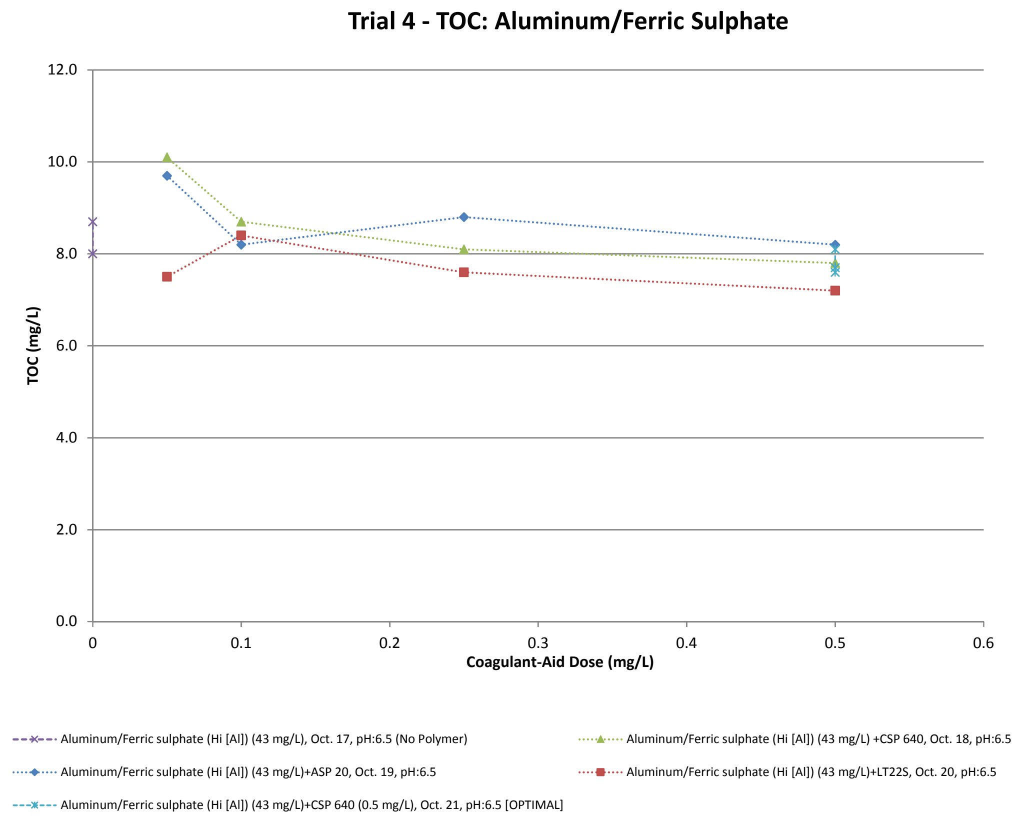


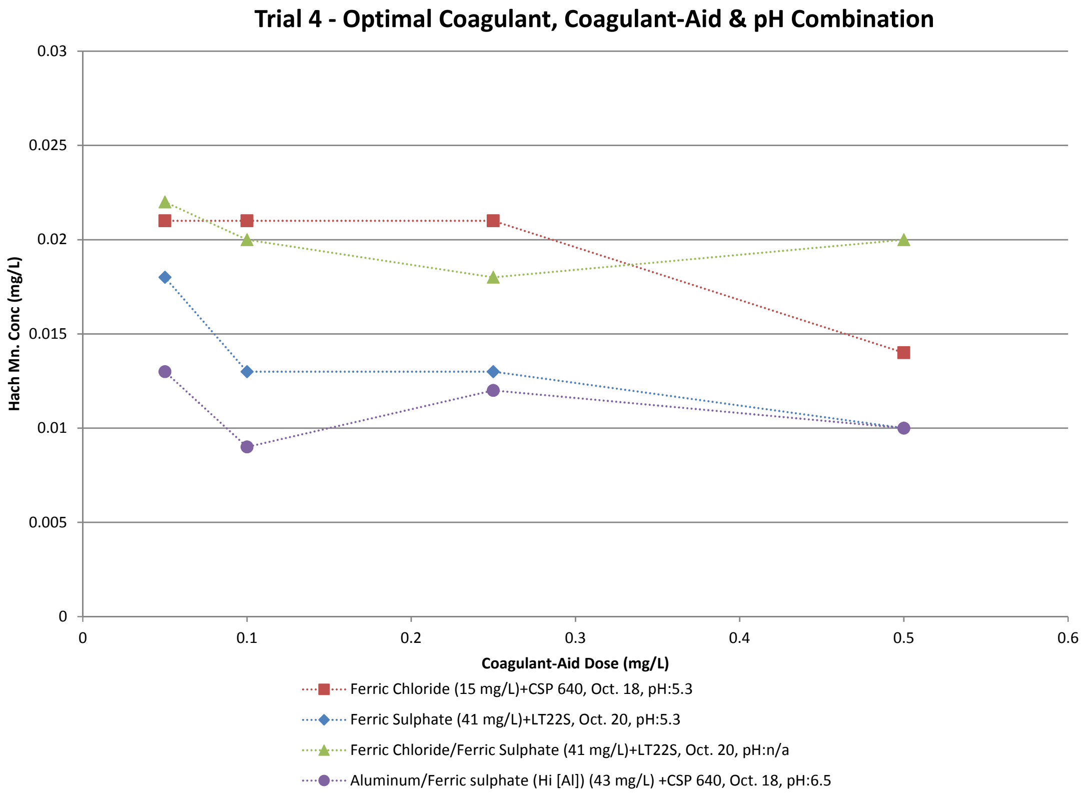
Trial 4 - Turbidity: Aluminum/Ferric Sulphate

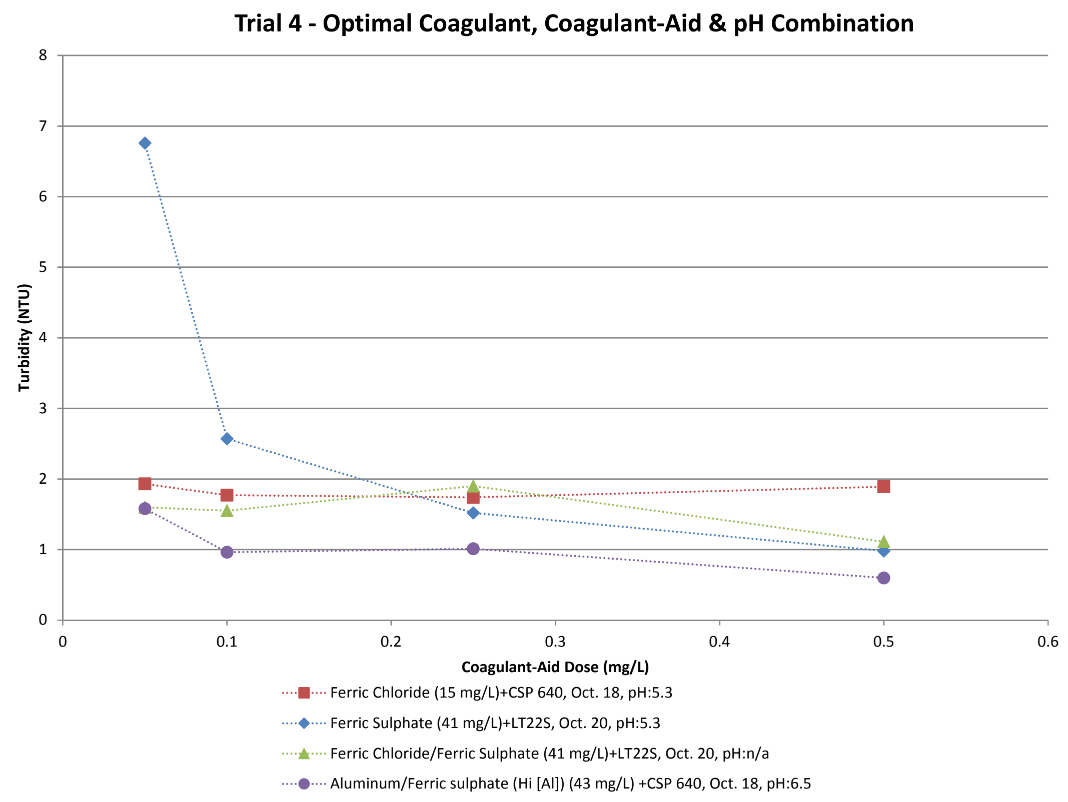


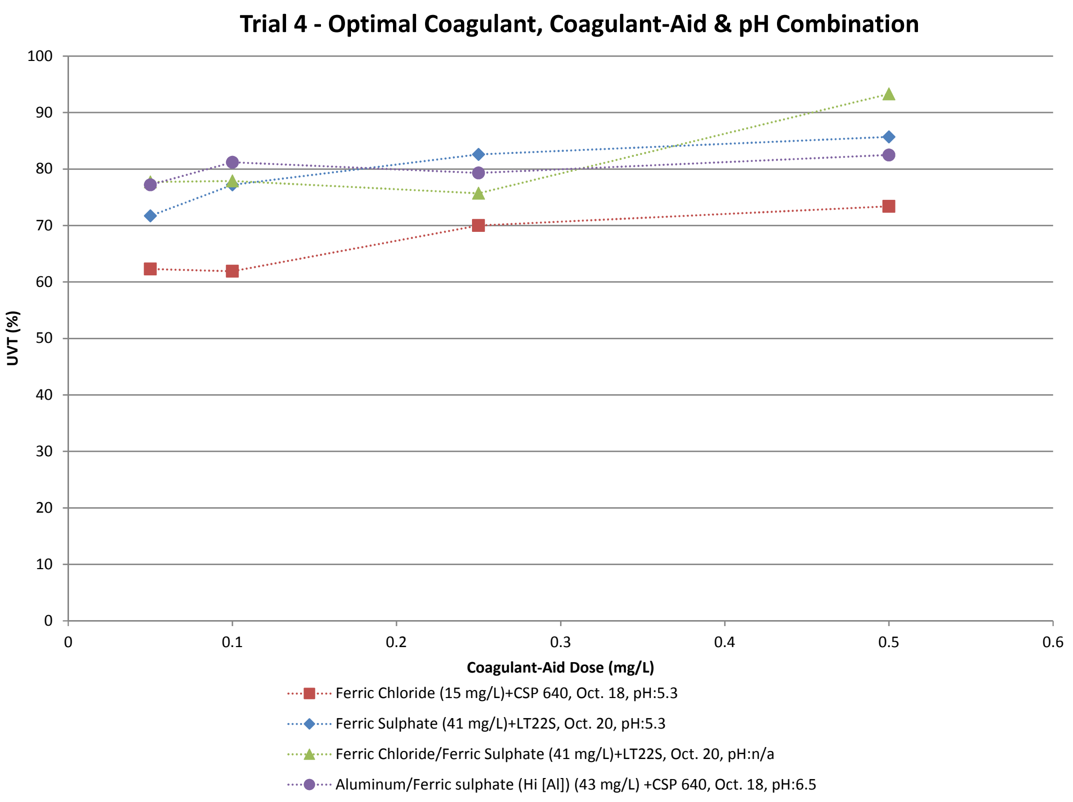

Trial 4 - Total Managanese: Aluminum/Ferric Sulphate
Total Mn. Conc (mg/L)
0.01
0.008
0.006
0.004
0.002
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17, pH:6.5 (No Polymer)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+ASP 20, Oct. 19, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+LT22S, Oct. 20, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:6.5 [OPTIMAL]

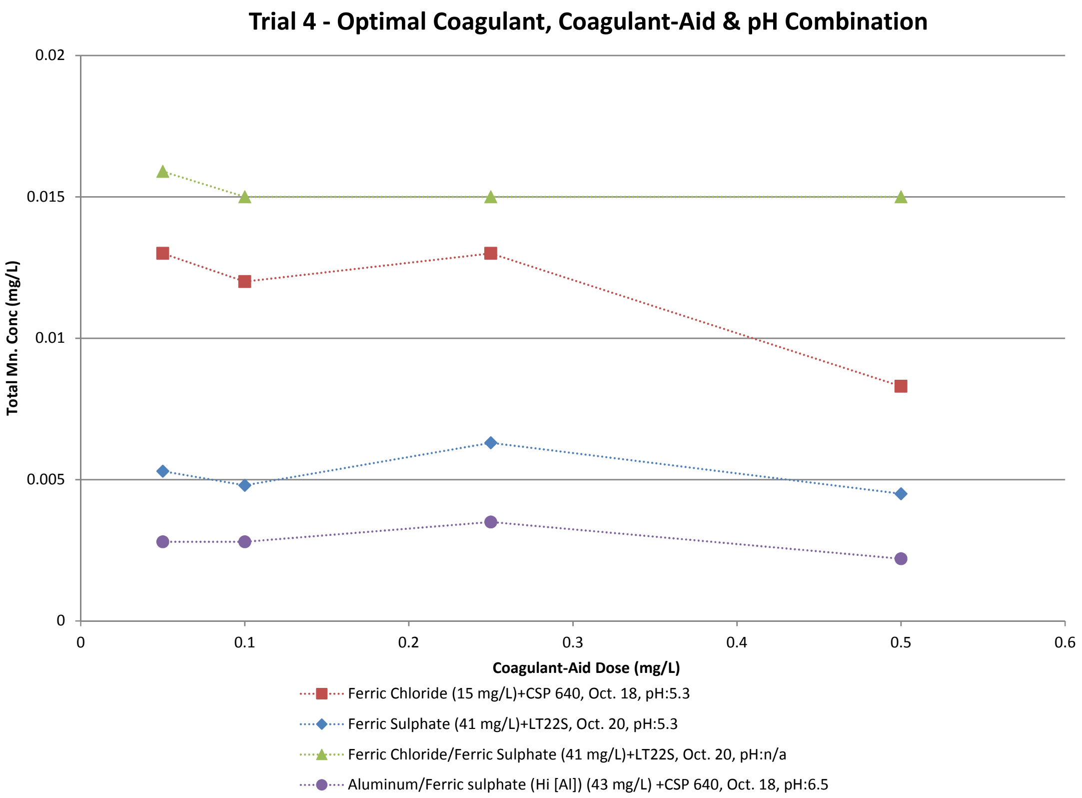

Trial 4 - Total Managanese: Aluminum/Ferric Sulphate
Total Mn. Conc (mg/L)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+ASP 20, Oct. 19, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+LT22S, Oct. 20, pH:6.5

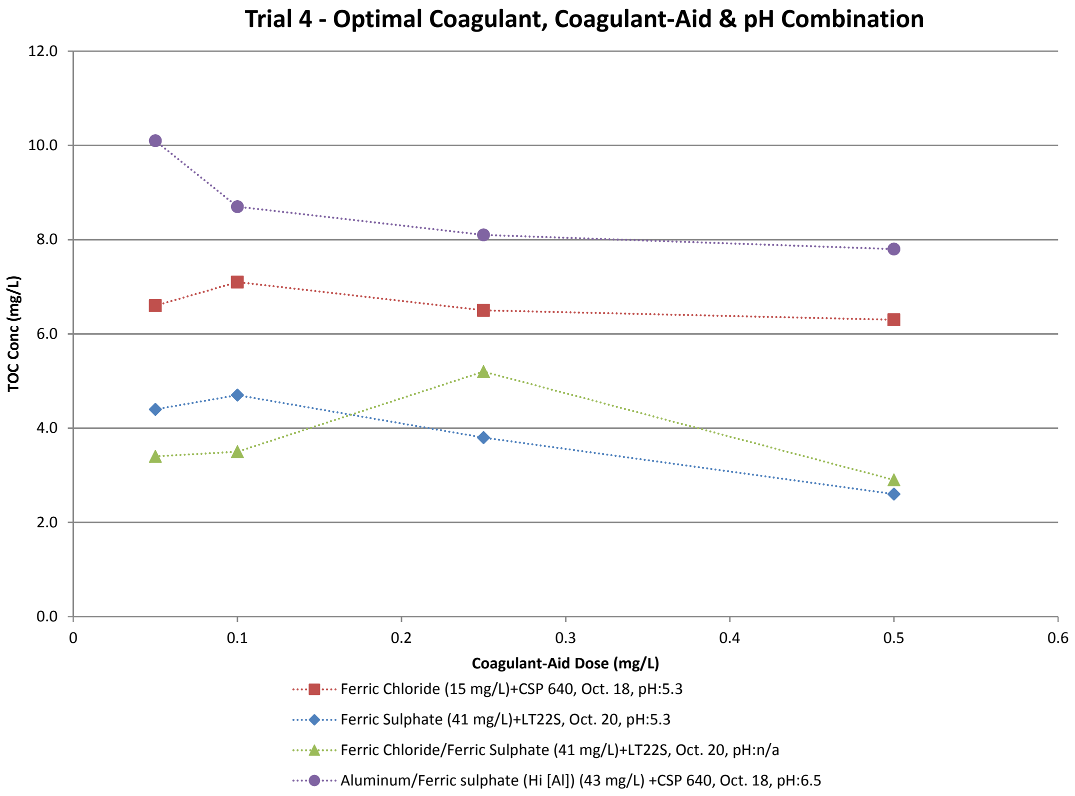

Trial 4 - TOC: Aluminum/Ferric Sulphate
TOC (mg/L)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L), Oct. 17, pH:6.5 (No Polymer)
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+ASP 20, Oct. 19, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+LT22S, Oct. 20, pH:6.5
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L)+CSP 640 (0.5 mg/L), Oct. 21, pH:6.5 [OPTIMAL]

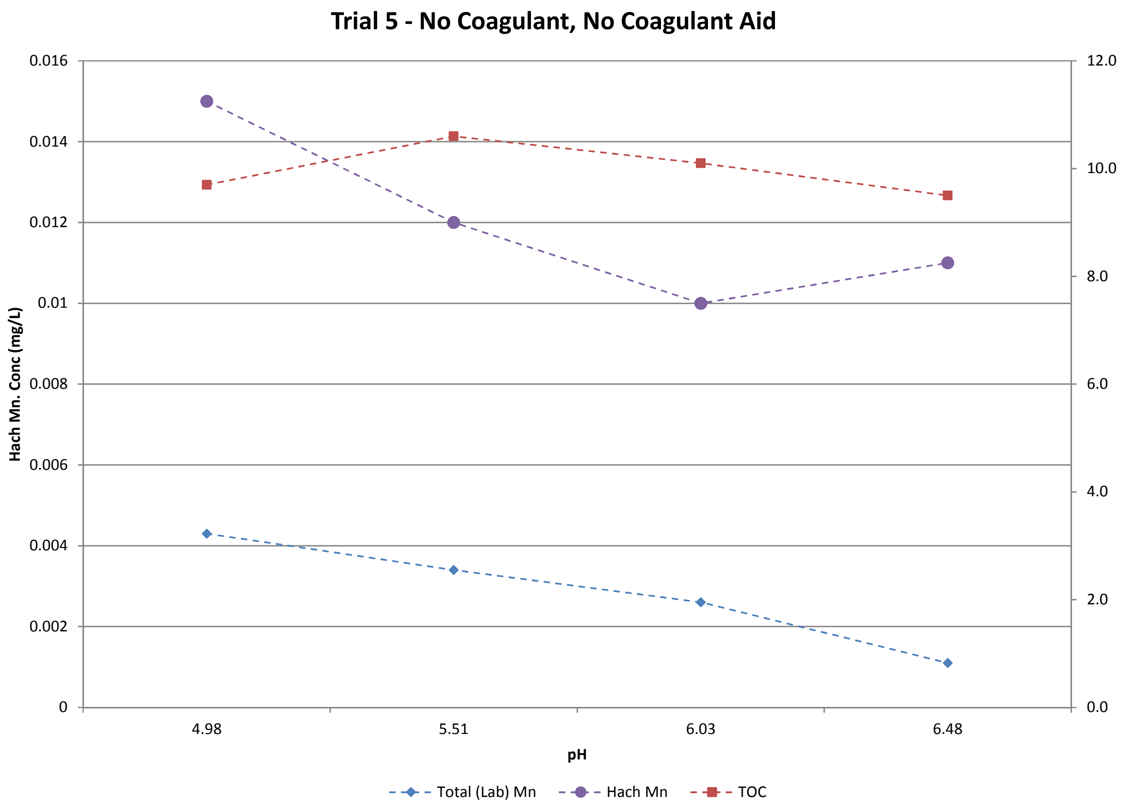

Trial 4 - Optimal Coagulant, Coagulant-Aid & pH Combination
Hach Mn. Conc (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5


Trial 4 - Optimal Coagulant, Coagulant-Aid & pH Combination
Turbidity (NTU)
0
1
2
3
4
5
6
7
8
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5

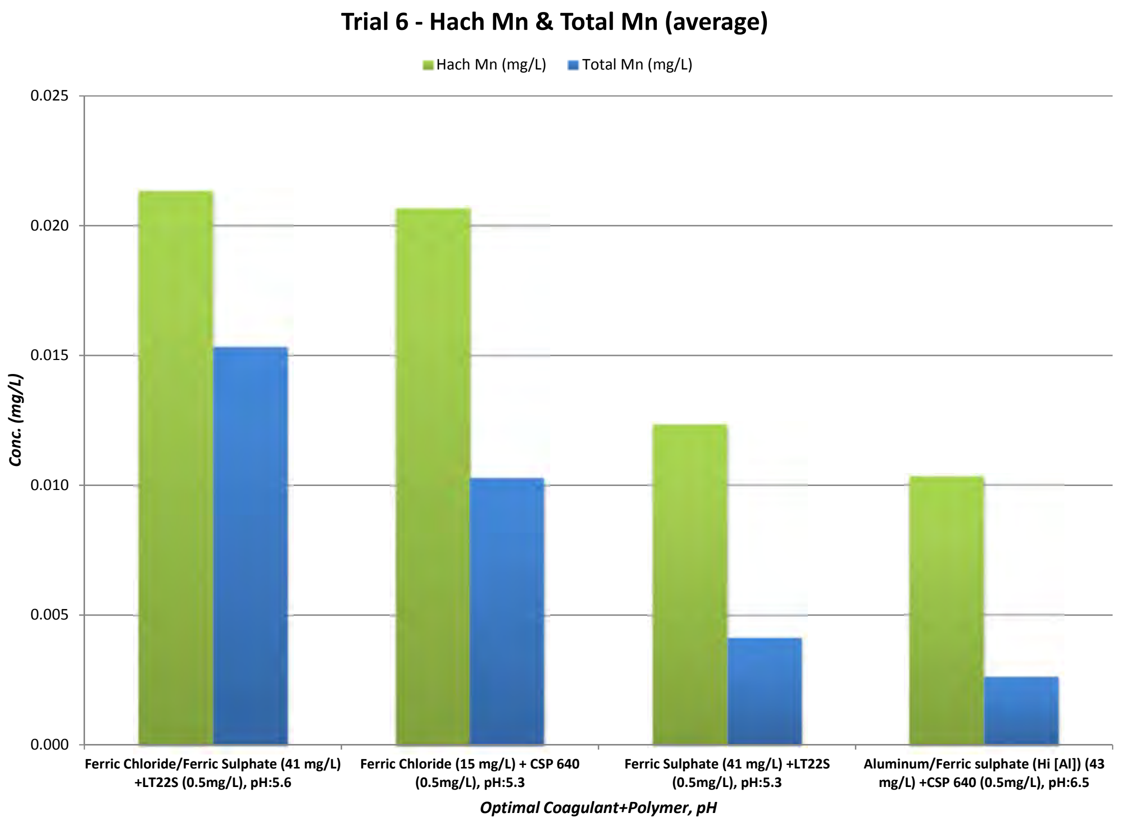

Trial 4 - Optimal Coagulant, Coagulant-Aid & pH Combination
UVT (%)
0
10
20
30
40
50
60
70
80
90
100
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5


Trial 4 - Optimal Coagulant, Coagulant-Aid & pH Combination
Total Mn. Conc (mg/L)
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5

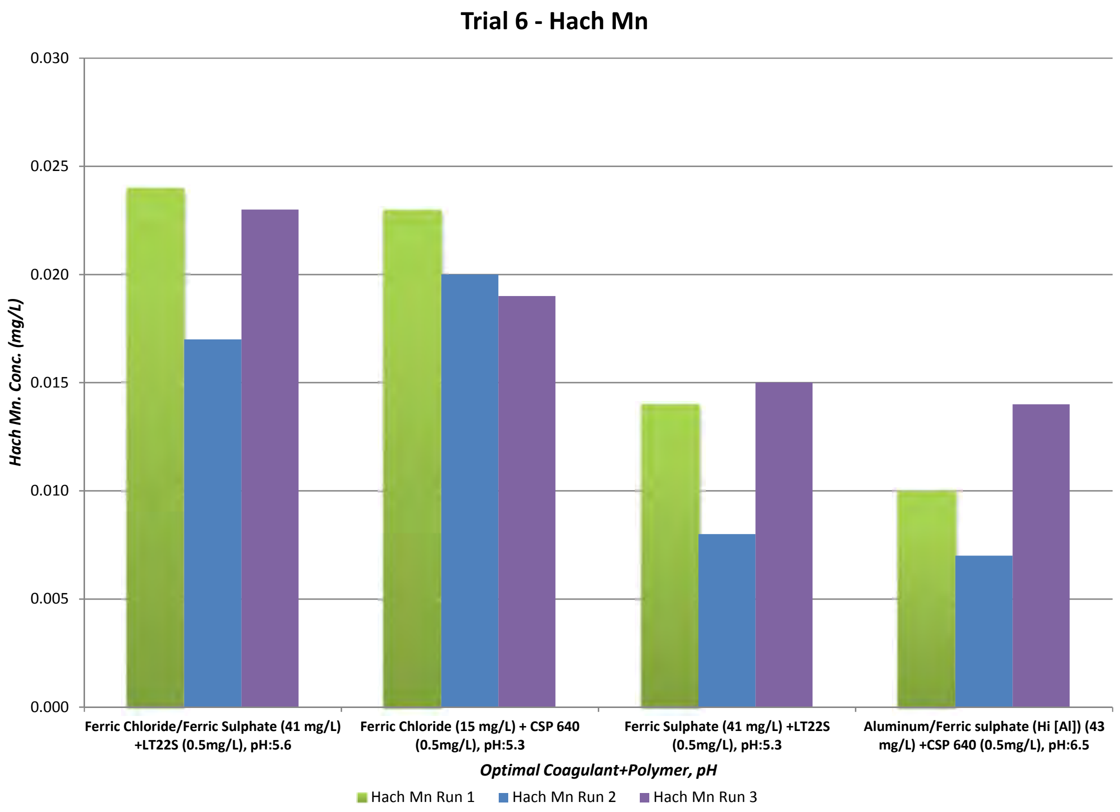

Trial 4 - Optimal Coagulant, Coagulant-Aid & pH Combination
TOC Conc (mg/L)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant-Aid Dose (mg/L)
Ferric Chloride (15 mg/L)+CSP 640, Oct. 18, pH:5.3
Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:5.3
Ferric Chloride/Ferric Sulphate (41 mg/L)+LT22S, Oct. 20, pH:n/a
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640, Oct. 18, pH:6.5

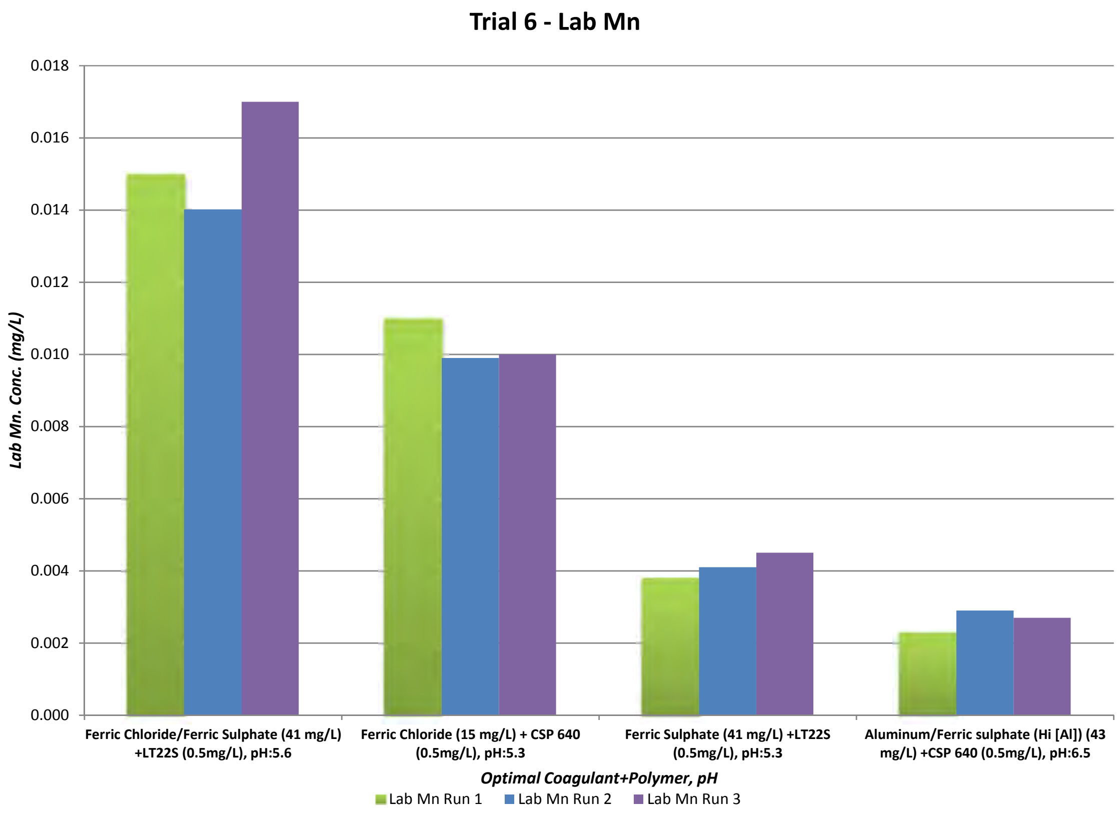


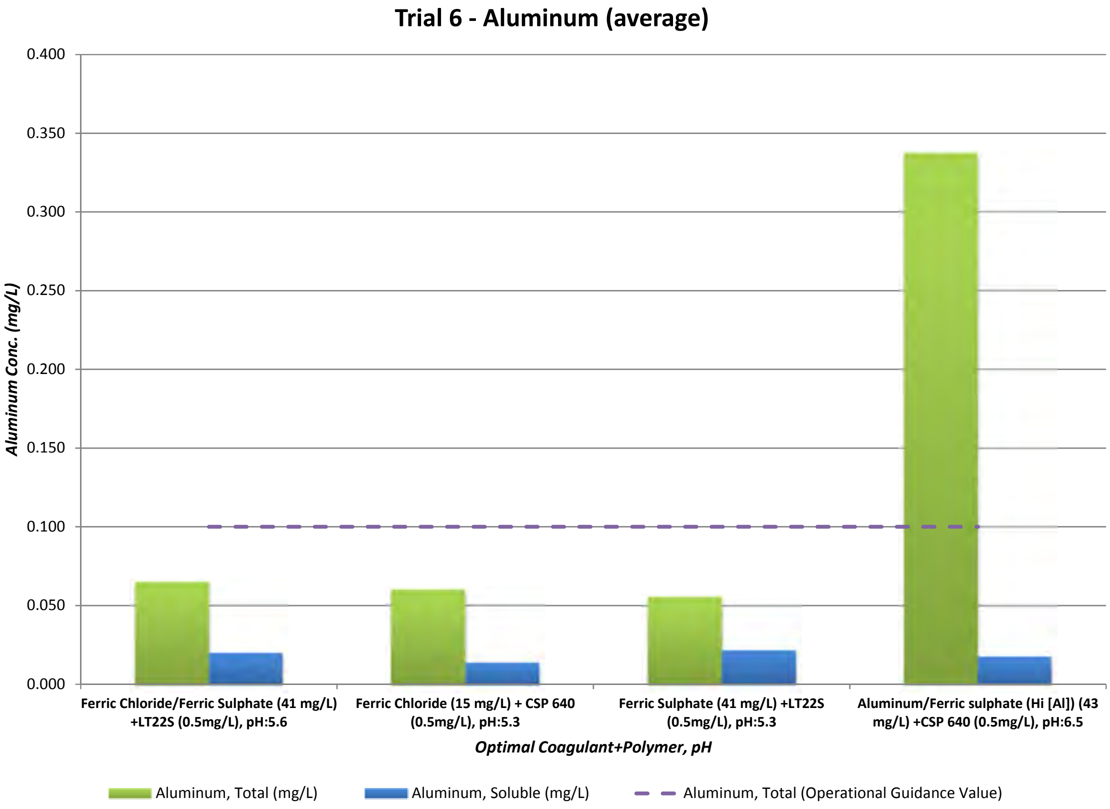
Trial 5 - No Coagulant, No Coagulant Aid

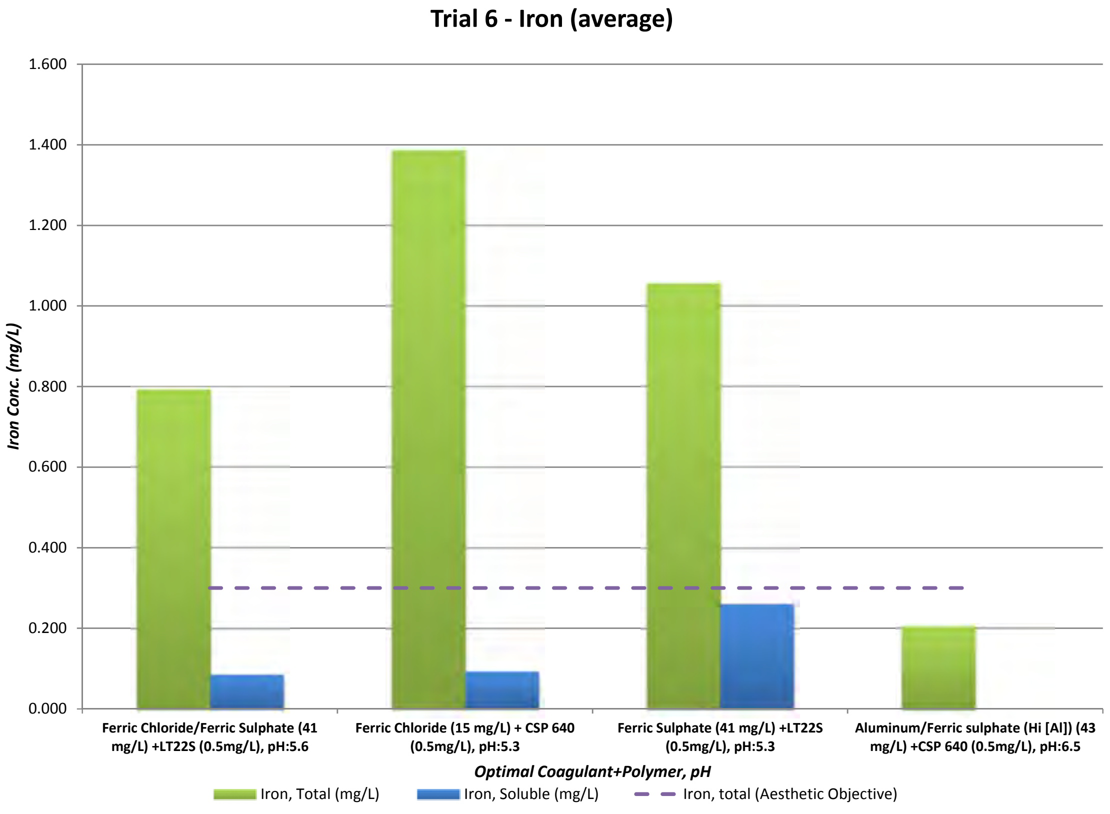


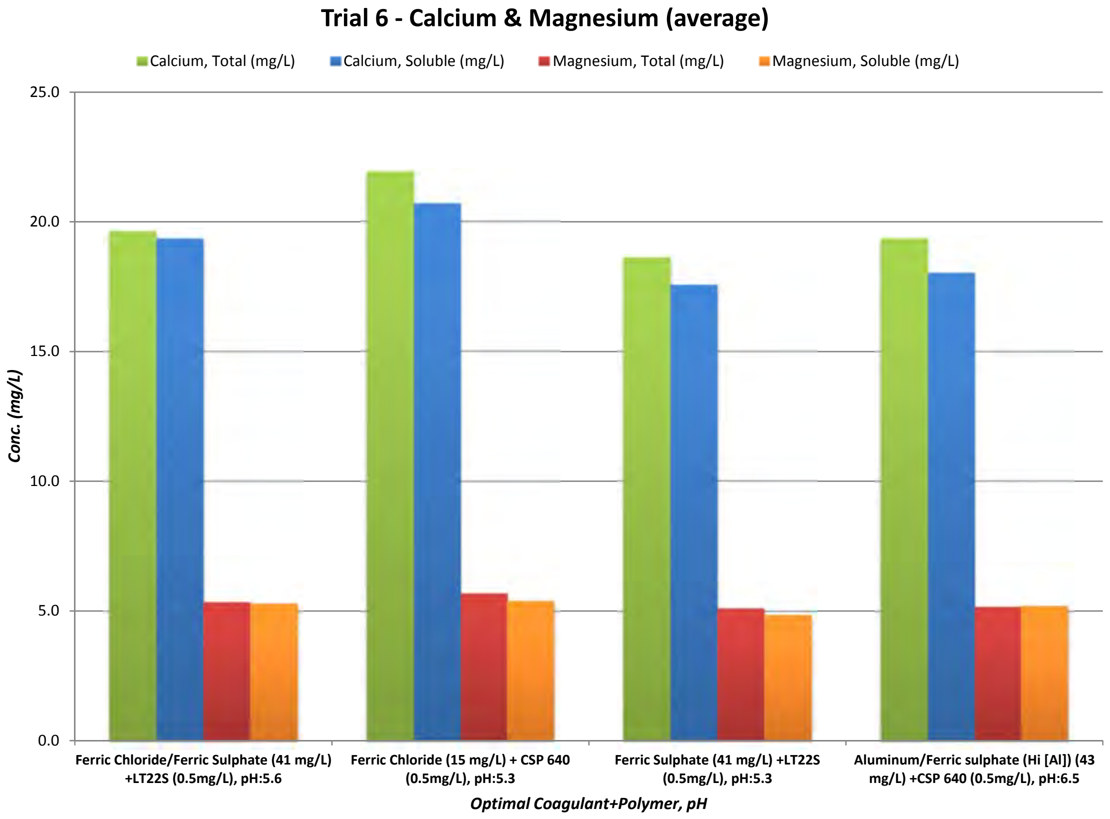
Trial 6 - Hach Mn & Total Mn (average)

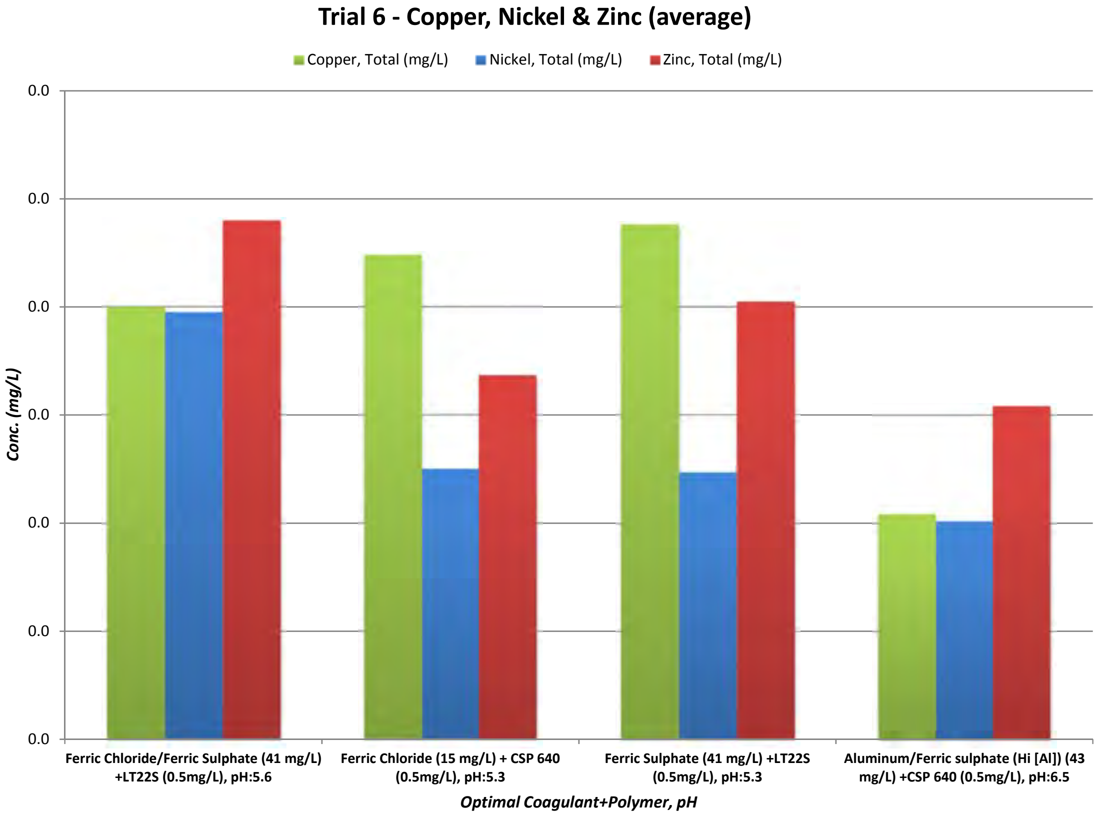

Trial 6 - Hach Mn
Hach Mn. Conc. (mg/L)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Ferric Chloride/Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.6
Ferric Chloride (15 mg/L) + CSP 640 (0.5mg/L), pH:5.3
Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.3
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640 (0.5mg/L), pH:6.5
Optimal Coagulant+Polymer, pH
Hach Mn Run 1
Hach Mn Run 2
Hach Mn Run 3

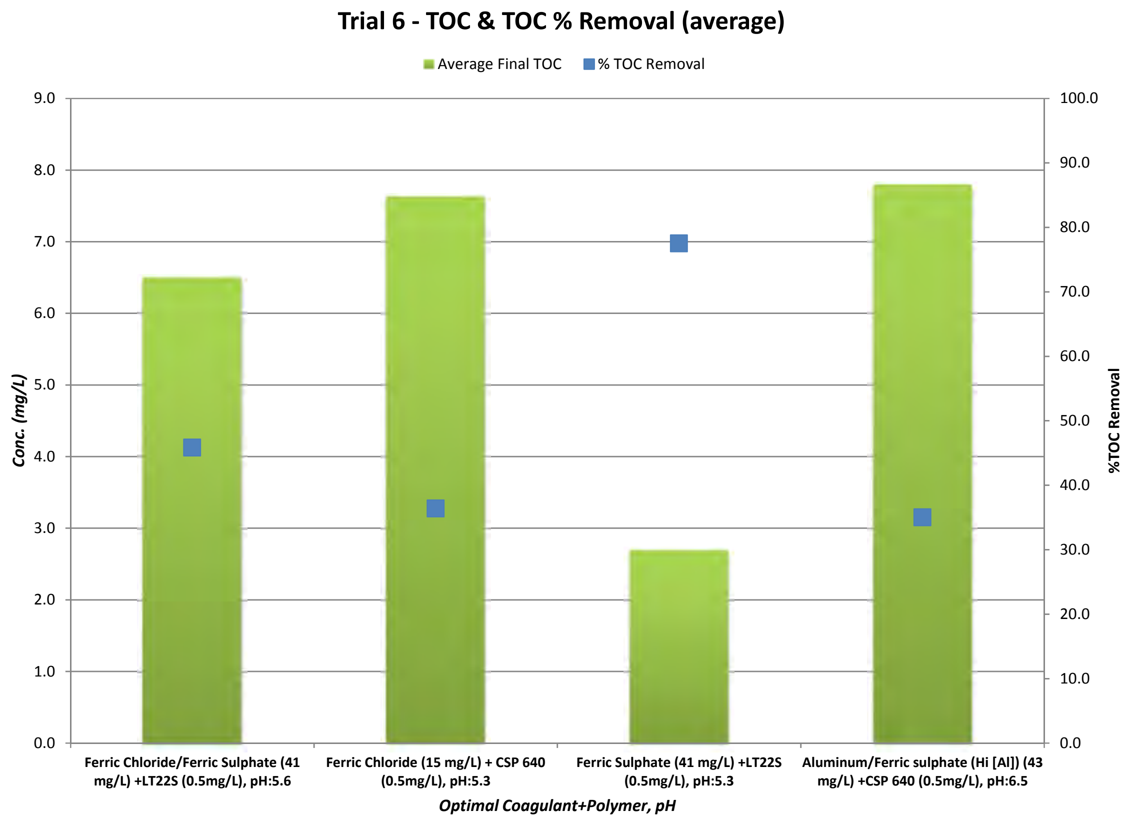

Trial 6 - Lab Mn
Lab Mn. Conc. (mg/L)
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Ferric Chloride/Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.6
Ferric Chloride (15 mg/L) + CSP 640 (0.5mg/L), pH:5.3
Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.3
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640 (0.5mg/L), pH:6.5
Optimal Coagulant+Polymer, pH
Lab Mn Run 1
Lab Mn Run 2
Lab Mn Run 3

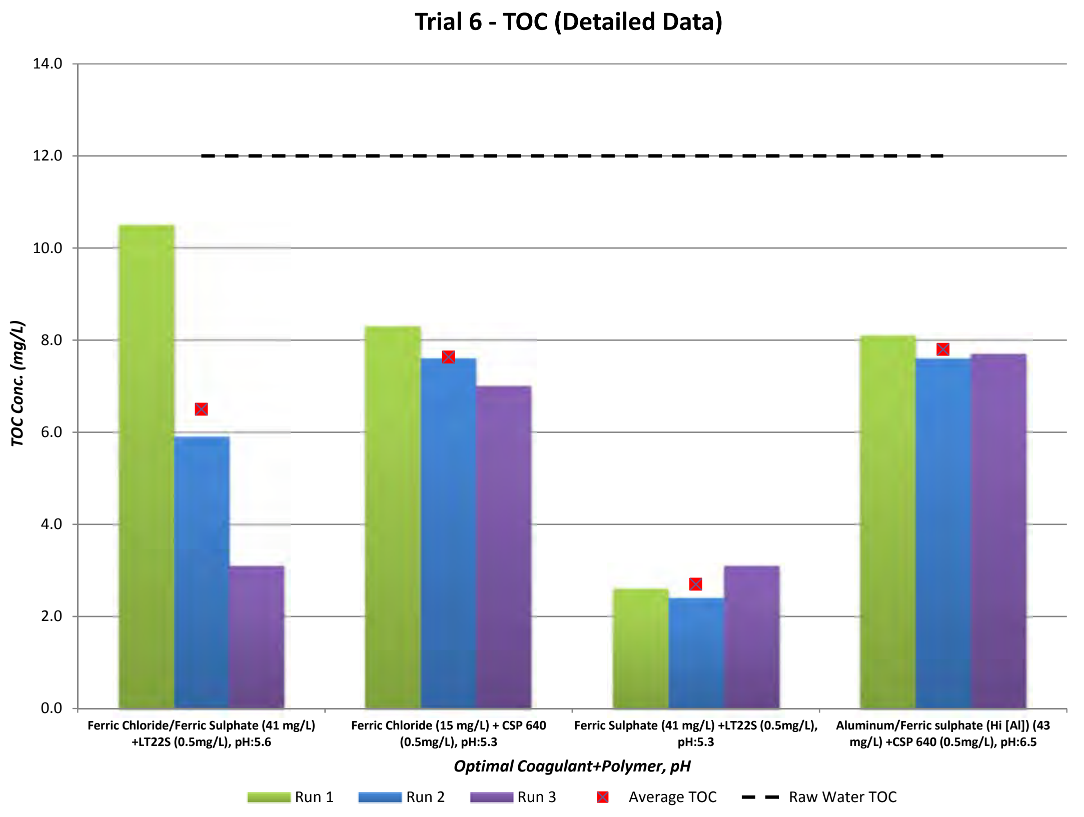

Trial 6 - Aluminum (average)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Aluminum Conc. (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.6
Ferric Chloride (15 mg/L) + CSP 640 (0.5mg/L), pH:5.3
Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.3
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640 (0.5mg/L), pH:6.5
Optimal Coagulant+Polymer, pH
Aluminum, Total (mg/L)
Aluminum, Soluble (mg/L)
Aluminum, Total (Operational Guidance Value)

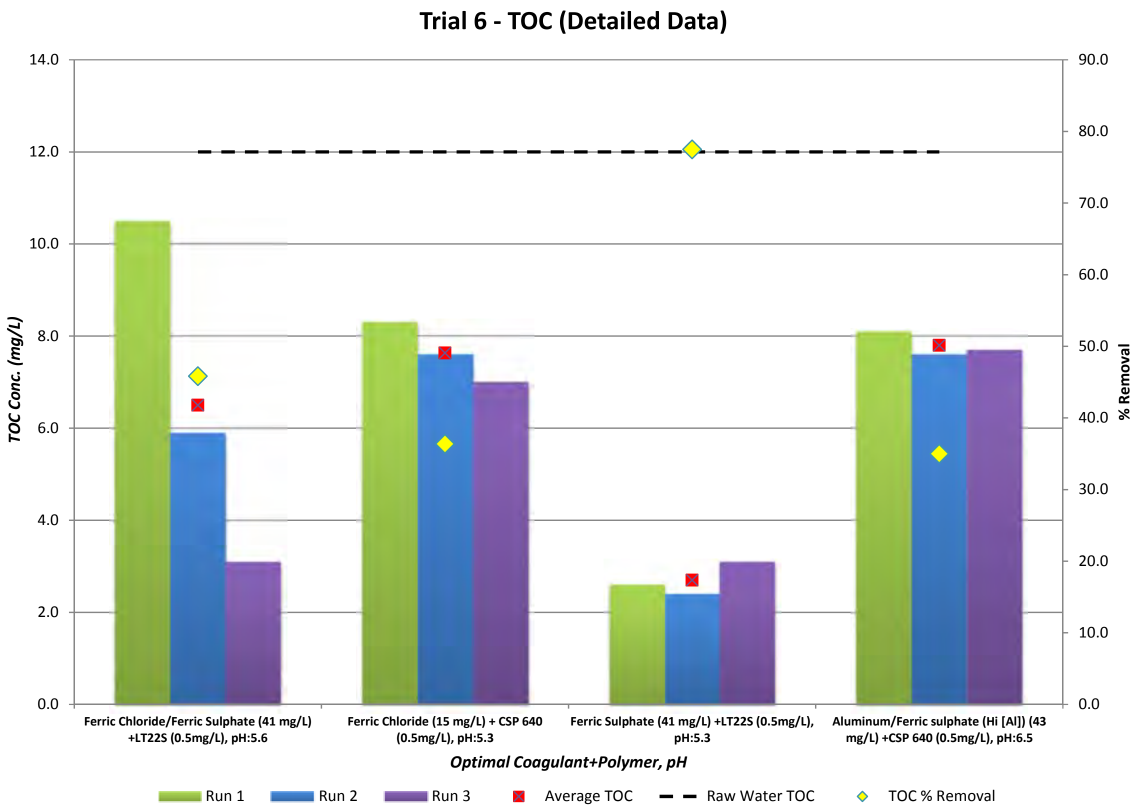

Trial 6 - Iron (average)
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Iron Conc. (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.6
Ferric Chloride (15 mg/L) + CSP 640 (0.5mg/L), pH:5.3
Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.3
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640 (0.5mg/L), pH:6.5
Optimal Coagulant+Polymer, pH
Iron, Total (mg/L)
Iron, Soluble (mg/L)
Iron, total (Aesthetic Objective)

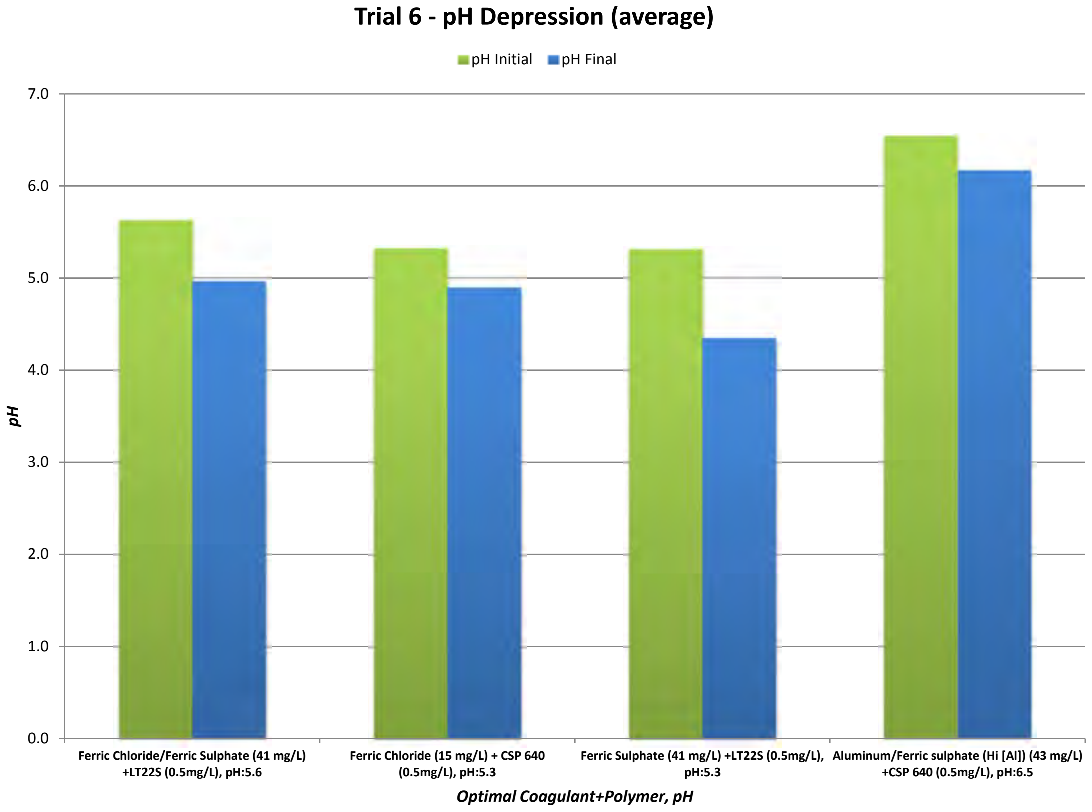

Trial 6 - Calcium & Magnesium (average)
Calcium, Total (mg/L)
Calcium, Soluble (mg/L)
Magnesium, Total (mg/L)
Magnesium, Soluble (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
Conc. (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.6
Ferric Chloride (15 mg/L) + CSP 640 (0.5mg/L), pH:5.3
Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.3
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640 (0.5mg/L), pH:6.5
Optimal Coagulant+Polymer, pH

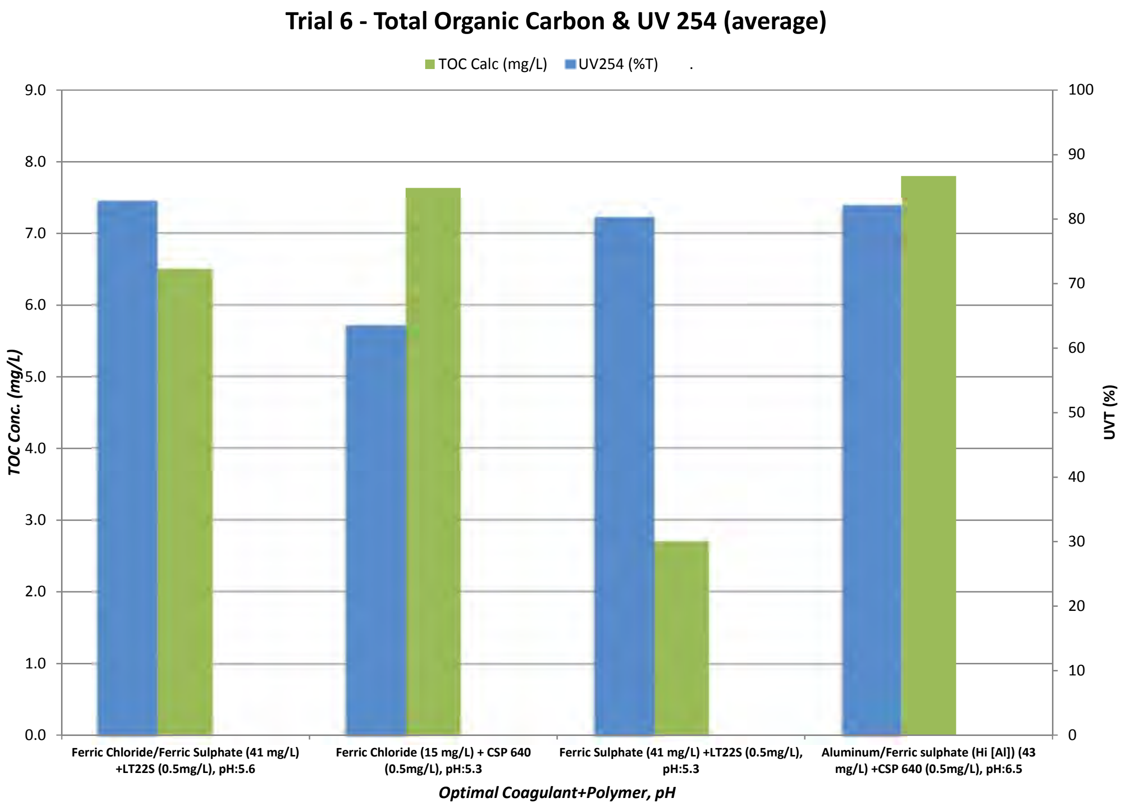

Trial 6 - Copper, Nickel & Zinc (average)
Copper, Total (mg/L)
Nickel, Total (mg/L)
Zinc, Total (mg/L)
0.0
0.0
0.0
0.0
0.0
0.0
0.0
Conc. (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.6
Ferric Chloride (15 mg/L) + CSP 640 (0.5mg/L), pH:5.3
Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.3
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640 (0.5mg/L), pH:6.5
Optimal Coagulant+Polymer, pH


Trial 6 - TOC & TOC % Removal (average)
Average Final TOC
% TOC Removal
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Conc. (mg/L)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
%TOC Removal
Ferric Chloride/Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.6
Ferric Chloride (15 mg/L) + CSP 640 (0.5mg/L), pH:5.3
Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.3
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640 (0.5mg/L), pH:6.5
Optimal Coagulant+Polymer, pH

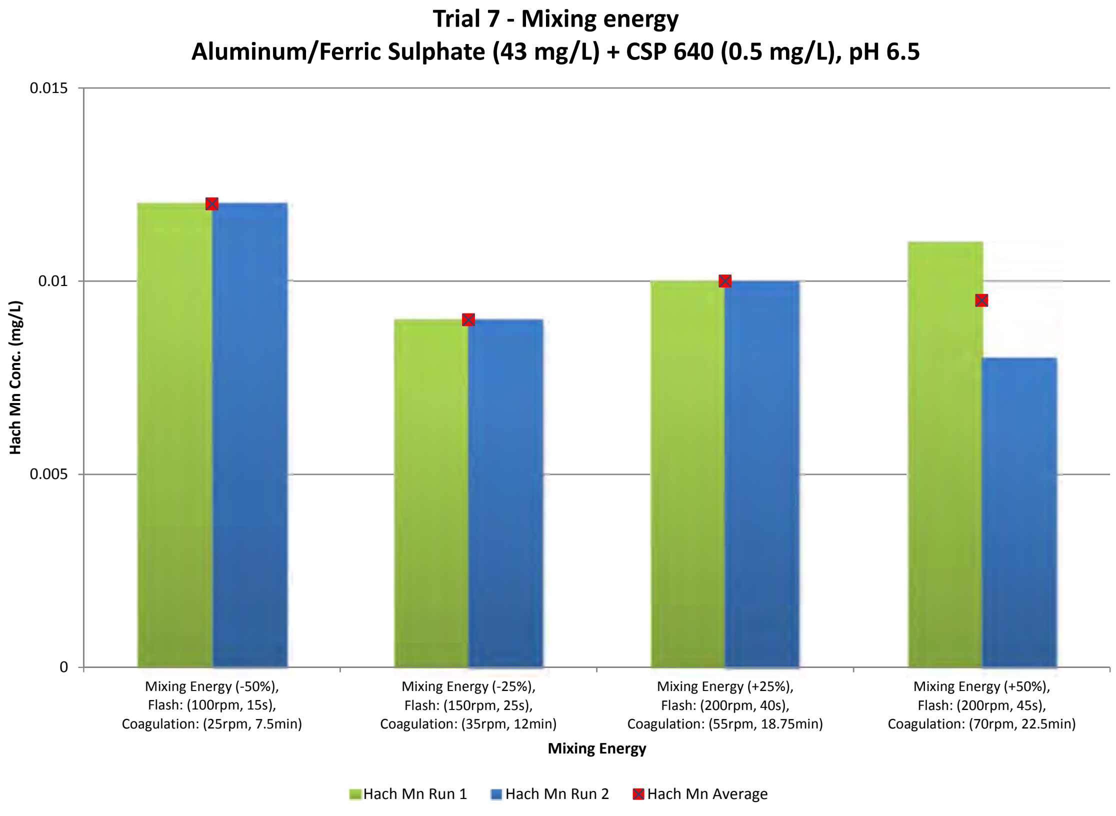

Trial 6 - TOC (Detailed Data)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
TOC Conc. (mg/L)
Ferric Chloride/Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.6
Ferric Chloride (15 mg/L) + CSP 640 (0.5mg/L), pH:5.3
Ferric Sulphate (41 mg/L) +LT22S (0.5mg/L), pH:5.3
Aluminum/Ferric sulphate (Hi [Al]) (43 mg/L) +CSP 640 (0.5mg/L), pH:6.5
Optimal Coagulant+Polymer, pH
Run 1
Run 2
Run 3
Average TOC
Raw Water TOC


Trial 6 - TOC (Detailed Data)


Trial 6 - pH Depression (average)

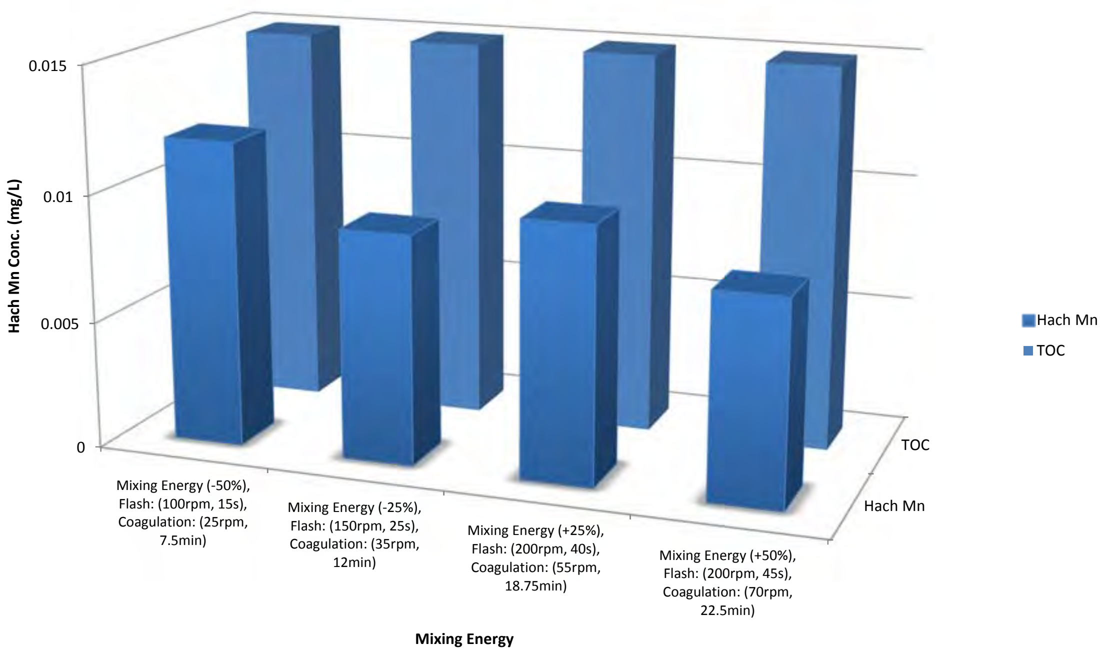


Trial 6 - Total Organic Carbon & UV 254 (average)

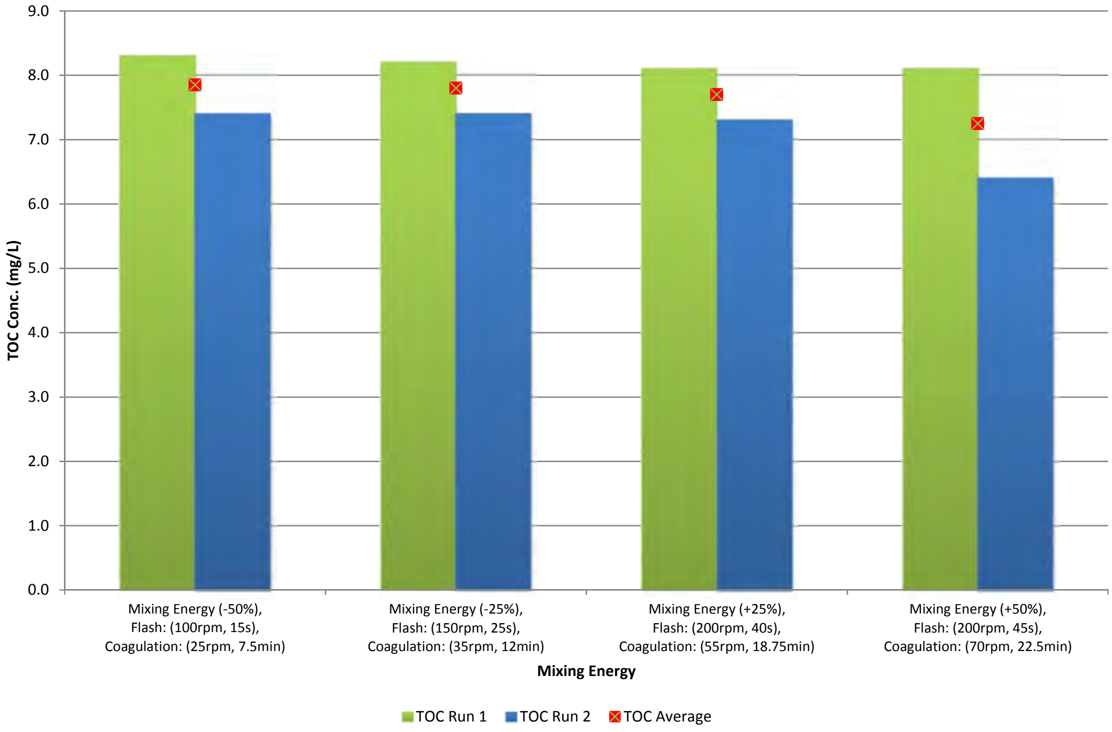


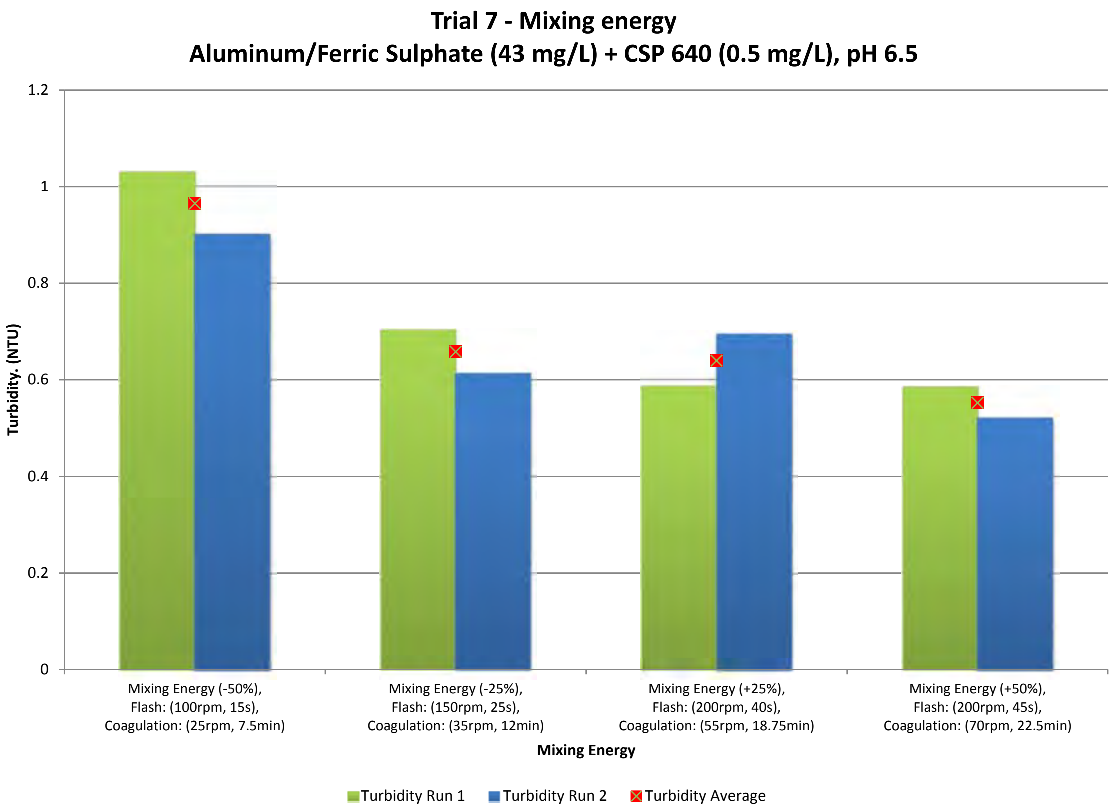
Trial 7 - Mixing energy
Aluminum/Ferric Sulphate (43 mg/L) + CSP 640 (0.5 mg/L), pH 6.5

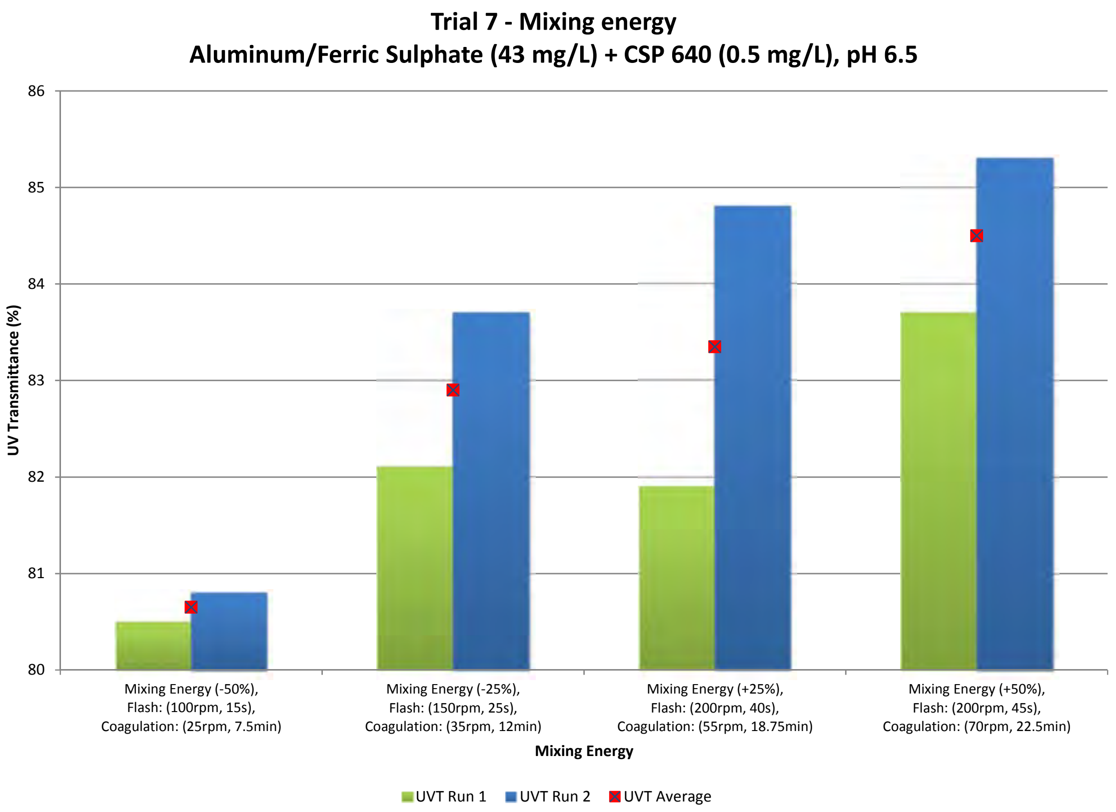
Trial 7 - Mixing energy
Aluminum/Ferric Sulphate (43 mg/L) + CSP 640 (0.5 mg/L), pH 6.5



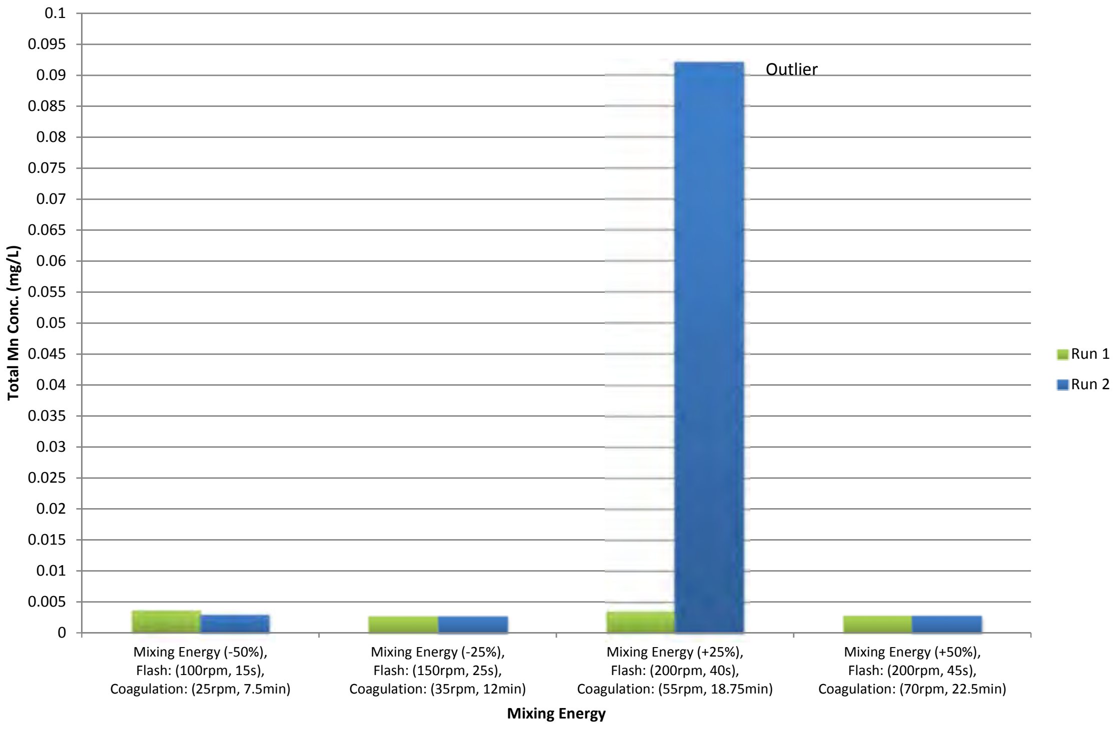
Trial 7 - Mixing energy
Aluminum/Ferric Sulphate (43 mg/L) + CSP 640 (0.5 mg/L), pH 6.5



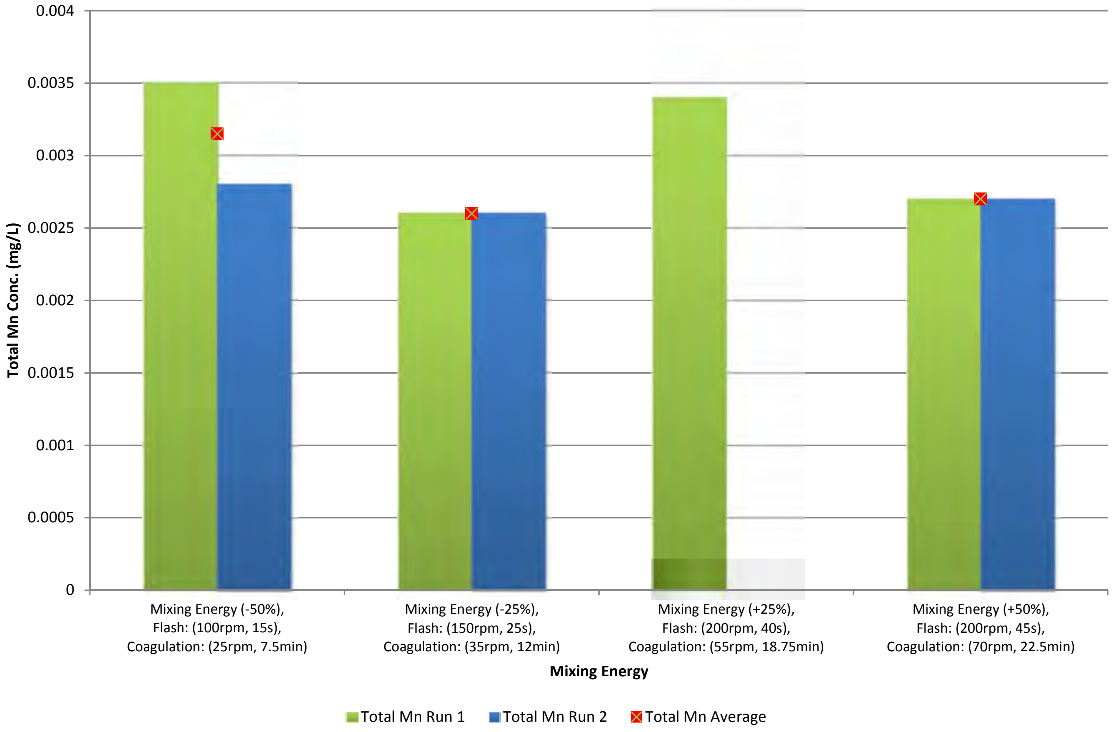

Trial 7 - Mixing energy
Aluminum/Ferric Sulphate (43 mg/L) + CSP 640 (0.5 mg/L), pH 6.5


Trial 7 - Mixing energy
Aluminum/Ferric Sulphate (43 mg/L) + CSP 640 (0.5 mg/L), pH 6.5

Trial 7 - Mixing energy
Aluminum/Ferric Sulphate (43 mg/L) + CSP 640 (0.5 mg/L), pH 6.5



Trial 7 - Mixing energy
Aluminum/Ferric Sulphate (43 mg/L) + CSP 640 (0.5 mg/L), pH 6.5



Appendix D – Re-Evaluation of Bench-Scale Testing (Second Round)

Comments Regarding Re-Evaluation of Bench-Scale Testing

City of Winnipeg

Completed by:
Andrews, Hofmann and Associates

Submitted to:
WSP

January 22nd, 2017

The objective of the study being completed for the City of Winnipeg is to identify an appropriate alternative coagulant to reduce the concentration of manganese in treated water without negatively impacting other water quality parameters or plant operations. Based on the results presented in Technical Memorandum #1, it was determined that a number of the previously completed bench-scale tests should be re-evaluated. Specifically, the following tests should be repeated:

- Optimization of coagulant dose
- Optimization of coagulation pH
- Optimization of coagulant aid (polymer addition)

These three tests were chosen as they were previously completed over multiple days, which resulted in varying raw water quality during the tests. In order to minimize some of the confounding factors previously encountered, it is suggested that enough raw water be collected to complete each of the three optimization trials using the same batch of water, if not completed in one day store at 4 C until needed. If conducting any of the three optimization trials over more than one day, monitor Mn, pH and temp in the pilot lab immediately before starting jar tests each day. Controlling these factors will provide more certainty in our recommendations of the best coagulant for the future pilot trials.

To accurately assess the impact of the DAF process, samples should be collected for a range of parameters. As indicated by WSP, an external lab will provide analyses for total and dissolved metals, total organic carbon, alkalinity, chloride and sulfate. Additionally, tests should be completed at bench-scale to determine temperature, turbidity, oxidation/reduction potential, pH, and metals (iron and manganese) by the respective HACH methods. To better establish the variation in performance, each test (optimization of dose, pH and coagulant aid) for each coagulant should be completed in triplicate. This will allow the standard deviation of the results to be calculated, and provide a higher level of confidence regarding which coagulant should be recommended for pilot studies.

In addition to the samples prepared using the bench-scale DAF unit, raw water and post-DAF water from the full-scale plant should be collected at the same time as raw water collection to allow for comparisons of the alternative coagulant to the existing process. These samples will also help to baseline the performance of the existing coagulant when sampled after full-scale and bench-scale DAF treatment.

Table 1 provides a summary of the samples completed and the parameters analyzed. Appendix A provides details from the original jar test document pertaining to the three tests of interest.

Table 1 Summary of Testing

Samples	**External Lab Parameters**	**Bench-scale Lab Parameters**
Raw water	Total and dissolved metals	Temperature
Full-scale post DAF	Total organic carbon	Turbidity
Optimized coagulant dose	Alkalinity	Oxidation/Reduction Potential
Optimized coagulation pH	Corrosion indicators	pH
Optimized coagulant aid		Metals by HACH (Mn and Fe)

Appendix A

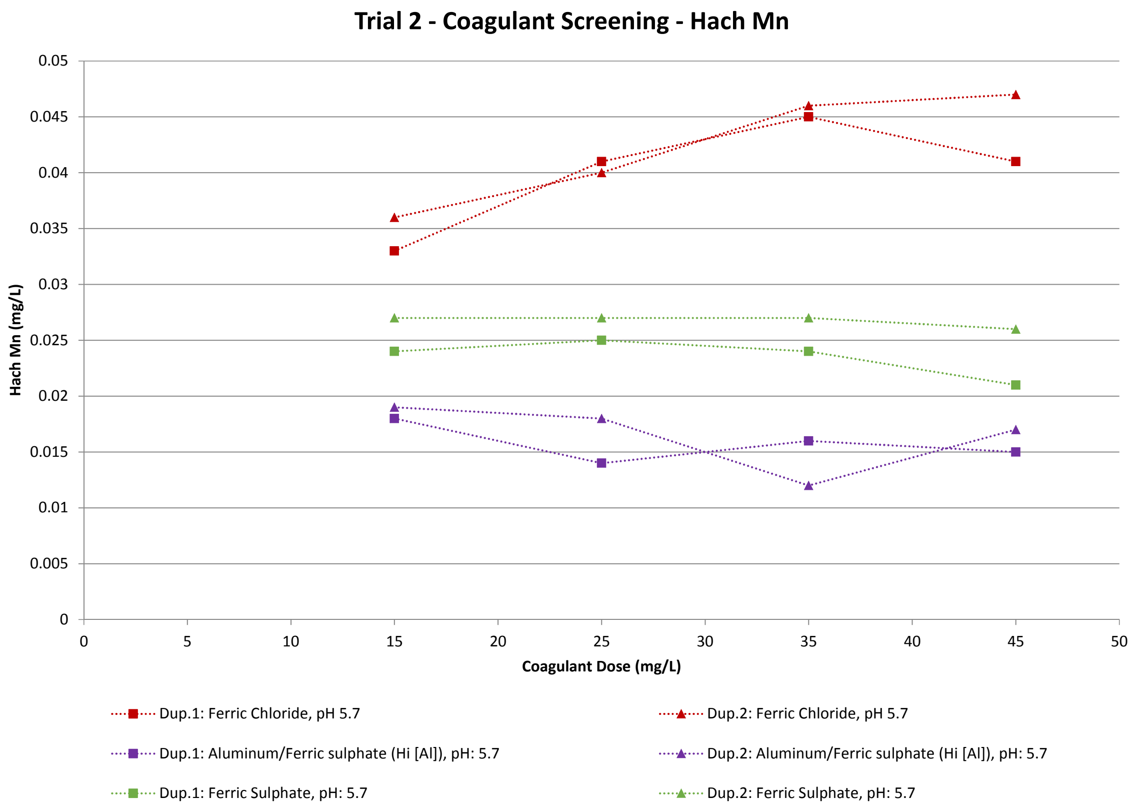
Highlights from Jar Test Procedure Document

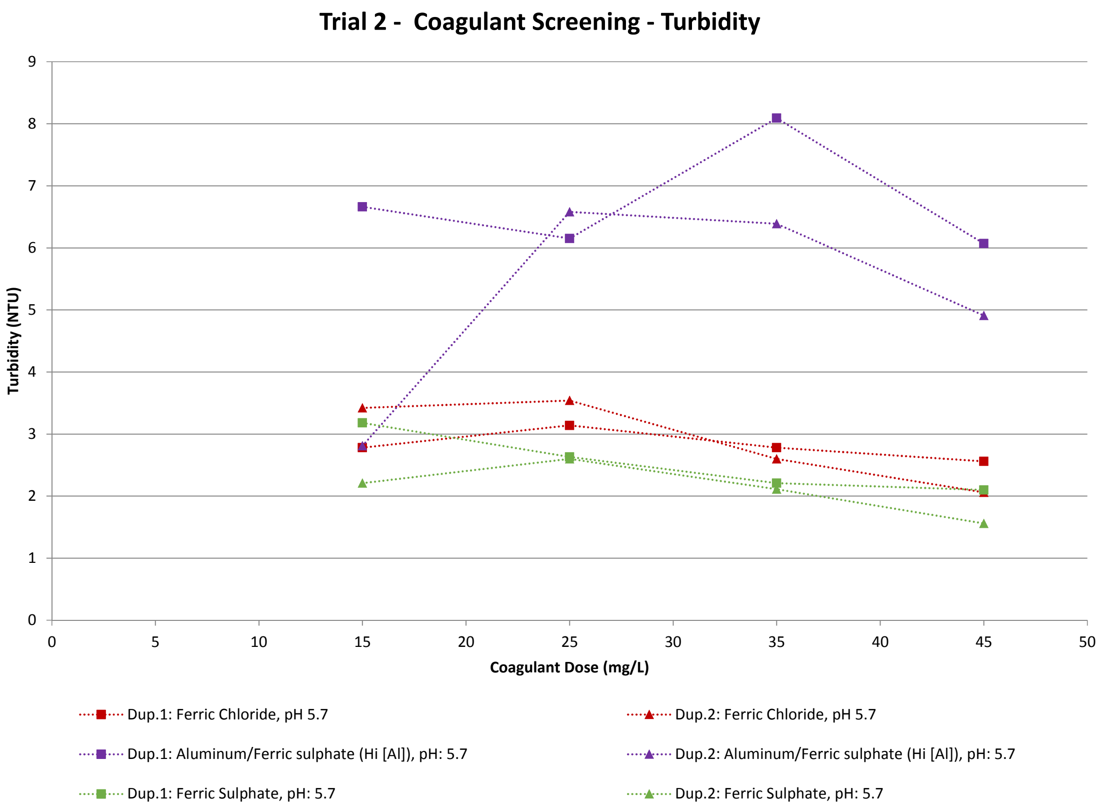
The tests which have been suggested to be completed again were originally referred to as Trials #2, 3 and 4 in the jar test procedure provided to the City of Winnipeg. Table 2 provides the trial details. If further details are required, please refer back to the jar test procedure document.

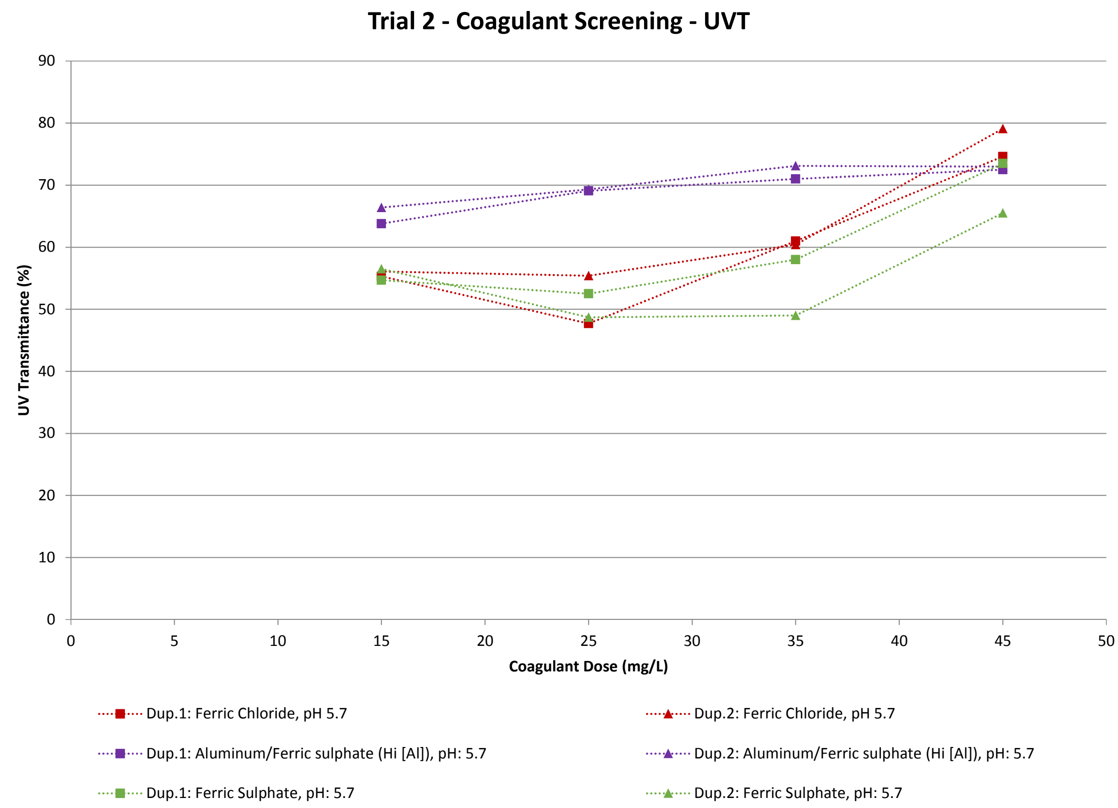
Table 2 Details of the Recommended Jar Tests

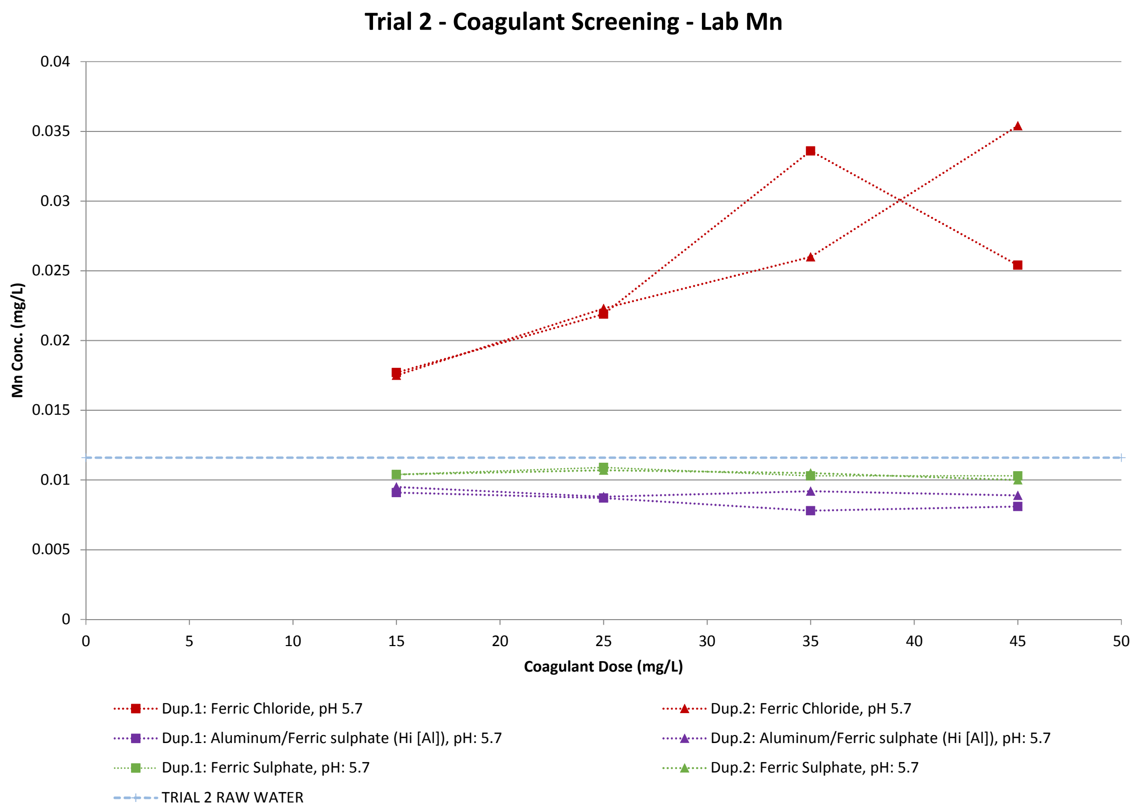
Trial #	**Description**	**Details**
2	Optimize coagulant dose	-Test 4 alternative coagulants -Reduce pH to match full-scale coagulation pH -Start with chemical doses of 15, 25, 35 and 45 mg/L -Refine by dosing ± 2 mg/L and ± 4 mg/L from the "best dose" as determined by the reduction of key parameters (Mn, turbidity, DOC, etc. as shown in Table 2 below), or, if two dosages generate equal water quality, apply four in-between doses
3	Optimize coagulation pH	-Alter pH using sulphuric acid to examine optimal coagulation pH -FeS containing coagulants tested at pH = 5, 5.3, 5.6 and 6 -AFS coagulants tested at pH = 5.5, 5.9, 6.2 and 6.5 -Refine pH by testing the best identified pH ± 0.1 and ± 0.2 unit, or four evenly spaced pH levels if two are identified as equal in the first tests -After optimal pH is established, retest the optimal coagulant dose ± 2 mg/L and ± 4 mg/L to ensure that the best dose has remained the same
4	Optimize coagulant aid (polymer addition)	-Test 3 different polymer formulations -Add 0.05, 0.1, 0.25 and 0.5 mg/L of polymer (based on dry mass) to optimized coagulant dose and pH -If 0.5 mg/L polymer is found to be the best dose, test increased concentrations (0.55, 0.7, 0.85, 1 mg/L). The maximum dose will be dictated by economic feasibility, as polymer is much more (10x or more) expensive than coagulant. If an optimal dose is not achieved by 1 mg/L, then polymer will be deemed to be unsuitable. -The lowest dose to achieve equivalent water quality will be deemed "optimal" to minimize implementation costs at full-scale

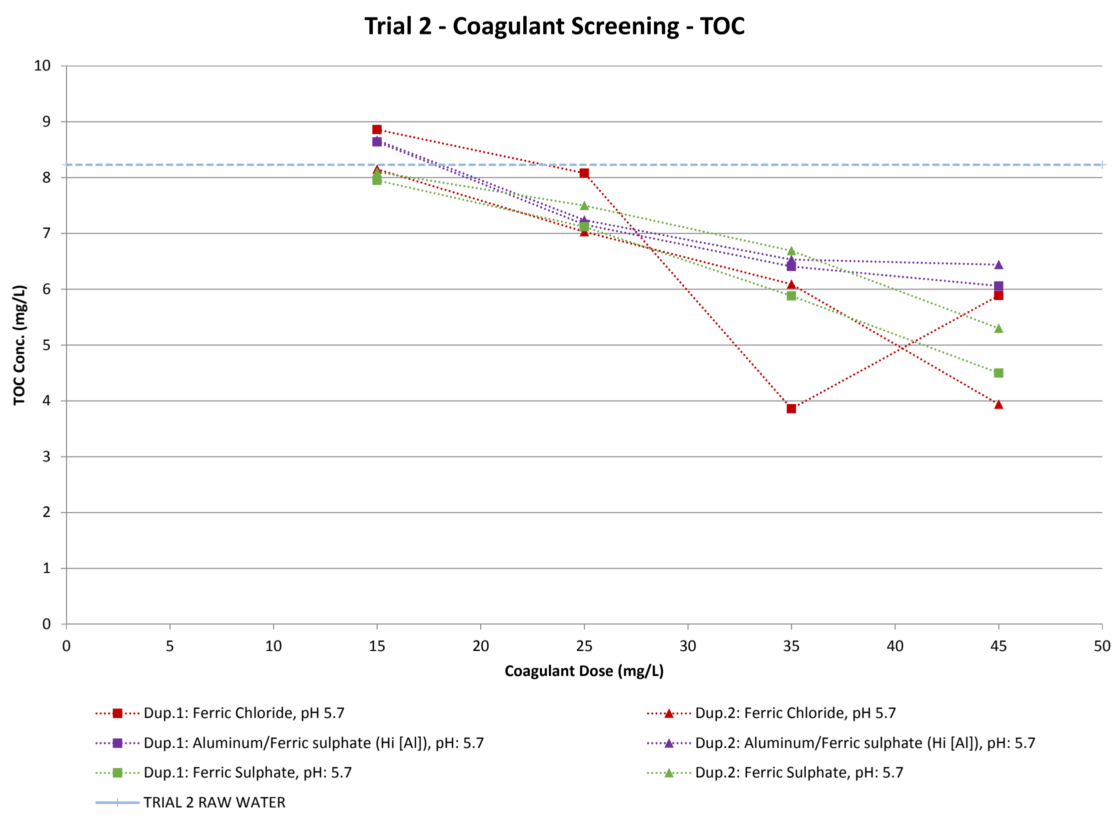
Appendix E – Second Round Bench Test Results

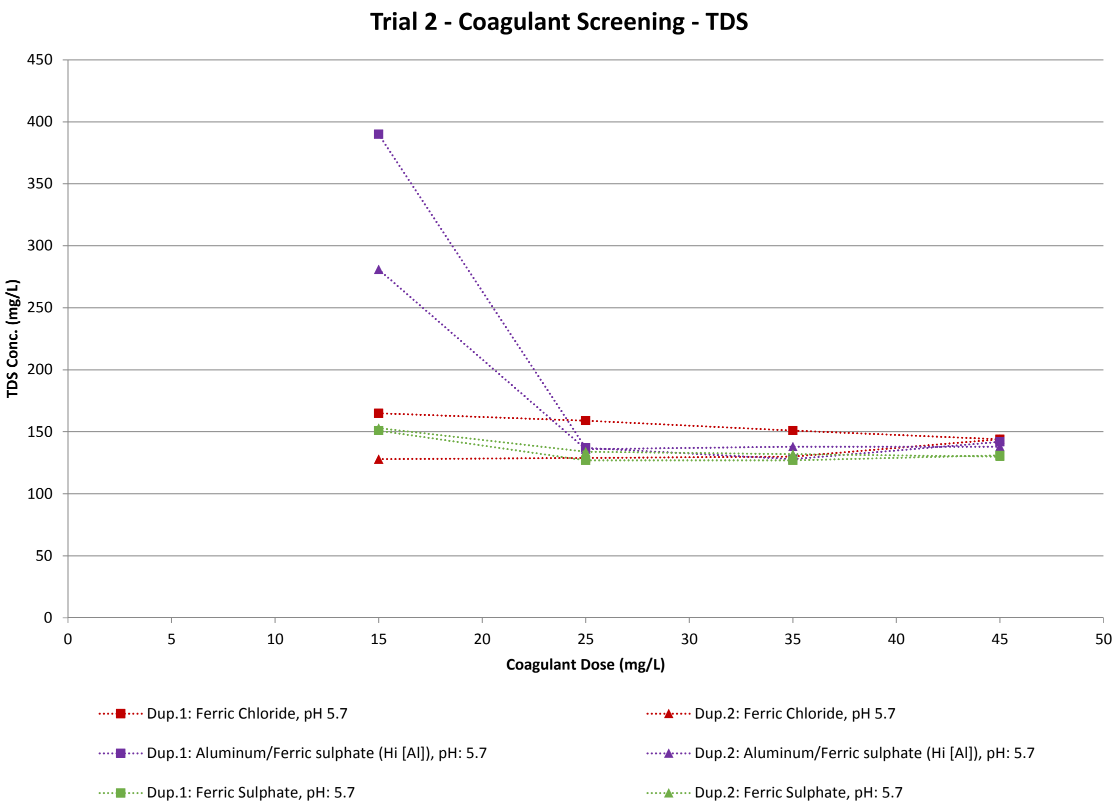

Trial 2 - Coagulant Screening - Hach Mn
Hach Mn (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

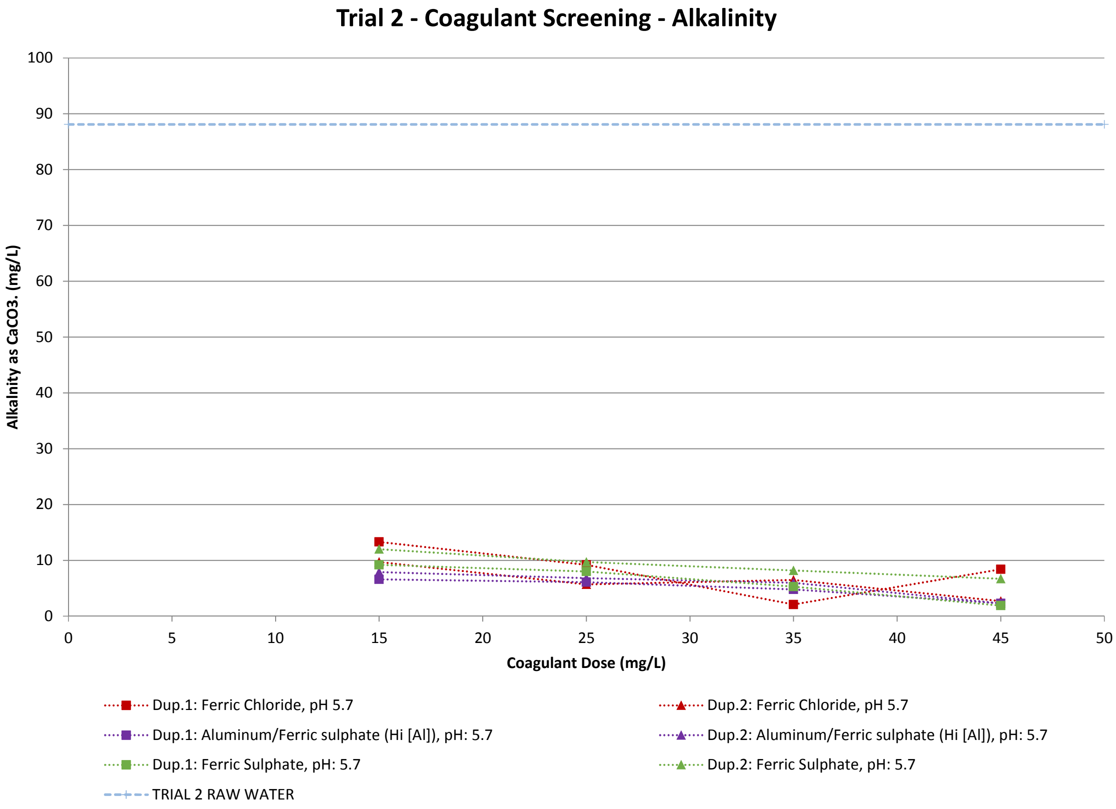

Trial 2 - Coagulant Screening - Turbidity
Turbidity (NTU)
9
8
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

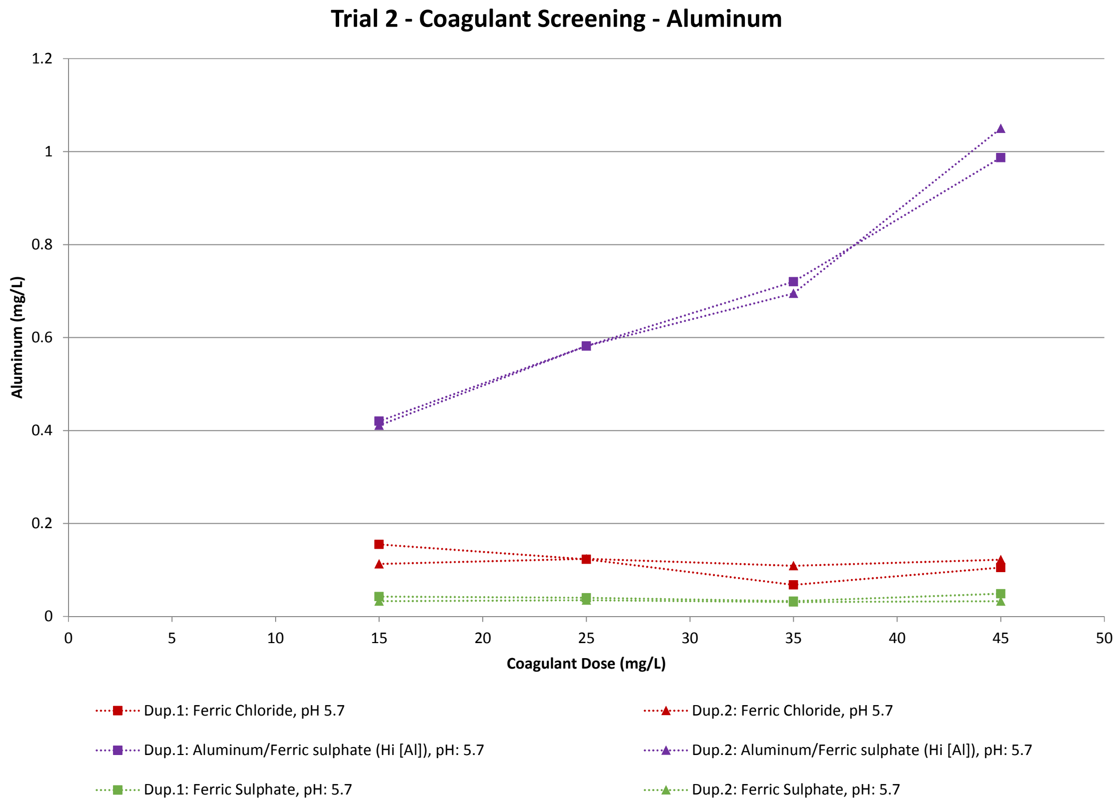

Trial 2 - Coagulant Screening - UVT
UV Transmittance (%)
0
10
20
30
40
50
60
70
80
90
Coagulant Dose (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

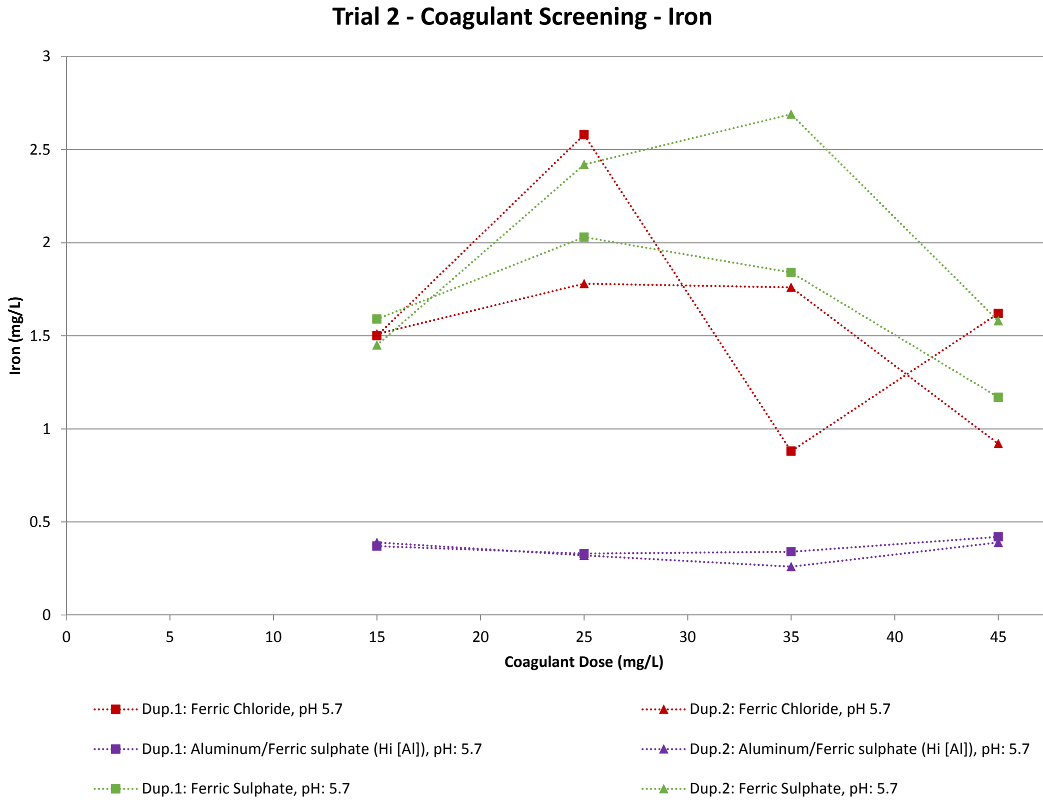

Trial 2 - Coagulant Screening - Lab Mn
Mn Conc. (mg/L)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
Coagulant Dose (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7
TRIAL 2 RAW WATER

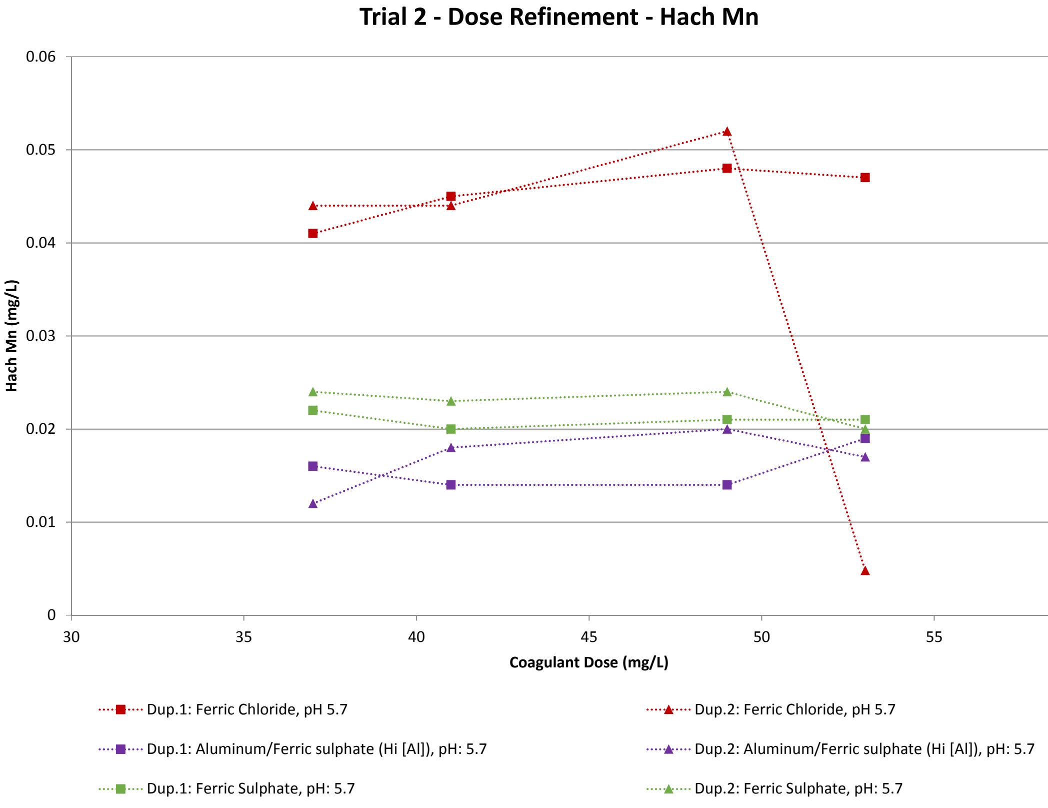

Trial 2 - Coagulant Screening - TOC
TOC Conc. (mg/L)
0
1
2
3
4
5
6
7
8
9
10
Coagulant Dose (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7
TRIAL 2 RAW WATER

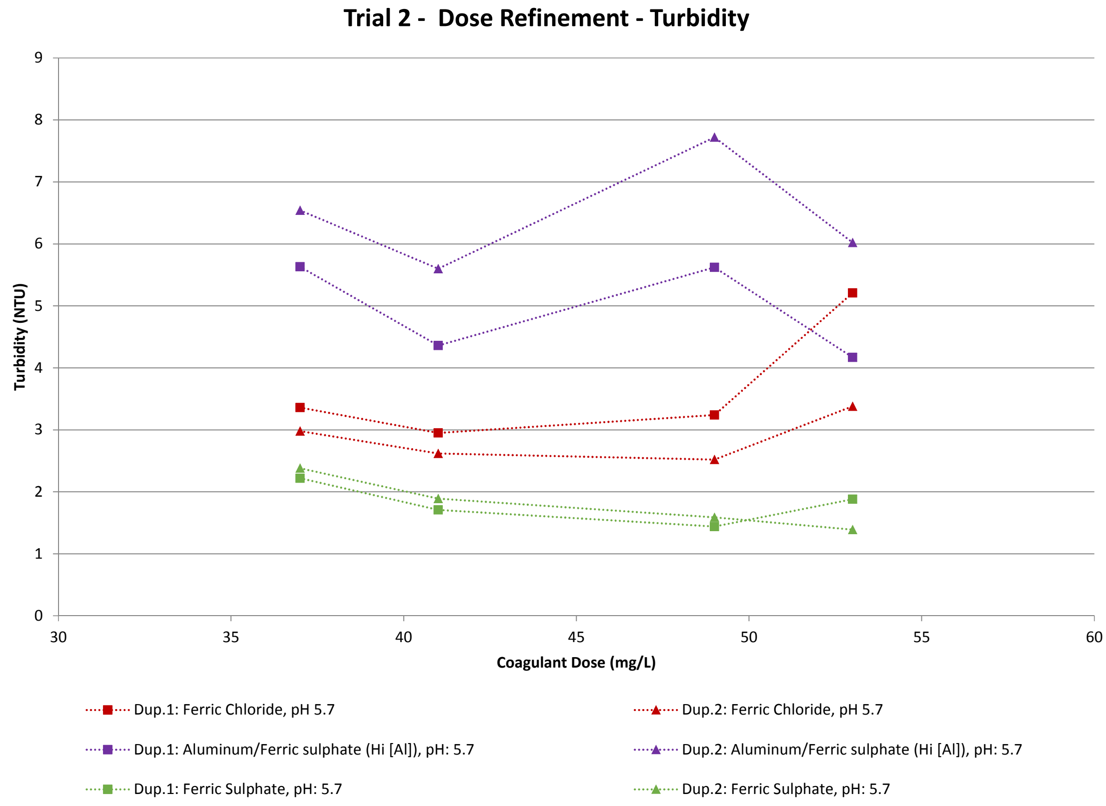

Trial 2 - Coagulant Screening - TDS
TDS Conc. (mg/L)
0
50
100
150
200
250
300
350
400
450
Coagulant Dose (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

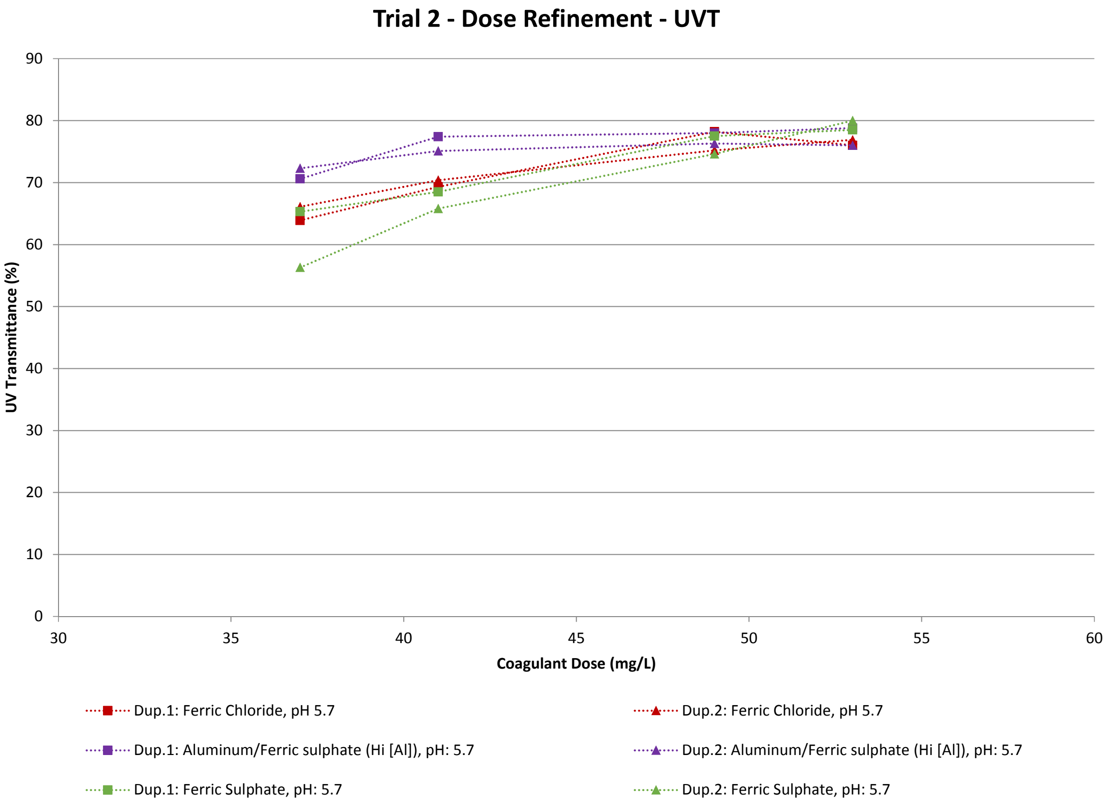

Trial 2 - Coagulant Screening - Alkalinity

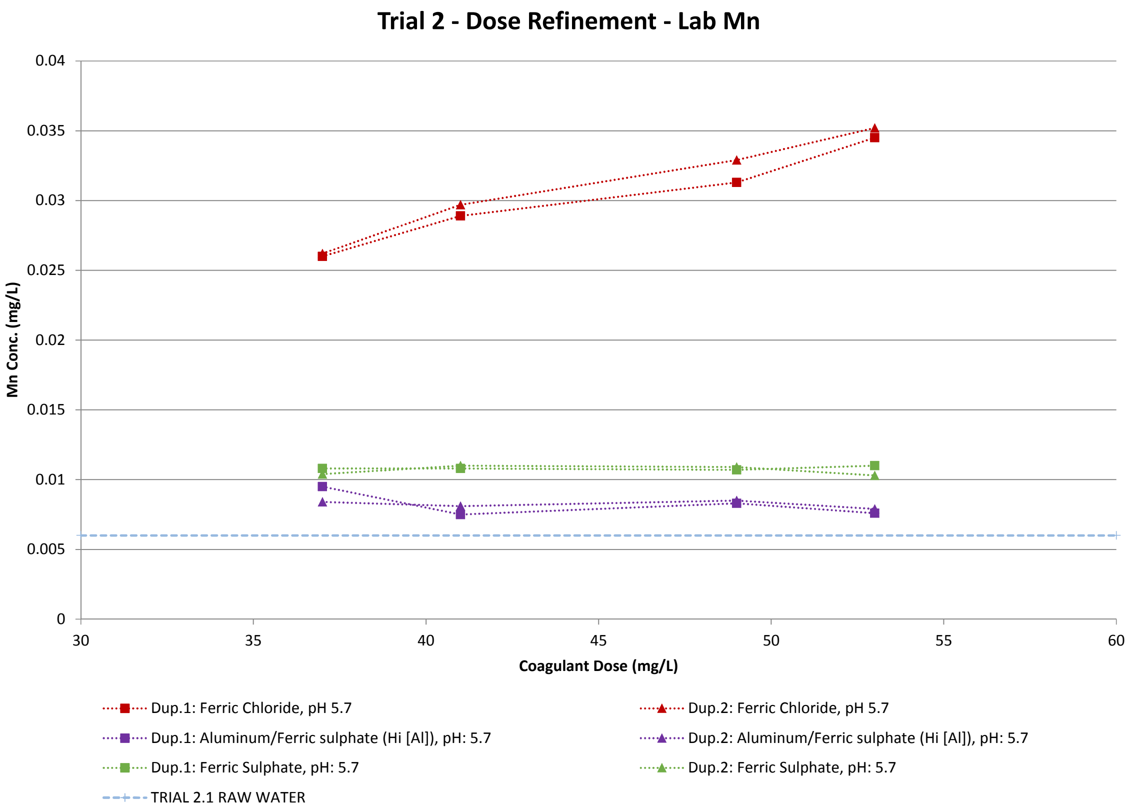

Trial 2 - Coagulant Screening - Aluminum

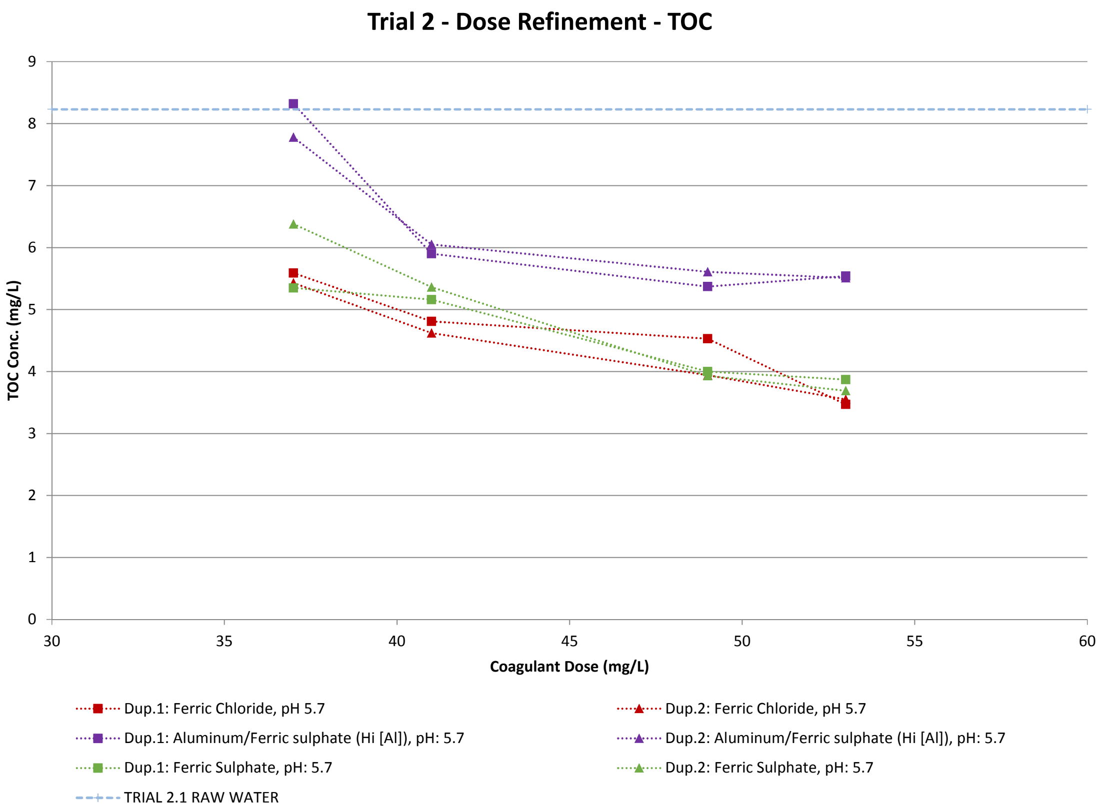

Trial 2 - Coagulant Screening - Iron
Iron (mg/L)
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
50
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

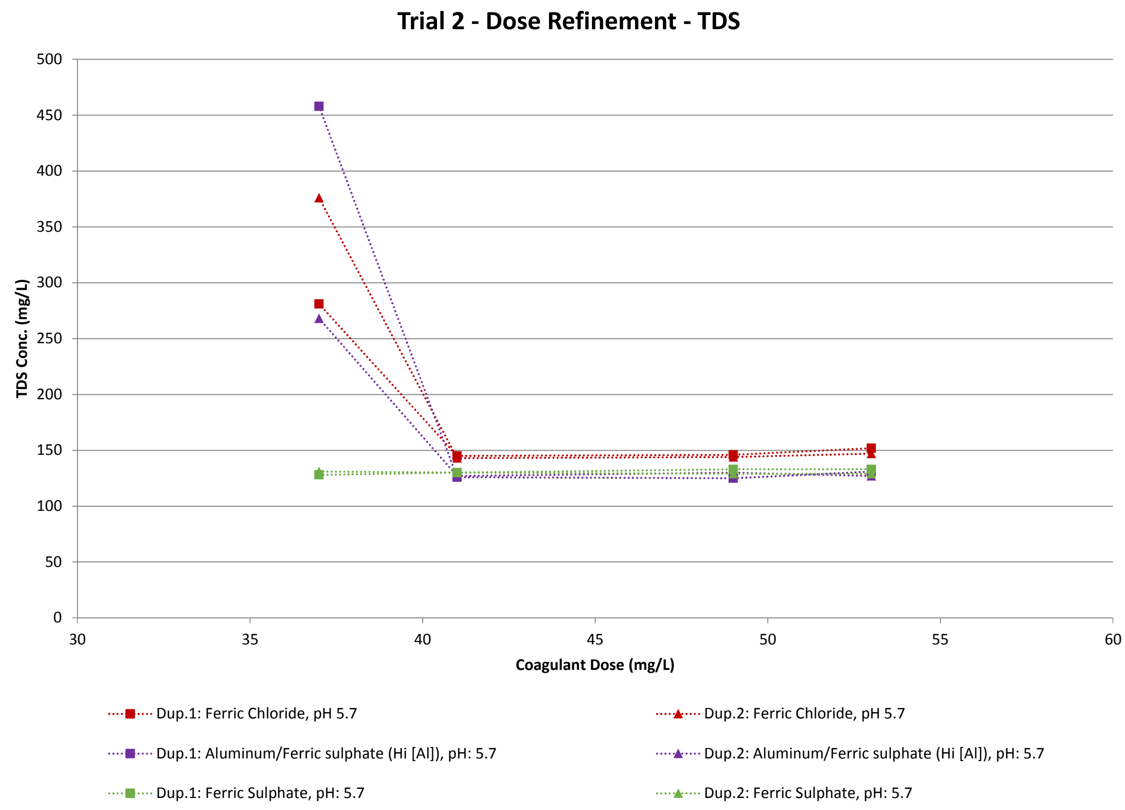

Trial 2 - Dose Refinement - Hach Mn
Hach Mn (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

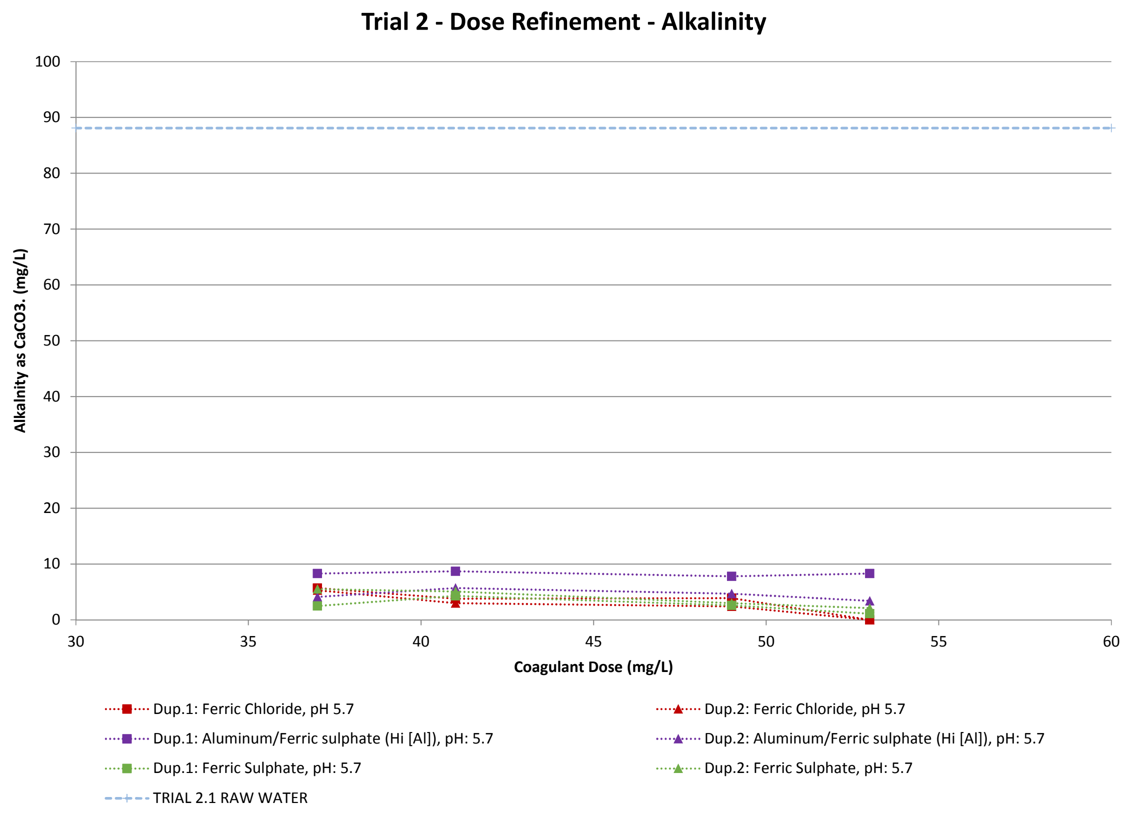

Trial 2 - Dose Refinement - Turbidity
Turbidity (NTU)
0
1
2
3
4
5
6
7
8
9
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

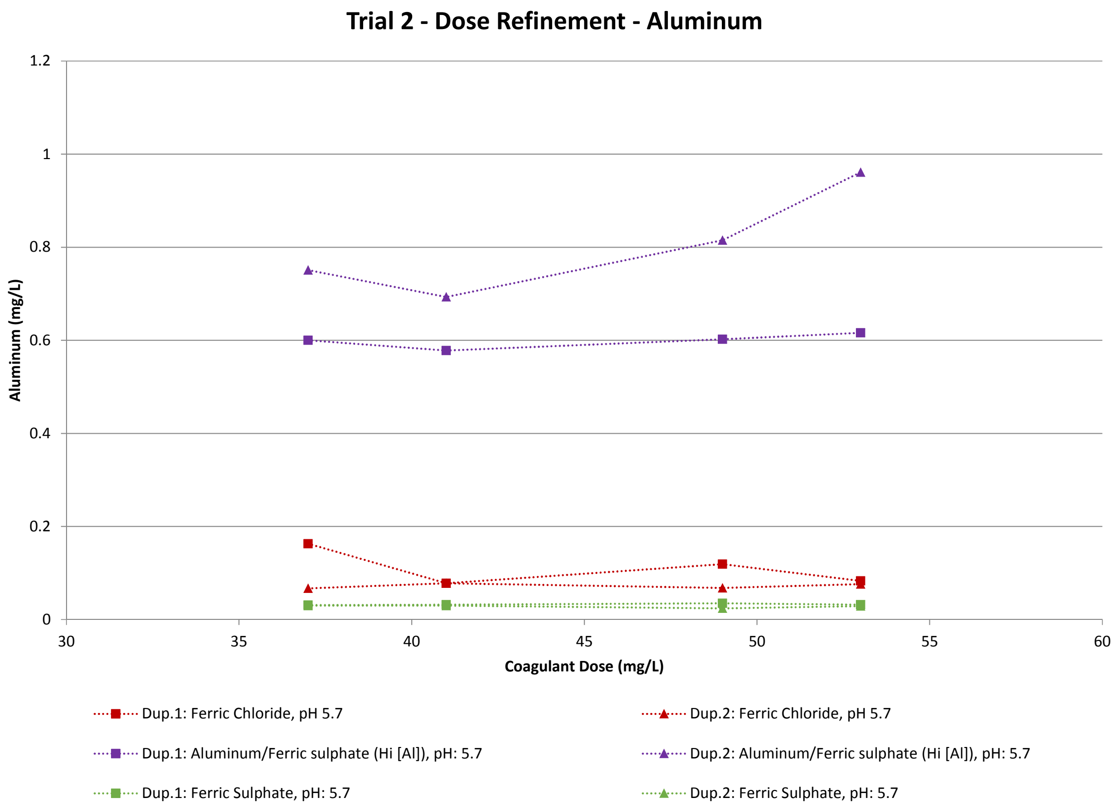

Trial 2 - Dose Refinement - UVT
UV Transmittance (%)
0
10
20
30
40
50
60
70
80
90
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

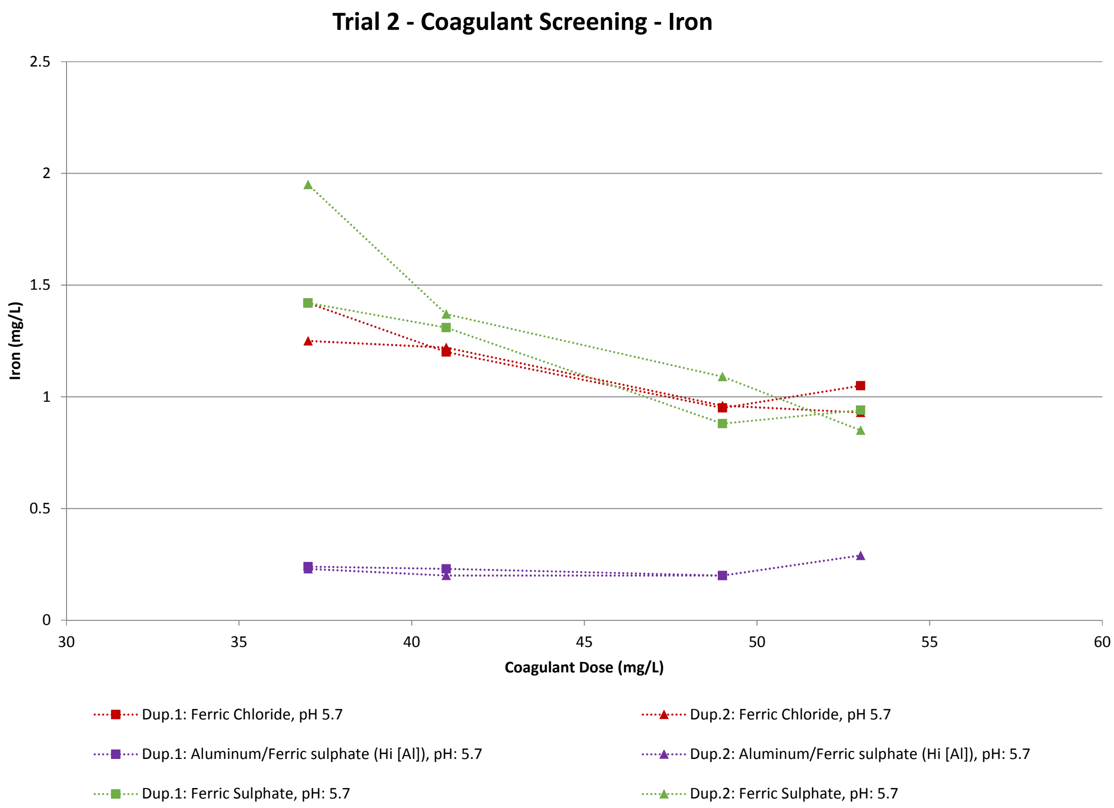

Trial 2 - Dose Refinement - Lab Mn
Mn Conc. (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7
TRIAL 2.1 RAW WATER

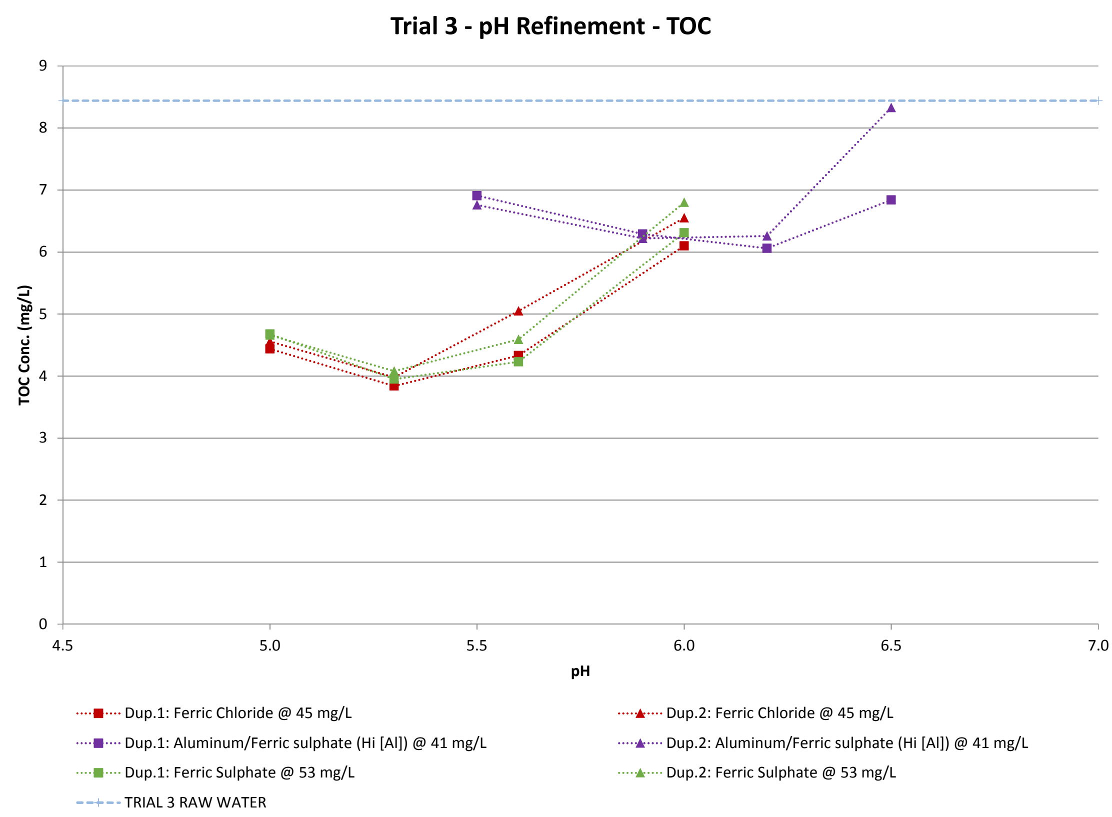

Trial 2 - Dose Refinement - TOC
TOC Conc. (mg/L)
9
8
7
6
5
4
3
2
1
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7
TRIAL 2.1 RAW WATER


Trial 2 - Dose Refinement - TDS

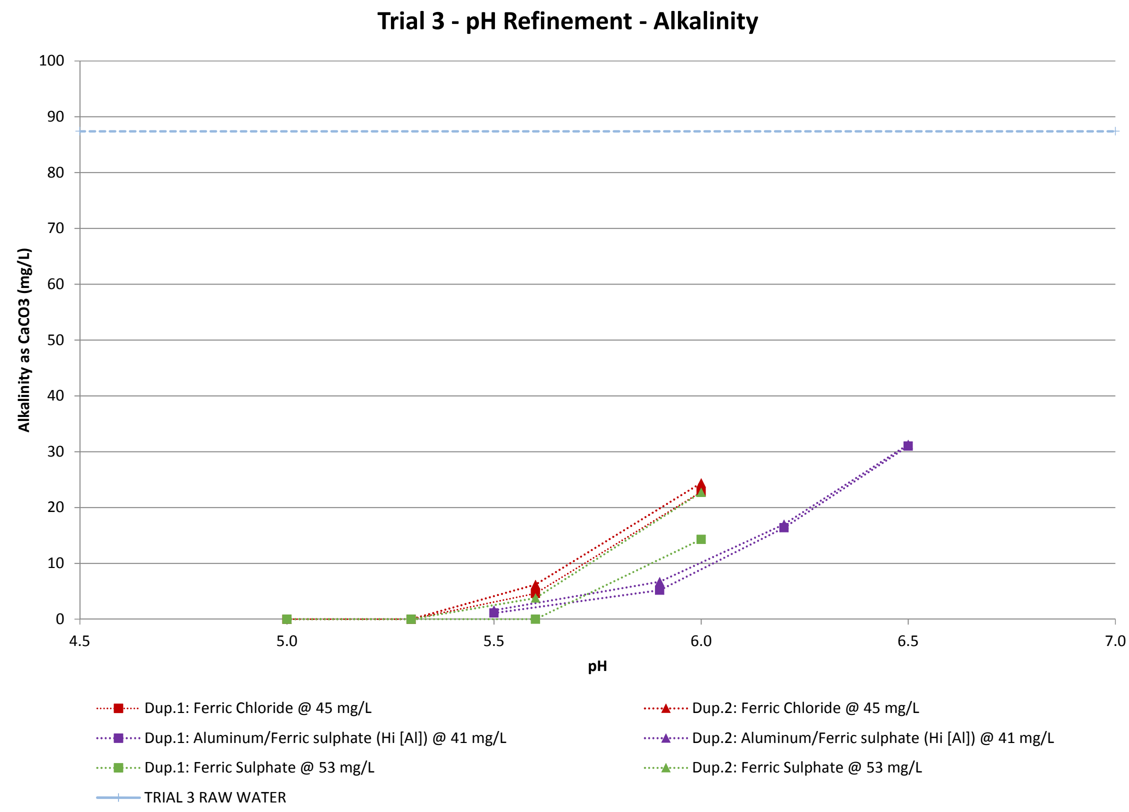

Trial 2 - Dose Refinement - Alkalinity

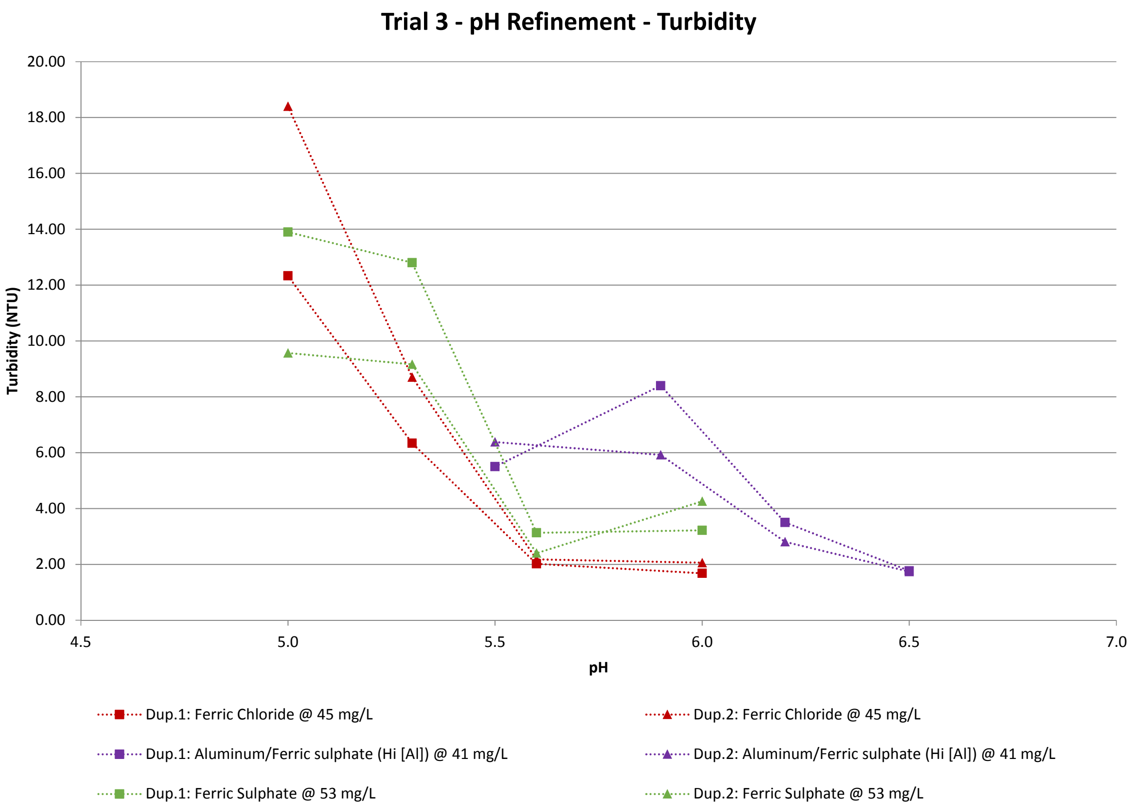

Trial 2 - Dose Refinement - Aluminum
Aluminum (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
Coagulant Dose (mg/L)
30
35
40
45
50
55
60
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

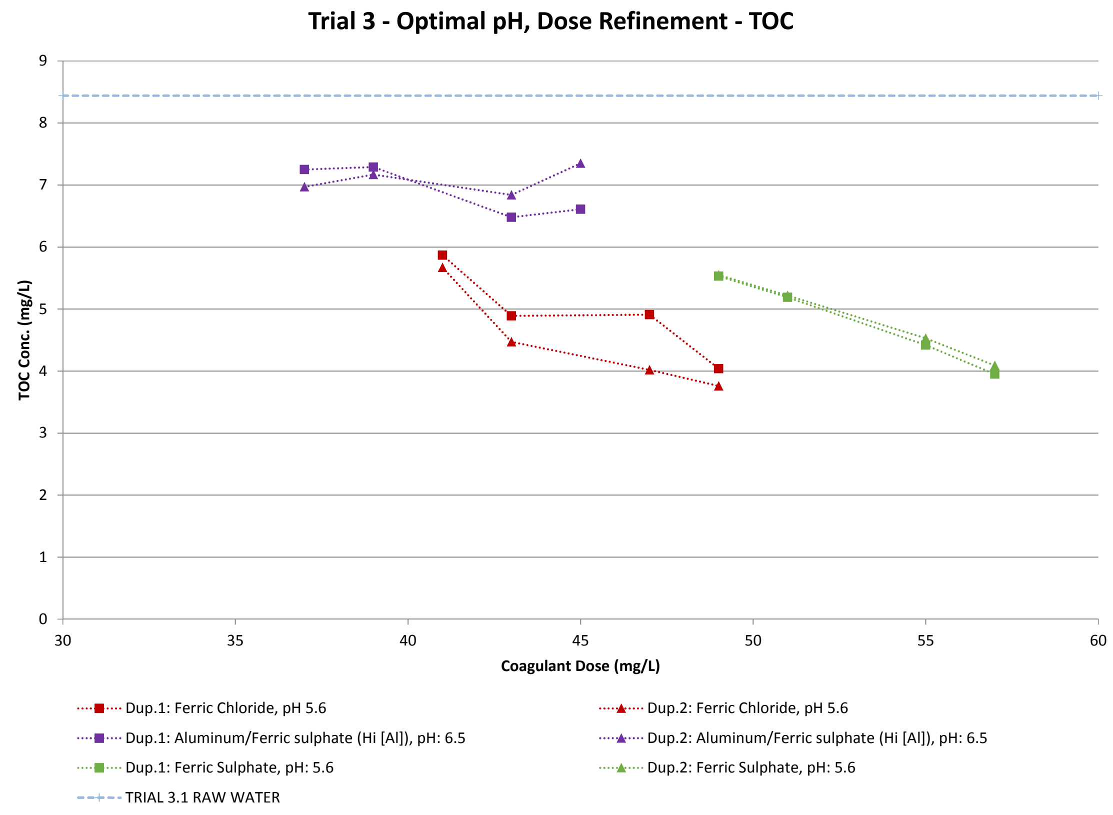

Trial 2 - Coagulant Screening - Iron
Iron (mg/L)
0
0.5
1
1.5
2
2.5
Coagulant Dose (mg/L)
30
35
40
45
50
55
60
Dup.1: Ferric Chloride, pH 5.7
Dup.2: Ferric Chloride, pH 5.7
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 5.7
Dup.1: Ferric Sulphate, pH: 5.7
Dup.2: Ferric Sulphate, pH: 5.7

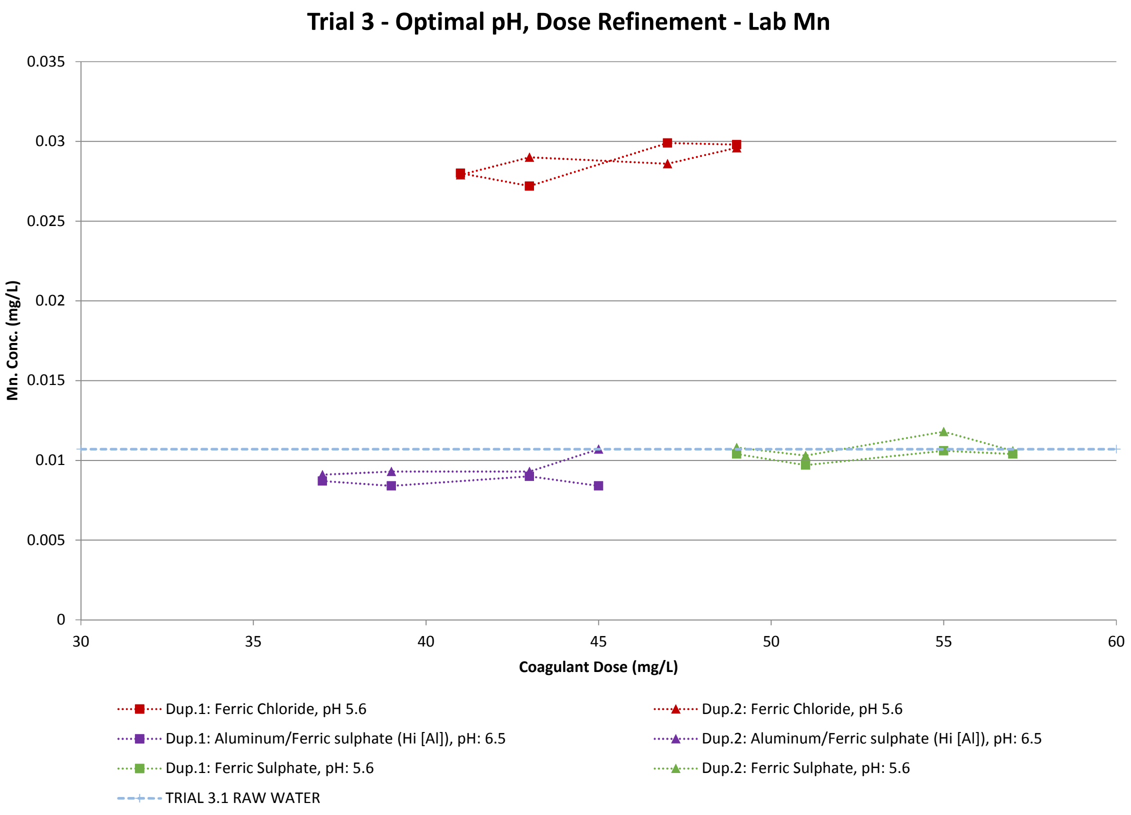

Trial 3 - pH Refinement - TOC
TOC Conc. (mg/L)
0
1
2
3
4
5
6
7
8
9
4.5
5.0
5.5
6.0
6.5
7.0
pH
Dup.1: Ferric Chloride @ 45 mg/L
Dup.2: Ferric Chloride @ 45 mg/L
Dup.1: Aluminum/Ferric sulphate (Hi [Al]) @ 41 mg/L
Dup.2: Aluminum/Ferric sulphate (Hi [Al]) @ 41 mg/L
Dup.1: Ferric Sulphate @ 53 mg/L
Dup.2: Ferric Sulphate @ 53 mg/L
TRIAL 3 RAW WATER

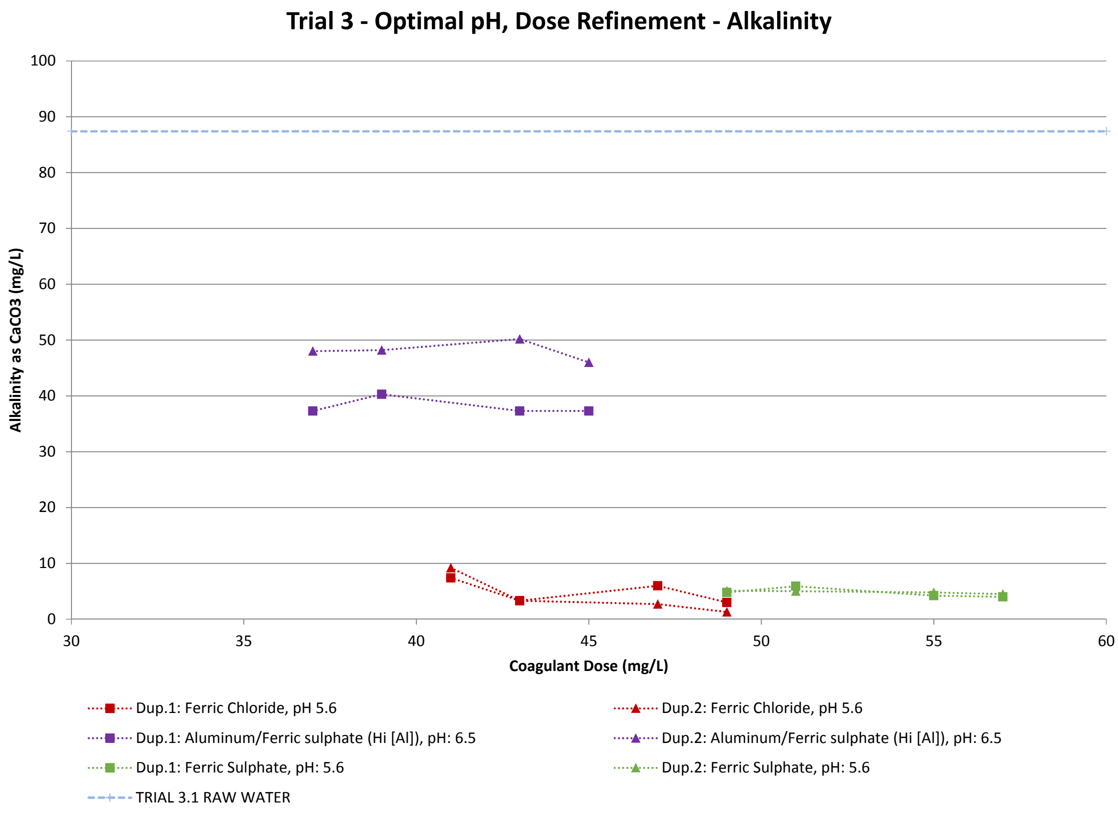

Trial 3 - pH Refinement - Lab Mn
Mn. Conc. (mg/L)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
4.5
5.0
5.5
6.0
6.5
7.0
pH
Dup.1: Ferric Chloride @ 45 mg/L
Dup.2: Ferric Chloride @ 45 mg/L
Dup.1: Aluminum/Ferric sulphate (Hi [Al]) @ 41 mg/L
Dup.2: Aluminum/Ferric sulphate (Hi [Al]) @ 41 mg/L
Dup.1: Ferric Sulphate @ 53 mg/L
Dup.2: Ferric Sulphate @ 53 mg/L
TRIAL 3 RAW WATER

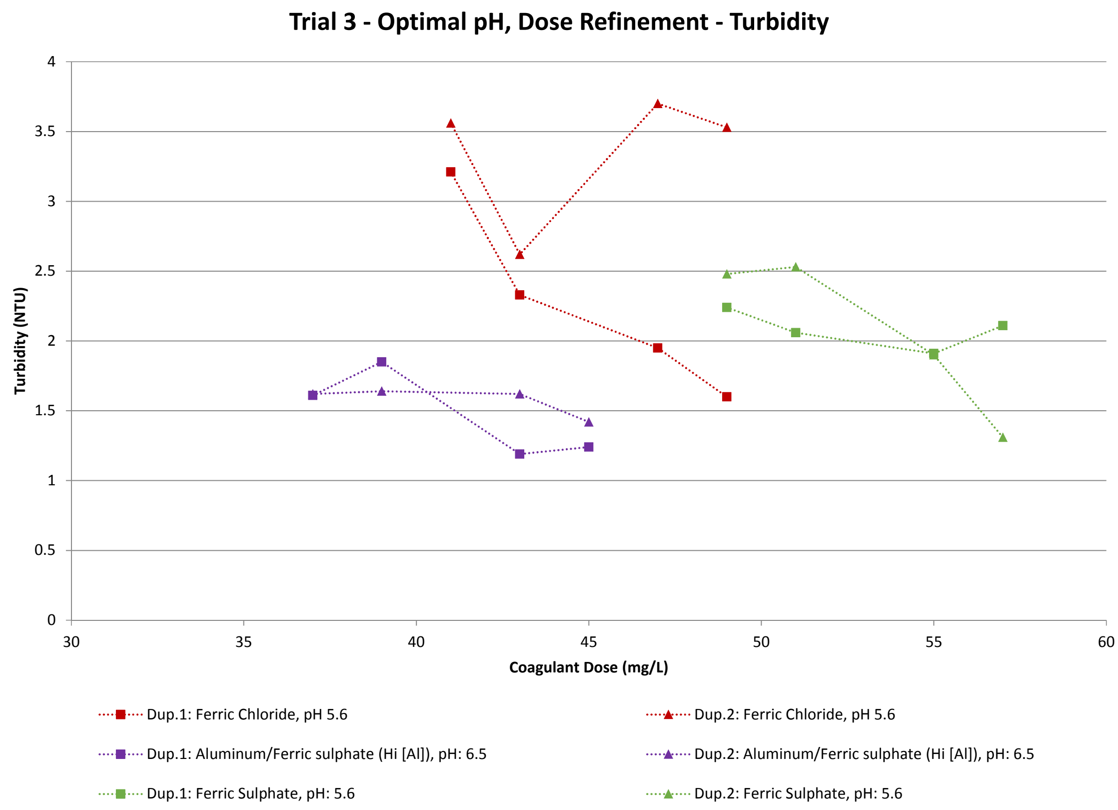

Trial 3 - pH Refinement - Alkalinity
Alkalinity as CaCO3 (mg/L)
100
90
80
70
60
50
40
30
20
10
0
4.5
5.0
5.5
6.0
6.5
7.0
pH
Dup.1: Ferric Chloride @ 45 mg/L
Dup.2: Ferric Chloride @ 45 mg/L
Dup.1: Aluminum/Ferric sulphate (Hi [Al]) @ 41 mg/L
Dup.2: Aluminum/Ferric sulphate (Hi [Al]) @ 41 mg/L
Dup.1: Ferric Sulphate @ 53 mg/L
Dup.2: Ferric Sulphate @ 53 mg/L
TRIAL 3 RAW WATER

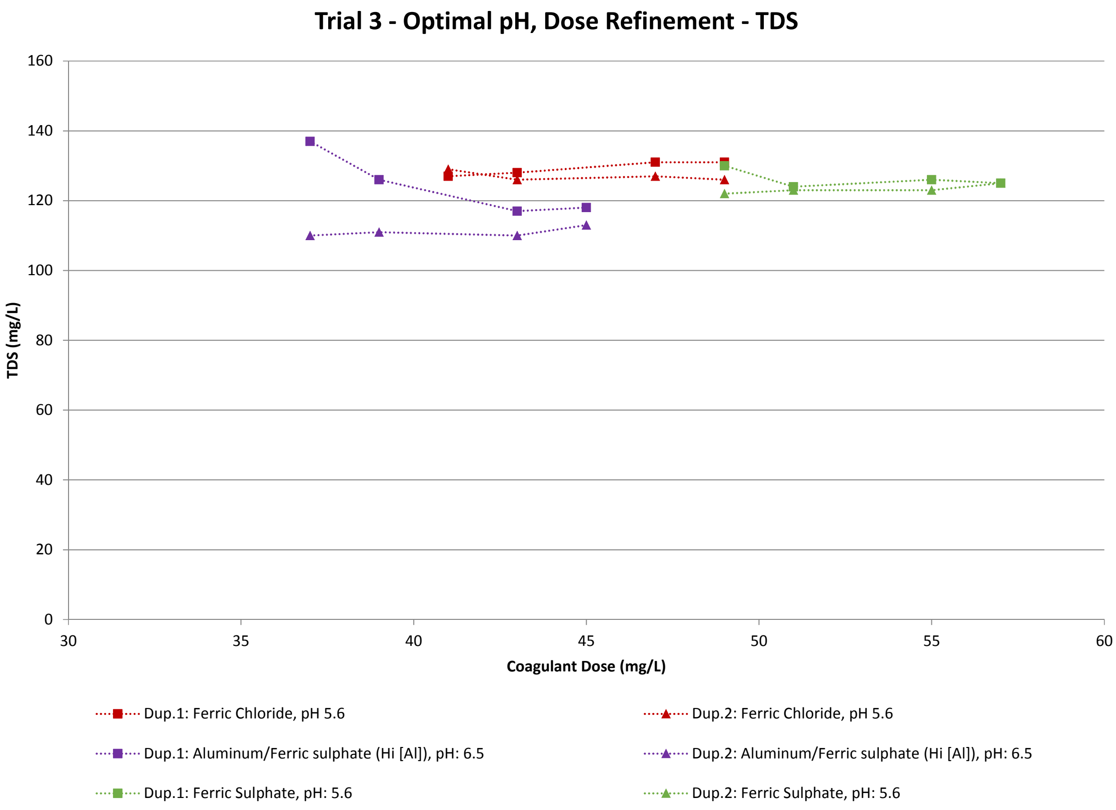

Trial 3 - pH Refinement - Turbidity
Turbidity (NTU)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
4.5
5.0
5.5
6.0
6.5
7.0
pH
Dup.1: Ferric Chloride @ 45 mg/L
Dup.2: Ferric Chloride @ 45 mg/L
Dup.1: Aluminum/Ferric sulphate (Hi [Al]) @ 41 mg/L
Dup.2: Aluminum/Ferric sulphate (Hi [Al]) @ 41 mg/L
Dup.1: Ferric Sulphate @ 53 mg/L
Dup.2: Ferric Sulphate @ 53 mg/L

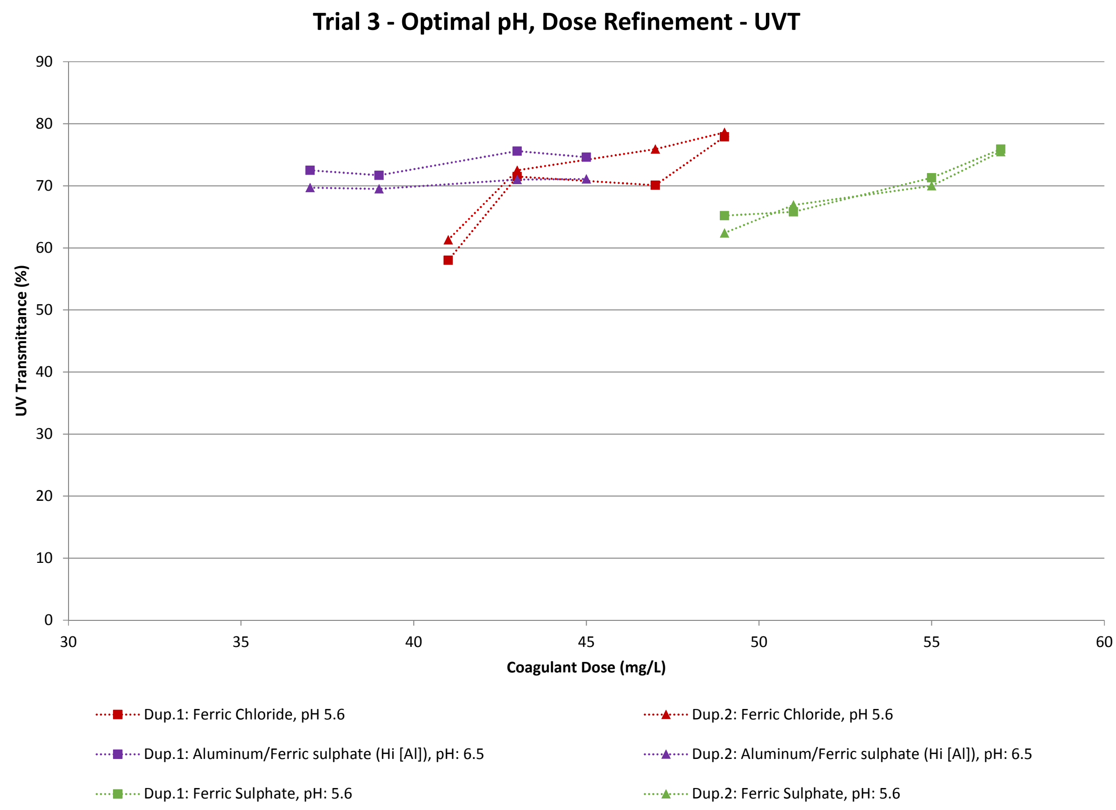

Trial 3 - Optimal pH, Dose Refinement - TOC
TOC Conc. (mg/L)
0
1
2
3
4
5
6
7
8
9
Coagulant Dose (mg/L)
30
35
40
45
50
55
60
Dup.1: Ferric Chloride, pH 5.6
Dup.2: Ferric Chloride, pH 5.6
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.1: Ferric Sulphate, pH: 5.6
Dup.2: Ferric Sulphate, pH: 5.6
TRIAL 3.1 RAW WATER

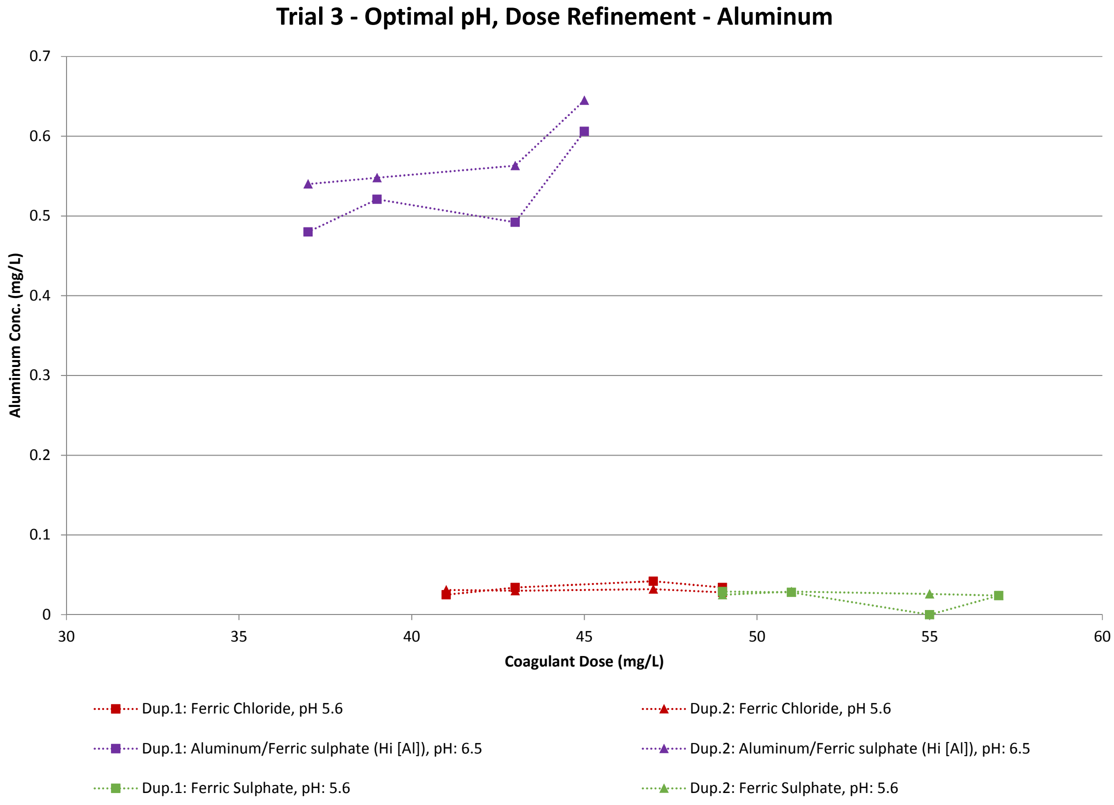

Trial 3 - Optimal pH, Dose Refinement - Lab Mn
Mn. Conc. (mg/L)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
Coagulant Dose (mg/L)
30
35
40
45
50
55
60
Dup.1: Ferric Chloride, pH 5.6
Dup.2: Ferric Chloride, pH 5.6
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.1: Ferric Sulphate, pH: 5.6
Dup.2: Ferric Sulphate, pH: 5.6
TRIAL 3.1 RAW WATER

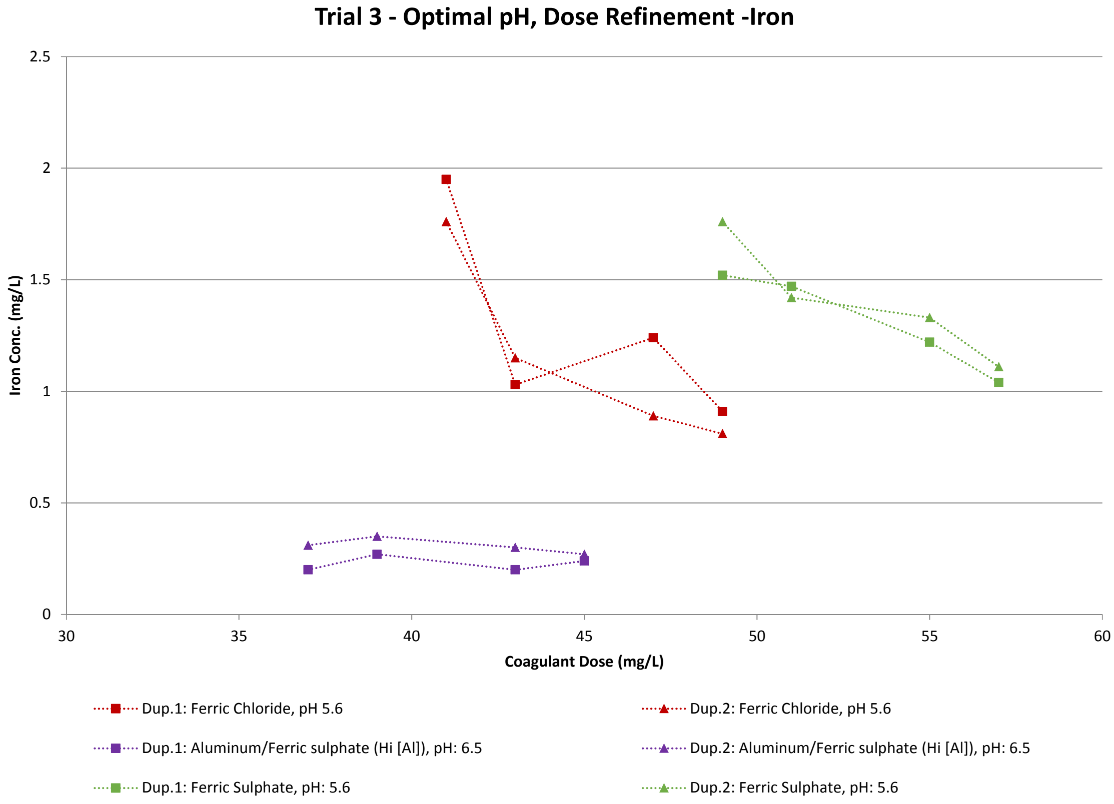

Trial 3 - Optimal pH, Dose Refinement - Alkalinity
Alkalinity as CaCO3 (mg/L)
100
90
80
70
60
50
40
30
20
10
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.6
Dup.2: Ferric Chloride, pH 5.6
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.1: Ferric Sulphate, pH: 5.6
Dup.2: Ferric Sulphate, pH: 5.6
TRIAL 3.1 RAW WATER

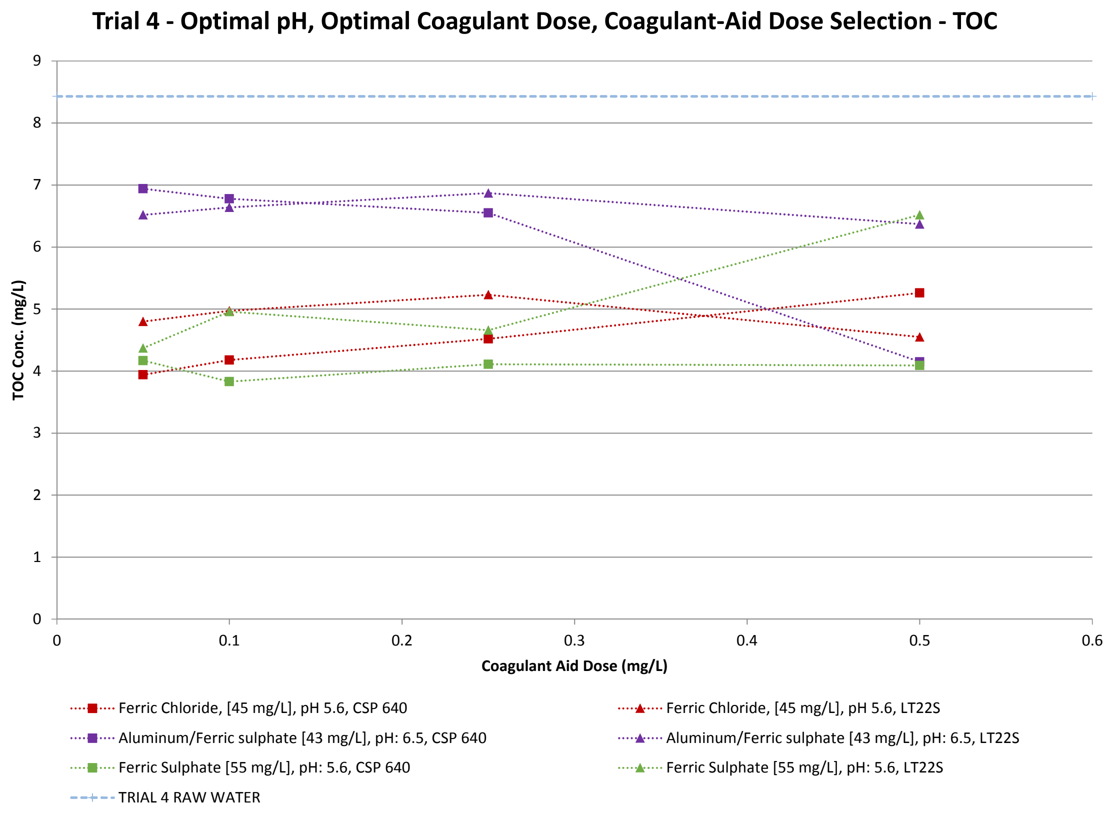

Trial 3 - Optimal pH, Dose Refinement - Turbidity
Turbidity (NTU)
4
3.5
3
2.5
2
1.5
1
0.5
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.6
Dup.2: Ferric Chloride, pH 5.6
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.1: Ferric Sulphate, pH: 5.6
Dup.2: Ferric Sulphate, pH: 5.6

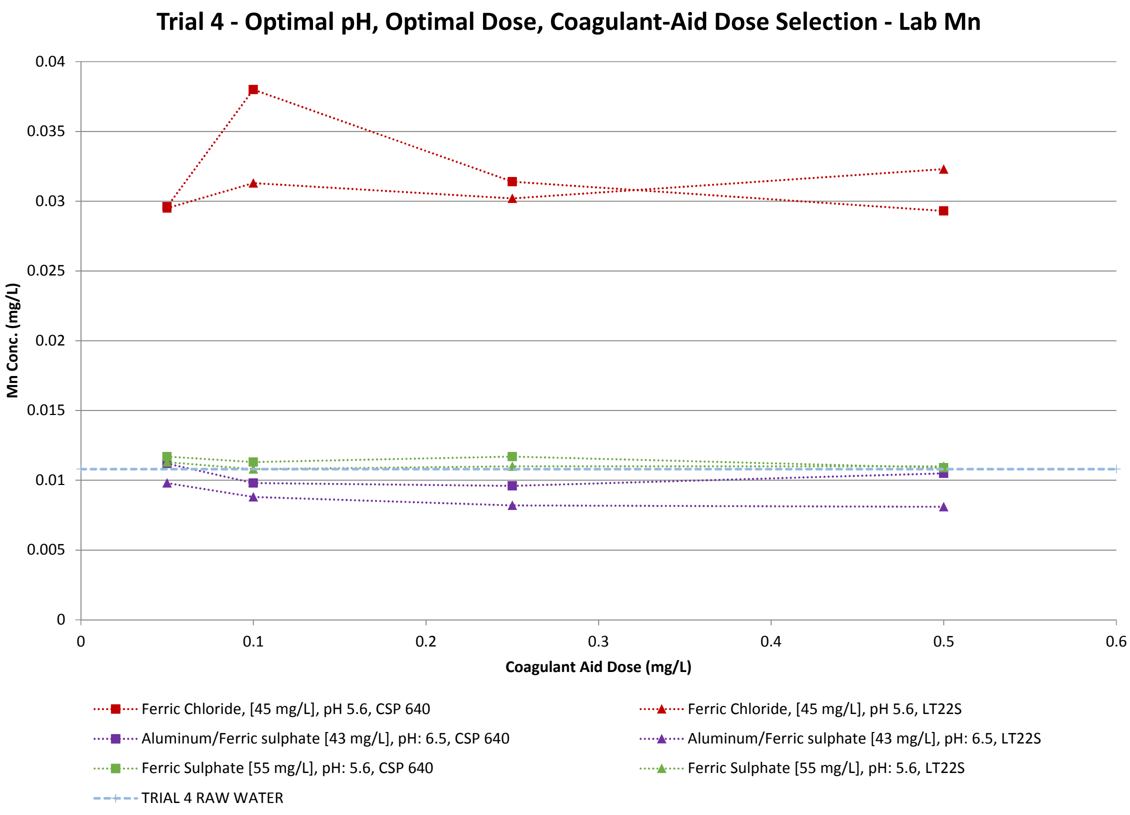

Trial 3 - Optimal pH, Dose Refinement - TDS
TDS (mg/L)
160
140
120
100
80
60
40
20
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.6
Dup.2: Ferric Chloride, pH 5.6
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.1: Ferric Sulphate, pH: 5.6
Dup.2: Ferric Sulphate, pH: 5.6

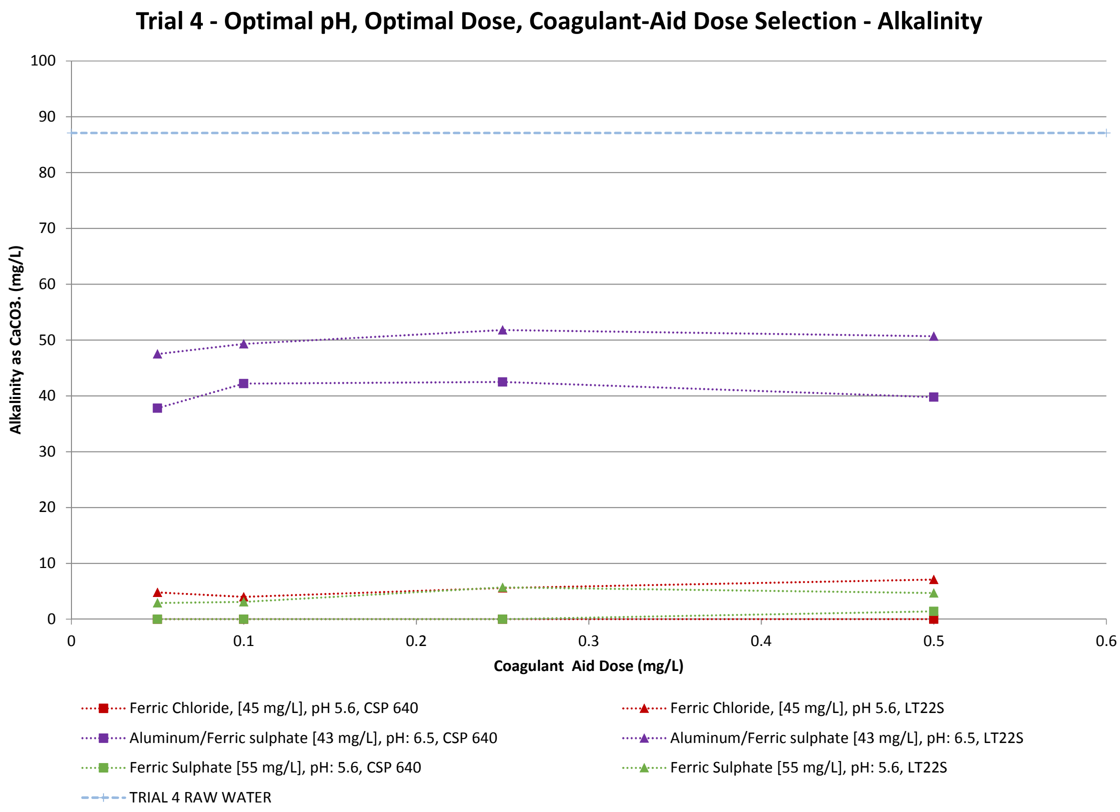

Trial 3 - Optimal pH, Dose Refinement - UVT
UV Transmittance (%)
90
80
70
60
50
40
30
20
10
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.6
Dup.2: Ferric Chloride, pH 5.6
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.1: Ferric Sulphate, pH: 5.6
Dup.2: Ferric Sulphate, pH: 5.6

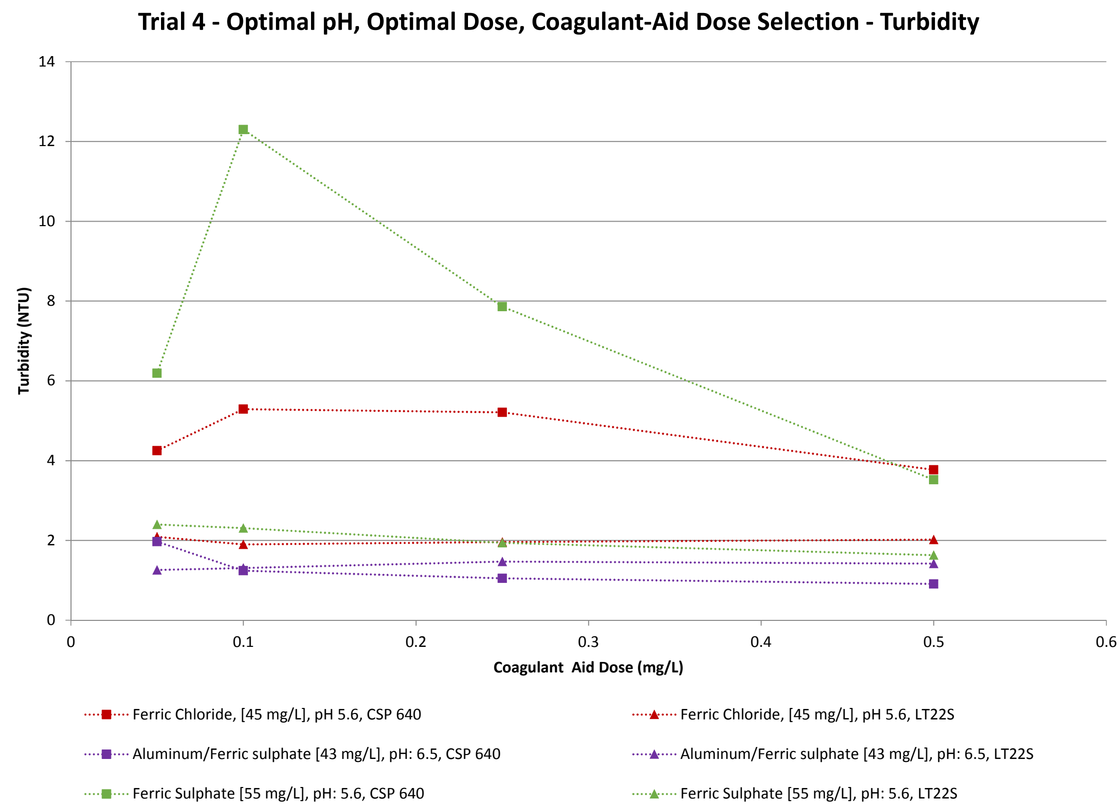

Trial 3 - Optimal pH, Dose Refinement - Aluminum
Aluminum Conc. (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.6
Dup.2: Ferric Chloride, pH 5.6
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.1: Ferric Sulphate, pH: 5.6
Dup.2: Ferric Sulphate, pH: 5.6

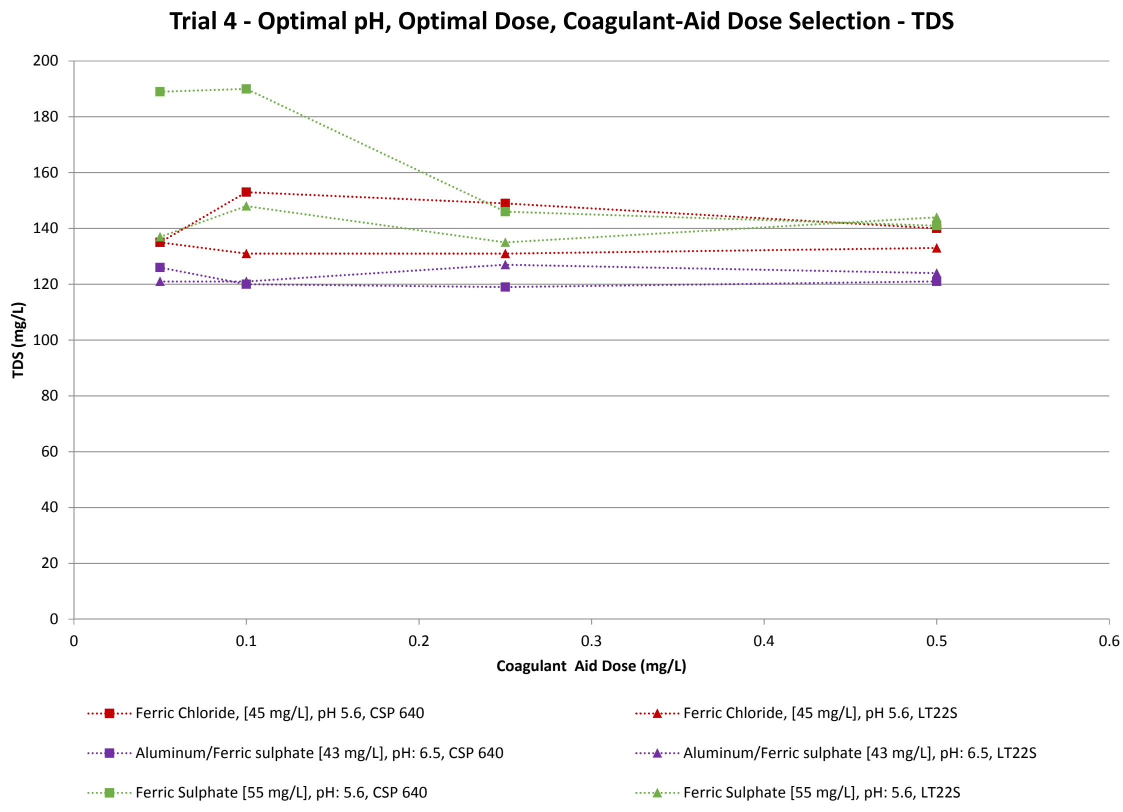

Trial 3 - Optimal pH, Dose Refinement -Iron
Iron Conc. (mg/L)
2.5
2
1.5
1
0.5
0
30
35
40
45
50
55
60
Coagulant Dose (mg/L)
Dup.1: Ferric Chloride, pH 5.6
Dup.2: Ferric Chloride, pH 5.6
Dup.1: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.2: Aluminum/Ferric sulphate (Hi [Al]), pH: 6.5
Dup.1: Ferric Sulphate, pH: 5.6
Dup.2: Ferric Sulphate, pH: 5.6

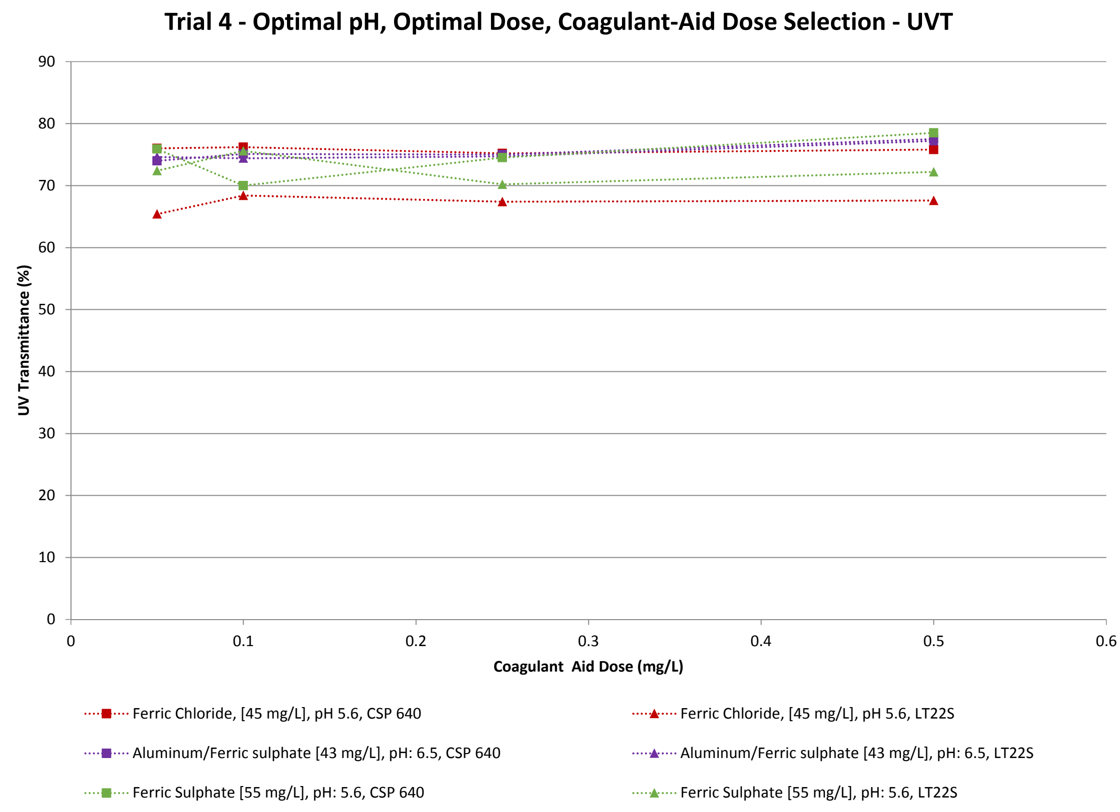

Trial 4 - Optimal pH, Optimal Coagulant Dose, Coagulant-Aid Dose Selection - TOC
TOC Conc. (mg/L)
9
8
7
6
5
4
3
2
1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant Aid Dose (mg/L)
Ferric Chloride, [45 mg/L], pH 5.6, CSP 640
Ferric Chloride, [45 mg/L], pH 5.6, LT22S
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, CSP 640
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, LT22S
Ferric Sulphate [55 mg/L], pH: 5.6, CSP 640
Ferric Sulphate [55 mg/L], pH: 5.6, LT22S
TRIAL 4 RAW WATER

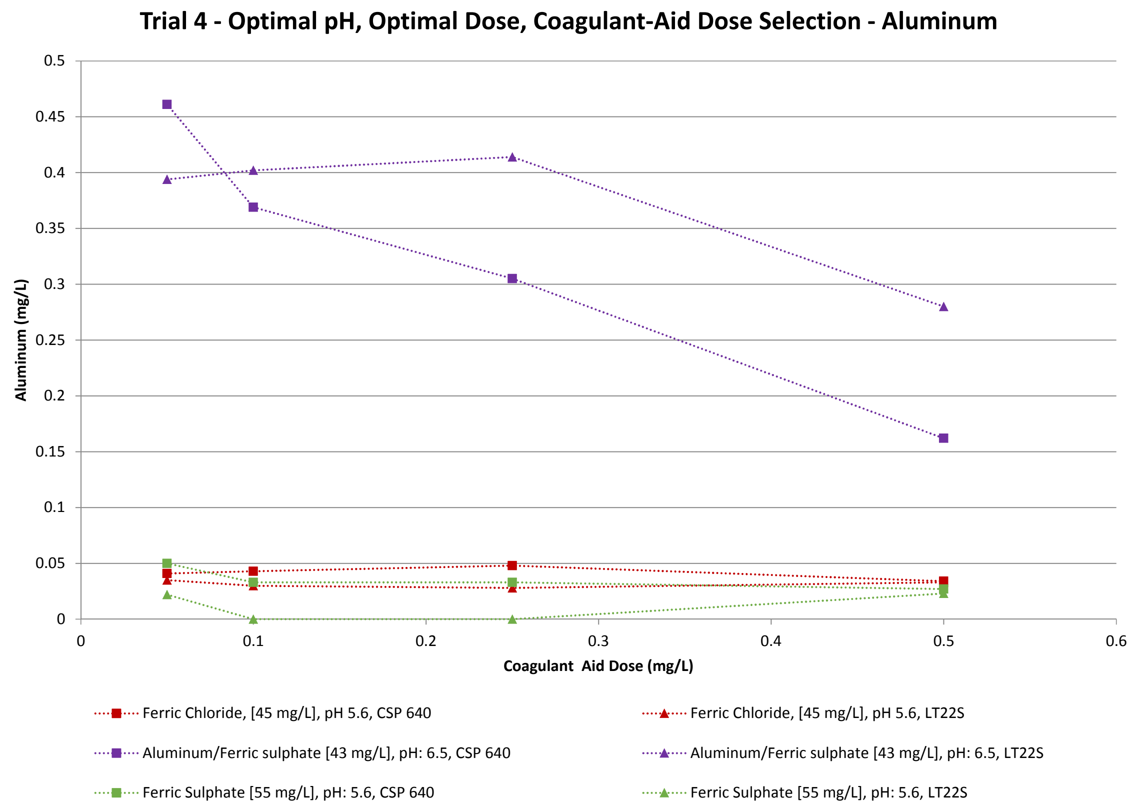

Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - Lab Mn
Mn Conc. (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant Aid Dose (mg/L)
Ferric Chloride, [45 mg/L], pH 5.6, CSP 640
Ferric Chloride, [45 mg/L], pH 5.6, LT22S
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, CSP 640
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, LT22S
Ferric Sulphate [55 mg/L], pH: 5.6, CSP 640
Ferric Sulphate [55 mg/L], pH: 5.6, LT22S
TRIAL 4 RAW WATER

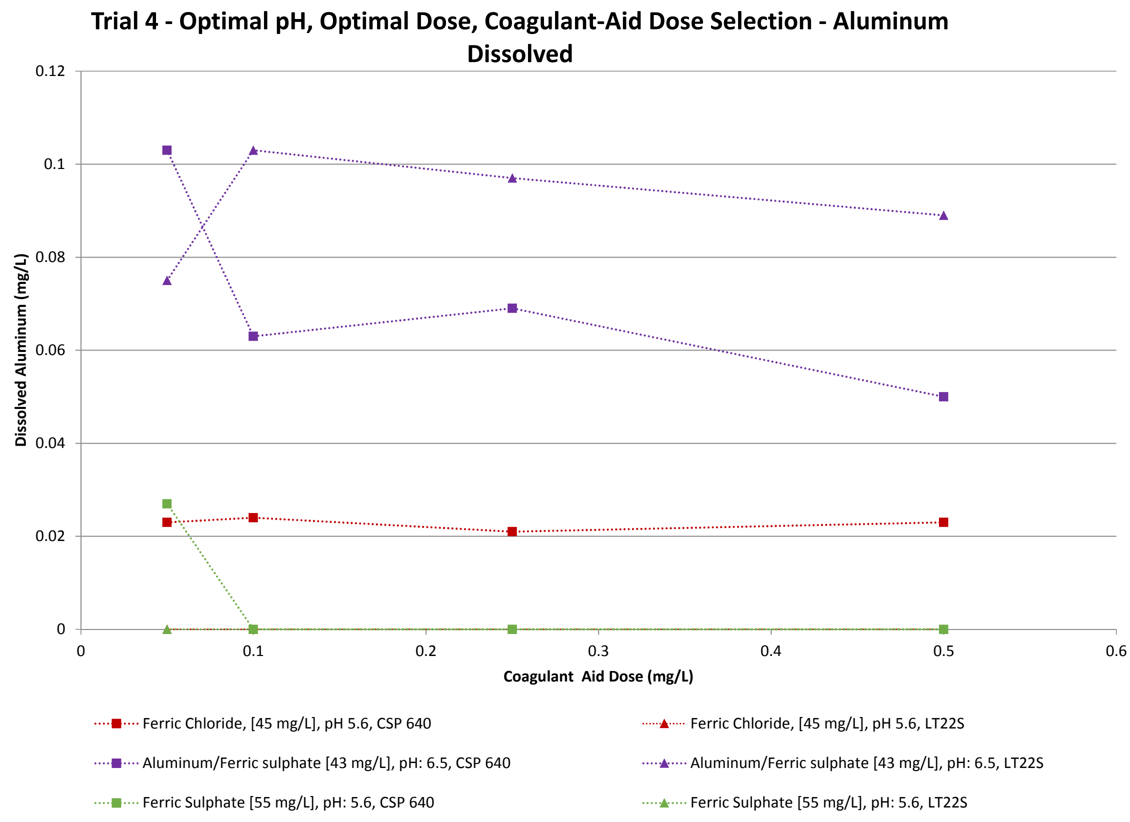

Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - Alkalinity
Alkalinity as CaCO3. (mg/L)
100
90
80
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant Aid Dose (mg/L)
Ferric Chloride, [45 mg/L], pH 5.6, CSP 640
Ferric Chloride, [45 mg/L], pH 5.6, LT22S
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, CSP 640
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, LT22S
Ferric Sulphate [55 mg/L], pH: 5.6, CSP 640
Ferric Sulphate [55 mg/L], pH: 5.6, LT22S
TRIAL 4 RAW WATER


Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - Turbidity
Turbidity (NTU)
14
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant Aid Dose (mg/L)
Ferric Chloride, [45 mg/L], pH 5.6, CSP 640
Ferric Chloride, [45 mg/L], pH 5.6, LT22S
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, CSP 640
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, LT22S
Ferric Sulphate [55 mg/L], pH: 5.6, CSP 640
Ferric Sulphate [55 mg/L], pH: 5.6, LT22S

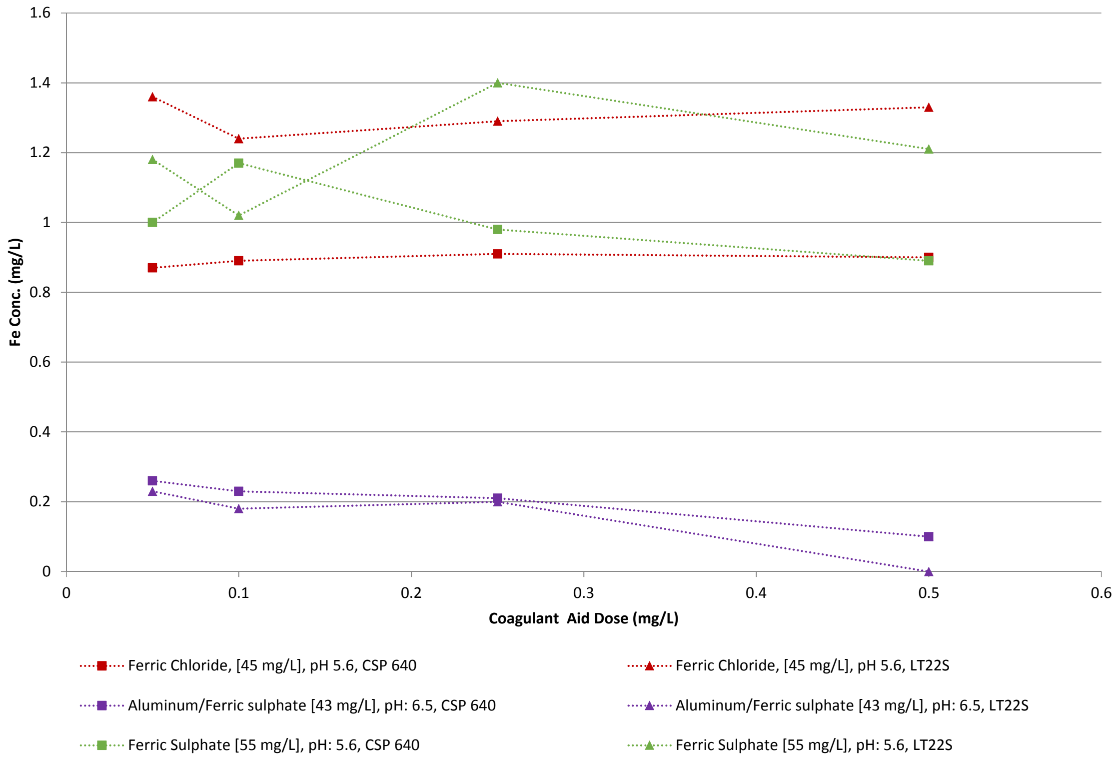

Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - TDS
TDS (mg/L)
0
20
40
60
80
100
120
140
160
180
200
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant Aid Dose (mg/L)
Ferric Chloride, [45 mg/L], pH 5.6, CSP 640
Ferric Chloride, [45 mg/L], pH 5.6, LT22S
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, CSP 640
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, LT22S
Ferric Sulphate [55 mg/L], pH: 5.6, CSP 640
Ferric Sulphate [55 mg/L], pH: 5.6, LT22S


Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - UVT
UV Transmittance (%)
0
10
20
30
40
50
60
70
80
90
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant Aid Dose (mg/L)
Ferric Chloride, [45 mg/L], pH 5.6, CSP 640
Ferric Chloride, [45 mg/L], pH 5.6, LT22S
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, CSP 640
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, LT22S
Ferric Sulphate [55 mg/L], pH: 5.6, CSP 640
Ferric Sulphate [55 mg/L], pH: 5.6, LT22S

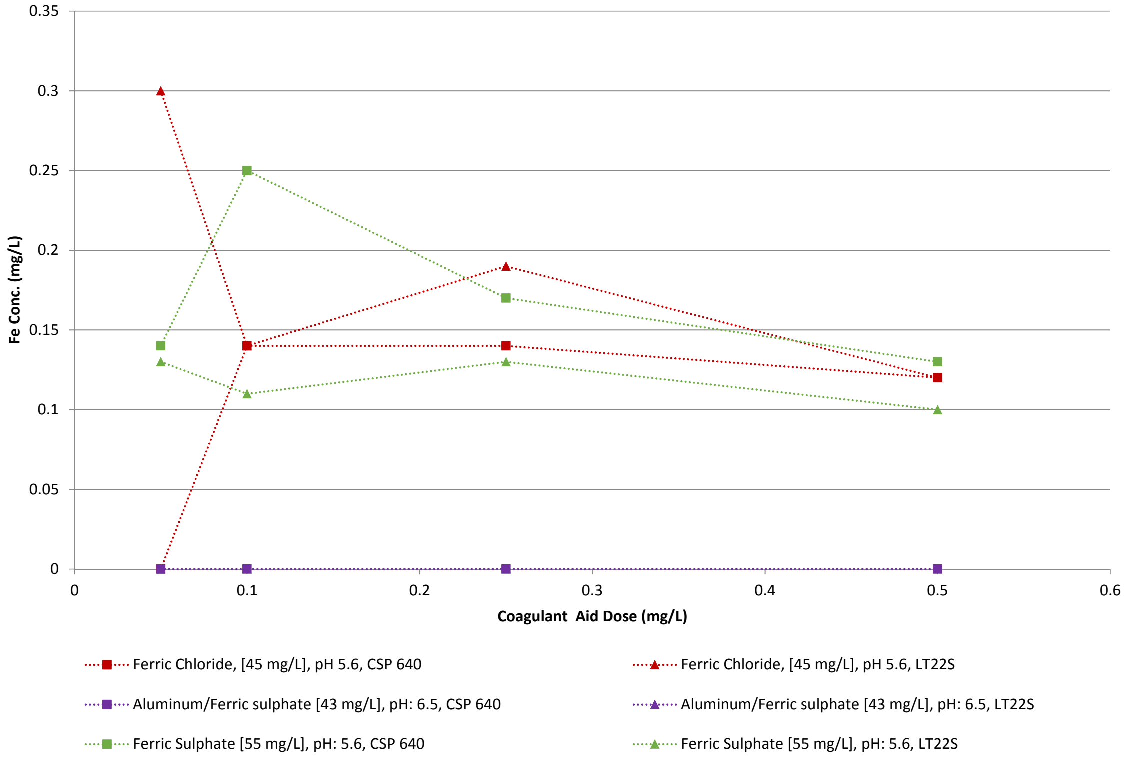

Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - Aluminum
Aluminum (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant Aid Dose (mg/L)
Ferric Chloride, [45 mg/L], pH 5.6, CSP 640
Ferric Chloride, [45 mg/L], pH 5.6, LT22S
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, CSP 640
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, LT22S
Ferric Sulphate [55 mg/L], pH: 5.6, CSP 640
Ferric Sulphate [55 mg/L], pH: 5.6, LT22S


Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - Aluminum Dissolved
Dissolved Aluminum (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Coagulant Aid Dose (mg/L)
Ferric Chloride, [45 mg/L], pH 5.6, CSP 640
Ferric Chloride, [45 mg/L], pH 5.6, LT22S
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, CSP 640
Aluminum/Ferric sulphate [43 mg/L], pH: 6.5, LT22S
Ferric Sulphate [55 mg/L], pH: 5.6, CSP 640
Ferric Sulphate [55 mg/L], pH: 5.6, LT22S

Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - Iron



Trial 4 - Optimal pH, Optimal Dose, Coagulant-Aid Dose Selection - Iron Dissolved



APPENDIX

B

TM NO. 2

DEVELOPMENT OF COAGULANT PILOTING WORK PROGRAM

TECHNICAL MEMORANDUM NO. 2

Project:	Pilot Testing an Alternative Coagulant for the Winnipeg Water Treatment Plant
Date:	May 10th, 2018
To:	Heather Buhler, City of Winnipeg
From:	Maika Pellegrino (WSP), Justin Rak-Banville (WSP), Robert Andrews (AHA), Ron Hofmann (AHA)
Project No.:	161-06111-00
Location:	Winnipeg Water Treatment Plant
Subject:	Development of Coagulant Piloting Work Program – Rev. 05 (FINAL)

1. Introduction

Since 2010, only a year after the Winnipeg Water Treatment Plant (WTP) was commissioned, the City of Winnipeg (City) has received customer inquiries and service requests regarding discoulored water. From previous studies carried out, it was established that the manganese (Mn) content in the treated water was the main reason for the discoloured water complaints. The sources of Mn were attributed to the raw water and the current coagulant chemical used (ferric chloride). The Winnipeg WTP treatment train cannot remove Mn to levels below 0.02 mg/L (the level at which water discoloration is detectable through observation). WSP was retained to select and test an alternative coagulant for the Winnipeg WTP that reduces the concentration of Mn in treated water without negatively impacting any of the other water quality parameters. The current project is divided into four phases: Review of Background Information, Developing the Coagulant Piloting Work program, piloting an alternative coagulant and Reporting. Phases 1 and 2 are discussed in the following sections.

Technical Memorandum No. 2 (TM No. 2) presents the Coagulant Piloting Work program developed, including the benchmarking and transition period for all piloting sessions (Winter, Direct Filtration, Spring, Summer and Fall). Results of each piloting session will be presented in upcoming technical memoranda (TMs). These TMs will also highlight any changes and deviations from this program. The final report will compile all the changes from the program and recommend the ones to be retained for future sessions.

Based on the request for proposal (RFP), the City will be responsible for pilot operation during benchmarking and coagulant transition periods, while WSP staff will be responsible for the testing of an alternative coagulant.

2. Review of Background Information

In Phase 1, WSP conducted a detailed review of the background information, which included various WTP reports, previous pilot studies, drawings, review of water quality data, and current operational parameters in the WTP and the distribution system. Based on the results of this review, the full-scale performance of the existing coagulant was benchmarked and used as a baseline for the evaluation of the coagulants for use in each of the four seasons. Furthermore, several coagulant types were identified and studied to ensure compliance with the evaluative criteria set by the City. Among them, candidate coagulants, including the coagulant currently in use, were selected and presented to the City in Technical Memorandum 1A (TM No.1A).

The bench testing program was developed during July and August of 2016, and the first-round bench testing was performed in September and October. A second bench test was performed in January 2017 for confirmatory purposes. The analysis of results was carried out and the results presented in Technical Memorandum 1 (TM No.1). The coagulants and coagulant-aids tested in the Bench Scale tests are summarized in Table 2-1 and Table 2-2 below.

Table 2-1 Bench Tested Coagulants Characteristics

Coagulant	Ferric Chloride	Ferric Chloride / Ferric Sulfate Blend	Ferric Sulfate	Blend 1 - Aluminum Ferric Sulfate	Blend 2 - Aluminum Ferric Sulfate
Constituent	$FeCl_3$	50% $FeCl_3$ 50% $Fe_2(SO_4)_3$	$Fe_2(SO_4)_3$	50% $Al_2(SO_4)_3.18H_2O$ 50% $Fe_2(SO_4)_3$	70% $Al_2(SO_4)_3.18H_2O$ 30% $Fe_2(SO_4)_3$
Concentration (%)	37% - 42%	40% - 42%	43%	45% - 46%	46% - 47%
Specific gravity	1.38 - 1.45	1.45 – 1.50	1.55	1.44	1.38
Iron Content (%$_{w/w}$)	12.7 -14.1%	12% - 13.5%	11.5-13%	6.0%	3.28%
Aluminum Content (%$_{w/w}$)	-	-	-	2.2%	3.0%
Suppliers	Kemira	Kemira	Kemira	Kemira	Kemira

Note: Even though Kemira is the only vendor that market these coagulant blends, these are not proprietary blends and other vendors that commercialize the main products (Brenntag and Univar) are able to supply these products.

Table 2-2 Bench Tested Coagulant-Aids Characteristics

Coagulant Aid	Magnafloc LT-22S	Prosedim ASP-20	Prosedim CSP-640
Constituent	Acrylamide co-polymer and quaternized cationic monomer	Acrylamide co-polymer	Acrylamide co-polymer
Charge	Low cationic	Non-ionic	Very low Cationic
Molecular weight	High	Very high	High
Type	Dry Powder	Dry Powder	Dry Powder
Supplier	Basf	Erpac	Erpac

The coagulant and coagulant-aid selected for testing at pilot scale are discussed in TM No. 1. *Safety Data Sheet* for the coagulants and coagulant-aids that are being tested during the pilot tests are presented in Appendix A.

3. Coagulant Piloting Work Program

Phase 2 aimed at developing the coagulant piloting work program. The objective of this TM is to evaluate the coagulant performance through:

- Evaluation and confirmation that the pilot plant can be baselined and is reflective of the WTP,
- Evaluation and definition of the pilot plant test targets,
- Provision of operational goals for the pilot plant.

This section outlines the piloting work program and includes a detailed pilot testing schedule, pilot run summary templates, water quality testing protocol and finished water quality sampling program.

3.1 Define pilot plant test targets and operating goals to evaluate candidate coagulant performance

To assess the application of an alternative coagulant, pilot studies will be conducted over a one-year period. These studies will expand on the previously completed bench-scale tests by examining the impact of coagulation, dissolved air floatation (DAF), ozonation, and filtration on a range of water quality parameters. Testing will also examine the impact of seasonal changes in water quality and potential variations in performance based on process flow rate. The primary objective of this pilot study is to evaluate the performance of an alternative coagulant for Mn reduction when compared to the existing coagulant and to minimize or prevent any potential negative impacts on the treated water quality, plant operations and water quality in the distribution system.

Performance of the existing and alternative coagulant with regards to treated water quality will be compared based on the parameters of interest provided in Table 3-1. Typical water quality for the existing coagulant is provided in Appendix B.

Table 3-1 Water Quality Parameters of Interest for Pilot Studies

PARAMETERS OF INTEREST		
Alkalinity	Metals (Soluble)	Total solids (TS)
2-methylisoborneol (MIB)	Metals (Total)	Total suspended solids (TSS)
Chloride (Cl^-)	pH	Total trihalomethane (T-THM)
Conductivity	Sulphate (SO_4^{2-})	True Colour
Dissolved organic carbon (DOC)	Threshold odour number (TON)	Turbidity
Geosmin	Total dissolved solids (TDS)	UVT transmittance (filtered)
Hardness	Total haloacetic acids (T-HAA)	

In addition to the key water quality parameters stated in Table 3-1, residual generation from the DAF unit will be quantified (TSS). The sludge production results will allow for the determination of the annual residual treatment requirements for comparison to existing capacity.

Filter performance will be evaluated by measuring filter effluent turbidity, particle counts, filter run times, unit filter run volumes (UFRV, when applicable), head loss development, and backwash duration by minimizing the filter-to-waste period. The parameters will be monitored from filters operated at seasonal average flow rates (0.3 L/s), and maximum capacity (0.6 L/s), to ensure the alternative coagulant is appropriate for use at a wide range of operating conditions.

3.2 Critical Path Method Schedule

The need for piloting an alternative coagulant in each of the four seasons has been identified. Based on historical treatment plant data and water temperature thresholds provided by the City, it is proposed that winter piloting begin in March 2017, spring piloting in May 2017, summer piloting in July 2017 and fall piloting in October 2017. Each test will occur for a period of three weeks, with WSP personnel on-site for up to 12 hours per day for a minimum of 21 consecutive days following the start of a given trial. Direct filtration will be evaluated over 14 consecutive days following the completion of the fall testing. Critical path schedules are provided in Appendix C (Figure 1 to Figure 3). A list of critical dates is provided in Table 3-2. Please note, this schedule is preliminary and dates are subject to change as per the benchmarking effort and water quality variation.

Table 3-2 Summary of Critical Project Dates

Activity	Proposed Timeline
Start Winter Piloting Session	February 2017
Begin Winter Sampling	March 2017
Submit Draft Memorandum #3	April 2017
Submit Final Memorandum #3	April 2017
Start Spring Piloting Session	April 2017
Begin Spring Sampling	May 2017
Submit Draft Memorandum #4	June 2017
Submit Final Memorandum #4	July 2017
Start Summer Piloting Session	June 2017
Begin Summer Sampling	July 2017
Submit Draft Memorandum #5	August 2017
Submit Final Memorandum #5	August 2017
Start Fall Piloting Session	September 2017
Begin Fall Sampling	October 2017
Submit Draft Memorandum #6	November 2017
Submit Final Memorandum #6	December 2017
Start Direct Filtration Piloting Session	January 2018
Begin Direct Filtration Sampling	January 2018
Submit Draft Memorandum #7	February 2018
Submit Final Memorandum #7	March 2018

3.3 Transition period

The first consideration that must be made with respect to the pilot studies is the changeover of coagulants. As such, it is expected that the pilot unit will be operated with the current coagulant (ferric chloride) in between the pilot sessions with the alternate coagulant, effectively serving as a “control” and will need to be transitioned over to the alternative coagulant for the five piloting sessions (noted above).

To ensure that steady-state conditions, which indicate process stability and accurately represent potential treatment performance, are achieved, it is suggested that the City begins operation with the alternative coagulant prior to the commencement of WSP-led testing. Pilot stability is defined as achieving a minimum of 5 days of operation where turbidity fluctuates ±0.2 NTU in post-DAF samples and ±0.05 NTU in the pilot filter effluent. The alternative coagulant dose, coagulant-aid dose and post-DAF pH for the transition period will be selected based on the bench-test or previous piloting session results. It is estimated that it will take 2 to 3 weeks to reach steady state conditions. If the coagulants are not changed prior to the start of the designated test period, it is likely that steady-state will not be achieved in the designated time, and representative data would not be obtained.

The transition period aimed to evaluate the stability of the pilot system following the change from the current coagulant to the alternate coagulant. Table 3-3 presents the four key parameters that will be analysed daily by the City of Winnipeg Environmental and Analytical Services laboratory (Lab) during transition period.

Table 3-3 Water Quality Parameters of Interest for Transition Period & Sampling Location

PARAMETERS	Sampling Locations	WTPP-Raw	WTPP-Post DAF	WTPP-Post Ozone Combined	WTPP-Post Filter No.1	WTPP-Post Filter No.2	WTPP-Post Filter No.3	WTPP-Post Filter No.4	WTPP-Post Filter No.5	WTPP-Post Filter No.6	WTPP-Post Filter No.7	WTPP-Post Filter No.8
Manganese, Total	mg/L	X	X	X	X	X	X	X	X	X	X	X
TOC	mg/L	X	X	X	X	X	X	X	X	X	X	X
pH [1]	-	X	X	X	X	X	X	X	X	X	X	X
Turbidity[1]	NTU	X	X	X	X	X	X	X	X	X	X	X

[1] Bench and Lab analysis.

[2] WTPP is the acronym for pilot-scale plant.

3.4 Piloting session activities

Piloting of the alternative coagulant will commence following a successful transition period. Table 3-4 and Table 3-5 present the parameters of interest and the sampling locations for full and pilot-scale. Samples will be collected at the pilot-scale raw water (raw water intake prior to chemical addition at the plant), post-DAF (sampled from the DAF overflow), post-ozone (combined from both contactors), from the effluent of the 8 filters and from the combined filter effluent for a total of 12 sampling points (see Figure 3-1 below).

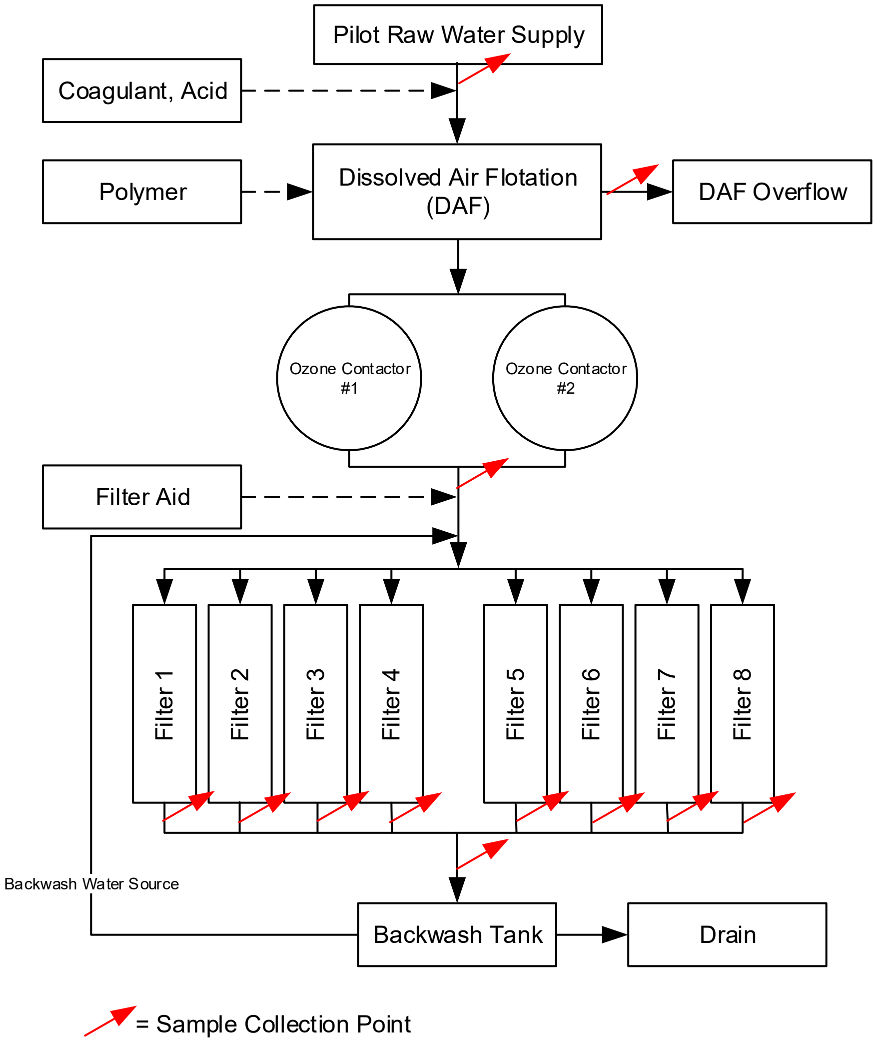


Figure 3-1 Summary of Sampling Locations at the Pilot Plant

Over the three (3) weeks of testing, pilot plant samples for laboratory analysis will be collected on a minimum of 6 days. Figure 2 and 3 of Appendix C provide the proposed sampling schedule. Type 1 testing, including metals, DOC, solids, colour, UVT, alkalinity, conductivity, pH, turbidity, DO and ORP (Table 3-4) will be evaluated on the first four (4) of the six (6) sampling days, for a total of 66 samples. Type 2 testing, including all the parameters tested as part of the Type 1 testing as well as threshold odour number, algal toxins (only in summer session), DBP formation potential and corrosion indicators (Table 3-5), will be carried out only on the final two (2) sampling days. Type 2 sampling will require an additional 20 to 22 samples. Conducting the Type 2 sampling on the final two (2) days at the optimum conditions will provide the maximum period of time for steady-state conditions to develop.

Filter performance monitoring is to be analyzed during and after testing, based on the on-line pressure data. Specifically, head loss development will be monitored from the differential pressure meters installed on each filter. Filter run times and UFRV will be calculated based on the time required to reach maximum headloss, and the average flowrate through the filter (if not monitored or controlled on-line).

Finally, sludge production will be evaluated at a minimum of two times per week to ensure that DAF performance does not significantly change after switching coagulants, and to confirm that existing sludge processing methods will continue to be applicable with the alternative coagulant. Sludge is to be collected from the sludge scrapper and tested as outlined in Table 3-4 and Table 3-5. All of the filter performance and sludge production measurements will be completed by WSP personnel, based on methods currently utilized by the City.

During the direct filtration trial, metals, DOC, solids, colour, UVT, alkalinity, conductivity, pH, turbidity, DO and ORP (Type 1 testing) will be evaluated on three separate days (for a total of 33 samples). Type 2 testing including: threshold odour number, DBP formation potential and corrosion indicators will be sampled only on the last two sampling dates (24 samples for these parameters).

Perhaps the most critical part of the pilot studies is the comparison of the pilot results for the alternative coagulant to the existing coagulant. To provide an accurate comparison, three sets of samples per Table 3-5 will be collected to quantify the water quality and operational performance of the existing coagulant. One set of samples will be collected from the pilot on the day prior to coagulant change over, the second set of samples will be collected from the full-scale plant on the last day of testing the alternative coagulant, and the third set will be collected two or three weeks after restarting the pilot on the existing coagulant. It was also recommended to match the pilot scale samplings with full scale weekly monitoring. This will provide adequate data to ensure that the source water did not significantly change over the test period, confirm that the pilot appropriately mimics the full-scale processes and allow for an appropriate comparison of the existing and alternative coagulants.

Table 3-4 Water Quality Parameters of Interest for Pilot Studies & Sampling Location (Type 1)

PARAMETERS	Sampling Locations[2]	TYPE 1 [3]															
		WTPP-Raw	WTPP-Post DAF	WTPP-Post Ozone Combined	WTPP-Post Filter No.1	WTPP-Post Filter No.2	WTPP-Post Filter No.3	WTPP-Post Filter No.4	WTPP-Post Filter No.5	WTPP-Post Filter No.6	WTPP-Post Filter No.7	WTPP-Post Filter No.8	WTPP- Post Filters Combined	WTPP-Post DAF Sludge	WTP - Post-DAF	WTP O3- Combined	WTP - Filtrate Combined
Metals, Soluble	mg/L	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Metals, Total	mg/L	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
DOC	mg/L	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
TDS	mg/L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TS	mg/L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TSS	mg/L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
True Colour	units	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
UVT filt	%	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Alkalinity	mg/L	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Conductivity[1]	µS/cm	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
pH [1]	-	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Turbidity[1]	NTU	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X

1 Bench Analysis as well.

2 WTPP is the acronym for pilot-scale plant and WTP is the acronym for the full-scale plant.

3 Type 1 sampling included: metals (dissolved and total): aluminum, arsenic, boron, calcium, cadmiun, chromium, copper, iron, potassium, magnesium, manganese, sodium, nickel, lead, antimony, silver, uranium, zinc, and zirconium. In addition, dissolved organic carbon (DOC), total dissolved solids (TDS), total solids (TS), total suspended solids (TSS), true colour, UV transmittance (filtered), alkalinity, conductivity, pH and turbidity.

Table 3-5 Water Quality Parameters of Interest for Pilot Studies & Sampling Location (Type 2)

PARAMETERS	Sampling Locations[2]	TYPE 2 [3]															
		WTPP-Raw	WTPP-Post DAF	WTPP-Post Ozone Combined	WTPP-Post Filter No.1	WTPP-Post Filter No.2	WTPP-Post Filter No.3	WTPP-Post Filter No.4	WTPP-Post Filter No.5	WTPP-Post Filter No.6	WTPP-Post Filter No.7	WTPP-Post Filter No.8	WTPP- Post Filters Combined	WTPP-Post DAF Sludge	WTP - Post-DAF	WTP O3- Combined	WTP - Filtrate Combined
Metals, Soluble	mg/L	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Metals, Total	mg/L	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
DOC	mg/L	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
TDS	mg/L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TS	mg/L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TSS	mg/L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
True Colour	units	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
UVT filt	%	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Alkalinity	mg/L	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Conductivity[1]	µS/cm	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
pH [1]	-	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Turbidity[1]	NTU	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
TON		X											X				
Geosmin[4]		X											X				X
MIB[4]		X											X				X
T-THM	µg/L	X											X				X
T-HAA	µg/L	X											X				X
SO4	mg/L	X											X				X
Chloride	mg/L	X											X				X
Hardness	mg/L	X											X				X

[1] Bench Analysis as well.

[2] WTPP is the acronym for pilot-scale plant and WTP is the acronym for the full-scale plant.

[3] Type 2 sampling included all of Type 1, and threshold odour number (TON), geosmin, 2-methylisoborneol (MIB), total trihalomethane (T-THM), total haloacetic acids (T-HAA), sulfate, chloride, and hardness.

[4] Only in summer piloting session.

Table 3-6 indicates that four filters will be operated at average flow (0.3 L/s), and four will be operated at maximum flow (0.6 L/s) during the pilot sessions, as required by the RFP. Backwash conditions will also be evaluated by operating two filters (operated at both high and average flow rates) with the same backwash procedure utilized at full-scale. Duplicating this procedure will provide confidence in the results, and allow for statistical comparison to full-scale and the existing coagulant. The other two filters will be operated with a backwash procedure shortened or extended by 25% of the average backwash time. This is anticipated to provide insight into the potential impact of altering backwash protocols on water quality and filter operation.

It should be noted the full-scale filters can be backwashed at a low and a high backwash flow rate. However, the low backwash flow rate is not easily achievable in the pilot-scale plant. Therefore, the backwash of the pilot-scale filters are mimics as much as possible the full-scale procedure, but it can't be duplicated for the reasons above.

Table 3-6 Summary of Filter Operating Conditions

Filter #	Flow Rate		Backwash Regime	Backwash Duration (Air - Air & Water – Water)/min
1	Average	0.3 L/s	Standard	10 – 5 - 10
2	Average	0.3 L/s	Standard	10 – 5 - 10
3	Average	0.3 L/s	Shortened	7.5 – 4.75 – 7.5
4	Average	0.3 L/s	Extended	12.5 – 6.25 – 12.5
5	Max	0.6 L/s	Standard	10 – 5 - 10
6	Max	0.6 L/s	Standard	10 – 5 - 10
7	Max	0.6 L/s	Shortened	7.5 – 4.75 – 7.5
8	Max	0.6 L/s	Extended	12.5 – 6.25 – 12.5

3.5 Database for Testing Results

The data collected from this study will be compiled in a database such that the City can reference this information for future plant optimization considerations. This database will be developed in Microsoft Excel and shared with all parties. Data will be coordinated by analyte and sampling date to facilitate future data analysis.

3.6 Water Quality Testing Protocol

Water quality tests will be conducted according to the methods outlined by the City of Winnipeg Analytical Services Branch. For samples that are analyzed at the benchtop (iron, manganese, colour, UVT, alkalinity, pH, turbidity, DO, and ORP), manufacturer's instructions or standard method's will be followed. All parameters will be analyzed in the same way as bench tests performed.

3.7 Finished water quality sampling for distribution system residuals

Biofilter effluent will be evaluated for possible distribution network residuals. These tests will include residual aluminum and iron, to determine if any coagulant carryover is occurring. Furthermore, Mn and the remaining metals will be measured in treated water to calculate the mass of these compounds entering the distribution system after treatment. Corrosion indicators, such as sodium, sulphate and chloride will be measured to evaluate potential corrosion impacts of the alternative coagulant.

3.8 Identification of WTP staff resources, duties and requirements

The City staff will be responsible for the operation of the pilot plant at all times other than the five sampling periods identified. The duties of the WTP staff will include backwashing the filters, preparing stock solutions, ensuring accurate online monitoring, ensuring continuous flow through the filters (whenever possible) and performing any other maintenance required to ensure that the pilot is operating in a manner that accurately represents full-scale operation.

Initially the City's WTP staff will be requested to determine the operating conditions at pilot-scale that are required to achieve treatment performance representative of the full-scale plant. The benchmarking requirements are discussed at the subsequent chapter (Chapter 4).

After ensuring that the pilot creates water of equivalent or near-equivalent quality of the full-scale plant, it will be the responsibility of the WTP personnel to switch coagulants two weeks prior to scheduled piloting activities. This is required to ensure that the system and filters can achieve stable treatment performance prior to collecting samples. If this cannot be completed, additional time may be required for each of the sampling events to ensure that the results of representative of potential future performance at full-scale.

Finally, it will be a requirement of the WTP staff to ensure that all pilot equipment and monitoring tools are functional and calibrated prior to and during pilot sampling to ensure that the same procedures are completed at full-scale and pilot-scale.

3.9 City Laboratory Requirements and Resources

The four seasonal sampling events will require that metals, TOC, solids, colour, UVT, alkalinity, conductivity, pH and turbidity be evaluated on six sampling days, for a total of 72 samples. Threshold odour number, algal toxins, DBP formation potential and corrosion indicators will be sampled on raw water and combined filtrate twice during piloting session from both the full-scale and pilot-scale plants (total of four samples).

During the direct filtration test, metals, TOC, solids, colour, UVT, alkalinity, conductivity, pH, turbidity, DO and ORP will be evaluated on three sampling days, for a total of 36 samples; threshold odour number, algal toxins and DBP formation potential will be sampled on two days for a total of four samples.

3.10 Safe work procedures

The pilot plant safe work procedures are presented in Appendix D.

4. Pilot Benchmarking

Upon commissioning of a pilot facility, it is critical that a comparison between the full-scale and pilot-scale plant be competed to make sure scaling differences between the two systems will not impact the performance. Adjustments to pilot-operation may be required to ensure an accurate representation of the full-scale plant. This chapter will highlight the pilot operation requirements, sample collection (full and pilot-scale), and analysis.

4.1 Pilot Operation

Perhaps the most critical component of benchmarking pilot performance is ensuring that the pilot is operated in the same manner as the full-scale plant particularly with respect to chemical dosing, flow rate, mixing duration, mixing intensity, DAF processes, ozonation, and filtration.

In the case of the Winnipeg WTP, the full-scale plant is considered to be operated in a very static manner in terms of flow. Chemical dosages in the pilot plant should be adjusted daily to match the full-scale conditions. The City has informed WSP that active filter media was harvested in the spring of 2016 and maintained through regular backwashing until the pilot plant was fully operational in November 2016, before the first benchmarking period.

4.2 Sample Collection

To effectively evaluate the performance of the pilot plant, sample collection at a number of points through the plant is required. WSP has identified 12 potential sampling locations within the pilot plant that would allow for effective pilot benchmarking, and sequential confirmation of pilot operation. These locations identified on Figure 3-1 are as follows:

- The pilot raw water supply (prior to chemical additions).
- The DAF overflow (representative of the DAF operating conditions).
- Post-ozonation (both ozone columns merge).
- The individual effluent from the eight filters (Filters 1-8).
- The combined filter effluent (the combined effluent from both filter banks).

Samples are to be concurrently collected from the previously noted analogous locations within the full-scale plant for comparison between the two systems.

Samples collected from the locations in Figure 3-1 are to be analyzed for the parameters presented in Table 4-1. The parameters are classified as being either primary or secondary priority. Parameters indicated as primary priority are critical to match between the pilot and full-scale processes. These parameters are indicative of chemical treatment performance, and variations in scaling will likely not impact significantly the concentration of these parameters. For example, it is expected that equal coagulant doses will result in the same change of pH, regardless of the amount of water that is treated.

Analytes of secondary priority may be impacted by the design of the pilot, and careful considerations must be made when comparing the results. For example, it is common for pilot filters to have an influent located at the top of a filter column. The flow that enters the filter may be fully exposed to the atmosphere, and potentially re-oxygenated. The same exposure to the atmosphere would not occur at full-scale, thereby impacting DO and ORP measurements. Finally, considerations may be made for algal toxins and taste and odour compounds. These are unlikely to be present in the upcoming winter months, but may be important in warmer water conditions.

Table 4-1 Water Quality Parameters of Interest for Proposed Pilot Studies

Parameter Priority	Parameter
Primary	pH Temperature Total Manganese Total organic carbon (TOC) Turbidity UV transmittance (UV_{254})
Secondary	Alkalinity Colour Conductivity Dissolved and Total Metals (aluminum, arsenic, boron, calcium, cadmium, chromium, copper, iron, potassium, magnesium, manganese, sodium, nickel, lead, antimony, silver, uranium, zinc and zirconium) Dissolved oxygen (DO) Oxidation reduction potential (ORP) Solids (total, suspended, dissolved)

4.3 Benchmarking Analysis

Due to schedule constraints and long laboratory turnaround time, it was determined to evaluate the stability of the pilot system and produce the best water quality with the current coagulant during the benchmarking period. Table 4-2 presents the four key parameters that will be analysed daily by the Lab during benchmarking period.

Table 4-2 Water Quality Parameters of Interest for Benchmarking Period & Sampling Location

PARAMETERS	Sampling Locations[2]	WTPP-Raw[3]	WTPP-Post DAF	WTPP-Post Ozone Combined	WTPP-Post Filter No.1	WTPP-Post Filter No.2	WTPP-Post Filter No.3	WTPP-Post Filter No.4	WTPP-Post Filter No.5	WTPP-Post Filter No.6	WTPP-Post Filter No.7	WTPP-Post Filter No.8
Manganese, Total	mg/L	X	X	X	X	X	X	X	X	X	X	X
TOC	mg/L	X	X	X	X	X	X	X	X	X	X	X
pH [1]	-	X	X	X	X	X	X	X	X	X	X	X
Turbidity[1]	NTU	X	X	X	X	X	X	X	X	X	X	X

[1] Bench and Lab analysis.
[2] WTPP is the acronym for pilot-scale plant.
[3] Measured in triplicate in the pilot plant

Stability is defined as a minimum of 5 days of operation where turbidity fluctuates ±0.2 NTU in post-DAF samples and ±0.05 NTU in the pilot filter effluent.

For future tests, statistical methods that can be used to ensure that the two systems provide equal performance will also be presented. Recommendation on how to improve the benchmarking pilot performance and a protocol to apply a statistical analysis are detailed on Appendix E.

5. Legacy Manganese Concerns

The current project being completed at the WTP focusses on reducing Mn concentrations in treated water by attempting to identify an alternative coagulant which will reduce the concentration of Mn in the distribution system. In the long-term, changing to a coagulant with a low concentration of Mn will minimize potential discoloured water issues, but may potentially impair water quality in the short-term due to the release of Mn from the existing filter media.

Legacy Mn in drinking water systems is present as a mineral scale, as a result of Mn oxidation. This scale attaches to surfaces in the plant or distribution system, and may act as a catalyst to aide in future Mn oxidation (Tobiason et al., 2008). Although this process conceivably assists in the removal of Mn, changing oxidation states due to process changes (such as reductions in dissolved oxygen) can result in the rapid release of Mn scale, potentially causing elevated concentrations of Mn in treated water.

Plants using ferric chloride as a coagulant have observed legacy Mn concentrations as high as 8,700 mg Mn per kilogram of filter media (Gabelich et al., 2006). Upon changing treatment conditions, Mn concentrations in the mg/L range were observed for several weeks. Gabelich et al. (2006) hypothesized that metals contained in coagulants (iron or aluminum) will displace Mn attached to the media in bulk water as oxidized Mn(III). Mn(III) further oxidizes within the deeper media layers to Mn(IV) or forms solid MnO_2. Any Mn(III) that is not further oxidized is understood to be released in the filter effluent.

Based on the potential risks presented by changing process conditions, further study of the legacy Mn on the filter media is proposed. This work would be completed in stages to determine whether legacy Mn is a concern at the Winnipeg WTP, and identify mitigation strategies such that the treated water quality is not impacted upon a potential coagulant change.

5.1 Stage 1: Quantification of Legacy Mn Concentration

The first tests would determine if a Mn-rich scale exists on the filter media, and quantify the total mass of Mn present in the system. Media samples should be collected from two depths to match the two depths available for sampling in the pilot plant, from two or more filters. Samples would be collected using a coring tool prior to backwash with the filter in a no flow condition. These results will provide information regarding the spatial distribution of Mn through the depth of the filter media, as well as the variability in Mn concentration between filters.

To quantify the concentration of Mn on the filter media, a hydroxylamine sulfate (HAS) extraction is used for analysis. The HAS method is described as follows:

- From the cored media, 2 g of sample is acidified with using 0.5% nitric acid. To this, 2 g of HAS is added, and the solution is mixed for 2 hours. The sample is then filtered using a 0.2 µm nylon filter and subsequently prepared for instrumental analysis (inductively coupled plasma mass spectrometry or atomic adsorption) (Tobiason et al., 2008).

5.2 Stage 2: Determination of Potential Mn Release

If elevated concentrations of Mn are observed on the filter media (greater than100 mg per kilogram), pilot studies should be adjusted to evaluate the potential Mn desorption upon treatment with an alternative coagulant. Notably, filter media would be collected from the full-scale filters to replace the media in the pilot-scale filters. The pilot filters would then operate at existing full- scale conditions (ferric chloride coagulation) to ensure that the performance at pilot matches full- scale, and no sudden release of Mn from the filter media occurs. Finally, the coagulation conditions would be altered to test the impact of the new coagulant on Mn release. Water samples would be collected daily, and media samples would be collected before and after a given test to develop a Mn mass balance.

5.3 Stage 3: Mitigation Measures

If changing the coagulant results in significant desorption of Mn from the filter media, such that discoloured water events would be expected, mitigation measures would be examined. One potential mitigation measure would be to monitor and control oxidation prior to filtration.

Oxidation reduction potential (ORP) monitoring would be completed to determine if any changes to the redox conditions are present in the filter influent. If ORP needs to be adjusted to meet pre- transition conditions, ozone dose, contact time and reducing agents such as sodium thiosulphate will be adjusted, as required. Backwashing will also be examined to determine whether physical removal of the Mn scale is possible under certain conditions (duration or backwash water chemistry). This may require additional backwash duration or frequency. Finally, if all chemical characteristics (dissolved oxygen, pH, ORP) indicate that large releases of dissolved Mn may occur, investigations into the replacement of the highest Mn density media may be considered.

5.4 Summary and Recommendations

It is currently unknown how much Mn is present in the WTP in the form of manganese oxides within the filter media. After transitioning to an alternative coagulant, it is possible that the currently stable scale will desorb from the media and be released to treated water as dissolved Mn. Tests should be completed to first estimate the amount of Mn present on the media, and then determine the potential impacts of changes to the treatment process. Finally, if Mn release is expected with the new coagulant, mitigation measures should be evaluated to ensure that the potential for adverse water quality issues and discoloured water events are minimized.

6. References

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Appendix A - Safety Data Sheets

Kemira
Where water
meets chemistry ™

Technical Data Sheet
(Ref: KWS-PIX-311)
31.10.2014

Kemira PIX-311

Ferric Chloride, 37-42% Solution

KEMIRA PIX-311 is an effective primary coagulant in liquid form based on trivalent iron (Fe^{3+}). It functions very well for both potable and wastewater clarification and can be used for color removal, arsenic removal, phosphate removal, heavy metal removal and lime softening applications. KEMIRA PIX-311 can also be used effectively for hydrogen sulfide control, struvite control and in sludge conditioning applications.

Product Specification

Appearance	Dark Brown liquid
$FeCl_3$	37 ± 42%
Fe (III)	12.7 – 14.5%
Fe (II)	< 0.5%
Specific Gravity (25°C)	1.38 - 1.45 Kg/L

Typical Analysis

pH (25°C)	< 1
Free HCL	< 1%
Freezing Point	-25˚C / -15˚F

Certification / Approval

KEMIRA PIX-311 meets or exceeds all AWWA standards for liquid ferric chloride and is NSF/ANSI Standard 60 certified for use in potable water treatment up to 250 mg/l.

Dosing

KEMIRA PIX-311 should be fed straight. No dilution or preparation is required. A diaphragm, metering pump of non-corrosive material is suitable.

Storage

Storage tanks and piping should be constructed of suitable material such as fiberglass, or cross-linked polyethylene. KEMIRA PIX-311 is highly corrosive and contact with metal equipment must be avoided. With this chemical it is recommended to clean the storage tank every 1-2 year.

Handling / Safety

The handling of any chemical requires care. Anyone responsible for using or handling KEMRIA PIX-311 should familiarize themselves with the full safety precautions outlined in our Material Safety Data Sheet.

Delivery

Shipping Instructions; Ferric Chloride Solution, 8, UN 2582, P.G. III

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Kemira

1000 Parkwood Circle, Ste 500
Atlanta, GA 30339
USA

www.kemira.com

United States
Tel +1 800 879 6353

Canada
Tel +1 450 652 0665

Material Safety Data Sheet

KEMIRA PIX-311

/REG_NA/EN

Revision Date: 03/13/2014 Previous date: 02/25/2014 Print Date:01/26/2016

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1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product information

KEMIRA PIX-311

Use of the Substance/Mixture

Water treatment chemical

Company Identification

Kemira Water Solutions Canada, Inc.
3405 Boulevard Marie-Victorin
Varennes QC J3X 1T6
CANADA
Telephone. +14506520665, Telefax. +14506527343

Emergency telephone number

2. HAZARDS IDENTIFICATION

3. COMPOSITION/INFORMATION ON INGREDIENTS

Hazardous or Regulated Components

CAS-number	Chemical name of the substance	Concentration
7705-08-0	Iron trichloride	35 - 45 %
7647-01-0	Hydrochloric acid	1 - 2 %

Further information

This material is hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29CFR 1910.1200.

This product contains WHMIS regulated (hazardous) components.

4. FIRST AID MEASURES

General advice

Show this safety data sheet to the doctor in attendance.

Inhalation

Rinse mouth and nose with water. Move to fresh air.
Call a physician if symptoms occur.

Skin contact

Take off contaminated clothing and shoes immediately. Rinse with plenty of water. Obtain medical attention.

Eye contact

Important! Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. If possible use lukewarm water. Consult a physician.

Ingestion

Do NOT induce vomiting. Rinse mouth with water. Drink 1 or 2 glasses of water or milk. Never give anything by mouth to an unconscious person. Consult a physician.

5. FIREFIGHTING MEASURES

Suitable extinguishing media

Not combustible.

Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Extinguishing media which shall not be used for safety reasons

No special requirements.

Specific hazards during firefighting

Heating above the decomposition temperature can cause formation of hydrogen chloride.

Special protective equipment for firefighters.

Exposure to decomposition products may be a hazard to health. In the event of fire, wear self-contained breathing apparatus.

Use NIOSH/MSHA approved respiratory protection.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions

For personal protection see section 8.

Environmental precautions

Prevent product from entering the environment.

Restrict the spread of the spillage by using inert absorbent material (sand, gravel). Cover the drains. Must be disposed of in accordance with local and national regulations.

Methods for cleaning up

Clean-up methods - small spillage

Dilute residues with water and then neutralize with lime or limestone powder to a solid consistency. Shovel or sweep up. Must be disposed of in accordance with local and national regulations.

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Clean-up methods - large spillage

Dilute residues with water and then neutralize with lime or limestone powder to a solid consistency. Shovel or sweep up remaining material. Must be disposed of in accordance with local and national regulations.

Additional advice

Inform the rescue service in case of entry into waterways, soil or drains.

7. HANDLING AND STORAGE

Handling

Handle and open container with care.

Danger for slipping. For personal protection see section 8. The work place and work methods shall be organized in such a way that direct contact with the product is prevented or minimized.

Storage

Avoid high temperatures. Avoid freezing.
Materials for packaging:
Suitable material: plastic (PE, PP, PVC), polyester with fibreglass reinforcement, rubber-coated steel, titanium

Materials to avoid:
Metals, Bases
Stainless steel, leather, non-acid proof metals (for example aluminium, copper and iron), Reaction with some metals may evolve flammable hydrogen gas.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Limit Values

Hydrochloric acid
ceiling occupational exposure limit = 2 ppm = 3 mg/m³, : Occupational exposure limit is based on irritation effects and its adjustment to compensate for unusual work schedules is not required., Hydrogen chloride C = 5 ppm = 7 mg/m³, (b): The value in mg/m³ is approximate., hydrogen chloride

Exposure controls

Occupational exposure controls

Handle in accordance with good industrial hygiene and safety practice.

Eye wash bottle or emergency eye-wash fountain must be found in the work place.

Respiratory protection

Respiratory protection is not required under normal handling conditions. If aerosols or mist are formed, eg. when cleaning containers with a high pressure washer, use half mask with filter B2.

Eye protection
Tightly fitting safety goggles. Eye wash bottle with pure water

9. PHYSICAL AND CHEMICAL PROPERTIES

General Information (appearance, odour)

Physical state	liquid,
Colour	dark brown
Odour	slightly acidic

Important health safety and environmental information

Boiling point/boiling range	100 - 105 °C
Flash point	not applicable

Explosive properties:	
Density	1.41 - 1.44 g/cm^3
Water solubility	(20 °C) completely soluble, At dilution to less than 1% of FeCl3, precipitation of iron hydroxide occurs.
Partition coefficient: n-octanol/water	not applicable, inorganic compound

Other data

VOC Content:	;Not applicable

10. STABILITY AND REACTIVITY

Conditions to avoid

Avoid freezing. Avoid storage at high temperatures.

Materials to avoid

Metals, Bases

Stainless steel, leather, non-acid proof metals (for example aluminium, copper and iron), Reaction with some metals may evolve flammable hydrogen gas.
Hazardous reactions :

Bases cause exothermic reactions.

Hazardous decomposition products

Heating above the decomposition temperature can cause formation of hydrogen chloride.

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Iron trichloride:
LD50/Oral/rat: 220 mg/kg
Remarks:Calculated as Fe

LD50/Dermal/rat: > 2,564 mg/kg
Remarks: Read-across (Analogy), CAS-No., 7758-94-3

LD50/Dermal/rat: > 881 mg/kg
Remarks: Calculated as Fe

Irritation and corrosion

Skin:
Corrosive

Eyes:
Corrosive to the eyes.

Iron trichloride:

Skin: rabbit/OECD Test Guideline 404: irritating
Remarks: Read-across (Analogy) CAS-No. 7758-94-3

Eyes: rabbit/OECD Test Guideline 405: Corrosive
Remarks: Read-across (Analogy) CAS-No. 7758-94-3

Sensitization

Not sensitizing.

Iron trichloride:

According to experience sensitization is not expected.

Long term toxicity

Iron trichloride:

Carcinogenicity

Not believed to be a carcinogen.

Reproductive toxicity

Not believed to be toxic for reproduction.

Human experience: Inhalation
Symptoms: Inhalation may provoke the following symptoms:, cough and difficulties in breathing
Human experience: Skin contact
Symptoms: Skin contact may provoke the following symptoms:, irritation, burns
Human experience: Eye contact
Symptoms: Contact with eyes may provoke the following symptoms:, Contact with eyes causes a smarting pain and a flood of tears., Causes burns.
Human experience: Ingestion
Symptoms: Ingestion may provoke the following symptoms:, May cause irritation of the mucous membranes., burns in upper digestive organs

12. ECOLOGICAL INFORMATION

Ecotoxicity effects

Aquatic toxicity

Iron trichloride:
LC50/96 h/Lepomis macrochirus (Bluegill sunfish): 59 mg/l
Remarks: hydrated substance

NOEC/96 h/Lepomis macrochirus (Bluegill sunfish): > 1 mg/l
Remarks: hydrated substance
EC50/48 h/Daphnia magna (Water flea): 27 mg/l
NOEC/21 d/Daphnia magna (Water flea): > 1 mg/l
EC50/15 d/algae/rate of growth: 58 mg/l
Remarks: Test is not appropriate due to the flocculating characteristics of the product.,The compound is considered to have no long term effects in aquatic systems due to the rapid formation of insoluble hydroxides.

Toxicity to other organisms

Iron trichloride:

Remarks: no data available

Mobility

Water solubility: completely soluble (20 °C)

Iron trichloride:

Persistence and degradability

Biological degradability:

The methods for determining the biological degradability are not applicable to inorganic substances.

Biological degradability:
Iron trichloride:

The methods for determining the biological degradability are not applicable to inorganic substances.

Bioaccumulative potential

Partition coefficient: n-octanol/water: not applicable, inorganic compound

Iron trichloride:
Partition coefficient: n-octanol/water: not applicable, inorganic compound

Other adverse effects

May lower the pH of water and thus be harmful to aquatic organisms.

13. DISPOSAL CONSIDERATIONS

Product	Classified as hazardous waste. Must be disposed of in accordance with local and national regulations. Thoroughly cleaned packaging material may be recycled.
Contaminated packaging	Classified as hazardous waste. Must be disposed of in

accordance with local and national regulations.

14. TRANSPORT INFORMATION

Land transport

DOT:

Description of the goods:	UN2582, Ferric chloride, solution
Proper shipping name	
Class:	8
Packaging group:	III
DOT-Labels	8
Reportable quantity	Ferric chloride

TDG:

Description of the goods:	UN2582, Ferric chloride, solution
Proper shipping name	
Class:	8
Packaging group:	III
TDG-Labels	8
Reportable quantity	Ferric chloride

Sea transport

IMDG:

Proper shipping name	UN2582, FERRIC CHLORIDE, SOLUTION
Class:	8
Packaging group:	III
IMDG-Labels:	8
Marine pollutant:	Not a Marine Pollutant

Air transport

ICAO/IATA:

Proper shipping name	UN2582, FERRIC CHLORIDE, SOLUTION
Class:	8
Packaging group:	III
ICAO-Labels:	8

Special precautions for user

15. REGULATORY INFORMATION

SARA Title III Section 311 Categories

Immediate (Acute) Health Effects: Yes;
Delayed (Chronic) Health Effects: No;
Sudden Release Of Pressure Hazard: No;
Fire Hazard: No;
Reactivity Hazard: No;

CERCLA Hazardous substance (Reportable Quantities)

Hydrochloric acid: 5,000 lb
Diiron tris(sulphate): 1,000 lb

Iron trichloride: 1,000 lb

WHMIS Classification
E Corrosive Material

Canadian Ingredient Disclosure List
Hydrochloric acid (7647-01-0)
Part 1 Group A Substances
Iron trichloride (7705-08-0)

California Proposition 65

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.
None Present ()

Notification status

:
:
: All components of this product are included in the United States TSCA Chemical Inventory or are not required to be listed on the United States TSCA Chemical Inventory.
: All components of this product are included in the Canada Domestic Substance List (DSL) or are not required to be listed on the Canada Domestic Substance List (DSL).
: All components of this product are included in the Australian Inventory of Chemical Substances (AICS) or are not required to be listed on the Australian Inventory of Chemical Substances (AICS).
: All components of this product are included on the Chinese inventory or are not required to be listed on the Chinese inventory.
: All components of this product are included in the Korean (ECL) inventory or are not required to be listed on the Korean (ECL) inventory.
: All components of this product are included on the Philippine (PICCS) inventory or are not required to be listed on the Philippine (PICCS) inventory.
: All components of this product are included on the Japanese (ENCS) inventory or are not required to be listed on the Japanese (ENCS) inventory.
: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) or are not required to be listed on EINECS.

: All components of this product are included in the New Zealand inventory (NZIoC) or are not required to be listed on the New Zealand inventory(NZIoC).

: This product's Taiwan Toxic Chemical Substances Control Act Inventory status has NOT been determined.

Miscellaneous Information

No restrictions identified other than those already covered in regulations.

16. OTHER INFORMATION

HMIS Rating

Health: 2
Flammability: 0
Reactivity: 1

NFPA Rating

Health: 2
Fire: 0
Reactivity: 1
Special:

MSDS preparatory statement

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Sources of key data used to compile the Safety Data Sheet

Regulations, databases, literature, own tests.

Additions, Deletions, Revisions

Relevant changes have been marked with vertical lines.

Where water
meets chemistry ™

Technical Data Sheet
(Ref: KWS-PIX-312)
15.3.2016

Kemira PIX-312

Ferric Sulfate Solution, 12% Fe

KEMIRA PIX-312 is an effective liquid ferric sulfate coagulant based on trivalent iron (Fe^{3+}). The product is manufactured using a patented process reacting high purity iron ore with sulfuric acid. KEMIRA PIX-312 functions very well for both potable and wastewater clarification and can be used for turbidity removal, color removal, phosphate removal, heavy metal removal, in lime softening applications as well as for sludge conditioning. KEMIRA PIX-312 can also effectively be used in hydrogen sulfide control applications to reduce odor and corrosion.

Product Specification

Appearance	Dark Brown liquid
Fe (III)	12.25 ± 0.25%
Fe (II)	< 0.15%
Specific Gravity (25°C)	Avg. 1.55 Kg/L

Typical Analysis

pH (25°C)	< 2.0
Free Acid	< 0.5%
Water-Insoluble Matter	<0.1%
Freezing Point	-50˚C / -58˚F

Certification / Approval

KEMIRA PIX-312 meets or exceeds all AWWA standards and is NSF/ANSI Standard 60 certified for use in potable water treatment up to 600 mg/l.

Dosing

KEMIRA PIX-312 should be fed straight. No dilution or preparation is required. A diaphragm-metering pump of non-corrosive material is suitable.

Storage

Storage tanks and piping should be constructed of suitable material such as stainless steel, fiberglass, or cross-linked polyethylene. KEMIRA PIX-312 has a recommended shelf life of twelve (12) months. With this chemical it is recommended to clean the storage tank every 1-2 years.

Handling / Safety

The handling of any chemical requires care. Anyone responsible for using or handling KEMIRA PIX-312 should familiarize themselves with the full safety precautions outlined in our Material Safety Data Sheet.

Delivery

Shipping Instructions : Corrosive Liquid, Acidic, Inorganic, n.o.s. 8, UN 3264, P.G. III.

Note: At a temperature below -20 C / -4 F, the viscosity of the product will increase which may affect pumping.

Kemira makes this information available as an accomodation to its customers and it is intended to be solely a guide in customer´s evaluation of the products. You must test our products, to determine if they are suitable for your intended uses and applications, as well as from the health, safety and environmental standpoint. You must also instruct employees, agents, contractors, customers or any third party which may be exposed to the products about all applicable precautions. All information and technical assistance is given without warranty or guarantee and is subject to change without notice. You assume full liability and responsibility for compliance with all information and precautions, and with all laws and statutes, ordinances and regulations of any governmental authority applicable to the processing, transportation, delivery, unloading, discharge,

Material Safety Data Sheet

KEMIRA PIX-312

/REG_NA/EN

Revision Date: 02/25/2014 Previous date: 00/00/0000 Print Date:01/26/2016

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1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product information

KEMIRA PIX-312

Use of the Substance/Mixture

Water treatment chemical

Company Identification

Kemira Water Solutions Canada, Inc.
3405 Boulevard Marie-Victorin
Varennes QC J3X 1T6
CANADA
Telephone. +14506520665, Telefax. +14506527343

Emergency telephone number

Carechem 24 International: +44 (0) 1235 239 670

2. HAZARDS IDENTIFICATION

Emergency Overview: Causes eye, skin, and respiratory tract irritation. Gastrointestinal irritation
Skin: Causes moderate skin irritation.
Eyes: Causes moderate-severe eye irritation.
Inhalation: May cause respiratory tract irritation.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Hazardous or Regulated Components

CAS-number	Chemical name of the substance	Concentration
7664-93-9	Sulphuric acid	<=0.25 %
10028-22-5	Diiron tris(sulphate)	63 - 73 %

Further information

This material is hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29CFR 1910.1200.

For the full text of the H-Statements mentioned in this Section, see Section 16.

For the full text of the R-phrases mentioned in this Section, see Section 16.

4. FIRST AID MEASURES

Inhalation

If breathing is difficult, remove to fresh air and provide oxygen. If not breathing, give artificial respiration. Seek medical attention if cough or other symptoms develop.

Skin contact

Wash off immediately with soap and plenty of water while removing all contaminated clothes and shoes. Get medical attention if irritation develops and persists.

Eye contact

Flush eyes with water at least 15 minutes. Get medical attention if eye irritation develops or persists.

Ingestion

Never give anything by mouth to an unconscious person. Do NOT induce vomiting. Drink 1 or 2 glasses of water. Obtain medical attention.

5. FIREFIGHTING MEASURES

Suitable extinguishing media

Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Specific hazards during firefighting

Not combustible. Thermal decomposition products:
Sulphur oxides, hydrogen sulfide

Special protective equipment for firefighters.

Use NIOSH/MSHA approved respiratory protection.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions

Wear personal protective equipment.

Environmental precautions

Should not be released into the soil, surface water or ground water system. Must be disposed of in accordance with local and national regulations.

Methods for cleaning up

Small amounts:

Absorb with materials such as; Clay. Neutralize with lime or soda.

Large amounts:

In case of large spillage, contain by damming up. Absorb with materials such as; Clay. Dilute residues with water and then neutralize with lime or limestone powder.

7. HANDLING AND STORAGE

Handling

Wear personal protective equipment. Wash contact areas after handling. Prevent eye and skin contact.

Storage

Keep at temperatures between 10 - 30 °C.
Keep containers tightly closed in a cool, well-ventilated place.

Materials for packaging:
Suitable material: butyl-rubber, plastic, Stainless steel
Unsuitable material: Metals
Materials to avoid:
Carbon steel, brass, mineral acids, Bases
Storage stability:

Storage period	12 Months

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Limit Values

Sulphuric acid
TWA = 1 mg/m³, A2: Suspected Human Carcinogen (means that the human data are accepted as adequate in quality but are conflicting or insufficient to classify the agent as A1), Sulphuric acid
STEL = 3 mg/m³, A2: Suspected Human Carcinogen (means that the human data are accepted as adequate in quality but are conflicting or insufficient to classify the agent as A1), Sulphuric acid
TWA = 0.2 mg/m³, Thoracic fraction, : Pulmonary function, Sulfuric acid
TWA = 1 mg/m³, Sulfuric acid
Diiron tris(sulphate)
Permissible exposure limit = 1 mg/m³, Iron
TWA: ACGIH = 1 mg/m³, Iron
TWA = 0.1 mg/m³, as persulfate

Exposure controls

Occupational exposure controls

Ensure adequate ventilation. Ensure that eyewash stations and safety showers are close to the workstation location.
When using do not eat, drink or smoke.

Respiratory protection

Where exposures are below the established exposure limit, no respiratory protection is required. Where exposures exceed the established exposure limits, use respiratory protection recommended for the material and level of exposure. Under conditions of misting or contact with head gases, respiratory protection may be needed. Consider respirator warning properties before use.
With limited contact use an appropriate chemical cartridge respirator with acid gas cartridges. When cleaning, decontaminating or preforming maintenance on tanks, containers, piping systems and accessories, and in any other situations where airborne contaminants and/or dust could be generated, use protective equipment to protect against ingestion or inhalation. HEPA or air supplied respirator, full protective coveralls with head cover, gloves, and boots or chemical suits, and boots are suggested.

Hand protection

Glove material: Neoprene, Wear protective gloves.

Eye protection

Tightly fitting safety goggles or face-shield.

Skin and body protection

Wear as appropriate: Protective clothing. Boots. Lab coat

9. PHYSICAL AND CHEMICAL PROPERTIES

General Information (appearance, odour)

Physical state	, liquid
Colour	red, brown
Odour	acidic

Important health safety and environmental information

pH	< 2
Explosive properties:	
Water solubility	soluble

Other data

VOC Content:	;Not applicable

10. STABILITY AND REACTIVITY

Conditions to avoid

Avoid freezing.

Avoid storage at high temperatures.

Materials to avoid

Carbon steel, brass, mineral acids, Bases

Hazardous reactions :

Hazardous polymerisation does not occur. Stable under recommended storage conditions.

Hazardous decomposition products

Thermal decomposition products:
Sulphur oxides

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Diiron tris(sulphate):
LD50/Oral/rat: 220 mg/kg
Remarks:Calculated as Fe

LC50/Inhalation:
Remarks: no data available, not applicable

LD50/Dermal/rat: > 3,154 mg/kg
Remarks: Read-across (Analogy), CAS-No., 7758-94-3

LD50/Dermal/rat: > 881 mg/kg
Remarks: Calculated as Fe

Irritation and corrosion

Diiron tris(sulphate):

Skin: rabbit/OECD Test Guideline 404: No skin irritation
Moistened solid is expected to be irritant as a consequence of low pH.

Eyes: rabbit/OECD Test Guideline 405: Causes serious eye damage.
Remarks: Read-across (Analogy) 7758-94-3 dry substance

Sensitization

Diiron tris(sulphate):

According to experience sensitization is not expected.

Long term toxicity

Diiron tris(sulphate):

Carcinogenicity
Oral/rat/2 years:
Remarks: Information given is based on data obtained from similar substances.
Not believed to be a carcinogen.

Reproductive toxicity
/rat/Reproductive effects:
NOAEL: > 500 mg/kg
NOAEL F1:
Remarks: Read-across (Analogy)

/rat/Developmental toxicity test:
NOAEL: > 1,000 mg/kg
NOAEL F1:
Remarks: Read-across (Analogy)
In animal studies, did not interfere with reproduction.

Teratogenicity
Oral/rat:
NOAEL: > 1,000 mg/kg
Did not show teratogenic effects in animal experiments. Information given is based on data obtained from similar substances.

12. ECOLOGICAL INFORMATION

Ecotoxicity effects

Aquatic toxicity

LC50/24 h/Gambusia affinis (Mosquito fish): 37.2 mg/l
LC50/96 h/Gambusia affinis (Mosquito fish): 37.2 mg/l
/7 d/Green algae (Selenastrum capricornutum): 10 mg/l

Diiron tris(sulphate):
LC50/96 h/Oncorhynchus mykiss (rainbow trout): > 100 mg/l
NOEC/90 d/Oncorhynchus kisutch (Coho salmon): > 1 mg/l
EC50/48 h/Daphnia: 82.8 mg/l
NOEC/21 d/Daphnia magna (Water flea): > 1 mg/l

The compound is considered to have no long term effects in aquatic systems due to the rapid formation of insoluble hydroxides.

Toxicity to other organisms

Mobility

Water solubility: soluble

Persistence and degradability

Biological degradability:
Diiron tris(sulphate):

The methods for determining the biological degradability are not applicable to inorganic substances.

Bioaccumulative potential

Diiron tris(sulphate):

Does not bioaccumulate.
Partition coefficient: n-octanol/water: not applicable, inorganic compound

Other adverse effects

May lower the pH of water and thus be harmful to aquatic organisms.

13. DISPOSAL CONSIDERATIONS

Product	Must be disposed of as hazardous waste.
Contaminated packaging	Must be disposed of in accordance with local and national regulations.

14. TRANSPORT INFORMATION

Land transport

DOT:
Description of the goods: UN3264, Corrosive liquid, acidic, inorganic n.o.s. (Ferric sulfate)
Proper shipping name
Class: 8
Packaging group: III
DOT-Labels 8
Reportable quantity Ferric sulfate

TDG:
Description of the goods: UN3264, Corrosive liquid, acidic, inorganic n.o.s. (Ferric sulfate)
Proper shipping name
Class: 8
Packaging group: III
TDG-Labels 8
Reportable quantity Ferric sulfate

Sea transport

IMDG:
Proper shipping name UN3264, CORROSIVE LIQUID, ACIDIC, INORGANIC N.O.S. (FERRIC SULFATE)
Class: 8
Packaging group: III
IMDG-Labels: 8

Air transport

ICAO/IATA:
Proper shipping name UN3264, CORROSIVE LIQUID, ACIDIC, INORGANIC N.O.S. (FERRIC SULFATE)
Class: 8
Packaging group: III
ICAO-Labels: 8

Special precautions for user

15. REGULATORY INFORMATION

SARA Title III Section 311 Categories

Immediate (Acute) Health Effects: Yes;
Delayed (Chronic) Health Effects: No;
Fire Hazard: No;
Sudden Release Of Pressure Hazard: No;
Reactivity Hazard: No;

SARA 313 - Specific Toxic Chemical Listings

Sulphuric acid (7664-93-9)
OSHA a. United States Occupational Safety and Health Administration substances, 29 CFR 1910.1000, Sub Part Z.

CERCLA Hazardous substance (Reportable Quantities)

Diiron tris(sulphate): 1,000 lb
Sulphuric acid: 1,000 lb

WHMIS Classification

E Corrosive Material

Canadian Ingredient Disclosure List

Diiron tris(sulphate) (10028-22-5)

California Proposition 65

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.
None Present () %

Remarks: This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

Notification status

: All components of this product are included in the United States TSCA Chemical Inventory or are not required to be listed on the United States TSCA Chemical Inventory.

: All components of this product are included in the Canada Domestic Substance List (DSL) or are not required to be listed on the Canada Domestic Substance List (DSL).

: All components of this product are included in the Australian Inventory of Chemical Substances (AICS) or are not required to be listed on the Australian Inventory of Chemical Substances (AICS).

: All components of this product are included on the Chinese inventory or are not required to be listed on the Chinese inventory.

: All components of this product are included in the Korean (ECL) inventory or are not required to be listed on the Korean (ECL) inventory.

: All components of this product are included on the Philippine (PICCS) inventory or are not required to be listed on the Philippine (PICCS) inventory.

: All components of this product are included on the Japanese (ENCS) inventory or are not required to be listed on the Japanese (ENCS) inventory.

: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) or are not required to be listed on EINECS.

: All components of this product are included in the New Zealand inventory (NZIoC) or are not required to be listed on the New Zealand inventory(NZIoC).

: This product's Taiwan Toxic Chemical Substances Control Act Inventory status has NOT been determined.

Miscellaneous Information

No restrictions identified other than those already covered in regulations.

16. OTHER INFORMATION

HMIS Rating

Health: 2
Flammability: 0
Reactivity: 0

NFPA Rating

Health: 2
Fire: 0
Reactivity: 0
Special:

MSDS preparatory statement

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Sources of key data used to compile the Safety Data Sheet

Regulations, databases, literature, own tests.

Additions, Deletions, Revisions

Relevant changes have been marked with vertical lines.

Where water
meets chemistry ™

Technical Data Sheet
(Ref: KWS-ALS-2260)
18.3.2015

Kemira ALS-2260

Aluminum Ferric Sulfate Solution

KEMIRA ALS-2260 is a formulation that combines the advantages of Aluminum Sulfate to the ones of Inorganic Iron Coagulants in order to meet the growing specific needs of our water treament and wastewater treatment customers KEMIRA ALS-2260 enables superior performance, such as enhanced phosphorous removal. Product is also highly effective for odor and corrosion control through dissovlved sulfide precipitation.

Product Specification

Appearance	Brown liquid
Aluminum (Al)	2.20 ± 0.11%
Specific Gravity (25°C)	1.44 ± 0.05

Typical Analysis

Iron (Fe^{tot})	6.0 ± 0.6%
pH	< 1
Freezing Point	-15°C / 5°F **

Certification / Approval

KEMIRA ALS-2260 meets or exceeds all AWWA standards and is NSF/ANSI Standard 60 certified for use in potable water treatment up to 400 mg/l.

Dosing

KEMIRA ALS-2260 should be feed straight. No dilution or preparation is required. A diaphragm-metering pump of non-corrosive material is suitable.

Storage

Storage tanks and piping should be constructed of suitable material such as stainless steel, fiberglass, cr0ss-linked polyethylene, or reinforced plastics. With this chemical it is recommended to clean the storage tank every 1-2 years.

Handling / Safety

The handling of any chemical requires care. Anyone responsible for using or handling of KEMIRA ALS-2260 should familiarize themselves with the full safety precautions outlined in our Material Safety Data Sheet.

Delivery

Shipping Instruction; Corrosive Liquid, Acidic, Inorganic, n.o.s., 8, UN 3264, P.G. III

**** Note: Product will show higher viscosity and could show signs of crystallization at higher temperatures, depending on storage conditions including humidity factor and presence of impurities**

Kemira

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Material Safety Data Sheet

KEMIRA ALS-2260

/REG_NA/EN

Revision Date: 02/24/2014 Previous date: 00/00/0000 Print Date:01/25/2016

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1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product information

KEMIRA ALS-2260

Use of the Substance/Mixture

odour control

Company Identification

Kemira Water Solutions Canada, Inc.
3405 Boulevard Marie-Victorin
Varennes QC J3X 1T6
CANADA
Telephone. +14506520665, Telefax. +14506527343

Emergency telephone number

2. HAZARDS IDENTIFICATION

Emergency Overview: Causes eye, skin, and respiratory tract irritation. Gastrointestinal irritation
Skin: Causes skin irritation.
Eyes: Causes severe eye irritation.
Inhalation: Inhalation overexposure to the mist or vapor may cause respiratory tract irritation.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Hazardous or Regulated Components

CAS-number	Chemical name of the substance	Concentration
10028-22-5	Diiron tris(sulphate)	40 - 60 %
7664-93-9	Sulphuric acid	<0.1 %
10043-01-3	Aluminium sulphate	20 - 30 %

Further information

This material is hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29CFR 1910.1200.

This product contains WHMIS regulated (hazardous) components.

4. FIRST AID MEASURES

Inhalation

Remove to fresh air. If breathing is difficult, give oxygen. If breathing has stopped, apply artificial respiration. If symptoms persist, call a physician.

Skin contact

Wash off with soap and plenty of water. If skin irritation persists, call a physician.

Eye contact

Rinse immediately with plenty of water for at least 15 minutes. Seek medical advice.

Ingestion

Never give anything by mouth to an unconscious person. Obtain medical attention. Do NOT induce vomiting. Administer 250 - 300 ml water to dilute material in the stomach.

5. FIREFIGHTING MEASURES

Suitable extinguishing media

Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Specific hazards during firefighting

Irritant and toxic fumes are formed in burning.

Special protective equipment for firefighters.

In the event of fire, wear self-contained breathing apparatus. Use NIOSH/MSHA approved respiratory protection.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions

For personal protection see section 8.

Environmental precautions

Prevent leakages from entering drains and ditches that lead to natural waterways.

Methods for cleaning up

Small spills: Dilute residues with water and then neutralize with lime or limestone powder to a solid consistency. Shovel or sweep up. Transfer into suitable containers for disposal.
Large spills: Dilute residues with water and then neutralize with lime or limestone powder to a solid consistency. Shovel or sweep up remaining material. Transfer into suitable containers for disposal.

7. HANDLING AND STORAGE

Handling

Avoid contact with skin, eyes and clothing. Handle in accordance with good industrial hygiene and safety practice. Wash thoroughly after handling. For personal protection see section 8. Keep away from incompatible materials. Follow the instructions for use issued by the producer.

Storage

Hydrogen is released when product reacts with metals. Store in rubber-lined, plastic, FRP or other corrosion resistant material.
Materials to avoid:
aluminium, Carbon steel, brass
mineral acids, Bases, Alkaline materials

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Limit Values

Diiron tris(sulphate)
Permissible exposure limit = 1 mg/m³, Iron
TWA: ACGIH = 1 mg/m³, Iron
TWA = 0.1 mg/m³, as persulfate

Sulphuric acid
TWA = 1 mg/m³, A2: Suspected Human Carcinogen (means that the human data are accepted as adequate in quality but are conflicting or insufficient to classify the agent as A1), Sulphuric acid
STEL = 3 mg/m³, A2: Suspected Human Carcinogen (means that the human data are accepted as adequate in quality but are conflicting or insufficient to classify the agent as A1), Sulphuric acid
TWA = 0.2 mg/m³, Thoracic fraction, : Pulmonary function, Sulfuric acid
TWA = 1 mg/m³, Sulfuric acid

Aluminium sulphate
Permissible exposure limit = 2 mg/m³, Aluminium

Exposure controls

Occupational exposure controls

Provide adequate general and local exhaust ventilation.
Ensure that eyewash stations and safety showers are close to the workstation location. Wash hands before eating, drinking, or smoking. Keep away from food and drink.

Respiratory protection

When there is a potential for airborne exposures in excess of applicable limits, wear NIOSH/MSHA approved respiratory protection.

Hand protection

Chemical resistant gloves.

Eye protection

Wear eye protection/ face protection. Tightly fitting safety goggles or face-shield.

Skin and body protection

Protective clothing.

9. PHYSICAL AND CHEMICAL PROPERTIES

General Information (appearance, odour)

Physical state	, liquid
Colour	reddish, brown
Odour	slightly pungent

Important health safety and environmental information

pH	< 2
Boiling point/boiling range	221 - 230 °F
Flash point	non flammable

Explosive properties:	
Density	1.36 - 1.52 g/cm³
Water solubility	soluble
Evaporation rate	similar to water

Other data

Freezing point :	0 °C 32 °F
VOC Content:	;Not applicable

10. STABILITY AND REACTIVITY

Conditions to avoid

Stable Avoid extreme temperatures.

Materials to avoid

aluminium, Carbon steel, brass

mineral acids, Bases, Alkaline materials

Hazardous reactions :

Hazardous polymerisation does not occur.

Hazardous decomposition products

Sulphur oxides (SOx), Aluminium oxide, Toxic fumes

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Diiron tris(sulphate):
LD50/Oral/rat: 220 mg/kg
Remarks:Calculated as Fe

LC50/Inhalation:
Remarks: no data available, not applicable

LD50/Dermal/rat: > 3,154 mg/kg
Remarks: Read-across (Analogy), CAS-No., 7758-94-3

LD50/Dermal/rat: > 881 mg/kg
Remarks: Calculated as Fe

Sulphuric acid:
LD50/Oral/rat: 2,140 mg/kg

LC50/Inhalation/4 h/rat: 0.375 mg/l
Remarks: aerosol
Although the LC50 values from the various inhalation toxicity studies performed with sulphuric acid theoretically trigger classification for Acute inhalation toxicity, classification is not proposed. The effects of sulphuric acid following inhalation are entirely due to local irritation of the respiratory tract: there is no evidence for the systemic toxicity of sulphuric acid in any study, as effects are limited to the site of contact. Classification for acute inhalation toxicity is not considered to be appropriate.

Aluminium sulphate:
LD50/Oral/rat: > 2,000 mg/kg
Not classified as harmful if swallowed.

LC50/Inhalation/rat: > 5 mg/l
Remarks: No known significant effects or critical hazards., Read-across (Analogy), CAS-No., 39290-78-3

LD50/Dermal/rabbit: > 5,000 mg/kg
Not classified as harmful to health.

Irritation and corrosion

Diiron tris(sulphate):

Skin: rabbit/OECD Test Guideline 404: No skin irritation
Moistened solid is expected to be irritant as a consequence of low pH.

Eyes: rabbit/OECD Test Guideline 405: Causes serious eye damage.
Remarks: Read-across (Analogy) 7758-94-3 dry substance
Aluminium sulphate:

Skin: rabbit/OECD Test Guideline 404: No skin irritation

Eyes: rabbit/OECD Test Guideline 405: Severe eye irritation
May cause irreversible eye damage.

Sensitization

Diiron tris(sulphate):

According to experience sensitization is not expected.

Sulphuric acid:

Not sensitizing.

Aluminium sulphate:
guinea pig/OECD Test Guideline 406
Remarks: Read-across (Analogy) CAS-No. 1327-41-9
Not sensitizing.

Long term toxicity

Diiron tris(sulphate):

Carcinogenicity
Oral/rat/2 years:
Remarks: Information given is based on data obtained from similar substances.
Not believed to be a carcinogen.

Reproductive toxicity
/rat/Reproductive effects:
NOAEL: > 500 mg/kg
NOAEL F1:
Remarks: Read-across (Analogy)

/rat/Developmental toxicity test:
NOAEL: > 1,000 mg/kg
NOAEL F1:
Remarks: Read-across (Analogy)
In animal studies, did not interfere with reproduction.

Teratogenicity
Oral/rat:
NOAEL: > 1,000 mg/kg
Did not show teratogenic effects in animal experiments. Information given is based on data obtained from similar substances.

Sulphuric acid:

Reproductive toxicity
/rabbit/Developmental toxicity test:
NOEL: = 0.020 mg/l
Did not show teratogenic effects in animal experiments.

Aluminium sulphate:

Carcinogenicity
Oral/rat/2 years:
Did not show carcinogenic effects in animal experiments.

Mutagenicity
Mutagenicity (Salmonella typhimurium - reverse mutation assay)/AMES test/OECD Test Guideline 471:
Result: negative
Metabolic activation: with and without

In vitro mammalian cells/micronucleus test/OECD Test Guideline 487:
Result: negative
Metabolic activation: with and without

In vitro gene mutation study in mammalian cells/Lymphoma/OECD Test Guideline 476:
Result: negative

Metabolic activation: with and without

Reproductive toxicity

Oral/rat/female/Reproductive effects/OECD Test Guideline 452:
NOAEL: 3,225 mg/kg
NOAEL F1:
Remarks: bw/day Read-across (Analogy) CAS-No. 31142-56-0
Not believed to be toxic for reproduction.

Oral/rat/female/Reproductive effects/OECD Test Guideline 452:
NOAEL: 300 mg/kg
NOAEL F1:
Remarks: bw/day Calculated as Al Read-across (Analogy) CAS-No. 31142-56-0

Oral/rat/male and female/Developmental toxicity test/OECD Test Guideline 422:
NOAEL: 1,000 mg/kg
NOAEL F1: 1,000 mg/kg
Remarks: bw/day Read-across (Analogy) CAS-No. 1327-41-9
Not believed to be toxic for reproduction. In animal studies, did not interfere with reproduction.

Oral/male and female/OECD Test Guideline 422:
NOAEL: 90 mg/kg
NOAEL F1: 90 mg/kg
Remarks: bw/day Calculated as Al Read-across (Analogy) CAS-No. 1327-41-9

Teratogenicity

Oral/rat/OECD Test Guideline 452:
NOAEL: 323 mg/kg
Mother: 3,225 mg/kg
bw/day Read-across (Analogy) CAS-No. 31142-56-0

Oral/rat/OECD Test Guideline 452:
NOAEL: 30 mg/kg
Mother: 300 mg/kg
bw/day Calculated as Al CAS-No. 31142-56-0 Read-across (Analogy)

Target organ

The substance is not classified.
STOT - repeated exposure

The substance is not classified.
STOT - single exposure

12. ECOLOGICAL INFORMATION

Ecotoxicity effects

Aquatic toxicity

Diiron tris(sulphate):
LC50/96 h/Oncorhynchus mykiss (rainbow trout): > 100 mg/l

NOEC/90 d/Oncorhynchus kisutch (Coho salmon): > 1 mg/l
EC50/48 h/Daphnia: 82.8 mg/l
NOEC/21 d/Daphnia magna (Water flea): > 1 mg/l

The compound is considered to have no long term effects in aquatic systems due to the rapid formation of insoluble hydroxides.

Sulphuric acid:
LC50/96 h/Lepomis macrochirus (bluegill sunfish)/static test: 16 - 28 mg/l
fresh water
NOEC/1,560 h/Jordanella floridae (Flagfish)/flow-through test: 0.025 mg/l
fresh water
EC50/48 h/Daphnia magna (Water flea)/static test/OECD Test Guideline 202: > 100 mg/l
fresh water
NOEC/Tanytarsus dissimilis (midge)/static test: 0.15 mg/l
fresh water
EC50/72 h/Desmodesmus subspicatus (green algae)/static test/OECD Test Guideline 201: > 100 mg/l
Remarks: May be harmful to aquatic organisms because of the low pH value.

Aluminium sulphate:
LC50/96 h/Danio rerio/semi-static test/OECD Test Guideline 203: > 562 mg/l
NOEC/96 h/Danio rerio/semi-static test/OECD Test Guideline 203: > 562 mg/l
LC50/96 h/Danio rerio/semi-static test/OECD Test Guideline 203: > 0.247 mg/l
Calculated as Al Maximum soluble concentration under the test conditions.

EC50/48 h/Daphnia magna (Water flea)/semi-static test/OECD Test Guideline 202: > 90 mg/l
NOEC/48 h/Daphnia magna (Water flea)/semi-static test/OECD Test Guideline 202: > 90 mg/l
LC50/48 h/Daphnia magna (Water flea)/OECD Test Guideline 202: > 0.176 mg/l
Calculated as Al Maximum soluble concentration under the test conditions.

EC50/72 h/Pseudokirchneriella subcapitata (green algae)/static test/OECD Test Guideline 201: 24 mg/l
EC50/72 h/Pseudokirchneriella subcapitata (green algae)/static test/OECD Test Guideline 201: 3.8 mg/l
Calculated as Al
NOEC/72 h/Pseudokirchneriella subcapitata (green algae)/static test/OECD Test Guideline 201: 1.7 mg/l
NOEC/72 h/Pseudokirchneriella subcapitata (green algae)/static test/OECD Test Guideline 201: 0.27 mg/l
Calculated as Al

Toxicity to other organisms

Sulphuric acid:
NOEC/37 d/active sludge/static test: 26 g/l
fresh water
NOEC/30 d/active sludge/static test: > 30 g/l
fresh water

Aluminium sulphate:

no data available

Mobility

Water solubility: soluble

Persistence and degradability

Biological degradability:
Diiron tris(sulphate):

The methods for determining the biological degradability are not applicable to inorganic substances.

Sulphuric acid:

The methods for determining biodegradability are not applicable to inorganic substances.

Aluminium sulphate:

The methods for determining the biological degradability are not applicable to inorganic substances.

Bioaccumulative potential

Diiron tris(sulphate):

Does not bioaccumulate.
Partition coefficient: n-octanol/water: not applicable, inorganic compound

Sulphuric acid:

Does not bioaccumulate.

Aluminium sulphate:

The product is not expected to bioaccumulate.
Partition coefficient: n-octanol/water: not applicable, inorganic compound

Other adverse effects

13. DISPOSAL CONSIDERATIONS

Product	Must be disposed of in accordance with local and national regulations. EPA Hazardous Waste - D002
Contaminated packaging	Packages that cannot be cleaned must be disposed of the same way as the unused product.

14. TRANSPORT INFORMATION

Land transport

DOT:
Description of the goods: UN3264, Corrosive liquid, acidic, inorganic n.o.s. (Aluminium
Proper shipping name sulphate, Ferric sulfate)
Class: 8
Packaging group: III
DOT-Labels 8
Reportable quantity Aluminium sulphate, Ferric sulfate
TDG:
Description of the goods: UN3264, Corrosive liquid, acidic, inorganic n.o.s. (Aluminium
Proper shipping name sulphate, Ferric sulfate)
Class: 8
Packaging group: III
TDG-Labels 8
Reportable quantity Aluminium sulphate, Ferric sulfate

Sea transport
IMDG:
Proper shipping name UN3264, CORROSIVE LIQUID, ACIDIC, INORGANIC N.O.S. (ALUMINIUM SULPHATE, FERRIC SULFATE)
Class: 8
Packaging group: III
IMDG-Labels: 8

Air transport
ICAO/IATA:
Proper shipping name UN3264, CORROSIVE LIQUID, ACIDIC, INORGANIC N.O.S. (ALUMINIUM SULPHATE, FERRIC SULFATE)
Class: 8
Packaging group: III
ICAO-Labels: 8

Special precautions for user

15. REGULATORY INFORMATION

SARA Title III Section 311 Categories
Immediate (Acute) Health Effects: Yes;
Delayed (Chronic) Health Effects: No;
Fire Hazard: No;
Sudden Release Of Pressure Hazard: No;
Reactivity Hazard: No;

SARA 313 - Specific Toxic Chemical Listings
Sulphuric acid (7664-93-9)
OSHA a. United States Occupational Safety and Health Administration substances, 29 CFR 1910.1000, Sub Part Z.

CERCLA Hazardous substance (Reportable Quantities)
Sulphuric acid: 1,000 lb
Diiron tris(sulphate): 1,000 lb
Aluminium sulphate: 5,000 lb

WHMIS Classification

E Corrosive Material

Canadian Ingredient Disclosure List

Diiron tris(sulphate) (10028-22-5)

Aluminium sulphate (10043-01-3)

California Proposition 65

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.
None Present ()

Notification status

:

:

: All components of this product are included in the United States TSCA Chemical Inventory or are not required to be listed on the United States TSCA Chemical Inventory.

: All components of this product are included in the Canada Domestic Substance List (DSL) or are not required to be listed on the Canada Domestic Substance List (DSL).

: All components of this product are included in the Australian Inventory of Chemical Substances (AICS) or are not required to be listed on the Australian Inventory of Chemical Substances (AICS).

: All components of this product are included on the Chinese inventory or are not required to be listed on the Chinese inventory.

: All components of this product are included in the Korean (ECL) inventory or are not required to be listed on the Korean (ECL) inventory.

: All components of this product are included on the Philippine (PICCS) inventory or are not required to be listed on the Philippine (PICCS) inventory.

: All components of this product are included on the Japanese (ENCS) inventory or are not required to be listed on the Japanese (ENCS) inventory.

: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) or are not required to be listed on EINECS.

: All components of this product are included in the New Zealand inventory (NZIoC) or are not required to be listed on the New Zealand inventory(NZIoC).

: This product's Taiwan Toxic Chemical Substances Control Act Inventory status has NOT been determined.

Miscellaneous Information

None

16. OTHER INFORMATION

HMIS Rating

Health: 2
Flammability: 0
Reactivity: 1

NFPA Rating

Health: 2
Fire: 0
Reactivity: 1
Special:

MSDS preparatory statement

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Additions, Deletions, Revisions

Relevant changes have been marked with vertical lines.

Where water
meets chemistry™

Technical Data Sheet
(Ref: KWS-ALS-3330)
18.3.2015

Kemira ALS-3330

Aluminum Ferric Sulfate Solution

KEMIRA ALS-3330 Is a formulation that combines the advantages of Amuminum Sulfate to those of Inorganic Iron Coagulants in order to meet the growing specific needs of our water treatment and wastewater treatment customers. KEMIRA ALS-3330 enables superior performance, such as enhanced phosphurous removal. Product is also highly effective for odor and corrosion control through dissolved sulfied precipitation.

Product Specification

Appearance	Brown liquid
Aluminum (Al)	3.28 ± 0.11%
Specific Gravity (25°C)	1.38 ± 0.05

Typical Analysis

Iron (Fe^{tot})	3.0 ± 0.6%
pH	< 1
Freezing Point	-15°C / 5°F **

Certification / Approval

KEMIRA ALS-3330 meets or exceeds all AWWA standards and is NSF/ANSI Standard 60 certified for use in potable water treatment up to 400 mg/l.

Dosing

KEMIRA ALS-3330 should be fed straight. No dilution or preparation is required. A diaphragm-metering pump of non-corrosive material is suitable.

Storage

Storage tanks and piping should be constructed of suitable material such as stainless steel, fiberglass, cross-linked polyethylene, or reinforced plastics. With this chemical it is recommended to clean the storage tank every 1-2 years.

Handling / Safety

The handling of any chemical requires care. Anyone responsible for using or handling of KEMIRA ALS-3330 should familiarize themselves with the full safety precautions outlined in our Material Safety Data Sheet.

Delivery

Shipping Instructions; Corrosive Liquid, Acidic, Inorganic, n.o.s., 8, UN 3264, P.G. III

**** Note: Product will show higher viscosity and could show signs of crystallization at higher temperatures, depending on storage conditions including humidity factor and presence of impurities**

Kemira makes this information available as an accomodation to its customers and it is intended to be solely a guide in customer´s evaluation of the products. You must test our products, to determine if they are suitable for your intended uses and applications, as well as from the health, safety and environmental standpoint. You must also instruct employees, agents, contractors, customers or any third party which may be exposed to the products about all applicable precautions. All information and technical assistance is given without warranty or guarantee and is subject to change without notice. You assume full liability and responsibility for compliance with all information and precautions, and with all laws and statutes, ordinances and regulations of any governmental authority applicable to the processing, transportation, delivery, unloading, discharge,

Kemira

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Material Safety Data Sheet

KEMIRA ALS-3330

/REG_NA/EN

Revision Date: 02/24/2014 Previous date: 00/00/0000 Print Date:01/25/2016

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1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product information

KEMIRA ALS-3330

Use of the Substance/Mixture

Water treatment chemical

Company Identification

Kemira Water Solutions Canada, Inc.
3405 Boulevard Marie-Victorin
Varennes QC J3X 1T6
CANADA
Telephone. +14506520665, Telefax. +14506527343

Emergency telephone number

2. HAZARDS IDENTIFICATION

Emergency Overview: Causes eye, skin, and respiratory tract irritation. Gastrointestinal irritation
Skin: Causes skin irritation.
Eyes: Causes severe eye irritation.
Inhalation: Inhalation overexposure to the mist or vapor may cause respiratory tract irritation.

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Hazardous or Regulated Components

CAS-number	Chemical name of the substance	Concentration
10028-22-5	Diiron tris(sulphate)	18 - 32 %
7664-93-9	Sulphuric acid	<0.1 %
10043-01-3	Aluminium sulphate	30 - 44 %

Further information

This material is hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29CFR 1910.1200.

This product contains WHMIS regulated (hazardous) components.

4. FIRST AID MEASURES

Inhalation

If breathing has stopped, apply artificial respiration. Remove to fresh air. If breathing is difficult, give oxygen. If symptoms persist, call a physician.

Skin contact

Wash off with soap and plenty of water. If skin irritation persists, call a physician.

Eye contact

Rinse immediately with plenty of water for at least 15 minutes. Seek medical advice.

Ingestion

Never give anything by mouth to an unconscious person. Obtain medical attention. Do NOT induce vomiting. Administer 250 - 300 ml water to dilute material in the stomach.

5. FIREFIGHTING MEASURES

Suitable extinguishing media

Not combustible.
Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Specific hazards during firefighting

Irritant and toxic fumes are formed in burning.

Special protective equipment for firefighters.

In the event of fire, wear self-contained breathing apparatus. Use NIOSH/MSHA approved respiratory protection.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions

Handle in accordance with good industrial hygiene and safety practice.

For personal protection see section 8.

Environmental precautions

Must be disposed of in accordance with local and national regulations.

Prevent leakages from entering drains and ditches that lead to natural waterways.

Methods for cleaning up

Small spills: Dilute residues with water and then neutralize with lime or limestone powder to a solid consistency. Shovel or sweep up. Transfer into suitable containers for disposal.
Large spills: Dilute residues with water and then neutralize with lime or limestone powder to a solid consistency. Shovel or sweep up remaining material. Transfer into suitable containers for disposal.

7. HANDLING AND STORAGE

Handling

Avoid contact with skin, eyes and clothing. Handle in accordance with good industrial hygiene and safety practice. Wash thoroughly after handling. For personal protection see section 8. Keep away from incompatible materials. Follow the instructions for use issued by the producer.

Storage

Hydrogen is released when product reacts with metals. Store in rubber-lined, plastic, FRP or other corrosion resistant material.
Materials to avoid:
aluminium, Carbon steel, brass

mineral acids, Bases, Alkaline materials

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Limit Values

Diiron tris(sulphate)
Permissible exposure limit = 1 mg/m³, Iron
TWA: ACGIH = 1 mg/m³, Iron
TWA = 0.1 mg/m³, as persulfate
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TWA = 1 mg/m³, A2: Suspected Human Carcinogen (means that the human data are accepted as adequate in quality but are conflicting or insufficient to classify the agent as A1), Sulphuric acid
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TWA = 0.2 mg/m³, Thoracic fraction, : Pulmonary function, Sulfuric acid
TWA = 1 mg/m³, Sulfuric acid
Aluminium sulphate
Permissible exposure limit = 2 mg/m³, Aluminium

Exposure controls

Occupational exposure controls

Ensure that eyewash stations and safety showers are close to the workstation location. Wash hands before eating, drinking, or smoking. Keep away from food and drink.

Respiratory protection

When there is potential for airborne exposures in excess of applicable limits, wear NIOSH/MSHA approved respiratory protection.

Hand protection

Protective gloves

Eye protection

Tightly fitting safety goggles or face-shield.

Skin and body protection

Protective clothing.

9. PHYSICAL AND CHEMICAL PROPERTIES

General Information (appearance, odour)

Physical state	liquid,
Colour	reddish, brown
Odour	slightly pungent

Important health safety and environmental information

pH	< 2
Boiling point/boiling range	105 - 110 °C
Boiling point/boiling range	221 - 230 °F

Flash point	not applicable, inorganic compound
Explosive properties:	
Density	1.30 - 1.46 g/cm³
Water solubility	soluble
Other data	
Freezing point :	< 0 °C 32 °F
VOC Content:	;not applicable

10. STABILITY AND REACTIVITY

Conditions to avoid

Stable Avoid extreme temperatures.

Materials to avoid

aluminium, Carbon steel, brass

mineral acids, Bases, Alkaline materials

Hazardous reactions :

Hazardous polymerisation does not occur.

Hazardous decomposition products

Sulphur oxides (SOx), Aluminium oxide, Toxic fumes

11. TOXICOLOGICAL INFORMATION

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Remarks: Read-across (Analogy), CAS-No., 7758-94-3

LD50/Dermal/rat: > 881 mg/kg
Remarks: Calculated as Fe

Sulphuric acid:
LD50/Oral/rat: 2,140 mg/kg
LC50/Inhalation/4 h/rat: 0.375 mg/l

Remarks: aerosol
Although the LC50 values from the various inhalation toxicity studies performed with sulphuric acid theoretically trigger classification for Acute inhalation toxicity, classification is not proposed. The effects of sulphuric acid following inhalation are entirely due to local irritation of the respiratory tract: there is no evidence for the systemic toxicity of sulphuric acid in any study, as effects are limited to the site of contact. Classification for acute inhalation toxicity is not considered to be appropriate.

Aluminium sulphate:
LD50/Oral/rat: > 2,000 mg/kg
Not classified as harmful if swallowed.

LC50/Inhalation/rat: > 5 mg/l
Remarks: No known significant effects or critical hazards., Read-across (Analogy), CAS-No., 39290-78-3

LD50/Dermal/rabbit: > 5,000 mg/kg
Not classified as harmful to health.

Irritation and corrosion

Skin: Irritating to skin.

Eyes:
May cause irreversible eye damage.

Diiron tris(sulphate):

Skin: rabbit/OECD Test Guideline 404: No skin irritation
Moistened solid is expected to be irritant as a consequence of low pH.

Eyes: rabbit/OECD Test Guideline 405: Causes serious eye damage.
Remarks: Read-across (Analogy) 7758-94-3 dry substance

Aluminium sulphate:

Skin: rabbit/OECD Test Guideline 404: No skin irritation

Eyes: rabbit/OECD Test Guideline 405: Severe eye irritation
May cause irreversible eye damage.

Sensitization

Diiron tris(sulphate):

According to experience sensitization is not expected.

Sulphuric acid:

Not sensitizing.

Aluminium sulphate:

guinea pig/OECD Test Guideline 406
Remarks: Read-across (Analogy) CAS-No. 1327-41-9
Not sensitizing.

Long term toxicity

Diiron tris(sulphate):

Carcinogenicity
Oral/rat/2 years:
Remarks: Information given is based on data obtained from similar substances.
Not believed to be a carcinogen.

Reproductive toxicity
/rat/Reproductive effects:
NOAEL: > 500 mg/kg
NOAEL F1:
Remarks: Read-across (Analogy)

/rat/Developmental toxicity test:
NOAEL: > 1,000 mg/kg
NOAEL F1:
Remarks: Read-across (Analogy)
In animal studies, did not interfere with reproduction.

Teratogenicity
Oral/rat:
NOAEL: > 1,000 mg/kg
Did not show teratogenic effects in animal experiments. Information given is based on data obtained from similar substances.

Sulphuric acid:

Reproductive toxicity
/rabbit/Developmental toxicity test:
NOEL: = 0.020 mg/l
Did not show teratogenic effects in animal experiments.

Aluminium sulphate:

Carcinogenicity
Oral/rat/2 years:
Did not show carcinogenic effects in animal experiments.

Mutagenicity
Mutagenicity (Salmonella typhimurium - reverse mutation assay)/AMES test/OECD Test Guideline 471:
Result: negative
Metabolic activation: with and without

In vitro mammalian cells/micronucleus test/OECD Test Guideline 487:
Result: negative

Metabolic activation: with and without

In vitro gene mutation study in mammalian cells/Lymphoma/OECD Test Guideline 476:
Result: negative
Metabolic activation: with and without

Reproductive toxicity

Oral/rat/female/Reproductive effects/OECD Test Guideline 452:
NOAEL: 3,225 mg/kg
NOAEL F1:
Remarks: bw/day Read-across (Analogy) CAS-No. 31142-56-0
Not believed to be toxic for reproduction.

Oral/rat/female/Reproductive effects/OECD Test Guideline 452:
NOAEL: 300 mg/kg
NOAEL F1:
Remarks: bw/day Calculated as Al Read-across (Analogy) CAS-No. 31142-56-0

Oral/rat/male and female/Developmental toxicity test/OECD Test Guideline 422:
NOAEL: 1,000 mg/kg
NOAEL F1: 1,000 mg/kg
Remarks: bw/day Read-across (Analogy) CAS-No. 1327-41-9
Not believed to be toxic for reproduction. In animal studies, did not interfere with reproduction.

Oral/male and female/OECD Test Guideline 422:
NOAEL: 90 mg/kg
NOAEL F1: 90 mg/kg
Remarks: bw/day Calculated as Al Read-across (Analogy) CAS-No. 1327-41-9

Teratogenicity

Oral/rat/OECD Test Guideline 452:
NOAEL: 323 mg/kg
Mother: 3,225 mg/kg
bw/day Read-across (Analogy) CAS-No. 31142-56-0

Oral/rat/OECD Test Guideline 452:
NOAEL: 30 mg/kg
Mother: 300 mg/kg
bw/day Calculated as Al CAS-No. 31142-56-0 Read-across (Analogy)

Target organ

The substance is not classified.
STOT - repeated exposure

The substance is not classified.
STOT - single exposure

Human experience: Inhalation

Symptoms: Inhalation may provoke the following symptoms:

Symptoms: cough and difficulties in breathing

Human experience: Skin contact

Symptoms: Repeated or prolonged skin contact may cause:, dry skin, irritation

Human experience: Eye contact

Symptoms: Contact with eyes causes a smarting pain and a flood of tears., Risk of serious damage to eyes.

Remarks: The product may harm the cornea by mechanical action.

Human experience: Ingestion

Symptoms: Ingestion may provoke the following symptoms:, Nausea, vomiting, irritation of mouth, oesophagus and stomach

12. ECOLOGICAL INFORMATION

Ecotoxicity effects

Aquatic toxicity

This material is not classified as dangerous for the environment. At environmentally relevant pH 5,5 – 8, the solubility of aluminium is low. Aluminium salts dissociate with water resulting in rapid formation and precipitation of aluminium hydroxides. At pH <5.5, the free ion (Al3+) becomes the prevalent form, the increased availability at this pH is reflected in higher toxicity. At pH 6.0–7.5, solubility declines due to the presence of insoluble Al(OH)3. At higher pH (pH >8.0), the more soluble Al(OH)4 - species predominate, which again increases availability.

Aluminium salts must not be released to rivers and lakes in an uncontrolled way and pH variations around 5 - 5.5 should be avoided.

Diiron tris(sulphate):

LC50/96 h/Oncorhynchus mykiss (rainbow trout): > 100 mg/l
NOEC/90 d/Oncorhynchus kisutch (Coho salmon): > 1 mg/l
EC50/48 h/Daphnia: 82.8 mg/l
NOEC/21 d/Daphnia magna (Water flea): > 1 mg/l

The compound is considered to have no long term effects in aquatic systems due to the rapid formation of insoluble hydroxides.

Sulphuric acid:

LC50/96 h/Lepomis macrochirus (bluegill sunfish)/static test: 16 - 28 mg/l
fresh water
NOEC/1,560 h/Jordanella floridae (Flagfish)/flow-through test: 0.025 mg/l
fresh water
EC50/48 h/Daphnia magna (Water flea)/static test/OECD Test Guideline 202: > 100 mg/l
fresh water
NOEC/Tanytarsus dissimilis (midge)/static test: 0.15 mg/l
fresh water
EC50/72 h/Desmodesmus subspicatus (green algae)/static test/OECD Test Guideline 201: > 100 mg/l
Remarks: May be harmful to aquatic organisms because of the low pH value.

Aluminium sulphate:

LC50/96 h/Danio rerio/semi-static test/OECD Test Guideline 203: > 562 mg/l

NOEC/96 h/Danio rerio/semi-static test/OECD Test Guideline 203: > 562 mg/l
LC50/96 h/Danio rerio/semi-static test/OECD Test Guideline 203: > 0.247 mg/l
Calculated as Al Maximum soluble concentration under the test conditions.

EC50/48 h/Daphnia magna (Water flea)/semi-static test/OECD Test Guideline 202: > 90 mg/l
NOEC/48 h/Daphnia magna (Water flea)/semi-static test/OECD Test Guideline 202: > 90 mg/l
LC50/48 h/Daphnia magna (Water flea)/OECD Test Guideline 202: > 0.176 mg/l
Calculated as Al Maximum soluble concentration under the test conditions.

EC50/72 h/Pseudokirchneriella subcapitata (green algae)/static test/OECD Test Guideline 201: 24 mg/l
EC50/72 h/Pseudokirchneriella subcapitata (green algae)/static test/OECD Test Guideline 201: 3.8 mg/l
Calculated as Al
NOEC/72 h/Pseudokirchneriella subcapitata (green algae)/static test/OECD Test Guideline 201: 1.7 mg/l
NOEC/72 h/Pseudokirchneriella subcapitata (green algae)/static test/OECD Test Guideline 201: 0.27 mg/l
Calculated as Al

Toxicity to other organisms

No data is available on the product itself.

Sulphuric acid:
NOEC/37 d/active sludge/static test: 26 g/l
fresh water
NOEC/30 d/active sludge/static test: > 30 g/l
fresh water

Aluminium sulphate:

no data available

Mobility

Water solubility: soluble

Persistence and degradability

Biological degradability:

The methods for determining biodegradability are not applicable to inorganic substances.
Chemical degradation:

Remarks: Reaction with water forms aluminium hydroxide precipitates.

Biological degradability:
Diiron tris(sulphate):

The methods for determining the biological degradability are not applicable to inorganic substances.

Sulphuric acid:

The methods for determining biodegradability are not applicable to inorganic substances.

Aluminium sulphate:

The methods for determining the biological degradability are not applicable to inorganic substances.

Bioaccumulative potential

Diiron tris(sulphate):

Does not bioaccumulate.
Partition coefficient: n-octanol/water: not applicable, inorganic compound

Sulphuric acid:

Does not bioaccumulate.

Aluminium sulphate:

The product is not expected to bioaccumulate.
Partition coefficient: n-octanol/water: not applicable, inorganic compound

Other adverse effects

May lower the pH of water and thus be harmful to aquatic organisms.

13. DISPOSAL CONSIDERATIONS

Product	Must be disposed of in accordance with local and national regulations. EPA Hazardous Waste - D002
Contaminated packaging	Packages that cannot be cleaned must be disposed of the same way as the unused product.

14. TRANSPORT INFORMATION

Land transport

DOT:	
Description of the goods: **Proper shipping name**	UN3264, Corrosive liquid, acidic, inorganic n.o.s. (Aluminium sulphate, Ferric sulfate)
Class:	8
Packaging group:	III
DOT-Labels	8
Reportable quantity	Aluminium sulphate, Ferric sulfate
TDG:	
Description of the goods: **Proper shipping name**	UN3264, Corrosive liquid, acidic, inorganic n.o.s. (Aluminium sulphate, Ferric sulfate)
Class:	8
Packaging group:	III
TDG-Labels	8

Reportable quantity	Aluminium sulphate, Ferric sulfate
Sea transport	
IMDG:	
Proper shipping name	UN3264, CORROSIVE LIQUID, ACIDIC, INORGANIC N.O.S. (ALUMINIUM SULPHATE, FERRIC SULFATE)
Class:	8
Packaging group:	III
IMDG-Labels:	8
Air transport	
ICAO/IATA:	
Proper shipping name	UN3264, CORROSIVE LIQUID, ACIDIC, INORGANIC N.O.S. (ALUMINIUM SULPHATE, FERRIC SULFATE)
Class:	8
Packaging group:	III
ICAO-Labels:	8

Special precautions for user

15. REGULATORY INFORMATION

SARA Title III Section 311 Categories

Immediate (Acute) Health Effects: Yes;
Delayed (Chronic) Health Effects: No;
Fire Hazard: No;
Sudden Release Of Pressure Hazard: No;
Reactivity Hazard: No;

SARA 313 - Specific Toxic Chemical Listings

Sulphuric acid (7664-93-9)
OSHA a. United States Occupational Safety and Health Administration substances, 29 CFR 1910.1000, Sub Part Z.

CERCLA Hazardous substance (Reportable Quantities)

Aluminium sulphate: 5,000 lb
Diiron tris(sulphate): 1,000 lb
Sulphuric acid: 1,000 lb

WHMIS Classification

E Corrosive Material

Canadian Ingredient Disclosure List

Diiron tris(sulphate) (10028-22-5)

Aluminium sulphate (10043-01-3)

California Proposition 65

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.
None Present ()

Notification status

:

:

: All components of this product are included in the United States TSCA Chemical Inventory or are not required to be listed on the United States TSCA Chemical Inventory.

: All components of this product are included in the Canada Domestic Substance List (DSL) or are not required to be listed on the Canada Domestic Substance List (DSL).

: All components of this product are included in the Australian Inventory of Chemical Substances (AICS) or are not required to be listed on the Australian Inventory of Chemical Substances (AICS).

: All components of this product are included on the Chinese inventory or are not required to be listed on the Chinese inventory.

: All components of this product are included in the Korean (ECL) inventory or are not required to be listed on the Korean (ECL) inventory.

: All components of this product are included on the Philippine (PICCS) inventory or are not required to be listed on the Philippine (PICCS) inventory.

: All components of this product are included on the Japanese (ENCS) inventory or are not required to be listed on the Japanese (ENCS) inventory.

: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) or are not required to be listed on EINECS.

: All components of this product are included in the New Zealand inventory (NZIoC) or are not required to be listed on the New Zealand inventory(NZIoC).

: This product's Taiwan Toxic Chemical Substances Control Act Inventory status has NOT been determined.

Miscellaneous Information

None

16. OTHER INFORMATION

HMIS Rating

Health: 2
Flammability: 0

Reactivity: 1

NFPA Rating

Health: 2
Fire: 0
Reactivity: 1
Special:

MSDS preparatory statement

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Sources of key data used to compile the Safety Data Sheet

Regulations, databases, literature, own tests.

Additions, Deletions, Revisions

Relevant changes have been marked with vertical lines.

Safety Data Sheet
Magnafloc® LT22S

1. Identification

Product identifier used on the label

Magnafloc® LT22S

Recommended use of the chemical and restriction on use
Recommended use*: flocculation agent

* The “Recommended use” identified for this product is provided solely to comply with a Federal requirement and is not part of the seller's published specification. The terms of this Safety Data Sheet (SDS) do not create or infer any warranty, express or implied, including by incorporation into or reference in the seller's sales agreement.

Details of the supplier of the safety data sheet

Company:
BASF Canada Inc.
100 Milverton Drive
Mississauga, ON L5R 4H1, CANADA

Telephone: +1 289 360-1300

Emergency telephone number

CANUTEC (reverse charges): (613) 996-6666
BASF HOTLINE: (800) 454-COPE (2673)

Other means of identification
Chemical family: polyacrylamide, cationic

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2. Hazards Identification

According to Hazardous Products Regulations (HPR) (SOR/2015-17)

Classification of the product

Aquatic Acute	3	Hazardous to the aquatic environment - acute

Label elements

Hazard Statement:

H402	Harmful to aquatic life.

Precautionary Statements (Prevention):

P273	Avoid release to the environment.

Precautionary Statements (Disposal):

P501	Dispose of contents/container to hazardous or special waste collection point.

Hazards not otherwise classified

Labeling of special preparations (GHS):
This product is not combustible in the form in which it is shipped by the manufacturer, but may form a combustible dust through downstream activities (e.g. grinding, pulverizing) that reduce its particle size.

According to Controlled Products Regulations (CPR) (SOR/88-66)

Emergency overview

May cause skin irritation.
May cause eye damage.
Use NIOSH approved respirator as needed to mitigate exposure.

3. Composition / Information on Ingredients

According to Hazardous Products Regulations (HPR) (SOR/2015-17)

CAS Number	Weight %	Chemical name
Trade Secret	80.0 - 95.0%	Acrylamide Copolymer
124-04-9	1.0 - 5.0%	adipic acid

According to Controlled Products Regulations (CPR) (SOR/88-66)

CAS Number	Weight %	Chemical name
124-04-9	>= 1.0 - <= 5.0%	adipic acid

4. First-Aid Measures

Description of first aid measures

General advice:
Remove contaminated clothing.

If inhaled:
If difficulties occur after dust has been inhaled, remove to fresh air and seek medical attention.

If on skin:
Wash thoroughly with soap and water.

If in eyes:
Wash affected eyes for at least 15 minutes under running water with eyelids held open.

If swallowed:
Rinse mouth and then drink plenty of water. Check breathing and pulse. Place victim in the recovery position, cover and keep warm. Loosen tight clothing such as a collar, tie, belt or waistband. Seek

medical attention. Never induce vomiting or give anything by mouth if the victim is unconscious or having convulsions.

Most important symptoms and effects, both acute and delayed

Symptoms: No significant symptoms are expected due to the non-classification of the product.
Hazards: No hazard is expected under intended use and appropriate handling.

Indication of any immediate medical attention and special treatment needed

Note to physician

Treatment:	Treat according to symptoms (decontamination, vital functions), no known specific antidote.

5. Fire-Fighting Measures

Extinguishing media

Suitable extinguishing media:
dry powder, foam

Unsuitable extinguishing media for safety reasons:
water jet, carbon dioxide

Additional information:
If water is used, restrict pedestrian and vehicular traffic in areas where slip hazard may exist.

Special hazards arising from the substance or mixture

Hazards during fire-fighting:
carbon oxides, nitrogen oxides
The substances/groups of substances mentioned can be released in case of fire. Very slippery when wet.

Advice for fire-fighters

Protective equipment for fire-fighting:
Wear a self-contained breathing apparatus.

Further information:
The degree of risk is governed by the burning substance and the fire conditions. Contaminated extinguishing water must be disposed of in accordance with official regulations.

Dusty conditions may ignite explosively in the presence of an ignition source causing flash fire.

6. Accidental release measures

Further accidental release measures:
Avoid dispersal of dust in the air (i.e., clearing dust surfaces with compressed air). Avoid the formation and build-up of dust - danger of dust explosion. Dust in sufficient concentration can result in an explosive mixture in air. Handle to minimize dusting and eliminate open flame and other sources of ignition. Forms slippery surfaces with water.

Personal precautions, protective equipment and emergency procedures

Use personal protective clothing.

Environmental precautions

Do not discharge into drains/surface waters/groundwater.

Methods and material for containment and cleaning up

For small amounts: Pick up with suitable appliance and dispose of.
For large amounts: Contain with dust binding material and dispose of.
Avoid raising dust.

Nonsparking tools should be used.

7. Handling and Storage

Precautions for safe handling

Breathing must be protected when large quantities are decanted without local exhaust ventilation. Handle in accordance with good industrial hygiene and safety practice. Forms slippery surfaces with water.

Protection against fire and explosion:
Avoid dust formation. Dust in sufficient concentration can result in an explosive mixture in air. Handle to minimize dusting and eliminate open flame and other sources of ignition. Routine housekeeping should be instituted to ensure that dusts do not accumulate on surfaces. Dry powders can build static electricity charges when subjected to the friction of transfer and mixing operations. Provide adequate precautions, such as electrical grounding and bonding, or inert atmospheres. Refer to NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids (2013 Edition) for safe handling.

Conditions for safe storage, including any incompatibilities

Further information on storage conditions: Store in unopened original containers in a cool and dry place. Avoid wet, damp or humid conditions, temperature extremes and ignition sources.

Storage stability:
Avoid extreme heat.

8. Exposure Controls/Personal Protection

Components with occupational exposure limits

adipic acid

ACGIH TLV TWA value 5 mg/m3 ;

Advice on system design:
Ensure adequate ventilation. Avoid the formation and deposition of dust.
It is recommended that all dust control equipment such as local exhaust ventilation and material transport systems involved in handling of this product contain explosion relief vents or an explosion suppression system or an oxygen deficient environment. Ensure that dust-handling systems (such as exhaust ducts, dust collectors, vessels, and processing equipment) are designed in a manner to prevent the escape of dust into the work area (i.e., there is no leakage from the equipment). Use only appropriately classified electrical equipment and powered industrial trucks.

Personal protective equipment

Respiratory protection:
Wear a NIOSH-certified (or equivalent) organic vapour/particulate respirator.

Hand protection:
Chemical resistant protective gloves

Eye protection:
Safety glasses with side-shields.

Body protection:
light protective clothing

General safety and hygiene measures:
Handle in accordance with good industrial hygiene and safety practice. Ensure adequate ventilation. Wearing of closed work clothing is recommended. Wear protective clothing as necessary to minimize contact. Handle in accordance with good industrial hygiene and safety practice. No eating, drinking, smoking or tobacco use at the place of work.

9. Physical and Chemical Properties

Form:	powder
Odour:	odourless
Odour threshold:	No data available.
Colour:	off-white
pH value:	3.5 - 4.5 (10 g/l)
Melting point:	The substance / product decomposes therefore not determined.
Boiling point:	not applicable
Sublimation point:	No data available.
Flash point:	not applicable
Flammability:	not highly flammable
Lower explosion limit:	For solids not relevant for classification and labelling.
Upper explosion limit:	For solids not relevant for classification and labelling.
Autoignition:	No data available.
Vapour pressure:	The product has not been tested.
Relative density:	No data available.
Bulk density:	approx. 750 kg/m3
Vapour density:	No data available.
Partitioning coefficient n-octanol/water (log Pow):	Study scientifically not justified.
Self-ignition temperature:	not self-igniting
Thermal decomposition:	No decomposition if stored and handled as prescribed/indicated.
Viscosity, dynamic:	not determined
% volatiles:	not applicable
Solubility in water:	Forms a viscous solution.
Solubility (quantitative):	No data available.
Solubility (qualitative):	No data available.
Evaporation rate:	The product is a non-volatile solid.
Other Information:	If necessary, information on other physical and chemical parameters is indicated in this section.

10. Stability and Reactivity

Reactivity
No hazardous reactions if stored and handled as prescribed/indicated.

Corrosion to metals:
No corrosive effect on metal.

Oxidizing properties:
not fire-propagating

Minimum ignition energy:
> 1 J

Chemical stability
The product is stable if stored and handled as prescribed/indicated.

Possibility of hazardous reactions
The product is not a dust explosion risk as supplied; however the build-up of fine dust can lead to a risk of dust explosions.

Conditions to avoid
Avoid extreme temperatures. Avoid humidity.
Avoid dust formation. Avoid electro-static discharge.

Incompatible materials
strong acids, strong bases, strong oxidizing agents

Hazardous decomposition products

Decomposition products:
Hazardous decomposition products: No hazardous decomposition products if stored and handled as prescribed/indicated.

Thermal decomposition:
No decomposition if stored and handled as prescribed/indicated.

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11. Toxicological information

Primary routes of exposure

Routes of entry for solids and liquids are ingestion and inhalation, but may include eye or skin contact. Routes of entry for gases include inhalation and eye contact. Skin contact may be a route of entry for liquefied gases.

Acute Toxicity/Effects

Acute toxicity
Assessment of acute toxicity: Virtually nontoxic after a single ingestion.

Oral
Type of value: LD50
Species: rat
Value: > 5,000 mg/kg (OECD Guideline 401)

Irritation / corrosion

Assessment of irritating effects: May cause slight irritation.

Skin
Species: rabbit
Result: non-irritant
Method: OECD Guideline 404

Eye
Species: rabbit
Result: non-irritant

Sensitization
Assessment of sensitization: Based on the ingredients, there is no suspicion of a skin-sensitizing potential.

Aspiration Hazard
No aspiration hazard expected.

Chronic Toxicity/Effects

Repeated dose toxicity
Assessment of repeated dose toxicity: Based on our experience and the information available, no adverse health effects are expected if handled as recommended with suitable precautions for designated uses. The product has not been tested. The statement has been derived from the properties of the individual components.

Genetic toxicity
Assessment of mutagenicity: Based on the ingredients, there is no suspicion of a mutagenic effect.

Carcinogenicity
Assessment of carcinogenicity: None of the components in this product at concentrations greater than 0.1% are listed by IARC; NTP, OSHA or ACGIH as a carcinogen.
The whole of the information assessable provides no indication of a carcinogenic effect.

Reproductive toxicity
Assessment of reproduction toxicity: Based on the ingredients, there is no suspicion of a toxic effect on reproduction.

Teratogenicity
Assessment of teratogenicity: No teratogenic effects reported.

Other Information
The product has not been tested. The statements on toxicology have been derived from products of a similar structure and composition.

Symptoms of Exposure

No significant symptoms are expected due to the non-classification of the product.

12. Ecological Information

Toxicity

Aquatic toxicity
Assessment of aquatic toxicity:

Fish toxicity and aquatic toxicity are drastically reduced by rapid irreversible adsorption onto suspended and/or dissolved organic matter. Acute effects on aquatic organisms are due to the cationic charge of the polymer, which is quickly neutralised in natural water courses by irreversible adsorption onto particles, hydrolysis and dissolved organic carbon. The hydrolysis products are not acutely harmful to aquatic organisms.

Toxicity to fish
LC50 (96 h) 10 - 100 mg/l, Fish (static)

Aquatic invertebrates
EC50 (48 h) 10 - 100 mg/l, daphnia

Persistence and degradability

Assessment biodegradation and elimination (H2O)
Not readily biodegradable (by OECD criteria).

Information on Stability in Water (Hydrolysis)
> 70 % (28 d) (pH value > 6)
In contact with water the substance will hydrolyse rapidly.

Bioaccumulative potential

Assessment bioaccumulation potential
Based on its structural properties, the polymer is not biologically available. Accumulation in organisms is not to be expected.

Mobility in soil

Assessment transport between environmental compartments

Information on: cationic polyacrylamide

Adsorption to solid soil phase is expected.

Additional information

Sum parameter

Chemical oxygen demand (COD):
not determined

Biochemical oxygen demand (BOD):
not determined

Other ecotoxicological advice:
Must not be discharged into the environment. The product has not been tested. The statement has been derived from substances/products of a similar structure or composition.

13. Disposal considerations

Waste disposal of substance:
Dispose of in accordance with national, state and local regulations.
Dispose of in accordance with local authority regulations.

Container disposal:
Packs that cannot be cleaned should be disposed of in the same manner as the contents. Uncontaminated packaging can be re-used.

14. Transport Information

Land transport
TDG

Not classified as a dangerous good under transport regulations

Sea transport
IMDG

Not classified as a dangerous good under transport regulations

Air transport
IATA/ICAO

Not classified as a dangerous good under transport regulations

15. Regulatory Information

VOC content:

not applicable

Federal Regulations

Registration status:
Chemical DSL, CA released / listed

According to Controlled Products Regulations (CPR) (SOR/88-66)

WHMIS classification: D2B: Materials Causing Other Toxic Effects - Toxic material

This product is WHMIS controlled.

THIS PRODUCT HAS BEEN CLASSIFIED IN ACCORDANCE WITH THE HAZARD CRITERIA OF THE CPR AND THE MSDS CONTAINS ALL THE INFORMATION REQUIRED BY THE CPR.

16. Other Information

SDS Prepared by:
BASF NA Product Regulations
SDS Prepared on: 2016/03/08

We support worldwide Responsible Care® initiatives. We value the health and safety of our employees, customers, suppliers and neighbors, and the protection of the environment. Our commitment to Responsible Care is integral to conducting our business and operating our facilities in a safe and environmentally responsible fashion, supporting our customers and suppliers in ensuring the safe and environmentally sound handling of our products, and minimizing the impact of our operations on society and the environment during production, storage, transport, use and disposal of our products.

Magnafloc® LT22S is a registered trademark of BASF Canada or BASF SE
END OF DATA SHEET

Les Produits Chimiques Erpac Inc.
180, rue St-Charles, bureau 110
Vaudreuil-Dorion (Qc.) J7V 2L1

Téléphone: (450) 218 7753
Fax: (450) 218 6947
Website : www.erpac.ca

MATERIAL SAFETY DATA SHEET

Identification of the substance:

Prosédim ASP-20

Identification: Non-Ionic water-soluble polymer

Regulated Components: None

Product Use: Processing aid for industrial application

HAZARDS IDENTIFICATION

Appearance and Odor:

Form: Granular Solid

Color: White

Odor: None

WHMIS Classification: Not controlled

Other information: Aqueous solutions or powder that becomes wet render surfaces extremely slippery.

FIRST AID MEASURES

Inhalation: Move to fresh air.

Skin contact: Wash with water and soap as a precaution. Get medical attention if irritation develops and persist.

Eye contact: Rinse thoroughly with plenty of water, also under the eyelids. Get medical attention.

Ingestion: Rinse mouth with water. Do not introduce vomiting. Get medical attention if symptoms occur.

FIRE-FIGHTING MEASURES

Suitable extinguishing media: Water. Water spray. Foam. Dry powder. Carbon dioxide (CO_2).

Precautions: Aqueous solutions or powders that become wet render surfaces extremely slippery.

Special protective equipment for firefighters: No special protective equipment required.

ACCIDENTAL RELEASE MEASURES

Personal precaution: No special precautions required.

Environmental precautions: As with all chemical products, do not flush into surface water.

Methods for cleaning up: Do not flush with water. Clean up promptly by sweeping or vacuum. Keep in suitable and closed containers for disposal. After cleaning, flush away traces with water.

HANDLING AND STORAGE

Handling: Avoid contact with skin and eyes. Avoid dust formation. Do not breathe dust

Storage: Keep in a dry place. Storage temperature = -40 ºF – 122 ºF (-40 ºC - 50 ºC).

EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering measures: Use local exhaust if dusting occurs. Natural ventilation is adequate in absence of dusts.

Personal protective equipment:

Respiratory protection: Dust safety masks are recommended where concentration of total dusts is more than 10 mg/m^3.

Hand protection: PVC or other plastic material gloves.

Eyes protection: Safety glasses with side-shields. Do not wear contact lenses where this product is used.

Skin and body protection: Chemical resistant apron or protective suit if splashing or repeated contact with solution is likely.

Hygiene measures: Handle in accordance with good industrial hygiene and safety practice.
Wash hands before breaks and at the end of workday.

PHYSICAL AND CHEMICAL PROPERTIES

Form: Granular solid.

Colour: White.

Odor: None.

pH: 4 - 6 @ 5 g/L

Melting point / range (ºC): Not applicable.

Flash point (ºC): Not applicable.

Autoignition temperature (ºC): Not applicable.

Approx. Bulk density: 0.6 – 0.9.

Water solubility: See Technical Bulletin

LogPow: 0

STABILITY AND REACTIVITY

Stability: Stable. Hazardous polymerisation does not occur.

Materials to avoid: Oxidizing agents may cause exothermic reactions.

Hazardous decomposition products: Thermal decomposition may produce: Nitrogen oxides (NOx), Carbon oxides (Cox).

TOXICOLOGICAL INFORMATION

Acute toxicity

Oral: LD50 / oral / rat > 5 000 mg/kg.

Dermal: The results of testing on rabbits showed this material to be non-toxic even at high dose levels.

Inhalation: Based on studies on similar products, this material is not expected to be toxic.

Irritation:

Skin: The results of testing on rabbits showed this material to be non-irritating to the skin.

Eyes: Testing conducted according to the Draize technique showed the material produces no corneal or iridial effects and only slight transitory conjunctival effects similar to those which all granular materials have on conjunctivae.

Sensitization: The results of testing on guinea pigs showed this material to be non-sensitizing.

Chronic toxicity: A two-years feeding study on rats did not reveal adverse health effects. A one-year feeding study on dogs did not reveal adverse health effects.

ECOLOGICAL INFORMATION

Aquatic Toxicity:

Toxicity to fish: LD50 / Danio rerio (Zebra fish) / 96 hours > 100 mg/L. (OECD 203).

Toxicity to daphnia: EC50 / Daphnia magna (Water flea) / 48 h. > 100 mg/L., (OEDC 202).

Toxicity to algae: IC50 / Chlorella vulgaris (Fresh water algae) / 72 hours > 100 mg/L. (OECD 201).

Environmental fate:

Persistence and degradability: Not readily biodegradable.

Hydrolysis: Does not hydrolyse.

LogPow: 0

Bioaccumulation: Does not boiaccumulate.

DISPOSAL CONSIDERATIONS:

Waste from residues / unused products: In accordance with local, state and federal regulations.

Contaminated packaging: Can be landfilled or incinerated, when in compliance with local, state and federal regulations. Rinse empty containers with water and use the rinse water to prepare the working solution.

TRANSPORT INFORMATION

Remarks: Not classified as dangerous in the meaning of Transport regulations.

REGULATORY INFORMATION

WHMIS Classification: Not controlled

Ingredients disclosure List (IDL): No components listed on the WHMIS ingredients disclosure list.

Domestic Substance List (DSL): All components of this product are either listed on the inventory or are exempt from listing.

OTHER INFORMATION

This MSDS was prepared in accordance with the following.

ISO11014-1: Material Safety Data Sheet for Chemical Products.

Contact: Area Manager.

Les Produits Chimiques Erpac Inc.
180, rue St-Charles, bureau 110
Vaudreuil-Dorion (Qc.) J7V 2L1

Téléphone: (450) 218 7753
Télécopieur: (450) 218 6947

SAFETY DATA SHEET

Identification of the substance:

Prosédim CSP-640

Identification: Cationic water-soluble polymer.

Product use: Processing aid for industrial applications.

HAZARDS IDENTIFICATION:

Aqueous solutions or powders that become wet render surface extremely slippery.

Canada hazard:

Canadian WHMIS Class: Not controlled

COMPOSITION / INFORMATION INGREDIENTS

Regulated components :

Name	CAS-No.	Weight %	Weight %
Adipic acid	124-04-9	<= 5	< = 5
Sulfamic acid	5329-14-6	<= 2,5	< = 5

FIRST AID MEASURES

Inhalation: No hazards which require special first aid measures.

Skin contact: Wash with water and soap as a precaution. In case of persistent skin irritation, consult a physician.

Eye contact: Rinse thoroughly with plenty of water, also under the eyelids. In case of persistent eye irritation, consult a physician.

Ingestion: No hazards which require special first aid measures. The product is not considered toxic based on studies on laboratory animals.

FIRE-FIGHTING MEASURES

Suitable extinguishing media: Water. Water spray. Foam. Carbon dioxide (CO_2). Dry Powder.

Precautions: Aqueous solutions or powder that become wet render surfaces extremely slippery.

Special protective equipment for firefighters: No special protective equipment required.

ACCIDENTAL RELEASE MEASURES

Personal precautions: No special precautions required.

Environmental precautions: As with all chemical products, do not flush into surface water.

Methods for cleaning up: Do not flush with water. Clean up promptly by sweeping or vacuum. Keep in suitable and closed containers for disposal. After cleaning, flush away traces with water.

HANDLING AND STORAGE

Handling: Do not breathe dust. Wash hands before breaks and at the end of workday. Avoid contact with skin and eyes. Avoid dust formation.

Storage: Keep in a cool, dry place. Storage temperature: (0 ºC - 35 ºC).

EXPOSURE CONTROLS / PERSONAL PROTECTION

	British Columbia OEL	Alberta OEL	Ontario OEL	Quebec OEL
Adipic acid	TWA: 5 mg/m³	TWA: 5 mg/m³	TWA: 5 mg/m³	TWA: 5 mg/m³

Engineering measures: Use local exhaust if dusting occurs. Natural ventilation is adequate in absence of dust.

Personal protective equipment:

Respiratory protection: Dust safety masks are recommended where concentration of total dust is more than 10 mg/m³.

Hand protection: Rubber gloves.

Eye protection: Safety glasses with side-shields. Do not wear contact lenses where this product is used.

Skin and body protection: Chemical resistant apron or protective suit if splashing or repeated contact with solution is likely.

Hygiene measures: Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workdays.

PHYSICAL AND CHEMICAL PROPERTIES

Form: Granular solid

Color: White

Odor: None

pH: 3,5 – 1,0 @ 5 g/L

Melting point / Range (ºC): Not applicable.

Flash Point (ºC): Not applicable.

Autoignition temperature (ºC): Not applicable.

Approx Bulk density: 075 ± 0,15.

Water solubility: See Technical Bulletin.

LogPow: 0.

STABILITY AND REACTIVITY

Stability: Stable. Hazardous polymerisation does not occur.

Materials to avoid: Oxidizing agents may cause exothermic reactions.

Hazardous decomposition products: Thermal decomposition may produce Hydrogen chloride gas, Nitrogen Oxydes (NOx). Carbon oxides (COx).

TOXICOLOGICAL INFORMATION

Acute toxicity:

Oral: LD50 / oral / rat > 5 000 mg/kg.

Skin: The results of testing on rabbits showed this material to be non-toxic even at high dose levels.

Inhalation: The product is not expected to be toxic by inhalation.

Irritation:

Skin: Based on laboratory tests, this product does not cause skin irritation.

Eyes: Testing conducted according to the Draize technique showed the material produces no corneal or iridial effects and only slight transitory conjuctival effects similar to those which all granular materials have on conjuctivae.

Regulated components:

Chimic name	Skin	Eye
Adipic acid	Not irritating	Irritating to eyes
Sulfamic acid	Irritating to skin	Irritating to eyes

Sensitization: The results of testing on guinea pigs showed this material to be non-sensitizing.

Chimic name	Sensitization
Adipic acid	Not sensitizing

Chronic toxicity: A one-year feeding study on dogs did not reveal adverse health effects. A two-year feeding study on rats did not reveal adverse health effects.

ECOLOGICAL INFORMATION

Product information:

Aquatic toxicity:

Toxicity to fish: LC50 / Danio rerio / 96 hours = 10-10 mg/L (OECD 203).

Toxicity to daphnia: EC50 / Daphnia magna / 48 hours > 50 mg/L (OECD 202).

Toxicity to algae: Algal inhibition tests are not appropriate. The flocculation characteristics of the product interfere directly in the test medium preventing homogenous distribution which invalidates the test.

Environmental fate:

Hydrolisis: At natural pHs (>6), the polymer degrades due to hydrolysis to more than 70% in 28 days. The hydrolysis products are not harmful to aquatic organisms.

Bioaccumulation: Does not bioaccumulate.

LogPow: 0

Other ecological information: The effects of this product on aquatic organisms are rapidly and significantly mitigated by the presence of dissolved organic carbon in the aquatic environment.

Regulated components:

Aquatic toxicity	Toxicity to fish:	Toxicity to daphnia:	Toxicity to algae
Adipic acid	LC50 / Fish / 96h > 100 mg/l	EC50 / Daphnia / 48h = 85,6 mg/l	EC50 / Algae / 72h = 31,3 mg/l
Sulfamic acid	LC50 / Fish / 96h = 70,3 mg/l	EC50 / Daphnia / 48h = 5 000 mg/l	No data available

Environmental fate:

	Persistence and degradability:	Hydrolysis :	Bioaccumulation :	Log Pow :
Adipic acid	Not readly biodegradable	No data available	Does not bioaccumulate	0,093

DISPOSAL CONSIDERATIONS

Waste from residues / unused products: In accordance with local, state, and federal regulations.

Contaminated Packaging: Rinse empty containers with water and use the rinse water to prepare the working solution. Can be landfilled or incinerated, when in compliance with local regulations.

TRANSPORT INFORMATION

TDG Canada: Not classified as dangerous in the meaning of TDG (Canada) regulations.

IMDG / IMO: Not classified as dangerous in the meaning of IMDG / IMO (Canada) regulations.

ICAO / IATA: Not classified as dangerous in the meaning of ICAO / IATA (Canada) regulations.

REGULATORY INFORMATION

Canadian WHMIS Class: Uncontrolled product based on test result.

Canadian Ingredients Disclosure List (IDL): Adipic acid

INTERNATIONAL INVENTORIES:

Canada (DSL): All components of this product are either listed on the inventory or are exempt from listing.

USA (TSCA): All components of this product are either listed on the inventory or are exempt from listing.

OTHER INFORMATION:

This MSDS was prepared in accordance with the following:
ISO 11014-1: Material Safety Data Sheet for Chemical Product

Contact: Area Manager.

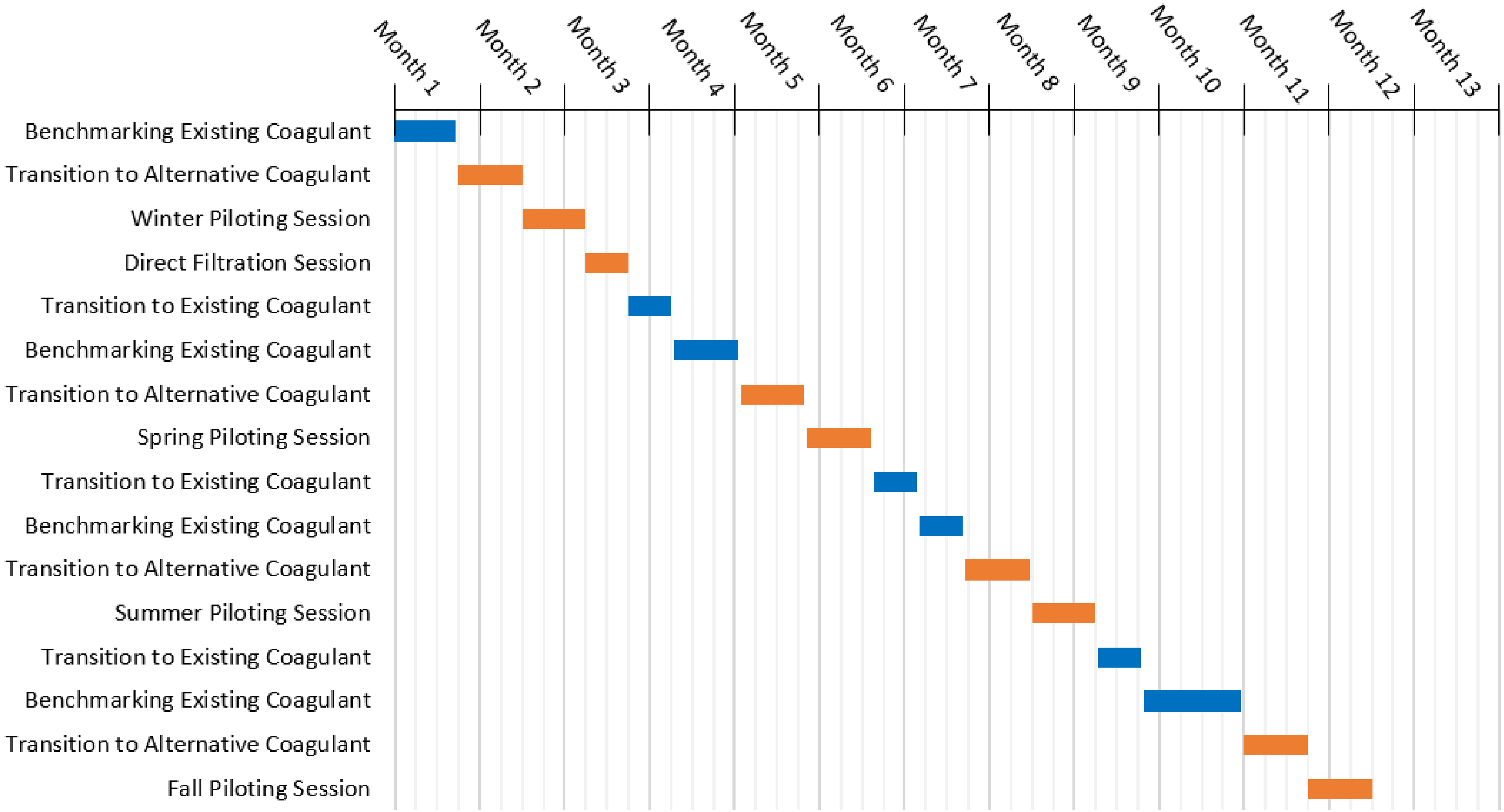
Appendix B – Current Coagulant Performance Benchmark

Table 1: Current Coagulant Performance Benchmark

Sample		Temperature	pH	Turbidity	True Color	Apparent Color	UVT Filtered	UVT Unfiltered	Threshold Odor Number	DOC	TOC	DO	ORP	Alkalinity	Conductivity	TDS	TS	Fe Total	Fe Soluble	Mn Total	Mn Soluble	Sodium	Sulphate	Chloride	CSMR	Total-THM	Total-HAA
		°C	-	NTU	units	units	%	%	TON	mg/L	mg/L	mg/L	mV	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	µg/L	µg/L
Raw Water Pumping Station	Avg	9.51	7.98	1.11	5.37	11.27	77.01	74.88	123.17	9.51	9.72	10.85	352.2	75.3	168.2	105.2	115.7	0.05	0.02	0.014	0.004	2.3	1.7	3.0	1.00	-	-
	Min	0.50	7.27	0.26	2.50	5.00	73.46	71.74	75.0	7.00	6.00	7.15	237.0	68.0	149.0	61.0	92.0	0.01	0.01	0.002	0.000	1.9	0.0	1.4	0.40	-	-
	Max	24.14	8.69	4.91	8.50	18.00	80.70	78.60	200.0	21.00	20.00	14.00	553.0	85.0	190.0	166.0	225.0	0.54	0.04	0.049	0.024	3.5	5.0	6.2	3.00	-	-
Post-DAF	Avg	-	5.59	0.54	-	-	92.94	86.10	-	4.19	4.33	11.31	361.3	8.7	-	-	-	0.59	0.24	0.049	0.045	-	50.3	20.2	0.41	-	-
	Min	-	4.92	0.21	-	-	90.30	78.10	-	3.00	2.80	7.46	258.0	5.0	-	-	-	0.05	0.09	0.029	0.029	-	40.0	14.0	0.28	-	-
	Max	-	6.41	1.45	-	-	94.40	91.60	-	7.00	7.00	14.30	544.0	16.0	-	-	-	1.79	0.65	0.100	0.097	-	62.0	48.0	1.04	-	-
Post-Ozone Contactor	Avg	-	5.58	0.79	0.79	-	-	-	-	-	4.17	12.58	350.3	-	-	-	-	0.65	0.18	0.042	0.033	-	-	-	-	-	3.50
	Min	-	5.31	0.37	0.50	-	-	-	-	-	1.00	8.78	258.0	-	-	-	-	0.04	0.04	0.028	0.015	-	-	-	-	-	3.00
	Max	-	6.09	1.42	2.50	-	-	-	-	-	8.00	16.10	508.0	-	-	-	-	1.31	0.49	0.076	0.059	-	-	-	-	-	4.00
Post-Carbon Filters	Avg	-	5.58	0.12	0.65	-	-	-	10.0	-	3.67	-	-	-	-	-	-	0.07	-	0.031	0.032	-	-	-	-	-	3.00
	Min	-	5.30	0.06	0.50	-	-	-	6.00	-	2.00	-	-	-	-	-	-	0.01	-	0.013	0.016	-	-	-	-	-	3.00
	Max	-	7.61	0.27	1.00	-	-	-	15.0	-	6.00	-	-	-	-	-	-	0.31	-	0.051	0.048	-	-	-	-	-	3.00
Clear Well	Avg	10.46	7.84	0.18	1.40	5.88	94.97	93.84	24.1	4.21	4.19	9.57	396.0	70.5	316.5	176.0	190.8	0.05	-	0.036	0.022	33.1	48.4	20.3	0.44	-	-
	Min	0.90	7.38	0.08	0.50	2.50	92.34	90.33	12.0	1.00	1.00	6.36	267.0	57.0	271.0	116.0	146.0	0.01	-	0.018	0.010	23.4	23.0	13.0	0.20	-	-
	Max	24.58	8.30	0.47	7.50	11.00	97.13	95.82	75.0	19.00	19.00	12.00	665.0	89.0	368.0	310.0	336.0	0.24	-	0.061	0.038	67.1	70.0	29.0	1.04	-	-
	Minimum	0.48	7.26	-	-	0.50	-	-	-	-	-	-	278.0	57.0	-	158.0	-	0.01	-	0.002	-	-	29.0	13.0	0.20	-	-
	Maximum	24.14	8.35	-	-	20.00	-	-	-	-	-	-	549.0	86.0	-	248.0	-	0.17	-	0.179	-	-	69.0	30.0	0.86	-	-

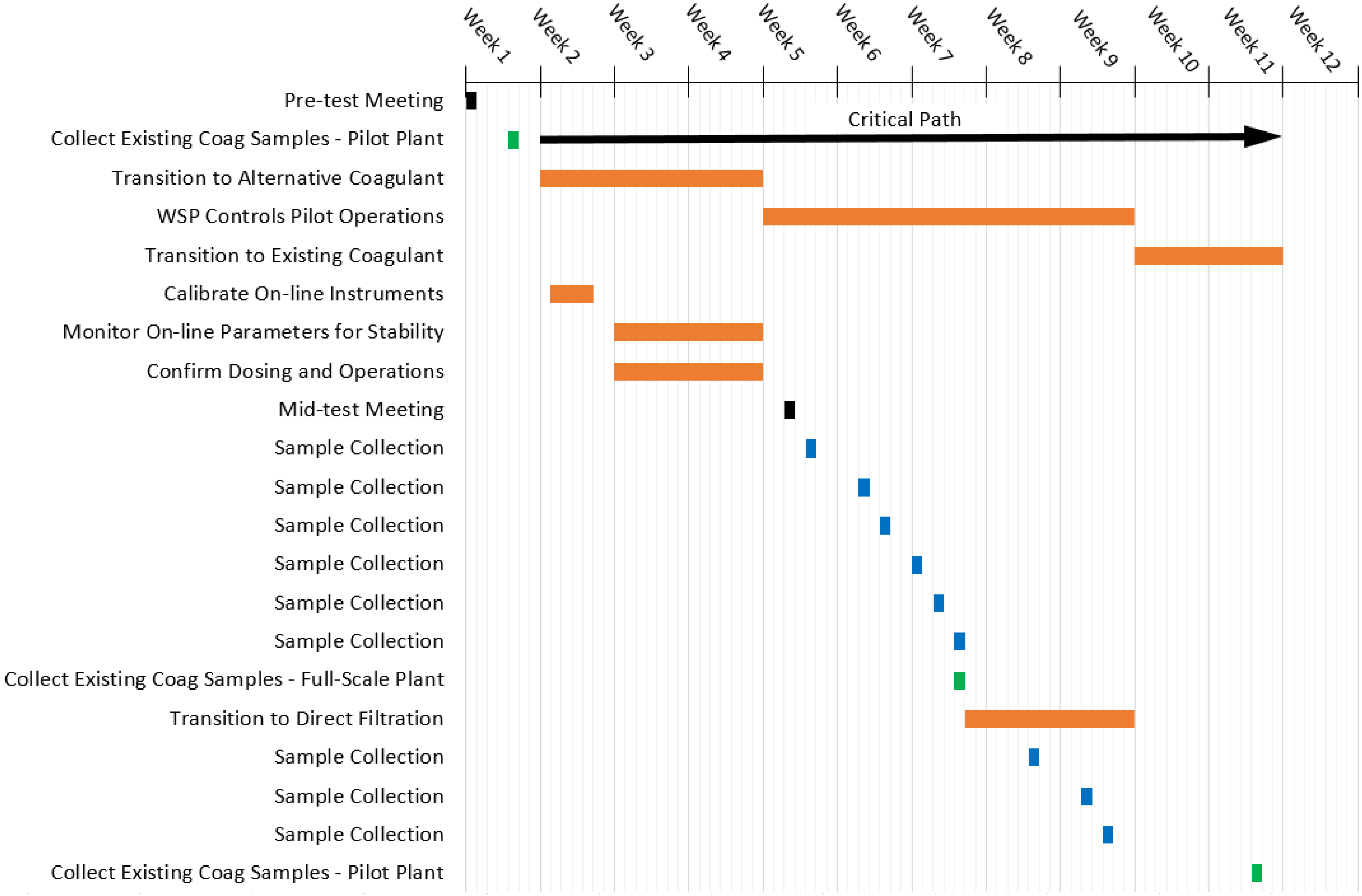
Note: Data from 2010 to beginning of 2016.

Appendix C – Project Schedules and Sampling Details



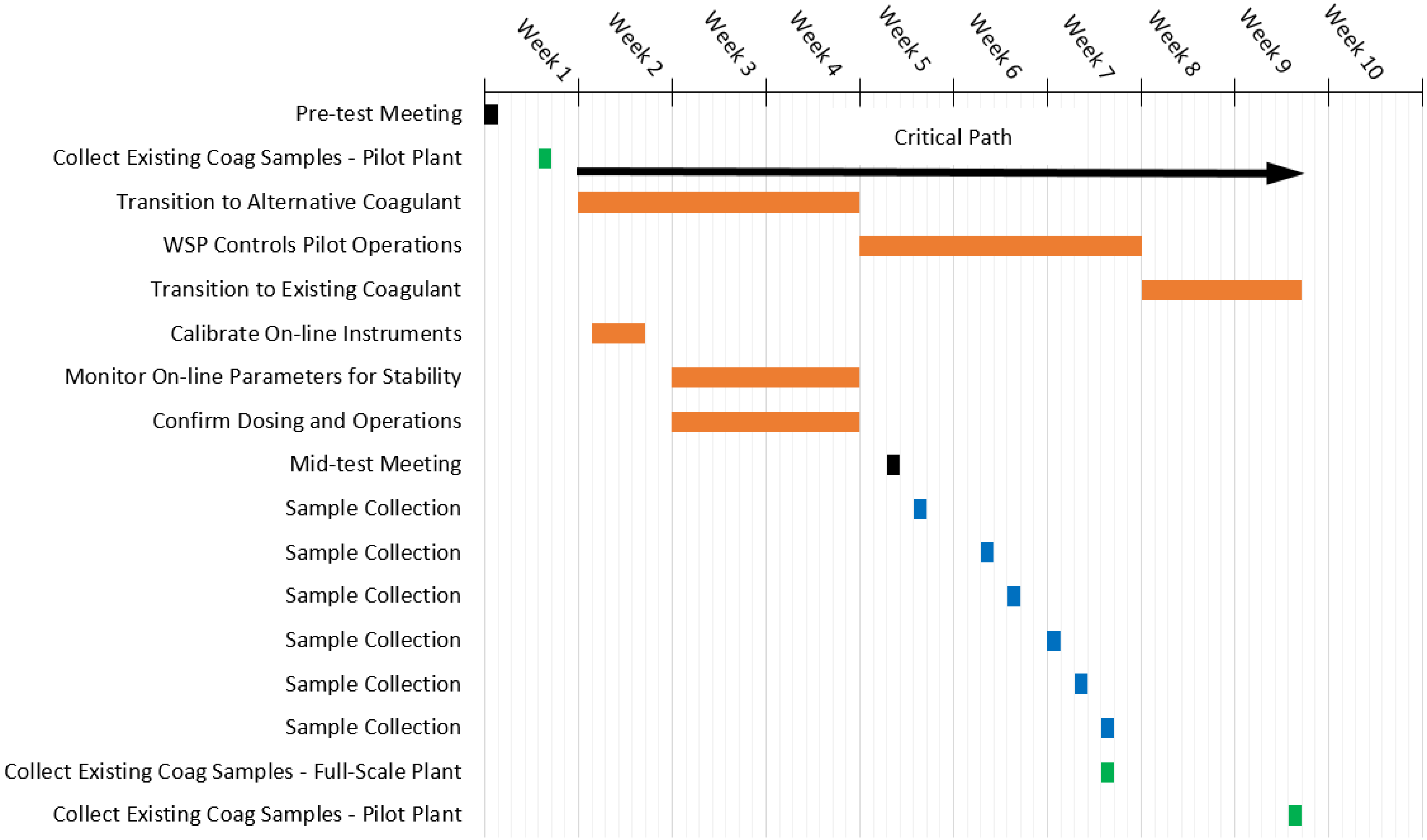
Note: Orange bars = Pilot operations with alternative coagulant; Blue bars = Pilot operations with existing coagulant

Figure 1: Summary of Proposed Annual Schedule



Note: Orange bars = Pilot activities; Blue bars = Alternative coagulant samples; Green bars = Existing coagulant samples; Black bars = Meetings

Figure 2: Summary of Proposed Winter Sampling Schedule



Note: Orange bars = Pilot activities; Blue bars = Alternative coagulant samples; Green bars = Existing coagulant samples; Black bars = Meetings

Figure 3: Summary of Proposed General Schedule for Spring, Summer and Fall Pilot Work

Appendix D – Pilot Plant Safe Work Procedures

1) Material Safety Data Sheets (MSDS)

- MSDS posted or readily available for all coagulants used pilot the plant.

2) Worksite Hazardous Material Information System (WHMIS) Labeling

- All chemical containers (coagulants/acid/polymers) properly labeled with WHMIS Supplier Label.

3) Safety Training

- Pilot plant operators have WHMIS Training or can identify one person on staff with WHMIS training.
- Pilot plant operators have first aid training or can identify one person on staff with first aid training.
- Pilot plant operators participates in regular safety meeting with the rest of the Water Treatment Plant staff.

4) Pilot plant Operators Can Identify

- All WHMIS symbols associated with coagulants and associated chemicals used in the pilot plant.
- First aid and emergency response procedures for all coagulants and chemicals used in the pilot plant.
- Storage and safe handling procedures for all coagulant and chemicals used in the plant.
- Coagulant and chemical spill response procedures.
- Emergency evacuation and critical firefighting responses.

5) First Aid Kit

- Pilot plant operators know where the closest first aid kit is.
- First Aid Kit to include: First aid manual and record book, surgical gloves, CPR pocket valve mask, various size bandages, surgical tapes, safety pins, antiseptic towelettes, tweezers, blunt scissors.
- Sign is posted identifying where the first aid kit is.

6) Eyewash Station

- Properly signed and clearly visible.
- Functional and checked regularly.

7) Fire Protection

- Fire extinguisher is BC type (Not ABC – ABC extinguishers may contain ammonium compounds that can react explosively with chlorine or other oxidants).
- Tag on fire extinguisher is current for monthly inspections and annual maintenance

- Gauge indicates pressure is OK (if stored pressure extinguisher).
- Local Fire department is aware of hazards associated with chemicals in the pilot plant and WTP.

8) Personal Protective Equipment (PPE)

- Safety glasses or full-face shield readily available.
- Respirator (NIOSH approved with chlorine cartridge with dust/mist pre-filter) when handling coagulants or associated pilot plant chemicals.
- Gloves (nitrile, neoprene or PVC).
- Chemical resistant lab coat, apron, or coveralls.
- Chemical resistant footwear.
- All PPE used when handling or mixing coagulant and associated pilot plant chemicals.

9) Housekeeping

- Entrance and exit stairways to pilot plant are cleaned from ice and snow.
- Work area is free of hazards - no boxes, equipment or other hazards blocking entrances, exits, stairways or walkways on either the inside or outside.
- In ground drains and piping connections/access ports are securely covered.
- Work area is clean and swept.
- Log book and other documentation related to pilot plant operation is readily available.

10) Signage

- Where applicable, hazards have appropriate signage.
- MSDS, First Aid Kit and Eyewash Station locations are clearly marked.

11) Ventilation

- Sufficient air movement and exchanges provided for pilot plant coagulant and associated chemical storage and mixing areas to minimize stagnation.

12) Chemical Storage

- Coagulant and associated chemical storage area is clean and dry.
- Coagulant and chemical containers are properly sealed and vented as required.
- Coagulants, oxidants and associated incompatible chemicals are not stored side by side.

13) Spill Containment and Response

- Spill containment is provided for coagulants and associated pilot plant chemicals.
- Floor drain drains to a known and acceptable location (i.e. not to the outside or to a sewer), and otherwise allows for spill containment.
- A Spill Response Plan is developed and made available to pilot plant operators and WTP staff.

14) Emergency Response

- An Emergency Response Plan is made available to pilot plant operators and WTP staff.

15) Laboratory Specific

- Lab area is clean and well organized.
- Reagents are stored in cool, dark, dry area; stock reagents with WHIMIS supplier labels.
- Equipment is cleaned and stored properly.

16) Structural

- Handrails are securely in place on stairs and elevated platforms.

17) Mechanical

- Shaft and pump guards are in place on pumps where applicable.

18) Electrical

- Electrical panels are located away from coagulant and associated chemical storage and mixing areas.
- Electrical panels are kept closed and locked.
- Electrical equipment and panels are checked for corrosion regularly.

Appendix E –Benchmarking Pilot Performance

Pilot Operation

Perhaps the most critical component of benchmarking pilot performance is ensuring that the pilot is operated in the same manner as the full-scale plant. Specifically, every possible effort must be made to ensure that the pilot is initially operated in the same manner as the full-scale plant with respect to chemical dosing, flow rate, mixing duration, mixing intensity, DAF processes, ozonation, and filtration. Matching performance may become more difficult when full-scale plant flows change. The ideal scenario is to operate one train of the full-scale plant under static conditions for a period of time to eliminate this variability. When this is not possible, the pilot operation should be adjusted daily to match the full-scale conditions. In the case of Winnipeg WTP, the full-scale plant is considered to be operated in a very static manner in terms of flow.

Biologically active filtration can be difficult to mimic in pilot systems; therefore, it would be recommended that media from the full-scale plant be harvested and installed in the pilot filters immediately prior to any benchmark testing. In addition to effluent water quality, it would be beneficial to characterize the media in the filters by measuring biomass concentration (adenosine triphosphate).

It is also critical to ensure that any oxidant added in the treatment process (chlorine or ozone) is measured before and after filtration. Sodium bisulphite is used as a quencher at full-scale to prevent oxidation of the biofilm, and should also be used at pilot-scale to prevent biofilm loss.

Sample Collection

To effectively evaluate the performance of the pilot plant, sample collection at a number of points through the plant is required. Twelve (12) potential sampling locations were identified within the pilot plant that would allow for effective pilot benchmarking, and sequential confirmation of pilot operation. Samples should be concurrently collected from the analogous locations within the full-scale plant for comparison between the two systems.

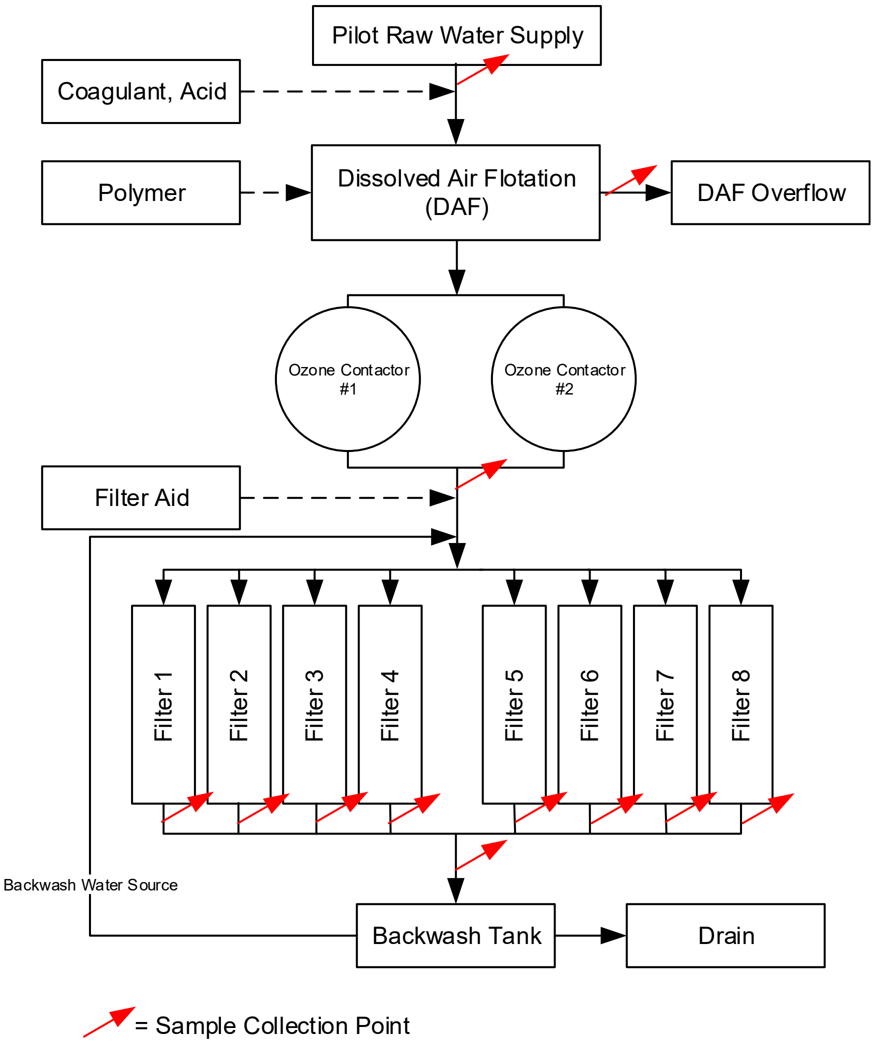


Figure 1: Summary of Sampling Locations at the Pilot Plant

Benchmarking performance sequentially will simplify troubleshooting by isolating individual processes, instead of attempting to correct everything at once.

First, raw water samples would be collected to confirm that no changes in raw water quality occur between the intake and the pilot. It is particularly important to ensure that temperature at the pilot is the same as the full-scale plant, as small changes can have large impacts in treatment performance.

Secondly, samples would be collected subsequent to the coagulation and dissolved air floatation processes. This would allow for isolation of the DAF process, and changes to coagulant dose, or DAF time can be made as necessary to match full-scale. Next, samples would be collected after ozone to confirm that the ozone dose and contact time are similar to those used at full-scale. Finally, samples would be collected before and after each of the eight filters.

Filter influent samples would be used to ensure that water quality matches full-scale, and that both trains of filters receive equal quality water. The effluent samples would confirm that the pilot-filters perform similarly to the full-scale filters, and that each of the pilot filters produces the same quality water.

Statistical Analysis

After the samples have been analyzed, the pilot and full-scale systems must be compared. To compare the two systems a two-tailed, t-test will be applied to the data with a 0.8 level of significance (α=0.2). The equation for the t-test that would be applied is shown below:

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where:

$$s_p^2 = \frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}$$

and: t = the t-test statistic distribution

x_1 = average of pilot plant parameter

x_2 = average of full-scale plant parameter

n_1 = number of data points collected at pilot-scale

n_2 = number of data points collected at full-scale

s_1 = standard deviation of pilot plant data

s_2 = standard deviation of full-scale plant data

These calculations can be accomplished using the statistics package in Microsoft Excel. Specifically, the formula used is called “t-test”, and requires 4 inputs. The first two inputs are the arrays of data which are to be compared. The third input is the number of tails for analysis. In this case we will be examining the “two-tail option”, as we cannot assume that the pilot results will be greater or less than the full-scale data. The final input dictates the analysis type. It is assumed that the results are “two-sample unequal variance” which provides the most conservative measurement of statistical significance. If the result of this calculation is >0.2, then the pilot will be deemed to be equivalent to the full-scale plant.

Changes in raw water quality may increase the variation in water quality, and limit the significance of the data. As such, the t-test will be performed on the water quality data (concentration as measured by the lab), and the percent change across the unit process. By evaluating the difference, the performance is normalized to the influent water quality, and the results are stronger statistically, as the variation is not increased due to variations outside of the experimental design (changes in raw water quality).

It is suggested that parameters which may be monitored online (pH, turbidity, UVT, DO, etc.) be monitored most closely. After a period of time in which the online measurements have matched based on the previous equations (pooled t-test on daily average values for 7 consecutive days), sampling for the remaining parameters should be completed. Grab samples should be collected twice a week for two weeks, which will provide a minimum of four samples at each location, however daily monitoring is preferred to better account for daily variations in the two systems. If there is no statistical difference calculated between the pilot and full-scale processes, the pilot plant will be deemed to match full-scale, and testing of the alternative coagulant may commence.

APPENDIX

C

TM No. 3

WINTER PILOTING SESSION #1
(MARCH 15 - APRIL 5, 2017)

TECHNICAL MEMORANDUM NO. 3

PROJECT: Pilot Testing an Alternative Coagulant for the Winnipeg Water Treatment

PROJECT No.: 161-06111-00

TO: Heather Buhler, City of Winnipeg

FROM: Maika Pellegrino (WSP), Justin Rak-Banville (WSP), Charles Goss (WSP)

SUBJECT: Winter Piloting Session (March 15 to April 5, 2017) – Rev. 5 (FINAL)

DATE: August 20, 2018

1 OVERVIEW

Technical Memorandum No. 3 (TM No. 3) evaluates the piloting results under cold water winter conditions (below 4ºC) and the alternative coagulant, ferric sulphate ($Fe_2(SO_4)_3$). Specifically, this technical memo examines the results of the Winter benchmarking period, the subsequent coagulant transition period, and the alternative coagulant piloting session, inclusive of recommendations regarding the following Spring piloting session. The piloting work program details and the guidelines for benchmarking and transition periods can be found in Technical Memorandum No. 2 (TM No. 2).

WSP conducted the Winter piloting session using the City's pilot-scale system and the selected alternative coagulant, ferric sulphate. The evaluation of potential coagulants in the pilot-scale system during winter conditions were defined as temperatures less than 4ºC. Note that due to scheduling constraints with the anticipated rapid onset of warmer raw water above 4ºC, operation of the pilot-scale system during cold water conditions via direct filtration was not included in this Winter piloting session.

The following tabulates the piloting activity during the Winter piloting session (Table 1-1). The benchmarking period for cold water conditions was carried out between February 4th and February 17th, 2017 using ferric chloride as the dissolved air flotation (DAF) coagulant. On February 24th, 2017, the coagulant was transitioned to ferric sulphate with coagulant-aid (LT-22S). The Winter piloting session began on March 15th and was completed on April 5th, 2017. Following completion of the Winter piloting session, the pilot-scale system's coagulant was switched back to ferric chloride and the coagulant-aid polymer discontinued.

Table 1-1: Winter Piloting Session Schedule

WINTER PILOTING SESSION (<4ºC)	DURATION	START	FINISH
1. Winter Benchmarking Period	14 days	February 4, 2017	February 17, 2017
2. Winter Transition Period	18 days	February 24, 2017	March 14, 2017
3. Winter Pre-Piloting Progress Meeting	1 day	March 9, 2017	March 9, 2017
4. Winter Piloting Session	21 days	March 15, 2017	April 5, 2017
5. Winter Mid-Point Progress Meeting	1 day	March 23, 2017	March 23, 2017

2 WINTER BENCHMARKING PERIOD

Following the conclusion of pilot-scale system commissioning, the subsequent task was a comparison between the full-scale and pilot-scale systems. The benchmarking of the pilot-scale system was conducted between February 4th and February 17th, 2017 by City personnel. During the benchmarking period, pilot-scale system operations were conducted to mimic the full-scale system operation, including chemical dose rate and flows. This included daily water quality analyses from both the full-scale and pilot-scale systems. It should be noted that the pilot-scale system and the full-scale system data herein after are referred to as “pilot-scale” and “full-scale” in corresponding graphs and tables.

The daily pilot-scale system samples were collected from the following locations:

- Pilot-scale system raw water feed source (prior to the first series of chemical injection points);
- Post-DAF (via the DAF overflow piping to the overflow tank);
- Post-Ozone (from the combined ozone column piping feeding the Ozone Contact tank);
- Individual filter effluents (Filters 1 through 8);

The full-scale system samples were collected from the following locations:

- Full-scale WTP raw water;
- Post-DAF;
- Individual filter effluents (Filters 1 through 8); and
- Post Filter Combined

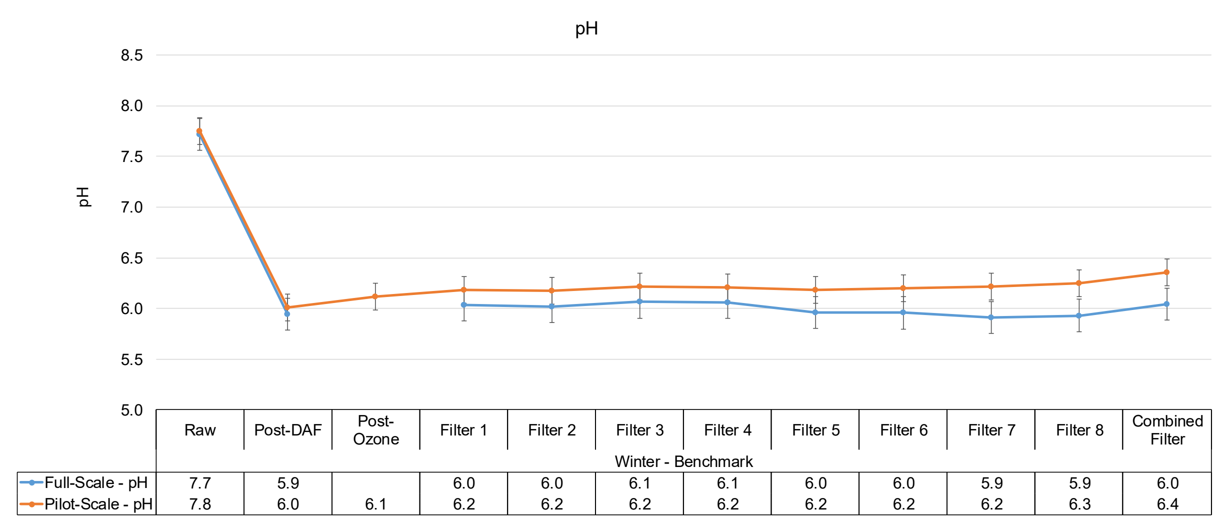
Post-Ozone effluent was not collected from the full-scale system during the Winter benchmarking period, because the ozone generator was offline in the full-scale and pilot-scale systems.

Section 2.1 to Section 2.3 demonstrate the results pertaining to the following five key parameters: pH, turbidity, total organic carbon (TOC), UV-transmittance (UVT), and manganese (total and dissolved), all of which were used for the comparison between the full-scale and the pilot-scale systems.

These sections present the average parameters measured for each process during the Winter benchmark period. The standard deviation for each sample is illustrated via error bars. The standard error estimates the variability between sample means that would be obtained by taking multiple samples from the same population, alternatively the standard error of the mean is used to determine how precisely the mean of the sample estimates the population mean. Smaller error bars indicate more precise estimates of the population mean, which can vary based on the number of samples. A full summary of the daily results for these key parameters, as well as the results for non-key parameters, are available in Appendix A. The benchtop and laboratory analysis can be found in Appendix D1. The laboratory analysis was completed by the City’s Analytical Services Branch (hereafter referred to as Lab).

2.1 pH

Figure 2-1 illustrates that during the Winter benchmarking period the raw water pH was 7.7, on average. In both systems, pH was reduced Post-DAF to approximately 6.0 following the addition of sulphuric acid and ferric chloride. The pH slightly increased following filtration in the pilot-scale system, whereas the pH in the full-scale system appeared to remain relatively constant throughout the treatment process. The observed differences in the final recorded pH is believed to be negligible between the two systems and is deemed acceptable for this study.

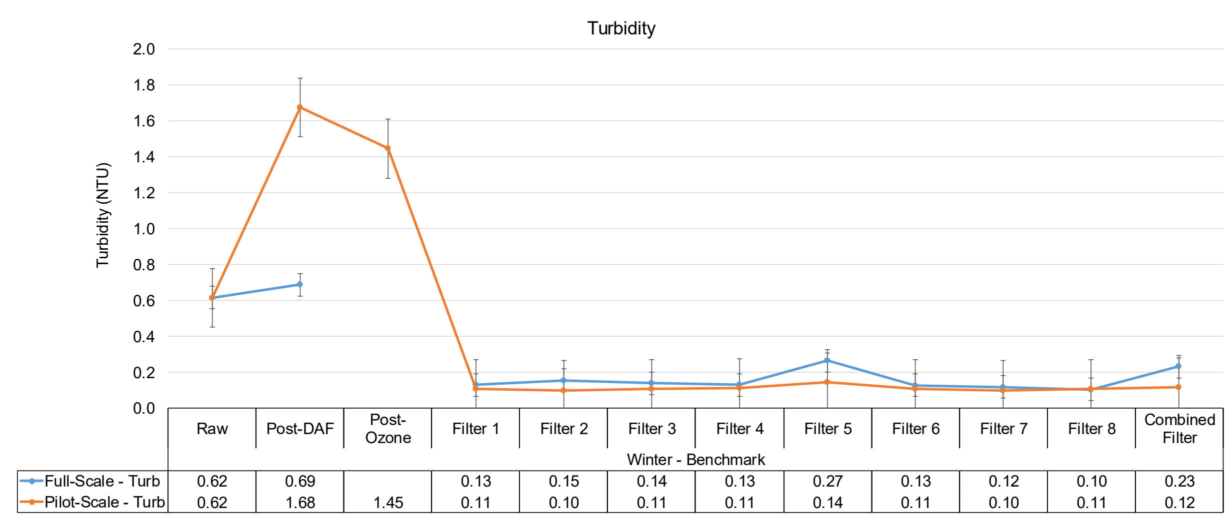


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full-Scale - pH	7.7	5.9		6.0	6.0	6.1	6.1	6.0	6.0	5.9	5.9	6.0
Pilot-Scale - pH	7.8	6.0	6.1	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.3	6.4

Figure 2-1: Average pH of the full-scale and pilot-scale systems during the Winter benchmarking period. Data originates from Lab analyses.

2.2 Turbidity

Turbidity results had the greatest deviation between the full-scale and pilot-scale systems, particularly when comparing the samples collected Post-DAF. On average, the turbidity significantly increased in the pilot-scale system Post-DAF, from 0.62 NTU to 1.68 NTU, whereas only a slight increase in turbidity was observed in the Post-DAF samples collected from the full-scale system (Figure 2-2). These differences in turbidity between the two systems can likely be attributed to the scaling differences between full-scale and pilot-scale system coagulation and flocculation tanks, and the smaller pilot-scale system DAF surface area. The smaller tank size in the pilot-scale system equates to a retention time of approximately 6 minutes, at a flow rate of 3.0 L/s, compared to the full-scale system where the retention time in the DAF is approximately 38 minutes, when operating at a flow rate of 200 MLD. The shorter retention time of the pilot-scale system DAF, and smaller surface area, increase the potential for carryover of air saturated water which would also contribute to the increase in turbidity values observed in the pilot-scale system.



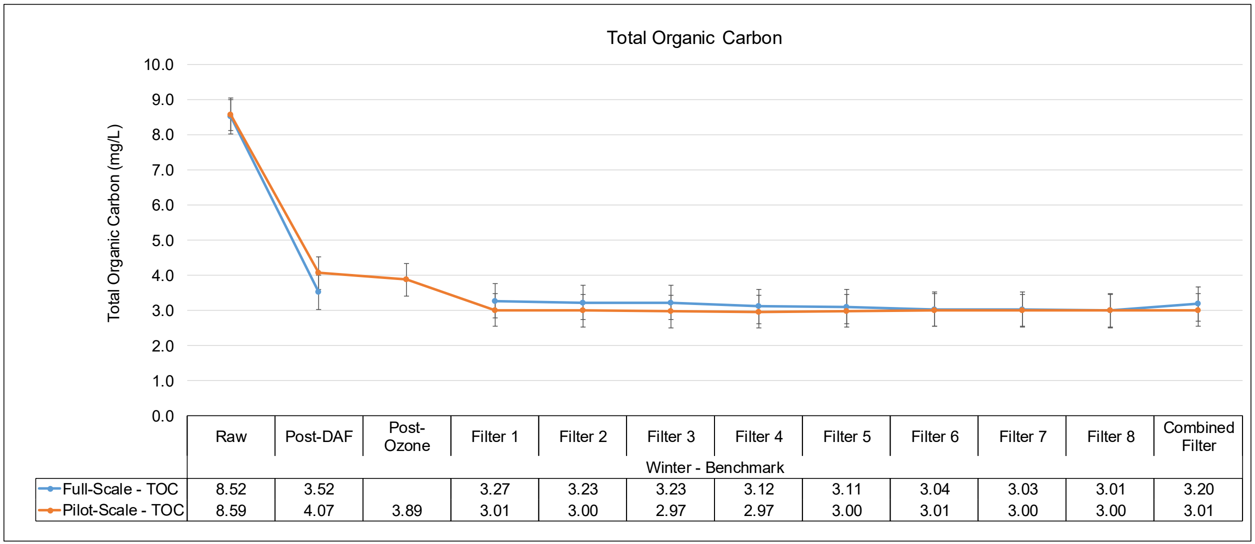
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full-Scale - Turb	0.62	0.69		0.13	0.15	0.14	0.13	0.27	0.13	0.12	0.10	0.23
Pilot-Scale - Turb	0.62	1.68	1.45	0.11	0.10	0.11	0.11	0.14	0.11	0.10	0.11	0.12

Figure 2-2: Average turbidity analysis of the full-scale and pilot-scale systems during the Winter benchmarking period. Data originates from Lab analyses.

Although a significant difference was observed for the Post-DAF turbidity between the full-scale and the pilot-scale systems (0.69 NTU versus 1.68 NTU respectively, on average), the final treated effluent was not found to be significantly different (0.23 NTU versus 0.12 NTU respectively on average). This observation concedes that the pilot-scale system's filters could remove the added turbidity; therefore, the results are deemed acceptable. However, higher turbidity prior to the filters can impact the filter run times. It is believed the difference in turbidity is a result of the different characteristics of the full-scale and pilot-scale system DAF units.

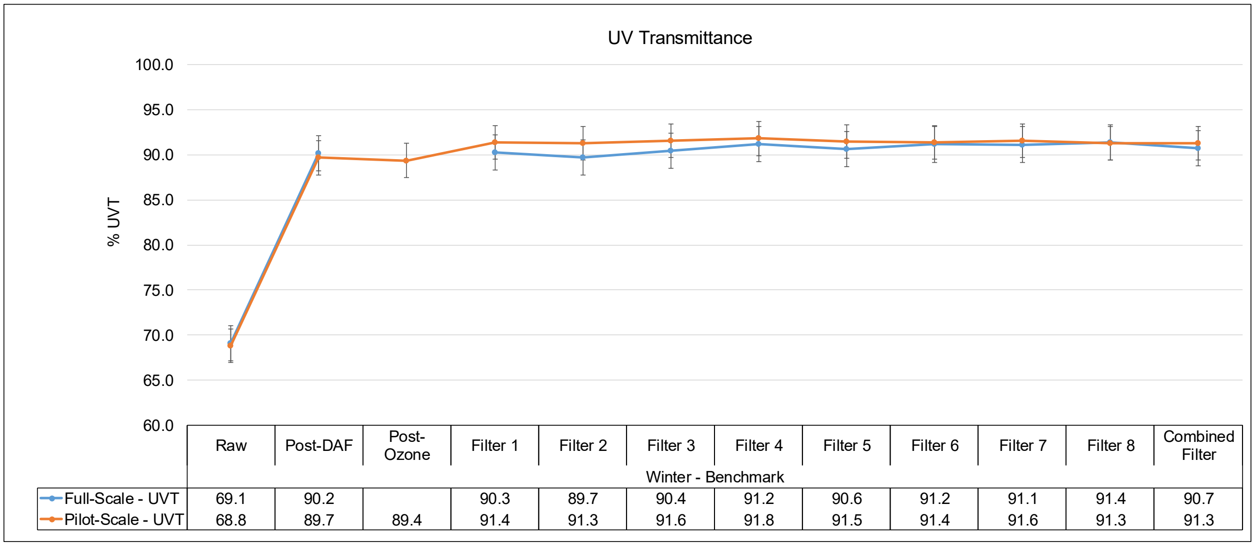
2.3 Total Organic Carbon, UV Transmittance, and Manganese (total and dissolved)

Comparison of the results for TOC (Figure 2-3), UVT (Figure 2-4), total manganese and dissolved manganese (Figure 2-5) presented strong correlations between the full-scale and the pilot-scale systems. Overall, the results indicate that the pilot-scale system is operating in a stable manner, and aside from the turbidity parameter in the pilot-scale system Post-DAF, it closely matches the operation and effluent quality of the full-scale system.



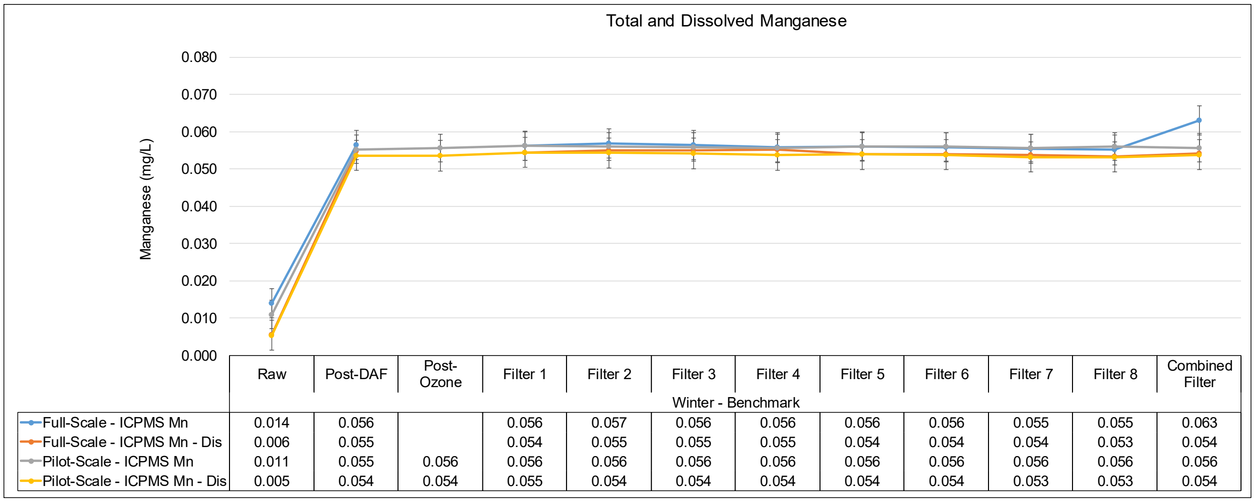
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full-Scale - TOC	8.52	3.52		3.27	3.23	3.23	3.12	3.11	3.04	3.03	3.01	3.20
Pilot-Scale - TOC	8.59	4.07	3.89	3.01	3.00	2.97	2.97	3.00	3.01	3.00	3.00	3.01

Figure 2-3: Average TOC of the full-scale and pilot-scale systems during the Winter benchmarking period. Data originates from Lab analyses.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full-Scale - UVT	69.1	90.2		90.3	89.7	90.4	91.2	90.6	91.2	91.1	91.4	90.7
Pilot-Scale - UVT	68.8	89.7	89.4	91.4	91.3	91.6	91.8	91.5	91.4	91.6	91.3	91.3

Figure 2-4: Average UVT of the full-scale and pilot-scale systems during the Winter benchmarking period. Data originates from Lab analyses.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full-Scale - ICPMS Mn	0.014	0.056		0.056	0.057	0.056	0.056	0.056	0.056	0.055	0.055	0.063
Full-Scale - ICPMS Mn - Dis	0.006	0.055		0.054	0.055	0.055	0.055	0.054	0.054	0.054	0.053	0.054
Pilot-Scale - ICPMS Mn	0.011	0.055	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
Pilot-Scale - ICPMS Mn - Dis	0.005	0.054	0.054	0.055	0.054	0.054	0.054	0.054	0.054	0.053	0.053	0.054

Figure 2-5: Average total and dissolved manganese of the full-scale and pilot-scale systems during the Winter benchmarking period. Data originates from Lab analyses.

2.4 Filters Operation (SCADA)

Both filter banks were operated at an average flow rate of 0.3 L/s to represent the full-scale system average flow rate during the 13 days of the Winter benchmarking period. The standard procedure was to backwash the filters daily at approximately the same time. The differential pressure values reported by the pilot-scale system's SCADA were evaluated on an average hourly basis to determine the following:

- the filter run times,
- the unit filter run volume (UFRV) values,
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter, and
- the rate of head loss increase of each filter.

The maximum differential pressure values were assessed just prior to a backwash cycle (dirty filter) and the minimum values were assessed as directly after the backwash (clean filter). To determine if the filters have reached their maximum head loss, or to have overflowed prior to the filter run was terminated, the average hourly differential pressures were compared against the typical overflow differential pressures shown in Table 2-1.

Table 2-1: Typical overflow differential pressures for the pilot-scale system filters during the Winter benchmarking period.

	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6	FILTER 7	FILTER 8
Overflow Pressure (kPa)	22.3	24.2	23.9	27.6	23.8	22.7	24.1	22.5

The observed filter run times and UFRV values were calculated using data which originated from the pilot-scale system’s SCADA, between the filtration start time and the filter overflow or the start of the subsequent backwash (whichever occurred first). For filters which did not reach the maximum head loss, the forecasted filter run times and UFRV values were calculated based on linear two-point extrapolations. The rate of head loss increase was calculated by dividing either the maximum differential pressure or the typical overflow differential pressure (whichever occurred first), by the observed filter run times.

The filter operation data was compared against filter effluent turbidity measured by the Lab, which was sampled approximately 4 hours from the start of the filtration cycle. The turbidity levels were used to verify if the filters failed on turbidity. According to the full-scale system operating license, individual filters effluent turbidity cannot exceed 0.3 NTU in 95% of the measurements in a monthly reporting cycle or for a period greater than 12 consecutive hours. To ensure this performance, the City has set an operational guideline limit of 0.1 NTU on all filter operations.

A summary of the filter operation data collected during the Winter benchmarking period is provided in Appendix D1. Figure 2-6 illustrates the average daily UFRV values.

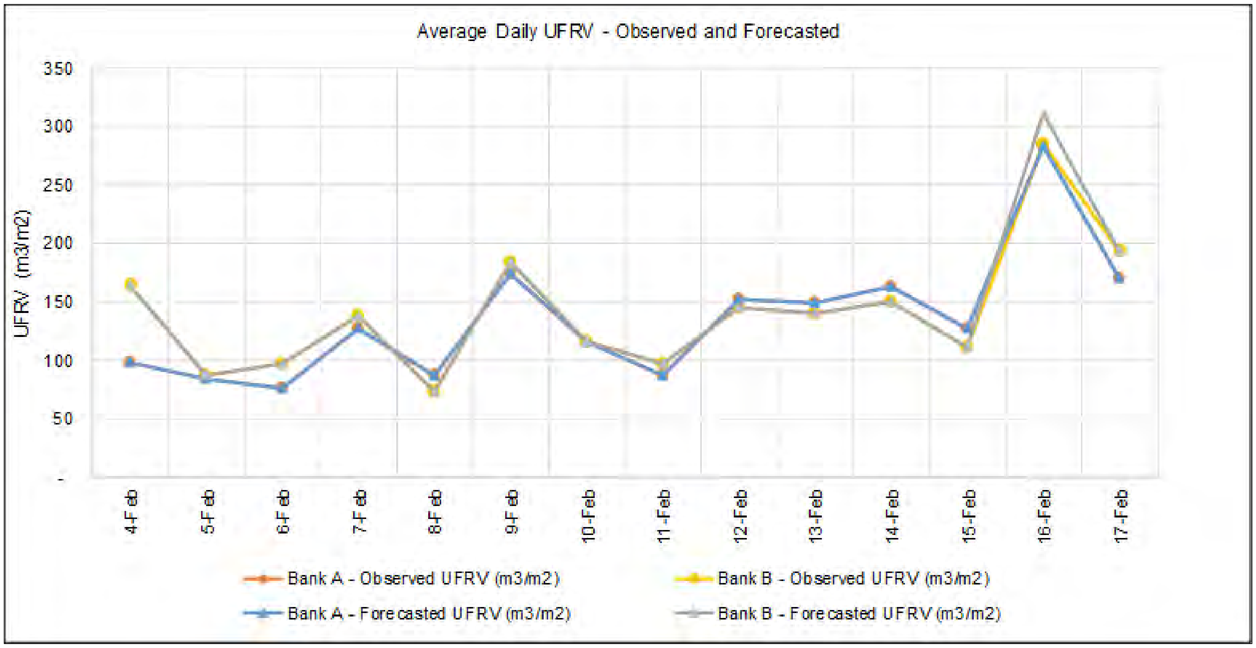


Figure 2-6: Average UFRV values of the pilot-scale system Bank A and Bank B at an average flow of 0.3 L/s during the Winter benchmarking period. UFRV = Filter Run Volume/ Filter Surface Area. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system’s SCADA dataset.

Table 2-2 tabulates the average filter run times and average UFRV values for the entire Winter benchmarking period, while also considering overall operation cycles and those which have not failed based on sampled turbidity.

Table 2-2: Average observed and forecasted filter run times and UFRV values during the Winter benchmarking period.

		FILTER RUN TIME (hour)			UFRV (m^3/m^2)		
		Bank A	**Bank B**	**All Filters**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	9.4	9.8	9.5	136	141	138
	Only cycles with turbidity ≤ 0.1 NTU	9.4	9.9	9.6	136	144	139
	Only cycles with turbidity ≤ 0.3 NTU	9.4	9.7	9.5	135	141	137
Forecasted Values	Overall Cycles	9.4	9.9	9.6	136	143	139
	Only cycles with turbidity ≤ 0.1 NTU	9.4	10.1	9.7	136	146	140
	Only cycles with turbidity ≤ 0.3 NTU	9.4	9.9	9.6	136	143	139

From the filter operation data, the following was noticed:

- During the Winter benchmarking period, all filters overflowed before the daily backwash, except for Filter 4, Filter 5 and Filter 7 on February 16th, 2017.
- The average post-ozone turbidity feeding the filters was 1.45 NTU and the average combined filter turbidity was 0.12 NTU during the Winter benchmarking period.
- The turbidity levels of Filter 1, Filter 2, Filter 4, Filter 5, and Filter 6 exceeded the City's operational guideline of 0.1 NTU two to three cycles out of 13 days of the Winter benchmarking period, but only once did Filter 5 exceed the operating license of 0.3 NTU.
- The overall average observed filter run time was 9.5 hours and the overall average observed UFRV was 138 m^3/m^2, and both filter banks presented similar results.
- No substantial difference was observed when comparing the overall average observed UFRV value (138 m^3/m^2) with the forecasted UFRV value (139 m^3/m^2) and the average UFRV values which considered only the filters which have not failed based on sampled turbidity above 0.1 or 0.3 NTU (137 to 140 m^3/m^2).
- The rate of head loss increase ranged from 0.9 to 7.9 kPa/h, with an average of 3.1 kPa/h. Substantial variability was also observed for each filter during the Winter benchmarking period and among the filters in the same day. Filter 1 and Filter 5 presented the highest rate of head loss increase, 7.4 and 7.9 kPa/h, respectively.

Based on full-scale system's historical benchmarking, the five-year average UFRV value is 495 m^3/m^2 with an average rate of head loss increase of 1.7 kPa/h and an average post-ozone turbidity of 0.79 NTU (see Table 2-1 and Table 2-2 of TM No. 1). The Winter benchmarking period presented a UFRV approximately one-third that of the full-scale system's historical value, while the rate of head loss increase was nearly double. This is indicative of the differences between the full-scale and pilot-scale system filters and their operations. It is believed the two main reasons for this difference are:

1. The full-scale system filters have higher head loss available, reaching an average maximum differential pressure of 48.9 kPa (see Table 2-2 of TM No. 1), while the pilot-scale system filters could only achieve 23.9 kPa on average before overflowing. This means that the pilot-scale system filter run times and UFRV values would likely to be half of the full-scale system values at the same conditions.

2. The higher turbidity yielded from the pilot-scale system DAF (1.69 NTU in average) is resulting in an additional load on the filters, thereby increasing the head loss in a shorter time, which reduces the filter run time, increases the rate of head loss and reduces the UFRV.

As observed in Figure 2-6, the pilot-scale system filters did not achieve the minimum UFRV value of 200 m^3/m^2 required to achieve a recovery (ratio between the net and total quantity of filtered water) greater than 95% (Crittenden *et al.*, 2005). However, these values would be expected to be doubled in the full-scale system, where the head loss available for filtration is twice that of the available at the pilot-scale system filters, in case the filters are able to maintain the effluent turbidity according to the City's operational guidelines. Thus, filter recovery would not be expected to be an issue when evaluating average UFRV values.

Nevertheless, when looking at the daily rate of head loss increase, the pilot-scale system filters exceeded the typical full-scale system rate of head loss increase of 1.7 kPa/h 88% of the time. In addition, the minimum filter run is expected to be 12.5 hours to achieve a minimum UFRV value of 200 m^3/m^2 at the average flow rate. This would represent a rate of head loss increase of 3.7 kPa/h when considering the full-scale system average head loss of 48.9 kPa. During the Winter benchmarking period, the pilot-scale system filters exceeded the maximum full-scale system rate of head loss increase of 3.7 kPa/h 30% of the time, which means the minimum recovery of 95% would not be achieved. Therefore, the performance of pilot-scale system filters was deemed poor.

2.5 Summary of Comparison with the Full-Scale System

When comparing the water quality results of the Winter benchmarking period with the results of full-scale system during the same period, pH, TOC, UVT, and total and dissolved manganese presented strong correlations between the full-scale and pilot-scale systems. On the other hand, Post-DAF turbidity was significantly higher in the pilot-scale system, but the pilot-scale system filters were able to remove the added turbidity. In terms of filters operation, the pilot-scale system filters presented higher rate of head loss increase and lower UFRV values than the historical data from the full-scale system.

Besides the differences in the Post-DAF turbidity and the filters operation of the pilot-scale and the full-scale systems, the water quality results from the benchmarking period from the pilot-scale system were sufficiently appropriate to draw operational comparisons to the full-scale system. As such, the project proceeded with the subsequent piloting session of the alternative coagulant, ferric sulphate.

3 WINTER TRANSITION PERIOD

On February 24th, 2017, the pilot-scale system coagulant was transitioned from ferric chloride to ferric sulphate. The Winter transition period was monitored to ensure the stability of the pilot-scale system with the new coagulant. In addition, ozonation commenced on February 27th, 2017 in the pilot-scale system. Appendix B presents a summary of the water quality analyses for samples collected between February 27th and March 14th, 2017.

Building on the extensive bench-scale testing performed in January 2017, the optimal pilot-scale system selected doses were 42 mg/L for ferric sulphate and 0.25 mg/L for coagulant-aid. These doses were applied at the commencement of the Winter transition period. During the Winter transition period the pilot-scale system's sulphuric acid dose was matched to the full-scale system, which was dosed at 42 mg/L resulting in a Post-DAF pH of 5.92±0.07 during the Winter transition period. Both ferric chloride and ferric sulphate are expected to coagulate effectively in the same pH range.

The coagulant-aid was initially added to the surface of the second flocculation tank; however, the City's pilot-scale system project engineer indicated that at the bench test chemical dose, floc was forming on the surface of the second flocculation tank, forming clumps approximately 5 to 30 mm in size. This observation was suggestive of poor performance of the coagulant-aid, requiring corrective action. This "mud-balling" effect was believed to be caused by an excessive dose of coagulant-aid to the second flocculation tank. The City attempted to rectify the mud-balling by changing the coagulant-aid dose location. On March 1st, 2017, the pilot-scale system was cleaned and the coagulant-aid dose location was moved from the second flocculation tank to the third flocculation tank. The coagulant-aid was slowly re-introduced to the system up to a maximum dose of 0.01 mg/L. However, mud-balling was still observed following the change in dose location and reduction in coagulant-aid addition. Further attempts to correct the mud-balling phenomenon are discussed in Section 5.6.2 of this report.

Section 3.1 to Section 3.3 illustrate the results pertaining to the four key parameters: pH, turbidity, TOC, and manganese (total and dissolved) during the Winter transition period after the transition from ferric chloride to ferric sulphate. During the Winter transition period, raw water was only sampled from the full-scale system and UVT data was not collected. The results of the raw water tests, which were collected in triplicate during the Winter benchmarking period, demonstrated that the raw water from the pilot-scale system is the same as that from the full-scale system.

Additional details such as a full summary of the daily results for the key parameters, as well as the results for non-key parameters, can be found in Appendix B. The benchtop and laboratory analysis can be found in Appendix D2. Turbidity, total manganese, pH, and TOC sampling showed relative stability over the period of March 10th to 14th, 2017. Stability is achieved following a minimum of 5 days of operations where turbidity fluctuates by ±0.2 NTU in Post-DAF samples and ±0.05 NTU in the pilot-scale system filter effluent. Based on the Winter transition period data, it appears that the pilot-scale system was operating in a stable manner prior to Winter piloting session.

3.1 pH

Figure 3-1 presents the pH results during the Winter transition period. The Post-DAF pH with an average of 5.92±0.07 is considered stable and the stability is likely attributed to the addition of sulphuric acid at a constant rate in the pilot-scale system. The pH remained stable following filtration, with an average pH of 6.03±0.02 for the filtered water from Filters 1-8. Therefore, the results indicate the transition to ferric sulphate did not affect the stability of the pilot-scale system with regards to pH.

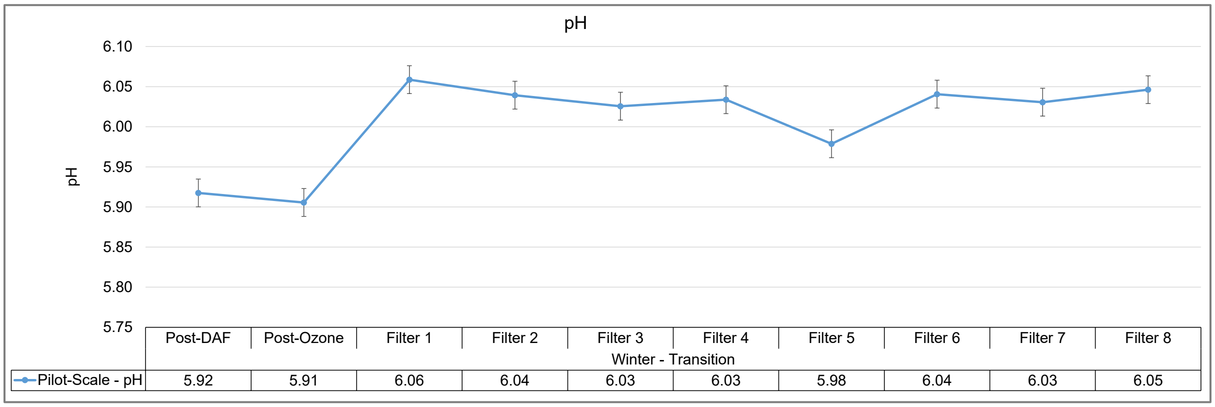


Figure 3-1: Average Post-DAF pH of the pilot-scale system during the Winter transition period. Data originates from Lab analyses.

3.2 Turbidity

Figure 3-2 and Table 3-1 present the turbidity results during the Winter transition period. Although turbidity in the Post-DAF samples were higher than desired for the pilot-scale system, stability (variation <0.2 NTU) was achieved from March 10th to 14th, 2017. Pilot-scale system filter effluent turbidity was stable (variation < 0.05 NTU) from March 9th to 14th, 2017. This dataset indicates a relative stability observed in filter performance producing similar water quality between filters. As such, the addition of ferric sulphate was deemed not to drastically affect the stability of the system with regards to turbidity values.

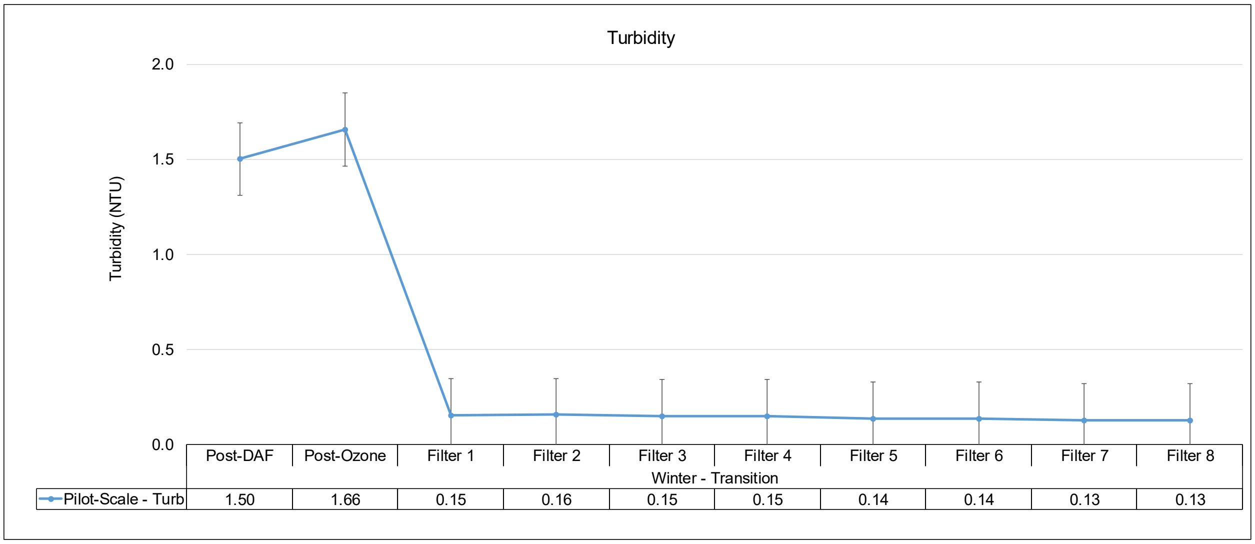


Figure 3-2: Average turbidity of the pilot-scale system during Winter transition period. Data originates from Lab analyses.

Table 3-1: Changes in pilot-scale system turbidity during the Winter transition period. Data originates from laboratory analyses.

Location	27/02/2017	28/02/2017	01/03/2017	02/03/2017	03/03/2017	04/03/2017	05/03/2017	06/03/2017	07/03/2017	08/03/2017	09/03/2017	10/03/2017	11/03/2017	12/03/2017	13/03/2017	14/03/2017	Average
Raw	0.52	0.50	0.53	0.55	0.52	0.57	0.55	0.57	0.59	0.66	0.66	0.55	0.62	0.61	0.61	0.62	0.58 ± 0.05
Post-DAF	1.31	1.52	1.49	2.07	1.83	1.46	1.46	1.69	1.32	1.40	1.53	1.37	1.41	1.38	1.34	1.44	1.50 ± 0.20
Post-Ozone	1.21	1.54	1.80	2.21	2.15	1.61	1.67	1.67	1.66	1.44	1.83	1.60	1.73	1.39	1.46	1.55	1.66 ± 0.26
Filter 1	0.09	0.10	0.09	0.15	0.16	0.16	0.18	0.17	0.20	0.18	0.19	0.13	0.11	0.14	0.16	0.22	0.15 ± 0.04
Filter 2	N/A	0.10	0.09	0.15	0.16	0.13	0.18	0.17	0.25	0.20	0.17	0.14	0.08	0.12	0.17	0.22	0.16 ± 0.05
Filter 3	0.05	0.10	0.09	0.16	0.15	0.13	0.16	0.17	0.21	0.20	0.16	0.14	0.11	0.12	0.17	0.28	0.15 ± 0.05
Filter 4	N/A	0.08	0.08	0.16	0.15	0.13	0.16	0.19	0.18	0.21	0.16	0.13	0.10	0.11	0.17	0.23	0.15 ± 0.04
Filter 5	N/A	0.09	0.08	0.14	0.15	0.12	0.16	0.17	0.19	0.11	0.13	0.13	0.09	0.10	0.13	0.25	0.14 ± 0.04
Filter 6	N/A	0.10	0.08	0.14	0.14	0.13	0.17	0.17	0.19	0.13	0.12	0.13	0.10	0.10	0.12	0.22	0.14 ± 0.04
Filter 7	0.07	0.09	0.08	0.14	0.16	0.12	0.16	0.16	0.19	0.12	0.12	0.12	0.09	0.10	0.12	0.22	0.13 ± 0.04
Filter 8	0.05	0.09	0.08	0.14	0.14	0.12	0.17	0.17	0.19	0.18	0.14	0.12	0.09	0.09	0.12	0.15	0.13 ± 0.04

3.3 Total Organic Carbon and Total Manganese

The TOC data (Figure 3-3) shows there was minimal deviation during the Winter transition period.

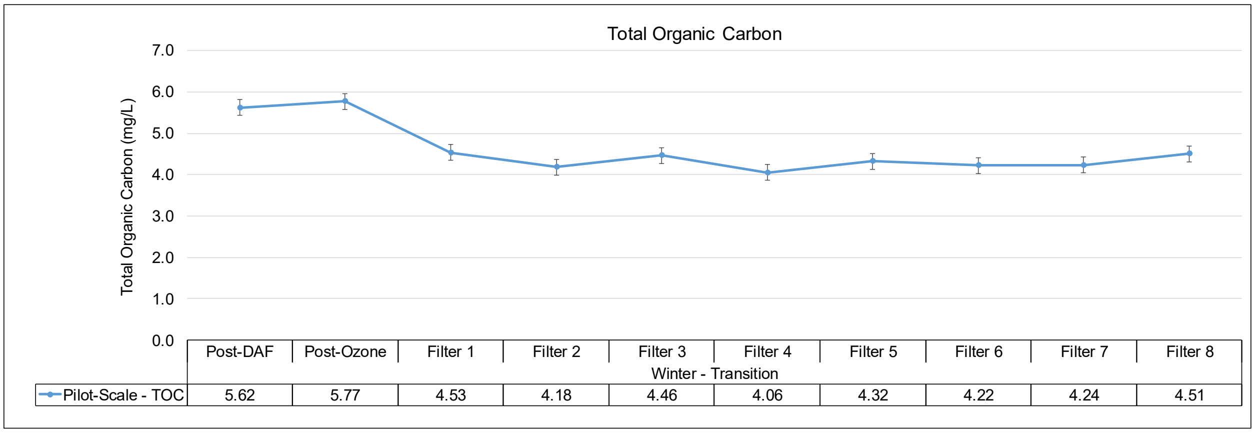


Figure 3-3: Average TOC of the pilot-scale system during the Winter transition period. Data originates from Lab analyses.

The Total Manganese data (Figure 3-4) shows there was minimal deviation during the Winter transition period. As such, the transition to the ferric sulphate and the coagulant-aid did not appear to cause significant instability in the pilot-scale system treatment process and was deemed successful.

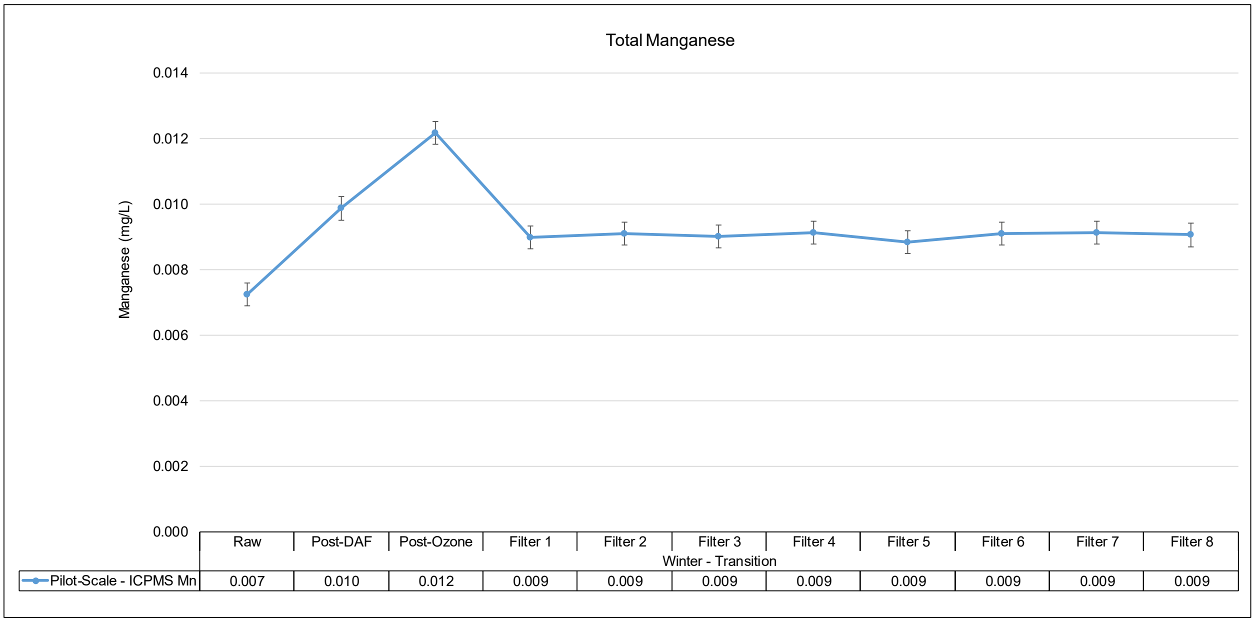


Figure 3-4: Average total manganese of the pilot-scale systems during the Winter transition period. Data originates from Lab analyses using Inductively Coupled Plasma Mass Spectrometry (ICPMS).

4 WINTER PILOTING SESSION ACTIVITY

Once the Winter transition period was completed, WSP operated the pilot-scale system from March 15th, 2017 to April 5th, 2017 (inclusive). Table 4-1 on the following page summarizes the piloting activities during the Winter piloting session. Appendix C presents the daily operational log forms detailing observations and additional information.

For the entirety of the Winter piloting session, Bank A (Filters 1 to 4) operated at an average flow of 0.3 L/s and Bank B (Filters 5 to 8) operated at an average flow of 0.6 L/s, representing average and maximum flow rates, respectively. Differing backwash conditions were explored for the first ten days (modified backwash conditions). Alterations to the backwash procedures during this time included increasing or decreasing the air scour and water backflush times to determine if these changes affected filter performance. On the 10th day (March 24th, 2017) of the Winter piloting session, the differing backwash regimes were abandoned due to the lack of observable benefit. Subsequent backwashing of all filters proceeded under the “standard” procedure for the duration of Winter piloting session as this procedure matched the full-scale system’s procedure as closely as possible.

Similar to the Winter benchmarking and transition periods, process samples were collected from the pilot-scale system at the following locations:

- Raw;
- Post-DAF;
- Post-Ozone;
- Effluents from each of the individual filters in Bank A and Bank B.

Samples were also collected from the full-scale system at the following locations for comparison purposes:

- Post-DAF;
- Post-Ozone (i.e. combined ozone from both tanks);
- Combined filter effluent (i.e., individual filter samples were not taken from the full-scale system).

Samples were tested using bench-scale analysis for temperature, turbidity, pH, conductivity, oxidation/reduction potential (ORP), dissolved oxygen, UVT, and total manganese.

Deviations from the original program presented in TM No. 2 are the following:

- The laboratory sampling was not performed on the full-scale and pilot-scale systems on the same day;
- TOC analysis was not conducted on the combined filter effluent (full-scale system);
- Total trihalomethanes (THM) and total haloacetic acids (HAA) analysis were not prepared for disinfection by-product formation potential analysis.

Table 4-1: Winter Piloting Session - Summary of Piloting Activity

DATE	COAGULANT DOSE (mg/L)	SULPHURIC ACID DOSE (mg/L)	COAGULANT-AID DOSE (mg/L)	CHANGE	BACKWASHING DURATION[1]	ANALYSIS
Wednesday, March 15, 2017	42	42	0.01		Standard	
Thursday, March 16, 2017	42	42	0.01	Backwash	Modified	
Friday, March 17, 2017	42	42	0.01	Backwash	Modified	
Saturday, March 18, 2017	42	42	0.01	Backwash	Modified	
Sunday, March 19, 2017	42	42	0.01	Backwash	Modified	Type 1[2]
Monday, March 20, 2017	42	42	0.01	Backwash	Modified	
Tuesday, March 21, 2017	42	42	0.01	Backwash	Modified	
Wednesday, March 22, 2017	42	42	0.01	Backwash	Modified	
Thursday, March 23, 2017	42	42	0.01	Backwash	Modified	
Friday, March 24, 2017	42	42	0.01	Backwash	Modified	
Saturday, March 25, 2017	34	42	0.01	Reduction in coagulant and system equalization	Standard	
Sunday, March 26, 2017	34	42	0.01	Bottom of coagulant range	Standard	
Monday, March 27, 2017	38	42	0.01	Increase coagulant by 10%	Standard	
Tuesday, March 28, 2017	42	42	0.01	Increase coagulant by 10%	Standard	
Wednesday, March 29, 2017	46	42	0.01	Increase coagulant by 10%	Standard	
Thursday, March 30, 2017	50	42	0.01	Top of coagulant range	Standard	Type 1
Friday, March 31, 2017	42	42	0.01	Return to effective baseline and backwash twice	Standard	
Saturday, April 01, 2017	42	42	0.02	Increase coagulant-aid	Standard	Type 1
Sunday, April 02, 2017	42	42	0.03	Increase coagulant-aid	Standard	Type 1
Monday, April 03, 2017	42	42	0.01	Return to effective baseline and backwash twice	Standard	
Tuesday, April 04, 2017	**46**	42	**0.02**	Optimal doses from previous stages used	Standard	Type 2[3]
Wednesday, April 05, 2017	**46**	42	**0.02**	Optimal doses from previous stages used	Standard	Type 2

[1] See Table 5-3 for details regarding backwash durations.

[2] Type 1 sampling included: metals (dissolved and total): aluminum, arsenic, boron, calcium, cadmium, chromium, copper, iron, potassium, magnesium, manganese, sodium, nickel, lead, antimony, silver, uranium, zinc, and zirconium. In addition, dissolved organic carbon (DOC), total dissolved solids (TDS), total solids (TS), total suspended solids (TSS), true colour, UVT, alkalinity, conductivity, pH and turbidity.

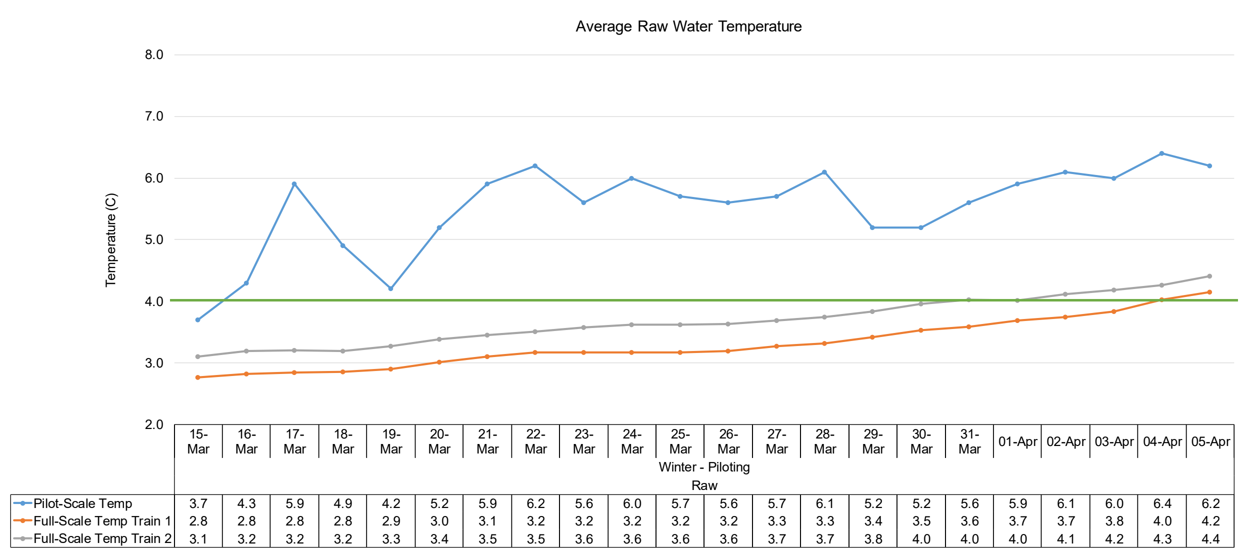
[3] Type 2 sampling included all of Type 1, and threshold odour number (TON), total trihalomethanes (THM), total haloacetic acids (HAA), sulphate, chloride, and hardness.

5 WINTER PILOTING SESSION RESULTS

This section summarizes the operational parameters and the water quality analyses for samples collected between March 15th and April 5th, 2017. Included in these results are comparisons between the full-scale and pilot-scale system operations pertaining to raw water, DAF, ozonation, and filtration for key parameters, as well as to the historical benchmarking data. All benchtop and lab results can be found in Appendix D3 and Appendix D4.

5.1 Raw Water Temperature

Figure 5-1 illustrates the raw water temperature for both the full-scale and pilot-scale systems during the Winter piloting session. The Winter piloting session intended to test an alternative coagulant under cold water conditions (<4°C; green-line Figure 5-1). During the Winter piloting session, morning raw water temperature readings were collected from two raw water temperature sensors used to measure Trains 1 and 2 of the full-scale system. For illustrative purposes, the average daily value for each sensor was requested from the City. The raw water temperature was also measured at the pilot-scale system using a hand-held digital thermometer for comparison.



	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar	01-Apr	02-Apr	03-Apr	04-Apr	05-Apr
Pilot-Scale Temp	3.7	4.3	5.9	4.9	4.2	5.2	5.9	6.2	5.6	6.0	5.7	5.6	5.7	6.1	5.2	5.2	5.6	5.9	6.1	6.0	6.4	6.2
Full-Scale Temp Train 1	2.8	2.8	2.8	2.8	2.9	3.0	3.1	3.2	3.2	3.2	3.2	3.2	3.3	3.3	3.4	3.5	3.6	3.7	3.7	3.8	4.0	4.2
Full-Scale Temp Train 2	3.1	3.2	3.2	3.2	3.3	3.4	3.5	3.5	3.6	3.6	3.6	3.6	3.7	3.7	3.8	4.0	4.0	4.0	4.1	4.2	4.3	4.4

Figure 5-1: Average daily raw water temperature for the full-scale and pilot-scale systems during the Winter piloting session. The green line represents the temperature (4°C) where a temperature inversion in the water is expected and the raw water would be considered as cool water conditions. Data originates from benchtop analysis and full-scale system SCADA data.

The data collected confirms that the raw water temperature measured at the full-scale system for Train 1 was consistently higher than Train 2. This difference in temperature is noted to be due to location of the sensor in Trains 1 when compared to Train 2. The City has indicated that this difference in temperature has been previously recognized and the recorded raw water temperature is taken as the average between the two trains.

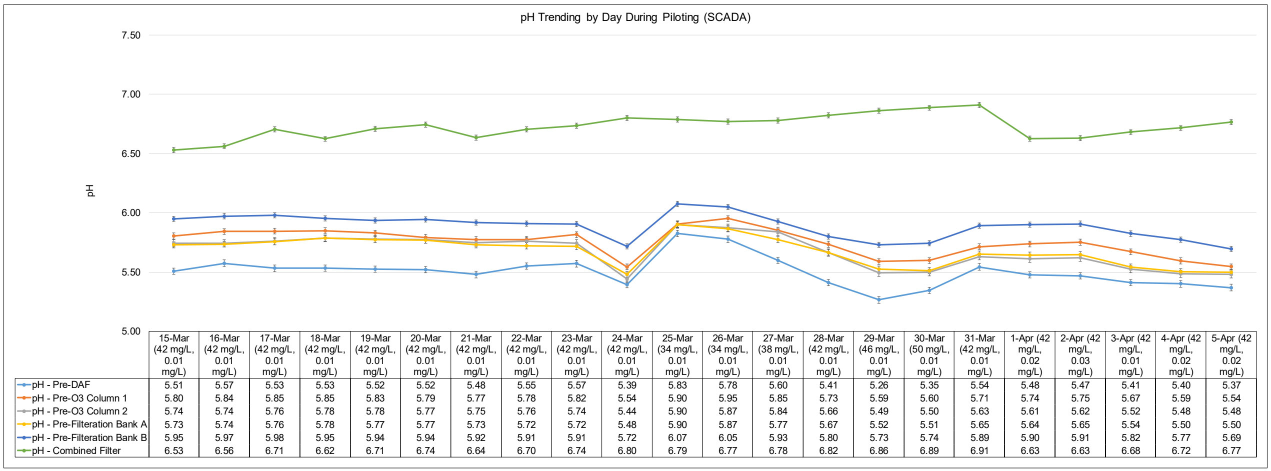
The average of the two trains remained below the desired 4°C temperature from March 15th to March 30th; however, Train 2 measured temperatures above 4°C from March 31st to April 4th, while Train 1 measured temperatures exceeding 4°C only on April 4. Trains 1 and 2 only exceeded the desired temperature by 0.02°C and 0.26°C, respectively. If the average temperature of each train is used, only April 4th exceeded the desired temperature by 0.14°C, which is believed to be negligible.

Although the intent was to test cold raw water conditions at temperatures below 4°C throughout the entirety of the Winter piloting session, it is unlikely that the slight exceedance experienced in the last trial day would greatly impact the results. Therefore, it is believed the raw water quality tested represented cold-water conditions.

The temperature measured in the pilot-scale system was consistently higher than the temperature measured from the full-scale system raw water temperature sensors. It is understood that the temperature increase is a result of the approximate 180 m of travel in piping located within the full-scale system. However, it is unlikely that this would affect the raw water quality conditions as the residence time is short.

5.2 pH Monitoring of the Pilot-Scale System (SCADA)

The pH was constantly monitored at the pilot-scale system using the SCADA system. Figure 5-2 shows the daily average pH during the Winter piloting session for the following locations: Pre-DAF (chemically treated raw water), Pre-Ozone (Columns #1 and #2), Pre-Filtration (Bank A and Bank B), and the combined filter effluent.



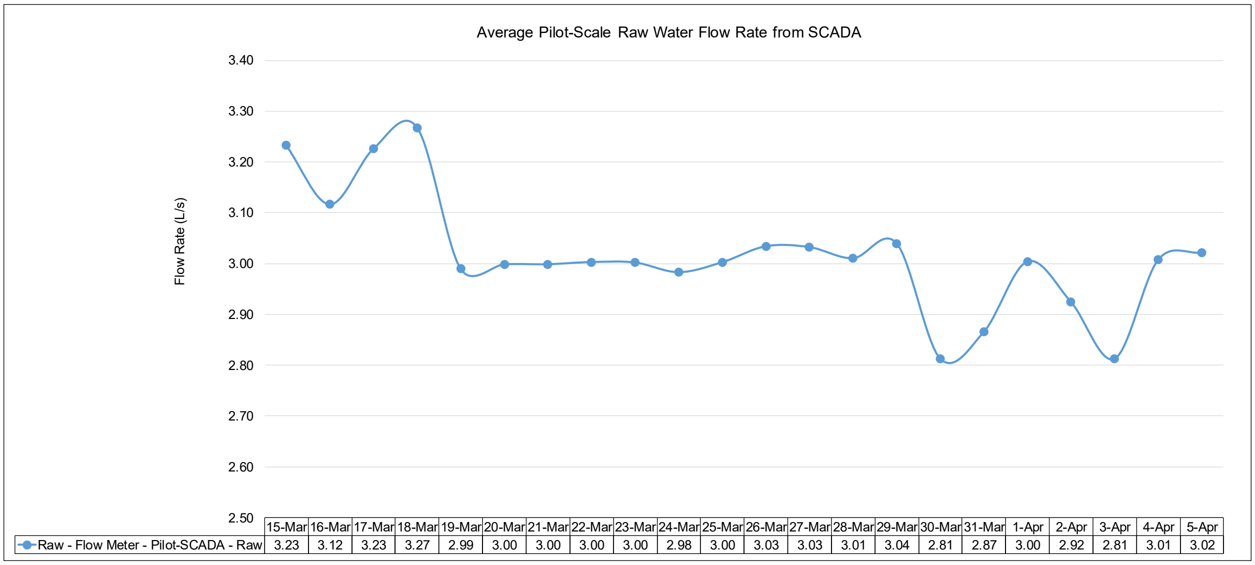
	15-Mar (42 mg/L, 0.01 mg/L)	16-Mar (42 mg/L, 0.01 mg/L)	17-Mar (42 mg/L, 0.01 mg/L)	18-Mar (42 mg/L, 0.01 mg/L)	19-Mar (42 mg/L, 0.01 mg/L)	20-Mar (42 mg/L, 0.01 mg/L)	21-Mar (42 mg/L, 0.01 mg/L)	22-Mar (42 mg/L, 0.01 mg/L)	23-Mar (42 mg/L, 0.01 mg/L)	24-Mar (42 mg/L, 0.01 mg/L)	25-Mar (34 mg/L, 0.01 mg/L)	26-Mar (34 mg/L, 0.01 mg/L)	27-Mar (38 mg/L, 0.01 mg/L)	28-Mar (42 mg/L, 0.01 mg/L)	29-Mar (46 mg/L, 0.01 mg/L)	30-Mar (50 mg/L, 0.01 mg/L)	31-Mar (42 mg/L, 0.01 mg/L)	1-Apr (42 mg/L, 0.02 mg/L)	2-Apr (42 mg/L, 0.03 mg/L)	3-Apr (42 mg/L, 0.01 mg/L)	4-Apr (42 mg/L, 0.02 mg/L)	5-Apr (42 mg/L, 0.02 mg/L)
pH - Pre-DAF	5.51	5.57	5.53	5.53	5.52	5.52	5.48	5.55	5.57	5.39	5.83	5.78	5.60	5.41	5.26	5.35	5.54	5.48	5.47	5.41	5.40	5.37
pH - Pre-O3 Column 1	5.80	5.84	5.85	5.85	5.83	5.79	5.77	5.78	5.82	5.54	5.90	5.95	5.85	5.73	5.59	5.60	5.71	5.74	5.75	5.67	5.59	5.54
pH - Pre-O3 Column 2	5.74	5.74	5.76	5.78	5.78	5.77	5.75	5.76	5.74	5.44	5.90	5.87	5.84	5.66	5.49	5.50	5.63	5.61	5.62	5.52	5.48	5.48
pH - Pre-Filteration Bank A	5.73	5.74	5.76	5.78	5.77	5.77	5.73	5.72	5.72	5.48	5.90	5.87	5.77	5.67	5.52	5.51	5.65	5.64	5.65	5.54	5.50	5.50
pH - Pre-Filteration Bank B	5.95	5.97	5.98	5.95	5.94	5.94	5.92	5.91	5.91	5.72	6.07	6.05	5.93	5.80	5.73	5.74	5.89	5.90	5.91	5.82	5.77	5.69
pH - Combined Filter	6.53	6.56	6.71	6.62	6.71	6.74	6.64	6.70	6.74	6.80	6.79	6.77	6.78	6.82	6.86	6.89	6.91	6.63	6.63	6.68	6.72	6.77

Figure 5-2: Average daily pH of the pilot-scale system during the Winter piloting session. Data originates from the pilot-scale system's SCADA dataset.

The Pre-DAF pH was consistently lower than the Pre-Ozone, Pre-Filtration and the combined filter effluent, which is expected following the addition of sulphuric acid and ferric sulphate prior to DAF treatment. The pH decreased in the Pre-DAF from March 25th to 29th according to the pilot-scale system online SCADA data. This decrease can be attributed to the increasing coagulant dose during the coagulant optimization phase and lack of adjustment to the sulphuric acid to compensate for the increase in coagulant. There is also an increase in pH after filtration (measured in the combined filter effluent). Although, LT-22S is added as a filter-aid, the addition of 0.01 mg/L is not expected to increase pH by 0.5-1.0. It is believed that the combined filter effluent pH probe may not have been measuring correctly, and may require calibration.

5.3 Pilot-Scale System Raw Water Flow (SCADA)

The raw water flow rate to the pilot-scale system was maintained at approximately 3.0 L/s (Figure 5-3) throughout the entirety of the Winter piloting session. The flow was controlled by WSP personnel daily using the hand-valve located on the raw water intake feeding the pilot-scale system. A reduced raw water flow was reported by WSP personnel on March 30th and 31st, as the target 3.0 L/s pilot-scale system flow was not achievable. The flow rate could not be increased to the desired 3.0 L/s, due to ferric build up in the raw water static mixer. However, since the chemical addition to the pilot-scale system is flow-paced, the reduced flow experienced during this period had minimal impact on the treatment.



	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr
● Raw - Flow Meter - Pilot-SCADA - Raw	3.23	3.12	3.23	3.27	2.99	3.00	3.00	3.00	3.00	2.98	3.00	3.03	3.03	3.01	3.04	2.81	2.87	3.00	2.92	2.81	3.01	3.02

Figure 5-3: Average daily pilot-scale system raw water flow rate during the Winter piloting session. Data originates from the pilot-scale system's SCADA dataset.

5.4 Pilot-Scale System Filters Operation (SCADA)

During the Winter piloting session, Bank A operated at an average flow rate of 0.3 L/s (representing the full-scale system average flow rate) and Bank B operated at an average flow of 0.6 L/s (representing the filters maximum flow rate). The standard procedure was to backwash the filters daily at the same time. The differential pressure values reported by the pilot-scale system's SCADA were evaluated on an average hourly basis to determine the following:

- the filter run times,
- the UFRV values,
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter, and
- the rate of head loss increase of each filter.

The calculations were performed as described in Section 2.4. The filter operational data was compared against the filter effluent turbidity measured by the benchtop analysis, which was sampled approximately 4 hours from the start of the filtration cycle. The summary of the filter operational data obtained during the Winter piloting session is provided in Appendix D3. Figure 5-4 illustrates the average daily UFRV values. Table 5-1 tabulates the average filter run times and average UFRV values for the entire Winter piloting session, while also considering overall operation cycles and those which have not failed based on sampled turbidity.

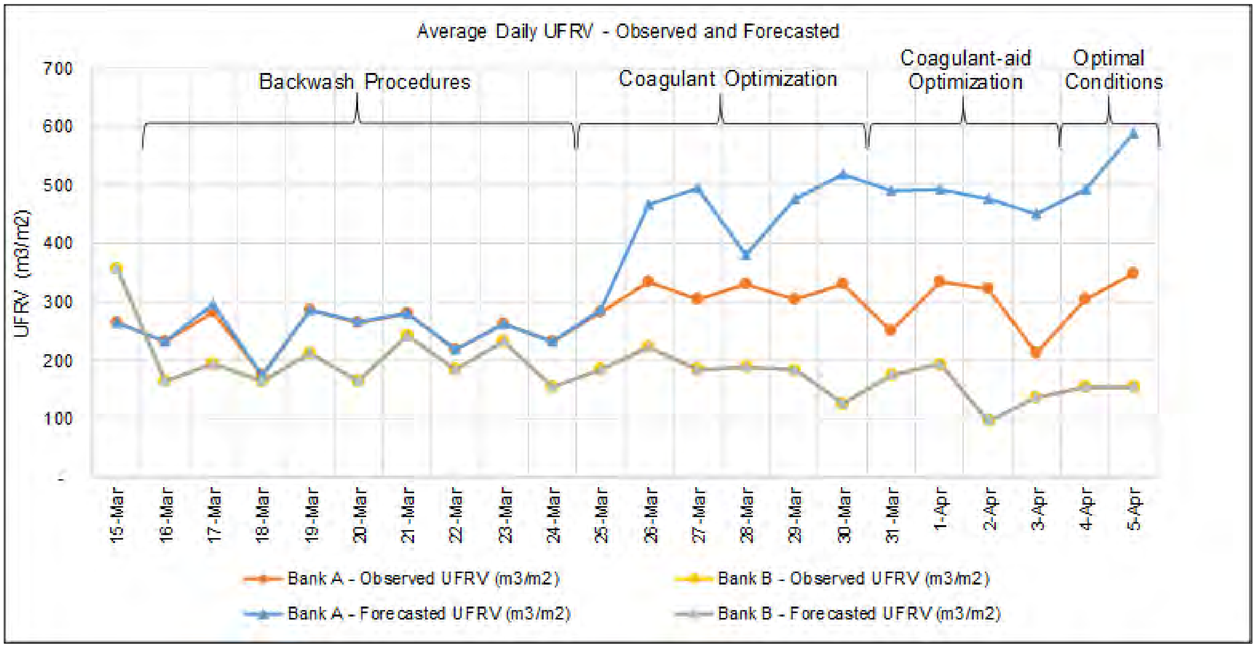


Figure 5-4: Average UFRV and average filter run of the pilot-scale system Bank A at an average flow rate of 0.3 L/s and Bank B at an average flow rate of 0.6 L/s during the Winter piloting session. UFRV = Filter Run Volume/Filter Surface Area. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

Table 5-1: Average observed and forecasted filter run times and UFRV values during the Winter piloting session.

		FILTER RUN TIME (h)		UFRV (m^3/m^2)		
		Bank A	**Bank B**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	19.5	6.4	283	185	240
	Only cycles with turbidity ≤ 0.1 NTU	18.5	6.2	268	179	211
	Only cycles with turbidity ≤ 0.3 NTU	19.5	6.4	283	185	238
Forecasted Values	Overall Cycles	26.1	6.4	378	185	293
	Only cycles with turbidity ≤ 0.1 NTU	25.6	6.2	371	179	248
	Only cycles with turbidity ≤ 0.3 NTU	26.1	6.3	354	182	277

Table 5-2 presents the typical rate of head loss increase expected and the maximum rate of head loss increase expected to achieve a minimum filter recovery of 95% per filter, when considering the full-scale system average head loss of 48.9 kPa.

Table 5-2: Typical and maximum rate of head loss increase for the pilot-scale system filters.

FLOW RATE	0.3 L/s	0.6 L/s
Typical rate of head loss increase (kPa/h)	1.7	3.1
Maximum rate of head loss increase for a 95% recovery (kPa/h)	3.7	7.1

From the filter operation data, the following observations were made:

- It should be noted that no data was collected by the SCADA for Filter 8 during the Winter piloting session.
- During the Winter piloting session, all filters overflowed before the daily backwash, except Filters 1 to 4 after March 25th.
- The turbidity levels from the filters exceeded the City's operational guideline of 0.1 NTU 68% of the cycles. In addition, the turbidity values also exceeded the full-scale system's operating license of 0.3 NTU 7% of the cycles.
- For Bank A, the observed overall average filter run was 19.5 h and the observed overall average UFRV was 283 m^3/m^2, while the forecasted overall UFRV was 378 m^3/m^2. When discarding the cycles where turbidity levels were above 0.1 NTU when sampled, the observed and forecasted UFRV values drop to 268 m^3/m^2 and 354 m^3/m^2, respectively. None of the filters failed based on a turbidity level above 0.3 NTU, the operating licence limit.
- For Bank B, the observed overall average filter run was 6.4 h and the observed overall average UFRV was 185 m^3/m^2. Since Bank B overflowed all cycles, no forecasted UFRV were calculated. When discarding the cycles that turbidity levels were above 0.1 NTU and 0.3 NTU when sampled, little difference was noticed for observed UFRV values (179 and 182 m^3/m^2, respectively).
- The rate of head loss increase ranged from 0.3 to 1.9 kPa/h, with an average of 1.0 kPa/h for Bank A operating at 0.3 L/s. While the rate of head loss increase ranged from 1.7 to 7.9 kPa/h, with an average of 4.0 kPa/h for Bank B operating at 0.6 L/s. Low variability was observed for each filter in Bank A during the Winter piloting session and among Bank A filters in the same day. Higher variability was observed for each filter in Bank B during the Winter piloting session, but low variability was observed among Bank B filters in the same day.
- Bank A filters only exceeded the typical full-scale system rate of head loss increase (1.7kPa/h) 4% of the time and never exceeded the maximum rate of head loss (3.7 kPa/h). On the other hand, Bank B filters exceeded the typical full-scale system rate of head loss increase (1.7kPa/h) 82% of the time and exceeded the maximum rate of head loss (3.7 kPa/h) 3% of the time.

It was expected that both filter banks would exhibit similar UFRV values, while it was expected that Bank A would exhibit a filter run twice that of Bank B, considering the different flow rates. However, Bank A UFRV values were approximately 50% higher than Bank B UFRV values. This discrepancy may be due to mechanical differences in the filter banks and their operation (shorter pipe runs, closer to the pumps, etc.), or even inconsistent filter-aid dosing. Note that there was no confirmation that the filter-aid dosing pump PX505 (Bank A) was operating consistently, and City staff have noted several times that this pump did not start consistently at low dosing rates.

Additional evaluation regarding UFRV is presented in Section 5.5, Section 5.8, Section 5.9 and Section 5.10. The effects of coagulant dose and coagulant-aid dose are further discussed in Section 5.7.

5.5 Evaluation of Pilot-Scale System Backwash Procedures

Alternative backwash conditions were explored for the first ten days of the Winter piloting session; however, the 10th day (March 24th, 2017) was excluded from the data set due to low pH (pH < 4.0; based on daily grab samples by WSP) measured in all samples collected from the pilot-scale system (Figure 5-2). The decrease in pH was a result of an interruption in flow to the pilot-scale system during a maintenance shutdown of the full-scale system. Raw water fed to the pilot-scale system is taken from the full-scale system raw water line before the addition of chemicals (i.e., coagulant and acid); however, there are no check valves on the raw water line between the DAF and the raw water pumps in the full-scale system. Therefore, during the full-scale system shutdown raw water that had been chemically treated was able to flow backwards into the line feeding the pilot-scale system. This caused the raw water entering the pilot-scale system to be double dosed with chemicals, significantly reducing the pH. Removal of this data point did not affect interpretations of the results for alterations in the backwash procedures.

Alterations to the backwash procedures included increasing and/or decreasing the air scour and water backflush durations to determine if these changes affect the filter performance. Table 5-3 summarizes the backwash conditions for each filter during the evaluation of alternative backwashing procedures.

Table 5-3: Winter Piloting Session – Pilot-scale System Operations - Biological Filter Backwash Procedures

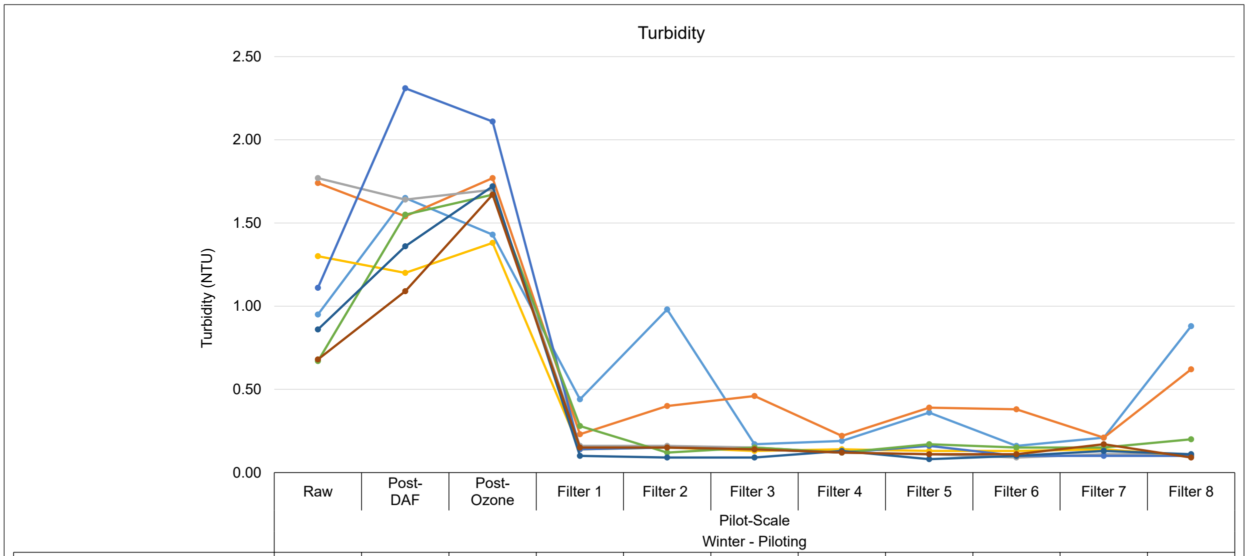
FILTER#	FLOW RATE (MARCH 15 TO APRIL 5, 2017)	BACKWASH DURATION (MARCH 15 TO MARCH 24, 2017)	BACKWASH ACTIVITY REFERENCE TIMINGS (MIN)[1]
1	Average	Standard	10 – 5 - 10
2	Average	Standard	10 - 5 - 10
3	Average	Shortened (-25%)	7.5 - 3.75 - 7.5
4	Average	Extended (+25%)	12.5 – 6.25 – 12.5
5	Maximum	Standard	10 - 5 - 10
6	Maximum	Standard	10 - 5 - 10
7	Maximum	Shortened (-25%)	7.5 - 3.75 - 7.5
8	Maximum	Extended (+25%)	12.5 – 6.25 – 12.5

Note 1: Backwash activity reference timing includes a period of air only, a period of air and water, and a period of water only. Standard backwash procedure includes 10 min of air, 5 min air and water, and 10 min of water, followed by approximately 30 min at reduced flow.

For the modified backwash procedure, Filters 1, 2, 5, 6 backwashes followed the standard backwash procedures, Filters 3 and 7 followed a shortened backwash procedure (less 25% in time), and Filters 4 and 8 followed an extended backwash (additional 25% in time).

Figure 5-5 to Figure 5-8 present the results for four key parameters measured in the pilot-scale system filter effluent, which were used to evaluate any variations in the filter performance during the assessment of alternative backwash procedures.

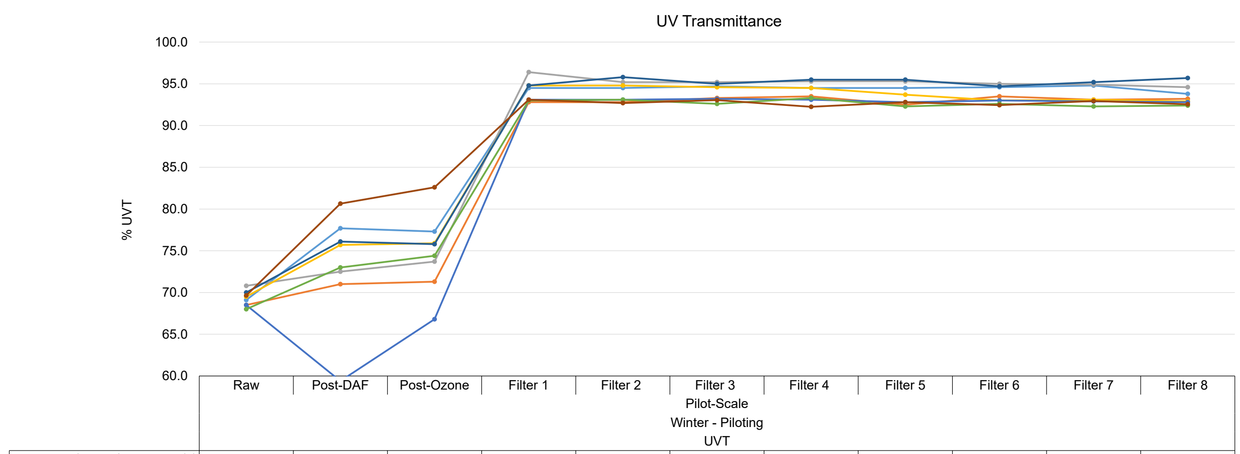
Figure 5-5 presents the turbidity results during the backwash evaluation period. The largest variation in turbidity was measured the first two days of operation (March 16th & 17th, 2017), which represents the 2nd and 3rd day of the Winter piloting session. It is suspected that this deviation in turbidity data was due to operational acclimatization of the WSP personnel with the pilot-scale system. From March 18th to March 24th, there was negligible difference between the standard, shortened and extended backwashing duration within Bank A or Bank B. The turbidity results show that there does not seem to be a significant difference in filter performance when the filter backwash duration in altered from the standard backwash sequence outlined by the City.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
Turb - 16-Mar (42 mg/L, 0.01 mg/L)	0.95	1.65	1.43	0.44	0.98	0.17	0.19	0.36	0.16	0.21	0.88
Turb - 17-Mar (42 mg/L, 0.01 mg/L)	1.74	1.54	1.77	0.23	0.40	0.46	0.22	0.39	0.38	0.21	0.62
Turb - 18-Mar (42 mg/L, 0.01 mg/L)	1.77	1.64	1.70	0.16	0.16	0.15	0.12	0.11	0.09	0.11	0.11
Turb - 19-Mar (42 mg/L, 0.01 mg/L)	1.30	1.20	1.38	0.14	0.15	0.13	0.14	0.13	0.13	0.14	0.10
Turb - 20-Mar (42 mg/L, 0.01 mg/L)	1.11	2.31	2.11	0.14	0.15	0.14	0.12	0.16	0.10	0.10	0.10
Turb - 21-Mar (42 mg/L, 0.01 mg/L)	0.67	1.55	1.67	0.28	0.12	0.15	0.12	0.17	0.15	0.15	0.20
Turb - 22-Mar (42 mg/L, 0.01 mg/L)	0.86	1.36	1.72	0.10	0.09	0.09	0.13	0.08	0.10	0.13	0.11
Turb - 23-Mar (42 mg/L, 0.01 mg/L)	0.68	1.09	1.67	0.15	0.15	0.14	0.12	0.11	0.11	0.17	0.09

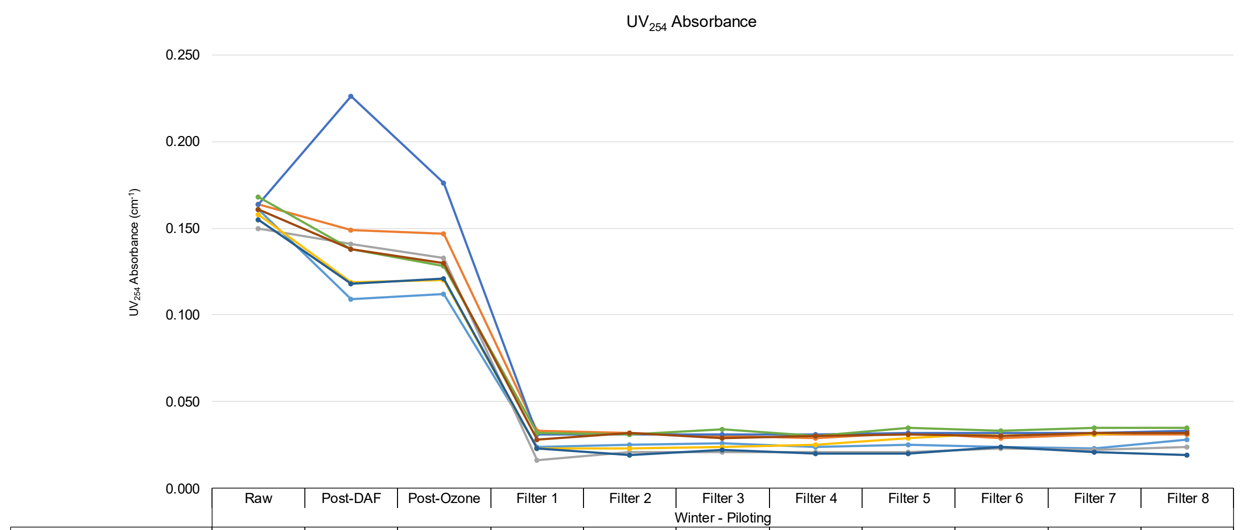
Figure 5-5: Turbidity measured in pilot-scale system filter effluent under varying backwash procedures for daily samples collected from March 16th to March 23rd. All samples were dosed at a consistent 42 mg/L ferric sulphate and 0.01 mg/L coagulant-aid. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.

The UVT (Figure 5-6), UV_{254nm} absorbance (Figure 5-7), and total manganese (Figure 5-8) were found to have little variation across the entire alternative backwashing evaluation period.



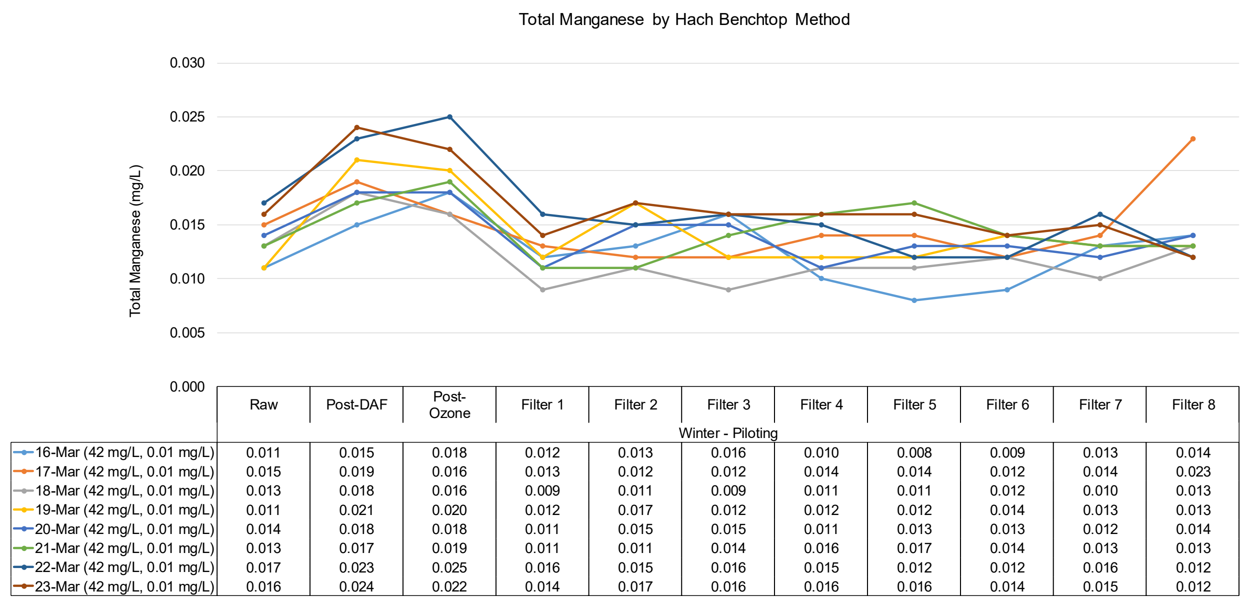
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
16-Mar (42 mg/L, 0.01 mg/L)	69.1	77.7	77.3	94.5	94.5	94.7	94.5	94.5	94.6	94.8	93.8
17-Mar (42 mg/L, 0.01 mg/L)	68.5	71.0	71.3	92.8	92.8	93.3	93.5	92.5	93.5	93.1	93.2
18-Mar (42 mg/L, 0.01 mg/L)	70.8	72.5	73.7	96.4	95.2	95.2	95.3	95.3	95.0	94.9	94.6
19-Mar (42 mg/L, 0.01 mg/L)	69.5	75.7	75.9	94.8	94.8	94.6	94.5	93.7	93.0	93.1	92.9
20-Mar (42 mg/L, 0.01 mg/L)	68.5	59.4	66.8	93.1	93.1	93.2	93.1	92.8	93.0	92.9	92.8
21-Mar (42 mg/L, 0.01 mg/L)	68.0	73.0	74.4	93.0	93.1	92.6	93.3	92.3	92.6	92.3	92.4
22-Mar (42 mg/L, 0.01 mg/L)	70.0	76.1	75.8	94.8	95.8	95.0	95.5	95.5	94.7	95.2	95.7
23-Mar (42 mg/L, 0.01 mg/L)	69.7	80.7	82.6	93.1	92.7	93.1	92.3	92.8	92.5	93.0	92.6

Figure 5-6: UVT measured in pilot-scale system filter effluent under varying backwash procedures for daily samples collected from March 16th to March 23rd. All samples were dosed at a consistent 42 mg/L ferric sulphate and 0.01 mg/L coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
16-Mar (42 mg/L, 0.01 mg/L)	0.161	0.109	0.112	0.024	0.025	0.026	0.024	0.025	0.024	0.023	0.028
17-Mar (42 mg/L, 0.01 mg/L)	0.164	0.149	0.147	0.033	0.032	0.030	0.029	0.032	0.029	0.031	0.031
18-Mar (42 mg/L, 0.01 mg/L)	0.150	0.141	0.133	0.016	0.021	0.021	0.021	0.021	0.023	0.022	0.024
19-Mar (42 mg/L, 0.01 mg/L)	0.158	0.119	0.120	0.023	0.023	0.024	0.025	0.029	0.032	0.031	0.033
20-Mar (42 mg/L, 0.01 mg/L)	0.164	0.226	0.176	0.031	0.031	0.031	0.031	0.032	0.032	0.032	0.033
21-Mar (42 mg/L, 0.01 mg/L)	0.168	0.138	0.128	0.032	0.031	0.034	0.030	0.035	0.033	0.035	0.035
22-Mar (42 mg/L, 0.01 mg/L)	0.155	0.118	0.121	0.023	0.019	0.022	0.020	0.020	0.024	0.021	0.019
23-Mar (42 mg/L, 0.01 mg/L)	0.161	0.138	0.130	0.028	0.032	0.029	0.030	0.031	0.030	0.032	0.032

Figure 5-7: UV_{254nm} Absorbance measured in pilot-scale system filter effluent under varying backwash procedures for daily samples collected from March 16th to March 23rd. All samples were dosed at a consistent 42 mg/L ferric sulphate and 0.01 mg/L coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
	Winter - Piloting										
16-Mar (42 mg/L, 0.01 mg/L)	0.011	0.015	0.018	0.012	0.013	0.016	0.010	0.008	0.009	0.013	0.014
17-Mar (42 mg/L, 0.01 mg/L)	0.015	0.019	0.016	0.013	0.012	0.012	0.014	0.014	0.012	0.014	0.023
18-Mar (42 mg/L, 0.01 mg/L)	0.013	0.018	0.016	0.009	0.011	0.009	0.011	0.011	0.012	0.010	0.013
19-Mar (42 mg/L, 0.01 mg/L)	0.011	0.021	0.020	0.012	0.017	0.012	0.012	0.012	0.014	0.013	0.013
20-Mar (42 mg/L, 0.01 mg/L)	0.014	0.018	0.018	0.011	0.015	0.015	0.011	0.013	0.013	0.012	0.014
21-Mar (42 mg/L, 0.01 mg/L)	0.013	0.017	0.019	0.011	0.011	0.014	0.016	0.017	0.014	0.013	0.013
22-Mar (42 mg/L, 0.01 mg/L)	0.017	0.023	0.025	0.016	0.015	0.016	0.015	0.012	0.012	0.016	0.012
23-Mar (42 mg/L, 0.01 mg/L)	0.016	0.024	0.022	0.014	0.017	0.016	0.016	0.016	0.014	0.015	0.012

Figure 5-8: Total Manganese measured in pilot-scale system filter effluent under varying backwash procedures for daily samples collected from March 16 to March 23. All samples were dosed at a consistent 42 mg/L ferric sulphate and 0.01 mg/L coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

Figure 5-9 presents the average filter run and UFRV for each filter throughout the same period. Calculated average UFRV values (Figure 5-9) did not indicate that the shortened or the extended backwashes had a different performance from the standard backwash procedure. This implies changes to the backwash procedures had little effect on the filter performance. Thus, normal backwashing procedures were maintained throughout the remainder of the winter piloting session as they matched the full-scale system procedures the closest.

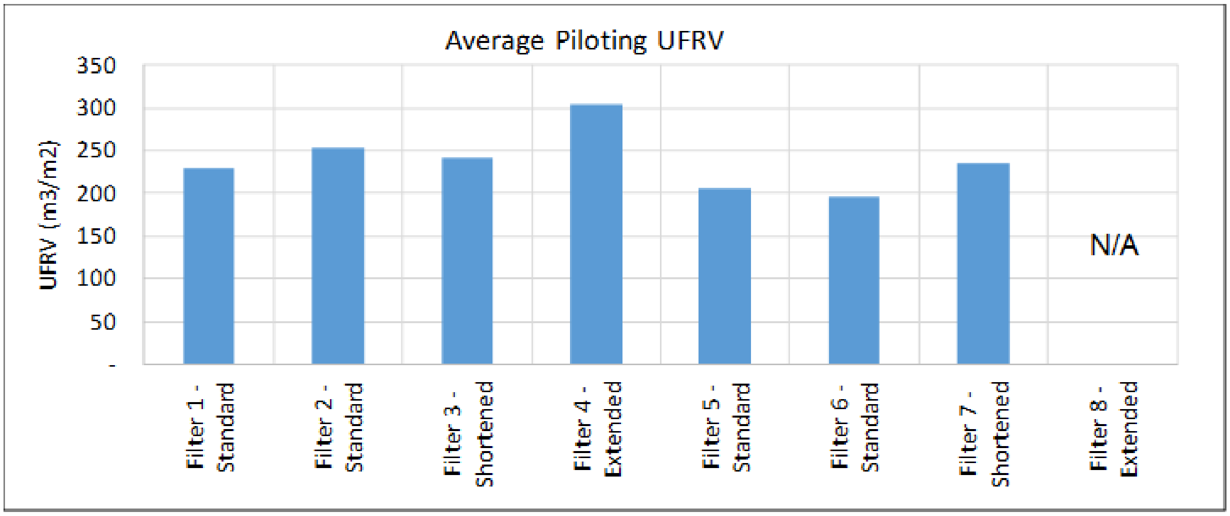
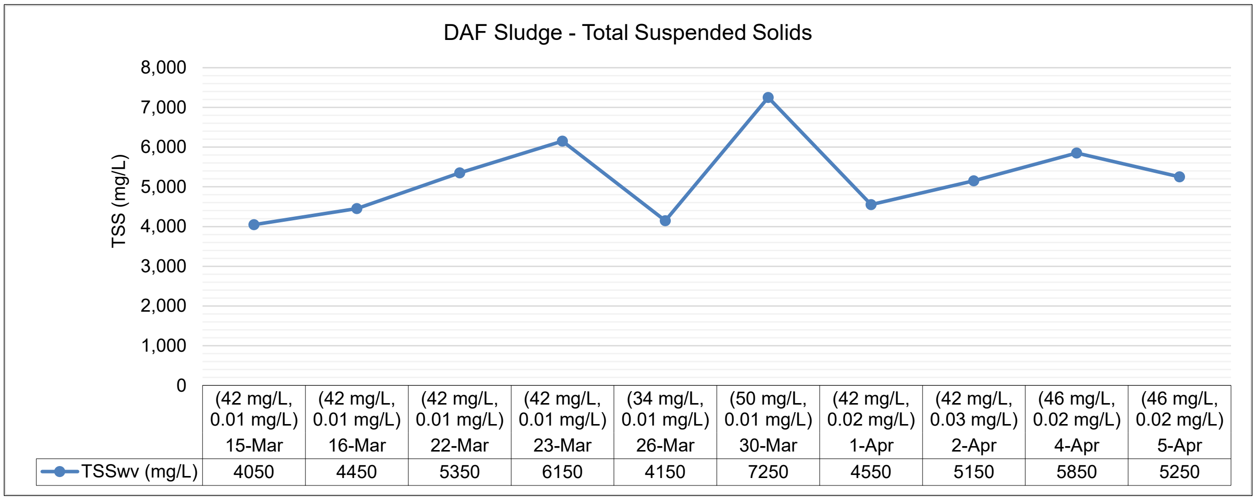


Figure 5-9: Average UFRV of pilot-scale system Bank A and Bank B from March 16 to March 23. Data originates from the pilot-scale system's SCADA dataset. Note: No data was collected by the SCADA for Filter 8.

5.6 DAF Sludge Production of the Pilot-Scale System

Figure 5-10 illustrates the total suspended solids (TSS) results for the residual generation from the pilot-scale system DAF unit. It can be observed the TSS concentration increases with the increase of coagulant dose, however, no relationship can be inferred from the coagulant-aid dose. From March 15th to March 23rd (coagulant and coagulant-aid doses remain constant at 42 mg/L and 0.01mg/L), the TSS slowly increased with time, suggesting there is likely accumulation of coagulant within the process. It should be noted that the sludge sampling from the DAF is rudimentarily collected from the DAF beach using a modified plastic container, and therefore it is subject to incomplete scrapper collection and/or variances in the scrapper level affecting the sludge blanket movement.



	(42 mg/L, 0.01 mg/L) 15-Mar	(42 mg/L, 0.01 mg/L) 16-Mar	(42 mg/L, 0.01 mg/L) 22-Mar	(42 mg/L, 0.01 mg/L) 23-Mar	(34 mg/L, 0.01 mg/L) 26-Mar	(50 mg/L, 0.01 mg/L) 30-Mar	(42 mg/L, 0.02 mg/L) 1-Apr	(42 mg/L, 0.03 mg/L) 2-Apr	(46 mg/L, 0.02 mg/L) 4-Apr	(46 mg/L, 0.02 mg/L) 5-Apr
TSSwv (mg/L)	4050	4450	5350	6150	4150	7250	4550	5150	5850	5250

Figure 5-10: TSS results for DAF sludge in the pilot-scale system during the Winter piloting session. Data originates from Lab analysis.

5.7 Optimization of Alternative Coagulant and Coagulant-Aid

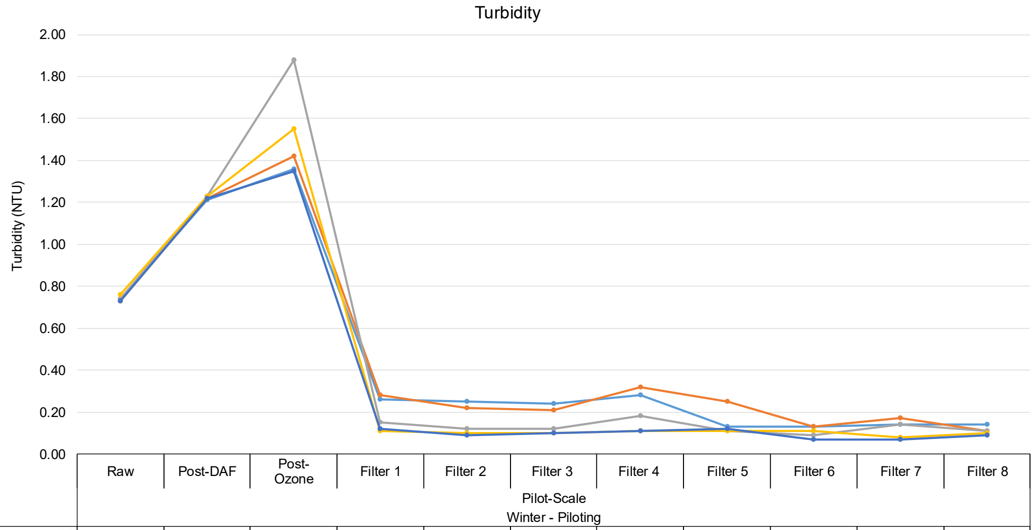
The following sections present the results used in determining the optimal dose for the alternative coagulant (ferric sulphate) and coagulant-aid (LT-22S).

5.7.1 Optimization of Ferric Sulphate

The optimal dose for the coagulant was tested from March 26th to March 30th, 2017. The optimal dose was determined by analyzing the following key parameters following treatment, with the attention given to the final (treated) water quality: turbidity, UVT, UV_{254nm} absorbance, and total manganese. These parameters were measured onsite using benchtop analysis by WSP personnel. Samples were collected daily from the following locations in the pilot-scale system: raw water, Post-DAF, combined Post-Ozone, individual filter effluent (Filters 1-8), and the combined filter effluent. The sulphuric acid dose remained at 42 mg/L for the optimization of ferric sulphate.

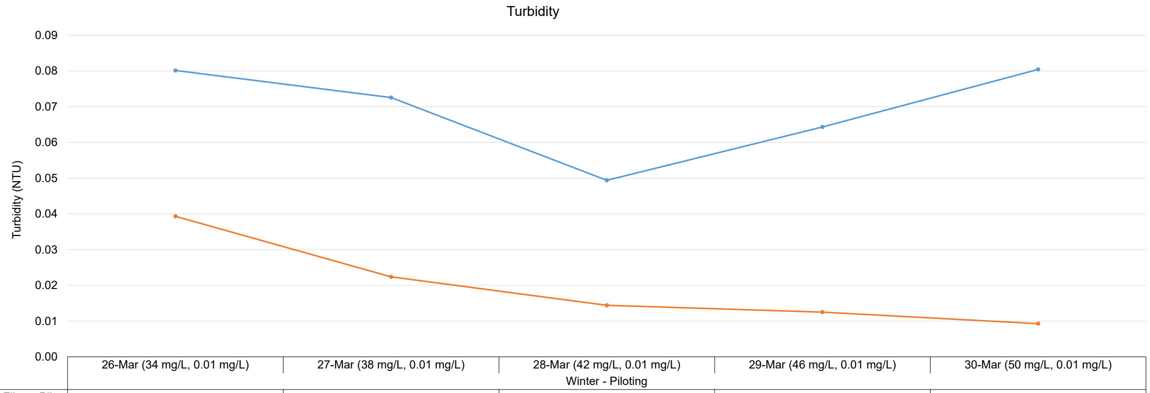
→ Turbidity

The turbidity results are presented in Figure 5-11 and Figure 5-12. The results illustrate that turbidity post-filter is decreasing with increasing coagulant dose, with the highest turbidity removal occurring at the maximum dose tested (50 mg/L). One observation to note was it appeared that Bank B (Filters 5-8) consistently outperformed Bank A (Filters 1-4). The reason for this occurrence is unclear; however, the cause is currently being explored by WSP and the City. Overall, the filters were able to remove 57 to 91% of the raw water turbidity (Figure 5-11), resulting in a finished water turbidity ranging from 0.07 NTU (March 30th; Filters 6&7; coagulant dose of 50 mg/L) to 0.32 NTU (March 27th; Filter 4; coagulant dose of 38 mg/L). Figure 5-12 shows the turbidity results monitored in Bank A (Filters 1-4) and Bank B (Filters 5-8) by the pilot-scale system SCADA.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
Turb - 26-Mar (34 mg/L, 0.01 mg/L)	0.74	1.21	1.36	0.26	0.25	0.24	0.28	0.13	0.13	0.14	0.14
Turb - 27-Mar (38 mg/L, 0.01 mg/L)	0.73	1.22	1.42	0.28	0.22	0.21	0.32	0.25	0.13	0.17	0.11
Turb - 28-Mar (42 mg/L, 0.01 mg/L)	0.74	1.23	1.88	0.15	0.12	0.12	0.18	0.11	0.09	0.14	0.11
Turb - 29-Mar (46 mg/L, 0.01 mg/L)	0.76	1.23	1.55	0.11	0.10	0.10	0.11	0.11	0.11	0.08	0.10
Turb - 30-Mar (50 mg/L, 0.01 mg/L)	0.73	1.22	1.35	0.12	0.09	0.10	0.11	0.12	0.07	0.07	0.09

Figure 5-11: Turbidity levels by all pilot-scale system treatment processes for the determination of the optimal dose of ferric sulphate. Each day represents an increased coagulant dose. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.



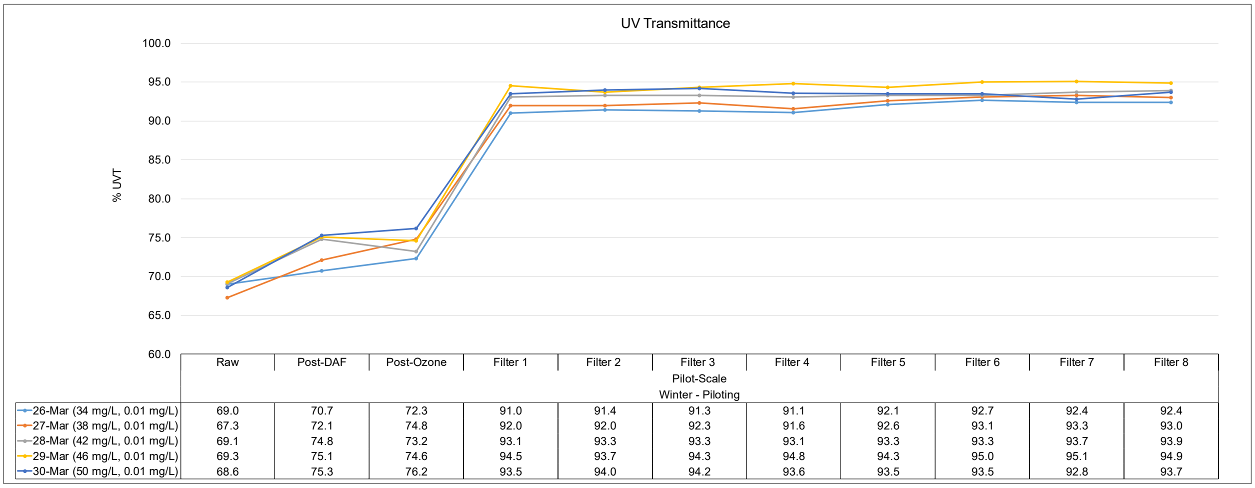
	26-Mar (34 mg/L, 0.01 mg/L)	27-Mar (38 mg/L, 0.01 mg/L)	28-Mar (42 mg/L, 0.01 mg/L)	29-Mar (46 mg/L, 0.01 mg/L)	30-Mar (50 mg/L, 0.01 mg/L)
Combined Filter - Pilot-SCADA - Turb Bank A	0.080	0.073	0.049	0.064	0.080
Combined Filter - Pilot-SCADA - Turb Bank B	0.039	0.022	0.014	0.012	0.009

Figure 5-12: Average daily turbidity of pilot-scale system for the determination of the optimal dose of ferric sulphate. Data originates from the pilot-scale system's SCADA dataset.

The turbidity reported in the pilot-scale system SCADA[1] was higher in Bank A compared to Bank B which was similar to the trend reported from the bench scale testing. However, the SCADA reported higher online turbidity values for Bank A compared to those measured by WSP personnel, but lower online turbidity values for Bank B in comparison to the values obtained by WSP personnel from daily benchtop testing. The reason for this deviation between monitoring systems is currently unclear, but it is suspected that the online turbidity monitor for Bank A may have experienced instrumental drift or probe fouling, causing higher recorded turbidity. The lower recorded online turbidity in Bank B, when compared to the benchtop analysis, is likely due to the sample collection cells used to monitor the turbidity by the SCADA system. The online turbidity probes are situated within a sample collection cell in order to provide limited flow, as higher flow could cause an error in the online turbidity readings. It is interesting to note that the City's instrument technician suspects that the sample collection cell may be acting as a small setting tank, thereby causing a lower online turbidity reading than expected. Improvements to the online turbidity meters are currently being explored by the City to account for the deviations experienced between online and benchtop analyses.

→ UVT & UV$_{254nm}$ Absorbance

The UVT and UV$_{254nm}$ absorbance results (Figure 5-13 and Figure 5-14) found that increased coagulant doses improved the removal of UV absorbing species (absorbance), as well as an increase in UVT up to a coagulant dose of 46 mg/L; however, a decrease in UVT and an increase in absorbance was found with a coagulant dose of 50 mg/L.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
26-Mar (34 mg/L, 0.01 mg/L)	69.0	70.7	72.3	91.0	91.4	91.3	91.1	92.1	92.7	92.4	92.4
27-Mar (38 mg/L, 0.01 mg/L)	67.3	72.1	74.8	92.0	92.0	92.3	91.6	92.6	93.1	93.3	93.0
28-Mar (42 mg/L, 0.01 mg/L)	69.1	74.8	73.2	93.1	93.3	93.3	93.1	93.3	93.3	93.7	93.9
29-Mar (46 mg/L, 0.01 mg/L)	69.3	75.1	74.6	94.5	93.7	94.3	94.8	94.3	95.0	95.1	94.9
30-Mar (50 mg/L, 0.01 mg/L)	68.6	75.3	76.2	93.5	94.0	94.2	93.6	93.5	93.5	92.8	93.7

Figure 5-13: UVT measured following pilot-scale system treatment processes for the determination of the optimal dose of ferric sulphate. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

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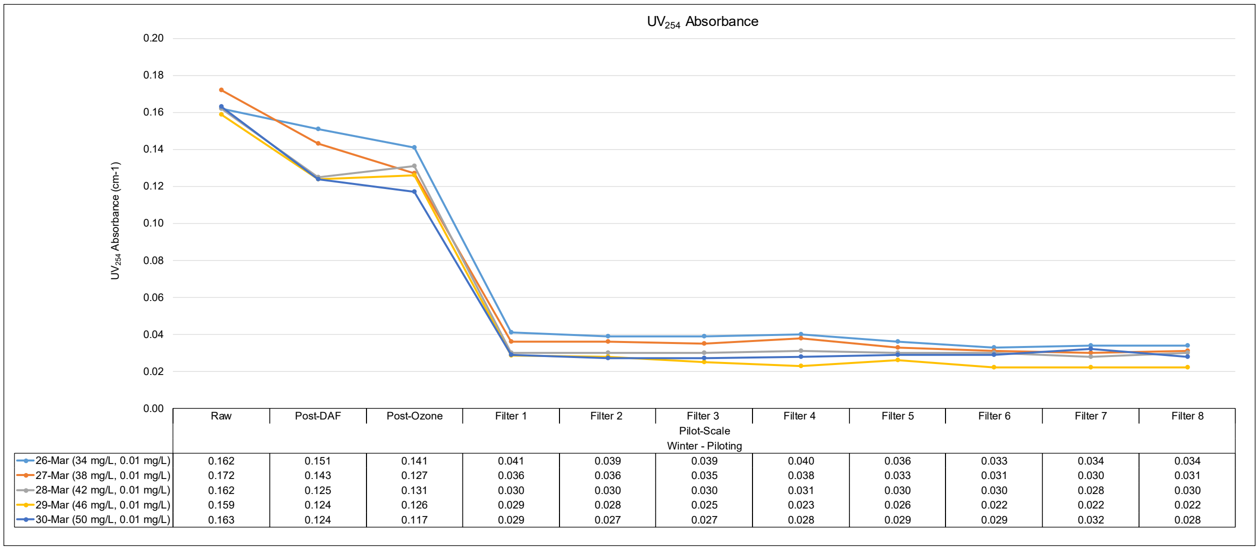
[1] Note: The pilot-scale SCADA system records the turbidity for 1 filter per bank (Bank A and B) for a 24-hour period.

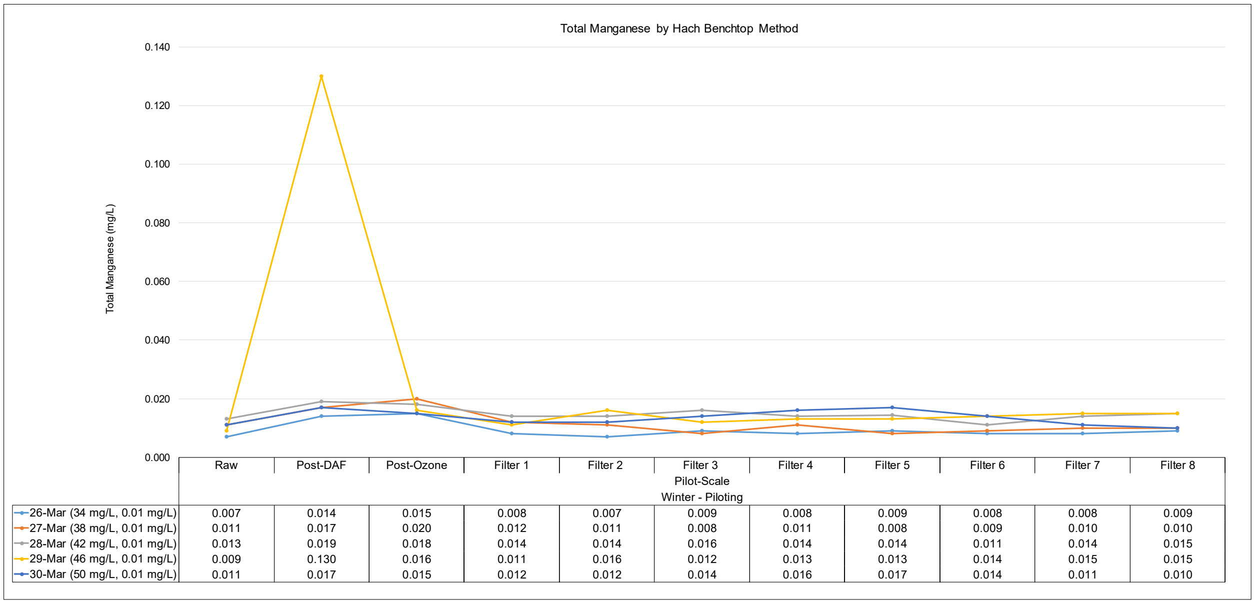


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
26-Mar (34 mg/L, 0.01 mg/L)	0.162	0.151	0.141	0.041	0.039	0.039	0.040	0.036	0.033	0.034	0.034
27-Mar (38 mg/L, 0.01 mg/L)	0.172	0.143	0.127	0.036	0.036	0.035	0.038	0.033	0.031	0.030	0.031
28-Mar (42 mg/L, 0.01 mg/L)	0.162	0.125	0.131	0.030	0.030	0.030	0.031	0.030	0.030	0.028	0.030
29-Mar (46 mg/L, 0.01 mg/L)	0.159	0.124	0.126	0.029	0.028	0.025	0.023	0.026	0.022	0.022	0.022
30-Mar (50 mg/L, 0.01 mg/L)	0.163	0.124	0.117	0.029	0.027	0.027	0.028	0.029	0.029	0.032	0.028

Figure 5-14: UV_{254nm} Absorbance measured following pilot-scale system treatment processes for the determination of the optimal dose of ferric sulphate. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

→ Total Manganese

One major focus for testing ferric sulphate as an alternative coagulant is to reduce the concentration of manganese in the treated water in order to prevent or to reduce the occurrences of discoloured water in the distribution system. Ferric sulphate is known to have lower residual manganese than the coagulant (ferric chloride) currently being applied in the full-scale system. However, due to small amounts of residual manganese in ferric sulphate, it is expected that an increased dose would result in higher manganese in the finished water verse a lower dose of ferric sulphate. This trend occurred up to a coagulant dose of 42 mg/L at which a maximum average of total manganese concentration was measured as average of Filters 1-8 (Figure 5-15). Higher coagulant doses of 46 mg/L and 50 mg/L resulted in lower total manganese concentrations of 0.0136 mg/L and 0.0133 mg/L, respectively as the average of Filters 1-8. This could be attributed to anticipated higher performance of the coagulation/flocculation processes.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
26-Mar (34 mg/L, 0.01 mg/L)	0.007	0.014	0.015	0.008	0.007	0.009	0.008	0.009	0.008	0.008	0.009
27-Mar (38 mg/L, 0.01 mg/L)	0.011	0.017	0.020	0.012	0.011	0.008	0.011	0.008	0.009	0.010	0.010
28-Mar (42 mg/L, 0.01 mg/L)	0.013	0.019	0.018	0.014	0.014	0.016	0.014	0.014	0.011	0.014	0.015
29-Mar (46 mg/L, 0.01 mg/L)	0.009	0.130	0.016	0.011	0.016	0.012	0.013	0.013	0.014	0.015	0.015
30-Mar (50 mg/L, 0.01 mg/L)	0.011	0.017	0.015	0.012	0.012	0.014	0.016	0.017	0.014	0.011	0.010

Figure 5-15: Total manganese measured following pilot-scale system treatment processes for the determination of the optimal dose of ferric sulphate. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

→ UFRV

Figure 5-16 illustrates the average observed and forecasted UFRV values obtained for each coagulant dose for Bank A and Bank B. During optimization of the coagulant dose, Bank A was observed to not overflow, while Bank B overflowed every cycle. However, when considering individual filters, failures were observed based on turbidity (> 0.1 NTU) at all coagulant doses tested.

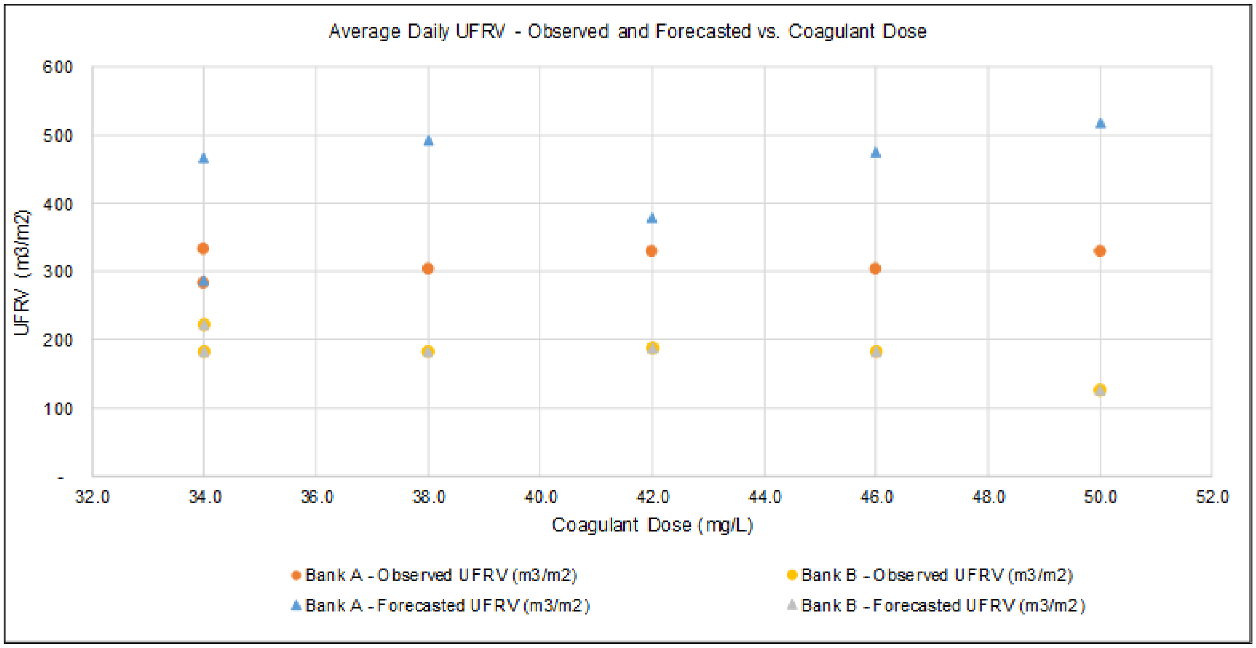


Figure 5-16: Average UFRV of pilot-scale system Bank A at an average flow rate of 0.3 L/s and Bank B at an average flow rate of 0.6 L/s during the Winter piloting session for determining the optimal dose of ferric sulphate. The coagulant-aid dose was maintained at 0.01 mg/L. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

Considering the observed UFRV values for Bank A, there was little change in doses from 34 to 50 mg/L of coagulant. In addition, there was little change in UFRV values for Bank B between a dose of 34 and 46 mg/L of coagulant. Although the observed UFRV values for Bank A were above 200 m^3/m^2 and the observed UFRV values for Bank B were close to 200 m^3/m^2 at ferric sulphate doses between 38 to 46 mg/L, all individual filters failed based on turbidity (> 0.1 NTU). Thus, the expected UFRV values would be lower than what was observed in Figure 5-16 and the performance of pilot-scale system filters was deemed poor at all doses. As such, it is not empirically possible to select the optimal ferric sulphate dose between 38 to 46 mg/L based solely upon URFV results as discussed.

→ Summary of Ferric Sulphate Optimization

Overall, the data demonstrates that the coagulant dose of 50 mg/L had the highest removal of turbidity and resulted in the lowest total manganese concentration; while a dose of 46 mg/L had the greatest removal of absorbance and improvement in UVT. With only minor differences found between these two doses for total manganese, it was determined that the optimal dose for ferric sulphate was 46 mg/L.

It should be noted that the pH of the water during chemical coagulation does effect the performance of the coagulant, and during the Winter piloting session the coagulant dose was not optimized for pH. The measured Post-DAF pH during optimal trials for ferric sulphate was approximately 5.75±0.10. Although it is unknown if the optimal dose determined would remain the same if the pH was optimized for the coagulation process, the measured pH of 5.75 is within the optimal operating pH for ferric sulphate according to literature. It is strongly recommended that future piloting sessions optimized the pH for coagulation to ensure the optimal operating conditions for coagulation with ferric sulphate is achieved.

5.7.2 Optimization of Coagulant-Aid

The optimization of coagulant-aid (LT-22S) dose was conducted from March 31st to April 2nd, 2017. An analogous approach to the coagulant dose optimization was taken in determining the ideal dose of the coagulant-aid. The optimal dose was determined by analyzing the removal of the following key parameters following treatment, with attention given to the final (treated) water quality: turbidity, UVT, UV_{254nm} absorbance, and total manganese.

These parameters were measured onsite using benchtop analysis by WSP personnel. Samples were collected daily from the following locations in the pilot-scale system: raw water, Post-DAF, combined Post-Ozone, and from the effluent of the filters (Filters 1-8). The dosage of coagulant remained constant (42 mg/L) throughout the optimization of coagulant-aid. This dosage was selected to perform the optimization of coagulant-aid based on the optimal dose from bench scale testing, opposed to the best coagulant dose determined during the coagulant optimization phase of the Winter piloting session, as there was already a thorough collection of established conditions at 42 mg/L to facilitate and distinguish any potential for differences caused by the coagulant-aid from the changes in coagulant dose.

During the optimization of the coagulant-aid, the coagulant-aid was dosed to the top of Floc Tank #3 of the DAF unit. Figure 5-17 displays the pipe placement above the tank and dropwise coagulant-aid addition to the top of the mixing Tank #3. The addition of coagulant-aid by this method resulted in poor mixing conditions of the coagulant-aid, and it was believed that much of the coagulant-aid remained in the upper portion of the mixing tank.

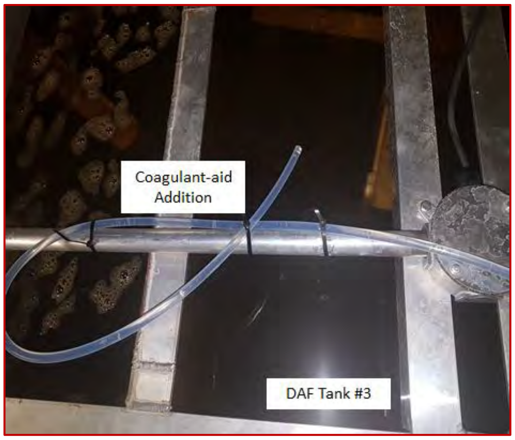


Figure 5-17: Original piping for the addition of coagulant-aid during the optimization of coagulant-aid dose

Poor mixing conditions resulted in the upper layer of the water having a higher concentration of coagulant-aid than intended. This resulted in the aggregation of large floc, or a mud-balling effect (Figure 5-18). This phenomenon was found to intensify quickly with increasing dose of coagulant-aid, causing the formation of larger aggregates. At the request of WSP personnel, the coagulant-aid pipe was modified from a flexible polyethylene tube to a PVC pipe that would extend approximately half-way (approximately 30 cm depth) into Floc Tank #3 (Figure 5-19). The change to the coagulant-aid pipe location significantly improved the mixing conditions in Floc Tank #3 and no aggregation of large floc, or mud-balling, occurred following this modification.

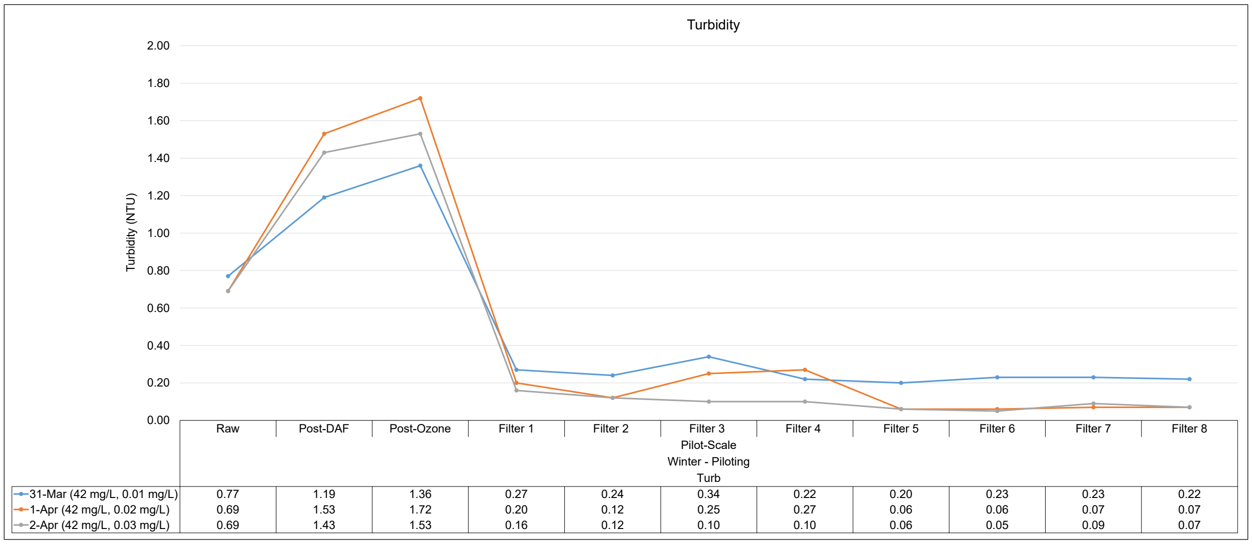
Figure 5-18: Aggregation of large floc (mud-balling effect) in DAF Tank #3

Figure 5-19: Change in piping for the addition of coagulant-aid in DAF Tank #3

Unfortunately, the pipe location was not changed until April 3rd, after the coagulant-aid optimization period. Therefore, only minor increases in coagulant-aid (0.01 mg/L) were explored, and in turn, the data collected for the optimization of coagulant-aid is believed to be subjective. Based upon observations following the modification to the coagulant-aid dosage delivery, it is believed that the previously tested higher doses of coagulant-aid which lead to mud-balling have been resolved. As such, WSP intends to explore wider ranges of coagulant-aid dosing in future piloting sessions.

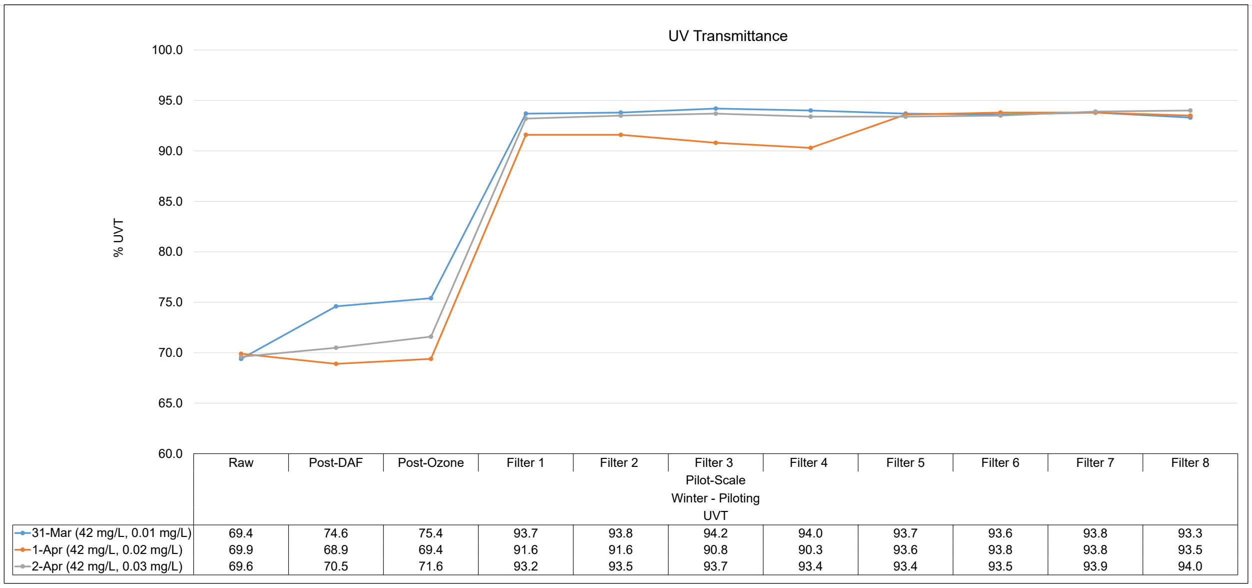
→ Turbidity, UVT & UV_{254nm} Absorbance, and Total Manganese

The results used to determine the optimal coagulant-aid dose are presented in Figure 5-20 to Figure 5-23. The turbidity results exhibit a decrease in filter effluent turbidity matched with increasing doses of coagulant-aid. The doses of 0.02 mg/L and 0.03 mg/L were closely matched when comparing Filter Bank B (Filters 5-8); however, the dose of 0.03 mg/L appeared to be better than 0.02 mg/L when comparing Bank A (Filters 1-4).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
31-Mar (42 mg/L, 0.01 mg/L)	0.77	1.19	1.36	0.27	0.24	0.34	0.22	0.20	0.23	0.23	0.22
1-Apr (42 mg/L, 0.02 mg/L)	0.69	1.53	1.72	0.20	0.12	0.25	0.27	0.06	0.06	0.07	0.07
2-Apr (42 mg/L, 0.03 mg/L)	0.69	1.43	1.53	0.16	0.12	0.10	0.10	0.06	0.05	0.09	0.07

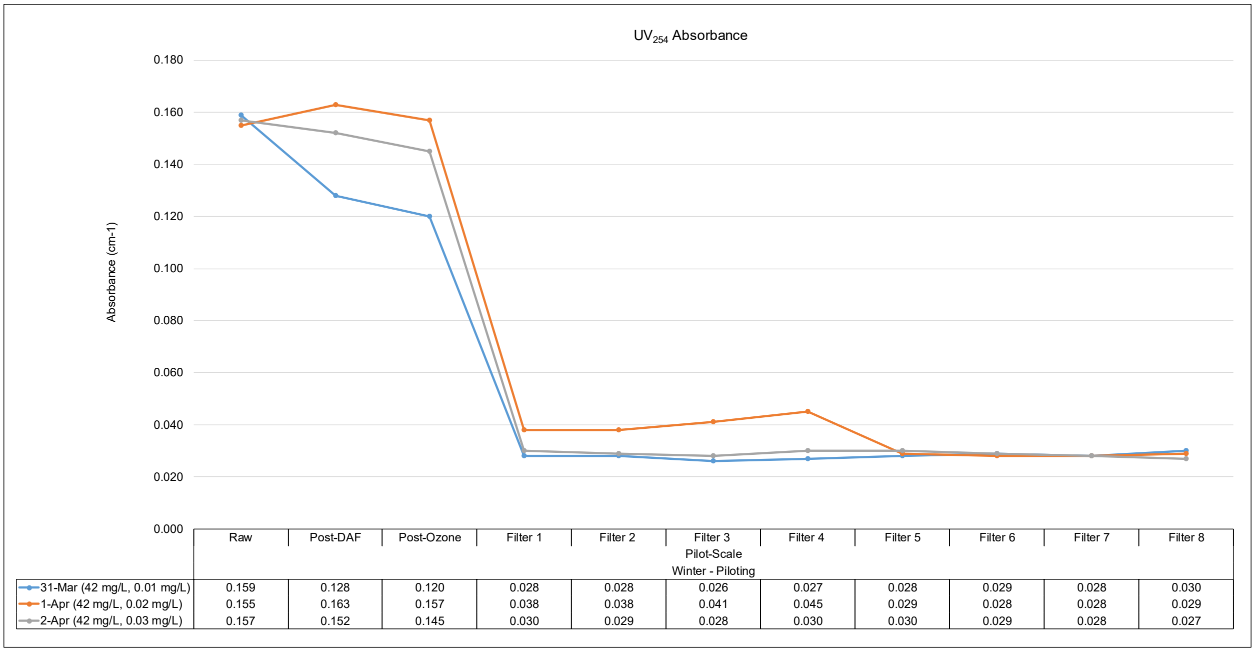
Figure 5-20: Turbidity levels by all pilot-scale system treatment processes for the determination of the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 42 mg/L and the pilot-scale system Post-DAF pH ranged from 5.66 and 6.1 at a constant sulphuric acid dose of 42 mg/L. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
31-Mar (42 mg/L, 0.01 mg/L)	69.4	74.6	75.4	93.7	93.8	94.2	94.0	93.7	93.6	93.8	93.3
1-Apr (42 mg/L, 0.02 mg/L)	69.9	68.9	69.4	91.6	91.6	90.8	90.3	93.6	93.8	93.8	93.5
2-Apr (42 mg/L, 0.03 mg/L)	69.6	70.5	71.6	93.2	93.5	93.7	93.4	93.4	93.5	93.9	94.0

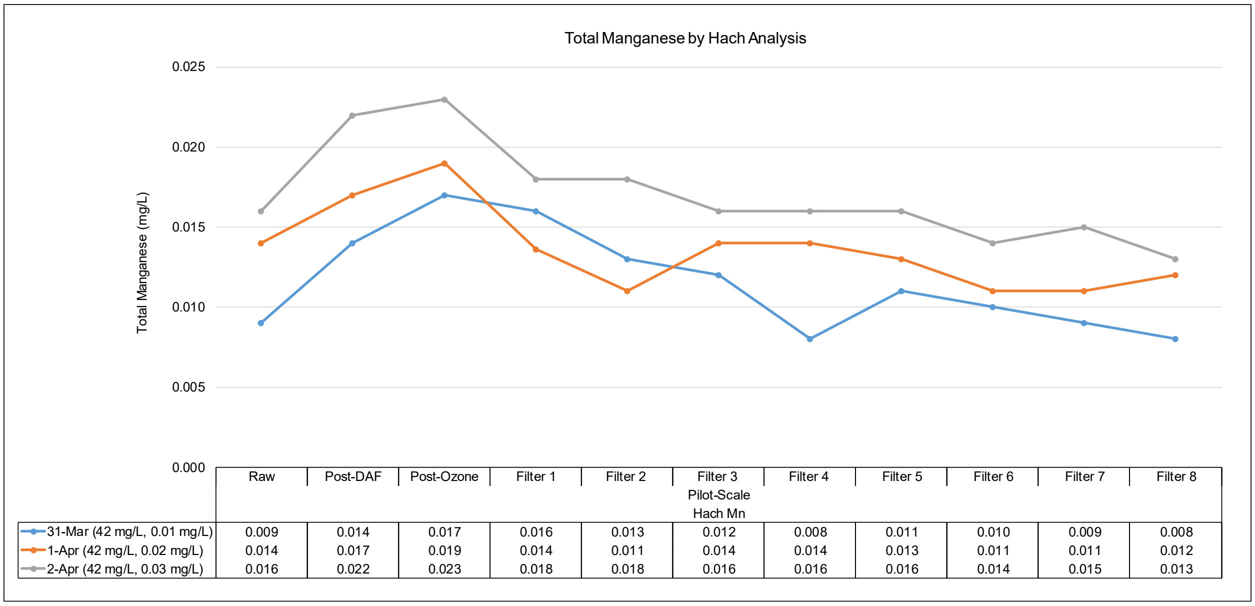
Figure 5-21: UVT following pilot-scale system treatment processes for the determination of the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 42 mg/L and the pilot-scale system Post-DAF pH ranged from 5.66 and 6.1 at a constant sulphuric acid dose of 42 mg/L. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

This trend was also observed with the UVT and UV_{254nm} absorbance results; where the dose of 0.02 mg/L and 0.03 mg/L were similar in Bank B but had larger deviations in Bank A. Total manganese was found to increase with increasing coagulant-aid dose, with the highest coagulant-aid dose of 0.03 mg/L having an average final filter effluent concentration for total manganese of 0.017 mg/L, when compared to 0.012 mg/L of total manganese with a coagulant-aid dose of 0.02 mg/L.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
31-Mar (42 mg/L, 0.01 mg/L)	0.159	0.128	0.120	0.028	0.028	0.026	0.027	0.028	0.029	0.028	0.030
1-Apr (42 mg/L, 0.02 mg/L)	0.155	0.163	0.157	0.038	0.038	0.041	0.045	0.029	0.028	0.028	0.029
2-Apr (42 mg/L, 0.03 mg/L)	0.157	0.152	0.145	0.030	0.029	0.028	0.030	0.030	0.029	0.028	0.027

Figure 5-22: UV_{254nm} Absorbance measured following pilot-scale system treatment processes for the determination of the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 42 mg/L and the pilot-scale system Post-DAF pH ranged from 5.66 and 6.1 at a constant sulphuric acid dose of 42 mg/L. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
31-Mar (42 mg/L, 0.01 mg/L)	0.009	0.014	0.017	0.016	0.013	0.012	0.008	0.011	0.010	0.009	0.008
1-Apr (42 mg/L, 0.02 mg/L)	0.014	0.017	0.019	0.014	0.011	0.014	0.014	0.013	0.011	0.011	0.012
2-Apr (42 mg/L, 0.03 mg/L)	0.016	0.022	0.023	0.018	0.018	0.016	0.016	0.016	0.014	0.015	0.013

Figure 5-23: Total Manganese measured following pilot-scale system treatment processes for the determination of the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 42 mg/L and the pilot-scale system Post-DAF pH ranged from 5.66 and 6.1 at a constant sulphuric acid dose of 42 mg/L. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

→ UFRV

Figure 5-24 demonstrates the average observed, and forecasted UFRV values, obtained for each coagulant-aid dose for Bank A and Bank B. During optimization of the coagulant-aid dose, Bank A was observed to not overflow, whereas Bank B overflowed every cycle. At a coagulant-aid dose of 0.01 mg/L, 89% of Bank A individual filters and 50% of Bank B individual filters failed based on turbidity (> 0.1 NTU). At a coagulant-aid dose of 0.02 mg/L, 100% of Bank A individual filters and none of Bank B individual filters failed based on turbidity (> 0.1 NTU). At coagulant-aid dose of 0.03 mg/L, 25% of Bank A individual filters and none of Bank B individual filters failed based on turbidity (> 0.1 NTU).

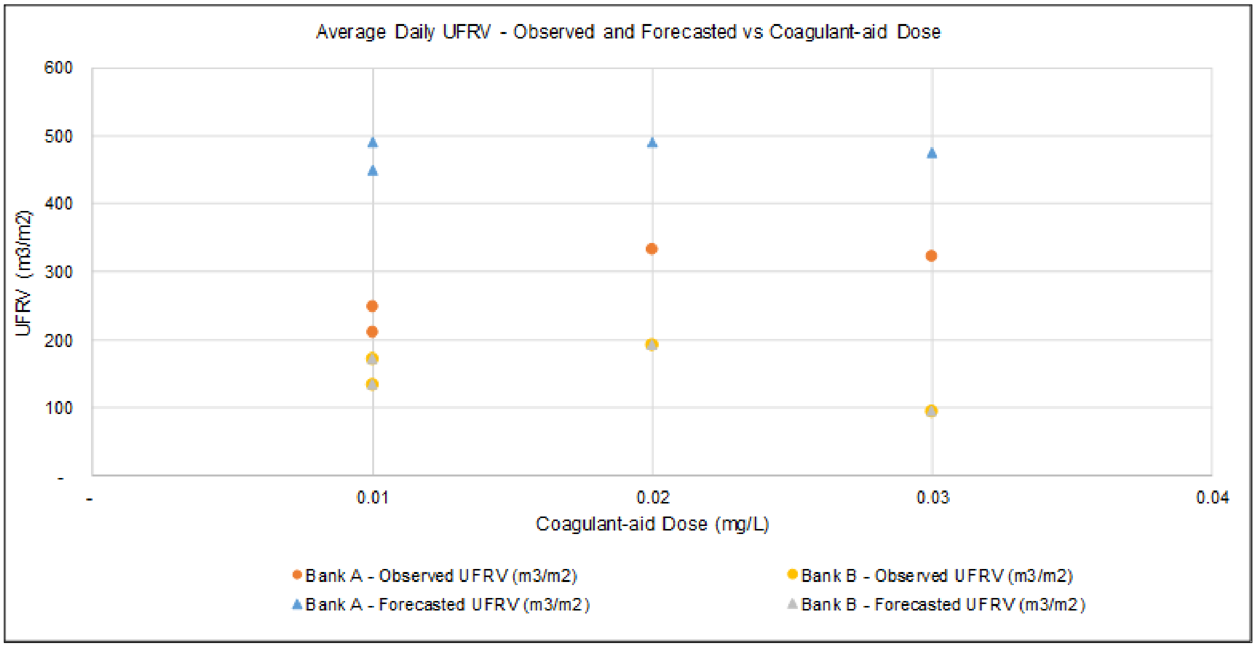


Figure 5-24: Average UFRV of pilot-scale system Bank A at an average flow rate of 0.3 L/s and Bank B at an average flow of rate 0.6 L/s during the Winter piloting session for determining the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 42 mg/L and the pilot-scale system Post-DAF pH ranged from 5.66 and 6.1 at a constant sulphuric acid dose of 42 mg/L. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

It was observed that in general, the average observed UFRV values increased as the coagulant-aid dose increased to 0.02 mg/L, whereas a decrease in UFRV values was observed at 0.03 mg/L. The highest observed UFRV values (333 and 193 m^3/m^2, for Bank A and Bank B, respectively) were obtained at a coagulant-aid dose of 0.02 mg/L.

Although the observed UFRV values for Bank A were above 200 m^3/m^2, most individual filters failed based on turbidity (> 0.1 NTU) at coagulant-aid doses of 0.01 mg/L and 0.02 mg/L. For Bank B, the observed UFRV values were below 200 m^3/m^2 at all coagulant-aid doses, but individual filters did not fail based on turbidity (> 0.1 NTU) at coagulant-aid doses of 0.02 mg/L and 0.03 mg/L.

While the UFRV values in the full-scale system would be expected to be double that for Bank B due to the higher head loss available, the performance of pilot-scale system filters was deemed poor at the smaller doses of coagulant-aid for Bank A with operational parameters closer to the full-scale system.

Considering the URFV results above, the coagulant-aid dose of 0.03 mg/L is considered the optimal dose if the results from Bank A are favoured. Thus, among the coagulant-aid doses tested, only the coagulant-aid dose of 0.03 mg/L would be deemed viable for full-scale system operation. However, it should be noted that this coagulant-aid dose is no longer optimal at higher water flows and additional chemical adjustments may be required.

→ Summary of Coagulant-aid Optimization

The optimal dose for coagulant-aid was determined to be 0.02 mg/L as this dose provided an overall lower total manganese concentration in the filter effluent compared to a dose of 0.03 mg/L, as well as improved removal of turbidity, absorbance and a greater increase in UVT when compared to the dose of 0.01 mg/L.

The UFRV analysis performed after the completion of the piloting session did not confirm the same optimal coagulant-aid dose of 0.02 mg/L and indicated that the preferred coagulant-aid dose was 0.03 mg/L based on filter performance. However, the coagulant-aid dose of 0.02 mg/L had already been carried forward based on the water quality parameters.

It should be noted that the optimal dose for coagulant-aid was determined during a period where the dosing point for coagulant-aid was not ideal (i.e., to the top of Floc Tank #3) and therefore it is not fully clear how the change in location will affect the performance of coagulant-aid, with regards to the optimum dose. Therefore, caution should be taken in future piloting sessions when establishing an appropriate testing range for the coagulant-aid. It is suspected that the improvement made to the coagulant-aid dosing location may result in a lower optimum dose.

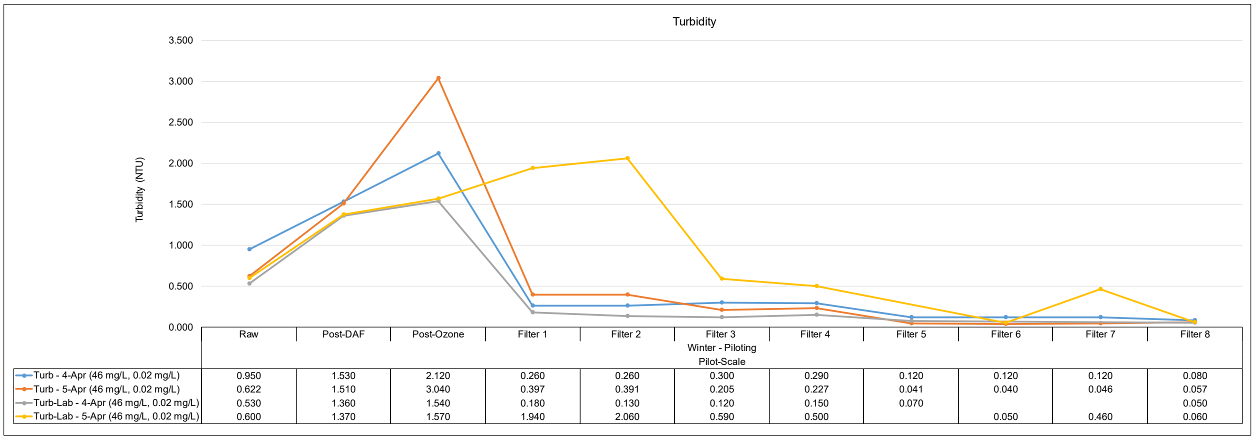
5.8 Optimized Condition Results

The optimal doses for coagulant and coagulant-aid were tested on April 4th and 5th, 2017, using the optimal dose determined for ferric sulphate and the coagulant-aid of 46 mg/L and 0.02 mg/L, respectively.

The pH during coagulation (measured as Post-DAF pH) was 5.65±0.02 for the optimal condition tests. The optimal doses were analyzed for the removal of the following key parameters following treatment: turbidity, UVT, UV_{254nm} absorbance, total manganese, and DOC. These parameters were measured onsite using benchtop analysis by WSP personnel; samples were also collected for analysis by the Lab. The results for key parameters measured and filters operation results during the optimal dose trials are presented in Figure 5-25 to Figure 5-30 and Table 5-4.

→ Turbidity

An increase in turbidity (Figure 5-25) was noted after the pilot-scale system DAF and ozone treatment, similarly observed during the Winter benchmarking period (Section 2), but a significant decline was observed after filtration. The lowest turbidity results for the entirety of the Winter piloting session was measured on April 5th from Bank B (Benchtop turbidity; Figure 5-5), with an average turbidity of 0.048 NTU as average of Filters 5-8. However, filtered water turbidity data produced by the Lab on April 5th, 2017 is believed to contain errors for Filter 1 and 2, as significant increase in turbidity was not seen from the benchtop data samples at the same time.

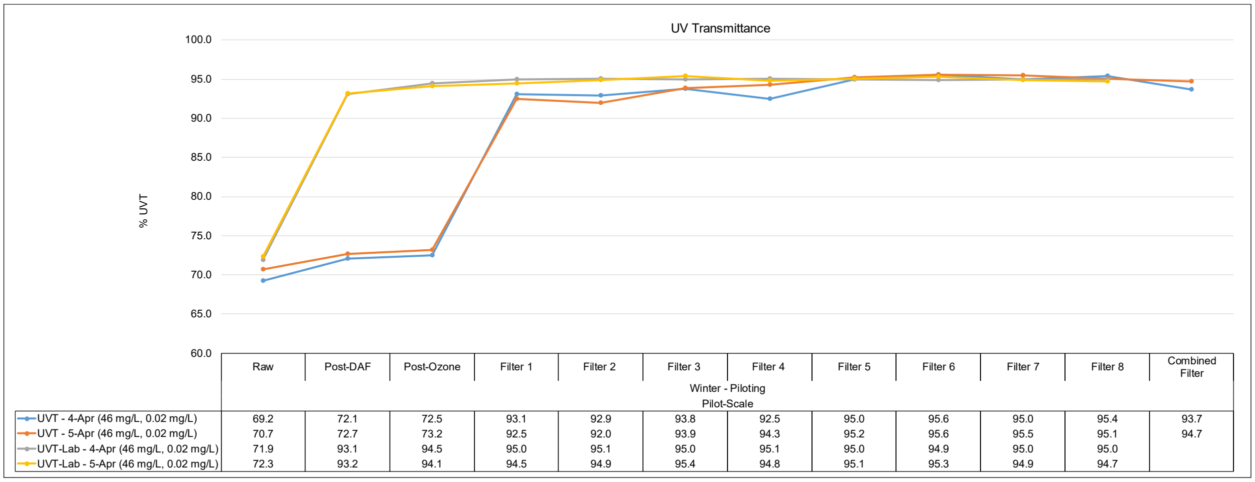


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
Turb - 4-Apr (46 mg/L, 0.02 mg/L)	0.950	1.530	2.120	0.260	0.260	0.300	0.290	0.120	0.120	0.120	0.080
Turb - 5-Apr (46 mg/L, 0.02 mg/L)	0.622	1.510	3.040	0.397	0.391	0.205	0.227	0.041	0.040	0.046	0.057
Turb-Lab - 4-Apr (46 mg/L, 0.02 mg/L)	0.530	1.360	1.540	0.180	0.130	0.120	0.150	0.070			0.050
Turb-Lab - 5-Apr (46 mg/L, 0.02 mg/L)	0.600	1.370	1.570	1.940	2.060	0.590	0.500		0.050	0.460	0.060

Figure 5-25: Turbidity results at 46 mg/L coagulant dose and 0.02 mg/L coagulant-aid dose in the pilot-scale system. Data originates from both the Lab and benchtop analyses using a Hach 2100Q turbidimeter. Note: Blank spaces indicate the sample was below the detection limit of 0.05 NTU; see Appendix A.

→ UVT & UV$_{254nm}$ Absorbance

Figure 5-26 and Figure 5-27 show UVT and UV$_{254nm}$ Absorbance results, respectively. Furthermore, the samples collected from Filter Bank B on April 5th had the highest UVT of all samples collected during the Winter piloting session (Figure 5-26).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
UVT - 4-Apr (46 mg/L, 0.02 mg/L)	69.2	72.1	72.5	93.1	92.9	93.8	92.5	95.0	95.6	95.0	95.4	93.7
UVT - 5-Apr (46 mg/L, 0.02 mg/L)	70.7	72.7	73.2	92.5	92.0	93.9	94.3	95.2	95.6	95.5	95.1	94.7
UVT-Lab - 4-Apr (46 mg/L, 0.02 mg/L)	71.9	93.1	94.5	95.0	95.1	95.0	95.1	95.0	94.9	95.0	95.0	
UVT-Lab - 5-Apr (46 mg/L, 0.02 mg/L)	72.3	93.2	94.1	94.5	94.9	95.4	94.8	95.1	95.3	94.9	94.7	

Figure 5-26: UVT results at 46 mg/L coagulant dose and 0.02mg/L coagulant-aid dose in the pilot-scale system Data originates from both the Lab and benchtop analyses using a Hach DR6000 UV-vis spectrophotometer, both samples sets are unfiltered prior to analysis.

	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Abs - 4-Apr (46 mg/L, 0.02 mg/L)	0.160	0.142	0.140	0.032	0.032	0.028	0.034	0.022	0.021	0.023	0.020	0.028
Abs - 5-Apr (46 mg/L, 0.02 mg/L)	0.150	0.138	0.136	0.033	0.036	0.028	0.025	0.022	0.019	0.020	0.021	0.023

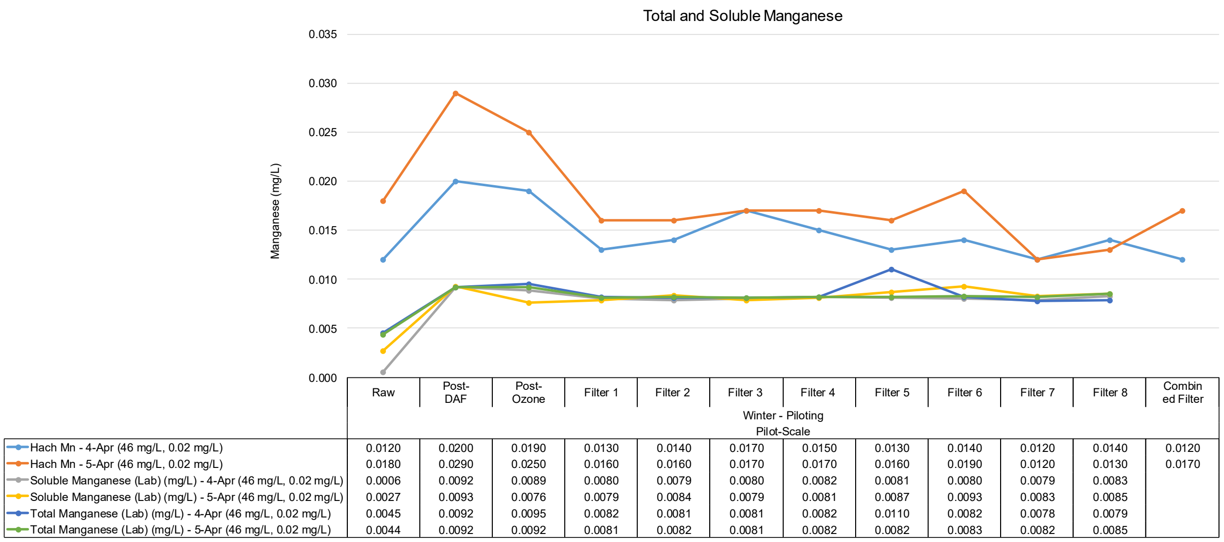
Figure 5-27: UV_{254nm} Absorbance results at 46 mg/L coagulant dose and 0.02 mg/L coagulant-aid dose in the pilot-scale system. Absorbance was not tested by the City of Winnipeg Lab. Data originates from benchtop analyses using a Hach DR6000 UV-vis spectrophotometer, samples sets are unfiltered prior to analysis.

Filter Bank B appeared to be performing better than Bank A, consistently producing better treated filter effluent water in terms of turbidity, UVT, and UV_{254nm} absorbance. During the Winter benchmarking period, these types of discrepancies were not observed. One likely contributor to the differences observed between Banks A and B is the flow rate. Bank A was operating at a lower flow rate compared to Bank B. It is suggested that the effect of flow rates be explored in future piloting sessions to establish if flow is the only contributor, or if other factors are causing the differences observed between the two banks.

→ Total Manganese

Total manganese was measured by both WSP (benchtop) and the Lab (Figure 5-28). The results show that the benchtop tests were consistently higher than those reported by the Lab. The reason for this difference is the sensitivity of the instrumentation used to measure manganese by each group. The Lab uses a highly sensitive instrument, Inductively Couple Plasma – Mass Spectrometry (ICP-MS), compared to the benchtop instrument available to WSP personnel. Therefore, the concentrations reported by the Lab are a more accurate representation of the concentration of manganese in each sample. However, the total manganese results reported using the benchtop instrument are valuable as the instrument is still capable of measuring changes in total manganese concentration and is useful in onsite analysis when determining daily changes to the pilot-scale system. This notion has been previously explored and demonstrated in Technical Memorandum No.1.

A major focus of this study is to determine an alternative coagulant which will produce treated water with a lower manganese content to prevent or reduce the occurrence of discoloured water in the distribution system. Although it is understood that ferric sulphate has a lower total manganese content compared to current coagulant in full-scale system operation (ferric chloride), the low total manganese concentration in the filter effluent (Figure 5-28) measured by the Lab for the ferric sulphate was an order of magnitude lower than those reported during the Winter benchmarking period where ferric chloride was used.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Hach Mn - 4-Apr (46 mg/L, 0.02 mg/L)	0.0120	0.0200	0.0190	0.0130	0.0140	0.0170	0.0150	0.0130	0.0140	0.0120	0.0140	0.0120
Hach Mn - 5-Apr (46 mg/L, 0.02 mg/L)	0.0180	0.0290	0.0250	0.0160	0.0160	0.0170	0.0170	0.0160	0.0190	0.0120	0.0130	0.0170
Soluble Manganese (Lab) (mg/L) - 4-Apr (46 mg/L, 0.02 mg/L)	0.0006	0.0092	0.0089	0.0080	0.0079	0.0080	0.0082	0.0081	0.0080	0.0079	0.0083	
Soluble Manganese (Lab) (mg/L) - 5-Apr (46 mg/L, 0.02 mg/L)	0.0027	0.0093	0.0076	0.0079	0.0084	0.0079	0.0081	0.0087	0.0093	0.0083	0.0085	
Total Manganese (Lab) (mg/L) - 4-Apr (46 mg/L, 0.02 mg/L)	0.0045	0.0092	0.0095	0.0082	0.0081	0.0081	0.0082	0.0110	0.0082	0.0078	0.0079	
Total Manganese (Lab) (mg/L) - 5-Apr (46 mg/L, 0.02 mg/L)	0.0044	0.0092	0.0092	0.0081	0.0082	0.0081	0.0082	0.0082	0.0083	0.0082	0.0085	

Figure 5-28: Total and dissolved manganese results at 46 mg/L coagulant dose and 0.02 mg/L coagulant-aid dose in the pilot-scale system. Data originates from both the Lab and benchtop analyses using a Hach DR6000 UV-vis spectrophotometer.

→ Filters operation

Table 5-4 presents the average UFRV values for the optimal days of the Winter piloting session, while also considering overall operating cycles and those which have not failed based on sampled turbidity.

Table 5-4: Average observed and forecasted UFRV values for optimal conditions during Winter piloting session.

UFRV (m^3/m^2)		OPTIMAL DAYS OF WINTER PILOTING SESSION		
		Bank A	**Bank B**	**All Filters**
Observed Values	Overall Cycles	326	155	252
	Only cycles with turbidity ≤ 0.1 NTU	N/R	152	152
	Only cycles with turbidity ≤ 0.3 NTU	319	155	237
Forecasted Values	Overall Cycles	540	155	375
	Only cycles with turbidity ≤ 0.1 NTU	N/R	152	152
	Only cycles with turbidity ≤ 0.3 NTU	561	155	358

N/R: No results

The filter effluent turbidity measured by the Lab is plotted against the differential pressure at 4 hours after start of filter cycle (or approximate sampling time) of each individual filter for April 4th and 5th during the Winter piloting session, as shown on Figure 5-29. This illustration also highlights the City's operational filter turbidity limit of 0.1 NTU, the full-scale system operating licence limit of 0.3 NTU, and the expected differential pressures at the sampling time per flow rate to match the full-scale system performance. The expected differential pressures of 6.8 kPa for filters at average flow rate and 12.4 kPa for filters at maximum flow rate are based on the historical benchmarking values of the full-scale system filters (average head loss of 48.9 kPa and average filter run of 28.9 h per Table 2-2 of TM No. 1).

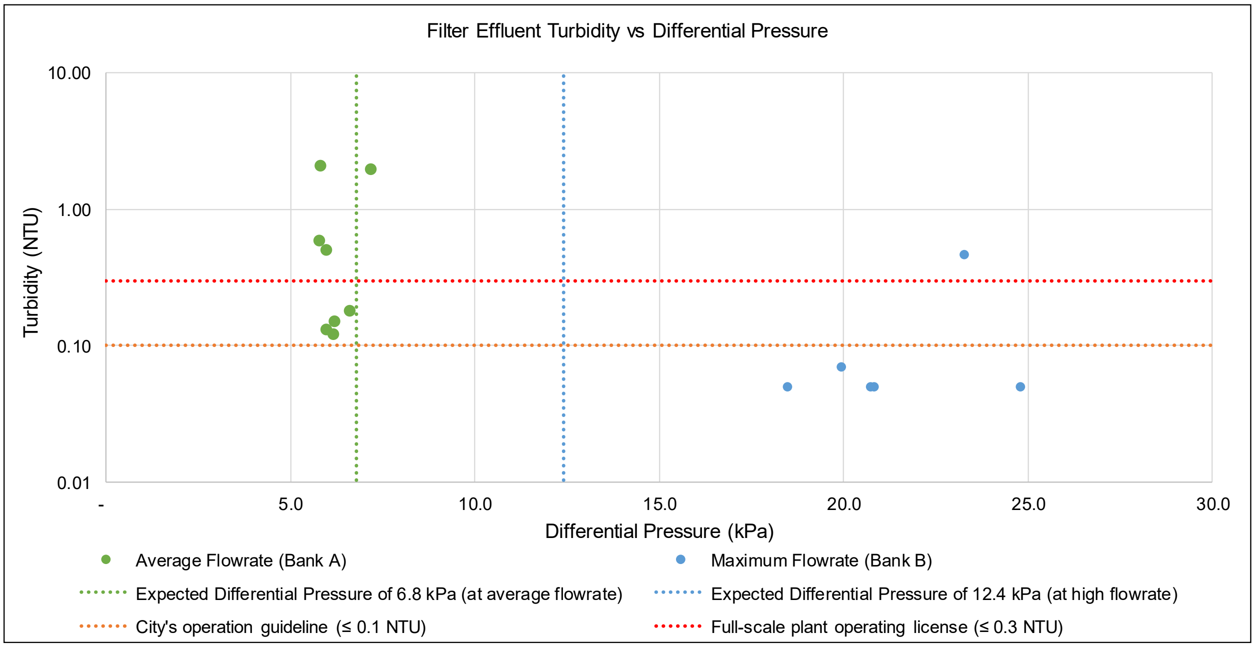


Figure 5-29: Filter effluent turbidity versus differential pressure at sampling time for each individual filter during optimal conditions testing for the Winter piloting session. Note the turbidity levels (y-axis) are displayed in a logarithmic scale to improve visualization.

Bank A filters presented effluent turbidity levels above 0.1 NTU and above 0.3 NTU for both optimal condition days, indicating an evident turbidity breakthrough. For Bank A, the observed overall average UFRV was 326 m^3/m^2 during the optimal conditions of the Winter piloting session. When discarding the cycles that turbidity levels were above 0.3 NTU when sampled, the observed UFRV values were 319 m^3/m^2. The average rate of head loss increase for Bank A was 0.6 kPa/h, 65% lower than the typical rate of head loss increase for filter bank operating at 0.3 L/s (1.7 kPa/h, Refer to Table 5-2). Bank A presented a differential pressure at 4 hours after the start of a filter cycle (5.8 – 7.2 kPa) which is similar to the expected differential pressure (6.8 kPa) for average flow rate, as well as the observed UFRV values, which were higher than 200 m^3/m^2. However, the expected UFRV value would be lower since Bank A presented turbidity above 0.1 NTU during the optimal conditions of the Winter piloting session.

For Bank B, the observed overall average UFRV was 155 m^3/m^2. When discarding the cycles that turbidity levels were above 0.1 NTU and 0.3 NTU when sampled, little difference was noticed on observed UFRV values (152 and 155 m^3/m^2, respectively). Only Filter 7 of Bank B presented effluent turbidity levels above 0.1 NTU on the second optimal condition day, however, the differential pressure at 4 hours after start of filter cycle (18.5 – 24.8 kPa) were substantially higher than the expected differential pressure (12.4 kPa) for maximum flow rate. The average rate of head loss increase for Bank B was 4.4 kPa/h, 42% higher than the typical rate of head loss increase for filter bank operating at 0.6 L/s (3.1 kPa/h, Refer to Table 5-2). During the Winter piloting session, Bank B pilot-scale system filters, which had not presented turbidity breakthrough, did not achieve the minimum UFRV value of 200 m^3/m^2 required to achieve a recovery greater than 95%, however, these values would likely be doubled in the full-scale system as explained in Section 2.4, where the head loss available for filtration is twice that of the available head loss at the pilot-scale system filters.

The UFRV values of Bank B at maximum flow rate suggest the filter recovery would not be an issue with ferric sulphate as coagulant, however, the performance of Bank A filters, with operational parameters closer to the full-scale system filters, was deemed poor due to turbidity breakthrough during the Winter piloting session.

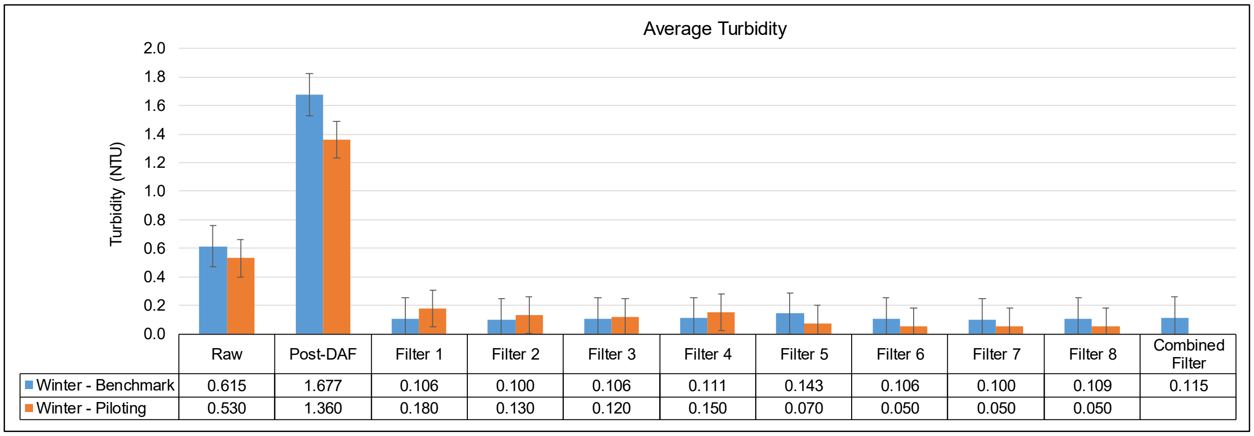
→ Summary of Optimal Conditions

Overall, the Winter piloting session was successful in determining an optimal ferric sulphate of dose of 46 mg/L for cold water conditions. Although an optimal coagulant-aid dose of 0.02 mg/L was presented above, it is believed further analysis into the optimal dose is required due to the change made to the addition of the coagulant-aid to the pilot-scale system. With this improvement, WSP believes that the coagulant-aid dose test range could be increased beyond those tested during the Winter piloting session, and plans to explore a wider range of coagulant-aid dose in future piloting sessions.

5.9 Comparison between the Winter Benchmarking Period and the Winter Piloting Session in the Pilot-Scale System

Figure 5-30 to Figure 5-32 compare the turbidity, total manganese and TOC/DOC yielded at the pilot-scale system during the Winter benchmarking period with ferric chloride and the optimal results at Winter piloting session with ferric sulphate. These are the key water quality parameters to be compared.

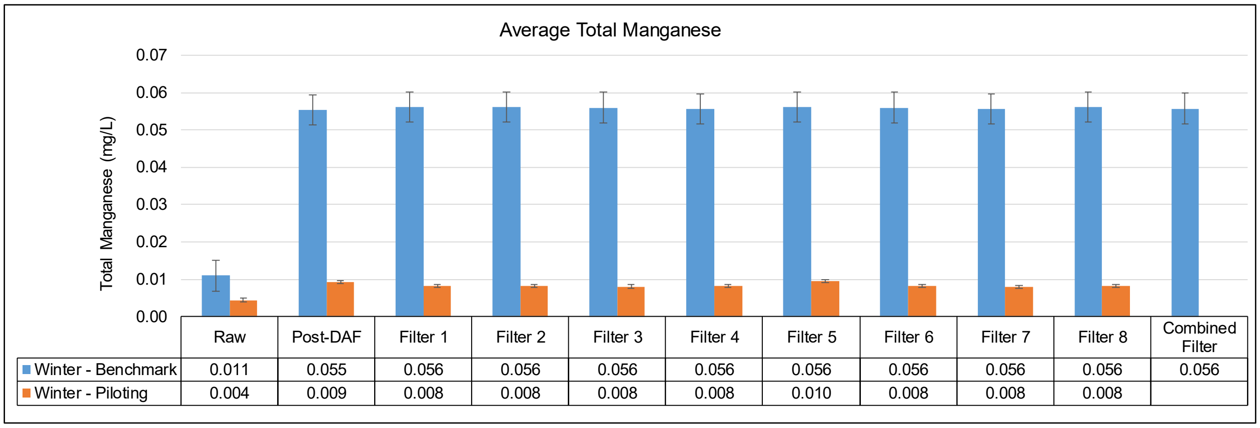
It is possible to observe that the use of ferric sulphate has generally not demonstrated a significant impact on turbidity when compared with ferric chloride Post-DAF (Figure 5-30). However, Bank A (Filters 1 to 4) exhibited a slightly higher average turbidity when compared to Bank B during the Winter piloting session. This potential deviation may be attributed to the previously noted mechanical differences in the pilot-scale system's filter banks or other reasons noted above, such as different flow rates. Further exploration into differences observed between the two filter banks is required to establish a more precise cause.



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
🟦 Winter - Benchmark	0.615	1.677	0.106	0.100	0.106	0.111	0.143	0.106	0.100	0.109	0.115
🟧 Winter - Piloting	0.530	1.360	0.180	0.130	0.120	0.150	0.070	0.050	0.050	0.050	

Figure 5-30: Comparison of average turbidity between the Winter benchmarking period (average values from February 4th and February 17th, 2017) and the Winter piloting session (April 4th to April 5th, 2017). Data originates from Lab analysis. Note that these results excluded the filtered water turbidity data produced by the Lab on April 5th, 2017, because it is believed that this data contains errors.

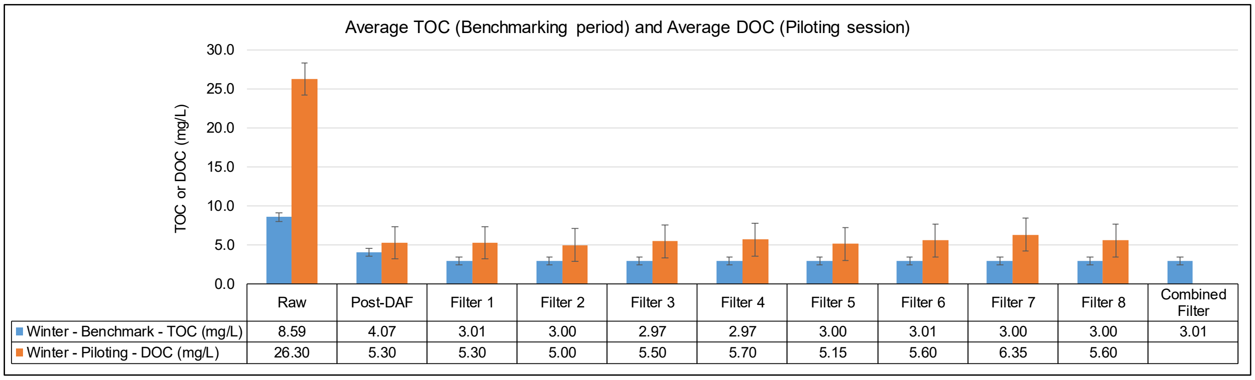
As previously discussed, the use of ferric sulphate has demonstrated a reduced average of total manganese concentration across the pilot-scale system's processes (Figure 5-31).



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
🟦 Winter - Benchmark	0.011	0.055	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
🟧 Winter - Piloting	0.004	0.009	0.008	0.008	0.008	0.008	0.010	0.008	0.008	0.008	

Figure 5-31: Comparison of average total manganese between the Winter benchmarking period (average values from February 4th and February 17th, 2017) and the Winter piloting session (April 4th to April 5th, 2017). Data originates from Lab analysis.

Since historical results of the full-scale system has demonstrated TOC and DOC levels are comparable, these two parameters were plotted as the same for comparison of the Winter benchmarking period and the Winter piloting session (Figure 5-32). Raw water DOC showed much higher values than expected, as DOC historical data shows an average of 9.51 mg/L, and maximum of 13 mg/L during cold water conditions. Investigations by the City indicate that the elevated DOC data was the result of laboratory errors. Therefore, it is not possible to conclude if the ferric sulphate impacted the organic matter removal by the pilot-scale system DAF when compared with ferric chloride results.



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Winter - Benchmark - TOC (mg/L)	8.59	4.07	3.01	3.00	2.97	2.97	3.00	3.01	3.00	3.00	3.01
Winter - Piloting - DOC (mg/L)	26.30	5.30	5.30	5.00	5.50	5.70	5.15	5.60	6.35	5.60	

Figure 5-32: Comparison of average total manganese between the Winter benchmarking period (average values from February 4th and February 17th, 2017) and the Winter piloting session (April 4th to April 5th, 2017). Data originates from Lab analysis. Note: Winter piloting TOC data contains laboratory errors and is believed to be 2-3 times higher than the actual TOC concentration.

Appendix E presents a comprehensive table comparing the average water quality results from the Winter benchmarking period and the Winter piloting session with the alternate coagulant. No concerns were noted.

Table 5-5 presents the average UFRV values for the Winter benchmarking period and the optimal days of the Winter piloting session, while also considering overall operation cycles and those which have not failed based on sampled turbidity.

Table 5-5: Average observed and forecasted UFRV values for the Winter benchmarking period and April 4th to April 5th of the Winter piloting session.

UFRV (m^3/m^2)		**WINTER BENCHMARKING PERIOD**	**APRIL 4TH TO APRIL 5TH OF WINTER PILOTING SESSION**		
		All Filters	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	138	326	155	252
	Only cycles with turbidity ≤ 0.1 NTU	139	N/R	152	152
	Only cycles with turbidity ≤ 0.3 NTU	137	319	155	237
Forecasted Values	Overall Cycles	139	540	155	375
	Only cycles with turbidity ≤ 0.1 NTU	140	N/R	152	152
	Only cycles with turbidity ≤ 0.3 NTU	139	561	155	358

N/R: No results

In terms of filter operation, the overall average observed UFRV for the Banks A and B was 138 m^3/m^2 during the Winter benchmarking period, while the overall average observed UFRV during the optimal conditions of the Winter piloting session was 326 m^3/m^2 and 155 m^3/m^2 for Bank A and Bank B, respectively.

Bank A achieved a twice as high a UFRV value with ferric sulphate than with ferric chloride, however has presented effluent turbidity levels above 0.1 NTU or above 0.3 NTU on April 4th to April 5th of the Winter piloting session. Bank B presented slightly higher UFRV values with ferric sulphate and ferric chloride, but Bank B filters have presented effluent turbidity levels above 0.1 NTU on April 4th, 2017. Considering only the second day of optimal conditions when the Bank B effluent turbidity levels were below 0.1 NTU and the average observed UFRV was 152 m^3/m^2, it can be considered that there was no significant difference between both coagulants in terms of URFV values.

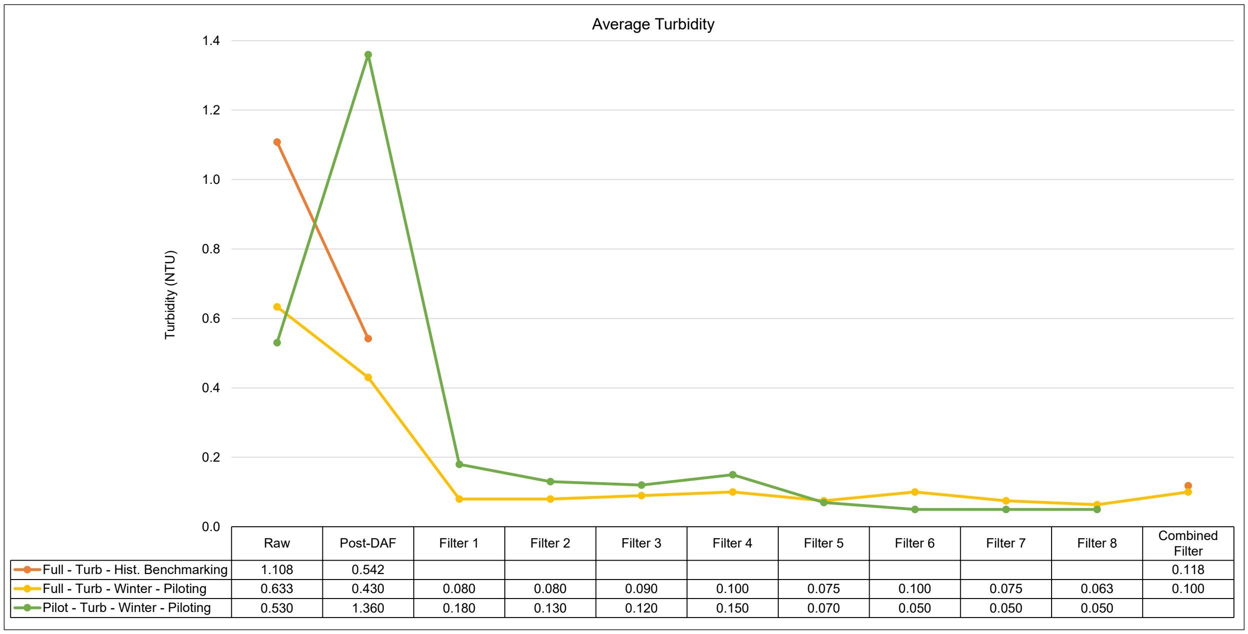
The UFRV values of Bank B at maximum flow rate suggests the filter recovery would not be an issue with ferric sulphate as coagulant, however, the performance of Bank A filters, with operational parameters closer to the full-scale system filters, was deemed poor due to turbidity breakthrough during the Winter piloting session. The Winter benchmarking period results shows the filter recovery would not be an issue as well with ferric chloride, however, the pilot-scale filters exceeded the maximum rate of head loss increase of 3.7 kPa/h during 30% of the time and the performance of pilot-scale system filters was also deemed poor during Winter benchmarking period.

5.10 Comparison between the Pilot-Scale and Full-Scale Systems during the Winter Piloting Session

The following results provide a comparison between the historical full-scale system water quality, and the full-scale and pilot-scale system water quality during the Winter piloting session. The comparison is made during the last two days of the Winter piloting session, when a coagulant dose of 46 mg/L and the optimal coagulant-aid dose (0.02mg/L) were used in the pilot-scale system and additional data is available for both systems. For the full-scale system historical benchmarking, only the combined filtered water quality is presented, not for each individual filter. It should also be noted that the pH was not optimized for ferric sulphate during the Winter piloting session.

5.10.1 Key Parameters

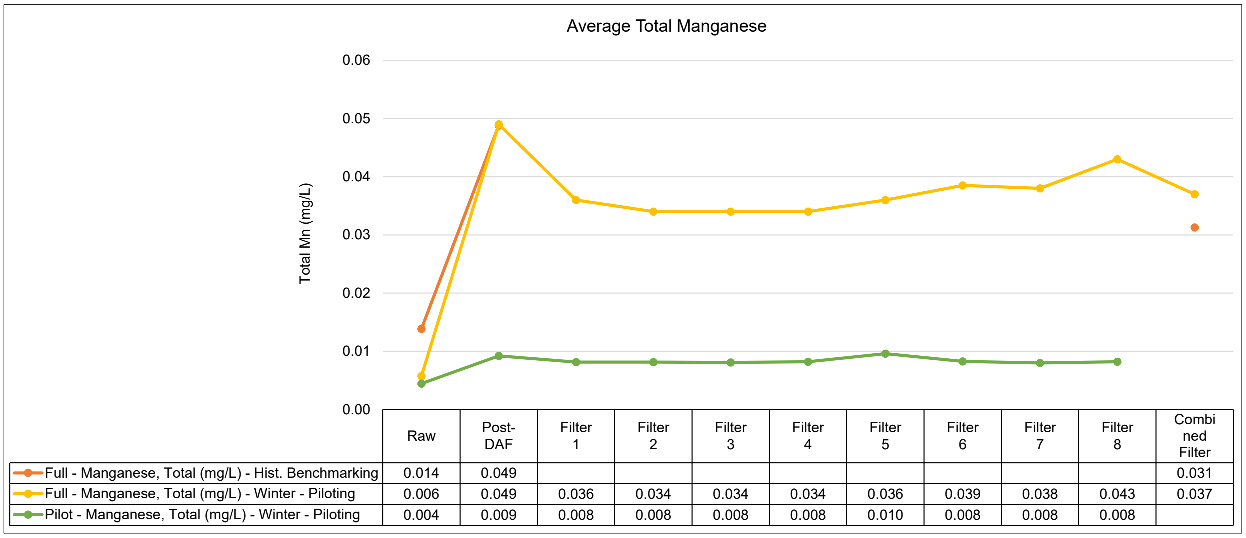
As observed in Figure 5-33, Filters 1 to 4 presented higher turbidity values compared to Filters 5 to 8 in the pilot-scale system. This was not expected since these filters operate at a lower flow rate. This variability should be observed closer and investigated further. Pilot-scale system Filters 5 to 8 presented effluent turbidity values closer to the full-scale system filters.



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - Turb - Hist. Benchmarking	1.108	0.542									0.118
Full - Turb - Winter - Piloting	0.633	0.430	0.080	0.080	0.090	0.100	0.075	0.100	0.075	0.063	0.100
Pilot - Turb - Winter - Piloting	0.530	1.360	0.180	0.130	0.120	0.150	0.070	0.050	0.050	0.050	

Figure 5-33: Comparison of turbidity between full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale system and the pilot-scale system (April 4th to April 5th, 2017) during the Winter piloting session. Data originates from Lab analysis. Note that these results excluded the filtered water turbidity data produced by the Lab on April 5th, 2017, because it is believed that this data contain errors.

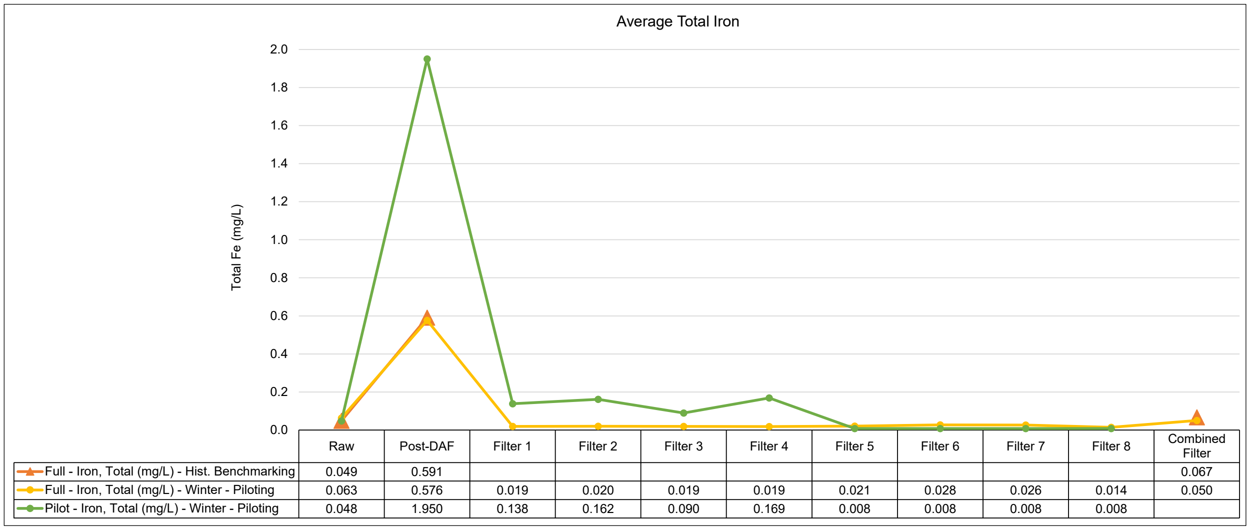
As per Figure 5-34, total manganese was noticeably lower in the pilot-scale system in comparison with full-scale system.



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - Manganese, Total (mg/L) - Hist. Benchmarking	0.014	0.049									0.031
Full - Manganese, Total (mg/L) - Winter - Piloting	0.006	0.049	0.036	0.034	0.034	0.034	0.036	0.039	0.038	0.043	0.037
Pilot - Manganese, Total (mg/L) - Winter - Piloting	0.004	0.009	0.008	0.008	0.008	0.008	0.010	0.008	0.008	0.008	

Figure 5-34: Comparison of total manganese between full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale system and the pilot-scale system (April 4th to April 5th, 2017) during the Winter piloting session. Data originates from Lab analysis.

As observed in Figure 5-35, total iron concentrations were noticeably higher in the Post-DAF, combined Post-Ozone and some of the filters effluent for the pilot-scale system. For the pilot-scale system, Filters 1 to 4 (Bank A) at a lower flow rate showed higher iron concentrations in the effluent when compared to Filters 5 to 8 (Bank B) operated at maximum flow rate. The ferric sulphate dose of 46 mg/L is equivalent to 12.7 mg/L of iron, while a ferric chloride dose of 30 mg/L is equivalent to 10.6 mg/L of iron. The 10% higher iron content does not justify the gap encountered by itself. It is possible that a poorer coagulation performance or mechanical difference between filter banks in the pilot-scale system contributed to the higher iron content.

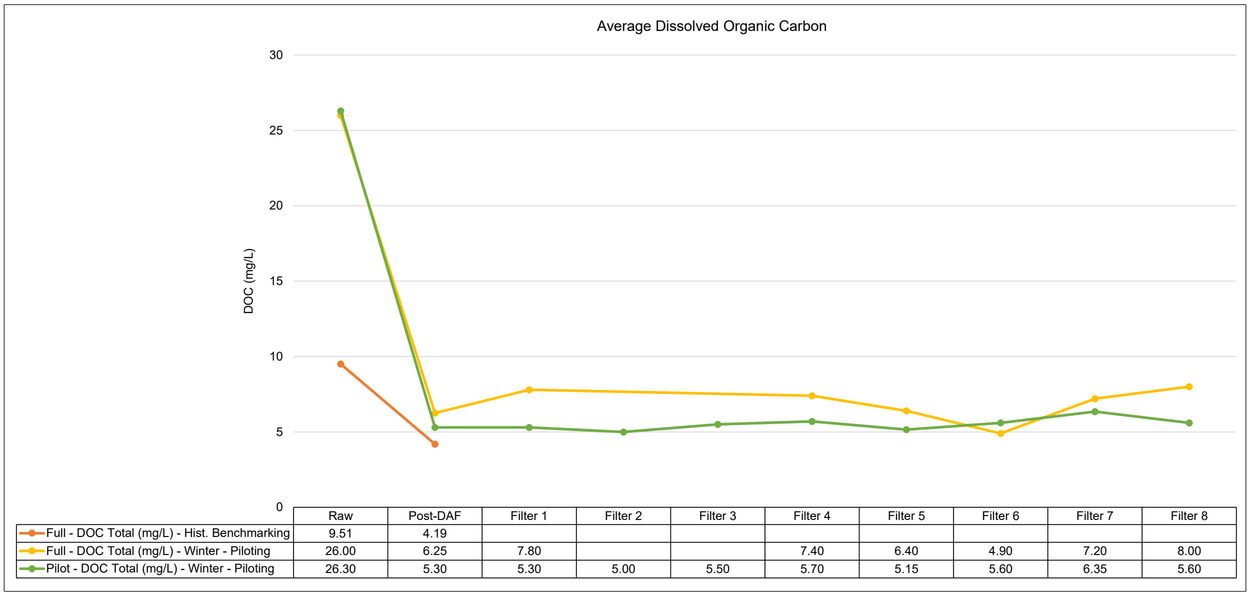


	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - Iron, Total (mg/L) - Hist. Benchmarking	0.049	0.591									0.067
Full - Iron, Total (mg/L) - Winter - Piloting	0.063	0.576	0.019	0.020	0.019	0.019	0.021	0.028	0.026	0.014	0.050
Pilot - Iron, Total (mg/L) - Winter - Piloting	0.048	1.950	0.138	0.162	0.090	0.169	0.008	0.008	0.008	0.008	

Figure 5-35: Comparison of total iron between full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale system and the pilot-scale system (April 4th to April 5th, 2017) during the Winter piloting session. Data originates from Lab analysis.

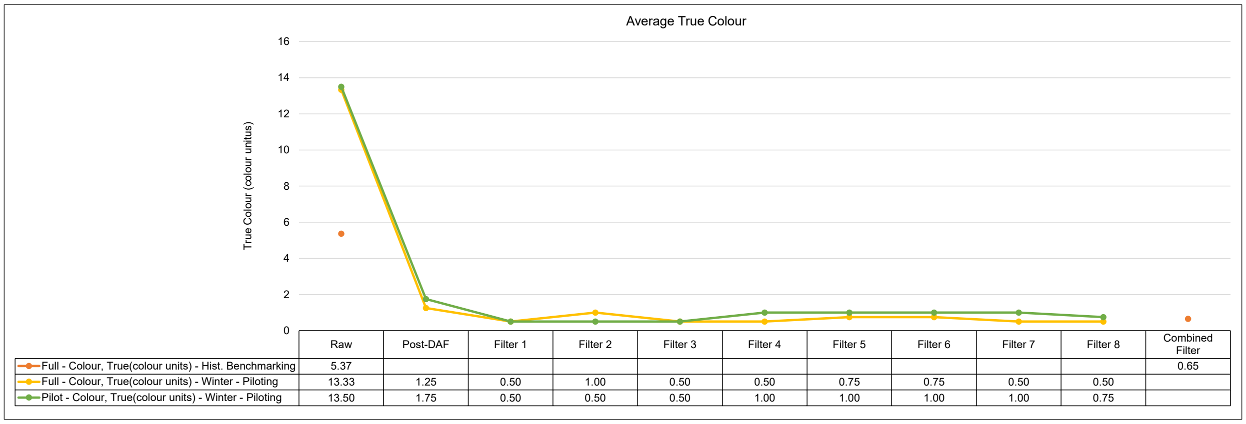
Pilot-scale Filters 1 to 4 presented poorer results for turbidity and total iron in comparison with Filters 5 to 8. Considering turbidity, iron and differential pressure results for Bank A, it is possible that Filters 1 to 4 were facing some limitations, either due to the different mechanical configuration or inconsistent filter-aid dosing.

Raw water DOC showed an average of 26 mg/L and a maximum of 28.6 mg/L during the Winter piloting session, these values are much higher than expected, as DOC historical data shows an average of 9.51 mg/L, and maximum of 13 mg/L during cold water conditions. DOC and colour results from full-scale and pilot-scale systems were similar (Figure 5-36 and Figure 5-37). Investigations by the City indicated that the elevated DOC data was the result of laboratory errors. Nevertheless, the trends observed from this data are correct as the laboratory values were consistently twice that of the expected values.



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
Full - DOC Total (mg/L) - Hist. Benchmarking	9.51	4.19								
Full - DOC Total (mg/L) - Winter - Piloting	26.00	6.25	7.80			7.40	6.40	4.90	7.20	8.00
Pilot - DOC Total (mg/L) - Winter - Piloting	26.30	5.30	5.30	5.00	5.50	5.70	5.15	5.60	6.35	5.60

Figure 5-36: Comparison of DOC between full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale system and the pilot-scale system (April 4th to April 5th, 2017) during the Winter piloting session. Data originates from Lab analysis. Note: The DOC measured in the Winter piloting session (full-scale system and pilot-scale system) contain error and are approximately 2-3 times the actual DOC concentration.



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - Colour, True(colour units) - Hist. Benchmarking	5.37										0.65
Full - Colour, True(colour units) - Winter - Piloting	13.33	1.25	0.50	1.00	0.50	0.50	0.75	0.75	0.50	0.50	
Pilot - Colour, True(colour units) - Winter - Piloting	13.50	1.75	0.50	0.50	0.50	1.00	1.00	1.00	1.00	0.75	

Figure 5-37: Comparison of true colour between full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale system and the pilot-scale system (April 4 to April 5, 2017) during Winter piloting session. Data originates from Lab analysis.

Considering the sludge production, the average TSS concentration from the full-scale system DAF residuals during the Winter piloting session was 5,250 mg/L, while the average TSS concentration from the pilot-scale system DAF was 5,550 mg/L on April 4th and 5th of the Winter piloting session. These values are considered to be similar.

Appendix E presents a comprehensive table comparing the average water quality results from the full-scale system historical benchmark and the Winter piloting session with the alternate coagulant. No concerns were noted.

The historical average of the full-scale system UFRV value is 495 m^3/m^2, while the overall average observed UFRV during on April 4th and 5th of the Winter piloting session were 326 m^3/m^2 and 155 m^3/m^2 for Bank A and Bank B, respectively (Table 5-5). However, the UFRV values would be expected to be lower for Bank A, which presented turbidity breakthrough, whereas the UFRV values for Bank B would be double that of the full-scale system. Even though similar UFRVs values are observed between the Winter benchmarking period and the April 4th and 5th days of Winter piloting session, it is not possible yet to conclude if this data was affected by to the change in coagulant, since the performance of pilot-scale filters was deemed poor during both periods.

5.10.2 Disinfection By-Product Formation Potential

Analysis of T-THM and T-HAA were only performed on the last two days. However, since the samples were not properly prepared for analysing the formation potential of THMs and HAAs, the results were below the detection limit of 3 µg/L. In light of this, a proper comparison of the formation of disinfection by-products is not possible at this stage and will be investigated in future piloting sessions.

5.10.3 Corrosive Indices

Table 5-6 summarizes the corrosiveness index calculated with the data available. The indices are calculated from laboratory results of samples taken the same day from the full-scale system post filtration and prior to pH adjustment with sodium hydroxide, and the pilot-scale system post-filtration operating under optimal conditions.

Chloride-Sulphate Mass Ratio (CSMR) was only measured from the filter effluent on April 4th and 5th. Missing chloride data from the full-scale system did not allow for the CSMR calculation to be completed for the full-scale system for comparison. Historical data is not available for the full-scale at this point. Alkalinity results, Langelier Stability Index (LSI) and Ryznar Stability Index (RSI) results from full-scale and pilot-scale system were similar.

Table 5-6: Winter Piloting Session - Corrosiveness - Chloride-Sulphate Mass Ratio (CSMR), Langelier Stability Index (LSI), Ryznar Stability Index (RSI).

TREATMENT STEP	CSMR PILOT	CSMR FULL	LSI PILOT	LSI FULL	RSI PILOT	RSI FULL
Raw Water	-	-	-0.70	-0.60	9.31	9.18
Post DAF	-	-	-3.98	-4.02	13.64	13.66
Post-Ozone	-	-	-3.97	-3.90	13.64	13.53
Filters (Average)	0.028	-	-3.81	-4.01	13.46	13.66

6 CONCLUSIONS AND RECOMMENDATIONS

From the results presented above, it is possible to conclude the following:

- The City was successful in benchmarking the pilot-scale system to the full-scale system, as well as transitioning from ferric chloride to an alternative coagulant, ferric sulphate, and a coagulant-aid as per the results of major test parameters, i.e. turbidity, UVT, TOC and total manganese;
- Raw water temperature was below 4°C, except for the final day of the Winter piloting session where the average temperature of the two trains exceeded 4°C by approximately 0.14°C. Therefore, it is believed that winter conditions were captured;
- Raw water temperature was generally higher by 2.0ºC on average in the pilot-scale system; however, this is understood to be the result of the length of pipe feeding the pilot-scale system. The change in temperature is not expected to greatly effect observations or results during the Winter piloting session;
- Alternative filter backwashing procedures for the pilot-scale system were explored; however, results found little difference in the filter performance following changes to the backwashing procedures. Standard backwashing procedures were maintained for the remainder of the Winter pilot session;
- An optimal dose for ferric sulphate was investigated in the pilot-scale system. The results found that the optimal dose during cold water conditions was 46 mg/L at a pH of 5.65±0.02. Since the pH was not optimized it is difficult to gauge the impact pH would have on the optimal coagulant dose;
- An optimal dose for a coagulant-aid was also investigated in the pilot-scale system for cold water conditions. The results found the optimal coagulant-aid dose was 0.02 mg/L, based on water quality parameters. Importantly, the optimal dose for coagulant-aid was tested using a coagulant dose of 42 mg/L, instead of the optimal coagulant dose of 46 mg/L. Future pilot-scale system testing of coagulant-aid should be conducted using the optimal coagulant dose determined during the optimal coagulant testing;
- An aggregation phenomenon, or mud-balling, was found with coagulant-aid doses exceeding 0.03 mg/L. This problem was rectified by changing the addition point of the coagulant-aid from the surface of DAF Floc Tank #3 to the mid-depth of the tank following the installation of a PVC pipe. Since this change, no aggregation of coagulant-aid in the Floc Tank #3 has been observed;
- Significantly lower manganese concentrations were measured in the pilot-scale system using ferric sulphate in all pilot-scale system processes;
- The best pilot-scale system treated water quality was produced at a coagulant dose of 46 mg/L and the optimal coagulant-aid dose of 0.02 mg/L, which indicates the that successful chemical doses were determined. Furthermore, it is noted that no trials were completed without the use of coagulant-aid and pH was also not optimized or controlled which can impact coagulation;
- The following parameters: total and dissolved iron content along the treatment train, TSS, and disinfection by-product formation potential should be observed and studied further
- Further study into the variance between pilot-scale system Filter Bank A and B should be addressed in future piloting sessions.

It is deemed that the issues encountered at the pilot-scale system, in particular the high Post-DAF turbidity and lower water quality at Filters 1 to 4, are related to scale of the pilot-scale system. Aspects such as filter bank flow and configuration, as well as the possibility of inconsistent addition of filter-aid to each filter bank, are believed to impact the filter performance in Bank A and B. Since these issues are isolated to the pilot-scale system, the impacts are not expected to occur in full-scale system operation if it were to transition to ferric sulphate.

For the remaining piloting sessions, the following adjustments are recommended:

- pH optimization for coagulation using the alternative coagulant and coagulant-aid should be explored in future piloting sessions;
- A wider range of coagulant-aid concentrations is recommended to be applied in future piloting sessions;
- Standard backwashing procedures should be maintained throughout the remaining piloting sessions;
- Full-scale system and pilot-scale system sampling shall be taken on the same day when possible, in order to enhance the comparison between the two systems; and
- Inclusion of a combined filter sample to facilitate analysis and comparison of the filtrate between pilot-scale and full-scale systems.

Piloting Results Database Summary

Season: Winter #1
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
February 4, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		105	15.3	16.5	16.6	17.2	17.3	17.1	16.2	16.2	16.1	16.6		16.3
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		8.8					5.8	10.8	9.3	13.4	8.2	6.5		
				N/D at <5.0		G/N	G/N	G/N	G/N								G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0047	0.0529	0.0533	0.0553	0.0544	0.0547	0.0547	0.0547	0.0539	0.0542	0.0539		0.0541
		Manganese, Total (mg/L)	Lab		0.0111	0.0565	0.0579	0.0567	0.0559	0.056	0.0549	0.0558	0.0547	0.055	0.0553		0.0542
				Avg. of filters 1 to 8												0.05554	
		pH	Lab		7.79	6.02	6.1	6.21	6.37	6.28	6.18	6.2	6.23	6.3	6.43		6.28
				Avg. of filters 1 to 8												6.275	
		TDS by Handheld Meter (mg/L)	Lab		103	160	154	148	147	144	151	151	151	148	153		139
		Temperature (ºC)	Lab					4.7	4.4	4.6	5	4.2	3.9	4.2	3.9		4.4
		TOC, Total (mg/L)	Lab		8.64	3.73	3.64	2.93	2.9	2.86	2.77	3.03	2.98	2.89	2.91		2.82
				Avg. of filters 1 to 8												2.90875	
		Total Alkalinity (mg/L CaCO3)	Lab		85.7	12.5	13.5	13.6	14.1	14.2	14	13.3	13.3	13.2	13.6		13.4
		TS (mg/L)	Lab		110	136	130	134	138	128	134	142	142	146	138		142
		Turbidity (NTU)	Lab		0.59	1.09	1.07	0.1	0.1	0.11	0.1	0.1	0.1	0.1	0.1		0.1
				Avg. of filters 1 to 8												0.10125	
		UVT @ 254nm, Unfiltered (%T)	Lab		68.5	89.7	89.1	91.2	91	90.8	91.2	89.7	91.4	90.8	91.2		90.6
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		104	14.4			16.7	16.6	16.2	12.8	11.8		11.7		14.9
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N			G/N	G/N	G/N	G/N	G/N		G/N		G/N
		Colour, True	Lab		8.4												
				N/D at <5.0		G/N			G/N	G/N	G/N	G/N	G/N		G/N		G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N			G/N	G/N	G/N	G/N	G/N		G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0051	0.0539			0.0541	0.0534	0.0545	0.0533	0.053		0.054		0.055
		Manganese, Total (mg/L)	Lab		0.0113	0.0593			0.0586	0.0576	0.0571	0.0641	0.0582		0.0579		0.0545
		pH	Lab		7.8	5.98			6.18	6.1	6.07	5.99	5.92		5.94		6.17
		TDS by Handheld Meter (mg/L)	Lab		117	140			143	121	142	148	144		144		152
		Temperature (ºC)	Lab												2.1		1.7
		TOC, Total (mg/L)	Lab		8.47	3.22			3.17	3.12	3.11	3.09	2.88		2.77		2.94
		Total Alkalinity (mg/L CaCO3)	Lab		85	11.8			13.7	13.6	13.3	10.5	9.7		9.6		12.2
		TS (mg/L)	Lab		108	130			134	132	130	144	126		138		144
		Turbidity (NTU)	Lab		0.56	0.55			0.14	0.12	0.1	2.01	0.14		0.1		0.15
		UVT @ 254nm, Unfiltered (%T)	Lab		69	89.3			89.1	90.2	90.2	88.9	90.8		91.2		90.6
February 5, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		105	15.5	15.7	16.2	17	15.7	17.4	17	17.1	16.6	16.1		16.8
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		8.9												
				N/D at <5.0		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0052	0.0539	0.0534	0.0537	0.0549	0.0543	0.054	0.0537	0.0543	0.0538	0.0529		0.0547
		Manganese, Total (mg/L)	Lab		0.0113	0.0568	0.0565	0.0557	0.058	0.0556	0.0571	0.0579	0.0578	0.0574	0.0571		0.057
				Avg. of filters 1 to 8												0.05708	
		pH	Lab		7.66	5.94	5.98	6.13	6.05	6.1	6.04	6.01	6.09	6.17	6.08		6.18
				Avg. of filters 1 to 8												6.08375	
		TDS by Handheld Meter (mg/L)	Lab		90	150	156			142			142	147			
		Temperature (ºC)	Lab		1.8	2.3	2.8	4.4	4.8	4	4.2		4.2	4.2	4.2		4.8
		TOC, Total (mg/L)	Lab		8.43	3.74	3.92	2.85	2.88	2.76	2.95	2.78	2.89	2.87	2.78		2.8
				Avg. of filters 1 to 8												2.845	
		Total Alkalinity (mg/L CaCO3)	Lab		85.9	12.7	12.9	13.3	13.9	12.9	14.3	13.9	14	13.6	13.2		13.8
		TS (mg/L)	Lab		114	152	150	126	126	124	124	132	130	130	44		98
		Turbidity (NTU)	Lab		0.56	1.54	2.1	0.14	0.1	0.1	0.2	0.16	0.1	0.1	0.21		0.1
				Avg. of filters 1 to 8												0.13875	
		UVT @ 254nm, Unfiltered (%T)	Lab		66.1	84.9	87.5	90	89.3	90.2	90.2	89.7	89.1	89.5	90.2		88.7
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		103	16.2		17.1	16.7	17.1		15.4		11.7	11.5		13.9
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N		G/N		G/N	G/N		G/N
		Colour, True	Lab		8.9												
				N/D at <5.0		G/N		G/N	G/N	G/N		G/N		G/N	G/N		G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N		G/N		G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0049	0.0534		0.0527	0.0531	0.0553		0.0528		0.0528	0.0519		0.0526
		Manganese, Total (mg/L)	Lab		0.0111	0.057		0.0552	0.0565	0.0547		0.0548		0.0544	0.0531		0.0746
		pH	Lab		7.66	5.88		5.97	6.06	6.08		5.98		5.79	5.84		5.87
		TDS by Handheld Meter (mg/L)	Lab		123	142		163	155	157		160			153		
		Temperature (ºC)	Lab		2.6	2.9		2.2	2	1.8		2.1		1.8	1.7		1.9
		TOC, Total (mg/L)	Lab		8.49	3.43		3.21	3.15	3.3		3.12		2.88	2.87		3.11
		Total Alkalinity (mg/L CaCO3)	Lab		84.8	13.3		14	13.7	14		12.6		9.6	9.4		11.4
		TS (mg/L)	Lab		106	142		140	148	144		138		128	126		
				N/D at <10													G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary
Season: Winter #1
Phase: Benchmarking

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
February 5, 2017	Full-Scale	Turbidity (NTU)	Lab		0.72	0.6		0.1	0.58	0.39		0.12		0.11	0.11		0.31
		UVT @ 254nm, Unfiltered (%T)	Lab		67.8	85.7		87.7	81.7	88.5		88.1		88.7	89.7		89.3
February 6, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		107	16.5	16.6	19.3	17.4	17.4	17.4	16.5	17.3	17.3	17.3		18.1
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		9.9												
				N/D at <5.0		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0065	0.0537	0.0534	0.0543	0.0549	0.0546	0.0541	0.0549	0.0542	0.0533	0.0533		0.0545
		Manganese, Total (mg/L)	Lab		0.0108	0.0548	0.0548	0.0549	0.0548	0.0563	0.0565	0.0543	0.0546	0.0555	0.0551		0.0571
				Avg. of filters 1 to 8												0.05525	
		pH	Lab		7.82	6.19	6.13	6.25	6.26	6.32	6.3	6.27	6.32	6.38	6.36		6.38
				Avg. of filters 1 to 8												6.3075	
		TDS by Handheld Meter (mg/L)	Lab		110	149	132	134	135	107	125	140	150	142	143		146
		Temperature (ºC)	Lab		2.3	2.4	3										
		TOC, Total (mg/L)	Lab		8.44	3.9	3.84	3.05	3.01	3.03	2.95	3.02	3	2.97	2.97		3.01
				Avg. of filters 1 to 8												3	
		Total Alkalinity (mg/L CaCO3)	Lab		87.8	13.5	13.6	15.8	14.3	14.3	14.3	13.5	14.2	14.2	14.2		14.8
		TS (mg/L)	Lab		120	156	154	144	152	124	138	146	134	134	128		140
		Turbidity (NTU)	Lab		0.6	1.24	1.28	0.1	0.1	0.1	0.1	0.11	0.1	0.1	0.1		0.12
				Avg. of filters 1 to 8												0.10125	
		UVT @ 254nm, Unfiltered (%T)	Lab		68.9	88.1	89.5	91	90.6	90.8	91.4	90.6	89.1	91.2	88.3		91.2
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		104	15.6		18.3	19	18.3		12.2		11.6			14.4
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N		G/N		G/N			G/N
		Colour, True	Lab		11.8												
				N/D at <5.0		G/N		G/N	G/N	G/N		G/N		G/N			G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N		G/N		G/N			G/N
		Manganese, Dissolved (mg/L)	Lab		0.0064	0.0549		0.0533	0.0538	0.0533		0.05245		0.0524			0.0536
		Manganese, Total (mg/L)	Lab		0.0105	0.0551		0.0551	0.0537	0.0542		0.0529		0.0549			0.0552
		pH	Lab		7.8	6.05		6.22	6.16	6.15		5.935		5.87			6.12
		TDS by Handheld Meter (mg/L)	Lab		114	146		137	151	155		148.5		142			145
		Temperature (ºC)	Lab		2.4	2.6		2.1	2.2	2		2.5		2.6			
		TOC, Total (mg/L)	Lab		8.82	3.4		3.17	3.16	3.12		2.97		3.02			3.13
		Total Alkalinity (mg/L CaCO3)	Lab		85.1	12.8		15	15.6	15		10		9.5			11.8
		TS (mg/L)	Lab		120	146		144	138	126		134		146			128
		Turbidity (NTU)	Lab		0.57	0.56		0.18	0.13	0.1		0.135		0.13			0.15
		UVT @ 254nm, Unfiltered (%T)	Lab		69.5	90.2		88.9	90.2	89.5		90.8		90.6			88.9
February 7, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		105	19	18.7	17.4	17.8	18.1	18.7	18.5	17.3	17.2	17.6		18.1
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		10.4												
				N/D at <5.0		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		DO (mg/L)	Lab		2	1.5	3.1	2.3	2.9	2	3	2.3	1.3	1.9	1.6		0.8
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0047	0.0512	0.0523	0.0523	0.053	0.0527	0.0524	0.0522	0.0525	0.053	0.0517		0.0521
		Manganese, Total (mg/L)	Lab		0.0108	0.0546	0.0532	0.055	0.0536	0.0539	0.0548	0.0552	0.0557	0.0554	0.0543		0.054
				Avg. of filters 1 to 8												0.05474	
		pH	Lab		7.75	6.13	6.14	6.29	6.35	6.25	6.31	6.24	6.34	6.25	6.3		6.42
				Avg. of filters 1 to 8												6.29125	
		TDS by Handheld Meter (mg/L)	Lab		107	113	147	137	138	136	138	139	143	128	135		129
		Temperature (ºC)	Lab		2.1	2.5	3.3	3.5	3.5	3.5	3.5	3.5	3.5		3.5		4.1
		TOC, Total (mg/L)	Lab		8.76	4.12	4.13	3.17	3.13	3.18	3.1	3.21	3.12	3.14	3.13		3.17
				Avg. of filters 1 to 8												3.1475	
		Total Alkalinity (mg/L CaCO3)	Lab		86.1	15.6	15.3	14.3	14.6	14.8	15.3	15.2	14.2	14.1	14.4		14.8
		TS (mg/L)	Lab		128	130	148	132	136	130	146	148	146	140	128		142
		Turbidity (NTU)	Lab		0.83	1.96	1.64	0.1	0.1	0.1	0.12	0.13	0.1	0.1	0.1		0.1
				Avg. of filters 1 to 8												0.10625	
		UVT @ 254nm, Unfiltered (%T)	Lab		69.3	90.4	90.6	92	91.8	92	92	91.8	91.8	92	91.8		91.6
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		108	15.5			17.4	17.7		14.25		13.2	12.2		14.6
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N			G/N	G/N		G/N		G/N	G/N		G/N
		Colour, True	Lab		9.3												
				N/D at <5.0		G/N			G/N	G/N		G/N		G/N	G/N		G/N
		DO (mg/L)	Lab		1.4	0.9			0.6	0.7		2.05		1.3	2.3		1.3
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N			G/N	G/N		G/N		G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0047	0.0533			0.0545	0.0539		0.05305		0.053	0.0524		0.0524
		Manganese, Total (mg/L)	Lab		0.0108	0.055			0.0552	0.0578		0.05555		0.0554	0.0544		0.0576
		pH	Lab		7.74	5.96			5.96	6.02		6.045		6.05	5.89		6.16
		TDS by Handheld Meter (mg/L)	Lab		114	141			128	133		135		137	138		141
		Temperature (ºC)	Lab		2.8	2.8			1.8	1.7		1.95		1.9	1.6		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
February 7, 2017	Full-Scale	TOC, Total (mg/L)	Lab		8.66	3.54			3.32	3.27		3.09		3.05	3.04		3.37
		Total Alkalinity (mg/L CaCO3)	Lab		88.4	12.7			14.3	14.5		11.7		10.8	10		12
		TS (mg/L)	Lab		134	152			138	126		140		142	146		138
		Turbidity (NTU)	Lab		0.55	1.17			0.1	0.1		0.175		0.1	0.1		0.11
		UVT @ 254nm, Unfiltered (%T)	Lab		69.8	91.2			91.2	91.2		91.5		92	92.3		91.6
February 8, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		105	19.3	17.7	17.6	18.8	19.6	17	17.1	17.3	16.6	17.8		17.8
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		11												
				N/D at <5.0		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		DO (mg/L)	Lab		2.3	2.7	1.4	3.2	3.7	2.9	3.3	2.2	2.4	3.7	2.5		1.7
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0069	0.0533	0.0555	0.0542	0.053	0.0522	0.0513	0.0514	0.0527	0.0511	0.0519		0.0532
		Manganese, Total (mg/L)	Lab		0.0113	0.0537	0.0559	0.0555	0.0545	0.0557	0.0532	0.0552	0.0546	0.0537	0.0544		0.0536
				Avg. of filters 1 to 8												0.0546	
		pH	Lab		7.76	6.31	6.25	6.35	6.42	6.42	6.38	6.26	6.43	6.27	6.46		6.44
				Avg. of filters 1 to 8												6.37375	
		TDS by Handheld Meter (mg/L)	Lab		113	146	146	138	127	139	139	141	142	159	145		146
		Temperature (ºC)	Lab		1.9	2.8	2.7	3.7	3.8	4	3.8	3.9	3.8	4	3.6		4
		TOC, Total (mg/L)	Lab		8.56	4.02	3.9	3.1	3.1	3.08	3.13	3.18	3.14	3.07	3.14		3.13
				Avg. of filters 1 to 8												3.1175	
		Total Alkalinity (mg/L CaCO3)	Lab		85.8	15.8	14.5	14.4	15.4	16.1	13.9	14	14.2	13.6	14.6		14.6
		TS (mg/L)	Lab		120	144	148	142	140	144	150	140	146	150	140		152
		Turbidity (NTU)	Lab		0.54	1.17	1.14	0.14	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.15
				Avg. of filters 1 to 8												0.105	
		UVT @ 254nm, Unfiltered (%T)	Lab		69.3	90	90.2	91.2	91.2	91.6	91.6	91.6	91.6	91	91.2		91.4
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		102	15		17.1		17.3		15.9	12.4	12.6	12.4		15.1
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N		G/N		G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		9.8												
				N/D at <5.0		G/N		G/N		G/N		G/N	G/N	G/N	G/N		G/N
		DO (mg/L)	Lab		3.7	3.5		3.7		3.3		2.9	3.1	2.7	2.1		2
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N		G/N		G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0072	0.0553		0.0539		0.0557		0.0547	0.0547	0.0547	0.0549		0.0536
		Manganese, Total (mg/L)	Lab		0.0111	0.0558		0.0554		0.0559		0.0564	0.0552	0.055	0.0555		0.083
		pH	Lab		7.64	5.95		6.13		6.18		6.08	5.99	5.98	6.05		6.09
		TDS by Handheld Meter (mg/L)	Lab		104	145		139		142		114	134	101	146		144
		Temperature (ºC)	Lab		3.5	3.2		1.9		1.9		2.4	1.9	2.1	2.1		2.1
		TOC, Total (mg/L)	Lab		8.39	3.52		3.37		3.31		3.28	3.04	3.01	3.01		3.3
		Total Alkalinity (mg/L CaCO3)	Lab		84	12.3		14		14.2		13	10.2	10.3	10.2		12.4
		TS (mg/L)	Lab		126	144		136		144		144	144	130	138		136
		Turbidity (NTU)	Lab		0.55	0.62		0.12		0.1		0.1	0.11	0.1	0.1		0.19
		UVT @ 254nm, Unfiltered (%T)	Lab		69.3	90.8		90.6		91		90.4	91.6	91.6	91.6		90.6
February 9, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		104	18.7		18.7	17.8	17.8	18.2	19.2	18.8	18.4	17.8		18.7
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		9.1												
				N/D at <5.0		G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		DO (mg/L)	Lab		3.4	3.8		3.9	4.2	4.8	3.2	3	4.2	3.5	2.5		4.1
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0064	0.0526		0.0527	0.053	0.0521	0.0518	0.0529	0.0528	0.0522	0.0522		0.0524
		Manganese, Total (mg/L)	Lab		0.0113	0.0553		0.0547	0.0546	0.0536	0.0537	0.0534	0.0549	0.0533	0.0544		0.0537
				Avg. of filters 1 to 8												0.05408	
		pH	Lab		7.76	6.24		6.22	6.17	6.25	6.33	6.41	6.33	6.31	6.34		6.5
				Avg. of filters 1 to 8												6.295	
		TDS by Handheld Meter (mg/L)	Lab		116	140		148	151	147	143	149	152	146	143		151
		TOC, Total (mg/L)	Lab		8.79	4.03		3.07	3.07	3.04	3.04	3.02	3.03	3.08	3.02		3.07
				Avg. of filters 1 to 8												3.04625	
		Total Alkalinity (mg/L CaCO3)	Lab		85.2	15.3		15.3	14.6	14.6	14.9	15.7	15.4	15.1	14.6		15.3
		TS (mg/L)	Lab		100	124		132	162	138	120	158	158	158	140		140
		Turbidity (NTU)	Lab		0.56	1.23		0.1	0.1	0.14	0.13	0.1	0.1	0.1	0.1		0.13
				Avg. of filters 1 to 8												0.10875	
		UVT @ 254nm, Unfiltered (%T)	Lab		70.1	90.6		91.8	91.8	91.8	92	92	91.8	92.3	92		91.8
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		105	12.6		14.3	11.2	14.3	12.2	10.9		11			13.3
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N	G/N	G/N		G/N			G/N
		Colour, True	Lab		8.6												
				N/D at <5.0		G/N		G/N	G/N	G/N	G/N	G/N		G/N			G/N
		DO (mg/L)	Lab		4.2	3.1		3	3.5	3.5	3.7	3.4		2.9			3
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N	G/N	G/N		G/N			G/N
		Manganese, Dissolved (mg/L)	Lab		0.0068	0.0579		0.059	0.0588	0.0593	0.0586	0.0575		0.0555			0.0589

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
February 9, 2017	Full-Scale	Manganese, Total (mg/L)	Lab		0.0122	0.0621		0.0612	0.0612	0.0629	0.0596	0.0606		0.0584			0.0769
		pH	Lab		7.74	5.88		6.03	5.91	6.06	5.89	5.98		5.86			6.01
		TDS by Handheld Meter (mg/L)	Lab		129	148		153	151	151	145	154		149			153
		TOC, Total (mg/L)	Lab		8.52	3.34		3.08	3.03	2.95	2.86	2.84		2.86			2.92
		Total Alkalinity (mg/L CaCO3)	Lab		86.2	10.3		11.7	9.2	11.7	10	8.9		9			10.9
		TS (mg/L)	Lab		120	122		126	142	136	130	162		156			132
		Turbidity (NTU)	Lab		0.59	0.56		0.22	0.1	0.1	0.1	0.11		0.11			0.15
		UVT @ 254nm, Unfiltered (%T)	Lab		69.3	91.8		92	91.6	92	92.3	92		92.3			92.3
February 10, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		106	18.1		17.7	17.6	17.7	18.2	18.3	17.4	17.7	17.6		18.2
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		10.8												
				N/D at <5.0		G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		DO (mg/L)	Lab		2.6	2.9		2.6	3.5	3.6	2.6	3.2	3	3.4	3.1		3
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0056	0.0547		0.0545	0.054	0.0536	0.0539	0.0534	0.0534	0.0528	0.0522		0.0542
		Manganese, Total (mg/L)	Lab		0.0111	0.0558		0.0538	0.0542	0.0531	0.0531	0.055	0.054	0.0526	0.0534		0.0532
				Avg. of filters 1 to 8												0.05365	
		pH	Lab		7.74	6.1		6.19	6.23	6.43	6.39	6.38	6.31	6.3	6.26		6.29
				Avg. of filters 1 to 8												6.31125	
		TDS by Handheld Meter (mg/L)	Lab		127	159		150	158	159	153	158	162	152	126		156
		TOC, Total (mg/L)	Lab		8.55	4.01		3.06	3.06	3.07	3.05	3.07	3.2	3.13	3.2		3.12
				Avg. of filters 1 to 8												3.105	
		Total Alkalinity (mg/L CaCO3)	Lab		86.7	14.8		14.5	14.4	14.5	14.9	15	14.3	14.5	14.4		14.9
		TS (mg/L)	Lab		114	132		128	154	132	150	144	150	150	132		154
		Turbidity (NTU)	Lab		0.5	1.27		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1
				Avg. of filters 1 to 8												0.1	
		UVT @ 254nm, Unfiltered (%T)	Lab		68.9	90.2		91	91.2	91.2	92	91.6	91.6	91.4	91.6		91.2
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		104	15.5			17	17.2	17.1		12.6	12.4	12.1		14.6
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N			G/N	G/N	G/N		G/N	G/N	G/N		G/N
		Colour, True	Lab		11.4												
				N/D at <5.0		G/N			G/N	G/N	G/N		G/N	G/N	G/N		G/N
		DO (mg/L)	Lab		3.6	2.9			2.6	2.5	3.5		2.3	2.9	3		3.1
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N			G/N	G/N	G/N		G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0057	0.0583			0.058	0.0583	0.0586		0.0567	0.0569	0.0568		0.0576
		Manganese, Total (mg/L)	Lab		0.0114	0.0588			0.0586	0.0592	0.0581		0.0567	0.0571	0.0566		0.06
		pH	Lab		7.67	5.9			6.04	6.1	6.11		5.97	5.93	5.9		6.19
		TDS by Handheld Meter (mg/L)	Lab		119	154			160	157	160		165	161	155		154
		TOC, Total (mg/L)	Lab		8.53	3.48			3.16	3.19	3.09		2.88	2.89	2.88		3.11
		Total Alkalinity (mg/L CaCO3)	Lab		85.1	12.7			13.9	14.1	14		10.3	10.2	9.9		12
		TS (mg/L)	Lab		120	156			150	132	142		140	156	150		150
		Turbidity (NTU)	Lab		0.54	0.57			0.14	0.12	0.13		0.16	0.1	0.1		0.11
		UVT @ 254nm, Unfiltered (%T)	Lab		69.3	90.4			90.8	90.4	90.8		91	91	91.4		91.4
February 11, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		107	17.6		17.2	17.8	17.3	14.8	16.8	17.6	16.7	16.7		17.4
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		8.4												
				N/D at <5.0		G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.004	0.0562		0.0576	0.0557	0.0571	0.0542	0.0558	0.0547	0.0545	0.0538		0.0546
		Manganese, Total (mg/L)	Lab		0.0106	0.0562		0.0583	0.0578	0.0589	0.0552	0.058	0.0578	0.0555	0.0568		0.0583
				Avg. of filters 1 to 8												0.05729	
		pH	Lab		7.77	6.09		6.17	6.22	6.22	6.27	6.31	6.28	6.37	6.39		6.4
				Avg. of filters 1 to 8												6.27875	
		TDS by Handheld Meter (mg/L)	Lab		92	122		126	124	124	122	126	128	132	128		135
		TOC, Total (mg/L)	Lab		8.84	4		3.12	3.03	3.06	3.11	3.05	3.07	3.16	3.09		3.07
				Avg. of filters 1 to 8												3.08625	
		Total Alkalinity (mg/L CaCO3)	Lab		88	14.4		14.1	14.6	14.2	12.1	13.8	14.4	13.7	13.7		14.3
		TS (mg/L)	Lab		100	156		118	148	146	144	150	144	150	148		150
		Turbidity (NTU)	Lab		0.64	1.29		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1
				Avg. of filters 1 to 8												0.1	
		UVT @ 254nm, Unfiltered (%T)	Lab		69	90.8		92	92.3	92.5	92.9	92.7	92.3	92.5	92.5		92.5
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		105	16.3		17.9	17			15.5	13.9	14	14.3		15.6
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N			G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		8.9												
				N/D at <5.0		G/N		G/N	G/N			G/N	G/N	G/N	G/N		G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N			G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0041	0.0566		0.0553	0.0568			0.0567	0.0554	0.0557	0.0539		0.0534
		Manganese, Total (mg/L)	Lab		0.0112	0.0567		0.0578	0.0566			0.057	0.0575	0.0564	0.0552		0.0622

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
February 11, 2017	Full-Scale	pH	Lab		7.75	6		6.03	6.01			6.07	5.96	6.08	5.96		6.06
		TDS by Handheld Meter (mg/L)	Lab		86	110		122	119			110	122	135	134		134
		TOC, Total (mg/L)	Lab		8.58	3.55		3.32	3.28			3.31	3.17	3.2	3.15		3.3
		Total Alkalinity (mg/L CaCO3)	Lab		86.2	13.4		14.7	13.9			12.7	11.4	11.5	11.7		12.8
		TS (mg/L)	Lab		102	128		124	140			132	130	140	144		154
		Turbidity (NTU)	Lab		0.6	0.52		0.14	0.12			0.11	0.11	0.1	0.1		0.16
		UVT @ 254nm, Unfiltered (%T)	Lab		69.2	91.2		91.2	91.2			91.2	91.4	91.2	92		91.6
February 12, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		106	17.6		17.2	17.1	17.1	18.3	16.7	16.7	15.5	16.7		17.4
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		8.5												
				N/D at <5.0		G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0046	0.0557		0.0575	0.0567	0.0567	0.0581	0.0576	0.057	0.0563	0.0568		0.0559
		Manganese, Total (mg/L)	Lab		0.0109	0.0561		0.0581	0.0576	0.0564	0.0574	0.0558	0.0555	0.0558	0.0552		0.0579
				Avg. of filters 1 to 8												0.05648	
		pH	Lab		7.76	6.14		6.19	6.18	6.38	6.33	6.2	6.15	6.2	6.22		6.39
				Avg. of filters 1 to 8												6.23125	
		TDS by Handheld Meter (mg/L)	Lab		116	124		89	136	143	144	159	155	149	149		156
		TOC, Total (mg/L)	Lab		8.51	3.78		3.04	3.17	3.03	2.98	2.98	2.98	2.96	2.96		2.96
				Avg. of filters 1 to 8												3.0125	
		Total Alkalinity (mg/L CaCO3)	Lab		86.5	14.4		14.1	14	14	15	13.7	13.7	12.7	13.7		14.3
		TS (mg/L)	Lab		124	146		158	148	138	136	150	144	148	146		142
		Turbidity (NTU)	Lab		0.59	1.21		0.1	0.1	0.1	0.1	0.6	0.13	0.1	0.1		0.15
				Avg. of filters 1 to 8												0.16625	
		UVT @ 254nm, Unfiltered (%T)	Lab		69.2	91		92	91.8	92.3	92.5	92.5	92.5	92.5	91.8		91.6
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		106	15.5		16.8	16.7	16.7	14.6	13.8		13.1			15.4
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N	G/N	G/N		G/N			G/N
		Colour, True	Lab		9												
				N/D at <5.0		G/N		G/N	G/N	G/N	G/N	G/N		G/N			G/N
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N	G/N	G/N		G/N			G/N
		Manganese, Dissolved (mg/L)	Lab		0.005	0.0537		0.0525	0.0553	0.055	0.0538	0.0543		0.0529			0.0543
		Manganese, Total (mg/L)	Lab		0.0115	0.0529		0.054	0.0545	0.0542	0.0535	0.0521		0.0532			0.0562
		pH	Lab		7.72	5.98		6.11	6.08	6.01	6.14	5.96		5.89			6.15
		TDS by Handheld Meter (mg/L)	Lab		89	136		133	147	143	139	140		115			153
		TOC, Total (mg/L)	Lab		8.45	3.53		3.24	3.19	3.28	3.16	3.09		3.07			3.11
		Total Alkalinity (mg/L CaCO3)	Lab		86.9	12.7		13.8	13.7	13.7	12	11.3		10.7			12.6
		TS (mg/L)	Lab		126	142		122	140	138	146	156		140			144
		Turbidity (NTU)	Lab		0.67	0.6		0.1	0.1	0.2	0.24	0.18		0.19			0.14
		UVT @ 254nm, Unfiltered (%T)	Lab		69.2	90.8		91.2	91.2	91.2	91.6	91.2		91.6			89.7
February 13, 2017	Pilot-Scale	Bicarbonate (mg/L CaCO3)	Lab		108	15.6		16.2	17.2	17.1	15.5	16	15.4	14.6	16.3		16.1
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Colour, True	Lab		11.6												
				N/D at <5.0		G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		DO (mg/L)	Lab		2.2	3.5		2.7	2.2	2.9	3.4	2.6	2.4	3.2	3		2.8
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0057	0.0526		0.053	0.0543	0.0542	0.0535	0.0531	0.0535	0.0515	0.0534		0.0526
		Manganese, Total (mg/L)	Lab		0.0116	0.0581		0.0584	0.0596	0.0576	0.0563	0.0578	0.0566	0.0555	0.0581		0.0584
				Avg. of filters 1 to 8												0.05749	
		pH	Lab		7.81	6.06		6.33	6.27	6.31	6.28	6.22	6.29	6.4	6.32		6.31
				Avg. of filters 1 to 8												6.3025	
		TDS by Handheld Meter (mg/L)	Lab		111	151		170	160	131	136	135	137	134	130		136
		TOC, Total (mg/L)	Lab		8.38	3.9		2.91	2.94	2.85	2.92	2.97	2.95	2.96	3.07		2.93
				Avg. of filters 1 to 8												2.94625	
		Total Alkalinity (mg/L CaCO3)	Lab		88.6	12.8		13.3	14.1	14	12.7	13.1	12.6	12	13.4		13.2
		TS (mg/L)	Lab		116	152		144	136	144	140	128	140	128	140		134
		Turbidity (NTU)	Lab		0.58	1.5		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11		0.1
				Avg. of filters 1 to 8												0.10125	
		UVT @ 254nm, Unfiltered (%T)	Lab		68.9	91		91.8	92	92.5	92.3	92.3	92.5	92.3	92.3		92.3
	Full-Scale	Bicarbonate (mg/L CaCO3)	Lab		110	16.6			17.3	17.6	17.3		14.4	14.4	13.8		15.7
		Carbonate (mg/L CaCO3)	Lab	N/D at <0.60	G/N	G/N			G/N	G/N	G/N		G/N	G/N	G/N		G/N
		Colour, True	Lab		11.1												
				N/D at <5.0		G/N			G/N	G/N	G/N		G/N	G/N	G/N		G/N
		DO (mg/L)	Lab		2.1	3.4			3.4	4.3	3.7		2.9	2.55	3.3		3.7
		Hydroxide (mg/L CaCO3)	Lab	N/D at <0.34	G/N	G/N			G/N	G/N	G/N		G/N	G/N	G/N		G/N
		Manganese, Dissolved (mg/L)	Lab		0.0061	0.0503			0.05	0.0511	0.0506		0.0498	0.0495	0.0498		0.05
		Manganese, Total (mg/L)	Lab		0.0115	0.0539			0.0557	0.0556	0.0536		0.0551	0.0549	0.0535		0.0556
		pH	Lab		7.83	6.02			6.09	6.07	6.19		6.15	6.04	6.06		6.16

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Benchmarking

Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
					Sample Location												
February 13, 2017	Full-Scale	TDS by Handheld Meter (mg/L)	Lab		125	138			157	161	166		146	132	168		131
		TOC, Total (mg/L)	Lab		8.4	3.58			3.31	3.28	3.24		3.17	3.1	3.15		3.25
		Total Alkalinity (mg/L CaCO3)	Lab		90.2	13.6			14.2	14.4	14.2		11.8	11.8	11.3		12.9
		TS (mg/L)	Lab		130	142			154	150	164		136	142	144		134
		Turbidity (NTU)	Lab		0.55	0.65			0.1	0.1	0.1		0.1	0.1	0.1		0.15
		UVT @ 254nm, Unfiltered (%T)	Lab		68.4	90.6			90.4	90	91		91	91.2	91.6		91.2
February 14, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab					0.0561	0.0568	0.0569	0.0568	0.0566	0.0567	0.0592	0.0586		
				Avg. of filters 1 to 8												0.05721	
		Manganese, Total (mg/L) (1)	Lab		0.0105	0.0568											
		Manganese, Total (mg/L) (2)	Lab		0.0108	0.0569											
		Manganese, Total (mg/L) (3)	Lab		0.0106	0.0586											
		pH	Lab					6.13	6.07	6.16	6.11	6.07	6.07	6.07	6.2		
				Avg. of filters 1 to 8												6.11	
		pH (1)	Lab		7.77	5.92											
		pH (2)	Lab		7.73	5.9											
		pH (3)	Lab		7.74	5.88											
		TOC, Total (mg/L)	Lab					2.97	2.95	2.87	2.92	2.86	2.85	2.88	2.93		
				Avg. of filters 1 to 8												2.90375	
		TOC, Total (mg/L) (1)	Lab		8.58	3.75											
		TOC, Total (mg/L) (2)	Lab		8.63	3.72											
		TOC, Total (mg/L) (3)	Lab		8.66	3.79											
		Turbidity (NTU)	Lab					0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
				Avg. of filters 1 to 8												0.1	
		Turbidity (NTU) (1)	Lab		0.52	1.42											
		Turbidity (NTU) (2)	Lab		0.6	1.4											
		Turbidity (NTU) (3)	Lab		0.54	1.42											
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0112	0.0545		0.0532		0.0529	0.0532	0.0531		0.0529	0.0538		0.0543
		pH	Lab		7.7	5.95		5.98		6.19	5.96	5.89		5.94	5.91		5.93
		TOC, Total (mg/L)	Lab		8.56	3.64		3.3		3.26	3.27	3.14		3.09	3.01		3.17
		Turbidity (NTU)	Lab		0.55	0.6		0.1		0.1	0.1	0.1		0.13	0.1		0.19
February 15, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab					0.0554	0.0544	0.0556	0.0528	0.0553	0.0554	0.0543	0.056		
				Avg. of filters 1 to 8												0.0549	
		Manganese, Total (mg/L) (1)	Lab		0.0107	0.0563											
		Manganese, Total (mg/L) (2)	Lab		0.0111	0.0549											
		Manganese, Total (mg/L) (3)	Lab		0.0108	0.056											
		pH	Lab					6.15	5.96	5.96	6.07	5.94	5.97	6	6.2		
				Avg. of filters 1 to 8												6.03125	
		pH (1)	Lab		7.69	5.95											
		pH (2)	Lab		7.68	5.84											
		pH (3)	Lab		7.65	5.83											
		TOC, Total (mg/L)	Lab					2.83	2.71	2.74	2.7	2.78	2.75	2.97	2.84		
				Avg. of filters 1 to 8												2.79	
		TOC, Total (mg/L) (1)	Lab		8.35	3.62											
		TOC, Total (mg/L) (2)	Lab		8.45	3.62											
		TOC, Total (mg/L) (3)	Lab		8.39	3.63											
		Turbidity (NTU)	Lab					0.11	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
				Avg. of filters 1 to 8												0.10125	
		Turbidity (NTU) (1)	Lab		0.58	1.38											
		Turbidity (NTU) (2)	Lab		0.58	1.37											
		Turbidity (NTU) (3)	Lab		0.56	1.47											
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0112	0.0538			0.054	0.0534		0.0537	0.0523	0.0531	0.0529		0.0686
		pH	Lab		7.63	5.84			5.91	5.94		5.87	5.82	5.79	6.01		5.91
		TOC, Total (mg/L)	Lab		8.3	3.6			3.42	3.21		3.17	3.06	3.06	3.01		3.43
		Turbidity (NTU)	Lab		0.78	0.61			0.14	0.14		0.15	0.17	0.15	0.14		0.14
February 16, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab					0.0577	0.0567	0.058	0.0575	0.0582	0.0586	0.0583	0.0593		
				Avg. of filters 1 to 8												0.05804	
		Manganese, Total (mg/L) (1)	Lab		0.0111	0.0532											
		Manganese, Total (mg/L) (2)	Lab		0.0115	0.0522											
		Manganese, Total (mg/L) (3)	Lab		0.0113	0.0508											
		pH	Lab					6.02	6	6.01	5.98	6.08	6.03	6.04	5.99		
				Avg. of filters 1 to 8												6.01875	
		pH (1)	Lab		7.87	6.05											
		pH (2)	Lab		7.83	6.01											
		pH (3)	Lab		7.8	6.13											
		TOC, Total (mg/L)	Lab					2.92	2.95	2.96	2.87	2.88	2.85	2.87	2.87		
				Avg. of filters 1 to 8												2.89625	
		TOC, Total (mg/L) (1)	Lab		8.39	4.81											

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
February 16, 2017	Pilot-Scale	TOC, Total (mg/L) (2)	Lab		8.38	5.31											
		TOC, Total (mg/L) (3)	Lab		8.78	5.62											
		Turbidity (NTU)	Lab					0.1	0.1	0.13	0.1	0.1	0.1	0.1	0.1		
				Avg. of filters 1 to 8												0.10375	
		Turbidity (NTU) (1)	Lab		0.87	3.35											
		Turbidity (NTU) (2)	Lab		0.74	3.13											
		Turbidity (NTU) (3)	Lab		0.61	2.7											
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0115	0.0568		0.0571	0.0576			0.0554	0.0555	0.0561	0.0541		0.0549
		pH	Lab		7.73	5.94		5.97	5.91			5.89	5.89	5.83	5.86		5.94
		TOC, Total (mg/L)	Lab		8.37	3.64		3.35	3.23			3.16	3.1	3.08	3.01		3.26
		Turbidity (NTU)	Lab		0.69	0.96		0.1	0.1			0.11	0.1	0.11	0.1		0.11
February 17, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab					0.0564	0.0571	0.0556	0.0586	0.0566	0.0566	0.057	0.0573		
				Avg. of filters 1 to 8												0.0569	
		Manganese, Total (mg/L) (1)	Lab		0.0109	0.0543											
		Manganese, Total (mg/L) (2)	Lab		0.011	0.0543											
		Manganese, Total (mg/L) (3)	Lab		0.0109	0.055											
		pH	Lab					5.95	5.9	5.93	5.89	5.97	5.94	5.91	5.95		
				Avg. of filters 1 to 8												5.93	
		pH (1)	Lab		7.66	5.85											
		pH (2)	Lab		7.7	5.81											
		pH (3)	Lab		7.81	5.81											
		TOC, Total (mg/L)	Lab					3.17	3.13	3.08	3.08	3.1	3.31	3.03	3.09		
				Avg. of filters 1 to 8												3.12375	
		TOC, Total (mg/L) (1)	Lab		8.74	4.17											
		TOC, Total (mg/L) (2)	Lab		8.88	4.08											
		TOC, Total (mg/L) (3)	Lab		8.76	4.14											
		Turbidity (NTU)	Lab					0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1		
				Avg. of filters 1 to 8												0.10625	
		Turbidity (NTU) (1)	Lab		0.65	1.75											
		Turbidity (NTU) (2)	Lab		0.66	2.12											
		Turbidity (NTU) (3)	Lab		0.63	1.88											
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0502	0.0592		0.0579	0.0609	0.0595		0.0602		0.059	0.0596		0.0704
		pH	Lab		7.63	5.85		5.85	5.87	5.87		5.76		5.75	5.82		5.88
		TOC, Total (mg/L)	Lab		8.8	3.85		3.43	3.35	3.48		3.19		3.13	3.16		3.33
		Turbidity (NTU)	Lab		0.71	1.07		0.1	0.1	0.1		0.1		0.1	0.1		1.2

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Transitioning

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
February 27, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.012	0.012	0.016	0.016	0.016	0.018	0.015	0.016	0.017	0.017	
		pH	Lab			5.86	5.74	5.92	5.8	6	5.92	5.87	5.93	5.96	5.97	
		TOC, Total (mg/L)	Lab			5	4.8	3.3	3.3	3.2	3.1	3.3	3.1	3.4	2.9	
		Turbidity (NTU)	Lab			1.31	1.21	0.09		0.05				0.07	0.05	
				N/D at <0.05					G/N		G/N	G/N	G/N			
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0079	0.049	0.047	0.046	0.045	0.045	0.044	0.042	0.041		0.041	0.043
				O/L										G/N		
		pH	Lab		7.57	5.69	5.75	5.68	5.7	5.72	5.76	5.63	5.61		5.64	5.65
				O/L										G/N		
		TOC, Total (mg/L)	Lab		15.2	5.9	7.2	4.6	4.9	4.4	5	4.1	4		3.7	3.9
				O/L										G/N		
		Turbidity (NTU)	Lab		0.52	0.54	0.68	0.12	0.1	0.1	0.1	0.1	0.11		0.08	0.15
				O/L										G/N		
February 28, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.011	
		pH	Lab			5.81	5.87	5.81	5.81	5.81	5.78	5.77	5.91	5.78	5.72	
		TOC, Total (mg/L)	Lab			3.3	3.2	2.7	3	3	2.5	5.1	2.5	2.7	2.8	
		Turbidity (NTU)	Lab			1.52	1.54	0.1	0.1	0.1	0.08	0.09	0.1	0.09	0.09	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0083	0.048	0.046	0.046	0.044	0.046		0.044	0.041	0.041	0.041	0.045
				O/L							G/N					
		pH	Lab		7.51	5.79	5.68	5.74	5.76	5.79		5.69	5.67	5.75	5.69	5.67
				O/L							G/N					
		TOC, Total (mg/L)	Lab		30.9	4.1	3.6	3.1	3.2	2.9		3.3	3	5.2	3	3.2
				O/L							G/N					
		Turbidity (NTU)	Lab		0.5	0.63	0.74	0.08	0.11	0.16		0.09	0.09	0.09	0.08	0.2
				O/L							G/N					
March 1, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.011	0.011	0.0093	0.0095	0.0096	0.0097	0.0094	0.0099	0.0099	0.01	
		pH	Lab			5.9	5.91	5.97	6.32	6	6.01	5.97	6.03	6.02	6.02	
		TOC, Total (mg/L)	Lab			4.3	4.8	6.3	4.2	3.8	3.5	3.3	3	3.2	5.8	
		Turbidity (NTU)	Lab			1.49	1.8	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0061	0.047	0.046	0.044	0.045	0.045	0.039	0.036		0.036	0.04	0.04
				O/L									G/N			
		pH	Lab		7.62	5.99	5.84	5.87	5.86	5.97	5.81	5.78		5.74	6.06	5.8
				O/L									G/N			
		TOC, Total (mg/L)	Lab		14	7.6	7.4	6.9	5.5	6.2	5.5	6.6		4.9	3.7	5.7
				O/L									G/N			
		Turbidity (NTU)	Lab		0.53	0.53	0.67	0.11	0.08	0.1	0.1	0.11		0.14	0.17	0.16
				O/L									G/N			
March 2, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.01	0.01	0.0097	0.0096	0.0096	0.0095	0.0095	0.0096	0.0099	0.0098	
		pH	Lab			5.91	5.94	5.96	5.94	5.99	5.99	5.94	6.14	6.24	6.19	
		TOC, Total (mg/L)	Lab			3.7	3.8	7.2	5.4	5.4	5.5	5.7	5.4	5.4	5.2	
		Turbidity (NTU)	Lab			2.07	2.21	0.15	0.15	0.16	0.16	0.14	0.14	0.14	0.14	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0066	0.046	0.045		0.045	0.045	0.045	0.043	0.036	0.039	0.036	0.041
				O/L				G/N								
		pH	Lab		7.79	6.22	5.94		5.98	6.19	6.05	6.02	6.05	5.9	5.92	6.03
				O/L				G/N								
		TOC, Total (mg/L)	Lab		11.9	3.9	3.8		4.2	3.9	4	3	3	3.4	3	3.3
				O/L				G/N								
		Turbidity (NTU)	Lab		0.55	0.5	0.65		0.1	0.1	0.11	0.12	0.1	0.09	0.09	0.22
				O/L				G/N								
March 3, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.01	0.0097	0.009	0.009	0.009	0.009	0.0088	0.0091	0.0093	0.0092	
		pH	Lab			5.87	5.95	6.05	6.02	5.97	6.18	5.95	6.19	5.97	5.97	
		TOC, Total (mg/L)	Lab			8.1	6.2	4	4.8	4.7	4.4	4	4	3.8	6.4	
		Turbidity (NTU)	Lab			1.83	2.15	0.16	0.16	0.15	0.15	0.15	0.14	0.16	0.14	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0077	0.045	0.046	0.045			0.045	0.042	0.035	0.036	0.037	0.041
				O/L					G/N	G/N						
		pH	Lab		7.6	5.91	5.7	5.84			5.77	5.83	5.73	5.79	5.63	5.72
				O/L					G/N	G/N						
		TOC, Total (mg/L)	Lab		28.1	7.8	5.5	6.5			7.3	6.8	5.6	6.2	6	5.6
				O/L					G/N	G/N						
		Turbidity (NTU)	Lab		0.52	0.54	0.67	0.09			0.08	0.07	0.12	0.1	0.1	0.2
				O/L					G/N	G/N						
March 4, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.01	0.0097	0.0087	0.0087	0.0086	0.0087	0.0085	0.0085	0.0087	0.0086	
		pH	Lab			5.94	5.97	6.18	6.1	6.14	6.15	5.98	6.06	6.07	6.04	
		TOC, Total (mg/L)	Lab			5.1	4.5	3.5	3.4	3.2	3	3	3.3	6.5	6.3	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Transitioning. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Transitioning

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 4, 2017	Pilot-Scale	Turbidity (NTU)	Lab			1.46	1.61	0.16	0.13	0.13	0.13	0.12	0.13	0.12	0.12	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0076	0.044	0.044	0.042	0.042	0.041	0.037	0.034	0.04	0.036		0.04
				O/L											G/N	
		pH	Lab		7.7	5.76	5.8	5.83	5.83	5.91	5.7	5.69	5.86	5.71		5.71
				O/L											G/N	
		TOC, Total (mg/L)	Lab		12.7	5.7	5.5	5.9	6	6.6	3.7	5.7	4.9	4.9		5
				O/L											G/N	
		Turbidity (NTU)	Lab		0.57	0.56	0.67	0.11	0.08	0.09	0.11	0.11	0.24	0.17		0.16
				O/L											G/N	
March 5, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0093	0.0093	0.0085	0.0091	0.0088	0.0086	0.0085	0.0086	0.009	0.0086	
		pH	Lab			6.05	5.9	6.1	6.08	6.07	6	6.06	6.02	6.12	6.05	
		TOC, Total (mg/L)	Lab			5.6	6	4.3	4.3	4.4	3.7	6.1	4.2	4.4	4.3	
		Turbidity (NTU)	Lab			1.46	1.67	0.18	0.18	0.16	0.16	0.16	0.17	0.16	0.17	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0073	0.044	0.043	0.042	0.042	0.043			0.035	0.034	0.037	0.04
				O/L							G/N	G/N				
		pH	Lab		7.65	5.85	5.82	5.87	5.86	5.92			5.74	5.68	5.77	5.77
				O/L							G/N	G/N				
		TOC, Total (mg/L)	Lab		17.4	7.4	6.8	7.7	6.7	6.5			4.8	6.7	5.3	5.7
				O/L							G/N	G/N				
		Turbidity (NTU)	Lab		0.55	0.54	0.7	0.08	0.09	0.13			0.12	0.11	0.1	0.15
				O/L							G/N	G/N				
March 6, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0094	0.0092	0.0082	0.0096	0.0082	0.0083	0.0082	0.0082	0.0081	0.0082	
		pH	Lab			5.83	5.84	6.03	5.98	5.95	5.97	5.92	5.93	5.92	5.92	
		TOC, Total (mg/L)	Lab			4.6	4.3	3.8	3.9	3.9	3.2	5.2	4.7	4.9	4.5	
		Turbidity (NTU)	Lab			1.69	1.67	0.17	0.17	0.17	0.19	0.17	0.17	0.16	0.17	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0071	0.044	0.043	0.041			0.043	0.039	0.034	0.034	0.034	0.039
				O/L					G/N	G/N						
		pH	Lab		7.6	5.71	5.8	5.86			5.75	5.6	5.62	5.59	5.58	5.58
				O/L					G/N	G/N						
		TOC, Total (mg/L)	Lab		12.2	5.5	4.9	5.2			5.4	4.2	6	4.2	4.3	4.7
				O/L					G/N	G/N						
		Turbidity (NTU)	Lab		0.57	0.59	0.75	0.09			0.08	0.08	0.17	0.12	0.12	0.16
				O/L					G/N	G/N						
March 7, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0094	0.0093	0.008	0.0079	0.0078	0.0079	0.0077	0.0078	0.0077	0.0078	
		pH	Lab			5.96	5.92	6.1	6.09	6.09	6.1	6.05	6.06	6.05	6.53	
		TOC, Total (mg/L)	Lab			7.3	6.1	4.8	4.1	6.5	4.2	4.2	3.6	4.6	4.2	
		Turbidity (NTU)	Lab			1.32	1.66	0.2	0.25	0.21	0.18	0.19	0.19	0.19	0.19	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0076	0.044	0.044	0.041	0.043	0.042	0.037	0.035	0.035			0.038
				O/L										G/N	G/N	
		pH	Lab		7.65	5.68	5.77	5.82	5.86	5.8	5.76	5.63	5.67			5.64
				O/L										G/N	G/N	
		TOC, Total (mg/L)	Lab		17.6	9.1	7.3	7.5	7.8	7.3	7	6.5	5.7			7.4
				O/L										G/N	G/N	
		Turbidity (NTU)	Lab		0.59	0.61	0.75	0.11	0.07	0.08	0.08	0.1	0.1			0.18
				O/L										G/N	G/N	
March 8, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.01	0.0098	0.0083	0.0082	0.0084	0.0085	0.0079	0.01	0.0083	0.0083	
		pH	Lab			5.95	5.95	6.18	6.11	6.09	6.12	6.11	6.11	6.15	6.19	
		TOC, Total (mg/L)	Lab			6.4	6.6	4.7	4.5	4.8	5	5	5.7	4.2	4.8	
		Turbidity (NTU)	Lab			1.4	1.44	0.18	0.2	0.2	0.21	0.11	0.13	0.12	0.18	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.008	0.047	0.046	0.045	0.044	0.046			0.038	0.038	0.039	0.043
				O/L							G/N	G/N				
		pH	Lab		7.56	5.77	5.8	5.9	5.89	5.88			5.69	5.64	5.62	5.67
				O/L							G/N	G/N				
		TOC, Total (mg/L)	Lab		15.7	6.7	6.9	5.3	5.7	5.4			4.9	5.9	4.8	4.9
				O/L							G/N	G/N				
		Turbidity (NTU)	Lab		0.66	0.57	0.73	0.07	0.08	0.1			0.11	0.09	0.09	0.29
				O/L							G/N	G/N				
March 9, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0097	0.0098	0.0082	0.0081	0.008	0.0078	0.0078	0.008	0.0079	0.0076	
		pH	Lab			5.88	5.92	6.04	5.96	5.96	5.96	5.94	5.97	6.02	5.98	
		TOC, Total (mg/L)	Lab			4.6	4.2	3.9	3.5	3.5	3.4	3.2	3.1	3.2	3.3	
		Turbidity (NTU)	Lab			1.53	1.83	0.19	0.17	0.16	0.16	0.13	0.12	0.12	0.14	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0076	0.047	0.046	0.045		0.045	0.045	0.036		0.035	0.035	0.041
				O/L					G/N				G/N			
		pH	Lab		7.68	5.99	5.71	5.86		5.86	5.8	5.72		5.73	5.62	5.7

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Transitioning. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Transitioning

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 9, 2017	Full-Scale	pH	Lab	O/L					G/N				G/N			
		TOC, Total (mg/L)	Lab		13	4.9	4.1	3.8		3.6	3.8	4.1		3.4	3.4	3.9
				O/L					G/N				G/N			
		Turbidity (NTU)	Lab		0.66	0.6	0.74	0.12		0.1	0.09	0.1		0.16	0.16	0.16
				O/L					G/N				G/N			
March 10, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0091	0.0095	0.0075	0.0074	0.008	0.0077	0.0077	0.0078	0.0078	0.0078	
		pH	Lab			5.95	6.01	6.14	6.07	6.09	6.1	6.06	6.05	6.08	6.01	
		TOC, Total (mg/L)	Lab			6.8	9.9	4.8	4.5	4.4	3.7	3.8	6.7	4.9	3.8	
		Turbidity (NTU)	Lab			1.37	1.6	0.13	0.14	0.14	0.13	0.13	0.13	0.12	0.12	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0071	0.045	0.045		0.044	0.043	0.043	0.036	0.036		0.036	0.041
				O/L				G/N						G/N		
		pH	Lab		7.67	5.72	5.84		5.93	5.86	5.88	5.72	5.74		5.68	5.82
				O/L				G/N						G/N		
		TOC, Total (mg/L)	Lab		13.6	5.9	5.7		5.5	4.9	5.8	4.5	4.4		4.5	9.3
				O/L				G/N						G/N		
		Turbidity (NTU)	Lab		0.55	0.59	0.7		0.09	0.1	0.12	0.12	0.11		0.12	0.14
				O/L				G/N						G/N		
March 11, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0096	0.046	0.0075	0.0076	0.0074	0.0076	0.0076	0.0075	0.0077	0.0077	
		pH	Lab			5.95	5.81	6.14	6.12	6.09	6.01	6.04	6.04	6.07	6.05	
		TOC, Total (mg/L)	Lab			6.3	8	4.9	5.8	4.8	5.6	4.9	4.3	4.5	4.9	
		Turbidity (NTU)	Lab			1.41	1.73	0.11	0.08	0.11	0.1	0.09	0.1	0.09	0.09	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0064	0.046	0.0094	0.045	0.045	0.046			0.036	0.036	0.036	0.04
				O/L							G/N	G/N				
		pH	Lab		7.73	5.72	5.7	5.81	5.73	5.79			5.58	5.6	5.6	5.69
				O/L							G/N	G/N				
		TOC, Total (mg/L)	Lab		20	4	4.6	6.8	6.3	7			4.9	5.8	7.4	6.2
				O/L							G/N	G/N				
		Turbidity (NTU)	Lab		0.62	0.52	0.62	0.06	0.1	0.11			0.1	0.1	0.08	0.17
				O/L							G/N	G/N				
March 12, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0094	0.011	0.0075	0.0075	0.0074	0.0073	0.0074	0.0073	0.0073	0.0075	
		pH	Lab			5.83	5.81	6.07	6.03	6.03	6.02	5.95	5.94	5.97	5.99	
		TOC, Total (mg/L)	Lab			4.6	5	3.9	4.1	4	3.9	2.8	4.4	3.7	3.4	
		Turbidity (NTU)	Lab			1.38	1.39	0.14	0.12	0.12	0.11	0.1	0.1	0.1	0.09	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0071	0.051	0.051		0.051	0.051	0.051	0.051		0.048	0.045	0.053
				O/L				G/N					G/N			
		pH	Lab		7.74	5.78	5.8		5.77	5.8	5.73	5.63		5.59	5.6	5.73
				O/L				G/N					G/N			
		TOC, Total (mg/L)	Lab		15.9	5.2	5.2		5.3	4.7	5.1	3.9		4.3	3.6	3.8
				O/L				G/N					G/N			
		Turbidity (NTU)	Lab		0.61	0.62	1.27		0.12	0.13	0.13	0.15		0.19	0.16	0.39
				O/L				G/N					G/N			
March 13, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0091	0.0092	0.0084	0.0082	0.0086	0.0085	0.0083	0.0082	0.0083	0.0086	
		pH	Lab			5.95	5.95	6.14	6.11	6.08	6.12	6.06	6.24	6.05	6.06	
		TOC, Total (mg/L)	Lab			8.6	9.4	5.8	3.9	7.8	6	5.9	5.6	4.9	5.9	
		Turbidity (NTU)	Lab			1.34	1.46	0.16	0.17	0.17	0.17	0.13	0.12	0.12	0.12	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0072	0.049	0.049		0.048	0.048	0.047	0.038	0.036		0.037	0.042
				O/L				G/N						G/N		
		pH	Lab		7.87	5.95	5.87		5.92	5.93	5.91	5.83	5.78		5.75	5.86
				O/L				G/N						G/N		
		TOC, Total (mg/L)	Lab		19.8	5.6	5.7		5.4	5.8	6.4	5.8	4.6		4.4	5.1
				O/L				G/N						G/N		
		Turbidity (NTU)	Lab		0.61	0.58	0.76		0.13	0.14	0.19	0.19	0.18		0.17	0.2
				O/L				G/N						G/N		
March 14, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.009	0.0084	0.0071	0.0071	0.007	0.0071	0.0072	0.0071	0.0073	0.0073	
		pH	Lab			6.04	6	6.11	6.09	6.05	6.11	5.99	6.03	6.02	6.05	
		TOC, Total (mg/L)	Lab			5.6	5.5	4.6	4.2	4	4.2	3.6	3.9	3.5	3.6	
		Turbidity (NTU)	Lab			1.44	1.55	0.22	0.22	0.28	0.23	0.25	0.22	0.22	0.15	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0062	0.054	0.048		0.042	0.042	0.043	0.042	0.04	0.0406	0.039	0.0404
				O/L				G/N								
		pH	Lab		7.72	5.74	5.71		5.84	5.89	5.88	5.79	5.71	5.7	5.72	5.69
				O/L				G/N								
		TOC, Total (mg/L)	Lab		15.7	7	6.5		6.3	5.7	5.6	4.5	4.4	4	4.4	4.3
				O/L				G/N								
		Turbidity (NTU)	Lab		0.62	0.48	0.71		0.18	0.14	0.17	0.09	0.13	0.13	0.11	0.13

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Transitioning. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Transitioning

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 14, 2017	Full-Scale	Turbidity (NTU)	Lab	O/L				G/N								

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Transitioning. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 13, 2017	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		83	11										
		Aluminum, Soluble (mg/L)	Lab	N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N											
		Antimony, Soluble (mg/L)	Lab		0.0015											
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N											
		Arsenic, Soluble (mg/L)	Lab		0.00092											
		Arsenic, Total (mg/L)	Lab		0.001											
		Boron, Soluble (mg/L)	Lab		0.012											
		Boron, Total (mg/L)	Lab		0.012											
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N											
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N											
		Calcium, Soluble (mg/L)	Lab		20.3											
		Calcium, Total (mg/L)	Lab		19.8											
		Chloride (mg/L)	Lab		3.5	28										
		Chlorine, Free(mg/L)	Lab		0.02											
		Chlorine, Total (mg/L)	Lab		0.03											
		Chromium, Soluble (mg/L)	Lab		0.00056											
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N											
		Colour, Apparent	Lab		25											
		Colour, True	Lab		15		0.5									
		Conductivity Total (µS/cm)	Bench		183											
		Copper, Soluble (mg/L)	Lab		0.0007											
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N											
		DO (mg/L)	Bench		13.3	13.1	13.9									14.1
		DOC calc (mg/L)	Lab		9.1	3.6										3.3
		E. Coli-QT(MPNU/100 mL)	Lab	N/D at <1	G/N											
		HardTotal-Colour (mg/LCaCO3)	Lab		89											
		HPC (cfu/mL)	Lab		14											1
				N/D at <1			G/N									
		Iron, Soluble (mg/L)	Lab		0.086	0.151	0.257									0.012
		Iron, Total (mg/L)	Lab		0.098	0.666	0.718									0.064
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N											
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N											
		Magnesium, Soluble (mg/L)	Lab		6.492											
		Magnesium, Total (mg/L)	Lab		6.5											
		Manganese, Soluble (mg/L)	Lab		0.00088	0.054	0.05									0.044
		Nickel, Soluble (mg/L)	Lab		0.00073											
		Nickel, Total (mg/L)	Lab	N/D at <0.001	G/N											
		Odour60C (-)	Lab	Musty	G/N											G/N
		Oxi-Red Potenital (ORP) (mV)	Bench		400	403	397									399
		pH	Bench				5.87									
		pH Coliform-QT(units)	Lab		7.87	5.95			5.92	5.93	5.91	5.83	5.78		5.75	5.86
				O/L				G/N						G/N		
		Potassium, Soluble (mg/L)	Lab		1.03											
		Potassium, Total (mg/L)	Lab		1.02											
		Sodium, Soluble (mg/L)	Lab		2.068											
		Sodium, Total (mg/L)	Lab		2.06											
		Sulfate Coliform-QT(mg/L)	Lab		2	48										
		TDSwv Coliform-QT(mg/L)	Lab		118											
		Temperature Coliform-QT(°C)	Lab		3.8											
		TOC, Total (mg/L)	Lab		14.65	4.55	4.75		5.4	5.8	6.4	5.8	4.6		4.4	4.35
				O/L				G/N						G/N		
		TON60C Total(T_O_N_60)	Lab		75											5
		Total Coliform-QT(MPNU/100 mL)	Lab		1											
		TSwv Total (mg/L)	Lab		121											
		Turbidity (NTU)	Lab		0.64	0.58	0.76		0.13	0.14	0.19	0.19	0.18		0.17	0.2
				N/D at <0.02					G/N	G/N	G/N		G/N		G/N	
				O/L				G/N						G/N		
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N											
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N											
		UVA @254nm, Unfiltered (/cm)	Bench		0.163											
		UVT @ 254nm, Filtered (%T)	Lab		69.8	91.2										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.7	84.9										
		Zinc, Soluble (mg/L)	Lab	N/D at <0.0009	G/N											

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location											
					Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 13, 2017	Full-Scale	Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N											
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N											
		Zirconium, Total (mg/L)	Lab	N/D at <0.0001	G/N											
March 14, 2017	Full-Scale	Chlorine, Free(mg/L)	Lab		0.03											
		Chlorine, Total (mg/L)	Lab		0.02											
		pH Coliform-QT(units)	Lab		7.72	5.74										
		Temperature Coliform-QT(ºC)	Lab		3.9											
		Turbidity (NTU)	Lab		0.665	0.48			0.18	0.08	0.105	0.09	0.13	0.075	0.11	
				N/D at <0.02					G/N			G/N	G/N		G/N	
				O/L				G/N								
		UVA @254nm, Unfiltered (/cm)	Bench		0.166											
		UVT @ 254nm, Filtered (%T)	Lab		69.5	90.7										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.2	84.7										
March 15, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		84	14	14	13	13	13	13	14	13	13	13	
		Aluminum, Soluble (mg/L)	Lab			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab											0.11		
				N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Antimony, Soluble (mg/L)	Lab		0.0012	0.001	0.0012	0.0009	0.0008	0.0009	0.0012	0.007	0.0012	0.0009	0.0012	
		Antimony, Total (mg/L)	Lab											0.11		
				N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Arsenic, Soluble (mg/L)	Lab		0.0009	0.00046	0.00035	0.00034	0.00034	0.00037	0.00035	0.00034	0.00039	0.00034	0.00034	
		Arsenic, Total (mg/L)	Lab		0.001									0.11		
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab		0.01	0.01								0.09		
				N/D at <0.009			G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Cadmium, Soluble (mg/L)	Lab		0.00001											
				N/D at <0.00001		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab											0.11		
				N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Calcium, Soluble (mg/L)	Lab		20.1	19.7	20.1	19.8	19.2	22.7	22.5	22.3	25.4	22.6	22.5	
		Calcium, Total (mg/L)	Lab		20	19.9	19.3	19.6	19.3	22.9	23.1	22.9	22.8	22	22.1	
		Chromium, Soluble (mg/L)	Lab		0.00042	0.00021	0.00018	0.00014	0.00015	0.00011	0.00008	0.0001	0.0001	0.00012	0.0001	
		Chromium, Total (mg/L)	Lab											0.1		
				N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Colour, True	Lab		17	13	7.5	5	4	5	5.5	6	4	3.5	2.5	
		Conductivity Total (µS/cm)	Bench		189.4	218.35	221.8	761.5	227.45	234.9	225.05	232.9	225.45	225.3	230.1	
		Copper, Soluble (mg/L)	Lab		0.0004	0.0003	0.0002	0.0004	0.0004	0.0005	0.0006	0.0005	0.0005	0.0004	0.0005	
		Copper, Total (mg/L)	Lab											0.1		
				N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		DO (mg/L)	Bench		10.4	10.7	10.4	9.4	10.4	10.4	10.4	10.5	10.5	10.3	10.6	
		DOC Total (mg/L)	Lab		28.6	8.2	7.4	6.9	7.1	6.7	7.1	7	7.4	6.8	7	
		Iron, Soluble (mg/L)	Lab		0.04	0.3	0.01	0.01	0.01	0.004	0.003	0.02	0.01	0.002		
				N/D at <0.002											G/N	
		Iron, Total (mg/L)	Lab		0.09	1.55	1.57	0.06	0.06	0.05	0.04	0.04	0.04	0.14	0.04	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab											0.11		
				N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Magnesium, Soluble (mg/L)	Lab		6.34	6	6.06	5.9	5.84	6.47	6.44	6.42	7.19	6.21	6.08	
		Magnesium, Total (mg/L)	Lab		6.38	6.23	5.93	6.01	5.76	6.49	6.68	6.36	6.3	6.19	6.24	
		Manganese, Soluble (mg/L)	Lab		0.0011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.01	0.0085	0.011	0.0125	0.012	0.0125	0.012	0.011	0.013	0.0655	0.011	
		Nickel, Soluble (mg/L)	Lab		0.00038	0.0043	0.0043	0.0042	0.0041	0.0041	0.0041	0.0041	0.0046	0.004	0.004	
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.11	0.004	
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		443.1	372.3	445.5	407.3	442.3	443.1	455.9	453.1	455.8	457.4	474.2	
		pH	Bench		7.785	6.095	6.14	6.3	6.335	6.3	6.3	6.215	6.245	6.225	6.195	
		Potassium, Soluble (mg/L)	Lab		1.03	1.01	1.01	1.01	1	1.24	1.21	1.23	1.38	1.2	1.19	
		Potassium, Total (mg/L)	Lab		1.02	1.01	0.96	1	0.99	1.23	1.26	1.23	1.19	1.22	1.18	
		Sodium, Soluble (mg/L)	Lab		2	2.03	1.99	2.31	2.32	2.71	2.65	2.64	2.94	2.67	2.56	
		Sodium, Total (mg/L)	Lab		2.04	1.97	1.97	2.22	2.27	2.69	2.82	2.65	2.62	2.55	2.52	
		TDSwv (mg/L)	Lab		111	129	133	140	133	131	137	133	134	132	136	
		Temperature (ºC)	Bench		3.7	4.2	4.6	4.6	5.9	6	6	6	6	5.9	5.9	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 15, 2017	Pilot-Scale	TSScalc Total (mg/L)	Lab		7	7	7	6	3	11	3	7	6	16	6	
		TSwv Total (mg/L)	Lab		118	136	140	146	136	142	140	140	140	148	142	
		Turbidity (NTU)	Bench		0.84	1.46	2.18	1.01	0.2	0.96	0.61	0.69	0.26	0.94	0.34	
			Lab		0.58	1.31	1.55	0.11	0.12	0.12	0.11	0.1	0.1	0.1	0.11	
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab											0.11		
				N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.13	0.12	0.95	0.04	0.04	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.4	81.65	83.8	52.35	92.55	87.6	93.6	92.8	94.55	93.6	93.45	
		Zinc, Soluble (mg/L)	Lab		0.001	0.001	0.0012	0.0012	0.0013	0.0023	0.0013	0.0009	0.0017	0.001		
				N/D at <0.0009											G/N	
		Zinc, Total (mg/L)	Lab											0.11		
				N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab											0.11		
				N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	
	Full-Scale	Chlorine, Free(mg/L)	Lab		0.02											
		Chlorine, Total (mg/L)	Lab		0.04											
		pH Coliform-QT(units)	Lab		7.69	5.6										
		Temperature (ºC), WTP Train 1	Lab		2.76											
		Temperature (ºC), WTP Train 2	Lab		3.1											
		Temperature Coliform-QT(ºC)	Lab		4											
		Turbidity (NTU)	Lab		0.645	0.55				0.07	0.1	0.065	0.095	0.065	0.12	
				N/D at <0.02							G/N				G/N	
				O/L				G/N	G/N							
		UVA @254nm, Unfiltered (/cm)	Bench		0.165											
		UVT @ 254nm, Filtered (%T)	Lab		70.1	91.2										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.4	84.8										
March 16, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		83	14	14	13	12	14	13	14	13	14	13	
		Aluminum, Soluble (mg/L)	Lab			0.01	0.01	0.004	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Antimony, Soluble (mg/L)	Lab		0.0011	0.0011	0.0012	0.0011	0.0011	0.0009	0.001	0.0011	0.0011	0.0012	0.001	
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00085	0.00043	0.00032	0.00035	0.00031	0.00033	0.00032	0.00037	0.00034	0.00032	0.00043	
		Arsenic, Total (mg/L)	Lab		0.001											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Calcium, Soluble (mg/L)	Lab		22.5	22.6	22	23.1	22.3	22	22.1	22.2	25.5	22.2	22.5	
		Calcium, Total (mg/L)	Lab		24.6	22.2	22.3	22.6	22	23.5	21.8	22.1	22	23.1	22	
		Chromium, Soluble (mg/L)	Lab		0.00035	0.00014	0.00016	0.0001	0.00012	0.00012	0.00011	0.00014	0.00028	0.00014	0.00012	
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		16	2.5	1	0.5	1	1	1	1	1	1	0.5	
		Conductivity Total (µS/cm)	Bench		194.25	221	236.55	212.7	212.55	213.2	212.35	215.65	214.85	214.5	214.5	
		Copper, Soluble (mg/L)	Lab		0.0004	0.0003	0.0003	0.0004	0.0004	0.0006	0.0005	0.0005	0.0006	0.0005	0.0004	
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		10.9	12.1	12.4	10.9	10.7	10.7	10.6	11.4	10.8	11.2	11	
		DOC Total (mg/L)	Lab		9.5	4.1	3.7	3.9	4	3.7	3.4	3.8	3.6	3.4	3.7	
		Iron, Soluble (mg/L)	Lab		0.04	0.16	0.01		0.004	0.01	0.004	0.003	0.04	0.002	0.01	
				N/D at <0.002				G/N								
		Iron, Total (mg/L)	Lab		0.09	1.52	1.38	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.21	6.13	6.2	6.3	6.02	6.32	6.18	6.02	6.91	6.21	6.2	
		Magnesium, Total (mg/L)	Lab		6.71	6.13	6.11	6.34	6.3	6.29	6.15	6.02	6.11	6.38	6	
		Manganese, Soluble (mg/L)	Lab		0.0011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.0105	0.0125	0.014	0.011	0.0115	0.013	0.01	0.009	0.0095	0.0115	0.012	
		Nickel, Soluble (mg/L)	Lab		0.00041	0.0041	0.0041	0.0039	0.004	0.004	0.004	0.0041	0.0046	0.0041	0.0041	
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		300.5	250.6	293	320.2	344.8	345.9	345.8	345.9	356	354.3	352.7	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 16, 2017	Pilot-Scale	pH	Bench		7.83	6.19	6.21	6.415	6.385	6.385	6.32	6.24	6.315	6.28	6.27	
		Potassium, Soluble (mg/L)	Lab		1.22	1.18	1.2	1.22	1.23	1.21	1.19	1.19	1.39	1.19	1.15	
		Potassium, Total (mg/L)	Lab		1.37	1.18	1.27	1.2	1.18	1.28	1.18	1.18	1.17	1.2	1.16	
		Sodium, Soluble (mg/L)	Lab		2.43	2.41	2.45	2.99	2.79	2.81	2.75	2.96	2.91	2.91	2.76	
		Sodium, Total (mg/L)	Lab		2.45	2.4	2.47	2.9	2.71	2.77	2.67	2.76	2.79	2.83	2.73	
		TDSwv (mg/L)	Lab		113	137	126	128	137	140	135	129	137	131	137	
		Temperature (ºC)	Bench		4.3	4.8	5.2	6	6	5.9	6.1	5.9	5.9	6.1	6.1	
		TSScalc Total (mg/L)	Lab			3	10	4	5	4	15	9	29	17	13	
				N/D at <3	G/N											
		TSwv Total (mg/L)	Lab		114	140	136	132	142	144	150	138	166	148	150	
		Turbidity (NTU)	Bench		0.95	1.65	1.43	0.44	0.98	0.17	0.19	0.36	0.16	0.21	0.88	
			Lab		0.6	1.18	1.4	0.14	0.09	0.11	0.1	0.09	0.08	0.08	0.09	
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.11	0.11	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.75	83.95	84.55	93.4	92.6	93.25	93.1	93.5	93.65	93.7	93.25	
		Zinc, Soluble (mg/L)	Lab			0.001			0.0015	0.0016	0.0011	0.001	0.0011			
				N/D at <0.0009	G/N		G/N	G/N						G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab						0.0001							
				N/D at <0.0001	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	
	Full-Scale	Chlorine, Free(mg/L)	Lab		0.03											
		Chlorine, Total (mg/L)	Lab		0.06											
		pH Coliform-QT(units)	Lab		7.65	5.61										
		Temperature (ºC), WTP Train 1	Lab		2.82											
		Temperature (ºC), WTP Train 2	Lab		3.2											
		Temperature Coliform-QT(ºC)	Lab		4.2											
		Turbidity (NTU)	Lab		0.67	0.5			0.13	0.085	0.11	0.07	0.06	0.09		
				N/D at <0.02					G/N		G/N					
				O/L				G/N							G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.165											
		UVT @ 254nm, Filtered (%T)	Lab		69.9	90.6										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.4	84.9										
March 17, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		164.1	202	200.7	204	211.8	211.9	203.9	203.6	210	205.3	201.6	
		DO (mg/L)	Bench		9.3	10.6	11.3	10	11.1	10.7	10.9	10.7	11.3	11.3	10.8	
		Manganese, Total (mg/L)	Bench		0.015	0.019	0.016	0.013	0.012	0.012	0.014	0.014	0.012	0.014	0.023	
		Oxi-Red Potenital (ORP) (mV)	Bench		251.8	258.9	281.1	289.9	300.6	308.5	316.7	325.7	329.9	331.4	334	
		pH	Bench		7.71	5.93	5.92	6.09	6.03	6.01	6.01	5.96	5.94	5.96	5.95	
		Temperature (ºC)	Bench		5.9	5.4	5.4	6.3	6.5	6.5	5.9	6.3	6.4	6.2	6.4	
		Turbidity (NTU)	Bench		1.74	1.54	1.77	0.23	0.4	0.46	0.22	0.39	0.38	0.21	0.62	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.15	0.15	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		68.5	71	71.3	92.8	92.8	93.3	93.5	92.5	93.5	93.1	93.2	
	Full-Scale	Chlorine, Free(mg/L)	Lab		0.02											
		Chlorine, Total (mg/L)	Lab		0.04											
		pH Coliform-QT(units)	Lab		7.71	5.63										
		Temperature (ºC), WTP Train 1	Lab		2.85											
		Temperature (ºC), WTP Train 2	Lab		3.2											
		Temperature Coliform-QT(ºC)	Lab		4.3											
		Turbidity (NTU)	Lab		0.72	0.52			0.1	0.08	0.12	0.1	0.09	0.09	0.07	
				N/D at <0.02					G/N		G/N		G/N	G/N	G/N	
				O/L				G/N								
		UVA @254nm, Unfiltered (/cm)	Bench		0.166											
		UVT @ 254nm, Filtered (%T)	Lab		70.1	91										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.3	85.2										
March 18, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		188.3	205.4	206.5	214.8	212	209.7	208.1	223	211.3	210.4	213	
		DO (mg/L)	Bench		10.6	10.6	11.1	11.6	11.3	11.2	11.6	11.9	11.3	11.4	11.4	
		Manganese, Total (mg/L)	Bench		0.013	0.018	0.016	0.009	0.011	0.009	0.011	0.011	0.012	0.01	0.013	
		Oxi-Red Potenital (ORP) (mV)	Bench		278.7	277.7	356.2	350.2	350.5	347.4	346.9	350.1	348.6	346.9	339.6	
		pH	Bench		7.71	5.98	5.92	6.06	6.04	6.06	6.04	5.96	6	5.97	5.95	
		Temperature (ºC)	Bench		4.9	4.3	5.3	6	5.9	6	6	5.8	5.7	5.7	5.7	
		Turbidity (NTU)	Bench		1.77	1.64	1.7	0.16	0.16	0.15	0.12	0.11	0.09	0.11	0.11	
		UVA @254nm, Unfiltered (/cm)	Bench		0.15	0.14	0.13	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
		UVT @ 254nm, Unfiltered (%T)	Bench		70.8	72.5	73.7	96.4	95.2	95.2	95.3	95.3	95	94.9	94.6	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 18, 2017	Full-Scale	Temperature (ºC), WTP Train 1	Lab		2.85											
		Temperature (ºC), WTP Train 2	Lab		3.2											
		Turbidity (NTU)	Bench					0.09								
			Lab	N/D at <0.02				G/N								
March 19, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		172.6	204.3	204.4	213.4	211.1	203.5	204.2	207.2	208.7	207.4	209.4	
		DO (mg/L)	Bench		10.5	10.7	11.7	10.7	10.5	10	10	10.3	10.4	10	10.6	
		Manganese, Total (mg/L)	Bench		0.011	0.021	0.02	0.012	0.017	0.012	0.012	0.012	0.014	0.013	0.013	
		Oxi-Red Potenital (ORP) (mV)	Bench		300.8	264.8	304.5	318.8	326.2	328.4	331.3	335.4	340.9	336.8	342.6	
		pH	Bench		7.78	5.93	5.91	6.06	6.05	6.07	6.05	6.04	5.99	6.01	5.98	
		Temperature (ºC)	Bench		4.2	4.1	4.9	5.7	5.8	5.7	5.8	5.7	5.6	5.6	5.6	
		Turbidity (NTU)	Bench		1.3	1.2	1.38	0.14	0.15	0.13	0.14	0.13	0.13	0.14	0.1	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.12	0.12	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.5	75.7	75.9	94.8	94.8	94.6	94.5	93.7	93	93.1	92.9	
	Full-Scale	Temperature (ºC), WTP Train 1	Lab		2.9											
		Temperature (ºC), WTP Train 2	Lab		3.27											
March 20, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		174.8	203.4	201.2	208.4	207.6	211.1	207.6	208.8	211.5	207.4	208.6	
		DO (mg/L)	Bench		10.9	10.8	10.6	10.6	10.8	11.2	10.6	10.9	11.6	11.1	10.6	
		Manganese, Total (mg/L)	Bench		0.014	0.018	0.018	0.011	0.015	0.015	0.011	0.013	0.013	0.012	0.014	
		Oxi-Red Potenital (ORP) (mV)	Bench		230	242.6	326	320.6	317.8	311.3	319.9	313.1	306.3	299.2	283.5	
		pH	Bench		7.7	6.14	6.18	6.07	6.05	6.02	6.02	6.02	5.98	6.02	5.96	
		Temperature (ºC)	Bench		5.2	5.4	5.4	6	6.1	6.1	6.1	6.1	6.1	6	6.1	
		Turbidity (NTU)	Bench		1.11	2.31	2.11	0.14	0.15	0.14	0.12	0.16	0.1	0.1	0.1	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.23	0.18	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		68.5	59.4	66.8	93.1	93.1	93.2	93.1	92.8	93	92.9	92.8	
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		83	12										
		Chloride (mg/L)	Lab		3.5	27										
		Chlorine, Free(mg/L)	Lab		0.02											
		Chlorine, Total (mg/L)	Lab		0.03											
		Colour, Apparent	Lab		25											
		Colour, True	Lab		15		2									
		Conductivity Total (µS/cm)	Bench		183											
		DO (mg/L)	Bench		12	12	12.6									11.9
		DOC calc (mg/L)	Lab		20.7	8.7										7.1
		E. Coli-QT(MPNU/100 mL)	Lab		1											
		HardTotal-Colour (mg/LCaCO3)	Lab		88											
		HPC (cfu/mL)	Lab		52											1
				N/D at <1			G/N									
		Iron, Soluble (mg/L)	Lab			0.383	0.042									0.013
		Iron, Total (mg/L)	Lab			0.615	0.604									0.057
		Manganese, Soluble (mg/L)	Lab			0.046	0.037									0.031
		Manganese, Total (mg/L)	Bench			0.048	0.048									0.033
		Odour60C (-)	Lab	Grassy	G/N											
				Musty												G/N
		Oxi-Red Potenital (ORP) (mV)	Bench		456	444	446									453
		pH	Bench				5.72									
		pH Coliform-QT(units)	Lab		7.79	5.68										5.63
		Sulfate Coliform-QT(mg/L)	Lab			48										
				N/D at <2	G/N											
		TDSwv Coliform-QT(mg/L)	Lab		121											
		Temperature (ºC), WTP Train 1	Lab		3.01											
		Temperature (ºC), WTP Train 2	Lab		3.38											
		Temperature Coliform-QT(ºC)	Lab		4.4											
		TOC, Total (mg/L)	Lab		25.9	7.5	9.8									7.4
		TON60C Total(T_O_N_60)	Lab		75											35
		Total Coliform-QT(MPNU/100 mL)	Lab		3											
		TSwv Total (mg/L)	Lab		126											
		Turbidity (NTU)	Lab		0.68	0.57	0.65	0.1	0.11	0.095	0.13		0.065		0.08	0.14
				N/D at <0.02				G/N	G/N		G/N				G/N	
				O/L								G/N		G/N		
		UVA @254nm, Unfiltered (/cm)	Bench		0.162											
		UVT @ 254nm, Filtered (%T)	Lab		71	91.3										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.8	85.6										
March 21, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		185.6	202.1	204.3	207	205.2	207.5	207.4	207.4	207.6	215.7	208.3	
		DO (mg/L)	Bench		10.1	10.9	11.9	10.8	10.8	10.9	10.9	10.9	10.6	10.9	10.7	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location										
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 21, 2017	Pilot-Scale	Manganese, Total (mg/L)	Bench		0.013	0.017	0.019	0.011	0.011	0.014	0.016	0.017	0.014	0.013	0.013	
		Oxi-Red Potenital (ORP) (mV)	Bench		263.2	245.8	293.5	300.4	308.8	321.1	326.4	333.6	340	333.1	328	
		pH	Bench		7.79	5.91	5.9	6.1	6.12	6.06	6.04	5.99	5.94	6.01	5.98	
		Temperature (ºC)	Bench		5.9	4.9	5.7	3.1	3.1	3	6.2	5.7	5.8	5.9	5.9	
		Turbidity (NTU)	Bench		0.67	1.55	1.67	0.28	0.12	0.15	0.12	0.17	0.15	0.15	0.2	
		UVA @254nm, Unfiltered (/cm)	Bench		0.17	0.14	0.13	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.04	
		UVT @ 254nm, Unfiltered (%T)	Bench		68	73	74.4	93	93.1	92.6	93.3	92.3	92.6	92.3	92.4	
	Full-Scale	Chlorine, Free(mg/L)	Lab		0.03											
		Chlorine, Total (mg/L)	Lab		0.06											
		pH Coliform-QT(units)	Lab		7.73	5.7										
		Temperature (ºC), WTP Train 1	Lab		3.11											
		Temperature (ºC), WTP Train 2	Lab		3.45											
		Temperature Coliform-QT(ºC)	Lab		4.6											
		Turbidity (NTU)	Lab		0.675	0.46		0.21		0.095	0.13	0.07	0.165	0.085	0.13	
				N/D at <0.02				G/N			G/N				G/N	
				O/L					G/N							
		UVA @254nm, Unfiltered (/cm)	Bench		0.162											
		UVT @ 254nm, Filtered (%T)	Lab		70.3	90.9										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.8	84.7										
March 22, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		83	13	12	11	12	14	11	13	12	12	12	
		Aluminum, Soluble (mg/L)	Lab			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.01	0.01			0.11						
				N/D at <0.01	G/N			G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		Antimony, Soluble (mg/L)	Lab		0.0014	0.001	0.001	0.0008	0.0012	0.001	0.0011	0.0013	0.0009	0.0009	0.0014	
		Antimony, Total (mg/L)	Lab							0.1						
				N/D at <0.0005	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00089	0.00045	0.00036	0.00034	0.00035	0.00034	0.00033	0.00034	0.00033	0.00036	0.00034	
		Arsenic, Total (mg/L)	Lab		0.0009					0.11						
				N/D at <0.0007		G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.14						
				N/D at <0.009							G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab		0.00001											
				N/D at <0.00001		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab							0.1						
				N/D at <0.0001	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		Calcium, Soluble (mg/L)	Lab		23.8	23.6	22.7	23.2	23.3	22.6	22.6	23	23.1	24.9	22.7	
		Calcium, Total (mg/L)	Lab		23.6	23.1	22.8	23.1	22.6	22.6	22.5	23.3	23	22.8	23.5	
		Chromium, Soluble (mg/L)	Lab		0.0004	0.00014	0.00017	0.00011	0.00011	0.0001	0.0001	0.00011	0.00008	0.00013	0.00012	
		Chromium, Total (mg/L)	Lab							0.1						
				N/D at <0.001	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		18	2.5	2.5	2	0.5	0.5	1	1	1	1	1	
		Conductivity Total (µS/cm)	Bench		175.55	209	210.1	213.55	212.95	212.9	212.45	216	215.65	215.8	213.85	
		Copper, Soluble (mg/L)	Lab		0.0005	0.0004	0.0034	0.0005	0.0006	0.0005	0.0005	0.0005	0.0004	0.0006	0.0004	
		Copper, Total (mg/L)	Lab				0.01			0.11						
				N/D at <0.005	G/N	G/N		G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		10.7	10.5	10.9	11.1	11.6	11.3	11.5	11.8	11.8	11.8	10.7	
		DOC Total (mg/L)	Lab		21.9	7.9	7.1	6.2	6.4	6.3	5.7	6.5	6.7	6.2	6.1	
		Iron, Soluble (mg/L)	Lab		0.03	0.17	0.21							0.01		
				N/D at <0.002				G/N	G/N	G/N	G/N	G/N	G/N		G/N	
		Iron, Total (mg/L)	Lab		0.07	1.54	1.88	0.03	0.02	0.13	0.02	0.02	0.02	0.02	0.02	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab							0.1						
				N/D at <0.0004	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.94	6.65	6.45	6.61	6.7	6.34	6.38	6.46	6.29	6.93	6.31	
		Magnesium, Total (mg/L)	Lab		6.88	6.6	6.5	6.73	6.47	6.45	6.47	6.49	6.32	6.22	6.48	
		Manganese, Soluble (mg/L)	Lab		0.00087	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.0135	0.0165	0.0175	0.013	0.0125	0.063	0.0125	0.011	0.011	0.013	0.011	
		Nickel, Soluble (mg/L)	Lab		0.00045	0.0045	0.0044	0.0042	0.0043	0.0042	0.0042	0.0043	0.0043	0.00047	0.0043	
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.11	0.004	0.004	0.004	0.004	0.004	
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		307.4	251.6	288.7	301.4	305	307.7	313.3	317.3	321.9	325.1	327.3	
		pH	Bench		7.81	5.93	5.94	6.165	6.115	6.095	6.085	5.97	5.995	6	5.995	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Combined Filtrate**
March 22, 2017	Pilot-Scale	Potassium, Soluble (mg/L)	Lab		1.3	1.31	1.25	1.25	1.28	1.23	1.24	1.25	1.23	1.34	1.25	
		Potassium, Total (mg/L)	Lab		1.29	1.24	1.23	1.32	1.26	1.26	1.27	1.26	1.21	1.19	1.24	
		Sodium, Soluble (mg/L)	Lab		2.48	2.4	2.44	2.69	2.78	2.88	2.73	2.82	2.71	2.8	2.81	
		Sodium, Total (mg/L)	Lab		2.45	2.39	2.43	3	2.74	2.65	2.76	2.76	2.78	2.86	2.77	
		TDSwv (mg/L)	Lab		97	118	126	123	117	120	118	126	127	119	113	
		Temperature (ºC)	Bench		6.2	5.8	7.2	6.5	6.4	6.6	6.5	6.1	6.5	6.7	6.7	
		TSScalc Total (mg/L)	Lab		29	20	30	15	25	8	16	14	3	7	29	
		TSwv Total (mg/L)	Lab		126	138	156	138	142	128	134	140	130	126	142	
		Turbidity (NTU)	Bench		0.86	1.36	1.72	0.1	0.09	0.09	0.13	0.08	0.1	0.13	0.11	
			Lab		0.86	1.07	2.19	0.43	0.15	0.1	0.15	0.09	0.1	0.09	0.09	
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab							0.12						
				N/D at <0.0004	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.12	0.12	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
		UVT @ 254nm, Unfiltered (%T)	Bench		70.1	82.5	83.15	93.6	94.2	93.75	94.1	93.85	93.2	93.8	94.05	
		Zinc, Soluble (mg/L)	Lab			0.0011	0.0035	0.0017	0.0018	0.0016	0.0022	0.0019	0.0015	0.0027	0.0017	
				N/D at <0.0009	G/N											
		Zinc, Total (mg/L)	Lab							0.11						
				N/D at <0.005	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab			0.0005										
				N/D at <0.0005	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab							0.11						
				N/D at <0.0001	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
	Full-Scale	Chlorine, Free(mg/L)	Lab		0.02											
		Chlorine, Total (mg/L)	Lab		0.05											
		pH Coliform-QT(units)	Lab		7.58	5.72										
		Temperature (ºC), WTP Train 1	Lab		3.17											
		Temperature (ºC), WTP Train 2	Lab		3.5											
		Temperature Coliform-QT(ºC)	Lab		4.9											
		Turbidity (NTU)	Lab		0.69	0.49		0.14	0.075	0.115	0.14	0.1	0.085			
				N/D at <0.02				G/N			G/N					
				O/L										G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.162											
		UVT @ 254nm, Filtered (%T)	Lab		69.9	90.4										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.8	84.5										
March 23, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		82	13	12	12	11	12	11	12	12	12	12	
		Aluminum, Soluble (mg/L)	Lab			0.01	0.01	0.004	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D <0.002	G/N											
		Aluminum, Total (mg/L)	Lab	N/D <0.01	G/N											
				N/D at <0.01		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Antimony, Soluble (mg/L)	Lab		0.0011								0.0008			
				N/D at <0.0004		G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	
		Antimony, Total (mg/L)	Lab										0.0008			
				N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00087	0.00053	0.00047	0.00036	0.00038	0.00035	0.00036	0.00035	0.00034	0.00033	0.00038	
		Arsenic, Total (mg/L)	Lab		0.0009											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab	N/D <0.009	G/N											
				N/D at <0.009		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab												0.00003	
				N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Calcium, Soluble (mg/L)	Lab		23.7	24.4	23	23.4	24	22.6	22.7	22.9	22.7	22.7	22.6	
		Calcium, Total (mg/L)	Lab		23.9	24.4	23	23.4	24	22.6	22.7	22.9	22.7	22.7	22.6	
		Chromium, Soluble (mg/L)	Lab		0.00057	0.00057	0.0005	0.0002	0.00022	0.00019	0.00018	0.00023	0.00017	0.00022	0.00023	
		Chromium, Total (mg/L)	Lab	N/D <0.001	G/N											
				N/D at <0.001		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		7.5	2.5	2	1.5	2.5	2	2	1.5	3	2	2	
		Conductivity Total (µS/cm)	Bench		177.15	208.05	208.7	208.5	193.1	204	205.65	186.95	207.1	217.7	210.4	
		Copper, Soluble (mg/L)	Lab		0.0005	0.0003	0.0005	0.0003	0.0004	0.0005	0.0004	0.0003	0.0005	0.0003	0.0003	
		Copper, Total (mg/L)	Lab	N/D <0.005	G/N											
				N/D at <0.005		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		11.3	10.4	11.4	10.8	10.9	10.4	10.8	10.9	10.5	11.1	11.7	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 23, 2017	Pilot-Scale	DOC Total (mg/L)	Lab		21.7	7.6	7.1	6.5	6.2	6	6.1	6.5	6.4	6.3	5.8	
		Iron, Soluble (mg/L)	Lab		0.02	1.34	1.13	0.01	0.02	0.02	0.02	0.02	0.004	0.01	0.02	
		Iron, Total (mg/L)	Lab		0.03	1.34	1.13	0.01	0.02	0.02	0.02	0.02		0.01	0.02	
				N/D at <0.008									G/N			
		Lead, Soluble (mg/L)	Lab							0.00004						
				N/D <0.00004	G/N											
				N/D at <0.00004		G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D <0.0004	G/N											
				N/D at <0.0004		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.74	7.18	6.48	6.79	6.84	6.47	6.37	6.32	6.42	6.36	6.41	
		Magnesium, Total (mg/L)	Lab		6.71	7.18	6.48	6.79	6.84	6.47	6.37	6.32	6.42	6.36	6.41	
		Manganese, Soluble (mg/L)	Lab		0.00069	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.00845	0.017	0.016	0.012	0.0135	0.013	0.013	0.013	0.012	0.0125	0.011	
		Nickel, Soluble (mg/L)	Lab		0.00043	0.0047	0.0043	0.0041	0.0044	0.0041	0.0041	0.0042	0.0042	0.0041	0.0042	
		Nickel, Total (mg/L)	Lab			0.01	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
				N/D <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		215	253.5	369.8	364.3	363.9	367.7	338.6	334.8	329.6	327.7	321	
		pH	Bench		7.855	5.985	6.01	6.12	6.13	6.1	6.115	6.035	6.01	5.985	6.005	
		Potassium, Soluble (mg/L)	Lab		1.3	1.35	1.24	1.24	1.33	1.24	1.24	1.23	1.23	1.23	1.27	
		Potassium, Total (mg/L)	Lab		1.35	1.35	1.24	1.24	1.33	1.24	1.24	1.23	1.23	1.23	1.27	
		Sodium, Soluble (mg/L)	Lab		2.7	2.69	2.74	2.98	2.92	3.06	2.93	2.92	3.06	3.03	2.87	
		Sodium, Total (mg/L)	Lab		2.75	2.69	2.74	2.98	2.92	3.06	2.93	2.92	3.06	3.03	2.87	
		TDSwv (mg/L)	Lab		101	126	125	126	129	127	131	137	144	138	144	
		Temperature (ºC)	Bench		5.6	5.7	6	6.5	6.6	6.6	6.7	6.3	6.3	6.3	6.5	
		TSScalc Total (mg/L)	Lab		31	34	41	32	45	27	37	19	14	24	4	
		TSwv Total (mg/L)	Lab		132	160	166	158	174	154	168	156	158	162	148	
		Turbidity (NTU)	Bench		0.68	1.09	1.67	0.15	0.15	0.14	0.12	0.11	0.11	0.17	0.09	
			Lab		0.58	1.17	2.02	0.11	0.12	0.12	0.11	0.18	0.11	0.1	0.12	
		Uranium, Soluble (mg/L)	Lab	N/D <0.0005	G/N											
				N/D at <0.0005		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab	N/D <0.0004	G/N											
				N/D at <0.0004		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.14	0.13	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.65	80.65	82.6	93.1	92.7	93.05	92.25	92.8	92.45	92.95	92.55	
		Zinc, Soluble (mg/L)	Lab	N/D <0.0009	G/N											
				N/D at <0.0009		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D <0.005	G/N											
				N/D at <0.005		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D <0.0005	G/N											
				N/D at <0.0005		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab		0.0001											
				N/D at <0.0001		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
	Full-Scale	Chlorine, Free(mg/L)	Lab	N/D at <0.02	G/N											
		Chlorine, Total (mg/L)	Lab		0.02											
		pH Coliform-QT(units)	Lab		7.7	5.64										
		Temperature (ºC), WTP Train 1	Lab		3.17											
		Temperature (ºC), WTP Train 2	Lab		3.57											
		Temperature Coliform-QT(ºC)	Lab		4.8											
		Turbidity (NTU)	Lab		0.665	0.51		0.11	0.08			0.07	0.12	0.08	0.11	
				N/D at <0.02				G/N					G/N		G/N	
				O/L						G/N	G/N					
		UVA @254nm, Unfiltered (/cm)	Bench		0.162											
		UVT @ 254nm, Filtered (%T)	Lab		70	90.6										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.9	84.5										
March 24, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench	Flow to pilot stopped	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench	Flow to pilot stopped	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Manganese, Total (mg/L)	Bench		0.008	0.014	0.014	0.013	0.013	0.014	0.013	0.01	0.018	0.013	0.013	
		Oxi-Red Potenital (ORP) (mV)	Bench	Flow to pilot stopped	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		pH	Bench	Flow to pilot stopped	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Temperature (ºC)	Bench		6	5.6	5.9	6.3	6.6	6.5	6.6	6.3	6.2	6.2	6.1	
		Turbidity (NTU)	Bench		0.75	1.16	1.81	0.08	0.09	0.09	0.12	0.15	0.15	0.08	0.09	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.12	0.13	0.03	0.03	0.03	0.06	0.03	0.04	0.03	0.04	
		UVT @ 254nm, Unfiltered (%T)	Bench		68.5	75.5	74.1	94.1	93	93	88	93	93.2	90.8	92	
	Full-Scale	Chlorine, Free(mg/L)	Lab		0.02											

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 24, 2017	Full-Scale	Chlorine, Total (mg/L)	Lab		0.02											
		pH Coliform-QT(units)	Lab		7.66	5.6										
		Temperature (ºC), WTP Train 1	Lab		3.17											
		Temperature (ºC), WTP Train 2	Lab		3.62											
		Temperature Coliform-QT(ºC)	Lab		5.1											
		Turbidity (NTU)	Lab		0.675	0.74			0.07	0.045	0.07	0.07		0.08	0.06	
				N/D at <0.02					G/N		G/N	G/N		G/N	G/N	
				O/L				G/N					G/N			
		UVA @254nm, Unfiltered (/cm)	Bench		0.168											
		UVT @ 254nm, Filtered (%T)	Lab		69.8	89.7										
		UVT @ 254nm, Unfiltered (%T)	Bench		67.9	81.5										
March 25, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		176	211.6	210.3	206.4	207.5	207.4	209	209.7	211.4	209.5	199.4	
		DO (mg/L)	Bench		10.9	11.4	11.9	11.2	11.1	11.2	11	11.4	11.6	11.4	11.6	
		Manganese, Total (mg/L)	Bench		0.011	0.021	0.014	0.007	0.009	0.009	0.009	0.01	0.01	0.01	0.009	
		Oxi-Red Potenital (ORP) (mV)	Bench		237.2	276.7	376.2	376.2	376	375.7	375	373.8	374.3	376.2	369.8	
		pH	Bench		7.81	6.05	6.06	6.1	6.09	6.08	6.05	6.02	6.07	6.04	6	
		Temperature (ºC)	Bench		5.7	5.2	5.7	6.4	6.5	6.5	6.5	6.3	6.2	6.2	6.2	
		Turbidity (NTU)	Bench		0.8	1.22	1.35	0.22	0.2	0.23	0.18	0.13	0.14	0.18	0.16	
		UVA @254nm, Unfiltered (/cm)	Bench		0.15	0.15	0.13	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	
		UVT @ 254nm, Unfiltered (%T)	Bench		70.7	71	73.2	92.7	92.5	92.7	92.6	93	92.8	92.7	92.3	
	Full-Scale	Temperature (ºC), WTP Train 1	Lab		3.17											
		Temperature (ºC), WTP Train 2	Lab		3.62											
March 26, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		82	17	23	15	15	14	14	15	15	16	18	
		Aluminum, Soluble (mg/L)	Lab			0.01	0.004	0.004	0.01	0.004	0.004	0.004	0.004	0.004	0.01	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Antimony, Soluble (mg/L)	Lab		0.0007	0.0007	0.0007	0.0005	0.001	0.0005	0.0007	0.0006	0.0007	0.0007	0.001	
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00078	0.00044	0.00034	0.00034	0.00034	0.00035	0.00034	0.00034	0.00033	0.00035	0.00033	
		Arsenic, Total (mg/L)	Lab		0.0008											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Calcium, Soluble (mg/L)	Lab		22	21.5	21.8	21	21.8	21.3	21	21.8	21.2	21.1	21.8	
		Calcium, Total (mg/L)	Lab		22.5	21.4	21.8	21.5	21.2	20.7	21.6	21.5	21.6	21.3	23.2	
		Chromium, Soluble (mg/L)	Lab		0.00038	0.00018	0.00016	0.00014	0.00015	0.00014	0.00013	0.00016	0.00016	0.00014	0.00016	
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		15	2.5	1	2	2.5	1	1.5	2	1	2	1	
		Conductivity Total (µS/cm)	Bench		177.65	208.55	207.45	207.4	207.8	208.3	208.4	209.25	211.5	211.15	206.35	
		Copper, Soluble (mg/L)	Lab		0.0005	0.0003	0.0004	0.0007	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0005	
		Copper, Total (mg/L)	Lab	N/D <0.005	G/N											
				N/D at <0.005		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		11	11.3	11.3	11.1	11.1	11.3	11.5	11.4	11.6	11.3	11.7	
		DOC Total (mg/L)	Lab		18.5	9.7	7.9	6.4	7	6.2	6.7	7.1	9.1	7.4	7.6	
		Iron, Soluble (mg/L)	Lab		0.03	0.22	0.01	0.01	0.09	0.04	0.01	0.03	0.02	0.01	0.07	
		Iron, Total (mg/L)	Lab		0.07	1.61	1.74	0.16	0.15	0.15	0.15	0.08	0.07	0.08	0.09	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D <0.0004	G/N											
				N/D at <0.0004		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.54	6.3	6.28	6.35	6.41	6.27	6.2	6.29	6.36	6.31	6.39	
		Magnesium, Total (mg/L)	Lab		6.66	6.23	6.21	6.31	6.18	6.16	6.14	6.36	6.14	6.29	6.68	
		Manganese, Soluble (mg/L)	Lab		0.00061	0.01	0.0068	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.0058	0.012	0.0125	0.009	0.0085	0.0095	0.009	0.0095	0.009	0.009	0.0095	
		Nickel, Soluble (mg/L)	Lab		0.00036	0.0032	0.0032	0.0032	0.0032	0.0032	0.0031	0.0031	0.0031	0.003	0.0031	
		Nickel, Total (mg/L)	Lab			0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	
				N/D <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		248.4	283.5	348.5	339.7	338.7	337.6	330.1	329	324.2	316.4	306.8	
		pH	Bench		7.83	6.095	6.065	6.305	6.305	6.38	6.345	6.22	6.18	6.185	6.15	
		Potassium, Soluble (mg/L)	Lab		1.2	1.19	1.19	1.23	1.2	1.18	1.17	1.18	1.17	1.17	1.19	
		Potassium, Total (mg/L)	Lab		1.21	1.17	1.18	1.19	1.18	1.15	1.14	1.16	1.15	1.2	1.25	
		Sodium, Soluble (mg/L)	Lab		2.61	2.49	2.61	2.99	3.02	2.95	2.86	2.87	2.97	2.94	2.88	
		Sodium, Total (mg/L)	Lab		2.56	2.49	2.61	2.94	2.89	2.93	2.84	2.91	2.95	2.78	2.87	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
					Sample Location											
March 26, 2017	Pilot-Scale	TDSwv (mg/L)	Lab		125	136	131	136	139	135	138	144	143	141	138	
		Temperature (ºC)	Bench		5.6	4.9	5.6	6.5	6.6	6.7	6.6	6.5	6.4	6.4	6.4	
		TSScalc Total (mg/L)	Lab		15	28	31	4	3	19	20		15	9	10	
				N/D at <3								G/N				
		TSwv Total (mg/L)	Lab		140	164	162	140	142	154	158	146	158	150	148	
		Turbidity (NTU)	Bench		0.74	1.21	1.36	0.26	0.25	0.24	0.28	0.13	0.13	0.14	0.14	
			Lab		0.62	1.24	1.43	0.32	0.19	0.21	0.19	0.12	0.12	0.12	0.13	
		Uranium, Soluble (mg/L)	Lab	N/D <0.0005	G/N											
				N/D at <0.0005		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.15	0.14	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		70	79.75	82	91.6	91.45	91.9	91.8	92.2	92.6	92.3	91.3	
		Zinc, Soluble (mg/L)	Lab			0.0017		0.0012	0.0015	0.0011	0.0009	0.001				
				N/D at <0.0009	G/N		G/N						G/N	G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab					0.0001								
				N/D at <0.0001	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	
	Full-Scale	Temperature (ºC), WTP Train 1	Lab		3.19											
		Temperature (ºC), WTP Train 2	Lab		3.63											
March 27, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		167.1	209.3	208.4	210.3	255.5	209.4	206.7	205.2	208.4	207.2	208.3	
		DO (mg/L)	Bench		10	10.7	11.4	10.4	10.3	10.7	10.2	10.6	10.8	10.6	10.1	
		Manganese, Total (mg/L)	Bench		0.011	0.017	0.02	0.012	0.011	0.008	0.011	0.008	0.009	0.01	0.01	
		Oxi-Red Potenital (ORP) (mV)	Bench		321.3	258.8	286.5	288.4	295.8	297.8	302.8	310.5	313	316.7	317.8	
		pH	Bench		7.82	5.97	5.93	6.15	6.13	6.11	6.09	6.02	5.96	6.03	5.98	
		Temperature (ºC)	Bench		5.7	5.4	5.8	6.5	6.4	6.7	6.9	6.7	6.6	6.5	6.4	
		Turbidity (NTU)	Bench		0.73	1.22	1.42	0.28	0.22	0.21	0.32	0.25	0.13	0.17	0.11	
		UVA @254nm, Unfiltered (/cm)	Bench		0.17	0.14	0.13	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		67.3	72.1	74.8	92	92	92.3	91.6	92.6	93.1	93.3	93	
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		79	10										
		Aluminum, Soluble (mg/L)	Lab	N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N											
		Antimony, Soluble (mg/L)	Lab		0.0009											
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N											
		Arsenic, Soluble (mg/L)	Lab		0.00075											
		Arsenic, Total (mg/L)	Lab		0.0008											
		Boron, Soluble (mg/L)	Lab		0.0074											
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N											
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N											
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N											
		Calcium, Soluble (mg/L)	Lab		23.8											
		Calcium, Total (mg/L)	Lab		23.3											
		Chloride (mg/L)	Lab		27	2.6										
		Chlorine, Free(mg/L)	Lab		0.02											
		Chlorine, Total (mg/L)	Lab		0.03											
		Chromium, Soluble (mg/L)	Lab		0.00029											
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N											
		Colour, Apparent	Lab		20											
		Colour, True	Lab		18		2.5									
		Conductivity Total (µS/cm)	Bench		181											
		Copper, Soluble (mg/L)	Lab		0.0008											
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N											
		DO (mg/L)	Bench		13.1	12.7	14.3									14.7
		DOC calc (mg/L)	Lab		22.1	8.3										7.7
		E. Coli-QT(MPNU/100 mL)	Lab		1											
		HardTotal-Colour (mg/LCaCO3)	Lab		87											
		HPC (cfu/mL)	Lab	N/D at <1			G/N									G/N
				Out Err	G/N											
		Iron, Soluble (mg/L)	Lab		0.046	0.233	0.133									0.003
		Iron, Total (mg/L)	Lab		0.077	0.629	0.641									0.035
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N											
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N											
		Magnesium, Soluble (mg/L)	Lab		6.772											
		Magnesium, Total (mg/L)	Lab		6.78											

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 27, 2017	Full-Scale	Manganese, Soluble (mg/L)	Lab		0.0018	0.051	0.04									0.035
		Manganese, Total (mg/L)	Bench		0.0061	0.051	0.049									0.036
		Nickel, Soluble (mg/L)	Lab		0.00054											
		Nickel, Total (mg/L)	Lab	N/D at <0.001	G/N											
		Odour60C (-)	Lab	Musty	G/N											G/N
		Oxi-Red Potenital (ORP) (mV)	Bench		487	495	491									491
		pH	Bench				5.59									
		pH Coliform-QT(units)	Lab		7.75	5.61										5.61
		Potassium, Soluble (mg/L)	Lab		1.28											
		Potassium, Total (mg/L)	Lab		1.25											
		Sodium, Soluble (mg/L)	Lab		2.635											
		Sodium, Total (mg/L)	Lab		2.63											
		Sulfate Coliform-QT(mg/L)	Lab			49										
				N/D at <2	G/N											
		TDSwv Coliform-QT(mg/L)	Lab		115											
		Temperature (ºC), WTP Train 1	Lab		3.28											
		Temperature (ºC), WTP Train 2	Lab		3.68											
		Temperature Coliform-QT(ºC)	Lab		4.9											
		TOC, Total (mg/L)	Lab		23.8	7.1	8.9									6.5
		TON60C Total(T_O_N_60)	Lab		75											5
		Total Coliform-QT(MPNU/100 mL)	Lab		1											
		TSwv Total (mg/L)	Lab		129											
		Turbidity (NTU)	Lab		0.675	0.41	0.63		0.07	0.05	0.08	0.09	0.08	0.06		0.17
				N/D at <0.02					G/N		G/N	G/N	G/N			
				O/L				G/N							G/N	
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N											
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N											
		UVA @254nm, Unfiltered (/cm)	Bench		0.159											
		UVT @ 254nm, Filtered (%T)	Lab		70.3	92.4										
		UVT @ 254nm, Unfiltered (%T)	Bench		69.4	87.1										
		Zinc, Soluble (mg/L)	Lab	N/D at <0.0009	G/N											
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N											
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N											
		Zirconium, Total (mg/L)	Lab	N/D at <0.0001	G/N											
March 28, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		166.7	208.8	208	21.7	209	208.1	207.5	210.4	212	210.8	211.4	
		DO (mg/L)	Bench		10.1	10.5	10	10.6	10.5	10	10.6	10.4	11	10.9	11.1	
		Manganese, Total (mg/L)	Bench		0.013	0.019	0.018	0.014	0.014	0.016	0.014	0.0144	0.011	0.014	0.015	
		Oxi-Red Potenital (ORP) (mV)	Bench		294.2	270.6	292.2	298.9	316	324.7	331.1	337	341.4	349.5	352.4	
		pH	Bench		7.69	5.66	5.6	5.81	5.78	5.83	5.77	5.65	5.6	5.6	5.67	
		Temperature (ºC)	Bench		6.1	5.4	5.7	6.6	6.7	6.6	6.6	6.5	6.5	6.4	6.5	
		Turbidity (NTU)	Bench		0.74	1.23	1.88	0.15	0.12	0.12	0.18	0.11	0.09	0.14	0.11	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.13	0.13	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.1	74.8	73.2	93.1	93.3	93.3	93.1	93.3	93.3	93.7	93.9	
	Full-Scale	Chlorine, Free(mg/L)	Lab		0.02											
		Chlorine, Total (mg/L)	Lab		0.03											
		pH Coliform-QT(units)	Lab		7.75	5.58										
		Temperature (ºC), WTP Train 1	Lab		3.32											
		Temperature (ºC), WTP Train 2	Lab		3.75											
		Temperature Coliform-QT(ºC)	Lab		4.9											
		Turbidity (NTU)	Lab		0.655	0.43		0.08	0.08	0.075			0.09	0.08	0.07	
				N/D at <0.02				G/N	G/N				G/N	G/N	G/N	
				O/L							G/N	G/N				
		UVA @254nm, Unfiltered (/cm)	Bench		0.162											
		UVT @ 254nm, Filtered (%T)	Lab		70.4	91.4										
		UVT @ 254nm, Unfiltered (%T)	Bench		68.9	86.3										
March 29, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		174.6	207.6	211.8	210.8	210.2	209	209.9	212.3	212.2	214.1	212.4	
		DO (mg/L)	Bench		10.8	11	11.7	10.4	10.8	10.7	10.8	11.1	11.1	11	11	
		Manganese, Total (mg/L)	Bench		0.009	0.13	0.016	0.011	0.016	0.012	0.013	0.013	0.014	0.015	0.015	
		Oxi-Red Potenital (ORP) (mV)	Bench		281.4	277	297.3	305.6	311.4	314.3	328.8	334.8	336.3	340.3	339.2	
		pH	Bench		7.8	5.7	5.76	5.93	5.87	5.93	5.9	5.8	5.79	5.79	5.83	
		Temperature (ºC)	Bench		5.2	5.2	5.9	6.4	6.6	6.6	6.5	6.3	6.2	6.2	6.3	
		Turbidity (NTU)	Bench		0.76	1.23	1.55	0.11	0.1	0.1	0.11	0.11	0.11	0.08	0.1	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.12	0.13	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.3	75.1	74.6	94.5	93.7	94.3	94.8	94.3	95	95.1	94.9	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Combined Filtrate**
March 29, 2017	Full-Scale	Chlorine, Free(mg/L)	Lab		0.02											
		Chlorine, Total (mg/L)	Lab		0.02											
		pH Coliform-QT(units)	Lab		7.79	5.62										
		Temperature (ºC), WTP Train 1	Lab		3.42											
		Temperature (ºC), WTP Train 2	Lab		3.83											
		Temperature Coliform-QT(ºC)	Lab		4.9											
		Turbidity (NTU)	Lab		0.67	0.41		0.09			0.07	0.07	0.06	0.08	0.07	
				N/D at <0.02				G/N			G/N	G/N		G/N	G/N	
				O/L					G/N	G/N						
		UVA @254nm, Unfiltered (/cm)	Bench		0.16											
		UVT @ 254nm, Filtered (%T)	Lab		70.6	91.4										
		UVT @ 254nm, Unfiltered (%T)	Bench		69.2	86.5										
March 30, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		82	7	6	7	7	7	7	7	7	7	7	
		Aluminum, Soluble (mg/L)	Lab			0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.02	0.02					0.02	0.01	0.01	0.02	
				N/D at <0.01	G/N			G/N	G/N	G/N	G/N					
		Antimony, Soluble (mg/L)	Lab			0.0008	0.0008	0.0012	0.001	0.0011	0.0012	0.001	0.0008	0.0009	0.0011	
				N/D at <0.0004	G/N											
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00077	0.00027	0.00018	0.0002	0.00022	0.00021	0.00022	0.00022	0.00023	0.00022	0.00025	
		Arsenic, Total (mg/L)	Lab		0.0008											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Calcium, Soluble (mg/L)	Lab		23.3	22.6	22.5	23.1	23.4	23.1	22.6	22.7	22.7	22.4	23.4	
		Calcium, Total (mg/L)	Lab		22.9	22.1	22	22.5	23.1	22.9	22.8	22.7	22.7	22.3	23.2	
		Chromium, Soluble (mg/L)	Lab		0.0001	0.00003	0.00006	0.00005			0.00004	0.00004	0.00003	0.00003		
				N/D at <0.00003					G/N	G/N					G/N	
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		15	2	2	1	1.5	1	0.5	1	0.5	1.5	1	
		Conductivity Total (µS/cm)	Bench		174.2	214.5	210	213.3	211.5	214.3	213.2	213.9	212	212.2	210.5	
			Lab		179	215	215	216	216	217	216	216	216	217	217	
		Copper, Soluble (mg/L)	Lab		0.0004	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0005	
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		10.9	11.1	11.5	11.3	10.8	10.6	10.4	10.8	10.7	10.9	11	
		DOC Total (mg/L)	Lab		26.2	5.6	5	5.3	4.7	4.8	4.7	4.9	4.9	4.1	4.8	
		Iron, Soluble (mg/L)	Lab		0.06	0.22	0.03	0.01			0.003	0.01		0.003	0.002	
				N/D at <0.002					G/N	G/N			G/N			
		Iron, Total (mg/L)	Lab		0.06	1.57	1.52	0.05	0.03	0.02	0.04			0.01		
				N/D at <0.008								G/N	G/N		G/N	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.62	6.41	6.37	6.54	6.39	6.58	6.35	6.38	6.46	6.33	6.52	
		Magnesium, Total (mg/L)	Lab		6.77	6.31	6.21	6.29	6.37	6.41	6.41	6.4	6.37	6.26	6.31	
		Manganese, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.011	0.017	0.015	0.012	0.012	0.014	0.016	0.017	0.014	0.011	0.01	
			Lab		0.0054	0.0099	0.0097	0.0087	0.0088	0.0087	0.0087	0.0087	0.0087	0.0086	0.0086	
		Nickel, Soluble (mg/L)	Lab		0.00045	0.0049	0.0049	0.0048	0.0048	0.0048	0.0048	0.01	0.01	0.0049	0.01	
		Nickel, Total (mg/L)	Lab			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		312	356.9	412.5	399.3	400	401.4	400.6	404.1	400.7	396.1	393	
		pH	Bench		7.82	5.58	5.6	5.8	5.8	5.77	5.75	5.62	5.62	5.65	5.64	
			Lab			5.74	5.79	6.08	6.03	6	6.01	5.76	5.87	5.87	5.86	
		Potassium, Soluble (mg/L)	Lab		1.22	1.2	1.21	1.21	1.2	1.21	1.19	1.19	1.22	1.17	1.2	
		Potassium, Total (mg/L)	Lab		1.22	1.2	1.17	1.17	1.2	1.18	1.22	1.17	1.23	1.17	1.17	
		Sodium, Soluble (mg/L)	Lab		2.68	2.57	3.1	2.81	2.85	2.85	2.76	2.84	2.8	2.98	2.89	
		Sodium, Total (mg/L)	Lab		2.6	2.6	2.68	2.74	2.7	2.79	2.74	2.87	2.77	2.7	2.79	
		TDSwv (mg/L)	Lab		118	141	139	146	141	143	140	147	138	140	141	
		Temperature (ºC)	Bench		5.2	5.2	5.6	6.4	6.5	6.5	6.4	6.4	6.3	6.4	6.6	
			Lab		5.2	5.2	5.6	6.4	6.5	6.5	6.4	6.4	6.3	6.3	6.4	
		TSScalc Total (mg/L)	Lab		4	7	11		7	11	8	7		10	7	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
March 30, 2017	Pilot-Scale	TSScalc Total (mg/L)	Lab	N/D at <3				G/N					G/N			
		TSwv Total (mg/L)	Lab		122	148	150	148	148	154	148	154	140	150	148	
		Turbidity (NTU)	Bench		0.73	1.22	1.35	0.12	0.09	0.1	0.11	0.12	0.07	0.07	0.09	
			Lab		0.61	1.17	1.47	0.19	0.08	0.08	0.08				0.06	
				N/D at <0.05								G/N	G/N	G/N		
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.12	0.12	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		68.6	75.3	76.2	93.5	94	94.2	93.6	93.5	93.5	92.8	93.7	
			Lab		70.5	91.8	93.6	94.5	94.5	94.7	94.5	94.4	94.5	94.4	94.4	
		Zinc, Soluble (mg/L)	Lab	N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab		0.0001											
				N/D at <0.0001		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
	Full-Scale	Chlorine, Free(mg/L)	Lab	N/D at <0.02	G/N											
		Chlorine, Total (mg/L)	Lab		0.02											
		pH	Lab		7.89											
		pH Coliform-QT(units)	Lab		7.75	5.6										
		Temperature (ºC), WTP Train 1	Lab		3.53											
		Temperature (ºC), WTP Train 2	Lab		3.95											
		Temperature Coliform-QT(ºC)	Lab		5.6											
		Turbidity (NTU)	Lab		0.66	0.43			0.07	0.055	0.09	0.08	0.07	0.055	0.12	
				N/D at <0.02					G/N		G/N	G/N	G/N		G/N	
				O/L				G/N								
		UVA @254nm, Unfiltered (/cm)	Bench		0.16											
		UVT @ 254nm, Filtered (%T)	Lab		70.4	91.2										
		UVT @ 254nm, Unfiltered (%T)	Bench		69.2	86.6										
March 31, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		210.6	205.4	205.6	207	206.9	203.6	205.2	207.1	205.8	207.6	207.1	
		DO (mg/L)	Bench		10.8	11	11.2	10.6	10.5	10.2	10.3	10.5	10.3	10.5	10.6	
		Manganese, Total (mg/L)	Bench		0.009	0.014	0.017	0.016	0.013	0.012	0.008	0.011	0.01	0.009	0.008	
		Oxi-Red Potenital (ORP) (mV)	Bench		263.3	299.9	367.9	379.8	381.8	383.1	380.6	381	390.8	392.4	389.9	
		pH	Bench		7.88	5.81	5.86	6.02	6	6.01	5.99	5.9	5.88	5.89	5.88	
		Temperature (ºC)	Bench		5.6	5.6	5.8	6.7	6.8	6.8	6.9	6.8	6.8	6.6	6.5	
		Turbidity (NTU)	Bench		0.77	1.19	1.36	0.27	0.24	0.34	0.22	0.2	0.23	0.23	0.22	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.13	0.12	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.4	74.6	75.4	93.7	93.8	94.2	94	93.7	93.6	93.8	93.3	
	Full-Scale	Chlorine, Free(mg/L)	Lab		0.03											
		Chlorine, Total (mg/L)	Lab		0.03											
		pH Coliform-QT(units)	Lab		7.83	5.65										
		Temperature (ºC), WTP Train 1	Lab		3.59											
		Temperature (ºC), WTP Train 2	Lab		4.02											
		Temperature Coliform-QT(ºC)	Lab		5.3											
		Turbidity (NTU)	Lab		0.695	0.44		0.08	0.08	0.07	0.1		0.09		0.07	
				N/D at <0.02				G/N	G/N		G/N		G/N		G/N	
				O/L								G/N		G/N		
		UVA @254nm, Unfiltered (/cm)	Bench		0.159											
		UVT @ 254nm, Filtered (%T)	Lab		69.6	91										
		UVT @ 254nm, Unfiltered (%T)	Bench		69.3	86.3										
April 1, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		83	9	9	9	9	9	9	9	9	9	9	
		Aluminum, Soluble (mg/L)	Lab			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.02	0.01									
				N/D at <0.01	G/N			G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Antimony, Soluble (mg/L)	Lab		0.0011	0.0012	0.0009	0.0008	0.0009	0.0012	0.0008	0.0004	0.0007	0.0008	0.0008	
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00076	0.00031	0.000021	0.00023	0.00022	0.000223	0.00023	0.00024	0.00024	0.00024	0.00026	
		Arsenic, Total (mg/L)	Lab		0.0008											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Calcium, Soluble (mg/L)	Lab		23.1	21.5	21.9	21.9	21.9	22.4	22.4	21.8	22.1	21.8	22.1	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 1, 2017	Pilot-Scale	Calcium, Total (mg/L)	Lab		22.6	22	21.7	22.1	21.8	22.9	21.8	21.9	22	22.1	21.5	
		Chromium, Soluble (mg/L)	Lab		0.00016		0.00004	0.00003		0.00003	0.00003		0.00004	0.00003		
				N/D at <0.00003		G/N			G/N			G/N			G/N	
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		15	2.5	2.5	1	2	1.5	1.5	2	0.5	2	1	
		Conductivity Total (µS/cm)	Bench		170.1	206.6	203.3	207.2	202.3	207.1	206.6	206.1	202.9	24.3	217.9	
			Lab		176	210	209	211	211	211	210	213	212	211	211	
		Copper, Soluble (mg/L)	Lab		0.0004	0.0003	0.0003	0.0004	0.0006	0.0006	0.0004	0.0004	0.0004	0.0005	0.0004	
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		10.7	11.2	10.8	11	11.3	11	11	10.7	11	10.9	10.7	
		DOC Total (mg/L)	Lab		24	5.8	5	5.9	5.7	5.7	5.8		6.1	6.1	4.8	
				N/D at <0.6								G/N				
		Iron, Soluble (mg/L)	Lab		0.02	0.24	0.21	0.02		0.01	0.02					
				N/D at <0.002					G/N			G/N	G/N	G/N	G/N	
		Iron, Total (mg/L)	Lab		0.06	2.15	2	0.15	0.18	0.12	0.2	0.01	0.01	0.01	0.02	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.46	6.15	6.14	6.17	6.12	6.28	6.24	6.13	6.18	6.12	6.18	
		Magnesium, Total (mg/L)	Lab		6.48	6.22	6.13	6.04	6.22	6.28	6.1	6.12	6.19	6.22	6.12	
		Manganese, Soluble (mg/L)	Lab		0.0011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.014	0.017	0.019	0.0136	0.011	0.014	0.014	0.013	0.011	0.011	0.012	
			Lab		0.0054	0.0088	0.0088	0.0078	0.008	0.0077	0.0076	0.0079	0.0079	0.008	75	
		Nickel, Soluble (mg/L)	Lab		0.00045	0.0041	0.0042	0.0041	0.0041	0.0042	0.0041	0.0042	0.0042	0.0042	0.0042	
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		205.9	268.2	337.7	335.6	336.2	337.2	336.9	337.2	332	328.4	323.5	
		pH	Bench		7.8	5.73	5.79	5.98	5.96	5.94	5.94	5.86	5.84	5.83	5.855	
			Lab		7.91	5.9	5.92	6.07	6.09	6.1	6.07	5.93	5.9	5.85		
		Potassium, Soluble (mg/L)	Lab		1.21	1.15	1.17	1.16	1.18	1.2	1.17	1.17	1.17	1.19	1.2	
		Potassium, Total (mg/L)	Lab		1.21	1.15	1.16	1.15	1.15	1.17	1.18	1.15	1.17	1.16	1.15	
		Sodium, Soluble (mg/L)	Lab		2.6	2.7	2.67	2.88	2.78	2.82	2.88	2.79	2.83	2.8	2.79	
		Sodium, Total (mg/L)	Lab		2.62	2.6	2.59	2.83	2.94	2.77	2.76	2.81	2.72	2.8	2.83	
		TDSwv (mg/L)	Lab		108	126	116	121	122	118	108	120	125	119	136	
		Temperature (ºC)	Bench		5.9	5.6	5.7	6.9	6.9	6.8	6.8	6.8	6.6	6.6	6.7	
			Lab		5.9	5.6	5.7	6.9	6.9	6.8	6.8	6.8		6.6		
		TSScalc Total (mg/L)	Lab		20	10	18	15	34	36	34	16	43	23	10	
		TSwv Total (mg/L)	Lab		128	136	134	136	156	154	142	136	168	142	146	
		Turbidity (NTU)	Bench		0.69	1.53	1.72	0.2	0.12	0.25	0.27	0.06	0.06	0.07	0.07	
			Lab		0.54	1.5	1.79	0.23	0.19	0.17	0.19	0.06	0.05	0.06	0.06	
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.16	0.16	0.04	0.04	0.04	0.05	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.9	68.9	69.4	91.6	91.6	90.8	90.3	93.6	93.8	93.8	93.5	
			Lab		71.2	92	93.3	94.3	94.3	94.5	94.2	94.3	94.1	94.1	94.2	
		Zinc, Soluble (mg/L)	Lab	N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
	Full-Scale	Temperature (ºC), WTP Train 1	Lab		3.69											
		Temperature (ºC), WTP Train 2	Lab		4.02											
April 2, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		87	10	10	9	8	9	11	9	9	9	9	
		Aluminum, Soluble (mg/L)	Lab			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.02	0.01									
				N/D at <0.01	G/N			G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Antimony, Soluble (mg/L)	Lab		0.0009	0.0006	0.001	0.0011	0.0009	0.001	0.0008	0.0009	0.0009	0.001	0.001	
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00069	0.00031	0.00027	0.00019	0.0002	0.00022	0.0002	0.00021	0.0002	0.0002	0.0002	
		Arsenic, Total (mg/L)	Lab		0.0008											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 2, 2017	Pilot-Scale	Calcium, Soluble (mg/L)	Lab		22.8	22.2	21.9	21.9	22.5	22.7	22.9	22.5	22.4	22	21.9	
		Calcium, Total (mg/L)	Lab		22.6	22.6	21.9	21.8	21.6	21.9	22.5	22	22	22	22	
		Chromium, Soluble (mg/L)	Lab		0.00014	0.00008	0.00015								0.00003	
				N/D at <0.00003				G/N	G/N	G/N	G/N	G/N	G/N	G/N		
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		15	1	1.5	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	
		Conductivity Total (µS/cm)	Bench		168.1	207.7	208.2	206.9	206.5	211.2	209.6	208.8	205	208	206.7	
			Lab		178	212	211	211	211	211	211	212	212	212	212	
		Copper, Soluble (mg/L)	Lab		0.0005	0.0004	0.0003	0.0005	0.0005	0.0004	0.0006	0.0004	0.0004	0.0004	0.0004	
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		10.5	11.1	11.6	10.8	10.9	10.9	10.7	11.1	10.7	10.8	10.9	
		DOC Total (mg/L)	Lab		25	5.9	6.7	4.7	4.8	5.6	5.2	5.6	6.3		5.7	
				N/D at <0.6										G/N		
		Iron, Soluble (mg/L)	Lab		0.02	0.5	0.9		0.01					0.003		
				N/D at <0.002				G/N		G/N	G/N	G/N	G/N		G/N	
		Iron, Total (mg/L)	Lab		0.06	2.04	1.91	0.04	0.04	0.04	0.04		0.01	0.01		
				N/D at <0.008								G/N			G/N	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab		0.0006											
				N/D at <0.0004		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.48	6.1	6.16	6.28	6.32	6.37	6.53	6.44	6.3	6.28	6.29	
		Magnesium, Total (mg/L)	Lab		6.35	6.16	6.17	6.18	6.24	6.25	6.37	6.22	6.23	6.22	6.21	
		Manganese, Soluble (mg/L)	Lab		0.00095	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.016	0.022	0.023	0.018	0.018	0.016	0.016	0.016	0.014	0.015	0.013	
			Lab		0.0049	0.011	0.0089	0.0074	0.0074	0.0073	0.0076	0.0075	0.0077	0.0087	0.0076	
		Nickel, Soluble (mg/L)	Lab		0.00047	0.0042	0.0042	0.004	0.0041	0.0041	0.0042	0.0042	0.0043	0.0042	0.0042	
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		217	287.8	394.5	395.1	394.6	393.4	390.4	388.7	386.2	379.9	367.6	
		pH	Bench		7.78	5.97	5.8	6.01	5.98	5.99	5.95	5.9	5.87	5.82	5.86	
			Lab		7.92	5.88	5.91	6.14	6.09	6.06	6.02	5.95	5.92	5.93	5.92	
		Potassium, Soluble (mg/L)	Lab		1.24	1.17	1.17	1.19	1.21	1.24	1.21	1.2	1.2	1.19	1.18	
		Potassium, Total (mg/L)	Lab		1.17	1.17	1.14	1.2	1.16	1.2	1.22	1.18	1.21	1.18	1.18	
		Sodium, Soluble (mg/L)	Lab		2.62	2.66	2.66	2.74	2.81	3	2.88	3.05	2.83	2.75	2.8	
		Sodium, Total (mg/L)	Lab		2.61	2.54	2.63	2.7	2.81	2.77	2.87	2.61	2.77	3.24	2.85	
		TDSwv (mg/L)	Lab		112	133	127	137	129	130	135	136	133	131	126	
		Temperature (ºC)	Bench		6.1	5.7	5.9	6.6	6.9	6.9	6.9	6.9	6.8	6.8	6.9	
			Lab		6.1	5.7	5.9	6.6	6.9	6.9	6.9	6.9	6.8	6.8	6.9	
		TSScalc Total (mg/L)	Lab		4	9	15	3	3		15	6		13	24	
				N/D at <3						G/N			G/N			
		TSwv Total (mg/L)	Lab		116	142	142	140	132	132	150	142	134	144	150	
		Turbidity (NTU)	Bench		0.69	1.43	1.53	0.16	0.12	0.1	0.1	0.06	0.05	0.09	0.07	
			Lab		0.56	1.52	1.64	0.17	0.08	0.1	0.11	0.09	0.06	0.11	0.07	
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.15	0.15	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.6	70.5	71.6	93.2	93.5	93.7	93.4	93.4	93.5	93.9	94	
			Lab		72.5	93.1	94.7	96	96.5	96.2	96.3	96.2	95.2	96	96.3	
		Zinc, Soluble (mg/L)	Lab										0.0025			
				N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
	Full-Scale	Temperature (ºC), WTP Train 1	Lab		3.75											
		Temperature (ºC), WTP Train 2	Lab		4.11											
April 3, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		171.2	211.2	215.7	206.8	204.5	204.4	205.7	505.5	203.9	203.2	205	
		DO (mg/L)	Bench		10.8	10.9	11.4	10.7	10.4	10.5	10.6	10.9	10.7	10.4	10.3	
		Manganese, Total (mg/L)	Bench		0.011	0.023	0.021	0.013	0.013	0.015	0.012	0.016	0.014	0.015	0.011	
		Oxi-Red Potenital (ORP) (mV)	Bench		257	249.8	288.8	292.9	307.7	312.3	320.1	334.5	335.9	335.6	337.7	
		pH	Bench		7.92	5.73	5.74	5.95	5.9	5.89	5.89	5.82	5.83	5.75	5.8	
		Temperature (ºC)	Bench		6	5.8	6.2	7.2	7.2	7.2	7.1	7	7.1	7.1	6.9	
		Turbidity (NTU)	Bench		0.85	1.7	1.9	0.17	0.1	0.15	0.19	0.07	0.08	0.13	0.08	
		UVA @254nm, Unfiltered (/cm)	Bench		0.15	0.16	0.15	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
		UVT @ 254nm, Unfiltered (%T)	Bench		69.1	70	71.1	94.1	94.3	93	94.1	94.4	94.2	94.2	94	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 3, 2017	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		79	8										
		Chloride (mg/L)	Lab		2.3	25										
		Chlorine, Free(mg/L)	Lab	N/D at <0.02	G/N											
		Chlorine, Total (mg/L)	Lab	N/D at <0.02	G/N											
		Colour, Apparent	Lab		20											
		Colour, True	Lab		14		1									
		Conductivity Total (µS/cm)	Bench		176											
		DO (mg/L)	Bench		12.5	12	14.1									14.3
		DOC calc (mg/L)	Lab		24	6.1										
		E. Coli-QT(MPNU/100 mL)	Lab	Data not recv	G/N											
		HardTotal-Colour (mg/LCaCO3)	Lab		87											
		HPC (cfu/mL)	Lab													1
				Data not recv	G/N											
				N/D at <1			G/N									
		Iron, Soluble (mg/L)	Lab			0.163	0.145									
				N/D at <0.002												G/N
		Iron, Total (mg/L)	Lab			0.625	0.601									0.05
		Manganese, Soluble (mg/L)	Lab			0.049	0.036									0.034
		Manganese, Total (mg/L)	Bench			0.05	0.048									0.037
		Odour60C (-)	Lab	Grassy	G/N											
				Musty												G/N
		Oxi-Red Potenital (ORP) (mV)	Bench	Data not recv	G/N	G/N	G/N									G/N
		pH	Bench				5.59									
		pH Coliform-QT(units)	Lab		7.88	5.57										5.5
		Sulfate Coliform-QT(mg/L)	Lab			47										
				N/D at <2	G/N											
		TDSwv Coliform-QT(mg/L)	Lab		111											
		Temperature (ºC), WTP Train 1	Lab		3.83											
		Temperature (ºC), WTP Train 2	Lab		4.18											
		Temperature Coliform-QT(ºC)	Lab		5.5											
		ThmBDCM Coliform-QT(ug/L)	Lab	N/D at <0.4	G/N											
		ThmCHBr3 Coliform-QT(ug/L)	Lab	N/D at <0.2	G/N											
		ThmCHCl3 Coliform-QT(ug/L)	Lab	N/D at <0.7	G/N											
		ThmCHCl3 Total(ug/L)	Lab	N/D at <0.7			G/N									
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N		G/N									
		ThmTotal,calc_ Total(ug/L)	Lab	N/D at <3	G/N		G/N									
		TOC, Total (mg/L)	Lab		24	6.2	6.5									6.2
		TON60C Total(T_O_N_60)	Lab		75											10
		Total Coliform-QT(MPNU/100 mL)	Lab	Data not recv	G/N											
		TSwv Total (mg/L)	Lab	Data not recv	G/N											
		Turbidity (NTU)	Lab		0.69	0.45	0.69	0.08	0.08	0.065	0.1		0.07		0.06	0.1
				N/D at <0.02				G/N	G/N		G/N		G/N		G/N	
				O/L								G/N		G/N		
		UVA @254nm, Unfiltered (/cm)	Bench		0.148											
		UVT @ 254nm, Filtered (%T)	Lab		72.9	93.4										
		UVT @ 254nm, Unfiltered (%T)	Bench		71.2	88.3										
April 4, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		81	8	7	7	7	7	8	7	7	7	8	
		Aluminum, Soluble (mg/L)	Lab			0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.02	0.02					0.01	0.01	0.01	0.01	
				N/D at <0.01	G/N			G/N	G/N	G/N	G/N					
		Antimony, Soluble (mg/L)	Lab		0.0007	0.0009	0.0008	0.0007	0.0006	0.0006	0.0009	0.001	0.0008	0.0007	0.0007	
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00069	0.00027	0.00027	0.00017	0.00017	0.00017	0.00019	0.00017	0.00016	0.0002	0.0002	
		Arsenic, Total (mg/L)	Lab		0.0007											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Calcium, Soluble (mg/L)	Lab		22.3	22	21.4	21.9	21.7	22	22.3	22.6	21.8	21.7	22.1	
		Calcium, Total (mg/L)	Lab		21.8	21.8	21.7	21.5	21.9	22	22.3	21.8	22.1	21.5	22	
		Chloride (mg/L)	Lab		1.9			2.2	2.3	2.1	2.1	2.1	2.1	2.4	2.3	
		Chromium, Soluble (mg/L)	Lab		0.00021	0.00009	0.00024	0.00003			0.00004	0.00003			0.00011	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
					Sample Location											
April 4, 2017	Pilot-Scale	Chromium, Soluble (mg/L)	Lab	N/D at <0.00003					G/N	G/N			G/N	G/N		
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		15	2.5	1	0.5	0.5	0.5	1	1	1	1	1	
		Conductivity Total (µS/cm)	Bench		174.4	210	210	209.8	211.1	211.5	210.8	211.2	212.2	210.2	201.6	230.6
			Lab		176	211	211	212	213	213	213	212	212	212	213	
		Copper, Soluble (mg/L)	Lab		0.00021	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0004	0.0003	
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		10.7	10.3	11	10.8	10.8	10.4	10.2	10.8	10.8	10.8	10.6	10.3
		DOC Total (mg/L)	Lab		28	4.9	4.6	5.2	4.8	5.5	5.7	5.1	5.6	6.9	5.8	
		HaaBCAA Total(ug/L)	Lab	N/D at <0.6	G/N	G/N										G/N
		HaaDBAA (ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		HaaDCAA Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3	G/N	G/N										G/N
		HaaMCAA (ug/L)	Lab			0.3										
				N/D at <0.3	G/N											G/N
		HaaTCAA (ug/L)	Lab	N/D at <0.7	G/N	G/N										G/N
		HaaTotal, calc_(ug/L)	Lab	N/D at <3	G/N	G/N										
		Hardness, Total calc (mg/L CaC..	Lab		80.2	80.1		78.8	80.7	80.4	81.4	80.2	81	78.9	80.5	
		Iron, Soluble (mg/L)	Lab		0.02	0.46	1.33	0.003	0.01		0.08					
				N/D at <0.002						G/N		G/N	G/N	G/N	G/N	
		Iron, Total (mg/L)	Lab		0.05	1.92	1.89	0.12	0.12	0.09	0.14					
				N/D at <0.008								G/N	G/N	G/N	G/N	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.4	6.24	6.02	6.31	6.23	6.18	6.38	6.27	6.29	6.23	6.2	
		Magnesium, Total (mg/L)	Lab		6.24	6.2	6.27	6.1	6.32	6.22	6.25	6.22	6.28	6.13	6.24	
		Manganese, Soluble (mg/L)	Lab		0.00058	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.012	0.02	0.019	0.013	0.014	0.017	0.015	0.013	0.014	0.012	0.014	0.012
			Lab		0.0045	0.0092	0.0095	0.0082	0.0081	0.0081	0.0082	0.011	0.0082	0.0078	0.0079	
		Nickel, Soluble (mg/L)	Lab		0.00045	0.0045	0.0044	0.0044	0.0044	0.0045	0.0045	0.0046	0.0046	0.0046	0.0046	
		Nickel, Total (mg/L)	Lab			0.01	0.004	0.004	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		232.8	282.8	372.2	378.1	380.2	381.4	383.3	387.1	367.9	365.4	360.5	349.1
		pH	Bench		7.83	5.63	5.67	5.86	5.84	5.82	5.81	5.68	5.73	5.72	5.7	5.83
			Lab		7.92	5.72	5.71	5.98	5.95	5.92	5.88	5.93	5.82	5.82	5.77	
		Potassium, Soluble (mg/L)	Lab		1.2	1.15	1.14	1.17	1.17	1.19	1.21	1.18	1.14	1.2	1.17	
		Potassium, Total (mg/L)	Lab		1.17	1.16	1.15	1.14	1.18	1.17	1.2	1.16	1.19	1.12	1.16	
		Sodium, Soluble (mg/L)	Lab		2.58	2.61	2.64	2.83	2.96	2.82	2.86	2.91	2.85	2.81	2.92	
		Sodium, Total (mg/L)	Lab		2.57	2.47	2.57	2.91	2.88	2.84	2.91	3.61	2.86	2.75	2.78	
		Sulfate (mg/L)	Lab					82	83	78	79	80	81	83	80	
				N/D at <2	G/N											
		TDSwv (mg/L)	Lab		116	124	126	137	133	135	134	124	140	135	136	
		Temperature (ºC)	Bench		6.4	5.9	6.2		6.9	6.9		6.8	6.7	6.7	6.6	7.1
			Lab		6.4	5.9	6.2	6.6	6.9	6.9	7.2	6.8	6.7	6.7	6.6	
		ThmBDCM Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N	G/N										G/N
		ThmCHCl3 Total(ug/L)	Lab	N/D at <0.7	G/N	G/N										G/N
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		ThmTotal,calc_ Total(ug/L)	Lab	N/D at <0.6												G/N
				N/D at <3	G/N	G/N										
		TSScalc Total (mg/L)	Lab		10	42	24	7	17	19	20	22	16	5	6	
		TSwv Total (mg/L)	Lab		126	166	150	144	150	154	154	146	156	140	142	
		Turbidity (NTU)	Bench		0.95	1.53	2.12	0.26	0.26	0.3	0.29	0.12	0.12	0.12	0.08	0.09
			Lab		0.53	1.36	1.54	0.18	0.13	0.12	0.15	0.07			0.05	
				N/D at <0.05									G/N	G/N		G/N
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.16	0.14	0.14	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03
		UVT @ 254nm, Unfiltered (%T)	Bench		69.2	72.1	72.5	93.1	92.9	93.8	92.5	95	95.6	95	95.4	93.7
			Lab		71.9	93.1	94.5	95	95.1	95	95.1	95	94.9	95	95	
		Zinc, Soluble (mg/L)	Lab	N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 4, 2017	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		85	8	8	9			9	8	6	6	6	
				O/L					G/N	G/N						
		Aluminum, Soluble (mg/L)	Lab			0.02	0.02	0.02			0.02	0.02	0.02	0.02	0.02	
				N/D at <0.002	G/N											
				O/L					G/N	G/N						
		Aluminum, Total (mg/L)	Lab			0.02	0.02	0.02			0.01	0.02	0.02	0.02	0.02	
				N/D at <0.01	G/N											
				O/L					G/N	G/N						
		Antimony, Soluble (mg/L)	Lab		0.0008	0.0007	0.0008	0.0007			0.0009	0.0007	0.0009	0.0009	0.001	
				O/L					G/N	G/N						
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Arsenic, Soluble (mg/L)	Lab		0.00068	0.00033	0.00033	0.00025			0.00022	0.00025	0.00028	0.00028	0.00027	
				O/L					G/N	G/N						
		Arsenic, Total (mg/L)	Lab		0.0007											
				N/D at <0.0007		G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01			0.01	0.01	0.01	0.01	0.01	
				O/L					G/N	G/N						
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Calcium, Soluble (mg/L)	Lab		22.9	21.5	22.1	21.3			22.1	21.3	22	21.4	21.7	
				O/L					G/N	G/N						
		Calcium, Total (mg/L)	Lab		22.2	24.1	21.5	21.7			21.3	21.7	22.1	21.4	21.5	
				O/L					G/N	G/N						
		Chloride (mg/L)	Lab		2.1											
		Chlorine, Free(mg/L)	Lab	N/D at <0.02	G/N											
		Chlorine, Total (mg/L)	Lab		0.02											
		Chromium, Soluble (mg/L)	Lab		0.00019	0.00011	0.00024	0.00019			0.00019	0.00017	0.00013	0.00014	0.0001	
				O/L					G/N	G/N						
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Colour, True	Lab		13	1.5	1	0.5			0.5	0.5	0.5	0.5	0.5	
				O/L					G/N	G/N						
		Conductivity Total (µS/cm)	Bench	O/L						G/N						
			Lab		177	218	218	217			218	219	222	221	223	
				O/L					G/N							
		Copper, Soluble (mg/L)	Lab		0.00019	0.0035	0.0036	0.0027			0.0029	0.003	0.0032	0.0043	0.0029	
				O/L					G/N	G/N						
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		DOC Total (mg/L)	Lab		28	6.4	6.2	7.8			7.4	6.4	4.9	7.2	8	
				O/L					G/N	G/N						
		HaaBCAA Total(ug/L)	Lab	N/D at <0.6	G/N	G/N										G/N
		HaaDBAA (ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		HaaDCAA Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3	G/N											G/N
		HaaMCAA (ug/L)	Lab	N/D at <0.3	G/N											G/N
		HaaTCAA (ug/L)	Lab	N/D at <0.7	G/N											G/N
		HaaTotal, calc_(ug/L)	Lab	N/D at <3	G/N											G/N
		Hardness, Total calc (mg/L CaC..	Lab		80.8	88.4										
		Iron, Soluble (mg/L)	Lab		0.02	0.14	0.36				0.01	0.02	0.004	0.003	0.003	
				N/D at <0.002				G/N								
				O/L					G/N	G/N						
		Iron, Total (mg/L)	Lab		0.05	0.56	0.53	0.02			0.02	0.02	0.03	0.02	0.01	
				O/L					G/N	G/N						
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 4, 2017	Full-Scale	Magnesium, Soluble (mg/L)	Lab		6.28	6.09	6.04	6.05			6.32	6.07	6.17	6.36	6.19	
				O/L					G/N	G/N						
		Magnesium, Total (mg/L)	Lab		6.17	6.82	6	6.11			6.16	6.18	6.23	6.13	6.06	
				O/L					G/N	G/N						
		Manganese, Soluble (mg/L)	Lab		0.0011	0.05	0.04	0.04			0.03	0.04	0.04	0.04	0.04	
				O/L					G/N	G/N						
		Manganese, Total (mg/L)	Lab		0.0055	0.049	0.047	0.036			0.034	0.035	0.038	0.039	0.043	
				O/L					G/N	G/N						
		Nickel, Soluble (mg/L)	Lab		0.00043	0.0028	0.0028	0.0028			0.0028	0.0028	0.0029	0.00296	0.0029	
				O/L					G/N	G/N						
		Nickel, Total (mg/L)	Lab			0.003	0.003	0.003			0.003	0.003	0.003	0.003	0.003	
				N/D at <0.001	G/N											
				O/L					G/N	G/N						
		Odour60C (-)	Lab	Musty	G/N											G/N
		pH	Lab		7.95	5.74	5.68	5.78			5.75	5.67	5.58	5.6	5.61	
				O/L					G/N	G/N						
		pH Coliform-QT(units)	Lab		7.89	5.56										
		Potassium, Soluble (mg/L)	Lab		1.19	1.14	1.16	1.13			1.16	1.12	1.17	1.16	1.15	
				O/L					G/N	G/N						
		Potassium, Total (mg/L)	Lab		1.19	1.29	1.18	1.14			1.14	1.12	1.17	1.14	1.17	
				O/L					G/N	G/N						
		Sodium, Soluble (mg/L)	Lab		2.51	2.71	2.61	2.9			2.95	3	2.99	3.05	3	
				O/L					G/N	G/N						
		Sodium, Total (mg/L)	Lab		2.58	2.61	2.56	2.93			2.96	2.97	2.93	2.92	2.87	
				O/L					G/N	G/N						
		Sulfate (mg/L)	Lab			45										
				N/D at <2	G/N											
		TDSwv (mg/L)	Lab		108	122	135	130			131	130	129	135	112	
				O/L					G/N	G/N						
		Temperature (ºC)	Bench					6			5.9					
			Lab			6.2	5.8					5.7	6.1	5.8	5.8	
				O/L					G/N	G/N						
		Temperature (ºC), WTP Train 1	Lab		4.02											
		Temperature (ºC), WTP Train 2	Lab		4.26											
		Temperature Coliform-QT(ºC)	Lab		5.6											
		ThmBDCM Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N	G/N										G/N
		ThmCHCl3 Total(ug/L)	Lab	N/D at <0.7	G/N	G/N										G/N
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		ThmTotal,calc_ Total(ug/L)	Lab	N/D at <3	G/N	G/N										G/N
		TON60C Total(T_O_N_60)	Lab		80											10
		TSScalc Total (mg/L)	Lab		8	36	11	24			19	22	41	31	52	
				O/L					G/N	G/N						
		TSwv Total (mg/L)	Lab		116	158	146	154			150	152	170	166	164	
				O/L					G/N	G/N						
		Turbidity (NTU)	Lab		0.69	0.42	0.56	0.08			0.1	0.075	0.115	0.075	0.065	
				N/D at <0.02				G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		UVA @254nm, Unfiltered (/cm)	Bench		0.157											
		UVT @ 254nm, Filtered (%T)	Lab		71.1	92										
		UVT @ 254nm, Unfiltered (%T)	Bench		69.7	86.3										
			Lab		70.8	92.4	94.5	94.7			95.1	94.6	94.8	95.2	95.4	
				O/L					G/N	G/N						
		Zinc, Soluble (mg/L)	Lab								0.0033					
				N/D at <0.0009	G/N	G/N	G/N	G/N				G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 4, 2017	Full-Scale	Zirconium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	
				O/L					G/N	G/N						
April 5, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		81	7	8	7	7	7	8	8	8	8	8	
		Aluminum, Soluble (mg/L)	Lab			0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.02	0.02					0.01	0.01	0.01	0.01	
				N/D at <0.01	G/N			G/N	G/N	G/N	G/N					
		Antimony, Soluble (mg/L)	Lab		0.0011	0.0011	0.0012	0.0006	0.0008	0.0006	0.0008	0.0011	0.0008	0.0009	0.0006	
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00067	0.00026	0.00016	0.00015	0.00019	0.00018	0.00017	0.00017	0.00016	0.00017	0.00019	
		Arsenic, Total (mg/L)	Lab		0.0007											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Calcium, Soluble (mg/L)	Lab		22.1	22.3	21.6	21.8	21.8	22.1	22.2	21.5	21.8	21.7	21.9	
		Calcium, Total (mg/L)	Lab		22.2	21.5	21.2	21.6	21.8	21.9	21.3	22	22.4	22	22.1	
		Chloride (mg/L)	Lab		1.8			2.2	2.3	2.3	2.3	2.4	2.4	2	2.2	
		Chromium, Soluble (mg/L)	Lab		0.00016	0.00004	0.00005		0.00005		0.00003	0.00003	0.00004	0.00004		
				N/D at <0.00003				G/N		G/N					G/N	
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Colour, True	Lab		12	1	1	0.5	0.5	0.5	1	1	1	1	0.5	
		Conductivity Total (µS/cm)	Bench		171.6	207	206.1	208.3	207.1	208.5	208.5	212.3	209	210.9	207.7	216.1
			Lab		175	212	209	211	211	212	213	213	214	213	212	
		Copper, Soluble (mg/L)	Lab		0.0004	0.0006	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0015	0.0004	
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		10.8	10.4	11	10.6	10.1	10.1	10.6	10.8	10.6	11.1	10.9	11.3
		DOC Total (mg/L)	Lab		24.6	5.7	6	5.4	5.2	5.5	5.7	5.2	5.6	5.8	5.4	
		HaaBCAA Total(ug/L)	Lab	N/D at <0.6	G/N	G/N										G/N
		HaaDBAA (ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		HaaDCAA Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3	G/N	G/N										G/N
		HaaMCAA (ug/L)	Lab		0.4											
				N/D at <0.3		G/N										G/N
		HaaTCAA (ug/L)	Lab	N/D at <0.7	G/N	G/N										G/N
		HaaTotal, calc_(ug/L)	Lab	N/D at <3	G/N	G/N										G/N
		Hardness, Total calc (mg/L CaC..	Lab		81.7	79.1		79	79.7	80.3	78.3	80.5	81.7	80.3	81.1	
		Iron, Soluble (mg/L)	Lab		0.03	0.36	0.05		0.12		0.06					
				N/D at <0.002				G/N		G/N		G/N	G/N	G/N	G/N	
		Iron, Total (mg/L)	Lab		0.05	1.98	2.08	0.16	0.2	0.09	0.2					
				N/D at <0.008								G/N	G/N	G/N	G/N	
		Lead, Soluble (mg/L)	Lab			0.00014										
				N/D at <0.00004	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Magnesium, Soluble (mg/L)	Lab		6.37	6.07	6.1	6.15	6.16	6.13	6.2	6.25	6.28	6.14	6.11	
		Magnesium, Total (mg/L)	Lab		6.36	6.18	6.04	6.1	6.18	6.24	6.1	6.23	6.24	6.16	6.26	
		Manganese, Soluble (mg/L)	Lab		0.0027	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Manganese, Total (mg/L)	Bench		0.018	0.029	0.025	0.016	0.016	0.017	0.017	0.016	0.019	0.012	0.013	0.017
			Lab		0.0044	0.0092	0.0092	0.0081	0.0082	0.0081	0.0082	0.0082	0.0083	0.0082	0.0085	
		Nickel, Soluble (mg/L)	Lab		0.00044	0.0044	0.0045	0.0044	0.0045	0.0044	0.0045	0.0046	0.0046	0.0047	0.0046	
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.01	0.004	0.01	0.01	0.01	0.01	
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		210.9	267.6	340.4	343.9	342.4	341.5	341.7	342.5	338.1	334.1	329.2	305.9
		pH	Bench		7.88	5.66	5.64	5.85	5.81	5.86	5.82	5.59	5.7	5.77	5.65	5.78
			Lab		7.91	5.67	5.67	5.87	5.81	5.89	5.79	5.71	5.76	5.75	5.72	
		Potassium, Soluble (mg/L)	Lab		1.17	1.17	1.17	1.16	1.16	1.18	1.17	1.19	1.16	1.16	1.19	
		Potassium, Total (mg/L)	Lab		1.17	1.13	1.14	1.15	1.16	1.18	1.09	1.21	1.17	1.17	1.17	
		Sodium, Soluble (mg/L)	Lab		2.57	2.63	2.53	2.74	2.79	2.8	2.88	2.83	3.03	2.77	2.77	
		Sodium, Total (mg/L)	Lab		2.53	2.42	2.55	2.74	2.7	2.65	2.72	2.72	2.73	2.78	2.9	
		Sulfate (mg/L)	Lab					80	81	79	79	79	81	79	79	
				N/D at <2	G/N											
		TDSwv (mg/L)	Lab		103	115	114	124	125	119	115	155	151	158	150	
		Temperature (ºC)	Bench		6.2	6	6.3	7.3	7.3	7.1	7.1	7	6.9	6.9	7	7.4

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 5, 2017	Pilot-Scale	Temperature (ºC)	Lab		6.2	6	6.3	7.3	7.3	7.1	7.1	7	6.9	6.9	7	7.4
		ThmBDCM Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N	G/N										G/N
		ThmCHCl3 Total(ug/L)	Lab	N/D at <0.7	G/N	G/N										G/N
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		ThmTotal,calc_ Total(ug/L)	Lab	N/D at <3	G/N	G/N										G/N
		TSScalc Total (mg/L)	Lab		23	39	46	24	35	35	35	19	7	50	20	
		TSwv Total (mg/L)	Lab		126	154	160	148	160	154	150	174	158	208	170	
		Turbidity (NTU)	Bench		0.62	1.51	3.04	0.4	0.39	0.21	0.23	0.04	0.04	0.05	0.06	0.18
			Lab		0.6	1.37	1.57	1.94	2.06	0.59	0.5		0.05	0.46	0.06	
				N/D at <0.05								G/N				
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.15	0.14	0.14	0.03	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02
		UVT @ 254nm, Unfiltered (%T)	Bench		70.7	72.7	73.2	92.5	92	93.9	94.3	95.2	95.6	95.5	95.1	94.7
			Lab		72.3	93.2	94.1	94.5	94.9	95.4	94.8	95.1	95.3	94.9	94.7	
		Zinc, Soluble (mg/L)	Lab								0.0011					
				N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Zirconium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		90	7	9		10	10	9	7	6	6		
				O/L				G/N							G/N	
		Aluminum, Soluble (mg/L)	Lab			0.02	0.02		0.02	0.02	0.02	0.02	0.02	0.02		
				N/D at <0.002	G/N											
				O/L				G/N							G/N	
		Aluminum, Total (mg/L)	Lab			0.02	0.02		0.02	0.02	0.02	0.02	0.02	0.02		
				N/D at <0.01	G/N											
				O/L				G/N							G/N	
		Antimony, Soluble (mg/L)	Lab		0.0007	0.0008	0.0007		0.0007	0.0008	0.001	0.0008	0.0007	0.0007		
				O/L				G/N							G/N	
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Arsenic, Soluble (mg/L)	Lab		0.00068	0.00036	0.00022		0.00025		0.00023	0.00027	0.00025	0.00025		
				O/L				G/N		G/N					G/N	
		Arsenic, Total (mg/L)	Lab		0.0007											
				N/D at <0.0007		G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Boron, Soluble (mg/L)	Lab		0.01	0.01	0.01		0.01	0.01	0.01	0.01	0.01	0.01		
				O/L				G/N							G/N	
		Boron, Total (mg/L)	Lab	N/D at <0.009	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Calcium, Soluble (mg/L)	Lab		22.6	21.7	21.7		22	22	21.8	22.1	22.3	21.5		
				O/L				G/N							G/N	
		Calcium, Total (mg/L)	Lab		23	22.1	21.2		22	21.8	21.7	22.1	22.3	22.1		
				O/L				G/N							G/N	
		Chloride (mg/L)	Lab		1.9											
		Chlorine, Free(mg/L)	Lab	N/D at <0.02	G/N											
		Chlorine, Total (mg/L)	Lab	N/D at <0.02	G/N											
		Chromium, Soluble (mg/L)	Lab		0.00017	0.00021	0.00018		0.00016	0.00015	0.00015	0.00013	0.00013	0.0001		
				O/L				G/N							G/N	
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Colour, True	Lab		13	1	1		1	0.5	0.5	1	1	0.5		
				O/L				G/N							G/N	
		Conductivity Total (µS/cm)	Lab		175	218	214		218	218	219	223	221	222		
				O/L				G/N							G/N	
		Copper, Soluble (mg/L)	Lab		0.0004	0.0037	0.003		0.0026	0.0026	0.0028	0.0033	0.0034	0.0031		
				O/L				G/N							G/N	
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 5, 2017	Full-Scale	Copper, Total (mg/L)	Lab	O/L				G/N							G/N	
		DOC Total (mg/L)	Lab	Data not recv	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		HaaBCAA Total(ug/L)	Lab	N/D at <0.6	G/N	G/N										G/N
		HaaDBAA (ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		HaaDCAA Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3	G/N											G/N
		HaaMCAA (ug/L)	Lab													0.3
				N/D at <0.3	G/N											
		HaaTCAA (ug/L)	Lab	N/D at <0.7	G/N											G/N
		HaaTotal, calc_(ug/L)	Lab	N/D at <3	G/N											G/N
		Hardness, Total calc (mg/L CaC..	Lab		84.1	80.9										
		Iron, Soluble (mg/L)	Lab		0.04	0.28	0.02		0.002	0.003	0.01	0.01	0.003			
				N/D at <0.002										G/N		
				O/L				G/N							G/N	
		Iron, Total (mg/L)	Lab		0.07	0.54	0.6		0.02	0.02	0.02	0.02	0.02	0.03		
				O/L				G/N							G/N	
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Magnesium, Soluble (mg/L)	Lab		6.36	6.15	6.18		6.33	6.3	6.32	6.44	6.33	6.27		
				O/L				G/N							G/N	
		Magnesium, Total (mg/L)	Lab		6.45	6.25	6.11		6.25	6.3	6.15	6.28	6.28	6.33		
				O/L				G/N							G/N	
		Manganese, Soluble (mg/L)	Lab		0.0024	0.05	0.01		0.03	0.03	0.04	0.04	0.04	0.04		
				O/L				G/N							G/N	
		Manganese, Total (mg/L)	Lab		0.006	0.048	0.047		0.034	0.0037	0.034	0.034	0.039	0.037		
				O/L				G/N							G/N	
		Nickel, Soluble (mg/L)	Lab		0.00046	0.0028	0.0028		0.0028	0.0028	0.0028	0.0029	0.0034	0.0029		
				O/L				G/N							G/N	
		Nickel, Total (mg/L)	Lab			0.003	0.003		0.003	0.003	0.003	0.003	0.004	0.003		
				N/D at <0.001	G/N											
				O/L				G/N							G/N	
		Odour60C (-)	Lab	Fishy	G/N											
				Weedy												G/N
		pH	Lab		8.02	5.52	5.78		5.68	5.74	5.68	5.47	5.48	5.5		
				O/L				G/N							G/N	
		pH Coliform-QT(units)	Lab		7.81	5.5										
		Potassium, Soluble (mg/L)	Lab		1.23	1.18	1.18		1.18	1.17	1.19	1.18	1.2	1.19		
				O/L				G/N							G/N	
		Potassium, Total (mg/L)	Lab		1.22	1.16	1.14		1.18	1.17	1.14	1.16	1.21	1.2		
				O/L				G/N							G/N	
		Sodium, Soluble (mg/L)	Lab		2.65	2.58	2.63		2.97	3.07	3.87	3.02	2.95	3.02		
				O/L				G/N							G/N	
		Sodium, Total (mg/L)	Lab		2.59	2.54	2.61		2.94	2.89	2.91	2.89	2.9	2.86		
				O/L				G/N							G/N	
		Sulfate (mg/L)	Lab			46										
				N/D at <2	G/N											
		TDSwv (mg/L)	Lab		124	163	168		152	166	170	159	174	161		
				O/L				G/N							G/N	
		Temperature (ºC)	Lab			5.6	5.6		6.1	5.9	6.2	5.9	6.5	6.2		5.9
				O/L				G/N							G/N	
		Temperature Coliform-QT(ºC)	Lab		5.7											
		ThmBDCM Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N	G/N										G/N
		ThmCHCl3 Total(ug/L)	Lab	N/D at <0.7	G/N	G/N										G/N
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N	G/N										G/N
		ThmTotal,calc_ Total(ug/L)	Lab	N/D at <3	G/N	G/N										G/N
		TON60C Total(T_O_N_60)	Lab		100											8
		TSScalc Total (mg/L)	Lab		26	39	10		18		46	5	6	79		
				N/D at <3						G/N						
				O/L				G/N							G/N	
		TSwv Total (mg/L)	Lab		150	202	178		170	168	216	164	180	240		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #1
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
April 5, 2017	Full-Scale	TSwv Total (mg/L)	Lab	O/L				G/N							G/N	
		Turbidity (NTU)	Lab		0.59	0.41	0.61	0.07	0.08	0.09	0.095	0.07	0.09	0.1		
				N/D at <0.02				G/N	G/N		G/N		G/N			
				O/L				G/N						G/N	G/N	
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		UVA @254nm, Unfiltered (/cm)	Bench		0.155											
		UVT @ 254nm, Filtered (%T)	Lab		71.2	91.8										
		UVT @ 254nm, Unfiltered (%T)	Bench		70.1	87.3										
			Lab		72.5	92.8	95.2		94.8	95.5	94.8	94.6	94	95.1		
				O/L				G/N							G/N	
		Zinc, Soluble (mg/L)	Lab	N/D at <0.0009	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	
		Zirconium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N		
				O/L				G/N							G/N	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary - Pilot DAF Float Sludge Sample Only

Season: Winter #1
Phase: Piloting

					Sample Location
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**DAF Sludge**
March 14, 2017	Full-Scale	Aluminum, Soluble (mg/L)	Lab		0.021
		Antimony, Soluble (mg/L)	Lab		0.0065
		Arsenic, Soluble (mg/L)	Lab		0.00087
		Boron, Soluble (mg/L)	Lab		0.043
		Cadmium, Soluble (mg/L)	Lab		0.00011
		Calcium, Soluble (mg/L)	Lab		20
		Chromium, Soluble (mg/L)	Lab		0.0009
		Copper, Soluble (mg/L)	Lab		0.0062
		Iron, Soluble (mg/L)	Lab		14.41
		Lead, Soluble (mg/L)	Lab		0.00016
		Magnesium, Soluble (mg/L)	Lab		6.327
		Manganese, Soluble (mg/L)	Lab		0.768
		Nickel, Soluble (mg/L)	Lab		0.009
		Potassium, Soluble (mg/L)	Lab		1.25
		Sodium, Soluble (mg/L)	Lab		11.43
		Temperature (ºC)	Lab		12.5
		TSSwv Total (mg/L)	Lab		5600
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N
		Zinc, Soluble (mg/L)	Lab		0.237
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N
March 15, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		32
		TSSwv Total (mg/L)	Lab		4050
		TSwv Total (mg/L)	Lab		4080
March 16, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		148
		TSSwv Total (mg/L)	Lab		4450
		TSwv Total (mg/L)	Lab		4600
March 20, 2017	Full-Scale	Aluminum, Soluble (mg/L)	Lab		0.042
		Antimony, Soluble (mg/L)	Lab		0.0054
		Arsenic, Soluble (mg/L)	Lab		0.00067
		Boron, Soluble (mg/L)	Lab		0.01
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N
		Calcium, Soluble (mg/L)	Lab		22.9
		Chromium, Soluble (mg/L)	Lab		0.0018
		Copper, Soluble (mg/L)	Lab		0.0045
		Iron, Soluble (mg/L)	Lab		5.846
		Lead, Soluble (mg/L)	Lab	N/D at <0.00004	G/N
		Magnesium, Soluble (mg/L)	Lab		6.666
		Manganese, Soluble (mg/L)	Lab		0.582
		Nickel, Soluble (mg/L)	Lab		0.0042
		Potassium, Soluble (mg/L)	Lab		1.5
		Sodium, Soluble (mg/L)	Lab		12.57
		Temperature (ºC)	Lab		7.5
		TSSwv Total (mg/L)	Lab		4560
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N
		Zinc, Soluble (mg/L)	Lab		0.069
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N
March 22, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		68
		TSSwv Total (mg/L)	Lab		5350
		TSwv Total (mg/L)	Lab		5420
March 23, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		24
		TSSwv Total (mg/L)	Lab		6150
		TSwv Total (mg/L)	Lab		6170
March 26, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		100

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter keeps DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary - Pilot DAF Float Sludge Sample Only

Season: Winter #1
Phase: Piloting

					Sample Location
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**DAF Sludge**
March 26, 2017	Pilot-Scale	TSSwv Total (mg/L)	Lab		4150
		TSwv Total (mg/L)	Lab		4250
March 27, 2017	Full-Scale	Aluminum, Soluble (mg/L)	Lab		2.936
		Aluminum, Total (mg/L)	Lab		2.94
		Antimony, Soluble (mg/L)	Lab		0.036
		Antimony, Total (mg/L)	Lab		0.036
		Arsenic, Soluble (mg/L)	Lab	N/D at <0.00002	G/N
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007	G/N
		Boron, Soluble (mg/L)	Lab		0.64
		Boron, Total (mg/L)	Lab		0.64
		Cadmium, Soluble (mg/L)	Lab	N/D at <0.00001	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N
		Calcium, Soluble (mg/L)	Lab		23.3
		Calcium, Total (mg/L)	Lab		23.3
		Chromium, Soluble (mg/L)	Lab		0.776
		Chromium, Total (mg/L)	Lab		0.776
		Copper, Soluble (mg/L)	Lab		0.369
		Copper, Total (mg/L)	Lab		0.369
		Iron, Soluble (mg/L)	Lab		1900
		Iron, Total (mg/L)	Lab		1900
		Lead, Soluble (mg/L)	Lab		0.00058
		Lead, Total (mg/L)	Lab		0.0006
		Magnesium, Soluble (mg/L)	Lab		4.483
		Magnesium, Total (mg/L)	Lab		4.48
		Manganese, Soluble (mg/L)	Lab		0.774
		Manganese, Total (mg/L)	Lab		0.774
		Nickel, Soluble (mg/L)	Lab		0.031
		Nickel, Total (mg/L)	Lab		0.031
		Potassium, Soluble (mg/L)	Lab		1.44
		Potassium, Total (mg/L)	Lab		1.44
		Sodium, Soluble (mg/L)	Lab		8.314
		Sodium, Total (mg/L)	Lab		8.31
		Temperature (ºC)	Lab		8.3
		TSSwv Total (mg/L)	Lab		4320
		Uranium, Soluble (mg/L)	Lab		0.0061
		Uranium, Total (mg/L)	Lab		0.0061
		Zinc, Soluble (mg/L)	Lab	N/D at <0.0009	G/N
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N
		Zirconium, Soluble (mg/L)	Lab		0.0035
		Zirconium, Total (mg/L)	Lab		0.0035
March 30, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		10
		TSSwv Total (mg/L)	Lab		7250
		TSwv Total (mg/L)	Lab		7260
April 1, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		350
		TSSwv Total (mg/L)	Lab		4550
		TSwv Total (mg/L)	Lab		4900
April 2, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		74
		TSSwv Total (mg/L)	Lab		5150
		TSwv Total (mg/L)	Lab		5220
April 3, 2017	Full-Scale	Aluminum, Soluble (mg/L)	Lab		0.024
		Antimony, Soluble (mg/L)	Lab		0.01
		Arsenic, Soluble (mg/L)	Lab		0.00057
		Boron, Soluble (mg/L)	Lab		0.019

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter keeps DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary - Pilot DAF Float Sludge Sample Only

Season: Winter #1

Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location DAF Sludge
April 3, 2017	Full-Scale	Cadmium, Soluble (mg/L)	Lab		0.00005
		Calcium, Soluble (mg/L)	Lab		23.2
		Chromium, Soluble (mg/L)	Lab		0.0011
		Copper, Soluble (mg/L)	Lab		0.005
		Iron, Soluble (mg/L)	Lab		5.796
		Lead, Soluble (mg/L)	Lab		0.0001
		Magnesium, Soluble (mg/L)	Lab		6.771
		Manganese, Soluble (mg/L)	Lab		0.942
		Nickel, Soluble (mg/L)	Lab		0.0082
		Potassium, Soluble (mg/L)	Lab		1.83
		Sodium, Soluble (mg/L)	Lab		9.943
		Temperature (ºC)	Lab		7.3
		TSSwv Total (mg/L)	Lab		6520
		Uranium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N
		Zinc, Soluble (mg/L)	Lab		0.406
		Zirconium, Soluble (mg/L)	Lab	N/D at <0.0005	G/N
April 4, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		196
		TSSwv Total (mg/L)	Lab		5850
		TSwv Total (mg/L)	Lab		6050
April 5, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		102
		TSSwv Total (mg/L)	Lab		5250
		TSwv Total (mg/L)	Lab		5350

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter keeps DAF Sludge. The Piloting_Season filter keeps Winter #1. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

APPENDIX

D

TM NO. 4

SPRING PILOTING SESSION (MAY 11 – MAY 31, 2017)

TECHNICAL MEMORANDUM NO. 4

PROJECT: Pilot Testing an Alternative Coagulant for the Winnipeg Water Treatment

PROJECT No.: 161-06111-00

TO: Heather Buhler, City of Winnipeg

FROM: Maika Pellegrino (WSP), Justin Rak-Banville (WSP), Charles Goss (WSP)

SUBJECT: Spring Piloting Session (May 11 – May 31, 2017) – Final

DATE: August 20, 2018

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1 OVERVIEW

Technical Memorandum No. 4 (TM No. 4) evaluates piloting results under cool water spring conditions (4-14°C) and the alternative coagulant and coagulant-aid, ferric sulphate ($Fe_2(SO_4)_3$) and LT-22S, respectively. This includes an examination of the results of the Spring benchmarking period, the subsequent Spring transition period, the alternative coagulant Spring piloting session, and recommendations regarding the subsequent Summer piloting session. Additional piloting work program details relating to the benchmark and the transition periods can be found in Technical Memorandum No. 2 (TM No. 2).

Table 1-1 summarizes the piloting events during the Spring piloting session. The Spring benchmarking period between April 10th and May 3rd, 2017 employed ferric chloride ($FeCl_3$) as the coagulant, whereas on May 6th, 2017, the coagulant was transitioned to ferric sulphate with a coagulant-aid. As such, the Spring piloting session commenced on May 11th, 2017 and was completed on May 31st, 2017, spanning 21 days. Following this period, the pilot-scale system coagulant was switched back to ferric chloride.

Table 1-1: Spring Piloting Session Schedule

SPRING PILOTING SESSION (4ºC - 14ºC)	DURATION	START	FINISH
1. Spring Benchmarking Period	23 days	April 10, 2017	May 3, 2017
2. Spring Pre-Piloting Progress Meeting	1 day	May 5, 2017	May 5, 2017
3. Spring Transition Period	5 days	May 6, 2017	May 10, 2017
4. Spring Piloting Session	21 days	May 11, 2017	May 31, 2017
5. Spring Mid-Point Progress Meeting	1 day	May 15, 2017	May 15, 2017

2 SPRING BENCHMARKING PERIOD

From April 10th to May 3rd, 2017, the Spring benchmarking period was completed by the City with the objective to match the pilot-scale system operational parameters to the full-scale system as best as possible to facilitate treatment process comparisons. This included scaling of mechanical aspects such as flows, but also water quality analyses of the treated water from both water treatment plants (WTP); herein after referred to as the full-scale system, and the pilot-scale system, respectively. The laboratory analysis data, compiled during the Summer benchmarking period, was completed by the City's Analytical Services Branch (hereafter referred as Lab), and is provided in Appendix A.

The pilot-scale system samples were collected daily from the following locations:

- Post-DAF (via the DAF overflow piping to the overflow tank);
- Post-Ozone (from the combined ozone column piping feeding the Ozone Contact tank);
- Individual filter effluents (Filters 1 through 8);

The full-scale system samples were collected from the following locations:

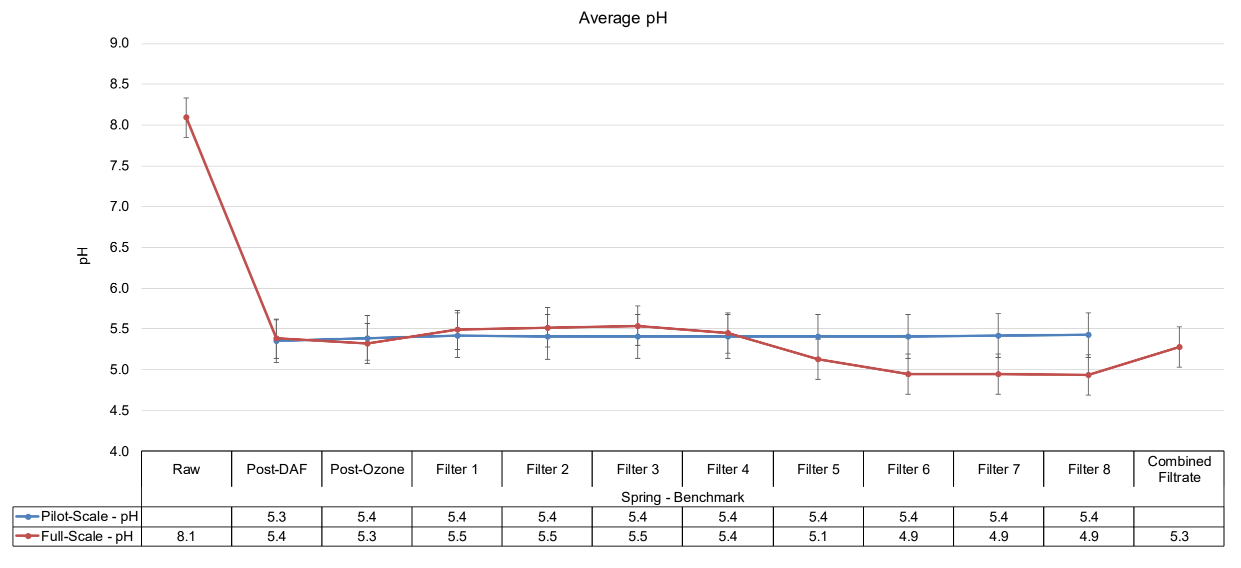
- Raw water (during the benchmarking and transitioning periods, raw water was sampled from this location);
- Post-DAF;
- Post-Ozone (i.e. combined ozone from both tanks);
- Individual filter effluents (Filters 1 through 8);
- Post Filter Combined;

Note: the raw water was only recorded for the full-scale system, as previous testing during the Winter #1 benchmarking period found nominal qualitative difference between the raw water for both the full-scale and pilot-scale systems. This excludes a temperature increase of approximately 1°C to 2°C. Pipe insulation can however improve and further control this variance but it is likely that this change will have minimal impact on this study. As such, for the purposes of this study, the water quality for the raw water at the pilot-scale system is assumed to be equivalent to the full-scale system.

Section 2.1 to Section 2.4 illustrate the results pertaining to the following four key parameters: pH, turbidity, total organic carbon (TOC), and total manganese, all of which were used for the comparison between the full-scale and pilot-scale systems. These figures are presented as the average parameters measured for each process across the Spring benchmarking period. The standard error for each sample is illustrated via error bars. The standard error estimates the variability between sample means that would be obtained by taking multiple samples from the same population, alternatively the standard error of the mean is used to determine how precisely the mean of the sample estimates the population mean, e.g. smaller error bars indicate more precise estimates of the population mean. A full summary of the daily results for above noted key parameters, as well as the results for non-key parameters are found in Appendix A.

2.1 pH

The average pH for the full-scale and pilot-scale systems during the Spring benchmarking period is reported in Figure 2-1. The average raw water pH observed was 8.1. Comparison between the pH values following Post-DAF, Post-Ozone, and Filters 1-4 had strong similarities between both the full-scale and pilot-scale systems. However, a lower pH was measured in the effluent from Filters 5-8 in the full-scale system, which was not observed in the pilot-scale system. A nominal difference when considering the full-scale system does not, on average, differentiate between filters when operating.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Pilot-Scale - pH		5.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	
Full-Scale - pH	8.1	5.4	5.3	5.5	5.5	5.5	5.4	5.1	4.9	4.9	4.9	5.3

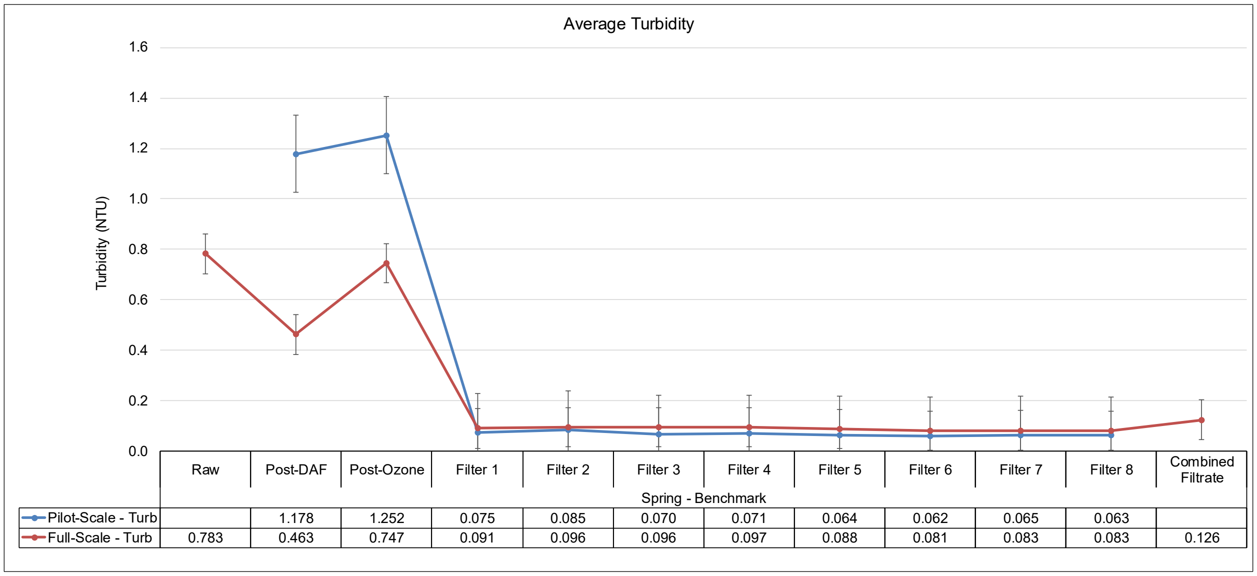
Figure 2-1: Average pH of the full-scale and pilot-scale systems during the Spring benchmarking period. Data originates from Lab analyses. Note: the raw water value was sampled from the full-scale system; however, for this study the water quality for the raw water is assumed to be the same.

The pH of the effluent from Filters 5-8 for the full-scale and pilot-scale systems were not found to be statistically similar during the Spring benchmarking period. The full-scale system appeared to also have a greater deviation (larger error bars) when compared to the pilot-scale system, an aspect likely attributed to daily operational adjustments of chemicals by plant operators. Although the combined filter effluent pH from the pilot-scale system was not measured, the average pH measured across all eight filters effluents was calculated to be 5.4.

Overall, a strong correlation between the full-scale and pilot-scale systems was observed. Although some variations in pH was discerned for Filters 5-8, the difference is believed to be negligible.

2.2 Turbidity

Significant variations were observed in the Post-DAF and Post-Ozone turbidity results between the full-scale and pilot-scale systems. The turbidity results are illustrated in Figure 2-2.



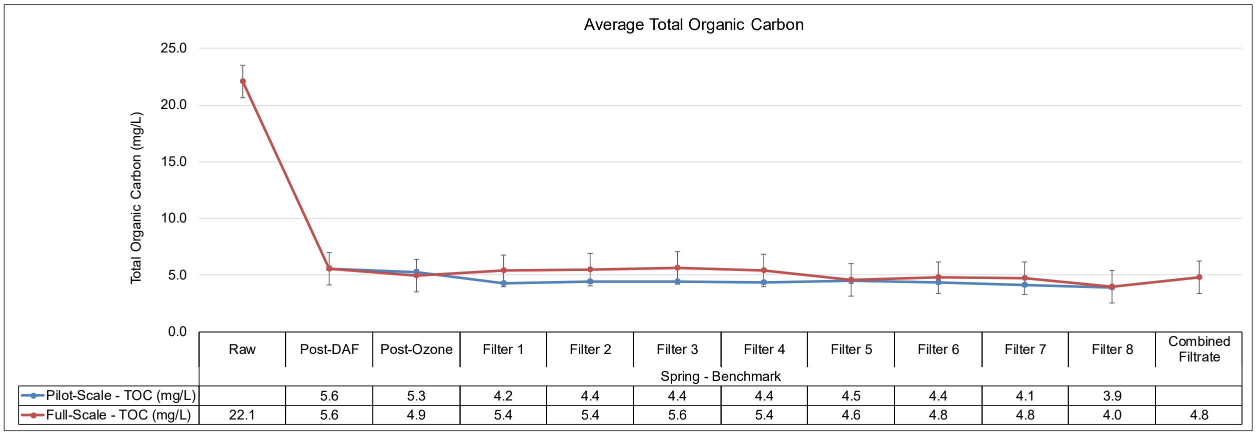
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Pilot-Scale - Turb		1.178	1.252	0.075	0.085	0.070	0.071	0.064	0.062	0.065	0.063	
Full-Scale - Turb	0.783	0.463	0.747	0.091	0.096	0.096	0.097	0.088	0.081	0.083	0.083	0.126

Figure 2-2: Average turbidity analysis of the full-scale and pilot-scale systems during the Spring benchmarking period. Data originates from Lab analyses. Note: the raw water was sampled from the full-scale system; however, for this study the water quality for the raw water is assumed to be the same.

Comparing the full-scale and pilot-scale systems, there is a 41% reduction in raw water turbidity following DAF treatment in the full-scale system, while the turbidity measured in the pilot-scale system DAF effluent increased by 37%. The increase in turbidity in pilot-scale system Post-DAF samples collected during the Winter #1 piloting session (Technical Memorandum No. 3 (TM No.3)) was attributed to scaling and operational differences between each system (i.e. flow rate and DAF retention times), as well as potential carryover of air saturated water in the Post-DAF effluent. In both the full-scale and pilot-scale systems there was an increase in turbidity following ozonation of 38% and 6%, respectively. Again, the increase in turbidity in the Post-Ozone samples for both systems could be attributed to an increase in dissolved gases (ozone and/or dissolved oxygen) following ozone treatment. Although a difference was observed for the Post-DAF and Post-Ozone turbidity between the full-scale and pilot-scale systems, strong correlation is observed in the final treated effluent. This observation implies that the increased turbidity measured in the pilot-scale system Post-DAF and Post-Ozone samples did not impact the final water quality. Therefore, the results are deemed acceptable.

2.3 Total Organic Carbon

The TOC results are illustrated in Figure 2-3.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Pilot-Scale - TOC (mg/L)		5.6	5.3	4.2	4.4	4.4	4.4	4.5	4.4	4.1	3.9	
Full-Scale - TOC (mg/L)	22.1	5.6	4.9	5.4	5.4	5.6	5.4	4.6	4.8	4.8	4.0	4.8

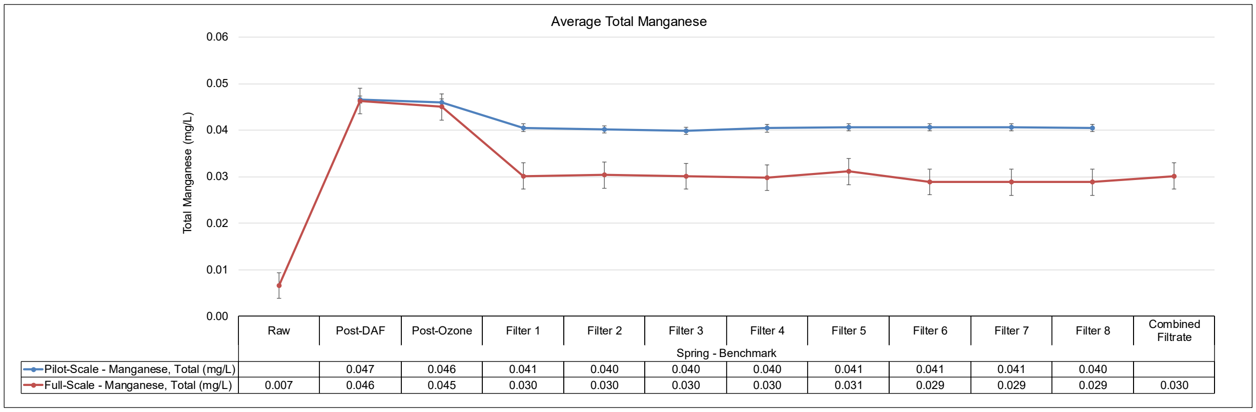
Figure 2-3: Average TOC of the full-scale and pilot-scale systems during the Spring benchmarking period. Data originates from Lab analyses. Note: the raw water was sampled from the full-scale system; however, for the purpose of this study the water quality for the raw water is assumed to be the same. Also, note that the TOC concentrations measured by the Lab during the benchmarking period contained instrumental error and were approximately 2-3 times higher than the actual TOC concentration.

The TOC concentration in the raw water was found to be high, exceeding 22 mg/L during the Spring benchmarking period (Figure 2-3). It should be noted that the City expressed some concerns regarding the TOC results received from the Lab, potentially leading to an underlining issue where the results were falsely analysed. Investigations revealed that there was in fact a laboratory error and a decision was taken that samples would be sent to an accredited laboratory (ALS Environmental) for confirmatory analysis to ensure accurate data was received. Nevertheless, a review of data received from the Lab found that the error in the data was due to a systematic instrumental error such that the offset was equal for both the full-scale and pilot-scale systems. Therefore, the trends observed in the results are still considered to be valid in terms of reduction and comparison.

Both the full-scale and pilot-scale systems were found to effectively reduce the TOC by a factor of four following DAF treatment; however, only a minor reduction in TOC was found following ozonation or filtration by either system (Figure 2-3). Overall, there was a strong correlation between the full-scale and pilot-scale systems for the removal of TOC.

2.4 Total Manganese

Total manganese had the poorest correlation between the full-scale and pilot-scale systems of the key parameters tested (Figure 2-4).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Pilot-Scale - Manganese, Total (mg/L)		0.047	0.046	0.041	0.040	0.040	0.040	0.041	0.041	0.041	0.040	
Full-Scale - Manganese, Total (mg/L)	0.007	0.046	0.045	0.030	0.030	0.030	0.030	0.031	0.029	0.029	0.029	0.030

Figure 2-4: Average total manganese of the full-scale and pilot-scale systems during the Spring benchmarking period. Data originates from Lab analyses. Note: the raw water value was actually sampled from the full-scale system; however, for the purpose of this study the water quality for the raw water is assumed to be the same.

The full-scale and pilot-scale systems exhibit a similar total manganese concentration in the Post-DAF and Post-Ozone samples; however, the pilot-scale system filter effluent had approximately 30-40% greater total manganese compared to the filter effluent from the full-scale system. This trend was not observed during the Winter #1 benchmarking period (TM No.3) and could be attributed to the buildup of residual manganese in the pilot-scale system during the Winter #1 piloting session and the differences in available filter surface area.

Although there is a difference in total manganese levels following filtration in each system, the pilot-scale system appears to be operating in a stable manner (a low degree of standard error). In turn, it is believed that the deviation in total manganese concentration in filter water from the full-scale and pilot-scale systems is unlikely to significantly impact transitioning and subsequent piloting of the alternative coagulant. Therefore, the results from the Spring benchmarking period were successful in comparing full-scale and pilot-scale systems operations and deemed acceptable for the transitioning and piloting of the alternative coagulant.

2.5 Filters Operation (SCADA)

Both filter banks in the pilot-scale system were operated at an average flow of 0.3 L/s to represent the full-scale system average flow rate during the 23 days of the Spring benchmarking period. The standard procedure was to backwash the filters daily at approximately the same time. The differential pressure values reported by the pilot-scale system SCADA were evaluated on an average hourly basis to determine the following:

- the filter run times,
- the unit filter run volume (UFRV) values,
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter, and
- the rate of head loss increase of each filter.

The calculations were performed as described in Section 2.4 of TM No. 3. The filter operational data was compared against filter effluent turbidity measurement by the Lab, which were sampled approximately 4 hours after the start of the filtration cycle. A summary of the filter operational data during the Spring benchmarking period is provided in Appendix A. Figure 2-5 illustrates the average daily UFRV values and Table 2-1 provides a tabulation of the average filter run times and average UFRV values for the entire Spring benchmarking period- while also considering the overall operation cycles and those which have not failed based on sampled turbidity.

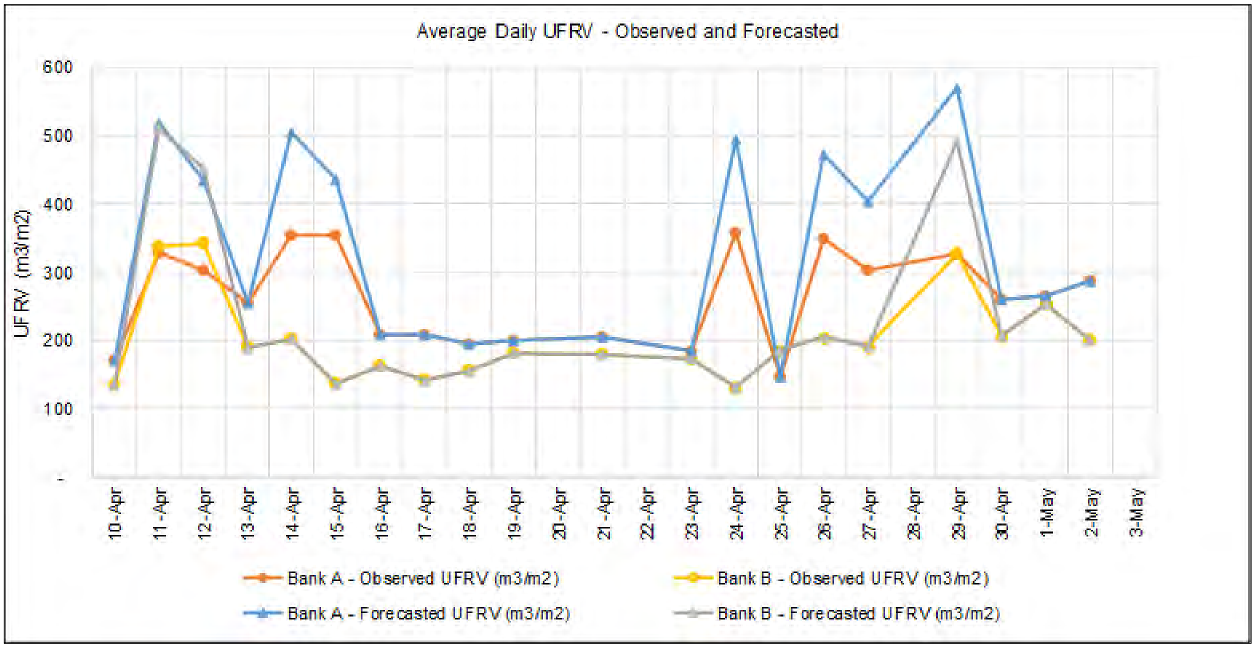


Figure 2-5: Average UFRV values of the pilot-scale system Bank A and Bank B at an average flow of 0.3 L/s during the Spring benchmarking period. UFRV = Filter Run Volume/Filter Surface Area. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

Table 2-1: Average observed and forecasted filter run times and UFRV values during the Spring benchmarking period.

		FILTER RUN TIME (h)			UFRV (m^3/m^2)		
		Bank A	**Bank B**	**All Filters**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	17.4	13.1	15.3	263	201	233
	Only cycles with turbidity ≤ 0.1 NTU	16.9	12.6	14.7	255	193	224
	Only cycles with turbidity ≤ 0.3 NTU	17.4	13.1	15.3	263	201	233
Forecasted Values	Overall Cycles	21.2	14.5	18.0	321	222	273
	Only cycles with turbidity ≤ 0.1 NTU	20.1	13.7	16.9	305	210	257
	Only cycles with turbidity ≤ 0.3 NTU	21.3	14.5	18.0	322	222	274

Based on the filter operation data, the following observations were made:

- During the Spring benchmarking period, there were a total of eight cycles that Bank A did not overflow before the daily backwash, versus three cycles for Bank B.
- The average post-ozone turbidity feeding the filters was 1.25 NTU and the average combined filter turbidity was 0.07 NTU during the Spring benchmarking period.
- The turbidity levels of all filters exceeded the City's operational guideline of 0.1 NTU for 4 of the 24 days of the Spring benchmarking period, whereas only Filter 2 exceeded the full-scale system operating license of 0.3 NTU on a single day.
- The overall average observed filter run time and overall average observed UFRV value was 17.4 h and 263 m^3/m^2 for Bank A and 13.1 h and 201 m^3/m^2 for Bank B.
- No substantial difference was observed when comparing the overall average UFRV values (233 m^3/m^2) to the UFRV values which considered only the filters to not have failed based on a sampled turbidity result above 0.1 or 0.3 NTU (224 and 233 m^3/m^2, respectively). The forecasted UFRV values were approximately 15% higher than the observed UFRV values.
- The rate of head loss increase ranged from 0.6 to 3.3 kPa/h, with an average of 1.6 kPa/h. No substantial variability was observed for each filter during the Spring benchmarking period and among the filters of the same filter bank throughout the same day. Although approximately half the filters exceeded the typical rate of head loss increase of 1.7 kPa/h, the maximum rate of head loss increase of 3.7 kPa/h was never exceeded. The typical and maximum rates of head loss increase (1.7 kPa/h and 3.7 kPa/h) are based on historical averages for the full-scale system (Refer to Table 5-2 of TM No. 3 for additional details).

Considering that both filter banks were operated at an average flow of 0.3 L/s during the Spring benchmarking period, it was expected that both filter banks would exhibit similar filter runs and UFRV values. Filter Bank A UFRV values were approximately 30% higher than Bank B UFRV values, an observation potentially attributed to the different mechanical configuration of the filter banks.

Based on full-scale system historical benchmarking, the five-year average UFRV value for the full-scale system was 495 m^3/m^2 with an average rate of head loss increase of 1.7 kPa/h and an average post-ozone turbidity of 0.79 NTU (see Table 2-1 and Table 2-2 of Technical Memo No. 1 (TM No. 1)). The average forecasted UFRV values of cycles with a sampled turbidity of less than or equal to 0.1 NTU, which are favoured for comparison between the full-scale system and the pilot-scale system, was 257 m^3/m^2 during the Spring benchmarking period. This UFRV value is approximately half that of the full-scale system's historical values, however the pilot-scale system had a similar rate of head loss increase (1.6 kPa/h in the pilot versus 1.7 kPa/h in the full-scale).

Nonetheless, the UFRV values cannot be directly compared since the head loss available for filtration at the full-scale system (48.9 kPa) is nearly double that of the available headloss at the pilot-scale system filters (23.9 kPa) (as explained in Section 2.4 of TM No. 3). Based on the comparable rate of head loss increase between the pilot-scale and full-scale systems, it is anticipated that if a comparable headloss was available in the pilot-scale system, the pilot-scale system would be able to achieve UFRVs comparable to the full-scale system. This further implies that the increased turbidity measured in the pilot-scale system Post-Ozone samples (1.25 NTU in average) may minimally impacted the filter operation.

2.6 Summary of the Comparison between the Spring Benchmarking Period and the Full-Scale System

When comparing the water quality results of the Spring benchmarking period with the results of full-scale system during the same period, pH and TOC presented strong correlations between the full-scale and pilot-scale systems. On the other hand, Post-DAF turbidity was significantly higher in the pilot-scale system, but the pilot-scale system filters were able to remove the added turbidity. The pilot-scale system filters produced effluent with higher total manganese concentrations than the full-scale system, even if the Post-DAF and Post-Ozone concentrations were similar. In terms of filters operation, the pilot-scale system filters presented a similar rate of head loss increase and lower UFRV values to the historical data of the full-scale system. However, based on the similar rate of headloss increase, it is assumed that the pilot-scale system could achieve equivalent UFRVs were there a comparable headloss to the full-scale system available.

Besides the differences in the Post-DAF turbidity and the filter effluent total manganese of the pilot-scale and the full-scale systems, the water quality results from the Spring benchmarking period of the pilot-scale system were sufficiently appropriate to draw operational comparisons to the full-scale system. As such, the project proceeded with the subsequent piloting of the alternative coagulant, ferric sulphate.

3 SPRING TRANSITION PERIOD

The coagulant was transitioned from ferric chloride to ferric sulphate on May 5th, 2017. Samples were collected from the pilot-scale system between May 6th and May 10th, 2017 at the same locations as the Spring benchmarking period, and tested for the following four key parameters: pH, turbidity, TOC, and total manganese.

The City informed WSP that on May 9th that no data was collected from the pilot-scale system raw water, Post-DAF, or Post-Ozone sources due to a maintenance shut-down of the full-scale system. Appendix B presents the summary of all the other water quality parameters tested during the Spring transition period. The chemical doses for the alternative coagulant was 42 mg/L from May 6th to 8th, and was increased to 46 mg/L on May 10th based on the optimal coagulant dose obtained during the Winter #1 piloting session. The coagulant-aid (LT-22S) dose remained at 0.02 mg/L throughout the Spring transition period. Filters Bank A (Filters 1-4) and Bank B (Filters 5-8) were both operated at a flowrate of 0.3 L/s during the Spring transition period.

The Spring transition period aimed to evaluate the stability of the pilot-scale system following the change from ferric chloride to ferric sulphate. Stability is achieved following a minimum of 5 days of operations where turbidity fluctuates by ±0.2 NTU in Post-DAF samples and ±0.05 NTU in the pilot-scale system filter effluent. Section 3-1 to Section 3-4 illustrate the results for the key parameters tested during the Spring transition period.

3.1 pH

The pH results did not exhibit a significant variation during the Spring transition period as illustrated in Figure 3-1.

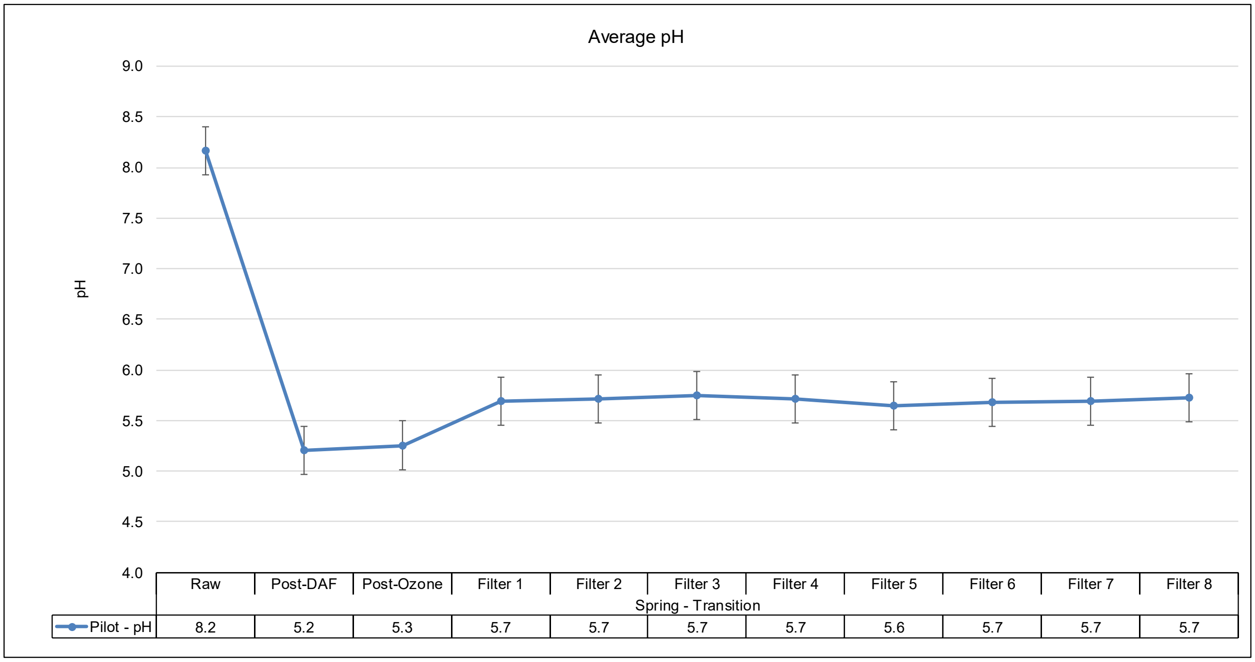


Figure 3-1: Average pH of the pilot-scale system during the Spring transition period. Data originates from Lab analyses.

3.2 Turbidity

Figure 3-2 and Table 3-1 present the turbidity results during the Spring transition period.

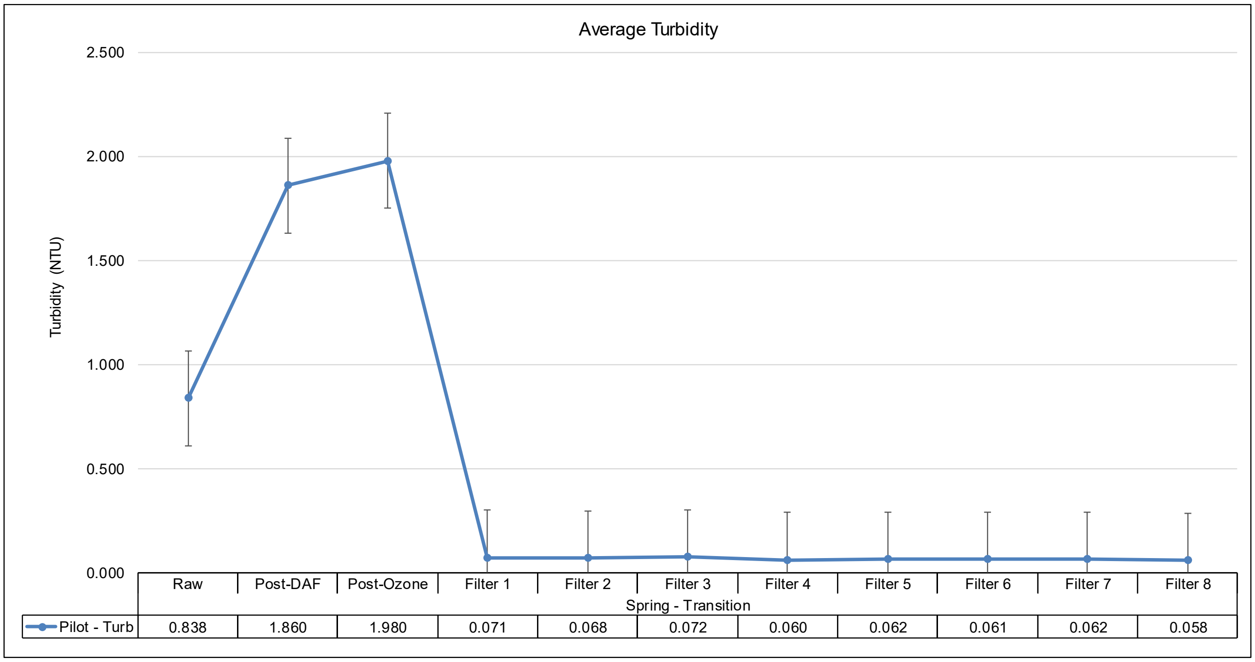


Figure 3-2: Average turbidity of the pilot-scale system during the Spring transition period. Data originates from Lab analyses.

Table 3-1: Changes in pilot-scale system turbidity during the Spring transition period. Data originates from Lab analyses.

LOCATION	MAY 6, 2017	MAY 7, 2017	MAY 8, 2017	MAY 10, 2017	AVERAGE
Raw	0.840	0.800	0.860	0.850	0.84 ± 0.03
Post-DAF	1.680	1.640	1.720	2.400	1.86 ± 0.36
Post-Ozone	1.660	1.790	2.160	2.310	1.98 ± 0.31
Filter 1	0.070	0.080	0.070	0.065	0.07 ± 0.01
Filter 2	0.050	BDL	0.070	0.085	0.06 ± 0.02
Filter 3	0.060	BDL	0.070	0.090	0.07 ± 0.02
Filter 4	0.050	0.050	0.055	0.080	0.06 ± 0.02
Filter 5	BDL	BDL	0.060	0.070	0.06 ± 0.02
Filter 6	0.060	0.060	0.060	0.065	0.06 ± 0.02
Filter 7	BDL	BDL	0.055	0.075	0.06 ± 0.01
Filter 8	BDL	0.050	0.060	0.065	0.06 ± 0.01

BDL = below detection limit; detection limit <0.050 NTU

The results demonstrate that the stability criteria for turbidity was not met for the Post-DAF sampling location (turbidity value of 1.86±0.36 NTU). The cause for the deviation of ±0.36 NTU is a result of the May 10th turbidity measuring 2.40 NTU. Assuming the May 10th Post-DAF turbidity result is an outlier, the fluctuation in turbidity is ±0.04 NTU (average turbidity value of 1.68 ± 0.04); which meets the criteria for stability.

On May 9th, the pilot-scale system was shut-down due to scheduled maintenance on the full-scale system. It is likely that the May 9th shutdown coupled with a change in the chemical dose to the pilot-scale system on May 10th impacted the pilot-scale system Post-DAF turbidity. As such, samples collected from the Post-DAF in the pilot-scale system on May 10th showed elevated turbidity levels that do not reflect the pilot-scale system post-filter turbidity values for Filters 1 to 8. The results from the filters meet the criteria of +/- 0.05 NTU when the data for May 10th is excluded. Therefore, it is believed that the deviation in pilot-scale system Post-DAF turbidity would not affect the Spring piloting session based on the stability observed in the pilot-scale system filter effluent.

3.3 Total Organic Carbon

The TOC did not exhibit significant variation during the Spring transition period as indicated in Figure 3-3.

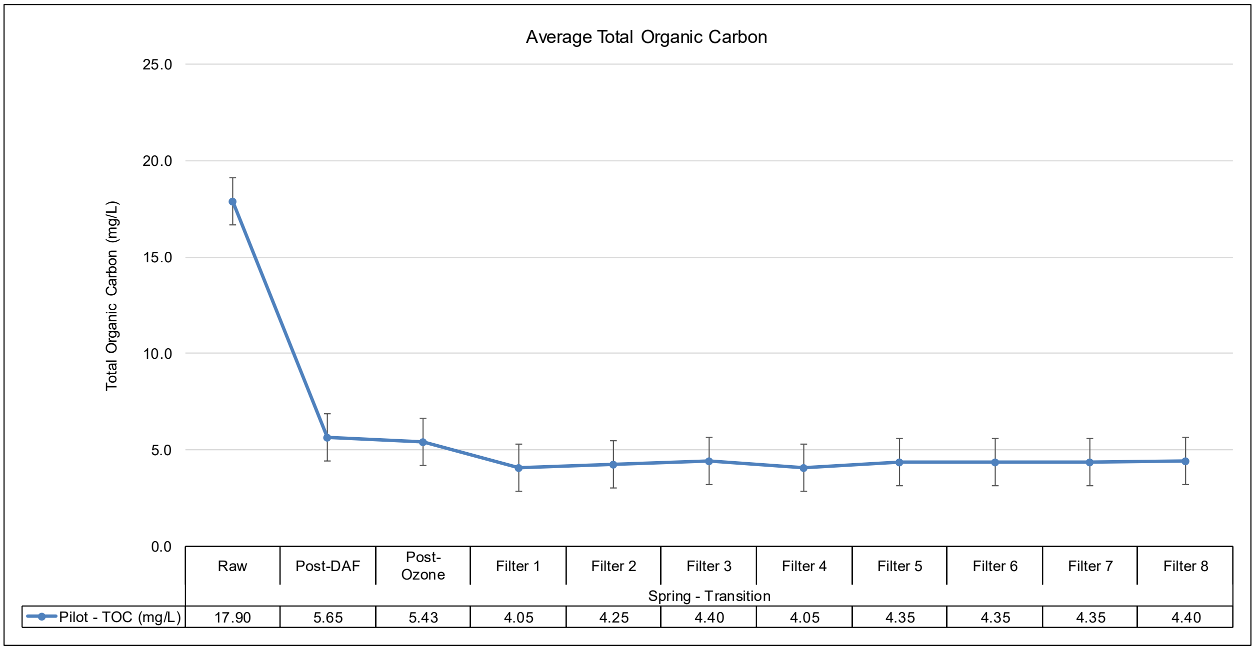


Figure 3-3: Average TOC of the pilot-scale system during the Spring transition period. Data originates from Lab analyses. Note: TOC measured by the Lab during the transition period are believed to contain instrumental errors and are approximately 2-3 times the actual TOC concentration.

3.4 Total Manganese

Similar to pH and TOC, the total manganese also did not exhibit significant variation during the Spring transition period as indicated in Figure 3-4.

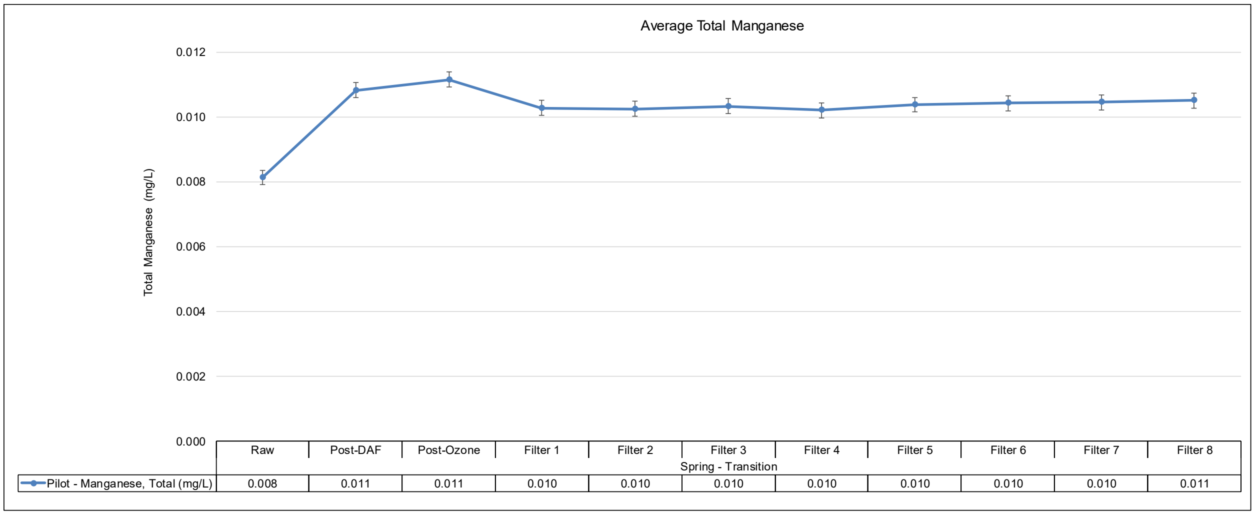


Figure 3-4: Average total manganese of the pilot-scale system during the Spring transition period. Data originates from Lab analyses.

Overall, the results suggest the pilot-scale system was operating in a stable manner during the entirety of the transition period following the change to ferric sulphate and the coagulant-aid. As such, the pilot-scale system was deemed acceptable for the Spring piloting session with the alternative coagulant and coagulant-aid.

4 SPRING PILOTING SESSION ACTIVITY

Following the successful Spring transition period to ferric sulphate and coagulant-aid, WSP operated the pilot-scale system from May 11th to May 31st, 2017 (inclusive). Table 4-1 outlines the activities undertaken during the Spring piloting session. Piloting work analytical results can be found in Appendix C, while Appendix D presents the daily operational log forms detailing observations and additional details. The detailed piloting work program can be found in Technical Memorandum No. 2 (TM No. 2).

Table 4-1: Spring Piloting Session - Summary of Piloting Activity

Date	Coagulant Dose (mg/L)	Coagulant-aid Dose (mg/L)	Target pH[1]	Sulphuric Acid Dose (mg/L)	Change	Analysis
Thursday, May 11, 2017	32	0.01	5.65	43.0	Increase coagulant dose	
Friday, May 12, 2017	35	0.01	5.65	44.0		
Saturday, May 13, 2017	38	0.01	5.65	44.0		
Sunday, May 14, 2017	42	0.01	5.65	44.0		
Monday, May 15, 2017	45	0.01	5.65	44.0		
Tuesday, May 16, 2017	48	0.01	5.65	41.0		
Wednesday, May 17, 2017	52	0.01	5.65	40.25		
Thursday, May 18, 2017	N/A	N/A	5.65	N/A	N/A (See Section 5)	
Friday, May 19, 2017	N/A	N/A	5.65	N/A		
Saturday, May 20, 2017	42	0.01	5.65	39.50	**Optimum** coagulant dose	Type 1[2]
Sunday, May 21, 2017	42	0.03	5.65	39.25	Increase Coagulant-aid Dose	
Monday, May 22, 2017	42	0.05	5.65	39.25		
Tuesday, May 23, 2017	42	0.10	5.65	39.25		
Wednesday, May 24, 2017	42	0.20	5.65	39.25		
Thursday, May 25, 2017	42	0.20	5.65	39.50	**Optimal** Coagulant and **Optimal** Coagulant-aid Dose	Type 2[3]
Friday, May 26, 2017	42	0.20	5.95	29.00	Increase pH (sulphuric acid dose)	
Saturday, May 27, 2017	42	0.20	6.25	23.65		
Sunday, May 28, 2017	42	0.20	6.55	10.00		
Monday, May 29, 2017	42	0.20	6.85	0.00		
Tuesday, May 30, 2017	42	0.20	6.10	25.00	**Optimal** Coagulant, Coagulant-aid, and pH	Type 1
Wednesday, May 31, 2017	42	0.20	6.10	29.50		Type 2

[1] Sulphuic acid dose was varied in order to produce the target pH.

[2] Type 1 sampling included: metals (dissolved and total): aluminum, arsenic, boron, calcium, cadmium, chromium, copper, iron, potassium, magnesium, manganese, sodium, nickel, lead, antimony, silver, uranium, zinc, and zirconium. In addition, dissolved organic carbon (DOC), total dissolved solids (TDS), total solids (TS), total suspended solids (TSS), true colour, UV transmittance, alkalinity, conductivity, pH and turbidity.

[3] Type 2 sampling included all of Type 1, and threshold odour number, total trihalomethane (T-THM), total haloacetic acids (T-HAA), sulphate, chloride, and hardness. T-THM and T-HAA formation potential were only tested in the raw water and filter effluent of the full-scale and pilot-scale systems.

During the Winter #1 piloting session, the flow rates for filter Bank A (Filters 1-4) and Bank B (Filters 5-8) were at 0.3 L/s and 0.6 L/s, respectively. The Winter #1 piloting session results found that Bank B consistently outperformed Bank A (TM No. 3); however, it was unclear if this was a result of the different flow rates to each bank, or a difference in their mechanical orientation. Therefore, to evaluate if the difference in filter banks performance during the Winter #1 piloting session was due to flow rate or mechanics, Bank A was operated at the maximum flow of 0.6 L/s and Bank B was operated at the minimum flow rate of 0.3 L/s for the Spring piloting session, i.e. filter bank flows were exchanged.

Similar to the Spring benchmarking and transition periods, process samples were collected from the pilot-scale system at the following locations:

- Post-DAF;
- Post-Ozone;
- Individual filter effluents.

Samples were also collected from the full-scale system at the following locations for comparison purposes:

- Raw
- Post-DAF;
- Post-Ozone (i.e. combined ozone from both tanks);
- Combined filter effluent (i.e., individual filter samples were not taken from the full-scale system).

Samples were tested using bench-scale analysis for temperature, turbidity, pH, conductivity, oxidation/reduction potential (ORP), dissolved oxygen, UVT, and total manganese. Lab analyses were planned based on the schedule provided in Table 4-1.

The deviation from the original program presented in TM No. 2 were:

- Raw water was only collected from the full-scale system.
- Backwash performance evaluation was not performed per recommendation of TM No. 3.
- The optimal pH for coagulation was tested. Sulphuric acid dose was adjusted to modify the pH throughout the Spring piloting session.
- TOC analysis was conducted on the raw water and combined filter effluent samples from the full – scale system.
- The optimal coagulant-aid dose was determined using the optimal coagulant dose determined during optimal coagulant testing.

5 SPRING PILOTING SESSION RESULTS

This section summarizes the operational parameters and the water quality analyses for samples collected between May 11th and May 31st, 2017 (the Spring piloting session). Included in these results are comparisons between full-scale and pilot-scale systems operation pertaining to DAF, ozonation, and combined filter effluent for key parameters.

Confirmatory laboratory analyses were performed by the Lab, while the benchtop analyses were performed by WSP staff. Data was also collected from the pilot-scale system SCADA for comparison between benchtop and online instrumentation.

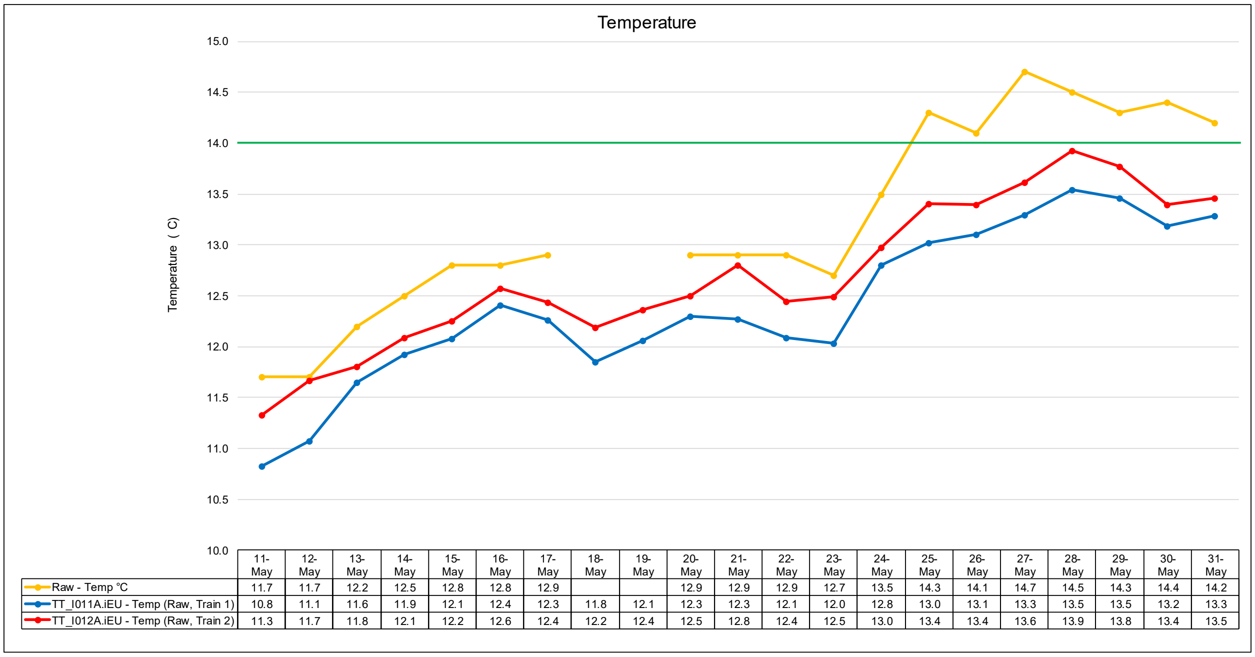
Figure 5-1: Sample of yellow coloured water from pilot-scale system Post-DAF

Samples were not collected on May 18th and 19th due to an unexpected occurrence of yellow discoloured water in the pilot-scale system filter effluent on May 18th (Figure 5-1). Following a discussion with City engineers, it was determined that the pilot-scale system might require maintenance and cleaning to diminish the occurrence of discoloured water. The yellow water incident which necessitated cleaning and maintenance was likely the result of operating the pilot-scale system at a high ferric sulphate dose (52 mg/L). The maintenance included several filter backwash cycles, as well as draining and physical cleaning the DAF system. Yellow discoloured water was observed on the morning of May 20th in the Post-DAF effluent only, and was not observed in the pilot-scale system treatment process effluent prior to sample collection on May 20th. It is assumed that the system had equilibrated by the end of day on May 20th, as the discoloured water concern appeared to have been resolved. The ferric dose was lowered after the system was cleaned and restarted.

It is interesting to note that prior to commencing the Spring piloting session, the City engineers informed WSP that the DAF recirculation rate was higher (approximately 0.75 L/s) than typically observed (approximately 0.55 – 0.6 L/s). The cause of this increased flow was unknown at the time. During the maintenance shut-down of the pilot-scale system, to address the occurrence of discoloured water, the City engineers discovered a crack in the DAF saturator pipe feeding the pilot-scale DAF system. This pipe was repaired during the May 18th and 19th shutdown, which resulted in the DAF recirculation rate reducing to 0.45 L/s for the remainder of the Spring piloting session. This recirculation rate was lower than previously seen, however within the standard recirculation rate for a DAF system.

5.1 Raw Water Temperature

The criteria for testing in Spring conditions (cool water) was that the raw water temperature would be between 4 and 14°C (represented by the green-line drawn at 14°C in Figure 5-2). The raw water temperature was collected from two temperature sensors used to measure each train (Train 1 and 2) in the full-scale system. In the pilot-scale system, the temperature was measured from raw water grab samples, using a hand-held digital thermometer.



	11-May	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May
Raw - Temp °C	11.7	11.7	12.2	12.5	12.8	12.8	12.9			12.9	12.9	12.9	12.7	13.5	14.3	14.1	14.7	14.5	14.3	14.4	14.2
TT_I011A.iEU - Temp (Raw, Train 1)	10.8	11.1	11.6	11.9	12.1	12.4	12.3	11.8	12.1	12.3	12.3	12.1	12.0	12.8	13.0	13.1	13.3	13.5	13.5	13.2	13.3
TT_I012A.iEU - Temp (Raw, Train 2)	11.3	11.7	11.8	12.1	12.2	12.6	12.4	12.2	12.4	12.5	12.8	12.4	12.5	13.0	13.4	13.4	13.6	13.9	13.8	13.4	13.5

Figure 5-2: Average daily raw water temperature for the full-scale system during the Spring piloting session. The green-line represents the upper temperature limit for cool water conditions (14°C). Pilot-scale system data originates from benchtop analysis and full-scale system data is measured with the online instruments and the SCADA system.

The results show that the raw water temperature measured by the full-scale system online sensors increased from approximately 11.0°C to 13.4°C, with the maximum temperature of 13.7°C occurring on May 27th (temperature is taken as the average temperature sensor reading between Train 1 and Train 2).

The grab samples collected from the raw water intake at the pilot-scale system were consistently higher than the full-scale system temperature sensor data. This is the result of the raw water travelling approximately 180 m (approximately 15- 20 minutes) within the WTP, feeding the pilot-scale system (previously highlighted; TM No.3: Section 5-1). The pilot-scale system's raw water exceeded 14°C from May 25th to May 31st, to a maximum of 14.7°C.

It is assumed that any changes in raw water quality at the pilot-scale system resulting from the change in temperature would be negligible. Therefore, the raw water quality tested during Spring piloting session was representative of cool water conditions.

5.2 Pilot-Scale System Raw Water Flow (SCADA)

Figure 5-3 presents the raw water flow maintained during the Spring piloting session. The desired raw water flow to the pilot-scale system is approximately 3.0 L/s.

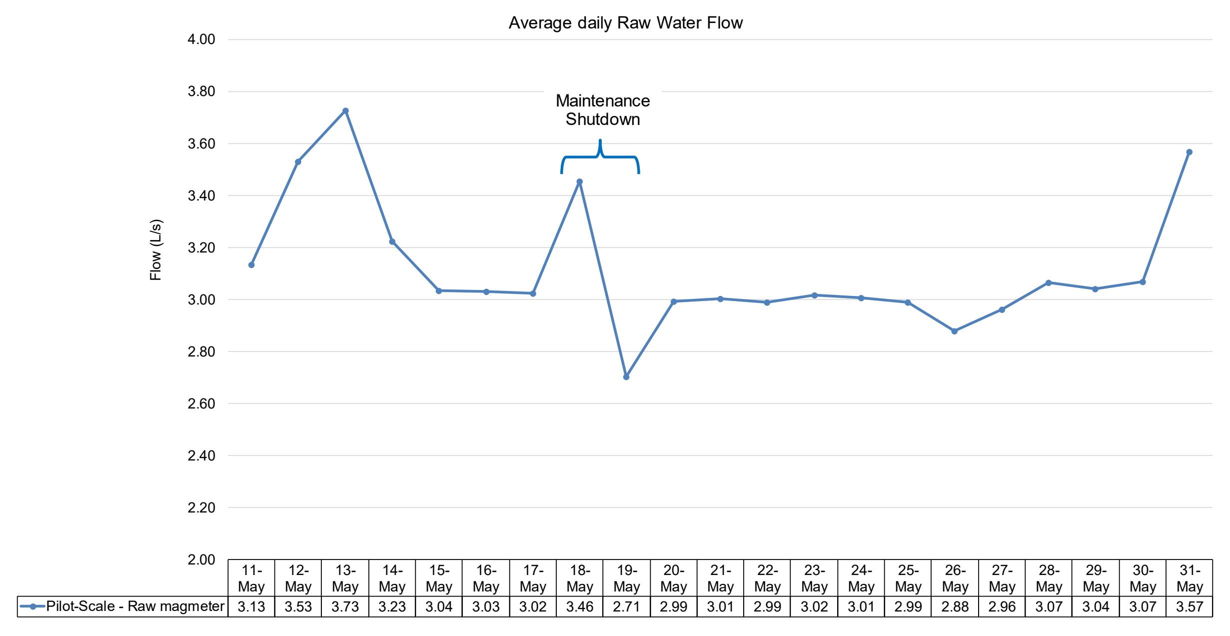


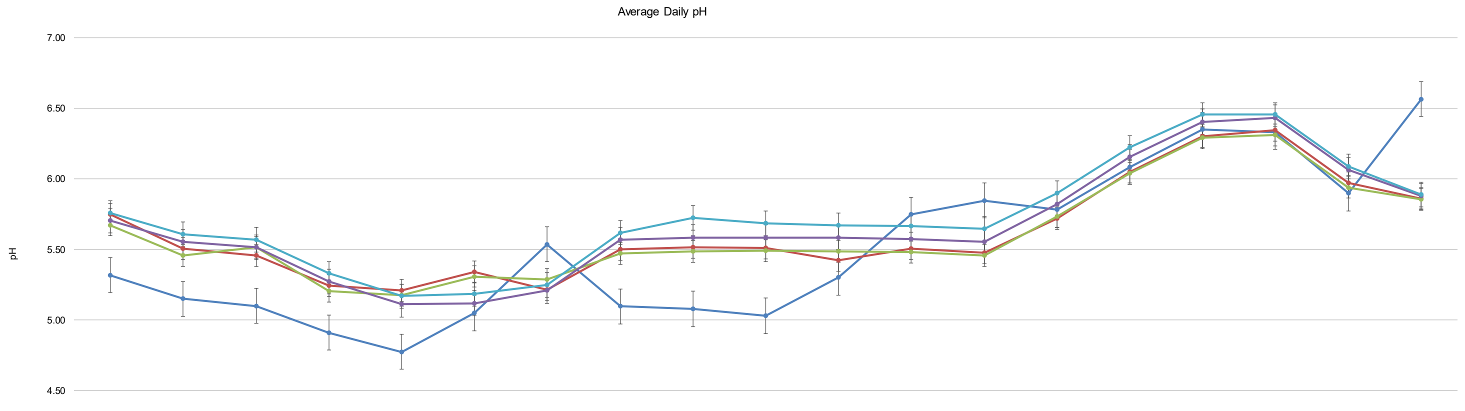
Figure 5-3: Average daily raw water flow rate to the pilot-scale system during the spring piloting session. Data originates from the pilot-scale system's SCADA dataset.

During the Winter #1 piloting session, the raw water flow was found to slowly decrease over time and required constant monitoring by the City and WSP staff to ensure the flow remained at the desired 3.0 L/s. On May 4th, the City's plumbers removed and cleaned the static mixers on the raw water intake feeding the pilot-scale system DAF tanks as part of the general maintenance activity for the system. During this maintenance, the City's Engineering Group found a significant buildup of coagulant within the static mixers on the raw water line (post chemical addition). The engineers found that once the buildup was removed from the mixers, the raw water flow remained at a stable rate, and did not decrease over time as observed during the Winter #1 piloting session.

The stability of the flow was generally well maintained at 3.0 L/s during the Spring piloting session. The flow on May 12th and 13th was higher than 3.0 L/s with flows of 3.5 L/s and 3.7 L/s, respectively. The increased flows could be attributed to the changes in raw water flowrates in the full-scale system. The increased flow on May 18th and lower flow on May 19th are attributed to the shut-down of the pilot-scale system for maintenance to address the discoloured water occurrence. The elevated raw water flowrate on May 31st was a result of the pilot-scale system being shutdown for cleaning and maintenance following the final day of the Spring piloting session.

5.3 pH Monitoring of Pilot-Scale System (SCADA)

The pH was constantly monitored in the pilot-scale system using the SCADA system. Figure 5-4 illustrates the daily average pH during the Spring piloting session for the following locations: Pre-DAF, Pre-Ozone (columns #1 and #2), and Pre-Filtration (Bank A and Bank B).

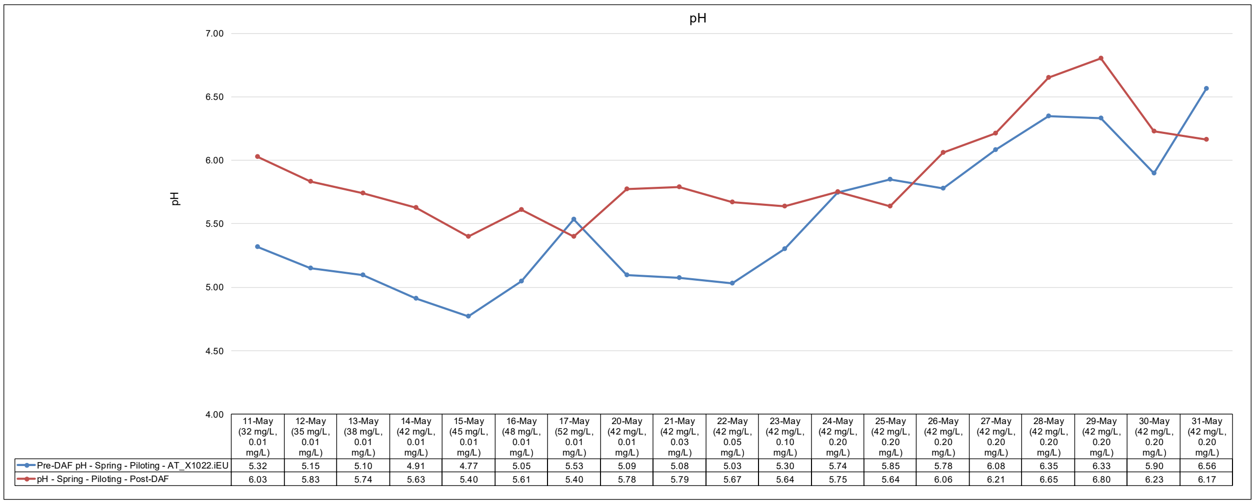


	11-May (32 mg/L, 0.01 mg/L)	12-May (35 mg/L, 0.01 mg/L)	13-May (38 mg/L, 0.01 mg/L)	14-May (42 mg/L, 0.01 mg/L)	15-May (45 mg/L, 0.01 mg/L)	16-May (48 mg/L, 0.01 mg/L)	17-May (52 mg/L, 0.01 mg/L)	20-May (42 mg/L, 0.01 mg/L)	21-May (42 mg/L, 0.03 mg/L)	22-May (42 mg/L, 0.05 mg/L)	23-May (42 mg/L, 0.10 mg/L)	24-May (42 mg/L, 0.20 mg/L)	25-May (42 mg/L, 0.20 mg/L)	26-May (42 mg/L, 0.20 mg/L)	27-May (42 mg/L, 0.20 mg/L)	28-May (42 mg/L, 0.20 mg/L)	29-May (42 mg/L, 0.20 mg/L)	30-May (42 mg/L, 0.20 mg/L)	31-May (42 mg/L, 0.20 mg/L)
Pre-DAF pH - Spring - Piloting - AT_X1022.iEU	5.32	5.15	5.10	4.91	4.77	5.05	5.53	5.09	5.08	5.03	5.30	5.74	5.85	5.78	6.08	6.35	6.33	5.90	6.56
Pre-Ozone pH Column 1 - Spring - Piloting - AT_X3150.iEU	5.75	5.50	5.45	5.24	5.21	5.34	5.21	5.50	5.52	5.51	5.42	5.50	5.47	5.72	6.05	6.30	6.34	5.97	5.86
Pre-Ozone pH Column 2 - Spring - Piloting - AT_X3160.iEU	5.67	5.46	5.51	5.20	5.17	5.31	5.28	5.47	5.49	5.49	5.48	5.48	5.46	5.73	6.04	6.29	6.31	5.94	5.85
Pre-filtration pH Bank A - Spring - Piloting - AT_X4210.iEU	5.70	5.55	5.51	5.27	5.11	5.12	5.21	5.57	5.58	5.58	5.58	5.57	5.55	5.82	6.15	6.40	6.43	6.06	5.88
Pre-filtration pH Bank B - Spring - Piloting - AT_X4230.iEU	5.76	5.61	5.57	5.33	5.17	5.18	5.25	5.62	5.72	5.68	5.67	5.66	5.64	5.90	6.22	6.45	6.45	6.09	5.89

Figure 5-4: Average daily pH of pilot-scale system during the Spring piloting session measured using SCADA. Data originates from the pilot-scale system's SCADA dataset. Note that these results excluded the data produced on May 18th and May 19th, 2017.

During the Winter #1 piloting session, Pre-DAF pH recorded by the pilot-scale system online SCADA had a pH lower than the pilot-scale system Pre-Ozone and Pre-Filtration, which was also observed during the Spring piloting session (Figure 5-4). TM No. 3 indicated the pilot-scale system Pre-DAF pH is measured shortly after acid addition, which is representative of the pH during coagulation in the pilot-scale system DAF tanks.

Furthermore, the pH measured by the pilot-scale system SCADA was lower than grab samples collected in the pilot-scale system Post-DAF (Figure 5-5). This deviation in pH made it difficult to monitor or control the pH during the first two weeks of the Spring piloting session, which included the optimization of coagulant and coagulant-aid.



	11-May (32 mg/L, 0.01 mg/L)	12-May (35 mg/L, 0.01 mg/L)	13-May (38 mg/L, 0.01 mg/L)	14-May (42 mg/L, 0.01 mg/L)	15-May (45 mg/L, 0.01 mg/L)	16-May (48 mg/L, 0.01 mg/L)	17-May (52 mg/L, 0.01 mg/L)	20-May (42 mg/L, 0.01 mg/L)	21-May (42 mg/L, 0.03 mg/L)	22-May (42 mg/L, 0.05 mg/L)	23-May (42 mg/L, 0.10 mg/L)	24-May (42 mg/L, 0.20 mg/L)	25-May (42 mg/L, 0.20 mg/L)	26-May (42 mg/L, 0.20 mg/L)	27-May (42 mg/L, 0.20 mg/L)	28-May (42 mg/L, 0.20 mg/L)	29-May (42 mg/L, 0.20 mg/L)	30-May (42 mg/L, 0.20 mg/L)	31-May (42 mg/L, 0.20 mg/L)
Pre-DAF pH - Spring - Piloting - AT_X1022.iEU	5.32	5.15	5.10	4.91	4.77	5.05	5.53	5.09	5.08	5.03	5.30	5.74	5.85	5.78	6.08	6.35	6.33	5.90	6.56
pH - Spring - Piloting - Post-DAF	6.03	5.83	5.74	5.63	5.40	5.61	5.40	5.78	5.79	5.67	5.64	5.75	5.64	6.06	6.21	6.65	6.80	6.23	6.17

Figure 5-5: pH comparison of pilot-scale system online Pre-DAF analyzer (average daily, AT-X1022) and pilot-scale system Post-DAF (grab sample). Data originates from the pilot-scale system's SCADA dataset and grab samples using a benchtop Thermo Scientific Orion STAR A325 pH probe.

The decrease in pH observed from May 11th to May 17th was a result of increasing coagulant dose during the coagulant optimization phase. During the optimization of coagulant-aid (May 20th to 24th) the pH for coagulation (measured as pilot-scale system Post-DAF-Benchtop; Figure 5-5) ranged between 5.67 and 5.75. Due to this, WSP concluded that pH control should be improved in the pilot-scale system to allow optimization of the pH during coagulation.

Following discussion with one of the City's instrumental technicians, an offset of 0.6 pH units was applied (3:00 pm on May 23rd) to the pH meter in the pilot-scale system, based upon the online pH deviation observed. This offset resulted in the pH of the pilot-scale system SCADA matching that of the grab samples collected by WSP on May 24th. However, as noted, this offset was not consistent on a daily basis and required constant adjustment and monitoring by the technician. The offset did allow for better control of the pH for the remainder of the Spring piloting session.

5.4 Pilot-Scale System Filters Operation (SCADA)

During the Spring piloting session, Bank A and Bank B operated at different flows as shown in Table 5.1.

Table 5-1: Average bank flow during the Spring piloting session.

Date	Average Flow Rate (L/s)	
	Bank A	**Bank B**
May 11, 2017	0.6	0.3
May 12, 2017 to May 15, 2017	0.3	0.6
May 16, 2017 to May 31, 2017	0.6	0.3

The standard procedure was to backwash the pilot-scale system filters daily approximately at the same time. The differential pressure values reported by the pilot-scale system SCADA were evaluated on an average hourly basis to determine the following:

- The filter run times;
- The UFRV values;
- If individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter; and
- The rate of head loss increase of each filter.

The calculations were performed as described in Section 2.4 of TM No. 3. The filter operational data was compared against filter effluent turbidity measured by the benchtop analysis, which was sampled approximately 4 hours after the start of the filtration cycle. The summary of the filter operational data obtained during the Spring piloting session is provided in Appendix C. Figure 5-6 illustrates the average daily UFRV values in the pilot-scale system.

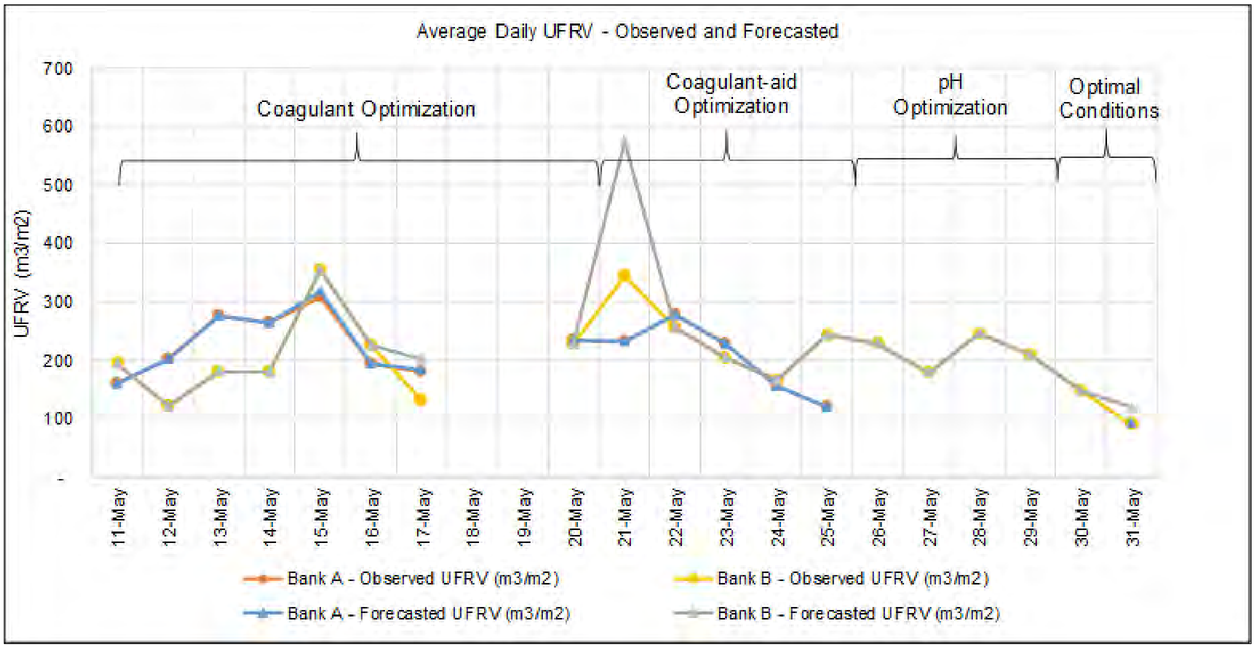


Figure 5-6: Average UFRV and average filter run of pilot-scale system Bank A and Bank B during the Spring piloting session. UFRV = (Filter Run Volume/Filter Surface Area). Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's historic SCADA logs.

Table 5-2 tabulates the average filter run times and average UFRV values for the entire Spring piloting session, while also considering overall operation cycles and those which did not fail based on sampled turbidity.

Table 5-2: Average observed and forecasted filter run times and UFRV values during the Spring piloting session.

	BANK OPERATION		FILTER RUN TIME (h)		UFRV (m^3/m^2)		
			Bank A	**Bank B**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Bank A at 0.3 L/s L/s, Bank B at 0.6 L/s L/s	Overall Cycles	17.2	6.9	262	208	235
		Only cycles with turbidity ≤ 0.1 NTU	17.8	7.0	273	206	232
		Only cycles with turbidity ≤ 0.3 NTU	16.3	5.0	247	150	212
	Bank A at 0.6 L/s L/s, Bank B at 0.3 L/s L/s	Overall Cycles	6.4	13.3	187	205	198
		Only cycles with turbidity ≤ 0.1 NTU	7.7	14.4	234	224	228
		Only cycles with turbidity ≤ 0.3 NTU	6.9	13.3	196	205	185
Forecasted Values	Bank A at 0.3 L/s L/s, Bank B at 0.6 L/s L/s	Overall Cycles	17.4	6.9	265	208	236
		Only cycles with turbidity ≤ 0.1 NTU	17.8	7.0	273	206	262
		Only cycles with turbidity ≤ 0.3 NTU	16.3	5.0	247	150	231
	Bank A at 0.6 L/s L/s, Bank B at 0.3 L/s L/s	Overall Cycles	6.4	14.8	187	227	211
		Only cycles with turbidity ≤ 0.1 NTU	7.7	16.7	234	260	228
		Only cycles with turbidity ≤ 0.3 NTU	6.9	14.8	196	227	185

From the filter operation data, the following observations were made:

- No results are available for Bank A from May 26th to 30th as differential pressure values reported by the pilot-scale system's SCADA presented multiple fluctuations and thus the data was discarded.
- During the Spring piloting session, Filters 1 to 4 overflowed before the daily backwash each time, except on May 15th and 17th. Filters 5 to 8 overflowed before the daily backwash each time, except on May 20th and 21th.
- The turbidity levels of the filters exceeded the City's operational guideline of 0.1 NTU for 77% of the Spring piloting session cycles for Bank A, similarly, this was observed in 61% of the cycles for Bank B. For additional context, Bank A's turbidity exceeded the full-scale system's operating license of 0.3 NTU in 30% of the filtration cycles, whereas Bank B exceeded the operating licence 11% of the cycles.
- For Bank A, when operating at 0.3 L/s the observed overall average filter run was 17.2 h and the observed overall average UFRV was 262 m^3/m^2. When operating at 0.6 L/s the observed overall average filter run was 6.4 h and the observed overall average UFRV was 187 m^3/m^2. When discarding the cycles with turbidity levels above 0.1 NTU, more similar UFRV values were observed at 0.3 L/s and at 0.6 L/s (273 m^3/m^2 and 234 m^3/m^2, respectively).
- For Bank B, when operating at 0.3L/s the observed overall average filter run were 13.3 h and the observed overall average UFRV was 205 m^3/m^2. When operating at 0.6 L/s the observed overall average filter run was 6.9 h and the observed overall average UFRV was 208 m^3/m^2. When discarding the cycles with turbidity levels above 0.1 NTU, minimal difference was observed in UFRV values at both flow rates (204 m^3/m^2 and 206 m^3/m^2, respectively).

- No substantial difference was observed when comparing the observed UFRV values with the forecasted UFRV values for both filter banks at both flow rates, due to the fact that both Banks almost always overflowed prior to backwashing.
- The rate of head loss increase ranged from 0.6 to 3.5 kPa/h, with an average of 1.7 kPa/h for individual filters operating at 0.3 L/s. While the rate of head loss increase ranged from 1.4 to 11.1 kPa/h, with an average of 4.4 kPa/h for individual filters operating at 0.6 L/s. Low variability was observed for each filter in Bank A and among these filters in the same day at both operating flow rates. Higher variability was observed for each filter in Bank B and among Bank B filters in the same day operating at 0.6 L/s. Comparably, low variability was observed for each filter of Bank B and among Bank B filters in the same day operating at 0.3 L/s.
- When considering individual filters operating at 0.3 L/s, approximately half of the operating times exceeded the typical rate of head loss increase of 1.7 kPa/h, but never the maximum rate of head loss increase of 3.7 kPa/h. (The typical and maximum rate of head loss increase for filter bank operating at 0.3 L/s,1.7 kPa and 3.7 kPa, respectively, are based on the historical averages of the full-scale system. Refer to Table 5-2 of TM No. 3 for additional details).
- Nonetheless, approximately 71% of the time individual filters operating at 0.6 L/s exceeded the typical rate of head loss increase of 3.1 kPa/h, whereas only 4% of the operating time the maximum rate of head loss increase of 7.1 kPa/h was exceeded. (The typical and maximum rate of head loss increase for filter bank operating at 0.6 L/s,3.1 kPa and 7.1 kPa, respectively, are based on the historical averages of the full-scale system. Refer to Table 5-2 of TM No. 3 for additional details).

It was expected that both banks would exhibit similar UFRV values, while it was expected that the individual filters operating at 0.3 L/s would exhibits a filter run twice as higher as the individual filters operating at 0.6 L/s. However, UFRV values of the individual filters operating at 0.6 L/s were 25% lower to 100% higher than UFRV values of the individual filters operating at 0.3 L/s. These discrepancies may be due to mechanical differences in the filter banks and their operation (shorter pipe runs, closer to the pumps, etc.), or even inconsistent filter-aid dosing. Furthermore, there is no confirmation that the filter-aid dosing pump PX505 (Bank A) was operating consistently, and City staff has noted several times that this pump did not start consistently at low dosing rates.

Bank A and Bank B exhibited similar UFRV values when either filter banks were operated at 0.6 L/s, as expected (Note: Bank A operated at 0.6 L/s from May 16th to May 31st and Bank B operated at 0.6 L/s from May 12th to 15th). However, Bank A exhibited UFRV values approximately 30% higher than Bank B when either filter banks were operated at 0.3 L/s, an observation similar to the Winter #1 piloting session. Taking into consideration the lower UFRV results from the Winter #1 and Spring piloting sessions, it is possible that the flow rate, lack of filter-aid dose adjustment, and/or mechanics of each bank are potentially impacting these values more than the influent water quality.

The effects of coagulant dose, pH and coagulant-aid dose are further discussed in Section 5.6. Additional evaluation regarding UFRVs are also presented in Section 5.7, Section 5.8 and Section 5.9.

5.5 DAF Sludge Production of the Pilot-Scale System

Figure 5-7 illustrates the total suspended solids (TSS) results for the residual generation from the pilot-scale system DAF unit. Substantial difference was observed between May 14th and 20th at the same conditions of coagulant dose, pH and coagulant-aid dose. At the same time, it can be observed the TSS concentration slightly increases with the pH increase and the coagulant-aid dose increase. It should be noted that the sludge sampling from the DAF is a rudimentary process, and is subject to incomplete scrapper collection and/or variances in the scrapper level affecting the sludge blanket movement.

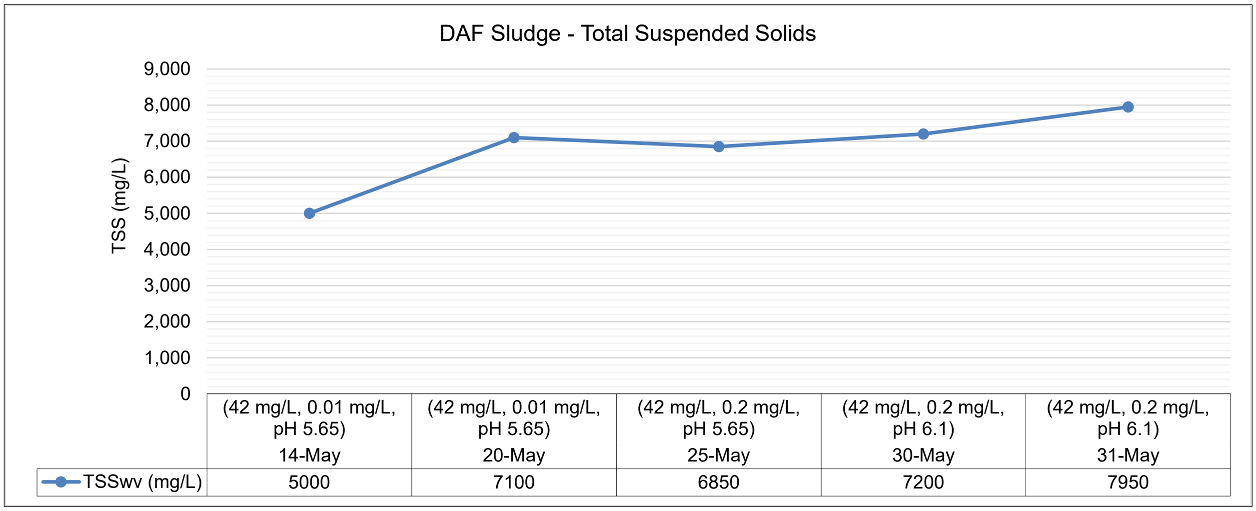


Figure 5-7: TSS results for DAF sludge in the pilot-scale system during the Spring piloting session. Data originates from Lab analysis.

5.6 Optimization of Alternative Coagulant, Coagulant-Aid, and pH

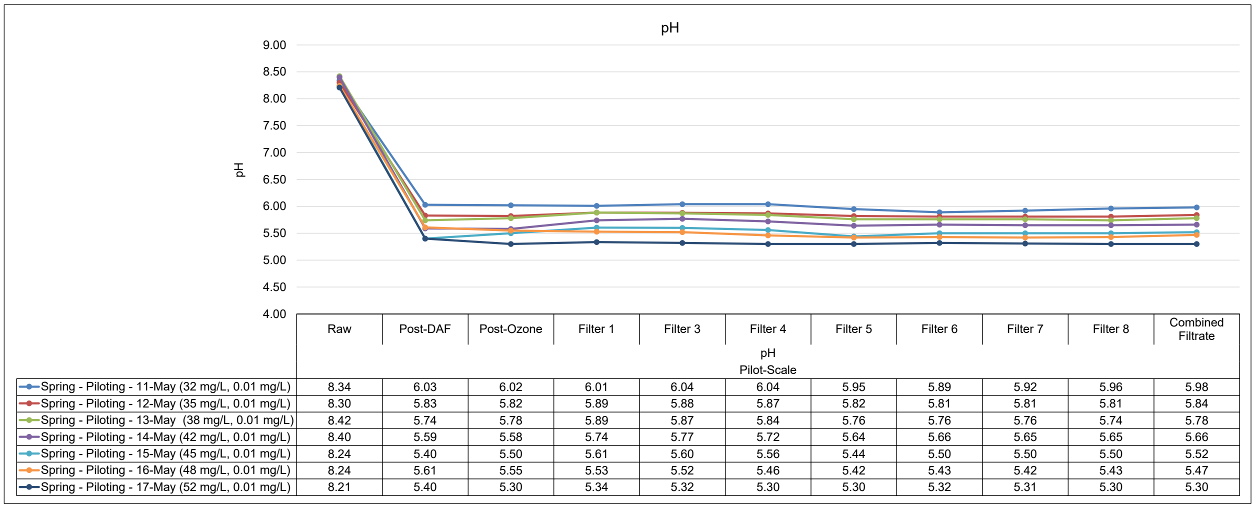
The following sections present the results used in determining of the optimal dose for the alternative coagulant, coagulant-aid, as well as the optimal pH for chemical coagulation within the pilot-scale DAF system.

5.6.1 Optimization of Ferric Sulphate

Dose optimization testing was conducted from May 11th to May 17th, 2017. The optimal chemical dose was based on daily grab samples that were tested using various benchtop analyses for the following key parameters: turbidity, UV transmittance (UVT), UV_{254nm} absorbance, and total manganese. Samples were collected daily from the following locations in the pilot-scale system: Raw water, Post-DAF, Post-Ozone, filter effluent (Filters 1-8), and the combined filter effluent. Samples were also collected from Post-DAF, Post-Ozone, and the combined filter effluent from the full-scale system and tested using benchtop analysis for the key parameter listed above. Along with key parameters, UFRV values were also calculated for the optimization of ferric sulphate. UFRV values were not considered in the optimization of the ferric sulphate dosage and were calculated after the completion of the Spring piloting session.

→ pH

During the optimization of ferric sulphate, the Pre-DAF pH was maintained at approximately 5.6, to mimic the operating conditions of the full-scale system. As mentioned, the pH was controlled by increasing or decreasing the sulphuric acid addition and monitoring the online Pre-DAF pH meter (tag: AT-X1022) and the grab sample results from Floc Tank No.1. Figure 5-8 shows that the pilot-scale system Post-DAF pH ranged from 5.40 to 6.03 during the coagulation optimization phase. The only days where the Post-DAF target pH of 5.6 was met was on May 14th and 16th. It should be noted that it was difficult to maintain a pH of 5.6 during the operation of the pilot-scale system which can significantly impact results. It is recommended that a system be implemented to better control and maintain the pH within the DAF system.

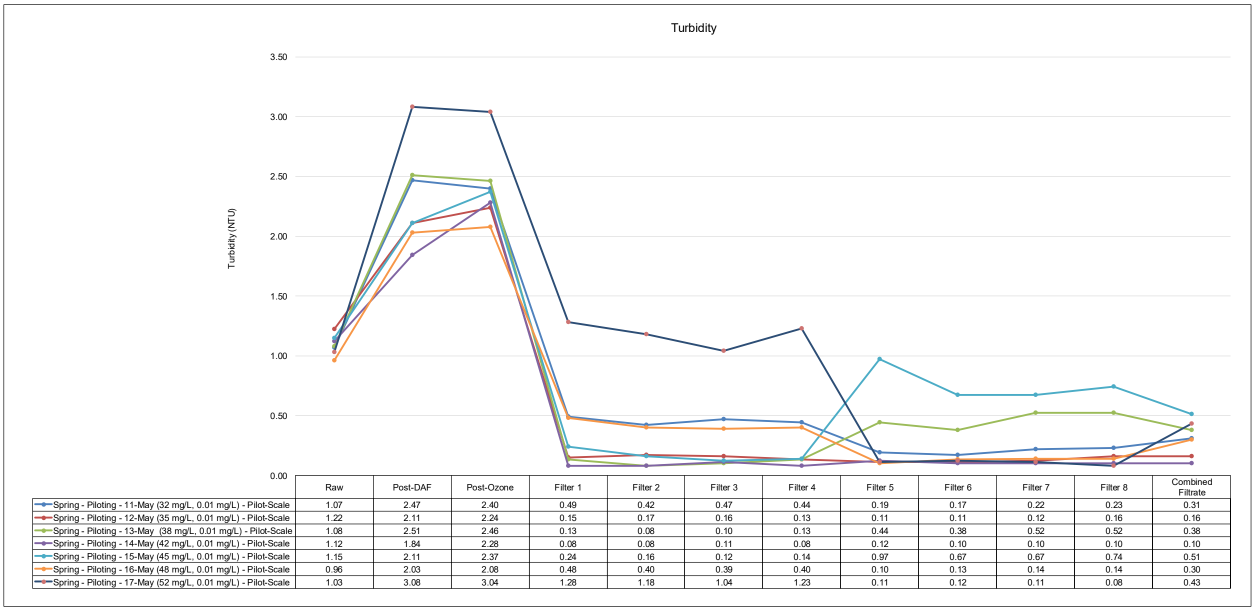


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Spring - Piloting - 11-May (32 mg/L, 0.01 mg/L)	8.34	6.03	6.02	6.01	6.04	6.04	5.95	5.89	5.92	5.96	5.98
Spring - Piloting - 12-May (35 mg/L, 0.01 mg/L)	8.30	5.83	5.82	5.89	5.88	5.87	5.82	5.81	5.81	5.81	5.84
Spring - Piloting - 13-May (38 mg/L, 0.01 mg/L)	8.42	5.74	5.78	5.89	5.87	5.84	5.76	5.76	5.76	5.74	5.78
Spring - Piloting - 14-May (42 mg/L, 0.01 mg/L)	8.40	5.59	5.58	5.74	5.77	5.72	5.64	5.66	5.65	5.65	5.66
Spring - Piloting - 15-May (45 mg/L, 0.01 mg/L)	8.24	5.40	5.50	5.61	5.60	5.56	5.44	5.50	5.50	5.50	5.52
Spring - Piloting - 16-May (48 mg/L, 0.01 mg/L)	8.24	5.61	5.55	5.53	5.52	5.46	5.42	5.43	5.42	5.43	5.47
Spring - Piloting - 17-May (52 mg/L, 0.01 mg/L)	8.21	5.40	5.30	5.34	5.32	5.30	5.30	5.32	5.31	5.30	5.30

Figure 5-8: Pilot-scale system pH measured during coagulation optimization during the Spring piloting session. Data originates from benchtop analysis using a Thermo Scientific Orion STAR A325 pH probe.

→ Turbidity

Figure 5-9 presents the changes in turbidity levels observed within the pilot-scale system in the process of determining the optimum ferric sulphate dose. The graph shows that the turbidity increased following coagulation (Post-DAF samples) for all coagulant doses. As mentioned, this increase is attributed to the fact that the pilot-scale system DAF has a smaller scale, along with potential carryover of air saturated water into the Post-DAF samples. Precautions were taken to ensure that samples analyzed in the lab yielded similar results to the online instruments. Samples collected for lab analysis were collected with no headspace, so gas would not easily be able to escape. The samples were stored in a refrigerator and brought to sampling temperature in a water bath, with lids still on the sample bottles. The lids were kept on the bottles to minimise any potential escape of gas, and to reduce the risk of each bottle having different amounts of saturated air in the water which could affect turbidity measurements.



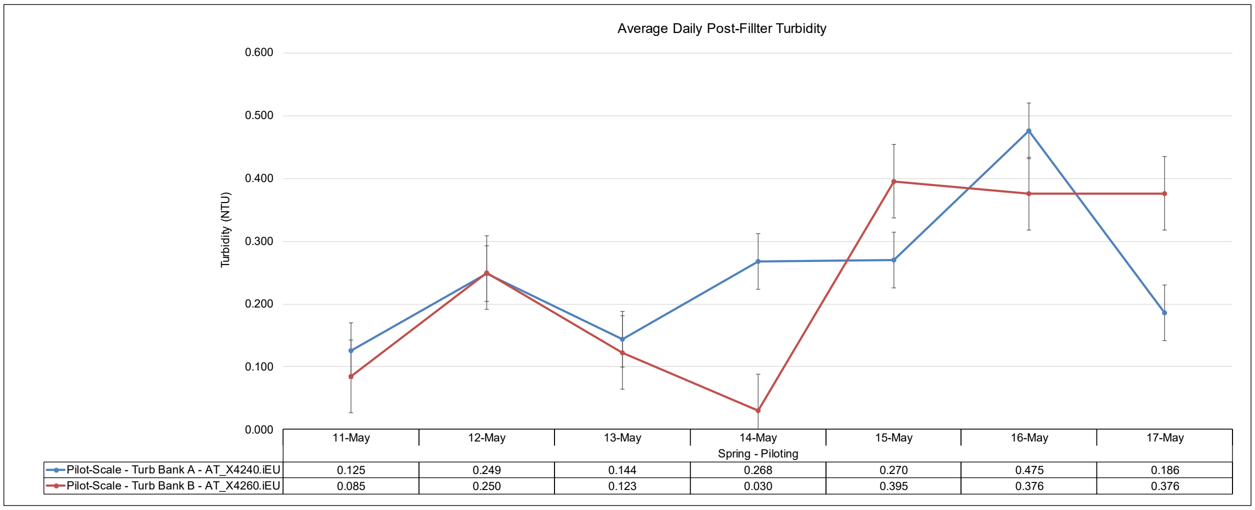
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Spring - Piloting - 11-May (32 mg/L, 0.01 mg/L) - Pilot-Scale	1.07	2.47	2.40	0.49	0.42	0.47	0.44	0.19	0.17	0.22	0.23	0.31
Spring - Piloting - 12-May (35 mg/L, 0.01 mg/L) - Pilot-Scale	1.22	2.11	2.24	0.15	0.17	0.16	0.13	0.11	0.11	0.12	0.16	0.16
Spring - Piloting - 13-May (38 mg/L, 0.01 mg/L) - Pilot-Scale	1.08	2.51	2.46	0.13	0.08	0.10	0.13	0.44	0.38	0.52	0.52	0.38
Spring - Piloting - 14-May (42 mg/L, 0.01 mg/L) - Pilot-Scale	1.12	1.84	2.28	0.08	0.08	0.11	0.08	0.12	0.10	0.10	0.10	0.10
Spring - Piloting - 15-May (45 mg/L, 0.01 mg/L) - Pilot-Scale	1.15	2.11	2.37	0.24	0.16	0.12	0.14	0.97	0.67	0.67	0.74	0.51
Spring - Piloting - 16-May (48 mg/L, 0.01 mg/L) - Pilot-Scale	0.96	2.03	2.08	0.48	0.40	0.39	0.40	0.10	0.13	0.14	0.14	0.30
Spring - Piloting - 17-May (52 mg/L, 0.01 mg/L) - Pilot-Scale	1.03	3.08	3.04	1.28	1.18	1.04	1.23	0.11	0.12	0.11	0.08	0.43

Figure 5-9: Turbidity levels following pilot-scale system treatment processes for the determination of the optimal dose of ferric sulphate during the Spring piloting session. Each day represents an increased coagulant dose (see Table 4-1). The concentration of coagulant-aid was maintained at 0.01 mg/L. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.

There was little change observed in the turbidity following ozonation. A similar trend was reported during the Winter #1 piloting session; however, the Post-DAF and Post-Ozone turbidity was found to be higher in the Spring piloting session compared to the Winter #1 piloting session. This is likely due to the increased organic matter concentration which typically occurs during spring runoff. Following filtration, the turbidity was reduced by 78-96% (based on combined filter effluent) indicating the filters could remove the added turbidity found in the Post-DAF effluent. Among the coagulant concentrations tested, the greatest reduction in turbidity occurred with a dose of 42 mg/L and a pH of 5.6 (May 14th). The slightly lower optimal dose for the Spring session is expected due to improved reaction kinetics arising from warmer water conditions (11-13°C) when compared to the Winter #1 piloting session (<4°C). The same trend was also observed in the full-scale system.

Following the dates plotted in Figure 5-9, a crack was discovered in the DAF saturator water pipe feeding the pilot-scale DAF system which was causing an increase in the Post-DAF turbidity. Once the cracked pipe was replaced (during the May 18th and 19th shutdown), the Post-DAF turbidity improved for the remainder of the Spring piloting session. Therefore, the increase in Post-DAF turbidity could also be attributed to the cracked saturated water pipe.

Figure 5-10 shows the turbidity measured by the online SCADA system for the filter bank effluent during optimization of the ferric sulphate dose. During the Spring piloting session, Bank A was operated at the maximum flowrate (0.6 L/s) while Bank B was operated at the minimum flowrate (0.3 L/s). The online SCADA system for Bank A (Filters 1-4) and Bank B (Filters 5-8) (Figure 5-12) indicated that the two trains have similar turbidity removals. This was not the same trend observed during the Winter #1 piloting session. It should be noted that during the Winter #1 piloting session, the filter-aid dosing pumps were potentially not operating consistently. Specifically, the pump feeding Bank A had more dosing issues than the pump feeding Bank B. It is recommended that during the subsequent piloting sessions, the water quality from the two banks be continuously monitored.

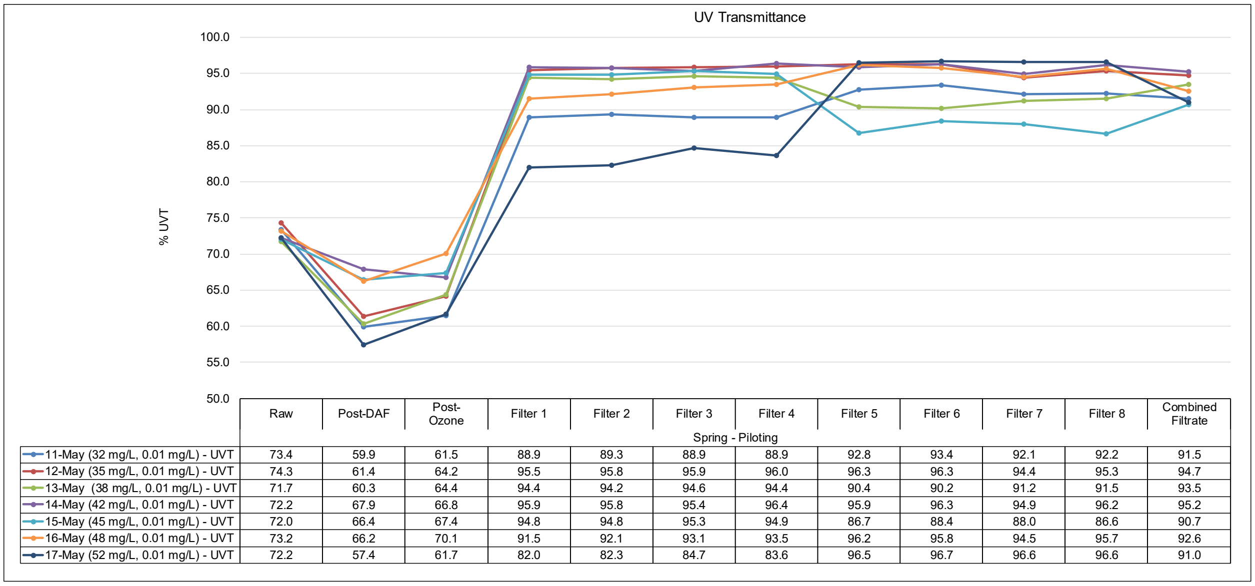


	11-May	12-May	13-May	14-May	15-May	16-May	17-May
Pilot-Scale - Turb Bank A - AT_X4240.iEU	0.125	0.249	0.144	0.268	0.270	0.475	0.186
Pilot-Scale - Turb Bank B - AT_X4260.iEU	0.085	0.250	0.123	0.030	0.395	0.376	0.376

Figure 5-10: Average daily turbidity for filter effluent from Bank A and B for the determination of the optimal dose of ferric sulphate during the Spring piloting session. Data originates from the pilot- scale system's SCADA dataset.

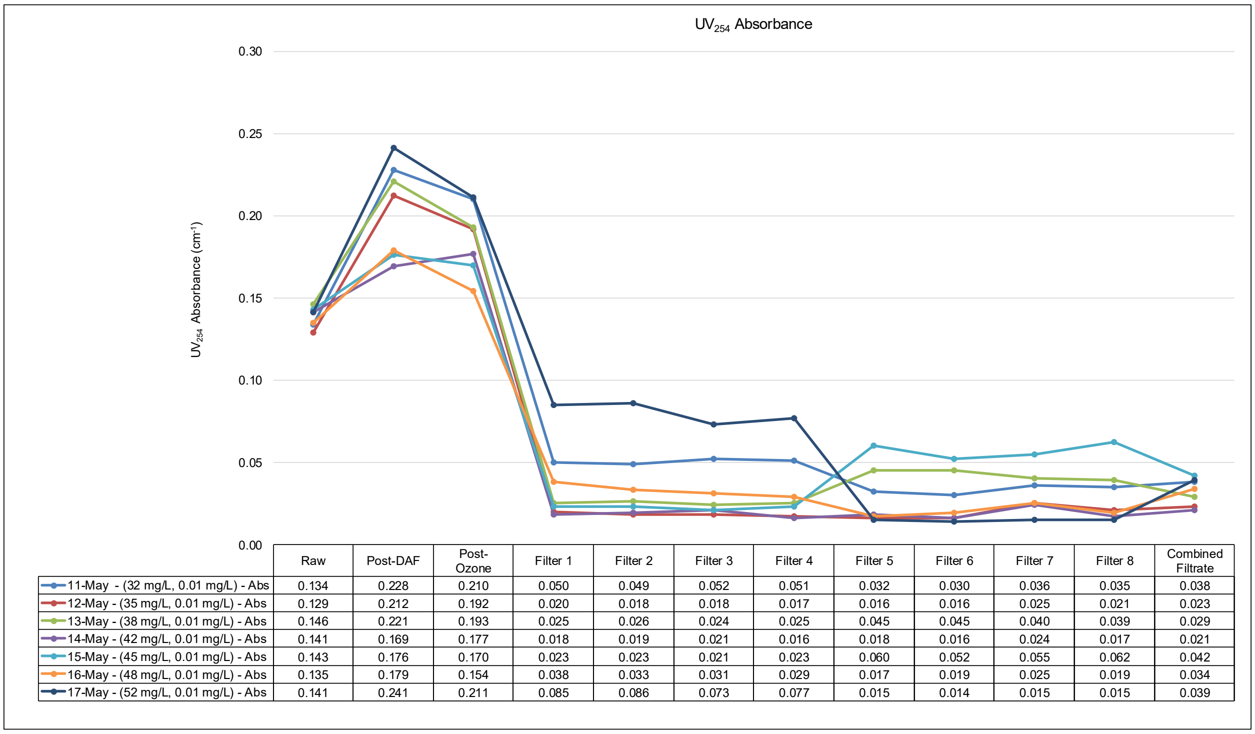
→ UVT & UV_{254nm} Absorbance

UVT (Figure 5-11) and UV_{254nm} absorbance (Figure 5-12) were found to have a similar trend as turbidity, i.e., lower UVT and UV_{254nm} absorbance, following DAF and ozonation; however, significantly improved post filtration. The optimal coagulant dose for this parameter was 42 mg/L (May 14th) with a UVT of 95.2% and UV_{254nm} absorbance of 0.021 cm^{-1}.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
11-May (32 mg/L, 0.01 mg/L) - UVT	73.4	59.9	61.5	88.9	89.3	88.9	88.9	92.8	93.4	92.1	92.2	91.5
12-May (35 mg/L, 0.01 mg/L) - UVT	74.3	61.4	64.2	95.5	95.8	95.9	96.0	96.3	96.3	94.4	95.3	94.7
13-May (38 mg/L, 0.01 mg/L) - UVT	71.7	60.3	64.4	94.4	94.2	94.6	94.4	90.4	90.2	91.2	91.5	93.5
14-May (42 mg/L, 0.01 mg/L) - UVT	72.2	67.9	66.8	95.9	95.8	95.4	96.4	95.9	96.3	94.9	96.2	95.2
15-May (45 mg/L, 0.01 mg/L) - UVT	72.0	66.4	67.4	94.8	94.8	95.3	94.9	86.7	88.4	88.0	86.6	90.7
16-May (48 mg/L, 0.01 mg/L) - UVT	73.2	66.2	70.1	91.5	92.1	93.1	93.5	96.2	95.8	94.5	95.7	92.6
17-May (52 mg/L, 0.01 mg/L) - UVT	72.2	57.4	61.7	82.0	82.3	84.7	83.6	96.5	96.7	96.6	96.6	91.0

Figure 5-11: UVT measured following pilot-scale system treatment processes for the determination of the optimal dose of ferric sulphate during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.



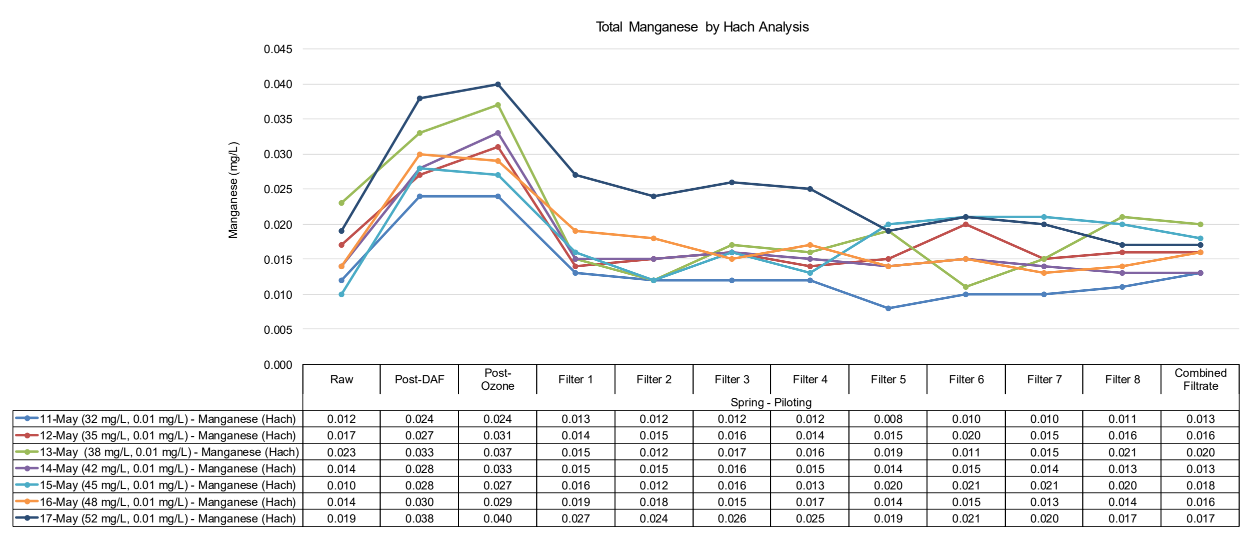
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
11-May - (32 mg/L, 0.01 mg/L) - Abs	0.134	0.228	0.210	0.050	0.049	0.052	0.051	0.032	0.030	0.036	0.035	0.038
12-May - (35 mg/L, 0.01 mg/L) - Abs	0.129	0.212	0.192	0.020	0.018	0.018	0.017	0.016	0.016	0.025	0.021	0.023
13-May - (38 mg/L, 0.01 mg/L) - Abs	0.146	0.221	0.193	0.025	0.026	0.024	0.025	0.045	0.045	0.040	0.039	0.029
14-May - (42 mg/L, 0.01 mg/L) - Abs	0.141	0.169	0.177	0.018	0.019	0.021	0.016	0.018	0.016	0.024	0.017	0.021
15-May - (45 mg/L, 0.01 mg/L) - Abs	0.143	0.176	0.170	0.023	0.023	0.021	0.023	0.060	0.052	0.055	0.062	0.042
16-May - (48 mg/L, 0.01 mg/L) - Abs	0.135	0.179	0.154	0.038	0.033	0.031	0.029	0.017	0.019	0.025	0.019	0.034
17-May - (52 mg/L, 0.01 mg/L) - Abs	0.141	0.241	0.211	0.085	0.086	0.073	0.077	0.015	0.014	0.015	0.015	0.039

Figure 5-12: UV$_{254nm}$ absorbance measured following pilot-scale system treatment processes for the determination of the optimal dose of ferric sulphate during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

→ Total Manganese

As previously highlighted in TM No.3, a significant directive of this study is to evaluate if an alternative coagulant to the current ferric chloride will prevent, or reduce, the occurrence of discoloured water in the distribution system (previously noted to be a result of high total manganese in the finished water).

Figure 5-13 presents the total manganese concentrations measured following a change in coagulant dose. The results indicate the lowest manganese in the combined filter effluent on May 11th and 14th, at coagulant doses of 32 mg/L and 42 mg/L, respectively. When considering which of these two dates would represent the optimal dose, there is slightly better reduction of raw water manganese at a coagulant dose of 42 mg/L, compared to 32 mg/L. Therefore, in terms of a reduction in manganese, the optimal dose is 42 mg/L.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
11-May (32 mg/L, 0.01 mg/L) - Manganese (Hach)	0.012	0.024	0.024	0.013	0.012	0.012	0.012	0.008	0.010	0.010	0.011	0.013
12-May (35 mg/L, 0.01 mg/L) - Manganese (Hach)	0.017	0.027	0.031	0.014	0.015	0.016	0.014	0.015	0.020	0.015	0.016	0.016
13-May (38 mg/L, 0.01 mg/L) - Manganese (Hach)	0.023	0.033	0.037	0.015	0.012	0.017	0.016	0.019	0.011	0.015	0.021	0.020
14-May (42 mg/L, 0.01 mg/L) - Manganese (Hach)	0.014	0.028	0.033	0.015	0.015	0.016	0.015	0.014	0.015	0.014	0.013	0.013
15-May (45 mg/L, 0.01 mg/L) - Manganese (Hach)	0.010	0.028	0.027	0.016	0.012	0.016	0.013	0.020	0.021	0.021	0.020	0.018
16-May (48 mg/L, 0.01 mg/L) - Manganese (Hach)	0.014	0.030	0.029	0.019	0.018	0.015	0.017	0.014	0.015	0.013	0.014	0.016
17-May (52 mg/L, 0.01 mg/L) - Manganese (Hach)	0.019	0.038	0.040	0.027	0.024	0.026	0.025	0.019	0.021	0.020	0.017	0.017

Figure 5-13: Total manganese measured following pilot-scale system treatment processes for the determination of the optimal dose of ferric sulphate during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

→ UFRV

Figure 5-14 illustrates the average observed and forecasted UFRV values obtained for each coagulant dose for Bank A and Bank B. During optimization of the coagulant dose, Bank A and Bank B overflowed every cycle, except Bank B at a coagulant dose of 52 mg/L. However, the individual filters failed based on turbidity (> 0.1 NTU) at all coagulant doses tested, except at 42 mg/L when only 2 filters out of 8 presented turbidity breakthrough. At ferric sulphate doses of 32 and 45 mg/L, both Banks presented a turbidity above 0.3 NTU, whereas at doses of 38 and 48 mg/L, only the bank operating at 0.6 L/s presented a turbidity above 0.3 NTU.

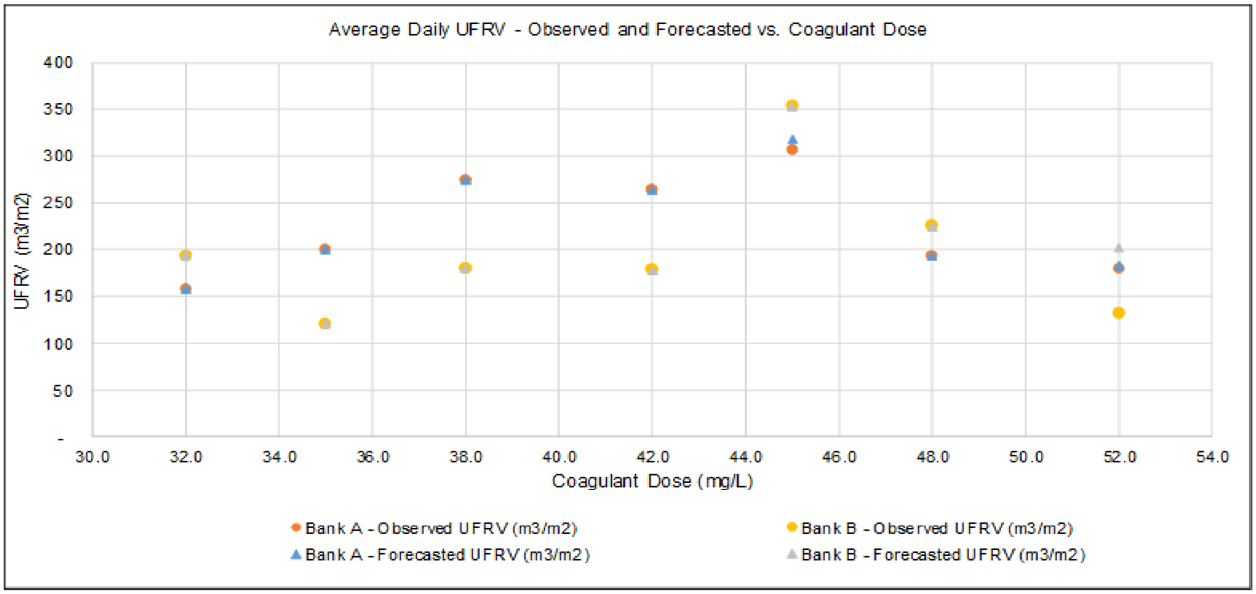


Figure 5-14: Average UFRV of pilot-scale system filter Bank A and filter Bank B during the Spring piloting session for determining the optimal dose of ferric sulphate. The pilot-scale system Post-DAF pH ranged from 5.4 to 6.03 and the coagulant-aid dose was maintained at 0.01 mg/L. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's historic SCADA logs.

The highest UFRV values were observed at a ferric sulphate dose of 42 mg/L (264 and 178 m^3/m^2 for Bank A and Bank B, respectively), where the filter bank average turbidity was 0.1 NTU or less. Only 25% of the individual filters failed based on turbidity (> 0.1 NTU). Consequently, a ferric sulphate dose of 42 mg/L is supported by the UFRV results to be the optimal coagulant dose observed.

→ Summary of Ferric Sulphate Optimization

Based on the key parameters tested, the optimal dose for ferric sulphate under cool water conditions was determined to be 42 mg/L. The UFRV analysis performed following the Spring piloting session confirmed the same optimal dose based on filter performance.

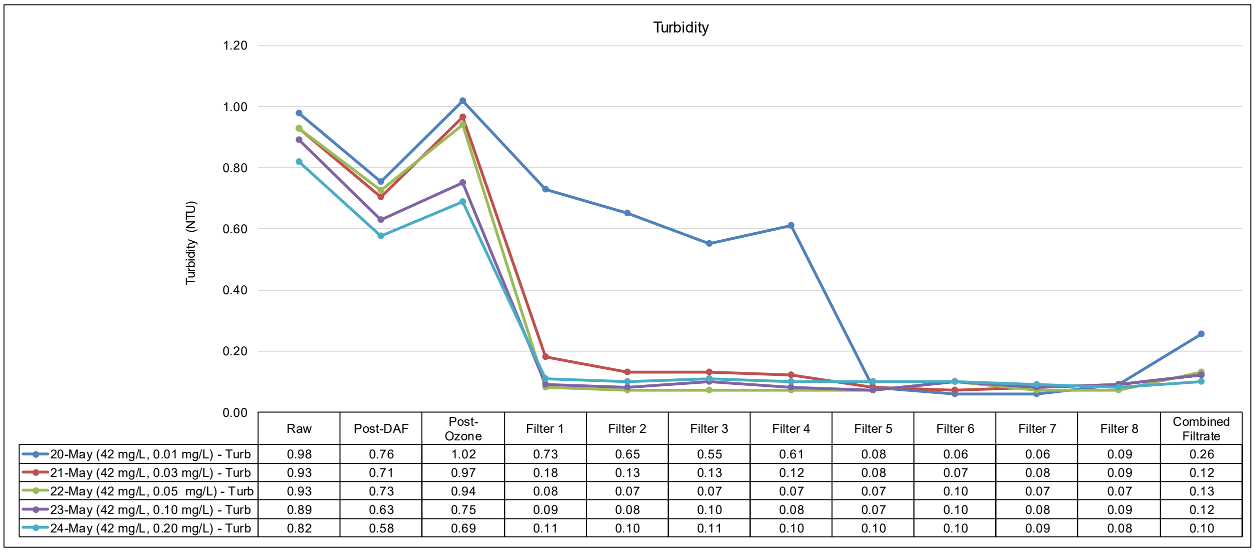
The target pH was difficult to maintain during the optimization of coagulant dose, and the target pH was only achieved on May 14th and May 16th. It is recommended that a system be implemented to better control the pH during the coagulation process. This could be achieved though means of a pH controller that would monitor the change in pH as coagulant is added, and adjust the addition of sulphuric acid according to a set pH.

5.6.2 Optimization of Coagulant-Aid

The optimization of coagulant-aid LT-22S dose was conducted from May 20th to May 24th, 2017. A similar approach to the optimization of the coagulant was taken in determining the ideal dose of the coagulant-aid. The coagulant dose used during this test was 42 mg/L while the target pH was 5.65.

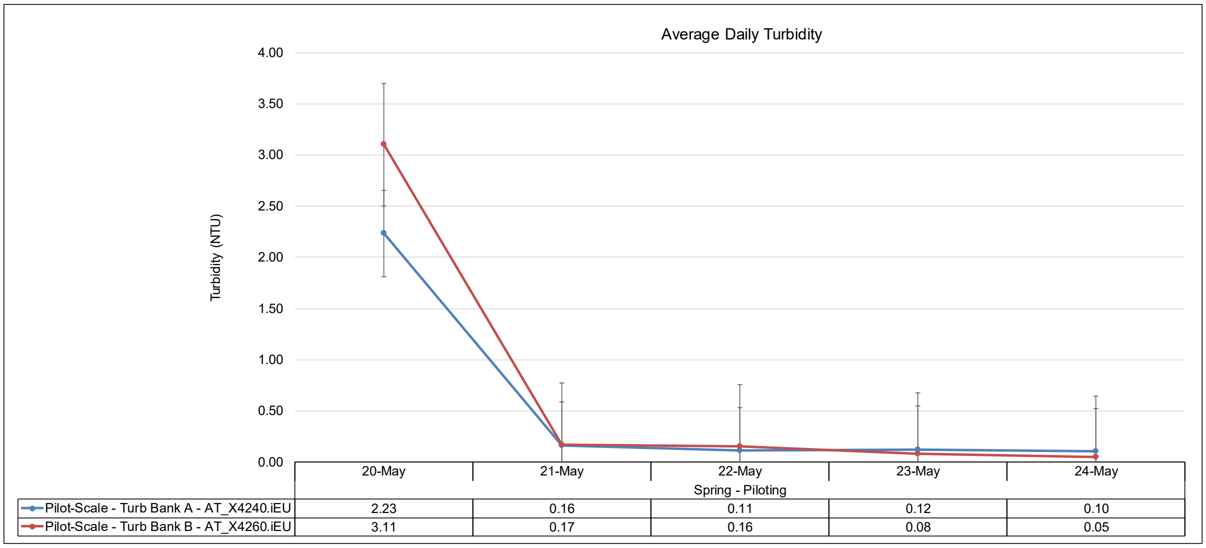
→ Turbidity

The turbidity results (Figure 5-15 and Figure 5-16) show that as the coagulant-aid dose increased, the turbidity in the Post-DAF and Post-Ozone decreased. On May 23rd and 24th, the turbidity in the Post-DAF and Post-Ozone was approximately equal to the raw water turbidity, which has not been typically measured in the previous Post-DAF or Post-Ozone samples from the pilot-scale system. This was likely due to the repair of the cracked DAF pipe. Lower turbidity in the Post-DAF and Post-Ozone may result in lower loading on the filters and consequently longer filter run times before the media exceeds the loading capacity. These results indicate that increasing the dose of the coagulant-aid up to 0.05 mg/L resulted in the lower levels of turbidity in the combined filter effluent. Subsequent increases in the dose of the coagulant-aid beyond 0.05 mg/L did not result in a significant change in turbidity. Benchtop turbidity results indicate the optimal dose was 0.05 mg/L; however, the online SCADA measured the lowest turbidity (Figure 5-16) at the highest coagulant-aid dose of 0.20 mg/L. Nevertheless, other issues were observed in the system at the coagulant-aid dose of 0.20 mg/L, such as an increased buildup of coagulant/coagulant-aid within the system, particularly in the DAF tank, and lower UFRV values. Buildup in the system increases the need for cleaning and maintenance in order for the pilot-scale system to operate in a stable and efficient manner.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
20-May (42 mg/L, 0.01 mg/L) - Turb	0.98	0.76	1.02	0.73	0.65	0.55	0.61	0.08	0.06	0.06	0.09	0.26
21-May (42 mg/L, 0.03 mg/L) - Turb	0.93	0.71	0.97	0.18	0.13	0.13	0.12	0.08	0.07	0.08	0.09	0.12
22-May (42 mg/L, 0.05 mg/L) - Turb	0.93	0.73	0.94	0.08	0.07	0.07	0.07	0.07	0.10	0.07	0.07	0.13
23-May (42 mg/L, 0.10 mg/L) - Turb	0.89	0.63	0.75	0.09	0.08	0.10	0.08	0.07	0.10	0.08	0.09	0.12
24-May (42 mg/L, 0.20 mg/L) - Turb	0.82	0.58	0.69	0.11	0.10	0.11	0.10	0.10	0.10	0.09	0.08	0.10

Figure 5-15: Turbidity levels following pilot-scale system treatment processes for the determination of the optimal dose of coagulant-aid during the Spring piloting session. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.

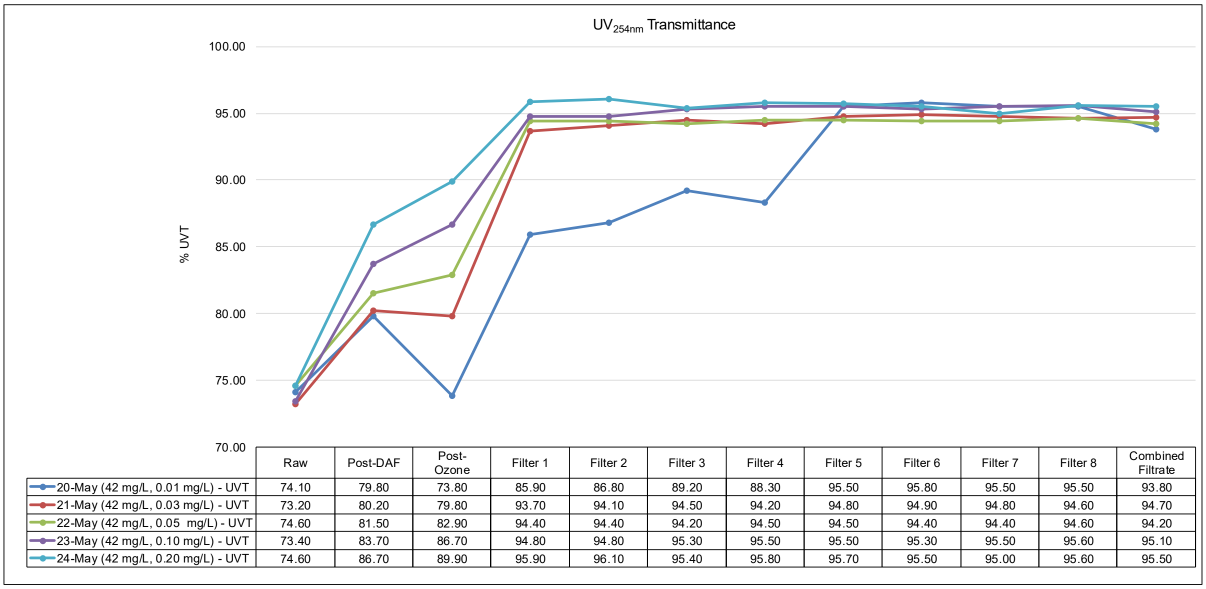


	20-May	21-May	22-May	23-May	24-May
Pilot-Scale - Turb Bank A - AT_X4240.iEU	2.23	0.16	0.11	0.12	0.10
Pilot-Scale - Turb Bank B - AT_X4260.iEU	3.11	0.17	0.16	0.08	0.05

Figure 5-16: Average daily turbidity for pilot-scale system filter effluent from Bank A and B during the Spring piloting session. Data originates from the pilot-scale system's SCADA dataset.

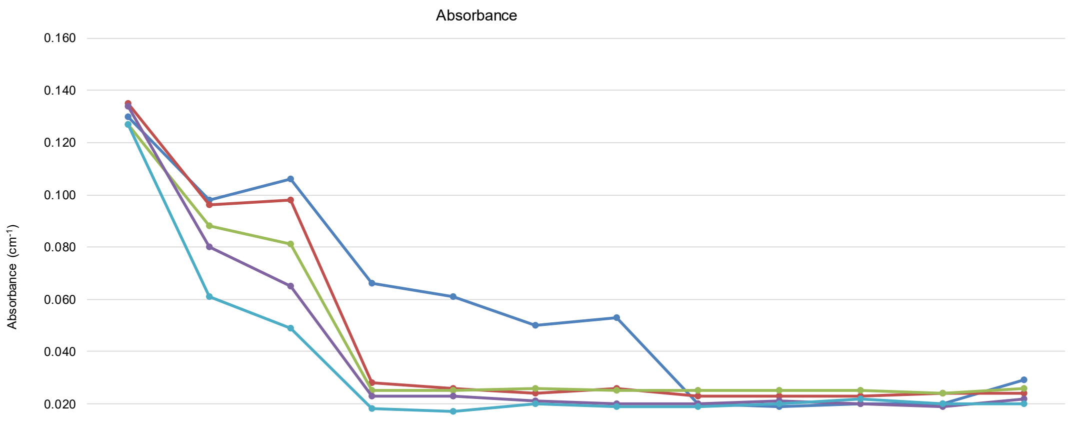
→ UVT & UV_{254nm} Absorbance

UVT and UV_{254nm} absorbance results are presented in Figure 5-17 and Figure 5-18. Both raw water UVT and UV_{254nm} absorbance values improved following coagulation and DAF treatment, with the best Post-DAF UVT and UV_{254nm} absorbance occurring at a coagulant-aid dose of 0.2 mg/L. Ozone treatment improved UVT and UV_{254nm} absorbance at coagulant-aid doses 0.05 – 0.2 mg/L, whereas, a decrease in water quality with regards to UVT and UV_{254nm} absorbance was measured at coagulant-aid doses of 0.01 mg/L and 0.03 mg/L, respectively. The lower UVT and higher UV_{254nm} absorbance at 0.01 mg/L and 0.03 mg/L may be due to the disruption of the polymers formed during coagulation by ozone, which is less pronounced when higher coagulant-aid doses are used.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
20-May (42 mg/L, 0.01 mg/L) - UVT	74.10	79.80	73.80	85.90	86.80	89.20	88.30	95.50	95.80	95.50	95.50	93.80
21-May (42 mg/L, 0.03 mg/L) - UVT	73.20	80.20	79.80	93.70	94.10	94.50	94.20	94.80	94.90	94.80	94.60	94.70
22-May (42 mg/L, 0.05 mg/L) - UVT	74.60	81.50	82.90	94.40	94.40	94.20	94.50	94.50	94.40	94.40	94.60	94.20
23-May (42 mg/L, 0.10 mg/L) - UVT	73.40	83.70	86.70	94.80	94.80	95.30	95.50	95.50	95.30	95.50	95.60	95.10
24-May (42 mg/L, 0.20 mg/L) - UVT	74.60	86.70	89.90	95.90	96.10	95.40	95.80	95.70	95.50	95.00	95.60	95.50

Figure 5-17: UVT measured following pilot-scale system treatment processes for the determination of the optimal dose of coagulant-aid during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
20-May (42 mg/L, 0.01 mg/L) - Abs	0.130	0.098	0.106	0.066	0.061	0.050	0.053	0.020	0.019	0.020	0.020	0.029
21-May (42 mg/L, 0.03 mg/L) - Abs	0.135	0.096	0.098	0.028	0.026	0.024	0.026	0.023	0.023	0.023	0.024	0.024
22-May (42 mg/L, 0.05 mg/L) - Abs	0.127	0.088	0.081	0.025	0.025	0.026	0.025	0.025	0.025	0.025	0.024	0.026
23-May (42 mg/L, 0.10 mg/L) - Abs	0.134	0.080	0.065	0.023	0.023	0.021	0.020	0.020	0.021	0.020	0.019	0.022
24-May (42 mg/L, 0.20 mg/L) - Abs	0.127	0.061	0.049	0.018	0.017	0.020	0.019	0.019	0.020	0.022	0.020	0.020

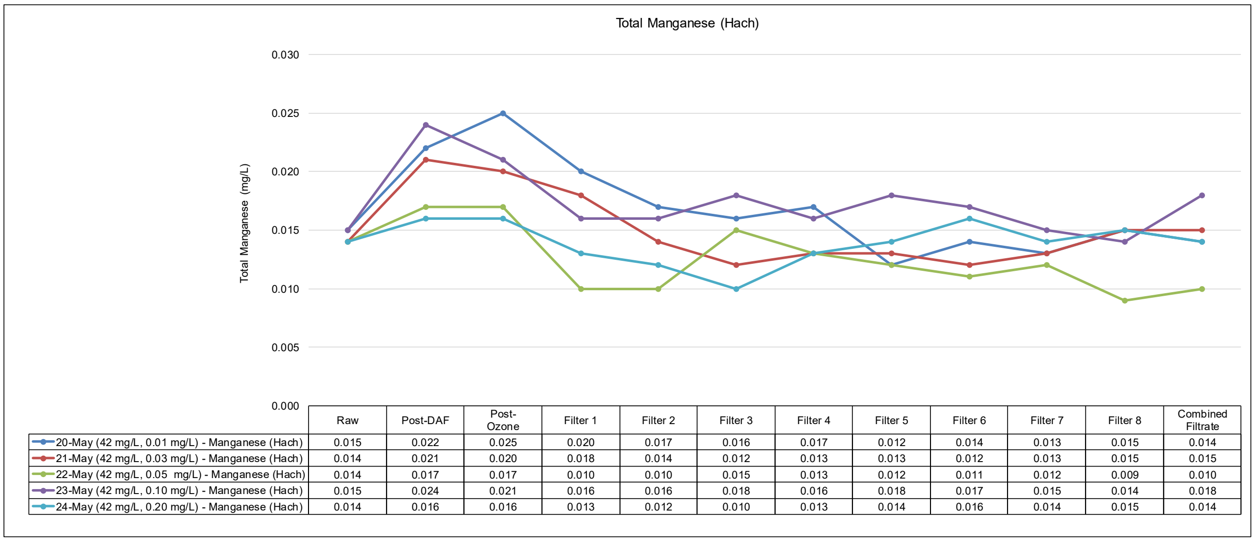
Figure 5-18: UV_{254nm} absorbance measured following pilot-scale treatment processes for the determination of the optimal dose of coagulant-aid during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

The coagulant-aid dose of 0.2 mg/L produced the best combined filter effluent water quality with regards to UVT and UV_{254nm} absorbance. When comparing the results between Bank A and B, there appears to be little difference in the average UVT and UV_{254nm} absorbance results for Bank B (Filters 5-8) for all coagulant-aid doses tested; however, Bank A (Filters 1-4) show improved UVT and UV_{254nm} absorbance with increasing coagulant-aid dose. It should be noted that Bank B operated at 0.3 L/s, which represents the average flow rate for the full-scale system, while Bank A operated at 0.6 L/s which represents the maximum flow rate for the full-scale system. Therefore, the results suggest that if the full-scale system were operated at the average flow rate there would be little improvement in UVT and UV_{254nm} absorbance with the addition of coagulant-aid; however, if the full-scale system were operated at a higher flow rate, the addition of coagulant-aid would improve finished water quality with respect to UVT and UV_{254nm} absorbance.

Overall the results illustrate that there both UVT and UV_{254nm} absorbance improved following DAF treatment, with a significant improvement in both parameters measured in the combined filter effluent. Likewise, UVT and UV_{254nm} absorbance was found to improve with increasing coagulant-aid dose for Post-DAF and combined filter effluent samples. The results indicate that the coagulant-aid dose of 0.20 produced the best UVT and UV_{254nm} absorbance results when evaluating the Post-DAF and filter effluent water quality.

→ Total Manganese

Total manganese results are presented in Figure 5-19. The total manganese concentration was found to decrease in the combined filter effluent with increasing coagulant-aid dose up to 0.05 mg/L. Further increases in the coagulant-aid resulted in higher total manganese concentrations. The optimal dose of coagulant-aid, based on total manganese, was found to be 0.05 mg/L.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
20-May (42 mg/L, 0.01 mg/L) - Manganese (Hach)	0.015	0.022	0.025	0.020	0.017	0.016	0.017	0.012	0.014	0.013	0.015	0.014
21-May (42 mg/L, 0.03 mg/L) - Manganese (Hach)	0.014	0.021	0.020	0.018	0.014	0.012	0.013	0.013	0.012	0.013	0.015	0.015
22-May (42 mg/L, 0.05 mg/L) - Manganese (Hach)	0.014	0.017	0.017	0.010	0.010	0.015	0.013	0.012	0.011	0.012	0.009	0.010
23-May (42 mg/L, 0.10 mg/L) - Manganese (Hach)	0.015	0.024	0.021	0.016	0.016	0.018	0.016	0.018	0.017	0.015	0.014	0.018
24-May (42 mg/L, 0.20 mg/L) - Manganese (Hach)	0.014	0.016	0.016	0.013	0.012	0.010	0.013	0.014	0.016	0.014	0.015	0.014

Figure 5-19: Total manganese levels measured following pilot-scale system treatment processes for the determination of the optimal dose of coagulant-aid during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

→ UFRV

Figure 5-20 illustrates the average observed and forecasted UFRV values obtained for each coagulant-aid dose for Bank A and Bank B. During optimization of the coagulant-aid dose, Bank A and Bank B overflowed every cycle, except for Bank B at 0.03 mg/L of coagulant-aid. Bank A filters failed based on turbidity (> 0.1 NTU) at coagulant-aid doses of 0.03 mg/L and 0.2 mg/L, and failed based on turbidity (> 0.3 NTU) at a coagulant-aid dose of 0.01 mg/L. No turbidity breakthrough was observed for Bank B at all coagulant-aid doses tested.

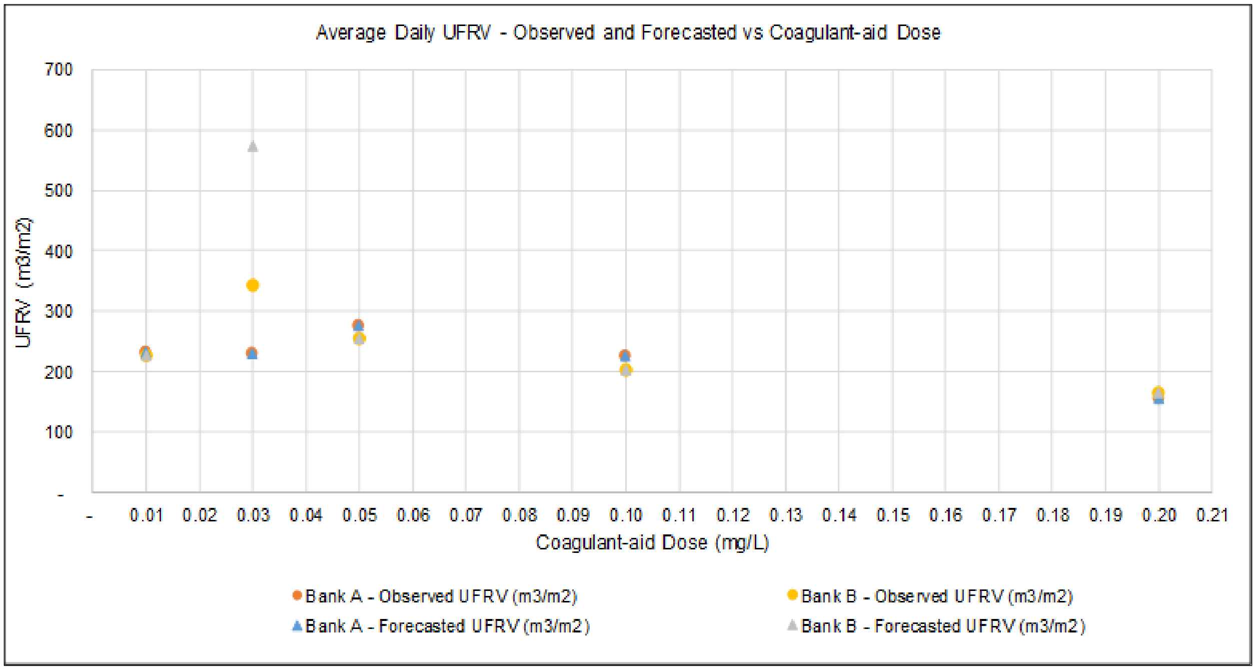


Figure 5-20: Average UFRV of the pilot-scale system Bank A at an average flow of 0.6 L/s and Bank B at an average flow of 0.3 L/s during the Spring piloting session for determining the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 42 mg/L and the pilot-scale system Post-DAF pH ranged from 5.64 and 5.75. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

It was observed that in general the average observed UFRV values increased as the coagulant-aid dose increased from a dose of 0.01 to 0.03 mg/L, whereas a decrease in UFRV values was observed from 0.05 to 0.2 mg/L. The highest observed UFRV values were obtained at the coagulant-aid dose of 0.03 mg/L (231 and 348 m^3/m^2 for Bank A and Bank B, respectively).

Although the observed UFRV values were above 200 m^3/m^2 for coagulant-aid doses up to 0.1 mg/L, turbidity breakthrough was not observed in either filter banks at doses of 0.05 and 0.1 mg/L. Among these two coagulant-aid doses, the highest observed UFRV values were obtained at the coagulant-aid of 0.05 mg/L (277 and 255 m^3/m^2 for Bank A and Bank B, respectively).

Considering the URFV results above, the coagulant-aid dose of 0.05 mg/L is considered to be the optimal dose and it is expected that the full-scale system will not have difficulty in producing sufficient treated water (inclusive of filter backwashing). As such, among the coagulant-aid doses tested, the coagulant-aid dose of 0.05 mg/L would be deemed a viable dose for full-scale system operation.

→ Summary of Coagulant-aid Optimization

The results obtained during the coagulant-aid optimization test suggested two possible optimal coagulant-aid doses of 0.05 mg/L and 0.20 mg/L. Based on the following logic, an optimal coagulant-aid dose of 0.20 mg/L was selected for the remainder of the Spring piloting session. Specifically:

- Aside from total manganese, the coagulant-aid dose of 0.20 mg/L had better turbidity removal (SCADA), and UVT and UV_{254nm} absorbance results when compared to a coagulant-aid dose of 0.05 mg/L.
- Due to the improvement in the pipe location for the addition of coagulant-aid completed during the Winter #1 piloting session, it was decided that it would be beneficial to evaluate the pilot-scale system operations at a higher coagulant-aid concentration.

The UFRV analysis performed following the completion of the Spring piloting session did not confirm the same optimal dose and indicated that the preferred coagulant-aid dose was 0.05 mg/L based on filter performance. However, the coagulant-aid dose of 0.20 mg/L had already been carried forward based on the water quality parameters.

5.6.3 Optimization of pH

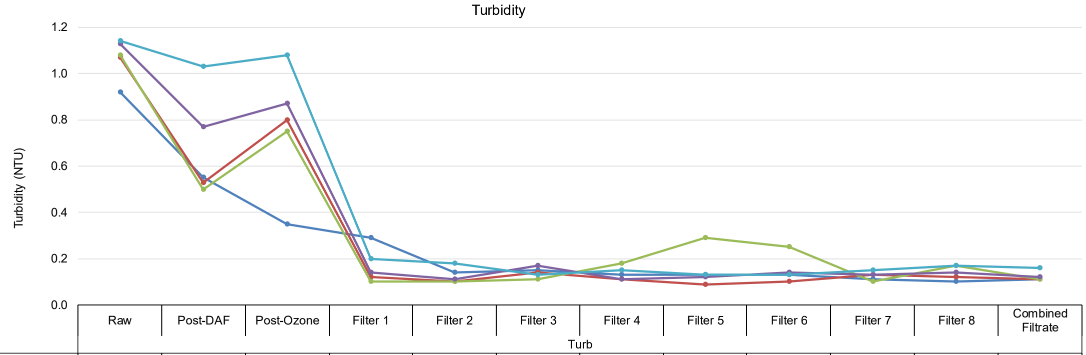
Using the optimal doses for coagulant (42 mg/L) and coagulant-aid (0.20 mg/L), the optimal pH for coagulation was tested from May 25th to May 29th, 2017. The pH was controlled by monitoring the online Pre-DAF pH meter (SCADA Tag AT-X1022) and manually adjusting the acid dose accordingly, until the desired pH was achieved in the DAF tank as illustrated in Table 4-1. During pH optimization, the actual pH measured from Post-DAF samples using the benchtop pH-probe found that the pH deviated from the target pH by >0.11 pH units (Table 5-3). The optimal pH was determined using a similar approach as used for the coagulant and coagulant-aid.

Table 5-3: Target pH used to determine the optimal pH for coagulation and the actual pH measured in the Post-DAF effluent. Note: actual pH was measured using benchtop analysis of grab samples.

Date	Target pH	Actual pH
May 25, 2017	5.65	5.60
May 26, 2017	5.95	6.06
May 27, 2017	6.25	6.21
May 28, 2017	6.55	6.65
May 29, 2017	6.85	6.83

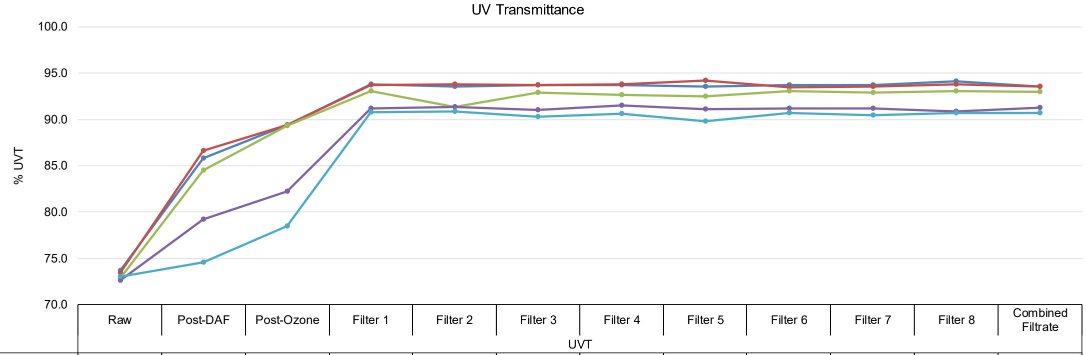
→ Turbidity, UVT & UV_{254nm} Absorbance, and Total Manganese

The results for the key parameters tested to determine the optimal pH for coagulation are presented in Figure 5-21 to Figure 5-24.



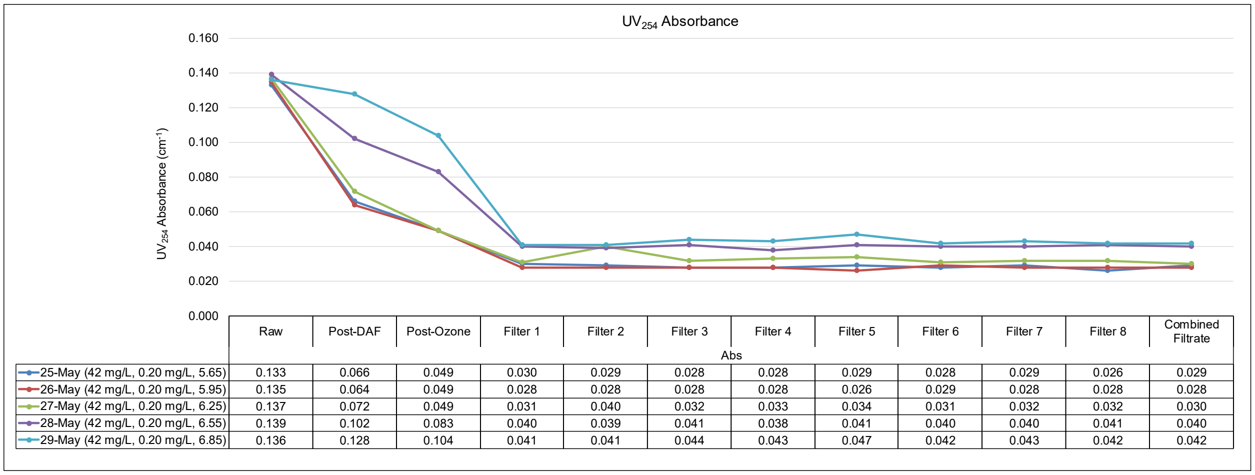
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
25-May (42 mg/L, 0.20 mg/L, 5.65)	0.920	0.550	0.350	0.290	0.140	0.150	0.130	0.130	0.130	0.110	0.100	0.110
26-May (42 mg/L, 0.20 mg/L, 5.95)	1.070	0.530	0.800	0.120	0.100	0.140	0.110	0.090	0.100	0.130	0.120	0.110
27-May (42 mg/L, 0.20 mg/L, 6.25)	1.080	0.500	0.750	0.100	0.100	0.110	0.180	0.290	0.250	0.100	0.170	0.110
28-May (42 mg/L, 0.20 mg/L, 6.55)	1.130	0.770	0.870	0.140	0.110	0.170	0.110	0.120	0.140	0.130	0.140	0.120
29-May (42 mg/L, 0.20 mg/L, 6.85)	1.140	1.030	1.080	0.200	0.180	0.130	0.150	0.130	0.130	0.150	0.170	0.160

Figure 5-21: Turbidity levels following pilot-scale system treatment processes for the determination of the optimal pH during the Spring piloting session. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
25-May (42 mg/L, 0.20 mg/L, 5.65)	73.7	85.8	89.4	93.8	93.6	93.7	93.7	93.6	93.7	93.7	94.1	93.6
26-May (42 mg/L, 0.20 mg/L, 5.95)	73.4	86.6	89.4	93.7	93.8	93.7	93.8	94.2	93.5	93.6	93.8	93.6
27-May (42 mg/L, 0.20 mg/L, 6.25)	72.9	84.5	89.3	93.1	91.4	92.9	92.7	92.5	93.1	92.9	93.1	93.0
28-May (42 mg/L, 0.20 mg/L, 6.55)	72.6	79.2	82.2	91.2	91.4	91.0	91.5	91.1	91.2	91.2	90.9	91.3
29-May (42 mg/L, 0.20 mg/L, 6.85)	73.0	74.6	78.5	90.8	90.9	90.3	90.6	89.8	90.7	90.5	90.7	90.7

Figure 5-22: UVT measured following pilot-scale system treatment processes for the determination of the optimal pH during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

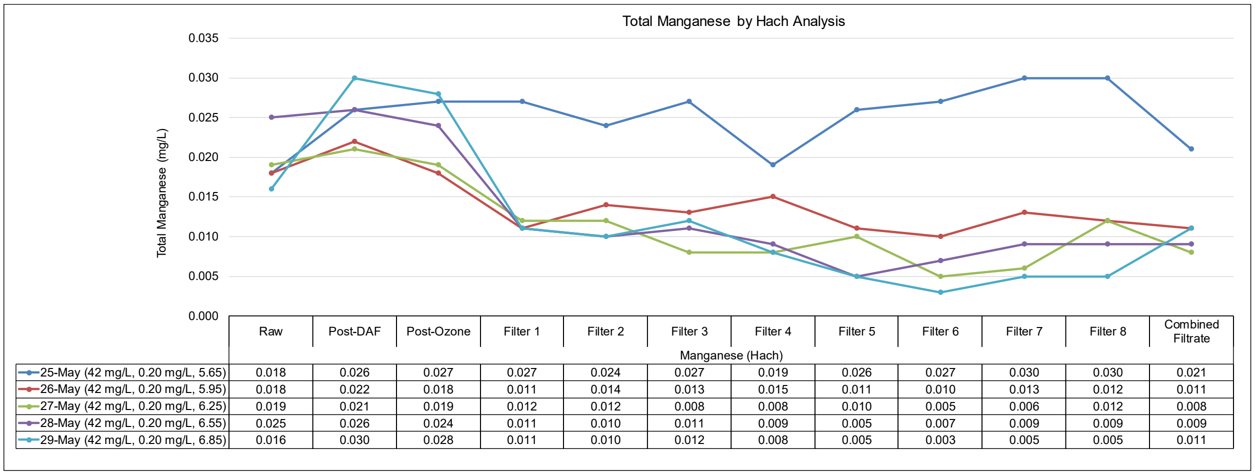


Abs	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
25-May (42 mg/L, 0.20 mg/L, 5.65)	0.133	0.066	0.049	0.030	0.029	0.028	0.028	0.029	0.028	0.029	0.026	0.029
26-May (42 mg/L, 0.20 mg/L, 5.95)	0.135	0.064	0.049	0.028	0.028	0.028	0.028	0.026	0.029	0.028	0.028	0.028
27-May (42 mg/L, 0.20 mg/L, 6.25)	0.137	0.072	0.049	0.031	0.040	0.032	0.033	0.034	0.031	0.032	0.032	0.030
28-May (42 mg/L, 0.20 mg/L, 6.55)	0.139	0.102	0.083	0.040	0.039	0.041	0.038	0.041	0.040	0.040	0.041	0.040
29-May (42 mg/L, 0.20 mg/L, 6.85)	0.136	0.128	0.104	0.041	0.041	0.044	0.043	0.047	0.042	0.043	0.042	0.042

Figure 5-23: UV_{254nm} absorbance measured following pilot-scale system treatment processes for the determination of the optimal pH during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

Turbidity, UVT, and UV_{254nm} absorbance (Figure 5-21 to Figure 5-23) did not change significantly during the first three days of pH optimization (pH range 5.60 to 6.21; results reported for actual measured pH from benchtop samples); however, subsequent increases in pH (6.65 and 6.83) resulted in a steady deterioration of water quality.

Figure 5-24 presents the change in total manganese during optimal pH testing. The results show that there was an increase in total manganese following the addition of ferric sulphate (measured in Post-DAF effluent). This increase is expected given the residual manganese found in ferric sulphate. Minimal change occurred following ozonation. Filtration reduced the manganese at all pH tested. When comparing the total manganese in the combined filter, there is a reduction in total manganese as pH increased from 5.65 to 6.25, where subsequent increases in pH (i.e. 6.55 and 6.85) there was a slight increase in total manganese measured in the combined filter effluent. According to the total manganese results, the optimal pH is 6.25.



Manganese (Hach)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
25-May (42 mg/L, 0.20 mg/L, 5.65)	0.018	0.026	0.027	0.027	0.024	0.027	0.019	0.026	0.027	0.030	0.030	0.021
26-May (42 mg/L, 0.20 mg/L, 5.95)	0.018	0.022	0.018	0.011	0.014	0.013	0.015	0.011	0.010	0.013	0.012	0.011
27-May (42 mg/L, 0.20 mg/L, 6.25)	0.019	0.021	0.019	0.012	0.012	0.008	0.008	0.010	0.005	0.006	0.012	0.008
28-May (42 mg/L, 0.20 mg/L, 6.55)	0.025	0.026	0.024	0.011	0.010	0.011	0.009	0.005	0.007	0.009	0.009	0.009
29-May (42 mg/L, 0.20 mg/L, 6.85)	0.016	0.030	0.028	0.011	0.010	0.012	0.008	0.005	0.003	0.005	0.005	0.011

Figure 5-24: Total manganese measured following pilot-scale system treatment processes for determining the optimal pH during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

→ UFRV

Figure 5-25 illustrates the average observed and forecasted UFRV values obtained for each pH at Bank A and Bank B.

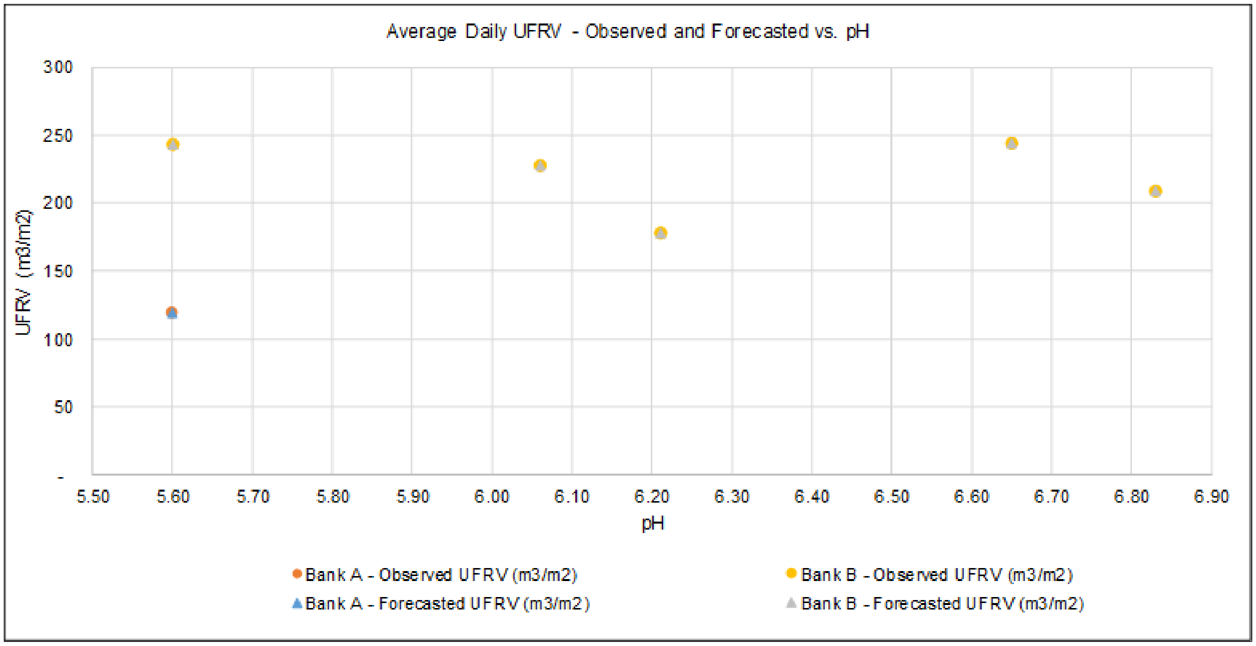


Figure 5-25: Average UFRV of the pilot-scale system Bank A at an average flow of 0.6 L/s and Bank B at an average flow of 0.3 L/s during the Spring piloting session for determining the optimal pH. The pilot-scale system coagulant dose was maintained at 42 mg/L and the coagulant-aid dose was maintained at 0.20 mg/L. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

Results are available for Bank A only at a pH of 5.6 as differential pressure values reported by the pilot-scale system SCADA presented multiple fluctuations for the other pH values tested, as such, the data was discarded. During pH optimization, Bank B overflowed every cycle. All Bank B individual filters failed based on turbidity (> 0.1 NTU) at a pH of 5.6, 6.65 and 6.83, while 50% of the individual filters failed at a pH of 6.1 and 75% failed at a pH of 6.21. No pattern between the pH and the UFRV values could be identified and the performance of the pilot-scale system filters was deemed poor at all doses. Consequently, is not possible to select the optimal pH based on the empirical URFV results observed.

→ Summary of pH Optimization

The results of the pH optimization period are consistent with literature results, which reports that the optimal pH for coagulation with ferric salts is between 5.5 and 6.5.

Total manganese concentrations in the filter effluent were found to decrease as the pH increased up to 6.21, with a subsequent increase in total manganese as pH levels increased above 6.21 (Figure 5-24).

These results suggest that ferric sulphate would be effective at a higher pH (6.0 to 6.2) which would also reduce deterioration of the existing concrete structures. Overall, per the turbidity, UVT, and UV_{254nm} absorbance results, the optimal pH was determined to be between 6.0 and 6.2, while total manganese results reinforced the optimal pH to be 6.2.

5.7 Optimized Condition Results

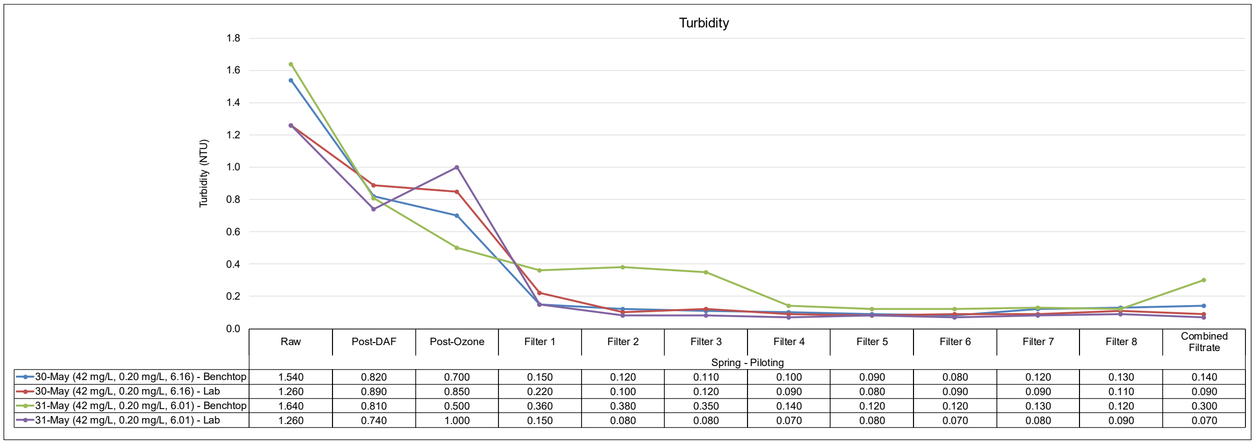
The optimal coagulant dose, coagulant-aid dose, and pH determined for the Spring piloting session were tested on May 30th and 31st, 2017. Since there was a range in optimal pH found (6.0 to 6.21), it was determined that the optimal pH range should be tested to observe potential differences which can be found when comparing results from the Lab. Samples were collected and sent to the Lab for more extensive analytical testing (Type 1 or 2; see Table 4-1). Table 5-4 indicates the pilot-scale system operating conditions (coagulant, coagulant-aid dose, and pH) for each of the optimal test days.

Table 5-4: Optimal chemical doses for ferric sulphate, coagulant-aid and pH (measured Post-DAF using benchtop analysis) for each of the optimal test days during the Spring piloting session.

Date	Coagulant Dose (mg/L)	Coagulant-aid Dose (mg/L)	pH	Acid Dose (mg/L)
May 30, 2017	42	0.20	6.16	25
May 31, 2017	42	0.20	6.01	28-30

→ Turbidity

The turbidity results (Figure 5-26) were found to be similar for combined filter effluent between the benchtop and Lab analyses. The exception to this observation was on May 31st, in which higher turbidity in the filtrate from Filters 1 to 3 for benchtop measurements (0.36 NTU, 0.38 NTU, and 0.35 NTU) was observed when compared to the Lab results (0.15 NTU, 0.08 NTU, and 0.08 NTU).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-May (42 mg/L, 0.20 mg/L, 6.16) - Benchtop	1.540	0.820	0.700	0.150	0.120	0.110	0.100	0.090	0.080	0.120	0.130	0.140
30-May (42 mg/L, 0.20 mg/L, 6.16) - Lab	1.260	0.890	0.850	0.220	0.100	0.120	0.090	0.080	0.090	0.090	0.110	0.090
31-May (42 mg/L, 0.20 mg/L, 6.01) - Benchtop	1.640	0.810	0.500	0.360	0.380	0.350	0.140	0.120	0.120	0.130	0.120	0.300
31-May (42 mg/L, 0.20 mg/L, 6.01) - Lab	1.260	0.740	1.000	0.150	0.080	0.080	0.070	0.080	0.070	0.080	0.090	0.070

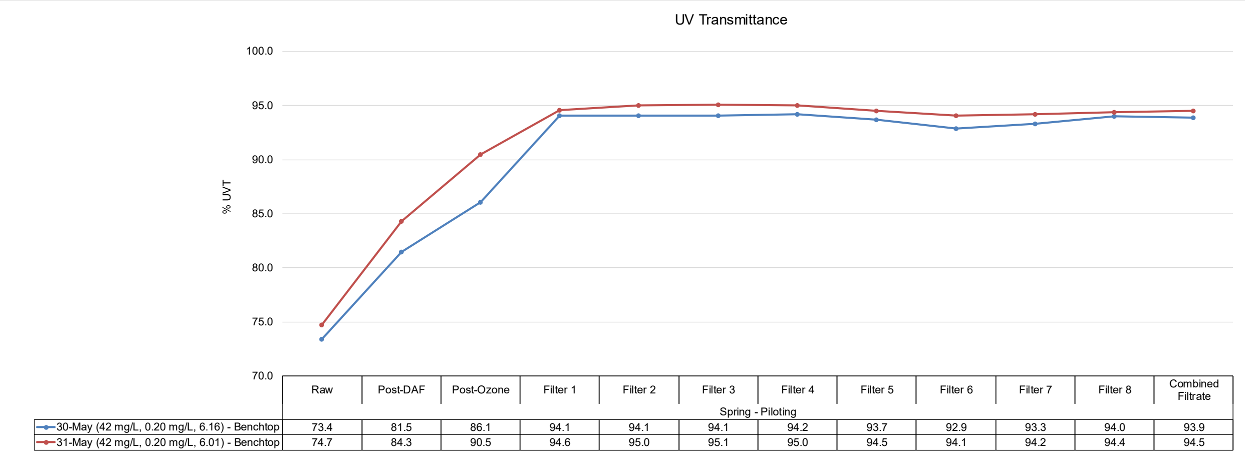
Figure 5-26: Turbidity levels measured following pilot-scale system treatment processes using optimal conditions during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer (benchtop) or from Lab analysis.

The origin of the discrepancy in the turbidity analyses from May 31st is unclear. However, since the samples were also provided to the lab, it is anticipated that the benchtop instrument experienced some form of instrument or measurement error in measuring the effluent from Filters 1-3. This error was not seen in the samples collected from Filters 4-8; therefore, it is suspected that the error was due to incomplete cleaning of the sample cell. Nonetheless, lab results are consistent with those observed throughout the Spring piloting session.

Building upon the turbidity results, the optimal removal occurred on May 31st (lab data indicating a reduction of turbidity from 1.26 to 0.07 NTU when compared to a reduction from 1.26 to 0.09 NTU on May 30th). Overall there is little difference in pilot-scale system performance when operating between a pH of approximately 6.0 to 6.2.

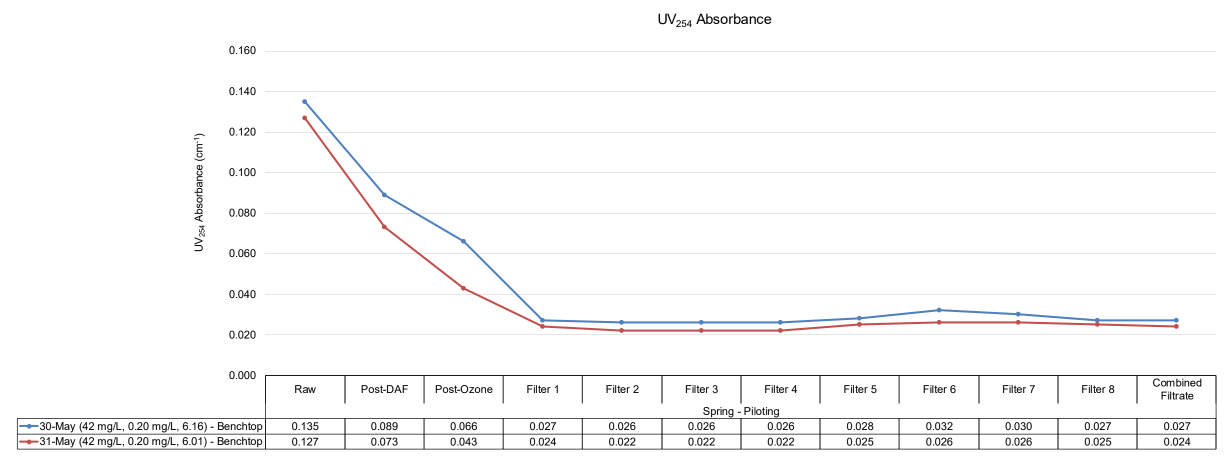
→ UVT and UV_{254nm} Absorbance

The UVT results (Figure 5-27) were similar for both optimal testing days, ranging from 93.9% to 94.5% (combined filter effluent), with the highest UVT occurring on May 31st. UV_{254nm} absorbance (Figure 5-28) was found to be higher in the sample collected from the combined filter effluent on May 30th (UV_{254nm} absorbance of 0.027 cm^{-1}).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-May (42 mg/L, 0.20 mg/L, 6.16) - Benchtop	73.4	81.5	86.1	94.1	94.1	94.1	94.2	93.7	92.9	93.3	94.0	93.9
31-May (42 mg/L, 0.20 mg/L, 6.01) - Benchtop	74.7	84.3	90.5	94.6	95.0	95.1	95.0	94.5	94.1	94.2	94.4	94.5

Figure 5-27: UVT measured following pilot-scale system treatment processes using optimal chemical doses (coagulant and coagulant-aid) and pH determined during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.



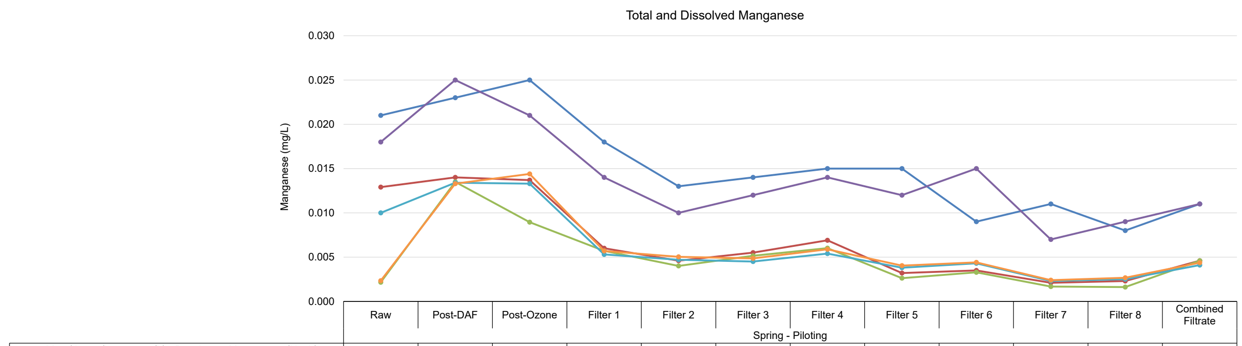
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-May (42 mg/L, 0.20 mg/L, 6.16) - Benchtop	0.135	0.089	0.066	0.027	0.026	0.026	0.026	0.028	0.032	0.030	0.027	0.027
31-May (42 mg/L, 0.20 mg/L, 6.01) - Benchtop	0.127	0.073	0.043	0.024	0.022	0.022	0.022	0.025	0.026	0.026	0.025	0.024

Figure 5-28: UV_{254nm} absorbance measured following pilot-scale system treatment processes using optimal chemical doses (coagulant and coagulant-aid) and pH determined during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-vis spectrophotometer.

Although only minor differences in measured UVT and UV_{254nm} absorbance were observed during the optimal testing days, the results indicate that the highest quality of finished water, according to UVT and UV_{254nm} absorbance, occurred on May 31st at a pH of 6.01.

→ Total Manganese

Figure 5-29 illustrates total and dissolved manganese concentrations during the optimized testing days. Lab measurement for total manganese was consistently lower than the benchtop analysis. This difference was discussed in TM No. 3 which noted that the benchtop instrument used for total manganese was operating near the instruments limit of detection. Lab results are believed to better represent manganese concentrations due to a higher sensitivity of the Lab instrumentation (with the use of ICP-MS).



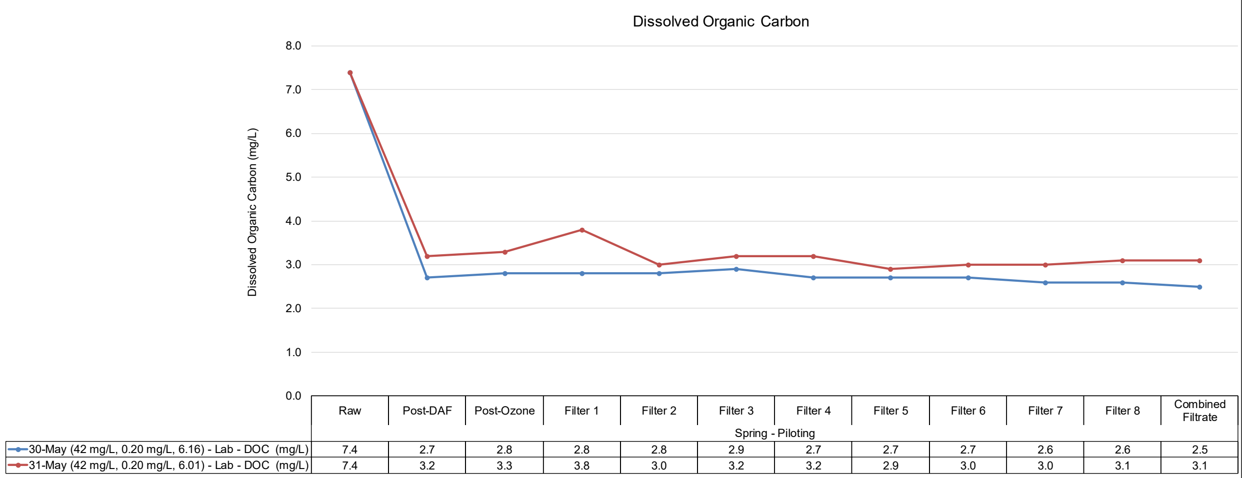
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-May (42 mg/L, 0.20 mg/L) - Benchtop - Manganese (Hach)	0.021	0.023	0.025	0.018	0.013	0.014	0.015	0.015	0.009	0.011	0.008	0.011
30-May (42 mg/L, 0.20 mg/L) - Lab - Manganese, Total (mg/L)	0.013	0.014	0.014	0.006	0.005	0.006	0.007	0.003	0.004	0.002	0.002	0.005
30-May (42 mg/L, 0.20 mg/L) - Lab - Manganese, Dissolved (mg/L)	0.002	0.014	0.009	0.006	0.004	0.005	0.006	0.003	0.003	0.002	0.002	0.005
31-May (42 mg/L, 0.20 mg/L) - Benchtop - Manganese (Hach)	0.018	0.025	0.021	0.014	0.010	0.012	0.014	0.012	0.015	0.007	0.009	0.011
31-May (42 mg/L, 0.20 mg/L) - Lab - Manganese, Total (mg/L)	0.010	0.013	0.013	0.005	0.005	0.005	0.005	0.004	0.004	0.002	0.003	0.004
31-May (42 mg/L, 0.20 mg/L) - Lab - Manganese, Dissolved (mg/L)	0.002	0.013	0.014	0.006	0.005	0.005	0.006	0.004	0.004	0.002	0.003	0.004

Figure 5-29: Total and dissolved manganese measured by the Lab and total manganese measured by the Hach method, following pilot-scale system treatment processes using optimal chemical doses (coagulant and coagulant-aid) and pH determined during the Spring piloting session. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer or from Lab analyses.

Generally, the concentration of total manganese in the combined filter effluent decreased with optimized testing (i.e., $[Mn]_{\text{Coagulant opt}} > [Mn]_{\text{Coagulant-aid opt}} > [Mn]_{\text{pH opt}}$). May 30th and 31st had lower manganese concentrations compared to previous tests when only the coagulant or the coagulant-aid was optimized.

→ Dissolved Organic Carbon

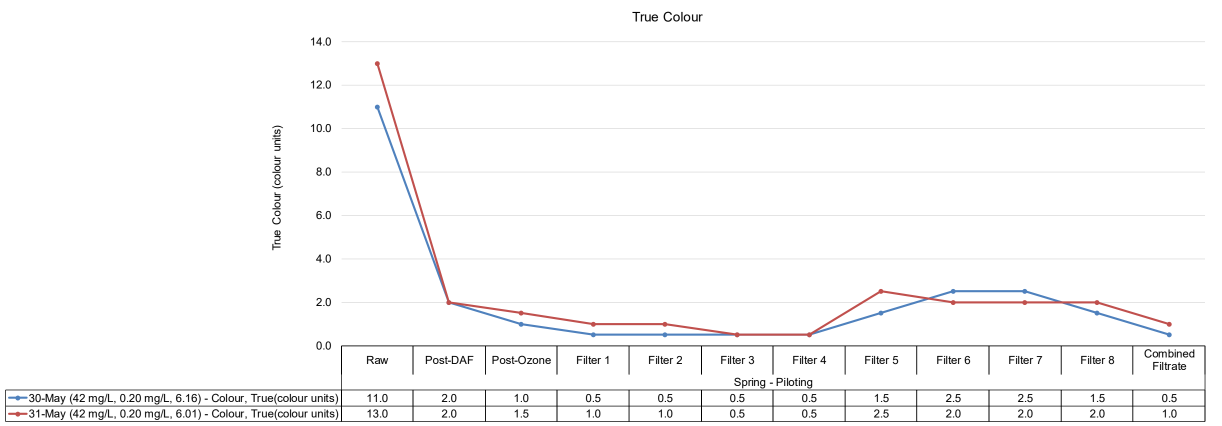
The greatest reduction in DOC was measured in the Post-DAF samples for all optimal conditions tested (56.7%-63.5%), observable in Figure 5-30. Furthermore, little to no reduction in DOC (<0.2 mg/L) was found following ozonation or filtration.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-May (42 mg/L, 0.20 mg/L, 6.16) - Lab - DOC (mg/L)	7.4	2.7	2.8	2.8	2.8	2.9	2.7	2.7	2.7	2.6	2.6	2.5
31-May (42 mg/L, 0.20 mg/L, 6.01) - Lab - DOC (mg/L)	7.4	3.2	3.3	3.8	3.0	3.2	3.2	2.9	3.0	3.0	3.1	3.1

Figure 5-30: DOC measured following pilot-scale system treatment processes using optimal chemical doses (coagulant and coagulant-aid) and pH determined during the Spring piloting session. Data originates from ALS laboratory analysis.

Figure 5-31 illustrates the true colour results during the optimized testing. Pilot-scale system Filters 5 to 8 have presented poorer results for colour in comparison with Filters 1 to 4. The cause for this discrepancy is unknown, however, it is believed turbidity, total manganese and DOC are not the source (as observed in Figure 5-26, Figure 5-29, and Figure 5-30).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-May (42 mg/L, 0.20 mg/L, 6.16) - Colour, True(colour units)	11.0	2.0	1.0	0.5	0.5	0.5	0.5	1.5	2.5	2.5	1.5	0.5
31-May (42 mg/L, 0.20 mg/L, 6.01) - Colour, True(colour units)	13.0	2.0	1.5	1.0	1.0	0.5	0.5	2.5	2.0	2.0	2.0	1.0

Figure 5-31: True colour measured following pilot-scale system treatment processes using optimal chemical doses (coagulant and coagulant-aid) and pH determined during the Spring piloting session. Data originates from Lab analyses.

→ Filters Operation

Table 5-5 tabulates the average UFRV values for optimal days during the Spring piloting session, while also considering overall operation cycles and those which have not failed based on sampled turbidity.

Table 5-5: Average observed and forecasted UFRV values for the optimal conditions of Spring piloting session.

UFRV (m^3/m^2)		OPTIMAL DAYS OF SPRING PILOTING SESSION		
		Bank A	**Bank B**	**All Filters**
Observed Values	Overall Cycles	92	118	109
	Only cycles with turbidity ≤ 0.1 NTU	N/R	137	137
	Only cycles with turbidity ≤ 0.3 NTU	123	118	119
Forecasted Values	Overall Cycles	92	119	105
	Only cycles with turbidity ≤ 0.1 NTU	N/R	137	137
	Only cycles with turbidity ≤ 0.3 NTU	123	133	132

N/R: No results

The filter effluent turbidity measured by the Lab is plotted against the differential pressure at 4 hours after start of filter cycle (or approximate sampling time) of each individual filter for the piloting days at optimal conditions, as shown on Figure 5-32. This illustration also highlights the City's operational filter turbidity limit of 0.1 NTU, the full-scale system operating licence limit of 0.3 NTU, and the expected differential pressures at the sampling time per flow rate to match the full-scale system's performance. The expected differential pressures of 6.8 kPa for filters at average flow rate and 12.4 kPa for filters at maximum flow rate are based on the historical benchmarking values of the full-scale system filters (average head loss of 48.9 kPa and average filter run of 28.9 h per Table 2-2 of TM No. 1).

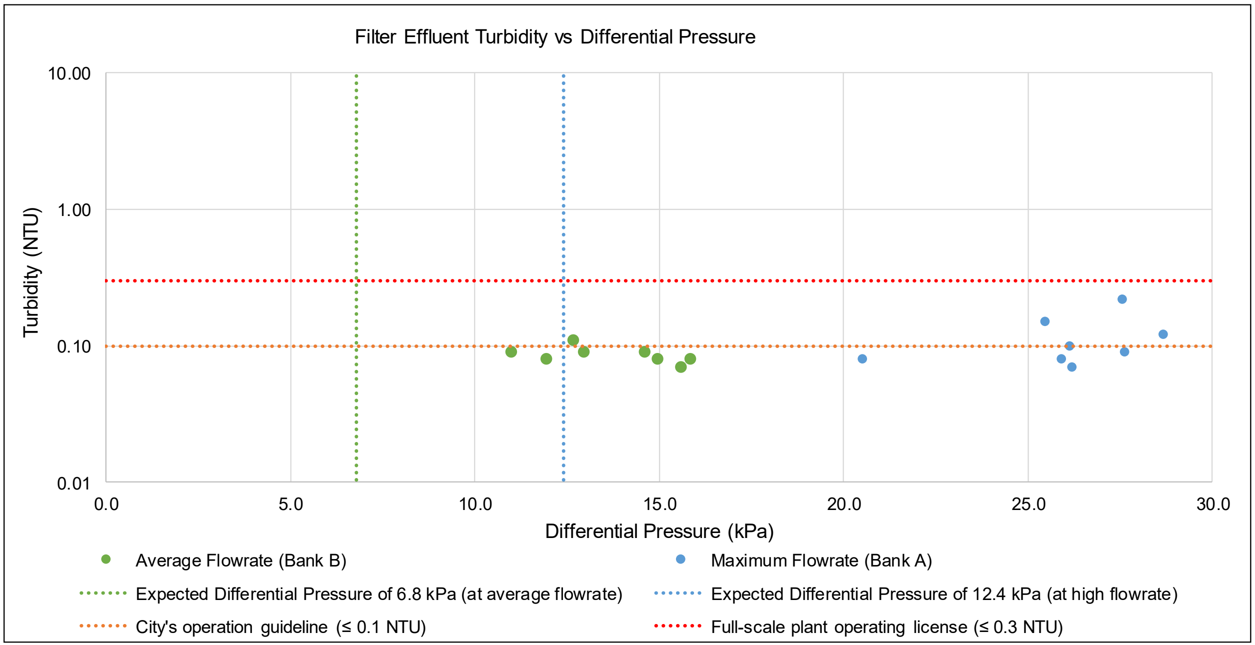


Figure 5-32: Filter effluent turbidity versus differential pressure at sampling time for each individual filter for the optimal conditions of Spring piloting session. Note the turbidity levels (y-axis) are displayed in a logarithmic scale to improve visualization.

Results are available only for Bank A on the second optimal day (May 31st) as differential pressure values reported by the pilot-scale system's SCADA presented multiple fluctuations and subsequently the data was discarded. On the second optimal day, the filter operation was terminated after 6 hours. All individual filters failed based on turbidity (> 0.1 NTU). For Bank A, the observed overall average UFRV was 92 m^3/m^2 during the optimal conditions of the Spring piloting session. When discarding the cycles where turbidity levels exceeded 0.3 NTU, the observed UFRV values were 123 m^3/m^2. The differential pressure at 4 hours after start of filter cycle (maximum differential pressure available is 20.5 – 28.7 kPa) was nearly double that of the expected differential pressure (12.4 kPa) for maximum flow rate. In addition, the average rate of head loss increase for Bank A was 8.5 kPa/h, representing an increase of 20% above the expectant maximal rate of head loss (7.1 kPa/h, Refer to Table 5-2 of TM No. 3).

Only Filter 8 of Bank B presented effluent turbidity levels above 0.1 NTU on the second optimal condition day, however, the differential pressure at 4 hours after start of filter cycle (11.0 – 15.9 kPa) were nearly double that of the expected differential pressure (6.8 kPa) for average flow rate. The average rate of head loss increase for Bank B was 2.7 kPa/h, approximately 60% higher than the typical rate of head loss (1.7 kPa/h, Refer to Table 5-2 of TM No. 3). For Bank B, the observed overall average UFRV was 118 m^3/m^2. When discarding the cycles that turbidity levels were above 0.1 NTU when sampled, the observed UFRV values were slightly higher (137 m^3/m^2). It is believed that this value would likely be doubled in the full-scale system as explained in Section 2.4, where the head loss available for filtration is twice that of the available head loss at the pilot-scale system filters.

During the Spring piloting session, both filler banks achieved UFRV values substantially lower than the minimal value of 200 m^3/m^2 required to achieve a recovery of greater than 95%. In addition, the Bank A presented turbidity breakthrough and both banks presented a high rate of head loss increase. Therefore, the performance of pilot-scale system filters was deemed poor. However, it is believed that the high dose of coagulant-aid was the main contributor and not the ferric sulphate, as discussed in Section 5.6.2.

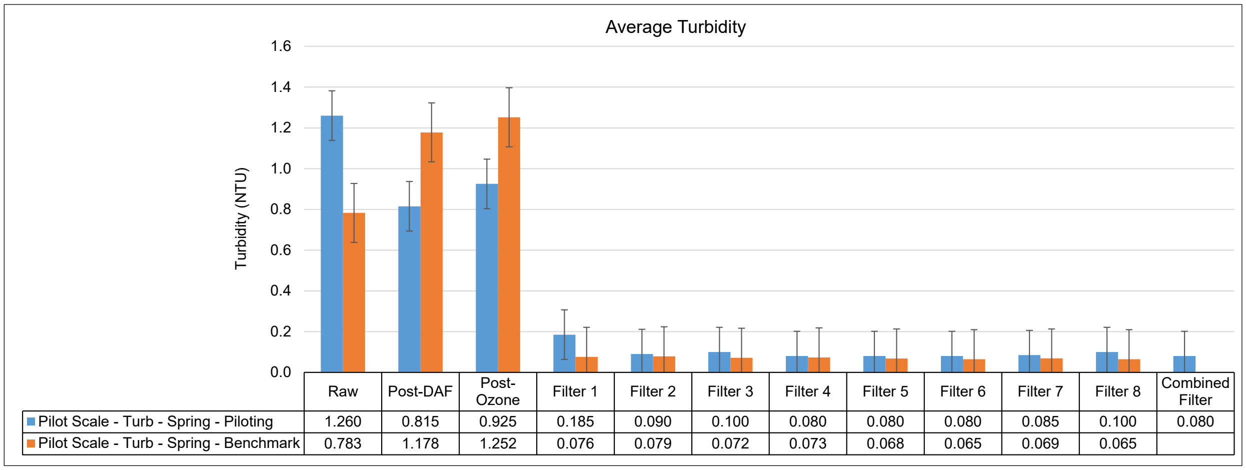
→ Summary of Optimal Conditions

Overall, the water quality results indicate that the optimal treated water quality (filter or combined filter effluent) in terms of turbidity, UVT, UV_{254nm} absorbance, and manganese concentration occurred on May 31st, 2017, at a ferric sulphate dose of 42 mg/L, a coagulant-aid dose of 0.20 mg/L, and the optimal pH of 6.01 (pH Post-DAF). However, the UFRV analysis showed the coagulant-aid dose was not necessarily optimal based on filter performance.

5.8 Comparison Between the Spring Benchmarking Period and the Spring Piloting Session of the Pilot-System

Figure 5-33 to Figure 5-35 compare the turbidity, total manganese and TOC yielded at the pilot-scale system during the Spring benchmarking period with ferric chloride and the optimal results at the Spring piloting session with ferric sulphate. These are the key water quality parameters to be compared. It is important to note that Post-DAF and Post-Ozone samples collected during the Spring benchmarking period may have been affected by the cracked DAF saturator water. Also, it is important to note that the raw water was only sampled from the full-scale system; however, for the purposes of this study the water quality for the raw water is assumed to be the same.

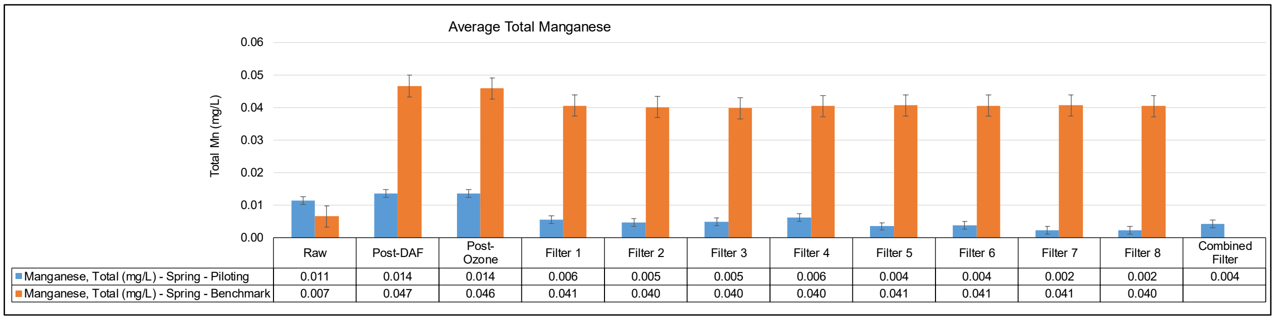
It is possible to observe that the use of ferric sulphate has generally demonstrated a lower Post-DAF and Post-Ozone turbidity (Figure 5-33) when compared with ferric chloride Post-DAF, possibly due to the repair of the DAF saturated water pipe, which occurred between the Spring benchmarking period and the Spring piloting session. However, slightly higher turbidity results were found in the filter effluent for the Spring piloting session when compared to the Spring benchmarking period.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
🟦 Pilot Scale - Turb - Spring - Piloting	1.260	0.815	0.925	0.185	0.090	0.100	0.080	0.080	0.080	0.085	0.100	0.080
🟧 Pilot Scale - Turb - Spring - Benchmark	0.783	1.178	1.252	0.076	0.079	0.072	0.073	0.068	0.065	0.069	0.065	

Figure 5-33: Comparison of turbidity levels between the pilot-scale system Spring benchmarking period (average values from April 10th and May 3rd, 2017) and pilot-scale system Spring piloting session (optimal conditions from May 30th and May 31st, 2017). Data originates from Lab analysis. Note: the raw water value was sampled from the full-scale system; however, for the purposes of this study the water quality for the raw water is assumed to be the same.

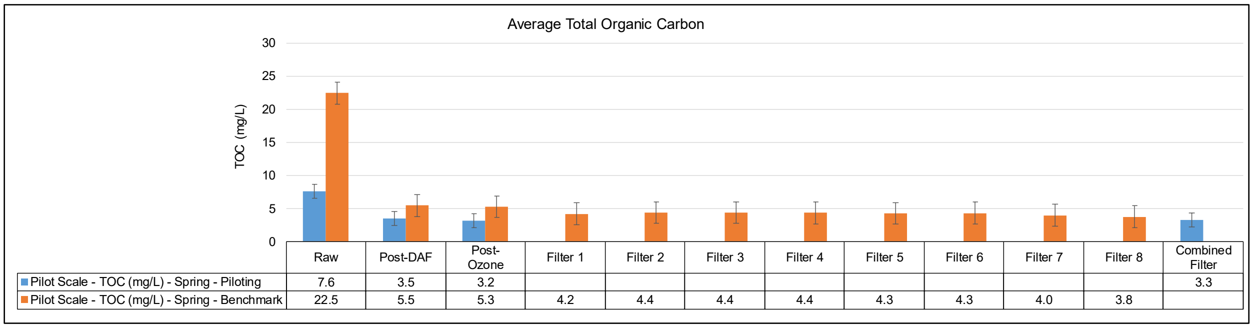
In terms of Post-DAF total manganese (Figure 5-34), there is minimal increase in total manganese with ferric sulphate; whereas, there is a significant increase in total manganese when ferric chloride is added. This equates manganese in the filter effluent approximately ten times lower with ferric sulphate than with ferric chloride as the coagulant. The results also indicate that there is no reduction in manganese by the filters with ferric chloride; however, there is a reduction in total manganese when ferric sulphate is added. The results also indicate that the total manganese reduction by the filters is twice the value during the piloting session in relation to the benchmarking period (0.01 mg/L vs 0.05 mg/L, respectively). This is best explained by the difference in pH between the two sample sets. More manganese would be dissolved at the lower pH (pH <5.5) used during the Spring benchmarking period with ferric chloride. At a higher pH, the manganese would be less soluble and more would precipitate out and be removed by filtration.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
■ Manganese, Total (mg/L) - Spring - Piloting	0.011	0.014	0.014	0.006	0.005	0.005	0.006	0.004	0.004	0.002	0.002	0.004
■ Manganese, Total (mg/L) - Spring - Benchmark	0.007	0.047	0.046	0.041	0.040	0.040	0.040	0.041	0.041	0.041	0.040	

Figure 5-34: Comparison of total manganese levels between the pilot-scale system Spring benchmarking period (average values from April 10th and May 3rd, 2017) and pilot-scale system Spring piloting session (optimal conditions from May 30th and May 31st, 2017). Data originates from Lab analysis. Note: the raw water value was sampled from the full-scale system; however, for the purposes of this study the water quality for the raw water is assumed to be the same.

Raw water TOC showed much higher values than expected during the Spring benchmarking period (Figure 5-35). Investigations by the City indicates that the elevated TOC data was the result of laboratory errors. Therefore, it is not possible to conclude if the ferric sulphate impacted the organic matter removal by the pilot-scale system DAF when compared with ferric chloride results. On the other hand, lower TOC concentrations were found in the Post-DAF, Post-Ozone and filter effluent samples for the Spring piloting session when compared to the Spring benchmarking period.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
■ Pilot Scale - TOC (mg/L) - Spring - Piloting	7.6	3.5	3.2									3.3
■ Pilot Scale - TOC (mg/L) - Spring - Benchmark	22.5	5.5	5.3	4.2	4.4	4.4	4.4	4.3	4.3	4.0	3.8	

Figure 5-35: Comparison of total organic carbon levels between the pilot-scale system Spring benchmarking period (average values from April 10th and May 3rd, 2017) and pilot-scale system Spring piloting session (optimal conditions from May 30th and May 31st, 2017). Data originates from Lab analysis. Note: the raw water value was sampled from the full-scale system; however, for the purposes of this study the water quality for the raw water is assumed to be the same. Also to note, the TOC concentration measured during the Spring benchmarking period are erroneous and are believed to be 2-3 times higher than the actual TOC concentration.

Appendix E presents a comprehensive table comparing the average water quality results from the Spring pilot-scale benchmark period and the Spring piloting session with the alternate coagulant. No concerns were noted.

Table 5-6 tabulates the average UFRV values for the Spring benchmarking period and the optimal days during the Spring piloting session, while also considering overall operation cycles and those which have not failed based on sampled turbidity.

Table 5-6: Average observed and forecasted UFRV values for the Spring benchmarking period and for the optimal conditions of Spring piloting session.

UFRV (m^3/m^2)		SPRING BENCHMARKING PERIOD	OPTIMAL DAYS OF SPRING PILOTING SESSION		
		All Filters	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	233	92	118	109
	Only cycles with turbidity ≤ 0.1 NTU	224	N/R	137	137
	Only cycles with turbidity ≤ 0.3 NTU	233	123	118	119
Forecasted Values	Overall Cycles	273	92	119	105
	Only cycles with turbidity ≤ 0.1 NTU	257	N/R	137	137
	Only cycles with turbidity ≤ 0.3 NTU	274	123	133	132

N/R: No results

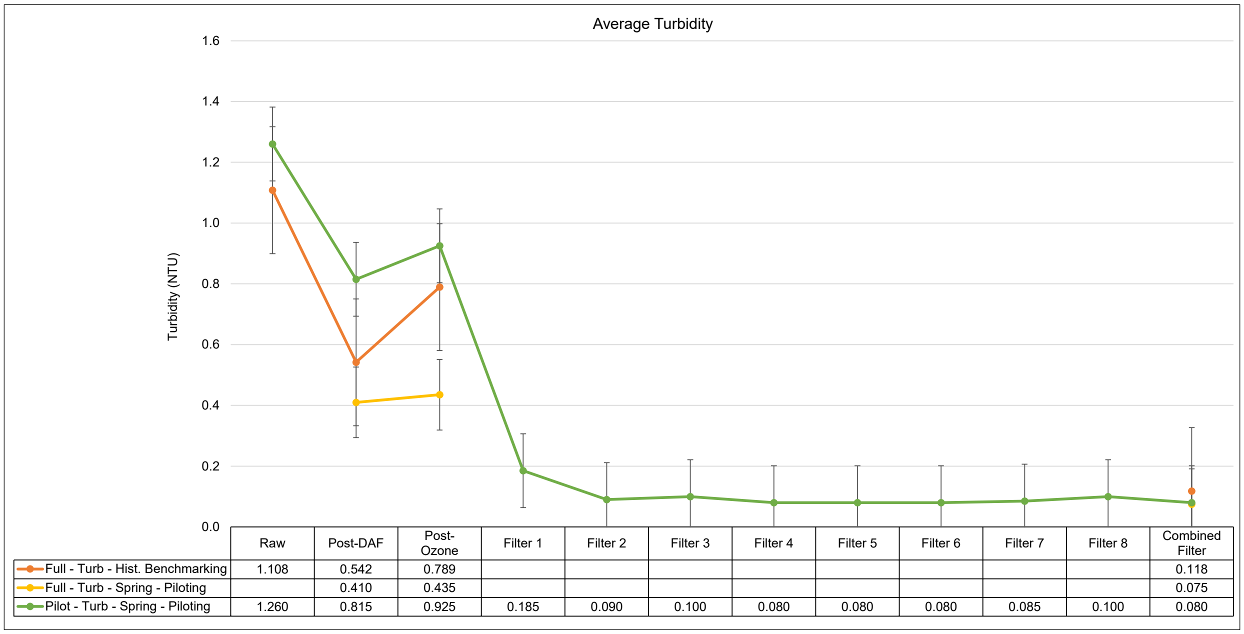
When considering an average filter loading rate and only cycles where the turbidity was less than or equal to 0.10 NTU during sampling, the average forecasted UFRV during the Spring benchmarking period was 257 m^3/m^2. In comparison, the UFRV for Bank B at optimal conditions during the Spring piloting session was 137 m^3/m^2. The UFRV values calculated during the Spring piloting session at the optimal chemical conditions (ferric sulphate dose of 42 mg/L, coagulant-aid dose of 0.20 mg/L and an operating pH of 6.0 to 6.2) are approximately two times lower than the Spring benchmarking period values. However, it is believed the high dose of coagulant-aid was the main contributor and not the ferric sulphate, as discussed in Section 5.6.2.

5.9 Comparison Between the Pilot-Scale and Full-Scale Systems During the Spring Piloting Session

5.9.1 Key Parameters

The following results provide a comprehensive comparison between the full-scale system (full-scale system historical benchmark and full-scale system operation during the Spring piloting session) and the pilot scale system results from the Spring piloting session for the key parameters. The comparison was made for the last two days of the Spring piloting session, when the optimal conditions in terms of coagulant, coagulant-aid and pH were applied at the pilot-scale system.

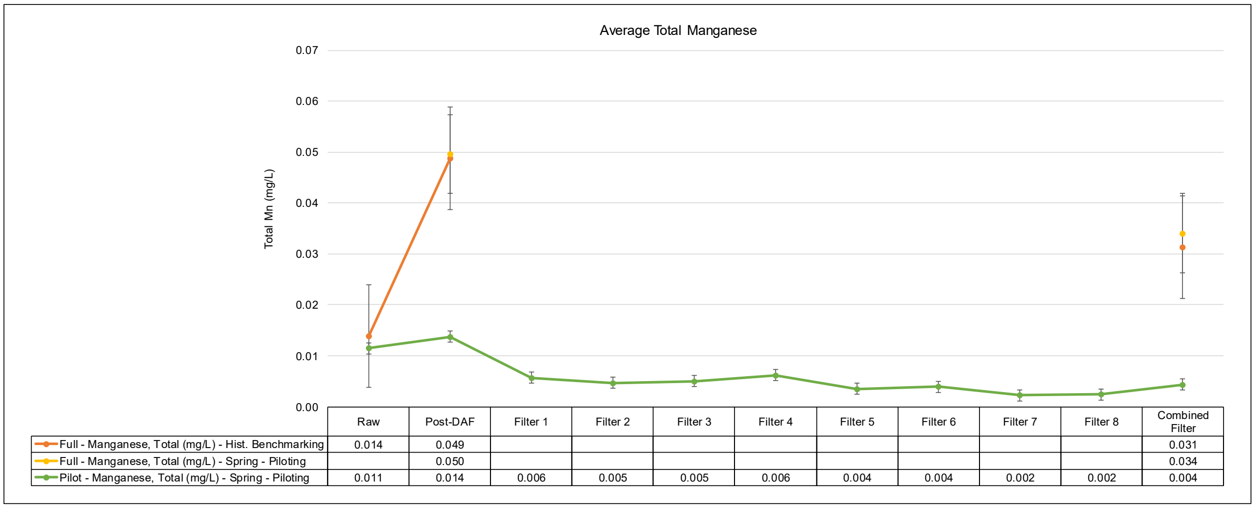
As observed in Figure 5-36, Filters 1 to 4 presented slightly higher turbidity compared to Filters 5 to 8 in pilot-scale system. This was not expected since these filters operated at a lower flowrate. This variability should be investigated further. The pilot-scale system combined filter effluent turbidly closely matched the full-scale system and was lower than the full-scale system historical benchmark average results.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - Turb - Hist. Benchmarking	1.108	0.542	0.789									0.118
Full - Turb - Spring - Piloting		0.410	0.435									0.075
Pilot - Turb - Spring - Piloting	1.260	0.815	0.925	0.185	0.090	0.100	0.080	0.080	0.080	0.085	0.100	0.080

Figure 5-36: Comparison of turbidity levels between the full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale and pilot-scale systems (optimal conditions from May 30th and May 31st, 2017) during the Spring piloting session. Data originates from Lab analysis.

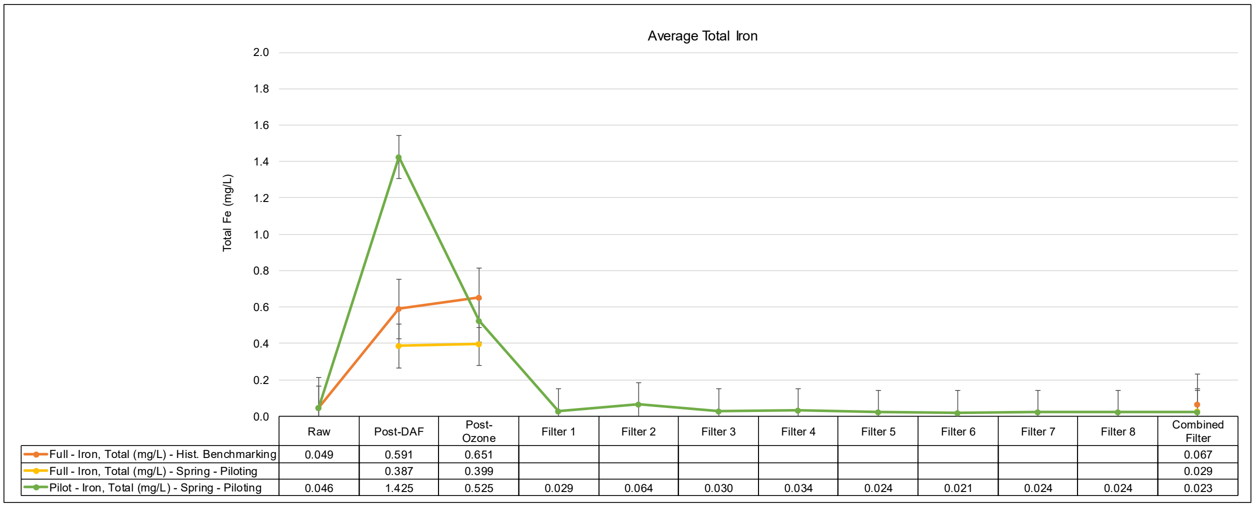
In Figure 5-37, total manganese was noticeably lower at the pilot-scale system in comparison with the full-scale system.



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - Manganese, Total (mg/L) - Hist. Benchmarking	0.014	0.049									0.031
Full - Manganese, Total (mg/L) - Spring - Piloting		0.050									0.034
Pilot - Manganese, Total (mg/L) - Spring - Piloting	0.011	0.014	0.006	0.005	0.005	0.006	0.004	0.004	0.002	0.002	0.004

Figure 5-37: Comparison of total manganese levels between the full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale and pilot-scale systems (optimal conditions from May 30th and May 31st, 2017) during the Spring piloting session. Data originates from Lab analysis.

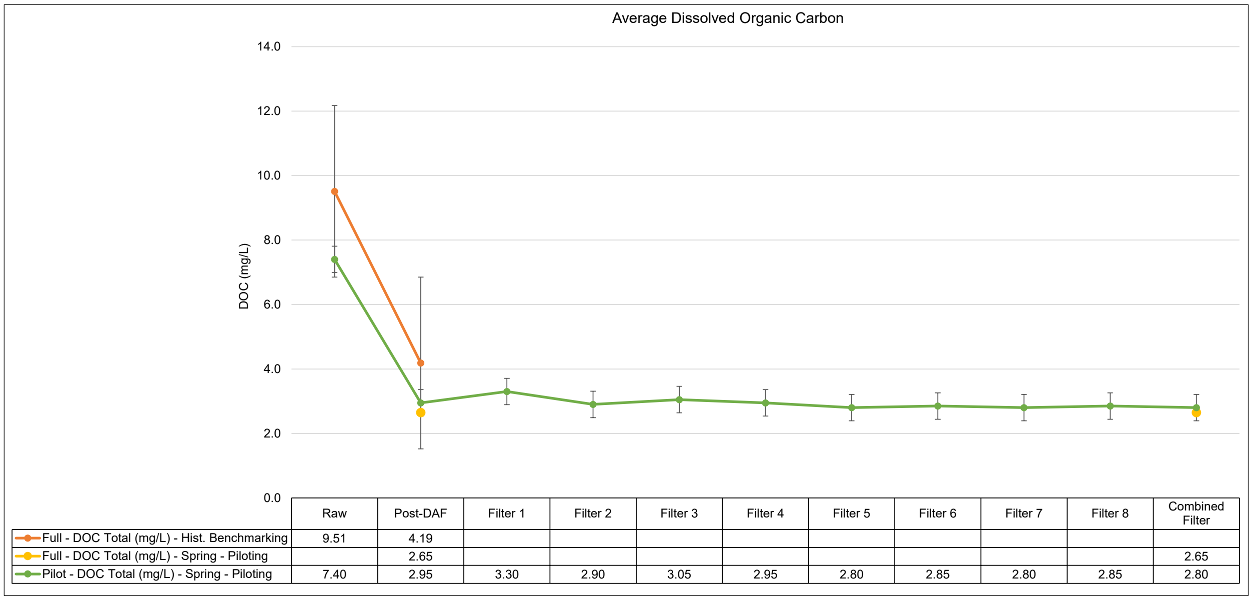
As seen in Figure 5-38, total iron parameters were significantly higher at Post-DAF and Post-Ozone for the pilot-scale system. However, a similar iron content was achieved in the pilot-scale system filter effluent, when compared to the full-scale system. The large reduction in total iron concentration between Post-DAF and Post-Ozone was only observed on May 30th and 31st, but not in the remaining dates (May 14th, 20th and 25th). This variation could be attributed to changes in pH, as May 30th and 31st operated in a higher pH from the previous days. This behavior should be monitored in the upcoming piloting sessions.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - Iron, Total (mg/L) - Hist. Benchmarking	0.049	0.591	0.651									0.067
Full - Iron, Total (mg/L) - Spring - Piloting		0.387	0.399									0.029
Pilot - Iron, Total (mg/L) - Spring - Piloting	0.046	1.425	0.525	0.029	0.064	0.030	0.034	0.024	0.021	0.024	0.024	0.023

Figure 5-38: Comparison of total iron levels between the full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale and pilot-scale systems (optimal conditions from May 30th and May 31st, 2017) during the Spring piloting session. Data originates from Lab analysis.

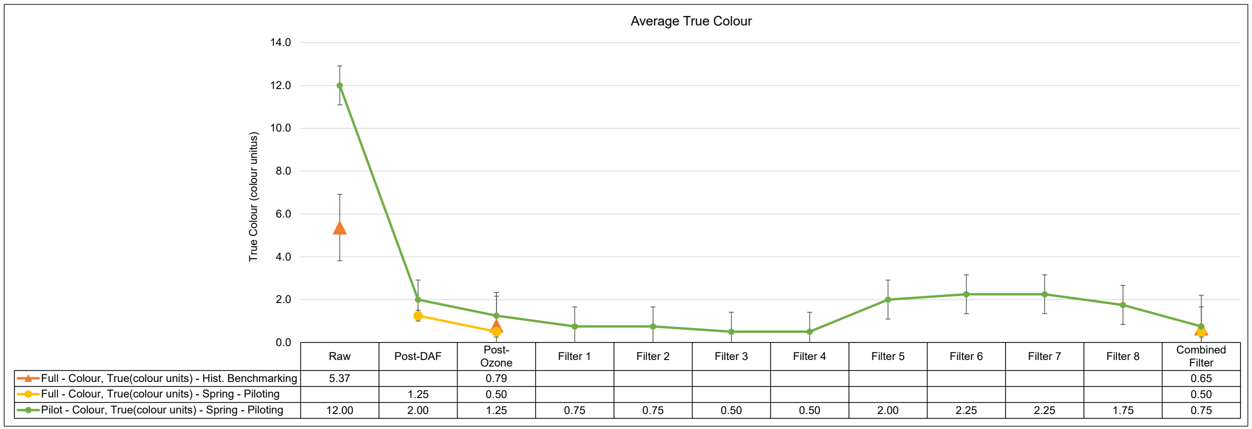
Post-DAF DOC results were higher for the pilot-scale system in comparison with the full-scale system during the Spring piloting session or the full-scale system historical benchmark (Figure 5-39). However, similar DOC concentrations were achieved at the pilot-scale system filter effluent, when compared to the full-scale system.



	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - DOC Total (mg/L) - Hist. Benchmarking	9.51	4.19									
Full - DOC Total (mg/L) - Spring - Piloting		2.65									2.65
Pilot - DOC Total (mg/L) - Spring - Piloting	7.40	2.95	3.30	2.90	3.05	2.95	2.80	2.85	2.80	2.85	2.80

Figure 5-39: Comparison of DOC levels between the full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale and pilot-scale systems (optimal conditions from May 30th and May 31st, 2017) during the Spring piloting session. The full-scale system data originates from Lab analysis, and the pilot-scale system data originates form ALS laboratory analysis.

Figure 5-40 indicates that there was elevated true colour in the raw water during the Spring piloting session, compared to the full–scale system historical average.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filter
Full - Colour, True(colour units) - Hist. Benchmarking	5.37		0.79									0.65
Full - Colour, True(colour units) - Spring - Piloting		1.25	0.50									0.50
Pilot - Colour, True(colour units) - Spring - Piloting	12.00	2.00	1.25	0.75	0.75	0.50	0.50	2.00	2.25	2.25	1.75	0.75

Figure 5-40: Comparison of true colour levels between the full-scale system historical benchmark (average values from 2010 to 2015) and the full-scale and pilot-scale systems (optimal conditions from May 30th and May 31st, 2017) during the Spring piloting session. Data originates from Lab analysis.

When comparing the removal of colour by the full-scale and pilot-scale systems, the full-scale DAF system removed more colour causing compounds, compared to the pilot-scale system (Note: full–scale system's historical data for DAF effluent colour is not available, only full-scale samples collected during the Spring piloting period provided data). Ozonation reduced the colour in both systems; however, the colour was lower in the full-scale system during the Spring piloting session when compared to the full–scale system's historical average. This suggests that ferric chloride may be better at removing colour causing compounds compared to ferric sulphate. In terms of removal by the filters, the combined filter effluent colour was slightly lower in the full-scale system, both during the Spring piloting session and the full–scale system's historical average, compared to the pilot-scale system Spring piloting session. However, the elevated colour measured in the combined filtrate from the pilot-scale system is likely due to elevated colour in Bank B. It is unclear why there is elevated colour in this bank as it does not appear to be caused by elevated levels of turbidity, DOC, or iron in Bank B. If the average colour of Bank A is compared to the full-scale-system during the Spring piloting session and the full–scale system historical average, there does not appear to be a difference between the two systems with regards to producing low coloured water.

Appendix E presents a comprehensive table comparing the average water quality results from the full-scale system historical benchmark and the Spring piloting session with the alternate coagulant. No concerns were noted.

→ UFRV

The historical average of the full-scale system UFRV value is 495 m^3/m^2, while the overall average observed UFRV during the optimal conditions of the Spring piloting session was 92 m^3/m^2 and 118 m^3/m^2 for Bank A and Bank B, respectively (Table 5-5). The UFRV values for the Spring piloting session would be presumably lower for both filter banks as most individual filters presented turbidity breakthrough. Substantial differences between the full-scale system with ferric chloride and the Spring piloting session with ferric sulphate were observed, indicating that ferric sulphate was impacted by the piloting conditions (coagulant and coagulant aid-dose, pH, and process flows) under cool water conditions, and that additional adjustment of these conditions should be considered prior to full-scale system operation adoption.

5.9.2 Disinfection by-Product Formation Potential

Disinfection by-product formation potential (DBPFP) test was conducted to determine the extent at which Trihalomethanes (THMs) and Haloacetic Acids (HAAs) form following disinfection of finished (filter effluent) water using sodium hypochlorite. Samples were collected from the raw water intake located in the pilot-scale system, as well as full-scale and pilot-scale system combined filter effluents on May 25th and 31st. Chemical doses on these dates were presented earlier in Table 4-1. Samples from each location were prepared onsite by WSP personnel for both THM formation potential (THMFP) and HAA formation potential (HAAFP) tests.

Both THMFP and HAAFP samples were prepared in the same manner. The samples were chlorinated using a 0.8% sodium hypochlorite aliquot taken from the full-scale system, which was collected by an onsite WTP operator. The final concentration of sodium hypochlorite for the formation potential tests was 2.0 mg/L based on discussion between onsite WSP personnel and the City operators, who indicated approximately 1.5 mg/L of hypochlorite was added at the full-scale system and an additional 0.5 mg/L was added in the distribution system to ensure the regulatory chlorine residual is maintained.

The pH was maintained at 7.0±0.2 using a sodium monophosphate buffer adjusted with sodium hydroxide. Although the operating pH of the distribution system is approximately 7.9, the pKa of the monophosphate buffer is 6.8-7.2, and therefore may not effectively buffer the system at a pH of 7.9. Although pH can impact the formation of THMs and HAAs, pH changes between 6 to 8 are not expected to significantly affect THM or HAA formations. Following sample preparation, the sample bottles were capped using polytetrafluoroethylene (PTFE) caps and stored at 4°C for 7-days. This temperature was determined to reflect cool water conditions during the Spring piloting session (4-14°C).

Following the 7-day reaction time, triplicate samples were collected from each THM and HAA reaction bottles, preserved according to the City's Standard Operating Procedures (SOP), and delivered to the Lab for quantitative analysis. THM used the SOP #116 and HAA used the SOP #29. The pH of each sample was measured following the 7-day reaction period to ensure the buffer was able to maintain a pH of approximately 7.0. The pH for each sample was not found to change during the 7-day reaction time indicating the samples were adequately buffered. Figure 5-41 presents a simple schematic for the sample preparation for THM and HAA formation potential testing.

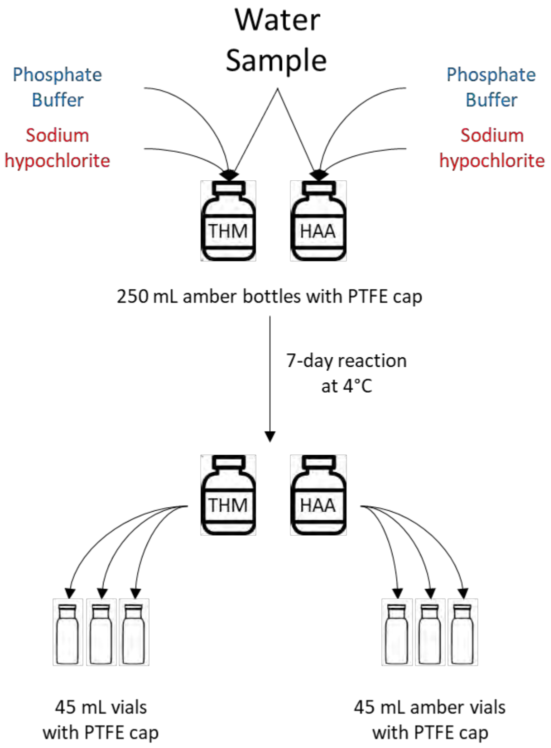


Figure 5-41: Schematic representation of the THM and HAA formation potential testing. The 45 mL vials (clear and amber) were sent to the Lab for quantitative analysis.

The THMFP results are presented in Table 5-7.

Table 5-7: Results for THM formation potential testing conducted on May 25th and 31st, 2017.

Sample Name	Date Sampled	THM-BDCM (µg/L)	THM-CHBr3 (µg/L)	THM-CHCl3 (µg/L)	THM-DBCM (µg/L)	Total THM (µg/L)	% Reduction
Raw Water	May 25, 2017	2.8	<0.2	68.6	<0.4	71	
WTP-Filter Effluent Combined	May 25, 2017	1.7	<0.2	23.1	<0.4	25	65
WTPP-Filter Effluent Combined	May 25, 2017	1.2	<0.2	17.2	<0.4	18	75
Raw Water	May 31, 2017	2	<0.2	38.4	<0.4	41	
WTP-Filter Effluent Combined	May 31, 2017	1.2	<0.2	11.8	<0.4	13	68
WTPP-Filter Effluent Combined	May 31, 2017	1.6	<0.2	19.3	<0.4	21	49

Note: BDCM = bromodichloromethane; CHBr3 = bromoform; CHCl3 = chloroform; DBCM = dibromochloromethane

The total THMFP for the raw water collected on May 25th and May 31st was 71 µg/L and 41 µg/L, respectively. The THM results imply that under the applied test conditions, the formation of THMs without treatment would not exceed provincial regulations of <100 µg/L for total THMs. A significant reduction in THMFP was found in the combined filter effluents from both the full-scale and pilot-scale systems. These results indicate that both ferric chloride (full-scale system) and ferric sulphate (pilot-scale system) are effective in reducing the formation of THMs.

The Winnipeg WTP is currently regulated for HAAs with a rolling average limit of 80 µg/L (implemented since the new license was obtained in 2015). It is hence important to understand the HAAFP in the raw water, as well as the removal of HAA precursors using ferric chloride and ferric sulphate.

The HAAFP results are presented in Table 5-8.

Table 5-8: Results for HAA formation potential testing conducted on May 25th and 31st, 2017.

Sample Name	Date Sampled	HAA-MBAA (µg/L)	HAA-MCAA (µg/L)	HAA-BCAA (µg/L)	HAA-TCAA (µg/L)	HAA-DBAA (µg/L)	HAA-DCAA (µg/L)	Total HAA (µg/L)	% Reduction
Raw Water	May 25, 2017	<0.3	0.8	4	21.5	3.2	23.7	53	
WTP-Filter Effluent Combined	May 25, 2017	<0.3	0.9	3.9	9.2	3.2	8.6	26	64
WTPP-Filter Effluent Combined	May 25, 2017	<0.3	0.9	3.8	12.4	3.2	9.4	30	60
Raw Water	May 31, 2017	<0.3	2.1	3.6	21.3	<0.4	26.6	54	
WTP-Filter Effluent Combined	May 31, 2017	2.6	1.8	3.7	10.6	2.8	11.3	33	58
WTPP-Filter Effluent Combined	May 31, 2017	2.5	1.9	3.5	17.9	<0.4	13.9	40	48

Note: MBAA = monobromoacetic acid; MCAA = monochloroacetic acid; BCAA = bromochloroacetic acid; TCAA = trichloroacetic acid; DBAA = dibromoacetic acid; DCAA = dichloroacetic acid

The raw water HAAFP on May 25th and May 31st was below the recommended 80 µg/L for total HAAs at 53 µg/L and 54 µg/L, respectively. Similar to the THMFP, the HAAFP was significantly reduced by both the full-scale and pilot-scale systems suggesting that both ferric coagulants are effectively reducing HAA precursors prior to disinfection.

Looking at the percentage of THMFP and HAAFP reduction, the pilot-scale system outperformed the full-scale system on May 25th when Post-DAF pH was 5.60, but not on May 31st when the Post-DAF pH was 6.01.

5.9.3 Corrosive Indices

Corrosive waters, often having elevated chloride concentrations, can lead to metal leaching and promote corrosion in water distribution systems. The Chloride-Sulphate Mass Ratio (CSMR) and the Larson-Skold Ratio (LR), are commonly used to indicate the potential to promote corrosion in water distribution systems, with high values indicating an increase in the potential to promote corrosion. The Langelier Saturation index (LSI) and the Ryznar Stability index (RSI) are indicators of corrosion attributed to the degree of saturation of calcium carbonate.

Though changes in treatment approaches at drinking water facilities are known to affect the corrosion indices, there is minimal information regarding how changes in the ionic composition of source waters may affect the corrosion indices. Nonetheless, these indices serve as indicators for corrosion discussions.

Table 5-9 presents the corrosivity indices in the raw water and combined filtrate for both pilot-scale and full-scale systems. The indices are calculated from laboratory results of samples taken the same day from the full-scale system post filtration and prior to pH adjustment with sodium hydroxide and the pilot-scale system post-filtration operating under optimal conditions. A comparison between the full-scale system and the pilot-scale system is made under the provision that samples taken from their respective sources on the same day share identical raw water quality. Furthermore, as these indices are of a strict predicative nature (the development of a general index is inherently difficult due to the multiple roles of chemical species in potable water), and do not necessarily correlate between theoretical and actual conditions, only a relative comparison is made.

Table 5-9: Spring piloting session corrosivity indices. Data obtained from May 31st optimal conditions laboratory analytical testing.

Treatment Step	CSMR Pilot	CSMR Full	LR Pilot	LR Full	LSI Pilot	LSI Full	RSI Pilot	RSI Full	Alkal. Pilot	Alkal. Full
Raw	1.05		0.05		-0.48		9.0		84	
Interpretation	Greater than 0.5 indicates a tendency to increase galvanic corrosion of lead solder connected to copper pipes.		At <0.8, chlorides and sulphates probably will not interfere with natural film formation of mild steel.		At 0, water is under saturated with respect to calcium carbonate. Tendency will be to remove existing calcium carbonate protective coatings.		Values >8.5, water is very aggressive towards corrosion.		Values <100 often corrosive & values > 200 result in possible scaling	
Combined Filtrate	0.03	0.48	3.4	11.3	-2.8	-4.2	9.1	9.6	21	6
Interpretation	Low corrosivity	Low corrosivity	At >1.2, there is a strong tendency towards high corrosion rates		Corrosive	Increasingly corrosive	Corrosive	Corrosive	Corrosive	Corrosive

Table 5-9 suggests that based on alkalinity, the raw water and combined filtrate for both the pilot-scale and full-scale systems would be corrosive. The LR, LSI, and RSI which are indices all dependent on the alkalinity show the same trend indicating that the pilot-scale system filter effluents are corrosive, but not more corrosive than the full-scale system ones. On the other hand, the CSMR value, which is based solely on the chloride and sulphate concentrations, indicates that ferric sulphate in the pilot-scale system produced less corrosive water when compared with ferric chloride in the full-scale system.

It is important to note that these comparisons take into consideration the combined filtrate water and does not account for any chemicals dosed in the full-scale system just prior to distribution.

6 CONCLUSIONS AND RECOMMENDATIONS

From the results presented above, the following may be concluded:

- Raw water temperature was below 14°C, with the exception of May 27th in which the pilot-scale system raw temperature was recorded at a maximum of 14.7°C. Raw water temperature data from the full-scale system, originating from the two temperature sensors used to measure each train, indicated that the temperature did not exceed 14°C for this date. It can therefore be concluded that spring conditions have been captured.
- The City was successful in benchmarking the pilot-scale system to the full-scale system, based on the results of tested key parameters, such as turbidity, TOC, and total manganese.
- The City successfully transitioned the pilot-scale system from ferric chloride to ferric sulphate. Success was defined as the stability in the pilot-scale system delineated i.e. Post-DAF turbidity of ±0.2 NTU and ±0.05 NTU in the filter effluent. Data relating to pH, TOC, turbidity, and total manganese did not exhibit significant variations during the Spring transition period. With the exception of a single turbidity outlier on May 10th, the pilot-scale system met the stability criteria.
- During Spring piloting session, Bank A and Bank B operation flows were reversed from the Winter #1 piloting session. Bank B presented lower UFRV values when compared to Bank A. This result was similar to the Winter #1 piloting session. However, the two banks operating at different flow rates were noted to have similar turbidity removals, which was not the observation in the Winter #1 piloting session. This observation suggests that both the flow and mechanics of each bank are impacting filter performance. It appears that Bank A can achieve higher contaminant removal at higher flow rates.
- During the Spring piloting session, on May 18th and May 19th, it was determined that the pilot-scale system required maintenance and cleaning to diminish the occurrence of discoloured water. Maintenance included cleaning and flushing cycles. The crack on the DAF recirculation pipe was repaired.
- During the optimization of coagulant-aid (May 20th to 24th), the pH for coagulation ranged between 5.67 and 5.75. Due to this variation, a daily offset of the pH probe was applied to assist in controlling the pH for the remainder of the Spring piloting session. Although the offset allowed for better control of the pH during pilot-scale system operation, it is recommended that a controller be implemented that would automatically adjust the addition of sulphuric acid to maintain a set desired pH.
- An optimal dose for the coagulant ferric sulphate was investigated in the pilot-scale system. The optimal dose during the Spring piloting session was found to be 42 mg/L.
- Using the optimal doses of coagulant (42 mg/L), the optimal coagulant-aid dose was investigated at the optimum coagulant dose in the pilot-scale system. Although the key parameters results obtained during the tests demonstrated 0.20 mg/L was the optimal dose, the UFRV analysis performed subsequently demonstrated this dose could not produce sufficient water and the preferred coagulant-aid dose was actually 0.05 mg/L. The optimal coagulant-aid dose was much higher than the Winter #1 piloting session (0.02 mg/L). This difference can be attributed to the modification to the coagulant-aid injection point in the pilot-scale system. Bench-scale analyses suggested that subsequent

increases in coagulant-aid doses did not significantly reduce turbidity. As such, smaller incremental variances to this value warrant further exploration.

- Using the optimal doses of coagulant (42 mg/L) and coagulant-aid (0.20 mg/L), the optimal pH for coagulation was explored from May 25th to May 29th, 2017. Turbidity, UVT, and UV_{254nm} absorbance did not change significantly during optimization. However, subsequent increases in pH to 6.65 and 6.83 caused a steady deterioration of the water quality. The optimum pH was determined to be between 6.0 and 6.2.
- Significantly lower manganese concentrations were measured in all pilot-scale system processes when the pilot-scale system was using ferric sulphate.
- The best pilot-scale treated water quality was produced when the optimal coagulant and coagulant-aid doses and optimal pH were applied on May 30th and May 31st, which indicates that the near-optimal conditions were successfully determined based on water quality. However, the URFV analysis performed after the completion of the Spring piloting session showed that these conditions were not necessarily optimal based on filter performance.
- THMFP and HAAFP were significantly reduced by both the pilot-scale and full-scale systems suggesting that both ferric coagulants can effectively reduce disinfection by-products precursors prior to disinfection.
- Corrosive indices such as CSMR, LR, LSI, and RSI suggest that the pilot-scale system effluent using ferric sulphate as a coagulant will benefit from the addition of alkalinity to improve said indices. Similar corrosive results are observed for full-scale system filter effluent results as sampled prior to the addition of sodium hydroxide (and the subsequent increase in alkalinity).

Recommendations regarding the remaining Summer and Fall piloting sessions are as follow:

- Maintain the reversed flow configuration of the filter banks to offset potential performance shortcomings arising from the mechanical differences between the pilot-scale system filter banks.
- Continued sampling both the full-scale and pilot-scale systems on the same day to allow valid comparison between the two systems using the same raw water.
- Current corrosion indicators are based on a single day sampling effort. Additional laboratory testing can provide a better perspective for the corrosivity of filter effluent water.
- Test the coagulant during the summer for a period without the coagulant-aid to allow a direct comparison with the full-scale system which does not use a coagulant-aid.
- Re-calibrate the filter-aid pumps to confirm polymer dosage accuracy.

Piloting Results Database Summary

Season: Spring
Phase: Benchmarking

					Sample Location												
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Filter Effluent Average**	**Combined Filtrate**
April 10, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0054	0.051	0.05	0.048	0.048	0.048	0.048	0.049	0.048	0.049	0.049		
				Avg. of filters 1 to 8												0.04838	
		pH	Lab			5.08	5.09	4.86	4.82	4.84	4.83	4.88	4.95	4.99	5.01		
				Avg. of filters 1 to 8												4.8975	
		TOC, Total (mg/L)	Lab		24.6	4.7	4.7	3.2	3.4	3.2	3.5	3.3	3.2	3.3	3.4		
				Avg. of filters 1 to 8												3.3125	
		Turbidity (NTU)	Bench					0.05	0.06	0.05	0.06	0.05	0.05	0.09	0.07		
			Lab		0.59	1.63	1.71	0.05	0.06	0.05	0.06	0.05	0.05	0.09	0.07		
				Avg. of filters 1 to 8												0.06	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.049	0.047										0.03
				No aliquot				G/N	G/N			G/N	G/N	G/N	G/N		
				O/L						G/N	G/N						
		pH	Lab				4.91	5.14	5.23			5.1	4.92	4.93	4.9		4.99
				O/L						G/N	G/N						
		TOC, Total (mg/L)	Lab			4.7	4.3										4.6
				No aliquot				G/N	G/N			G/N	G/N	G/N	G/N		
				O/L						G/N	G/N						
		Turbidity (NTU)	Lab				0.95										0.07
April 11, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0056	0.051	0.049	0.042	0.041	0.041	0.041	0.042	0.044	0.041	0.042		
				Avg. of filters 1 to 8												0.04175	
		pH	Lab			5.29	5.27	4.92	4.9	4.89	4.89	5	5	4.98	4.96		
				Avg. of filters 1 to 8												4.9425	
		TOC, Total (mg/L)	Lab		23.9	4.4	4.3	3.2	3.5	3.1	3.2	3.3	3.2	3.4	3.2		
				Avg. of filters 1 to 8												3.2625	
		Turbidity (NTU)	Bench					0.05	0.06	0.06	0.07	0.05	0.05	0.05	0.05		
			Lab		0.55	1.23	1.38	0.05	0.05	0.06	0.07	0.05	0.05		0.05		
				Avg. of filters 1 to 8												0.05429	
				N/D at <0.05										G/N			
	Full-Scale	Manganese, Total (mg/L)	Lab			0.051	0.048		0.033	0.032	0.031	0.032		0.032	0.029		0.031
				O/L				G/N					G/N				
		pH	Lab				5.19		5.35	5.31	5.25	4.98		4.88	4.92		5.19
				O/L				G/N					G/N				
		TOC, Total (mg/L)	Lab			4.3	4		4	4.1	4.1	3.7		3.3	3.4		3.7
				O/L				G/N					G/N				
		Turbidity (NTU)	Lab				0.79										0.07
April 12, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.006	0.04	0.04	0.037	0.038	0.037	0.038	0.037	0.037	0.042	0.037		
				Avg. of filters 1 to 8												0.03788	
		pH	Lab			5.61	5.72	5.23	5.21	5.17	5.18	5.19	5.19	5.2	5.18		
				Avg. of filters 1 to 8												5.19375	
		TOC, Total (mg/L)	Lab		22	6.7	6.7	3.8	4.1	4	3.8	3.7	4.1	3.5	3.5		
				Avg. of filters 1 to 8												3.8125	
		Turbidity (NTU)	Bench					0.14	0.12	0.11	0.14	0.17	0.12	0.13	0.12		
			Lab		0.58	1.2	1.25	0.14	0.12	0.11	0.14	0.17	0.12	0.13	0.12		
				Avg. of filters 1 to 8												0.13125	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.053	0.063	0.033	0.032	0.032	0.03		0.033		0.033		0.032
				O/L								G/N		G/N			
		pH	Lab				5.3	5.3	5.31	5.35	5.19		4.87		4.84		5.23
				O/L								G/N		G/N			
		TOC, Total (mg/L)	Lab			4.6	5.1	4	6.1	4.3	6.2		3.4		3.6		4.2
				O/L								G/N		G/N			
		Turbidity (NTU)	Lab				0.73										0.06
April 13, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.007	0.053	0.05	0.042	0.041	0.042	0.042	0.042	0.042	0.042	0.042		
				Avg. of filters 1 to 8												0.04188	
		pH	Lab		7.95	5.36	5.38	5.39	5.39	5.41	5.38	5.33	5.38	5.34	5.4		
				Avg. of filters 1 to 8												5.3775	
		TOC, Total (mg/L)	Lab		20.4	4.7	4.4	3.4	4.1	4.2	3.7	3.7	4	3.5	3.5		
				Avg. of filters 1 to 8												3.7625	
		Turbidity (NTU)	Bench					0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05		
			Lab		0.55	1.14	1.17	0.06		0.05	0.05						
				Avg. of filters 1 to 8												0.05333	
				N/D at <0.05					G/N			G/N	G/N	G/N	G/N		
	Full-Scale	Manganese, Total (mg/L)	Lab			0.05	0.048	0.032			0.034	0.033	0.031	0.033	0.031		0.032
				O/L					G/N	G/N							
		pH	Lab			5.29	5.25	5.36			5.36	5.1	4.91	4.87	4.9		5.24
				O/L					G/N	G/N							
		TOC, Total (mg/L)	Lab			4.4	4.6	4.9			4	3.7	3.3	3.3	3		4
				O/L					G/N	G/N							

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
April 13, 2017	Full-Scale	Turbidity (NTU)	Lab			0.48	0.72	0.06					0.06	0.05			0.08
				N/D at <0.05							G/N	G/N			G/N		
				O/L					G/N	G/N							
April 14, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0051	0.053	0.056	0.042	0.043	0.043	0.043	0.043	0.043	0.043	0.043		
				Avg. of filters 1 to 8												0.04288	
		pH	Lab		8.06	5.38	5.38	5.39	5.39	5.41	5.41	5.37	5.43	5.39	5.43		
				Avg. of filters 1 to 8												5.4025	
		TOC, Total (mg/L)	Lab		21	3.9	4.1	3.6	3.5	3.5	4	3.9	3.6	3.6	3.7		
				Avg. of filters 1 to 8												3.675	
		Turbidity (NTU)	Bench					0.1	0.13	0.12	0.1	0.11	0.06	0.07	0.06		
			Lab		1.05	1.26	1.27	0.1	0.13	0.12	0.1	0.11	0.06	0.07	0.06		
				Avg. of filters 1 to 8												0.09375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.05	0.045		0.033	0.032	0.032	0.031		0.03	0.028		
				Not Rcvd													G/N
				O/L				G/N					G/N				
		pH	Lab			5.29	5.1		5.36	5.4	5.25	4.89		4.8	4.89		
				Not Rcvd													G/N
				O/L				G/N					G/N				
		TOC, Total (mg/L)	Lab			4.4	4.3		5.3	5.2	4.4	3.8		4.2	3.5		
				Not Rcvd													G/N
				O/L				G/N					G/N				
		Turbidity (NTU)	Lab			0.62	0.77		0.09	0.05	0.1	0.06		0.06	0.07		
				Not Rcvd													G/N
				O/L				G/N					G/N				
April 15, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0059	0.051	0.056	0.042	0.041	0.042	0.042	0.043	0.042	0.042	0.042		
				Avg. of filters 1 to 8												0.042	
		pH	Lab		8.05	5.42	5.38	5.52	5.42	5.43	5.48	5.4	5.38	5.55	5.45		
				Avg. of filters 1 to 8												5.45375	
		TOC, Total (mg/L)	Lab		21.3	4.2	4.2	3.7	3.4	3.3	2.8	3.8	3.4	3.4	3.3		
				Avg. of filters 1 to 8												3.3875	
		Turbidity (NTU)	Bench					0.09	0.12	0.08	0.07	0.06	0.06	0.05	0.06		
			Lab		0.7	0.92	1.22	0.09	0.12	0.08	0.07	0.06	0.06		0.06		
				Avg. of filters 1 to 8												0.07714	
				N/D at <0.05										G/N			
	Full-Scale	Manganese, Total (mg/L)	Lab			0.048	0.046	0.032	0.032	0.031	0.03		0.031		0.032		0.033
				O/L								G/N		G/N			
		pH	Lab			5.3	5.23	5.38	5.4	5.46	5.33		4.88		4.85		5.2
				O/L								G/N		G/N			
		TOC, Total (mg/L)	Lab			4.5	3.8	4.4	4.7	4.4	3.6		3.5		3.5		4.2
				O/L								G/N		G/N			
		Turbidity (NTU)	Lab			0.52	0.73	0.09	0.12	0.07	0.14		0.08		0.09		0.1
				O/L								G/N		G/N			
April 16, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0062	0.05	0.054	0.043	0.043	0.044	0.043	0.044	0.044	0.043	0.043		
				Avg. of filters 1 to 8												0.04338	
		pH	Lab		8.1	5.46	5.61	5.48	5.47	5.63	5.48	5.92	5.48	5.54	5.53		
				Avg. of filters 1 to 8												5.56625	
		TOC, Total (mg/L)	Lab		22.1	4.1	3.6	3.8	3.5	3.6	3.5	3.5	3.9	3.6	3.3		
				Avg. of filters 1 to 8												3.5875	
		Turbidity (NTU)	Bench					0.05	0.06	0.06	0.06	0.06	0.05	0.06	0.06		
			Lab		0.88	1	1.05		0.06	0.06	0.06	0.06		0.06	0.06		
				Avg. of filters 1 to 8												0.06	
				N/D at <0.05				G/N					G/N				
	Full-Scale	Manganese, Total (mg/L)	Lab			0.053	0.052	0.033	0.032		0.035	0.035		0.033	0.032		0.033
				O/L						G/N			G/N				
		pH	Lab			5.36	5.3	5.55	5.55		5.57	5.26		4.94	4.94		5.27
				O/L						G/N			G/N				
		TOC, Total (mg/L)	Lab			4.6	4.2	4.6	4.9		4.3	3.5		4	3.2		3.7
				O/L						G/N			G/N				
		Turbidity (NTU)	Lab			0.52	0.71	0.06	0.07					0.06	0.06		0.12
				N/D at <0.05							G/N	G/N					
				O/L						G/N			G/N				
April 17, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0063	0.055	0.053	0.043	0.042	0.033	0.043	0.043	0.043	0.043	0.043		
				Avg. of filters 1 to 8												0.04163	
		pH	Lab		8.01	5.58	5.59	5.56	5.57	5.66	5.69	5.56	5.62	5.66	5.71		
				Avg. of filters 1 to 8												5.62875	
		TOC, Total (mg/L)	Lab		21.3	4.1	4.1	3.4	3.3	3.8	3.3	3.3	3.4	3.4	3.4		
				Avg. of filters 1 to 8												3.4125	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
April 17, 2017	Pilot-Scale	Turbidity (NTU)	Bench					0.07	0.06	0.09	0.15	0.05	0.06	0.08	0.06		
			Lab		1.05	1.05	1.16	0.07	0.06	0.09	0.15		0.06	0.08	0.06		
				Avg. of filters 1 to 8												0.08143	
				N/D at <0.05								G/N					
	Full-Scale	Manganese, Total (mg/L)	Lab			0.054	0.053		0.033	0.043	0.033	0.032	0.034	0.032			
				Not Rcvd													G/N
				O/L				G/N							G/N		
		pH	Lab			5.43	5.29		5.6	5.71	5.56	5.14	4.89	4.94			
				Not Rcvd													G/N
				O/L				G/N							G/N		
		TOC, Total (mg/L)	Lab			4.1	3.9		4.4	3.5	4.3	3.3	3.1	3.5			
				Not Rcvd													G/N
				O/L				G/N							G/N		
		Turbidity (NTU)	Lab			0.54	0.66		0.08	0.07	0.05	0.09	0.06	0.08			
				Not Rcvd													G/N
				O/L				G/N							G/N		
April 18, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0058	0.052	0.049	0.048	0.042	0.042	0.042	0.043	0.043	0.043	0.043		
				Avg. of filters 1 to 8												0.04325	
		pH	Lab		8	5.72	5.68	5.63	5.62	5.58	5.63	5.6	5.55	5.62	5.47		
				Avg. of filters 1 to 8												5.5875	
		TOC, Total (mg/L)	Lab		19	4.5	4.5	3.4	3.2	3.5	3.3	3.7	3.5	3.6	3.4		
				Avg. of filters 1 to 8												3.45	
		Turbidity (NTU)	Bench					0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.05		
			Lab		0.72	1.03	1.17	0.05	0.06	0.06	0.06				0.05		
				Avg. of filters 1 to 8												0.056	
				N/D at <0.05								G/N	G/N	G/N			
	Full-Scale	Manganese, Total (mg/L)	Lab			0.05	0.047	0.033	0.04	0.032	0.031		0.033		0.033		0.034
				O/L								G/N		G/N			
		pH	Lab			5.61	5.45	5.54	5.57	5.55	5.3		4.9		4.85		5.4
				O/L								G/N		G/N			
		TOC, Total (mg/L)	Lab			4.2	4.1	4.2	4.2	4.2	3.8		3.2		3.3		3.9
				O/L								G/N		G/N			
		Turbidity (NTU)	Lab			0.51	0.66	0.09	0.06	0.09	0.08		0.08		0.05		0.2
				O/L								G/N		G/N			
April 20, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0069	0.047	0.047	0.041	0.04	0.041	0.041	0.042	0.041	0.041	0.04		
				Avg. of filters 1 to 8												0.04088	
		pH	Lab		8.09	5.35	5.38	5.72	5.71	5.7	5.76	5.7	5.73	5.67	5.66		
				Avg. of filters 1 to 8												5.70625	
		TOC, Total (mg/L)	Lab		25.4	11.1	8.7	5.3	7.6	5.8	7.2	6.9	8.1	6.2	7		
				Avg. of filters 1 to 8												6.7625	
		Turbidity (NTU)	Bench					0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05		
			Lab		0.68	0.97	1.08	0.06			0.05	0.05	0.06				
				Avg. of filters 1 to 8												0.055	
				N/D at <0.05					G/N	G/N				G/N	G/N		
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0489	0.045		0.0329	0.0336	0.0394	0.0343	0.0356	0.0331			0.032
				O/L				G/N							G/N		
		pH	Lab			5.02	5.39		5.5	5.5	5.44	5.08	4.98	5.05			5.25
				O/L				G/N							G/N		
		TOC, Total (mg/L)	Lab			7.5	5.6		8.4	9	9.2	7.5	7.9	9.4			8.4
				O/L				G/N							G/N		
		Turbidity (NTU)	Lab			0.43	0.69			0.05	0.05	0.06	0.05	0.06			0.1
				N/D at <0.05					G/N								
				O/L				G/N							G/N		
April 21, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0072	0.049	0.048	0.043	0.044	0.044	0.045	0.044	0.045	0.044	0.044		
				Avg. of filters 1 to 8												0.04413	
		pH	Lab		8.11	5.41	5.41	5.6	5.57	5.58	5.56	5.59	5.64	5.52	5.61		
				Avg. of filters 1 to 8												5.58375	
		TOC, Total (mg/L)	Lab		26.1	7.7	7.1	5.9	5.9	5.9	6	6.3	5.7	5.7	5.5		
				Avg. of filters 1 to 8												5.8625	
		Turbidity (NTU)	Bench					0.06	0.5	0.06	0.05	0.06	0.05	0.05	0.05		
			Lab		0.66	1.04	1.17	0.06		0.06	0.05	0.06					
				Avg. of filters 1 to 8												0.0575	
				N/D at <0.05					G/N				G/N	G/N	G/N		
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0507	0.046	0.0349	0.0325	0.0325	0.0325		0.0351		0.0362		0.032
				O/L								G/N		G/N			
		pH	Lab			5.4	5.43	5.48	5.52	5.52	5.43		4.88		4.91		5.29
				O/L								G/N		G/N			

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
April 21, 2017	Full-Scale	TOC, Total (mg/L)	Lab			8.1	8.4	8.5	7.6	8	7.2		6.4		6.2		5.1
				O/L								G/N		G/N			
		Turbidity (NTU)	Lab			0.47	0.7	0.05		0.06	0.07		0.05				0.08
				N/D at <0.05					G/N						G/N		
				O/L								G/N		G/N			
April 22, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0061	0.049	0.048	0.042	0.043	0.043	0.043	0.045	0.044	0.045	0.044		
				Avg. of filters 1 to 8												0.04363	
		pH	Lab		8.12	5.43	5.42	5.53	5.52	5.48	5.49	5.52	5.47	5.53	5.5		
				Avg. of filters 1 to 8												5.505	
		TOC, Total (mg/L)	Lab		25.3	6.9	6.9	5.7	5	5.9	5.7	5.9	5.6	5.2	0.6		
				Avg. of filters 1 to 8												4.95	
		Turbidity (NTU)	Bench					0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05		
			Lab		1.11	1.12	1.16	0.06									
				Avg. of filters 1 to 8												0.06	
				N/D at <0.05					G/N	G/N	G/N	G/N	G/N	G/N	G/N		
	Full-Scale	Manganese, Total (mg/L)	Lab			0.053	0.046	0.0351	0.0319			0.0343	0.0324	0.0355	0.0332		0.031
				O/L						G/N	G/N						
		pH	Lab			5.45	5.48	5.57	5.54			5.1	4.88	4.87	4.87		5.33
				O/L						G/N	G/N						
		TOC, Total (mg/L)	Lab			6.7	6.6	6.8	6.2			5.5	5.1	5.4	5		
				O/L						G/N	G/N						
		Turbidity (NTU)	Lab			0.52	0.9		0.05				0.06		0.06		0.09
				N/D at <0.05				G/N				G/N		G/N			
				O/L						G/N	G/N						
April 23, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.007	0.048	0.047	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043		
				Avg. of filters 1 to 8												0.043	
		pH	Lab		8.13	5.63	5.63	5.63	5.67	5.67	5.66	5.63	5.69	5.75	5.77		
				Avg. of filters 1 to 8												5.68375	
		TOC, Total (mg/L)	Lab		26.1	5.8	6.3	4.9	4.7	5.1	4.4	4.4	4.4	3.9	4.6		
				Avg. of filters 1 to 8												4.55	
		Turbidity (NTU)	Bench					0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.06		
			Lab		0.88	1.05	1	0.05			0.06			0.05	0.06		
				Avg. of filters 1 to 8												0.055	
				N/D at <0.05					G/N	G/N		G/N	G/N				
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0518	0.046	0.0312	0.0317		0.0323	0.0321		0.0315	0.0296		0.03
				O/L						G/N			G/N				
		pH	Lab			5.55	5.53	5.72	5.84		5.84	5.46		5.13	5.09		5.44
				O/L						G/N			G/N				
		TOC, Total (mg/L)	Lab				6	3.6	5.8								
				O/L						G/N			G/N				
		Turbidity (NTU)	Lab			0.53	0.75	0.11	0.12		0.1	0.1		0.08	0.08		0.11
				O/L						G/N			G/N				
April 24, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0076	0.0394	0.041	0.042	0.0448	0.0407	0.0399	0.0408	0.0414	0.0406	0.041		
				Avg. of filters 1 to 8												0.0414	
		pH	Lab		8.1	5.3	5.42	5.62	5.56	5.56	5.64	5.57	5.61	5.57	5.6		
				Avg. of filters 1 to 8												5.59125	
		TOC, Total (mg/L)	Lab		24	6	6.3	5.4	6	5.1	6.7						
				Avg. of filters 1 to 8												5.8	
		Turbidity (NTU)	Bench					0.08	0.08	0.08	0.07	0.06	0.06	0.06	0.07		
			Lab		1.03	1.32	1.31	0.08	0.08	0.08	0.07	0.06	0.06	0.06	0.07		
				Avg. of filters 1 to 8												0.07	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0445	0.0457	0.0259		0.0303	0.0252	0.0235	0.0244	0.0235			0.0457
				O/L					G/N						G/N		
		pH	Lab			5.34	5.33	5.69		5.67	5.57	5.1	5.04	5.12			5.42
				O/L					G/N						G/N		
		TOC, Total (mg/L)	Lab			7.2		7.1		7.4	6.9						
				O/L					G/N						G/N		
		Turbidity (NTU)	Lab			0.47	0.87	0.13		0.12	0.12	0.11	0.1	0.13			0.16
				O/L					G/N						G/N		
April 25, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0068	0.0426	0.0413	0.0389	0.0392	0.0399	0.0399	0.0397	0.0389	0.0399	0.04		
				Avg. of filters 1 to 8												0.03955	
		pH	Lab		8.12	5.08	5.14	5.46	5.38	5.46	5.45	5.39	5.43	5.47	5.51		
				Avg. of filters 1 to 8												5.44375	
		TOC, Total (mg/L)	Lab		25	5.6	5.8			6		5	5.5	5.2	5.2		
				Avg. of filters 1 to 8												5.38	
		Turbidity (NTU)	Bench					0.05	0.05	0.05	0.05	0.05	0.07	0.08	0.07		
			Lab		0.72	1.18	1.23			0.05			0.07	0.08	0.07		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring

Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
April 25, 2017	Pilot-Scale	Turbidity (NTU)	Lab	Avg. of filters 1 to 8												0.0675	
				N/D at <0.05				G/N	G/N		G/N	G/N					
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0434	0.0446		0.0264	0.0266	0.0252	0.0237	0.0247		0.0241		0.0261
				O/L				G/N						G/N			
		pH	Lab			5.25	5.36		5.54	5.61	5.54	5.22	5.04		5.08		5.28
				O/L				G/N						G/N			
		TOC, Total (mg/L)	Lab			6.8	6.6					5.7	6.1		5.7		5.9
				O/L				G/N						G/N			
		Turbidity (NTU)	Lab			0.43	0.79		0.12	0.13	0.14	0.11	0.11		0.09		0.15
				O/L				G/N						G/N			
April 26, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0069	0.0426	0.0417	0.0398	0.0385	0.0437	0.0396	0.0393	0.0395	0.0398	0.0397		
				Avg. of filters 1 to 8												0.03999	
		pH	Lab		8.13	5.16	5.15	5.35	5.4	5.35	5.37	5.32	5.36	5.4	5.45		
				Avg. of filters 1 to 8												5.375	
		TOC, Total (mg/L)	Lab			5.9	5.7	4.6	5.8		5.3						
				Avg. of filters 1 to 8												5.23333	
				Not Rcvd	G/N												
		Turbidity (NTU)	Bench					0.11	0.11	0.09	0.08	0.07	0.07	0.05	0.08		
			Lab		0.74	1.27	1.23	0.11	0.11	0.09	0.08	0.07	0.07	0.05	0.08		
				Avg. of filters 1 to 8												0.0825	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0405	0.0405		0.0297	0.0292	0.0302		0.0272	0.0292	0.0306		0.0287
				O/L				G/N				G/N					
		pH	Lab			5.3	5.23		5.56	5.57	5.51		4.91	4.88	4.86		5.15
				O/L				G/N				G/N					
		TOC, Total (mg/L)	Lab				4.3										5.2
				Not Rcvd		G/N			G/N	G/N	G/N						
				O/L				G/N									
		Turbidity (NTU)	Lab			0.43	1.12		0.07	0.08	0.1		0.08	0.07	0.07		0.12
				O/L				G/N				G/N					
April 27, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0063	0.0449	0.0441	0.0401	0.0426	0.0397	0.0407	0.04	0.0399	0.0407	0.042		
				Avg. of filters 1 to 8												0.04071	
		pH	Lab		8.06	5.09	5.11	5.35	5.27	5.22	5.25	5.25	5.25	5.23	5.24		
				Avg. of filters 1 to 8												5.2575	
		TOC, Total (mg/L)	Lab		25	4.5	4			5.6		3.3	3.2	2.7	2.7		
				Avg. of filters 1 to 8												3.5	
		Turbidity (NTU)	Bench					0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05		
			Lab		0.68	1.28	1.35	0.06	0.06	0.06	0.06		0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.05571	
				N/D at <0.05								G/N					
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0419	0.0398	0.0268	0.0259	0.0253	0.026			0.0254	0.0244		0.0265
				O/L								G/N	G/N				
		pH	Lab			5.3	5.31	5.51	5.51	5.52	5.5			4.82	4.87		5.36
				O/L								G/N	G/N				
		TOC, Total (mg/L)	Lab			5.2	3.8							4.3	2.3		3.5
				O/L								G/N	G/N				
		Turbidity (NTU)	Lab			0.46	0.73	0.09	0.1	0.13	0.08			0.08	0.07		0.17
				O/L								G/N	G/N				
April 28, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.007	0.0437	0.043	0.0396	0.0391	0.039	0.0395	0.0393	0.0449	0.0411	0.0399		
				Avg. of filters 1 to 8												0.0403	
		pH	Lab		8.19	5.15	5.15	5.28	5.23	5.23	5.24	5.13	5.23	5.34	5.31		
				Avg. of filters 1 to 8												5.24875	
		TOC, Total (mg/L)	Lab		19.8	4.6	4.5	3.9	3.9		3.7						
				Avg. of filters 1 to 8												3.83333	
		Turbidity (NTU)	Bench					0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05		
			Lab		0.78	1.33	1.34	0.06							0.05		
				Avg. of filters 1 to 8												0.055	
				N/D at <0.05					G/N	G/N	G/N	G/N	G/N	G/N			
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0402	0.0404	0.0257		0.0262	0.0256		0.025	0.0277	0.023		0.0255
				O/L					G/N			G/N					
		pH	Lab			5.35	5.3	5.49		5.49	5.41		4.86	4.89	4.9		5.24
				O/L					G/N			G/N					
		TOC, Total (mg/L)	Lab			5.2	4.8	4.9		5.5	4.9						4.7
				O/L					G/N			G/N					
		Turbidity (NTU)	Lab			0.37	0.75	0.1		0.09	0.09		0.07	0.08	0.09		0.15
				O/L					G/N			G/N					
April 29, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0067	0.0439	0.0435	0.0394	0.04	0.0399	0.0408	0.045	0.0399	0.0404	0.04		
				Avg. of filters 1 to 8												0.04068	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
April 29, 2017	Pilot-Scale	pH	Lab		8.07	5.14	5.29	5.52	5.53	5.55	5.47	5.6	5.53	5.43	5.49		
				Avg. of filters 1 to 8												5.515	
		TOC, Total (mg/L)	Lab		17.9	5	5.1			3.6		4.7	4.5	4.2	4.3		
				Avg. of filters 1 to 8												4.26	
		Turbidity (NTU)	Bench					0.12	0.08	0.07	0.06	0.05	0.06	0.06	0.05		
			Lab		0.84	1.31	1.5	0.12	0.08	0.07	0.06	0.05	0.06	0.06	0.05		
				Avg. of filters 1 to 8												0.06875	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0399	0.0391	0.0252	0.0257	0.0289	0.0237		0.0243	0.0228			0.0266
				O/L								G/N			G/N		
		pH	Lab			5.41	5.34	5.59	5.55	5.62	5.31		4.97	4.93			5.42
				O/L								G/N			G/N		
		TOC, Total (mg/L)	Lab				4.9						4.3	3.9			4.7
				O/L								G/N			G/N		
		Turbidity (NTU)	Lab			0.45	0.67	0.1	0.09	0.1	0.09		0.08	0.11			0.13
				O/L								G/N			G/N		
April 30, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0073	0.0432	0.042	0.0412	0.0361	0.0373	0.0362	0.0362	0.0367	0.0364	0.036		
				Avg. of filters 1 to 8												0.03701	
		pH	Lab		8.12	5.19	5.24	5.42	5.45	5.4	5.38	5.28	5.39	5.32	5.43		
				Avg. of filters 1 to 8												5.38375	
		TOC, Total (mg/L)	Lab		16.7	5.4	5	4.6	4.1		4.1						
				Avg. of filters 1 to 8												4.26667	
		Turbidity (NTU)	Bench					0.08	0.05	0.05	0.05	0.05	0.05	0.06	0.06		
			Lab		0.77	1.2	1.29	0.08	0.05	0.05		0.05		0.06	0.06		
				Avg. of filters 1 to 8												0.05833	
				N/D at <0.05							G/N		G/N				
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0365	0.0357		0.0248	0.0243	0.0236		0.0231	0.0244	0.0232		0.0244
				O/L				G/N				G/N					
		pH	Lab			5.53	5.51		5.67	5.63	5.58		5.12	5.03	5.04		5.36
				O/L				G/N				G/N					
		TOC, Total (mg/L)	Lab			7.3	5.3		3.1	6.1	6.5						5.2
				O/L				G/N									
		Turbidity (NTU)	Lab			0.35	0.71		0.13	0.15	0.17		0.12	0.11	0.09		0.17
				O/L				G/N				G/N					
May 1, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0075	0.0385	0.0375	0.0325	0.0319	0.0323	0.0323	0.0315	0.0319	0.0325	0.0323		
				Avg. of filters 1 to 8												0.03215	
		pH	Lab		8.15	5.3	5.3	5.31	5.31	5.3	5.29	5.25	5.29	5.28	5.3		
				Avg. of filters 1 to 8												5.29125	
		TOC, Total (mg/L)	Lab			6.2	5.2			4.1		5	4.9	4.6	4.7		
				Avg. of filters 1 to 8												4.66	
		Turbidity (NTU)	Bench					0.09	0.06	0.08	0.07	0.06	0.07	0.06	0.07		
			Lab		0.88	1.2	1.27	0.09	0.06	0.08	0.07	0.06	0.07	0.06	0.07		
				Avg. of filters 1 to 8												0.07	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0372	0.0414	0.0294	0.0239	0.0241			0.0221	0.023	0.0222		0.0244
				O/L							G/N	G/N					
		pH	Lab			5.54	5.34	5.55	5.58	5.64			5.04	4.99	5.01		5.27
				O/L							G/N	G/N					
		TOC, Total (mg/L)	Lab										5.8	6.1	4.3		
				O/L							G/N	G/N					
		Turbidity (NTU)	Lab			0.42	0.68	0.11	0.13	0.15			0.14	0.1	0.1		0.27
				O/L							G/N	G/N					
May 2, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0072	0.0445	0.0376	0.0311	0.0307	0.03	0.0352	0.0302	0.0298	0.0312	0.0314		
				Avg. of filters 1 to 8												0.0312	
		pH	Lab		8.13	5.42	5.75	5.48	5.35	5.35	5.35	5.31	5.32	5.35	5.32		
				Avg. of filters 1 to 8												5.35375	
		TOC, Total (mg/L)	Lab		18.7	5.9	5.2	4.6	4.3		4.2	6.6	4.7	4.6	4.4		
				Avg. of filters 1 to 8												4.77143	
		Turbidity (NTU)	Bench					0.09	0.07	0.07	0.07	0.06	0.06	0.07	0.07		
			Lab		0.67	1.22	1.24	0.09	0.07	0.07	0.07	0.06	0.06	0.07	0.07		
				Avg. of filters 1 to 8												0.07	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0387	0.0384	0.0273	0.0272		0.0282		0.0273	0.0269	0.0259		0.0274
				O/L						G/N		G/N					
		pH	Lab			5.44	5.45	5.62	5.61		5.59		5.05	4.97	5.06		5.24
				O/L						G/N		G/N					
		TOC, Total (mg/L)	Lab			6.4	4.7	6	6.1		6.2		4.8	5	4.4		4.8
				O/L						G/N		G/N					
		Turbidity (NTU)	Lab			0.36	0.54	0.09	0.12		0.09		0.07	0.08	0.09		0.11
				O/L						G/N		G/N					

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Benchmarking

					Sample Location												
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Filter Effluent Average**	**Combined Filtrate**
May 3, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0073	0.0396	0.0371	0.0318	0.0316	0.0312	0.0315	0.0328	0.0318	0.0313	0.0324		
				Avg. of filters 1 to 8												0.0318	
		pH	Lab		8.15	5.46	5.49	5.45	5.51	5.45	5.46	5.46	5.43	5.44	5.45		
				Avg. of filters 1 to 8												5.45625	
		TOC, Total (mg/L)	Lab		18.4	6.4	5.1			4.4		4.4	4.2	4.2	4.5		
				Avg. of filters 1 to 8												4.34	
		Turbidity (NTU)	Bench					0.07	0.09	0.07	0.06	0.06	0.07	0.06	0.07		
			Lab		0.89	1.14	1.24	0.07	0.09	0.07	0.06	0.06	0.07	0.06	0.07		
				Avg. of filters 1 to 8												0.06875	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0391	0.0374	0.0278	0.0286	0.0288	0.0281		0.0275	0.0271	0.0288		0.0277
				O/L								G/N					
		pH	Lab			5.45	5.37	5.33	5.58	5.62	5.44		4.94	5	5.03		5.23
				O/L								G/N					
		TOC, Total (mg/L)	Lab			5.4	4.6						5	4.6	4.2		5.7
				O/L								G/N					
		Turbidity (NTU)	Lab			0.38	0.55	0.1	0.09	0.1	0.08		0.08	0.1	0.15		0.13
				O/L								G/N					

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Transitioning

					Sample Location										
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**
May 6, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0085	0.01	0.01	0.0105	0.0105		0.0104	0.0107	0.0104	0.0105	0.0102
				NR						G/N					
		pH	Lab		8.15	5.03	5.07	5.93	5.99	6.12	6.08	5.86	5.94	5.93	6
		TOC, Total (mg/L)	Lab		18.3	4.5	4.4	3.9	4.2	4.4	4.1				
		Turbidity (NTU)	Lab		0.84	1.68	1.66	0.07	0.05	0.06	0.05		0.06		
				N/D at <0.05								G/N		G/N	G/N
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0431									
		pH	Lab			5.25									
		TOC, Total (mg/L)	Lab			4.5									
		Turbidity (NTU)	Lab			0.42									
May 7, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0076	0.0118	0.0135	0.0115	0.0113	0.0116	0.0113	0.0115	0.0116	0.0119	0.0117
		pH	Lab		8.19	5.11	5.11	5.75	5.71	5.74	5.72	5.69	5.7	5.72	5.78
		TOC, Total (mg/L)	Lab		17.8	4.3	5					4	4.1	3.8	4
		Turbidity (NTU)	Lab		0.8	1.64	1.79	0.08			0.05		0.06		0.05
				N/D at <0.05					G/N	G/N		G/N		G/N	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0425									
		pH	Lab			5.38									
		TOC, Total (mg/L)	Lab			4.9									
		Turbidity (NTU)	Lab			0.42									
May 8, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0105	0.0105	0.0109	0.0108	0.0111	0.011	0.0109	0.0115	0.0111	0.0113
		pH	Lab		8.17	5.13	5.2	5.62	5.69	5.69	5.63	5.56	5.65	5.62	5.69
		TOC, Total (mg/L)	Lab		16.6	6.6	5.9	4.2	4.3	4.4	4				
		Turbidity (NTU)	Bench					0.07	0.05	0.06	0.05	0.05	0.06	0.05	0.05
			Lab		0.86	1.72	2.16	0.07	0.09	0.08	0.06	0.07	0.06	0.06	0.07
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0374									
		pH	Lab			5.21									
		TOC, Total (mg/L)	Lab			5.9									
		Turbidity (NTU)	Lab			0.45									
May 9, 2017	Pilot-Scale	Turbidity (NTU)	Bench					0.08	0.05	0.05	0.05	0.05	0.06	0.05	0.05
May 10, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0083	0.011	0.0106	0.0082	0.0084	0.0083	0.0081	0.0084	0.0082	0.0083	0.0088
		pH	Lab		8.14	5.54	5.64	5.47	5.46	5.43	5.41	5.48	5.42	5.49	5.43
		TOC, Total (mg/L)	Lab		18.9	7.2	6.4					4.7	4.6	4.9	4.8
		Turbidity (NTU)	Bench					0.07	0.09	0.08	0.06	0.07	0.06	0.06	0.07
			Lab		0.85	2.4	2.31	0.06	0.08	0.1	0.1	0.07	0.07	0.09	0.06

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Transitioning. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 11, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		157.1	187.1	185.3	186	185.2	185.8	185.1	184.8	183.7	183.1	181	184.5
		DO (mg/L)	Bench		10.1	10.3	11.1	10.4	10.5	10.4	10.3	10.1	10	10.1	10.1	10.2
		Manganese, Total (mg/L)	Bench		0.012	0.024	0.024	0.013	0.012	0.012	0.012	0.008	0.01	0.01	0.011	0.013
		Oxi-Red Potenital (ORP) (mV)	Bench		273.5	227.4	267.5	285.2	293.7	299.8	305.7	311.4	322.8	327.9	340.5	336.3
		pH	Bench		8.34	6.03	6.02	6.01		6.04	6.04	5.95	5.89	5.92	5.96	5.98
		Temperature (ºC)	Bench		11.7	11.4	11.8	12.1	11.9	12	12.1	12.3	12.5	12.3	12.3	12
		Turbidity (NTU)	Bench		1.07	2.47	2.4	0.49	0.42	0.47	0.44	0.19	0.17	0.22	0.23	0.31
		UVA @254nm, Unfiltered (/cm)	Bench		0.134	0.228	0.21	0.05	0.049	0.052	0.051	0.032	0.03	0.036	0.035	0.038
		UVT @ 254nm, Unfiltered (%T)	Bench		73.4	59.9	61.5	88.9	89.3	88.9	88.9	92.8	93.4	92.1	92.2	91.5
	Full-Scale	Conductivity Total (µS/cm)	Bench			193.6	195.1									198.8
		DO (mg/L)	Bench			11	12.1									11.3
		Manganese, Total (mg/L)	Bench			0.043	0.039									0.031
		Oxi-Red Potenital (ORP) (mV)	Bench			284.4	374.5									292.6
		pH	Bench			5.62	5.79									5.44
		Temperature (ºC)	Bench			12.1	11.3									11.4
		Turbidity (NTU)	Bench			0.37	0.64									0.65
		UVA @254nm, Unfiltered (/cm)	Bench			0.055	0.053									0.019
		UVT @ 254nm, Unfiltered (%T)	Bench			88.2	88.5									95.7
May 12, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab					5	5	5	5					
		Aluminum, Dissolved (mg/L)	Lab					0.01	0.01	0.01	0.011					
		Aluminum, Total (mg/L)	Lab	N/D at <0.01				G/N	G/N	G/N	G/N					
		Antimony, Dissolved (mg/L)	Lab					0.001	0.0022	0.001	0.0009					
		Antimony, Total (mg/L)	Lab	N/D at <0.0005				G/N	G/N	G/N	G/N					
		Arsenic, Dissolved (mg/L)	Lab					0.00028	0.00036	0.0003	0.0003					
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007				G/N	G/N	G/N	G/N					
		Cadmium, Dissolved (mg/L)	Lab						0.00005							
				N/D at <0.00001				G/N		G/N	G/N					
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001				G/N	G/N	G/N	G/N					
		Calcium, Dissolved (mg/L)	Lab					20.7	20.6	20.8	21.6					
		Calcium, Total (mg/L)	Lab					20.7	21	21.2	21.7					
		Chromium, Dissolved (mg/L)	Lab					0.00026	0.00039	0.00024	0.00029					
		Chromium, Total (mg/L)	Lab	N/D at <0.001				G/N	G/N	G/N	G/N					
		Colour, True	Lab					1	2.5	2	2.5					
		Conductivity Total (µS/cm)	Bench		156.9	189.5	189.5	188.2	189.5	189.1	190.1	189.2	190.7	190.6	191.1	189.8
			Lab					201	203	202	202					
		Copper, Dissolved (mg/L)	Lab					0.0007	0.0008	0.0007	0.0007					
		Copper, Total (mg/L)	Lab	N/D at <0.005				G/N	G/N	G/N	G/N					
		DO (mg/L)	Bench		10.1	10.4	10.7	10	10	9.8	9.9	10	10.3	10.3	10.4	9.8
		DOC Total (mg/L)	Lab					4.2	4.2	4.3	3.9					
		Iron, Dissolved (mg/L)	Lab						0.002							
				N/D at <0.002				G/N		G/N	G/N					
		Iron, Total (mg/L)	Lab							0.012						
				N/D at <0.008				G/N	G/N		G/N					
		Lead, Dissolved (mg/L)	Lab						0.00008							
				N/D at <0.00004				G/N		G/N	G/N					
		Lead, Total (mg/L)	Lab	N/D at <0.0004				G/N	G/N	G/N	G/N					
		Magnesium, Dissolved (mg/L)	Lab					5.98	5.96	5.84	5.98					
		Magnesium, Total (mg/L)	Lab					6.02	5.73	5.91	5.96					
		Manganese, Dissolved (mg/L)	Lab					0.00906	0.00891	0.00853	0.00917					
		Manganese, Total (mg/L)	Bench		0.017	0.027	0.031	0.014	0.015	0.016	0.014	0.015	0.02	0.015	0.016	0.016
			Lab					0.0092	0.0089	0.0084	0.0095					
		Nickel, Dissolved (mg/L)	Lab					0.00365	0.00375	0.00353	0.00373					
		Nickel, Total (mg/L)	Lab					0.004	0.004	0.004	0.004					
		Oxi-Red Potenital (ORP) (mV)	Bench		313.1	270.5	299.5	313	327.5	330.3	335.3	337.3	344.5	348.1	336.8	344.7
		pH	Bench		8.3	5.83	5.82	5.885		5.88	5.87	5.82	5.81	5.81	5.81	5.84
			Lab					5.94	5.96	5.93	5.88					
		Potassium, Dissolved (mg/L)	Lab					1.07	1.09	1.05	1.11					
		Potassium, Total (mg/L)	Lab					1.1	1.07	1.06	1.1					
		Sodium, Dissolved (mg/L)	Lab					2.55	2.62	2.6	2.51					
		Sodium, Total (mg/L)	Lab					2.59	2.63	2.59	2.61					
		TDSwq (mg/L)	Lab					106	112	100	104					
		Temperature (ºC)	Bench		11.7	11.6	11.8	12.5	12.3	12.6	12.5	12.5	12.5	12.6	12.5	12.3
			Lab					13.3	13.4	13.4	13.4					
		TSScalc Total (mg/L)	Lab					56	26	46	34					

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 12, 2017	Pilot-Scale	TSwv Total (mg/L)	Lab					162	138	146	138					
		Turbidity (NTU)	Bench		1.22	2.11	2.24	0.15	0.17	0.16	0.13	0.11	0.11	0.12	0.16	0.16
			Lab					0.14	0.05	0.09	0.06					
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005				G/N	G/N	G/N	G/N					
		Uranium, Total (mg/L)	Lab	N/D at <0.0004				G/N	G/N	G/N	G/N					
		UVA @254nm, Unfiltered (/cm)	Bench		0.129	0.212	0.192	0.02	0.018	0.018	0.017	0.016	0.016	0.025	0.021	0.023
		UVT @ 254nm, Filtered (%T)	Lab					95.3	95.1	95.1	95.2					
		UVT @ 254nm, Unfiltered (%T)	Bench		74.3	61.4	64.2	95.5	95.8	95.9	96	96.3	96.3	94.4	95.3	94.7
		Zinc, Dissolved (mg/L)	Lab	N/D at <0.0009				G/N	G/N	G/N	G/N					
		Zinc, Total (mg/L)	Lab	N/D at <0.005				G/N	G/N	G/N	G/N					
	Full-Scale	Conductivity Total (µS/cm)	Bench			195.5	193.5									197.3
		DO (mg/L)	Bench			10.2	11.5									11.8
		Manganese, Total (mg/L)	Bench			0.044	0.04									0.029
		Oxi-Red Potenital (ORP) (mV)	Bench			305.3	361.7									373.7
		pH	Bench			5.48	5.76									5.44
		Temperature (ºC)	Bench			11.7	11.2									11.9
		Turbidity (NTU)	Bench			0.44	0.57									0.22
		UVA @254nm, Unfiltered (/cm)	Bench			0.056	0.059									0.015
		UVT @ 254nm, Unfiltered (%T)	Bench			88	87.3									96.6
May 13, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		159	189.4	189.9	190.3	190.6	190.8	190.6	191	191.6	191.1	193.9	192.2
		DO (mg/L)	Bench		10.1	10.2	10.3	9.8	9.7	10	10.1	10.1	10.2	9.9	10.3	9.5
		Manganese, Total (mg/L)	Bench		0.023	0.033	0.037	0.015	0.012	0.017	0.016	0.019	0.011	0.015	0.021	0.02
		Oxi-Red Potenital (ORP) (mV)	Bench		233.4	279	364.5	366	372.9	370.5	373.2	369.2	377.8	411.3	408.7	413.1
		pH	Bench		8.42	5.74	5.78	5.885		5.87	5.84	5.76	5.76	5.76	5.74	5.78
		Temperature (ºC)	Bench		12.2	12.3	12.6	13	13	13	13	12.7	12.9	12.7	12.9	12.7
		Turbidity (NTU)	Bench		1.08	2.51	2.46	0.13	0.08	0.1	0.13	0.44	0.38	0.52	0.52	0.38
		UVA @254nm, Unfiltered (/cm)	Bench		0.146	0.221	0.193	0.025	0.026	0.024	0.025	0.045	0.045	0.04	0.039	0.029
		UVT @ 254nm, Unfiltered (%T)	Bench		71.7	60.3	64.4	94.4	94.2	94.6	94.4	90.4	90.2	91.2	91.5	93.5
	Full-Scale	Conductivity Total (µS/cm)	Bench			192.2	196									221.2
		DO (mg/L)	Bench			10.3	12.6									11.8
		Manganese, Total (mg/L)	Bench			0.043	0.041									0.031
		Oxi-Red Potenital (ORP) (mV)	Bench			346.2	434.5									346.5
		pH	Bench			5.58	5.61									5.55
		Temperature (ºC)	Bench			11.9	12									12.1
		Turbidity (NTU)	Bench			0.4	0.5									0.52
		UVA @254nm, Unfiltered (/cm)	Bench			0.068	0.06									0.028
		UVT @ 254nm, Unfiltered (%T)	Bench			85.7	87.2									93.7
May 14, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		76	6	6					6	6	6	6	6
		Aluminum, Dissolved (mg/L)	Lab		0.002	0.015	0.015					0.013	0.013	0.013	0.017	0.012
		Aluminum, Total (mg/L)	Lab			0.02	0.02					0.01	0.01	0.01	0.01	0.01
				N/D at <0.01	G/N											
		Antimony, Dissolved (mg/L)	Lab		0.0012	0.0009	0.001					0.0011	0.0013	0.0009	0.0015	0.001
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N					G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00068	0.00034	0.00027					0.00028	0.00027	0.00027	0.00027	0.00026
		Arsenic, Total (mg/L)	Lab		0.0007											
				N/D at <0.0007		G/N	G/N					G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab									0.00001				
				N/D at <0.00001	G/N	G/N	G/N						G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N					G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		21.5	21	20.3					21.3	21.2	21.7	21.7	21.8
		Calcium, Total (mg/L)	Lab		21.6	21	21.2					21.4	21.9	21.8	21.5	21.7
		Chromium, Dissolved (mg/L)	Lab		0.00154	0.00031	0.00044					0.00036	0.00038	0.0003	0.00033	0.00033
		Chromium, Total (mg/L)	Lab		0.001	0.001	0.001									
				N/D at <0.001								G/N	G/N	G/N	G/N	G/N
		Cobalt, Total (mg/L)	Lab													0.0017
		Colour, True	Lab		11	1.5	1					1	1	1	1	1
		Conductivity Total (µS/cm)	Bench		156.2	190	188.8	190	192.4	191.7	190.5	190.6	192.7	193.2	192.8	192.8
			Lab		165	201	201					203	204	204	204	203
		Copper, Dissolved (mg/L)	Lab		0.0005	0.0008	0.0004					0.0006	0.0008	0.0007	0.0007	0.0087
		Copper, Total (mg/L)	Lab													0.009
				N/D at <0.005	G/N	G/N	G/N					G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		9.3	10	10.2	9.6	9.8	9.7	9.7	9.9	10	10	10.1	9.9
		DOC Total (mg/L)	Lab		19.3	4.6	5					4.3	4.8	4.4	4.7	4.6
		Hardness (dCa, mg/L CaCO3)	Lab													54.2

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Combined Filtrate**
May 14, 2017	Pilot-Scale	Iron, Dissolved (mg/L)	Lab		0.018	0.21	0.165									
				N/D at <0.002								G/N	G/N	G/N	G/N	G/N
		Iron, Total (mg/L)	Lab		0.019	2.54	2.58									
				N/D at <0.008								G/N	G/N	G/N	G/N	G/N
		Lead, Dissolved (mg/L)	Lab			0.00034										0.00007
				N/D at <0.00004	G/N		G/N					G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N					G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.98	5.83	5.69					5.82	5.75	6.04	5.91	5.77
		Magnesium, Total (mg/L)	Lab		5.89	5.81	5.91					5.92	5.98	5.96	5.95	5.91
		Manganese, Dissolved (mg/L)	Lab		0.00334	0.0107	0.0063					0.00944	0.0107	0.00855	0.009	0.00881
		Manganese, Total (mg/L)	Bench		0.014	0.028	0.033	0.015	0.015	0.016	0.015	0.014	0.015	0.014	0.013	0.013
			Lab		0.0061	0.0112	0.0111					0.0098	0.0107	0.0087	0.0091	0.0086
		Molybdenum, Total (mg/L)	Lab	N/D at <0.001												G/N
		Nickel, Dissolved (mg/L)	Lab		0.00026	0.00414	0.00406					0.0039	0.00383	0.00389	0.004	0.00377
		Nickel, Total (mg/L)	Lab			0.004	0.004					0.004	0.004	0.004	0.004	0.004
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		365	277.9	332.8	355.6	362.9	371.5	373.8	376.7	373.1	372	366.7	362.2
		pH	Bench		8.4	5.59	5.58	5.74		5.77	5.72	5.64	5.66	5.65	5.65	5.66
			Lab		8.23	5.66	5.66					5.82	5.77	5.81	5.8	5.84
		Phosphorus, Total (mg/L)	Lab	N/D at <0.02												G/N
		Potassium, Dissolved (mg/L)	Lab		1.11	1.09	1.08					1.09	1.05	1.1	1.12	1.11
		Potassium, Total (mg/L)	Lab		1.14	1.06	1.05					1.06	1.12	1.07	1.08	1.12
		Selenium, Total (mg/L)	Lab	N/D at <0.003												G/N
		Silver, Total (mg/L)	Lab	N/D at <0.0002												G/N
		Sodium, Dissolved (mg/L)	Lab		2.24	2.19	2.22					2.62	2.61	2.47	2.58	2.6
		Sodium, Total (mg/L)	Lab		2.33	2.16	2.14					2.65	2.6	2.52	2.58	2.53
		TDSwq (mg/L)	Lab		67	105	104					95	101	108	102	108
		Temperature (ºC)	Bench		12.5	12.5	12.8	13.3	13.4	13.4	13.4	13.3	13.3	13.3	13.2	12.9
			Lab		12.5	12.3	12.8					13.3	13.3	13.3	13.2	12.9
		TSScalc Total (mg/L)	Lab		43	21	34					35	27	32	24	8
		TSwv Total (mg/L)	Lab		110	126	138					130	128	140	126	116
		Turbidity (NTU)	Bench		1.12	1.84	2.28	0.08	0.08	0.11	0.08	0.12	0.1	0.1	0.1	0.1
			Lab		0.89	1.82	2.31					0.06	0.06	0.05	0.07	0.06
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N					G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N					G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.141	0.169	0.177	0.018	0.019	0.021	0.016	0.018	0.016	0.024	0.017	0.021
		UVT @ 254nm, Filtered (%T)	Lab		73.6	92.7	94.8					95	95.2	94.7	95.3	95.1
		UVT @ 254nm, Unfiltered (%T)	Bench		72.2	67.9	66.8	95.9	95.8	95.4	96.4	95.9	96.3	94.9	96.2	95.2
		Zinc, Dissolved (mg/L)	Lab			0.0012	0.001									
				N/D at <0.0009	G/N							G/N	G/N	G/N	G/N	G/N
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N					G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			7	8									7
		Aluminum, Dissolved (mg/L)	Lab			0.014	0.012									0.016
		Aluminum, Total (mg/L)	Lab			0.01	0.01									0.02
		Antimony, Dissolved (mg/L)	Lab			0.0012	0.0013									0.0012
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00043	0.0004									0.00034
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			20.8	20.7									20.8
		Calcium, Total (mg/L)	Lab			20.9	20.7									20.4
		Chromium, Dissolved (mg/L)	Lab			0.00062	0.00068									0.0007
		Chromium, Total (mg/L)	Lab			0.001										0.001
				N/D at <0.001			G/N									
		Cobalt, Total (mg/L)	Lab	N/D at <0.0008		G/N	G/N									G/N
		Colour, True	Lab			1.5	1									1
		Conductivity Total (µS/cm)	Bench			195.6	195.3									195.6
			Lab			205	203									205
		Copper, Dissolved (mg/L)	Lab			0.0028	0.0027									0.0029
		Copper, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
		DO (mg/L)	Bench			10.1	10.1									10.9
		DOC Total (mg/L)	Lab			5.7	5.5									5.8
		Hardness (dCa, mg/L CaCO3)	Lab			52.2	51.7									51

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 14, 2017	Full-Scale	Iron, Dissolved (mg/L)	Lab			0.039	0.249									0.049
		Iron, Total (mg/L)	Lab			0.402	0.448									0.074
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.72	5.82									5.74
		Magnesium, Total (mg/L)	Lab			5.72	5.67									5.74
		Manganese, Dissolved (mg/L)	Lab			0.0389	0.0332									0.0271
		Manganese, Total (mg/L)	Bench			0.044	0.039									0.034
			Lab			0.0385	0.0363									0.028
		Molybdenum, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Nickel, Dissolved (mg/L)	Lab			0.00206	0.00208									0.00198
		Nickel, Total (mg/L)	Lab			0.002	0.002									0.002
		Oxi-Red Potenital (ORP) (mV)	Bench			322	308.2									332.1
		pH	Bench			5.58	5.8									5.59
			Lab			5.77	5.97									5.68
		Phosphorus, Total (mg/L)	Lab	N/D at <0.02		G/N	G/N									G/N
		Potassium, Dissolved (mg/L)	Lab			1.12	1.07									1.06
		Potassium, Total (mg/L)	Lab			1.08	1.07									1.05
		Selenium, Total (mg/L)	Lab	N/D at <0.003		G/N	G/N									G/N
		Silver, Total (mg/L)	Lab	N/D at <0.0002		G/N	G/N									G/N
		Sodium, Dissolved (mg/L)	Lab			2.19	2.22									2.36
		Sodium, Total (mg/L)	Lab			2.12	2.25									2.24
		TDSwq (mg/L)	Lab			128	111									116
		Temperature (ºC)	Bench			12.7	12									12.4
			Lab			12.7	12									12.4
		TSScalc Total (mg/L)	Lab			10	19									8
		TSwv Total (mg/L)	Lab			138	130									124
		Turbidity (NTU)	Bench			0.46	0.66									0.2
			Lab			0.4	0.48									0.22
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.062	0.057									0.026
		UVT @ 254nm, Filtered (%T)	Lab			91.4	94.6									94.7
		UVT @ 254nm, Unfiltered (%T)	Bench			86.6	87.7									94.1
		Zinc, Dissolved (mg/L)	Lab			0.0016										0.0014
				N/D at <0.0009			G/N									
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
May 15, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		156.6	191.5	191	190.7	193	193.4	193.5	193.4	194.8	194.6	194.2	194
		DO (mg/L)	Bench		10	9.9	10.4	9.7	9.7	9.7	9.7	9.8	10.1	10.1	9.8	9.8
		Manganese, Total (mg/L)	Bench		0.01	0.028	0.027	0.016	0.012	0.016	0.013	0.02	0.021	0.021	0.02	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		419.1	364.9	485.3	432.6	451	453.2	456.2	453.1	448.8	451.6	447.6	440.4
		pH	Bench		8.24	5.4	5.5	5.605		5.6	5.56	5.44	5.5	5.5	5.5	5.52
		Temperature (ºC)	Bench		12.8	12.4	12.5	13.5	13.3	13.5	13.5	13.4	13.3	13.4	13.3	13.6
		Turbidity (NTU)	Bench		1.15	2.11	2.37	0.24	0.16	0.12	0.14	0.97	0.67	0.67	0.74	0.51
		UVA @254nm, Unfiltered (/cm)	Bench		0.143	0.176	0.17	0.023	0.023	0.021	0.023	0.06	0.052	0.055	0.062	0.042
		UVT @ 254nm, Unfiltered (%T)	Bench		72	66.4	67.4	94.8	94.8	95.3	94.9	86.7	88.4	88	86.6	90.7
	Full-Scale	Conductivity Total (µS/cm)	Bench			195.1	193.2									196.9
		DO (mg/L)	Bench			9.8	11.2									11.2
		Manganese, Total (mg/L)	Bench			0.048	0.046									0.04
		Oxi-Red Potenital (ORP) (mV)	Bench			390	449.7									459.2
		pH	Bench			5.53	5.73									5.56
		Temperature (ºC)	Bench			12.4	12.1									12.5
		Turbidity (NTU)	Bench			0.54	0.51									0.18
		UVA @254nm, Unfiltered (/cm)	Bench			0.059	0.051									0.026
		UVT @ 254nm, Unfiltered (%T)	Bench			87.2	88.9									94.2
May 16, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		151.1	188.6	189.6	188.8	190.2	190.2	189.1	189.3	188.7	189.2	189.2	190
		DO (mg/L)	Bench		9.3	9.4	10	9.7	9.7	9.7	9.6	9.4	9.3	9.4	9.4	9.4
		Manganese, Total (mg/L)	Bench		0.014	0.03	0.029	0.019	0.018	0.015	0.017	0.014	0.015	0.013	0.014	0.016
		Oxi-Red Potenital (ORP) (mV)	Bench		322.1	265.4	316.2	340.4	345.8	352.2	631.5	366.2	368.6	374.2	375.6	374.1
		pH	Bench		8.24	5.61	5.55	5.53		5.52	5.46	5.42	5.43	5.42	5.43	5.47
		Temperature (ºC)	Bench		13.4	13.5	13.7	13.7	14	14.1	14	14.2	14.1	14.4	14.3	14.6
		Turbidity (NTU)	Bench		0.96	2.03	2.08	0.48	0.4	0.39	0.4	0.1	0.13	0.14	0.14	0.3
		UVA @254nm, Unfiltered (/cm)	Bench		0.135	0.179	0.154	0.038	0.033	0.031	0.029	0.017	0.019	0.025	0.019	0.034
		UVT @ 254nm, Unfiltered (%T)	Bench		73.2	66.2	70.1	91.5	92.1	93.1	93.5	96.2	95.8	94.5	95.7	92.6

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location											
					Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 16, 2017	Full-Scale	Conductivity Total (µS/cm)	Bench			194.2	192.9									195
		DO (mg/L)	Bench			9.7	10.5									10.7
		Manganese, Total (mg/L)	Bench			0.048	0.046									0.034
		Oxi-Red Potenital (ORP) (mV)	Bench			332.4	340.3									351.8
		pH	Bench			5.55	5.75									5.51
		Temperature (ºC)	Bench			13.2	13.3									13.6
		Turbidity (NTU)	Bench			0.47	0.56									0.15
		UVA @254nm, Unfiltered (/cm)	Bench			0.066	0.054									0.023
		UVT @ 254nm, Unfiltered (%T)	Bench			86	88.3									94.8
May 17, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		152.9	189.9	190.5	192.8	193.1	192.9	192.7	191	191.1	192.3	192.7	192.8
		DO (mg/L)	Bench		9.3	9.8	10.2	10.1	10	9.9	9.8	9.6	9.6	9.6	9.5	9.7
		Manganese, Total (mg/L)	Bench		0.019	0.038	0.04	0.027	0.024	0.026	0.025	0.019	0.021	0.02	0.017	0.017
		Oxi-Red Potenital (ORP) (mV)	Bench		314.4	249.2	317.9	326.3	333.4	340.1	339.1	350.9	359.9	366.5	370	363.8
		pH	Bench		8.21	5.4	5.3	5.335		5.32	5.3	5.3	5.32	5.31	5.3	5.3
		Temperature (ºC)	Bench		12.9	12.7	13.1	13.3	13.4	13.4	13.5	13.5	13.8	13.6	13.9	13.7
		Turbidity (NTU)	Bench		1.03	3.08	3.04	1.28	1.18	1.04	1.23	0.11	0.12	0.11	0.08	0.43
		UVA @254nm, Unfiltered (/cm)	Bench		0.141	0.241	0.211	0.085	0.086	0.073	0.077	0.015	0.014	0.015	0.015	0.039
		UVT @ 254nm, Unfiltered (%T)	Bench		72.2	57.4	61.7	82	82.3	84.7	83.6	96.5	96.7	96.6	96.6	91
	Full-Scale	Conductivity Total (µS/cm)	Bench			193.5	191.2									192.6
		DO (mg/L)	Bench			9.9	10.4									10.9
		Manganese, Total (mg/L)	Bench			0.05	0.039									0.034
		Oxi-Red Potenital (ORP) (mV)	Bench			323	324.5									339.6
		pH	Bench			5.49	5.66									5.49
		Temperature (ºC)	Bench			12.7	12.5									12.8
		Turbidity (NTU)	Bench			0.51	0.58									0.22
		UVA @254nm, Unfiltered (/cm)	Bench			0.058	0.053									0.022
		UVT @ 254nm, Unfiltered (%T)	Bench			87.6	88.6									95.1
May 20, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		76	8		10	10	11	10	11	12	12	12	11
				N/D at <2			G/N									
		Aluminum, Dissolved (mg/L)	Lab			0.008	0.011	0.002	0.002		0.003	0.003	0.003	0.002	0.002	0.003
				N/D at <0.002	G/N					G/N						
		Aluminum, Total (mg/L)	Lab				0.01									
				N/D at <0.01	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab			0.0006										
				N/D at <0.0004	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Total (mg/L)	Lab											0.0008		
				N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00063	0.00033	0.00026	0.00029	0.00026	0.0003	0.00027	0.00029	0.00028	0.0003	0.00028	0.00028
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab					0.00001								
				N/D at <0.00001	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		22.1	22	21.8	23.7	22.5	22.9	23.4	23.1	23.7	23.2	23.6	23.1
		Calcium, Total (mg/L)	Lab		22.2	22.6	22.5		22.9	23	23.7	23.9	23.6	23.3	23.9	23.3
				N/D at <0.06				G/N								
		Chromium, Dissolved (mg/L)	Lab		0.00188	0.00059	0.00043	0.00053	0.00052	0.00044	0.00048	0.00043	0.00054	0.0005	0.00047	0.00043
		Chromium, Total (mg/L)	Lab		0.002	0.001										
				N/D at <0.001			G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cobalt, Total (mg/L)	Lab													0.0011
		Colour, True	Lab		12	2	1.5	1.5	1	1	1	1.5	1.5	1	1.5	1.5
		Conductivity Total (µS/cm)	Bench		164.1	188.5	187.5	194.8	194.6	194.5	194.8	196	196.4	196.8	196.9	194.5
			Lab		166	199	227	204	204	205	204	206	207	207	208	205
		Copper, Dissolved (mg/L)	Lab		0.0007	0.0005	0.0004	0.0005	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		9.5	10	10.5	10.1	9.9	10	10	9.8	9.7	9.7	9.7	9.8
		DOC Total (mg/L)	Lab		8.1	3.4	3.1	3.3	3.2	3.1	3.3	3.4	3.4	3.3	3	3.1
		Hardness (dCa, mg/L CaCO3)	Lab													58.2
		Iron, Dissolved (mg/L)	Lab		0.017	0.287	0.081	0.072	0.071	0.029	0.227	0.009	0.012	0.005	0.003	0.03
		Iron, Total (mg/L)	Lab		0.032	1.27	1.28		0.803	0.677	0.896	0.016	0.014	0.013	0.013	0.243
				N/D at <0.008				G/N								
		Lead, Dissolved (mg/L)	Lab					0.00004								
				N/D at <0.00004	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		6.62	6.41	6.45	6.59	6.49	6.64	6.27	6.96	6.71	6.61	6.75	6.68

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 20, 2017	Pilot-Scale	Magnesium, Total (mg/L)	Lab		6.46	6.56	6.44	6.73	6.72	6.36	6.61	6.59	6.6	6.77	6.65	6.42
		Manganese, Dissolved (mg/L)	Lab		0.00191	0.0114	0.00933	0.00837	0.00848	0.0079	0.00849	0.00674	0.00709	0.00549	0.00536	0.00772
		Manganese, Total (mg/L)	Bench		0.015	0.022	0.025	0.02	0.017	0.016	0.017	0.012	0.014	0.013	0.015	0.014
			Lab		0.007	0.0117	0.0111		0.0089	0.0084	0.0091	0.0068	0.0069	0.0056	0.0057	0.0078
				N/D at <0.0005				G/N								
		Molybdenum, Total (mg/L)	Lab	N/D at <0.001												G/N
		Nickel, Dissolved (mg/L)	Lab		0.0003	0.00399	0.00391	0.00248	0.00255	0.00235	0.00238	0.00191	0.00189	0.00176	0.00173	0.00228
		Nickel, Total (mg/L)	Lab			0.004	0.004		0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002
				N/D at <0.001	G/N			G/N								
		Oxi-Red Potenital (ORP) (mV)	Bench		316.4	269.5	284.6	293.8	300.6	309.8	312.6	316.8	320	323.6	323.4	330.6
		pH	Bench		8.04	5.75	5.68	5.96		5.98	5.95	6.04	6.08	6.09	6.13	6.05
			Lab		8.16	5.8	5.34	6.14	6.09	6.15	6.14	6.2	6.28	6.24	6.26	6.18
		Phosphorus, Total (mg/L)	Lab	N/D at <0.02												G/N
		Potassium, Dissolved (mg/L)	Lab		1.3	1.2	1.19	1.21	1.21	1.21	1.19	1.21	1.22	1.2	1.23	1.23
		Potassium, Total (mg/L)	Lab		1.24	1.19	1.21	1.26	1.21	1.21	1.22	1.2	1.21	1.22	1.25	1.23
		Selenium, Total (mg/L)	Lab	N/D at <0.003												G/N
		Silver, Total (mg/L)	Lab	N/D at <0.0002												G/N
		Sodium, Dissolved (mg/L)	Lab		2.37	2.33	5.05	2.73	2.68	2.69	2.61	2.78	2.81	2.75	2.69	2.84
		Sodium, Total (mg/L)	Lab		2.39	2.37	5.1		2.67	2.65	2.68	2.75	2.71	2.8	2.72	2.81
				N/D at <0.07				G/N								
		TDSwq (mg/L)	Lab		106	122	128	124	129	132	132	128	140	125	127	127
		Temperature (ºC)	Bench		12.9	12.3	13.3	13.3	13.5	13.4	13.5	13.6	13.5	13.4	13.5	14
			Lab		12.9	12.7	13.3	13.3	13.5	13.4	13.5	13.6	13.5	13.4	13.5	14
		TSScalc Total (mg/L)	Lab		42	62	54	28	21	16	22	22	16	21	23	15
		TSwv Total (mg/L)	Lab		148	184	182	152	150	148	154	150	156	146	150	142
		Turbidity (NTU)	Bench		0.98	1.13	1.35	0.73	0.65	0.55	0.61	0.08	0.06	0.06	0.09	0.25
			Lab		0.91	1.12	1.59	0.95	0.82	0.62	0.69	0.06	0.07	0.06	0.08	0.33
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.13	0.098	0.106	0.066	0.061	0.05	0.053	0.02	0.019	0.02	0.02	0.029
		UVT @ 254nm, Filtered (%T)	Lab		74.2	91.8	94.3	93.8	94.1	94.3	94.2	93.3	93.5	94.1	93.8	94.2
		UVT @ 254nm, Unfiltered (%T)	Bench		74.1	79.8	73.8	85.9	86.8	89.2	88.3	95.5	95.8	95.5	95.5	93.8
		Zinc, Dissolved (mg/L)	Lab										0.0018			0.001
				N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			7	9									7
		Aluminum, Dissolved (mg/L)	Lab			0.017	0.013									0.015
		Aluminum, Total (mg/L)	Lab			0.02	0.01									0.01
		Antimony, Dissolved (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00042	0.00037									0.0003
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			22.5	21.6									21.3
		Calcium, Total (mg/L)	Lab				21.1									22.5
				N/D at <0.06		G/N										
		Chromium, Dissolved (mg/L)	Lab			0.00107	0.00091									0.00097
		Chromium, Total (mg/L)	Lab			0.001										0.001
				N/D at <0.001			G/N									
		Cobalt, Total (mg/L)	Lab	N/D at <0.0008		G/N	G/N									G/N
		Colour, True	Lab			1.5	1									1
		Conductivity Total (µS/cm)	Bench			195.8	192.2									196.7
			Lab			206	203									209
		Copper, Dissolved (mg/L)	Lab			0.0029	0.0025									0.0024
		Copper, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
		DO (mg/L)	Bench			10.4	10.7									11
		DOC Total (mg/L)	Lab			3.2	3.5									3.1
		Hardness (dCa, mg/L CaCO3)	Lab			53	52.7									83
		Iron, Dissolved (mg/L)	Lab			0.331	0.365									0.027
		Iron, Total (mg/L)	Lab				0.562									0.046
				N/D at <0.008		G/N										
		Lead, Dissolved (mg/L)	Lab			0.00007	0.00004									
				N/D at <0.00004												G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 20, 2017	Full-Scale	Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			6.48	6.43									6.49
		Magnesium, Total (mg/L)	Lab			6.31	6.26									6.51
		Manganese, Dissolved (mg/L)	Lab			0.0443	0.0352									0.0293
		Manganese, Total (mg/L)	Bench			0.05	0.05									0.033
			Lab				0.0428									0.0316
				N/D at <0.0005		G/N										
		Molybdenum, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Nickel, Dissolved (mg/L)	Lab			0.00222	0.00212									0.00213
		Nickel, Total (mg/L)	Lab				0.002									0.002
				N/D at <0.001		G/N										
		Oxi-Red Potenital (ORP) (mV)	Bench			317.5	316.3									320.6
		pH	Bench			5.54	5.76									5.5
			Lab			5.69	5.91									5.59
		Phosphorus, Total (mg/L)	Lab	N/D at <0.02		G/N	G/N									G/N
		Potassium, Dissolved (mg/L)	Lab			1.21	1.2									1.17
		Potassium, Total (mg/L)	Lab			1.18	1.2									1.18
		Selenium, Total (mg/L)	Lab	N/D at <0.003		G/N	G/N									G/N
		Silver, Total (mg/L)	Lab	N/D at <0.0002		G/N	G/N									G/N
		Sodium, Dissolved (mg/L)	Lab			2.4	2.43									2.49
		Sodium, Total (mg/L)	Lab				2.4									2.47
				N/D at <0.07		G/N										
		TDSwq (mg/L)	Lab			129	133									137
		Temperature (ºC)	Bench			12.3	12.2									12.5
			Lab			12.3	12.2									12.5
		TSScalc Total (mg/L)	Lab			29	25									13
		TSwv Total (mg/L)	Lab			158	158									150
		Turbidity (NTU)	Bench			0.38	0.69									0.26
			Lab			0.44	0.48									0.1
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.06	0.056									0.018
		UVT @ 254nm, Filtered (%T)	Lab			92	94.6									95.2
		UVT @ 254nm, Unfiltered (%T)	Bench			87.1	87.9									96.1
		Zinc, Dissolved (mg/L)	Lab			0.0013	0.0012									0.0014
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
May 21, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		155.5	187.1	187.3	190.5	191.1	191.1	191.6	189.1	190.2	190.5	190.6	190.6
		DO (mg/L)	Bench		9.2	9.8	10.3	9.9	9.9	9.7	9.9	9.6	9.5	9.5	9.4	9.5
		Manganese, Total (mg/L)	Bench		0.014	0.021	0.02	0.018	0.014	0.012	0.013	0.013	0.012	0.013	0.015	0.015
		Oxi-Red Potenital (ORP) (mV)	Bench		368.8	287.9	303.9	312.1	318.4	320.5	325.8	328.9	330.7	326.9	331	336
		pH	Bench		8.08	5.79	5.72	5.84		5.88	5.84	5.9	5.94	5.95	5.97	5.9
		Temperature (ºC)	Bench		12.9	13.2	13	13.5	13.6	13.5	13.7	13.6	13.8	13.8	13.8	13.8
		Turbidity (NTU)	Bench		0.93	1.01	1.43	0.18	0.13	0.13	0.12	0.08	0.07	0.08	0.09	0.13
		UVA @254nm, Unfiltered (/cm)	Bench		0.135	0.096	0.098	0.028	0.026	0.024	0.026	0.023	0.023	0.023	0.024	0.024
		UVT @ 254nm, Unfiltered (%T)	Bench		73.2	80.2	79.8	93.7	94.1	94.5	94.2	94.8	94.9	94.8	94.6	94.7
	Full-Scale	Conductivity Total (µS/cm)	Bench			195	191.7									196.4
		DO (mg/L)	Bench			9.6	10.4									10.6
		Manganese, Total (mg/L)	Bench			0.05	0.0489									0.037
		Oxi-Red Potenital (ORP) (mV)	Bench			348.6	403.8									373.4
		pH	Bench			5.45	5.66									5.38
		Temperature (ºC)	Bench			13	12.5									12.9
		Turbidity (NTU)	Bench			0.4	0.5									0.11
		UVA @254nm, Unfiltered (/cm)	Bench			0.057	0.054									0.019
		UVT @ 254nm, Unfiltered (%T)	Bench			87.8	88.3									95.7
May 22, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		156.4	187.8	187.5	189.9	189.4	189.4	190.3	189	189.6	189.3	189.7	190.3
		DO (mg/L)	Bench		9.6	10	9.9	9.8	9.9	9.8	9.9	9.7	9.7	9.7	9.6	9.7
		Manganese, Total (mg/L)	Bench		0.014	0.017	0.017	0.01	0.01	0.015	0.013	0.012	0.011	0.012	0.009	0.01
		Oxi-Red Potenital (ORP) (mV)	Bench		227.4	284.1	359.1	355.5	359.7	358.9	359.1	360	356	354.6	347.8	342.5
		pH	Bench		8.01	5.67	5.7	5.815		5.83	5.83	5.87	5.87	5.84	5.85	5.79
		Temperature (ºC)	Bench		12.9	12.5	13.1	13.2	13.4	13.2	13.5	13.4	13.7	13.6	13.7	13.4
		Turbidity (NTU)	Bench		0.93	1.06	1.17	0.08	0.07	0.07	0.07	0.07	0.1	0.07	0.07	0.08
		UVA @254nm, Unfiltered (/cm)	Bench		0.127	0.088	0.081	0.025	0.025	0.026	0.025	0.025	0.025	0.025	0.024	0.026
		UVT @ 254nm, Unfiltered (%T)	Bench		74.6	81.5	82.9	94.4	94.4	94.2	94.5	94.5	94.4	94.4	94.6	94.2
	Full-Scale	Conductivity Total (µS/cm)	Bench			196.1	192.7									197.1

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location											
					Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 22, 2017	Full-Scale	DO (mg/L)	Bench			10.3	10.9									10.8
		Manganese, Total (mg/L)	Bench			0.05	0.048									0.03
		Oxi-Red Potenital (ORP) (mV)	Bench			353.6	411.6									377.4
		pH	Bench			5.4	5.64									5.41
		Temperature (ºC)	Bench			12.7	12.4									12.9
		Turbidity (NTU)	Bench			0.39	0.71									0.18
		UVA @254nm, Unfiltered (/cm)	Bench			0.058	0.06									0.024
		UVT @ 254nm, Unfiltered (%T)	Bench			87.4	87.1									94.6
May 23, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		156	188.4	187	191.9	192.3	192.6	191.9	192.5	192.5	193	193.2	193.9
		DO (mg/L)	Bench		9.8	9.7	10.5	9.8	9.7	9.9	10	9.7	9.7	9.7	9.8	9.9
		Manganese, Total (mg/L)	Bench		0.015	0.024	0.021	0.016	0.016	0.018	0.016	0.018	0.017	0.015	0.014	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		276.6	276.6	322.1	313.4	306.2	314.8	303.4	277.7	336.2	329.3	318.6	307.9
		pH	Bench		8.01	5.64	5.69	5.79		5.81	5.74	5.78	5.81	5.79	5.79	5.73
		Temperature (ºC)	Bench		12.7	12.6	12.9	13.1	13.3	13.2	13.4	13.5	13.6	13.6	13.8	13.4
		Turbidity (NTU)	Bench		0.89	0.91	0.9	0.09	0.08	0.1	0.08	0.07	0.1	0.08	0.09	0.09
		UVA @254nm, Unfiltered (/cm)	Bench		0.134	0.08	0.065	0.023	0.023	0.021	0.02	0.02	0.021	0.02	0.019	0.022
		UVT @ 254nm, Unfiltered (%T)	Bench		73.4	83.7	86.7	94.8	94.8	95.3	95.5	95.5	95.3	95.5	95.6	95.1
	Full-Scale	Conductivity Total (µS/cm)	Bench			195.6	192.8									191
		DO (mg/L)	Bench			10.7	10.9									10.5
		Manganese, Total (mg/L)	Bench			0.055	0.053									0.034
		Oxi-Red Potenital (ORP) (mV)	Bench			320	348.8									323.1
		pH	Bench			5.44	5.61									5.36
		Temperature (ºC)	Bench			12.5	12.7									12.6
		Turbidity (NTU)	Bench			0.35	0.6									0.15
		UVA @254nm, Unfiltered (/cm)	Bench			0.056	0.058									0.022
		UVT @ 254nm, Unfiltered (%T)	Bench			88.1	87.6									95
May 24, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		157.4	187.9	187.6	189.8	189.8	189.9	190.2	189.3	190.7	188.9	189.3	191.1
		DO (mg/L)	Bench		9.4	9.5	10	9.7	9.6	9.5	9.7	9.5	9.5	9.5	9.5	9.4
		Manganese, Total (mg/L)	Bench		0.014	0.016	0.016	0.013	0.012	0.01	0.013	0.014	0.016	0.014	0.015	0.014
		Oxi-Red Potenital (ORP) (mV)	Bench		214.7	269.5	338.3	338	335.3	331.5	323	307.3	302.2	303.9	299.1	289.3
		pH	Bench		7.98	5.75	5.7	5.83		5.85	5.81	5.82	5.83	5.82	5.81	5.83
		Temperature (ºC)	Bench		13.5	13.3	13.6	13.8	13.9	13.8	14	14.1	14.3	14.1	14.4	14.3
		Turbidity (NTU)	Bench		0.82	0.78	0.81	0.11	0.1	0.11	0.1	0.1	0.1	0.09	0.08	0.1
		UVA @254nm, Unfiltered (/cm)	Bench		0.127	0.061	0.049	0.018	0.017	0.02	0.019	0.019	0.02	0.022	0.02	0.02
		UVT @ 254nm, Unfiltered (%T)	Bench		74.6	86.7	89.9	95.9	96.1	95.4	95.8	95.7	95.5	95	95.6	95.5
	Full-Scale	Conductivity Total (µS/cm)	Bench			196.1	192.3									200.5
		DO (mg/L)	Bench			9.5	10.2									9.6
		Manganese, Total (mg/L)	Bench			0.052	0.052									0.029
		Oxi-Red Potenital (ORP) (mV)	Bench			300.2	348.4									339
		pH	Bench			5.43	5.65									5.46
		Temperature (ºC)	Bench			13.3	12.9									13.3
		Turbidity (NTU)	Bench			0.37	0.57									0.1
		UVA @254nm, Unfiltered (/cm)	Bench			0.056	0.052									0.017
		UVT @ 254nm, Unfiltered (%T)	Bench			87.6	88.8									96.2
May 25, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		74	7	7	8	8	8	8	9	9	9	10	8
		Aluminum, Dissolved (mg/L)	Lab			0.011	0.011	0.008	0.009	0.009	0.007	0.006	0.006	0.006	0.006	0.008
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.01	0.01									
				N/D at <0.01	G/N			G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab		0.0009	0.0012	0.0013	0.001	0.0011	0.0014	0.0008	0.001	0.0014	0.0011	0.0009	0.001
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00073	0.00033	0.00035	0.00033	0.00031	0.00037	0.00032	0.00031	0.00032	0.00032	0.00033	0.00031
		Arsenic, Total (mg/L)	Lab		0.0008											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		21.5	20.6	20.6	21.5	20	24.2	20.3	21	21.2	22.6	22.2	22.4
		Calcium, Total (mg/L)	Lab		22.5	19.6	20.1	22.2	20.4	19.9	20.4	21.3	21.4	22.7	22.1	22.3
		Chloride (mg/L)	Lab		1.9											1.9
		Chromium, Dissolved (mg/L)	Lab		0.0005	0.00017	0.00016	0.00018	0.00014	0.00022	0.0002	0.00013	0.00015	0.00023	0.00022	0.00019
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		11	2.5	1.5	0.5	1	0.5	1	0.5	1.5	0.5	0.5	0.5
		Conductivity Total (µS/cm)	Bench		156.3	187.4	187.9	191.3	190.5	190.2	190	190.9	190.7	192.9	195.5	191.2
			Lab		166	198	197	200	202	201	200	205	202	202	202	201

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary
Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 25, 2017	Pilot-Scale	Copper, Dissolved (mg/L)	Lab		0.0006	0.0004	0.0003	0.0005	0.0005	0.0007	0.0006	0.0006	0.0005	0.0006	0.0006	0.0005
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		9.4	9.5	9.5	9.4	9.4	9.3	9.4	9.3	9.2	9.1	9.2	9.4
		DOC Total (mg/L)	Lab		7.7	2.6	2.5	2.5	2.7	2.4	3.3	2.4	2.4	2.4	2.4	2.4
		HaaBCAA Total(ug/L)	Lab		4											3.8
		HaaDBAA Total(ug/L)	Lab		3.2											3.2
		HaaDCAA Total(ug/L)	Lab		23.7											9.4
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3	G/N											G/N
		HaaMCAA (mg/L(ug/L)	Lab		0.8											0.9
		HaaTCAA (ug/L)	Lab		21.5											12.4
		HaaTotal, calc_(ug/L)	Lab		53											30
		Hardness (dTot, mg/L CaCO3)	Lab		83											82
		Iron, Dissolved (mg/L)	Lab		0.017	0.142	0.132	0.011	0.004	0.004	0.021	0.003	0.005	0.009	0.005	0.005
		Iron, Total (mg/L)	Lab		0.041	0.634	0.428	0.053	0.044	0.042	0.04	0.036	0.038	0.038	0.037	0.041
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		6.31	6.1	6.07	6.28	5.66	6.78	5.95	6.06	6.06	6.4	6.25	6.36
		Magnesium, Total (mg/L)	Lab		6.5	5.81	6.01	6.41	5.96	5.82	5.98	6.1	6.1	6.43	6.37	6.39
		Manganese, Dissolved (mg/L)	Lab		0.00379	0.0111	0.012	0.0114	0.0106	0.0119	0.0106	0.00993	0.0101	0.0101	0.0112	0.0108
		Manganese, Total (mg/L)	Bench		0.018	0.026	0.027	0.027	0.024	0.027	0.019	0.026	0.027	0.03	0.03	0.021
			Lab		0.0083	0.0108	0.0122	0.0115	0.0107	0.0116	0.011	0.0097	0.0101	0.01	0.0112	0.0109
		Nickel, Dissolved (mg/L)	Lab		0.00037	0.00419	0.00418	0.00434	0.004	0.00478	0.00415	0.00396	0.00404	0.00414	0.00422	0.00425
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
				N/D at <0.001	G/N											
		Odour60C (-)	Lab	Musty												G/N
		Oxi-Red Potenital (ORP) (mV)	Bench		208.2	265.5	278.4	326.4	321.6	338.1	338.6	330.8	328.8	338.2	329.5	309.2
		pH	Bench		7.84	5.6	5.59	5.685		5.69	5.68	5.72	5.72	5.72	5.72	5.7
			Lab		8.02	5.68	5.67	5.71	5.78	5.79	5.8	5.76	5.87	5.73	5.86	5.83
		Potassium, Dissolved (mg/L)	Lab		1.14	1.1	1.11	1.18	1.04	1.27	1.11	1.11	1.12	1.21	1.19	1.2
		Potassium, Total (mg/L)	Lab		1.23	1.05	1.06	1.2	1.07	1.02	1.06	1.1	1.13	1.21	1.18	1.19
		Sodium, Dissolved (mg/L)	Lab		2.13	2.12	2.08	2.53	2.34	2.42	2.37	2.49	2.43	2.52	2.46	2.55
		Sodium, Total (mg/L)	Lab		2.28	2.02	2.04	2.54	2.39	2.4	2.39	2.38	2.42	2.47	2.4	2.59
		Sulfate (mg/L)	Lab													78
				N/D at <2	G/N											
		TDSwq (mg/L)	Lab		111	139	142	139	140	131	143	144	139	144	140	145
		Temperature (ºC)	Bench		14.3	14.2	14	14.2	14.1	14.3	14.4	14.4	14.6	14.6	14.6	14.4
			Lab		14.3	14.2	14	14.2	14.1	14.3	14.4	14.4	14.6	14.6	14.6	14.4
		ThmBDCM Total(ug/L)	Lab		2.8											1.2
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N											G/N
		ThmCHCl3 Total(ug/L)	Lab		68.6											17.2
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N											G/N
		ThmTotal,calc_ Total(ug/L)	Lab		71											18
		TOC, Total (mg/L)	Lab		8.8	2.3	2.7									2.4
		TON60C Total(T_O_N_60)	Lab													5
		TSScalc Total (mg/L)	Lab		13	19	10	11	14	23	17	6	17	24	8	13
		TSwv Total (mg/L)	Lab		124	158	152	150	154	154	160	150	156	168	148	158
		Turbidity (NTU)	Bench		0.92	0.55	0.35	0.29	0.14	0.15	0.13	0.13	0.13	0.11	0.1	0.11
			Lab		0.84	0.7	0.42	0.2	0.13	0.15	0.14	0.12	0.14	0.12	0.13	0.12
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.133	0.066	0.049	0.03	0.029	0.028	0.028	0.029	0.028	0.029	0.026	0.029
		UVT @ 254nm, Filtered (%T)	Lab		75.6	94.2	93.5	95	94	94.5	95	94.9	94.5	94	94.4	94.2
		UVT @ 254nm, Unfiltered (%T)	Bench		73.7	85.8	89.4	93.8	93.6	93.7	93.7	93.6	93.7	93.7	94.1	93.6
		Zinc, Dissolved (mg/L)	Lab							0.0011		0.0013				
				N/D at <0.0009	G/N	G/N	G/N	G/N	G/N		G/N		G/N	G/N	G/N	G/N
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			7	8									7
		Aluminum, Dissolved (mg/L)	Lab			0.007	0.012									0.008
		Aluminum, Total (mg/L)	Lab	N/D at <0.01		G/N	G/N									G/N
		Antimony, Dissolved (mg/L)	Lab			0.0009	0.0019									0.0013
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00042	0.00035									0.00037
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 25, 2017	Full-Scale	Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			21.9	21.5									21.6
		Calcium, Total (mg/L)	Lab			22	20.8									21.8
		Chloride (mg/L)	Lab													20
		Chromium, Dissolved (mg/L)	Lab			0.00015	0.00015									0.00029
		Chromium, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Colour, True	Lab			2.5	2									0.5
		Conductivity Total (µS/cm)	Bench			194.9	189.1									184.5
			Lab			203	201									203
		Copper, Dissolved (mg/L)	Lab			0.0034	0.0005									0.0025
		Copper, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
		DO (mg/L)	Bench			9.9	10.6									10.5
		DOC Total (mg/L)	Lab			2.7	2.9									2.5
		HaaBCAA Total(ug/L)	Lab													3.9
		HaaDBAA Total(ug/L)	Lab													3.2
		HaaDCAA Total(ug/L)	Lab													8.6
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3												G/N
		HaaMCAA (mg/L(ug/L)	Lab													0.9
		HaaTCAA (ug/L)	Lab													9.2
		HaaTotal, calc_(ug/L)	Lab													26
		Hardness (dTot, mg/L CaCO3)	Lab													80
		Iron, Dissolved (mg/L)	Lab			0.06	0.155									0.011
		Iron, Total (mg/L)	Lab			0.468	0.536									0.045
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			6.13	6.12									6.19
		Magnesium, Total (mg/L)	Lab			6.08	5.79									6.22
		Manganese, Dissolved (mg/L)	Lab			0.0444	0.0129									0.0282
		Manganese, Total (mg/L)	Bench			0.062	0.057									0.046
			Lab			0.0452	0.0437									0.0306
		Nickel, Dissolved (mg/L)	Lab			0.00252	0.00437									0.00244
		Nickel, Total (mg/L)	Lab			0.002	0.002									0.002
		Oxi-Red Potenital (ORP) (mV)	Bench			311.6	349.2									346.6
		pH	Bench			5.44	5.67									5.37
			Lab			5.44	5.67									5.58
		Potassium, Dissolved (mg/L)	Lab			1.19	1.17									1.18
		Potassium, Total (mg/L)	Lab			1.19	1.1									1.19
		Sodium, Dissolved (mg/L)	Lab			2.05	2.17									2.26
		Sodium, Total (mg/L)	Lab			2.13	2.02									2.18
		Sulfate (mg/L)	Lab													45
		TDSwq (mg/L)	Lab			135	134									144
		Temperature (ºC)	Bench			13.3	13.5									14
			Lab			13.3	13.5									14
		ThmBDCM Total(ug/L)	Lab													1.7
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2												G/N
		ThmCHCl3 Total(ug/L)	Lab													23.1
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4												G/N
		ThmTotal,calc_ Total(ug/L)	Lab													25
		TOC, Total (mg/L)	Lab			2.9	2.9									2.5
		TSScalc Total (mg/L)	Lab			39	58									22
		TSwv Total (mg/L)	Lab			174	192									166
		Turbidity (NTU)	Bench			0.38	0.55									0.2
			Lab			0.41	0.51									0.13
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.062	0.058									0.027
		UVT @ 254nm, Filtered (%T)	Lab			93.9	95.8									96
		UVT @ 254nm, Unfiltered (%T)	Bench			86.6	87.5									93.9
		Zinc, Dissolved (mg/L)	Lab													0.0013
				N/D at <0.0009		G/N	G/N									
		Zinc, Total (mg/L)	Lab			0.005										
				N/D at <0.005			G/N									G/N
May 26, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		214.7	181.2	181.4	178.3	178.6	179.2	178.9	174.4	174.8	173.4	178.9	181.8
		DO (mg/L)	Bench		9.5	9.8	10.1	9.6	9.5	9.5	9.5	9.3	9.5	9.59	9.43	9.4

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 26, 2017	Pilot-Scale	Manganese, Total (mg/L)	Bench		0.018	0.022	0.018	0.011	0.014	0.013	0.015	0.011	0.01	0.013	0.012	0.011
		Oxi-Red Potenital (ORP) (mV)	Bench		214.7	232.2	323.6	320.8	325	320.9	315.4	301.1	277.7	298.5	275.4	275
		pH	Bench		7.66	6.06	6.07	6.04		6.02	6	5.89	5.83	5.78	5.74	6.19
		Temperature (ºC)	Bench		14.1	14.2	14.7	14.6	14.6	14.5	14.7	14.5	14.6	14.7	14.7	14.5
		Turbidity (NTU)	Bench		1.07	0.53	0.8	0.12	0.1	0.14	0.11	0.09	0.1	0.13	0.12	0.11
		UVA @254nm, Unfiltered (/cm)	Bench		0.135	0.064	0.049	0.028	0.028	0.028	0.028	0.026	0.029	0.028	0.028	0.028
		UVT @ 254nm, Unfiltered (%T)	Bench		73.4	86.6	89.4	93.7	93.8	93.7	93.8	94.2	93.5	93.6	93.8	93.6
	Full-Scale	Conductivity Total (µS/cm)	Bench			195.2	240.4									195.8
		DO (mg/L)	Bench			9.8	10.9									11.2
		Manganese, Total (mg/L)	Bench			0.054	0.058									0.044
		Oxi-Red Potenital (ORP) (mV)	Bench			337.4	374.8									340
		pH	Bench			5.47	5.63									5.5
		Temperature (ºC)	Bench			13.5	13.7									13.8
		Turbidity (NTU)	Bench			0.46	0.58									0.13
		UVA @254nm, Unfiltered (/cm)	Bench			0.058	0.057									0.02
		UVT @ 254nm, Unfiltered (%T)	Bench			87.6	87.7									95.4
May 27, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		154.3	179.5	179.1	178.4	178	178.3	180	259.9	174.8	176.7	175.5	177.6
		DO (mg/L)	Bench		9.4	9.8	10.3	9.6	9.5	9.5	9.6	9.5	9.4	9.4	9	9.4
		Manganese, Total (mg/L)	Bench		0.019	0.021	0.019	0.012	0.012	0.008	0.008	0.01	0.005	0.006	0.012	0.008
		Oxi-Red Potenital (ORP) (mV)	Bench		241.3	245.5	351.5	353	350.2	346.4	342.9	336.7	326	307.1	346	283.6
		pH	Bench		7.7	6.21	6.23	6.255		6.25	6.2	6.16	6.11	6.04	5.86	6.46
		Temperature (ºC)	Bench		14.7	14.1	14.5	15	15.1	14.9	15.1	14.8	15.1	14.9	15	14.8
		Turbidity (NTU)	Bench		1.08	0.5	0.75	0.1	0.1	0.11	0.18	0.29	0.25	0.1	0.17	0.11
		UVA @254nm, Unfiltered (/cm)	Bench		0.137	0.072	0.049	0.031	0.04	0.032	0.033	0.034	0.031	0.032	0.032	0.03
		UVT @ 254nm, Unfiltered (%T)	Bench		72.9	84.5	89.3	93.1	91.4	92.9	92.7	92.5	93.1	92.9	93.1	93
	Full-Scale	Conductivity Total (µS/cm)	Bench			193.7	191									195.1
		DO (mg/L)	Bench			9.6	10.9									11.3
		Manganese, Total (mg/L)	Bench			0.057	0.052									0.041
		Oxi-Red Potenital (ORP) (mV)	Bench			292.2	316.7									333.3
		pH	Bench			5.5	5.79									5.5
		Temperature (ºC)	Bench			14.1	14									14.1
		Turbidity (NTU)	Bench			0.3	0.47									0.14
		UVA @254nm, Unfiltered (/cm)	Bench			0.054	0.052									0.021
		UVT @ 254nm, Unfiltered (%T)	Bench			88.3	88.8									95.2
May 28, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		161.8	172.9	173.6	170.2	170.7	169.6	169.9	166.2	164.1	164.5	164	168.5
		DO (mg/L)	Bench		9.2	9.7	10.2	9.6	9.8	9.4	9.4	9.5	9.3	9.2	9.3	9.3
		Manganese, Total (mg/L)	Bench		0.025	0.026	0.024	0.011	0.01	0.011	0.009	0.005	0.007	0.009	0.009	0.009
		Oxi-Red Potenital (ORP) (mV)	Bench		172.4	191.6	233.1	237.6	249.2	256	253.7	264.5	270	278.5	278.8	279.5
		pH	Bench		7.52	6.65	6.63	6.63		6.65	6.63	6.6	6.58	6.59	6.57	6.61
		Temperature (ºC)	Bench		14.5	14.1	14.7	14.7	14.5	14.7	14.7	14.7	14.8	14.8	14.7	14.7
		Turbidity (NTU)	Bench		1.13	0.77	0.87	0.14	0.11	0.17	0.11	0.12	0.14	0.13	0.14	0.12
		UVA @254nm, Unfiltered (/cm)	Bench		0.139	0.102	0.083	0.04	0.039	0.041	0.038	0.041	0.04	0.04	0.041	0.04
		UVT @ 254nm, Unfiltered (%T)	Bench		72.6	79.2	82.2	91.2	91.4	91	91.5	91.1	91.2	91.2	90.9	91.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			193.5	196.5									196
		DO (mg/L)	Bench			9.4	10.7									10.7
		Manganese, Total (mg/L)	Bench			0.059	0.056									0.039
		Oxi-Red Potenital (ORP) (mV)	Bench			303.7	298.9									321.7
		pH	Bench			5.54	5.73									5.49
		Temperature (ºC)	Bench			14.1	14									14.4
		Turbidity (NTU)	Bench			0.35	0.45									0.14
		UVA @254nm, Unfiltered (/cm)	Bench			0.054	0.051									0.019
		UVT @ 254nm, Unfiltered (%T)	Bench			88.4	89									95.7
May 29, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		155.2	168.2	167.3	165.8	166.8	165	165.4	160.4	159.3	160.1	160.6	164.2
		DO (mg/L)	Bench		9.5	9.8	10.3	9.7	9.7	9.8	9.7	9.4	9.4	9.4	9.4	9.6
		Manganese, Total (mg/L)	Bench		0.016	0.03	0.028	0.011	0.01	0.012	0.008	0.005	0.003	0.005	0.005	0.011
		Oxi-Red Potenital (ORP) (mV)	Bench		175.9	231.9	339.7	339.6	338	340.6	341.8	346.7	352.1	351.6	350.3	349.9
		pH	Bench		7.74	6.8	6.83	6.825		6.82	6.78	6.76	6.75	6.77	6.76	6.79
		Temperature (ºC)	Bench		14.3	14.2	14.5	14.8	14.5	14.6	14.8	14.7	14.9	14.8	14.8	14.6
		Turbidity (NTU)	Bench		1.14	1.03	1.08	0.2	0.18	0.13	0.15	0.13	0.13	0.15	0.17	0.16
		UVA @254nm, Unfiltered (/cm)	Bench		0.136	0.128	0.104	0.041	0.041	0.044	0.043	0.047	0.042	0.043	0.042	0.042
		UVT @ 254nm, Unfiltered (%T)	Bench		73	74.6	78.5	90.8	90.9	90.3	90.6	89.8	90.7	90.5	90.7	90.7
	Full-Scale	Conductivity Total (µS/cm)	Bench			193.3	191.3									197.2
		DO (mg/L)	Bench			10.1	10.7									10.9
		Manganese, Total (mg/L)	Bench			0.056	0.052									0.038

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 29, 2017	Full-Scale	Oxi-Red Potenital (ORP) (mV)	Bench			376	385.2									344.7
		pH	Bench			5.47	5.62									5.3
		Temperature (ºC)	Bench			14.3	14									14.4
		Turbidity (NTU)	Bench			0.36	0.48									0.29
		UVA @254nm, Unfiltered (/cm)	Bench			0.05	0.047									0.019
		UVT @ 254nm, Unfiltered (%T)	Bench			89	89.6									97.5
May 30, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		72	20	20	21	20	22	20	20	20	20	20	20
		Aluminum, Dissolved (mg/L)	Lab		0.002		0.002	0.003	0.002	0.002	0.002		0.002	0.002	0.002	0.002
				N/D at <0.002		G/N						G/N				
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab		0.0008	0.0008	0.001	0.0015	0.0012	0.0012	0.0012	0.0014	0.0023	0.0014	0.0012	0.0012
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00071	0.00035	0.00035	0.00034	0.00034	0.00034	0.00033	0.00034	0.00035	0.00033	0.00035	0.00033
		Arsenic, Total (mg/L)	Lab		0.0007											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab										0.00002			
				N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		22.6	20.8	22.5	23	22.5	22.3	22	22.3	22.9	22.5	21.5	22.7
		Calcium, Total (mg/L)	Lab		21.9	21.2	20.6	21.1	22.3	22	22.2	23.1	21.3	21.1	21.9	22.6
		Chromium, Dissolved (mg/L)	Lab		0.00024	0.0001	0.00012	0.00016	0.00015	0.00015	0.00013	0.00013	0.00017	0.00014	0.00014	0.00015
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		11	2	1	0.5	0.5	0.5	0.5	1.5	2.5	2.5	1.5	0.5
		Conductivity Total (µS/cm)	Bench		157.9	182.3	181.5	186.7	184.8	185.3	184.8	185.1	185.9	187	186.4	187.7
			Lab		167	193	192	197	196	199	197	196	196	197	197	197
		Copper, Dissolved (mg/L)	Lab		0.0007	0.0004	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		9.4	9.7	10	9.8	9.7	9.8	9.7	9.5	9.4	9.5	9.3	9.9
		DOC Total (mg/L)	Lab		7.4	2.7	2.8	2.8	2.8	2.9	2.7	2.7	2.7	2.6	2.6	2.5
		Iron, Dissolved (mg/L)	Lab		0.018	0.133	0.072	0.021	0.01	0.031	0.01	0.005	0.009	0.007	0.009	0.026
		Iron, Total (mg/L)	Lab		0.055	1.05	0.625	0.041	0.042	0.042	0.053	0.028	0.023	0.028	0.033	0.034
		Lead, Dissolved (mg/L)	Lab										0.00007			
				N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		6.363	5.876	6.262	6.468	6.203	6.171	5.939	6.002	6.299	5.925	5.923	6.295
		Magnesium, Total (mg/L)	Lab		6.18	5.97	5.95	5.88	6.01	6.06	6.2	6.19	5.88	5.77	6.21	6.14
		Manganese, Dissolved (mg/L)	Lab		0.00216	0.0135	0.00895	0.0057	0.004	0.00515	0.00601	0.00262	0.00328	0.00168	0.00161	0.00459
		Manganese, Total (mg/L)	Bench		0.021	0.023	0.025	0.018	0.013	0.014	0.015	0.015	0.009	0.011	0.008	0.011
			Lab		0.0129	0.014	0.0137	0.006	0.0046	0.0055	0.0069	0.0032	0.0035	0.0021	0.0023	0.0046
		Nickel, Dissolved (mg/L)	Lab		0.00048	0.00413	0.00442	0.00353	0.00344	0.00341	0.00335	0.00305	0.00307	0.00289	0.00282	0.00328
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		312.6	281.1	398.3	402	405.2	403.6	398.4	401	396.5	402.3	403.5	396.4
		pH	Bench		7.8	6.16	6.25	6.3		6.27	6.25	6.3	6.32	6.25	6.27	6.13
			Lab		8.06	6.3	6.33	6.39	6.4	6.41	6.41	6.5	6.49	6.51	6.5	6.44
		Potassium, Dissolved (mg/L)	Lab		1.26	1.17	1.29	1.25	1.25	1.22	1.23	1.21	1.27	1.24	1.19	1.26
		Potassium, Total (mg/L)	Lab		1.25	1.21	1.16	1.14	1.21	1.2	1.2	1.24	1.17	1.16	1.2	1.23
		Sodium, Dissolved (mg/L)	Lab		2.428	2.282	2.388	2.743	2.731	2.553	2.649	2.757	2.699	2.627	2.573	2.682
		Sodium, Total (mg/L)	Lab		2.34	2.26	2.22	2.52	2.61	2.64	2.66	2.7	2.57	2.55	2.63	2.6
		TDSwq (mg/L)	Lab		74	92	106	106	92	112	92	82	96	102	98	120
		Temperature (ºC)	Bench		14.4	13.5	14.1	14.2	14.3	14.1	14.4	14.5	14.6	14.5	14.6	13.6
			Lab		14.4	13.5	14.1	14.2	14.3	14.1	14.4	14.5	14.6	14.5	14.6	13.6
		TSScalc Total (mg/L)	Lab		22	8	16	18	40	20	30	14	4	24	22	4
		TSwv Total (mg/L)	Lab		96	100	122	124	132	132	122	96	100	126	120	124
		Turbidity (NTU)	Bench		1.54	0.82	0.7	0.15	0.12	0.11	0.1	0.09	0.08	0.12	0.13	0.14
			Lab		1.26	0.89	0.85	0.22	0.1	0.12	0.09	0.08	0.09	0.09	0.11	0.09
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.135	0.089	0.066	0.027	0.026	0.026	0.026	0.028	0.032	0.03	0.027	0.027
		UVT @ 254nm, Filtered (%T)	Lab		75.7	91.7	93.9	93.8	94	94.5	94.3	92.9	94.4	93	94	94.4
		UVT @ 254nm, Unfiltered (%T)	Bench		73.4	81.5	86.1	94.1	94.1	94.1	94.2	93.7	92.9	93.3	94	93.9
		Zinc, Dissolved (mg/L)	Lab				0.001	0.0011	0.0009				0.001			
				N/D at <0.0009	G/N	G/N				G/N	G/N	G/N		G/N	G/N	G/N
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 30, 2017	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			6	6									6
		Aluminum, Dissolved (mg/L)	Lab			0.011	0.01									0.011
		Aluminum, Total (mg/L)	Lab	N/D at <0.01		G/N	G/N									G/N
		Antimony, Dissolved (mg/L)	Lab			0.0014	0.0015									0.001
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.0004	0.00032									0.00035
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			22.6	22.5									22.3
		Calcium, Total (mg/L)	Lab			21.8	21.3									21.6
		Chromium, Dissolved (mg/L)	Lab			0.0001	0.00025									0.00024
		Chromium, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Colour, True	Lab			1.5	0.5									0.5
		Conductivity Total (µS/cm)	Bench			197.7	194.8									202
			Lab			208	206									209
		Copper, Dissolved (mg/L)	Lab			0.0039	0.0034									0.0033
		Copper, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
		DO (mg/L)	Bench			10.1	10.66									10.7
		DOC Total (mg/L)	Lab			2.4	2.3									2.3
		Iron, Dissolved (mg/L)	Lab			0.053	0.037									0.021
		Iron, Total (mg/L)	Lab			0.399	0.384									0.03
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			6.016	6.035									6.317
		Magnesium, Total (mg/L)	Lab			6.11	5.79									5.93
		Manganese, Dissolved (mg/L)	Lab			0.05	0.0212									0.0342
		Manganese, Total (mg/L)	Bench			0.055	0.05									0.036
			Lab			0.0499	0.0471									0.0345
		Nickel, Dissolved (mg/L)	Lab			0.00292	0.00282									0.00284
		Nickel, Total (mg/L)	Lab			0.003	0.003									0.003
		Oxi-Red Potenital (ORP) (mV)	Bench			381.9	381.1									294
		pH	Bench			5.36	5.47									5.36
			Lab			5.46	5.63									5.53
		Potassium, Dissolved (mg/L)	Lab			1.32	1.23									1.24
		Potassium, Total (mg/L)	Lab			1.27	1.17									1.2
		Sodium, Dissolved (mg/L)	Lab			2.511	2.304									2.482
		Sodium, Total (mg/L)	Lab			2.44	2.27									2.42
		TDSwq (mg/L)	Lab			138	132									124
		Temperature (ºC)	Bench			13.5	13.3									14.2
			Lab			13.5	13.3									14.2
		TSScalc Total (mg/L)	Lab			30										44
				N/D at <3			G/N									
		TSwv Total (mg/L)	Lab			168	134									168
		Turbidity (NTU)	Bench			0.55	0.47									0.32
			Lab			0.44	0.42									0.07
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.056	0.045									0.02
		UVT @ 254nm, Filtered (%T)	Lab			93.7	96.5									96.1
		UVT @ 254nm, Unfiltered (%T)	Bench			88	90.3									95.5
		Zinc, Dissolved (mg/L)	Lab			0.002	0.0013									0.002
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
May 31, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		84	17	16	17	17	17	17	19	19	17	18	21
		Aluminum, Dissolved (mg/L)	Lab		0.002	0.002	0.003	0.004	0.002	0.003	0.002	0.002	0.003	0.002	0.005	0.002
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab		0.0009	0.0011	0.0009	0.0015	0.001	0.0014	0.0011	0.001	0.0006	0.0006	0.0013	0.0006
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.0007	0.00036	0.00035	0.00034	0.00034	0.00033	0.00033	0.00032	0.00033	0.0003	0.00029	0.00028
		Arsenic, Total (mg/L)	Lab		0.0007											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		23.3	23.2	22.6	23	22.9	23.3	23.5	23.4	23.9	22.3	22.9	23

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
					Sample Location											
May 31, 2017	Pilot-Scale	Calcium, Total (mg/L)	Lab		21	22.3	20.4	21.3	21.4	21.6	21	23.1	23.3	21.5	21	20.9
		Chloride (mg/L)	Lab		2.1											2.2
		Chromium, Dissolved (mg/L)	Lab		0.00034	0.00011	0.00012	0.00014	0.00013	0.00012	0.00012	0.00014	0.00015	0.00003	0.00005	0.00005
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		13	2	1.5	1	1	0.5	0.5	2.5	2	2	2	1
		Conductivity Total (µS/cm)	Bench		156.6	184	183.5	189.4	189.8	188.9	188.9	191.2	192.3	189.1	189.7	190.8
			Lab		166	193	193	199	199	201	199	202	203	199	200	201
		Copper, Dissolved (mg/L)	Lab		0.0007	0.0004	0.0004	0.0005	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0007	0.0005
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		9.4	9.6	9.8	9.3	9.3	9.4	9.2	9.4	9.3	9.3	9.9	9.4
		DOC Total (mg/L)	Lab		7.4	3.2	3.3	3.8	3	3.2	3.2	2.9	3	3	3.1	3.1
		HaaBCAA Total(ug/L)	Lab		3.6											3.5
		HaaDBAA Total(ug/L)	Lab	N/D at <0.4	G/N											G/N
		HaaDCAA Total(ug/L)	Lab		26.6											13.9
		HaaMBAA Total(ug/L)	Lab													2.5
				N/D at <0.3	G/N											
		HaaMCAA (mg/L(ug/L)	Lab		2.1											1.9
		HaaTCAA (ug/L)	Lab		21.3											17.9
		HaaTotal, calc_(ug/L)	Lab		54											40
		Hardness (dTot, mg/L CaCO3)	Lab		76.9											77.4
		Iron, Dissolved (mg/L)	Lab		0.028	0.149	0.145	0.012	0.013	0.008	0.007	0.007	0.009		0.006	
				N/D at <0.002										G/N		G/N
		Iron, Total (mg/L)	Lab		0.037	1.8	0.424	0.017	0.086	0.018	0.014	0.02	0.018	0.019	0.014	0.011
		Lead, Dissolved (mg/L)	Lab					0.00004								
				N/D at <0.00004	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		6.332	6.163	6.223	6.291	6.276	6.246	6.19	6.313	6.377	6.377	6.407	6.335
		Magnesium, Total (mg/L)	Lab		5.94	6.14	5.86	5.77	5.82	5.77	5.68	6.34	6.23	5.87	6.09	6.11
		Manganese, Dissolved (mg/L)	Lab		0.00234	0.0133	0.0144	0.00569	0.00503	0.00486	0.00588	0.00404	0.0044	0.0024	0.00267	0.00437
		Manganese, Total (mg/L)	Bench		0.018	0.025	0.021	0.014	0.01	0.012	0.014	0.012	0.015	0.007	0.009	0.011
			Lab		0.01	0.0134	0.0133	0.0053	0.0047	0.0045	0.0054	0.0038	0.0043	0.0023	0.0025	0.0041
		Nickel, Dissolved (mg/L)	Lab		0.00051	0.00449	0.00452	0.00419	0.00417	0.00409	0.00413	0.00383	0.00364	0.00353	0.00363	0.0039
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.004
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		182	216.6	236.6	300.4	296.1	286.6	272.4	291.1	282	290.4	283.8	261.5
		pH	Bench		8	6.01	5.98	6.085		6.08	6.08	6.09	6.1	6.12	6.03	5.95
			Lab		8.01	6.32	6.21	6.29	6.32	6.36	6.31	6.38	6.37	6.33	6.36	6.28
		Potassium, Dissolved (mg/L)	Lab		1.3	1.25	1.28	1.27	1.25	1.25	1.26	1.23	1.25	1.22	1.24	1.25
		Potassium, Total (mg/L)	Lab		1.19	1.23	1.16	1.14	1.15	1.16	1.1	1.22	1.24	1.14	1.15	1.16
		Sodium, Dissolved (mg/L)	Lab		2.501	2.444	2.369	2.785	2.718	2.812	2.651	2.71	2.707	2.667	2.782	2.688
		Sodium, Total (mg/L)	Lab		2.19	2.31	2.17	2.52	2.51	2.51	2.53	2.62	2.67	2.56	2.48	2.49
		Sulfate (mg/L)	Lab		2											70
		TDSwq (mg/L)	Lab		88	124	130	140	136	124	118	128	144	116	124	114
		Temperature (ºC)	Bench		14.2	14.1	14.7	15.3	14.7	14.7	15	15.3	15	15.2	15	14.4
			Lab		14.2	14.1	14.7	15.3	14.7	14.7	15	15.3	15	15.2	15	14.4
		ThmBDCM Total(ug/L)	Lab		2											1.6
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N											G/N
		ThmCHCl3 Total(ug/L)	Lab		38.4											19.3
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N											G/N
		ThmTotal,calc_ Total(ug/L)	Lab		41											21
		TOC, Total (mg/L)	Lab		7.6	3.5	3.2									3.3
		TSScalc Total (mg/L)	Lab		20	14	12	8	6	38	52	116		24	22	42
				N/D at <3									G/N			
		TSwv Total (mg/L)	Lab		114	138	142	148	142	162	170	244	146	140	146	156
		Turbidity (NTU)	Bench		1.64	0.81	0.5	0.36	0.38	0.35	0.14	0.12	0.12	0.13	0.12	0.3
			Lab		1.26	0.74	1	0.15	0.08	0.08	0.07	0.08	0.07	0.08	0.09	0.07
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.127	0.073	0.043	0.024	0.022	0.022	0.022	0.025	0.026	0.026	0.025	0.024
		UVT @ 254nm, Filtered (%T)	Lab		75	91.5	91.9	92.8	92.7	92.7	93.3	92.5	92.8	91.8	93	92.2
		UVT @ 254nm, Unfiltered (%T)	Bench		74.7	84.3	90.5	94.6	95	95.1	95	94.5	94.1	94.2	94.4	94.5
		Zinc, Dissolved (mg/L)	Lab			0.0014				0.001	0.0009		0.0009			
				N/D at <0.0009	G/N		G/N	G/N	G/N			G/N		G/N	G/N	G/N
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
					Sample Location											
May 31, 2017	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			6	6									6
		Aluminum, Dissolved (mg/L)	Lab			0.011	0.009									0.011
		Aluminum, Total (mg/L)	Lab	N/D at <0.01		G/N	G/N									G/N
		Antimony, Dissolved (mg/L)	Lab				0.0007									0.0013
				N/D at <0.0004		G/N										
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00036	0.0003									0.00036
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			21.3	20.7									21.4
		Calcium, Total (mg/L)	Lab			21.4	20.3									20.2
		Chloride (mg/L)	Lab													22
		Chromium, Dissolved (mg/L)	Lab			0.00015	0.0002									0.00006
		Chromium, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Colour, True	Lab			1	0.5									0.5
		Conductivity Total (µS/cm)	Bench			199.1	195.2									196.5
			Lab			205	204									206
		Copper, Dissolved (mg/L)	Lab			0.0036	0.0034									0.0037
		Copper, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
		DO (mg/L)	Bench			9.9	10.5									10.7
		DOC Total (mg/L)	Lab			2.9	3									3
		HaaBCAA Total(ug/L)	Lab													3.7
		HaaDBAA Total(ug/L)	Lab													2.8
		HaaDCAA Total(ug/L)	Lab													11.3
		HaaMBAA Total(ug/L)	Lab													2.6
		HaaMCAA (mg/L(ug/L)	Lab													1.8
		HaaTCAA (ug/L)	Lab													10.6
		HaaTotal, calc_(ug/L)	Lab													33
		Hardness (dTot, mg/L CaCO3)	Lab													73.9
		Iron, Dissolved (mg/L)	Lab			0.24	0.062									0.033
		Iron, Total (mg/L)	Lab			0.374	0.413									0.027
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			6.159	6.159									6.317
		Magnesium, Total (mg/L)	Lab			6.23	5.87									5.72
		Manganese, Dissolved (mg/L)	Lab			0.0498	0.0211									0.0491
		Manganese, Total (mg/L)	Bench			0.042	0.054									0.054
			Lab			0.0494	0.0446									0.0336
		Nickel, Dissolved (mg/L)	Lab			0.00279	0.00275									0.00288
		Nickel, Total (mg/L)	Lab			0.003	0.003									0.003
		Oxi-Red Potenital (ORP) (mV)	Bench			346.9	346.4									296.8
		pH	Bench			5.37	5.55									5.46
			Lab			5.5	5.69									5.42
		Potassium, Dissolved (mg/L)	Lab			1.2	1.2									1.22
		Potassium, Total (mg/L)	Lab			1.22	1.17									1.15
		Sodium, Dissolved (mg/L)	Lab			2.32	2.272									2.215
		Sodium, Total (mg/L)	Lab			2.25	2.14									2.29
		Sulfate (mg/L)	Lab													46
		TDSwq (mg/L)	Lab			134	114									94
		Temperature (ºC)	Bench			13.9	13.8									15.2
			Lab			13.9	13.8									15.2
		ThmBDCM Total(ug/L)	Lab													1.2
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2												G/N
		ThmCHCl3 Total(ug/L)	Lab													11.8
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4												G/N
		ThmTotal,calc_ Total(ug/L)	Lab													13
		TOC, Total (mg/L)	Lab			3	3									2.6
		TSScalc Total (mg/L)	Lab			28	18									54
		TSwv Total (mg/L)	Lab			162	132									148
		Turbidity (NTU)	Bench			0.57	0.68									0.3
			Lab			0.38	0.45									0.08
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Spring
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
May 31, 2017	Full-Scale	UVA @254nm, Unfiltered (/cm)	Bench			0.044	0.039									0.021
		UVT @ 254nm, Filtered (%T)	Lab			92.8	95.7									93.1
		UVT @ 254nm, Unfiltered (%T)	Bench			90.2	91.4									95.4
		Zinc, Dissolved (mg/L)	Lab			0.001										0.0015
				N/D at <0.0009			G/N									
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary - Pilot DAF Float Sludge Sample Only

Season: Spring
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location DAF Sludge
May 14, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		240
		Temperature (ºC)	Lab		13.5
		TSSwv Total (mg/L)	Lab		5000
		TSwv Total (mg/L)	Lab		5240
May 20, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		438
		Temperature (ºC)	Lab		13.1
		TSSwv Total (mg/L)	Lab		7100
		TSwv Total (mg/L)	Lab		7540
May 25, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		400
		Temperature (ºC)	Lab		14.7
		TSSwv Total (mg/L)	Lab		6850
		TSwv Total (mg/L)	Lab		7250
May 30, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		92
		Temperature (ºC)	Lab		14.8
		TSSwv Total (mg/L)	Lab		7200
		TSwv Total (mg/L)	Lab		7290
May 31, 2017	Pilot-Scale	TDScalc (mg/L)	Lab	NR	G/N
		Temperature (ºC)	Lab		16.2
		TSSwv Total (mg/L)	Lab		7950
		TSwv Total (mg/L)	Lab		7880

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter keeps DAF Sludge. The Piloting_Season filter keeps Spring. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

APPENDIX

E

TM NO. 5

SUMMER PILOTING SESSION
(JULY 24 – AUGUST 17, 2017)

TECHNICAL MEMORANDUM NO. 5

PROJECT: Pilot Testing an Alternative Coagulant for the Winnipeg Water Treatment

PROJECT No.: 161-06111-00

TO: Heather Buhler, City of Winnipeg

FROM: Maika Pellegrino (WSP), Justin Rak-Banville (WSP), Charles Goss (WSP)

SUBJECT: Summer Piloting Session (July 24 – August 17, 2017) - Final

DATE: August 20, 2018

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1. OVERVIEW

Technical Memorandum No. 5 (TM No. 5) evaluates the performance of the alternative coagulant, ferric sulphate ($Fe_2(SO_4)_3$) as the dissolved air flotation (DAF) coagulant, under warm Summer water conditions (>15°C). This includes an examination of the results of the Summer benchmarking period, the subsequent Summer transition period, and the alternative coagulant Summer piloting session, inclusive of recommendations regarding the subsequent Fall piloting session. Note that additional details relating to the setup of the benchmarking and the transition periods are found in Technical Memorandum No. 2 (TM No. 2).

Table 1-1 provides a summary of the Summer piloting session events. The raw water reached warm water conditions, greater than 15°C, on June 8th, 2017. As such, the Summer benchmarking period was carried out between June 23th and July 10th, 2017 using ferric chloride as the coagulant. On July 11th, 2017, the pilot-scale system's coagulant was transitioned to ferric sulphate and was monitored for stablization until July 23rd, 2017. The Summer piloting session commenced on July 24th, 2017 and was completed on August 17th, 2017.

Following completion of the Summer piloting session, the coagulant was not returned to ferric chloride, contrary to historic piloting sessions. Ferric sulphate remained in use to allow for the City to evaluate the performance of ferric sulphate over an extended period.

Table 1-1: Summer piloting session schedule

SUMMER PILOTING SESSION (> 14ºC)	DURATION	START DATE	END DATE
1. Summer Benchmarking Period	18 days	June 23, 2017	July 10, 2017
2. Summer Transition Period	13 days	July 11, 2017	July 23, 2017
3. Summer Pre-Piloting Progress Meeting	-	July 18, 2017	July 18, 2017
4. Summer Piloting Session[1]	21 days	July 24, 2017	August 17, 2017
5. Summer Mid-Point Progress Meeting	-	August 8, 2017	August 8, 2017
6. Summer Mid-Point Progress Meeting #2	-	August 11, 2017	August 11, 2017

[1] The Summer piloting session was interrupted from August 10th to 13th, 2017 (inclusive).

2. SUMMER BENCHMARKING PERIOD

The Summer benchmarking period was completed by the City between June 23rd and July 10th, 2017. The objective of the benchmarking period was to attempt to match operational parameters between the full-scale and pilot-scale systems and to draw comparisons between the treatment processes. This included scaling of mechanical aspects such as flows, but also water quality analyses of the treated water from the full-scale and pilot-scale systems. The laboratory analysis data, compiled during the Summer benchmarking period, was completed by the City's Analytical Services Branch (hereafter referred as Lab), and is provided in Appendix A.

The pilot-scale system samples were collected daily from the following locations:

→ Post-DAF (via the DAF overflow piping to the overflow tank);

→ Post-Ozone (from the combined ozone column piping feeding the Ozone Contact Tank); and

→ Individual filter effluents (Filters 1 through 8);

The full-scale system samples were collected from the following locations:

→ Raw water;

→ Post-DAF;

→ Post-Ozone (i.e. combined ozone from both tanks);

→ Individual filter effluents (Filters 1 through 8); and

→ Post Filter Combined.

Note: the raw water was only recorded in one location, either the full-scale or the pilot-scale system, as testing during the Winter #1 benchmarking period found a nominal quantitative difference between the raw water for both full-scale and pilot-scale systems. This excludes a temperature increase of approximately 1°C to 2°C. As such, for the purposes of this study, differences in the raw water quality at the full-scale and pilot-scale systems were assumed to negligible.

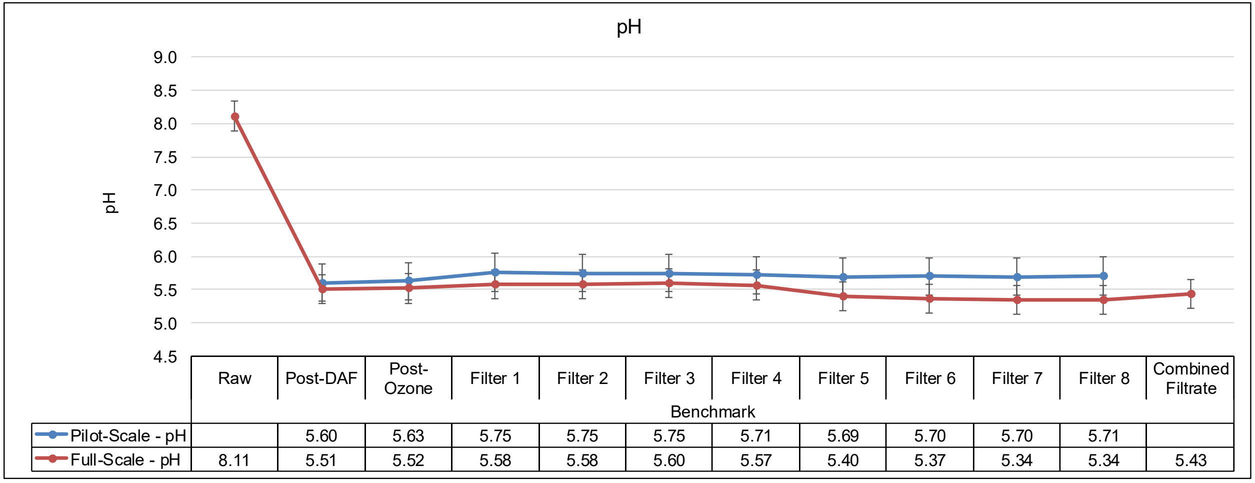
On June 26th, the City noted that the pressure switch on the DAF saturator required adjustment due to a loss of microbubbles at the low end of the pressure range for approximately 20 minutes until the air compressor re-pressurized. This switch was repaired by City personnel on June 26th. No loss of microbubbles was observed following the repair.

Sections 2.1 to Section 2.4 discuss the results pertaining to the following four key parameters: pH, turbidity, total organic carbon (TOC), and total manganese. These parameters were used for the comparison between the full-scale and pilot-scale systems, and are expressed as the average value measured for each process across the Summer benchmarking period. The standard error for each sample is also noted via error bars.

The standard error estimates the variability between sample means that would be obtained by taking multiple samples from the same population. Alternatively, the standard error of the mean is used to determine how precisely the mean of the sample estimates the population mean. For example, smaller error bars indicate more precise estimates of the population mean. A full summary of the daily results for above noted key parameters, as well as the results for non-key parameters, are found in Appendix A.

2.1 pH

Figure 2-1 presents the average pH for both the full-scale and pilot-scale systems. When compared to the pilot-scale system, a slightly lower pH was observed in the full-scale system operation. During the Summer benchmarking period, the City operated the pilot-scale system with a slightly higher sulphuric acid dose of 36.5 mg/L whereas the full-scale system operated at a dose of 35.5 mg/L. To better match the pH between the two systems, on June 27th the sulphuric acid dose in the pilot-scale system was increased to 37.0 mg/L; 1.5 mg/L beyond the full-scale system dose. This acid increase was intended to improve the pH match between the full-scale and pilot-scale systems. A consequence of this refinement was increased deviation in the pilot-scale system pH, specifically, larger error bars during the Summer benchmarking period.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Pilot-Scale - pH		5.60	5.63	5.75	5.75	5.75	5.71	5.69	5.70	5.70	5.71	
Full-Scale - pH	8.11	5.51	5.52	5.58	5.58	5.60	5.57	5.40	5.37	5.34	5.34	5.43

Figure 2-1: Average pH of the full-scale and pilot-scale systems during the Summer benchmarking period. Data originates from Lab analyses. Note the raw water value was sampled from the full-scale system; however, for the purpose of this study the water quality for the raw water is assumed to be the same.

Overall, a comparison between the two systems demonstrated the similarity between the pH following Post-DAF, Post-Ozone, and Filters 1-4 (within standard error). However, Filters 5-8 were found not be within standard error between the full-scale and pilot-scale systems. A similar trend was noted during the Spring benchmarking period (Technical Memorandum No. 4 - TM No. 4; Figure 2-1).

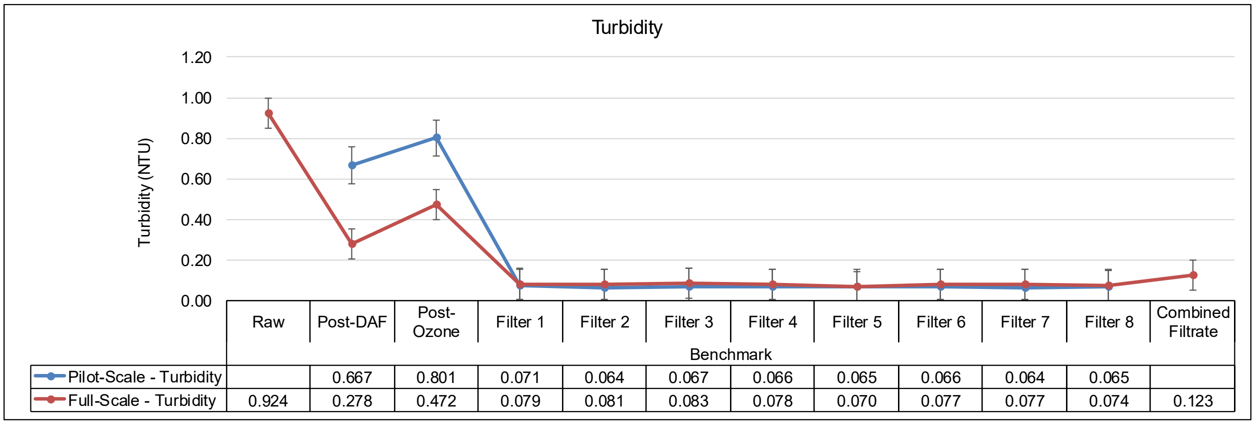
Although some variation in pH was observed in the filter effluent between the two systems, there appears to be a good correlation between the full-scale and pilot-scale systems.

2.2 Turbidity

During the Summer benchmarking period, the City observed high Post-DAF turbidity from June 15th to 23rd, ranging from 0.6 NTU to 1.4 NTU. The City attempted to reduce the turbidity by cleaning the DAF saturator filter; however, this effort only marginally improved Post-DAF turbidity.

On June 23rd, the City noted the weir plate on the DAF tank had shifted (lowered) causing poor floc removal by the scrapper. The City repositioned the weir plate significantly improving Post-DAF turbidity within 24 hours. The City added a marker to the weir plant to identify the correct location and to identify any potential future movement.

Similar trends in turbidity removal were found for the full-scale and pilot-scale systems, where turbidity decreased following DAF and increased after ozonation (Figure 2-2). However, the results indicate that there was overall better turbidity removal by the full-scale DAF system compared to the pilot-scale DAF system. The difference in turbidity removal by DAF and ozone between the full-scale and pilot-scale systems was observed in previous piloting sessions (Winter #1 and Spring) and has been attributed to scaling and operational differences between the two systems. The turbidity was reduced in both systems following filtration, and strong correlations were observed for the filter effluent (Filters 1-8).



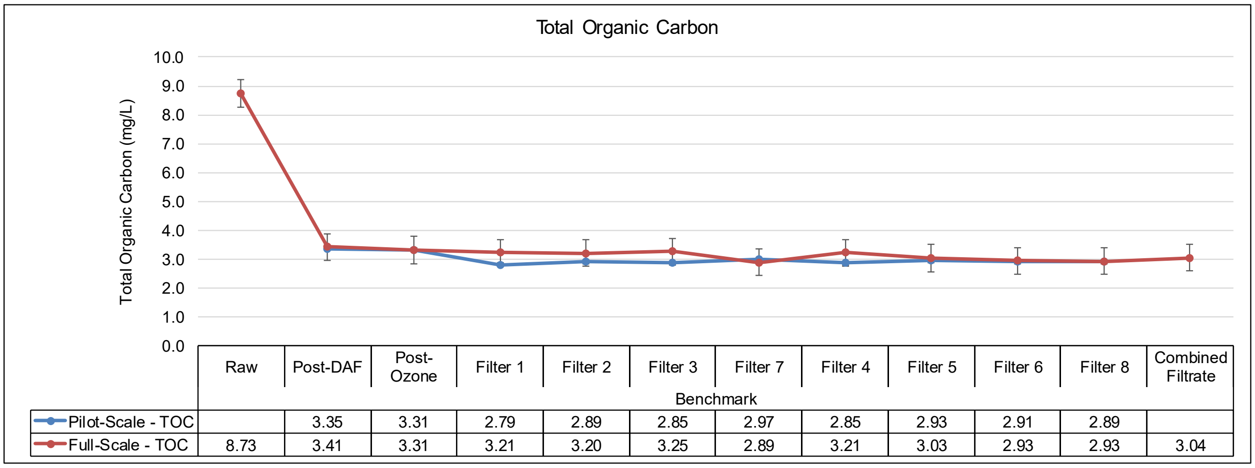
Benchmark	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Pilot-Scale - Turbidity		0.667	0.801	0.071	0.064	0.067	0.066	0.065	0.066	0.064	0.065	
Full-Scale - Turbidity	0.924	0.278	0.472	0.079	0.081	0.083	0.078	0.070	0.077	0.077	0.074	0.123

Figure 2-2: Average turbidity analysis of the full-scale and pilot-scale systems during the Summer benchmarking period. Data originates from Lab analyses. Note the raw water value was sampled from the full-scale system; however, for the purpose of this study the water quality for the raw water is assumed to be the same.

Although the comparison found a significant difference in the Post-DAF and Post-Ozone turbidity, the elevated turbidity observed in the pilot-scale system was effectively removed following filtration. This accounted for strong correlations between the full-scale and pilot-scale systems with regards to final filter effluent. Therefore, the results are considered acceptable.

2.3 Total Organic Carbon

The concentration of TOC in the raw water was, on average, 8.73 mg/L during the Summer benchmarking period (Figure 2-3). Both the full-scale and pilot-scale systems reduced TOC, following DAF, by approximately 60%. Ozonation did not appear to reduce TOC in either system and filtration was only able to remove approximately 10% of the Post-Ozone TOC at both the full-scale and pilot-scale systems. The total reduction in TOC by both the full-scale and pilot-scale systems was nearly 66%, with a final effluent concentration of approximately 3.0 mg/L. Overall, there appears to be a strong correlation with regards to TOC removal between both systems.

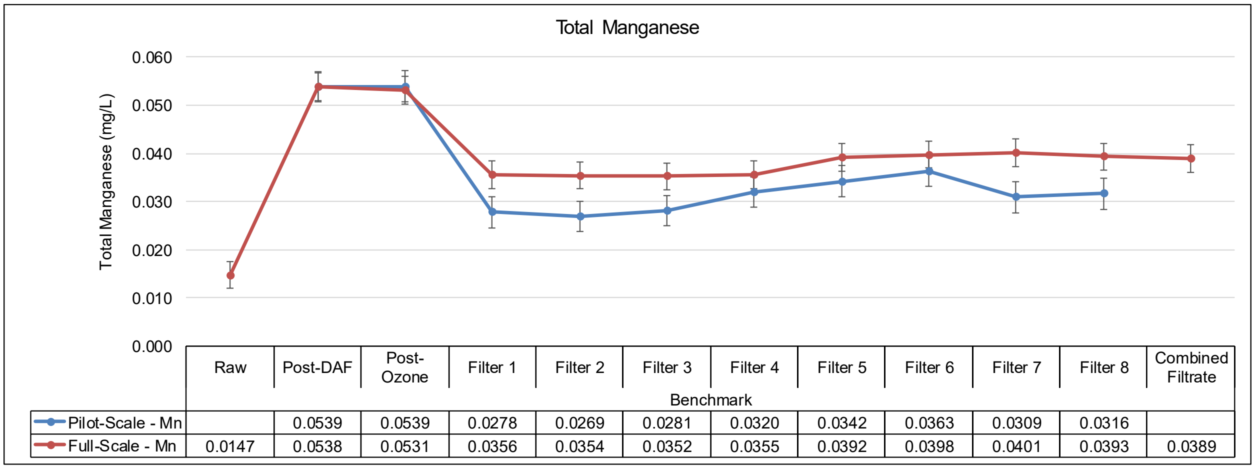


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 7	Filter 4	Filter 5	Filter 6	Filter 8	Combined Filtrate
Pilot-Scale - TOC		3.35	3.31	2.79	2.89	2.85	2.97	2.85	2.93	2.91	2.89	
Full-Scale - TOC	8.73	3.41	3.31	3.21	3.20	3.25	2.89	3.21	3.03	2.93	2.93	3.04

Figure 2-3: Average TOC of the full-scale and pilot-scale systems during the Summer benchmarking period. Data originates from Lab analyses. Note the raw water value was sampled from the full-scale system; however, for the purpose of this study the water quality for the raw water is assumed to be the same.

2.4 Total Manganese

Following the addition of ferric chloride, the total manganese in the raw to Post-DAF increased from approximately 0.015 mg/L to 0.054 mg/L. This was observed in both the full-scale and pilot-scale systems (Figure 2-4).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Pilot-Scale - Mn		0.0539	0.0539	0.0278	0.0269	0.0281	0.0320	0.0342	0.0363	0.0309	0.0316	
Full-Scale - Mn	0.0147	0.0538	0.0531	0.0356	0.0354	0.0352	0.0355	0.0392	0.0398	0.0401	0.0393	0.0389

Figure 2-4: Average total manganese of the full-scale and pilot-scale systems during the Summer benchmarking period. Data originates from Lab analyses. Note the raw water value was sampled from the full-scale system; however, for the purpose of this study the water quality for the raw water is assumed to be the same.

Total manganese does not appear to be influenced by ozonation, whereas, the full-scale and pilot-scale systems exhibit a strong correlation for total manganese in Post-DAF and Post-Ozone samples. However, it was observed that the total manganese in the filter effluent was statistically different between the full-scale and pilot-scale systems. Specifically, there was a 33-50% reduction in manganese by the pilot-scale system filters, whereas the full-scale system filters only reduced manganese by 25-34%. This trend was reversed to what was observed during the Spring benchmarking period, where a greater reduction in manganese was measured in the full-scale system (TM No. 4; Figure 2-4).

The cause for higher total manganese in the pilot-scale system filter effluent reported in the Spring piloting session, at the time, was attributed to the possible buildup of residual manganese in the pilot-scale system and the differences in available filter surface area and dosage dissimilarities between each system. This disparity between the Spring and Summer benchmarking periods is likely the result of substantial cleaning and maintenance efforts invested by the City before the start of the Summer benchmarking period. These efforts have likely resulted in the reduction of manganese buildup in the system, in turn leading to the improved manganese removal.

2.5 Filter Operation (SCADA)

Both filter banks were operated at an average flow of 0.3 L/s, which is representative of the full-scale system average conditions, for 17 days of the Summer benchmarking period. The standard procedure was used to backwash the filters daily at approximately the same time prior to the start of the Summer benchmarking period day. The differential pressure values reported by the pilot-scale system SCADA were evaluated on an average hourly basis to determine the following:

- the filter run times;
- the unit filter run volume (UFRV) values;
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter; and
- the rate of head loss increase of each filter.

The calculations were as described in Section 2.4 of TM No. 3. The filter operational data was compared against filter effluent turbidity measurements by the Lab, which were sampled approximately 4 hours from the start of the filtration cycle. A summary of the filter operational data during the Summer benchmarking period is provided in Appendix A. Figure 2-5 illustrates the average daily UFRV values.

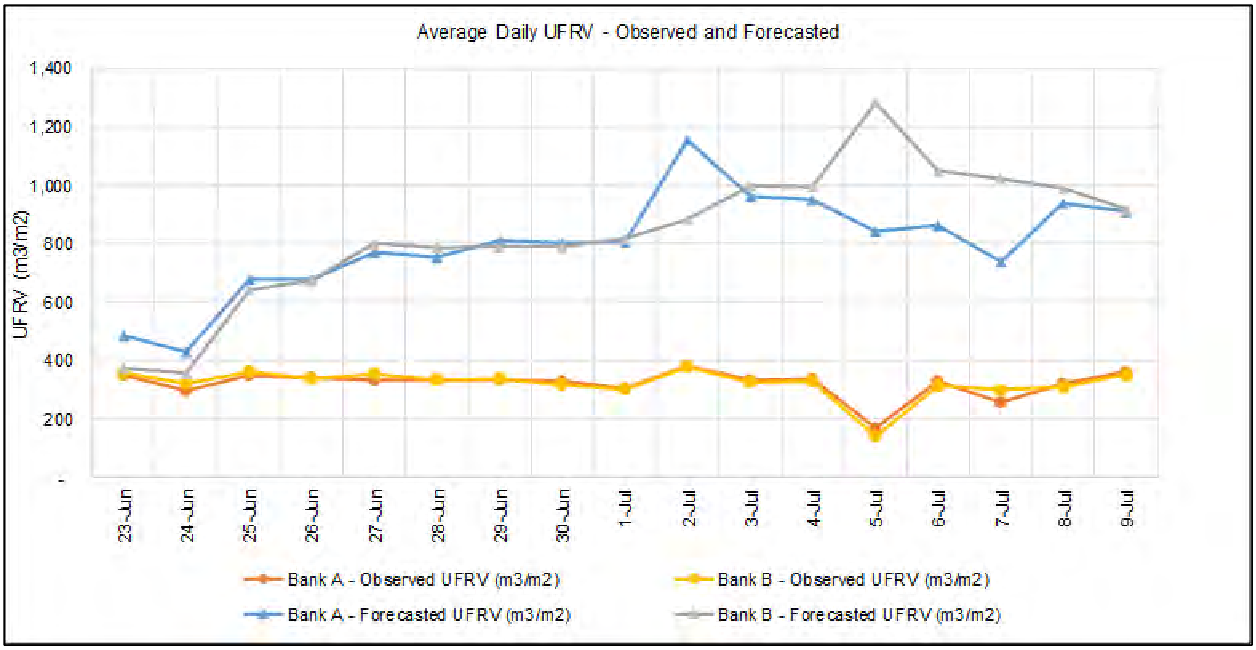


Figure 2-5: Average UFRV values of the pilot-scale system Bank A and Bank B at an average flow of 0.3 L/s during the Summer benchmarking period. UFRV = Filter Run Volume/Filter Surface Area. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

Table 2.1 tabulates the average filter run times and average UFRV values for the entire Summer benchmarking period, while also considering the overall operation cycles and those which have not failed based on sampled turbidity measurements.

Table 2-1: Average observed and forecasted pilot-scale system filter run times and UFRV values during the Summer benchmarking period.

		FILTER RUN TIME (h)			**UFRV (m^3/m^2)**		
		Bank A	**Bank B**	**All Filters**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	21.2	20.7	20.9	322	322	322
	Only cycles with turbidity ≤ 0.1 NTU	21.2	20.7	20.9	322	322	322
	Only cycles with turbidity ≤ 0.3 NTU	21.2	20.7	20.9	322	322	322
Forecasted Values	Overall Cycles	52.9	53.9	53.4	806	833	820
	Only cycles with turbidity ≤ 0.1 NTU	52.9	53.9	53.4	806	833	820
	Only cycles with turbidity ≤ 0.3 NTU	52.9	53.9	53.4	806	833	820

From the pilot-scale system filter operation data, the following observations were made:

- During the Summer benchmarking period, Bank A and Bank B filters did not overflow every cycle.
- The average Post-Ozone turbidity feeding the filters was 0.80 NTU, and the average combined filter turbidity was 0.07 NTU throughout the Summer benchmarking period.

- The turbidity measurements of all filters did not exceed the City's operational guideline of 0.1 NTU or the full-scale system operating license requirement of 0.3 NTU.
- The average observed filter run time was 20.9 hours and the subsequent observed average UFRV was 322 m^3/m^2. Both filter banks presented similar results based on termination of filter runs for scheduled backwashing.
- No difference was observed when comparing the overall average UFRV values (322 m^3/m^2) with the UFRV values of filters which did not exceed sampled turbidity measurements above 0.1 or 0.3 NTU (322 and 322 m^3/m^2) because turbidity measurements never exceeded 0.1 or 0.3 NTU.
- The forecasted UFRV values were approximately 150% higher than the observed UFRV values.
- The rate of head loss increase ranged from 0.2 to 1.2 kPa/h, with an average of 0.5 kPa/h. No substantial variability was observed for each filter during the Summer benchmarking period and among the filters throughout the same day. None of the filters exceeded the typical rate of head loss increase of 1.7 kPa/h or the maximum rate of head loss increase of 3.7 kPa/h. The typical and maximum rate of head loss increase (1.7 kPa/h and 3.7 kPa/h) are based on historical averages for the full-scale system (Refer to Table 5-2 of TM No. 3 for additional details).
- On July 5th, two backwashes were performed in the same day, resulting in a reduction in UFRV value due to a lower run time (10.7 h) than typically observed for this phase.

Both banks exhibited similar filter runs and UFRV values, an observation expected since both filter banks were operated at an average flow of 0.3 L/s during the Summer benchmarking period.

It should be noted that the forecasted filter run times and UFRV values are substantially higher than the observed UFRVs. However, it is very unlikely that these high forecasted values would actually be achieved either due to the effluent turbidity exceeding 0.1 NTU or earlier termination based on operating time. It should be noted that the full-scale system typically cycles the filters every 30 h, while pilot–scale system filtration cycles typically last 20 to 22 h.

The increase of the forecasted UFRV values during the Summer benchmarking period, observed in Figure 2-5 especially for Bank B, could be associated with the decrease of the pH across the pilot-scale system (from approximately 5.8 to 5.45 in the Post-DAF). It should be noted that the Post-DAF pH in the pilot-scale system was being matched with the full-scale system.

The Summer benchmarking period presented higher filter run times and UFRV when compared to the Winter #1 and Spring benchmarking periods (TM No. 3; Table 2-2 and TM No. 4; Table 2-1) as shown in Table 2-2. This observation could be attributed to improved performance of the DAF and/or warmer raw water temperatures.

Table 2-2: Comparison of the average filter run times and UFRV values for the Winter #1, Spring and Summer benchmarking periods.

BENCHMARKING PERIOD	AVERAGE FILTER RUN TIME (h)		UFRV (m^3/m^2)	
	Bank A	**Bank B**	**Bank A**	**Bank B**
Winter #1	9.4	9.8	136	141
Spring	17.4	13.1	263	201
Summer	21.2	20.7	322	322

Based on the full-scale system historical benchmarking, the five-year average UFRV value is 495 m^3/m^2 with an average rate of head loss increase of 1.7 kPa/h and an average post-ozone turbidity of 0.79 NTU (see Table 2-1 and Table 2-2 of TM No. 1). The Summer benchmarking period presented an average UFRV value one-third smaller than the full-scale system historical value, and lower rate of head loss increase, with similar average Post-Ozone turbidity (0.80 NTU). However, the UFRV values increase cannot be directly compared since the head loss available at full-scale system (48.9 kPa) is approximately double that of the available pilot-scale system head loss (23.9 kPa) as described in Section 2.4 of TM No 3. As such, it is expected that the pilot-scale system filter run times and UFRV values would likely be one-half that of the full-scale system UFRV values at the same rate of head loss increase. Therefore, the performance of pilot-scale system filters was deemed to meet, or exceed that of the full-scale system.

2.6 Summary of Comparison with Full-Scale System

When comparing the water quality results of the Summer benchmarking period with the results of full-scale system during the same period, pH (except for Filters 5-8) and TOC results presented strong correlations between the full-scale and pilot-scale systems. On the other hand, Post-DAF and Post-Ozone turbidity results were significantly higher at the pilot-scale system, but the pilot-scale system filters were able to remove the added turbidity. The pilot-scale system filters produced effluent with lower total manganese concentrations than the full-scale system, even if the Post-DAF and Post-Ozone concentrations were similar. In terms of filters operation, the pilot-scale system filters presented a smaller rate of head loss increase and higher forecasted UFRV values when compared to the historical data of the full-scale system.

Besides the differences in the Post-DAF and Post-Ozone turbidity results and the filter effluent total manganese of the full-scale and pilot-scale systems, the water quality results from the Summer benchmarking period of the pilot-scale system were sufficiently appropriate to draw operational comparisons to the full-scale system. As such, the project proceeded with the subsequent piloting of the alternative coagulant, ferric sulphate.

3. SUMMER TRANSITION PERIOD

The pilot-scale system was transitioned to the alternative coagulant, ferric sulphate, on July 11th, 2017. Samples were collected from the pilot-scale system between July 11th and July 23rd, 2017 at the same locations as the Summer benchmarking period, and tested for the following four key parameters: pH, turbidity, TOC, and total manganese. Appendix B presents the summary of all water quality parameters tested during the Summer transition period. Filter Banks A (Filters 1-4) and B (Filters 5-8) were operated at 0.3 L/s throughout the Summer transition period.

The coagulant dose and coagulant-aid (LT-22S) dose were initially set to 42 mg/L and 0.2 mg/L; however, within 24 hours of operation the City observed significant buildup of coagulant and coagulant aid in the pre-ozone strainer and visible coagulant floc in the DAF overflow tank. Furthermore, the City noted a significant reduction in filter performance while operating at these chemical doses. It became immediately apparent that the system required maintenance and the need to re-evaluate doses.

On July 12th, the pilot-scale system was shut-down and underwent a full cleaning to remove the buildup of coagulant/coagulant-aid from the system. On July 13th, the pilot-scale system was started using lower coagulant and coagulant-aid doses of 35 mg/L and 0.02 mg/L, respectively. Subsequently, the City did not observe coagulant carry-over into the DAF overflow tank or significant buildup on the pre-ozone strainer. Of note is that there were no samples collected by the City on July 13th, a consequence of the effort needed to remove the buildup of coagulant and coagulant-aid. On July 19th, at the request of WSP, the coagulant dose was further reduced to 25 mg/L and the coagulant-aid dose reduced to 0 mg/L, in preparation for the Summer piloting session.

On July 21st, the City reported the ozone generator in the pilot-scale system failed; therefore, no ozonation occurred on July 22nd or 23rd.

The transition period is aimed to evaluate the stability of the pilot-scale system following the change from ferric chloride to ferric sulphate. Stability is achieved following a minimum of 5 days of operations where turbidity fluctuates by ±0.2 NTU in Post-DAF samples and ±0.05 NTU in the pilot-scale system filter effluent. Section 3.1 to Section 3.4 illustrate the results for the key parameters tested during the Summer transition period.

3.1 pH

The pH value did not vary significantly during the Summer transition period as shown in Figure 3-1. The Post-DAF pH was maintained at approximately 6.0 during the Summer transition period.

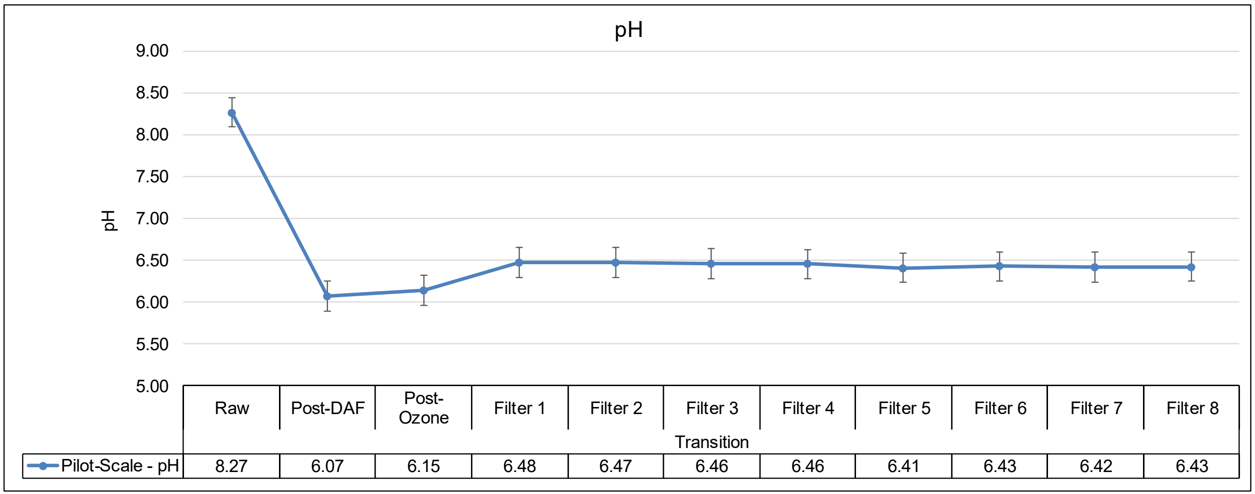
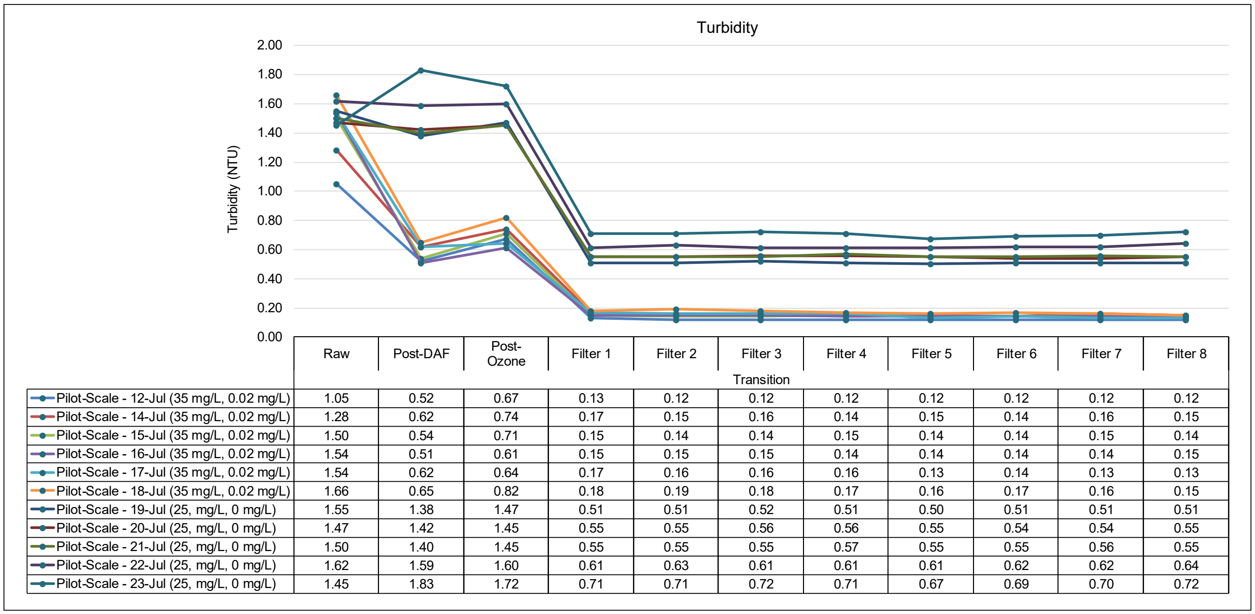


Figure 3-1: Average pH of the pilot-scale system during the Summer transition period. From July 12th-18th, 2017, the coagulant and coagulant-aid doses were 35 mg/L and 0.02 mg/L. From July 19th-23rd, 2017, the coagulant dose was 25 mg/L and no coagulant-aid was added. Data originates from Lab analyses.

3.2 Turbidity

During the Summer transition period, two different chemical doses were used for the coagulant and coagulant-aid. From July 12th to July 18th, the coagulant and the coagulant-aid dose were 35 mg/L and 0.02 mg/L, respectively. The turbidity results from this time can be seen in Figure 3-2 and Table 3-1. On July 19th, the coagulant dose was reduced to 25 mg/L with no coagulant-aid to be used (Figure 3-2; Table 3-2). The Post-DAF pH was maintained at approximately 6.0 throughout the Summer transition period. The transition period evaluates the stability of the system under constant operating conditions therefore the stability was assessed for each of the pilot-scale system operating conditions independently.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
● Pilot-Scale - 12-Jul (35 mg/L, 0.02 mg/L)	1.05	0.52	0.67	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12
● Pilot-Scale - 14-Jul (35 mg/L, 0.02 mg/L)	1.28	0.62	0.74	0.17	0.15	0.16	0.14	0.15	0.14	0.16	0.15
● Pilot-Scale - 15-Jul (35 mg/L, 0.02 mg/L)	1.50	0.54	0.71	0.15	0.14	0.14	0.15	0.14	0.14	0.15	0.14
● Pilot-Scale - 16-Jul (35 mg/L, 0.02 mg/L)	1.54	0.51	0.61	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.15
● Pilot-Scale - 17-Jul (35 mg/L, 0.02 mg/L)	1.54	0.62	0.64	0.17	0.16	0.16	0.16	0.13	0.14	0.13	0.13
● Pilot-Scale - 18-Jul (35 mg/L, 0.02 mg/L)	1.66	0.65	0.82	0.18	0.19	0.18	0.17	0.16	0.17	0.16	0.15
● Pilot-Scale - 19-Jul (25, mg/L, 0 mg/L)	1.55	1.38	1.47	0.51	0.51	0.52	0.51	0.50	0.51	0.51	0.51
● Pilot-Scale - 20-Jul (25, mg/L, 0 mg/L)	1.47	1.42	1.45	0.55	0.55	0.56	0.56	0.55	0.54	0.54	0.55
● Pilot-Scale - 21-Jul (25, mg/L, 0 mg/L)	1.50	1.40	1.45	0.55	0.55	0.55	0.57	0.55	0.55	0.56	0.55
● Pilot-Scale - 22-Jul (25, mg/L, 0 mg/L)	1.62	1.59	1.60	0.61	0.63	0.61	0.61	0.61	0.62	0.62	0.64
● Pilot-Scale - 23-Jul (25, mg/L, 0 mg/L)	1.45	1.83	1.72	0.71	0.71	0.72	0.71	0.67	0.69	0.70	0.72

Figure 3-2: Turbidity of the pilot-scale system during the Summer transition period. From July 12th-18th, 2017, the coagulant and coagulant-aid doses were 35 mg/L and 0.02 mg/L. From July 19th-23rd, 2017, the coagulant dose was 25 mg/L and no coagulant-aid was added. Post-DAF pH was maintained at 6.0 throughout the Summer transition period. Data originates from Lab analyses.

Table 3-1: Changes in pilot-scale system turbidity during the Summer transition period. From July 12th-18th, 2017, the coagulant and coagulant-aid doses were 35 mg/L and 0.02 mg/L. Data originates from Lab analysis.

Location	July 12, 2017	July 14, 2017	July 15, 2017	July 16, 2017	July 17, 2017	July 18, 2017	AVERAGE
Raw	1.05	1.28	1.50	1.54	1.54	1.66	1.43 ± 0.22
Post-DAF	0.52	0.62	0.54	0.51	0.62	0.65	0.58 ± 0.06
Post-Ozone	0.67	0.74	0.71	0.61	0.64	0.82	0.70 ± 0.08
Filter 1	0.13	0.17	0.15	0.15	0.17	0.18	0.16 ± 0.02
Filter 2	0.12	0.15	0.14	0.15	0.16	0.19	0.15 ± 0.02
Filter 3	0.12	0.16	0.14	0.15	0.16	0.18	0.15 ± 0.02
Fitler 4	0.12	0.14	0.15	0.14	0.16	0.17	0.15 ± 0.02
Fitler 5	0.12	0.15	0.14	0.14	0.13	0.16	0.14 ± 0.01
Fitler 6	0.12	0.14	0.14	0.14	0.14	0.17	0.14 ± 0.02
Fitler 7	0.12	0.16	0.15	0.14	0.13	0.16	0.14 ± 0.02
Fitler 8	0.12	0.15	0.14	0.15	0.13	0.15	0.14 ± 0.01

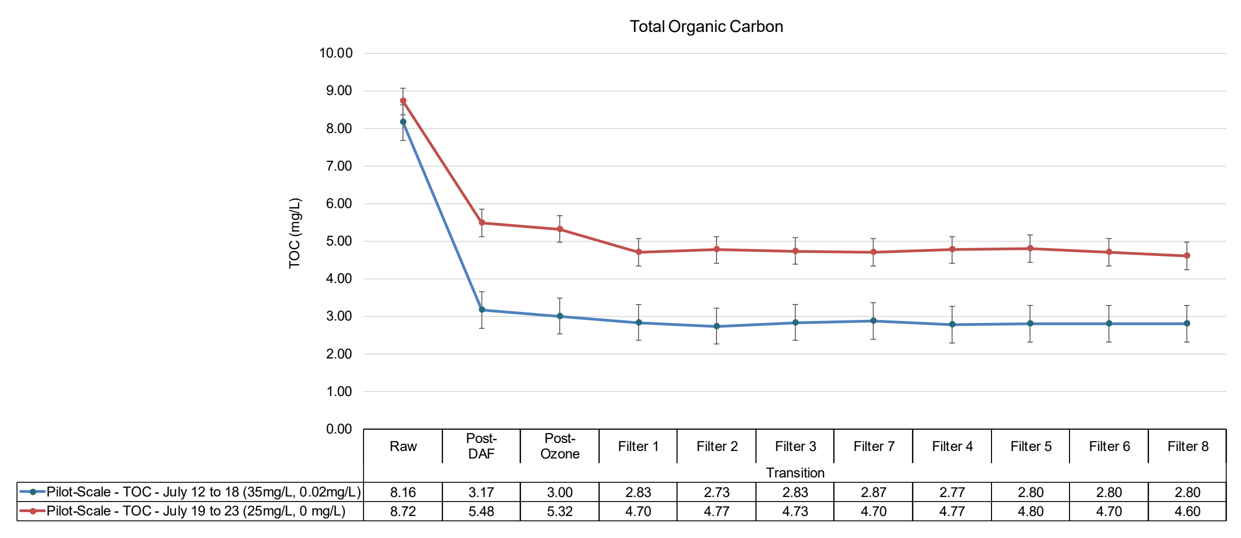
Table 3-2: Changes in pilot-scale system turbidity during the Summer transition period. From July 19th-23rd, 2017, the coagulant dose was 25 mg/L and no coagulant-aid was added. Data originates from Lab analysis.

Location	July-19-17	July-20-17	July-21-17	July-22-17	July-23-17	AVERAGE
Raw	1.55	1.47	1.50	1.62	1.45	1.52 ± 0.07
Post-DAF	1.38	1.42	1.40	1.59	1.83	1.52 ± 0.19
Post-Ozone	1.47	1.45	1.45	1.60	1.72	1.54 ± 0.12
Filter 1	0.51	0.55	0.55	0.61	0.71	0.59 ± 0.08
Filter 2	0.51	0.55	0.55	0.63	0.71	0.59 ± 0.08
Filter 3	0.52	0.56	0.55	0.61	0.72	0.59 ± 0.08
Fitler 4	0.51	0.56	0.57	0.61	0.71	0.59 ± 0.07
Fitler 5	0.50	0.55	0.55	0.61	0.67	0.58 ± 0.07
Fitler 6	0.51	0.54	0.55	0.62	0.69	0.58 ± 0.07
Fitler 7	0.51	0.54	0.56	0.62	0.70	0.59 ± 0.08
Fitler 8	0.51	0.55	0.55	0.64	0.72	0.59 ± 0.09

The pilot-scale system was found to operate in a very stable manner following the transition to ferric sulphate and coagulant-aid, meeting all criteria for stability. During the change to a lower coagulant dose with no coagulant-aid addition, there was slightly more deviation in turbidity in all samples collected. However, the criteria for pilot-scale system stability was still met. This is indicative of the pilot-scale system's stability despite significant changes to chemical additions, such as a substantial reduction in coagulant and ceasing the addition of coagulant-aid. The data also shows a reduction in the Post-DAF turbidity at a coagulant dose of 35 mg/L and a coagulant-aid dose of 0.02 mg/L. This equates to lower filter effluent turbidity compared to the coagulant dose of 25 mg/L and with no coagulant-aid. The lower Post-DAF turbidity is likely due to the coagulant approaching a more optimal dose.

3.3 Total Organic Carbon

The TOC measured in the pilot-scale system during the Summer transition period is reported in Figure 3-3. The results show a reduction in raw water TOC at both coagulant/coagulant-aid doses used during the Summer transition period. However, the results indicate that there was better removal of TOC by the pilot-scale system when operated with the higher coagulant dose of 35 mg/L and 0.02 mg/L coagulant-aid. Again, this is likely due to the coagulant dose of 35 mg/L approaching a more optimal dose.

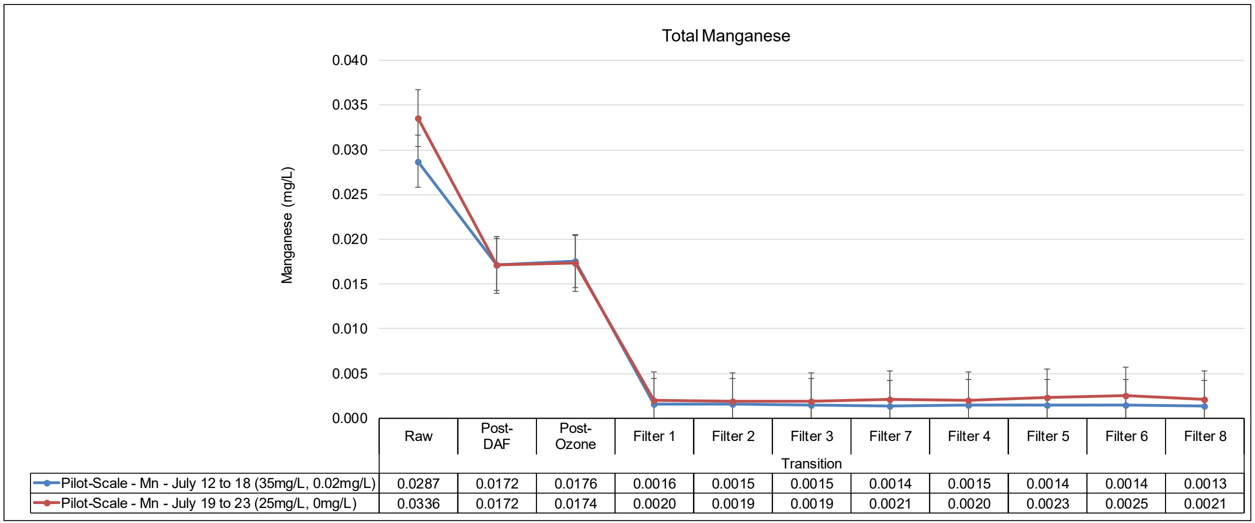


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 7	Filter 4	Filter 5	Filter 6	Filter 8
Pilot-Scale - TOC - July 12 to 18 (35mg/L, 0.02mg/L)	8.16	3.17	3.00	2.83	2.73	2.83	2.87	2.77	2.80	2.80	2.80
Pilot-Scale - TOC - July 19 to 23 (25mg/L, 0 mg/L)	8.72	5.48	5.32	4.70	4.77	4.73	4.70	4.77	4.80	4.70	4.60

Figure 3-3: Average TOC of the pilot-scale system during the Summer transition period. From July 12th-18th, 2017, the coagulant and coagulant-aid doses were 35 mg/L and 0.02 mg/L. From July 19th-23rd, 2017, the coagulant dose was 25 mg/L and no coagulant-aid was added. Data originates from Lab analyses.

3.4 Total Manganese

The total manganese did not show significant variation at either of the two coagulant/coagulant-aid doses used during the Summer transition period, as observed in Figure 3-4.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 7	Filter 4	Filter 5	Filter 6	Filter 8
Pilot-Scale - Mn - July 12 to 18 (35mg/L, 0.02mg/L)	0.0287	0.0172	0.0176	0.0016	0.0015	0.0015	0.0014	0.0015	0.0014	0.0014	0.0013
Pilot-Scale - Mn - July 19 to 23 (25mg/L, 0mg/L)	0.0336	0.0172	0.0174	0.0020	0.0019	0.0019	0.0021	0.0020	0.0023	0.0025	0.0021

Figure 3-4: Average total manganese of the pilot-scale system during the Summer transition period. From July 12th-18th, 2017, the coagulant and coagulant-aid doses were 35 mg/L and 0.02 mg/L. From July 19th-23th, 2017, the coagulant dose was 25 mg/L and no coagulant-aid was added. Data originates from Lab analyses.

Overall, the pilot-scale system operated in a stable manner during the entirety of the Summer transition period following the change to ferric sulphate and coagulant-aid, as well as following a significant reduction in coagulant dose and suspending the addition of coagulant-aid. As such, the pilot-scale system was deemed acceptable for the Summer piloting session using the alternative coagulant and coagulant-aid.

4. SUMMER PILOTING SESSION ACTIVITY

Following the successful transition to ferric sulphate and coagulant-aid, WSP operated the pilot-scale system from July 24th to August 17th, 2017 (inclusive), except for the period of August 10th to August 13th, 2017 when the City operated the system. Table 4-1 outlines the activities undertaken during the Summer piloting session. Piloting analytical work results completed by the Lab can be found in Appendix C, while Appendix D presents the daily operational log forms detailing observations and additional details. The detailed piloting work program can be found in Technical Memorandum No. 2 (TM No. 2).

Table 4-1: Summer piloting session: Summary of Piloting Activity.

Date	Coagulant (mg/L)	Coagulant Aid (mg/L)	Target Post-DAF pH	Avg Daily Sulphuric Acid (mg/L)	Change	Lab Analysis
Monday, July, 24	25.0	0.0	6.00	42.30	Increase coagulant dose	
Tuesday, July, 25	28.0	0.0	6.00	40.50		
Wednesday, July, 26	32.0	0.0	6.00	39.64		
Thursday, July, 27	35.0	0.0	6.00	36.15		
Friday, July, 28	38.0	0.0	6.00	32.02		
Saturday, July, 29	42.0	0.0	6.00	31.00		
Sunday, July, 30	38.0	0.0	6.00	31.00	Optimum coagulant dose	Type 1[1]
Monday, July, 31	38.0	0.0	5.65	33.41	Increase in pH	
Tuesday, August, 01	38.0	0.0	5.95	29.05		
Wednesday, August, 02	38.0	0.0	6.25	28.13		
Thursday, August, 03	38.0	0.0	5.80	36.30		
Friday, August, 04	38.0	0.0	5.80	36.30	Optimum coagulant dose and pH	Type 2[2]
Saturday, August, 05	38.0	0.05	5.80	47.74	Increase in coagulant-aid dose	
Sunday, August, 06	38.0	0.10	5.80	60.00		
Monday, August, 07	38.0	0.15	5.80	60.00		
Tuesday, August, 08	38.0	0.20	5.80	45.49		
Wednesday, August, 09	38.0	0.25	5.80	36.80		
Thursday, August, 10	Offline					
Friday, August, 11	Offline					
Saturday, August, 12	Offline					
Sunday, August, 13	Offline					
Monday, August, 14	38.0	0.10	5.80	34.00	Optimum coagulant, pH, and coagulant-aid.	Type 2
Tuesday, August, 15	38.0	0.10	5.80	34.00	Filter run time under optimal conditions	
Wednesday, August, 16	38.0	0.10	5.80	34.00		Type 1
Thursday, August, 17	38.0	0.10	5.80	34.00		Type1

[1] Type 1 sampling included: metals (dissolved and total): aluminum, arsenic, boron, calcium, cadmium, chromium, copper, iron, potassium, magnesium, manganese, sodium, nickel, lead, antimony, silver, uranium, zinc, and zirconium. In addition, dissolved organic carbon (DOC), total dissolved solids (TDS), total solids (TS), total suspended solids (TSS), true colour, UV-Transmittance (UVT), alkalinity, conductivity, pH and turbidity.

[2] Type 2 sampling included all of Type 1, and threshold odour number, total trihalomethane (T-THM), total haloacetic acids (T-HAA), sulphate, chloride, and hardness. T-THM and T-HAA formation potential were only tested in the raw water and filter effluent of the full-scale and pilot-scale systems.

Samples were collected from the pilot-scale system on a daily basis at the following locations:

- Raw (same as full-scale system raw water);
- Post-DAF;
- Post-Ozone;
- Individual filter effluents; and
- Combined filter effluent.

Samples were also collected from the full-scale system at the following locations for comparison purposes:

- Post-DAF;
- Post-Ozone (i.e. combined ozone from both tanks); and
- Combined filter effluent (i.e., individual filter samples were not taken from the full-scale system).

Samples were tested using the same bench-scale instruments daily. Laboratory analyses were planned based on the schedule provided in Table 4-1.

During the Summer piloting session, the flow rates for filter Bank A (Filters 1-4) and filter Bank B (Filters 5-8) were 0.6 L/s and 0.3 L/s, respectively.

Deviations from the original program presented in TM No. 2 were as follows:

- Raw water analysis was taken from the pilot-scale system only;
- Combined Filter effluent samples were collected from the pilot-plant system;
- Backwash performance evaluation was not performed as per recommendations in TM No. 3;
- TOC analysis was conducted on the raw water and combined filter effluent samples from the full-scale system;
- Optimal coagulant dose was determined without the addition of coagulant-aid;
- Optimal pH was determined without the addition of coagulant-aid; and
- Inclusion of dedicated test days to evaluate unit filter run times under optimal conditions.

5. SUMMER PILOTING SESSION RESULTS

This section summarizes the operational parameters and the water quality analyses for samples collected between July 24th and Aug 17th, 2017. Included in these results are comparisons between the full-scale and pilot-scale system operations pertaining to the DAF, ozonation, and combined filter effluent for key parameters.

Confirmatory laboratory analyses were performed by the Lab, while the benchtop analyses were performed by WSP staff. Data was also collected from the pilot-scale system SCADA for comparison between benchtop and online instrumentation.

The ozone was not operating from July 21st to August 13th, 2017, due to a failure in the ozone generator. Therefore, coagulant, pH, and coagulant-aid optimization occurred without the addition of ozone. City technicians repaired the ozone generator and ozonation commenced at approximately 2:00 pm on August 14th.

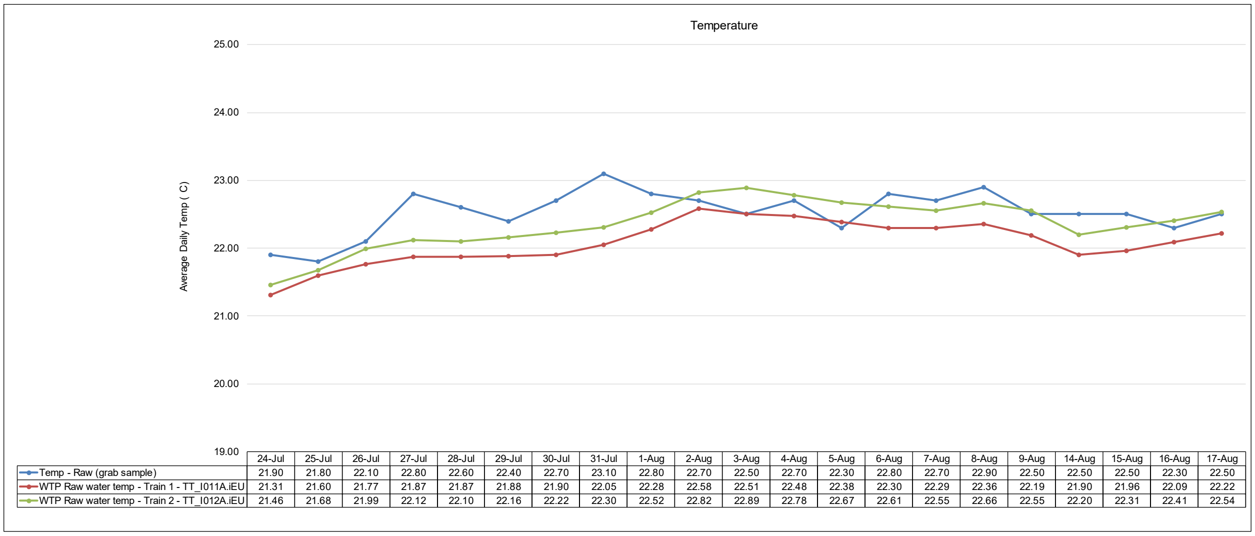
From August 10th to 13th, 2017, the pilot-scale system was shut down and cleaned to remove the excessive buildup of coagulant-aid from the DAF tank and to allow technicians time to repair the damaged ozone generator. While cleaning the DAF, the City reported to WSP that there were difficulties creating microbubbles. This appeared to be due to the buildup of coagulant/coagulant-aid in the air saturation water line. Subsequent cleaning removed the buildup and microbubbles returned to normal.

No samples were collected from August 10th to August 13th due to the shutdown and maintenance of the pilot-scale system.

5.1 Raw Water Temperature

The criteria for testing in Summer conditions (warm water) was that the raw water temperature to be greater than 15°C. Raw water temperature was collected from two temperature sensors used to measure each train (Train 1 and 2) in the full-scale system. In the pilot-scale system, the temperature was measured from the raw water grab sample location, using a hand-held digital thermometer.

Figure 5-1 confirms that the temperature measured by both online sensors, as well as grab samples, exceeded 21°C for the entirety of the Summer piloting session. Therefore, the criteria for testing the alternative coagulant in warm water conditions was met.

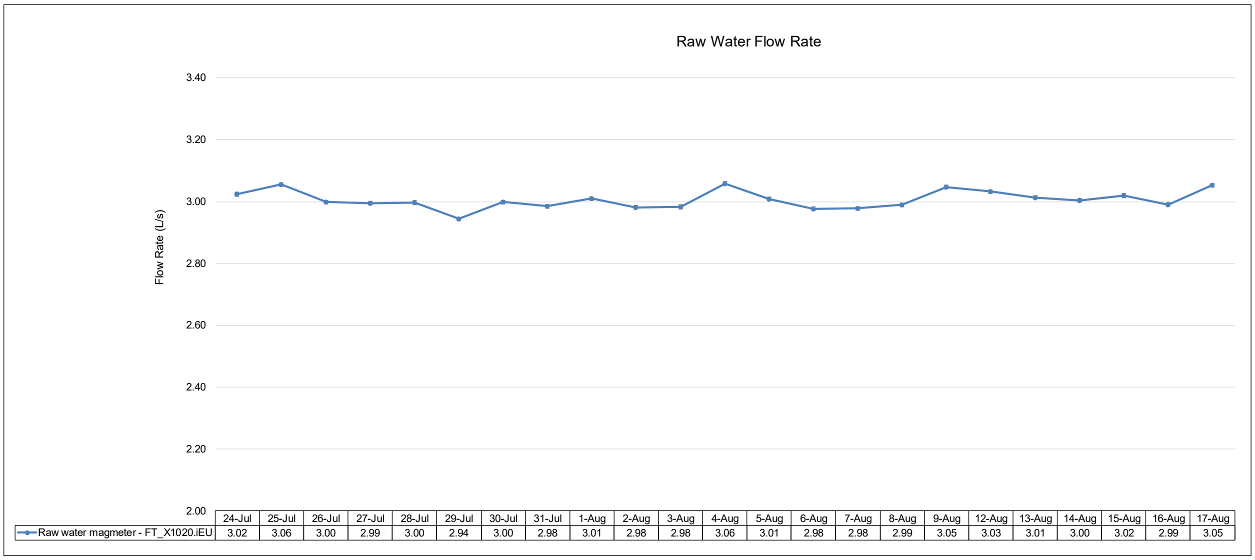


	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	14-Aug	15-Aug	16-Aug	17-Aug
Temp - Raw (grab sample)	21.90	21.80	22.10	22.80	22.60	22.40	22.70	23.10	22.80	22.70	22.50	22.70	22.30	22.80	22.70	22.90	22.50	22.50	22.50	22.30	22.50
WTP Raw water temp - Train 1 - TT_I011A.iEU	21.31	21.60	21.77	21.87	21.87	21.88	21.90	22.05	22.28	22.58	22.51	22.48	22.38	22.30	22.29	22.36	22.19	21.90	21.96	22.09	22.22
WTP Raw water temp - Train 2 - TT_I012A.iEU	21.46	21.68	21.99	22.12	22.10	22.16	22.22	22.30	22.52	22.82	22.89	22.78	22.67	22.61	22.55	22.66	22.55	22.20	22.31	22.41	22.54

Figure 5-1: Raw water temperature for the full-scale system (Train 1 (Red) and Train 2 (Green)) and the pilot-scale system (Blue) during the Summer piloting session. Data for Trains 1 and 2 originates from the full-scale system SCADA dataset. Pilot-scale system data originates from benchtop analysis using a hand-held digital thermometer.

5.2 Pilot-Scale System Raw Water Flow (SCADA)

Figure 5-2 presents the raw water flow maintained during the Summer piloting session. The desired raw water flow to the pilot-scale system is approximately 3.0 L/s. During the Summer piloting session, the flow rate was well maintained between 2.94 L/s and 3.05 L/s (reported as average daily flow).

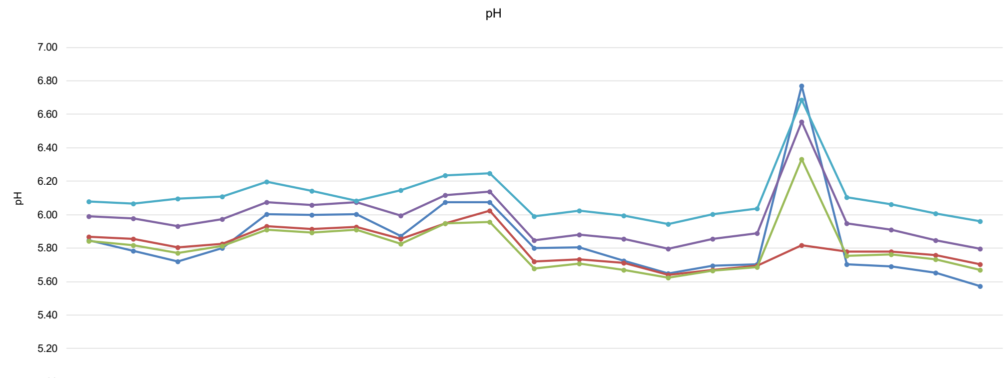


	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug
Raw water magmeter - FT_X1020.iEU	3.02	3.06	3.00	2.99	3.00	2.94	3.00	2.98	3.01	2.98	2.98	3.06	3.01	2.98	2.98	2.99	3.05	3.03	3.01	3.00	3.02	2.99	3.05

Figure 5-2: Raw water flow rate to the pilot-scale system during the Summer piloting session. Data originates from the pilot-scale system's SCADA dataset.

5.3 pH Monitoring of the Pilot-Scale System(SCADA)

The pH was constantly monitored at the pilot-scale system using the SCADA system. Figure 5-3 illustrates the average daily pH during the Summer piloting session for the following locations: Pre-DAF, Pre-Ozone (Columns 1 and 2), and Pre-Filtration (Bank A & Bank B).



	Piloting 24-Jul	Piloting 25-Jul	Piloting 26-Jul	Piloting 27-Jul	Piloting 28-Jul	Piloting 29-Jul	Piloting 30-Jul	Piloting 31-Jul	Piloting 01-Aug	Piloting 02-Aug	Piloting 03-Aug	Piloting 04-Aug	Piloting 05-Aug	Piloting 06-Aug	Piloting 07-Aug	Piloting 08-Aug	Piloting 09-Aug	Piloting 15-Aug	Piloting 16-Aug	Piloting 17-Aug	Piloting 18-Aug
Pilot-SCADA - AT_X1022.iEU	5.85	5.79	5.72	5.80	6.00	6.00	6.00	5.87	6.08	6.08	5.80	5.80	5.73	5.65	5.70	5.70	6.77	5.70	5.69	5.65	5.57
Pilot-SCADA - AT_X3150.IEU_Pre-Ozone pH Column 1	5.87	5.85	5.80	5.82	5.93	5.92	5.93	5.86	5.95	6.02	5.72	5.73	5.71	5.64	5.67	5.70	5.82	5.78	5.78	5.76	5.70
Pilot-SCADA - AT_X3160.iEU_Pre-Ozone pH Column 2	5.84	5.82	5.77	5.81	5.91	5.89	5.91	5.83	5.95	5.96	5.68	5.71	5.67	5.62	5.67	5.69	6.33	5.75	5.76	5.73	5.67
Pilot-SCADA - AT_X4210.iEU_Prefiltration pH Bank A	5.99	5.98	5.93	5.97	6.07	6.06	6.08	5.99	6.12	6.14	5.85	5.88	5.85	5.79	5.86	5.89	6.56	5.95	5.91	5.85	5.80
Pilot-SCADA - AT_X4230.iEU_Prefiltration pH Bank B	6.08	6.07	6.10	6.11	6.20	6.14	6.08	6.15	6.24	6.25	5.99	6.02	5.99	5.95	6.00	6.04	6.69	6.10	6.06	6.01	5.96

Figure 5-3: Daily average pH of the pilot-scale system during the Summer piloting session. Data originates from the pilot-scale system's SCADA dataset. Note: August 10th to August 13th were omitted due to a pilot-scale system shutdown.

During the Spring piloting session, the pH was controlled by adjusting the sulphuric acid dose to the raw water feeding the DAF tanks and monitoring the DAF effluent pH. Adjustments to the sulphuric acid addition were made based on the Post-DAF pH, to achieve the desired pH. Typically, an offset was added to the pH probe monitoring the pH of the chemically fed raw water to account for the pH change within the DAF tank. This offset appeared to provide sufficient adjustment needed to maintain a specific pH. As such, this practice was used in the Summer piloting session from July 24th to July 26th. This adjustment was monitored via Post-DAF grab samples, and minor adjustments to the acid addition were made on an as-needed basis.

It was recommended following the Spring piloting session that a pH controller be implemented that would adjust the addition of sulphuric acid to the raw water feeding the DAF, based on a pH set point. On July 27th, the City initiated the pH controller. Figure 5-4 outlines the pH controller's operation during the Summer piloting session. From July 27th to August 5th, the controller was operating and adjusting acid addition based on a set point. During this period the online pH meter closely matched Post-DAF grab samples. Deviations seen on July 31st and August 2nd are likely a result of minor adjustments to the controller logic by the City to better improve the pH control by accounting for minor changes in the raw water flow rate. As can be seen by the grab samples collected by onsite WSP personnel, the deviations observed in the online data on July 31st and Aug 2nd did not affect the Post-DAF pH.

On August 5th, an unexpected error occurred in the pH controller and City technicians were not onsite to correct the malfunction. The error also deactivated the ability for onsite WSP personnel to manually adjust the sulphuric acid dose using the online SCADA program. To achieve the desired Post-DAF pH, the sulphuric acid pump was removed from the SCADA system and manually adjusted to reach the desired pH. During manual operation of the sulphuric acid pump (August 5th to August 8th), acid addition was not flow-paced resulting in constant monitoring to maintain the desired pH. On August 8th at approximately 11:00 am, the City corrected the error in the controller logic and re-initiated the pH controller, which remained operational for the remainder of the Summer piloting session.

Although the pH controller allowed for improved pH control within the DAF system, the addition of the coagulant-aid (August 8th to 9th and August 14th to 17th) affected the pH greater than when compared to operation without the coagulant-aid. As such, close monitoring and iterative acid dose adjustments were needed, in turn affecting the offset to the pH set point. Specifically, the observable increase in pH illustrated in Figure 5-4 on August 9th is due to a change in offset to account for the addition of coagulant-aid in the DAF Floc Tank #3, and the subsequent difficulty encountered meeting the desired Post-DAF pH. This offset accounts for the deviation between the online and grab samples taken from August 8th to 9th and August 14th to 17th.

	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	14-Aug	15-Aug	16-Aug	17-Aug
Post-DAF - pH	6.04	6.00	5.95	5.95	6.06	6.01	6.10	5.71	5.99	6.27	5.83	5.85	5.80	5.83	5.83	5.79	5.81	5.89	5.86	5.91	5.82
AT_X1022.iEU - Raw pH & temp	5.85	5.79	5.72	5.80	6.00	6.00	6.00	5.87	6.08	6.08	5.80	5.80	5.73	5.65	5.70	5.70	6.77	5.75	5.70	5.69	5.65

Figure 5-4: pH comparison of the pilot-scale system online Pre-DAF analyzer (AT-X1022) and Post-DAF. Data originates from the pilot-scale system's SCADA dataset and benchtop analysis using a benchtop Thermo Scientific Orion STAR A325 pH probe.

5.4 Pilot-Scale System Filter Operation (SCADA)

During the Summer piloting session, Bank A operated at an average flow of 0.6 L/s and Bank B operated at an average flow of 0.3 L/s. The standard procedure was to backwash the filters daily (approximately at the same time). The differential pressure values reported by the pilot-scale system SCADA were evaluated on an average hourly basis to determine the following:

- the filter run times,
- the UFRV values,
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter, and
- the rate of head loss increase of each filter.

The calculations were performed as described in Section 2.4 of Technical Memo No. 3. The filter operational data were compared against filter effluent turbidity measured by benchtop analysis, which was sampled approximately 4 hours from the start of the filtration cycle. The summary of the filter operational data obtained during the Summer piloting session is provided in Appendix C1. Figure 5-5 illustrates the average daily UFRV values.

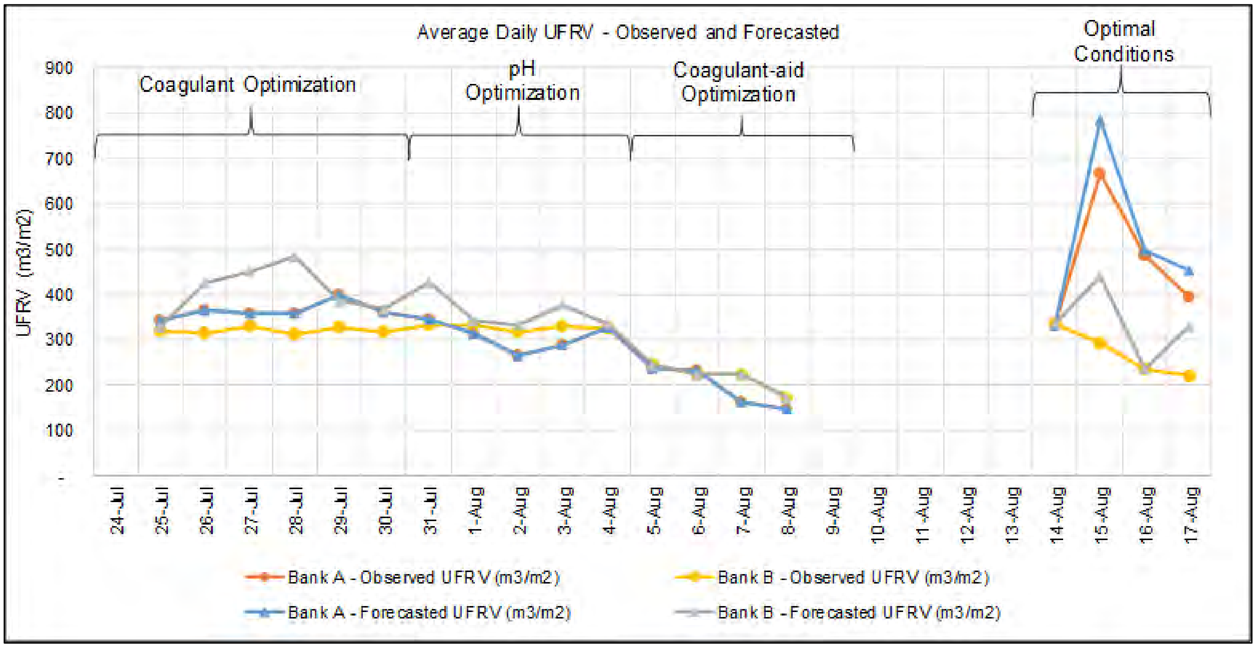


Figure 5-5: Average UFRV values of the pilot-scale system Bank A and Bank B during the Summer piloting session. UFRV = Filter Run Volume/Filter Surface Area. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

Table 5-1 tabulates the average filter run times and average UFRV values for the entire Summer piloting session, while also considering overall operation cycles and those which did not fail based on sampled turbidity.

Table 5-1: Average observed and forecasted filter run times and UFRV values for the Summer piloting session.

		FILTER RUN TIME (h)		UFRV (m^3/m^2)		
		Bank A	**Bank B**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	10.7	18.9	336	291	314
	Only cycles with turbidity ≤ 0.1 NTU	5.5	N/R	161	N/R	161
	Only cycles with turbidity ≤ 0.3 NTU	10.5	18.5	329	284	307
Forecasted Values	Overall Cycles	11.0	22.1	346	340	343
	Only cycles with turbidity ≤ 0.1 NTU	5.5	N/R	161	N/R	161
	Only cycles with turbidity ≤ 0.3 NTU	10.8	21.6	341	332	336

N/R: No results

From the filter operation data, the following observations were made:

- August 10th and 14th, the pilot-scale system was switched off for cleaning and maintenance, consequently no data was collected.
- The pump feeding Bank B was turned on and off during the last 6 hours of the filter cycle on August 15th (the second optimal day of the Summer piloting session), causing a flow rate variation which

could have extended Bank B filter run times and impacting the UFRV and head loss evaluation. Therefore the data from this day was not used in the average calculations.

- During the Summer piloting session, Filters 1 to 4 overflowed before the daily backwash each time, except during the two days of the optimal conditions on August 15th and 17th. At the same time, Filters 5 to 8 did not overflow, except during the coagulant-aid optimization period and two days of the optimal conditions on August 14th and 16th.
- The turbidity levels of the filters exceeded the City's operational guideline of 0.1 NTU in all filtration cycles for both filter banks, while the turbidity levels exceeded the full-scale system's operating license of 0.3 NTU in 18% of the filtration cycles for both filter banks. Filter 1 presented turbidity levels on average 20% higher than the other individual filters; however, the percentage of filtration cycles turbidity levels exceeded the full-scale system operating license of 0.3 NTU remains at 18% when discarding Filter 1 data.
- For Bank A, the observed overall average filter run time was 10.7 h and the observed overall average UFRV was 336 m^3/m^2. When discarding the cycles that sampled turbidity levels exceeded 0.1 NTU when sampled, the observed and forecasted UFRV values drop to 161 m^3/m^2. No substantial difference was observed when comparing the overall average observed UFRV value for all cycles (336 m^3/m^2) with the observed UFRV value for filters which did not present turbidity above 0.3 NTU (329 m^3/m^2).
- For Bank B, the observed overall average filter run was 18.9 h and the observed overall average UFRV was 291 m^3/m^2. All Bank B cycles presented sampled turbidity measurements above 0.1 NTU. No substantial difference was observed when comparing the overall average observed UFRV value for all cycles (291 m^3/m^2) with the observed UFRV value for filters which did not present sampled turbidity above 0.3 NTU (284 m^3/m^2).
- No substantial difference was observed when comparing the observed UFRV values with the forecasted UFRV values for Bank A; however, the forecasted UFRV values were 17% higher than the observed UFRV values for Bank B.
- The rate of head loss increase ranged from 0.9 to 7.4 kPa/h, with an average of 2.6 kPa/h for Bank A operating at 0.6 L/s, while the rate of head loss increase ranged from 0.7 to 2.3 kPa/h, with an average of 1.1 kPa/h for Bank B operating at 0.3 L/s. Low variability was observed for each filter of Bank B during the Summer piloting session and among Bank B filters in the same day. Higher variability was observed for each filter of Bank A during the Summer piloting session and among Bank A filters in the same day, especially during the coagulant-aid optimization period.
- Bank A filters, operating at 0.6 L/s, exceeded 25% of the time the typical rate of head loss increase of 3.1 kPa/h, but only Filter 1 exceeded once the maximum rate of head loss increase of 7.1 kPa/h. (The typical and maximum rate of head loss increase for filter bank operating at 0.6 L/s, 3.1 kPa and 7.1 kPa, respectively, are based on the historical averages of the full-scale system. Refer to Table 5-2 of TM No. 3 for additional details).
- Bank B filters, operating at 0.3 L/s, exceeded only 5% of the time the typical rate of head loss increase of 1.7 kPa/h and never the maximum rate of head loss increase of 3.7 kPa/h. (The typical and maximum rate of head loss increase for filter bank operating at 0.3 L/s, 1.7 kPa/h and 3.7 kPa/h, respectively, are based on historical averages of the full-scale system. Refer to Table 5-2 of TM No. 3 for additional details).

As expected, both filter banks exhibited relative similar UFRV values, and on average, Bank B exhibited a filter run time almost twice that of Bank A.

Although both filter banks presented turbidity breakthrough in all filtration cycles based on the benchtop results, all individual filters with the exception of Filter 1 presented turbidity below 0.1 NTU or very close to this value on August 4th, 14th, 16th and 17th based on the Lab analysis, indicating that the pilot-scale system filters were able to meet the operating licence on these days.

A significant decrease in UFRV and filter run time was observed for both filter banks after August 5th, 2017, coinciding with the commencement of the coagulant-aid dosing. It is believed that the UFRV and filter run time results were influenced by the addition of coagulant-aid during the coagulant-aid optimization phase, when the ozone generator was not in service (ozone was offline from July 21st to August 13th, 2017). In the absence of ozone during the coagulant-aid optmization period, the theory is that coagulant-aid was not oxidized, and with the addition of filter-aid as well, there is the propensity for polymerization to occur within the processes which may have contributed to faster filter clogging. This theory will need to be confirmed in future piloting sessions when the coagulant-aid optimization occurs in the presence of ozone.

The effects of coagulant dose, pH and coagulant-aid dose are further discussed in Section 5.6. Additional evaluation regarding UFRV is also presented in Section 5.7, Section 5.8 and Section 5.9.

5.5 DAF Sludge Production of the Pilot-Scale System

Figure 5-6 illustrates the total suspended solids (TSS) results for the residual generation from the pilot-scale system DAF unit. It can be observed the TSS concentration increases with the pH increase; however, no relationship can be inferred from the coagulant-aid dose as the dose only ranged from 0.0 - 0.1 mg/L. It should be noted that the sludge sampling from the DAF is a rudimentary process and is subject to incomplete scrapper collection and/or variances in the scrapper level affecting the sludge blanket movement.

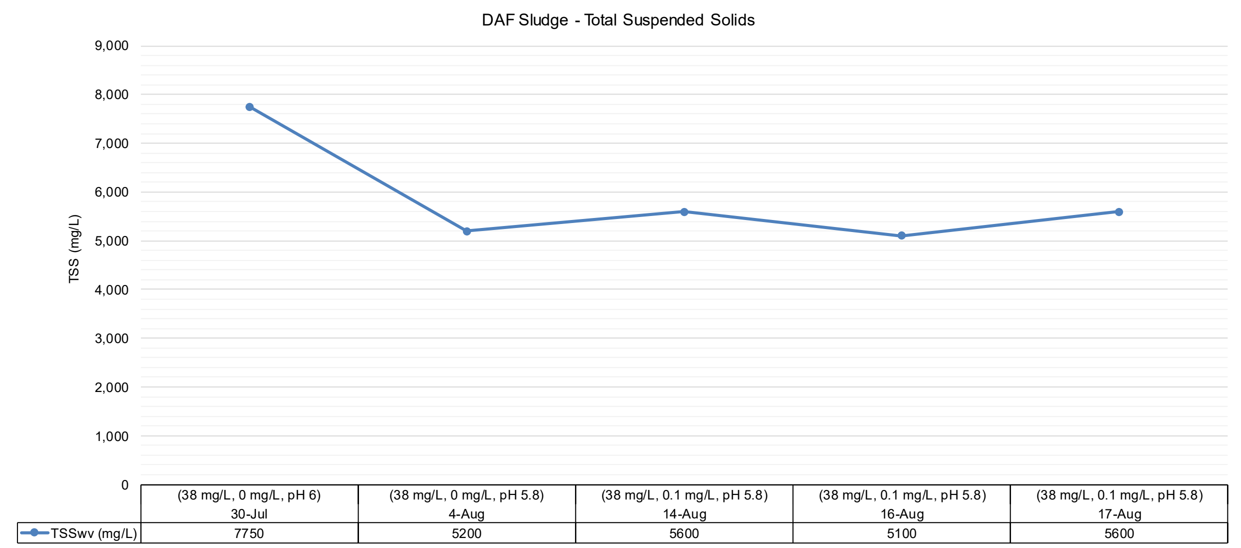


Figure 5-6: TSS results for DAF sludge in the pilot-scale system during the Summer piloting session. Data originates from Lab analysis.

5.6 Optimization of Alternative Coagulant, Coagulant-Aid, and pH

The following sections present the results used in determining the optimal dose for the alternative coagulant, coagulant-aid, as well as the optimal pH for chemical coagulation within the DAF system.

5.6.1 Optimization of Ferric Sulphate

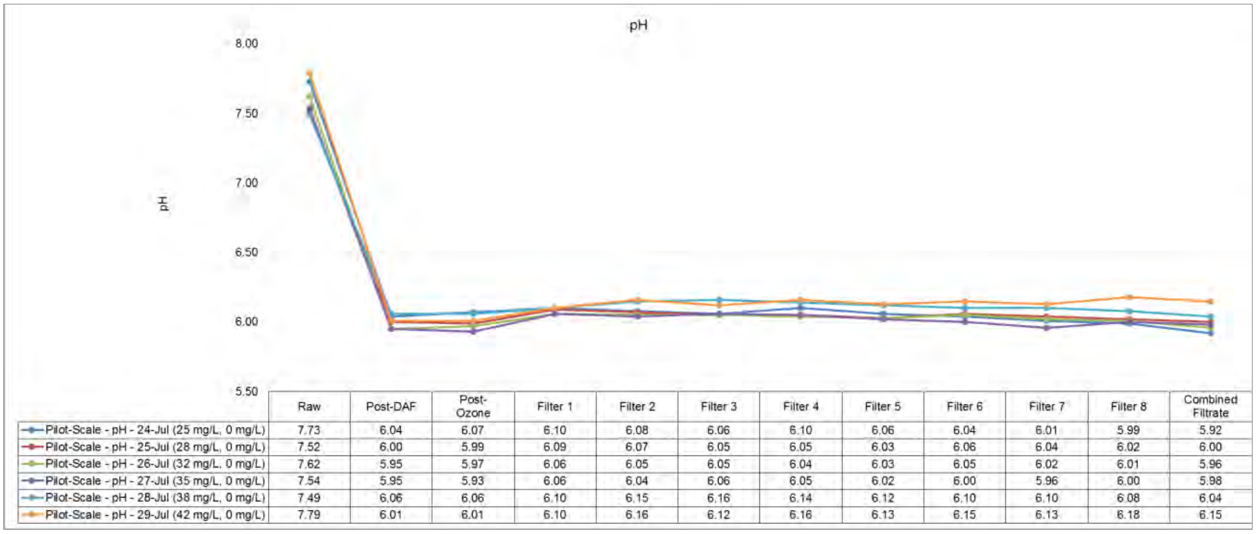
Dose optimization testing was conducted from July 24th to July 29th, 2017. The optimal chemical dose was based on the daily grab samples that were tested using various benchtop analyses for the following key parameters: turbidity, UV-transmittance (UVT), UV-absorbance (absorbance), and total manganese. Samples were collected daily from the following locations in the pilot-scale system: Raw, Post-DAF, Post-Ozone, filter effluent (Filters 1-8), and the combined filter effluent. Samples were also collected from Post-DAF, Post-Ozone, and the combined filter effluent of the full-scale system and tested using benchtop analyses for the key parameter listed above. It should be noted that no coagulant-aid was added during the optimization of ferric sulphate.

Along with key parameters, UFRV values were also calculated for the optimization of ferric sulphate. UFRV values were not considered in the optimization of the ferric sulphate dosage and were calculated after the completion of the Summer piloting session.

→ pH

The pH during the optimization of ferric sulphate in the Summer piloting session was 6.0, based on the Post-DAF pH. Figure 5-7 illustrates the pH was consistent during the optimization of ferric sulphate, with an average Post-DAF pH of 6.00±0.05. There was little change in pH following ozonation and only a slight increase in pH in the filter effluent, likely due to the addition of 0.01 mg/L filter-aid (LT-22S) before filtration.

In previous piloting sessions (Winter #1 and Spring), a decrease in pH occurred with increasing coagulant dose; however, this was not observed in the Summer piloting session. This is likely attributed to the pH controller reducing the addition of sulphuric acid and accounting for the acidity produced with an increase in coagulant dose. As such, this allowed for improved observations of the coagulant dose at a specific pH, and equally providing reasoning for the implementation of a pH controller (see Section 5.3).

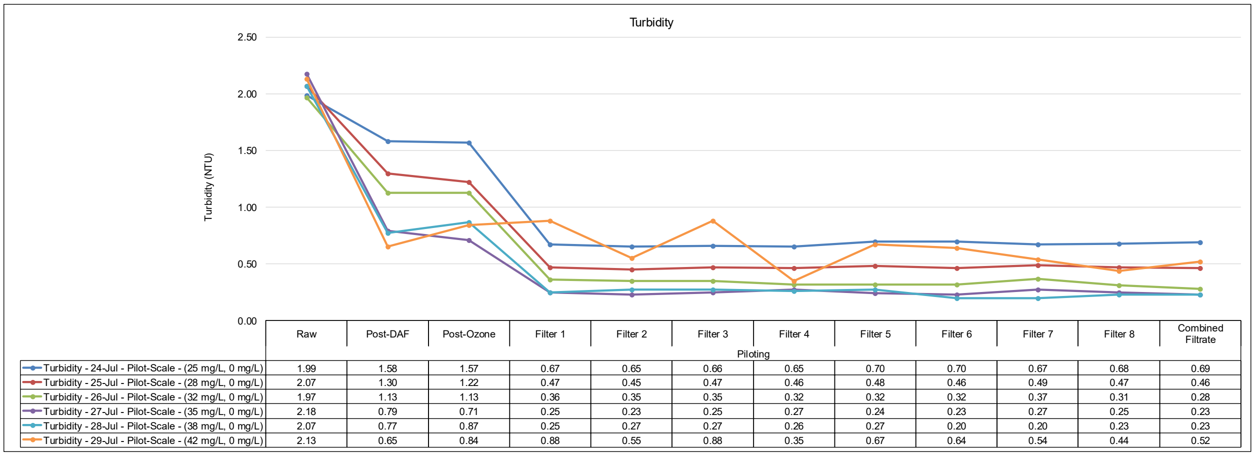


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Pilot-Scale - pH - 24-Jul (25 mg/L, 0 mg/L)	7.73	6.04	6.07	6.10	6.08	6.06	6.10	6.06	6.04	6.01	5.99	5.92
Pilot-Scale - pH - 25-Jul (28 mg/L, 0 mg/L)	7.52	6.00	5.99	6.09	6.07	6.05	6.05	6.03	6.06	6.04	6.02	6.00
Pilot-Scale - pH - 26-Jul (32 mg/L, 0 mg/L)	7.62	5.95	5.97	6.06	6.05	6.05	6.04	6.03	6.05	6.02	6.01	5.96
Pilot-Scale - pH - 27-Jul (35 mg/L, 0 mg/L)	7.54	5.95	5.93	6.06	6.04	6.06	6.05	6.02	6.00	5.96	6.00	5.98
Pilot-Scale - pH - 28-Jul (38 mg/L, 0 mg/L)	7.49	6.06	6.06	6.10	6.15	6.16	6.14	6.12	6.10	6.10	6.08	6.04
Pilot-Scale - pH - 29-Jul (42 mg/L, 0 mg/L)	7.79	6.01	6.01	6.10	6.16	6.12	6.16	6.13	6.15	6.13	6.18	6.15

Figure 5-7: pH during the Summer piloting session for determining the optimal dose of ferric sulphate. Data originates from benchtop analysis using a Thermo Scientific Orion Star A325 pH probe.

→ Turbidity

Figure 5-8 presents the results for turbidity levels by the pilot-scale system during the optimization of the ferric sulphate dose.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Turbidity - 24-Jul - Pilot-Scale - (25 mg/L, 0 mg/L)	1.99	1.58	1.57	0.67	0.65	0.66	0.65	0.70	0.70	0.67	0.68	0.69
Turbidity - 25-Jul - Pilot-Scale - (28 mg/L, 0 mg/L)	2.07	1.30	1.22	0.47	0.45	0.47	0.46	0.48	0.46	0.49	0.47	0.46
Turbidity - 26-Jul - Pilot-Scale - (32 mg/L, 0 mg/L)	1.97	1.13	1.13	0.36	0.35	0.35	0.32	0.32	0.32	0.37	0.31	0.28
Turbidity - 27-Jul - Pilot-Scale - (35 mg/L, 0 mg/L)	2.18	0.79	0.71	0.25	0.23	0.25	0.27	0.24	0.23	0.27	0.25	0.23
Turbidity - 28-Jul - Pilot-Scale - (38 mg/L, 0 mg/L)	2.07	0.77	0.87	0.25	0.27	0.27	0.26	0.27	0.20	0.20	0.23	0.23
Turbidity - 29-Jul - Pilot-Scale - (42 mg/L, 0 mg/L)	2.13	0.65	0.84	0.88	0.55	0.88	0.35	0.67	0.64	0.54	0.44	0.52

Figure 5-8: Turbidity during the Summer piloting session for determining the optimal dose of ferric sulphate. The pilot-scale system pH was maintained at pH 6.0 with no addition of coagulant-aid. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.

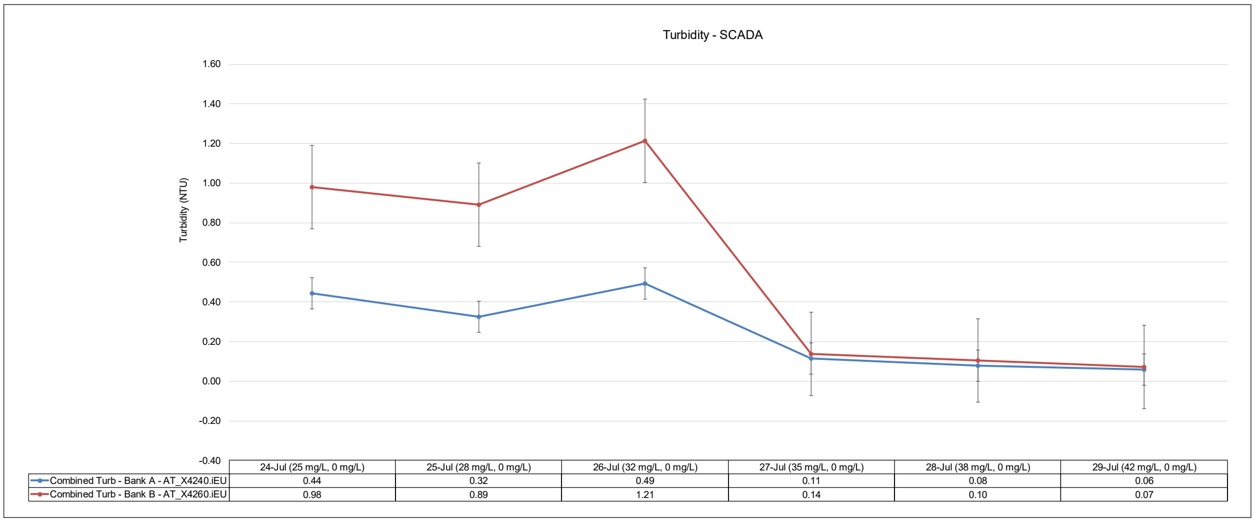
The turbidity in previous piloting sessions (Winter #1 and Spring) was found to increase in Post-DAF samples consistently. This phenomenon was attributed to factors such as possible carryover of air saturated water from the DAF tank due to a smaller surface area compared to the full-scale system, or mechanical issues, such as a damaged pipe in the DAF saturated water pipe feeding the DAF tank (TM No. 4).

In the Summer piloting session, the raw water turbidity decreased following coagulation and DAF in the pilot-scale system. This is most likely a result of several compounding factors. First, the repairs to the DAF saturated water pipe (TM No.4), as well as the repairs to the weir plate noted in Section 2.2, improved the Post-DAF turbidity. Secondly, the Winter #1 and Spring piloting sessions represented cold and cool water conditions, respectively. In cold or cool water, there is a greater solubility for dissolved gases (such as oxygen and nitrogen), when compared to warm water. Therefore, in the Summer where there was warm water conditions, the solubility of gases would be low and less likely for carryover following DAF treatment. Finally, warm water improves chemical kinetics for coagulation which would account for lower turbidity following DAF treatment.

During the coagulation optimization period the pilot-scale system's ozone system was not active; therefore, the turbidity did not significantly change in the Post-Ozone samples. As observed in the Spring piloting session, there was not a consistent increase or decrease in the turbidity between Post-DAF and Post-Ozone.

Following filtration, the turbidity was reduced by 38-75%, based on combined filter effluent (Figure 5-8). The lowest turbidity measured in the combined filter effluent was 0.23 NTU, which occurred on July 27th and 28th, at coagulant dosages of 35 mg/L and 38 mg/L, respectively.

The online turbidity readings for Bank A (Filters 1-4) and Bank B (Filters 5-8) indicate a reduction in turbidity with increasing coagulant dose, aside from July 26th (Figure 5-9). It should be noted that on July 26th City technicians cleaned the piping feeding the post-filter turbidity meters to remove the buildup of coagulant/coagulant-aid. This maintenance accounts for the increased turbidity noted for this day. The buildup within the lines is believed to have caused a slight increase in turbidity readings due to contamination from the residual coagulant. Furthermore, the contamination from the piping is also a potential cause for deviations between Bank A and Bank B on July 24th and July 25th. There was no significant difference (within error) in turbidity for Bank A and Bank B, according to the online instrumentation, following the maintenance.



	24-Jul (25 mg/L, 0 mg/L)	25-Jul (28 mg/L, 0 mg/L)	26-Jul (32 mg/L, 0 mg/L)	27-Jul (35 mg/L, 0 mg/L)	28-Jul (38 mg/L, 0 mg/L)	29-Jul (42 mg/L, 0 mg/L)
Combined Turb - Bank A - AT_X4240.iEU	0.44	0.32	0.49	0.11	0.08	0.06
Combined Turb - Bank B - AT_X4260.iEU	0.98	0.89	1.21	0.14	0.10	0.07

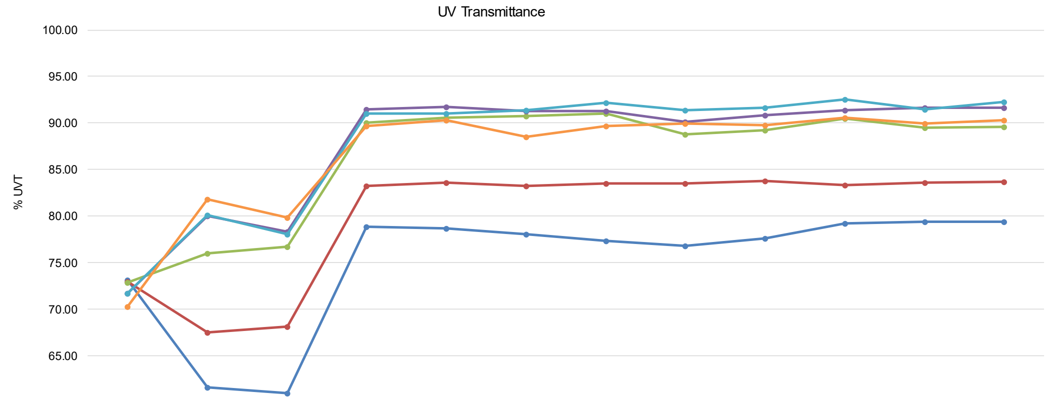
Figure 5-9: Daily average turbidity of the pilot-scale system final combined filter effluent (Bank A being Filters 1-4 and Bank B being Filters 5-8) for determining the optimal dose of ferric sulphate during the Summer piloting session. The pilot-scale system pH was maintained at pH 6.0 with no addition of coagulant-aid. Data originates from the pilot-scale system's SCADA dataset.

According to the online turbidity dataset, the coagulant dose of 42 mg/L on July 29th, had the lowest turbidity; however, this was not observed in benchtop samples collected by WSP (Figure 5-8). It is unclear as to the cause for the deviation between online and grab samples for July 29th; however, WSP considers the grab as a better indicator due to improved cleaning frequencies and low standard calibration of the handheld turbidimeter.

The optimized dose for ferric sulphate, under warm water conditions, is between 35 to 38 mg/L, based on the turbidity of combined filtrate measured using benchtop analyses.

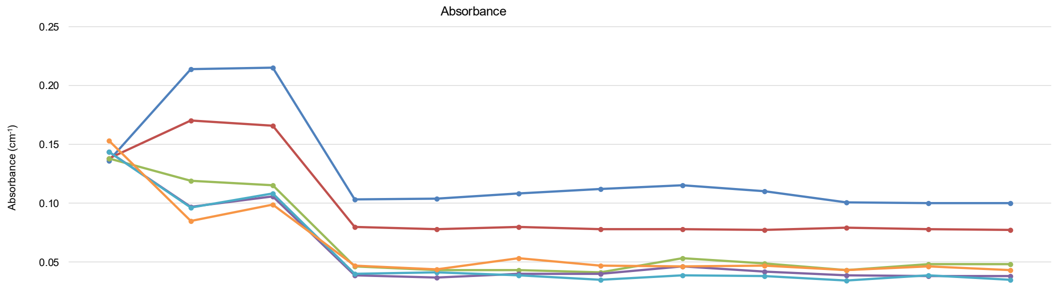
→ UV-Transmittance and Absorbance

The UVT (Figure 5-10) and absorbance (Figure 5-11) was found to decrease in quality, i.e. lower UVT and higher absorbance, in Post-DAF samples collected from July 24th to July 26th. However, from July 27th to July 28th, the UVT and absorbance improved in Post-DAF samples. There was little change in UVT or absorbance measured in Post-Ozone samples. Although the ozone was inactive in the pilot-scale system during this period, previous piloting sessions (Winter #1 and Spring) also found little change in UVT and absorbance following ozone treatment. Filtration improved the UVT and absorbance for all coagulant doses tested, with the greatest improvement occurring at a ferric sulphate dose of 38 mg/L.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
	Piloting											
UVT - 24-Jul - Pilot-Scale - (25 mg/L, 0 mg/L)	73.10	61.60	60.90	78.80	78.70	78.00	77.30	76.80	77.60	79.20	79.40	79.40
UVT - 25-Jul - Pilot-Scale - (28 mg/L, 0 mg/L)	72.90	67.50	68.10	83.20	83.60	83.20	83.50	83.50	83.80	83.30	83.60	83.70
UVT - 26-Jul - Pilot-Scale - (32 mg/L, 0 mg/L)	72.80	76.00	76.70	90.00	90.60	90.70	91.00	88.80	89.20	90.50	89.50	89.60
UVT - 27-Jul - Pilot-Scale - (35 mg/L, 0 mg/L)	71.70	80.00	78.30	91.50	91.70	91.30	91.30	90.10	90.80	91.40	91.60	91.60
UVT - 28-Jul - Pilot-Scale - (38 mg/L, 0 mg/L)	71.70	80.10	78.00	91.00	91.00	91.40	92.20	91.40	91.60	92.50	91.50	92.30
UVT - 29-Jul - Pilot-Scale - (42 mg/L, 0 mg/L)	70.20	81.80	79.80	89.70	90.30	88.50	89.70	89.90	89.80	90.60	89.90	90.30

Figure 5-10: UVT during the Summer piloting session for determining the optimal dose of ferric sulphate. The pilot-scale system pH was maintained at pH 6.0 with no addition of coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
	Piloting											
ABS - 24-Jul - Pilot-Scale - (25 mg/L, 0 mg/L)	0.14	0.21	0.22	0.10	0.10	0.11	0.11	0.12	0.11	0.10	0.10	0.10
ABS - 25-Jul - Pilot-Scale - (28 mg/L, 0 mg/L)	0.14	0.17	0.17	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
ABS - 26-Jul - Pilot-Scale - (32 mg/L, 0 mg/L)	0.14	0.12	0.12	0.05	0.04	0.04	0.04	0.05	0.05	0.04	0.05	0.05
ABS - 27-Jul - Pilot-Scale - (35 mg/L, 0 mg/L)	0.14	0.10	0.11	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04
ABS - 28-Jul - Pilot-Scale - (38 mg/L, 0 mg/L)	0.14	0.10	0.11	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04
ABS - 29-Jul - Pilot-Scale - (42 mg/L, 0 mg/L)	0.15	0.09	0.10	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.05	0.04

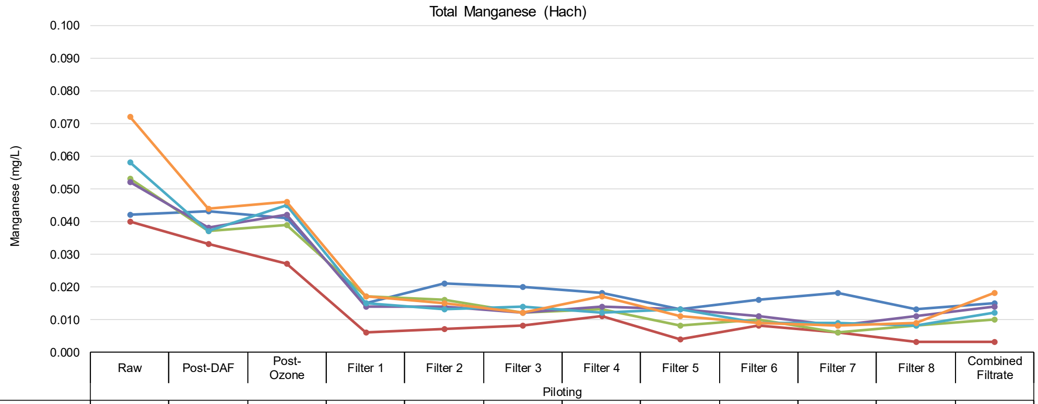
Figure 5-11: Absorbance during the Summer piloting session for determining the optimal dose of ferric sulphate. The pilot-scale system pH was maintained at pH 6.0 with no addition of coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

→ Total Manganese

As stated in TM No.3, a major focus of this project is to test if an alternative coagulant will reduce the concentrations of manganese entering the distribution system. Reducing the amount of manganese entering the distribution system may reduce the occurrence of discoloured water. The current alternative coagulant under investigation, ferric sulphate, has a lower residual manganese content compared to the current coagulant used in the full-scale system, ferric chloride.

It should be noted that the total manganese concentration in the raw water during the Summer piloting session was significantly higher than in the Winter #1 or Spring piloting sessions. Water treatment systems on the Canadian Shield often experience increased total manganese concentrations in summer months, which has historically been the case for the City of Winnipeg. The increase in manganese in these waters is due to an increase in solubility, which is a function of water temperature. Specifically, increases in surface water temperatures encourage water column inversion (due to changes in density). The result is that predominantly anoxic conditions found at the bottom of water bodies become more distributed throughout. With the mixing of decaying organic matter into the water column comes the probability that the raw water will exhibit an increased total manganese concentration. Furthermore, increased manganese may also be the result of the reduction of manganese oxide by anaerobic bacteria typically found in the bottom sediment. These compounding factors are likely the cause for the increase in raw water manganese measured during the Summer piloting session.

In the previous piloting sessions (Winter #1 and Spring), there was an increase in total manganese concentration Post-DAF, attributed to the addition of residual manganese from the ferric sulphate and natural manganese found in the source water. However, during the Summer piloting session, there was a lower concentration of total manganese measured in the Post-DAF samples compared to the incoming raw water (Figure 5-12).



Piloting	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Mn - 24-Jul - Pilot-Scale - (25 mg/L, 0 mg/L)	0.042	0.043	0.041	0.015	0.021	0.020	0.018	0.013	0.016	0.018	0.013	0.015
Mn - 25-Jul - Pilot-Scale - (28 mg/L, 0 mg/L)	0.040	0.033	0.027	0.006	0.007	0.008	0.011	0.004	0.008	0.006	0.003	0.003
Mn - 26-Jul - Pilot-Scale - (32 mg/L, 0 mg/L)	0.053	0.037	0.039	0.017	0.016	0.012	0.013	0.008	0.010	0.006	0.008	0.010
Mn - 27-Jul - Pilot-Scale - (35 mg/L, 0 mg/L)	0.052	0.038	0.042	0.014	0.014	0.012	0.014	0.013	0.011	0.008	0.011	0.014
Mn - 28-Jul - Pilot-Scale - (38 mg/L, 0 mg/L)	0.058	0.037	0.045	0.015	0.013	0.014	0.012	0.013	0.009	0.009	0.008	0.012
Mn - 29-Jul - Pilot-Scale - (42 mg/L, 0 mg/L)	0.072	0.044	0.046	0.017	0.015	0.012	0.017	0.011	0.009	0.008	0.009	0.018

Figure 5-12: Total manganese during the Summer piloting session for determining the optimal dose of ferric sulphate. The pilot-scale system pH was maintained at pH 6.0 with no addition of coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

All ferric sulphate dosages tested (with the exception of 42 mg/L) achieved the combined filtrate total manganese target of 0.015 mg/L. A ferric sulphate dose of 42 mg/L produced a combined filtrate total manganese concentration of 0.018 mg/L. The lowest total manganese concentration in the combined filtrate (0.003mg/L) occurred on July 25th, at a ferric sulphate dose of 28 mg/L. It should be noted, however, that there was a large range of raw water total manganese concentrations (0.040mg/L to 0.072mg/L) with the lowest raw water total manganese concentration occurring simultaneously to testing the dosage of 28 mg/L and the highest raw water total manganese concentration occurring when testing the dosage of 42 mg/L. It can therefore not be determined with certainty which dosage was the optimal dose for manganese reduction. However, it can be said that ferric sulphate was successful at reducing manganese levels in the combined filtrate at all concentrations tested.

→ UFRV

Figure 5-13 illustrates the average observed and forecasted UFRV values obtained for each coagulant dose for Bank A and Bank B. During optimization of the coagulant dose, Bank A overflowed every cycle, while Bank B did not. However, all individual filters failed based on turbidity (> 0.1 NTU) at all coagulant doses tested. At ferric sulphate doses of 28, 32 and 42 mg/L, both banks presented turbidity measurements above 0.3 NTU .

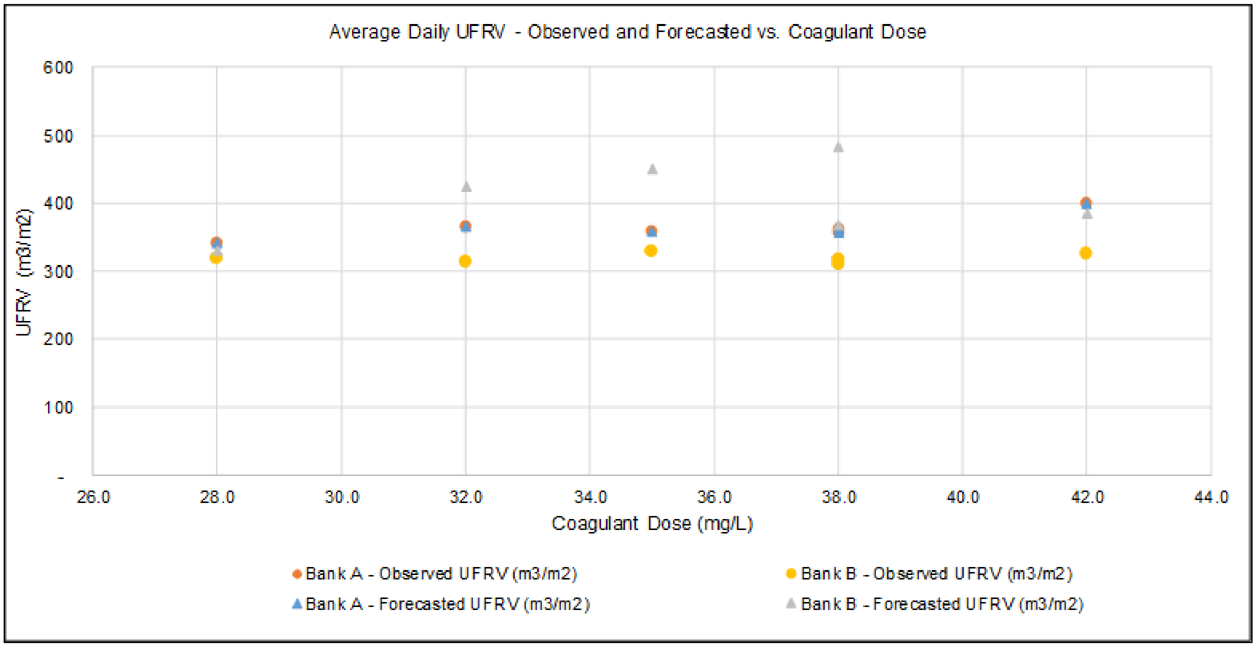


Figure 5-13: Average UFRV values of the pilot-scale system Bank A at an average flow of 0.6 L/s and Bank B at an average flow of 0.3 L/s during the Summer piloting session for determining the optimal dose of ferric sulphate. The pilot-scale system pH was maintained at pH 6.0 with no addition of coagulant-aid. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

Considering the results for Bank B, the average forecasted UFRV values increased as the coagulant dose increased to 38 mg/L, whereas a decrease in UFRV values was observed at 42 mg/L. The highest observed UFRV value for Bank A (400 m^3/m^2) was obtained at the coagulant dose of 42 mg/L, but all individual filters failed based on turbidity measurements above 0.3 NTU at this dose the expected UFRV would be smaller. The highest forecasted UFRV value for Bank B (483 m^3/m^2) was obtained at the coagulant dose of 38 mg/L; however, all individual filters failed based on turbidity above 0.1 NTU at this dose therefore the expected UFRV is actually smaller.

Although all UFRV values for both filter banks were above 200 m^3/m^2, all individual filters failed based on turbidity (> 0.1 NTU) and the full-scale system operating license of 0.3 NTU at ferric sulphate doses of 28, 32 and 42 mg/L. Thus, the expected UFRV values would be lower than what observed in Figure 5-13, as such, the performance of pilot-scale system filters was deemed poor at all doses.

Considering the URFV results above, the coagulant dose of 38 mg/L is considered to be the optimal dose under the context that the results from Bank B are favoured as its operational parameters are closer to that of the full-scale system. However, based on this, it is not possible to establish if the full-scale system would experience difficulties in meeting demands to produce sufficient treated water (inclusive of filter backwashing) at these operating conditions.

→ Summary of Ferric Sulphate Optimization

Overall, the results from the four key parameters testing found the optimal dose of ferric sulphate under warm water conditions to be 38 mg/L. The UFRV analysis conducted following the Summer piloting session confirmed the same optimal dose.

5.6.2 Optimization of pH

Optimal pH testing was conducted between July 31st and August 3rd, 2017. An analogous approach to the optimization of the coagulant was taken in determining the optimal pH. The optimal pH was determined using the optimal ferric sulphate dose of 38 mg/L, and no coagulant-aid. It should be noted that the initial intended pH range for testing was between 5.65 and 6.55, however, during testing, a significant reduction in water quality was found with increasing pH. Therefore, following consultation with the City, it was determined that the pH of 6.55 would be abandoned and alternatively a pH of range of 5.65 – 6.25 would be tested.

As previously noted, the pH during coagulation was controlled by adjusting the sulphuric acid dose to the raw water before coagulation, according to a pH set point within the pH controller which is set according to a desired target Post-DAF pH. Table 5-2 tabulates the target Post-DAF pH and illustrates that the pH was well maintained by the pH controller, with the greatest deviation from the target pH occurring on July 31st.

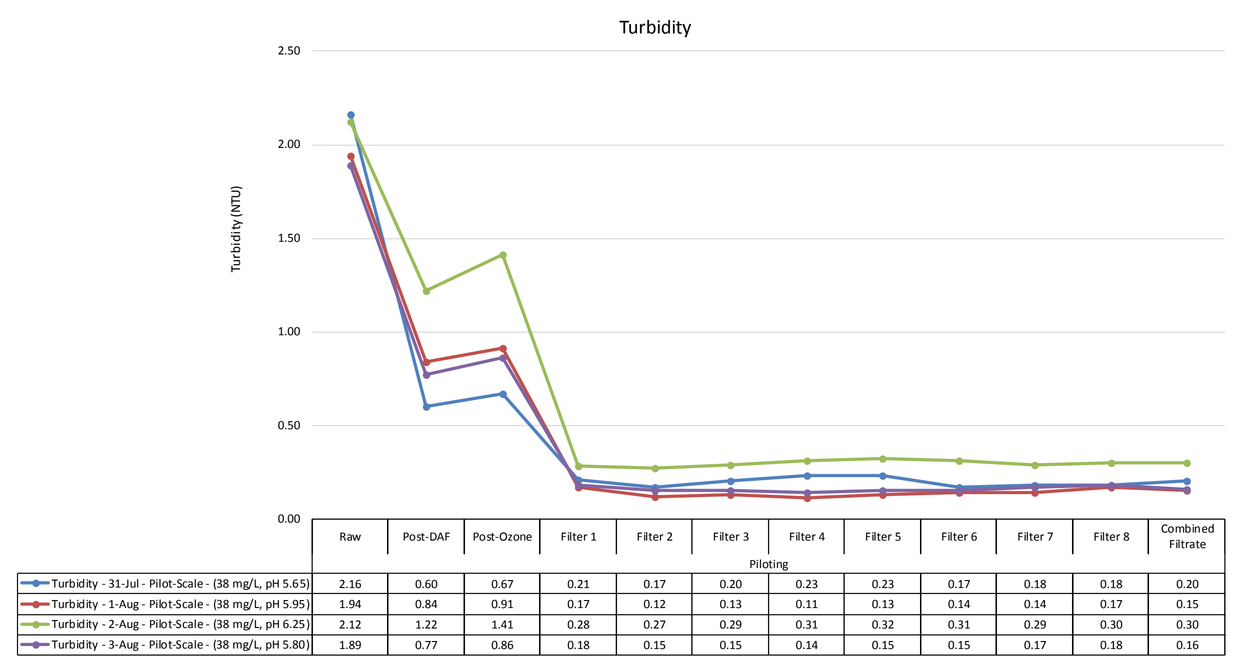
Table 5-2: Target and Post-DAF pH during pH optimization. Data originates from benchtop analysis of grab samples collected from the Post-DAF overflow using a Thermo Scientific Orion Star A325 pH probe.

Date	Target Post-DAF pH	Measured Post-DAF pH
31-Jul-17	5.65	5.71
01-Aug-17	5.95	5.99
02-Aug-17	6.25	6.27
03-Aug-17	5.80	5.83

On July 31st, onsite WSP personnel noted fluctuations in the Post-DAF pH before the daily sampling. Following discussion with the City instrumental technician, it was determined that an improvement in the controller logic was required to better control acid addition based on small fluctuations in raw water flow rate. Correction in the logic reduced the deviation from the target Post-DAF pH for the remainder of the pH optimization period. The minor deviations from target Post-DAF pH are unlikely to alter the results significantly.

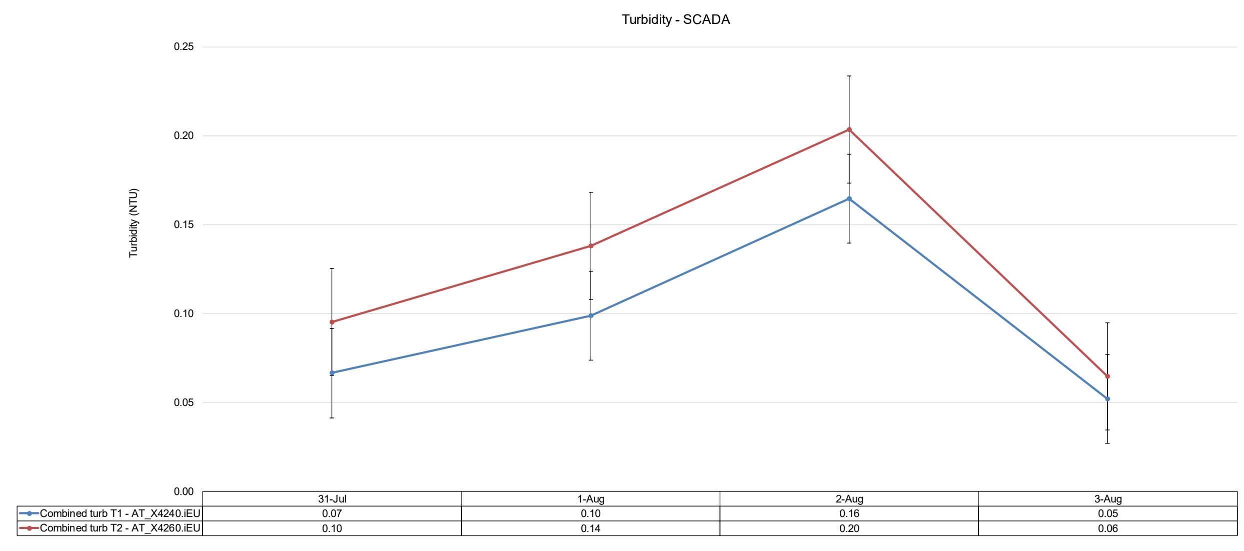
→ Turbidity

The turbidity results show the Post-DAF turbidity increased with increasing pH, with the optimal reduction occurring at a measured pH of 5.71 (target pH of 5.65). However, the filtered water turbidity was found to decrease with increasing pH from 5.71 to 5.99 (target pH of 5.65 to 5.95), followed by a significant increase in turbidity at a pH of 6.27 (target pH of 6.25) (Figure 5-14). Therefore, when taking into consideration the reduction in turbidity in Post-DAF water and combined filter effluent, the optimal pH was determined to be 5.83 (target pH of 5.80). The online turbidity meters for the combined filter effluent from Bank A and Bank B also exhibit the lowest turbidity occurred at a pH of 5.83 providing confirmatory results to the grab samples collected (Figure 5-15).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Turbidity - 31-Jul - Pilot-Scale - (38 mg/L, pH 5.65)	2.16	0.60	0.67	0.21	0.17	0.20	0.23	0.23	0.17	0.18	0.18	0.20
Turbidity - 1-Aug - Pilot-Scale - (38 mg/L, pH 5.95)	1.94	0.84	0.91	0.17	0.12	0.13	0.11	0.13	0.14	0.14	0.17	0.15
Turbidity - 2-Aug - Pilot-Scale - (38 mg/L, pH 6.25)	2.12	1.22	1.41	0.28	0.27	0.29	0.31	0.32	0.31	0.29	0.30	0.30
Turbidity - 3-Aug - Pilot-Scale - (38 mg/L, pH 5.80)	1.89	0.77	0.86	0.18	0.15	0.15	0.14	0.15	0.15	0.17	0.18	0.16

Figure 5-14: Turbidity during the Summer piloting session for determining the optimal pH. The pilot-scale system coagulant dose was maintained at 38 mg/L with no addition of coagulant-aid. Data originates from benchtop analysis using a Hach 2100Q turbidimeter. pH listed are the target pH for each day.

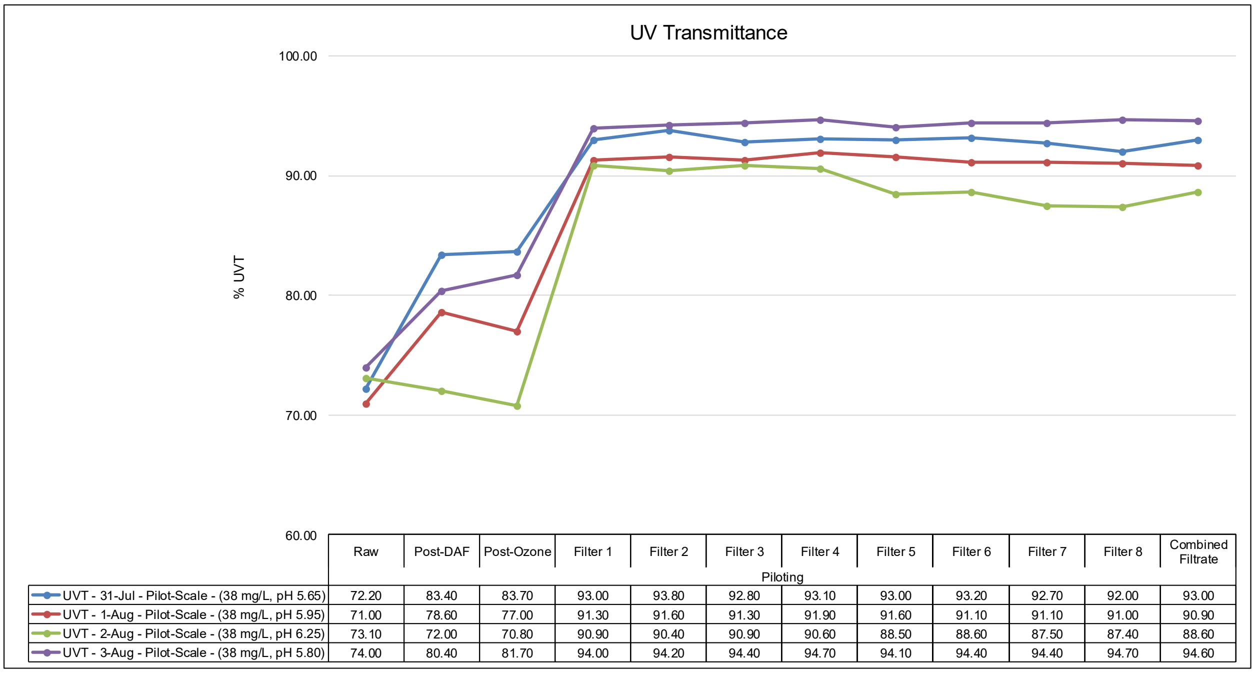


	31-Jul	1-Aug	2-Aug	3-Aug
Combined turb T1 - AT_X4240.iEU	0.07	0.10	0.16	0.05
Combined turb T2 - AT_X4260.iEU	0.10	0.14	0.20	0.06

Figure 5-15: Daily average turbidity of the pilot-scale system final combined filter effluent (Bank A being Filters 1-4 and Bank B being Filters 5- 8) during the Summer piloting session for determining the optimal pH. The pilot-scale system coagulant dose was maintained at 38 mg/L with no addition of coagulant-aid. Data originates from the pilot-scale system's SCADA dataset.

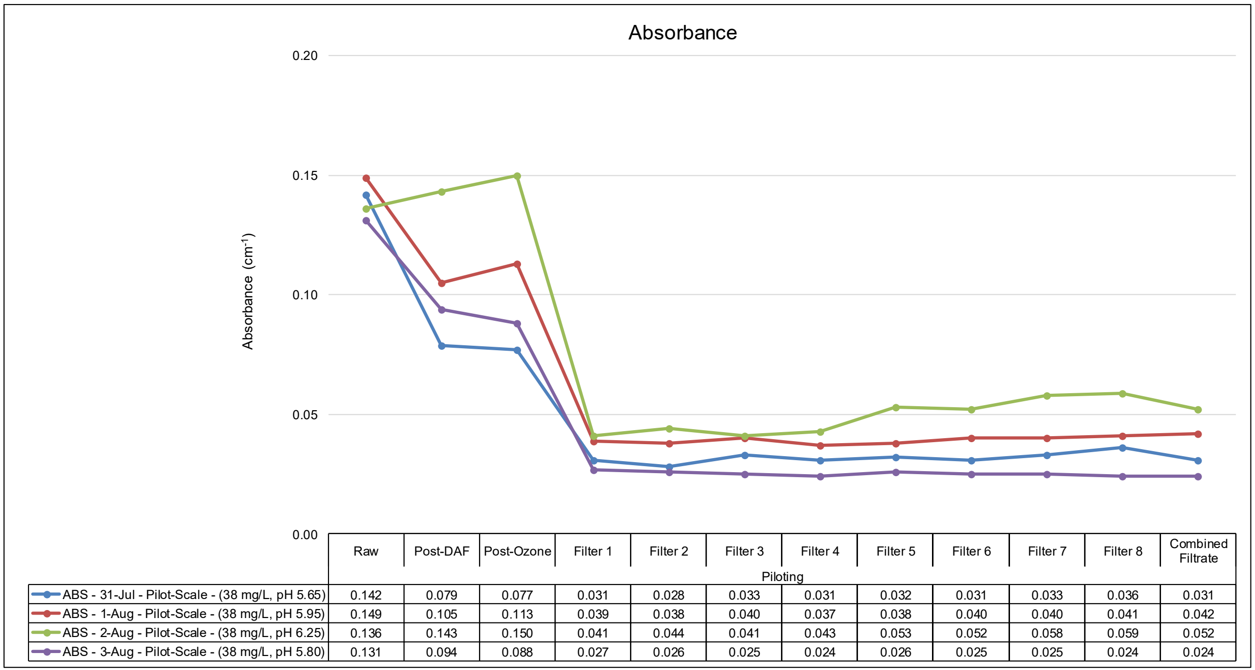
→ UV-Transmittance and Absorbance

The UVT and absorbance results are presented in Figure 5-16 and Figure 5-17. The results show from pH 5.71 to 5.99 (target pH of 5.65 to 5.95) there was a slight improvement in UVT and absorbance in Post-DAF samples. However, at pH 6.27 (target pH of 6.25) there was a decline in water quality with regards to UVT and absorbance following coagulation and DAF. The combined filter results indicate the best UVT and absorbance occurred at a measured pH of 5.83 (target pH of 5.80), with a steady decline in quality as pH increased.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
UVT - 31-Jul - Pilot-Scale - (38 mg/L, pH 5.65)	72.20	83.40	83.70	93.00	93.80	92.80	93.10	93.00	93.20	92.70	92.00	93.00
UVT - 1-Aug - Pilot-Scale - (38 mg/L, pH 5.95)	71.00	78.60	77.00	91.30	91.60	91.30	91.90	91.60	91.10	91.10	91.00	90.90
UVT - 2-Aug - Pilot-Scale - (38 mg/L, pH 6.25)	73.10	72.00	70.80	90.90	90.40	90.90	90.60	88.50	88.60	87.50	87.40	88.60
UVT - 3-Aug - Pilot-Scale - (38 mg/L, pH 5.80)	74.00	80.40	81.70	94.00	94.20	94.40	94.70	94.10	94.40	94.40	94.70	94.60

Figure 5-16: UVT during the Summer piloting session for determining the optimal pH. The pilot-scale system coagulant dose was maintained at 38 mg/L with no addition of coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer. pH listed are the target pH for each day.

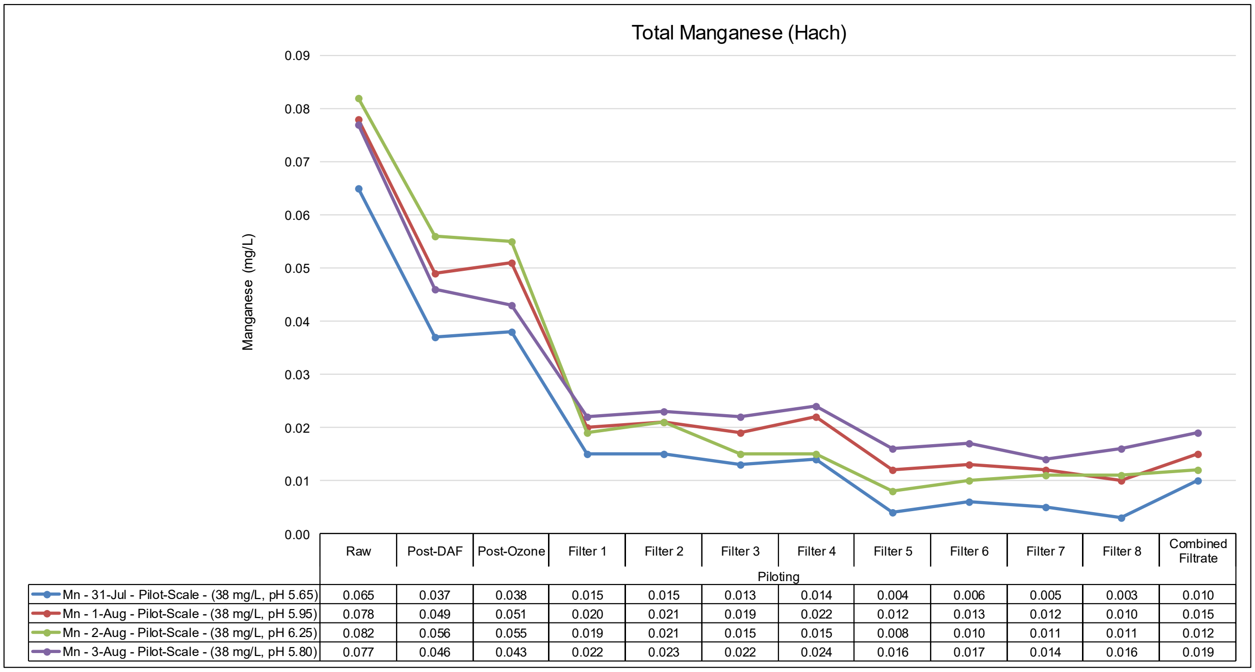


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
ABS - 31-Jul - Pilot-Scale - (38 mg/L, pH 5.65)	0.142	0.079	0.077	0.031	0.028	0.033	0.031	0.032	0.031	0.033	0.036	0.031
ABS - 1-Aug - Pilot-Scale - (38 mg/L, pH 5.95)	0.149	0.105	0.113	0.039	0.038	0.040	0.037	0.038	0.040	0.040	0.041	0.042
ABS - 2-Aug - Pilot-Scale - (38 mg/L, pH 6.25)	0.136	0.143	0.150	0.041	0.044	0.041	0.043	0.053	0.052	0.058	0.059	0.052
ABS - 3-Aug - Pilot-Scale - (38 mg/L, pH 5.80)	0.131	0.094	0.088	0.027	0.026	0.025	0.024	0.026	0.025	0.025	0.024	0.024

Figure 5-17: Absorbance during the Summer piloting session for determining the optimal pH. The pilot-scale system coagulant dose was maintained at 38 mg/L with no addition of coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer. pH listed are the target pH for each day.

→ Total Manganese

The raw water manganese concentration is illustrated in Figure 5-18. All pH levels tested (with the exception of 5.8 (target)) achieved the combined filtrate total manganese target of 0.015 mg/L. A pH of 5.8 (target) produced a combined filtrate total manganese concentration of 0.019 mg/L. The lowest total manganese concentration in the combined filtrate (0.010 mg/L) occurred at a pH of 5.65 (target). It should be noted, however, that the lowest raw water total manganese concentration (0.065 mg/L) occurred at a pH level of 5.65 (target). At all other pH levels tested, the raw water total manganese levels were very similar (between 0.077 to 0.082 mg/L of total manganese). Of these, a pH level of 6.25 (target) produced the lowest total manganese concentration in the combined filtrate (0.012 mg/L).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Mn - 31-Jul - Pilot-Scale - (38 mg/L, pH 5.65)	0.065	0.037	0.038	0.015	0.015	0.013	0.014	0.004	0.006	0.005	0.003	0.010
Mn - 1-Aug - Pilot-Scale - (38 mg/L, pH 5.95)	0.078	0.049	0.051	0.020	0.021	0.019	0.022	0.012	0.013	0.012	0.010	0.015
Mn - 2-Aug - Pilot-Scale - (38 mg/L, pH 6.25)	0.082	0.056	0.055	0.019	0.021	0.015	0.015	0.008	0.010	0.011	0.011	0.012
Mn - 3-Aug - Pilot-Scale - (38 mg/L, pH 5.80)	0.077	0.046	0.043	0.022	0.023	0.022	0.024	0.016	0.017	0.014	0.016	0.019

Figure 5-18: Total manganese during the Summer piloting session for determining the optimal pH. The pilot-scale system coagulant dose was maintained at 38 mg/L with no addition of coagulant-aid. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer. pH listed are the target pH for each day.

→ UFRV

Figure 5-19 illustrates the average observed and forecasted UFRV values obtained for each pH. During pH optimization, Bank A overflowed every cycle, while Bank B did not overflow every cycle. However, all individual filters failed based on turbidity (> 0.1 NTU) at all pH tested. At the highest pH of 6.27 (target pH of 6.25), Filters 4, 5 and 6 presented a turbidity measurement above 0.3 NTU .

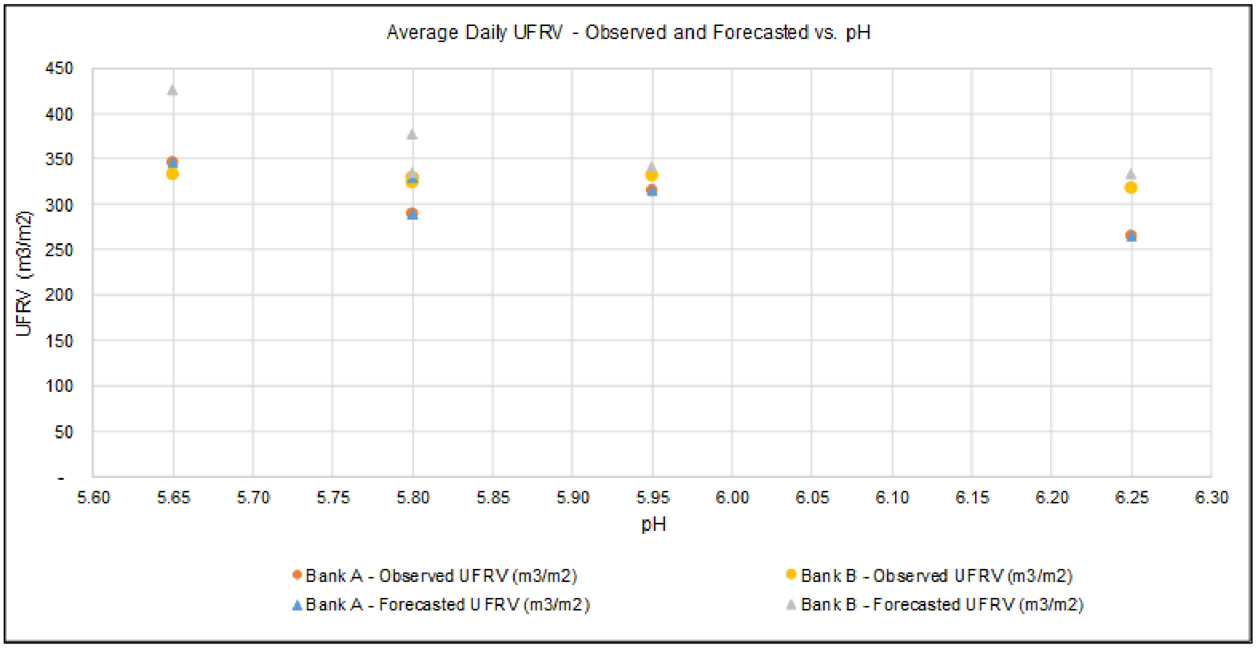


Figure 5-19: Average UFRV values of the pilot-scale system Bank A at an average flow of 0.6 L/s and Bank B at an average flow of 0.3 L/s during the Summer piloting session for determining the optimal pH. The pilot-scale system coagulant dose was maintained at 38 mg/L with no addition of coagulant-aid. Note: Observed and forecasted UFRV values may overlap. Note: pH of 5.8 was tested for two days. Data originates from the pilot-scale system's SCADA dataset.

The forecasted UFRV values for both filter banks decreased with increasing pH. The highest forecasted UFRV values (345 and 426 m^3/m^2 for Bank A and Bank B, respectively) were obtained at the lowest target pH of 5.65.

Although the forecasted UFRV values ranged the minimum UFRV value of 200 m^3/m^2 from half to double of this value at the target pH's of 5.65 and 5.80, all individual filters failed based on turbidity (> 0.1 NTU) at these pH values when considering the bench-top analysis of turbidity. Thus, the expected UFRV would be lower than what observed on Figure 5-19.

When observing the turbidity Lab analysis available for a target pH of 5.80 (August 4th) and discarding Filter 1 data, the combined filter effluent turbidity was 0.11 NTU (Figure 5-26). Therefore, the target pH of 5.80 could be applied at the full-scale system to meet the production demands (inclusive of filter backwashing) and it is considered to be the optimal pH.

→ Summary of pH Optimization

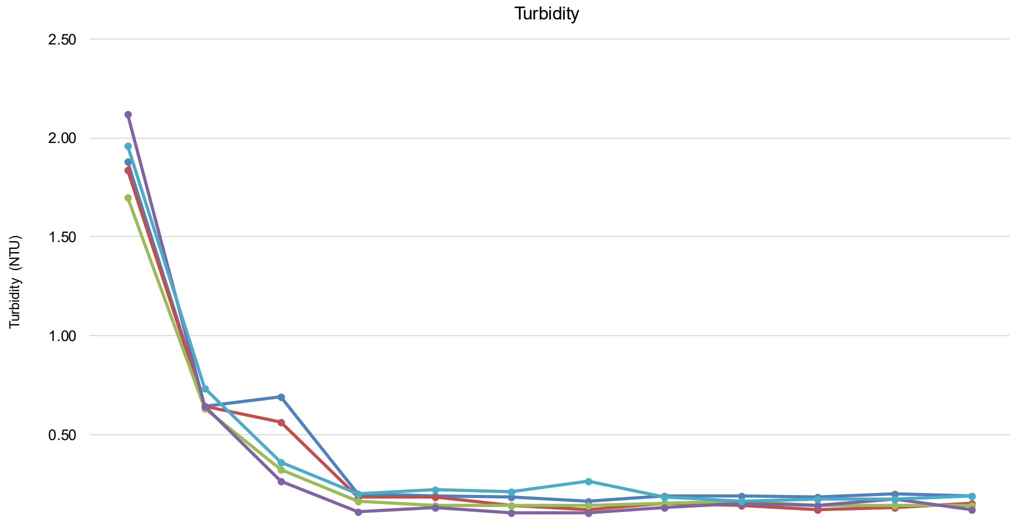
Overall, the optimal pH was determined to be 5.83 (the target pH of 5.80), based on turbidity, UVT, and absorbance results. A pH level of 5.83 (the target pH of 5.80) was not determined to be the optimal pH for manganese removal however it did yield a 75% reduction of total manganese (based on the combined filter). The turbidity, UVT, absorbance, as well as the significant decrease in total manganese indicated a target pH of 5.80 as the optimal pH for ferric sulphate in warm water conditions.

5.6.3 Optimization of Coagulant-aid

The optimization of the coagulant-aid LT-22S dose was conducted from August 5th to August 9th, 2017. An analogous approach to the optimization of the coagulant was taken in determining the ideal dose of the coagulant-aid. The optimal coagulant dose of 38 mg/L and a target Post-DAF pH of 5.80 was maintained throughout the optimization of coagulant-aid.

→ Turbidity

Turbidity results during the optimization of coagulant-aid are shown in Figure 5-20. The results found a significant reduction in raw water turbidity following DAF treatment for all doses of coagulant-aid tested. The turbidity in the combined filtrate was found to decrease as the coagulant-aid dose was increased; however, there was an increase in turbidity at the highest coagulant-aid dose tested (0.25 mg/L). The optimal dose of coagulant-aid, based on the turbidity of the combined filter effluent was 0.20 mg/L.



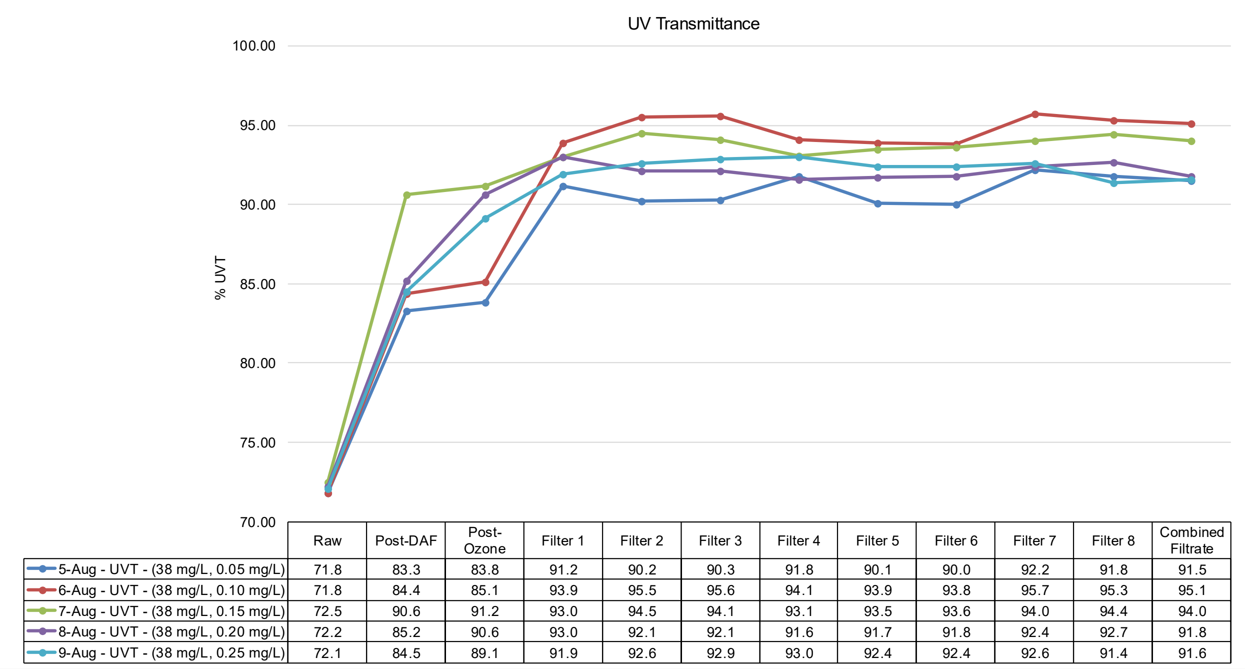
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Turbidity - 5-Aug (38 mg/L, 0.05 mg/L)	1.88	0.64	0.69	0.20	0.19	0.18	0.16	0.19	0.19	0.18	0.20	0.19
Turbidity - 6-Aug (38 mg/L, 0.10 mg/L)	1.84	0.64	0.56	0.18	0.18	0.14	0.12	0.15	0.14	0.12	0.13	0.15
Turbidity - 7-Aug (38 mg/L, 0.15 mg/L)	1.70	0.63	0.32	0.16	0.14	0.14	0.14	0.15	0.16	0.14	0.14	0.14
Turbidity - 8-Aug (38 mg/L, 0.20 mg/L)	2.12	0.64	0.26	0.11	0.13	0.10	0.10	0.13	0.15	0.14	0.17	0.12
Turbidity - 9-Aug (38 mg/L, 0.25 mg/L)	1.96	0.73	0.36	0.20	0.22	0.21	0.26	0.18	0.16	0.17	0.17	0.19

Figure 5-20: Turbidity during the Summer piloting session for determining the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 38 mg/L and pH was maintained at pH 5.80. Data originated from benchtop analyses using a Hach 2100Q turbidimeter.

Observations of the pilot-scale system found that the pilot-scale system had better overall turbidity removal for all doses of coagulant-aid. This implies the addition of coagulant-aid to the full-scale system DAF may improve both Post-DAF and filter effluent turbidity.

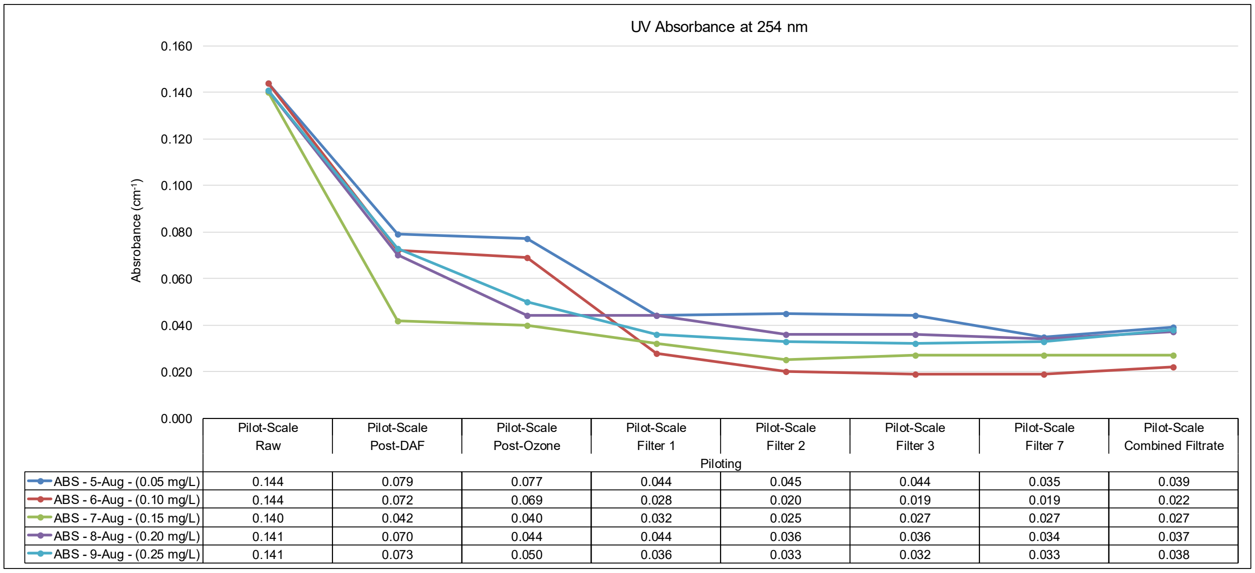
→ UV-Transmittance and Absorbance

The UVT and absorbance results are illustrated in Figure 5-21 and Figure 5-22. The results indicate both parameters improved following coagulation and DAF treatment up to 0.15 mg/L, where subsequent increases in coagulant-aid reduced water quality with regards to UVT and absorbance. The combined filter effluent results show the greatest improvement occurred at a coagulant-aid dose of 0.10 mg/L, with UVT and an absorbance of 95.1% and 0.022 cm^{-1}, respectively.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
5-Aug - UVT - (38 mg/L, 0.05 mg/L)	71.8	83.3	83.8	91.2	90.2	90.3	91.8	90.1	90.0	92.2	91.8	91.5
6-Aug - UVT - (38 mg/L, 0.10 mg/L)	71.8	84.4	85.1	93.9	95.5	95.6	94.1	93.9	93.8	95.7	95.3	95.1
7-Aug - UVT - (38 mg/L, 0.15 mg/L)	72.5	90.6	91.2	93.0	94.5	94.1	93.1	93.5	93.6	94.0	94.4	94.0
8-Aug - UVT - (38 mg/L, 0.20 mg/L)	72.2	85.2	90.6	93.0	92.1	92.1	91.6	91.7	91.8	92.4	92.7	91.8
9-Aug - UVT - (38 mg/L, 0.25 mg/L)	72.1	84.5	89.1	91.9	92.6	92.9	93.0	92.4	92.4	92.6	91.4	91.6

Figure 5-21: UVT during the Summer piloting session for determining the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 38 mg/L and pH was maintained at pH 5.80. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

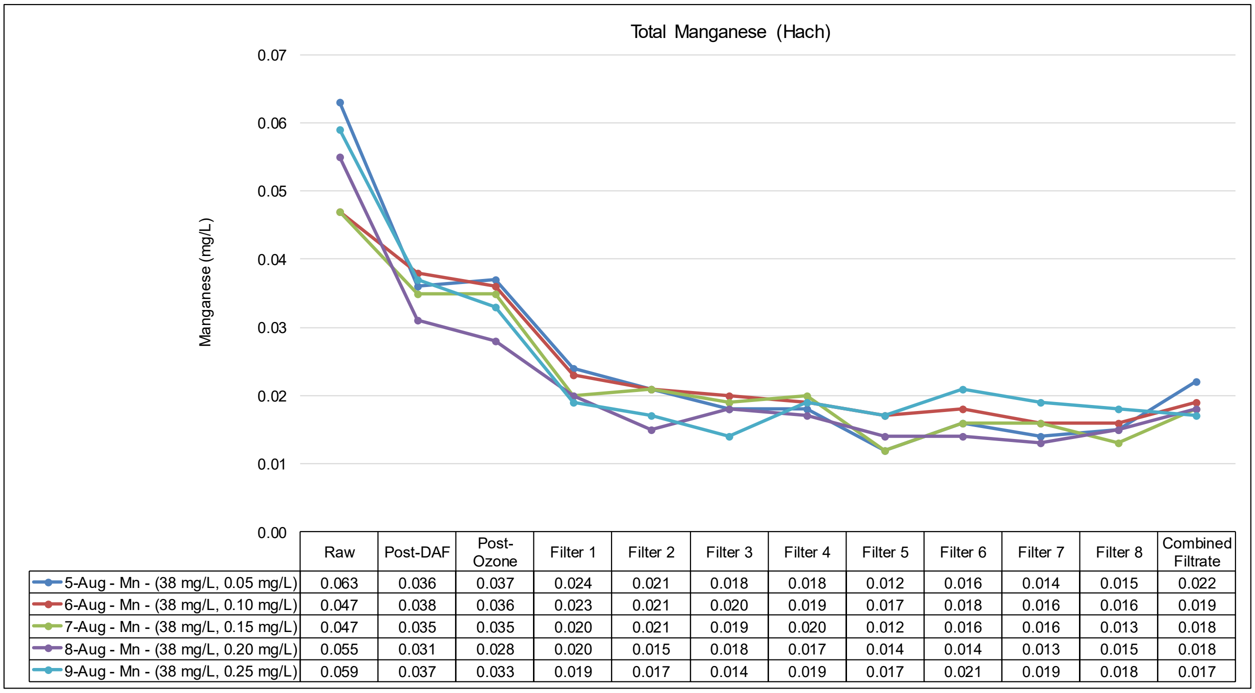


	Pilot-Scale Raw	Pilot-Scale Post-DAF	Pilot-Scale Post-Ozone	Pilot-Scale Filter 1	Pilot-Scale Filter 2	Pilot-Scale Filter 3	Pilot-Scale Filter 7	Pilot-Scale Combined Filtrate
ABS - 5-Aug - (0.05 mg/L)	0.144	0.079	0.077	0.044	0.045	0.044	0.035	0.039
ABS - 6-Aug - (0.10 mg/L)	0.144	0.072	0.069	0.028	0.020	0.019	0.019	0.022
ABS - 7-Aug - (0.15 mg/L)	0.140	0.042	0.040	0.032	0.025	0.027	0.027	0.027
ABS - 8-Aug - (0.20 mg/L)	0.141	0.070	0.044	0.044	0.036	0.036	0.034	0.037
ABS - 9-Aug - (0.25 mg/L)	0.141	0.073	0.050	0.036	0.033	0.032	0.033	0.038

Figure 5-22: Absorbance during the Summer piloting session for determining the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 38 mg/L and pH was maintained at pH 5.80. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

→ Total Manganese

The reduction of total manganese during coagulant-aid optimization is presented in Figure 5-23. The results indicate DAF treatment reduced total manganese by 19-44% for all coagulant-aid doses tested. Filtration removed an additional 36-49% of the raw water total manganese (based on combined filter concentration). The total manganese in the final combined filter effluent did not deviate greatly between coagulant-aid doses, ranging from 0.017 mg/L to 0.022 mg/L. The lowest total manganese concentration in the final effluent occurred at a coagulant-aid dose of 0.25 mg/L.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
5-Aug - Mn - (38 mg/L, 0.05 mg/L)	0.063	0.036	0.037	0.024	0.021	0.018	0.018	0.012	0.016	0.014	0.015	0.022
6-Aug - Mn - (38 mg/L, 0.10 mg/L)	0.047	0.038	0.036	0.023	0.021	0.020	0.019	0.017	0.018	0.016	0.016	0.019
7-Aug - Mn - (38 mg/L, 0.15 mg/L)	0.047	0.035	0.035	0.020	0.021	0.019	0.020	0.012	0.016	0.016	0.013	0.018
8-Aug - Mn - (38 mg/L, 0.20 mg/L)	0.055	0.031	0.028	0.020	0.015	0.018	0.017	0.014	0.014	0.013	0.015	0.018
9-Aug - Mn - (38 mg/L, 0.25 mg/L)	0.059	0.037	0.033	0.019	0.017	0.014	0.019	0.017	0.021	0.019	0.018	0.017

Figure 5-23: Total Manganese during the Summer piloting session for determining the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 38 mg/L and pH was maintained at pH 5.80. Data originated from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

→ UFRV

Figure 5-24 illustrates the average observed and forecasted UFRV values obtained for each coagulant-aid dose for Bank A and Bank B. During optimization of the coagulant-aid dose, Bank A and Bank B overflowed every cycle. However, all individual filters failed based on turbidity mesurements (> 0.1 NTU) at all coagulant-aid doses tested, except Filters 3 and 4 at coagulant-aid dose of 0.2 mg/L. No breakthrough with a turbidity measurement above 0.3 NTU was observed for both filter banks at sampling time.

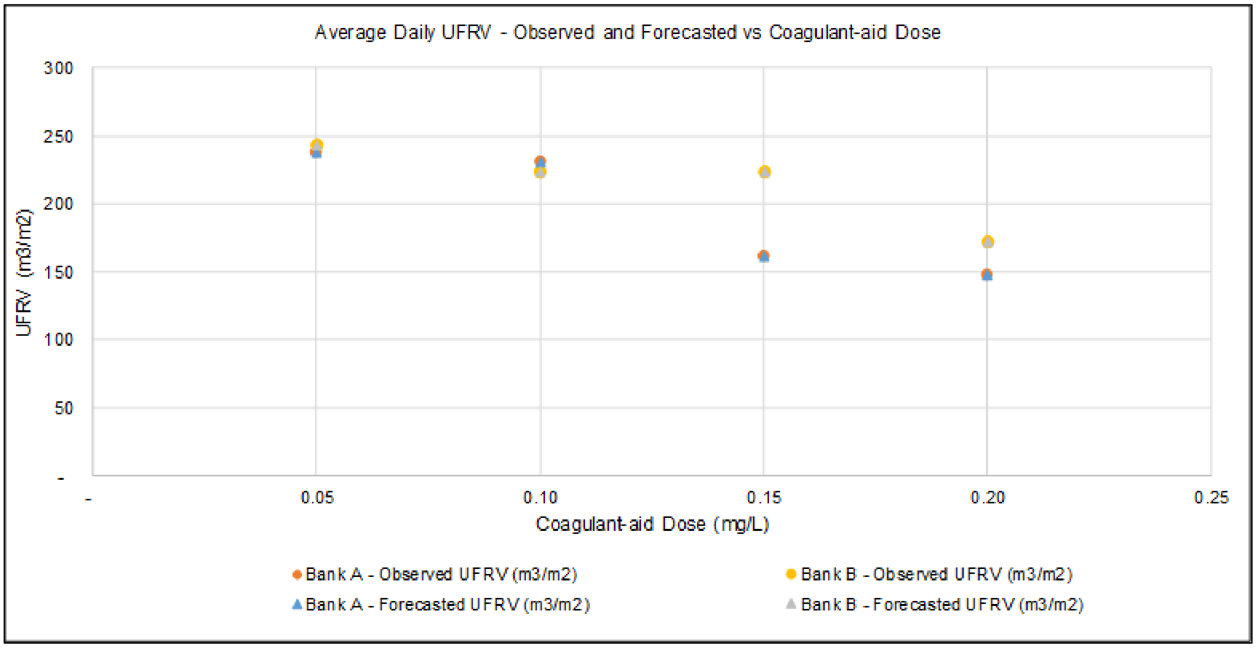


Figure 5-24: Average UFRV values of the pilot-scale Bank A at an average flow of 0.6 L/s and Bank B at an average flow of 0.3 L/s during the Summer piloting session for determining the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 38 mg/L and pH was maintained at pH 5.80. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

The observed UFRV values for both filter banks decreased when the coagulant-aid dose increase. The highest observed UFRV values (238 and 244 m^3/m^2 for Bank A and Bank B, respectively) were obtained at the lowest coagulant-aid dose of 0.05 mg/L and is thus considered to be the optimal coagulant-aid dose.

Although the forecasted UFRV values were higher than 200 m^3/m^2 at the coagulant-aid doses of 0.05 and 0.1 mg/L, all individual filters failed based on turbidity measurements above 0.1 NTU at these doses and, as such, the expected UFRV would be smaller. Due to this, it is not possible to establish if the full-scale system would meet production demands (inclusive of backwashing water) at these coagulant-aid doses.

→ Summary of Coagulant-aid Optimization

In summary, from onsite observations, it is believed that the minor improvements in total manganese reduction at a coagulant-aid dose of 0.25 mg/L does not justify the increased cleaning required to maintain the system. Therefore, based on turbidity, UVT, and absorbance, the optimal dose for coagulant-aid was determined to be 0.10 mg/L. The UFRV analysis performed following the piloting session did not confirm the same optimal dose and found the highest UFRVs are the coagulant-aid dose of 0.05 mg/L. However, filters failed based on turbidity measurements above 0.1 NTU at all coagulant-aid doses.

It should be noted that onsite WSP personnel reported carryover of floc in the Post-DAF overflow pipe with a coagulant-aid dose of 0.25 mg/L. Furthermore, it was reported that significant buildup of coagulant and/or coagulant-aid in the online instrumentation occurred at higher coagulant-aid doses. It is expected that the addition of coagulant-aid would increase the adhesive properties of the coagulant which, in turn, leads to a greater likelihood of residual buildup of coagulant and or coagulant-aid within the system (equipment and online instrumentation). This would require increased maintenance to remove the buildup from the system and maintain accurate online monitoring of treatment parameters, namely turbidity.

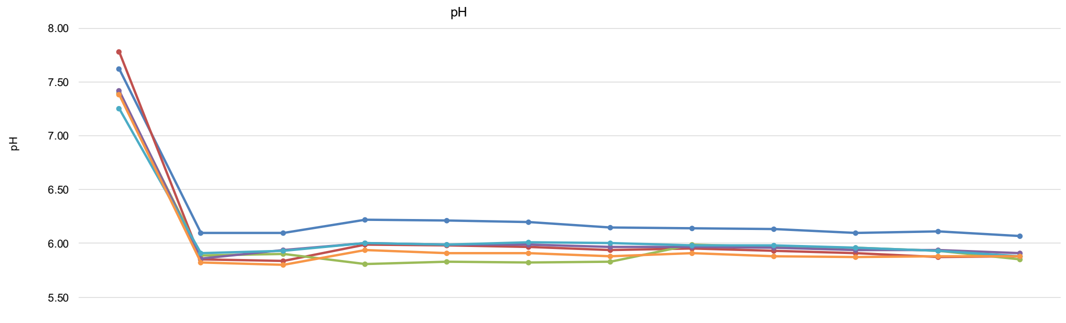
5.7 Optimized Condition Results

The following sections present results for the optimized chemical conditions found during the Summer piloting session. During the Summer piloting session, the optimal conditions were tested for each optimization period.

- July 30th represents the optimal coagulant dose of 38 mg/L at a pH of 6.0 and no coagulant-aid addition.
- August 4th tested the optimal pH of 5.80, at the optimal coagulant dose of 38 mg/L, and no coagulant-aid.
- August 14th to August 17th represent testing periods where all three optimal conditions were used: coagulant dose of 38 mg/L; pH of 5.80; and a coagulant-aid dose of 0.10 mg/L, respectively.

→ pH

Figure 5-25 shows the results for the change in pH during optimized conditions. The target Post-DAF was well maintained; however, during the addition of coagulant-aid between August 14th and August 17th, there was difficulty in achieving the desired Post-DAF pH. This was due to the aforementioned pH change from the addition of coagulant-aid that was not accounted for by the pH controller. August 17th had the closest Post-DAF pH to target pH of 5.82.

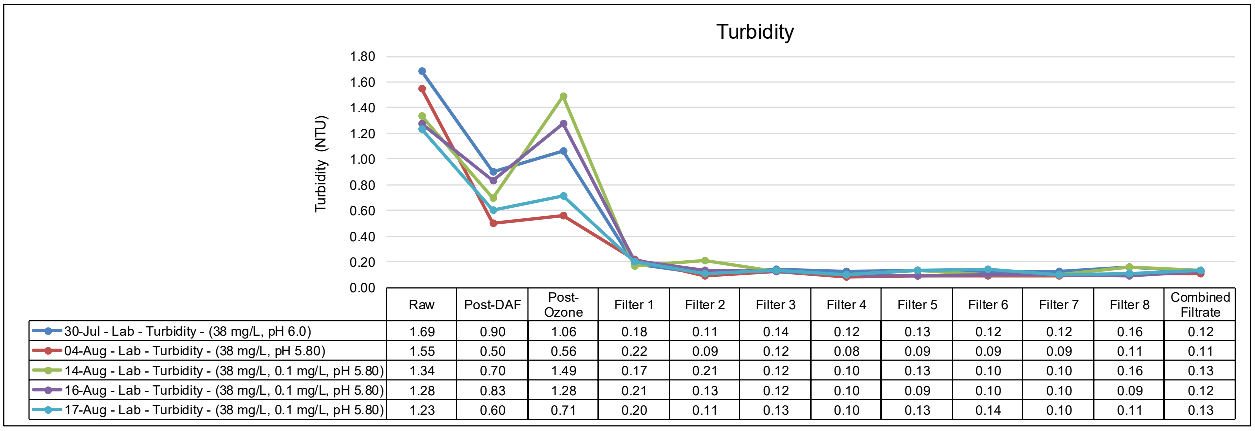


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-Jul - pH - (38 mg/L, pH 6.0)	7.62	6.10	6.10	6.22	6.21	6.20	6.15	6.14	6.13	6.10	6.11	6.07
4-Aug - pH - (38 mg/L, pH 5.80)	7.78	5.85	5.84	5.99	5.98	5.97	5.94	5.95	5.93	5.91	5.87	5.88
14-Aug - pH - (38 mg/L, 0.1 mg/L, pH 5.80)	7.40	5.89	5.90	5.81	5.83	5.82	5.83	5.99	5.97	5.96	5.93	5.85
15-Aug - pH - (38 mg/L, 0.1 mg/L, pH 5.80)	7.42	5.86	5.94	6.00	5.99	5.99	5.97	5.97	5.96	5.94	5.94	5.91
16-Aug - pH - (38 mg/L, 0.1 mg/L, pH 5.80)	7.25	5.91	5.93	6.00	5.99	6.01	6.00	5.98	5.98	5.96	5.93	5.88
17-Aug - pH - (38 mg/L, 0.1 mg/L, pH 5.80)	7.38	5.82	5.80	5.94	5.91	5.91	5.88	5.91	5.88	5.87	5.88	5.88

Figure 5-25: pH during the Summer piloting session at optimal conditions. Data originates from benchtop analysis using a Thermo Scientific Orion Star A325 pH probe.

→ Turbidity

The turbidity levels at the optimal conditions can be found in Figure 5-26. These results, under optimal conditions, found similar trends for the reduction of turbidity with a significant reduction following coagulation and DAF, and a further reduction in turbidity following filtration.



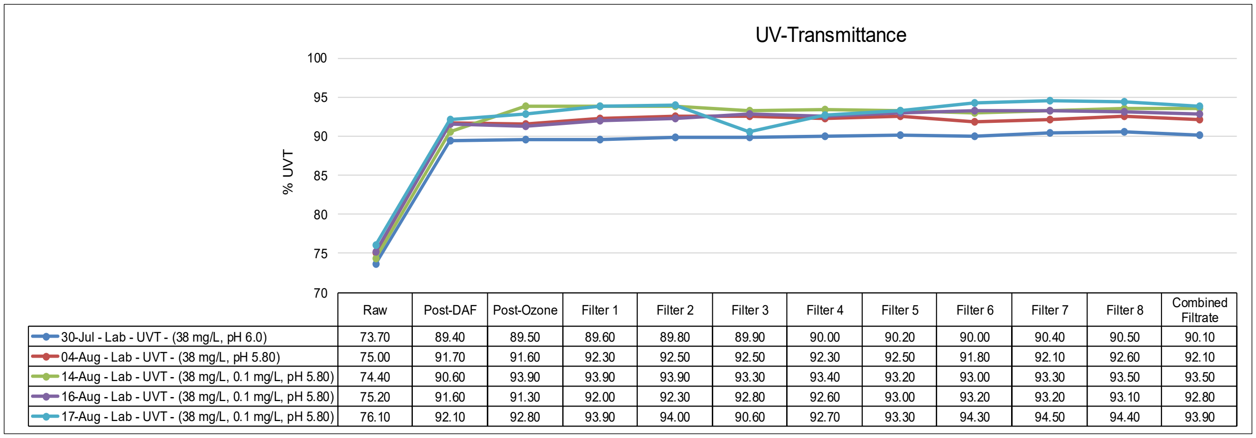
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-Jul - Lab - Turbidity - (38 mg/L, pH 6.0)	1.69	0.90	1.06	0.18	0.11	0.14	0.12	0.13	0.12	0.12	0.16	0.12
04-Aug - Lab - Turbidity - (38 mg/L, pH 5.80)	1.55	0.50	0.56	0.22	0.09	0.12	0.08	0.09	0.09	0.09	0.11	0.11
14-Aug - Lab - Turbidity - (38 mg/L, 0.1 mg/L, pH 5.80)	1.34	0.70	1.49	0.17	0.21	0.12	0.10	0.13	0.10	0.10	0.16	0.13
16-Aug - Lab - Turbidity - (38 mg/L, 0.1 mg/L, pH 5.80)	1.28	0.83	1.28	0.21	0.13	0.12	0.10	0.09	0.10	0.10	0.09	0.12
17-Aug - Lab - Turbidity - (38 mg/L, 0.1 mg/L, pH 5.80)	1.23	0.60	0.71	0.20	0.11	0.13	0.10	0.13	0.14	0.10	0.11	0.13

Figure 5-26: Turbidity during the Summer piloting session at optimal conditions. Data originated from Lab analyses.

The lowest final effluent turbidity of 0.11 NTU occurred on August 4th (no coagulant-aid) and 0.12 NTU occurred on August 16th (with coagulant-aid). It should be noted that these two days represent test days where the measured Post-DAF pH was the closest to the target pH of 5.80. Furthermore, August 4th applied optimal conditions for coagulant and pH, only, while August 16th applied optimal conditions for all chemical doses, including coagulant-aid. This implies that turbidity removal is closely dependant on pH conditions during coagulation and that under optimal pH conditions coagulant-aid does not necessarily increase the reduction of turbidity.

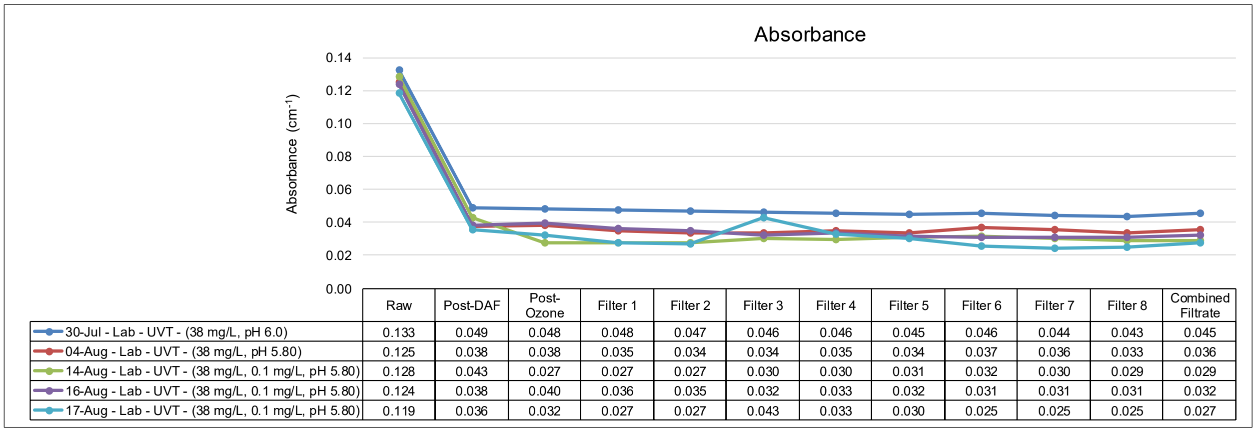
→ UV-Transmittance and Absorbance

The UVT and absorbance results are presented in Figure 5-27 and Figure 5-28. A similar trend to the reduction of turbidity was found with the reduction of UV reactive species under optimal conditions. Both UVT and absorbance improved following DAF treatment, followed by a significant improvement in both parameters after filtration. The best Post DAF and finished water quality (combined filter effluent) occurred on August 17th, which underscores the benefit of acquiring and maintaining the optimal pH during coagulation.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-Jul - Lab - UVT - (38 mg/L, pH 6.0)	73.70	89.40	89.50	89.60	89.80	89.90	90.00	90.20	90.00	90.40	90.50	90.10
04-Aug - Lab - UVT - (38 mg/L, pH 5.80)	75.00	91.70	91.60	92.30	92.50	92.50	92.30	92.50	91.80	92.10	92.60	92.10
14-Aug - Lab - UVT - (38 mg/L, 0.1 mg/L, pH 5.80)	74.40	90.60	93.90	93.90	93.90	93.30	93.40	93.20	93.00	93.30	93.50	93.50
16-Aug - Lab - UVT - (38 mg/L, 0.1 mg/L, pH 5.80)	75.20	91.60	91.30	92.00	92.30	92.80	92.60	93.00	93.20	93.20	93.10	92.80
17-Aug - Lab - UVT - (38 mg/L, 0.1 mg/L, pH 5.80)	76.10	92.10	92.80	93.90	94.00	90.60	92.70	93.30	94.30	94.50	94.40	93.90

Figure 5-27: UVT during the Summer piloting session at optimal conditions. Data originates from Lab analyses.

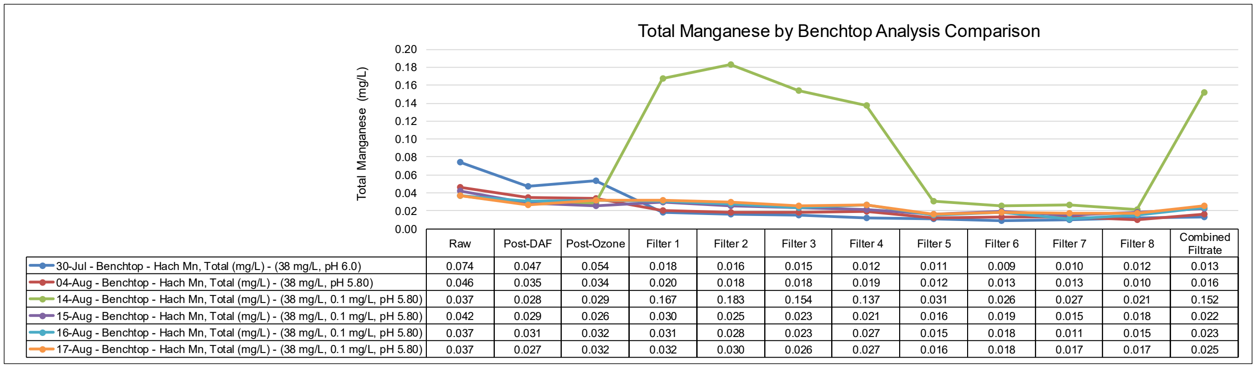


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-Jul - Lab - UVT - (38 mg/L, pH 6.0)	0.133	0.049	0.048	0.048	0.047	0.046	0.046	0.045	0.046	0.044	0.043	0.045
04-Aug - Lab - UVT - (38 mg/L, pH 5.80)	0.125	0.038	0.038	0.035	0.034	0.034	0.035	0.034	0.037	0.036	0.033	0.036
14-Aug - Lab - UVT - (38 mg/L, 0.1 mg/L, pH 5.80)	0.128	0.043	0.027	0.027	0.027	0.030	0.030	0.031	0.032	0.030	0.029	0.029
16-Aug - Lab - UVT - (38 mg/L, 0.1 mg/L, pH 5.80)	0.124	0.038	0.040	0.036	0.035	0.032	0.033	0.032	0.031	0.031	0.031	0.032
17-Aug - Lab - UVT - (38 mg/L, 0.1 mg/L, pH 5.80)	0.119	0.036	0.032	0.027	0.027	0.043	0.033	0.030	0.025	0.025	0.025	0.027

Figure 5-28: Absorbance during the Summer piloting session at optimal conditions. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.

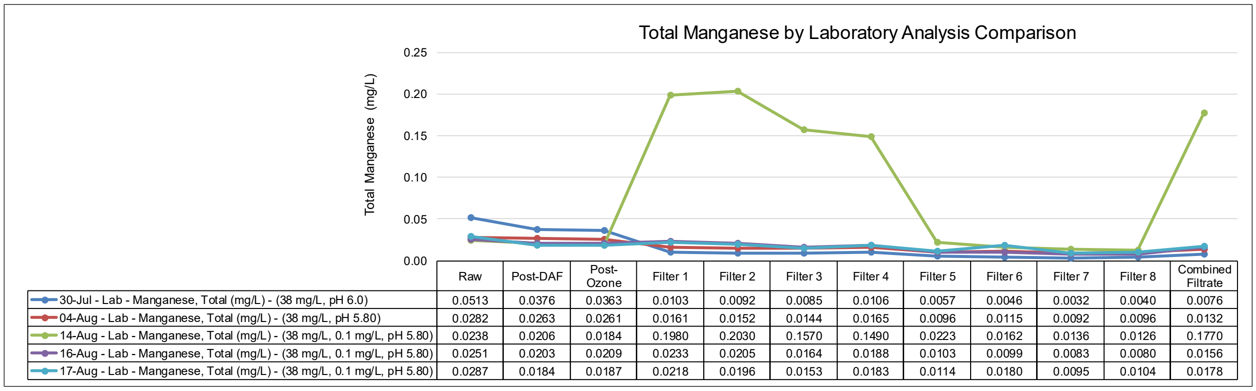
→ Total Manganese

Figure 5-29 and Figure 5-30 illustrate total manganese concentrations during the optimized testing. Lab measurement for total manganese was consistently lower than the benchtop analysis. This difference was addressed in TM No. 3, and highlights that the benchtop instrumentation used for total manganese analyses was near the instrument's limit of detection. Nonetheless, lab results are believed to better represent total manganese concentrations due to the higher sensitivity found in the Lab instrumentation, with the use of ICP-MS noted in previous technical memoranda.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-Jul - Benchtop - Hach Mn, Total (mg/L) - (38 mg/L, pH 6.0)	0.074	0.047	0.054	0.018	0.016	0.015	0.012	0.011	0.009	0.010	0.012	0.013
04-Aug - Benchtop - Hach Mn, Total (mg/L) - (38 mg/L, pH 5.80)	0.046	0.035	0.034	0.020	0.018	0.018	0.019	0.012	0.013	0.013	0.010	0.016
14-Aug - Benchtop - Hach Mn, Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	0.037	0.028	0.029	0.167	0.183	0.154	0.137	0.031	0.026	0.027	0.021	0.152
15-Aug - Benchtop - Hach Mn, Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	0.042	0.029	0.026	0.030	0.025	0.023	0.021	0.016	0.019	0.015	0.018	0.022
16-Aug - Benchtop - Hach Mn, Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	0.037	0.031	0.032	0.031	0.028	0.023	0.027	0.015	0.018	0.011	0.015	0.023
17-Aug - Benchtop - Hach Mn, Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	0.037	0.027	0.032	0.032	0.030	0.026	0.027	0.016	0.018	0.017	0.017	0.025

Figure 5-29: Total manganese during the Summer piloting session at optimal conditions. Data originates from benchtop analysis using a Hach DR6000 UV-VIS spectrophotometer.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-Jul - Lab - Manganese, Total (mg/L) - (38 mg/L, pH 6.0)	0.0513	0.0376	0.0363	0.0103	0.0092	0.0085	0.0106	0.0057	0.0046	0.0032	0.0040	0.0076
04-Aug - Lab - Manganese, Total (mg/L) - (38 mg/L, pH 5.80)	0.0282	0.0263	0.0261	0.0161	0.0152	0.0144	0.0165	0.0096	0.0115	0.0092	0.0096	0.0132
14-Aug - Lab - Manganese, Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	0.0238	0.0206	0.0184	0.1980	0.2030	0.1570	0.1490	0.0223	0.0162	0.0136	0.0126	0.1770
16-Aug - Lab - Manganese, Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	0.0251	0.0203	0.0209	0.0233	0.0205	0.0164	0.0188	0.0103	0.0099	0.0083	0.0080	0.0156
17-Aug - Lab - Manganese, Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	0.0287	0.0184	0.0187	0.0218	0.0196	0.0153	0.0183	0.0114	0.0180	0.0095	0.0104	0.0178

Figure 5-30: Total manganese during the Summer piloting session at optimal conditions. Data originates from Lab analyses.

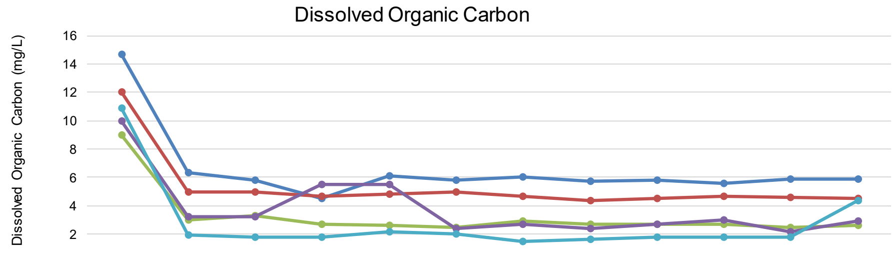
There were extremely elevated concentrations of total manganese (greater than ten times) measured in filter Bank A (Filters 1-4) on August 14th. It appeared that the increase in total manganese found in Bank A coincided with the initiation of the ozone generator, which went online approximately 2 hours before the daily sampling on August 14th. However, it remains unclear as to the exact source of total manganese and the mechanism to which caused an increased observation. Also, total manganese appears to be the only parameter affected by the ozone start-up and was isolated to Bank A.

Aside from August 14th, manganese was significantly reduced following pilot-scale system treatment (based on combined filter effluent) during optimal testing. However, this trend opposed turbidity results (Figure 5-30), where optimal turbidity removal occurred at a lower pH (5.82), where the manganese concentration was lower at a higher pH (pH at 6.1; Benchtop$_{\text{MnTotal}}$ was 0.013 mg/L; Lab$_{\text{MnTotal}}$ was 0.008 mg/L).

The greatest concentration of total manganese occurred on August 17th, which was the lowest pH tested during optimal trails. These results are attributed to the solubility of metals increasing with a decreasing pH. Therefore, a lower pH in full-scale system operation should be avoided to discourage increased concentrations of total manganese. Furthermore, the greatest reduction of manganese occurred on July 30th, at a pH of 6.10, and on August 4th, at a pH of 5.80, where no coagulant-aid was added. This implies that in warm water conditions coagulant-aid did not improve the removal of manganese.

→ Dissolved Organic Carbon

The DOC data is illustrated in Figure 5-31 which present the DOC removal in the pilot-scale system under three conditions, optimal coagulant dose (38 mg/L) at pH of 6.0, optimal coagulant dose at the optimal target pH of 5.80, and the optimal coagulant and pH with the optimal coagulant-aid dose of 0.10 mg/L.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
30-Jul - Lab - DOC Total (mg/L) - (38 mg/L, pH 6.0)	14.7	6.3	5.8	4.5	6.1	5.8	6.0	5.7	5.8	5.6	5.9	5.9
04-Aug - Lab - DOC Total (mg/L) - (38 mg/L, pH 5.80)	12.0	5.0	5.0	4.7	4.8	5.0	4.7	4.4	4.5	4.7	4.6	4.5
14-Aug - Lab - DOC Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	9.0	3.0	3.3	2.7	2.6	2.5	2.9	2.7	2.7	2.7	2.5	2.6
16-Aug - Lab - DOC Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	10.0	3.2	3.2	5.5	5.5	2.4	2.7	2.4	2.7	3.0	2.2	2.9
17-Aug - Lab - DOC Total (mg/L) - (38 mg/L, 0.1 mg/L, pH 5.80)	10.9	1.9	1.8	1.8	2.2	2.0	1.5	1.6	1.8	1.8	1.8	4.4

Figure 5-31: DOC during the Summer piloting session at optimal conditions. Data originates from Lab analyses.

Of the three piloting conditions, there was only a 57% reduction in DOC by DAF treatment on July 30th, at a pH of 6.00, and only a minor improvement in DOC removal by pilot-scale system DAF (58%) when the pH was reduced to 5.80 (August 4th). The addition of 0.10 mg/L of coagulant-aid (August 14th to 16th) improved the removal of DOC by the pilot-scale system DAF to 72±0.09%.

When comparing the DOC concentration in the combined filter effluent, there was 60% and 63% raw water DOC removal with a coagulant dose of 38 mg/L at pH of 6.00 and 5.80, respectively. The addition of coagulant-aid improved the overall removal of DOC by the pilot-scale system to 75±7% (presented as the average of August 14th to 16th).

It should be noted that the combined filter effluent DOC concentration on August 17th is suspect. For all other testing periods, the combined filter effluent was close to the average DOC from the individual filters. However, on August 17th, the combined filter effluent was double that of the average DOC of the individual filters. This discrepancy is believed to be either a sampling or analytical error in the combined filtrate sample collected on August 17th. It is assumed the final DOC concentration on August 17th to be closer to the average of the DOC concentrations measured from the individual filter effluent of approximately 1.8 mg/L. Therefore, a final combined filter effluent DOC concentration of 1.8 mg/L was used for the August 17th analysis.

Filtration was not found to significantly reduce DOC for all optimal trials. Overall, the results indicate that the addition of coagulant-aid at a target pH of 5.80 improved the removal of DOC, compared to no coagulant-aid.

→ Filter Operation

Table 5-3 presents the average UFRV values for the optimal days of the Summer piloting session, while also considering overall operation cycles and those which did not fail based on sampled turbidity. During the optimal days of the Summer piloting session (August 14th to August 17th), overflow conditions from both Banks were observed mostly on August 14th and 16th, while only a few individual filters were observed to be overflowing on August 15th and 17th. Filter 5 and Filter 8 did not overflow on August 4th.

Table 5-3: Average observed and forecasted UFRV values for the optimal conditions of the Summer piloting session.

UFRV (M^3/M^2)		**JULY 30TH (Optimal coagulant dose of 38 mg/L at a pH of 6.00, no coagulant-aid)**			**AUGUST 4TH (Optimal coagulant dose of 38 mg/L, optimal pH of 5.80, no coagulant-aid)**			**AUGUST 14TH TO AUGUST 17TH (Optimal coagulant dose of 38 mg/L, optimal pH of 5.80, coagulant-aid dose of 0.10 mg/L)**		
		Bank A	**Bank B**	**All Filters**	**Bank A**	**Bank B**	**All Filters**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	361	318	340	328	324	326	470	278	380
	Only cycles with turbidity ≤ 0.1 NTU	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	Only cycles with turbidity ≤ 0.3 NTU	361	318	340	328	324	326	475	278	380
Forecasted Values	Overall Cycles	361	368	364	328	335	332	516	335	432
	Only cycles with turbidity ≤ 0.1 NTU	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	Only cycles with turbidity ≤ 0.3 NTU	361	368	364	328	335	332	525	335	433

N/R: No results

For Bank A, the observed overall average UFRV were 361 m^3/m^2, 328 m^3/m^2 and 470 m^3/m^2 during July 30th, August 4th and August 14th to 17th, respectively. For Bank B, the observed overall average UFRV's were 318 m^3/m^2, 324 m^3/m^2 and 278 m^3/m^2 during July 30th, August 4th and August 14th to 17th, respectively. While the addition of coagulant-aid improved Bank A UFRV values, it decreased by 14% the UFRV values of Bank B operating at similar operating conditions of the full-scale system.

Table 5-4 presents the average rate of head loss increase for the optimal days of the Summer piloting session. The results do not show significance difference between the three piloting conditions in terms of rate of head loss increase. All values are lower than the typical rate of head loss increase (1.7 kPa/h for average filter bank flow rate of 0.3 L/s and 3.1 kPa/h for average filter bank flow rate of 0.6 L/s).

Table 5-4: Average rate of head loss increase for the optimal conditions of the Summer piloting session.

RATE OF HEAD LOSS INCREASE (kPa/h)		**JULY 30TH** optimal coagulant dose of 38 mg/L at a pH of 6.00, no coagulant-aid	**AUGUST 4TH** optimal coagulant dose of 38 mg/L, optimal pH of 5.80, no coagulant-aid	**AUGUST 14TH TO AUGUST 17TH** optimal coagulant dose of 38 mg/L, optimal pH of 5.80, coagulant-aid dose of 0.10 mg/L
Bank A	at 0.6 L/s	2.2	2.4	1.8
Bank B	at 0.3 L/s	1.0	1.1	1.1

All individual filters failed based on turbidity (> 0.1 NTU) during July 30th, August 4th, and August 14th to 17th, and Filter 1 presented turbidity above 0.3 NTU on August 17th, based on the bench top analysis. Although both filter banks presented turbidity breakthrough in all piloting optimal conditions based on the benchtop results, all individual filters except for Filter 1 presented turbidity below 0.1 NTU or very close to this value based on the Lab analysis (0.11 to 0.13 NTU, Figure 5-26). Based on the Lab analysis the pilot-scale filters were able to achieve a good performance on these days.

In order to better understand the relationship between the filter operation and the filter effluent turbidity, the filter effluent turbidity measured by the Lab is plotted against the differential pressure at 4 hours after start of filter cycle (or approximate sampling time) of each individual filter for the piloting days at optimal conditions with coagulant-aid only, as shown on Figure 5-32. This illustration also highlights the City's operational filter turbidity limit of 0.1 NTU, the full-scale system operating licence limit of 0.3 NTU, and the expected differential pressures at the sampling time per flow rate to match the full-scale system's performance. The expected differential pressures of 6.8 kPa for filters at average flow rate and 12.4 kPa for filters at maximum flow rate are based on the historical benchmarking values of the full-scale system filters (average head loss of 48.9 kPa and average filter run of 28.9 h per Table 2-2 of TM No. 1). For Bank A, the differential pressure at 4 hours after start of filter cycle (8.0 – 13.5 kPa) was similar to the expected differential pressure (12.4 kPa) for maximum flow rate. For Bank B, the differential pressure at 4 hours after start of filter cycle (1.4 – 5.0 kPa) were lower that of the expected differential pressure (6.8 kPa) for average flow rate.

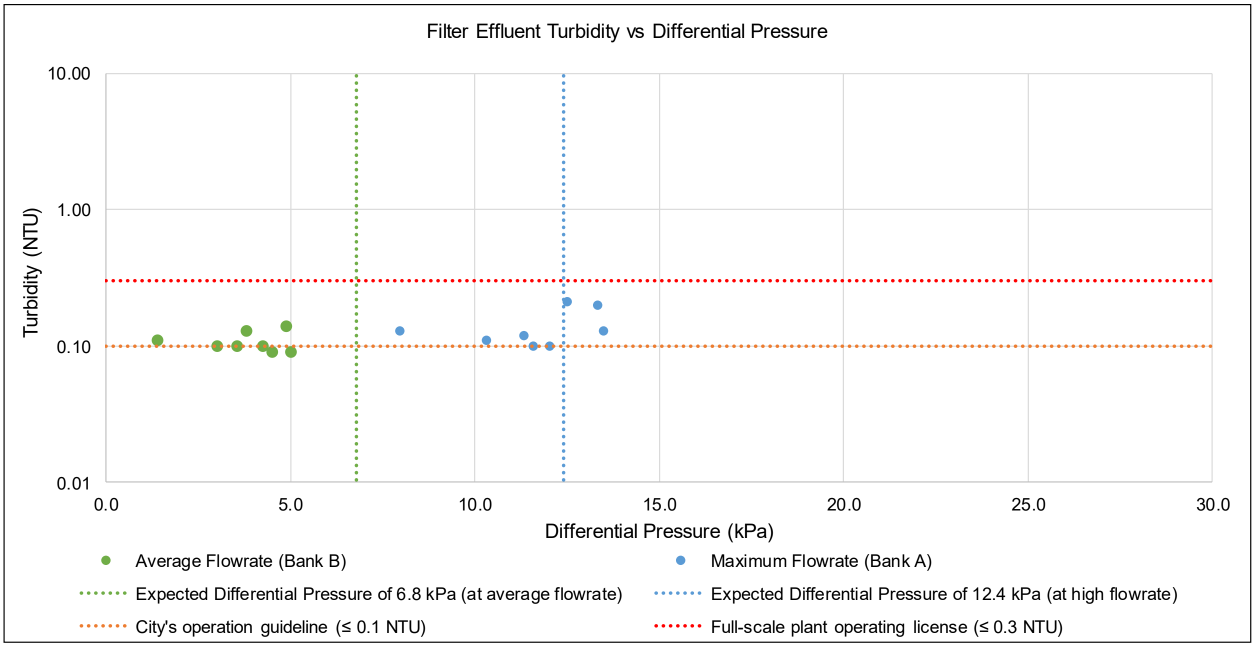


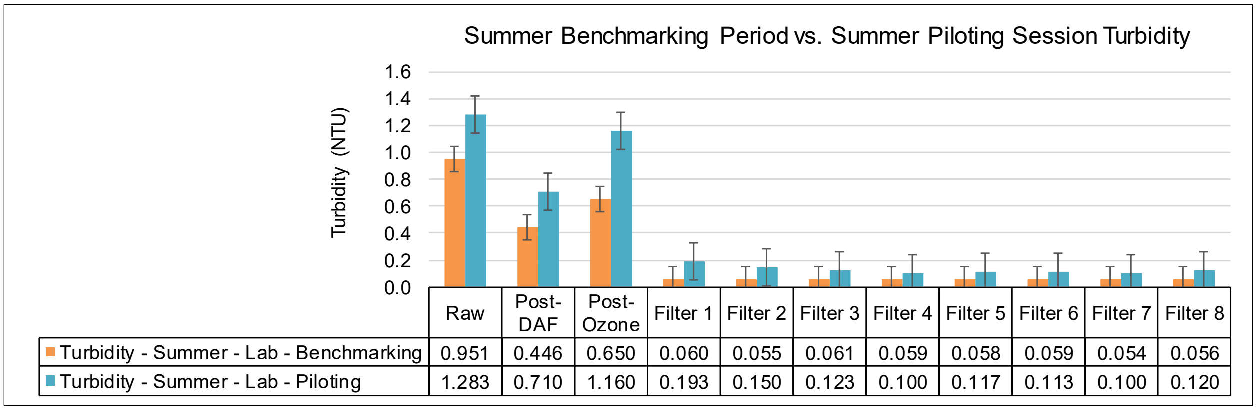
Figure 5-32: Filter effluent turbidity versus differential pressure at sampling time for each individual filter for the optimal conditions of the Summer piloting session (August 16th and August 17th). Note the turbidity levels (y-axis) are displayed in a logarithmic scale to improve visualization.

→ Summary of Optimal Conditions

Overall, the water quality results indicate the optimal treated water quality (filter or combined filter effluent) in terms of UVT, absorbance, and DOC occurred at a ferric sulphate dose of 38 mg/L, a coagulant-aid dose of 0.10 mg/L, and the optimal target pH of 5.8 (pH Post-DAF). However, the best total manganese removal was obtained on July 30th with a pH of 6.0 and the best filter effluent turbidity removal was obtained on August 4th with no addition of coagulant-aid. In terms of filter operation, the UFRV analysis showed the best results were obtained on August 4th, without the addition of coagulant-aid.

5.8 Comparison Between the Summer Benchmarking Period and Summer Piloting Session of the Pilot-Scale System

Figure 5-33 to Figure 5-35 present a comparison between coagulants, ferric chloride and ferric sulphate, used in pilot-scale system operation during the Summer benchmarking period (June 23rd to July 10th, 2017) and the Summer piloting session (optimal conditions being 14th, 16th, 17th, 2017).

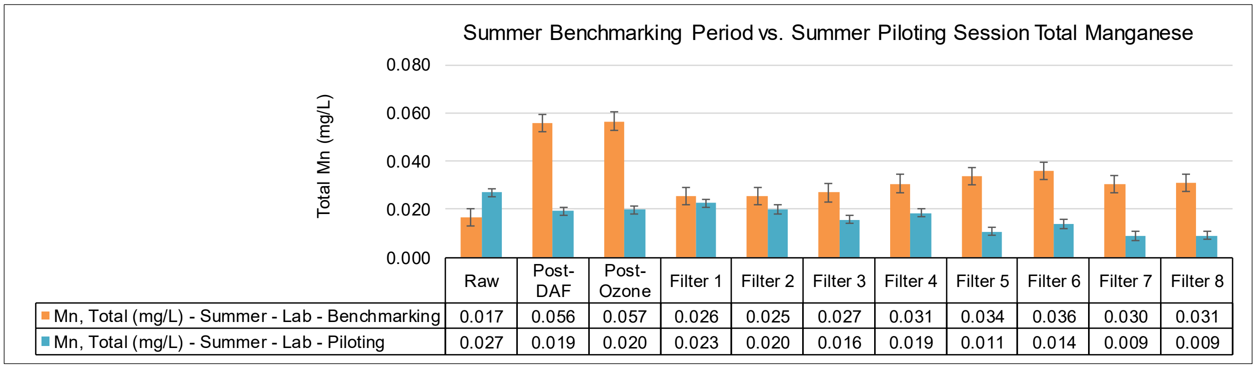


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
🟧 Turbidity - Summer - Lab - Benchmarking	0.951	0.446	0.650	0.060	0.055	0.061	0.059	0.058	0.059	0.054	0.056
🟦 Turbidity - Summer - Lab - Piloting	1.283	0.710	1.160	0.193	0.150	0.123	0.100	0.117	0.113	0.100	0.120

Figure 5-33: Comparison of turbidity between the pilot-scale Summer benchmarking period (average values from June 23rd to July 10th, 2017) and the pilot-scale Summer piloting session (average of optimal conditions from August 14th, 16th, 17th, 2017). Benchmark and piloting data originates from Lab analyses.

As observed in Figure 5-33, the raw water turbidity was higher during the Summer piloting session. There was a lower Post-DAF turbidity measured and higher reduction in turbidity Post-DAF during the benchmarking using ferric chloride. Specifically, there was more than a 53% reduction in turbidity following Post-DAF using ferric chloride, compared to a 46% reduction in turbidity using ferric sulphate. For both coagulants, the turbidity removal in the filters were around 90%. The results indicate that the floc formed using ferric chloride is likely better removed by DAF treatment; while floc formed during coagulation using ferric sulphate and ferric chloride have similar removal by filtration.

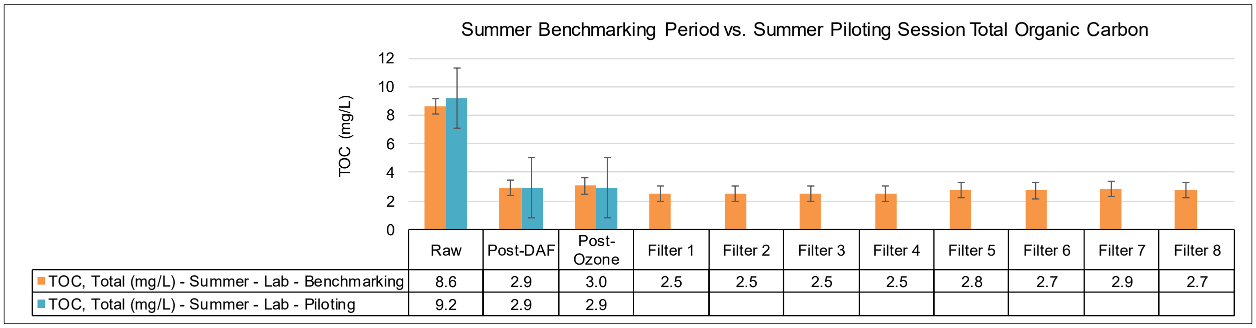
Although during the Summer benchmarking period there was a lower concentration of total manganese in the raw water (Figure 5-34), there was increased total manganese in the DAF and following filtration. This increase is expected as ferric chloride has a higher residual manganese content, compared to ferric sulphate. Overall, total manganese appeared to be well removed following filtration with ferric sulphate as the coagulant, reaching 44% of overall removal of total manganese. Note that piloting data for August 14th has been excluded from Figure 5-34 due to laboratory analysis results indicating anomalies in select metals, including both total and dissolved manganese.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
🟧 Mn, Total (mg/L) - Summer - Lab - Benchmarking	0.017	0.056	0.057	0.026	0.025	0.027	0.031	0.034	0.036	0.030	0.031
🟦 Mn, Total (mg/L) - Summer - Lab - Piloting	0.027	0.019	0.020	0.023	0.020	0.016	0.019	0.011	0.014	0.009	0.009

Figure 5-34: Comparison of total manganese between the pilot-scale Summer benchmarking period (average values from June 23rd to July 10th, 2017) and the pilot-scale Summer piloting session (average of optimal conditions being August 16th and 17th, 2017). Data originates from Lab analyses.

For the removal of TOC (Figure 5-35), there does not appear to be a significant difference between ferric chloride and ferric sulphate.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
■ TOC, Total (mg/L) - Summer - Lab - Benchmarking	8.6	2.9	3.0	2.5	2.5	2.5	2.5	2.8	2.7	2.9	2.7
■ TOC, Total (mg/L) - Summer - Lab - Piloting	9.2	2.9	2.9								

Figure 5-35: Comparison of TOC between the pilot-scale Summer benchmarking period (average values from June 23rd to July 10th, 2017) and the pilot-scale Summer piloting session (average of optimal conditions being August 14th, 16th, 17th, 2017). Data originates from Lab analyses.

Table 5-5 presents the average UFRV values for the Summer benchmarking period and the optimal days of the Summer piloting session, while also considering overall operation cycles and those which did not fail based on sampled turbidity.

Table 5-5: Average observed and forecasted UFRV values for the Summer benchmarking period and optimal conditions of the Summer piloting session.

UFRV (M^3/M^2)		SPRING BENCHMARKING PERIOD	OPTIMAL DAYS OF SPRING PILOTING SESSION		
		All Filters	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	322	470	278	380
	Only cycles with turbidity ≤ 0.1 NTU	322	N/R	N/R	N/R
	Only cycles with turbidity ≤ 0.3 NTU	322	475	278	380
Forecasted Values	Overall Cycles	820	516	335	432
	Only cycles with turbidity ≤ 0.1 NTU	820	N/R	N/R	N/R
	Only cycles with turbidity ≤ 0.3 NTU	820	525	335	433

N/R: No results

In terms of filter operation, the overall average observed UFRV for Bank A and Bank B was 322 m^3/m^2 during the Summer benchmarking period, while the overall average observed UFRV during the optimal conditions of the Summer piloting session was 470 m^3/m^2 and 278 m^3/m^2 for Bank A and Bank B, respectively. The UFRV values for Bank B with ferric sulphate and coagulant-aid were lower than those observed with ferric chloride, as well as all individual filters failed based on turbidity measurements above 0.1 NTU based on the benchtop analysis with ferric sulphate and the expected UFRV could be smaller for the Summer piloting session. As such, it is considered that the pilot-scale system filters presented lower performance using ferric sulphate and coagulant-aid than using ferric chloride only.

5.9 Comparison Between the Pilot-Scale and Full-Scale Systems During the Summer Piloting Session

The following results provide a comprehensive comparison between the full-scale system (five-year average historical benchmark and Summer piloting session) and the pilot-scale system for key parameters. The comparison was made for the last four days of Summer piloting session (August 14th to 17th), when the optimal conditions in terms of coagulant, coagulant-aid and pH were applied at the pilot-scale system.

5.9.1 Key Parameters

→ Turbidity

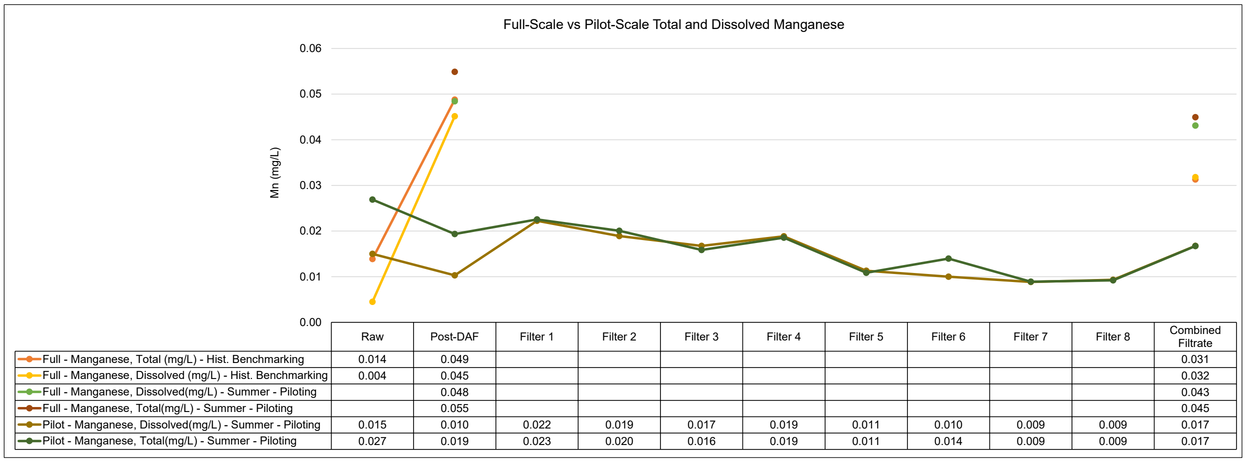
Figure 5-36 indicates that the full-scale system was removing Post-Ozone and Post-DAF turbidity similar to that recorded during historical benchmarking. Slightly elevated turbidity was found in the pilot-scale system Post-DAF and Post-Ozone samples, compared to the full-scale system. However, the pilot-scale combined filter turbidity is lower than full-scale, and is also more comparable to the historical benchmarking. Overall, it appears that the pilot-scale system operation using ferric sulphate is capable of meeting turbidity reported during historical benchmarking.

	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full - Turbidity - Hist. Benchmarking	1.108	0.542	0.789									0.118
Full - Turbidity - Summer - Piloting		0.530	0.737									0.170
Pilot - Turbidity - Summer - Piloting	1.283	0.710	1.160	0.193	0.150	0.123	0.100	0.117	0.113	0.100	0.120	0.127

Figure 5-36: Comparison of turbidity between full-scale historical benchmark (five-year average), the full-scale Summer piloting session (average from August 14th, 16th, 17th, 2017) and the pilot-scale Summer piloting session (average of optimal conditions from August 14th, 16th, 17th, 2017). Data originates from Lab analyses.

→ Total and Dissolved Manganese

Figure 5-37 provides the comparison for manganese (total and dissolved) removal between full-scale and pilot-scale systems. As expected, the pilot-scale system has a significantly lower manganese concentration (total and dissolved) compared to the full-scale system and the historical benchmarking data, due to the lower residual manganese concentration in ferric sulphate. The results from August 14th were excluded since there were extremely elevated concentrations of total and dissolved manganese measured in filter Bank A on this day, as discussed previously.

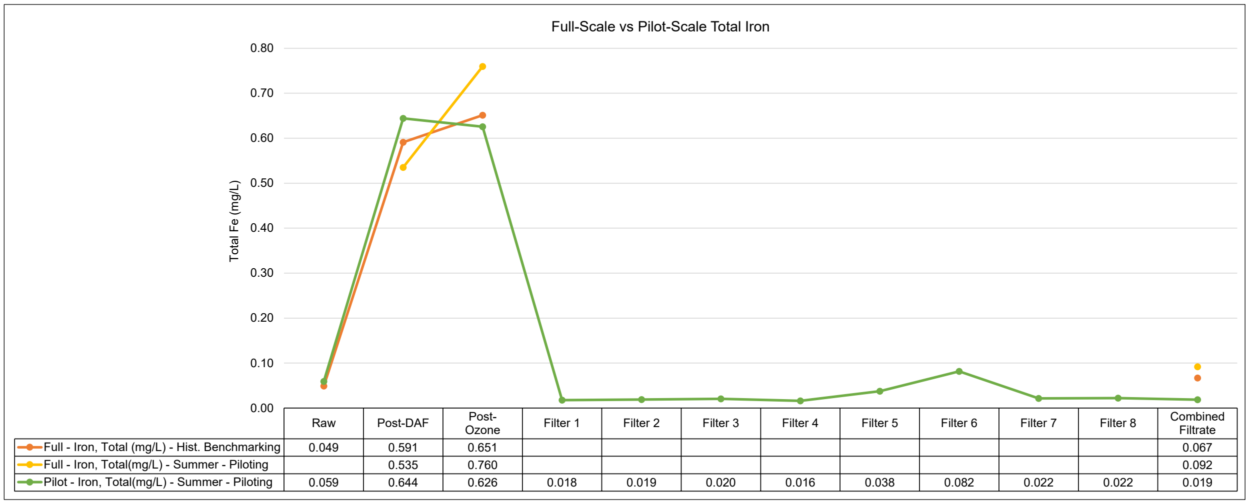


	Raw	Post-DAF	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full - Manganese, Total (mg/L) - Hist. Benchmarking	0.014	0.049									0.031
Full - Manganese, Dissolved (mg/L) - Hist. Benchmarking	0.004	0.045									0.032
Full - Manganese, Dissolved(mg/L) - Summer - Piloting		0.048									0.043
Full - Manganese, Total(mg/L) - Summer - Piloting		0.055									0.045
Pilot - Manganese, Dissolved(mg/L) - Summer - Piloting	0.015	0.010	0.022	0.019	0.017	0.019	0.011	0.010	0.009	0.009	0.017
Pilot - Manganese, Total(mg/L) - Summer - Piloting	0.027	0.019	0.023	0.020	0.016	0.019	0.011	0.014	0.009	0.009	0.017

Figure 5-37: Comparison of total and dissolved manganese between full-scale historical benchmark (five-year average), the full-scale Summer piloting session (average from August 16th and 17th, 2017) and the pilot-scale Summer piloting session (average of optimal conditions from August 16th and 17th, 2017). Data originated from Lab analyses.

→ Total Iron

Figure 5-38 shows the removal of iron from the full-scale and pilot-scale systems during the Summer piloting session. The results show that the pilot-scale system Post-DAF sample has slightly higher iron concentration compared to both the full-scale system and the historical benchmarking. A reduction in the iron concentration following ozonation was found in the pilot-scale system; however, the iron concentration increased following ozonation in the full-scale system and historical benchmarking. The final filter effluent from the full-scale system was significantly higher than the pilot-scale system filter effluent. This result indicates that either residual iron from ferric sulphate is better removed compared to ferric chloride, or that optimized coagulant conditions, such as those in the pilot-scale system, prevented the carryover of excess iron.

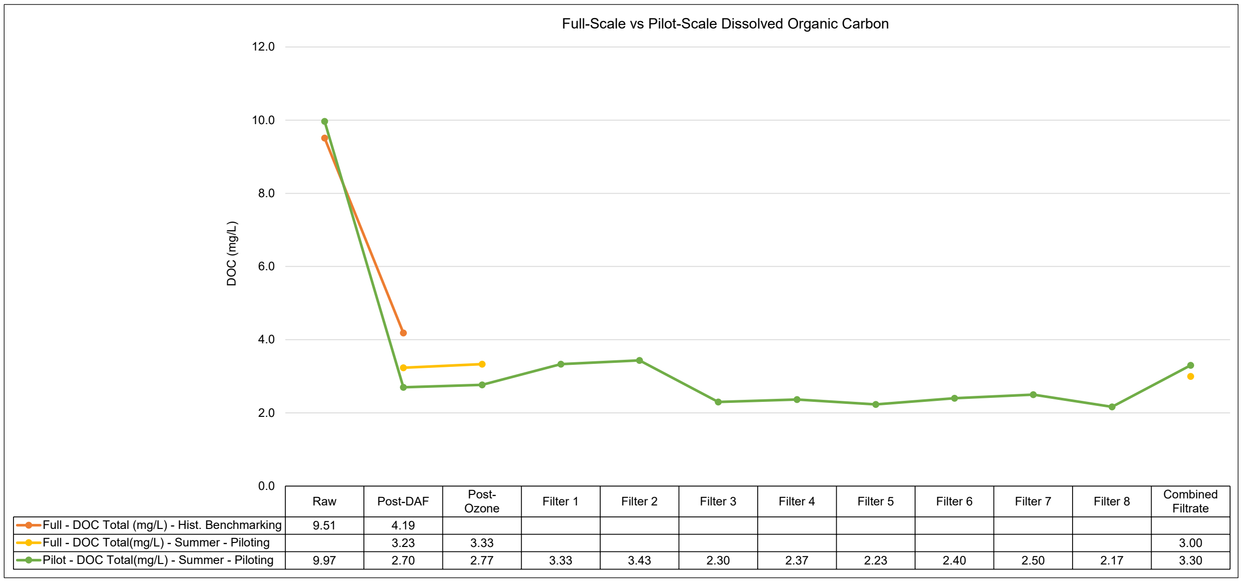


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full - Iron, Total (mg/L) - Hist. Benchmarking	0.049	0.591	0.651									0.067
Full - Iron, Total(mg/L) - Summer - Piloting		0.535	0.760									0.092
Pilot - Iron, Total(mg/L) - Summer - Piloting	0.059	0.644	0.626	0.018	0.019	0.020	0.016	0.038	0.082	0.022	0.022	0.019

Figure 5-38: Comparison of total iron between full-scale system historical benchmark (five-year average), the full-scale system Summer piloting session (average from August 14th, 16th, 17th, 2017) and the pilot-scale system Summer piloting session (average of optimal conditions from August 14th, 16th, 17th, 2017). Data originated from Lab analyses.

→ DOC

The pilot-scale system was found to better remove DOC compared to the full-scale system, or historical benchmarking data (Figure 5-39). Although a greater DOC concentration was measured in the combined filter effluent in the pilot-scale system, the DOC from Filter 1 and 2 effluents are greater than the DOC in the Post-Ozone effluent feeding the filters. Although the cause for the elevated DOC in Filters 1 and 2 is unclear, it does imply a possible buildup of organic matter within the pipes feeding Filters 1 and 2, which would account for the higher combined filter DOC. If Filters 1 and 2 are excluded, an average DOC in the combined filter effluent is 2.2 mg/L.

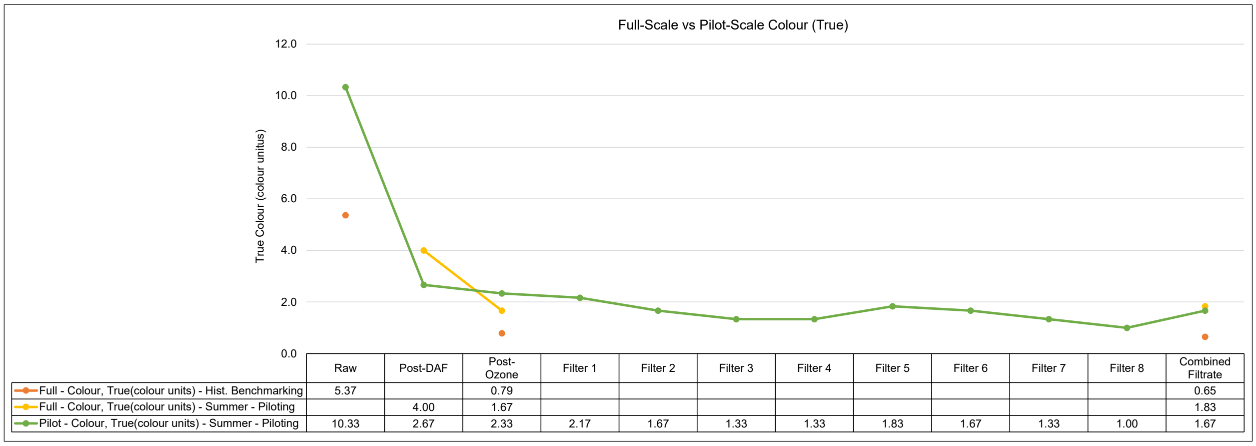


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full - DOC Total (mg/L) - Hist. Benchmarking	9.51	4.19										
Full - DOC Total(mg/L) - Summer - Piloting		3.23	3.33									3.00
Pilot - DOC Total(mg/L) - Summer - Piloting	9.97	2.70	2.77	3.33	3.43	2.30	2.37	2.23	2.40	2.50	2.17	3.30

Figure 5-39: Comparison of DOC between full-scale system historical benchmark (five-year average), the full-scale system Summer piloting session (average from August 14th, 16th, 17th, 2017) and the pilot-scale system Summer piloting session (average of optimal conditions from August 14th, 16th, 17th, 2017). Data originated from Lab analyses.

→ True Colour

There does not appear to be a significant difference in the reduction of true colour between the full-scale and pilot-scale systems (Figure 5-40). However, both the full-scale and pilot-scale systems have higher colour in the combined filter effluent compared to the historical benchmark. This is likely attributed to the higher colour found in the raw water during the Summer piloting session compared to when the historical benchmarking was conducted. These results indicate that ferric sulphate would be comparable to ferric chloride for the reduction of colour.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full - Colour, True(colour units) - Hist. Benchmarking	5.37		0.79									0.65
Full - Colour, True(colour units) - Summer - Piloting		4.00	1.67									1.83
Pilot - Colour, True(colour units) - Summer - Piloting	10.33	2.67	2.33	2.17	1.67	1.33	1.33	1.83	1.67	1.33	1.00	1.67

Figure 5-40: Comparison of true colour between full-scale system historical benchmark (five-year average), the full-scale system Summer piloting session (average from August 14th, 16th, 17th, 2017) and the pilot-scale system Summer piloting session (average of optimal conditions from August 14th, 16th, 17th, 2017). Data for originates from Lab analyses.

→ UFRV

The pilot-scale system average UFRV was 470 m^3/m^2 and 278 m^3/m^2 for Bank A and Bank B, respectively, during the optimal conditions of the Summer piloting session (Table 5-3), results that are less than the historical average of the full-scale system UFRV value of 495 m^3/m^2. The actual UFRV values for the Summer piloting session would be lower for both filter banks as most individual filters presented turbidity breakthrough based on the benchtop analysis. Substantial differences between the full-scale system with ferric chloride and the Summer piloting session with ferric sulphate were observed, indicating that the pilot-scale system performance with ferric sulphate was impacted by operating conditions (coagulant and coagulant-aid dose, pH, process flows) under warm water conditions, and that additional adjustment of these conditions should be considered prior to full-scale system operation adoption.

5.9.2 Disinfection By-Product Formation Potential

The disinfection by-product (DBP) formation potential (DBPFP) test was conducted to determine the extent at which trihalomethanes (THM) and haloacetic acids (HAA) form following disinfection of finished (filter effluent) water using sodium hypochlorite. Samples were collected from the raw water intake located in the pilot-scale system, as well as full-scale and pilot-scale systems' combined filter effluents on August 4th and August 14th. Chemical doses on these dates were presented earlier in Table 4-1. Samples from each location were prepared onsite by WSP personnel for both THM formation potential (THMFP) and HAA formation potential (HAAFP) tests.

The DBPFP procedure is analogous to the procedure outlined in TM No. 4, with two minor alterations. First, raw water samples were collected and analyzed for the presence of THM or HAA, i.e., DBP baseline at time 0; $THM_{t=0}$ and $HAA_{T=0}$). As there is chlorine added to the raw water intake at Shoal Lake (raw water source) to control algal formation within the aqueduct, there is a potential for the raw water sample to form DBPs before full-scale system treatment. Any formation of DBPs found in the raw water baseline samples at time=0 would be subtracted from the DBP concentration formed following the 7-day chlorine reaction time (Equation 1). The THM and HAA concentrations at T=0 are presented in Table 5-4.

$$DBPFP = DBP\ Formation_{T=7day} - DBP\ Formation_{T=0\ day} \quad \text{(Equation 1)}$$

Table 5-4: DBP Formation Potential testing for THM and HAA concentration in raw water at initial conditions (time zero).

Date	$CHCl_3$ (µg/L)	$CHBr_3$ (µg/L)	BDCM (µg/L)	DBCM (µg/L)	MCAA (µg/L)	DCAA (µg/L)	TCAA (µg/L)	MBAA (µg/L)	DBAA (µg/L)	BCAA (µg/L)
August 4th, 2017	BDL	BDL	BDL	BDL	BDL	BDL	1.2	BDL	BDL	BDL
August 14th, 2017	BDL	BDL	BDL	BDL	BDL	0.7	1.1	BDL	BDL	BDL

BDL: Below detection limit.

A second alteration to the DBPFP procedure was the 7-day reaction period was conducted at room temperature (approximately 22°C) to best mimic current Summer water conditions without the need for incubation equipment.

Table 5-5 and Table 5-6 present the results of the THMFP and HAAFP tests, respectively. DBP formations presented have been adjusted according to Equation 1 and the results from Table 5-4.

Table 5-5: THMFP results for August 4th and August 14th, 2017.

August 4th	$CHCl_3$ (µg/L)	$CHBr_3$ (µg/L)	BDCM (µg/L)	DBCM (µg/L)	**Total THMs (µg/L)**	**% reduction/ increase**
Raw	67.3	BDL	2.7	BDL	**70.0**	
Combined (Full)	44.9	BDL	3.6	BDL	**49.0**	**-30%**
Combined (Pilot)	50.6	BDL	3.5	BDL	**54.0**	**-23%**
August 14th						
Raw	60.1	BDL	3.9	BDL	**64.0**	
Combined (Full)	76.8	BDL	3.3	BDL	**80.0**	**+25%**
Combined (Pilot)	50.7	BDL	3.6	BDL	**54.0**	**-16%**

BDL: Below detection limit.

The total THMFP for the raw water on August 4th and August 14th was 70.0 µg/L and 64 µg/L, respectively. This indicates the raw water, before treatment, has a low THMFP. During the Winter #1 piloting session, both the full-scale and pilot-scale systems failed to significantly reduce THMFP following treatment. In the Spring piloting session (TM No. 4, Table 5-2), THMs were reduced between 64-68% by the full-scale system and 49-75% by the pilot-scale system. However, during Summer piloting session, there was only a 30% reduction in THMFP by the full-scale system on August 4th, and an increase of 25% in THMFP for the August 14th samples. Similarly, with the pilot-scale system, only a 23% and 16% reduction in THMFP was measured.

In the Summer months, typical increases in DOC observed in surface waters is due to an increase in the humic matter. The humic matter is known to have a greater THMFP compared to the non-humic fraction. Goss and Gorczyca (2013) previously reported that the humic fraction of DOC is poorly removed by biological filtration (in a Manitoba surface water source), and was observed to be primarily responsible for elevated THMs in the finished water. As such, this fraction may be the likely cause of increasing the THMFP during the Summer piloting session.

If the DOC concentration of the raw Shoal Lake water is largely humic in nature during the Summer months, as suspected, then the results found during the Summer piloting session may be similar to the results reported by Goss and Gorczyca, in that GAC filtration was ineffective at removing humic matter and leading to an increase THM formation. As noted in the DOC results during the optimized trials, it was observed that the GAC filter did not reduce the DOC concentration. To confirm the hypothesis of increased humic matter in the raw water, it would be recommended to conduct an organic matter characterization test, similar to that outline in Goss *et al.* (2017), on the raw and treated water to determine the fraction concentration and removal efficiency for the humic matter.

Overall, the THMFP in the combined filter effluent, in both the full-scale and pilot-scale systems, was not found to exceed provincial regulations.

Similar results as THMFP were found for HAAFP during the Summer piloting session (Table 5-6). Both the full-scale and pilot-scale systems removed less than 20% of the HAAFP following treatment. As with the THMFP of the combined effluent from the full-scale system on August 14th, an increase of 9% in HAAFP was measured following treatment. A similar cause for the elevated THMs noted above could result in elevated HAAs. Overall, the HAAFP in the combined filter effluent, in both the full-scale and pilot-scale systems, was not found to exceed provincial regulations.

Table 5-6: HAAFP results for August 4th and August 14th, 2017.

August 4th	MCAA (µg/L)	DCAA (µg/L)	TCAA (µg/L)	MBAA (µg/L)	DBAA (µg/L)	BCAA (µg/L)	**Total HAA (µg/L)**	**% reduction/ increase**
Raw	2.7	22.3	15.8	BDL	BDL	BDL	**40.8**	
Combined (Full)	2.9	17.7	12.4	BDL	BDL	BDL	**33.0**	**-19%**
Combined (Pilot)	2.7	17.1	14.4	BDL	BDL	BDL	**34.2**	**-16%**
August 14th								
Raw	3.3	25.1	16.8	2.3	BDL	1.4	**48.9**	
Combined (Full)	2.3	27.7	22.2	0.7	BDL	0.6	**53.5**	**+9%**
Combined (Pilot)	3.3	23.4	16.9	1.8	BDL	1.2	**46.6**	**-5%**

BDL: Below detection limit.

Looking at the percentage of THMFP and HAAFP reduction, the pilot-scale system outperformed the full-scale system on August 14th when ozone was dosed at both systems, but not on August 4th without the addition of ozone at the pilot-scale system.

5.9.3 Corrosive Indices

Corrosive waters, often having elevated chloride concentrations, can lead to metal leaching and promote corrosion in water distribution systems. The Chloride-Sulfate Mass Ratio (CSMR) is commonly used to indicate the potential to promote corrosion in water distribution systems, with high values indicating an increase in the potential to promote corrosion. The Langelier Saturation index (LSI) and the Ryznar Stability index (RSI) are indicators of corrosion attributed to the degree of saturation of calcium carbonate.

Though changes in treatment approaches at drinking water facilities are known to affect the corrosion indices, there is minimal information regarding how changes in the ionic composition of source waters may affect the corrosion indices. Nonetheless, these indices serve as indicators for corrosion discussions.

Table 5-7 presents the corrosivity indices in the raw water and combined filtrate for both pilot-scale and full-scale systems during the Summer piloting session. The indices are calculated from laboratory results of samples taken the same day from the full-scale system post filtration and prior to pH adjustment with sodium hydroxide and the pilot-scale system post-filtration operating under optimal conditions. A comparison between the full-scale system and the pilot-scale system is made under the provision that samples taken from their respective sources on the same day share identical raw water quality. Furthermore, as these indices are of a strict predicative nature (the development of a general index is inherently difficult due to the multiple roles of chemical species in potable water), and do not necessarily correlate between theoretical and actual conditions, only a relative comparison is made.

Table 5-7: Summer piloting session corrosivity indices. Data obtained from August 14th optimal conditions laboratory analytical testing.

Treatment Step	CSMR Pilot	CSMR Full	LSI Pilot	LSI Full	RSI Pilot	RSI Full	Alkalinity Pilot-Scale	Alkalinity Full-Scale
Raw Water	N/A (Sulphate < 2 mg/L)	0.06	-2.17		12.26		73	
Interpretation	Greater than 0.5 indicates a tendency to increase galvanic corrosion of lead solder connected to copper pipes.		At 0, water is under saturated with respect to calcium carbonate. Tendency will be to remove existing calcium carbonate protective coatings.		Values > 8.5, water is very aggressive towards corrosion.		Reported as mg/L $CaCO_3$, values < 100 often corrosive & values > 200 results in possible scaling	
Combined Filtrate	0.04	0.38	-4.78	-5.60	15.74	16.80	9	6
Interpretation	-	Low corrosivity	Corrosive	Increasingly corrosive	Corrosive	Corrosive	Corrosive	Corrosive

Table 5-7 suggests that based on alkalinity, the raw water and combined filtrate for both the pilot-scale and full-scale systems would be corrosive. The LSI and RSI, which are indices dependent on the alkalinity, indicate that the pilot-scale system filter effluent is corrosive, but not more corrosive than the full-scale system. CSMR data regarding the pilot-scale and full-scale systems suggest low corrosivity in general, with the pilot-scale system tending to exhibit less than the full-scale system.

It is important to note that these comparisons take into consideration the combined filtrate water and does not account for any chemicals dosed in the full-scale system just prior to distribution.

5.9.4 Taste and Odour Compounds

In addition to an evaluation of water quality, water treatment facilities must also meet customer expectations regarding the waters' organoleptic qualities, namely taste, odour, and appearance. Likewise, it is well established that most contaminants that cause aesthetic concerns are not considered a concern for public health, however taste and odour are the most common sources of customer complaints. As such, these aesthetic qualities substantially influence consumers to seek alternative water sources such as bottled water.

Taste and odour problems can stem from microbiological or chemical causes, and are prompted by conditions in the raw water source, as part of the treatment process, or in the distribution system. The primary sources of these taste and odour compounds are largely the result of algae and bacteria, aspects typically found during the Summer months. Secondary sources are typically the result of anthropogenic activities, such as contamination by wastewater, chemical spills, pollution, etc.

Common salts and metals such as those associated with iron, copper, manganese, or zinc can lead to an undesirable mineral taste in water. The presence of blue-green algae and actinomycetes found in surface water sources can impart an earthy-musty taste often the result of the presence of geosmin, whereas oscillatoria species are often associated with the formation of 2-methylisoborneo (MIB). Most literature advise that minimizing algae-induced odours necessitates WTPs to first identify the odours source, namely the specific algae and subsequent taste and odour compounds, and second, to develop an understanding for the environmental factors which promote algal growth.

As such, the Summer piloting session efforts include the analysis of common taste and odour compounds. Analytical results were submitted to ALS Laboratories (Winnipeg, MB) for analysis. Samples were collected on August 14th, 2017, representing the optimum coagulant dose, filter-aid dose, operating pH. Findings are summarized on Table 5-6, note that all results are reported as nanograms per litre.

Table 5-6: Summer piloting session –Taste and Odour Compounds. Data obtained from August 14th optimal conditions laboratory analytical testing.

SOURCE	**2-ISOPROPYL-3-METHOXYPYRAZINE**	**2-ISOBUTYL-3-METHOXYPYRAZINE**	**2-METHYL ISOBORNEOL**	**2,4,6-TRICHLOROANISOLE**	**2,3,6-TRICHLOROANISOLE**	**GEOSMIN**	**3,4,5-TRICHLOROVERATROLE**
Raw Water at Pilot	<0.19	<0.19	<9.7	<0.49	<0.49	12.7	<0.19
Qualifier	Not detected above EDL						
Detection Limit	0.19	0.19	9.7	0.49	0.49	0.97	0.19
Pilot-Scale Filter Effluent	<0.20	<0.20	<9.8	<0.49	<0.49	1.18	<0.20
Qualifier	Not detected above EDL					Detected below calibration but above EDL	
Detection Limit	0.20	0.20	9.8	0.49	0.49	0.98	0.20
Full-Scale Filter Effluent	<0.19	<0.19	<9.7	<0.49	<0.49	5.47	<0.19
Qualifier	Not detected above EDL						
Detection Limit	0.19	0.19	9.7	0.49	0.49	0.97	0.19

Note: EDL = Estimated Detection Limit

Analytical results have identified geosmin present in the raw water at 12.7 ng/L, with the full-scale system filter effluent reducing this to 5.47 ng/L and the pilot-scale system filter effluent further reducing the concentration to 1.18 ng/L. Similarly taste and odour compounds, inclusive of MIB, were not detected in the raw water source, nor the final treated filter effluents from the full-scale or pilot-scale systems in the August 14th dataset.

Detection levels for geosmin and MIB are considered quite low, specifically concentrations in the order of 5 ng/L are detectable by the human pallet. Although many utilities employ powdered activated carbon of varying specifications and at a number of points throughout a water treatment system to remove such compounds, these treatment methods exhibit mixed results for further reduction at such a low concentration.

6. CONCLUSIONS AND RECOMMENDATIONS

From the results presented above, the following may be concluded:

- The City was successful in benchmarking the pilot-scale system to the full-scale system, as per the results of tested key parameters, such as pH, turbidity, TOC, and total manganese.
- The City was successful in transitioning the pilot-scale system from ferric chloride to ferric sulphate, as per the results of tested key parameters, including turbidity, TOC, and total manganese. Stability was observed despite the significant changes to chemical dosages during this period.
- Raw water temperature exceeded 21°C for the entirely Summer piloting session. It can therefore be concluded that warm water conditions have been captured.
- During the Summer piloting session, the Post-DAF pH was controlled by adjusting the sulphuric acid dose to the raw water based on a pH set-point, allowing a significant improvement on the pH control. The practice was monitored via Post-DAF grab samples to ensure the appropriateness of such a feedback loop.
- During the Summer piloting session, Bank A and Bank B were operated at a flow rate of 0.3 L/s and 0.6 L/s, respectively. Both filter banks exhibited similar UFRV values, and on average Bank B exhibited a filter run time twice that of Bank A, as expected. A significant decrease in UFRV and filter run is observed for both banks following the addition of coagulant-aid dosing starting on August 5th, 2017.
- An optimal dose for the coagulant ferric sulphate was investigated in the pilot-scale system from July 25th to July 29th, 2017, with no addition of coagulant-aid and target pH of 6.00. The optimal dose during Summer conditions was found to be 38 mg/L based on the four key parameters investigated.
- Using the optimal dose of coagulant (38 mg/L), the optimal pH for coagulation was explored from July 31st to August 3rd, 2017. The turbidity, UVT, absorbance, as well as the significant decrease in total manganese, indicating a target pH of 5.80 as the optimal value for ferric sulphate in warm water conditions.
- Using the optimal doses of coagulant (38 mg/L) and optimal target pH (5.80), an optimal coagulant-aid dose was investigated at the optimum coagulant dose in the pilot-scale system from August 5th to August 9th, 2017. The optimal coagulant-aid dose was found to be 0.10 mg/L. However, the results indicate that coagulation, without the addition of coagulant-aid, produced better operational conditions, i.e. longer filter run times and produced equivalent treated water quality to coagulation using 0.1 mg/L LT-22S.
- Significantly lower total manganese concentrations were measured in all pilot-scale system processes using ferric sulphate.
- The best pilot-scale treated water quality was produced when the optimal coagulant and coagulant-aid doses and optimal pH were applied from August 14th to August 17th. The results from these days were also compared with the results from July 30th and August 4th when no coagulant-aid were dose and at pH between 5.80 and 6.00. It was observed that the pilot-scale system's performance had a closer dependence on pH conditions during coagulation and the coagulant-aid did not necessarily

increase the reduction of turbidity under optimal pH conditions. In terms of filter operation, the UFRV analysis showed the best results were obtained on August 4th, without the addition of coagulant-aid.

- The pilot-scale system never achieved the City's operational guideline of 0.1 NTU for filter effluent turbidity during the Summer piloting session, impeding a more conclusive UFRV analysis. However, based on the Lab analysis under optimal conditions, all individual filters (except for Filter 1) presented turbidity below, or very close to, 0.1 NTU, which were similar values to the full-scale system.
- THMFP and HAAFP were not significantly reduced by both pilot-scale and full-scale systems probably due to the organic matter composition. The pilot-scale system outperformed the full-scale system on August 14th when the ozone was dosed at both systems, but not on August 4th without the addition of ozone at pilot-scale system.
- Corrosive indices such as CSMR, LR, LSI, and RSI suggest that the pilot-scale system effluent using ferric sulphate as a coagulant will benefit from the addition of alkalinity to improve said indices. Similar corrosive results are observed for full-scale system filter effluent results as sampled prior to the addition of sodium hydroxide (and the subsequent increase in alkalinity).
- The pilot-scale system outperformed the full-scale system on August 14th regarding geosmin reduction. Other taste and odour compounds, inclusive of MIB were not detected in the raw water source, nor in the final treat filter effluents from the full-scale or pilot-scale systems.

Recommendations regarding the remaining Fall and Winter #2 piloting sessions and future sessions are as follow:

- Maintain the reversed flow configuration of the filter banks to offset potential performance shortcomings arising from the mechanical differences between the pilot-scale system filter banks.
- Continuation of sampling of both the full-scale and pilot-scale systems on the same day for laboratory testing, to allow valid comparison between the two systems using the same raw water.
- Investigate the effects of coagulant-aid in the filter cycles and the filter effluent water quality's impact on the UFRV values and the frequency of cleaning and maintenance. However, this will be subject to additional scrutiny given the marginally observed water quality benefits.
- Current corrosion indicators are based on a single day sampling effort. Additional laboratory testing can provide a better perspective for the corrosivity of filter effluent water.
- Verify the calibration of filter-aid pumps periodically to confirm polymer dosage accuracy and their influence on the filters performance.
- That the City perform additional ferric sulphate pilot–scale system testing in warm water (Summer conditions) prior to the coagulant switchover to further optimise chemical conditions to ensure that ferric sulphate would be capable of achieving the City's operational guideline of 0.1 NTU for filter effluent turbidity.

Piloting Results Database Summary

Season: Summer
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
June 3, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0122	0.0523	0.0502	0.0113	0.0083	0.0059	0.0108	0.0118	0.0128	0.0079	0.0089		
				Avg. of filters 1 to 8												0.00971	
		pH	Lab		8.05	5.6	5.61	6.24	6.25	6.27	6.2	6.13	6.2	6.17	6.2		
				Avg. of filters 1 to 8												6.2075	
		TOC, Total (mg/L)	Lab		8.6	3	3.4	3	3	3	3						
				Avg. of filters 1 to 8												3	
		Turbidity (NTU)	Lab		1.12	0.55	0.65	0.08	0.08	0.07	0.08	0.08	0.08	0.09	0.1		
				Avg. of filters 1 to 8												0.0825	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0535	0.0551	0.0379	0.0374	0.0364	0.0368	0.0343		0.0366	0.0353		0.0439
		pH	Lab			5.41	5.46	5.48	5.45	5.51	5.46	5.42		5.45	5.46		5.44
		TOC, Total (mg/L)	Lab			3.3	3.4	3	3	2.8	2.8						3.1
		Turbidity (NTU)	Lab			0.36	0.49	0.07	0.08	0.1	0.09	0.08		0.08	0.08		0.11
June 4, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0122	0.0511	0.0493	0.0248	0.0223	0.0176	0.0259	0.0276	0.029	0.0226	0.0227		
				Avg. of filters 1 to 8												0.02406	
		pH	Lab		8.03	5.68	5.72	6.01	6.01	6.04	5.99	6.05	6.12	6.07	6.1		
				Avg. of filters 1 to 8												6.04875	
		TOC, Total (mg/L)	Lab		8.4	3.4	3.4					2.9	2.9	3	2.8		
				Avg. of filters 1 to 8												2.9	
		Turbidity (NTU)	Lab		1.11	0.61	0.69	0.07	0.06	0.07	0.06	0.07	0.06	0.06	0.06		
				Avg. of filters 1 to 8												0.06375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0532	0.0522	0.0364		0.038	0.0363	0.0373	0.0363	0.0347	0.0341		0.0464
		pH	Lab			5.39	5.46	5.49		5.52	5.44	5.43	5.52	5.44	5.48		5.38
		TOC, Total (mg/L)	Lab			3.4	3.3										3
		Turbidity (NTU)	Lab			0.33	0.51	0.08		0.08	0.08	0.09	0.08	0.09	0.1		0.12
June 5, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0513	0.0482	0.0308	0.029	0.0276	0.0343	0.0351	0.0369	0.0313	0.0327		
				Avg. of filters 1 to 8												0.03221	
		pH	Lab		8.11	5.68	5.71	5.88	5.92	5.94	5.89	5.79	5.8	5.88	5.84		
				Avg. of filters 1 to 8												5.8675	
		TOC, Total (mg/L)	Lab			3.4	3.4	2.7	2.7	2.8	2.6						
				Avg. of filters 1 to 8												2.7	
		Turbidity (NTU)	Lab		0.88	0.54	0.67	0.08	0.09	0.08	0.07	0.08	0.08	0.08	0.09		
				Avg. of filters 1 to 8												0.08125	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0531	0.052	0.0362	0.0372	0.0359	0.0356	0.0373	0.0377	0.0368			0.041
		pH	Lab			5.48	5.51	5.63	5.55	5.59	5.58	5.45	5.53	5.49			5.43
		TOC, Total (mg/L)	Lab					3.1	3.3	3.2	3						
		Turbidity (NTU)	Lab			0.34	0.49	0.09	0.08	0.09	0.09	0.06	0.07	0.1			0.15
June 6, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0105	0.0499	0.0517	0.0313	0.0311	0.0315	0.0358	0.0369	0.0384	0.0332	0.0348		
				Avg. of filters 1 to 8												0.03413	
		pH	Lab		8	5.54	5.6	5.81	5.75	5.76	5.72	5.78	5.76	5.82	5.81		
				Avg. of filters 1 to 8												5.77625	
		TOC, Total (mg/L)	Lab		9.4	4.1	4.1					3.7	3.7	3.5	3.9		
				Avg. of filters 1 to 8												3.7	
		Turbidity (NTU)	Lab		0.83	0.57	0.74	0.09	0.09	0.09	0.1	0.1	0.1	0.1	0.1		
				Avg. of filters 1 to 8												0.09625	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0524	0.0509	0.0362	0.037	0.0354		0.0392	0.0397	0.0416	0.04		0.0391
		pH	Lab			5.48	5.46	5.58	5.59	5.6		5.45	5.42	5.37	5.38		5.37
		TOC, Total (mg/L)	Lab			4.4	4.1					4	3.4	3.8	3.7		3.7
		Turbidity (NTU)	Lab			0.27	0.45	0.1	0.08	0.09		0.07	0.09	0.07	0.09		0.12
June 7, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.013	0.0527	0.0527	0.0315	0.0303	0.0316	0.0364	0.037	0.0386	0.0338	0.0345		
				Avg. of filters 1 to 8												0.03421	
		pH	Lab		7.97	5.56	5.62	5.77	5.8	5.75	5.71	5.78	5.82	5.78	5.77		
				Avg. of filters 1 to 8												5.7725	
		TOC, Total (mg/L)	Lab		9.7	4.3	2.2	3.8	4.1	3.6	3.8						
				Avg. of filters 1 to 8												3.825	
		Turbidity (NTU)	Lab		0.88	0.56	0.79	0.11	0.09	0.09	0.08	0.09	0.09	0.09	0.09		
				Avg. of filters 1 to 8												0.09125	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0527	0.0519		0.0343	0.034	0.0367	0.0385	0.0414	0.0405	0.0399		0.0385
		pH	Lab			5.64	5.6		5.74	5.75	5.68	5.47	5.41	5.4	5.4		5.46
		TOC, Total (mg/L)	Lab			4.2	4.5		3.8	4.1	4.3						4.3
		Turbidity (NTU)	Lab			0.27	0.45		0.09	0.1	0.08	0.09	0.07	0.08	0.08		0.1
June 8, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0122	0.0521	0.0516	0.0311	0.031	0.0322	0.0352	0.0366	0.0387	0.0342	0.0346		
				Avg. of filters 1 to 8												0.0342	
		pH	Lab		7.98	5.62	5.68	5.82	5.81	5.8	5.77	5.8	5.78	5.8	5.82		
				Avg. of filters 1 to 8												5.8	
		TOC, Total (mg/L)	Lab		9.7	4.3	4.3					3.5	3.9	3.8	3.7		
				Avg. of filters 1 to 8												3.725	
		Turbidity (NTU)	Lab		0.82	0.64	0.74	0.1	0.09	0.09	0.08	0.09	0.09	0.08	0.09		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
June 8, 2017	Pilot-Scale	Turbidity (NTU)	Lab	Avg. of filters 1 to 8												0.08875	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0531	0.0522	0.0354		0.0355	0.0361	0.0406	0.0405	0.0404	0.039		0.0389
		pH	Lab			5.48	5.48	5.6		5.6	5.61	5.47	5.4	5.38	5.43		5.39
		TOC, Total (mg/L)	Lab			4.3	4.5					3.7	3.7	3.8	3.4		4.2
		Turbidity (NTU)	Lab			0.32	0.45	0.08		0.08	0.08	0.06	0.07	0.08	0.07		0.11
June 9, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0105	0.0504	0.0482	0.0291	0.0287	0.03	0.0329	0.0357	0.0352	0.0312	0.0327		
				Avg. of filters 1 to 8												0.03194	
		pH	Lab		8.09	5.63	5.67	5.79	5.76	5.8	5.73	5.71	5.72	5.7	5.74		
				Avg. of filters 1 to 8												5.74375	
		TOC, Total (mg/L)	Lab		12.2	3.3	3.2	3	4.9	4.5	4.3						
				Avg. of filters 1 to 8												4.175	
		Turbidity (NTU)	Lab		0.83	0.6	0.8	0.14	0.1	0.11	0.11	0.13	0.11	0.12	0.1		
				Avg. of filters 1 to 8												0.115	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.05	0.0473	0.0344	0.0348	0.0349	0.0333	0.0378	0.037		0.0395		0.0345
		pH	Lab			5.5	5.67	5.61	5.6	5.61	5.6	5.41	5.38		5.3		5.46
		TOC, Total (mg/L)	Lab			4.9	4.7	4.6	4.7	4.9	4.9						4.5
		Turbidity (NTU)	Lab			0.34	0.45	0.11	0.11	0.08	0.09	0.08	0.13		0.12		0.21
June 10, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.021	0.0562	0.0579	0.0342	0.0334	0.0316	0.0374	0.0389	0.0403	0.0355	0.0361		
				Avg. of filters 1 to 8												0.03593	
		pH	Lab		7.94	5.68	5.72	5.84	5.78	5.79	5.77	5.71	5.68	5.7	5.71		
				Avg. of filters 1 to 8												5.7475	
		TOC, Total (mg/L)	Lab		8.3	3.4	3.5					3	2.9	3	2.9		
				Avg. of filters 1 to 8												2.95	
		Turbidity (NTU)	Lab		0.89	0.59	0.76	0.12	0.07	0.08	0.09	0.08	0.07	0.08	0.08		
				Avg. of filters 1 to 8												0.08375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0588	0.0571	0.036	0.0379	0.0365	0.0409	0.0415		0.0427	0.0423		0.0403
		pH	Lab			5.52	5.52	5.56	5.59	5.74	5.58	5.41		5.39	5.4		5.43
		TOC, Total (mg/L)	Lab			3.4	3.3					3.1		2.9	2.7		3.1
		Turbidity (NTU)	Lab			0.31	0.45	0.09	0.08	0.1	0.07	0.06		0.08	0.07		0.08
June 11, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0126	0.0566	0.0553	0.0358	0.0338	0.0355	0.0404	0.0413	0.0434	0.0357	0.037		
				Avg. of filters 1 to 8												0.03786	
		pH	Lab		8.13	5.57	5.57	5.7	5.71	5.69	5.67	5.66	5.68	5.66	5.68		
				Avg. of filters 1 to 8												5.68125	
		TOC, Total (mg/L)	Lab		7.9	3.5	3.5	3	2.8	2.7	3.1						
				Avg. of filters 1 to 8												2.9	
		Turbidity (NTU)	Lab		0.89	0.63	0.67	0.08	0.07	0.08	0.07	0.07	0.07	0.07	0.06		
				Avg. of filters 1 to 8												0.07125	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0573	0.0544		0.0358	0.036	0.0378	0.0401	0.0417	0.0405	0.0407		0.0379
		pH	Lab			5.47	5.49		5.57	5.58	5.53	5.51	5.34	5.3	5.31		5.35
		TOC, Total (mg/L)	Lab			3.2	3.2		3.1	2.9	3.2						3
		Turbidity (NTU)	Lab			0.27	0.5		0.1	0.09	0.09	0.09	0.06	0.07	0.08		0.1
June 12, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0118	0.0555	0.0569	0.0411	0.0389	0.0397	0.0434	0.0427	0.0448	0.0401	0.0407		
				Avg. of filters 1 to 8												0.04143	
		pH	Lab		8.11	5.74	5.76	5.71	5.72	5.72	5.74	5.71	5.73	5.75	5.72		
				Avg. of filters 1 to 8												5.725	
		TOC, Total (mg/L)	Lab			3.5	3.4					2.8	2.9	2.9	2.7		
				Avg. of filters 1 to 8												2.825	
		Turbidity (NTU)	Lab		0.88	0.79	0.73	0.06	0.05	0.06	0.07	0.05	0.08	0.1	0.08		
				Avg. of filters 1 to 8												0.06875	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0551	0.0539	0.0361	0.0359		0.0362	0.0409	0.0397	0.0402	0.0375		0.039
		pH	Lab			5.53	5.62	5.65	5.66		5.7	5.52	5.49	5.46	5.46		5.53
		TOC, Total (mg/L)	Lab									2.9	2.9	3	3.1		
		Turbidity (NTU)	Lab			0.25	0.48	0.08	0.1		0.09	0.1	0.07	0.09	0.08		0.42
June 13, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.013	0.0509	0.0519	0.0385	0.0354	0.0401	0.0399	0.04	0.0442	0.0383	0.0386		
				Avg. of filters 1 to 8												0.03938	
		pH	Lab		8.19	5.72	5.54	5.69	5.7	5.7	5.66	5.64	5.65	5.66	5.65		
				Avg. of filters 1 to 8												5.66875	
		Turbidity (NTU)	Lab		1.18	0.61	0.78	0.07	0.06	0.06	0.07	0.06	0.07	0.08	0.07		
				Avg. of filters 1 to 8												0.0675	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0528	0.0519	0.0355	0.0344	0.0333	0.0337	0.0398	0.0377	0.0381			0.0384
		pH	Lab			5.69	5.64	5.72	5.72	5.73	5.69	5.46	5.48	5.42			5.51
		Turbidity (NTU)	Lab			0.34	0.44	0.11	0.1	0.11	0.09	0.06	0.08	0.11			0.09
June 14, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0138	0.0519	0.0494	0.0369	0.032	0.0364	0.0393	0.0385	0.041	0.0349	0.0374		
				Avg. of filters 1 to 8												0.03705	
		pH	Lab		8.05	5.59	5.63	5.58	5.7	5.68	5.62	5.66	5.69	5.7	5.7		
				Avg. of filters 1 to 8												5.66625	
		TOC, Total (mg/L)	Lab		8.5	3.6	3.6					3.2	3.1	2.9	2.8		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer

Phase: Benchmarking

					Sample Location												
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Filter Effluent Average**	**Combined Filtrate**
June 14, 2017	Pilot-Scale	TOC, Total (mg/L)	Lab	Avg. of filters 1 to 8												3	
		Turbidity (NTU)	Lab		0.92	0.64	0.81	0.08	0.07	0.07	0.07	0.06	0.07	0.07	0.07		
				Avg. of filters 1 to 8												0.07	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0513	0.0524	0.0344	0.0353	0.0355	0.0366	0.0387		0.0389	0.0394		0.0375
		pH	Lab			5.51	5.53	5.63	5.61	5.64	5.6	5.39		5.32	5.34		5.48
		TOC, Total (mg/L)	Lab			3.5	3.2					3		2.8	3		3
		Turbidity (NTU)	Lab			0.26	0.44	0.11	0.09	0.09	0.07	0.07		0.07	0.07		0.12
June 15, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0114	0.0506	0.0528	0.0286	0.0291	0.0311	0.0345	0.0366	0.0389	0.0338	0.0341		
				Avg. of filters 1 to 8												0.03334	
		pH	Lab		8.06	5.62	5.65	5.75	5.75	5.72	5.68	5.68	5.66	5.66	5.64		
				Avg. of filters 1 to 8												5.6925	
		TOC, Total (mg/L)	Lab		8.5	4.1	4	3.4	3	3	3						
				Avg. of filters 1 to 8												3.1	
		Turbidity (NTU)	Lab		0.89	1.36	1.29	0.07	0.06	0.07	0.06	0.06	0.06	0.05	0.05		
				Avg. of filters 1 to 8												0.06	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0487	0.0499	0.0346	0.0327		0.0344	0.037	0.0374	0.0378	0.0363		0.038
		pH	Lab			5.5	5.51	5.65	5.69		5.68	5.42	5.38	5.36	5.32		5.43
		TOC, Total (mg/L)	Lab			3.4	3.4	3.3	3.5		3.2						3.3
		Turbidity (NTU)	Lab			0.24	0.43	0.08	0.1		0.1	0.07	0.06	0.07	0.07		0.09
June 16, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0176	0.0528	0.053	0.0288	0.0273	0.03	0.0332	0.0357	0.0385	0.0333	0.0342		
				Avg. of filters 1 to 8												0.03263	
		pH	Lab		8.08	5.6	5.64	5.67	5.69	5.7	5.65	5.66	5.58	5.63	5.65		
				Avg. of filters 1 to 8												5.65375	
		TOC, Total (mg/L)	Lab		8.7	4	3.7					3	3.1	3	2.9		
				Avg. of filters 1 to 8												3	
		Turbidity (NTU)	Lab		1.06	1.16	1.3	0.06	0.07	0.06	0.06	0.06	0.05	0.06	0.06		
				Avg. of filters 1 to 8												0.06	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0539	0.0516	0.035	0.036	0.0353	0.0333	0.0394	0.04		0.0403		0.0392
		pH	Lab			5.47	5.57	5.54	5.6	5.63	5.56	5.38	5.32		5.26		5.46
		TOC, Total (mg/L)	Lab			3.4	3.3					3	2.8		2.7		3.2
		Turbidity (NTU)	Lab			0.29	0.43	0.09	0.11	0.09	0.09	0.06	0.07		0.06		0.13
June 17, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0122	0.0534	0.0534	0.0296	0.0287	0.0311	0.0344	0.0375	0.0393	0.0347	0.0354		
				Avg. of filters 1 to 8												0.03384	
		pH	Lab		8.05	5.55	5.6	5.66	5.63	5.66	5.64	5.6	5.63	5.62	5.69		
				Avg. of filters 1 to 8												5.64125	
		TOC, Total (mg/L)	Lab		8.7	4.1	4.1	3.1	3	3	3						
				Avg. of filters 1 to 8												3.025	
		Turbidity (NTU)	Lab		0.87	1.15	1.16	0.06	0.05	0.06	0.07	0.06	0.06	0.05	0.06		
				Avg. of filters 1 to 8												0.05875	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0531	0.0512		0.0346	0.0338	0.0363	0.0375		0.0395	0.038		0.0374
		pH	Lab			5.65	5.49		5.58	5.58	5.54	5.34		5.19	5.19		5.43
		TOC, Total (mg/L)	Lab			3.2	3.4		3.4	3.6	3						3.2
		Turbidity (NTU)	Lab			0.37	0.39		0.08	0.08	0.08	0.07		0.07	0.07		0.1
June 18, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0127	0.0534	0.0512	0.0308	0.0286	0.0301	0.0341	0.0376	0.0391	0.0351	0.0349		
				Avg. of filters 1 to 8												0.03379	
		pH	Lab		8.07	5.55	5.61	5.64	5.66	5.66	5.61	5.58	5.58	5.56	5.64		
				Avg. of filters 1 to 8												5.61625	
		TOC, Total (mg/L)	Lab		8.6	3.5	3.5					2.9	2.7	2.8	2.8		
				Avg. of filters 1 to 8												2.8	
		Turbidity (NTU)	Lab		0.83	1.12	1.2	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.05375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0532	0.0521	0.0368	0.0354		0.0357	0.0384	0.0392	0.0383	0.0374		0.0376
		pH	Lab			5.51	5.51	5.58	5.62		5.58	5.37	5.27	5.24	5.25		5.41
		TOC, Total (mg/L)	Lab			3.7	3.1					3.3	3.1	3.2	3		2.9
		Turbidity (NTU)	Lab			0.26	0.45	0.07	0.1		0.08	0.06	0.06	0.07	0.07		0.11
June 19, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0101	0.0521	0.0491	0.0278	0.0274	0.0293	0.0312	0.0354	0.0371	0.0322	0.0326		
				Avg. of filters 1 to 8												0.03163	
		pH	Lab		8.02	5.56	5.64	5.71	5.73	5.73	5.71	5.65	5.64	5.61	5.64		
				Avg. of filters 1 to 8												5.6775	
		TOC, Total (mg/L)	Lab			4.2	3.8	2.7	2.8	2.7	2.7						
				Avg. of filters 1 to 8												2.725	
		Turbidity (NTU)	Lab		0.8	1.6	1.57	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05		
				Avg. of filters 1 to 8												0.06625	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0509	0.0473	0.0379	0.0379	0.0381	0.0348	0.0377	0.0383		0.0381		0.0393
		pH	Lab			5.4	5.53	5.5	5.48	5.5	5.5	5.43	5.46		5.45		5.47
		TOC, Total (mg/L)	Lab					2.8	2.8	2.9	2.8						
		Turbidity (NTU)	Lab			0.28	0.43	0.08	0.07	0.07	0.09	0.07	0.1		0.08		0.14

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
June 21, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0116	0.0488	0.0484	0.0213	0.0209	0.0228	0.0245	0.0277	0.0301	0.0251	0.0258		
				Avg. of filters 1 to 8												0.02478	
		pH	Lab		8.07	5.61	5.61	5.71	5.67	5.71	5.65	5.63	5.64	5.61	5.64		
				Avg. of filters 1 to 8												5.6575	
		TOC, Total (mg/L)	Lab		7.8	3.8	3.7					2.8	2.7	2.9	2.9		
				Avg. of filters 1 to 8												2.825	
		Turbidity (NTU)	Lab		0.76	1.32	1.26	0.07	0.06	0.07	0.05	0.06	0.06	0.05	0.06		
				Avg. of filters 1 to 8												0.06	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0509	0.0485	0.0337	0.0353	0.0318	0.031	0.0371	0.036		0.0356		0.0343
		pH	Lab			5.56	5.63	5.64	5.65	5.68	5.61	5.49	5.47		5.54		5.48
		TOC, Total (mg/L)	Lab			3.4	3.3					2.9	2.9		2.8		2.9
		Turbidity (NTU)	Lab			0.26	0.46	0.07	0.07	0.07	0.08	0.05	0.06		0.05		0.1
June 22, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0119	0.0504	0.049	0.0203	0.0194	0.0208	0.0242	0.026	0.0284	0.0219	0.0236		
				Avg. of filters 1 to 8												0.02308	
		pH	Lab		8.12	5.63	5.71	5.74	5.73	5.7	5.7	5.66	5.62	5.63	5.64		
				Avg. of filters 1 to 8												5.6775	
		TOC, Total (mg/L)	Lab		7.9	4.1		2.9	3	3	2.9						
				Avg. of filters 1 to 8												2.95	
		Turbidity (NTU)	Lab		0.65	1.39	1.16	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.0525	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0512	0.0476	0.0327	0.032	0.0309	0.0338	0.0368		0.0373	0.0371		0.0339
		pH	Lab			5.51	5.52	5.61	5.58	5.61	5.59	5.41		5.36	5.36		5.43
		TOC, Total (mg/L)	Lab			3.1	3.2	2.8	3	3.1	3						2.9
		Turbidity (NTU)	Lab			0.28	0.47	0.08	0.06	0.07	0.06	0.06		0.06	0.06		0.13
June 23, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0131	0.0523	0.0536	0.0188	0.0185	0.019	0.022	0.0233	0.0262	0.0202	0.0208		
				Avg. of filters 1 to 8												0.0211	
		pH	Lab		8.1	5.71	5.73	5.79	5.79	5.79	5.78	5.73	5.74	5.68	5.74		
				Avg. of filters 1 to 8												5.755	
		TOC, Total (mg/L)	Lab		8.1	4.6	5.4					3.3	2.9	3.6	2.9		
				Avg. of filters 1 to 8												3.175	
		Turbidity (NTU)	Lab		0.88	1.86	3.48	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.05125	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0524	0.0495	0.0354	0.032		0.034	0.0385	0.0394	0.038	0.0371		0.0355
		pH	Lab			5.57	5.71	5.66	5.62		5.64	5.52	5.5	5.41	5.4		5.55
		TOC, Total (mg/L)	Lab			3.4	3.2					3	3	2.9	3.4		2.8
		Turbidity (NTU)	Lab			0.33	0.43	0.07	0.08		0.07	0.06	0.08	0.07	0.07		0.08
June 24, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0131	0.0514	0.0512	0.0184	0.0179	0.0178	0.0219	0.0263	0.0283	0.0217	0.0223		
				Avg. of filters 1 to 8												0.02183	
		pH	Lab		8.1	5.67	5.69	5.81	5.78	5.81	5.77	5.73	5.74	5.76	5.78		
				Avg. of filters 1 to 8												5.7725	
		TOC, Total (mg/L)	Lab		8.7	3.4	3.4	3.1	3.3	3.2	3.1						
				Avg. of filters 1 to 8												3.175	
		Turbidity (NTU)	Lab		0.78	0.47	0.52	0.07	0.05	0.05	0.06	0.05	0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.05375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0528	0.0523	0.035	0.0361	0.0351	0.0347	0.0408	0.0403	0.0398			0.0384
		pH	Lab			5.56	5.5	5.6	5.64	5.67	5.59	5.36	5.35	5.33			5.48
		TOC, Total (mg/L)	Lab			3.9	3.3	3.5	3	3.2	3.3						3.2
		Turbidity (NTU)	Lab			0.27	0.38	0.06	0.08	0.07	0.07	0.06	0.07	0.07			0.1
June 25, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0125	0.0541	0.0563	0.0184	0.018	0.0183	0.023	0.027	0.0295	0.0227	0.0227		
				Avg. of filters 1 to 8												0.02245	
		pH	Lab		8.12	5.72	5.74	5.86	5.84	5.85	5.79	5.75	5.8	5.77	5.76		
				Avg. of filters 1 to 8												5.8025	
		TOC, Total (mg/L)	Lab		8.2	3.4	4					3.4	3.2	3.4	3.1		
				Avg. of filters 1 to 8												3.275	
		Turbidity (NTU)	Lab		0.79	0.48	0.59	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.07		
				Avg. of filters 1 to 8												0.06625	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0529	0.0544	0.0336	0.0356	0.0332	0.0363	0.039		0.0407	0.0388		0.04
		pH	Lab			5.56	5.55	5.64	5.61	5.65	5.61	5.42		5.29	5.31		5.49
		TOC, Total (mg/L)	Lab			3.6	3.6					3.2		2.7	3		3.1
		Turbidity (NTU)	Lab			0.27	0.45	0.09	0.06	0.07	0.06	0.06		0.06	0.06		0.11
June 26, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.011	0.0521	0.0528	0.0154	0.0152	0.014	0.0186	0.0233	0.0253	0.0192	0.0186		
				Avg. of filters 1 to 8												0.0187	
		pH	Lab		8.12	5.79	5.84	5.85	5.87	5.86	5.83	5.78	5.8	5.78	5.8		
				Avg. of filters 1 to 8												5.82125	
		TOC, Total (mg/L)	Lab			3.7	3.5	3	3	3.1	3.4						
				Avg. of filters 1 to 8												3.125	
		Turbidity (NTU)	Lab		0.72	0.48	0.63	0.07	0.05	0.08	0.06	0.06	0.06	0.06	0.06		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer

Phase: Benchmarking

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
June 26, 2017	Pilot-Scale	Turbidity (NTU)	Lab	Avg. of filters 1 to 8												0.0625	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0511	0.0511	0.035	0.0329		0.0335	0.038	0.039	0.0379	0.0371		0.0367
		pH	Lab			5.43	5.38	5.58	5.59		5.59	5.37	5.29	5.26	5.27		5.52
		TOC, Total (mg/L)	Lab					3.3	3		3						
		Turbidity (NTU)	Lab			0.24	0.51	0.06	0.08		0.06	0.06	0.07	0.08	0.06		0.15
June 27, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0119	0.0511	0.0519	0.0152	0.0141	0.0142	0.0176	0.0212	0.0235	0.017	0.0175		
				Avg. of filters 1 to 8												0.01754	
		pH	Lab		8.2	5.76	5.8	5.88	5.87	5.9	5.83	5.87	5.85	5.84	5.83		
				Avg. of filters 1 to 8												5.85875	
		TOC, Total (mg/L)	Lab		8	3.6	3.9					3.2	3.1	3	3.1		
				Avg. of filters 1 to 8												3.1	
		Turbidity (NTU)	Lab		0.81	0.42	0.58	0.07	0.06	0.07	0.07	0.06	0.06	0.06	0.06		
				Avg. of filters 1 to 8												0.06375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.052	0.0515	0.0352	0.0361	0.0348	0.0344	0.0389	0.0389		0.0391		0.0375
		pH	Lab			5.48	5.44	5.55	5.54	5.56	5.51	5.3	5.22		5.16		5.4
		TOC, Total (mg/L)	Lab			3.2	3.2					2.8	2.8		2.6		3.2
		Turbidity (NTU)	Lab			0.26	0.49	0.07	0.06	0.06	0.08	0.07	0.08		0.05		0.09
June 28, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0119	0.0538	0.0541	0.0137	0.0139	0.0144	0.0185	0.0208	0.0235	0.0166	0.0167		
				Avg. of filters 1 to 8												0.01726	
		pH	Lab		8.19	5.79	5.78	5.97	5.92	5.92	5.93	5.83	5.82	5.84	5.85		
				Avg. of filters 1 to 8												5.885	
		TOC, Total (mg/L)	Lab		8	3.2	3.4	2.7	2.7	2.7	2.6						
				Avg. of filters 1 to 8												2.675	
		Turbidity (NTU)	Lab		0.73	0.42	0.54	0.07	0.07	0.06	0.06	0.06	0.08	0.06	0.06		
				Avg. of filters 1 to 8												0.065	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0549	0.0542		0.0366	0.0363	0.0376	0.038	0.0419	0.0413	0.0403		0.0408
		pH	Lab			5.43	5.37		5.48	5.53	5.49	5.24	5.11	5.08	5.07		5.27
		TOC, Total (mg/L)	Lab			2.8	2.8		2.6	2.8	2.9						2.5
		Turbidity (NTU)	Lab			0.24	0.49		0.07	0.07	0.06	0.06	0.06	0.06	0.06		0.1
June 29, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0118	0.0546	0.053	0.0122	0.0123	0.0134	0.0171	0.0205	0.0231	0.0156	0.0163		
				Avg. of filters 1 to 8												0.01631	
		pH	Lab		8.18	5.78	5.8	5.94	5.94	5.95	5.9	5.85	5.87	5.9	5.91		
				Avg. of filters 1 to 8												5.9075	
		TOC, Total (mg/L)	Lab		8	3.1	3.1					2.7	2.8	2.8	2.7		
				Avg. of filters 1 to 8												2.75	
		Turbidity (NTU)	Lab		0.81	0.43	0.56	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.07		
				Avg. of filters 1 to 8												0.06375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0541	0.0547	0.0372		0.0378	0.0362	0.0406	0.0417	0.0406	0.0389		0.0403
		pH	Lab			5.46	5.41	5.56		5.55	5.48	5.25	5.18	5.19	5.24		5.37
		TOC, Total (mg/L)	Lab			2.8	2.7					2.6	2.4	2.4	2.4		2.7
		Turbidity (NTU)	Lab			0.24	0.47	0.06		0.07	0.08	0.06	0.06	0.08	0.07		0.07
June 30, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0121	0.0535	0.0525	0.0141	0.0135	0.014	0.0177	0.0223	0.0227	0.017	0.0175		
				Avg. of filters 1 to 8												0.01735	
		pH	Lab		8.21	5.73	5.71	5.91	5.86	5.86	5.83	5.78	5.84	5.78	5.85		
				Avg. of filters 1 to 8												5.83875	
		TOC, Total (mg/L)	Lab		12.2	1.2	1.1	1	1	1	0.9						
				Avg. of filters 1 to 8												0.975	
		Turbidity (NTU)	Lab		0.82	0.27	0.38	0.06	0.05	0.06	0.06	0.05	0.06	0.05	0.05		
				Avg. of filters 1 to 8												0.055	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.055	0.0551	0.0355	0.0368	0.036		0.0404	0.0391	0.0433	0.042		0.0402
		pH	Lab			5.48	5.58	5.53	5.49	5.53		5.25	5.17	5.11	5.1		5.27
		TOC, Total (mg/L)	Lab			3.7	0.9	3.2	3.3	3.3							0.8
		Turbidity (NTU)	Lab			0.23	0.49	0.06	0.06	0.07		0.07	0.09	0.07	0.06		0.08
July 1, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0109	0.0546	0.0528	0.0277	0.027	0.0259	0.0314	0.0384	0.0381	0.0314	0.0319		
				Avg. of filters 1 to 8												0.03148	
		pH	Lab		8.26	5.43	5.45	5.72	5.71	5.72	5.68	5.66	5.63	5.66	5.66		
				Avg. of filters 1 to 8												5.68	
		TOC, Total (mg/L)	Lab		6.8	1	1					2.8	2.8	2.8	2.8		
				Avg. of filters 1 to 8												2.8	
		Turbidity (NTU)	Lab		0.72	0.27	0.39	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.06		
				Avg. of filters 1 to 8												0.0575	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0545	0.0527	0.0384	0.0347	0.0337	0.0379	0.0422	0.0419	0.0424	0.0415		0.0393
		pH	Lab			5.46	5.45	5.47	5.47	5.48	5.42	5.24	5.13	5.13	5.12		5.33
		TOC, Total (mg/L)	Lab			1.2	3.4							2.2	2.5		3
		Turbidity (NTU)	Lab			0.3	0.48	0.06	0.07	0.08	0.06	0.08	0.07	0.06	0.07		0.1
July 2, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0112	0.0537	0.057	0.029	0.0278	0.0301	0.0359	0.0396	0.041	0.0346	0.0348		
				Avg. of filters 1 to 8												0.0341	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer

Phase: Benchmarking

					Sample Location												
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Filter Effluent Average**	**Combined Filtrate**
July 2, 2017	Pilot-Scale	pH	Lab		8.23	5.48	5.51	5.69	5.69	5.66	5.67	5.55	5.63	5.58	5.61		
				Avg. of filters 1 to 8												5.635	
		TOC, Total (mg/L)	Lab		10.5	3.1	3.1	2.8	2.8	2.8	2.8						
				Avg. of filters 1 to 8												2.8	
		Turbidity (NTU)	Lab		0.88	0.28	0.42	0.05	0.06	0.05	0.06	0.06	0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.05375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0531	0.0534	0.0345	0.0349	0.0335	0.0337	0.0385	0.0386		0.0417		0.0383
		pH	Lab			5.49	5.49	5.54	5.55	5.57	5.52	5.34	5.27		5.24		5.4
		TOC, Total (mg/L)	Lab			3.9	3.3	3.2	3.2	3.2	3.2						3
		Turbidity (NTU)	Lab			0.23	0.54	0.09	0.07	0.09	0.1	0.07	0.08		0.06		0.13
July 3, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0136	0.0551	0.0586	0.0297	0.0306	0.0339	0.0376	0.0394	0.0409	0.0377	0.0384		
				Avg. of filters 1 to 8												0.03603	
		pH	Lab		8.3	5.48	5.49	5.63	5.61	5.59	5.55	5.53	5.5	5.49	5.52		
				Avg. of filters 1 to 8												5.5525	
		TOC, Total (mg/L)	Lab		10.6	3.1	3					2.7	2.7	2.8	2.8		
				Avg. of filters 1 to 8												2.75	
		Turbidity (NTU)	Lab		0.86	0.28	0.45	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.0525	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0534	0.0553	0.0338	0.0325	0.0325	0.035	0.0387		0.041	0.0393		0.0364
		pH	Lab			5.42	5.4	5.5	5.5	5.55	5.51	5.32		5.22	5.25		5.38
		TOC, Total (mg/L)	Lab			3.4	3.3					2.9		2.9	2.9		3.1
		Turbidity (NTU)	Lab			0.21	0.55	0.1	0.07	0.09	0.07	0.08		0.07	0.07		0.22
July 4, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0201	0.0628	0.0641	0.0342	0.0349	0.0386	0.0419	0.0439	0.0491	0.0434	0.044		
				Avg. of filters 1 to 8												0.04125	
		pH	Lab		8.16	5.41	5.45	5.61	5.65	5.61	5.6	5.5	5.55	5.56	5.53		
				Avg. of filters 1 to 8												5.57625	
		TOC, Total (mg/L)	Lab			2.5	2.7	2.2	2.3	2.2	2.2						
				Avg. of filters 1 to 8												2.225	
		Turbidity (NTU)	Lab		1.06	0.27	0.39	0.05	0.05	0.06	0.05	0.06	0.06	0.05	0.06		
				Avg. of filters 1 to 8												0.055	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0576	0.0593	0.0338	0.0324		0.0325	0.0406	0.0456	0.0441	0.0432		0.0382
		pH	Lab			5.46	5.43	5.65	5.62		5.62	5.37	5.36	5.3	5.28		5.41
		TOC, Total (mg/L)	Lab					2.8	3.1		2.6						
		Turbidity (NTU)	Lab			0.24	0.59	0.06	0.1		0.09	0.07	0.09	0.09	0.09		0.11
July 5, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0209	0.056	0.0562	0.0364	0.0362	0.0408	0.0443	0.0452	0.0484	0.0433	0.0444		
				Avg. of filters 1 to 8												0.04238	
		pH	Lab		8.03	5.43	5.47	5.59	5.58	5.58	5.54	5.51	5.54	5.52	5.55		
				Avg. of filters 1 to 8												5.55125	
		TOC, Total (mg/L)	Lab		7.7	2.4	2.7					2.1	2.1	2.1	2.4		
				Avg. of filters 1 to 8												2.175	
		Turbidity (NTU)	Lab		1.03	0.28	0.39	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.05	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.053	0.0575	0.0334	0.0339	0.0334	0.0344	0.0406	0.0411	0.0404			0.0407
		pH	Lab			5.47	5.42	5.56	5.51	5.6	5.53	5.29	5.26	5.28			5.41
		TOC, Total (mg/L)	Lab			2.7	3.2					2.4	2.4	2.4			2.6
		Turbidity (NTU)	Lab			0.21	0.54	0.07	0.06	0.07	0.08	0.07	0.08	0.1			0.12
July 6, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0227	0.0608	0.0623	0.0387	0.0384	0.0421	0.0455	0.0481	0.0511	0.0462	0.0463		
				Avg. of filters 1 to 8												0.04455	
		pH	Lab		8.1	5.39	5.35	5.55	5.47	5.51	5.48	5.46	5.45	5.45	5.44		
				Avg. of filters 1 to 8												5.47625	
		TOC, Total (mg/L)	Lab		8.7	3	3	2.8	2.5	2.5	2.9						
				Avg. of filters 1 to 8												2.675	
		Turbidity (NTU)	Lab		1.09	0.35	0.38	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06		
				Avg. of filters 1 to 8												0.0575	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0576	0.0576	0.0368	0.0378	0.0379	0.0403	0.0451		0.0466	0.0465		0.0423
		pH	Lab			5.53	5.43	5.56	5.55	5.61	5.56	5.47		5.67	5.33		5.41
		TOC, Total (mg/L)	Lab			3.7	3.5	3.2	2.9	2.9	3.2						2.7
		Turbidity (NTU)	Lab			0.2	0.5	0.09	0.08	0.08	0.07	0.08		0.08	0.08		0.09
July 7, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0268	0.0584	0.064	0.0394	0.0397	0.0418	0.044	0.0464	0.0478	0.0442	0.0456		
				Avg. of filters 1 to 8												0.04361	
		pH	Lab		8.2	5.49	5.49	5.52	5.52	5.5	5.45	5.45	5.46	5.46	5.47		
				Avg. of filters 1 to 8												5.47875	
		TOC, Total (mg/L)	Lab		8.3	3.3	3.2					2.5	2.5	2.8	2.8		
				Avg. of filters 1 to 8												2.65	
		Turbidity (NTU)	Lab		1.35	0.45	0.59	0.06	0.05	0.08	0.05	0.08	0.07	0.05	0.05		
				Avg. of filters 1 to 8												0.06125	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0554	0.0583	0.0362	0.0344	0.0344	0.0362		0.0423	0.0416	0.0417		0.0407

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
July 7, 2017	Full-Scale	pH	Lab			5.64	5.73	5.67	5.7	5.7	5.63		5.42	5.47	6		5.49
		TOC, Total (mg/L)	Lab			3.2	3.4						3.1	2.8	2.9		2.9
		Turbidity (NTU)	Lab			0.32	0.46	0.06	0.08	0.13	0.07		0.08	0.09	0.11		0.16
July 8, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0292	0.0578	0.0582	0.0375	0.0375	0.0398	0.0431	0.0443	0.047	0.0427	0.0446		
				Avg. of filters 1 to 8												0.04206	
		pH	Lab		8.19	5.41	5.42	5.54	5.56	5.49	5.5	5.45	5.44	5.49	5.45		
				Avg. of filters 1 to 8												5.49	
		TOC, Total (mg/L)	Lab		7.8	2.5	2.6	2.3	2.2	2.6	2.2						
				Avg. of filters 1 to 8												2.325	
		Turbidity (NTU)	Lab		1.32	0.27	0.36	0.05	0.05	0.05	0.08	0.06	0.06	0.06	0.05		
				Avg. of filters 1 to 8												0.0575	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0555	0.053	0.0367	0.038	0.0382	0.0362	0.04	0.0397	0.0386			0.0394
		pH	Lab			5.54	5.6	5.52	5.48	5.49	5.51	5.48	5.56	5.5			5.53
		TOC, Total (mg/L)	Lab			3	2.8	2.9	2.7	2.6	2.9						2.7
		Turbidity (NTU)	Lab			0.29	0.4	0.06	0.06	0.06	0.06	0.06	0.07	0.08			0.09
July 9, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0327	0.0646	0.0629	0.0367	0.036	0.0393	0.0423	0.0439	0.0474	0.043	0.0447		
				Avg. of filters 1 to 8												0.04166	
		pH	Lab		8.18	5.55	5.52	5.54	5.54	5.54	5.47	5.43	5.43	5.45	5.46		
				Avg. of filters 1 to 8												5.4825	
		TOC, Total (mg/L)	Lab		7.5	2.5	2.6					2.3	2.3	2.4	2.1		
				Avg. of filters 1 to 8												2.275	
		Turbidity (NTU)	Lab		1.51	0.31	0.4	0.05	0.05	0.06	0.05	0.06	0.05	0.05	0.06		
				Avg. of filters 1 to 8												0.05375	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0678	0.0629	0.038	0.0394	0.0392		0.0406	0.0414	0.0425	0.0411		0.041
		pH	Lab			5.54	5.56	5.57	5.5	5.58		5.51	5.54	5.52	5.52		5.46
		TOC, Total (mg/L)	Lab			2.9	2.9					2.6	2.7	2.6	2.7		2.6
		Turbidity (NTU)	Lab			0.29	0.57	0.09	0.08	0.09		0.08	0.1	0.07	0.08		0.11

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Transitioning

					Sample Location										
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
July 12, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0233	0.0166	0.0175	0.0021	0.0021	0.0021	0.002	0.002	0.0021	0.002	0.002
		pH	Lab		8.27	6.06	6.19	6.52	6.52	6.5	6.48	6.46	6.45	6.47	6.46
		TOC, Total (mg/L)	Lab		8.4	3.5	3.3	3.2	3.2	3.1	3.2				
		Turbidity (NTU)	Lab		1.05	0.52	0.67	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12
July 14, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0232	0.0172	0.0183	0.0011	0.0011	0.0009	0.0009	0.0008	0.0007	0.0007	0.0007
		pH	Lab		8.11	6.1	6.17	7.16	7.18	7.13	7.13	7.1	7.16	7.1	7.15
		TOC, Total (mg/L)	Lab		8	3.2	3.5					3.1	3.5	3.4	3.3
		Turbidity (NTU)	Lab		1.28	0.62	0.74	0.17	0.15	0.16	0.14	0.15	0.14	0.16	0.15
July 15, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0308	0.0153	0.0159	0.0011	0.0011	0.0012	0.001	0.001	0.001	0.0009	0.0009
		pH	Lab		8.27	6.05	6.1	6.55	6.56	6.57	6.54	6.5	6.52	6.53	6.53
		TOC, Total (mg/L)	Lab		8.2	3.2	3.1	2.9	2.6	2.9	2.8				
		Turbidity (NTU)	Lab		1.5	0.54	0.71	0.15	0.14	0.14	0.15	0.14	0.14	0.15	0.14
July 16, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0317	0.0168	0.0169	0.0014	0.0014	0.0013	0.0014	0.0014	0.0013	0.0013	0.0013
		pH	Lab		8.31	6.02	6.09	6.41	6.42	6.45	6.41	6.38	6.39	6.36	6.37
		TOC, Total (mg/L)	Lab		8.2	3.2	2.7					2.7	2.5	2.6	2.7
		Turbidity (NTU)	Lab		1.54	0.51	0.61	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.15
July 17, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0346	0.0173	0.0172	0.0017	0.0016	0.0016	0.0016	0.0015	0.0014	0.0014	0.0013
		pH	Lab		8.27	6.15	6.24	6.42	6.44	6.36	6.39	6.31	6.35	6.33	6.34
		TOC, Total (mg/L)	Lab			2.9	2.7	2.4	2.4	2.5	2.3				
		Turbidity (NTU)	Lab		1.54	0.62	0.64	0.17	0.16	0.16	0.16	0.13	0.14	0.13	0.13
July 18, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0286	0.0198	0.0195	0.0019	0.0019	0.0019	0.0018	0.0019	0.002	0.0018	0.0018
		pH	Lab		8.19	6.06	6.13	6.43	6.39	6.4	6.39	6.37	6.35	6.31	6.33
		TOC, Total (mg/L)	Lab		8	3	2.7					2.6	2.4	2.6	2.4
		Turbidity (NTU)	Lab		1.66	0.65	0.82	0.18	0.19	0.18	0.17	0.16	0.17	0.16	0.15
July 19, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab	Data not recv	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		pH	Lab		8.28	6.17	6.28	6.47	6.45	6.44	6.44	6.41	6.42	6.4	6.41
		TOC, Total (mg/L)	Lab		8	4.5	4.2	3.6	3.9	3.6	3.7				
		Turbidity (NTU)	Lab		1.55	1.38	1.47	0.51	0.51	0.52	0.51	0.5	0.51	0.51	0.51
July 20, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0325	0.0169	0.0158	0.002	0.0019	0.0019	0.0019	0.0019	0.002	0.0019	0.0021
		pH	Lab		8.3	6.12	6.22	6.42	6.42	6.42	6.42	6.38	6.4	6.4	6.39
		TOC, Total (mg/L)	Lab		8.7	5.5	5.3					4.9	4.8	4.7	4.6
		Turbidity (NTU)	Lab		1.47	1.42	1.45	0.55	0.55	0.56	0.56	0.55	0.54	0.54	0.55
July 21, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0318	0.0154	0.015	0.0021	0.0021	0.0019	0.002	0.0022	0.0024	0.002	0.0021
		pH	Lab		8.47	6	6.07	6.38	6.33	6.34	6.37	6.31	6.31	6.32	6.35
		TOC, Total (mg/L)	Lab		9	5.2	5.1	4.5	4.5	4.6	4.5				
		Turbidity (NTU)	Lab		1.5	1.4	1.45	0.55	0.55	0.55	0.57	0.55	0.55	0.56	0.55
July 22, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0405	0.0177	0.0187	0.0017	0.0015	0.0015	0.0016	0.0022	0.0023	0.0018	0.0017
		pH	Lab		8.2	6.04	6.03	6.26	6.25	6.23	6.25	6.16	6.18	6.22	6.22
		TOC, Total (mg/L)	Lab		8.8	5.3	5.3					4.7	4.6	4.7	4.6
		Turbidity (NTU)	Lab		1.62	1.59	1.6	0.61	0.63	0.61	0.61	0.61	0.62	0.62	0.64
July 23, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab		0.0296	0.0187	0.0199	0.0022	0.002	0.0021	0.0025	0.003	0.0034	0.0026	0.0026
		pH	Lab		8.29	6.04	6.08	6.24	6.25	6.23	6.19	6.15	6.18	6.14	6.14
		TOC, Total (mg/L)	Lab		9.1	6.9	6.7	6	5.9	6	6.1				
		Turbidity (NTU)	Lab		1.45	1.83	1.72	0.71	0.71	0.72	0.71	0.67	0.69	0.7	0.72

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Transitioning. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
July 24, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		148.5	174.4	174.3	177.4	177	176.8	176.6	176.3	176	176.5	176.4	176.7
		DO (mg/L)	Bench		8.3	8.4	8.4	8.3	8.2	8.1	8.3	7.8	7.9	8.2	8	8.1
		Manganese, Total (mg/L)	Bench		0.042	0.043	0.041	0.015	0.021	0.02	0.018	0.013	0.016	0.018	0.013	0.015
		Oxi-Red Potenital (ORP) (mV)	Bench		308.8	313.5	337.5	411.8	409.2	409.9	403.9	404	406.3	400.1	391	388.5
		pH	Bench		7.73	6.04	6.07	6.1	6.08	6.06	6.1	6.06	6.04	6.01	5.99	5.92
		Temperature (ºC)	Bench		21.9	22	22	22	22	22.2	22.2	22.1	22.1	22.3	22.1	
		Turbidity (NTU)	Bench		1.99	1.58	1.57	0.67	0.65	0.66	0.65	0.7	0.7	0.67	0.68	0.69
		UVA @254nm, Unfiltered (/cm)	Bench		0.136	0.214	0.215	0.103	0.104	0.108	0.112	0.115	0.11	0.101	0.1	0.1
		UVT @ 254nm, Unfiltered (%T)	Bench		73.1	61.6	60.9	78.8	78.7	78	77.3	76.8	77.6	79.2	79.4	79.4
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.8	187									193.3
		DO (mg/L)	Bench			8.5	9.7									9.3
		Manganese, Total (mg/L)	Bench			0.062	0.06									0.043
		Oxi-Red Potenital (ORP) (mV)	Bench			387.2	416.8									417
		pH	Bench			5.37	5.51									5.32
		Temperature (ºC)	Bench			21.5	21.8									21.9
		Turbidity (NTU)	Bench			0.24	0.49									0.23
		UVA @254nm, Unfiltered (/cm)	Bench			0.027	0.024									0.017
		UVT @ 254nm, Unfiltered (%T)	Bench			93.9	94.7									96.1
July 25, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		148.7	175.1	175.2	177.5	178.1	176.8	177.4	176.5	176.3	176.1	176.3	176.6
		DO (mg/L)	Bench		8.4	8.5	8.4	8.3	8.4	8.3	8.2	8	8	7.9	8	8.2
		Manganese, Total (mg/L)	Bench		0.04	0.033	0.027	0.006	0.007	0.008	0.011	0.004	0.008	0.006	0.003	0.003
		Oxi-Red Potenital (ORP) (mV)	Bench		214.4	242.8	271.9	319.3	311.9	318.8	314.7	313.4	307.5	303.6	298.7	294.3
		pH	Bench		7.52	6	5.99	6.09	6.07	6.05	6.05	6.03	6.06	6.04	6.02	6
		Temperature (ºC)	Bench		21.8	21.7	22	21.9	22.1	22	22	22.2	22.1	22.2	22.1	
		Turbidity (NTU)	Bench		2.07	1.3	1.22	0.47	0.45	0.47	0.46	0.48	0.46	0.49	0.47	0.46
		UVA @254nm, Unfiltered (/cm)	Bench		0.138	0.17	0.166	0.08	0.078	0.08	0.078	0.078	0.077	0.079	0.078	0.077
		UVT @ 254nm, Unfiltered (%T)	Bench		72.9	67.5	68.1	83.2	83.6	83.2	83.5	83.5	83.8	83.3	83.6	83.7
	Full-Scale	Conductivity Total (µS/cm)	Bench			187.4	187.5									190.5
		DO (mg/L)	Bench			8.1	10.1									9.6
		Manganese, Total (mg/L)	Bench			0.055	0.059									0.037
		Oxi-Red Potenital (ORP) (mV)	Bench			242.1	287.2									304.7
		pH	Bench			5.27	5.45									5.31
		Temperature (ºC)	Bench			21.7	21.9									22
		Turbidity (NTU)	Bench			0.32	0.56									0.11
		UVA @254nm, Unfiltered (/cm)	Bench			0.044	0.038									0.018
		UVT @ 254nm, Unfiltered (%T)	Bench			90.4	91.5									96
July 26, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.2	176.7	176.2	179	178.7	178.7	179.5	179.1	179	178.5	178.7	178.9
		DO (mg/L)	Bench		8.3	8.5	8.4	8.2	8.1	8.1	8.1	7.8	8	7.7	7.9	8
		Manganese, Total (mg/L)	Bench		0.053	0.037	0.039	0.017	0.016	0.012	0.013	0.008	0.01	0.006	0.008	0.01
		Oxi-Red Potenital (ORP) (mV)	Bench		194.5	221.7	242.5	335.9	336.1	331.8	331	324.2	319.4	315.8	308.3	300.5
		pH	Bench		7.62	5.95	5.97	6.06	6.05	6.05	6.04	6.03	6.05	6.02	6.01	5.96
		Temperature (ºC)	Bench		22.1	22	22.3	22	22.3	22.2	22.3	22.4	22.4	22.3	22.4	
		Turbidity (NTU)	Bench		1.97	1.13	1.13	0.36	0.35	0.35	0.32	0.32	0.32	0.37	0.31	0.28
		UVA @254nm, Unfiltered (/cm)	Bench		0.138	0.119	0.115	0.046	0.043	0.043	0.041	0.053	0.049	0.043	0.048	0.048
		UVT @ 254nm, Unfiltered (%T)	Bench		72.8	76	76.7	90	90.6	90.7	91	88.8	89.2	90.5	89.5	89.6
	Full-Scale	Conductivity Total (µS/cm)	Bench			190.5	187.7									190.1
		DO (mg/L)	Bench			8.6	9.5									8.8
		Manganese, Total (mg/L)	Bench			0.075	0.069									0.057
		Oxi-Red Potenital (ORP) (mV)	Bench			314.1	319.2									316.8
		pH	Bench			5.32	5.5									5.34
		Temperature (ºC)	Bench			22	22.2									22.2
		Turbidity (NTU)	Bench			0.65	0.62									0.36
		UVA @254nm, Unfiltered (/cm)	Bench			0.041	0.048									0.017
		UVT @ 254nm, Unfiltered (%T)	Bench			91	89.5									96.1
July 27, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.2	176.4	176.1	178.3	177.8	177.4	178.2	177.5	177.7	176.5	177	177.8
		DO (mg/L)	Bench		8.3	8.5	8.3	8.1	8.2	8	8.1	7.9	7.7	7.7	7.7	8
		Manganese, Total (mg/L)	Bench		0.052	0.038	0.042	0.014	0.014	0.012	0.014	0.013	0.011	0.008	0.011	0.014
		Oxi-Red Potenital (ORP) (mV)	Bench		192.8	229.9	255.8	347.8	345.9	346.8	347.4	346.3	345.7	342.4	339.8	330.9
		pH	Bench		7.54	5.95	5.93	6.06	6.04	6.06	6.05	6.02	6	5.96	6	5.98
		Temperature (ºC)	Bench		22.8	22.5	22.5	22.9	22.6	22.6	23.1	22.6	22.8	22.7	22.9	
		Turbidity (NTU)	Bench		2.18	0.79	0.71	0.25	0.23	0.25	0.27	0.24	0.23	0.27	0.25	0.23
		UVA @254nm, Unfiltered (/cm)	Bench		0.144	0.097	0.106	0.039	0.037	0.04	0.04	0.046	0.042	0.039	0.038	0.038
		UVT @ 254nm, Unfiltered (%T)	Bench		71.7	80	78.3	91.5	91.7	91.3	91.3	90.1	90.8	91.4	91.6	91.6
	Full-Scale	Conductivity Total (µS/cm)	Bench			189.6	187.3									189.2

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
July 27, 2017	Full-Scale	DO (mg/L)	Bench			8.6	9.7									9.2
		Manganese, Total (mg/L)	Bench			0.07	0.065									0.05
		Oxi-Red Potenital (ORP) (mV)	Bench			307.8	351.4									329.7
		pH	Bench			5.24	5.41									5.29
		Temperature (ºC)	Bench			22.6	22.2									22.5
		Turbidity (NTU)	Bench			0.55	0.7									0.23
		UVA @254nm, Unfiltered (/cm)	Bench			0.045	0.047									0.015
		UVT @ 254nm, Unfiltered (%T)	Bench			90.1	89.8									96.5
July 28, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		148.7	174.8	174.3	175.6	175.8	175.2	176.4	174.6	175	174	173.8	175.4
		DO (mg/L)	Bench		8.2	8.3	8.4	8	8.1	8	8	7.7	7.8	7.8	7.7	8.1
		Manganese, Total (mg/L)	Bench		0.058	0.037	0.045	0.015	0.013	0.014	0.012	0.013	0.009	0.009	0.008	0.012
		Oxi-Red Potenital (ORP) (mV)	Bench		186.8	225.1	259.5	326	323.1	319.2	316.7	312.7	308.6	304	298.3	289
		pH	Bench		7.49	6.06	6.06	6.1	6.15	6.16	6.14	6.12	6.1	6.1	6.08	6.04
		Temperature (ºC)	Bench		22.6	22.5	22.7	22.5	22.7	22.6	22.7	23	22.8	23	22.9	
		Turbidity (NTU)	Bench		2.07	0.77	0.87	0.25	0.27	0.27	0.26	0.27	0.2	0.2	0.23	0.23
		UVA @254nm, Unfiltered (/cm)	Bench		0.144	0.096	0.108	0.04	0.041	0.039	0.035	0.039	0.038	0.034	0.039	0.035
		UVT @ 254nm, Unfiltered (%T)	Bench		71.7	80.1	78	91	91	91.4	92.2	91.4	91.6	92.5	91.5	92.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			189.3	188.1									188.6
		DO (mg/L)	Bench			8.6	9.4									9
		Manganese, Total (mg/L)	Bench			0.069	0.063									0.045
		Oxi-Red Potenital (ORP) (mV)	Bench			307.2	325.9									294.1
		pH	Bench			5.27	5.42									5.26
		Temperature (ºC)	Bench			22.5	22.3									22.45
		Turbidity (NTU)	Bench			0.55	0.78									0.29
		UVA @254nm, Unfiltered (/cm)	Bench			0.043	0.048									0.013
		UVT @ 254nm, Unfiltered (%T)	Bench			90.6	89.4									97
July 29, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		222.8	173.8	174.9	176.4	176.3	176	176.2	176.3	175.9	174.8	175	176.5
		DO (mg/L)	Bench		7.9	8.2	8.3	8.1	8.1	8.1	8	7.9	7.7	7.8	7.9	8.1
		Manganese, Total (mg/L)	Bench		0.072	0.044	0.046	0.017	0.015	0.012	0.017	0.011	0.009	0.008	0.009	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		252.2	242.4	211.5	239.6	250	258.7	297.1	302.6	303.3	306.7	309.7	311
		pH	Bench		7.79	6.01	6.01	6.1	6.16	6.12	6.16	6.13	6.15	6.13	6.18	6.15
		Temperature (ºC)	Bench		22.4	22.5	22.6	22.7	22.8	22.8	22.7	22.9	22.9	22.9	22.9	
		Turbidity (NTU)	Bench		2.13	0.65	0.84	0.88	0.55	0.88	0.35	0.67	0.64	0.54	0.44	0.52
		UVA @254nm, Unfiltered (/cm)	Bench		0.153	0.085	0.099	0.047	0.044	0.053	0.047	0.046	0.047	0.043	0.046	0.043
		UVT @ 254nm, Unfiltered (%T)	Bench		70.2	81.8	79.8	89.7	90.3	88.5	89.7	89.9	89.8	90.6	89.9	90.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			190	187.8									188.7
		DO (mg/L)	Bench			8.1	9.7									9.2
		Manganese, Total (mg/L)	Bench			0.08	0.07									0.055
		Oxi-Red Potenital (ORP) (mV)	Bench			317.5	304.8									320.2
		pH	Bench			5.36	5.42									5.27
		Temperature (ºC)	Bench			22.5	22.5									22.75
		Turbidity (NTU)	Bench			0.89	0.92									0.46
		UVA @254nm, Unfiltered (/cm)	Bench			0.055	0.056									0.029
		UVT @ 254nm, Unfiltered (%T)	Bench			88.3	88									93.7
July 30, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		75	19	19	18	17	18	18	17	17	17	17	17
		Aluminum, Dissolved (mg/L)	Lab		0.002		0.002	0.003	0.002	0.002	0.003	0.002	0.003	0.003	0.003	0.003
				N/D at <0.002		G/N										
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab		0.0015	0.0019	0.0012	0.0017	0.0018	0.002	0.0013	0.0016	0.0019	0.0014	0.002	0.0022
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00093	0.00046	0.00047	0.00045	0.00043	0.00048	0.00046	0.00044	0.00042	0.00045	0.00043	0.00043
		Arsenic, Total (mg/L)	Lab		0.0011											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab					0.00001		0.00004	0.00003	0.00002				
				N/D at <0.00001	G/N	G/N	G/N		G/N				G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		20.7	19.5	20.4	20.7	20.1	20.3	20.5	19.6	20.3	20	19.9	20.8
		Calcium, Total (mg/L)	Lab		20.6	20.5	19.4	19.8	20.6	19.6	20.2	19.8	19.6	19.9	20.8	20.7
		Chromium, Dissolved (mg/L)	Lab		0.00013	0.00004		0.00008	0.00008	0.00011	0.0001	0.00009	0.0001	0.00018	0.00012	0.0001
				N/D at <0.00003			G/N									
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		13	5.5	3	2	1	2.5	2.5	2	3	2.5	2.5	2.5
		Conductivity Total (µS/cm)	Bench		148.8	173.2	173.8	174.8	174.3	175.1	174.7	174.5	174.7	173.7	173.7	175.1
			Lab		157	182	183	184	185	184	184	184	184	183	183	184

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
July 30, 2017	Pilot-Scale	Copper, Dissolved (mg/L)	Lab		0.0007	0.0006	0.0004	0.0007	0.001	0.001	0.0008	0.0008	0.0008	0.001	0.0009	0.0007
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		7.6	8.2	8.2	8	8	7.9	7.9	7.6	7.5	7.8	7.9	8.1
		DOC Total (mg/L)	Lab		14.7	6.3	5.8	4.5	6.1	5.8	6	5.7	5.8	5.6	5.9	5.9
		Iron, Dissolved (mg/L)	Lab		0.003	0.103	0.057						0.008	0.016		
				N/D at <0.002				G/N	G/N	G/N	G/N	G/N			G/N	G/N
		Iron, Total (mg/L)	Lab		0.048	1.15	1.13	0.022	0.02	0.022	0.02	0.025	0.024	0.029	0.032	0.02
		Lead, Dissolved (mg/L)	Lab							0.00004	0.00004					
				N/D at <0.00004	G/N	G/N	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.668	5.45	5.683	5.821	5.611	5.73	5.845	5.515	5.604	5.529	5.554	5.69
		Magnesium, Total (mg/L)	Lab		5.58	5.63	5.4	5.78	5.67	5.51	5.55	5.57	5.42	5.56	5.67	5.62
		Manganese, Dissolved (mg/L)	Lab		0.00758	0.0351	0.0357	0.0103	0.00925	0.00843	0.0105	0.00583	0.00484	0.00343	0.00418	0.00778
		Manganese, Total (mg/L)	Bench		0.074	0.047	0.054	0.018	0.016	0.015	0.012	0.011	0.009	0.01	0.012	0.013
			Lab		0.0513	0.0376	0.0363	0.0103	0.0092	0.0085	0.0106	0.0057	0.0046	0.0032	0.004	0.0076
		Nickel, Dissolved (mg/L)	Lab		0.0004	0.00373	0.00372	0.00297	0.00302	0.00303	0.00309	0.00276	0.0027	0.00309	0.00303	0.00284
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		230.5	272.4	287.1	367.2	365.3	362.4	360.9	359.9	350.1	340.7	333.3	321.8
		pH	Bench		7.62	6.1	6.1	6.22	6.21	6.2	6.15	6.14	6.13	6.1	6.11	6.07
			Lab		7.96	6.3	6.28	6.43	6.45	6.39	6.38	6.4	6.38	6.38	6.32	6.5
		Potassium, Dissolved (mg/L)	Lab		1.15	1.11	1.13	1.2	1.15	1.17	1.21	1.11	1.17	1.13	1.15	1.18
		Potassium, Total (mg/L)	Lab		1.18	1.13	1.11	1.15	1.15	1.1	1.12	1.13	1.07	1.15	1.18	1.17
		Sodium, Dissolved (mg/L)	Lab		2.258	2.165	2.197	2.642	2.755	2.659	2.66	2.649	2.761	2.563	2.723	2.672
		Sodium, Total (mg/L)	Lab		2.29	2.15	2.1	2.7	2.66	2.6	2.57	2.57	2.52	2.62	2.65	2.63
		TDSwq (mg/L)	Lab		103	134	125	119	117	122	119	123	119	122	120	127
		Temperature (ºC)	Bench		22.7	23	22.8	23.2	23.4	23.3	23.3	23.3	23.2	23.1	23.1	
			Lab		22.7	23	22.8	23.2	23.4	23.3	23.3	23.3	23.2	23.1	23.1	23
		TSScalc Total (mg/L)	Lab		5	18	3	15	43	14		5		4	4	81
				N/D at <3							G/N		G/N			
		TSwv Total (mg/L)	Lab		108	152	128	134	160	136	120	128	120	126	124	208
		Turbidity (NTU)	Bench		1.92	0.89	1.02	0.19	0.19	0.16	0.2	0.2	0.22	0.22	0.19	0.2
			Lab		1.69	0.9	1.06	0.18	0.11	0.14	0.12	0.13	0.12	0.12	0.16	0.12
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.144	0.1	0.109	0.035	0.036	0.035	0.035	0.034	0.034	0.033	0.034	0.033
		UVT @ 254nm, Filtered (/cm)	Lab		73.7	89.4	89.5	89.6	89.8	89.9	90	90.2	90	90.4	90.5	90.1
		UVT @ 254nm, Unfiltered (%T)	Bench		71.8	79.5	77.8	92.2	92.1	92.3	92.3	92.5	92.4	92.6	92.4	92.6
		Zinc, Dissolved (mg/L)	Lab		0.0009	0.0017			0.0013	0.0022	0.0014	0.0012	0.001	0.0039	0.002	0.0018
				N/D at <0.0009			G/N	G/N								
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			6	9									6
		Aluminum, Dissolved (mg/L)	Lab			0.01	0.006									0.008
		Aluminum, Total (mg/L)	Lab	N/D at <0.01		G/N	G/N									G/N
		Antimony, Dissolved (mg/L)	Lab			0.0023	0.0014									0.0018
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00052	0.0004									0.00043
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			19.8	19.1									20.5
		Calcium, Total (mg/L)	Lab			19.9	19.2									19.6
		Chromium, Dissolved (mg/L)	Lab			0.00004	0.00014									0.0001
		Chromium, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Colour, True	Lab			6	3.5									3
		Conductivity Total (µS/cm)	Bench			186.5	184.8									185.1
			Lab			196	194									195
		Copper, Dissolved (mg/L)	Lab			0.004	0.0046									0.0028
		Copper, Total (mg/L)	Lab				0.005									
				N/D at <0.005		G/N										G/N
		DO (mg/L)	Bench			8.4	9.1									8.7
		DOC Total (mg/L)	Lab			5.1	4.7									4.5
		Iron, Dissolved (mg/L)	Lab			0.035										
				N/D at <0.002			G/N									G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
July 30, 2017	Full-Scale	Iron, Total (mg/L)	Lab			0.265	0.4									0.009
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.454	5.251									5.395
		Magnesium, Total (mg/L)	Lab			5.44	5.46									5.51
		Manganese, Dissolved (mg/L)	Lab			0.0767	0.0323									0.0422
		Manganese, Total (mg/L)	Bench			0.083	0.074									0.053
			Lab			0.0748	0.0643									0.0475
		Nickel, Dissolved (mg/L)	Lab			0.00279	0.00263									0.00254
		Nickel, Total (mg/L)	Lab			0.003	0.003									0.003
		Oxi-Red Potenital (ORP) (mV)	Bench			339.5	345									347.8
		pH	Bench			5.43	5.62									5.48
			Lab			5.52	5.84									5.56
		Potassium, Dissolved (mg/L)	Lab			1.1	1.1									1.15
		Potassium, Total (mg/L)	Lab			1.09	1.08									1.16
		Sodium, Dissolved (mg/L)	Lab			2.172	2.202									2.251
		Sodium, Total (mg/L)	Lab			2.11	2.13									2.28
		TDSwq (mg/L)	Lab			135	129									137
		Temperature (ºC)	Bench			22.4	22.5									22.75
			Lab			22.4	22.5									22.5
		TSScalc Total (mg/L)	Lab			41	51									77
		TSwv Total (mg/L)	Lab			176	180									214
		Turbidity (NTU)	Bench			1.03	0.65									0.23
			Lab			0.3	0.57									0.14
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.066	0.055									0.022
		UVT @ 254nm, Filtered (/cm)	Lab			91.8	93.9									94
		UVT @ 254nm, Unfiltered (%T)	Bench			86	88									95.1
		Zinc, Dissolved (mg/L)	Lab			0.0032	0.0013									0.0016
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
July 31, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		148.7	175.9	176.9	181.9	181.9	181.8	181.7	182.5	184	184.5	185.3	183.1
		DO (mg/L)	Bench		7.6	8.1	8	7.8	7.8	7.8	7.7	7.5	7.6	7.5	7.7	7.9
		Manganese, Total (mg/L)	Bench		0.065	0.037	0.038	0.015	0.015	0.013	0.014	0.004	0.006	0.005	0.003	0.01
		Oxi-Red Potenital (ORP) (mV)	Bench		164.1	215.9	240.1	312	311.7	308.3	309	306.5	304.4	301.4	286.7	275.3
		pH	Bench		7.48	5.71	5.8	6.03	6.02	6.03	6.02	6.07	6.07	6.06	6	5.9
		Temperature (ºC)	Bench		23.1	22.8	22.9	23.2	23	23.4	23.3	23.2	23.4	23.2	23.2	
		Turbidity (NTU)	Bench		2.16	0.6	0.67	0.21	0.17	0.2	0.23	0.23	0.17	0.18	0.18	0.2
		UVA @254nm, Unfiltered (/cm)	Bench		0.142	0.079	0.077	0.031	0.028	0.033	0.031	0.032	0.031	0.033	0.036	0.031
		UVT @ 254nm, Unfiltered (%T)	Bench		72.2	83.4	83.7	93	93.8	92.8	93.1	93	93.2	92.7	92	93
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.1	186.3									188.2
		DO (mg/L)	Bench			8.1	9.4									9
		Manganese, Total (mg/L)	Bench			0.073	0.071									0.045
		Oxi-Red Potenital (ORP) (mV)	Bench			288.3	287.2									263.4
		pH	Bench			5.33	5.48									5.3
		Temperature (ºC)	Bench			22.7	22.5									22.9
		Turbidity (NTU)	Bench			0.36	0.75									0.36
		UVA @254nm, Unfiltered (/cm)	Bench			0.058	0.052									0.023
		UVT @ 254nm, Unfiltered (%T)	Bench			87.6	88.8									94.9
August 1, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		148.7	172	174.4	176.7	176.6	176.8	176.8	176.9	176.7	175.4	175.5	175.3
		DO (mg/L)	Bench		7.3	8	8.2	8.1	8	7.9	7.8	7.7	7.7	7.6	7.9	7.7
		Manganese, Total (mg/L)	Bench		0.078	0.049	0.051	0.02	0.021	0.019	0.022	0.012	0.013	0.012	0.01	0.015
		Oxi-Red Potenital (ORP) (mV)	Bench		178.7	222.9	250.3	285.8	282.7	279.2	271.8	274.6	270	265.9	260.8	222.4
		pH	Bench		7.66	5.99	5.98	6.07	6.1	6.09	6.08	6.11	6.07	6.04	6	6.09
		Temperature (ºC)	Bench		22.8	22.6	22.8	22.7	22.7	22.9	22.9	23	22.9	23	22.9	
		Turbidity (NTU)	Bench		1.94	0.84	0.91	0.17	0.12	0.13	0.11	0.13	0.14	0.14	0.17	0.15
		UVA @254nm, Unfiltered (/cm)	Bench		0.149	0.105	0.113	0.039	0.038	0.04	0.037	0.038	0.04	0.04	0.041	0.042
		UVT @ 254nm, Unfiltered (%T)	Bench		71	78.6	77	91.3	91.6	91.3	91.9	91.6	91.1	91.1	91	90.9
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.8	186.6									191.1
		DO (mg/L)	Bench			8.2	8.3									9.2
		Manganese, Total (mg/L)	Bench			0.092	0.089									0.06
		Oxi-Red Potenital (ORP) (mV)	Bench			273.7	266.9									264.9
		pH	Bench			5.34	5.46									5.33
		Temperature (ºC)	Bench			22.6	22.4									22.65

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 1, 2017	Full-Scale	Turbidity (NTU)	Bench			0.44	0.89									0.27
		UVA @254nm, Unfiltered (/cm)	Bench			0.052	0.056									0.021
		UVT @ 254nm, Unfiltered (%T)	Bench			88.6	87.9									95.3
August 2, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		148.6	170	169.2	171.4	171.3	170.9	171.2	169.7	169.5	168.8	168	170.4
		DO (mg/L)	Bench		7	8.1	8.1	7.9	7.8	7.8	7.8	7.8	7.6	7.6	7.7	8
		Manganese, Total (mg/L)	Bench		0.082	0.056	0.055	0.019	0.021	0.015	0.015	0.008	0.01	0.011	0.011	0.012
		Oxi-Red Potenital (ORP) (mV)	Bench		223.2	240.7	262.7	286.1	285.5	284.7	283.3	281.4	279.7	277.3	273.2	266
		pH	Bench		7.54	6.27	6.25	6.33	6.32	6.31	6.28	6.3	6.29	6.26	6.25	6.22
		Temperature (ºC)	Bench		22.7	22.8	22.9	22.8	22.9	22.9	23	22.8	23	22.9	23.1	
		Turbidity (NTU)	Bench		2.12	1.22	1.41	0.28	0.27	0.29	0.31	0.32	0.31	0.29	0.3	0.3
		UVA @254nm, Unfiltered (/cm)	Bench		0.136	0.143	0.15	0.041	0.044	0.041	0.043	0.053	0.052	0.058	0.059	0.052
		UVT @ 254nm, Unfiltered (%T)	Bench		73.1	72	70.8	90.9	90.4	90.9	90.6	88.5	88.6	87.5	87.4	88.6
	Full-Scale	Conductivity Total (µS/cm)	Bench			187.1	186.8									188.3
		DO (mg/L)	Bench			7.9	9.4									9
		Manganese, Total (mg/L)	Bench			0.088	0.079									0.056
		Oxi-Red Potenital (ORP) (mV)	Bench			287.7	288.1									272.3
		pH	Bench			5.32	5.47									5.21
		Temperature (ºC)	Bench			22.7	22.8									22.95
		Turbidity (NTU)	Bench			0.46	0.81									0.29
		UVA @254nm, Unfiltered (/cm)	Bench			0.045	0.038									0.013
		UVT @ 254nm, Unfiltered (%T)	Bench			90.2	91.7									97
August 3, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.2	178.2	178.3	181	180.8	180.9	180.8	181	180.7			181
				O/L										180.7	180	
		DO (mg/L)	Bench		7.4	8.6	8.6	8.1	8.3	8.1	7.9	7.7	7.9	7.7	7.8	8
		Manganese, Total (mg/L)	Bench		0.077	0.046	0.043	0.022	0.023	0.022	0.024	0.016	0.017	0.014	0.016	0.019
		Oxi-Red Potenital (ORP) (mV)	Bench		172.7	212	256.2	295.8	293.2	289	285.9	279.7	275.5	273	267.9	256.3
		pH	Bench		7.58	5.83	5.82	5.99	5.98	5.97	5.97	6	5.98	5.93	5.93	5.98
		Temperature (ºC)	Bench		22.5	22.7	22.8	22.5	22.8	22.5	22.6	22.6	22.7	22.6	22.6	
		Turbidity (NTU)	Bench		1.89	0.77	0.86	0.18	0.15	0.15	0.14	0.15	0.15	0.17	0.18	0.16
		UVA @254nm, Unfiltered (/cm)	Bench		0.131	0.094	0.088	0.027	0.026	0.025	0.024	0.026	0.025	0.025	0.024	0.024
		UVT @ 254nm, Unfiltered (%T)	Bench		74	80.4	81.7	94	94.2	94.4	94.7	94.1	94.4	94.4	94.7	94.6
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.9	187.3									189.5
		DO (mg/L)	Bench			8.5	9.6									8.43
		Manganese, Total (mg/L)	Bench			0.085	0.082									0.06
		Oxi-Red Potenital (ORP) (mV)	Bench			269.1	319.8									314
		pH	Bench			5.34	5.52									5.21
		Temperature (ºC)	Bench			22.5	22.6									22.8
		Turbidity (NTU)	Bench			0.39	0.82									0.3
		UVA @254nm, Unfiltered (/cm)	Bench			0.034	0.044									0.021
		UVT @ 254nm, Unfiltered (%T)	Bench			92.4	90.4									95.2
August 4, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		75	13	13	12	12	12	12	12	12	11	11	12
		Aluminum, Dissolved (mg/L)	Lab			0.003	0.002	0.003	0.002	0.004	0.002	0.002	0.002	0.003	0.002	0.002
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab		0.0022		0.0017	0.0017	0.0016	0.0019	0.0017	0.002	0.0012	0.0017	0.0019	0.0014
				N/D at <0.0004		G/N										
		Antimony, Total (mg/L)	Lab				0.0018									
				N/D at <0.0005	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.0009	0.00042	0.00039	0.00039	0.0004	0.00039	0.00041	0.00038	0.00039	0.00042	0.00043	0.0004
		Arsenic, Total (mg/L)	Lab		0.0011											
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		19.2	19.3	19.9	19.9	19.9	19.9	20.4	19.7	19.7	20	19.6	19.6
		Calcium, Total (mg/L)	Lab		19.7	19.6	20.2	20.5	20.1	20.3	20.6	19.4	19.5	18.9	19.8	19.9
		Chloride (mg/L)	Lab		3											3
		Chromium, Dissolved (mg/L)	Lab		0.0002	0.00022			0.00003							0.00005
				N/D at <0.00003			G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		11	2.5	2.5	1.5	2.5	2	2	2.5	1.5	2	2	2.5
		Conductivity Total (µS/cm)	Bench		149.4	177.2	177.1	178.9	179.3	179.5			179.2	178	177.5	178.4
				O/L							179.4	178.8				
			Lab		158	186	186	188	188	189	189	188	188	187	187	188
		Copper, Dissolved (mg/L)	Lab	N/D at <0.0002	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 4, 2017	Pilot-Scale	Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		8.2	8.5	8.2	8	8	8	8	7.8	7.8	7.7	8.1	8.2
		DOC Total (mg/L)	Lab		12	5	5	4.7	4.8	5	4.7	4.4	4.5	4.7	4.6	4.5
		dTot, Hardness (mg/L CaCO3)	Lab		70.8	71.4	71.5	72.6	73.7	71.8	74.8	72	69	68.3	72.8	70.8
		HaaBCAA Total(ug/L)	Lab	N/D at <0.3	G/N											
		HaaDBAA Total(ug/L)	Lab	N/D at <0.3	G/N											
		HaaDCAA Total(ug/L)	Lab	N/D at <0.6	G/N											
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3	G/N											
		HaaMCAA (mg/L(ug/L)	Lab	N/D at <0.7	G/N											
		HaaTCAA (ug/L)	Lab		1.2											
		HaaTotal, calc_(ug/L)	Lab	N/D at <4	G/N											
		Iron, Dissolved (mg/L)	Lab			0.58	0.105									
				N/D at <0.002	G/N			G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Iron, Total (mg/L)	Lab		0.011	0.624	0.106									
				N/D at <0.008				G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Lead, Dissolved (mg/L)	Lab													0.00006
				N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.473	5.439	5.676	5.419	5.629	5.669	5.665	5.647	5.458	5.641	5.66	5.513
		Magnesium, Total (mg/L)	Lab		5.59	5.34	5.74	5.58	5.83	5.65	5.7	5.68	5.41	5.54	5.77	5.65
		Manganese, Dissolved (mg/L)	Lab		0.0101	0.026	0.0267	0.0157	0.0155	0.0148	0.0167	0.00966	0.0116	0.00951	0.00959	0.0136
		Manganese, Total (mg/L)	Bench		0.046	0.035	0.034	0.02	0.018	0.018	0.019	0.012	0.013	0.013	0.01	0.016
			Lab		0.0282	0.0263	0.0261	0.0161	0.0152	0.0144	0.0165	0.0096	0.0115	0.0092	0.0096	0.0132
		Nickel, Dissolved (mg/L)	Lab		0.00035	0.00359	0.00372	0.00348	0.00355	0.00369	0.00364	0.0034	0.00345	0.00354	0.00342	0.00364
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.004
				N/D at <0.001	G/N											
		Odour60C (-)	Lab	Grassy	G/N											
				Musty												G/N
		Oxi-Red Potenital (ORP) (mV)	Bench		171.8	218.5	244.3	298.8	296.7	290.7	288	282.2	278	268.5	262.9	241.1
		pH	Bench		7.78	5.85	5.84	5.99	5.98	5.97	5.94	5.95	5.93	5.91	5.87	5.88
			Lab		8.26	5.95	5.93	6.08	6.08	6.07	6.04	6.07	6.05	6.02	6	6.28
		Potassium, Dissolved (mg/L)	Lab		1.08	1.06	1.15	1.08	1.17	1.16	1.21	1.14	1.09	1.15	1.12	1.13
		Potassium, Total (mg/L)	Lab		1.08	1.07	1.16	1.13	1.11	1.1	1.19	1.11	1.13	1.1	1.18	1.17
		Sodium, Dissolved (mg/L)	Lab		2.142	2.101	2.219	2.567	2.624	2.668	2.772	2.683	2.656	2.621	2.706	2.592
		Sodium, Total (mg/L)	Lab		2.2	2.15	2.2	2.64	2.67	2.65	2.68	2.66	2.76	2.61	2.75	2.59
		Sulfate (mg/L)	Lab													72
				N/D at <2	G/N											
		TDSwq (mg/L)	Lab		90	118	110	118	110	120	131	123	124	122	114	120
		Temperature (ºC)	Bench		22.7	22.8	22.5	22.9	23	23	23	23.1	23.1	23.1	23	
			Lab		22.7	22.8	22.5	22.9	23	23	23	23.1	23.1	23.1	23	22.9
		ThmBDCM Total(ug/L)	Lab	N/D at <0.4	G/N											
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N											
		ThmCHCl3 Total(ug/L)	Lab	N/D at <0.7	G/N											
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N											
		ThmTotal,calc_ Total(ug/L)	Lab	N/D at <3	G/N											
		TOC, Total (mg/L)	Lab		10.9	4.6	4.8									4.2
		TON60C Total(T_O_N_60)	Lab		75											6
		TSScalc Total (mg/L)	Lab		16	10	38	12	54	18	7	21	10	12	24	14
		TSwv Total (mg/L)	Lab		106	128	148	130	164	138	138	144	134	134	138	134
		Turbidity (NTU)	Bench		1.9	0.63	0.57	0.22	0.19	0.15	0.17	0.16	0.19	0.18	0.17	0.16
			Lab		1.55	0.5	0.56	0.22	0.09	0.12	0.08	0.09	0.09	0.09	0.11	0.11
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.139	0.083	0.081	0.037	0.035	0.036	0.036	0.035	0.036	0.036	0.034	0.045
		UVT @ 254nm, Filtered (/cm)	Lab		75	91.7	91.6	92.3	92.5	92.5	92.3	92.5	91.8	92.1	92.6	92.1
		UVT @ 254nm, Unfiltered (%T)	Bench		72.7	82.5	82.8	91.8	92.3	92.1	92.1	92.4	92.1	92.1	92.5	91.6
		Zinc, Dissolved (mg/L)	Lab		0.0009		0.0027	0.0022	0.0024	0.0039	0.0017	0.0013	0.0015	0.0027	0.0013	0.0041
				N/D at <0.0009		G/N										
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			13	8									6
		Aluminum, Dissolved (mg/L)	Lab			0.009	0.005									0.008
		Aluminum, Total (mg/L)	Lab	N/D at <0.01		G/N	G/N									G/N
		Antimony, Dissolved (mg/L)	Lab			0.0013	0.0018									0.0014
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 4, 2017	Full-Scale	Arsenic, Dissolved (mg/L)	Lab			0.0005	0.00039									0.00042
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			19.3	19.9									19.7
		Calcium, Total (mg/L)	Lab			20.6	20.1									20.3
		Chloride (mg/L)	Lab													24
		Chromium, Dissolved (mg/L)	Lab				0.00012									0.00011
				N/D at <0.00003		G/N										
		Chromium, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Colour, True	Lab			4	3									2.5
		Conductivity Total (µS/cm)	Bench			188.5	186.3									188.8
			Lab			186	196									197
		Copper, Dissolved (mg/L)	Lab			0.0027	0.0051									0.0016
		Copper, Total (mg/L)	Lab				0.006									
				N/D at <0.005		G/N										G/N
		DO (mg/L)	Bench			8.5	9.5									9.1
		DOC Total (mg/L)	Lab			4	4.1									1.9
		dTot, Hardness (mg/L CaCO3)	Lab			73.4	75.2									73.8
		Iron, Dissolved (mg/L)	Lab			0.067										
				N/D at <0.002			G/N									G/N
		Iron, Total (mg/L)	Lab			0.31	0.494									0.02
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.507	5.507									5.5
		Magnesium, Total (mg/L)	Lab			5.71	5.6									5.61
		Manganese, Dissolved (mg/L)	Lab			0.075	0.0234									0.041
		Manganese, Total (mg/L)	Bench			0.079	0.076									0.053
			Lab			0.0772	0.0736									0.0493
		Nickel, Dissolved (mg/L)	Lab			0.00281	0.00274									0.00268
		Nickel, Total (mg/L)	Lab			0.003	0.003									0.003
		Oxi-Red Potenital (ORP) (mV)	Bench			252.8	309.5									291.5
		pH	Bench			5.42	5.62									5.33
			Lab			5.94	5.72									5.42
		Potassium, Dissolved (mg/L)	Lab			1.11	1.1									1.1
		Potassium, Total (mg/L)	Lab			1.14	1.12									1.16
		Sodium, Dissolved (mg/L)	Lab			2.188	2.183									2.234
		Sodium, Total (mg/L)	Lab			2.18	2.27									2.28
		Sulfate (mg/L)	Lab													39
		TDSwq (mg/L)	Lab			112	133									122
		Temperature (ºC)	Bench			22.8	22.4									22.75
			Lab			22.8	22.4									22.6
		TOC, Total (mg/L)	Lab			3.9	1.7									1.7
		TSScalc Total (mg/L)	Lab			18	25									24
		TSwv Total (mg/L)	Lab			130	158									146
		Turbidity (NTU)	Bench			0.35	0.65									0.32
			Lab			0.55	0.61									0.16
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.051	0.052									0.018
		UVT @ 254nm, Filtered (/cm)	Lab			91.3	94.8									95.5
		UVT @ 254nm, Unfiltered (%T)	Bench			89	88.9									95.8
		Zinc, Dissolved (mg/L)	Lab			0.0026	0.0023									0.0018
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
August 5, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		151	178.7	177.7	179	178.8	178.6	178.4	177.5	177.7	176.7	176.2	178.1
		DO (mg/L)	Bench		7.9	8.2	8.2	8	8	8	7.9	7.6	7.7	7.8	7.7	8
		Manganese, Total (mg/L)	Bench		0.063	0.036	0.037	0.024	0.021	0.018	0.018	0.012	0.016	0.014	0.015	0.022
		Oxi-Red Potenital (ORP) (mV)	Bench		182.6	216.2	250.8	291.1	288.3	286.6	282.4	280.6	274.9	272.3	268.1	256
		pH	Bench		7.53	5.8	5.86	6.01	6.01	6	5.99	6.01	6	5.97	5.98	5.95
		Temperature (ºC)	Bench		22.3	22.2	22.4	22.5	22.5	22.6	22.6	22.6	22.5	22.5	22.5	22.5
		Turbidity (NTU)	Bench		1.88	0.64	0.69	0.2	0.19	0.18	0.16	0.19	0.19	0.18	0.2	0.19
		UVA @254nm, Unfiltered (/cm)	Bench		0.144	0.079	0.077	0.044	0.045	0.044	0.037	0.045	0.046	0.035	0.037	0.039
		UVT @ 254nm, Unfiltered (%T)	Bench		71.8	83.3	83.8	91.2	90.2	90.3	91.8	90.1	90	92.2	91.8	91.5
	Full-Scale	Conductivity Total (µS/cm)	Bench			190.7	187.2									190.9

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 5, 2017	Full-Scale	DO (mg/L)	Bench			8.6	9.4									9.1
		Manganese, Total (mg/L)	Bench			0.08	0.075									0.064
		Oxi-Red Potenital (ORP) (mV)	Bench			273.2	294									273.4
		pH	Bench			5.29	5.48									5.37
		Temperature (ºC)	Bench			22.3	22.3									22.6
		Turbidity (NTU)	Bench			0.42	0.66									0.35
		UVA @254nm, Unfiltered (/cm)	Bench			0.046	0.055									0.024
		UVT @ 254nm, Unfiltered (%T)	Bench			88.9	88.2									94.5
August 6, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.3	179.2	178.4	180	180.1	180	179.8	178.6	177.8	177.6	177.2	183.2
		DO (mg/L)	Bench		8.3	8.3	8.2	8	8	8	7.8	7.8	7.8	7.7	7.9	8.1
		Manganese, Total (mg/L)	Bench		0.047	0.038	0.036	0.023	0.021	0.02	0.019	0.017	0.018	0.016	0.016	0.019
		Oxi-Red Potenital (ORP) (mV)	Bench		291.9	273.7	257.1	264.4	266.1	266.3	266.4	265.5	166.6	267.2	264.6	258.7
		pH	Bench		7.77	5.83	5.8	5.92	5.89	5.91	5.9	5.91	5.91	5.9	5.91	5.89
		Temperature (ºC)	Bench		22.8	22.7	22.7	22.7	22.85	22.7	22.7	22.8	22.8	22.7	22.8	22.8
		Turbidity (NTU)	Bench		1.84	0.64	0.56	0.18	0.18	0.14	0.12	0.15	0.14	0.12	0.13	0.15
		UVA @254nm, Unfiltered (/cm)	Bench		0.144	0.072	0.069	0.028	0.02	0.019	0.027	0.027	0.028	0.019	0.021	0.022
		UVT @ 254nm, Unfiltered (%T)	Bench		71.8	84.4	85.1	93.9	95.5	95.6	94.1	93.9	93.8	95.7	95.3	95.1
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.4	187.9									189.1
		DO (mg/L)	Bench			8.8	9.5									9.4
		Manganese, Total (mg/L)	Bench			0.063	0.06									0.046
		Oxi-Red Potenital (ORP) (mV)	Bench			276.8	275.1									269.9
		pH	Bench			5.41	5.59									5.3
		Temperature (ºC)	Bench			22.7	22.4									23
		Turbidity (NTU)	Bench			0.36	0.68									0.24
		UVA @254nm, Unfiltered (/cm)	Bench			0.04	0.046									0.011
		UVT @ 254nm, Unfiltered (%T)	Bench			91.2	89.9									97.5
August 7, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.7	177.2	177.8	179.2	178.5	177.8	177.9	178	177.7	177.4	176.9	178.6
		DO (mg/L)	Bench		8.2	8.1	8.2	8	7.8	7.8	7.9	7.7	7.7	7.9	7.8	7.7
		Manganese, Total (mg/L)	Bench		0.047	0.035	0.035	0.02	0.021	0.019	0.02	0.012	0.016	0.016	0.013	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		395.5	423.3	445	534	532.9	530.3	529.8	527.6	523.3	526.1	526	521.6
		pH	Bench		7.61	5.83	5.78	5.9	5.88	5.88	5.87	5.9	5.91	5.89	5.84	5.82
		Temperature (ºC)	Bench		22.7	22.4	22.45	23	22.45	22.45	23	23.05	23	23.05	23.05	22
		Turbidity (NTU)	Bench		1.7	0.63	0.32	0.16	0.14	0.14	0.14	0.15	0.16	0.14	0.14	0.14
		UVA @254nm, Unfiltered (/cm)	Bench		0.14	0.042	0.04	0.032	0.025	0.027	0.031	0.029	0.029	0.027	0.025	0.027
		UVT @ 254nm, Unfiltered (%T)	Bench		72.5	90.6	91.2	93	94.5	94.1	93.1	93.5	93.6	94	94.4	94
	Full-Scale	Conductivity Total (µS/cm)	Bench			189.3	186.5									191.3
		DO (mg/L)	Bench			8.4	9.3									9.2
		Manganese, Total (mg/L)	Bench			0.06	0.053									0.047
		Oxi-Red Potenital (ORP) (mV)	Bench			548.7	545.2									529.4
		pH	Bench			5.22	5.48									5.31
		Temperature (ºC)	Bench			22.4	22.35									########
		Turbidity (NTU)	Bench			0.43	0.65									0.18
		UVA @254nm, Unfiltered (/cm)	Bench			0.047	0.046									0.011
		UVT @ 254nm, Unfiltered (%T)	Bench			89.8	88.9									97.5
August 8, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.1	177.4	178	176.1	176.7	177.4	176.7	173.6	173.5	173.1	173	174.2
		DO (mg/L)	Bench		7.9	8.3	8.2	8	7.9	8.1	7.8	7.8	7.7	7.7	7.6	8
		Manganese, Total (mg/L)	Bench		0.055	0.031	0.028	0.02	0.015	0.018	0.017	0.014	0.014	0.013	0.015	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		394.3	417.7	423.8	535.6	535.4	536.5	531.8	529.7	522.3	517.2	516.9	513.7
		pH	Bench		7.73	5.79	5.83	6	5.99	5.96	5.95	5.95	5.97	5.94	5.97	5.95
		Temperature (ºC)	Bench		22.9	23	23	23.1	23.1	23.1	23.1	23.1	23.2	23.2	23.1	23.1
		Turbidity (NTU)	Bench		2.12	0.64	0.26	0.11	0.13	0.1	0.1	0.13	0.15	0.14	0.17	0.12
		UVA @254nm, Unfiltered (/cm)	Bench		0.141	0.07	0.044	0.044	0.036	0.036	0.038	0.038	0.037	0.034	0.033	0.037
		UVT @ 254nm, Unfiltered (%T)	Bench		72.2	85.2	90.6	93	92.1	92.1	91.6	91.7	91.8	92.4	92.7	91.8
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.8	186.1									187.7
		DO (mg/L)	Bench			8.6	9.5									8.9
		Manganese, Total (mg/L)	Bench			0.059	0.061									0.046
		Oxi-Red Potenital (ORP) (mV)	Bench			520.3	532.9									513.4
		pH	Bench			5.3	5.53									5.27
		Temperature (ºC)	Bench			22.9	22.8									22.9
		Turbidity (NTU)	Bench			0.36	0.68									0.25
		UVA @254nm, Unfiltered (/cm)	Bench			0.047	0.064									0.024
		UVT @ 254nm, Unfiltered (%T)	Bench			89.6	86.1									94.7
August 9, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.7	177.3	177.3	178.2	178	178.6	177.9	177.6	177.3	176.3	170.1	176.8
		DO (mg/L)	Bench		8.1	8.4	8.5	7.2	7.5	7.5	7.5	7.9	7.7	7.8	7.9	7.4

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 9, 2017	Pilot-Scale	Manganese, Total (mg/L)	Bench		0.059	0.037	0.033	0.019	0.017	0.014	0.019	0.017	0.021	0.019	0.018	0.017
		Oxi-Red Potenital (ORP) (mV)	Bench		364.9	416.8	427.6	545.8	545.2	544	542.1	539.2	537.8	531.9	524	503.7
		pH	Bench		7.67	5.81	5.82	5.94	5.95	5.94	5.92	5.92	5.91	5.89	5.84	5.89
		Temperature (ºC)	Bench		22.5	22.5	22.6	22.8	22.8	22.8	22.8	22.7	22.8	22.8	22.7	22.8
		Turbidity (NTU)	Bench		1.96	0.73	0.36	0.2	0.22	0.21	0.26	0.18	0.16	0.17	0.17	0.19
		UVA @254nm, Unfiltered (/cm)	Bench		0.141	0.073	0.05	0.036	0.033	0.032	0.032	0.034	0.034	0.033	0.039	0.038
		UVT @ 254nm, Unfiltered (%T)	Bench		72.1	84.5	89.1	91.9	92.6	92.9	93	92.4	92.4	92.6	91.4	91.6
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.8	186.2									189.4
		DO (mg/L)	Bench			8.7	9.3									8.8
		Manganese, Total (mg/L)	Bench			0.065	0.067									0.046
		Oxi-Red Potenital (ORP) (mV)	Bench			534	543.5									535.6
		pH	Bench			5.3	5.51									5.33
		Temperature (ºC)	Bench			22.4	22.4									22.6
		Turbidity (NTU)	Bench			0.4	0.66									0.22
		UVA @254nm, Unfiltered (/cm)	Bench			0.054	0.067									0.027
		UVT @ 254nm, Unfiltered (%T)	Bench			88.3	85.8									94
August 11, 2017	Pilot-Scale	HaaBCAA Total(ug/L)	Lab	N/D at <0.3	G/N											G/N
		HaaDBAA Total(ug/L)	Lab	N/D at <0.3	G/N											G/N
		HaaDCAA Total(ug/L)	Lab		22.3											17.1
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3	G/N											G/N
		HaaMCAA (mg/L(ug/L)	Lab		2.7											2.7
		HaaTCAA (ug/L)	Lab		17											15.6
		HaaTotal, calc_(ug/L)	Lab		42											36
		ThmBDCM Total(ug/L)	Lab		2.7											3.5
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N											G/N
		ThmCHCl3 Total(ug/L)	Lab		67.3											50.6
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N											G/N
		ThmTotal,calc_ Total(ug/L)	Lab		70											54
	Full-Scale	HaaBCAA Total(ug/L)	Lab	N/D at <0.3												G/N
		HaaDBAA Total(ug/L)	Lab	N/D at <0.3												G/N
		HaaDCAA Total(ug/L)	Lab													17.7
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3												G/N
		HaaMCAA (mg/L(ug/L)	Lab													2.9
		HaaTCAA (ug/L)	Lab													13.6
		HaaTotal, calc_(ug/L)	Lab													34
		ThmBDCM Total(ug/L)	Lab													3.6
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2												G/N
		ThmCHCl3 Total(ug/L)	Lab													44.9
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4												G/N
		ThmTotal,calc_ Total(ug/L)	Lab													49
August 14, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		73	13	13	8	8	9	8	14	12	12	11	9
		Aluminum, Dissolved (mg/L)	Lab			0.002	0.002	0.003	0.003	0.003	0.004	0.003	0.002	0.002	0.002	0.003
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab		0.0016	0.0015	0.0016	0.0016	0.0016	0.0012	0.0011	0.0017	0.0025	0.0014	0.0014	0.002
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00124	0.00069	0.00062	0.00067	0.00067	0.00066	0.0007	0.00052	0.00066	0.00065	0.00065	0.00064
		Arsenic, Total (mg/L)	Lab		0.0015	0.0008	0.0008									
				N/D at <0.0007				G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab							0.00001		0.00002				
				N/D at <0.00001	G/N	G/N	G/N	G/N	G/N		G/N		G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		18.9	18.9	19	18.9	19.3	19.2	18.9	19.9	20.1	19.5	19.3	20
		Calcium, Total (mg/L)	Lab		19.3	19.1	19.2	19.1	19.7	19.2	19	20.2	20.6	20	19.6	21.3
		Chloride (mg/L)	Lab		3											3.7
		Chromium, Dissolved (mg/L)	Lab		0.00027	0.00008	0.00012	0.00008	0.00007	0.00011	0.00012	0.00014	0.00012	0.0001	0.00009	0.00009
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		10	2	2.5	2	2	1	1.5	1	1	1	1	2.5
		Conductivity Total (µS/cm)	Bench		148.9	175.8	175.5	178.2	179	179.2	178.8	184.2	185.5	184.6	184.6	195.2
			Lab		157	184	184	188	189	190	189	195	195	195	196	252
		Copper, Dissolved (mg/L)	Lab		0.0004	0.0003	0.0004	0.0007	0.0007	0.0006	0.001	0.0007	0.0006	0.0007	0.0006	0.0007
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		7.6	8	8.7	8	8	7.9	7.7	7.5	7.5	7.3	7.4	7.6
		DOC Total (mg/L)	Lab		9	3	3.3	2.7	2.6	2.5	2.9	2.7	2.7	2.7	2.5	2.6

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 14, 2017	Pilot-Scale	dTot, Hardness (mg/L CaCO3)	Lab		70.8	71.6	69.4	67.5	69.2	69.2	69.4	70.2	72	70.4	72.1	75.6
		HaaBCAA Total(ug/L)	Lab	N/D at <0.3	G/N											
		HaaDBAA Total(ug/L)	Lab	N/D at <0.3	G/N											
		HaaDCAA Total(ug/L)	Lab		0.7											
		HaaMBAA Total(ug/L)	Lab	N/D at <0.3	G/N											
		HaaMCAA (mg/L(ug/L)	Lab	N/D at <0.7	G/N											
		HaaTCAA (ug/L)	Lab		1.1											
		HaaTotal, calc_(ug/L)	Lab	N/D at <4	G/N											
		Iron, Dissolved (mg/L)	Lab		0.006	0.093	0.002		0.008	0.002	0.02	0.024	0.003			
				N/D at <0.002				G/N						G/N	G/N	G/N
		Iron, Total (mg/L)	Lab		0.048	0.611	0.572	0.02	0.018	0.019	0.017	0.022	0.042	0.026	0.023	0.016
		Lead, Dissolved (mg/L)	Lab									0.00005				0.00008
				N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.243	5.219	5.274	5.036	4.995	5.049	4.997	5.165	5.064	5.056	4.996	5.106
		Magnesium, Total (mg/L)	Lab		5.36	5.31	5.28	5.04	5.07	5.04	4.97	5.19	5.23	5.24	5.07	5.24
		Manganese, Dissolved (mg/L)	Lab		0.00415	0.0199	0.0104	0.21	0.203	0.157	0.149	0.0229	0.0156	0.0126	0.0119	0.173
		Manganese, Total (mg/L)	Bench		0.037	0.028	0.029	0.167	0.183	0.154	0.137	0.031	0.026	0.027	0.021	0.152
			Lab		0.0238	0.0206	0.0184	0.198	0.203	0.157	0.149	0.0223	0.0162	0.0136	0.0126	0.177
		Nickel, Dissolved (mg/L)	Lab		0.00033	0.00363	0.00362	0.0044	0.00415	0.00377	0.00412	0.00274	0.00292	0.00248	0.00253	0.00353
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.004
				N/D at <0.001	G/N											
		Odour60C (-)	Lab	Grassy	G/N											
				NS												G/N
		Oxi-Red Potenital (ORP) (mV)	Bench		181.6	213.7	310.2	313.6	310.2	307.8	304.6	297.2	294.7	295.8	296	283.4
		pH	Bench		7.4	5.89	5.9	5.81	5.83	5.82	5.83	5.99	5.97	5.96	5.93	5.85
			Lab		7.92	6.18	6.25	5.98	6.01	6.09	6.02	6.32	6.27	6.28	6.26	6.19
		Potassium, Dissolved (mg/L)	Lab		1.1	1.1	1.08	1.08	1.08	1.08	1.08	1.09	1.08	1.06	1.05	1.05
		Potassium, Total (mg/L)	Lab		1.08	1.07	1.08	1.13	1.1	1.1	1.1	1.08	1.07	1.12	1.05	1.07
		Sodium, Dissolved (mg/L)	Lab		2.287	2.286	2.352	3.821	3.839	3.911	4.025	4.078	4.174	4.106	4.409	14.22
		Sodium, Total (mg/L)	Lab		2.3	2.32	2.18	3.83	3.85	3.99	3.98	4.02	4.18	4.1	4.46	14.4
		Sulfate (mg/L)	Lab													99
				N/D at <2	G/N											
		TDSwq (mg/L)	Lab		110	140	139	143	143	144	150	144	154	152	146	192
		Temperature (ºC)	Bench		22.5	22.8	22.9	23.4	23.5	23.5	23.4	23.4	23.3	23.3	23.2	23.3
			Lab		22.5	22.8	22.9	23.4	23.5	23.5	23.4	23.4	23.3	23.3	23.2	23.3
		ThmBDCM Total(ug/L)	Lab	N/D at <0.4	G/N											
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N											
		ThmCHCl3 Total(ug/L)	Lab	N/D at <0.7	G/N											
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N											
		ThmTotal,calc_ Total(ug/L)	Lab	N/D at <3	G/N											
		TOC, Total (mg/L)	Lab		9.2	2.9	2.9									2.6
		TON60C Total(T_O_N_60)	Lab		75											
				NS												G/N
		TSScalc Total (mg/L)	Lab		48	52	35	29	49	24	32	42	80	28	60	28
		TSwv Total (mg/L)	Lab		158	192	174	172	192	168	182	186	234	180	206	220
		Turbidity (NTU)	Bench		1.29	0.64	0.54	0.19	0.19	0.19	0.2	0.17	0.19	0.2	0.16	0.17
			Lab		1.34	0.7	1.49	0.17	0.21	0.12	0.1	0.13	0.1	0.1	0.16	0.13
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.139	0.079	0.058	0.034	0.031	0.03	0.03	0.031	0.031	0.033	0.028	0.031
		UVT @ 254nm, Filtered (/cm)	Lab		74.4	90.6	93.9	93.9	93.9	93.3	93.4	93.2	93	93.3	93.5	93.5
		UVT @ 254nm, Unfiltered (%T)	Bench		72.6	83.4	87.5	92.5	93.1	93.4	93.3	93.1	93.1	92.7	93.7	93
		Zinc, Dissolved (mg/L)	Lab			0.0021	0.0023	0.0021	0.0037	0.0024	0.0031	0.0014	0.0023	0.0012	0.0011	0.0022
				N/D at <0.0009	G/N											
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Zirconium, Total (mg/L)	Lab	Result NA	G/N											
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			6	8									6
		Aluminum, Dissolved (mg/L)	Lab			0.014	0.01									0.013
		Aluminum, Total (mg/L)	Lab			0.01										0.01
				N/D at <0.01			G/N									
		Antimony, Dissolved (mg/L)	Lab			0.0022	0.0015									0.0019
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00079	0.00074									0.00071

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 14, 2017	Full-Scale	Arsenic, Total (mg/L)	Lab			0.0009	0.0008									
				N/D at <0.0007												G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			19.2	18.6									18.9
		Calcium, Total (mg/L)	Lab			19.2	19.2									19.1
		Chloride (mg/L)	Lab													18
		Chromium, Dissolved (mg/L)	Lab			0.00008	0.0015									0.00021
		Chromium, Total (mg/L)	Lab				0.002									
				N/D at <0.001		G/N										G/N
		Colour, True	Lab			5	2.5									2.5
		Conductivity Total (µS/cm)	Bench			185.1	183.5									185.8
			Lab			194	192									195
		Copper, Dissolved (mg/L)	Lab			0.0028	0.0028									0.0029
		Copper, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
		DO (mg/L)	Bench			8.4	9.4									8.9
		DOC Total (mg/L)	Lab			2.7	3									2.8
		dTot, Hardness (mg/L CaCO3)	Lab			70.2	69.8									71.2
		Iron, Dissolved (mg/L)	Lab			0.049	0.353									0.055
		Iron, Total (mg/L)	Lab			0.436	0.662									0.063
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.155	5.138									5.172
		Magnesium, Total (mg/L)	Lab			5.15	5.14									5.13
		Manganese, Dissolved (mg/L)	Lab			0.0511	0.0428									0.0395
		Manganese, Total (mg/L)	Bench			0.064	0.06									0.046
			Lab			0.0512	0.0492									0.0404
		Nickel, Dissolved (mg/L)	Lab			0.00208	0.00303									0.00221
		Nickel, Total (mg/L)	Lab			0.002	0.003									0.002
		Odour60C (-)	Lab	Musty												G/N
		Oxi-Red Potenital (ORP) (mV)	Bench			300.6	296.8									288.3
		pH	Bench			5.46	5.6									5.24
			Lab			5.6	5.94									5.59
		Potassium, Dissolved (mg/L)	Lab			1.07	1.07									1.09
		Potassium, Total (mg/L)	Lab			1.06	1.05									1.08
		Sodium, Dissolved (mg/L)	Lab			2.282	2.343									2.355
		Sodium, Total (mg/L)	Lab			2.29	2.33									2.41
		Sulfate (mg/L)	Lab													47
		TDSwq (mg/L)	Lab			165	152									149
		Temperature (ºC)	Bench			22.5	22.6									22.5
			Lab			22.5	22.6									22.5
		TOC, Total (mg/L)	Lab			2.2	3.2									2.6
		TON60C Total(T_O_N_60)	Lab													6
		TSScalc Total (mg/L)	Lab			35	32									63
		TSwv Total (mg/L)	Lab			200	184									212
		Turbidity (NTU)	Bench			0.54	0.76									0.29
			Lab			0.45	0.71									0.18
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.074	0.078									0.028
		UVT @ 254nm, Filtered (/cm)	Lab			90.7	93									93.5
		UVT @ 254nm, Unfiltered (%T)	Bench			84.4	83.6									93.8
		Zinc, Dissolved (mg/L)	Lab			0.0034	0.0021									0.003
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
August 15, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149	175.6	175.3	181.7	181.1	181.2	181.7	182.6	182.6	182.5	182.1	182.3
		DO (mg/L)	Bench		7.5	8	8.7	8	8	8	7.8	7.9	7.6	7.5	7.6	8
		Manganese, Total (mg/L)	Bench		0.042	0.029	0.026	0.03	0.025	0.023	0.021	0.016	0.019	0.015	0.018	0.022
		Oxi-Red Potenital (ORP) (mV)	Bench		230.5	267.6	388.7	388.9	392.9	401.3	406.8	400.4	400.3	402	397.8	371.5
		pH	Bench		7.42	5.86	5.94	6	5.99	5.99	5.97	5.97	5.96	5.94	5.94	5.91
		Temperature (ºC)	Bench		22.5	22.5	22.8	22.7	22.8	22.8	22.8	23	23	23	22.45	22
		Turbidity (NTU)	Bench		1.74	0.7	0.72	0.25	0.21	0.19	0.21	0.21	0.17	0.19	0.18	0.2
		UVA @254nm, Unfiltered (/cm)	Bench		0.149	0.086	0.056	0.029	0.028	0.027	0.026	0.027	0.027	0.025	0.025	0.026
		UVT @ 254nm, Unfiltered (%T)	Bench		70.9	82.1	87.5	93.6	93.8	94	94.2	94	93.9	94.4	94.3	94.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			185.8	184.4									195.4

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 15, 2017	Full-Scale	DO (mg/L)	Bench			8.3	9.3									9.1
		Manganese, Total (mg/L)	Bench			0.056	0.051									0.044
		Oxi-Red Potenital (ORP) (mV)	Bench			384.3	586.1									384.6
		pH	Bench			5.4	5.55									5.4
		Temperature (ºC)	Bench			22.15	22.15									22.5
		Turbidity (NTU)	Bench			0.59	0.8									0.3
		UVA @254nm, Unfiltered (/cm)	Bench			0.076	0.09									0.039
		UVT @ 254nm, Unfiltered (%T)	Bench			84	81.3									91.5
August 16, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		71	14	14	13	13	13	13	13	13	14	13	13
		Aluminum, Dissolved (mg/L)	Lab		0.002	0.002	0.003	0.003	0.002	0.004	0.003	0.002	0.002	0.003	0.003	0.002
		Aluminum, Total (mg/L)	Lab	N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab		0.0013	0.0014	0.0016	0.0013	0.0017	0.0021	0.0019	0.0016	0.0018	0.0017	0.0015	0.0021
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.0013	0.00067	0.00072	0.00069	0.00068	0.00067	0.00053	0.00063	0.00064	0.00066	0.00068	0.00068
		Arsenic, Total (mg/L)	Lab		0.0015	0.0008	0.0008									
				N/D at <0.0007				G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		B, Dissolved (mg/L)	Lab	Result NA	G/N											
		Boron, Total (mg/L)	Lab	Result NA	G/N											
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		19.5	18.8	19.4	20.3	19.5	19.9	19.4	19.3	19.5	19.4	19.5	19.2
		Calcium, Total (mg/L)	Lab		19.2	19	19.1	19.9	19.9	19.9	19.6	19.5	19.8	19.6	19.8	19.7
		Chromium, Dissolved (mg/L)	Lab		0.00021	0.00005	0.00009	0.00011	0.00013	0.00011	0.00009	0.00011	0.00011	0.00009	0.0001	0.00008
		Chromium, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		11	3	2	2	1	2	1	2	2	2	1	1
		Conductivity Total (µS/cm)	Bench		149	175.6	175.7	181.9	181.8	182	182.1	182.2	182.9	182.5	182.5	182.5
			Lab		156	184	184	191	191	191	193	192	192	192	192	191
		Copper, Dissolved (mg/L)	Lab		0.0005	0.0003	0.0006	0.0008	0.0006	0.0007	0.001	0.0006	0.0007	0.0006	0.0006	0.0011
		Copper, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		7.2	7.8	8	7.6	7.5	7.6	7.6	7.5	7.4	7.3	7.4	7.6
		DOC Total (mg/L)	Lab		10	3.2	3.2	5.5	5.5	2.4	2.7	2.4	2.7	3	2.2	2.9
		Iron, Dissolved (mg/L)	Lab		0.029	0.067	0.083				0.009					
				N/D at <0.002				G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N
		Iron, Total (mg/L)	Lab		0.051	0.677	0.535	0.008	0.012	0.012	0.008					
				N/D at <0.008								G/N	G/N	G/N	G/N	G/N
		Lead, Dissolved (mg/L)	Lab								0.00004					
				N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.476	5.265	5.348	5.631	5.506	5.469	5.337	5.406	5.39	5.377	5.328	5.183
		Magnesium, Total (mg/L)	Lab		5.48	5.33	5.39	5.72	5.58	5.5	5.33	5.46	5.39	5.39	5.43	5.42
		Manganese, Dissolved (mg/L)	Lab		0.0147	0.0201	0.0215	0.0229	0.02	0.0167	0.0195	0.0108	0.00951	0.00835	0.00812	0.0161
		Manganese, Total (mg/L)	Bench		0.037	0.031	0.032	0.031	0.028	0.023	0.027	0.015	0.018	0.011	0.015	0.023
			Lab		0.0251	0.0203	0.0209	0.0233	0.0205	0.0164	0.0188	0.0103	0.0099	0.0083	0.008	0.0156
		Nickel, Dissolved (mg/L)	Lab		0.00035	0.00349	0.00359	0.00401	0.00351	0.00343	0.00349	0.00315	0.00307	0.00302	0.00302	0.00332
		Nickel, Total (mg/L)	Lab			0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
				N/D at <0.001	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		208.8	214	276.6	425.3	426.8	435	453.8	457	461.3	465.8	472.5	454.9
		pH	Bench		7.25	5.91	5.93	6	5.99	6.01	6	5.98	5.98	5.96	5.93	5.88
			Lab		7.85	6.08	6.05	6.2	6.2	6.18	6.15	6.19	6.24	6.25	6.19	6.24
		Potassium, Dissolved (mg/L)	Lab		1.12	1.09	1.1	1.17	1.15	1.15	1.12	1.08	1.08	1.13	1.12	1.05
		Potassium, Total (mg/L)	Lab		1.16	1.12	1.1	1.11	1.13	1.13	1.1	1.12	1.1	1.11	1.1	1.08
		Sodium, Dissolved (mg/L)	Lab		2.27	2.236	2.281	3.371	3.339	3.374	3.344	3.309	3.281	3.407	3.431	3.459
		Sodium, Total (mg/L)	Lab		2.26	2.28	2.2	3.37	3.4	3.24	3.28	3.27	3.32	3.32	3.46	3.34
		TDSwq (mg/L)	Lab		113	130	137	132	134	124	130	127	130	131	131	129
		Temperature (ºC)	Bench		22.3	22.4	22.4	22.6	22.6	22.6	22.6	22.7	22.7	22.6	22.6	
			Lab		22.3	22.4	22.4	22.6	22.6	22.6	22.6	22.7	22.7	22.6	22.6	22.6
		TSScalc Total (mg/L)	Lab		33	38	77	12	30	42	26	41	30	47	27	37
		TSwv Total (mg/L)	Lab		146	168	214	144	164	166	156	168	160	178	158	166
		Turbidity (NTU)	Bench		1.42	0.69	0.51	0.22	0.19	0.17	0.18	0.16	0.18	0.17	0.2	0.22
			Lab		1.28	0.83	1.28	0.21	0.13	0.12	0.1	0.09	0.1	0.1	0.09	0.12
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.133	0.083	0.065	0.034	0.032	0.035	0.036	0.031	0.031	0.034	0.034	0.033
		UVT @ 254nm, Filtered (/cm)	Lab		75.2	91.6	91.3	92	92.3	92.8	92.6	93	93.2	93.2	93.1	92.8

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 16, 2017	Pilot-Scale	UVT @ 254nm, Unfiltered (%T)	Bench		73.7	82.7	86	92.5	92.8	92.4	92.1	93	93	92.5	92.5	92.7
		Zinc, Dissolved (mg/L)	Lab		0.0012	0.0012	0.0015	0.0019	0.0017	0.0031	0.0026	0.0016	0.002	0.0043	0.0021	0.0017
		Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Zirconium, Dissolved (mg/L)	Lab	Result NA	G/N											
		Zirconium, Total (mg/L)	Lab	Result NA	G/N											
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			6	9									6
		Aluminum, Dissolved (mg/L)	Lab			0.012	0.016									0.012
		Aluminum, Total (mg/L)	Lab			0.02	0.01									0.01
		Antimony, Dissolved (mg/L)	Lab			0.002	0.0014									0.0016
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00075	0.00082									0.00069
		Arsenic, Total (mg/L)	Lab			0.0007	0.0009									
				N/D at <0.0007												G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			18.6	19									18.7
		Calcium, Total (mg/L)	Lab			18.8	19									19.5
		Chromium, Dissolved (mg/L)	Lab			0.00043	0.00016									0.00018
		Chromium, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Colour, True	Lab			4	1.5									2
		Conductivity Total (µS/cm)	Bench			184.8	182.5									184.6
			Lab			194	192									194
		Copper, Dissolved (mg/L)	Lab			0.0028	0.0025									0.0025
		Copper, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
		DO (mg/L)	Bench			8	9.1									8.8
		DOC Total (mg/L)	Lab			2.9	2.9									2.5
		Iron, Dissolved (mg/L)	Lab			0.585	0.173									0.012
		Iron, Total (mg/L)	Lab			0.538	0.749									0.12
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.237	5.183									5.146
		Magnesium, Total (mg/L)	Lab			5.35	5.29									5.43
		Manganese, Dissolved (mg/L)	Lab			0.0458	0.0567									0.0429
		Manganese, Total (mg/L)	Bench			0.066	0.052									0.046
			Lab			0.0572	0.0507									0.0462
		Nickel, Dissolved (mg/L)	Lab			0.00204	0.00196									0.00198
		Nickel, Total (mg/L)	Lab			0.002	0.002									0.002
		Oxi-Red Potenital (ORP) (mV)	Bench			450.4	455.2									457.4
		pH	Bench			5.36	5.55									5.24
			Lab			5.52	5.83									5.5
		Potassium, Dissolved (mg/L)	Lab			1.05	1									1.09
		Potassium, Total (mg/L)	Lab			1.06	1.1									1.09
		Sodium, Dissolved (mg/L)	Lab			2.145	2.366									2.288
		Sodium, Total (mg/L)	Lab			2.2	2.4									2.27
		TDSwq (mg/L)	Lab			127	143									130
		Temperature (ºC)	Bench			22.3	22.3									22.5
			Lab			22.3	22.3									22.4
		TSScalc Total (mg/L)	Lab			43	33									68
		TSwv Total (mg/L)	Lab			170	176									198
		Turbidity (NTU)	Bench			0.71	0.8									0.33
			Lab			0.55	0.71									0.22
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.076	0.083									0.036
		UVT @ 254nm, Filtered (/cm)	Lab			91.3	93.9									94.7
		UVT @ 254nm, Unfiltered (%T)	Bench			83.9	82.5									92.1
		Zinc, Dissolved (mg/L)	Lab			0.0031	0.002									0.0025
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
August 17, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		71	12	12	10	10	11	11	12	12	12	12	11
		Aluminum, Dissolved (mg/L)	Lab			0.003	0.005	0.002	0.002	0.003	0.002	0.012	0.002	0.002	0.002	0.005
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab										0.09			
				N/D at <0.01	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		Antimony, Dissolved (mg/L)	Lab		0.0011	0.0016	0.0009	0.0017	0.0011	0.0007	0.0009	0.0014	0.0014	0.0013	0.0009	0.0012

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 17, 2017	Pilot-Scale	Antimony, Total (mg/L)	Lab										0.0989			
				N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00107	0.00047	0.00047	0.00041	0.00037	0.00042	0.0004	0.00038	0.0004	0.00039	0.00039	0.0004
		Arsenic, Total (mg/L)	Lab		0.0013								0.0983			
				N/D at <0.0007		G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		B, Dissolved (mg/L)	Lab	Result NA	G/N											
		Boron, Total (mg/L)	Lab	Result NA	G/N											
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab										0.103			
				N/D at <0.0001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		19.2	19	19.2	19	17.6	19.6	18.4	19.4	19	19	19.1	19.3
		Calcium, Total (mg/L)	Lab		19.7		18.6	19.3	18.8	17.5	18.9	19.7	19.8	19.5	19.3	19.4
				N/D at <0.06		G/N										
		Chromium, Dissolved (mg/L)	Lab								0.00016	0.00016		0.00004	0.00004	
				N/D at <0.00003	G/N	G/N	G/N	G/N	G/N	G/N			G/N			G/N
		Chromium, Total (mg/L)	Lab										0.102			
				N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		Colour, True	Lab		10	3	2.5	2.5	2	1	1.5	2.5	2	1	1	1.5
		Conductivity Total (µS/cm)	Bench		149.4	176.3	176.6	182.9	182.7	183.1	181.7	184.4	185.3	183.9	184.6	185.2
			Lab		156	185	186	192	192	192	193	194	194	194	195	194
		Copper, Dissolved (mg/L)	Lab		0.0003	0.0003	0.0003	0.0005	0.0004	0.0005	0.0006	0.002	0.0008	0.0005	0.0005	0.0009
		Copper, Total (mg/L)	Lab										0.1			
				N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		DO (mg/L)	Bench		7.5	7.6	7.8	7.6	7.5	7.5	7.5	7.3	7.2	7.1	7.3	7.9
		DOC Total (mg/L)	Lab		10.9	1.9	1.8	1.8	2.2	2	1.5	1.6	1.8	1.8	1.8	4.4
		Iron, Dissolved (mg/L)	Lab		0.051	0.175	0.167	0.018	0.012	0.029	0.024	0.053	0.006	0.007	0.012	0.012
		Iron, Total (mg/L)	Lab		0.078		0.77	0.025	0.027	0.03	0.023	0.053	0.121	0.017	0.021	0.021
				N/D at <0.008		G/N										
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Lead, Total (mg/L)	Lab										0.108			
				N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.948	5.697	5.948	5.802	5.354	5.875	5.573	5.667	5.709	5.749	5.814	5.948
		Magnesium, Total (mg/L)	Lab		6.03		5.7	5.68	5.72	5.36	5.76	5.93	6.6	5.94	5.96	6
				N/D at <0.01		G/N										
		Manganese, Dissolved (mg/L)	Lab		0.0153	0.0005	0.0185	0.0216	0.0178	0.0168	0.0182	0.0118	0.0105	0.00935	0.0105	0.0174
		Manganese, Total (mg/L)	Bench		0.037	0.027	0.032	0.032	0.03	0.026	0.027	0.016	0.018	0.017	0.017	0.025
			Lab		0.0287	0.0184	0.0187	0.0218	0.0196	0.0153	0.0183	0.0114	0.018	0.0095	0.0104	0.0178
		Nickel, Dissolved (mg/L)	Lab		0.00022	0.0038	0.00374	0.00361	0.00338	0.00367	0.00437	0.00443	0.00337	0.00335	0.00332	0.00368
		Nickel, Total (mg/L)	Lab				0.004	0.004	0.004	0.003	0.004	0.004	0.11	0.003	0.003	0.004
				N/D at <0.001	G/N	G/N										
		Oxi-Red Potenital (ORP) (mV)	Bench		219.4	257.3	292.6	413.7	416.9	417.9	418.5	416.3	412.9	408.3	407.1	373.4
		pH	Bench		7.38	5.82	5.8	5.94	5.91	5.91	5.88	5.91	5.88	5.87	5.88	5.88
			Lab		7.89	5.95	5.92	6.12	6.13	6.1	6.04	6.1	6.12	6.11	6.12	6.1
		Potassium, Dissolved (mg/L)	Lab		1.17	1.16	1.16	1.15	1.05	1.17	1.07	1.17	1.13	1.14	1.13	1.15
		Potassium, Total (mg/L)	Lab		1.18		1.12	1.15	1.16	1.01	1.13	1.17	2.14	1.14	1.13	1.17
				N/D at <0.06		G/N										
		Sodium, Dissolved (mg/L)	Lab		2.395	2.288	2.346	3.376	3.29	3.449	3.349	3.497	3.594	3.471	3.467	3.664
		Sodium, Total (mg/L)	Lab		2.36		2.19	3.36	3.31	3.11	3.32	3.55	4.39	3.65	3.49	3.7
				N/D at <0.07		G/N										
		TDSwq (mg/L)	Lab		111	134	142	130	138	135	139	146	143	141	141	139
		Temperature (ºC)	Bench		22.5	22.4	22.6	22.7	22.8	22.8	22.8	22.8	22.8	22.8	22.8	
			Lab		22.5	22.4	22.6	22.7	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8
		TSScalc Total (mg/L)	Lab		67	64	30	36	30	23	29	22	57	61	57	57
		TSwv Total (mg/L)	Lab		178	198	172	166	168	158	168	168	200	202	198	196
		Turbidity (NTU)	Bench		1.44	0.64	0.52	0.38	0.2	0.18	0.17	0.17	0.15	0.17	0.16	0.16
			Lab		1.23	0.6	0.71	0.2	0.11	0.13	0.1	0.13	0.14	0.1	0.11	0.13
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab										0.103			
				N/D at <0.0004	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.119	0.056	0.046	0.022	0.022	0.022	0.021	0.019	0.019	0.019	0.019	0.021
		UVT @ 254nm, Filtered (/cm)	Lab		76.1	92.1	92.8	93.9	94	90.6	92.7	93.3	94.3	94.5	94.4	93.9
		UVT @ 254nm, Unfiltered (%T)	Bench		76	87.9	90	95.1	95	95	95.4	95.8	95.8	95.7	95.8	95.3
		Zinc, Dissolved (mg/L)	Lab		0.0012	0.002	0.0034	0.0017	0.0033	0.0037	0.002	0.0097	0.0025	0.0022	0.0055	0.0032
		Zinc, Total (mg/L)	Lab										0.108			

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 17, 2017	Pilot-Scale	Zinc, Total (mg/L)	Lab	N/D at <0.005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N
		Zirconium, Dissolved (mg/L)	Lab	Result NA	G/N											
		Zirconium, Total (mg/L)	Lab	Result NA	G/N											
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			6	8									6
		Aluminum, Dissolved (mg/L)	Lab			0.016	0.011									0.014
		Aluminum, Total (mg/L)	Lab			0.02	0.01									0.01
		Antimony, Dissolved (mg/L)	Lab			0.0007	0.0006									0.0012
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00054	0.00049									0.00045
		Arsenic, Total (mg/L)	Lab	N/D at <0.0007		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00001		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0001		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			18.6	18.6									19
		Calcium, Total (mg/L)	Lab			19.3	18.9									18.9
		Chromium, Dissolved (mg/L)	Lab			0.0001	0.00031									0.00013
		Chromium, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Colour, True	Lab			3	1									1
		Conductivity Total (µS/cm)	Bench			184.8	182.9									186.5
			Lab			194	191									194
		Copper, Dissolved (mg/L)	Lab			0.0023	0.0037									0.0025
		Copper, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
		DO (mg/L)	Bench			8.2	8.9									8.5
		DOC Total (mg/L)	Lab			4.1	4.1									3.7
		Iron, Dissolved (mg/L)	Lab			0.268	0.523									0.081
		Iron, Total (mg/L)	Lab			0.631	0.868									0.092
		Lead, Dissolved (mg/L)	Lab	N/D at <0.00004		G/N	G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.684	5.815									5.777
		Magnesium, Total (mg/L)	Lab			5.77	5.78									5.77
		Manganese, Dissolved (mg/L)	Lab			0.0511	0.0413									0.0433
		Manganese, Total (mg/L)	Bench			0.062	0.061									0.053
			Lab			0.0526	0.048									0.0437
		Nickel, Dissolved (mg/L)	Lab			0.00197	0.00203									0.00204
		Nickel, Total (mg/L)	Lab			0.002	0.002									0.002
		Oxi-Red Potenital (ORP) (mV)	Bench			370.2	370.7									345.4
		pH	Bench			5.42	5.58									5.23
			Lab			5.5	5.83									5.46
		Potassium, Dissolved (mg/L)	Lab			1.12	1.11									1.14
		Potassium, Total (mg/L)	Lab			1.13	1.12									1.16
		Sodium, Dissolved (mg/L)	Lab			2.289	2.269									2.317
		Sodium, Total (mg/L)	Lab			2.25	2.31									2.35
		TDSwq (mg/L)	Lab			137	158									139
		Temperature (ºC)	Bench			22.3	22.4									22.6
			Lab			22.3	22.4									22.4
		TSScalc Total (mg/L)	Lab			89	66									91
		TSwv Total (mg/L)	Lab			226	224									230
		Turbidity (NTU)	Bench			0.65	0.83									0.33
			Lab			0.59	0.79									0.11
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0004		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.065	0.08									0.022
		UVT @ 254nm, Filtered (/cm)	Lab			92	94.8									95.2
		UVT @ 254nm, Unfiltered (%T)	Bench			86.1	93.1									95.1
		Zinc, Dissolved (mg/L)	Lab			0.0013	0.0131									0.0089
		Zinc, Total (mg/L)	Lab	N/D at <0.005		G/N	G/N									G/N
August 21, 2017	Pilot-Scale	HaaBCAA Total(ug/L)	Lab		1.4											1.2
		HaaDBAA Total(ug/L)	Lab	N/D at <0.3	G/N											G/N
		HaaDCAA Total(ug/L)	Lab		25.8											24.1
		HaaMBAA Total(ug/L)	Lab		2.3											1.8
		HaaMCAA (mg/L(ug/L)	Lab		3.3											3.3
		HaaTCAA (ug/L)	Lab		17.9											18
		HaaTotal, calc_(ug/L)	Lab		51											48
		ThmBDCM Total(ug/L)	Lab		3.9											3.6
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2	G/N											G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Summer
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
August 21, 2017	Pilot-Scale	ThmCHCl3 Total(ug/L)	Lab		60.1											50.7
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4	G/N											G/N
		ThmTotal,calc_ Total(ug/L)	Lab		64											54
	Full-Scale	HaaBCAA Total(ug/L)	Lab													0.6
		HaaDBAA Total(ug/L)	Lab	N/D at <0.3												G/N
		HaaDCAA Total(ug/L)	Lab													28.4
		HaaMBAA Total(ug/L)	Lab													0.7
		HaaMCAA (mg/L(ug/L)	Lab													2.3
		HaaTCAA (ug/L)	Lab													23.3
		HaaTotal, calc_(ug/L)	Lab													55
		ThmBDCM Total(ug/L)	Lab													3.3
		ThmCHBr3 Total(ug/L)	Lab	N/D at <0.2												G/N
		ThmCHCl3 Total(ug/L)	Lab													76.8
		ThmDBCM Total(ug/L)	Lab	N/D at <0.4												G/N
		ThmTotal,calc_ Total(ug/L)	Lab													80

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary - Pilot DAF Float Sludge Sample Only

Season: Summer
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location DAF Sludge
July 30, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		92
		Temperature (ºC)	Lab		23.2
		TSSwv Total (mg/L)	Lab		7750
		TSwv Total (mg/L)	Lab		7840
August 4, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		1100
		Temperature (ºC)	Lab		22.9
		TSSwv Total (mg/L)	Lab		5200
		TSwv Total (mg/L)	Lab		6300
August 14, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		240
		Temperature (ºC)	Lab		23.1
		TSSwv Total (mg/L)	Lab		5600
		TSwv Total (mg/L)	Lab		5840
August 16, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		344
		Temperature (ºC)	Lab		23.1
		TSSwv Total (mg/L)	Lab		5100
		TSwv Total (mg/L)	Lab		5440
August 17, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		122
		Temperature (ºC)	Lab		23.1
		TSSwv Total (mg/L)	Lab		5600
		TSwv Total (mg/L)	Lab		5720

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter keeps DAF Sludge. The Piloting_Season filter keeps Summer. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

APPENDIX

F

TM NO. 6

FALL PILOTING SESSION (OCTOBER 16 – OCTOBER 31, 2017)

TECHNICAL MEMORANDUM NO. 6

PROJECT:	Pilot Testing an Alternative Coagulant for the Winnipeg Water Treatment
TO:	Heather Buhler, City of Winnipeg
FROM:	Maika Pellegrino (WSP), Jacque-Ann Grant (WSP), Justin Rak-Banville (WSP), Charles Goss (WSP)
SUBJECT:	Fall Piloting Session (October 16 – October 31, 2017) – Final
DATE:	August 20, 2018

1. OVERVIEW

Technical Memorandum No. 6 (TM No. 6) evaluates the piloting results for the alternative coagulant, ferric sulphate ($Fe_2(SO_4)_3$) as the dissolved air flotation (DAF) coagulant, under cool water/Fall conditions (4 to 14°C). Unlike previous piloting sessions, a benchmarking period was not conducted prior to the commencement of the Fall piloting session. In addition, the pilot-scale system was not transitioned back to ferric chloride following the completion of the previous Summer piloting session. Instead, the pilot-scale system continued to operate using ferric sulphate for an extended period to observe the potential onset of long term effects of using ferric sulphate as an alternative coagulant to ferric chloride. Subsequently, this period is referred to as the extended pilot operation period.

Prior to the commencement of Fall piloting session, the pilot-scale system was monitored for a short period of time to evaluate the stability of system. This period is similar to the transition period in previous piloting sessions; however, there was no physical transition between coagulants, and only stability of the system was monitored. However, to maintain consistency between previous technical memos this period will still be referred to as the Fall transition period.

Table 1-1 provides a summary of the Fall piloting session events which commenced on October 16th, 2017. The original intent was to complete the Fall piloting efforts on November 6th, 2017. However, on November 1st, 2017 the pilot-scale system experienced a process upset forcing an unexpected stoppage in the Fall piloting session. This upset was eventually resolved and the pilot-scale system returned to operation; however, by this time, the temperature had dropped to less than 4˚C (further discussed in Section 5.1). Consequently, the Fall piloting session was conducted for 16 days from October 16th to 31st, 2017.

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Table 1-1: Fall piloting session schedule.

FALL PILOTING SESSION (4°C - 14°C)	DURATION	START DATE	END DATE
1. Extended Pilot-Scale System Operation	49 days	August 21, 2017	October 9, 2017
2. Fall Transition Period	6 days	October 10, 2017	October 15, 2017
3. Fall Pre-Piloting Progress Meeting	1 day	October 13, 2017	October 13, 2017
4. Fall Piloting Session	16 days	October 16, 2017	October 31, 2017
5. Fall Mid-Point Progress Meeting	1 day	November 1, 2017	November 1, 2017

2. EXTENDED PILOT OPERATION PERIOD

Following the completion of the Summer piloting session, the City continued to operate the pilot-scale system using ferric sulphate from August 21st to October 9th, 2017. This period was to evaluate the pilot-scale system's operation over an extended period of time and to observe the potential long term effects of using ferric sulphate as an alternative to ferric chloride. During this period, the City collected samples from both the full-scale and pilot-scale systems for daily laboratory analysis of turbidity, pH, total organic carbon (TOC), and total manganese. The laboratory analysis data, compiled during the extended pilot operation period, completed by the City's Analytical Services Branch (hereafter referred to as Lab), is provided in Appendix A.

The pilot-scale system samples were collected daily from the following locations:

- Post-DAF (via the DAF overflow piping to the overflow tank,);
- Post-Ozone (from the combined ozone column piping feeding the Ozone Contact Tank);
- Individual filter effluents (Filters 1 through 8);

The full-scale system samples were collected from the following locations:

- Raw water (during the extended pilot operation period, raw water was sampled from this location only);
- Post-DAF;
- Post Ozone (i.e. combined ozone from both tanks);
- Individual filter effluents (Filters 1 through 8); and
- Post Filter Combined;

Note: the raw water was only recorded for the full-scale system, as previous testing during the Winter #1 benchmarking period (February 4th -17th, 2017) found nominal quantitative differences between the raw water collected from both full-scale and pilot-scale systems. This excludes a temperature increase of approximately 1°C to 2°C. As such, for the purposes of this study, the water quality for the raw water at the pilot-scale system is assumed to be similar to the full-scale system.

2.1 Overview of Extended Pilot Operation Period Activity

The following section describes the full-scale and pilot-scale system operations and activities undertaken during the extended pilot operation period. The City generally operated the pilot-scale system under the optimal conditions for coagulant dose (38 mg/L of ferric sulphate), Post-DAF pH (5.80), and coagulant-aid dose (0 mg/L) determined during the Spring piloting session. Deviations from the normal pilot-scale system operations during the extended pilot operation period were provided by City and are described below. Maintenance or operational issues that occurred during the extended piloting operation period are also noted.

On August 23rd, the full-scale system was shutdown at 9:00 am for approximately 30 minutes. The full-scale system shutdown did not affect pilot-scale system operation. The City did however report a fault that occurred in the pilot-scale system ozone air compressor, which appeared to be unrelated to the shutdown of the full-scale system. The fault was repaired and the pilot-scale system ozone was restarted at approximately 3:30 pm.

On August 25th, the pilot-scale system ozone compressor was repaired and the desiccant cells in the ozone system's air dryer were replaced. The ozone generator was then operated in Dry Mode from August 25th to 27th, in an attempt to lower the dew point to the set point. However, on August 28th, the City reported the ozone generator air compressor failed sometime on August 26th or 27th (exact time unknown), prior to reaching the dew point. Water was found in the piping, air drier and generator in the pilot-scale system ozone system on September 4th, causing the ozone system to fail. It was determined the check valves on the ozone line failed allowing water to flow back from the ozonation columns into the generation system.

The pilot-scale system was offline on September 6th to complete maintenance to the DAF system, in particular, the DAF scrapper. The City reported that the DAF scrapper was not evenly removing floc, leaving approximately 2 inches of buildup along the edge of the tank. This was due to one of the scrapper support chains becoming stretched causing one side of the scrapper to dip below the surface of the water. The front cogs of the DAF scrapper were replaced, and the DAF system was restarted on September 7th. The ferric sulphate dose was reduced from 38 mg/L to 36 mg/L on September 7th, to reduce the buildup of coagulant in the DAF saturator strainer and Post-DAF strainer.

On September 14th, prior to daily backwash, the City identified a failure in the DAF saturator release valve. The release valve was replaced, and the DAF saturator system was reinitiated at approximately 4:00 pm.

On September 18th, DAF mixer MXR-2 failed due to a blown fuse. City technicians repaired the blown fuse, as well as drained and cleaned the DAF tank. The pilot-scale system returned to normal operation at approximately 4:30 pm.

The ferric sulphate dose was increased from 36 mg/L to 38 mg/L on September 20th to address increases in Post-DAF turbidity and to improve filter performance. The pH controller was set to 5.60 to achieve the desired Post-DAF pH of 5.80.

The pilot-scale system was offline on September 28th for maintenance and cleaning of the DAF tank. The maintenance included replacing the rear cogs on the DAF scrapper and adjusting the scrapper support chains, installation of a rebuilt air compressor, and the calibration of online pH-meters within the pilot-scale system.

On September 29th, the City noted the DAF weir plate in the pilot-scale system had lowered, which likely occurred during the maintenance to the DAF tank on September 28th. City personnel adjusted the weir plate to the set mark.

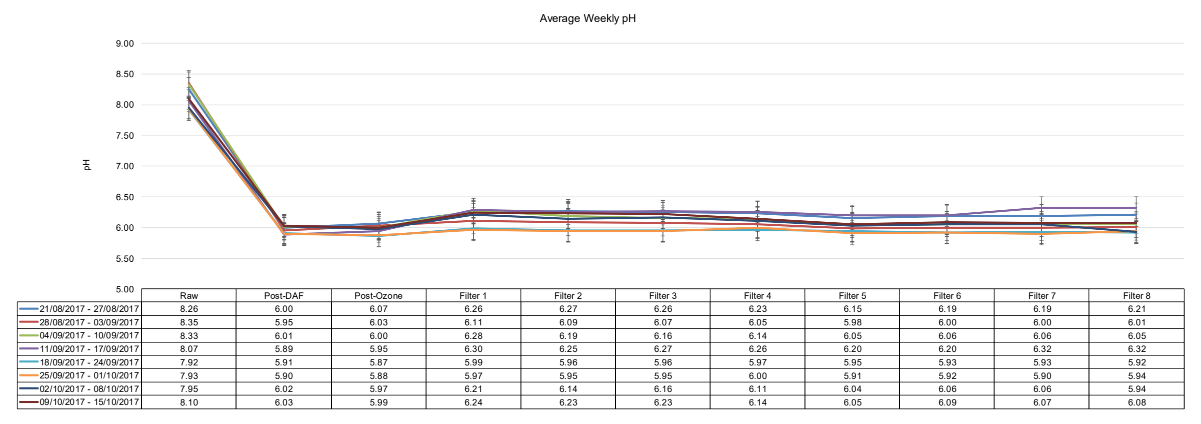
On October 2nd, the City determined the ferric sulphate barrel had run empty sometime between September 29th and October 1st (exact time unknown). The City noted there was no coagulant in the line feeding the pilot-scale system DAF tank and therefore the coagulation process was offline for an unknown period of time. The City replaced the ferric sulphate barrel and the pilot-scale system was returned to normal operation.

2.2 Results from Extended Pilot Operation Period

The following sections present the key parameter results for samples collected from the pilot-scale system during the extended pilot operation period. For presentation purposes, the data has been tabulated as a 7-day average. The daily results are found in Appendix A.

→ pH

The raw water weekly average pH ranged from 7.92 to 8.35 during the extended pilot operation period (Figure 2-1). There was a significant reduction in pH following coagulation and DAF treatment due to the addition of coagulant and sulphuric acid prior to DAF system. The average Post-DAF pH over the extended pilot operation period was 5.97 ± 0.06. There was no significant change in pH following ozonation and there was a slight increase in pH following filtration. The weekly average pH in the pilot-scale system filter effluent ranged from 5.94 to 6.22 with deviations of <0.1 pH units. The results show that the pilot-scale system operated in a very stable manner during the extended pilot operation period. The benefit of maintaining a stable pH over long periods of time is that it allows better predictions to be made regarding coagulation and DAF operations, as well as DAF effluent water quality.



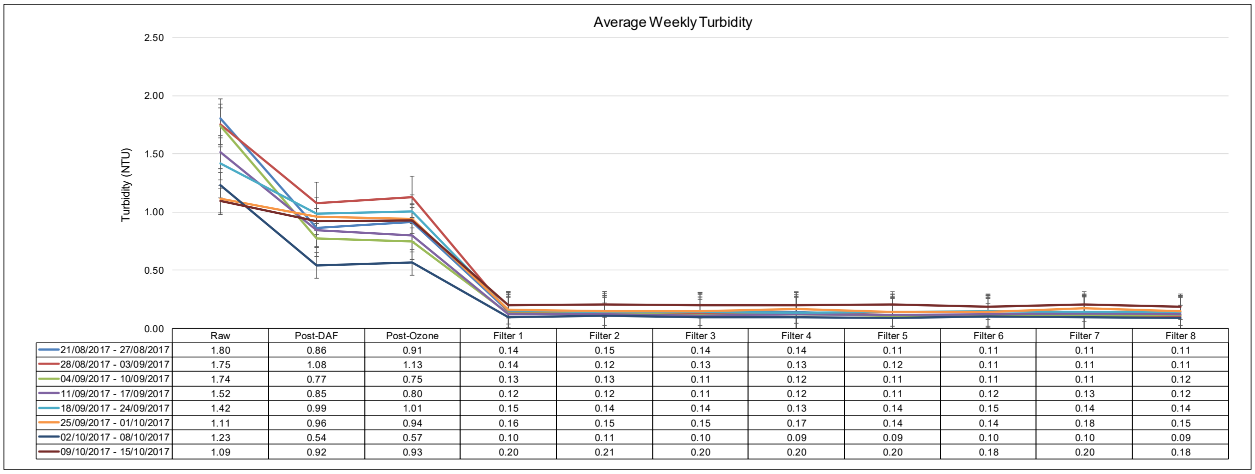
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
21/08/2017 - 27/08/2017	8.26	6.00	6.07	6.26	6.27	6.26	6.23	6.15	6.19	6.19	6.21
28/08/2017 - 03/09/2017	8.35	5.95	6.03	6.11	6.09	6.07	6.05	5.98	6.00	6.00	6.01
04/09/2017 - 10/09/2017	8.33	6.01	6.00	6.28	6.19	6.16	6.14	6.05	6.06	6.06	6.05
11/09/2017 - 17/09/2017	8.07	5.89	5.95	6.30	6.25	6.27	6.26	6.20	6.20	6.32	6.32
18/09/2017 - 24/09/2017	7.92	5.91	5.87	5.99	5.96	5.96	5.97	5.95	5.93	5.93	5.92
25/09/2017 - 01/10/2017	7.93	5.90	5.88	5.97	5.95	5.95	6.00	5.91	5.92	5.90	5.94
02/10/2017 - 08/10/2017	7.95	6.02	5.97	6.21	6.14	6.16	6.11	6.04	6.06	6.06	5.94
09/10/2017 - 15/10/2017	8.10	6.03	5.99	6.24	6.23	6.23	6.14	6.05	6.09	6.07	6.08

Figure 2-1: Weekly average pH for the pilot-scale system collected during the extended pilot operation period. Data originates from Lab analysis.

→ Turbidity

The average weekly raw water turbidity slowly declined from 1.84 NTU to 1.09 NTU during the extended pilot operation period (Figure 2-2).

This reduction in raw water turbidity coincides with the change from warmer Summer water to cooler Fall water, which is typically observed in historical trends for seasonal changes in raw water turbidity. There was a significant reduction in turbidity following coagulation and DAF treatment, with Post-DAF turbidity ranging from 0.54 NTU to 1.08 NTU. There was no significant change in turbidity in the Post-Ozone samples. There was a substantial reduction (79 - 89%) from the Post-Ozone turbidity following filtration. Furthermore, the combined average filter effluent turbidity was 0.13 ± 0.03 NTU for the entirety of the extended pilot operation period. This shows that the pilot-scale system was operating in a stable manner during the extended pilot operation period, both in terms of stability and treatment efficiency.

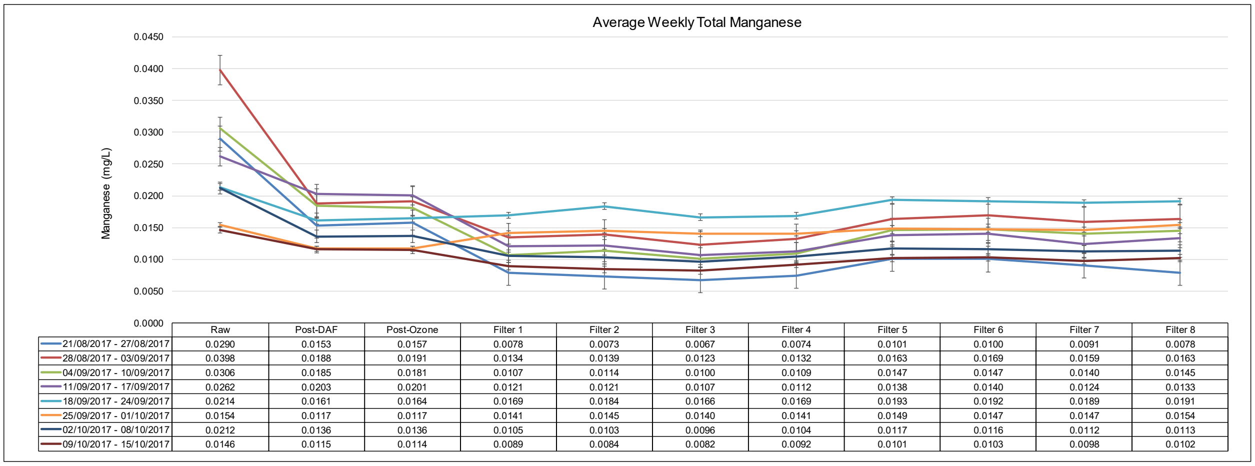


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
21/08/2017 - 27/08/2017	1.80	0.86	0.91	0.14	0.15	0.14	0.14	0.11	0.11	0.11	0.11
28/08/2017 - 03/09/2017	1.75	1.08	1.13	0.14	0.12	0.13	0.13	0.12	0.11	0.11	0.11
04/09/2017 - 10/09/2017	1.74	0.77	0.75	0.13	0.13	0.11	0.12	0.11	0.11	0.11	0.12
11/09/2017 - 17/09/2017	1.52	0.85	0.80	0.12	0.12	0.11	0.12	0.11	0.12	0.13	0.12
18/09/2017 - 24/09/2017	1.42	0.99	1.01	0.15	0.14	0.14	0.13	0.14	0.15	0.14	0.14
25/09/2017 - 01/10/2017	1.11	0.96	0.94	0.16	0.15	0.15	0.17	0.14	0.14	0.18	0.15
02/10/2017 - 08/10/2017	1.23	0.54	0.57	0.10	0.11	0.10	0.09	0.09	0.10	0.10	0.09
09/10/2017 - 15/10/2017	1.09	0.92	0.93	0.20	0.21	0.20	0.20	0.20	0.18	0.20	0.18

Figure 2-2: Weekly average turbidity for the full-scale system and the pilot-scale system collected during the extended pilot operation period. Data originates from Lab analysis.

→ Total Manganese

A weekly average raw water total manganese reduction from 0.0389 mg/L spanning August 28th to September 3rd to 0.0146 mg/L spanning October 9th to October 15th was observed. This reduction is typical for seasonal changes in raw water total manganese, coinciding with the transition from warm Summer water to cooler Fall water (Figure 2-3). As expected, given the low residual manganese in ferric sulphate, there is a reduction in total manganese following DAF treatment. Filtration was able to remove 18-47% of the manganese remaining in the water after ozone treatment, except for Week 5 (Sept 14th to 24th) and Week 6 (Sept 25th to Oct 1st) where there was a 10% and 25% increase in manganese measured in the filter effluent (average of Filters 1-8). The poor removal of the manganese by the pilot-scale system during this period may be related to the issues in the DAF operation reported by the City during this period (See Section 2-1). However, the average total manganese in the combined filter effluent (reported as the average manganese for Filters 1-8) was 0.013±0.003 mg/L during the entirety of the extended pilot operation period. These results show that the pilot-scale system can maintain good removal of manganese over an extended period of operation. Furthermore, the results indicate that manganese in the finished water is likely to meet the City's criteria for total manganese in the finished water being <0.015 mg/L.

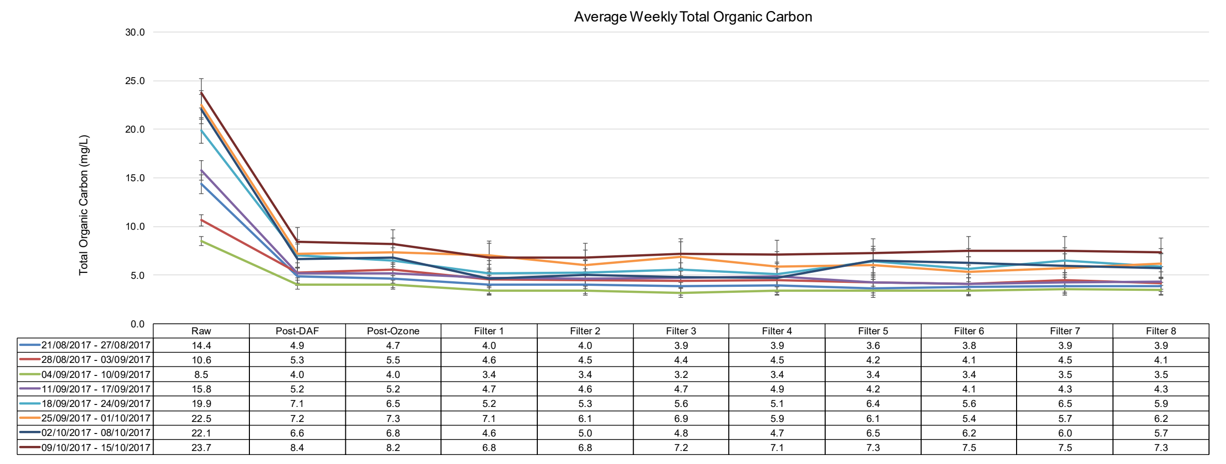


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
21/08/2017 - 27/08/2017	0.0290	0.0153	0.0157	0.0078	0.0073	0.0067	0.0074	0.0101	0.0100	0.0091	0.0078
28/08/2017 - 03/09/2017	0.0398	0.0188	0.0191	0.0134	0.0139	0.0123	0.0132	0.0163	0.0169	0.0159	0.0163
04/09/2017 - 10/09/2017	0.0306	0.0185	0.0181	0.0107	0.0114	0.0100	0.0109	0.0147	0.0147	0.0140	0.0145
11/09/2017 - 17/09/2017	0.0262	0.0203	0.0201	0.0121	0.0121	0.0107	0.0112	0.0138	0.0140	0.0124	0.0133
18/09/2017 - 24/09/2017	0.0214	0.0161	0.0164	0.0169	0.0184	0.0166	0.0169	0.0193	0.0192	0.0189	0.0191
25/09/2017 - 01/10/2017	0.0154	0.0117	0.0117	0.0141	0.0145	0.0140	0.0141	0.0149	0.0147	0.0147	0.0154
02/10/2017 - 08/10/2017	0.0212	0.0136	0.0136	0.0105	0.0103	0.0096	0.0104	0.0117	0.0116	0.0112	0.0113
09/10/2017 - 15/10/2017	0.0146	0.0115	0.0114	0.0089	0.0084	0.0082	0.0092	0.0101	0.0103	0.0098	0.0102

Figure 2-3: Weekly average total manganese for the pilot-scale system during the extended pilot operation period. Data originates from Lab analysis.

→ Total Organic Carbon

The TOC data for pilot-scale system measured during the extended pilot operation period is presented in Figure 2-4. It should be noted that during the extended pilot operation period the Lab experienced issues with their TOC analyzer, where concentrations measured were artificially 2 to 3 times higher than the actual concentration. However, because all samples analyzed had the same instrumental error, the trends can still be evaluated for discussion purposes.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
21/08/2017 - 27/08/2017	14.4	4.9	4.7	4.0	4.0	3.9	3.9	3.6	3.8	3.9	3.9
28/08/2017 - 03/09/2017	10.6	5.3	5.5	4.6	4.5	4.4	4.5	4.2	4.1	4.5	4.1
04/09/2017 - 10/09/2017	8.5	4.0	4.0	3.4	3.4	3.2	3.4	3.4	3.4	3.5	3.5
11/09/2017 - 17/09/2017	15.8	5.2	5.2	4.7	4.6	4.7	4.9	4.2	4.1	4.3	4.3
18/09/2017 - 24/09/2017	19.9	7.1	6.5	5.2	5.3	5.6	5.1	6.4	5.6	6.5	5.9
25/09/2017 - 01/10/2017	22.5	7.2	7.3	7.1	6.1	6.9	5.9	6.1	5.4	5.7	6.2
02/10/2017 - 08/10/2017	22.1	6.6	6.8	4.6	5.0	4.8	4.7	6.5	6.2	6.0	5.7
09/10/2017 - 15/10/2017	23.7	8.4	8.2	6.8	6.8	7.2	7.1	7.3	7.5	7.5	7.3

Figure 2-4: Weekly average total organic carbon results collected in the pilot-scale system during the extended pilot operation period. Data originates from Lab analysis. Note that during the extended piloting period the TOC measurements by the Lab were 2-3 times higher than the actual TOC values.

The most significant reduction in TOC occurred with DAF treatment, where the raw water TOC was reduced by 50.7 – 69.9%, based on weekly average results during the entire extended pilot operation period. There was little change in TOC following ozone treatment. Likewise, filtration was only minimally effective in reducing the TOC concentration remaining in the Post-Ozone water, with removals ranging from 12% to 21% based on the weekly average TOC.

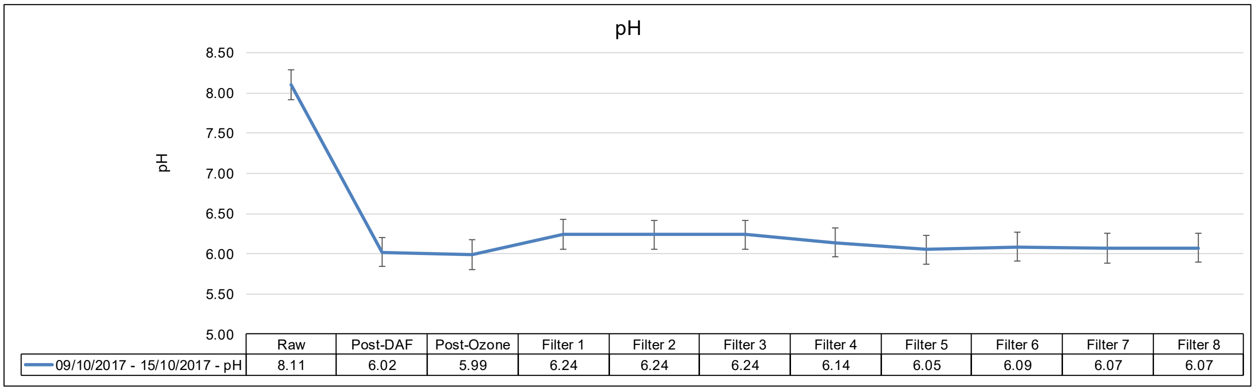
The extended pilot operation period did not indicate that there would be any concerns with using ferric sulphate as a coagulant for long periods of operation. Furthermore, the results provide further evidence that using ferric sulphate as an alternative coagulant to ferric chloride would reduce total manganese in the finished water. It is anticipated that the finished water quality will still meet the objectives with further chemical optimization.

3. FALL TRANSITION PERIOD

The Fall transition period from October 10th to 15th, 2017, was used to verify that the operation of the pilot-scale system was stable before commencing the Fall piloting session. Stability is achieved following a minimum of 5 days of operations where turbidity fluctuates by ±0.2 NTU in Post-DAF samples and ±0.05 NTU in the pilot-scale system filter effluent. The pilot-scale system DAF was operated with a raw water flow of 3.0 L/s, ferric sulphate dose of 38 mg/L and a Post-DAF pH of 5.80.

3.1 pH

The pH results for the Fall transition period are illustrated in Figure 3-1. The raw water pH was consistent during the Fall transition period with an average pH of 8.11 ± 0.02. There was little variation in pH following treatment during the Fall transition period with Post-DAF and Post-Ozone samples fluctuation by ±0.04 and ±0.03 pH units, respectively. Likewise, there was little change in pH measured from the individual filter effluent, which varied by ±0.03 to ±0.05 pH units. The stability in pH is attributed to the implementation of a pH controller on the DAF system. Overall, with regards to pH, the pilot-scale system was operating in a stable manner during this period.

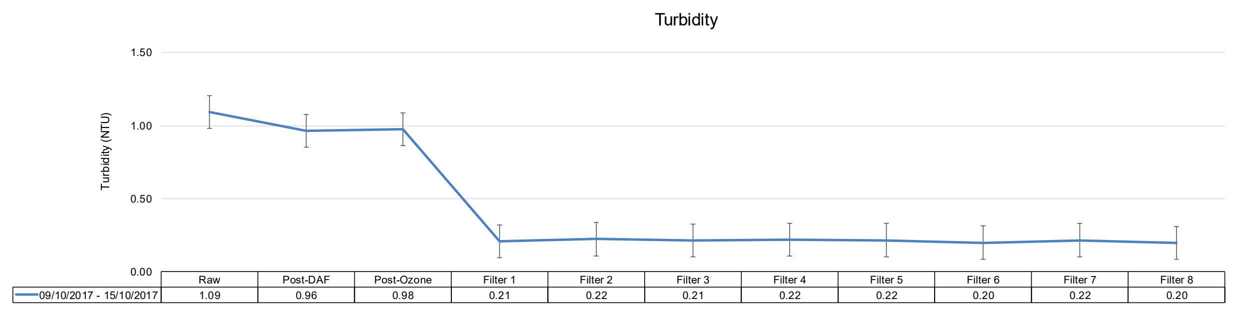


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
09/10/2017 - 15/10/2017 - pH	8.11	6.02	5.99	6.24	6.24	6.24	6.14	6.05	6.09	6.07	6.07

Figure 3-1: pH of the pilot-scale system measured during the Fall transition period. Data originates from Lab analysis.

3.2 Turbidity

The turbidity results from the Fall transition period can be seen in Figure 3-2 and Table 3-1.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
09/10/2017 - 15/10/2017	1.09	0.96	0.98	0.21	0.22	0.21	0.22	0.22	0.20	0.22	0.20

Figure 3-2: Turbidity of the pilot-scale system measured during the Fall transition period. Data originates from Lab analysis.

Table 3-1: Turbidity of the pilot-scale system measured during the Fall transition period. Data originates from Lab analysis.

Location	October 10, 2017	October 11, 2017	October 12, 2017	October 13, 2017	October 14, 2017	October 15, 2017	Average
Raw	1.10	1.07	1.12	1.19	1.04	1.04	1.09 ± 0.06
Post-DAF	0.80	0.87	1.11	0.94	1.00	1.06	0.96 ± 0.12
Post-Ozone	0.77	0.86	0.89	1.19	0.95	1.19	0.98 ± 0.18
Filter 1	0.13	0.16	0.17	0.34	0.22	0.22	0.21 ± 0.07
Filter 2	0.13	0.21	0.19	0.35	0.21	0.24	0.22 ± 0.07
Filter 3	0.14	0.19	0.18	0.34	0.20	0.22	0.21 ± 0.07
Filter 4	0.13	0.17	0.17	0.45	0.18	0.20	0.22 ± 0.12
Filter 5	0.12	0.16	0.20	0.38	0.19	0.24	0.22 ± 0.09
Filter 6	0.14	0.15	0.17	0.32	0.18	0.23	0.20 ± 0.07
Filter 7	0.13	0.15	0.17	0.40	0.19	0.25	0.27 ± 0.10
Filter 8	0.12	0.15	0.17	0.35	0.18	0.21	0.20 ± 0.08
Filter Average	0.13	0.17	0.18	0.37	0.19	0.23	0.21 ± 0.08

The average Post-DAF turbidity during the Fall transition period was 0.96±0.12 NTU, which meets the criteria for stable DAF operation (Figure 3-2). When evaluating variation in filter effluent turbidity (Filters 1-8), there is only minor variation in filter effluent turbidity observed on a given day, with fluctuations ranging from 0.01 – 0.04 NTU. However, when evaluating the final filter effluent over the 6-day Fall transition period, there is a combined filter effluent turbidity of 0.21 ± 0.08 NTU, which does not meet the criteria for stable pilot-scale system operation. It should be noted the combined filter effluent was not measured during the Fall transition period. The combined filter effluent is based on the average turbidity of individual filters (Filters 1-8).

The variance in turbidity measured in the average combined filter effluent over the 6-day period is largely due to elevated turbidity on October 13th. This day had the highest raw water turbidity of 1.19 NTU, which could have contributed to higher filter effluent turbidity on October 13th. If the results from October 13th are omitted from the data set, the average combined filter turbidity is 0.18 ± 0.04 NTU, which would meet the criteria for stable pilot-scale operation.

Although, the filter effluent turbidity did not meet the 0.05 NTU stability criteria, the individual filter effluent was largely consistent between the 8 filters. Furthermore, the combined filter effluent met the criteria for stability for 5 of the 6 days, therefore it was deemed acceptable for further piloting under cool water conditions.

3.3 Total Manganese

The average raw water total manganese during the pilot-scale system Fall transition period was 0.0145 ±0.0009 mg/L (Figure 3-3), which appeared stable compared to the raw water total manganese measured during the extended pilot operation period. The total manganese concentration in the Post-DAF water remained relatively constant during the Fall transition period at 0.0112±0.0007 mg/L. The total manganese in the final individual filter effluent also showed little fluctuation during the Fall transition period, where the total manganese concentration varied by 0.0005 – 0.0010 mg/L. Although total manganese removal is not within the criteria for establishing pilot-scale system stability, the minimal fluctuations in total manganese concentration in the individual filter effluents indicate that the pilot-scale system was operating in a stable manner with regards to total manganese removal.

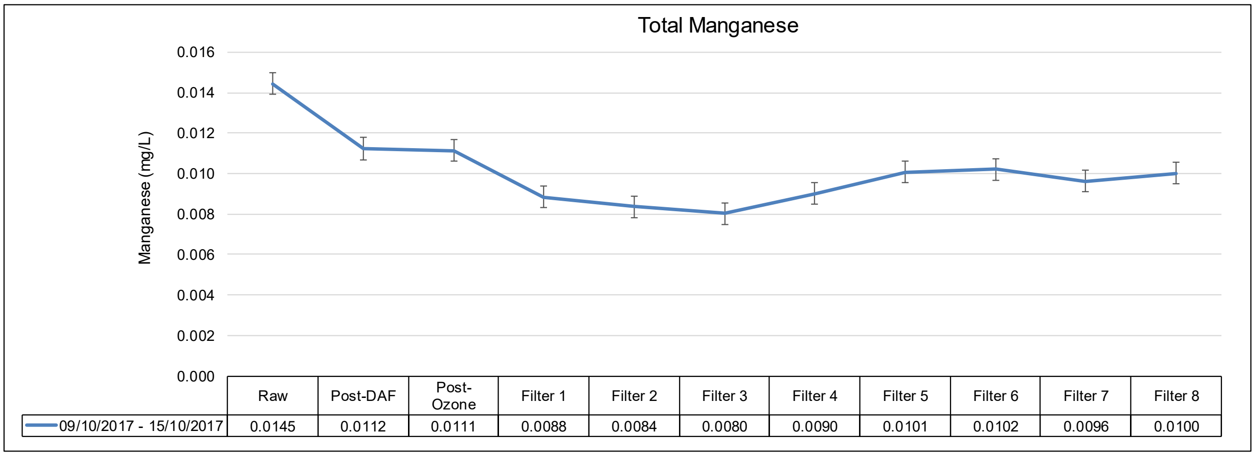
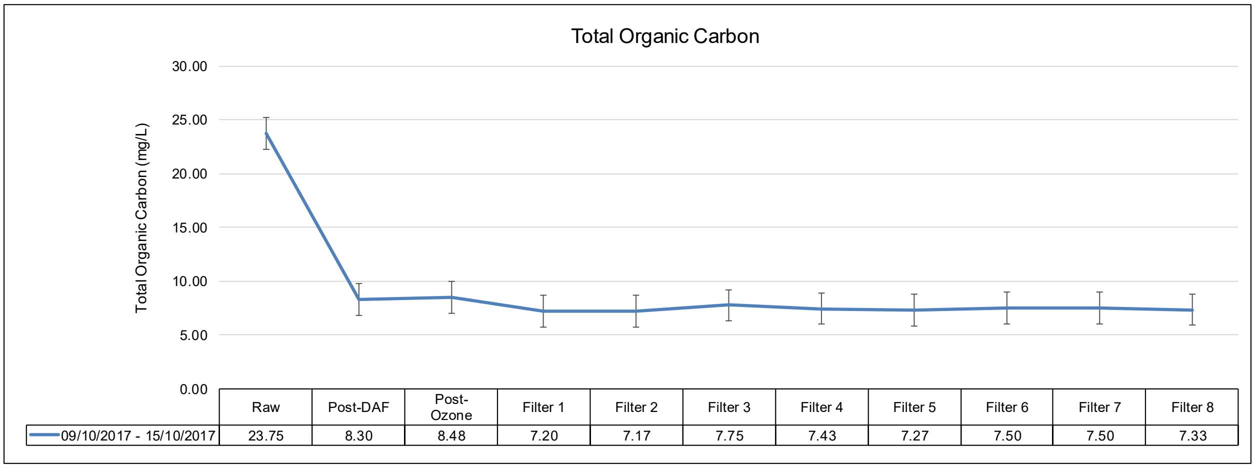


Figure 3-3: Total manganese of the pilot-scale system measured during the Fall transition period. Data originates from Lab analysis.

3.4 Total Organic Carbon

The TOC results for the pilot-scale system, measured during the Fall transition period, are reported in Figure 3-4. It should be noted that the Lab was still experiencing issues with their TOC analyzer, where concentrations measured were artificially 2 to 3 times higher than the actual concentration.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
09/10/2017 - 15/10/2017	23.75	8.30	8.48	7.20	7.17	7.75	7.43	7.27	7.50	7.50	7.33

Figure 3-4: TOC of the pilot-scale system during the Fall transition period. Data originates from Lab analysis. Note: TOC measured during the Fall transition period contained error from the Lab and is approximately 2-3 times higher than the actual TOC concentration.

There was significant variation in TOC measured in the Post-DAF samples which ranged from 7.10 mg/L to 9.20 mg/L during the Fall transition period. Similar results were found for the Post-Ozone samples, which ranged from 7.50 mg/L to 9.40 mg/L, as well as the final effluent TOC concentration, where individual filter effluent TOC concentrations varied by as much as 1.4 mg/L.

Although significant variation in the TOC results were found during the Fall transition period, TOC is not a parameter of concern when evaluating pilot-scale system stability. Furthermore, the TOC results are subjective and are known to contain error, therefore it is not believed that the variance reported in TOC is significant.

Overall, the results from the pH, turbidity, total manganese and TOC indicate that the pilot-scale system was operating in a relatively stable manner. The pilot-scale system Fall transition period was therefore deemed acceptable such that the Fall piloting session in cool water conditions could commence.

4. FALL PILOTING SESSION ACTIVITY

WSP operated the pilot-scale system from October 16th to October 31st, 2017 (inclusive). The specific activities and test conditions that were investigated during this period are outlined in Table 4-1. The results of the analytical work on the pilot-scale system samples completed by the Lab are provided in Appendix B. The daily operational logs, which detail observations and additional details, are also provided in Appendix B. A detailed description of the piloting work was previously outlined in TM No. 2.

Table 4-1: Summary of the Test Conditions for the Fall Piloting Session.

DATE	COAGULANT DOSE (mg/L)	PILOT pH	COAGULANT-AID DOSE (mg/L)	SAMPLE SCHEDULE	COMMENTS
October 16, 2017	36	5.80	None		
October 17, 2017	38	5.80			
October 18, 2017	40	5.80			Raw water flow stopped
October 19, 2017	42	5.80			
October 20, 2017	44	5.80			
October 21, 2017	42	5.80		[1]Type 1	
October 22, 2017	42	5.70			
October 23, 2017	42	5.80			
October 24, 2017	42	5.90			
October 25, 2017	42	6.00			
October 26, 2017	42	5.70		Type 1	
October 27, 2017	42	5.70		[2]Type 2	
October 28, 2017	42	5.70	0.05		
October 29, 2017	42	5.70	0.07		
October 30, 2017	42	5.70	0.13		
October 31, 2017	42	5.70	0.07	Type 2	
November 01, 2017	Clean Day				

[1] Type 1 sampling included: metals (dissolved and total): aluminum, arsenic, boron, calcium, cadmium, chromium, copper, iron, potassium, magnesium, manganese, sodium, nickel, lead, antimony, silver, uranium, zinc, and zirconium. In addition, dissolved organic carbon (DOC), total dissolved solids (TDS), total solids (TS), total suspended solids (TSS), true colour, UV-Transmittance, alkalinity, conductivity, pH and turbidity.

[2] Type 2 sampling included all of Type 1, and threshold odour number, total trihalomethane (T-THM), total haloacetic acids (T-HAA), sulphate, chloride, and hardness. T-THM and T-HAA formation potential were only tested in the raw water and filter effluent of the full-scale and pilot-scale systems.

Process samples were collected from the pilot-scale system on a daily basis at the following locations:

- Raw (same as full-scale raw water)
- Post-DAF (via the DAF overflow piping to the overflow tank);
- Post-Ozone (from the combined ozone column piping feeding the Ozone Contact Tank);
- Individual filter effluents (Filters 1 through 8); and
- Combined filter effluent.

Samples were also collected from the full-scale system at the following locations for comparison purposes:

- Post-DAF
- Post-Ozone (i.e. combined ozone from both tanks);
- Post Filter Combined.

Samples were tested on a daily basis using the available bench-scale apparatus. Lab analyses were planned based on the schedule provided in Table 4-1.

During the Fall piloting session, the flow rate for the raw water was approximately 3.0 L/s and the recycle flow was approximately 0.4 L/s. The flow rates for filter Bank A (Filters 1 to 4) and filter Bank B (Filters 5 to 8) were 0.6 L/s and 0.3 L/s, respectively.

Deviations from the original program presented in TM No. 2 were as follows:

- Raw water analysis was taken from the pilot-scale system intake only;
- Backwash performance evaluation was not performed as per recommendations in TM No. 3;
- TOC analysis was conducted on the raw water and combined filter effluent samples from the full-scale system;
- Optimal coagulant dose was determined without the addition of coagulant-aid;
- Optimal pH was determined without the addition of coagulant-aid.

5. FALL PILOTING SESSION RESULTS

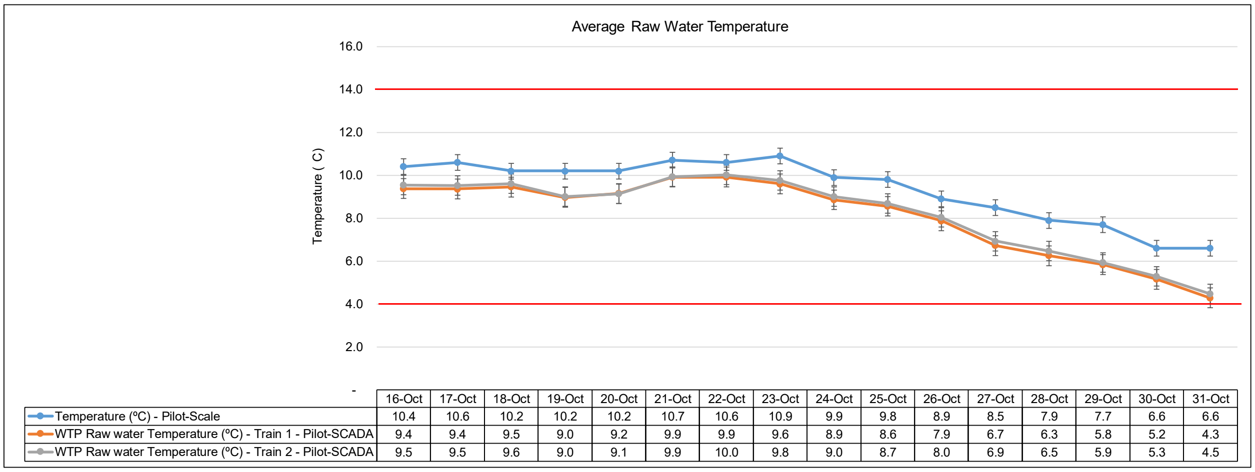
This section summarizes the operational parameters and the water quality analyses for samples collected from October 16th to October 31st, 2017, inclusive.

Ozone was not generated during the operation of the pilot-scale system from the October 16th to October 26th due to the failure of the generator. Therefore, coagulant and pH optimization occurred without ozone addition. The ozone generator was repaired, and ozone generation resumed on October 27th, 2017 such that coagulant-aid optimization occurred with ozone addition.

5.1 Raw Water Temperature

The criteria for testing in Fall conditions (cool water) was that the raw water temperature should be between 4°C and 14°C. Raw water temperature was measured by two SCADA temperature sensors for each train of the full-scale system (SCADA tags TTI011A and TTI012A). In the pilot-scale system, the raw water temperature was measured in grab samples using a hand-held digital thermometer.

Figure 5-1 shows that the raw water temperature remained within the range for cool water conditions, ranging from approximately 10.0°C to 4.3°C, based on the raw water temperature sensors for Trains 1 and 2 of the full-scale system. As observed in previous piloting sessions, the raw water temperature measured via grab samples from the pilot-scale system raw water intake was on average approximately 1 to 2°C warmer than the temperatures measured in Train 1 and 2 of the full-scale system. This temperature increase is attributed to the movement of raw water within the water treatment plant (WTP) (approximately 180 m), feeding the pilot-scale system. The pilot-scale system raw water sample temperatures ranged from 10.9°C to 6.6°C during the Fall piloting session, meeting the criteria for cool water conditions.



	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct	24-Oct	25-Oct	26-Oct	27-Oct	28-Oct	29-Oct	30-Oct	31-Oct
Temperature (°C) - Pilot-Scale	10.4	10.6	10.2	10.2	10.2	10.7	10.6	10.9	9.9	9.8	8.9	8.5	7.9	7.7	6.6	6.6
WTP Raw water Temperature (°C) - Train 1 - Pilot-SCADA	9.4	9.4	9.5	9.0	9.2	9.9	9.9	9.6	8.9	8.6	7.9	6.7	6.3	5.8	5.2	4.3
WTP Raw water Temperature (°C) - Train 2 - Pilot-SCADA	9.5	9.5	9.6	9.0	9.1	9.9	10.0	9.8	9.0	8.7	8.0	6.9	6.5	5.9	5.3	4.5

Figure 5-1: Raw water temperature for the full-scale system and the pilot-scale system during the Fall piloting session. Red lines indicate the upper (14°C) and lower (4°C) temperature limits for cool water conditions. Data for Trains 1 and 2 originates from the full-scale system SCADA dataset. Pilot-scale system data originates from benchtop analysis using a hand-held digital thermometer.

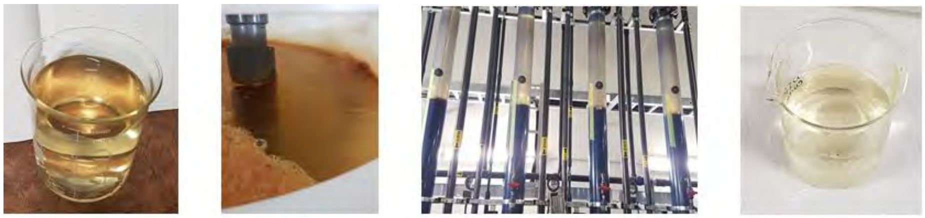
It is important to note that from October 16th to October 23rd, the raw water temperature remained relatively constant, according to both the online temperature sensors and grab samples obtained from the pilot-scale system. However, from October 23rd to October 31st, a rapid decline in temperature occurred. The raw water temperature sensors (full-scale system) indicated a temperature reduction from approximately 10°C to 4.5°C during this time. Likewise, the raw water temperature in the pilot-scale system declined from 10.9°C to 6.6°C.

It is believed that this change in the surface water temperature in the retention cells resulted in a rapid destratification of the thermocline, the net result being the anticipated abrupt seasonal turnover. This turnover also coincided with the shutdown of the WTP aqueduct resulting in lower water levels in the four retention cells, potentially compounding the effects of the temperature change. This rapid change in water density appeared to affect both the raw water quality and the operation of the pilot-scale DAF system.

On November 2nd, onsite WSP personnel observed the formation of discoloured water in the pilot-scale system Post-DAF effluent, Post-Ozone effluent, and filter effluents (Banks A and B). It is believed that the formation of discoloured water was the result of the rapid reduction in raw water temperature resulting from the seasonal turnover in the retention cells. City engineers and technicians attempted to improve the DAF operation from November 2nd to 4th, 2017 via the following:

- Full cleaning and check of mechanical systems;
- DAF saturator system was inspected and cleaned; no concern with the orifice was observed;
- Raw water static mixers were removed and cleaned. Some buildup was observed; however, the City indicated that this was minimal compared to buildup observed during the previous maintenance of the static mixers. This is not assumed to be the cause for the poor DAF operation; and
- Reduction of coagulant dose to 34 mg/L; which appeared to improve the DAF operation and reduce the occurrence of the yellow water.

On November 5th, WSP personnel attempted to continue the Fall piloting session by increasing the coagulant dose gradually from 34 mg/L to the desired optimal coagulant dose of 40 mg/L. However, an increase in dose from 34 mg/L to 36 mg/L caused yellow water in the Post-DAF (within 30 minutes of coagulant increase), which was carried thoughout the pilot-scale system (Figure 5-2).



Post-DAF

Post-Ozone (Break Tank)

Filter Bank B

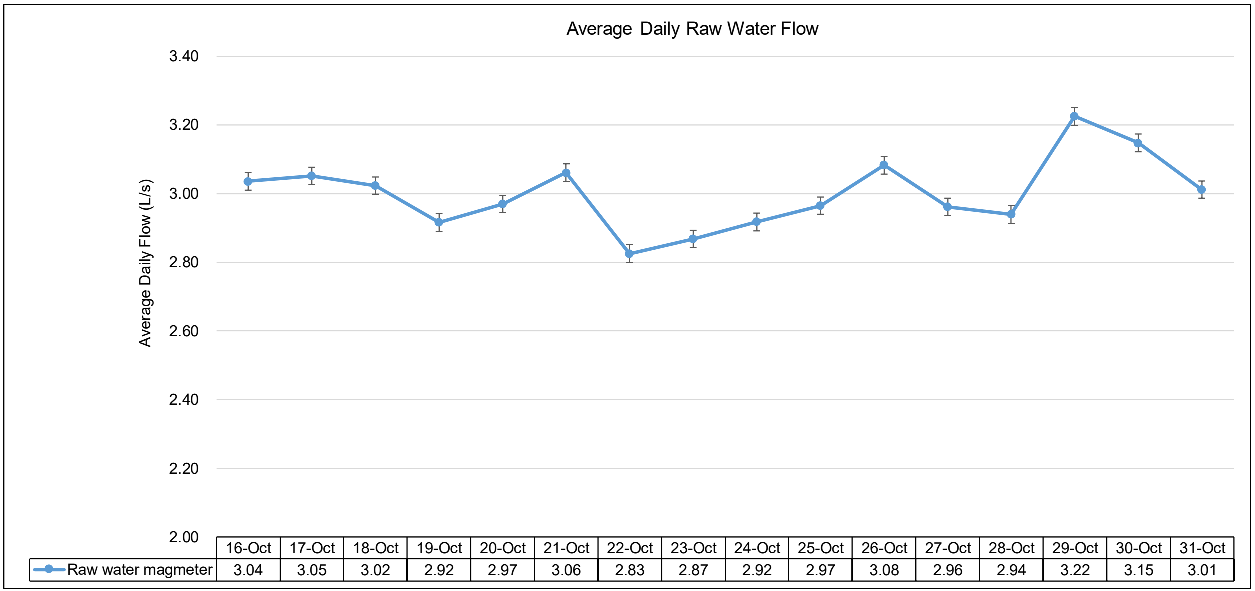
Filter Effluent (Filter 8)

Figure 5-2: Yellow water produced in the pilot-scale system following suspected destratification of the thermocline in the raw water retention cells. Photos were taken on November 5th, 2017.

Due to the inefficient operation of the DAF system following the turnover of the raw water ponds, the City decided to cancel the remainder of the Fall piloting session to further address the concerns with DAF operation and the production of yellow water in the pilot-scale system. By the time the City was able to stabilize the system the raw water temperature had dropped below the temperature limit for cool water conditions, which also contributed to the termination of Fall piloting session.

5.2 Pilot-Scale System Raw Water Flow (SCADA)

Figure 5-3 presents the raw water flow during the Fall piloting session. The desired raw water flow to the pilot-scale DAF system is 3.0 L/s. During the Fall piloting session, the flow ranged from 2.8 to 3.2 L/s with an overall average of 3.0 ± 0.1 L/s. The observed fluctuation in the flow is not expected to have a significant effect on the treatment process as chemical addition in the pilot-scale system is based on the flow rate.

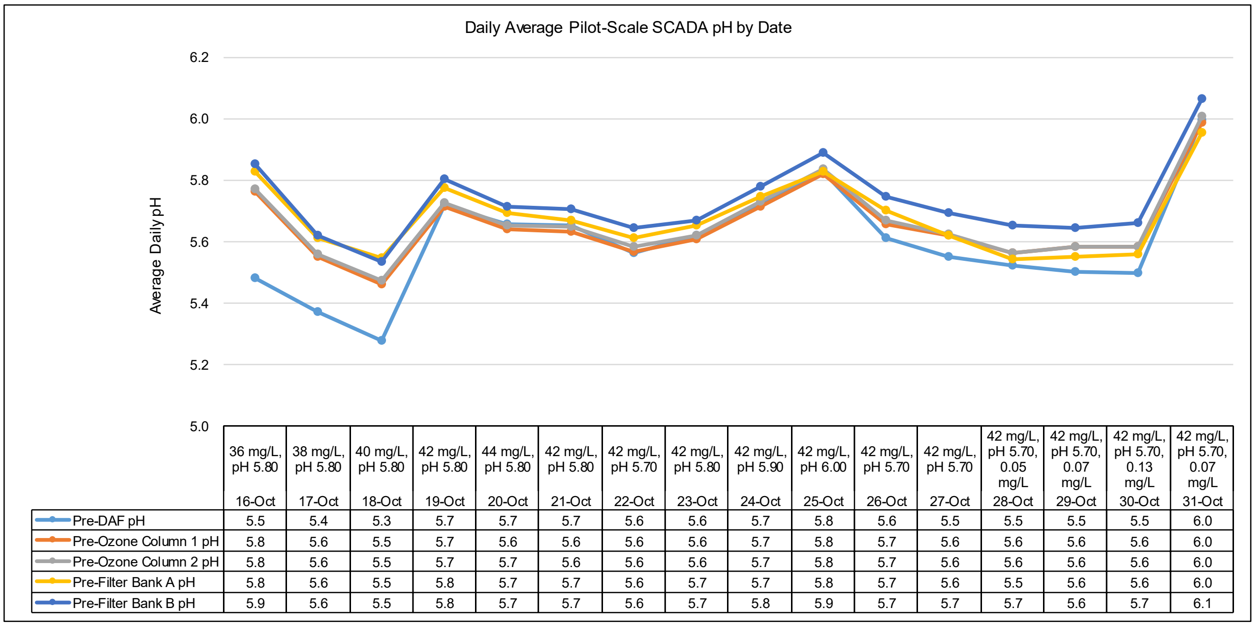


	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct	24-Oct	25-Oct	26-Oct	27-Oct	28-Oct	29-Oct	30-Oct	31-Oct
Raw water magmeter	3.04	3.05	3.02	2.92	2.97	3.06	2.83	2.87	2.92	2.97	3.08	2.96	2.94	3.22	3.15	3.01

Figure 5-3: Average daily raw water flow rate to the pilot-scale system during the Fall piloting session. Data originates from the pilot-scale system's SCADA dataset.

5.3 pH Monitoring of the Pilot-Scale System (SCADA)

The pH was monitored continuously at the pilot-scale system using the SCADA system. Figure 5-4 illustrates the average daily pH during the Fall piloting session for the following locations: Pre-DAF, Pre-Ozone (columns 1 & 2), and Pre-Filtration (Bank A and Bank B). As illustrated in Figure 5-4, the pH was relatively constant throughout the Fall piloting session.

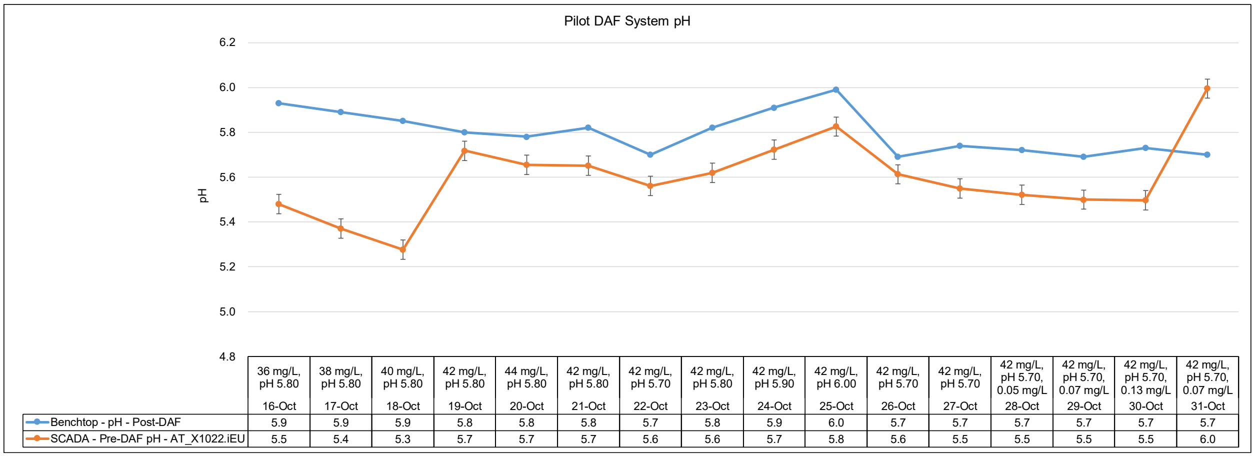


	36 mg/L, pH 5.80 16-Oct	38 mg/L, pH 5.80 17-Oct	40 mg/L, pH 5.80 18-Oct	42 mg/L, pH 5.80 19-Oct	44 mg/L, pH 5.80 20-Oct	42 mg/L, pH 5.80 21-Oct	42 mg/L, pH 5.70 22-Oct	42 mg/L, pH 5.80 23-Oct	42 mg/L, pH 5.90 24-Oct	42 mg/L, pH 6.00 25-Oct	42 mg/L, pH 5.70 26-Oct	42 mg/L, pH 5.70 27-Oct	42 mg/L, pH 5.70, 0.05 mg/L 28-Oct	42 mg/L, pH 5.70, 0.07 mg/L 29-Oct	42 mg/L, pH 5.70, 0.13 mg/L 30-Oct	42 mg/L, pH 5.70, 0.07 mg/L 31-Oct
Pre-DAF pH	5.5	5.4	5.3	5.7	5.7	5.7	5.6	5.6	5.7	5.8	5.6	5.5	5.5	5.5	5.5	6.0
Pre-Ozone Column 1 pH	5.8	5.6	5.5	5.7	5.6	5.6	5.6	5.6	5.7	5.8	5.7	5.6	5.6	5.6	5.6	6.0
Pre-Ozone Column 2 pH	5.8	5.6	5.5	5.7	5.7	5.6	5.6	5.6	5.7	5.8	5.7	5.6	5.6	5.6	5.6	6.0
Pre-Filter Bank A pH	5.8	5.6	5.5	5.8	5.7	5.7	5.6	5.7	5.7	5.8	5.7	5.6	5.5	5.6	5.6	6.0
Pre-Filter Bank B pH	5.9	5.6	5.5	5.8	5.7	5.7	5.6	5.7	5.8	5.9	5.7	5.7	5.7	5.6	5.7	6.1

Figure 5-4: Average daily pH of the pilot-scale system during the Fall piloting session. Data originates from the pilot-scale system's SCADA dataset.

Originally, the pH was controlled by adjusting the sulphuric acid dose to the raw water feeding the pilot-scale system DAF tank and monitoring the DAF effluent pH. Adjustments to the sulphuric acid dose were made based on the Post-DAF pH to achieve the desired DAF pH for the piloting sessions. Typically, an offset was added to the pH probe monitoring the pH of the chemically fed raw water to account for the pH change within the DAF tank. This offset appeared to provide sufficient adjustment needed to maintain a specific pH. This adjustment was monitored via Post-DAF grab samples, and minor adjustments to the acid addition were made on an as-needed basis.

A pH control routine was implemented in July 2017, based on the recommendation in TM No. 4, to adjust the sulphuric acid based on a pH set-point. Figure 5-5 compares the pH values obtained from the online analyzer on the Pre-DAF (average daily), and the Post-DAF grab samples analyzed using benchtop analysis.



	36 mg/L, pH 5.80 16-Oct	38 mg/L, pH 5.80 17-Oct	40 mg/L, pH 5.80 18-Oct	42 mg/L, pH 5.80 19-Oct	44 mg/L, pH 5.80 20-Oct	42 mg/L, pH 5.80 21-Oct	42 mg/L, pH 5.70 22-Oct	42 mg/L, pH 5.80 23-Oct	42 mg/L, pH 5.90 24-Oct	42 mg/L, pH 6.00 25-Oct	42 mg/L, pH 5.70 26-Oct	42 mg/L, pH 5.70 27-Oct	42 mg/L, pH 5.70, 0.05 mg/L 28-Oct	42 mg/L, pH 5.70, 0.07 mg/L 29-Oct	42 mg/L, pH 5.70, 0.13 mg/L 30-Oct	42 mg/L, pH 5.70, 0.07 mg/L 31-Oct
Benchtop - pH - Post-DAF	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.8	5.9	6.0	5.7	5.7	5.7	5.7	5.7	5.7
SCADA - Pre-DAF pH - AT_X1022.iEU	5.5	5.4	5.3	5.7	5.7	5.7	5.6	5.6	5.7	5.8	5.6	5.5	5.5	5.5	5.5	6.0

Figure 5-5: pH comparison of the pilot-scale system online Pre-DAF analyzer (pilot tag AT-X1022) and Post-DAF. Data originates from the pilot-scale system's SCADA dataset and from benchtop analyses using a Thermo Scientific Orion Star A325 pH probe.

Except for the first three days (October 16th to October 18th) and the last day (October 31st) of the Fall piloting session, the pH of the online and the grab samples are in close agreement with a percentage difference of 0.02%. The deviations observed from October 16th to October 18th are attributed to the malfunctioning of the sulphuric acid pump heads.

October 31st was the last day the pilot-scale system operated correctly before it was shut down during the Fall piloting session. Despite the apparent deviation observed for the October 16th to 18th, and October 31st data, the measurements are similar as the percentage difference was 0.1% or less.

5.4 Pilot-Scale System Filter Operation (SCADA)

During the Summer piloting session, Bank A operated at an average flow rate of 0.6 L/s and Bank B operated at an average flow rate of 0.3 L/s. The standard procedure was to backwash the filters at approximately the same time daily. The differential pressure values reported by the pilot-scale system's SCADA were evaluated on an average hourly basis to determine the following:

- the filter run times,
- the unit filter run volume (UFRV) values,
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter, and
- the rate of head loss increase of each filter.

The calculations were performed as described in Section 2.4 of TM No. 3. The filter's operational data was compared against filter effluent turbidity measured by the benchtop analyses, which was sampled approximately 4 hours from the start of the filtration cycle. The summary of the filter's operational data obtained during the Fall piloting session is provided in Appendix B. Figure 5-6 illustrates the average daily UFRV values.

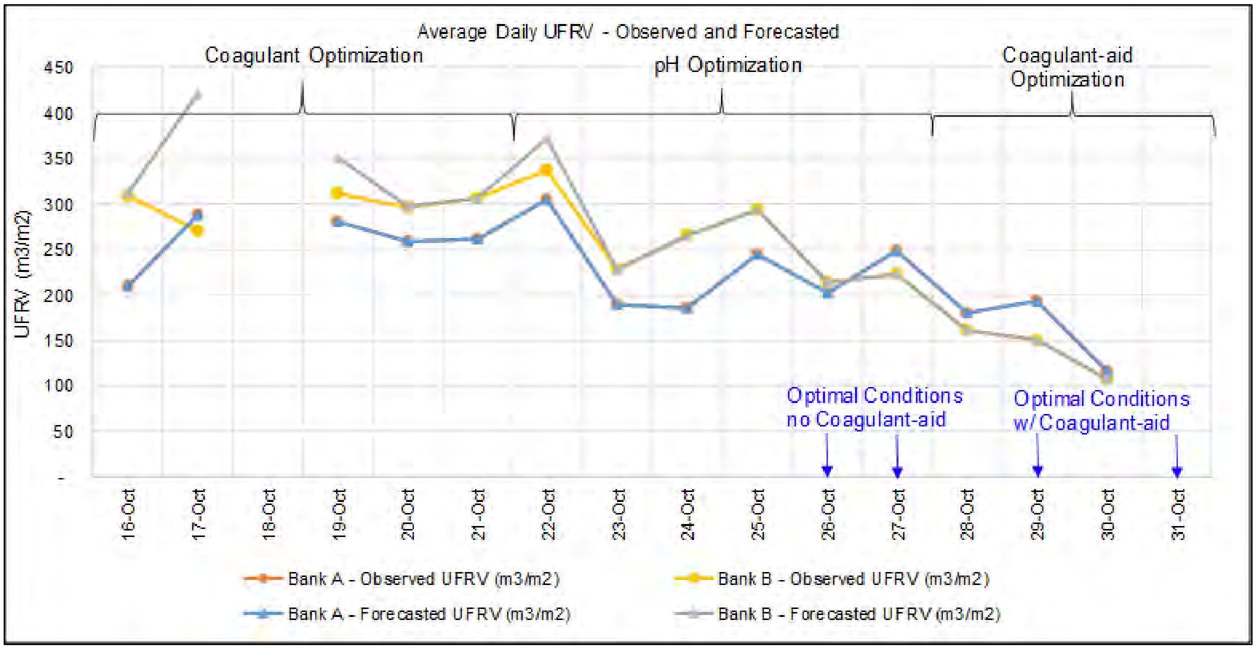


Figure 5-6: Average UFRV values of the pilot-scale system Bank A at an average flow of 0.6 L/s and Bank B at an average flow of 0.3 L/s during the Fall piloting session. UFRV = Filter Run Volume/Filter Surface Area. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's historic SCADA logs.

Table 5-1 tabulates the average filter run times and average UFRV values for the entire Fall piloting session, while also considering overall operation cycles and those which have not failed based on sampled turbidity.

Table 5-1: Average observed and forecasted filter run times and UFRV values during the Fall piloting session.

		FILTER RUN TIME (h)		**UFRV (m^3/m^2)**		
		Bank A	**Bank B**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	7.3	16.0	226	248	237
	Only cycles with turbidity ≤ 0.1 NTU	8.3	15.4	257	237	241
	Only cycles with turbidity ≤ 0.3 NTU	7.4	15.6	225	241	234
Forecasted Values	Overall Cycles	7.3	17.1	226	265	245
	Only cycles with turbidity ≤ 0.1 NTU	8.3	16.0	257	247	249
	Only cycles with turbidity ≤ 0.3 NTU	7.4	16.0	225	247	237

From the filter operation data, the following observations were made:

- During the Fall piloting session, the individual filters typically overflowed before the daily backwash each time, except for filters of Bank B on October 17th, October 19th and October 22nd. Filter 5 did not overflow on October 16th, October 24th and October 25th, and Filter 7 did not overflow on October 16th.
- The turbidity levels of the filters have exceeded the City's operational guideline of 0.1 NTU 89% of the time for Bank A and 54% of the time for Bank B, while the turbidity levels have exceeded the full-

scale system operating license of 0.3 NTU 30% of the time for Bank A, and 14% of the time for Bank B.

- For Bank A, the observed overall average filter run was 7.3 h and the observed overall average UFRV was 226 m^3/m^2. When discarding cycles in which sampled turbidity was observed above 0.1 NTU, the observed UFRV value increased to 257 m^3/m^2. No substantial difference was observed when comparing the overall average observed UFRV value for all cycles (226 m^3/m^2) with the observed UFRV value for filters which have not presented a turbidity above 0.3 NTU (225 m^3/m^2).
- For Bank B, the observed overall average filter run was 16.0 h and the observed overall average UFRV was 248 m^3/m^2. When discarding the cycles that turbidity levels were above 0.1 NTU when sampled, the observed UFRV value dropped slightly to 237 m^3/m^2. No substantial difference was observed when comparing the overall average observed UFRV value for all cycles (248 m^3/m^2) with the observed UFRV value for filters which have not presented turbidity above 0.3 NTU (241 m^3/m^2).
- No substantial difference was observed when comparing the observed UFRV values with the forecasted UFRV values for both filter banks.
- The rate of head loss increase ranged from 2.1 to 7.4 kPa/h, with an average of 3.7 kPa/h for Bank A operating at 0.6 L/s, while the rate of head loss increase ranged from 0.8 to 3.4 kPa/h, with an average of 1.6 kPa/h for Bank B operating at 0.3 L/s. Low variability was observed among Bank B filters in the same day, but higher variability was observed for each filter of Bank B after October 26th. Higher variability was observed among Bank A filters in the same day and higher variability was observed for each filter of Bank A after October 28th when coagulant-aid was added.
- Bank A filters exceeded the typical rate of head loss increase of 3.1 kPa/h, 63% of the time, but only once did Filter 1 exceed the maximum rate of head loss increase of 7.1 kPa/h. (The typical and maximum rate of head loss increase for filter bank operating at 0.6 L/s,3.1 kPa and 7.1 kPa, respectively, are based on the historical averages of the full-scale system. Refer to Table 5-2 of TM No. 3 for additional details).
- In comparison, 30% of the time Bank B filters exceeded the typical rate of head loss increase of 1.7 kPa/h and never the exceeded the maximum rate of head loss increase of 3.7 kPa/h. (The typical and maximum rate of head loss increase for filter bank operating at 0.3 L/s, 1.7 kPa/h and 3.7 kPa/h, respectively, are based on historical averages of the full-scale system. Refer to Table 5-2 of TM No. 3 for additional details).

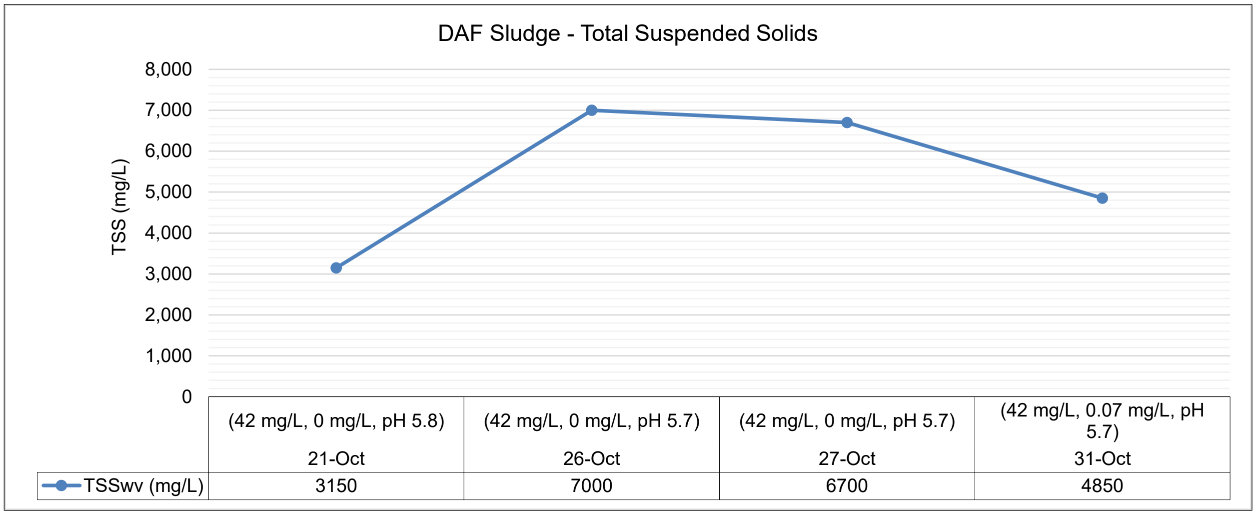
It would be expected that both banks exhibit similar UFRV values, while it would be expected that Bank B exhibits a filter run double that of Bank A. However, Bank A UFRV values varied from 10% less to 43% higher than Bank B UFRV values. In comparing the daily averages, as shown in Figure 5-6, it was observed that the UFRV differences between Bank A and Bank B were proportionally constant from October 19th to October 25th, which subsequently corresponds to the stages for coagulation and pH optimization. With the addition of coagulant-aid, Bank B UFRV values gradually decreased until October 30th and it fell behind that of Bank A on October 26th.

When the dosing of the coagulant-aid commenced on October 28th, 2017, there was also a decrease in UFRV values for Bank A. Even with ozone addition, which could oxidize some of the coagulant-aid, the decrease in the filter run times could be attributed to a more significant and quicker build-up of solids within the filter and/or the potenital for non-oxidized coagulant-aid carryover to the filters, all of which may contribute to an accelerated rate of filter clogging.

The effects of coagulant dose, pH and coagulant-aid dose are further discussed in Section 5.6. Additional evaluation regarding UFRV also is presented in Section 5.7 and Section 5.8.1.

5.5 DAF Sludge Production of the Pilot-Scale System

Figure 5-7 illustrates the total suspended solids (TSS) results for the residual generation from the pilot-scale system DAF. It can be observed that the TSS concentration increases as the pH decreases, contrary to what was observed in the Spring and Summer piloting sessions. In addition, the TSS concentration decreased with the coagulant-aid addition, which was not observed in previous piloting sessions. It should be noted that the sludge sampling from the DAF is rudimentary and subject to incomplete scrapper collection and/or variances in the scrapper level affecting the sludge blanket movement.



	(42 mg/L, 0 mg/L, pH 5.8) 21-Oct	(42 mg/L, 0 mg/L, pH 5.7) 26-Oct	(42 mg/L, 0 mg/L, pH 5.7) 27-Oct	(42 mg/L, 0.07 mg/L, pH 5.7) 31-Oct
TSSwv (mg/L)	3150	7000	6700	4850

Figure 5-7: TSS results for DAF sludge in the pilot-scale system during the Fall piloting session. Data originates from Lab analysis.

5.6 Optimization of Alternative Coagulant, pH, and Coagulant-Aid

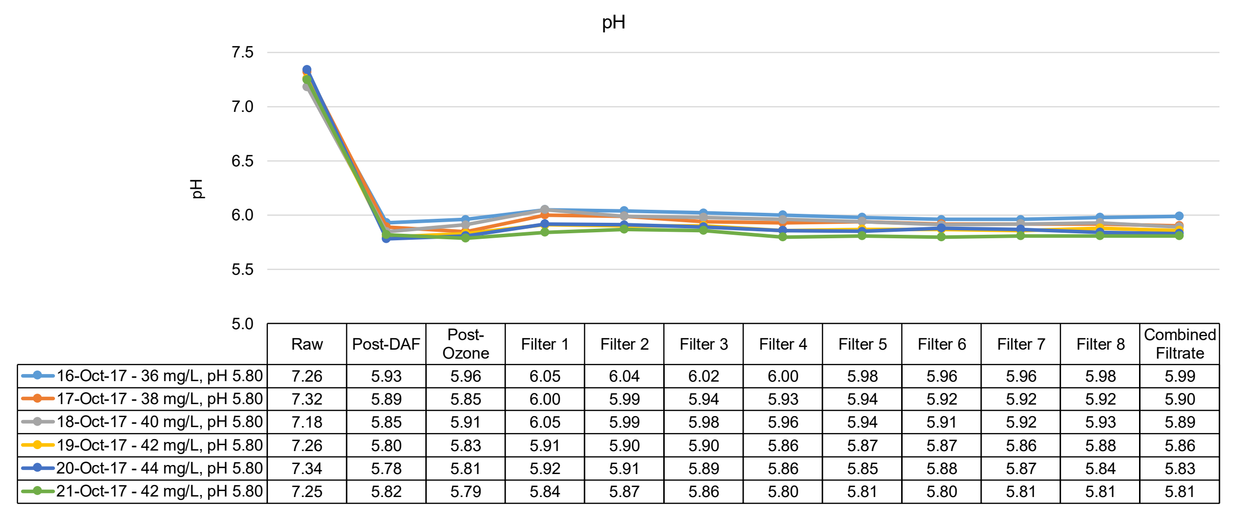
The following sections present the results used in determining the optimal dose for the alternative coagulant and the coagulant-aid, as well as the optimal pH for chemical coagulation within the DAF system.

5.6.1. Optimization of Ferric Sulphate Dose

Coagulant dose optimization tests were conducted from October 16th to October 21st, 2017 with ferric sulphate doses ranging between 36 to 44 mg/L at a pH of 5.8. The optimal chemical dose was based on daily grab samples that were tested using various benchtop analyses for the following critical parameters: turbidity, UV-transmittance (UVT), UV-absorbance at 254 nm (absorbance), and total manganese. Samples were collected daily from the following locations in the pilot-scale system: raw, Post-DAF, Post-Ozone, filter effluent (Filters 1 to 8), and the combined filter effluent. Samples were also collected from Post-DAF, Post-Ozone, and the combined filter effluent of the full-scale system and tested using benchtop analyses for the critical parameters listed above. It is important to note that no coagulant-aid was added during the optimization of ferric sulphate. The UFRV at the different coagulant doses was also noted.

→ pH

The target pH during the optimization of ferric sulphate in the Fall piloting session was 5.80. Figure 5-8 shows that the pH levels were consistent during the optimization tests. Based on the Post-DAF values, the average pH was 5.85 ± 0.06. In previous piloting sessions (Winter #1 and Spring), a decrease in pH occurred with increasing coagulant dose. However, this pH decrease was not observed in the Summer piloting session or this Fall piloting session due to the addition of a pH controller. The controller automatically adjusts the sulphuric acid dose to compensate for the change in coagulant dose. Hence, the pH remains constant. Based on the observations in both the Summer and Fall piloting sessions, the implementing of the pH controller was beneficial to the process.



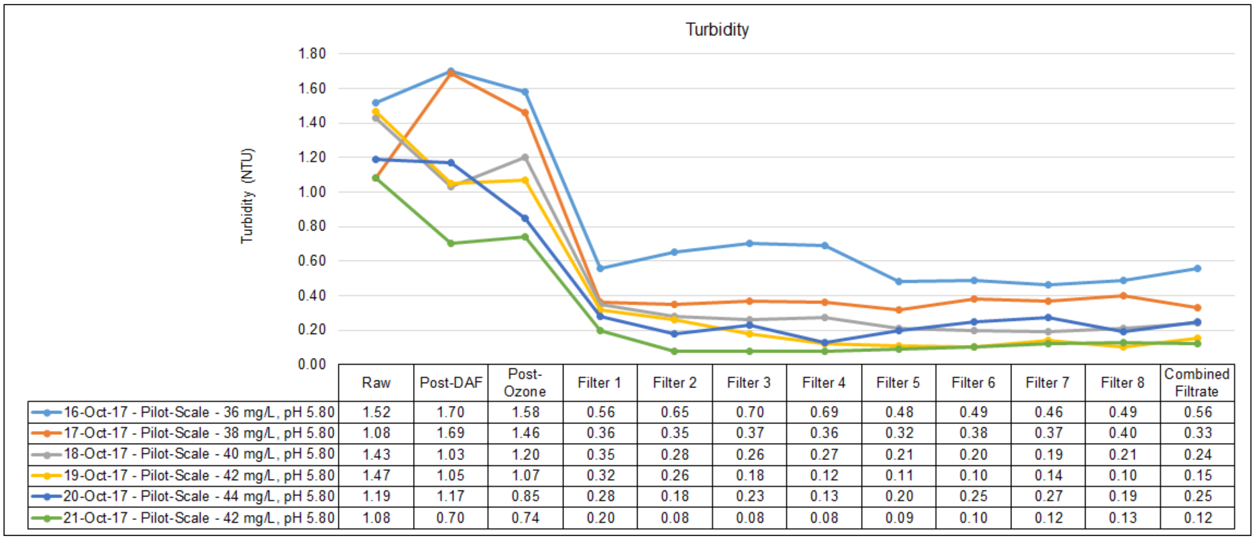
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
16-Oct-17 - 36 mg/L, pH 5.80	7.26	5.93	5.96	6.05	6.04	6.02	6.00	5.98	5.96	5.96	5.98	5.99
17-Oct-17 - 38 mg/L, pH 5.80	7.32	5.89	5.85	6.00	5.99	5.94	5.93	5.94	5.92	5.92	5.92	5.90
18-Oct-17 - 40 mg/L, pH 5.80	7.18	5.85	5.91	6.05	5.99	5.98	5.96	5.94	5.91	5.92	5.93	5.89
19-Oct-17 - 42 mg/L, pH 5.80	7.26	5.80	5.83	5.91	5.90	5.90	5.86	5.87	5.87	5.86	5.88	5.86
20-Oct-17 - 44 mg/L, pH 5.80	7.34	5.78	5.81	5.92	5.91	5.89	5.86	5.85	5.88	5.87	5.84	5.83
21-Oct-17 - 42 mg/L, pH 5.80	7.25	5.82	5.79	5.84	5.87	5.86	5.80	5.81	5.80	5.81	5.81	5.81

Figure 5-8: Pilot-scale system pH levels during the optimization of ferric sulphate at pH 5.8 in the Fall piloting session. Data originates from benchtop analyses using a Thermo Scientific Orion Star A325 pH probe.

It is important to note that some difficulty was encountered on October 16th and 17th in achieving the target pH, recording values of 5.93 and 5.89 respectively. This was due to a problem with the pump head on the sulphuric acid dosing peristaltic pump which was subsequently replaced on October 18th, resolving the matter. Although there was some concern that the elevated pH measured in the Post-DAF samples collected from October 16th to 18th may have affected the treated water quality, the pH on October 18th was only 0.05 pH units higher than the target pH of 5.80. This minor deviation from the target pH is not expected to produce the significant differences in water quality measured between October 18th (prior to repair of the sulphuric acid pump) and October 19th (after repair of the sulphuric acid pump). The difference in water quality observed between these two days is more likely attributed to the increase in coagulant dose (Figure 5-9 to Figure 5-13).

→ Turbidity

Figure 5-9 shows the turbidity levels achieved in the pilot-scale system during optimization of the ferric sulphate dose during the Fall piloting session. There was a decrease in the turbidity following coagulation and DAF for doses above 40 mg/L as was similarly observed in the Summer piloting session.



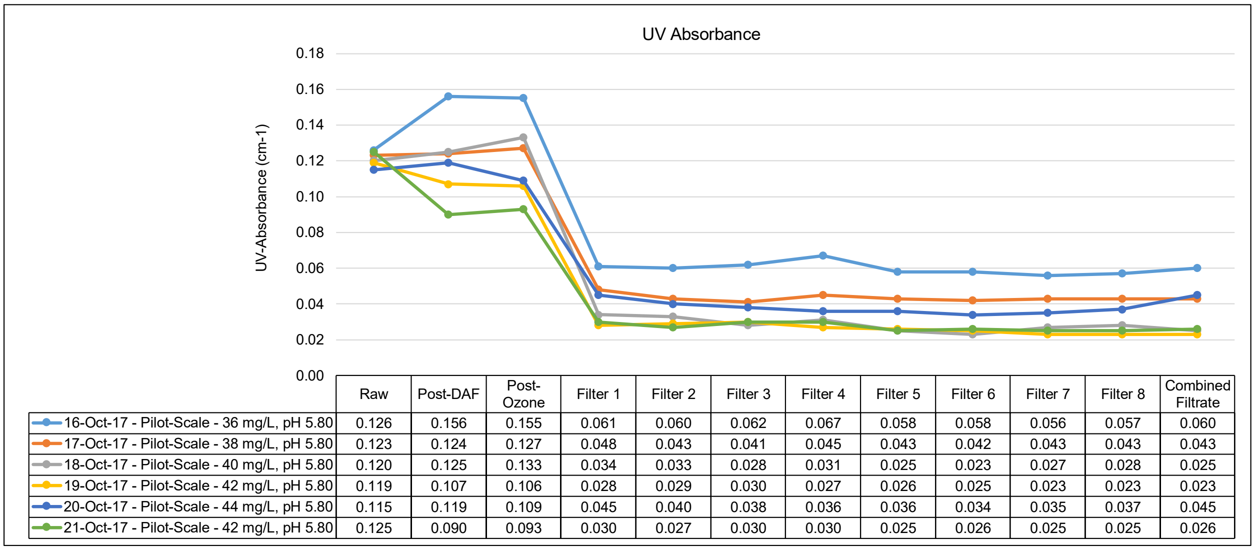
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
16-Oct-17 - Pilot-Scale - 36 mg/L, pH 5.80	1.52	1.70	1.58	0.56	0.65	0.70	0.69	0.48	0.49	0.46	0.49	0.56
17-Oct-17 - Pilot-Scale - 38 mg/L, pH 5.80	1.08	1.69	1.46	0.36	0.35	0.37	0.36	0.32	0.38	0.37	0.40	0.33
18-Oct-17 - Pilot-Scale - 40 mg/L, pH 5.80	1.43	1.03	1.20	0.35	0.28	0.26	0.27	0.21	0.20	0.19	0.21	0.24
19-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	1.47	1.05	1.07	0.32	0.26	0.18	0.12	0.11	0.10	0.14	0.10	0.15
20-Oct-17 - Pilot-Scale - 44 mg/L, pH 5.80	1.19	1.17	0.85	0.28	0.18	0.23	0.13	0.20	0.25	0.27	0.19	0.25
21-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	1.08	0.70	0.74	0.20	0.08	0.08	0.08	0.09	0.10	0.12	0.13	0.12

Figure 5-9: Pilot-scale system turbidity levels during the ferric sulphate optimization at pH 5.8 during the Fall piloting session. Data originates from benchtop analyses using a HACH 2100Q turbidimeter.

During optimization of the ferric sulphate dose, ozone was not being added to the pilot-scale system. As such, there was no significant change in the Post-Ozone samples when compared to the Post-DAF samples. This was followed by significant reductions throughout the filters. Overall, following filtration and based on the combined filter effluent, there was a 63% to 90% reduction in turbidity. The lowest turbidity was obtained at a ferric sulphate dose of 42 mg/L and was reproducible with similar turbidity values of 0.15 NTU and 0.12 NTU on October 19th and 21st (representing 89% and 90% removal respectively).

→ UV-Transmittance and Absorbance

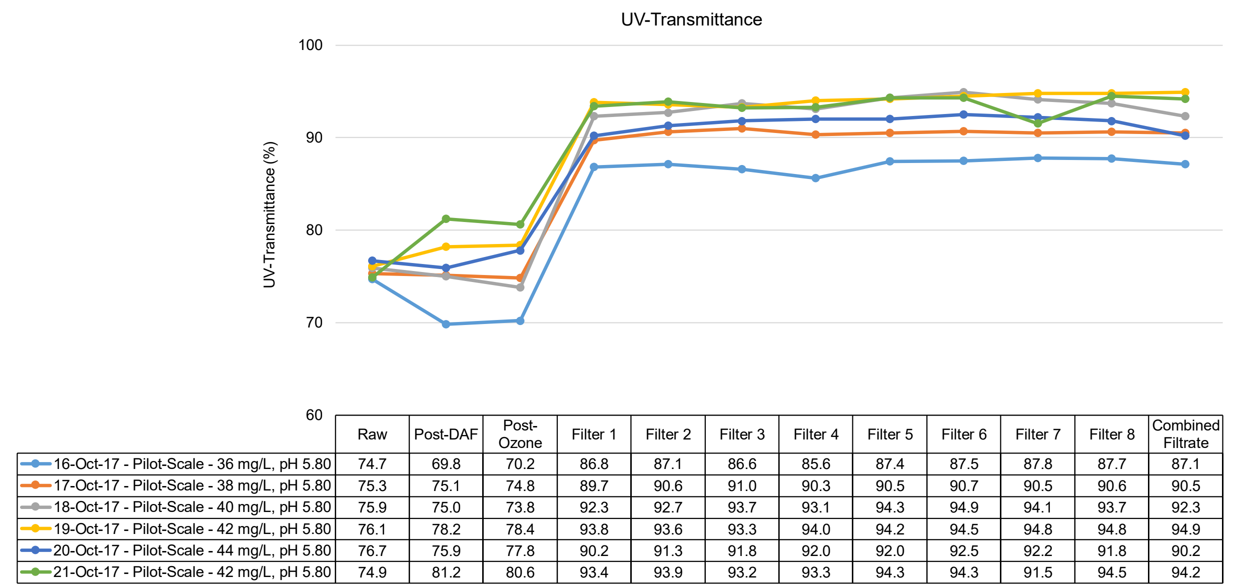
The absorbance of the samples during the ferric sulphate optimization are shown in Figure 5-10. Based on the combined filter effluent, the absorbance decreased between 54% to 79%. The lowest absorbance value of 0.023 cm^{-1} was obtained with a ferric sulphate dose of 42 mg/L on October 19th.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
16-Oct-17 - Pilot-Scale - 36 mg/L, pH 5.80	0.126	0.156	0.155	0.061	0.060	0.062	0.067	0.058	0.058	0.056	0.057	0.060
17-Oct-17 - Pilot-Scale - 38 mg/L, pH 5.80	0.123	0.124	0.127	0.048	0.043	0.041	0.045	0.043	0.042	0.043	0.043	0.043
18-Oct-17 - Pilot-Scale - 40 mg/L, pH 5.80	0.120	0.125	0.133	0.034	0.033	0.028	0.031	0.025	0.023	0.027	0.028	0.025
19-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	0.119	0.107	0.106	0.028	0.029	0.030	0.027	0.026	0.025	0.023	0.023	0.023
20-Oct-17 - Pilot-Scale - 44 mg/L, pH 5.80	0.115	0.119	0.109	0.045	0.040	0.038	0.036	0.036	0.034	0.035	0.037	0.045
21-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	0.125	0.090	0.093	0.030	0.027	0.030	0.030	0.025	0.026	0.025	0.025	0.026

Figure 5-10: Pilot-scale system absorbance levels during the optimization of ferric sulphate during the Fall piloting session. Data originates from the benchtop analysis using a DR6000 UV-VIS spectrophotometer.

A corresponding improvement in the UVT of the water was observed with increasing coagulant dose in Figure 5-11.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
16-Oct-17 - Pilot-Scale - 36 mg/L, pH 5.80	74.7	69.8	70.2	86.8	87.1	86.6	85.6	87.4	87.5	87.8	87.7	87.1
17-Oct-17 - Pilot-Scale - 38 mg/L, pH 5.80	75.3	75.1	74.8	89.7	90.6	91.0	90.3	90.5	90.7	90.5	90.6	90.5
18-Oct-17 - Pilot-Scale - 40 mg/L, pH 5.80	75.9	75.0	73.8	92.3	92.7	93.7	93.1	94.3	94.9	94.1	93.7	92.3
19-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	76.1	78.2	78.4	93.8	93.6	93.3	94.0	94.2	94.5	94.8	94.8	94.9
20-Oct-17 - Pilot-Scale - 44 mg/L, pH 5.80	76.7	75.9	77.8	90.2	91.3	91.8	92.0	92.0	92.5	92.2	91.8	90.2
21-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	74.9	81.2	80.6	93.4	93.9	93.2	93.3	94.3	94.3	91.5	94.5	94.2

Figure 5-11: Pilot-scale system UVT for the samples during the optimization of ferric sulphate during the Fall piloting session. Data originates from the benchtop analysis using a DR6000 UV-VIS spectrophotometer.

The UVT of the raw water ranged from 75% to 77% and with coagulation improved to the UVT from 87 to 95% (based on the combined filtrate effluent). It was noted that a coagulant dose of 40 mg/L yielded a relatively similar low absorbance value (0.025 cm^{-1}) and 95% UVT. However, since the dose optimization testing indicated that 42 mg/L was the optimal ferric sulphate dose and the lowest absorbance in the combined filtrate effluent was obtained with 42 mg/L, a duplicate test at this concentration was done. This duplicate test showed similar reductions in absorbance with an absorbance of 0.026 cm^{-1} and an increase in the UVT to 94% in the combined filtrate effluent.

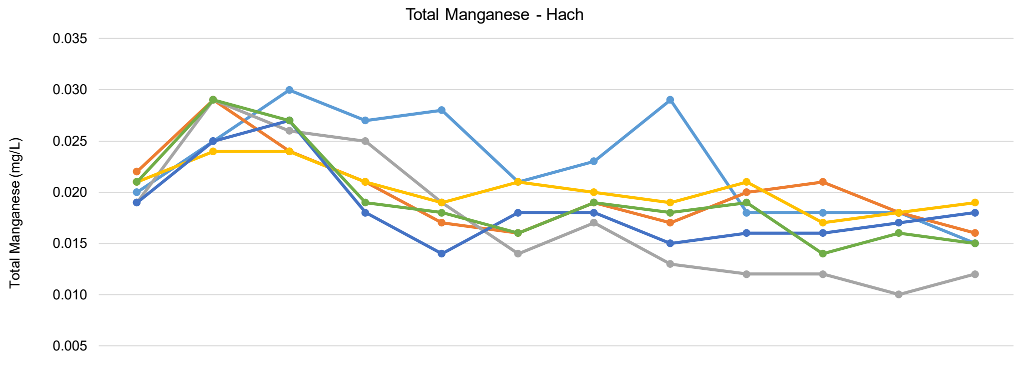
There was little change in the absorbance and UVT in the Post-Ozone samples which was expected as ozone was not supplied during optimization of the ferric sulphate.

For the combined filtrate, based on the absorbance and UVT values, the optimum ferric sulphate dose was 42 mg/L.

→ Total Manganese

As stated in TM No.3, a major focus of this project is to test if an alternative coagulant will reduce the occurrence of discoloured water in the distribution system. This concern has arisen due to the presence of elevated concentrations of total manganese in the treated water. Reducing the amount of total manganese entering the distribution system may reduce the occurrence of discoloured water. The current alternative coagulant under investigation, ferric sulphate, has a lower residual manganese content compared to the current coagulant used in the full-scale system, ferric chloride.

For the Fall piloting session, total manganese concentration increased in the pilot-scale system Post-DAF as shown in Figure 5-12. This trend was similar to that observed in the previous Winter #1 and Spring piloting sessions, although Summer had much higher raw water manganese levels. These observed increases in all the piloting sessions are attributed to the combination of the residual manganese from the ferric sulphate and the natural manganese in the source water. Following this with filtration, there was overall a general decrease in the total manganese concentration when the combined filtrate is compared to the raw water with the reductions ranging from 5 to 37%. The largest reduction (37%) was observed at the coagulant dose of 40 mg/L. At the optimal dose (42 mg/L) determined from the turbidity, absorbance, and UVT testing, there was considerable variation in the percent removal attained in the duplicate tests where October 19th test demonstrated a 19% removal and October 21st test demonstrated 29% removal. It should also be noted that a total manganese concentration of 0.015 mg/L or less was being targeted in the combined filtrate effluent as this concentration minimizes the accumulation or release of manganese in the distribution system. This target was only achieved on 3 of the 6 sampling days. It should be noted that the Hach instrument is not as sensitive as the ICPMS used by the Lab. Therefore, it is likely that manganese is lower that the concentrations reported by the Hach instrument. Furthermore, a consistent trend in manganese reduction with increasing coagulant dose was not observed serving as a reminder that this concentration target is at the lower end of the detection range for the benchtop analytical method.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
16-Oct-17 - Pilot-Scale - 36 mg/L, pH 5.80	0.020	0.025	0.030	0.027	0.028	0.021	0.023	0.029	0.018	0.018	0.018	0.015
17-Oct-17 - Pilot-Scale - 38 mg/L, pH 5.80	0.022	0.029	0.024	0.021	0.017	0.016	0.019	0.017	0.020	0.021	0.018	0.016
18-Oct-17 - Pilot-Scale - 40 mg/L, pH 5.80	0.019	0.029	0.026	0.025	0.019	0.014	0.017	0.013	0.012	0.012	0.010	0.012
19-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	0.021	0.024	0.024	0.021	0.019	0.021	0.020	0.019	0.021	0.017	0.018	0.019
20-Oct-17 - Pilot-Scale - 44 mg/L, pH 5.80	0.019	0.025	0.027	0.018	0.014	0.018	0.018	0.015	0.016	0.016	0.017	0.018
21-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	0.021	0.029	0.027	0.019	0.018	0.016	0.019	0.018	0.019	0.014	0.016	0.015

Figure 5-12: Total manganese levels in pilot-scale system during the optimization of ferric sulphate during the Fall piloting session. Data originates from benchtop analyses using a HACH DR 6000 UV-VIS spectrophotometer.

→ UFRV

Figure 5-13 illustrates the average observed and forecasted UFRV values obtained for each coagulant dose for Bank A and Bank B. During optimization of the coagulant dose, Bank B did not overflow on two days (36 and 42 mg/L), while Bank A overflowed every cycle. However, all individual filters failed based on turbidity (> 0.1 NTU) at all coagulant doses tested, except two of Bank B filters at a ferric sulphate dose of 42 mg/L. At ferric sulphate doses of 36 and 38 mg/L, both filter banks presented turbidity measurements above 0.3 NTU.

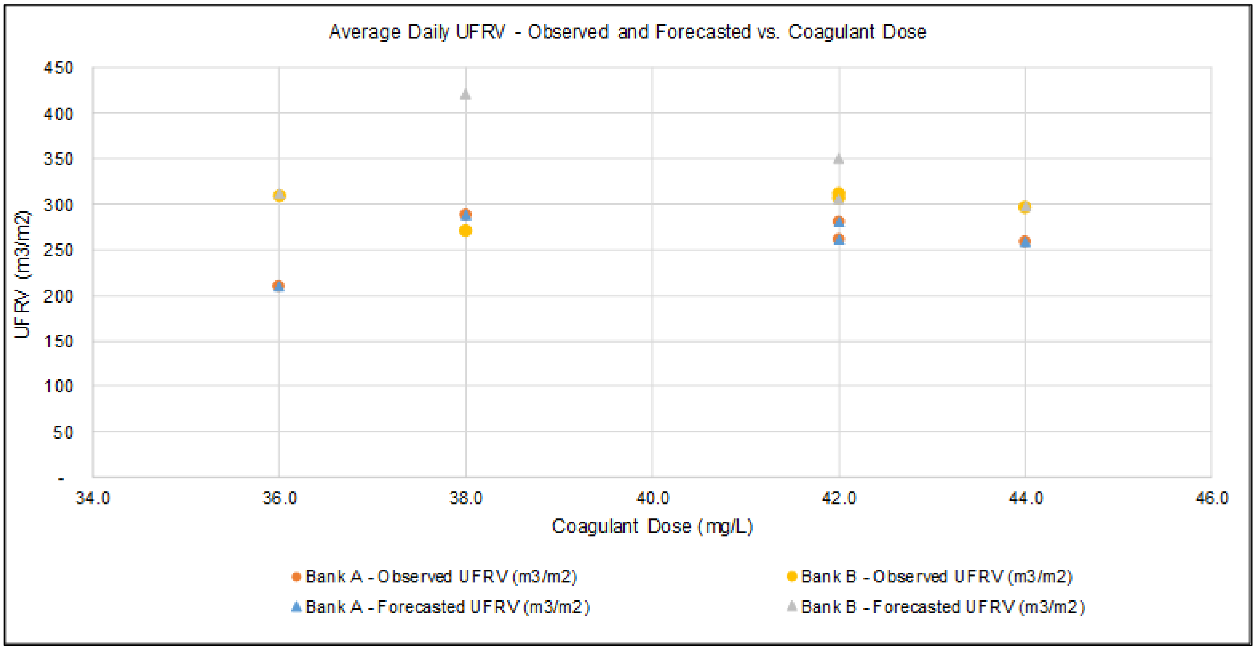


Figure 5-13: Average observed and forecasted UFRV values of the pilot-scale system Bank A at 0.6 L/s and Bank B at 0.3 L/s during the optimization of ferric sulphate during the Fall piloting session. The pilot-scale system pH was maintained at pH 5.8 with no addition of coagulant-aid. Note the observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset. Note there is no UFRV data available on October 18th, 2017 (40 mg/L) since the raw water flow was interrupted on this day.

Considering the forecasted UFRV values, the values decreased at the lower and higher coagulant doses tested, reaching the maximum values (288 and 422 m^3/m^2 for Bank A and Bank B, respectively) at coagulant dose of 38 mg/L for both filter banks; however, all individual filters failed based on turbidity measurements above 0.3 NTU at this dose. The highest observed UFRV values (281 and 312 m^3/m^2 for Bank A and Bank B, respectively) were obtained at the coagulant dose of 42 mg/L, where only 50% of Bank B filters failed based on turbidity (> 0.1 NTU). Consequently, a ferric sulphate dose of 42 mg/L was deemed by UFRV results to be the optimal coagulant dose observed.

The UFRV values were above the minimum UFRV value of 200 m^3/m^2 at ferric sulphate dose of 42 mg/L. Given the UFRV values at the full-scale system are expected to be twice as high as the pilot-scale system due to the higher head loss available for filtration and only 25% of the individual filters failed based on turbidity (> 0.1 NTU), the ferric sulphate dose of 42 mg/L is also deemed a viable dose for full-scale system operation.

→ Summary of Ferric Sulphate Optimization

In this phase of optimization of the ferric sulphate dose, when considering the results from water quality parameters, demonstrate that the optimal dose under cool water, fall conditions was 42 mg/L. The UFRV analysis performed following the piloting session confirmed the same optimal dose.

5.6.2. Optimization of pH

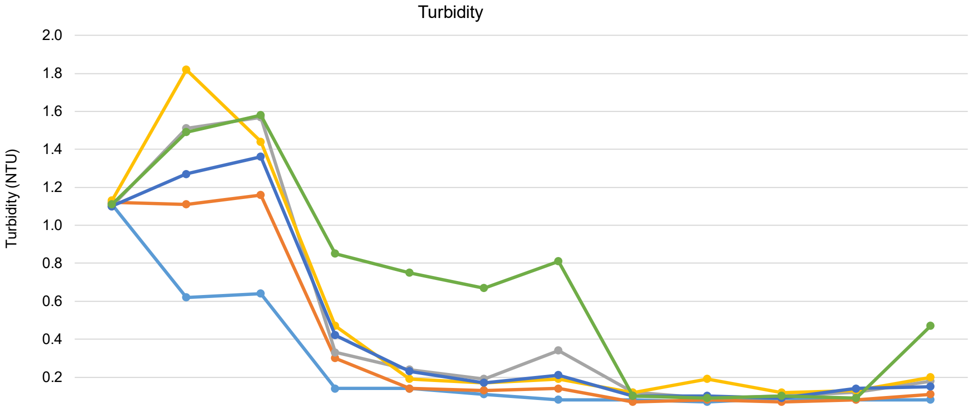
Optimal pH testing was conducted between October 22nd and October 27th. An analogous approach to the optimization of the coagulant dose was taken in determining the optimum pH. Using the optimal ferric sulphate dose of 42 mg/L and no coagulant-aid, the optimal pH was determined. A range of pH 5.70 to 6.00 was used for this series of analyses as previous testing suggests that the optimal pH would lie in the range of 5.60 and 5.95. The pH during coagulation was controlled by adjusting the sulphuric acid dose to the raw water before coagulation. This dosing was achieved by setting a pH set point within the controller to the desired target Post-DAF pH and subsequently monitoring pH via grab samples. Table 5-2 illustrates the target and measured pH values during the Fall piloting session.

Table 5-2: Comparison of target and measured pilot-scale system Post DAF pH

Date	Target Post-DAF pH	Measured Post-DAF pH
22-Oct	5.70	5.70
23-Oct	5.80	5.82
24-Oct	5.90	5.91
25-Oct	6.00	5.99
26-Oct	5.70	5.69
27-Oct	5.70	5.74

→ Turbidity

The turbidity results presented in Figure 5-14 show the Post-DAF turbidity increased with increasing pH, and a significant reduction in raw water turbidity was only achieved at a pH of 5.70 (October 22nd) where raw water turbidity was reduced by 44% following DAF treatment. Filtration was able to remove from 70% to 91% of the Post-Ozone turbidity with the lowest combined filter effluent turbidity of 0.08 NTU measured on October 22nd, at a Post-DAF pH of 5.70. The conditions on October 22nd were repeated on October 26th and 27th for validation; however, the duplicate tests did not achieve the low turbidity measured on October 22nd. One potential explanation for the low Post-DAF turbidity measured on October 22nd could be the low raw water flow rate used for that day (Figure 5-3).



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
22-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	1.11	0.62	0.64	0.14	0.14	0.11	0.08	0.08	0.07	0.09	0.08	0.08
23-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	1.12	1.11	1.16	0.30	0.14	0.13	0.14	0.07	0.08	0.07	0.08	0.11
24-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.90	1.10	1.51	1.57	0.33	0.24	0.19	0.34	0.12	0.09	0.10	0.12	0.18
25-Oct-17 - Pilot-Scale - 42 mg/L, pH 6.00	1.13	1.82	1.44	0.47	0.19	0.17	0.19	0.12	0.19	0.12	0.13	0.20
26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	1.10	1.27	1.36	0.42	0.23	0.17	0.21	0.10	0.10	0.09	0.14	0.15
27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	1.11	1.49	1.58	0.85	0.75	0.67	0.81	0.10	0.09	0.10	0.09	0.47

Figure 5-14: Pilot-scale system turbidity levels during the pH optimization with the optimum ferric sulphate dose (42 mg/L) and no coagulant-aid in the Fall piloting session. Data originates from benchtop analyses using a HACH 2100Q turbidimeter.

On October 22nd, onsite WSP personnel noted high water levels in the pilot-scale DAF tank causing poor removal of floc by the scrapper. It was advised by City engineers that the raw water flow should be reduced to lower the water level in the DAF tank and improve the floc removal by the scrapper. The reduction in raw water flow may have increased the retention time within the tank, allowing more time for microbubbles to push floc to the surface, improving turbidity in the Post-DAF sample. On October 26th and 27th the raw water flow was operating at ~3.0 L/s which equated to increased turbidity in the Post-DAF samples.

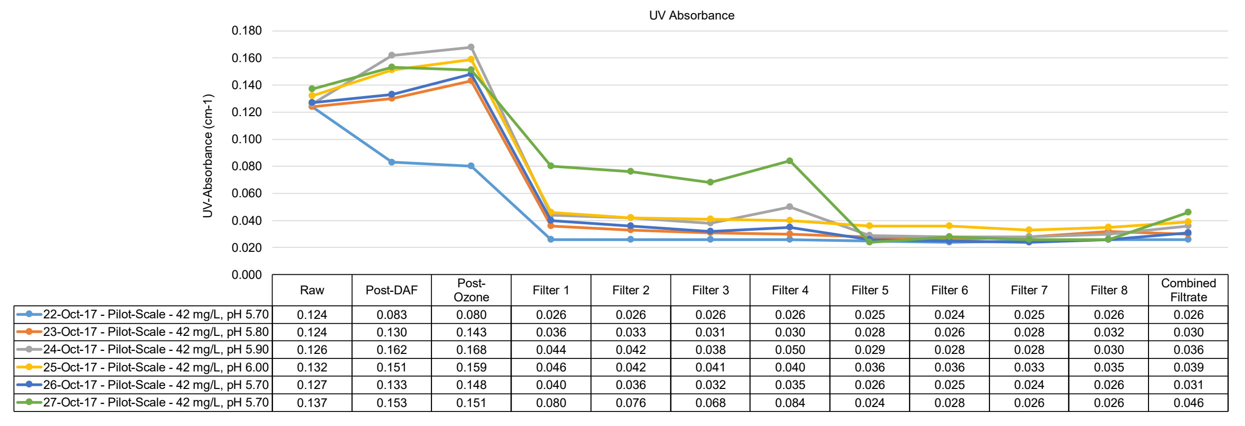
It should be noted that on October 27th, onsite WSP personnel observed the presence of a yellow particulate in the water for samples collected from Filter Bank A, believed to be due to the release of built up coagulant in the piping feeding Bank A. The yellow particulate was more noticeable on the disposable filters used to separate dissolved samples during optimal testing (Figure 5-15). No yellow particulate matter was observed in samples collected from Bank B, and the phenomena appeared to be isolated to Bank A only.

Figure 5-15: Disposable filters used to isolate dissolved fractions for analytical testing by the City Lab. Disposable filters (left to right) were used for samples collected from the individual filter effluents (Filters 1-4). A yellow precipitate was observed on the filter paper after they were used.

Overall, the lowest turbidity measured in the combined filter effluent was achieved at a pH of 5.70.

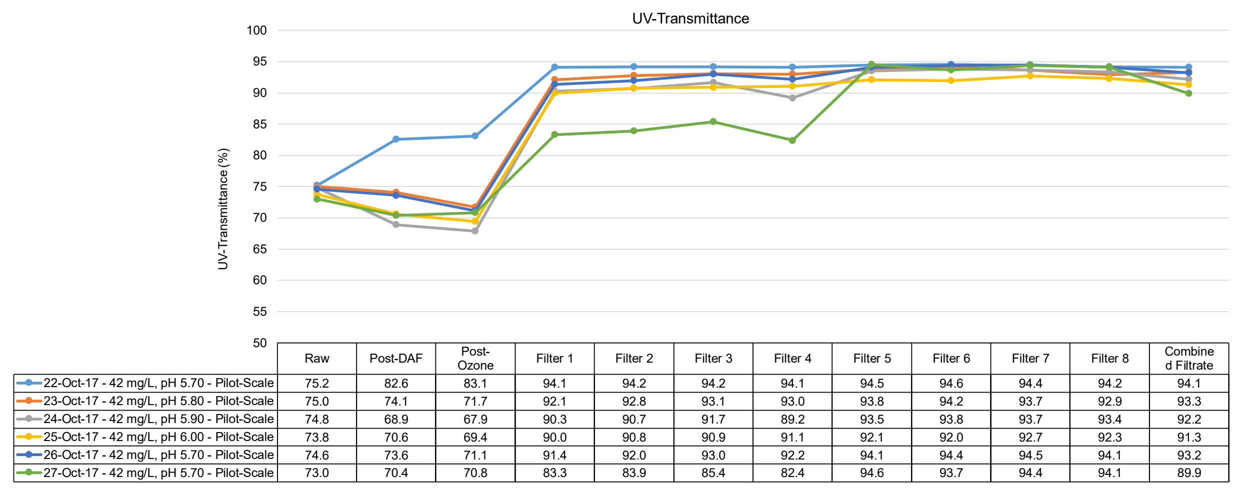
→ Absorbance and UV Transmittance

The absorbance and UVT results are presented in Figure 5-16 and Figure 5-17, respectively. Except October 22nd at a pH of 5.7, absorbance of the pilot-scale system samples increased after Post-DAF and Post-Ozone. Following filtration, there was a significant decrease in absorbance of the samples in the combined filtrate ranging from 79 to 81%. This decrease in absorbance corresponds to an increase in the UVT of the water with UVT values of 90% to 94% in the combined filtrate compared to 73% to 75% UVT of the raw water. It was observed that as the pH increased, the quality of the water regarding absorbance and UVT decreased. In comparing all the tests, the lowest absorbance (0.026 cm^{-1}) and best UVT (94%) was obtained at a pH of 5.7. The absorbance and UVT values obtained from Bank A on October 27th were significantly higher than the overall results due to the release of built up coagulant in the piping feeding Bank A.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
22-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.124	0.083	0.080	0.026	0.026	0.026	0.026	0.025	0.024	0.025	0.026	0.026
23-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	0.124	0.130	0.143	0.036	0.033	0.031	0.030	0.028	0.026	0.028	0.032	0.030
24-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.90	0.126	0.162	0.168	0.044	0.042	0.038	0.050	0.029	0.028	0.028	0.030	0.036
25-Oct-17 - Pilot-Scale - 42 mg/L, pH 6.00	0.132	0.151	0.159	0.046	0.042	0.041	0.040	0.036	0.036	0.033	0.035	0.039
26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.127	0.133	0.148	0.040	0.036	0.032	0.035	0.026	0.025	0.024	0.026	0.031
27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.137	0.153	0.151	0.080	0.076	0.068	0.084	0.024	0.028	0.026	0.026	0.046

Figure 5-16: Pilot-scale system absorbance obtained during pH optimization with the optimum ferric sulphate dose (42 mg/L) and no coagulant-aid in the Fall piloting session. Data originates from benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

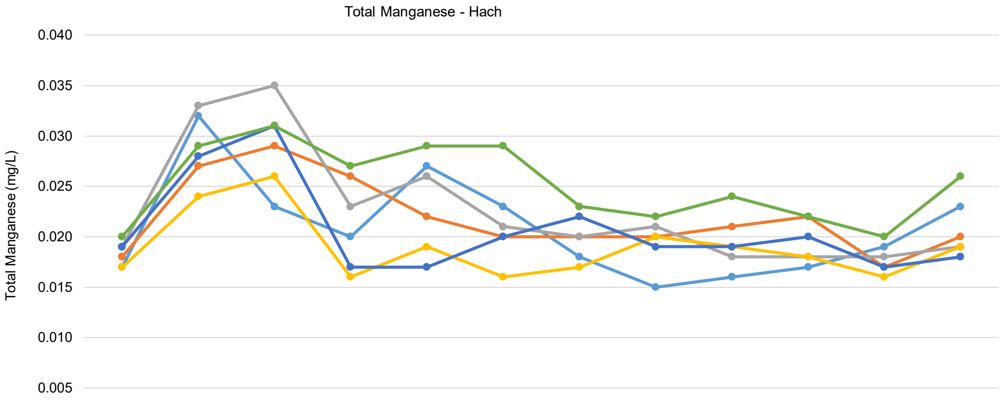


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
22-Oct-17 - 42 mg/L, pH 5.70 - Pilot-Scale	75.2	82.6	83.1	94.1	94.2	94.2	94.1	94.5	94.6	94.4	94.2	94.1
23-Oct-17 - 42 mg/L, pH 5.80 - Pilot-Scale	75.0	74.1	71.7	92.1	92.8	93.1	93.0	93.8	94.2	93.7	92.9	93.3
24-Oct-17 - 42 mg/L, pH 5.90 - Pilot-Scale	74.8	68.9	67.9	90.3	90.7	91.7	89.2	93.5	93.8	93.7	93.4	92.2
25-Oct-17 - 42 mg/L, pH 6.00 - Pilot-Scale	73.8	70.6	69.4	90.0	90.8	90.9	91.1	92.1	92.0	92.7	92.3	91.3
26-Oct-17 - 42 mg/L, pH 5.70 - Pilot-Scale	74.6	73.6	71.1	91.4	92.0	93.0	92.2	94.1	94.4	94.5	94.1	93.2
27-Oct-17 - 42 mg/L, pH 5.70 - Pilot-Scale	73.0	70.4	70.8	83.3	83.9	85.4	82.4	94.6	93.7	94.4	94.1	89.9

Figure 5-17: Pilot-scale system UVT obtained during the pH optimization with the optimum ferric sulphate dose (42 mg/L) and no coagulant-aid in the Fall piloting session. Data originates from benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ Total Manganese

The total manganese concentrations during pH optimization are illustrated in Figure 5-18. Similar to the coagulant dose optimization tests, total manganese concentration increased in the pilot-scale system Post-DAF and Post-Ozone samples. With filtration, there was some decrease in the total manganese concentrations on all sampling days.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
22-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.017	0.032	0.023	0.020	0.027	0.023	0.018	0.015	0.016	0.017	0.019	0.023
23-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	0.018	0.027	0.029	0.026	0.022	0.020	0.020	0.020	0.021	0.022	0.017	0.020
24-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.90	0.019	0.033	0.035	0.023	0.026	0.021	0.020	0.021	0.018	0.018	0.018	0.019
25-Oct-17 - Pilot-Scale - 42 mg/L, pH 6.00	0.017	0.024	0.026	0.016	0.019	0.016	0.017	0.020	0.019	0.018	0.016	0.019
26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.019	0.028	0.031	0.017	0.017	0.020	0.022	0.019	0.019	0.020	0.017	0.018
27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.020	0.029	0.031	0.027	0.029	0.029	0.023	0.022	0.024	0.022	0.020	0.026

Figure 5-18: Pilot-scale system total manganese levels during the pH optimization with the optimum ferric sulphate dose (42 mg/L) and no coagulant-aid during the Fall piloting session. Data originates from benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

As observed in Figure 5-18, increases in pH related to a decrease in the total manganese levels in the combined filtrate. However, one outlier was seen in the lowest manganese concentration of 0.018 mg/L which was obtained at the lowest pH 5.7 on October 26th. A pH of 5.7 was tested on three separate days (October 17th, October 26th and October 27th) and marked differences were noted between the total manganese measured for the same chemical conditions, combined filtrate values of 0.023 mg/L, 0.018 mg/L and 0.026 mg/L were measured respectively. The total manganese measured on October 17th and Oct 27th were comparable values at 0.023 mg/L and 0.026 mg/L and were also the highest total manganese measured. Therefore, it is likely that the manganese value obtained on October 26th was not representative of the conditions at a pH of 5.7. Based on these results, the optimal pH would be a pH of 5.9 or 6.0, both obtaining values of 0.019 mg/L for total manganese.

→ UFRV

Figure 5-19 illustrates the average observed and forecasted UFRV values obtained for each pH for Bank A and Bank B. Of the two Banks, Bank A overflowed on all the days during the pH optimization tests and Bank B did not overflow on the first day of operation at pH of 5.7. All individual filters of Bank A failed based on turbidity (> 0.1 NTU) at all pH values tested. At the highest pH of 6.0, all individuals filters of Bank B failed, while only Filter 5 and Filter 8 failed at pH of 5.9.

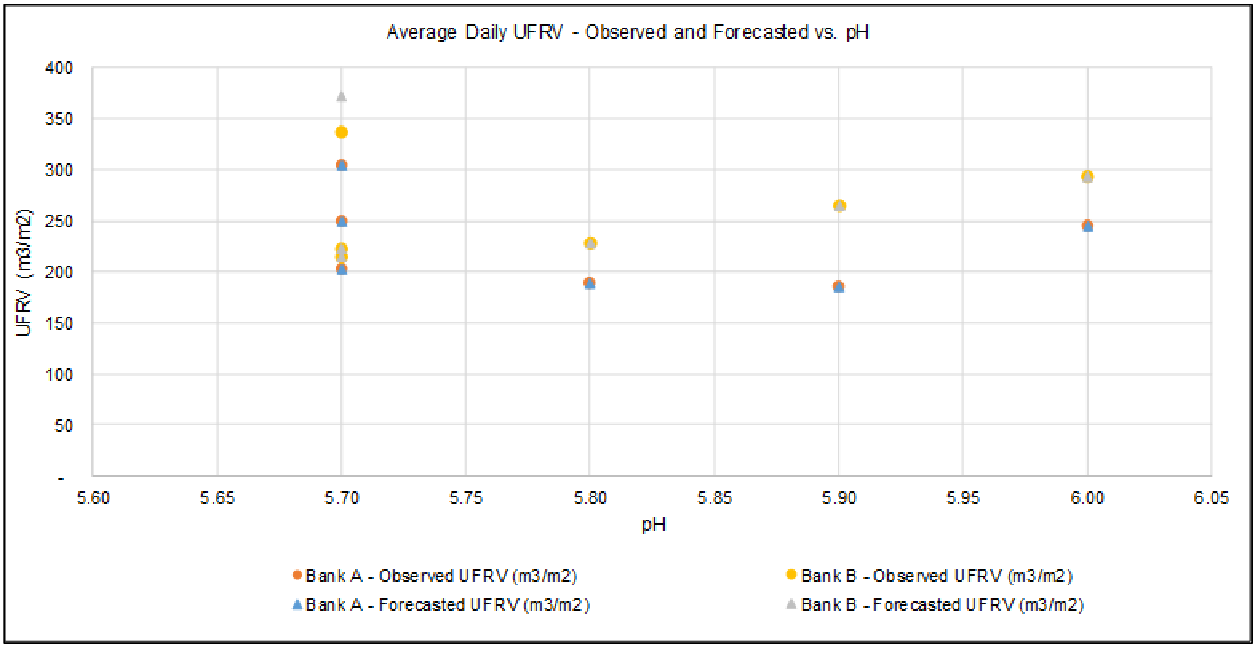


Figure 5-19: Average UFRV values of pilot-scale system Bank A (at 0.6 L/s) and Bank B (at 0.3 L/s) during the pH optimization during the Fall piloting session. The pilot-scale system coagulant dose was maintained at 42 mg/L with no addition of coagulant-aid. Note the observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

From a pH of 5.7 to 5.8, the average observed UFRV values decreased as the pH values increased up to 5.8. After a pH of 5.8 an increase in UFRV was observed at pH 6.0. The highest observed UFRV value (305 m^3/m^2 for Bank A and 372 m^3/m^2 for Bank B) was obtained at the lowest pH of 5.7 and is considered to be the optimal pH. However, taking the average of observed UFRV values for all three days with pH of 5.7, the observed UFRV values dropped to 252 m^3/m^2 for Bank A and 258 m^3/m^2 for Bank B. Based on the average UFRV value with a pH of 5.7, the optimal pH could also be at 6.0 (244 m^3/m^2 for Bank A and 294 m^3/m^2 for Bank B) which showed slightly lower UFRV values for Bank A but higher UFRVs for Bank B.

All observed UFRV values were above the minimum UFRV value of 200 m^3/m^2 on all days with a pH of 5.7 and 6.0. However, at a pH of 6.0 all individuals filters in Bank B failed based on turbidity above 0.1 NTU. Given the UFRV values at the full-scale system are expected to be twice as high due to the higher head loss available for filtration, and Bank B filters did not present turbidity breakthrough at a pH of 5.7, 5.7 is deemed a viable pH for the full-scale system operation.

→ Summary of pH Optimization

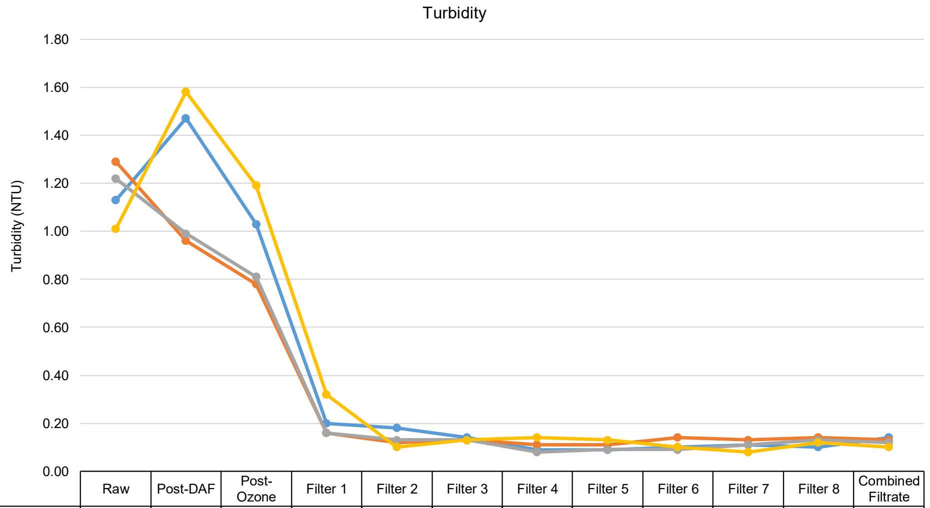
Overall, based on the turbidity, absorbance, and UVT, the optimal pH was determined to be 5.7. However, the data indicates that based on the results for total manganese removal a pH 5.9 to 6.0 would be preferable. Despite conflicting results, a pH of 5.7 was selected as the optimal pH for ferric sulphate in cool water conditions typical to the Fall piloting session. The UFRV analysis performed following the piloting session confirmed the same optimal pH of 5.7.

5.6.3. Optimization of Coagulant-Aid Dose

The optimization of the coagulant-aid LT-22S dose was conducted from October 28th to October 31st. To determine the optimal dose of the coagulant-aid, an analogous approach to the optimization of the coagulant dose was undertaken. During testing, the optimum ferric sulphate dose (42 mg/L) and Post-DAF pH of 5.70 was maintained while varying the coagulant-aid concentrations from 0.05 to 0.13 mg/L.

→ Turbidity

The turbidity results obtained during the optimization of coagulant-aid dose are shown in Figure 5-20. The results show a decrease in raw water turbidity following coagulation and DAF treatment for coagulant-aid doses of 0.07 mg/L and 0.13 mg/L; however, an increase in turbidity was measured in the Post-DAF sample collected on October 28th, at a coagulant-aid dose of 0.05 mg/L. A reduction in turbidity was observed following ozonation for all coagulant-aid doses tested. It should be noted that the pilot-scale ozone system was activated on October 27th, following daily sample collecting. Prior to the start of the ozone system, there was generally an increase in turbidity between the Post-DAF samples and the Post-Ozone samples, as seen in Figure 5-14. Therefore, these current results show that the ozone system, when operating, can be useful in reducing turbidity. Whether or not the coagulant-aid is improving turbidity in conjunction with ozonation cannot be confirmed based on the data available.



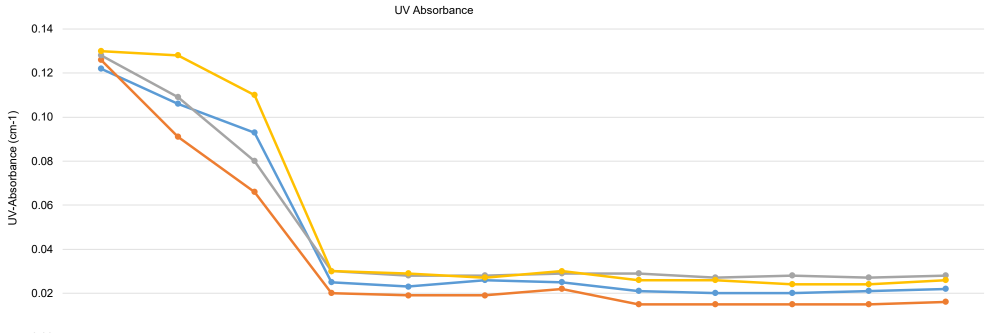
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
28-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.05 mg/L	1.13	1.47	1.03	0.20	0.18	0.14	0.09	0.09	0.10	0.11	0.10	0.14
29-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	1.29	0.96	0.78	0.16	0.12	0.13	0.11	0.11	0.14	0.13	0.14	0.13
30-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.13 mg/L	1.22	0.99	0.81	0.16	0.13	0.13	0.08	0.09	0.09	0.11	0.13	0.12
31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	1.01	1.58	1.19	0.32	0.10	0.13	0.14	0.13	0.10	0.08	0.12	0.10

Figure 5-20: Pilot-scale system turbidity levels during the coagulant-aid optimization at 42 mg/L ferric sulphate and pH 5.7 in the Fall piloting session. Data originated from benchtop analyses using a HACH 2100Q Turbidimeter.

Filtration had the greatest impact on turbidity removal, reducing raw water turbidity by 88 – 90%, for the coagulant-aid doses tested. Although, the combined filter effluent turbidity was lowest at a coagulant-aid dose of 0.13 mg/L, the coagulant-aid dose of 0.07 mg/L had the same overall % reduction of raw water turbidity of 90%. Since similar turbidity removal and combined filter effluent results were obtained for coagulant-aid doses of 0.07 mg/L and 0.13 mg/L, it was determined that the lower dose of 0.07 mg/L would be the optimal dose based on the desire to reduce maintenance and cleaning of the pilot-scale system when higher coagulant-aid doses are used. The optimal coagulant-aid dose of 0.07 mg/L was duplicated on October 31st, which produced the lowest combined filter effluent turbidity of 0.10 NTU, and an overall reduction in raw water turbidity of 90%.

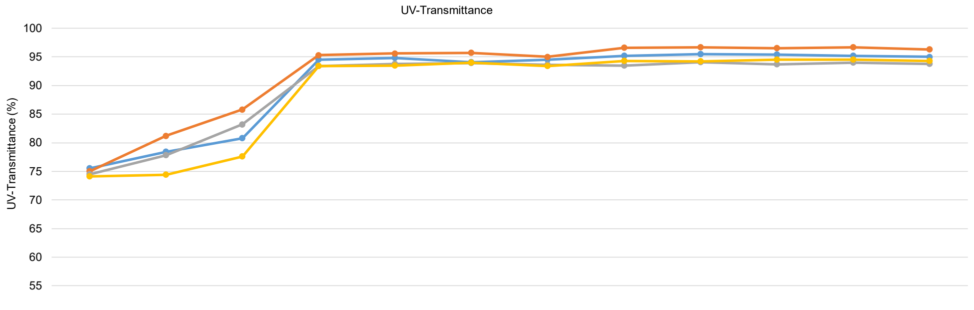
→ Absorbance and UV Transmittance

The absorbance and the UVT results are illustrated in Figure 5-21 and Figure 5-22. Both figures demonstrate that there was a significant improvement in the water quality with a reduction in the absorbance of the samples after Post-DAF, Post-Ozone, and filtration. This was observed at all concentrations of the coagulant-aid, but the combined filtrate with a coagulant-aid dose of 0.07 mg/L had the lowest absorbance (0.016 cm^{-1}) and the corresponding high UVT of 96.30%.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
28-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.05 mg/L	0.122	0.106	0.093	0.025	0.023	0.026	0.025	0.021	0.020	0.020	0.021	0.022
29-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	0.126	0.091	0.066	0.020	0.019	0.019	0.022	0.015	0.015	0.015	0.015	0.016
30-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.13 mg/L	0.128	0.109	0.080	0.030	0.028	0.028	0.029	0.029	0.027	0.028	0.027	0.028
31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	0.130	0.128	0.110	0.030	0.029	0.027	0.030	0.026	0.026	0.024	0.024	0.026

Figure 5-21: Pilot-scale system absorbance levels during the coagulant-aid optimization with 42 mg/L ferric chloride and pH 5.7 in the Fall piloting session. Data originates from benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

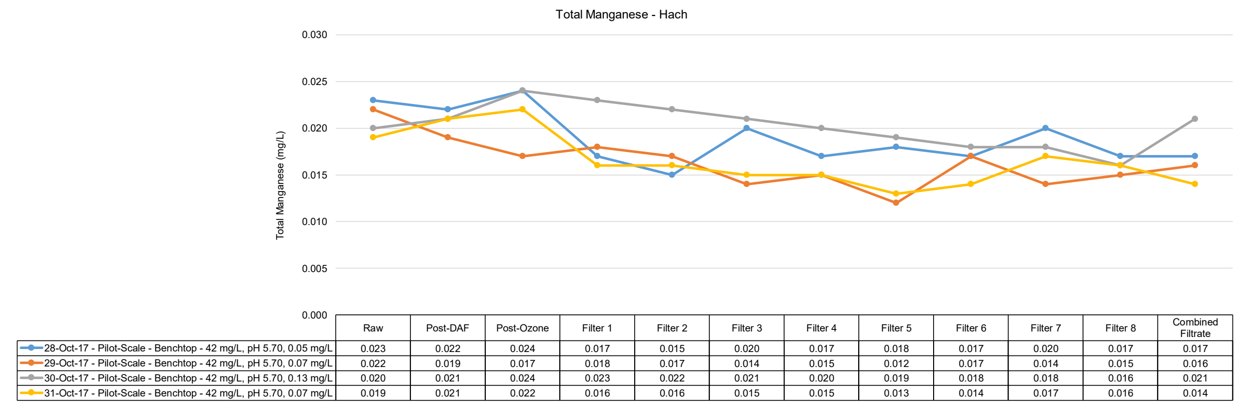


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
28-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.05 mg/L	75.5	78.4	80.8	94.5	94.8	94.1	94.5	95.2	95.5	95.4	95.2	95.0
29-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	75.0	81.2	85.8	95.3	95.6	95.7	95.0	96.6	96.7	96.5	96.7	96.3
30-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.13 mg/L	74.5	77.8	83.2	93.4	93.8	93.9	93.6	93.5	94.1	93.7	94.0	93.8
31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	74.1	74.4	77.6	93.4	93.5	94.0	93.4	94.3	94.2	94.5	94.5	94.3

Figure 5-22: Pilot-scale system UVT during coagulant-aid optimization with 42 mg/L ferric sulphate and pH 5.7 in the Fall piloting session. Data originates from benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ Total Manganese

The reduction of total manganese during coagulant-aid optimization is presented in Figure 5-23. The total manganese results showed a slight increase in total manganese concentration in the Post-Ozone samples. Reductions in total manganese concentration based on the combined filtrate ranged from 10 to 36%. The lowest total manganese concentration in the combined filtrate in the pilot-scale system was achieved with a coagulant-aid dose of 0.07 mg/L on October 29th and was reproduced on October 31st. The total manganese in the combined filtrate total for these two days were 0.016 and 0.014 mg/L, respectively.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
28-Oct-17 - Pilot-Scale - Benchtop - 42 mg/L, pH 5.70, 0.05 mg/L	0.023	0.022	0.024	0.017	0.015	0.020	0.017	0.018	0.017	0.020	0.017	0.017
29-Oct-17 - Pilot-Scale - Benchtop - 42 mg/L, pH 5.70, 0.07 mg/L	0.022	0.019	0.017	0.018	0.017	0.014	0.015	0.012	0.017	0.014	0.015	0.016
30-Oct-17 - Pilot-Scale - Benchtop - 42 mg/L, pH 5.70, 0.13 mg/L	0.020	0.021	0.024	0.023	0.022	0.021	0.020	0.019	0.018	0.018	0.016	0.021
31-Oct-17 - Pilot-Scale - Benchtop - 42 mg/L, pH 5.70, 0.07 mg/L	0.019	0.021	0.022	0.016	0.016	0.015	0.015	0.013	0.014	0.017	0.016	0.014

Figure 5-23: Pilot-scale system total manganese levels during the coagulant-aid optimization with 42 mg/L ferric sulphate and pH 5.7 in the Fall piloting session. Data originated from benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ UFRV

Figure 5-24 illustrates the average observed and forecasted UFRV values obtained for each coagulant-aid dose for Bank A and Bank B. During optimization of the coagulant-aid dose, all the filters overflowed. All individual filters of Bank A failed based on turbidity (> 0.1 NTU) at all coagulant-aid doses tested, except Filter 4 at coagulant-aid dose of 0.05 mg/L. All individual filters of Bank B failed based on turbidity (> 0.1 NTU), except Filter 4. Filters 5, 6 and 8 failed at the lowest coagulant-aid dose of 0.05 mg/L and Filters 5 and 6 failed at the highest dose of 0.13 mg/L.

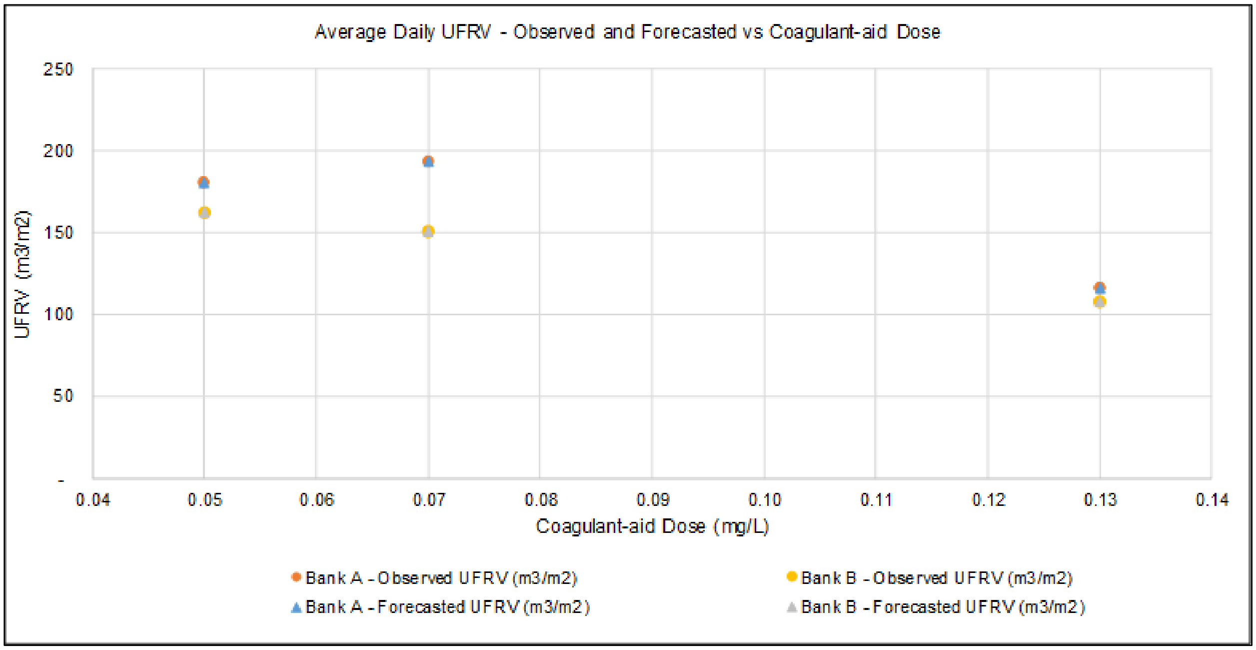


Figure 5-24: Average UFRV values of pilot-scale system Bank A at an average flow of 0.6 L/s and Bank B at an average flow of 0.3 L/s during the Fall piloting session for determining the optimal dose of coagulant-aid. The pilot-scale system coagulant dose was maintained at 42 mg/L and pH was maintained at pH 5.7. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

For Bank B, the UFRV decreased with increasing coagulant-aid dose. In contrast, Bank A showed a slight increase in the UFRV as the dose of coagulant-aid increased up to 0.07 mg/L followed by a decrease again at a coagulant-aid dose of 0.13 mg/L. Both Banks exhibited a considerable decrease in the UFRV value at a coagulant-aid dose of 0.13 mg/L. This decrease was similarly observed during the Summer piloting session.

When considering Bank B results, as its operational parameters are closer to the full-scale system, the highest UFRV value (161 m^3/m^2) was obtained at the lowest coagulant-aid dose of 0.05 mg/L and is thus considered to be the optimal dose. Given the UFRV values of the full-scale system are expected to be twice as high due to the higher head loss available for filtration and only 25% of Bank B filters presented turbidity breakthrough at this dose, the dose of 0.05 mg/L is also deemed a viable for full-scale operation.

→ Summary of Coagulant-aid Optimization

Overall, the optimal coagulant-aid was determined to be 0.07 mg/L, based on turbidity, UVT, absorbance and total manganese results. The UFRV analysis performed following the piloting session did not confirm the same optimal dose and indicated that the preferred coagulant-aid dose was 0.05 mg/L based on filter performance.

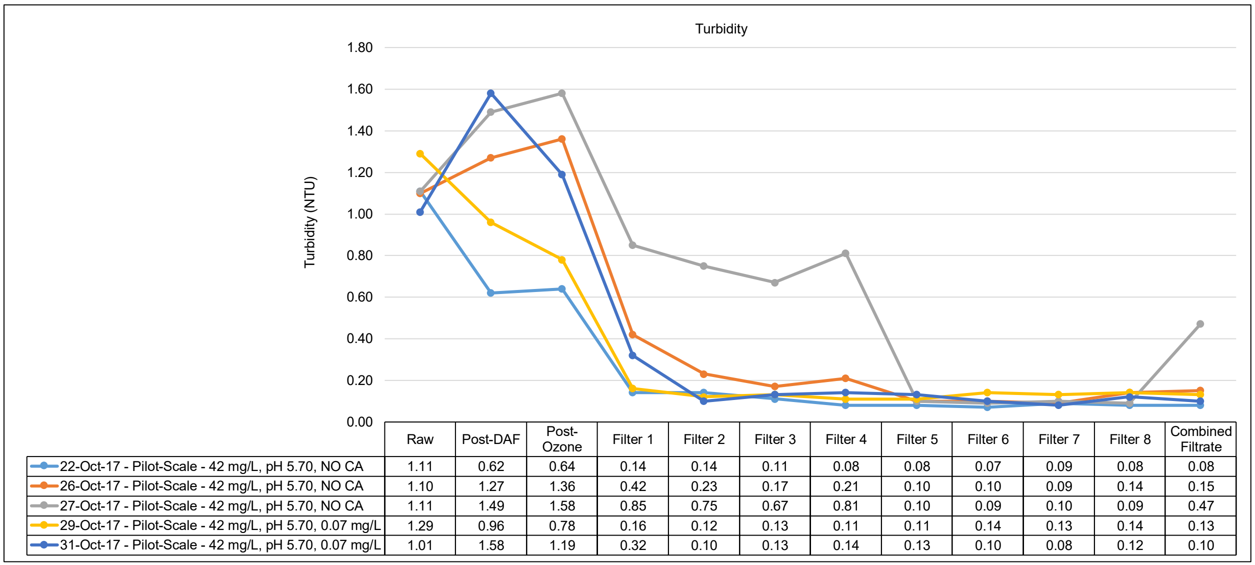
5.7 Optimized Condition Results

This section assesses the performance of the pilot-scale system in the presence and absence of the coagulant-aid as well as the impacts on the UFRV at the optimum conditions of 42 mg/L ferric sulphate and pH 5.7. The parameters turbidity, pH, absorbance, UVT, total manganese, total iron, DOC and true colour were evaluated on the specific test dates, and the conditions are as follows:

- October 22nd, 26th, and 27th with 42 mg/L ferric sulphate, pH 5.70 and no coagulant-aid
- October 29th and 31st with 42 mg/L ferric sulphate, pH 5.70 and 0.07 mg/L coagulant-aid

→ Turbidity

The change in the turbidity in the absence and presence of the coagulant-aid (at the optimal dose) is shown in Figure 5-25.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
22-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	1.11	0.62	0.64	0.14	0.14	0.11	0.08	0.08	0.07	0.09	0.08	0.08
26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	1.10	1.27	1.36	0.42	0.23	0.17	0.21	0.10	0.10	0.09	0.14	0.15
27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	1.11	1.49	1.58	0.85	0.75	0.67	0.81	0.10	0.09	0.10	0.09	0.47
29-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	1.29	0.96	0.78	0.16	0.12	0.13	0.11	0.11	0.14	0.13	0.14	0.13
31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	1.01	1.58	1.19	0.32	0.10	0.13	0.14	0.13	0.10	0.08	0.12	0.10

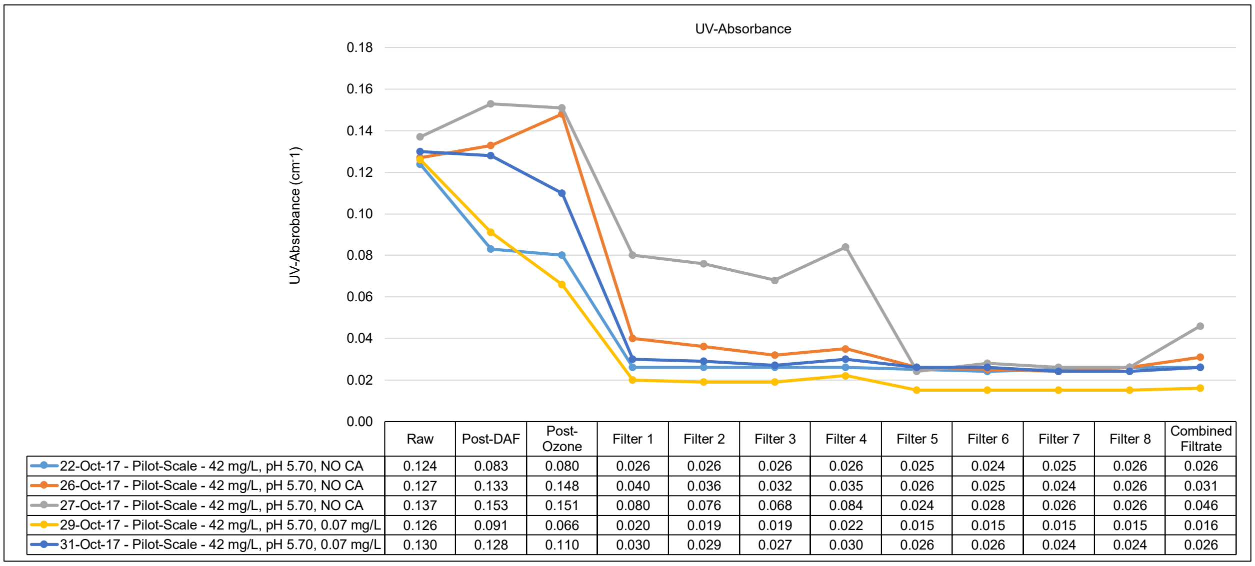
Figure 5-25: Pilot-scale system turbidity levels in the absence and presence of the coagulant-aid (0.07 mg/L) with the optimal ferric sulphate dose (42 mg/L) and pH 5.7 during the Fall piloting session. Data originated from benchtop analyses using a HACH 2100Q Turbidimeter.

Without the coagulant-aid, there was 44% reduction in turbidity in the Post-DAF on October 22nd, but the Post-DAF turbidity levels were higher than the raw water turbidity levels on October 26th and 27th. As stated in Section 5.5.2, the raw water flow rate was the lowest during Fall piloting session on October 22nd, at a rate of 2.83 L/s. This slow flow rate likely caused the improved turbidity removal by the pilot-scale DAF system. The low Post-DAF turbidity on October 22nd equated to the lowest turbidity in the combined filter effluent of 0.08 NTU, during optimal conditions testing. However, when comparing optimal conditions where raw water flow rates were similar (i.e., October 26th, 27th, 29th and 31st), the results show that there was better turbidity removal with coagulant-aid added, compared to coagulation without coagulant-aid.

The results show that raw water flow rate into the DAF tank is likely impacting turbidity levels in Post-DAF effluent; however, the addition of coagulant-aid may reduce the negative effects observed at higher flows.

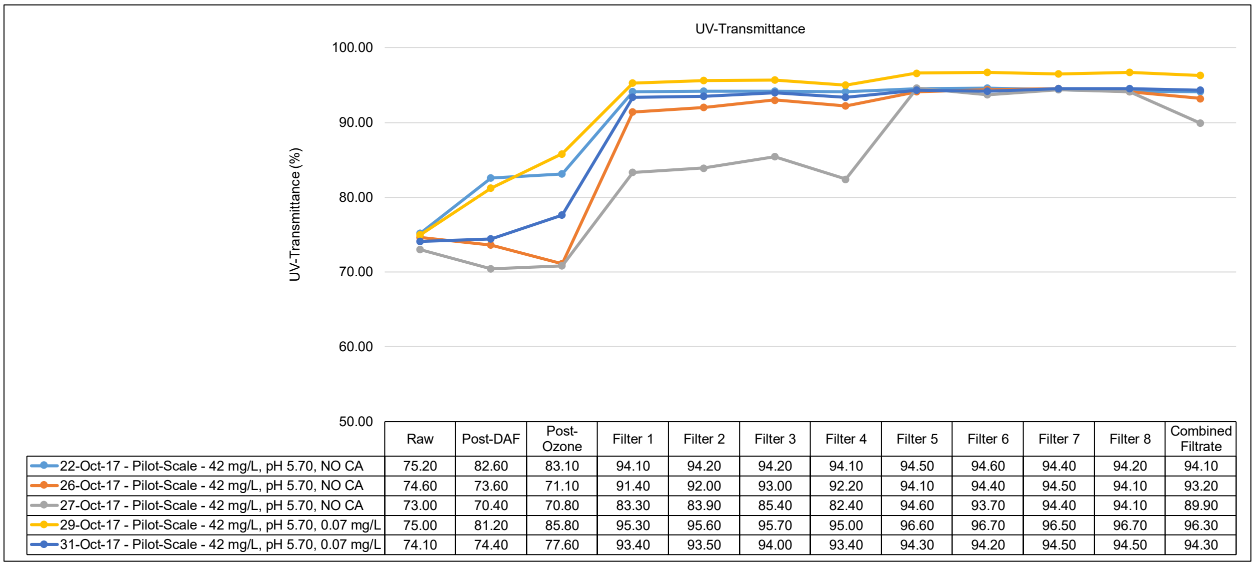
→ Absorbance and UV Transmittance

The absorbance and UVT in the absence and presence of the coagulant-aid at 0.07 mg/L is illustrated in Figure 5-26 and Figure 5-27, respectively. Similar to turbidity results, the greatest improvement in Post-DAF UVT and absorbance occurred on October 22nd and is believed to be related to the low raw water flow rate used on that day. There was a little change in absorbance and UVT following ozonation for tests conducted without the use of coagulant-aid; however, when coagulant-aid was applied on October 29th and 31st there was an improvement in absorbance and UVT after ozonation. It should be noted that ozone was not active prior to October 27th and therefore it is difficult to gauge the impact of ozone on water quality for days tested without the addition of coagulant-aid.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
22-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	0.124	0.083	0.080	0.026	0.026	0.026	0.026	0.025	0.024	0.025	0.026	0.026
26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	0.127	0.133	0.148	0.040	0.036	0.032	0.035	0.026	0.025	0.024	0.026	0.031
27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	0.137	0.153	0.151	0.080	0.076	0.068	0.084	0.024	0.028	0.026	0.026	0.046
29-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	0.126	0.091	0.066	0.020	0.019	0.019	0.022	0.015	0.015	0.015	0.015	0.016
31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	0.130	0.128	0.110	0.030	0.029	0.027	0.030	0.026	0.026	0.024	0.024	0.026

Figure 5-26: Pilot-scale system absorbance levels in the absence and presence of the coagulant-aid (0.07 mg/L) with the optimal ferric sulphate dose (42 mg/L) and pH 5.7 during the Fall piloting session. Data originates from benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

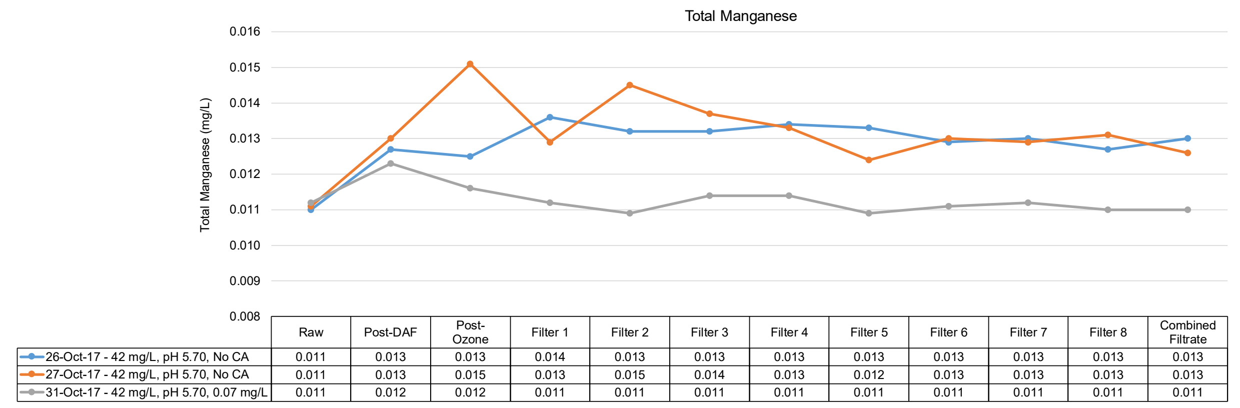


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
22-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	75.20	82.60	83.10	94.10	94.20	94.20	94.10	94.50	94.60	94.40	94.20	94.10
26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	74.60	73.60	71.10	91.40	92.00	93.00	92.20	94.10	94.40	94.50	94.10	93.20
27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, NO CA	73.00	70.40	70.80	83.30	83.90	85.40	82.40	94.60	93.70	94.40	94.10	89.90
29-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	75.00	81.20	85.80	95.30	95.60	95.70	95.00	96.60	96.70	96.50	96.70	96.30
31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	74.10	74.40	77.60	93.40	93.50	94.00	93.40	94.30	94.20	94.50	94.50	94.30

Figure 5-27: Pilot-scale system UVT in the absence and presence of the coagulant-aid (0.07 mg/L) with the optimal ferric sulphate dose (42 mg/L) and pH 5.70 during the Fall piloting session. Data originates from benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ Total Manganese

The reduction of total manganese for the pilot-scale system is presented in Figure 5-28. There was a slight increase in total manganese following DAF for all optimal testing days, due to the presence of residual manganese in ferric sulphate. Ozone did not appear to have any impact on total manganese concentrations with or without the addition of coagulant-aid. At optimal conditions, with or without the addition of coagulant-aid, the results show that coagulation using ferric sulphate should produce finished water with manganese concentrations below the City’s operational target of <0.015 mg/L.

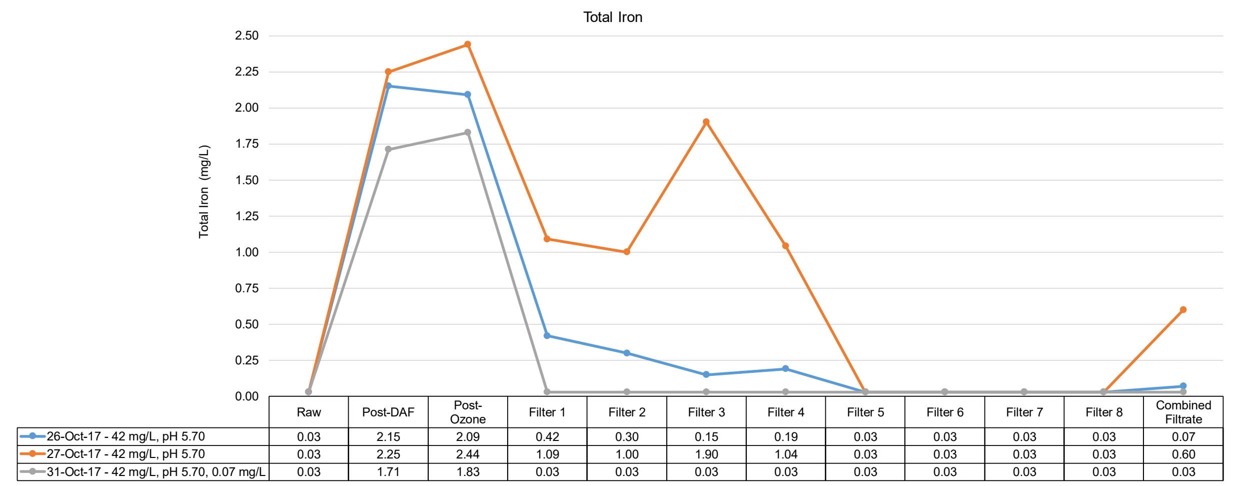


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
26-Oct-17 - 42 mg/L, pH 5.70, No CA	0.011	0.013	0.013	0.014	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
27-Oct-17 - 42 mg/L, pH 5.70, No CA	0.011	0.013	0.015	0.013	0.015	0.014	0.013	0.012	0.013	0.013	0.013	0.013
31-Oct-17 - 42 mg/L, pH 5.70, 0.07 mg/L	0.011	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011

Figure 5-28: Pilot-scale system total manganese levels in the absence and presence of the coagulant-aid (0.07 mg/L) with the optimal ferric sulphate dose (42 mg/L) and pH 5.7 during the Fall piloting session. Data originated from Lab analyses*. Note that laboratory analyses are not available on October 22nd and 29th.*

→ Total Iron

The change in total iron for the pilot-scale system is presented in Figure 5-29. The results show an increase in iron in the Post-DAF samples, as expected with the addition of a ferric based coagulant. When comparing the results, with or without coagulant-aid, there is better removal of the residual iron by the DAF system when coagulant-aid is added. There was a significant reduction in total iron following filtration for all three optimal days. Note: the elevated iron concentration in Bank A (Filters 1-4) on October 27th is the results of a release of built up coagulant in the piping feeding Bank A, which occurred prior to sample collection. If only Bank B is considered, there appears to be no difference in iron removal with the addition of coagulant-aid.

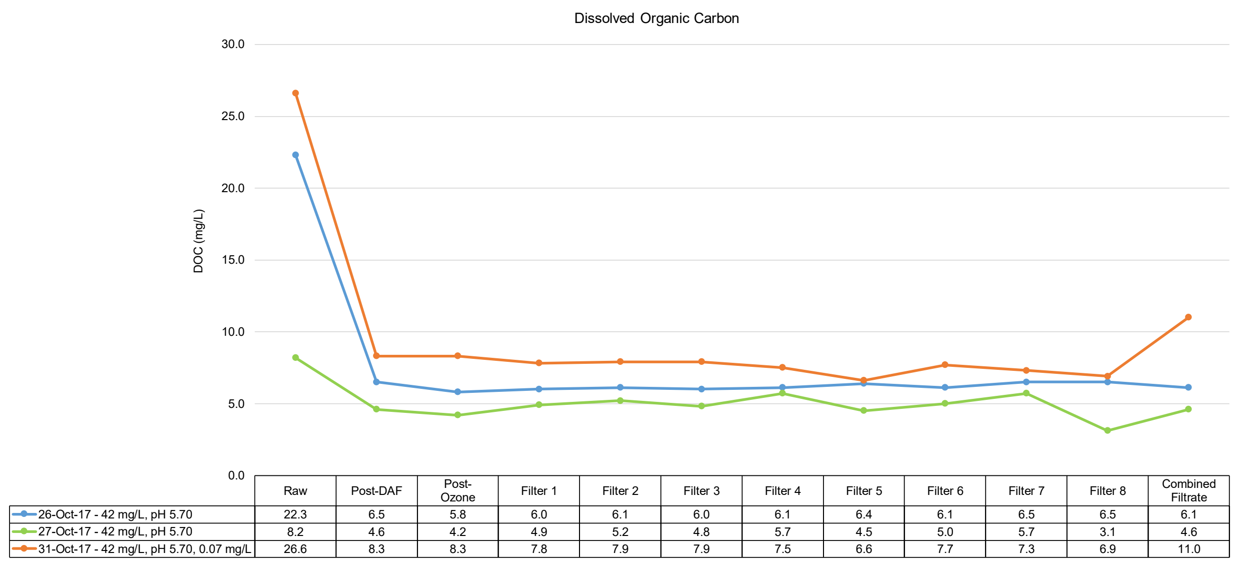


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
26-Oct-17 - 42 mg/L, pH 5.70	0.03	2.15	2.09	0.42	0.30	0.15	0.19	0.03	0.03	0.03	0.03	0.07
27-Oct-17 - 42 mg/L, pH 5.70	0.03	2.25	2.44	1.09	1.00	1.90	1.04	0.03	0.03	0.03	0.03	0.60
31-Oct-17 - 42 mg/L, pH 5.70, 0.07 mg/L	0.03	1.71	1.83	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Figure 5-29: Pilot-scale system total iron levels in the absence and presence of the coagulant-aid (0.07 mg/L) with the optimal ferric sulphate dose (42 mg/L) and pH 5.7 during the Fall piloting session. Data originated from Lab analyses. *Note that laboratory analyses are not available on October 22nd and 29th.*

→ Dissolved Organic Carbon

As mentioned, the DOC data analyzed by the City Lab was subject to an error causing concentrations to be artificially elevated by 2-3 times the actual DOC concentration. Samples collected on October 27th were not processed by the Lab and instead were analyzed by a third party accredited lab (ALS Environmental Laboratories, referred to as ALS). The results obtained from ALS justify the City's belief that the DOC measured by the Lab were approximately 2-3 times the actual DOC concentration. Therefore, the DOC concentrations reported in Figure 5-30 for samples collected on October 27th are accurate. Samples analyzed by the Lab on October 26th and 31st are subject to instrumental error and are approximately 2-3 times the expected DOC concentration. The reduction of DOC for the pilot-scale system presented in Figure 5-30.



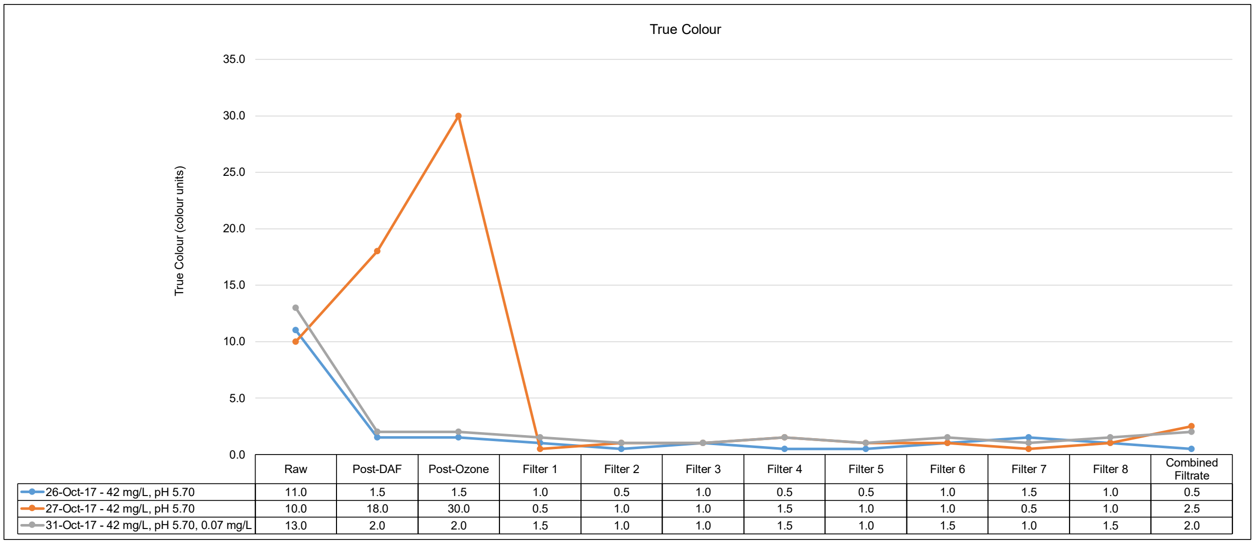
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
26-Oct-17 - 42 mg/L, pH 5.70	22.3	6.5	5.8	6.0	6.1	6.0	6.1	6.4	6.1	6.5	6.5	6.1
27-Oct-17 - 42 mg/L, pH 5.70	8.2	4.6	4.2	4.9	5.2	4.8	5.7	4.5	5.0	5.7	3.1	4.6
31-Oct-17 - 42 mg/L, pH 5.70, 0.07 mg/L	26.6	8.3	8.3	7.8	7.9	7.9	7.5	6.6	7.7	7.3	6.9	11.0

Figure 5-30: Pilot-scale system DOC levels in the absence and presence of the coagulant-aid (0.07 mg/L) with the optimal ferric sulphate dose (42 mg/L) and pH 5.7 during the Fall piloting session. Data originated from Lab analyses*. Note that laboratory analyses are not available on October 22nd and 29th. Note: Samples collected on October 26th and 31st contain errors from the Lab and are 2-3 times higher than expected.*

In the absence of coagulant-aid, there was 44 – 73% reduction in DOC in the Post-DAF, while 69% reduction occurred in the presence of coagulant-aid. The DOC level of the combined filtrate in the presence of coagulant-aid on Oct 31st is higher than the DOC levels of each individual filters. Hence, this value is considered an anomaly. Comparing the individual filters DOC values, the DOC removal with and without coagulant-aid were similar.

→ True Colour

The reduction of true colour for the pilot-scale system is presented in Figure 5-31. In the absence of coagulant-aid on October 26th, there was 86% reduction in true colour in the Post-DAF, while 85% reduction occurred when coagulant-aid was added. These results show strong similarity, which suggests that the Post-DAF true colour is determined by other factors than the use of coagulant-aid. Comparing the individual filters true colour results, the true colour removal with and without coagulant-aid were similar. Note the Post-DAF and Post-Ozone true colour levels on October 27th were unusually high. Also, the true colour values of combined filtrate on October 27th and 31st are higher than the true colour levels of each individual filters. Hence, these values are considered an anomaly.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
26-Oct-17 - 42 mg/L, pH 5.70	11.0	1.5	1.5	1.0	0.5	1.0	0.5	0.5	1.0	1.5	1.0	0.5
27-Oct-17 - 42 mg/L, pH 5.70	10.0	18.0	30.0	0.5	1.0	1.0	1.5	1.0	1.0	0.5	1.0	2.5
31-Oct-17 - 42 mg/L, pH 5.70, 0.07 mg/L	13.0	2.0	2.0	1.5	1.0	1.0	1.5	1.0	1.5	1.0	1.5	2.0

Figure 5-31: Pilot-scale system true colour *levels in the absence and presence of the coagulant-aid (0.07 mg/L) with the optimal ferric* sulphate *dose (42 mg/L) and pH 5.7 during the Fall piloting session.* Data originated from Lab analyses*. Note that laboratory analyses are not available on October 22nd and 29th.*

→ Filters Operation

Figure 5-32 illustrates the average observed and forecasted UFRV values in the absence and presence of the coagulant-aid (0.07 mg/L) at the optimal conditions of 42 mg/L coagulant dose and pH 5.7. Table 5-3 tabulates the average UFRV values in the absence and presence of the coagulant-aid for optimal days during the Fall piloting session, while also considering overall operation cycles and those filters which have not failed based on sampled turbidity.

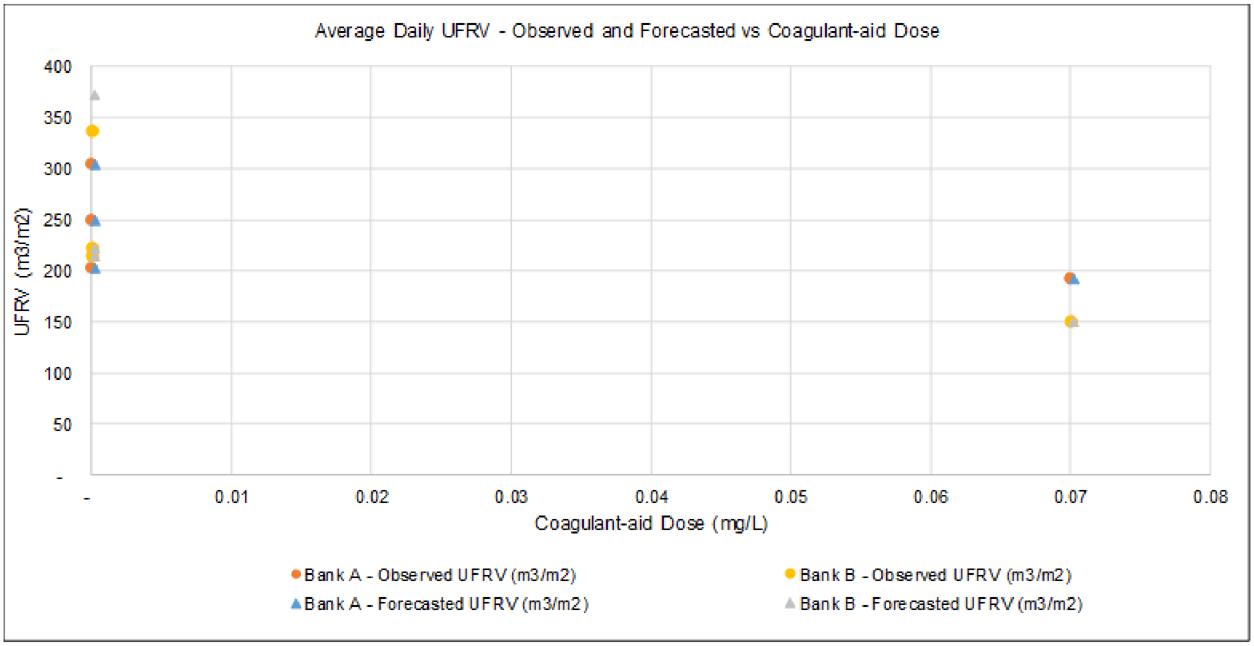


Figure 5-32: Pilot-scale system UFRV in the absence and presence of the coagulant-aid (0.07 mg/L) with optimal ferric sulphate dose (42 mg/L) and pH of 5.7 during the Fall piloting season. Data originates from the pilot-scale system's SCADA dataset.

Table 5-3: Average observed and forecasted UFRV values for the optimal conditions of the Fall piloting session, in the absence and presence of the coagulant-aid.

UFRV (m^3/m^2)		OPTIMAL DAYS OF FALL PILOTING SESSION					
		WITHOUT COAGULANT-AID			WITH COAGULANT-AID (0.7mg/L)		
		Bank A	**Bank B**	**All Filters**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	252	258	255	193	150	172
	Only cycles with turbidity ≤ 0.1 NTU	355	262	270	N/R	N/R	N/R
	Only cycles with turbidity ≤ 0.3 NTU	272	258	263	193	150	172
Forecasted Values	Overall Cycles	252	258	255	193	150	172
	Only cycles with turbidity ≤ 0.1 NTU	355	262	270	N/R	N/R	N/R
	Only cycles with turbidity ≤ 0.3 NTU	272	270	271	193	150	172

N/R: No results

The observed overall average UFRV values without coagulant-aid was 252 and 258 m^3/m^2 for Bank A and Bank B, respectively (October 22th, 26th and 27th). The observed overall average UFRV values with coagulant-aid was 193 and 150 m^3/m^2 for Bank A and Bank B, respectively (October 29th). Thus, the UFRV values suggest that the presence of coagulant-aid negatively impacts the UFRV with a reduction in performance up to 58%. In addition, only 8% of the individual filters failed based on turbidity (> 0.1 NTU) without coagulant-aid, while all individual filters failed based on turbidity (> 0.1 NTU) with the presence of coagulant-aid.

Table 5-4 presents the average rate of head loss increase for the optimal days of the Fall piloting session in the absence and presence of the coagulant-aid (0.07 mg/L) at the optimal conditions of 42 mg/L coagulant dose and pH 5.7. The results do show significance difference between the two piloting conditions in terms of rate of head loss increase (25% and 70% higher for Bank A and Bank B respectively with the addition of coagulant-aid). All values are lower than the typical rate of head loss increase (1.7 kPa/h for average filter bank flow rate of 0.3 L/s and 3.1 kPa/h for average filter bank flow rate of 0.6 L/s) without the addition of coagulant-aid. However, the rate of head loss increase for both banks are higher than typical in the presence of coagulant-aid.

Table 5-4: Average rate of head loss increase for the optimal conditions of the Fall piloting session.

RATE OF HEAD LOSS INCREASE (kPa/h)		OPTIMAL DAYS OF SPRING PILOTING SESSION	
		WITHOUT COAGULANT-AID	WITH COAGULANT-AID (0.7mg/L)
Bank A	at 0.6 L/s	3.2	4.0
Bank B	at 0.3 L/s	1.4	2.4

In order to better understand the relationship between the filter operation and the filter effluent turbidity, the filter effluent turbidity measured by the Lab is plotted against the differential pressure at 4 hours after start of filter cycle (or approximate sampling time) of each individual filter for the piloting days at optimal conditions with coagulant-aid only, as shown on Figure 5-33. This illustration also highlights the City's operational filter turbidity limit of 0.1 NTU, the full-scale system operating licence limit of 0.3 NTU, and the expected differential pressures at the sampling time per flow rate to match the full-scale system's performance. The expected differential pressures of 6.8 kPa for filters at average flow rate and 12.4 kPa for filters at maximum flow rate are based on the historical benchmarking values of the full-scale system filters (average head loss of 48.9 kPa and average filter run of 28.9 h per Table 2-2 of TM No. 1). For Bank A, the differential pressure at 4 hours after start of filter cycle (13.8 – 27 kPa) of some filters reached nearly double that of the expected differential pressure (12.4 kPa) for maximum flow rate. For Bank B, the differential pressure at 4 hours after start of filter cycle (6.7 – 17.9 kPa) of some filters also reached nearly double that of the expected differential pressure (6.8 kPa) for average flow rate.

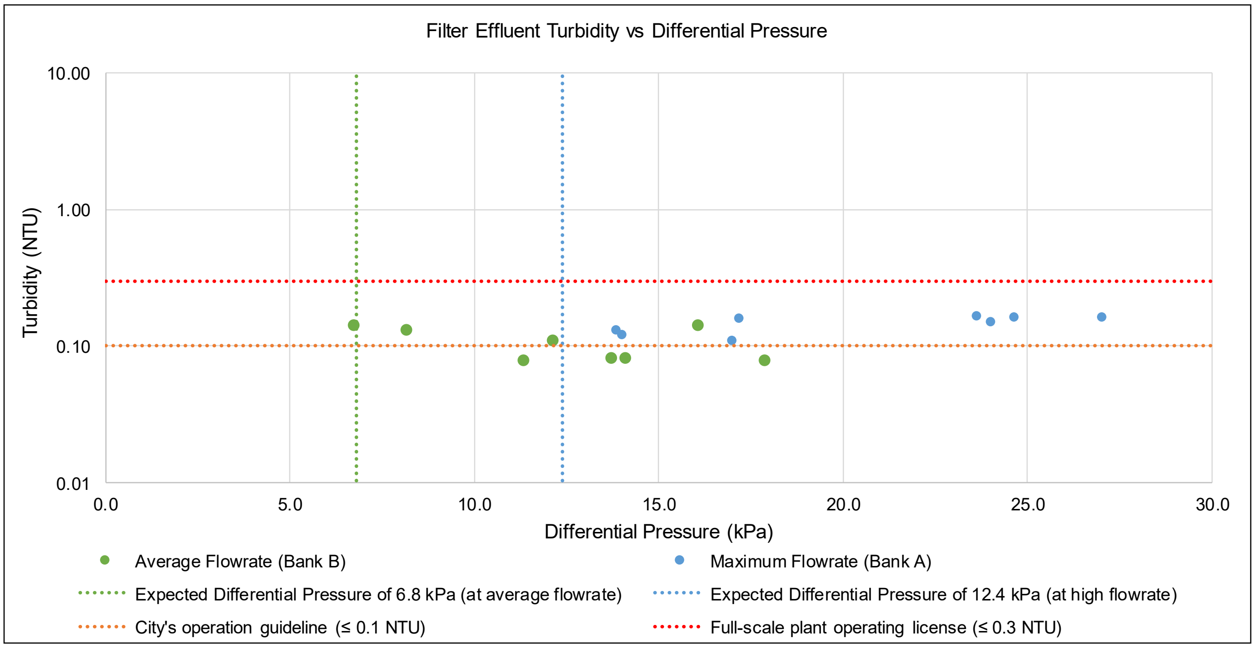


Figure 5-33: Filter effluent turbidity versus differential pressure at sampling time for each individual filter for the optimal conditions of the Fall piloting session. Note the turbidity levels (y-axis) are displayed in a logarithmic scale to improve visualization.

→ Summary of Optimal Conditions

Overall, the use of coagulant-aid improves the overall performance of the coagulant and the final quality of the treated water. The data shows that higher UVT, lower absorbance, lower total manganese, and lower total iron values are achieved in the combined filtrate when the coagulant-aid is used. However, there was a significant impact on the UFRV values and filter performance. The use of coagulant-aid also had no effect on colour and DOC.

When discarding the elevated turbidity, absorbance and total iron levels in Bank A (Filters 1-4) on October 27th as a result of a release of built up coagulant in the piping feeding Bank A, the pilot-scale system was able to produce acceptable filter effluent in terms of water quality in the absence of coagulant-aid, and the pilot-scale filters performed well.

5.8 Comparison of the Pilot-Scale System with Ferric Chloride to the Pilot-Scale System with Ferric Sulphate

No Fall benchmarking period was conducted during the Fall period, as a result a direct comparison between the pilot-scale system operating with ferric chloride and the pilot-scale system operating with ferric sulphate is not available for this time period.

5.9 Comparison of the Pilot-Scale and Full-Scale Systems During the Fall Piloting Session

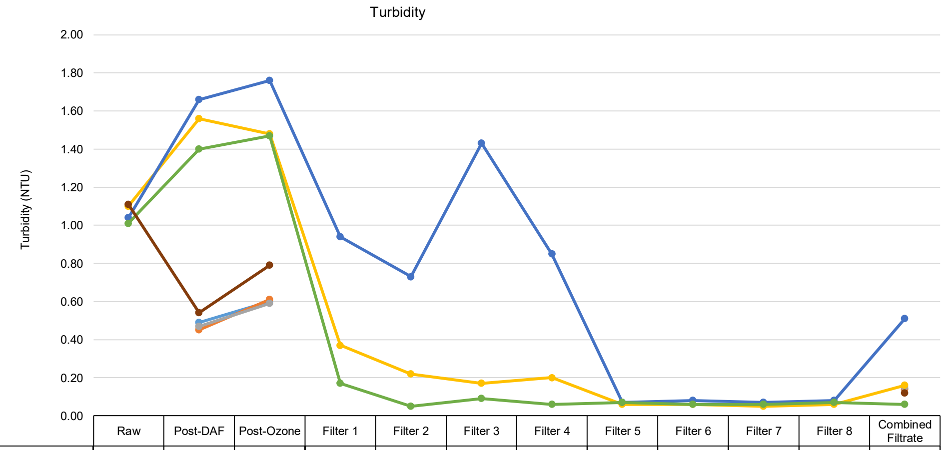
This section provides a comprehensive comparison between the full-scale system (consisting of the historical benchmark and Fall piloting session) and the pilot-scale system. The comparison was made for the last two days with no coagulant-aid (represented as the average of October 26th and 27th) and the last day with the optimal concentration of coagulant-aid (October 31st), when the optimal conditions in terms of coagulant (42 mg/L) and pH (5.7) were applied at the pilot-scale system. Historical benchmarking for the full-scale system is an average of 5 years of data.

5.9.1. Key Parameters

The following sections provide a comparison based on key parameters such as turbidity, total manganese, total iron, DOC, true colour, and UFRV. Disinfection by-products (DBPs) and corrosion indices are also discussed.

→ Turbidity

Comparing the Fall piloting session results with the average full-scale system available data during the same period and the full-scale system historical average (see Figure 5-34), the pilot-scale system filtrate turbidity was below the full-scale system levels, when not considering Bank A results.



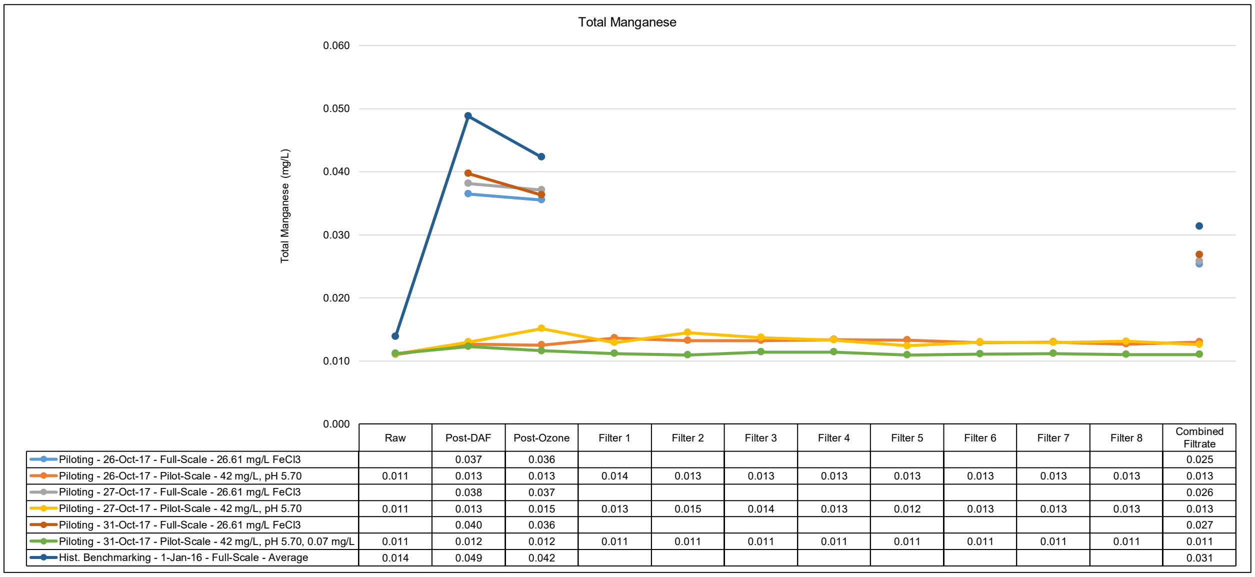
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - Full-Scale - 26.61 mg/L FeCl3 - 26-Oct-17		0.49	0.60									0.14
Piloting - Full-Scale - 26.61 mg/L FeCl3 - 27-Oct-17		0.45	0.61									0.14
Piloting - Full-Scale - 26.61 mg/L FeCl3 - 31-Oct-17		0.47	0.59									0.15
Piloting - Pilot-Scale - 42 mg/L, pH 5.70 - 26-Oct-17	1.10	1.56	1.48	0.37	0.22	0.17	0.20	0.06	0.06	0.05	0.06	0.16
Piloting - Pilot-Scale - 42 mg/L, pH 5.70 - 27-Oct-17	1.04	1.66	1.76	0.94	0.73	1.43	0.85	0.07	0.08	0.07	0.08	0.51
Piloting - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L - 31-Oct-17	1.01	1.40	1.47	0.17	0.05	0.09	0.06	0.07	0.06	0.06	0.07	0.06
Hist. Benchmarking - Full-Scale - Average - 1-Jan-16	1.11	0.54	0.79									0.12

Figure 5-34: Comparison of the average historical turbidity levels for the full-scale system, the full-scale system and the pilot-scale system (at optimum conditions with 42 mg/L ferric sulphate and pH 5.70) during the Fall piloting session. Data originated from Lab analyses.

As previously noted, Bank A presented low performance on October 26th and 27th, influencing the combined filtrate turbidity observation. Overall, it appears that pilot-scale system operation using ferric sulphate is capable of meeting turbidity levels reported during historical benchmarking, even though the Post-DAF and Post-Ozone turbidity levels were substantially higher.

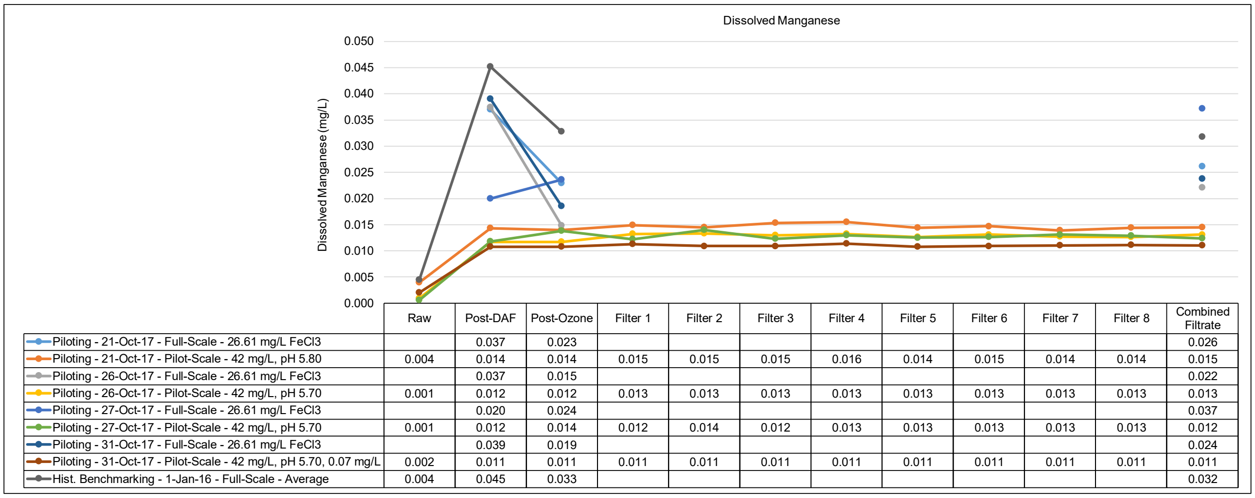
→ Total and Dissolved Manganese

Figure 5-35 and Figure 5-36 provide a comparison of the total and dissolved manganese concentrations, respectively, for the pilot-scale system with the full-scale system during the same period and the historical averages for the full-scale system. As expected, the pilot-scale system has a significantly lower manganese concentration when compared to the full-scale system and the historical benchmarking dataset. When compared to the historical average, the percentage differences between the pilot-scale system and the historical average ranged from 58 to 64%. The results indicate the use of ferric sulphate as an alternative coagulant should meet the objective of <0.015 mg/L in the final effluent.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - 26-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		0.037	0.036									0.025
Piloting - 26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.011	0.013	0.013	0.014	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Piloting - 27-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		0.038	0.037									0.026
Piloting - 27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.011	0.013	0.015	0.013	0.015	0.014	0.013	0.012	0.013	0.013	0.013	0.013
Piloting - 31-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		0.040	0.036									0.027
Piloting - 31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	0.011	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Hist. Benchmarking - 1-Jan-16 - Full-Scale - Average	0.014	0.049	0.042									0.031

Figure 5-35: Comparison of the average historical total manganese levels for the full-scale system, the full-scale system and the pilot-scale system (at optimum conditions with 42 mg/L ferric sulphate and pH 5.70) during the Fall piloting session. Data originated from Lab analyses.

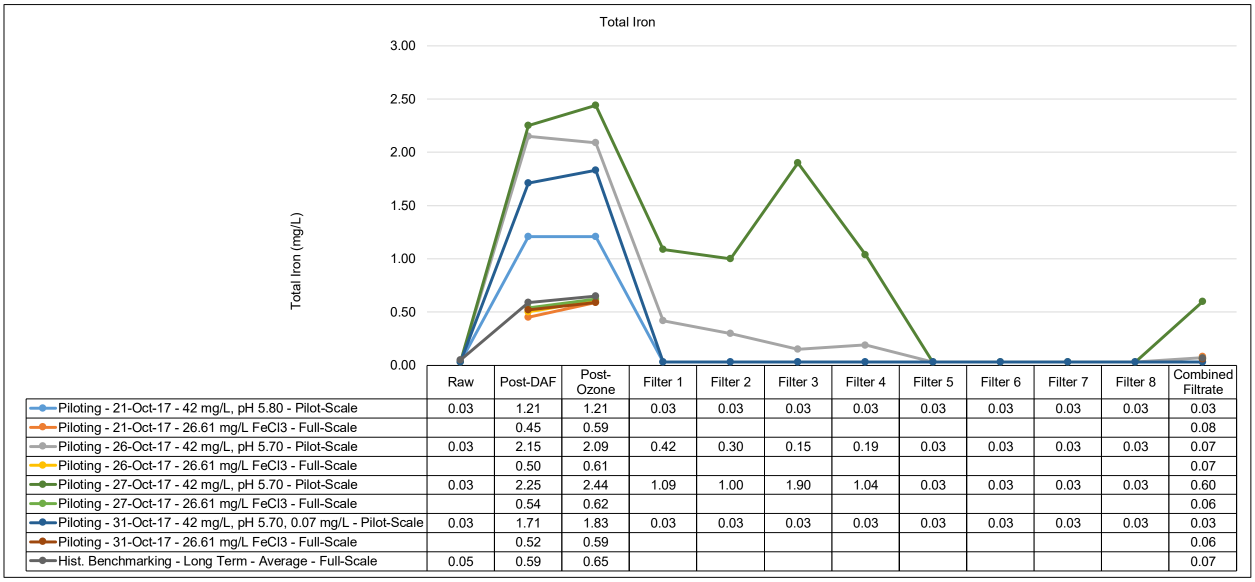


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - 21-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		0.037	0.023									0.026
Piloting - 21-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.80	0.004	0.014	0.014	0.015	0.015	0.015	0.016	0.014	0.015	0.014	0.014	0.015
Piloting - 26-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		0.037	0.015									0.022
Piloting - 26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.001	0.012	0.012	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Piloting - 27-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		0.020	0.024									0.037
Piloting - 27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	0.001	0.012	0.014	0.012	0.014	0.012	0.013	0.013	0.013	0.013	0.013	0.012
Piloting - 31-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		0.039	0.019									0.024
Piloting - 31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	0.002	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Hist. Benchmarking - 1-Jan-16 - Full-Scale - Average	0.004	0.045	0.033									0.032

Figure 5-36: Comparison of the average historical dissolved manganese levels for the full-scale system, the full-scale system and the pilot-scale system (at optimum conditions with 42 mg/L ferric sulphate and pH 5.70) during the Fall piloting session. Data originated from Lab analyses.

→ Total Iron

Figure 5-37 illustrates the removal of iron levels from the full-scale and pilot-scale systems during the Fall piloting session at optimum conditions. The results demonstrate the pilot-scale system Post-DAF sample had higher iron concentration compared to both the full-scale system and historical benchmarking dataset. However, the final iron concentrations in the combined filtrate are similar for the pilot-scale system, full-scale system and the historical average, when not considering Bank A results. As discussed before, Bank A exhibited a lower performance on October 26th and 27th. The data indicates that the residual iron from ferric sulphate is adequately removed.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - 21-Oct-17 - 42 mg/L, pH 5.80 - Pilot-Scale	0.03	1.21	1.21	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Piloting - 21-Oct-17 - 26.61 mg/L FeCl3 - Full-Scale		0.45	0.59									0.08
Piloting - 26-Oct-17 - 42 mg/L, pH 5.70 - Pilot-Scale	0.03	2.15	2.09	0.42	0.30	0.15	0.19	0.03	0.03	0.03	0.03	0.07
Piloting - 26-Oct-17 - 26.61 mg/L FeCl3 - Full-Scale		0.50	0.61									0.07
Piloting - 27-Oct-17 - 42 mg/L, pH 5.70 - Pilot-Scale	0.03	2.25	2.44	1.09	1.00	1.90	1.04	0.03	0.03	0.03	0.03	0.60
Piloting - 27-Oct-17 - 26.61 mg/L FeCl3 - Full-Scale		0.54	0.62									0.06
Piloting - 31-Oct-17 - 42 mg/L, pH 5.70, 0.07 mg/L - Pilot-Scale	0.03	1.71	1.83	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Piloting - 31-Oct-17 - 26.61 mg/L FeCl3 - Full-Scale		0.52	0.59									0.06
Hist. Benchmarking - Long Term - Average - Full-Scale	0.05	0.59	0.65									0.07

Figure 5-37: Comparison of the average historical total iron levels for the full-scale system, the full-scale system and the pilot-scale system (at optimum conditions with 42 mg/L ferric sulphate and pH 5.70) during the Fall piloting session. Data originated from Lab analyses.

One important factor to consider with regards to elevated iron levels would be the iron content in each coagulant. For example, the full-scale system operated at an approximate ferric chloride dose of 26.6 mg/L. The equivalent ferric sulphate dose would be approximately 32.8 mg/L, based on a mass equivalent ratio (See below).

$$\%\ Fe\ in\ FeCl_3 = 34.4\%$$

$$\%\ Fe\ in\ Fe_2(SO_4)_3 = 27.9\%$$

$$FeCl_3 * \%Fe_{FeCl_2} = Fe_2(SO_4)_3 * \%Fe_{Fe_2(SO_4)_3}$$

$$Fe_2(SO_4)_3 = FeCl_3 * \frac{\%Fe_{FeCl_2}}{\%Fe_{Fe_2(SO_4)_3}}$$

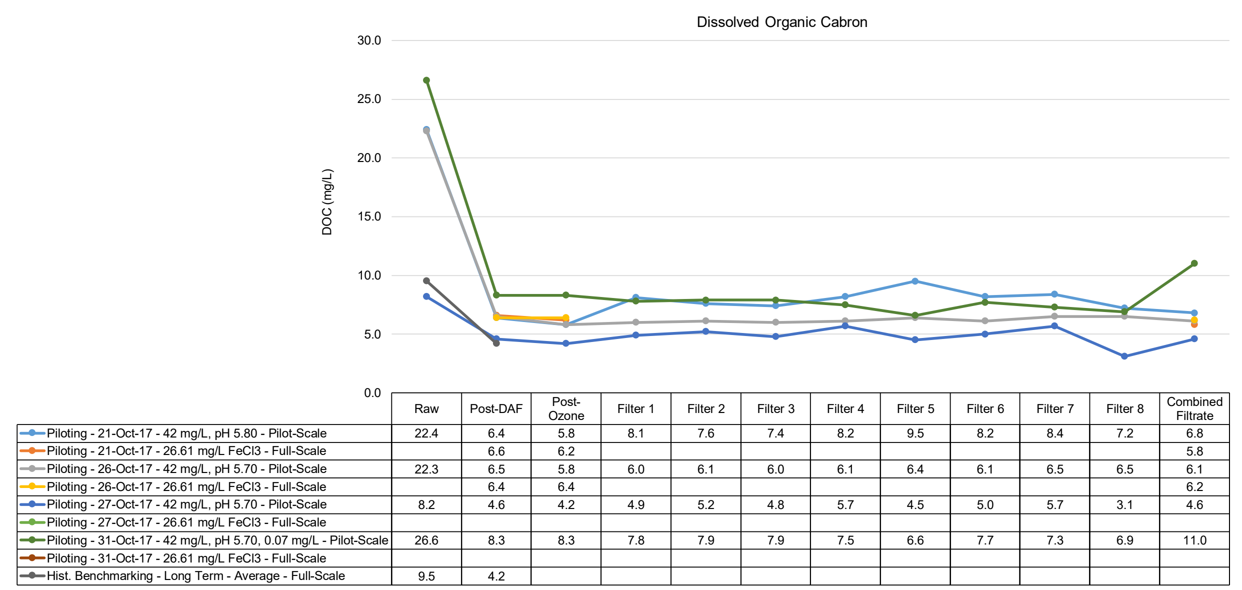
$$Fe_2(SO_4)_3 = FeCl_3 * \frac{34.4\%}{27.9\%} = 32.8\,mg/L$$

Therefore, at the optimal dose found during the Fall piloting session for ferric sulphate (42 mg/L), there is an additional 28% iron content added using ferric sulphate compared to the dose of ferric chloride applied in the full-scale system. This is likely a major contributor to the elevated iron measured in the pilot-scale system. Low raw water alkalinity also acts as a limiting reagent for the formation of ferric hydroxides which impacts coagulation increasing the concentration of unreacted iron in the DAF effluent.

→ Dissolved Organic Carbon

Figure 5-38 illustrates the DOC removal by the full-scale and pilot-scale systems during the Fall piloting season, as well as the historical average for the full-scale system. The pilot-scale system achieved a 71% reduction in DOC in the Post-DAF samples compared to a 56% removal in the historical average when compared to the raw water.

Historical data is not available for the combined effluent; nevertheless, following the initial removal of the DOC in the Post-DAF samples, the DOC concentrations are similar with minor fluctuations among the individual filters for the pilot-scale system. These fluctuations suggest there are differences in the buildup of organic matter on the individual filters. Despite, these fluctuations, where the data is available for comparison, both the pilot-scale and the full-scale systems had similar DOC results in the combined filtrate.



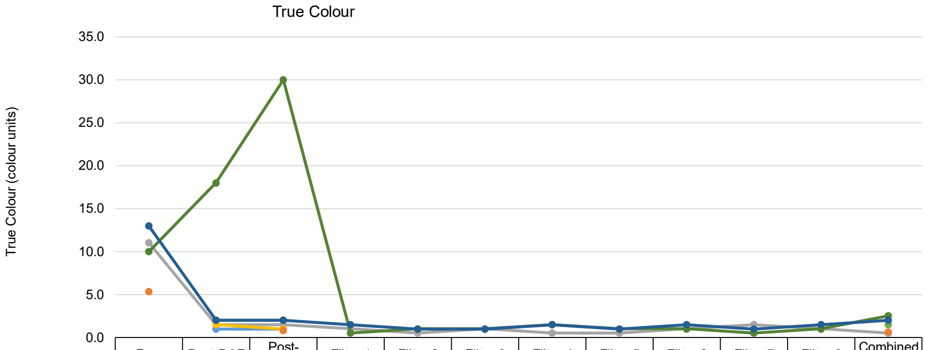
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - 21-Oct-17 - 42 mg/L, pH 5.80 - Pilot-Scale	22.4	6.4	5.8	8.1	7.6	7.4	8.2	9.5	8.2	8.4	7.2	6.8
Piloting - 21-Oct-17 - 26.61 mg/L FeCl3 - Full-Scale		6.6	6.2									5.8
Piloting - 26-Oct-17 - 42 mg/L, pH 5.70 - Pilot-Scale	22.3	6.5	5.8	6.0	6.1	6.0	6.1	6.4	6.1	6.5	6.5	6.1
Piloting - 26-Oct-17 - 26.61 mg/L FeCl3 - Full-Scale		6.4	6.4									6.2
Piloting - 27-Oct-17 - 42 mg/L, pH 5.70 - Pilot-Scale	8.2	4.6	4.2	4.9	5.2	4.8	5.7	4.5	5.0	5.7	3.1	4.6
Piloting - 27-Oct-17 - 26.61 mg/L FeCl3 - Full-Scale												
Piloting - 31-Oct-17 - 42 mg/L, pH 5.70, 0.07 mg/L - Pilot-Scale	26.6	8.3	8.3	7.8	7.9	7.9	7.5	6.6	7.7	7.3	6.9	11.0
Piloting - 31-Oct-17 - 26.61 mg/L FeCl3 - Full-Scale												
Hist. Benchmarking - Long Term - Average - Full-Scale	9.5	4.2										

Figure 5-38: Comparison of the average historical DOC levels for the full-scale system, the full-scale system and the pilot-scale system (at optimum conditions with 42 mg/L ferric sulphate and pH 5.70) during the Fall piloting session. Data originated from Lab analyses. Note: samples collected on October 21st, 26th and 31st contain errors from the Lab and are approximately 2-3 times higher than the actual DOC concentration.

→ True Colour

Figure 5-39 compares the true colour of the samples from the full-scale system, pilot-scale system and the historical average. Based on the values obtained for the combined filtrate, there was no significant difference between the pilot-scale and the full-scale systems for true colour during the Fall piloting session.

There was an unusually high true colour value in one of the Post-DAF samples during the testing in the pilot-scale system that is not explainable, and as such, it is considered an anomaly. Overall the historical average is lower than both the pilot-scale and full-scale systems. This is likely due to the higher initial colour of the raw water compared to the historical average.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - 26-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		1.0	1.0									0.5
Piloting - 26-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	11.0	1.5	1.5	1.0	0.5	1.0	0.5	0.5	1.0	1.5	1.0	0.5
Piloting - 27-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		1.5	1.0									2.0
Piloting - 27-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70	10.0	18.0	30.0	0.5	1.0	1.0	1.5	1.0	1.0	0.5	1.0	2.5
Piloting - 31-Oct-17 - Full-Scale - 26.61 mg/L FeCl3		2.0	2.0									1.5
Piloting - 31-Oct-17 - Pilot-Scale - 42 mg/L, pH 5.70, 0.07 mg/L	13.0	2.0	2.0	1.5	1.0	1.0	1.5	1.0	1.5	1.0	1.5	2.0
Hist. Benchmarking - Long Term - Full-Scale - Average	5.4		0.8									0.7

Figure 5-39: Comparison of the average historical true colour levels for the full-scale system, the full-scale system and the pilot-scale system (at optimum conditions with 42 mg/L ferric sulphate and pH 5.70) during the Fall piloting session. Data originated from Lab analyses.

→ UFRV

The historical average of the full-scale system UFRV value is 495 m^3/m^2. In the absence of coagulant-aid, the Bank A filters failed based on turbidity (> 0.1 NTU), while Bank B filters did not present turbidity breakthrough. The observed overall average UFRV values without coagulant-aid were 252 and 258 m^3/m^2 for Bank A and Bank B, respectively (October 22th, 26th and 27th). With coagulant-aid, all individual filters failed based on turbidity (> 0.1 NTU) and the observed overall average UFRV values was 193 and 150 m^3/m^2 for Bank A and Bank B, respectively (October 29th). The UFRV values for the Fall piloting session would be presumably lower for both filter banks as most individual filters presented turbidity breakthrough in the presence of coagulant-aid. Substantial differences between the full-scale system with ferric chloride and the Fall piloting session with ferric sulphate were observed, indicating that ferric sulphate was impacted by piloting conditions, especially with the addition of coagulant-aid under cool water conditions, and that additional adjustment of these conditions should be considered prior to full-scale system operation adoption.

5.9.2. Disinfection By-Product Formation Potential

The disinfection by-product formation potential (DBPFP) test was conducted to determine the extent at which trihalomethanes (THM) and haloacetic acids (HAA) form following disinfection of finished (filter effluent) water using sodium hypochlorite. Samples were collected from the pilot-scale raw water intake, as well as the full-scale and pilot-scale system combined filter effluents on October 27th and October 31st. The chemical doses used for DBPFP are outlined in Table 4-1 in Section 4.0. Samples from each location were prepared onsite by WSP personnel for both THM formation potential (THMFP) and HAA formation potential (HAAFP) tests.

The DBPFP procedure is analogous to the procedure outlined in TM No. 4. Table 5-5 and Table 5-6 report the results for THMFP and HAAFP for October 27th and October 31st. The results for October 27th appear to contain an error with regards to the raw water sample, as both THMFP and HAAFP were lower in the raw than in the final effluent from the full-scale and pilot-scale systems. It is believed that there was either a sampling or labeling error that occurred, or the release of the coagulant buildup in Bank A observed on October 27th, which caused the deviation in DBP results. Therefore, the data on October 27th is determined to be not reliable.

Table 5-5: THMFP results for October 27 and 31, 2017.

October 27, 2017	BDCM (µg/L)	CHBr3 (µg/L)	CHCl3 (µg/L)	DBCM (µg/L)	Total THM (µg/L)
Raw	0.7	<0.2	9.4	<0.4	10
Combined (Full)	2.6	<0.2	23.9	<0.4	27
Combined (Pilot)	2.7	<0.2	38.2	<0.4	41
October 31, 2017					
Raw	1.5	<0.2	28	<0.4	30
Combined (Full)	2.3	<0.2	15.9	<0.4	19
Combined (Pilot)	2.5	<0.2	25.4	<0.4	28

Table 5-6: HAAFP results for October 27 and 31, 2017.

October 27, 2017	BCAA (µg/L)	DBAA (µg/L)	DCAA (µg/L)	MBAA (µg/L)	MCAA (µg/L)	TCAA (µg/L)	Total HAA (µg/L)
Raw	0.8	<0.3	9.8	<0.3	<0.7	4.2	15
Combined (Full)	0.9	1.8	7.8	<0.3	<0.7	6.6	17
Combined (Pilot)	0.9	<0.3	12.8	<0.3	<0.7	15.5	29
October 31, 2017							
Raw	0.5	<0.3	12	<0.3	<0.7	7.7	20
Combined (Full)	0.7	1.7	4.3	<0.3	<0.7	4.2	11
Combined (Pilot)	0.7	<0.3	6.2	<0.3	<0.7	6.8	14

The THMFP and HAAFP of samples collected on October 31st demonstrate that the overall concentration of THMs and HAAs in the raw water are well below provincial standards. The full-scale system reduced the THMFP by 37%, while only a 7% reduction in THMFP was achieved by the pilot-scale system. Comparison between the two systems for HAAFP found the full-scale system decreased the HAAFP by 45%, while only a 37% reduction in HAAFP was achieved by the pilot-scale system.

Overall, the results show that there is little concern with regards to meeting THMs or HAAs using either ferric based coagulants. However, should THMs and HAAs become an issue in the raw water in the future, the ferric sulphate appears to be less capable for reducing THMs and HAAs then the ferric chloride.

5.9.3. Corrosive Indices

The degree of corrosion is typically determined primarily by the characteristics of various metal and water, and nature and duration in which the two are in contact with each other. Table 5-7 highlights some factors that can influence the corrosivity of drinking water.

Table 5-7: Factors Affecting the Corrosivity of Drinking Water

CORROSION VECTOR	**GENERAL EFFECTS**
pH	Lowering the pH generally accelerates corrosion.
Dissolved oxygen	Higher rates of DO typically induces corrosion, particularly in ferrous and copper materials.
Low buffering capacity	Low or insufficient alkalinity reduce the ability to buffer corrosion activities.
High halogen and sulfate-alkalinity	With a molar ratio greater than 0.5 of halogen to sulphate, the conditions become favourable for corrosion (pitting in ferrous and copper materials).
Total dissolved solids and conductivity	High concentrations of dissolved salts often increase conductivity and subsequently can stimulate corrosive tendencies.
Various metals	The types of corrosion products present depends on the metals availability and their oxidation state. For example, copper can aggravate corrosion of downstream materials within distribution networks.

The magnitude of galvanic corrosion between lead and copper is largely governed by the relative concentration of chloride to sulfate. As such, the chloride-to-sulfate mass ratio (CSMR) serves to explain this effect. A CSMR above 0.5 is considered to increase galvanic corrosion of lead solder connected to copper pipe, as evidenced by increased galvanic voltage measurements first detailed by Walker and Oliphant (1983)[1] and Gregory (1990)[2].

The Langelier Saturation Index (LSI) indicates scale or corrosion forming tendencies based on the hardness, alkalinity, pH, dissolved solids, and pH of the water. The ideal index value is zero, indicative of a minimal tendency to form scale or be corrosive, whereas when greater than zero, the LSI suggests that scale will form, and less than zero indicates the water to be corrosive.

The Ryznar Index is used to consider pitting corrosion depth, as it is a measure of the amount of calcium carbonate in saturation compared to the actual amount present. Like the LSI, is used to calculate scale and corrosion tendencies in water and distribution networks. If the index is above 6, the indices suggest there is a tendency for pitting to occur.

Corrosion rates are influenced to some extent by all mineral substances found in water; however, corrosion effects are so interrelated that it is not generally possible to isolate the quantitative impact of particular ions or metals. As such, many of the indices rely on multiple contributing factors to establish a tendency. In this context, the adverse effects can be somewhat mitigated by the water's alkalinity and calcium content.

Literature suggests that to benefit from corrosively buffering by alkalinity, a total alkalinity and calcium concentration should be at least 50 to 100 mg/L $CaCO_3$. In general, elevated concentration of alkalinity

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[1] Walker, R. and Oliphant, R., 1983. A cell to study corrosion of materials in the water industry. *Jour. Water Engineers and Scientists*, *32*(2), pp.143-150.

[2] Gregory, R., 1990. Galvanic corrosion of lead solder in copper pipework. *Water and Environment Journal*, *4*(2), pp.112-118.

and calcium improve the water's capacity for corrosion retardation, yet too much can promote scale formation.

Table 5-8 outlines the corrosive indices observed in the raw water and combined filtrate for both pilot-scale and full-scale systems during the Fall piloting session. The indices are calculated from laboratory results of samples taken the same day from the full-scale system post filtration and prior to pH adjustment with sodium hydroxide and the pilot-scale system post-filtration operating under optimal conditions. A comparison between the full-scale system and the pilot-scale system is made under the provision that samples taken from their respective sources on the same day share identical raw water quality. Furthermore, as these indices are of a strict predicative nature (the development of a general index is inherently difficult due to the multiple roles of chemical species in potable water), and do not necessarily correlate between theoretical and actual conditions, only a relative comparison is made.

Table 5-8: Corrosive Indices in the Raw water and Combined Filtrate for the Pilot-scale and Full-scale systems during the Fall piloting session

TEST CONDITION	CSMR[1]	LSI[2]	RSI[3]	ALKALINITY (mg/L as $CaCO_3$)[4]
Best coagulant dose, best pH (October 27th)				
Raw	No detectable sulphate	-1.01	9.35	75
Pilot-Scale Combined Filtrate	0.03	-3.41	12.60	11
Full-Scale Combined Filtrate	0.35	-3.92	13.19	9
Best coagulant dose, best pH, best coagulant-aid dose (October 31st)				
Raw	No detectable sulphate	-0.91	8.35	75
Pilot-Scale Combined Filtrate	0.03	-3.54	12.86	9
Full-Scale Combined Filtrate	0.36	-3.84	13.21	8

[1] Greater than 0.5 indicates a tendency to increase galvanic corrosion of lead solder connected to copper pipes.
[2] At 0, water is under saturated with respect to calcium carbonate. Tendency will be to remove existing calcium carbonate protective coatings.
[3] Values > 8.5, water is very aggressive towards corrosion.
[4] Reported as mg/L $CaCO_3$, very low values << 100 are corrosive & values > 200 result in possible scaling

Based on the CSMR values for the pilot-scale and full-scale systems, the observed water quality is not expected to increase the galvanic corrosion of lead solder connected to copper pipes. However, the LSI and RSI indices suggest similar corrosive tendencies, specifically; it is likely to dissolve calcium carbonite coatings within the distribution network. In such a context, the observed low alkalinity in the pilot-scale and full-scale systems provides minimal potential to impede such corrosive tendencies. Lastly, marginal numerical differences were observed with the use of coagulant-aid. Given these small differences, the use of coagulant-aid is expected provide minimal impact to the corrosive indices.

It is important to note that these comparisons take into consideration the combined filtrate water and does not account for any chemicals dosed in the full-scale system just prior to distribution.

6. CONCLUSIONS AND RECOMMENDATIONS

From the results presented above, the following may be concluded:

- Raw water temperature was in the range of 4 to 14°C for the Fall piloting session indicating that cool water conditions were maintained during all testing. However, a process upset on November 1st, 2017, caused the pilot-scale system shutdown for a few days. Since the raw water temperature was below 4°C target when the issue was resolved, the Fall piloting session was shortened by six days.
- During the Fall piloting session, the Post-DAF pH was controlled by adjusting the sulphuric acid dose to the raw water based on a pH set-point, allowing a significant improvement in the pH control. The practice was monitored via Post-DAF grab samples to ensure the appropriateness of such a feedback loop.
- An optimal dose for the ferric sulfate coagulant was evaluated in the pilot-scale system from October 16th to 20th, 2017 with no addition of coagulant-aid and a target pH of 5.8. The optimal dose was established to be 42 mg/L. The optimal coagulant dose was then repeated on October 21st, 2017.
- Using the optimal coagulant dose (42 mg/L), the optimal pH for coagulation was determined in the period from October 22nd to 25th, 2017. The turbidity, UVT, and absorbance indicated the optimal pH was 5.7 for ferric sulphate in cool water conditions. The optimal coagulant dose and pH conditions were then repeated on October 26th and October 27th, 2017.
- Using the optimal coagulant dose (42 mg/L) and optimal target pH (5.7), an optimal coagulant-aid dose was investigated from October 28th to 30th, 2017. The optimal coagulant-aid dose was found to be 0.07 mg/L. The optimal conditions were then repeated on October 31st, 2017.
- Bank A filters presented low performance on October 27th which substantially impacted the combined filtrate water quality, while Bank B filters' operation was consistent with previous data for the same day.
- The water quality of the pilot-scale system under optimum conditions of pH and coagulant dose was compared with the presence and absence of the coagulant-aid. Using the coagulant-aid yielded lower absorbance values, higher UVT values, lower total manganese and lower total iron concentrations in the final combined filtrate. Turbidity, DOC and true colour levels were not influenced by the use of coagulant-aid. However, the UFRV values were negatively impacted by up to a 58% reduction in filter performance when coagulant-aid was used. Furthermore, the pilot-scale system was able to produce filter effluent within the acceptable water quality in the absence of coagulant-aid.
- Reductions in THMFP (37%) and HAAFP (45%) were higher in the full-scale system compared to the pilot-scale system removals of THMFP (7%) and HAAFP (37%). However, in both systems the concentrations were well below provincial standards indicating that THMs or HAAs should not be of significant concern when using ferric sulphate. However, should raw water TOC levels increase in the future, the ferric sulphate appears to be less capable of reducing THMs and HAAs when compared to the ferric chloride.
- For the Fall piloting session, the CSMR corrosive indices suggest that the quality of the treated water is not expected to increase galvanic corrosion. Although the LSI and RSI of the pilot-scale system were slightly better, the difference is considered marginal and the likelihood that the treated water may dissolve calcium carbonite coatings in the distribution system remains. It was noted that the addition of the coagulant-aid had minimal impact on the corrosive indices.
- During the optimal dose days, the ferric chloride dose in the full-scale system was 26.61 mg/L. The equivalent ferric sulphate dose would be 32.8 mg/L. The optimal dose used during the period was 28% greater in iron content than the calculated equivalent full-scale system dose.

Recommendations regarding the future piloting sessions are as follow:

- Maintain the reversed flow configuration of the filter banks to offset potential performance shortcomings arising from the mechanical differences between the pilot-scale system filter banks.
- Maintain sampling of both full-scale and pilot-scale systems on the same day for laboratory testing, to allow a valid comparison between the two systems using the same raw water.
- Although the Post-DAF pH control was improved significantly, installation of a second pH controller within the DAF (DAF Tank #4) would further improve monitoring and pH correction within the pilot-scale system. It should be noted this would require additional equipment.
- There appeared to be better pilot-scale system Post-DAF turbidity at raw water flow rates <3.0 L/s. It is recommended that in cool, and likely cold, water conditions lower flow rates should be used to improve turbidity removal by the DAF system.
- Current corrosion indicators are based on two days sampling at different conditions (in the presence and the absence of coagulant-aid). Additional laboratory testing can provide a better perspective for the corrosivity of filter effluent water.
- Verify the calibration of filter-aid pumps periodically and before each piloting sessions (as performed before the Fall piloting session) to confirm polymer dosage accuracy and their influence on the filters performance.

Piloting Results Database Summary

Season: Fall

Phase: Extended Piloting

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
August 21, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0143	0.0142	0.0117	0.0099	0.0093	0.0099	0.0117	0.0102	0.0111	0.0079		
				Avg. of filters 1 to 8												0.01021	
		pH	Lab			5.86	6.02	6.58	6.63	6.66	6.64	6.51	6.57	6.55	6.62		
				Avg. of filters 1 to 8												6.595	
		TOC, Total (mg/L)	Lab				2.6	2.3	2.2	2.1	2.3						
				Avg. of filters 1 to 8												2.225	
		Turbidity (NTU)	Lab			0.64	0.73	0.14	0.15	0.15	0.15	0.12	0.12	0.11	0.12		
				Avg. of filters 1 to 8												0.1325	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0391	0.046	0.0457	0.0329	0.0339	0.0343	0.0323	0.0378	0.0382		0.0384		0.0357
		pH	Lab		8.24	5.5	5.43	5.61	5.61	5.65	5.61	5.3	5.15		5.12		5.43
		Temperature (ºC)	Lab		22.5												
		TOC, Total (mg/L)	Lab		12.4	2.4	2.4		2.9	3.2	2.6						1.5
		Turbidity (NTU)	Lab		1.6	0.46	0.57	0.2	0.18	0.2	0.22	0.08	0.1		0.09		0.16
August 22, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0146	0.0141	0.008	0.006	0.0065	0.0067	0.0082	0.0081	0.0073	0.0059		
				Avg. of filters 1 to 8												0.00709	
		pH	Lab			6.04	6.17	6.35	6.37	6.4	6.34	6.26	6.31	6.36	6.35		
				Avg. of filters 1 to 8												6.3425	
		TOC, Total (mg/L)	Lab			2.3	2.2					1.8	2.1	2	1.9		
				Avg. of filters 1 to 8												1.95	
		Turbidity (NTU)	Lab			0.78	0.87	0.16	0.16	0.15	0.16	0.13	0.13	0.12	0.12		
				Avg. of filters 1 to 8												0.14125	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0399	0.0523	0.0475		0.0346	0.0344	0.035	0.0368	0.0404	0.0398	0.0455		0.0381
		pH	Lab		8.14	5.1	5.19		5.51	5.53	5.51	5.29	5.03	5.07	5.04		5.26
		Temperature (ºC)	Lab		21.9												
		TOC, Total (mg/L)	Lab									2.1	2.2	1.1	1.1		
		Turbidity (NTU)	Lab		1.91	0.32	0.5		0.14	0.16	0.16	0.13	0.07	0.08	0.09		0.24
August 23, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0145	0.0152	0.0072	0.0067	0.006	0.0064	0.0102	0.0096	0.0084	0.0072		
				Avg. of filters 1 to 8												0.00771	
		pH	Lab			5.98	6.03	6.18	6.21	6.18	6.15	6.09	6.13	6.18	6.16		
				Avg. of filters 1 to 8												6.16	
		TOC, Total (mg/L)	Lab			5.4	6.2	4.8	4.5	4.5	4.5						
				Avg. of filters 1 to 8												4.575	
		Turbidity (NTU)	Lab			0.74	0.77	0.17	0.15	0.14	0.15	0.11	0.12	0.11	0.11		
				Avg. of filters 1 to 8												0.1325	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0339	0.0513	0.0503	0.0414		0.0457	0.0438	0.0513	0.0523	0.0519	0.0507		0.0485
		pH	Lab		8.15	5.25	5.21	5.51		5.53	5.51	5.08	4.91	4.94	4.94		5.2
		Temperature (ºC)	Lab		21.5												
		TOC, Total (mg/L)	Lab		14.7	4.6	4.7	4.6		4.5	4.8						3.6
		Turbidity (NTU)	Lab		1.69	0.33	0.38	0.11		0.12	0.16	0.07	0.06	0.06	0.07		0.11
August 24, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0169	0.0184	0.0057	0.005	0.0045	0.005	0.007	0.0066	0.0057	0.0052		
				Avg. of filters 1 to 8												0.00559	
		pH	Lab			6.03	6.08	6.2	6.19	6.18	6.14	6.06	6.09	6.07	6.09		
				Avg. of filters 1 to 8												6.1275	
		TOC, Total (mg/L)	Lab			5.7	5.4					4.8	4.8	4.6	4.7		
				Avg. of filters 1 to 8												4.725	
		Turbidity (NTU)	Lab			1.05	1.15	0.13	0.14	0.14	0.14	0.11	0.11	0.1	0.11		
				Avg. of filters 1 to 8												0.1225	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0319	0.0516	0.0494	0.0355	0.0344	0.0355		0.0373	0.0383	0.04	0.0383		0.0397
		pH	Lab		8.19	5.15	5.16	5.46	5.44	5.49		5.07	4.92	4.85	4.83		5.18
		Temperature (ºC)	Lab		20.3												
		TOC, Total (mg/L)	Lab		13.9	3.6	3.7					3.1	3.9	3	2.9		3.8
		Turbidity (NTU)	Lab		1.71	0.22	0.5	0.12	0.1	0.11		0.07	0.09	0.06	0.06		0.23
August 25, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0147	0.0154	0.0067	0.0072	0.0061	0.0071	0.009	0.0097	0.0088	0.0083		
				Avg. of filters 1 to 8												0.00786	
		pH	Lab			6.04	6.04	6.16	6.14	6.12	6.11	6.04	6.04	6.03	6.07		
				Avg. of filters 1 to 8												6.08875	
		TOC, Total (mg/L)	Lab			5.3	5.4	4.4	4.7	4.5	4.5						
				Avg. of filters 1 to 8												4.525	
		Turbidity (NTU)	Lab			0.85	0.9	0.14	0.16	0.14	0.13	0.1	0.1	0.11	0.1		
				Avg. of filters 1 to 8												0.1225	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0216	0.0505	0.0493	0.0366	0.0342	0.0367	0.0361		0.0385	0.0366	0.0375		0.0359
		pH	Lab		8.45	5.17	5.26	5.44	5.41	5.46	5.34		4.78	4.79	4.92		5.15
		TOC, Total (mg/L)	Lab		15.5	3.9	4.1	4.3	4	4	3.8						3.2
		Turbidity (NTU)	Lab		1.91	0.25	0.53	0.1	0.11	0.14	0.1		0.08	0.08	0.08		0.11
August 26, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0147	0.0146	0.007	0.0071	0.0065	0.0073	0.0106	0.0115	0.0092	0.009		
				Avg. of filters 1 to 8												0.00853	
		pH	Lab			5.96	6.03	6.15	6.12	6.09	6.1	6.05	6.08	6.05	6.07		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Extended Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall

Phase: Extended Piloting

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
August 26, 2017	Pilot-Scale	pH	Lab	Avg. of filters 1 to 8												6.08875	
		TOC, Total (mg/L)	Lab			5	5.2					4.2	4.4	5	5		
				Avg. of filters 1 to 8												4.65	
		Turbidity (NTU)	Lab			0.92	0.89	0.13	0.12	0.12	0.12	0.1	0.1	0.11	0.09		
				Avg. of filters 1 to 8												0.11125	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0144	0.0492	0.0491	0.0373	0.0379	0.0389	0.0373	0.0386	0.0386	0.0379			0.0438
		pH	Lab		8.34	5.16	5.16	5.37	5.34	5.41	5.35	5.02	4.85	4.87			5.25
		Temperature (ºC)	Lab		20.9												
		TOC, Total (mg/L)	Lab		14.5	4.3	3.6					3	3.1	3			3.5
		Turbidity (NTU)	Lab		1.88	0.27	0.44	0.1	0.08	0.09	0.09	0.07	0.08	0.08			0.23
August 27, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0172	0.0181	0.0084	0.0089	0.0082	0.0092	0.0141	0.0144	0.0129	0.0114		
				Avg. of filters 1 to 8												0.01094	
		pH	Lab			6.09	6.09	6.17	6.2	6.19	6.13	6.05	6.1	6.11	6.11		
				Avg. of filters 1 to 8												6.1325	
		TOC, Total (mg/L)	Lab			5.4	5.6	4.4	4.7	4.3	4.4						
				Avg. of filters 1 to 8												4.45	
		Turbidity (NTU)	Lab			1.05	1.07	0.14	0.14	0.13	0.14	0.09	0.11	0.13	0.11		
				Avg. of filters 1 to 8												0.12375	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.022	0.0515	0.05	0.0387	0.0372	0.0384	0.0386	0.0389		0.0406	0.04		0.0377
		pH	Lab		8.31	5.17	5.16	5.37	5.35	5.41	5.35	5.07		4.86	4.86		5.23
		Temperature (ºC)	Lab		20.7												
		TOC, Total (mg/L)	Lab		15.1	3.9	4	3.6	4	3.7	3.6						3.3
		Turbidity (NTU)	Lab		1.93	0.22	0.44	0.11	0.09	0.1	0.08	0.08		0.08	0.08		0.11
August 28, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0182	0.018	0.0282	0.0296	0.0273	0.0282	0.0209	0.0201	0.0201	0.02		
				Avg. of filters 1 to 8												0.0243	
		pH	Lab			6.05	6.04	6.17	6.12	6.13	6.07	5.98	6.03	6.08	6.06		
				Avg. of filters 1 to 8												6.08	
		TOC, Total (mg/L)	Lab			6.3	6.8					4.9	4.9	5	4.6		
				Avg. of filters 1 to 8												4.85	
		Turbidity (NTU)	Lab			1.16	1.31	0.18	0.15	0.14	0.15	0.15	0.14	0.14	0.15		
				Avg. of filters 1 to 8												0.15	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0404	0.0574	0.055	0.0407	0.0407		0.0397	0.0412	0.0419	0.0411	0.0409		0.0547
		pH	Lab		8.27	5.13	5.62	5.37	5.34		5.36	4.99	4.82	4.84	4.83		5.07
		Temperature (ºC)	Lab		20.1												
		TOC, Total (mg/L)	Lab									4.4	4.2	4.3	4.5		
		Turbidity (NTU)	Lab		1.98	0.38	0.59	0.1	0.13		0.11	0.08	0.09	0.1	0.09		0.13
August 29, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0205	0.0216	0.0114	0.0107	0.0102	0.0111	0.0149	0.0157	0.0142	0.0139		
				Avg. of filters 1 to 8												0.01276	
		pH	Lab			6	6.2	6.15	6.13	6.13	6.1	6.03	6.02	6.02	6.06		
				Avg. of filters 1 to 8												6.08	
		TOC, Total (mg/L)	Lab			6.7	6	5.3	5.2	5	5.2						
				Avg. of filters 1 to 8												5.175	
		Turbidity (NTU)	Lab			1.7	1.8	0.15	0.14	0.14	0.14	0.12	0.12	0.13	0.12		
				Avg. of filters 1 to 8												0.1325	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0391	0.0577	0.0559	0.0413	0.0414	0.0422	0.0438	0.0406	0.0419	0.0418	0.0437		0.0427
		pH	Lab		8.21	5	5.05	5.29	5.27	5.34	5.27	4.99	4.81	4.78	4.78		5.24
		Temperature (ºC)	Lab		20.8												
		TOC, Total (mg/L)	Lab		15.2	4.5	4.9	4.7	4.4	4.8	4.2						4.1
		Turbidity (NTU)	Lab		1.5	0.27	0.49	0.09	0.08	0.09	0.12	0.07	0.09	0.07	0.07		0.17
August 30, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0194	0.0201	0.0136	0.0153	0.0146	0.0159	0.0179	0.019	0.0193	0.019		
				Avg. of filters 1 to 8												0.01683	
		pH	Lab			5.96	6.12	6.16	6.11	6.1	6.08	6	6.02	6.01	6.02		
				Avg. of filters 1 to 8												6.0625	
		TOC, Total (mg/L)	Lab			5	5.9					4.5	4.3	5.4	4.5		
				Avg. of filters 1 to 8												4.675	
		Turbidity (NTU)	Lab			1.2	1.28	0.14	0.13	0.13	0.14	0.13	0.11	0.11	0.1		
				Avg. of filters 1 to 8												0.12375	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0534	0.0546	0.0551		0.0379	0.0384	0.0405	0.0388	0.041	0.0392	0.0404		0.0395
		pH	Lab		8.17	5.34	5.43		5.38	5.43	5.39	5.1	4.89	4.89	4.91		5.11
		Temperature (ºC)	Lab		20.6												
		TOC, Total (mg/L)	Lab		12.8	4.7	4.8					4	3.9	4	3.7		4.2
		Turbidity (NTU)	Lab		1.81	0.37	0.54		0.1	0.1	0.09	0.1	0.07	0.08	0.08		0.1
August 31, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0185	0.0189	0.0098	0.0101	0.0083	0.009	0.0141	0.0147	0.0129	0.0144		
				Avg. of filters 1 to 8												0.01166	
		pH	Lab			5.94	6.01	6.1	6.06	6.06	6.07	6.03	6.01	6.04	5.99		
				Avg. of filters 1 to 8												6.045	
		Turbidity (NTU)	Lab			0.94	1.02	0.16	0.12	0.13	0.13	0.11	0.1	0.1	0.1		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Extended Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall

Phase: Extended Piloting

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
August 31, 2017	Pilot-Scale	Turbidity (NTU)	Lab	Avg. of filters 1 to 8												0.11875	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0347	0.0544	0.053	0.0372	0.0371		0.0367	0.0405	0.0405	0.0406	0.0389		0.0375
		pH	Lab		8.63	5.39	5.57	5.48	5.46		5.52	5.21	5.09	5.08	5.13		5.28
		Temperature (ºC)	Lab		20.8												
		Turbidity (NTU)	Lab		1.63	0.34	0.47	0.09	0.12		0.09	0.08	0.08	0.08	0.09		0.1
September 1, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0191	0.0187	0.0099	0.0102	0.008	0.0089	0.0141	0.0156	0.013	0.0139		
				Avg. of filters 1 to 8												0.0117	
		pH	Lab			5.95	6.08	6.06	6.04	6.05	6.04	5.96	5.95	5.97	5.96		
				Avg. of filters 1 to 8												6.00375	
		TOC, Total (mg/L)	Lab			4.5	5.8					3.7	3.6	3.7	3.8		
				Avg. of filters 1 to 8												3.7	
		Turbidity (NTU)	Lab			1.08	0.98	0.13	0.12	0.15	0.13	0.1	0.11	0.11	0.12		
				Avg. of filters 1 to 8												0.12125	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0377	0.0537	0.0528	0.037	0.038	0.0377	0.0361	0.0396	0.0403		0.0413		0.04
		pH	Lab		8.45	5.39	5.43	5.5	5.49	5.52	5.47	5.2	5.11		5.1		5.34
		TOC, Total (mg/L)	Lab		8	3.3	3.8					2.6	2.6		2.5		3.4
		Turbidity (NTU)	Lab		1.82	0.31	0.5	0.1	0.09	0.1	0.11	0.09	0.08		0.07		0.17
September 2, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0185	0.0191	0.0109	0.0111	0.0088	0.0097	0.0166	0.0171	0.0163	0.0171		
				Avg. of filters 1 to 8												0.01345	
		pH	Lab			5.87	5.86	6.06	6.07	6	5.99	5.94	6.01	5.94	5.99		
				Avg. of filters 1 to 8												6	
		TOC, Total (mg/L)	Lab			4.7	4.4	3.8	3.8	3.8	3.8						
				Avg. of filters 1 to 8												3.8	
		Turbidity (NTU)	Lab			0.82	0.85	0.09	0.1	0.1	0.12	0.11	0.09	0.09	0.08		
				Avg. of filters 1 to 8												0.0975	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0382	0.0529	0.0528	0.0353	0.0367	0.0362		0.0388	0.0394	0.0407	0.0409		0.0395
		pH	Lab		8.35	5.34	5.35	5.52	5.47	5.61		5.27	5.17	5.13	5.14		5.35
		Temperature (ºC)	Lab		20.1												
		TOC, Total (mg/L)	Lab		8	3.1	3.6	3	3.1	3.1							3.5
		Turbidity (NTU)	Lab		1.68	0.37	0.46	0.11	0.1	0.1		0.08	0.12	0.07	0.07		0.14
September 3, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0173	0.0175	0.01	0.0104	0.0088	0.0096	0.0157	0.0164	0.0157	0.0161		
				Avg. of filters 1 to 8												0.01284	
		pH	Lab			5.89	5.91	6.1	6.1	6.05	6.03	5.95	5.98	5.95	5.99		
				Avg. of filters 1 to 8												6.01875	
		TOC, Total (mg/L)	Lab			4.3	4.3					3.8	3.6	3.7	3.6		
				Avg. of filters 1 to 8												3.675	
		Turbidity (NTU)	Lab			0.65	0.66	0.11	0.1	0.1	0.11	0.09	0.08	0.08	0.08		
				Avg. of filters 1 to 8												0.09375	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.035	0.0535	0.0502	0.0361	0.0346		0.0357	0.0389	0.0404	0.0399	0.0389		0.0393
		pH	Lab		8.38	5.38	5.34	5.51	5.49		5.56	5.25	5.11	5.14	5.12		5.35
		Temperature (ºC)	Lab		20.1												
		TOC, Total (mg/L)	Lab		9.2	3.7	3.6					3.5	4.3	3.2	3.3		3.3
		Turbidity (NTU)	Lab		1.85	0.27	0.41	0.08	0.1		0.09	0.07	0.08	0.09	0.08		0.11
September 4, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0183	0.0178	0.0106	0.011	0.0102	0.0111	0.0164	0.0164	0.0157	0.0167		
				Avg. of filters 1 to 8												0.01351	
		pH	Lab			5.84	5.86	6.07	6.07	6.01	5.97	5.93	5.93	5.94	5.93		
				Avg. of filters 1 to 8												5.98125	
		TOC, Total (mg/L)	Lab			4	3.5	3.1	3.1	3.1	3.3						
				Avg. of filters 1 to 8												3.15	
		Turbidity (NTU)	Lab			0.67	0.72	0.12	0.11	0.11	0.12	0.1	0.09	0.1	0.09		
				Avg. of filters 1 to 8												0.105	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0379	0.0516	0.0503	0.0348	0.0378	0.0374	0.037	0.042	0.0404		0.0426		0.0408
		pH	Lab		8.39	5.39	5.34	5.48	5.48	5.5	5.46	5.19	5.1		5.08		5.28
		Temperature (ºC)	Lab		20												
		TOC, Total (mg/L)	Lab		9.1	3.6	3	3.5	3.5	3.4	3.4						2.7
		Turbidity (NTU)	Lab		1.92	0.24	0.41	0.08	0.08	0.08	0.1	0.09	0.09		0.07		0.13
September 5, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0171	0.0172	0.0098		0.0096	0.0105	0.0152	0.0149	0.0143	0.0147		
				Avg. of filters 1 to 8												0.01271	
		pH	Lab			6.04	6.03	6.13	6.13	6.12	6.08	6	6.02	6.01	6.03		
				Avg. of filters 1 to 8												6.065	
		TOC, Total (mg/L)	Lab			4.5	4.4					3.6	3.6	3.7	3.7		
				Avg. of filters 1 to 8												3.65	
		Turbidity (NTU)	Lab			1.05	0.96	0.15	0.14	0.14	0.14	0.12	0.13	0.12	0.12		
				Avg. of filters 1 to 8												0.1325	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0357	0.0489	0.048	0.032	0.0328	0.0325	0.0329	0.0371		0.0378	0.0372		0.0388
		pH	Lab		8.31	5.31	5.38	5.56	5.51	5.58	5.51	5.25		5.07	5.06		5.42
		Temperature (ºC)	Lab		19.2												

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Extended Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall

Phase: Extended Piloting

Sample Location

Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
September 5, 2017	Full-Scale	TOC, Total (mg/L)	Lab									2.7		2.7	2.7		
		Turbidity (NTU)	Lab		1.83	0.27	0.46	0.13	0.1	0.11	0.1	0.09		0.09	0.09		0.14
September 8, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0195	0.0191	0.0148	0.0153	0.0139	0.0144	0.0178	0.0176	0.0178	0.0175		
				Avg. of filters 1 to 8												0.01614	
		pH	Lab			5.89	5.9	6.21	6.12	6.12	6.14	6.03	6.03	6.09	6.04		
				Avg. of filters 1 to 8												6.0975	
		TOC, Total (mg/L)	Lab			3.6	3.8					3.2	3.1	3.3	3.2		
				Avg. of filters 1 to 8												3.2	
		Turbidity (NTU)	Lab			0.7	0.68	0.13	0.13	0.1	0.11	0.1	0.1	0.1	0.13		
				Avg. of filters 1 to 8												0.1125	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0265	0.0474	0.046		0.031	0.0323	0.0314	0.0333	0.0346	0.0357	0.0353		0.0335
		pH	Lab		8.4	5.45	5.54		5.57	5.61	5.6	5.35	5.13	5.18	5.14		5.41
		TOC, Total (mg/L)	Lab		8.1	2.9	3.3					2.9	2.7	2.8	2.5		2.9
		Turbidity (NTU)	Lab		1.51	0.34	0.5		0.11	0.12	0.09	0.09	0.08	0.07	0.07		0.12
September 10, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0189	0.0184	0.0075	0.0078	0.0064	0.0075	0.0092	0.0099	0.0081	0.009		
				Avg. of filters 1 to 8												0.00818	
		pH	Lab			6.25	6.22	6.7	6.44	6.39	6.38	6.22	6.25	6.21	6.21		
				Avg. of filters 1 to 8												6.35	
		TOC, Total (mg/L)	Lab			3.9	4.2	3.6	3.6	3.2	3.4						
				Avg. of filters 1 to 8												3.45	
		Turbidity (NTU)	Lab			0.67	0.62	0.12	0.12	0.1	0.1	0.11	0.13	0.12	0.12		
				Avg. of filters 1 to 8												0.115	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0223	0.0473	0.0462	0.0309	0.0315	0.0308	0.0309		0.0323	0.0331			0.0332
		pH	Lab		8.23	5.71	5.72	5.94	5.87	5.94	5.85	5.52	5.41	5.44			5.72
		Temperature (ºC)	Lab		19.7												
		TOC, Total (mg/L)	Lab		8.3	3.3	8.4	3	2.9	3	2.8						2.9
		Turbidity (NTU)	Lab		1.69	0.35	0.42	0.11	0.11	0.1	0.13	0.07	0.08	0.09			0.13
September 12, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0188	0.018	0.0069	0.0066	0.0064	0.0068	0.0085	0.0091	0.0072	0.0078		
				Avg. of filters 1 to 8												0.00741	
		pH	Lab			5.93	5.96	6.42	6.32	6.25	6.25	6.28	6.24	6.27	6.28		
				Avg. of filters 1 to 8												6.28875	
		TOC, Total (mg/L)	Lab			3.9	3.7					3.5	3.4	3.6	3.5		
				Avg. of filters 1 to 8												3.5	
		Turbidity (NTU)	Lab			0.62	0.63	0.15	0.14	0.14	0.14	0.14	0.16	0.15	0.15		
				Avg. of filters 1 to 8												0.14625	
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0501	0.0486		0.0322	0.0326	0.0326	0.0321		0.034	0.0341		0.0321
		pH	Lab		8.14	5.45	5.5		5.69	5.64	5.58	5.31		5.38	5.3		5.43
		Temperature (ºC)	Lab		18.9												
		TOC, Total (mg/L)	Lab									2.7		2.7	2.9		
		Turbidity (NTU)	Lab		1.63	0.3	0.52		0.12	0.14	0.11	0.08		0.08	0.09		0.14
September 13, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0201	0.0199	0.0084	0.0077	0.0073	0.0079	0.0094	0.0098	0.0079	0.0089		
				Avg. of filters 1 to 8												0.00841	
		pH	Lab			6.09	6.11	6.4	6.39	6.41	6.38	6.27	6.26	6.74	6.62		
				Avg. of filters 1 to 8												6.43375	
		TOC, Total (mg/L)	Lab			3.9	4.2	3.4	3.8	3.5	3.3						
				Avg. of filters 1 to 8												3.5	
		Turbidity (NTU)	Lab			0.62	0.63	0.12	0.13	0.12	0.12	0.11	0.11	0.12	0.13		
				Avg. of filters 1 to 8												0.12	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0278	0.0508	0.0486	0.0322	0.0324	0.0327	0.0335			0.0364	0.0351		0.0366
		pH	Lab		8.18	5.62	5.63	5.74	5.76	5.78	5.79			5.42	5.31		5.55
		Temperature (ºC)	Lab		19.4												
		TOC, Total (mg/L)	Lab		8.1	3.3		3.2	3.6	3.3	3.2						
		Turbidity (NTU)	Lab		1.39	0.33	0.43	0.09	0.11	0.13	0.08			0.08	0.08		0.28
September 15, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0219	0.0216	0.0142	0.014	0.0104	0.011	0.0157	0.015	0.0134	0.0141		
				Avg. of filters 1 to 8												0.01348	
		pH	Lab			5.67	5.72	6.26	6.24	6.31	6.28	6.21	6.26	6.28	6.31		
				Avg. of filters 1 to 8												6.26875	
		TOC, Total (mg/L)	Lab			4.9	4.7					4.9	4.7	4.9	5.1		
				Avg. of filters 1 to 8												4.9	
		Turbidity (NTU)	Lab			0.97	0.87	0.09	0.11	0.08	0.08	0.09	0.09	0.11	0.09		
				Avg. of filters 1 to 8												0.0925	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.027	0.0497	0.0476	0.0423		0.0441	0.0433	0.0437		0.0426	0.0422		0.0426
		pH	Lab		8.01	5.61	5.61	5.57		5.7	5.64	5.38		5.35	5.6		5.49
		Temperature (ºC)	Lab		18.2												
		TOC, Total (mg/L)	Lab		18.9	4.3	3.7					3.4		3.1	3.4		3.8
		Turbidity (NTU)	Lab		1.44	0.37	0.45	0.16		0.14	0.14	0.1		0.11	0.09		0.13
September 17,	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0203	0.0208	0.0187	0.0202	0.0186	0.019	0.0216	0.0222	0.0211	0.0225		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Extended Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall

Phase: Extended Piloting

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
September 17, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab	Avg. of filters 1 to 8												0.02049	
		pH	Lab			5.88	5.99	6.1	6.06	6.11	6.13	6.03	6.03	6	6.08		
				Avg. of filters 1 to 8												6.0675	
		TOC, Total (mg/L)	Lab			8.1	8.2	6	5.4	5.9	6.4						
				Avg. of filters 1 to 8												5.925	
		Turbidity (NTU)	Lab			1.17	1.07	0.11	0.09	0.1	0.14	0.11	0.12	0.14	0.11		
				Avg. of filters 1 to 8												0.115	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0237	0.0484	0.0455	0.0405	0.0417	0.0422		0.0402		0.0397	0.04		0.0441
		pH	Lab		7.93	5.57	5.51	5.76	5.79	5.97		5.54		5.27	5.27		5.57
		Temperature (ºC)	Lab		16.1												
		TOC, Total (mg/L)	Lab		20.3	7	4.7	6.2	6.5	5.7							7.9
		Turbidity (NTU)	Lab		1.6	0.42	0.42	0.11	0.09	0.14		0.1		0.19	0.07		0.26
September 19, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0184	0.019	0.0141	0.0165	0.0138	0.0139	0.0164	0.0169	0.0158	0.0167		
				Avg. of filters 1 to 8												0.01551	
		pH	Lab			5.98	5.98	6.18	6.14	6.14	6.16	6.16	6.17	6.13	6.17		
				Avg. of filters 1 to 8												6.15625	
		TOC, Total (mg/L)	Lab			8.1	7					6.8	6.8	6.3	6.3		
				Avg. of filters 1 to 8												6.55	
		Turbidity (NTU)	Lab			1.1	1.15	0.17	0.14	0.15	0.14	0.16	0.16	0.16	0.14		
				Avg. of filters 1 to 8												0.1525	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0229	0.0485	0.0474	0.0343	0.0343	0.0338	0.0371			0.041	0.0402		0.0373
		pH	Lab		7.84	5.49	5.54	5.64	5.62	5.75	5.6			5.22	5.16		5.52
		Temperature (ºC)	Lab		16.4												
		TOC, Total (mg/L)	Lab		18.6	8	5.3							5.7	5.8		5.4
		Turbidity (NTU)	Lab		1.37	0.37	0.42	0.09	0.12	0.13	0.07			0.07	0.09		0.17
September 20, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0171	0.0176	0.0182	0.0188	0.0178	0.018	0.0203	0.0208	0.0206	0.0204		
				Avg. of filters 1 to 8												0.01936	
		pH	Lab			5.67	5.77	5.96	5.93	5.93	5.95	5.93	5.88	5.91	5.96		
				Avg. of filters 1 to 8												5.93125	
		TOC, Total (mg/L)	Lab			6.4	6.4	4.7	4.5	4.9	5						
				Avg. of filters 1 to 8												4.775	
		Turbidity (NTU)	Lab			1.02	1.04	0.13	0.09	0.1	0.1	0.1	0.1	0.1	0.1		
				Avg. of filters 1 to 8												0.1025	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0235	0.049	0.0483	0.0332		0.0335	0.0334	0.0402	0.0406	0.0401			0.0379
		pH	Lab		7.97	5.51	5.47	5.63		5.63	5.57	5.11	5.13	5.13			5.3
		Temperature (ºC)	Lab		16.3												
		TOC, Total (mg/L)	Lab		18.3	5.2	4.7	6.1		5.3	5.7						5.5
		Turbidity (NTU)	Lab		1.46	0.3	0.43	0.1		0.08	0.09	0.07	0.08	0.07			0.09
September 22, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0147	0.015	0.0181	0.0188	0.0171	0.0182	0.0201	0.0201	0.0202	0.0202		
				Avg. of filters 1 to 8												0.0191	
		pH	Lab			6.08	5.89	5.88	5.88	5.87	5.87	5.83	5.84	5.82	5.68		
				Avg. of filters 1 to 8												5.83375	
		TOC, Total (mg/L)	Lab			6.5	6.5					6	4.4	6.7	5.5		
				Avg. of filters 1 to 8												5.65	
		Turbidity (NTU)	Lab			0.87	0.87	0.15	0.17	0.17	0.15	0.16	0.13	0.17	0.14		
				Avg. of filters 1 to 8												0.155	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0232	0.0461	0.0451		0.0322	0.0314		0.0324	0.037	0.0372	0.0363		0.0353
		pH	Lab		7.95	5.48	5.51		5.55	5.61		5.47	5.23	5.22	5.19		5.34
		Temperature (ºC)	Lab		16.1												
		TOC, Total (mg/L)	Lab		22.2	5.2	5.8					4.9	3.3	5	5.9		6.1
		Turbidity (NTU)	Lab		1.49	0.31	0.55		0.1	0.1		0.12	0.12	0.09	0.09		0.28
September 24, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0141	0.014	0.0173	0.0193	0.0177	0.0173	0.0205	0.0189	0.0188	0.019		
				Avg. of filters 1 to 8												0.0186	
		pH	Lab			5.89	5.83	5.93	5.89	5.9	5.89	5.86	5.81	5.85	5.87		
				Avg. of filters 1 to 8												5.875	
		TOC, Total (mg/L)	Lab			7.2	6	5.7	6	6.2	5.1						
				Avg. of filters 1 to 8												5.75	
		Turbidity (NTU)	Lab			0.95	0.96	0.15	0.16	0.15	0.14	0.15	0.2	0.14	0.17		
				Avg. of filters 1 to 8												0.1575	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0159	0.044	0.0419	0.0343	0.0345	0.0345	0.0348	0.0378	0.0379				0.0403
		pH	Lab		7.93	5.31	5.34	5.57	5.61	5.6	5.46	5.31	5.27				5.46
		Temperature (ºC)	Lab		15.3												
		TOC, Total (mg/L)	Lab		20.4	5.2	5.5	4.6	5.3	4.6	3.7						5.6
		Turbidity (NTU)	Lab		1.35	0.41	0.51	0.17	0.15	0.16	0.13	0.09	0.1				0.28
September 26, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0138	0.0134	0.0163	0.0169	0.0168	0.0166	0.0166	0.0171	0.0173	0.0181		
		pH	Lab			5.89	5.9	5.96	5.92	5.91	5.91	5.88	5.89	5.89	5.93		
		TOC, Total (mg/L)	Lab			6	5.2					5.4	4.6	4.9	5.5		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Extended Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Extended Piloting

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
September 26, 2017	Pilot-Scale	Turbidity (NTU)	Lab			1.02	1.05	0.13	0.13	0.13	0.14	0.13	0.12	0.12	0.12		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0179	0.0435	0.0421	0.0329			0.0331	0.0336	0.0355	0.0351	0.0353		0.034
		pH	Lab		7.9	5.28	5.32	5.5			5.46	5.18	5.02	5.04	5.04		5.19
		Temperature (ºC)	Lab		15.1												
		TOC, Total (mg/L)	Lab		21.9	4.5	3.5					3.6	3.2	4.3	4.1		3.8
		Turbidity (NTU)	Lab		1.15	0.45	0.57	0.19			0.21	0.1	0.09	0.15	0.09		0.14
September 27, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0112	0.0115	0.0136	0.0137	0.0135	0.0134	0.0143	0.0142	0.0138	0.015		
		pH	Lab			5.87	5.88	5.93	5.92	5.93	6.16	5.91	5.93	5.88	5.92		
		TOC, Total (mg/L)	Lab			7.8	7	6.2	6.1	7.7	6.7						
		Turbidity (NTU)	Lab			1.46	1.31	0.16	0.14	0.14	0.14	0.14	0.14	0.29	0.15		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0135	0.0376	0.0356	0.0273	0.0271	0.0282	0.0284	0.0314			0.0322		0.029
		pH	Lab		7.9	5.42	5.41	5.5	5.49	5.52	5.4	5.17			4.96		5.36
		Temperature (ºC)	Lab		14.9												
		TOC, Total (mg/L)	Lab		22.3	7.2	6.2	5.9	6.3	5.1	5.2						5.1
		Turbidity (NTU)	Lab		1.18	0.39	0.57	0.18	0.14	0.17	0.11	0.09			0.07		0.16
September 29, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0108	0.0109	0.0139	0.0145	0.014	0.0141	0.0147	0.0145	0.0151	0.0149		
		pH	Lab			5.91	5.86	6.01	5.98	5.97	5.97	5.93	5.97	5.91	5.96		
		TOC, Total (mg/L)	Lab			6.6	9.7					6.7	6.1	6.5	6.9		
		Turbidity (NTU)	Lab			0.64	0.69	0.16	0.13	0.13	0.21	0.13	0.13	0.12	0.15		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0174	0.0375		0.027			0.0272	0.0284	0.0307	0.0297	0.029		0.0283
		pH	Lab		7.95	5.35	5.47	5.59			5.53	5.17	4.93	4.92	4.95		5.15
		Temperature (ºC)	Lab		14.3												
		TOC, Total (mg/L)	Lab		24.2	6.4						5.8	4.5	4.1	3.1		5.6
		Turbidity (NTU)	Lab		1.06	0.46	0.6	0.16			0.17	0.12	0.09	0.11	0.1		0.12
October 1, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0108	0.0108	0.0127	0.0128	0.0117	0.0121	0.0138	0.0129	0.0124	0.0136		
		pH	Lab			5.91	5.86	5.98	5.97	5.98	5.95	5.91	5.9	5.91	5.95		
		TOC, Total (mg/L)	Lab			8.4	7.4	7.9	6	6.1	5.1						
		Turbidity (NTU)	Lab			0.73	0.71	0.18	0.18	0.18	0.17	0.16	0.16	0.17	0.16		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0128	0.0377	0.0375		0.0258	0.0268		0.0283	0.0319	0.0315	0.0315		0.0291
		pH	Lab		7.97	5.61	5.65		5.7	5.76		5.54	5.33	5.33	5.37		5.5
		Temperature (ºC)	Lab		14.4												
		TOC, Total (mg/L)	Lab		21.7	6.9	6.3		5.6	5.8							4.6
		Turbidity (NTU)	Lab		1.06	0.45	0.55		0.19	0.22		0.17	0.08	0.08	0.09		0.15
October 3, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0105	0.0108	0.0102	0.0098	0.01	0.0103	0.0112	0.0113	0.0109	0.0114		
		pH	Lab			6.02	5.97	6.11	6.1	6.09	6.05	5.99	5.97	6	5.26		
		TOC, Total (mg/L)	Lab			6.8	6.9					5.4	5.1	5.1	5		
		Turbidity (NTU)	Lab			0.54	0.53	0.1	0.12	0.11	0.11	0.1	0.11	0.14	0.11		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0121	0.04	0.0383	0.0259	0.0267	0.0267	0.0272	0.0325	0.0315				0.029
		pH	Lab		7.92	5.51	5.53	5.65	5.64	5.71	5.57	5.32	5.26				5.51
		Temperature (ºC)	Lab		14.2												
		TOC, Total (mg/L)	Lab		22.6	5.2	5					3.6	3.6				5.2
		Turbidity (NTU)	Lab		1.05	0.36	0.52	0.17	0.14	0.16	0.14	0.07	0.1				0.18
October 4, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0131	0.0135	0.011	0.012	0.0112	0.0121	0.0121	0.0122	0.0131	0.0122		
		pH	Lab			5.98	5.93	6.13	6.08	6.09	6.03	5.99	5.98	5.98	6		
		TOC, Total (mg/L)	Lab			3.9	4	2.8	3.4	3	3.1						
		Turbidity (NTU)	Lab			0.5	0.51	0.1	0.11	0.07	0.08	0.09	0.08	0.08	0.09		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0143	0.0448	0.0394		0.028	0.0274	0.0285	0.0309		0.0341	0.0334		0.0312
		pH	Lab		7.94	5.63	5.56		5.67	5.72	5.7	5.55		5.25	5.26		5.47
		Temperature (ºC)	Lab		14.1												
		TOC, Total (mg/L)	Lab		19.7	3.4	3.9		4.4	4	4.1						3.6
		Turbidity (NTU)	Lab		1.2	0.4	0.59		0.15	0.19	0.22	0.11		0.07	0.07		0.13
October 6, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.017	0.0161	0.0108	0.0103	0.0091	0.0099	0.0118	0.0116	0.0108	0.0109		
		pH	Lab			6.09	5.99	6.4	6.12	6.21	6.18	6.09	6.13	6.13	6.15		
		TOC, Total (mg/L)	Lab			8.5	9.3					7	7	5.7	5.5		
		Turbidity (NTU)	Lab			0.56	0.68	0.09	0.12	0.08	0.09	0.06	0.09	0.07	0.07		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.047	0.0382	0.0361	0.0249	0.0264	0.0275	0.0276	0.0319	0.0309				0.0279
		pH	Lab		7.92	5.4	5.47	5.68	5.66	5.65	5.48	5.33	5.28				5.53
		TOC, Total (mg/L)	Lab		21.3	6.2	6.4					5.2	5.5				5.9
		Turbidity (NTU)	Lab		1.81	0.31	0.43	0.11	0.09	0.09	0.09	0.08	0.08				0.11
October 7, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0141	0.0141	0.011	0.0104	0.0086	0.0095	0.0122	0.0116	0.0105	0.0107		
		pH	Lab			6.01	6	6.18	6.21	6.2	6.13	6.04	6.09	6.07	6.12		
		TOC, Total (mg/L)	Lab			6.5	6.4	6.4	6.6	6.5	6.3						
		Turbidity (NTU)	Lab			0.52	0.51	0.09	0.09	0.14	0.1	0.09	0.12	0.11	0.09		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0164	0.039	0.0369	0.0284	0.0262	0.0254	0.0247	0.0284	0.0305	0.03	0.031		0.0307
		pH	Lab		7.97	5.36	5.43	5.48	5.43	5.47	5.43	5.44	5.43	5.55	5.4		5.43
		TOC, Total (mg/L)	Lab		23.4	6	5.1	5.7	5.9	5.5	5.2						5.6
		Turbidity (NTU)	Lab		1.05	0.25	0.38	0.11	0.06	0.07	0.09	0.08	0.08	0.2	0.09		0.13

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Extended Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Extended Piloting

					Sample Location												
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Filter Effluent Average**	**Combined Filtrate**
October 8, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0133	0.0136	0.0095	0.0089	0.0091	0.0103	0.0113	0.0113	0.0107	0.0113		
		pH	Lab			6.02	5.98	6.25	6.21	6.22	6.16	6.08	6.11	6.1	6.15		
		TOC, Total (mg/L)	Lab			7.5	7.2					7	6.6	7.1	6.7		
		Turbidity (NTU)	Lab			0.57	0.61	0.11	0.1	0.08	0.09	0.09	0.1	0.09	0.08		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0163	0.0381	0.0362	0.0252	0.0289		0.0255		0.0297	0.0297	0.0293		0.029
		pH	Lab		8	5.53	5.53	5.49	5.51		5.51		5.51	5.51	5.49		5.47
		Temperature (ºC)	Lab		12.6												
		TOC, Total (mg/L)	Lab		23.3	6.7	5.7						6	6.9	5.3		5.4
		Turbidity (NTU)	Lab		1.04	0.32	0.49	0.1	0.13		0.09		0.1	0.11	0.13		0.17
October 9, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0134	0.0133	0.0092	0.0086	0.0091	0.0101	0.0105	0.0109	0.0105	0.0109		
		pH	Lab			6.08	6.02	6.25	6.23	6.17	6.14	6.07	6.08	6.11	6.1		
		TOC, Total (mg/L)	Lab			9	6.4	5.6	5.7	6.1	6.1						
		Turbidity (NTU)	Lab			0.65	0.65	0.16	0.11	0.11	0.1	0.13	0.1	0.14	0.11		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0158	0.0385	0.0364	0.0243	0.0251	0.0246	0.0265	0.03	0.0309				0.0269
		pH	Lab		8.05	5.53	5.54	5.52	5.5	5.55	5.55	5.55	5.5				5.48
		Temperature (ºC)	Lab		12.1												
		TOC, Total (mg/L)	Lab		23.5	6.2	7.2	6	6.7	5.7	6.5						5.4
		Turbidity (NTU)	Lab		1.09	0.32	0.51	0.11	0.09	0.11	0.1	0.1	0.18				0.16

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Extended Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Stabilization

					Sample Location											
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Combined Filtrate**
October 10, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0122	0.0126	0.0098	0.009	0.0092	0.0099	0.0111	0.0115	0.0104	0.0114	
		pH	Lab			6.09	6.01	6.25	6.25	6.24	6.14	6.05	6.09	6.09	6.08	
		TOC, Total (mg/L)	Lab			8.7	7.8					6.8	7.5	6.8	7.7	
		Turbidity (NTU)	Lab			0.8	0.77	0.13	0.13	0.14	0.13	0.12	0.14	0.13	0.12	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0148	0.0408	0.0391		0.0251	0.0253		0.0268	0.0323	0.0312	0.0302	0.0291
		pH	Lab		8.13	5.5	5.57		5.55	5.55		5.56	5.54	5.56	5.55	5.55
		Temperature (ºC)	Lab		11.5											
		TOC, Total (mg/L)	Lab		20.9	8.6	8.7					6.7	8.5	7	6.3	8.8
		Turbidity (NTU)	Lab		1.1	0.45	0.57		0.12	0.13		0.12	0.1	0.11	0.1	0.14
October 11, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0115	0.0114	0.0093	0.0087	0.0079	0.0091	0.0105	0.0107	0.0099		
		pH	Lab			5.97	5.94	6.23	6.22	6.23	6.15	6.05	6.09	6.1	6.09	
		TOC, Total (mg/L)	Lab			7.8	8.9	7.1	7.3		6.9					
		Turbidity (NTU)	Lab			0.87	0.86	0.16	0.21	0.19	0.17	0.16	0.15	0.15	0.15	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0155	0.0389	0.038	0.0245			0.0252	0.0277	0.0306	0.0297	0.0302	0.0279
		pH	Lab		8.08	5.52	5.57	5.53			5.54	5.53	5.57	5.53	5.53	5.5
		Temperature (ºC)	Lab		11.4											
		TOC, Total (mg/L)	Lab		23.4	6.6	6.3	6.5			5.9					6.3
		Turbidity (NTU)	Lab		1.07	0.27	0.48	0.09			0.11	0.09	0.1	0.14	0.12	0.14
October 12, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0116	0.0113	0.0092	0.0089	0.0078	0.0092	0.0103	0.0106	0.0103	0.0105	
		pH	Lab			6.02	5.98	6.21	6.21	6.26	6.16	6.05	6.08	6.07	6.08	
		TOC, Total (mg/L)	Lab			8.8	9.1					6.9	7.9	8.8	7.3	
		Turbidity (NTU)	Lab			1.11	0.89	0.17	0.19	0.18	0.17	0.2	0.17	0.17	0.17	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0142	0.0422	0.0395	0.0247	0.0256	0.0264	0.0282	0.0305			0.0314	0.0283
		pH	Lab		8.11	5.46	5.52	5.56	5.56	5.57	5.56	5.58			5.55	5.5
		Temperature (ºC)	Lab		11.1											
		TOC, Total (mg/L)	Lab		23.9	6.2	5.7					6.6			5.9	6.5
		Turbidity (NTU)	Lab		1.12	0.26	0.45	0.11	0.1	0.09	0.1	0.1			0.09	0.13
October 13, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0113	0.0106	0.0092	0.0085	0.0083	0.0089	0.0104	0.0099	0.0096	0.0099	
		pH	Lab			6.01	5.97	6.23	6.21	6.16	6.09	5.98	6.02	5.97	5.98	
		TOC, Total (mg/L)	Lab			8.2	7.5	6.8	6	7.1	6.5					
		Turbidity (NTU)	Lab			0.94	1.19	0.34	0.35	0.34	0.45	0.38	0.32	0.4	0.35	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0144	0.0408	0.0399	0.0271	0.0264	0.0266			0.0324	0.0322	0.0311	0.0302
		pH	Lab		8.08	5.49	5.55	5.55	5.51	5.54			5.52	5.57	5.47	5.42
		TOC, Total (mg/L)	Lab		25.2	4.2	4	4.9	5	4.3						3.8
		Turbidity (NTU)	Lab		1.19	0.38	0.45	0.08	0.08	0.09			0.08	0.08	0.08	0.12
October 14, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0105	0.0108	0.0079	0.0076	0.0074	0.0085	0.0092	0.0093	0.009	0.0094	
		pH	Lab			6	6	6.24	6.24	6.24	6.14	6.07	6.11	6.08	6.09	
		TOC, Total (mg/L)	Lab			7.1	8.2					8.1	7.1	6.9	7	
		Turbidity (NTU)	Lab			1	0.95	0.22	0.21	0.2	0.18	0.19	0.18	0.19	0.18	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0149	0.0407	0.0392	0.0264			0.0265	0.0285	0.0314	0.0306	0.03	0.0305
		pH	Lab		8.12	5.5	5.54	5.52			5.49	5.53	5.57	5.54	5.56	5.54
		TOC, Total (mg/L)	Lab		25.2	4.4	3.8					8.3	4.5	3.7	5	4.3
		Turbidity (NTU)	Lab		1.04	0.27	0.39	0.07			0.07	0.07	0.1	0.1	0.1	0.14
October 15, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0103	0.0101	0.0076	0.0075	0.0076	0.0085	0.0089	0.0092	0.0086	0.0089	
		pH	Lab			6.03	6.04	6.29	6.28	6.29	6.16	6.11	6.13	6.1	6.12	
		TOC, Total (mg/L)	Lab			9.2	9.4	7.7	8.2	8.4	8.9					
		Turbidity (NTU)	Lab			1.06	1.19	0.22	0.24	0.22	0.2	0.24	0.23	0.25	0.21	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0129	0.0411	0.0393	0.026	0.0264	0.026	0.0281	0.031			0.0313	0.0289
		pH	Lab		8.11	5.47	5.54	5.51	5.51	5.53	5.57	5.56			5.54	5.5
		Temperature (ºC)	Lab		10											
		TOC, Total (mg/L)	Lab		23.9	6.2	7.3	6.1	6.6	5.5	6.4					6.9
		Turbidity (NTU)	Lab		1.04	0.32	0.45	0.1	0.08	0.08	0.08	0.09			0.08	0.12

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Stabilization. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 16, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.3	179.2	177.2	178.9	178.9	178.6	178.8	180.8	180.3	181.1	181	179.4
		DO (mg/L)	Bench		10.1	9.4	10.9	10.7	10.7	10.8	10.5	10.6	10.3	10.5	10.6	10.6
		Manganese, Total (mg/L)	Bench		0.02	0.025	0.03	0.027	0.028	0.021	0.023	0.029	0.018	0.018	0.018	0.015
		Oxi-Red Potenital (ORP) (mV)	Bench		271.3	244.6	326.3	448.6	447.6	452.4	441.6	444.6	448.6	446.4	445.6	443.2
		pH	Bench		7.26	5.93	5.96	6.05	6.04	6.02	6	5.98	5.96	5.96	5.98	5.99
		Temperature (ºC)	Bench		10.4	10.5	11	11.4	11.4	11.3	11.4	11.4	11.5	11.5	11.6	11.5
		Turbidity (NTU)	Bench		1.52	1.7	1.58	0.56	0.65	0.7	0.69	0.48	0.49	0.46	0.49	0.56
		UVA @254nm, Unfiltered (/cm)	Bench		0.126	0.156	0.155	0.061	0.06	0.062	0.067	0.058	0.058	0.056	0.057	0.06
		UVT @ 254nm, Unfiltered (%T)	Bench		74.7	69.8	70.2	86.8	87.1	86.6	85.6	87.4	87.5	87.8	87.7	87.1
	Full-Scale	Conductivity Total (µS/cm)	Bench			187.8	184.9									186.2
		DO (mg/L)	Bench			11	12.7									10.1
		Manganese, Total (mg/L)	Bench			0.051	0.047									0.041
		Oxi-Red Potenital (ORP) (mV)	Bench			456.3	513.9									349.4
		pH	Bench			5.51	5.63									5.6
		Temperature (ºC)	Bench			10.2	10.3									10.1
		Turbidity (NTU)	Bench			0.54	0.58									0.41
		UVA @254nm, Unfiltered (/cm)	Bench			0.05	0.044									0.023
		UVT @ 254nm, Unfiltered (%T)	Bench			89.1	90.3									94.9
October 17, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.3	178.6	177.5	178.3	177.8	177.5	179.2	178.5	179.1	178.9	179.5	178.9
		DO (mg/L)	Bench		10.5	10.4	10.3	10.2	10.2	10.2	10	10.1	10	10.1	10.2	10.5
		Manganese, Total (mg/L)	Bench		0.022	0.029	0.024	0.021	0.017	0.016	0.019	0.017	0.02	0.021	0.018	0.016
		Oxi-Red Potenital (ORP) (mV)	Bench		248.2	238.5	292	336.5	351.8	353	333	301	394.6	398.8	406.1	402.2
		pH	Bench		7.32	5.89	5.85	6	5.99	5.94	5.93	5.94	5.92	5.92	5.92	5.9
		Temperature (ºC)	Bench		10.6	10.5	11.1	11	11.1	11.1	11	11.1	11.2	11.1	11	10.9
		Turbidity (NTU)	Bench		1.08	1.69	1.46	0.36	0.35	0.37	0.36	0.32	0.38	0.37	0.4	0.33
		UVA @254nm, Unfiltered (/cm)	Bench		0.123	0.124	0.127	0.048	0.043	0.041	0.045	0.043	0.042	0.043	0.043	0.043
		UVT @ 254nm, Unfiltered (%T)	Bench		75.3	75.1	74.8	89.7	90.6	91	90.3	90.5	90.7	90.5	90.6	90.5
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.2	186.6									188
		DO (mg/L)	Bench			10.7	11.7									10.9
		Manganese, Total (mg/L)	Bench			0.052	0.047									0.039
		Oxi-Red Potenital (ORP) (mV)	Bench			389.7	384.6									327.3
		pH	Bench			5.55	5.66									5.63
		Temperature (ºC)	Bench			10.1	10.3									10.7
		Turbidity (NTU)	Bench			0.54	0.57									0.16
		UVA @254nm, Unfiltered (/cm)	Bench			0.049	0.043									0.015
		UVT @ 254nm, Unfiltered (%T)	Bench			89.3	90.5									96.5
October 18, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		150.9	177.6	184.5	174.8	175.1	175.3	176.3	172.4	175.5	172.5	172.5	173.5
		DO (mg/L)	Bench		10.8	10	10.8	10.7	10.7	10.8	10.7	10.4	10.4	10.5	10.6	10.9
		Manganese, Total (mg/L)	Bench		0.019	0.029	0.026	0.025	0.019	0.014	0.017	0.013	0.012	0.012	0.01	0.012
		Oxi-Red Potenital (ORP) (mV)	Bench		174.4	197.4	263.1	298.3	297.2	284.4	285.5	286.7	281.9	279	274.1	255.9
		pH	Bench		7.18	5.85	5.91	6.05	5.99	5.98	5.96	5.94	5.91	5.92	5.93	5.89
		Temperature (ºC)	Bench		10.2	10.3	10.6	10.9	11	10.9	11	11.1	11.3	11.3	11.2	10.8
		Turbidity (NTU)	Bench		1.43	1.03	1.2	0.35	0.28	0.26	0.27	0.21	0.2	0.19	0.21	0.24
		UVA @254nm, Unfiltered (/cm)	Bench		0.12	0.125	0.133	0.034	0.033	0.028	0.031	0.025	0.023	0.027	0.028	0.025
		UVT @ 254nm, Unfiltered (%T)	Bench		75.9	75	73.8	92.3	92.7	93.7	93.1	94.3	94.9	94.1	93.7	92.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			187.6	188.2									184.4
		DO (mg/L)	Bench			10.5	11.2									9.9
		Manganese, Total (mg/L)	Bench			0.044	0.043									0.038
		Oxi-Red Potenital (ORP) (mV)	Bench			261.6	264.2									272.5
		pH	Bench			5.51	5.63									5.41
		Temperature (ºC)	Bench			9.9	10.4									10.1
		Turbidity (NTU)	Bench			0.54	0.5									0.29
		UVA @254nm, Unfiltered (/cm)	Bench			0.048	0.057									0.025
		UVT @ 254nm, Unfiltered (%T)	Bench			89.5	97.6									94.4
October 19, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		147.9	176.8	177.3	177.3	176.5	179.8	179.6	180.8	182.1	181.8	179.7	180.4
		DO (mg/L)	Bench		9.1	9.9	11	10.3	10.1	10.2	10.5	10.2	10	10.1	10.4	10.7
		Manganese, Total (mg/L)	Bench		0.021	0.024	0.024	0.021	0.019	0.021	0.02	0.019	0.021	0.017	0.018	0.019
		Oxi-Red Potenital (ORP) (mV)	Bench		205.8	247.4	261.1	356.9	353.6	350.5	347.4	339	330.9	317.2	307.1	287.2
		pH	Bench		7.26	5.8	5.83	5.91	5.9	5.9	5.86	5.87	5.87	5.86	5.88	5.86
		Temperature (ºC)	Bench		10.2	10.3	11	11.2	11.2	11.3	11.3	11.3	11.4	11.3	11.5	10.7
		Turbidity (NTU)	Bench		1.47	1.05	1.07	0.32	0.26	0.18	0.12	0.11	0.1	0.14	0.1	0.15
		UVA @254nm, Unfiltered (/cm)	Bench		0.119	0.107	0.106	0.028	0.029	0.03	0.027	0.026	0.025	0.023	0.023	0.023
		UVT @ 254nm, Unfiltered (%T)	Bench		76.1	78.2	78.4	93.8	93.6	93.3	94	94.2	94.5	94.8	94.8	94.9
	Full-Scale	Conductivity Total (µS/cm)	Bench			182.5	181.3									187.5

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 19, 2017	Full-Scale	DO (mg/L)	Bench			10.6	10.8									8.1
		Manganese, Total (mg/L)	Bench			0.05	0.047									0.05
		Oxi-Red Potenital (ORP) (mV)	Bench			276.2	273.1									284.8
		pH	Bench			5.47	5.56									5.48
		Temperature (ºC)	Bench			9.9	10.3									10.9
		Turbidity (NTU)	Bench			0.38	0.51									0.2
		UVA @254nm, Unfiltered (/cm)	Bench			0.046	0.056									0.031
		UVT @ 254nm, Unfiltered (%T)	Bench			89.9	87.9									93.1
October 20, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		149.9	185.1	175.5	176.4	176.6	177.1	178.8	178	179.2	179.5	178.4	176.4
		DO (mg/L)	Bench		9.7	10.9	10.2	10.1	10.2	10.4	10.3	10.1	10.1	10.2	10.1	10.3
		Manganese, Total (mg/L)	Bench		0.019	0.025	0.027	0.018	0.014	0.018	0.018	0.015	0.016	0.016	0.017	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		197.8	230.2	239.8	393.3	347.6	345.8	337.4	341.5	346.3	341.7	340.3	328.8
		pH	Bench		7.34	5.78	5.81	5.92	5.91	5.89	5.86	5.85	5.88	5.87	5.84	5.83
		Temperature (ºC)	Bench		10.2	10.5	11	11.1	11.2	11.2	1.1	11.2	11.4	11.5	11.3	10.6
		Turbidity (NTU)	Bench		1.19	1.17	0.85	0.28	0.18	0.23	0.13	0.2	0.25	0.27	0.19	0.25
		UVA @254nm, Unfiltered (/cm)	Bench		0.115	0.119	0.109	0.045	0.04	0.038	0.036	0.036	0.034	0.035	0.037	0.045
		UVT @ 254nm, Unfiltered (%T)	Bench		76.7	75.9	77.8	90.2	91.3	91.8	92	92	92.5	92.2	91.8	90.2
	Full-Scale	Conductivity Total (µS/cm)	Bench			185.1	186.1									191.3
		DO (mg/L)	Bench			10.4	11.9									11.6
		Manganese, Total (mg/L)	Bench			0.046	0.041									0.038
		Oxi-Red Potenital (ORP) (mV)	Bench			330.6	375.3									323.5
		pH	Bench			5.53	5.7									5.63
		Temperature (ºC)	Bench			9.8	10.3									10.1
		Turbidity (NTU)	Bench			0.43	0.67									0.21
		UVA @254nm, Unfiltered (/cm)	Bench			0.054	0.053									0.02
		UVT @ 254nm, Unfiltered (%T)	Bench			88.4	88.5									95.4
October 21, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		74	11	11	11	11	11	11	11	11	11	12	11
		Aluminum, Dissolved (mg/L)	Lab			0.004	0.006	0.003	0.003	0.003	0.004	0.003	0.003	0.003	0.003	0.003
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.008	0.008				0.004	0.003	0.003	0.003	0.003	0.003
				N/D at <0.003	G/N			G/N	G/N	G/N						
		Antimony, Dissolved (mg/L)	Lab		0.0009	0.0012	0.0008	0.00171	0.00105	0.00146	0.00236	0.00108	0.00136	0.0014	0.00132	0.00083
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00071	0.00036	0.00037	0.00033	0.00032	0.00034	0.00034	0.00032	0.00033	0.00032	0.00034	0.00032
		Arsenic, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		19.3	19.3	19.1	18.8	19.1	18.9	19.4	19.4	20	19	19.5	19.4
		Calcium, Total (mg/L)	Lab		19.3	18.3	19.3	19	19.5	18.7	19.6	19.3	19.6	19.2	19.6	20
		Chromium, Dissolved (mg/L)	Lab							0.00004						
				N/D at <0.00003	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N
		Chromium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		12	3	3	2.5	1.5	1	2	1	1	1.5	1	2
		Conductivity Total (µS/cm)	Bench		149.7	180.1	181	180.1	179.2	178.8	180	178.9	178.8	179.3	177.6	178.1
			Lab		160	189	189	189	189	189	189	190	191	190	190	189
		Copper, Dissolved (mg/L)	Lab		0.0012	0.0004	0.0005	0.0004	0.0004	0.0005	0.0006	0.0005	0.0005	0.0005	0.0005	0.0016
		Copper, Total (mg/L)	Lab													0.002
				N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		10.3	10.4	11.1	10.7	10.4	10.3	10.1	9.7	9.6	9.7	9.6	9.9
		DOC Total (mg/L)	Lab		22.4	6.4	5.8	8.1	7.6	7.4	8.2	9.5	8.2	8.4	7.2	6.8
		Iron, Dissolved (mg/L)	Lab		0.009	0.174	0.31	0.004		0.004	0.003					
				N/D at <0.003					G/N			G/N	G/N	G/N	G/N	G/N
		Iron, Total (mg/L)	Lab		0.03	1.21	1.21	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		Lead, Dissolved (mg/L)	Lab		0.00003	0.00002		0.00003	0.00002	0.00002	0.00002	0.00002		0.00002		0.00002
				N/D at <0.003			G/N						G/N		G/N	
		Lead, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.814	5.708	5.701	5.798	5.786	5.821	5.764	5.593	5.928	5.67	5.705	5.873
		Magnesium, Total (mg/L)	Lab		5.73	5.72	5.77	5.72	5.76	5.75	6.02	5.8	5.94	5.86	5.82	5.74
		Manganese, Dissolved (mg/L)	Lab		0.00395	0.0143	0.014	0.0149	0.0145	0.0153	0.0155	0.0144	0.0147	0.0139	0.0144	0.0145
		Manganese, Total (mg/L)	Bench		0.021	0.029	0.027	0.019	0.018	0.016	0.019	0.018	0.019	0.014	0.016	0.015
			Lab		0.0112	0.0143	0.0144	0.0149	0.0148	0.0148	0.0153	0.0142	0.0143	0.0139	0.0143	0.0148
		Nickel, Dissolved (mg/L)	Lab		0.00023	0.00299	0.003	0.00267	0.00264	0.0027	0.00275	0.00262	0.00258	0.00257	0.00256	0.00259
		Nickel, Total (mg/L)	Lab			0.0029	0.0029	0.0026	0.0026	0.0026	0.0027	0.0026	0.0026	0.0025	0.0026	0.0027
				N/D at <0.0005	G/N											

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 21, 2017	Pilot-Scale	Oxi-Red Potenital (ORP) (mV)	Bench		184.7	245.7	237.7	257.9	343.2	338.6	325.7	326.5	316.1	318.8	308.5	279.8
		pH	Bench		7.25	5.82	5.79	5.84	5.87	5.86	5.8	5.81	5.8	5.81	5.81	5.81
			Lab		7.98	5.84	5.8	5.95	5.94	5.91	5.9	5.88	5.89	5.9	5.9	5.97
		Potassium, Dissolved (mg/L)	Lab		1.17	1.13	1.13	1.17	1.14	1.18	1.17	1.13	1.13	1.13	1.11	1.14
		Potassium, Total (mg/L)	Lab		1.14	1.14	1.1	1.14	1.22	1.11	1.13	1.15	1.16	1.16	1.16	1.24
		Sodium, Dissolved (mg/L)	Lab		2.303	2.275	2.259	2.248	2.242	2.228	2.265	2.246	2.257	2.228	2.266	2.263
		Sodium, Total (mg/L)	Lab		2.18	2.16	2.16	2.21	2.29	2.21	2.17	2.18	2.19	2.24	2.2	2.25
		TDSwq (mg/L)	Lab		114	123	121	112	107	107	110	123	133	125	121	129
		Temperature (ºC)	Lab		10.7	11.2	11.6	12	12.1	12.1	12.2	12.1	12.3	12.2	12.2	11.4
		TSScalc Total (mg/L)	Lab		12	19	19	30	33	27	28	9		13	23	
				N/D at <3									G/N			G/N
		TSwv Total (mg/L)	Lab		126	142	140	142	140	134	138	132	134	138	144	130
		Turbidity (NTU)	Bench		1.08	0.7	0.74	0.2	0.08	0.08	0.08	0.09	0.1	0.12	0.13	0.12
			Lab		0.94	0.74	0.77	0.2	0.06	0.08	0.07	0.09	0.06	0.05	0.08	0.08
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D <0.0006	G/N	G/N	G/N			G/N	G/N	G/N	G/N	G/N	G/N	
				N/D at <0.0006				G/N	G/N							G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.125	0.09	0.093	0.03	0.027	0.03	0.03	0.025	0.026	0.025	0.025	0.026
		UVT @ 254nm, Filtered (/cm)	Lab		76.9	93.5	93.2	93.9	93.9	93.9	94.1	94.6	94.6	94.4	94.5	94.1
		UVT @ 254nm, Unfiltered (%T)	Bench		74.9	81.2	80.6	93.4	93.9	93.2	93.3	94.3	94.3	91.5	94.5	94.2
		Zinc, Dissolved (mg/L)	Lab		0.0235	0.0012		0.0014	0.0017	0.0039	0.0012	0.0017	0.0011	0.0017		0.0032
				N/D at <0.0009			G/N								G/N	
		Zinc, Total (mg/L)	Lab									0.001				
				N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			9	11									8
		Aluminum, Dissolved (mg/L)	Lab			0.006	0.004									0.019
		Aluminum, Total (mg/L)	Lab			0.007	0.006									0.015
		Antimony, Dissolved (mg/L)	Lab			0.00162	0.00127									0.00155
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00045	0.00036									0.00034
		Arsenic, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			18.5	18.5									19
		Calcium, Total (mg/L)	Lab			19.4	18.8									19
		Chromium, Dissolved (mg/L)	Lab			0.00008	0.00019									0.00011
		Chromium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Colour, True	Lab			2	2									1
		Conductivity Total (µS/cm)	Bench			184.2	182.8									187
			Lab			194	193									198
		Copper, Dissolved (mg/L)	Lab			0.0041	0.0042									0.0029
		Copper, Total (mg/L)	Lab			0.004	0.005									0.003
		DO (mg/L)	Bench			10.2	11.5									12.4
		DOC Total (mg/L)	Lab			6.6	6.2									5.8
		Iron, Dissolved (mg/L)	Lab			0.159	0.13									0.031
		Iron, Total (mg/L)	Lab			0.45	0.59									0.08
		Lead, Dissolved (mg/L)	Lab			0.00003	0.00001									
				N/D at <0.003												G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.612	5.443									5.675
		Magnesium, Total (mg/L)	Lab			5.86	5.54									5.68
		Manganese, Dissolved (mg/L)	Lab			0.037	0.0229									0.0261
		Manganese, Total (mg/L)	Bench			0.041	0.036									0.027
			Lab			0.0374	0.0381									0.0281
		Nickel, Dissolved (mg/L)	Lab			0.00199	0.00183									0.00201
		Nickel, Total (mg/L)	Lab			0.002	0.0019									0.0019
		Oxi-Red Potenital (ORP) (mV)	Bench			276.8	305.7									304.1
		pH	Bench			5.6	5.74									5.51
			Lab			5.63	5.84									5.57
		Potassium, Dissolved (mg/L)	Lab			1.11	1.1									1.17
		Potassium, Total (mg/L)	Lab			1.12	1.13									1.13
		Sodium, Dissolved (mg/L)	Lab			2.181	2.156									2.438
		Sodium, Total (mg/L)	Lab			2.13	2.21									2.44
		TDSwq (mg/L)	Lab			132	129									106

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 21, 2017	Full-Scale	Temperature (ºC)	Lab			10.7	10.8									10.8
		TSScalc Total (mg/L)	Lab			22	21									42
		TSwv Total (mg/L)	Lab			154	150									148
		Turbidity (NTU)	Bench			0.64	0.55									0.33
			Lab			0.43	0.53									0.13
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.063	0.06									0.022
		UVT @ 254nm, Filtered (/cm)	Lab			92.3	95.2									95.4
		UVT @ 254nm, Unfiltered (%T)	Bench			86.6	87									95
		Zinc, Dissolved (mg/L)	Lab			0.0033	0.0028									0.0019
		Zinc, Total (mg/L)	Lab			0.002	0.0012									0.0015
October 22, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		151.3	180.1	182.1	181.1	180.8	182.1	181.9	182.4	180.6	183.5	182.7	182.5
		DO (mg/L)	Bench		9.9	10.3	10.3	9.9	10.2	10.3	10	9.8	9.9	9.7	9.9	9.5
		Manganese, Total (mg/L)	Bench		0.017	0.032	0.023	0.02	0.027	0.023	0.018	0.015	0.016	0.017	0.019	0.023
		Oxi-Red Potenital (ORP) (mV)	Bench		212.1	249.5	265.9	342.2	341.4	334.9	333.1	346.5	341.9	342.5	334.7	314.4
		pH	Bench		7.24	5.7	5.72	5.82	5.82	5.8	5.78	5.78	5.78	5.78	5.78	5.79
		Temperature (ºC)	Bench		10.6	10.6	10.9	11.5	11.4	11.4	11.5	11.8	11.7	11.8	11.8	11.1
		Turbidity (NTU)	Bench		1.11	0.62	0.64	0.14	0.14	0.11	0.08	0.08	0.07	0.09	0.08	0.08
		UVA @254nm, Unfiltered (/cm)	Bench		0.124	0.083	0.08	0.026	0.026	0.026	0.026	0.025	0.024	0.025	0.026	0.026
		UVT @ 254nm, Unfiltered (%T)	Bench		75.2	82.6	83.1	94.1	94.2	94.2	94.1	94.5	94.6	94.4	94.2	94.1
	Full-Scale	Conductivity Total (µS/cm)	Bench			186.4	183									184
		DO (mg/L)	Bench			10	11.6									9.6
		Manganese, Total (mg/L)	Bench			0.048	0.042									0.036
		Oxi-Red Potenital (ORP) (mV)	Bench			322.2	365.3									331.8
		pH	Bench			5.62	5.73									5.57
		Temperature (ºC)	Bench			10.7	11									10.6
		Turbidity (NTU)	Bench			0.45	0.56									0.25
		UVA @254nm, Unfiltered (/cm)	Bench			0.074	0.071									0.03
		UVT @ 254nm, Unfiltered (%T)	Bench			84.3	85									93.3
October 23, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		152.2	180.1	179	178.3	179.1	176.9	180.5	180.6	180.4	179.5	178.6	178.3
		DO (mg/L)	Bench		10.4	10.7	10.2	10.6	10.5	10.3	10.2	10.5	10.1	10.4	10.4	10.2
		Manganese, Total (mg/L)	Bench		0.018	0.027	0.029	0.026	0.022	0.02	0.02	0.02	0.021	0.022	0.017	0.02
		Oxi-Red Potenital (ORP) (mV)	Bench		180.8	229.6	258.3	328.5	323.8	320.3	317.7	310.4	305.6	301.2	286.7	272.9
		pH	Bench		7.57	5.82	5.85	5.83	5.84	5.82	5.8	5.78	5.8	5.8	5.82	5.8
		Temperature (ºC)	Bench		10.9	10.6	11.1	11.3	11.4	11.4	11.5	11.6	11.9	11.7	11.5	10.9
		Turbidity (NTU)	Bench		1.12	1.11	1.16	0.3	0.14	0.13	0.14	0.07	0.08	0.07	0.08	0.11
		UVA @254nm, Unfiltered (/cm)	Bench		0.124	0.13	0.143	0.036	0.033	0.031	0.03	0.028	0.026	0.028	0.032	0.03
		UVT @ 254nm, Unfiltered (%T)	Bench		75	74.1	71.7	92.1	92.8	93.1	93	93.8	94.2	93.7	92.9	93.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			186.9	176.2									189.4
		DO (mg/L)	Bench			10.5	11.9									9.8
		Manganese, Total (mg/L)	Bench			0.045	0.047									0.04
		Oxi-Red Potenital (ORP) (mV)	Bench			270.1	283.5									319.8
		pH	Bench			5.67	5.74									5.5
		Temperature (ºC)	Bench			10.5	10.6									10.6
		Turbidity (NTU)	Bench			0.42	0.6									0.47
		UVA @254nm, Unfiltered (/cm)	Bench			0.067	0.077									0.04
		UVT @ 254nm, Unfiltered (%T)	Bench			85.5	83.7									91.2
October 24, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		147.9	177.5	176.5	175.9	174.6	175.1	175.4	176.5	175.5	176.9	177.1	177.9
		DO (mg/L)	Bench		10.1	10.4	10.3	10.7	10.4	10.3	10.7	10.1	10.4	10.7	10.7	11.1
		Manganese, Total (mg/L)	Bench		0.019	0.033	0.035	0.023	0.026	0.021	0.02	0.021	0.018	0.018	0.018	0.019
		Oxi-Red Potenital (ORP) (mV)	Bench		190.1	229.3	249.3	323.1	322.5	317.5	318.6	317.7	313.2	314.7	305.1	286
		pH	Bench		7.46	5.91	5.92	5.94	5.94	5.93	5.89	5.89	5.87	5.87	5.88	5.9
		Temperature (ºC)	Bench		9.9	10.2	10.3	10.5	10.6	10.7	10.7	10.7	10.8	10.8	10.7	10.1
		Turbidity (NTU)	Bench		1.1	1.51	1.57	0.33	0.24	0.19	0.34	0.12	0.09	0.1	0.12	0.18
		UVA @254nm, Unfiltered (/cm)	Bench		0.126	0.162	0.168	0.044	0.042	0.038	0.05	0.029	0.028	0.028	0.03	0.036
		UVT @ 254nm, Unfiltered (%T)	Bench		74.8	68.9	67.9	90.3	90.7	91.7	89.2	93.5	93.8	93.7	93.4	92.2
	Full-Scale	Conductivity Total (µS/cm)	Bench			183.6	177.8									179.9
		DO (mg/L)	Bench			11.7	12.4									11.8
		Manganese, Total (mg/L)	Bench			0.044	0.037									0.033
		Oxi-Red Potenital (ORP) (mV)	Bench			295.9	331.8									338
		pH	Bench			5.65	5.75									5.51
		Temperature (ºC)	Bench			9.6	10									9.7
		Turbidity (NTU)	Bench			0.47	0.62									0.35

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

					Sample Location											
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Combined Filtrate**
October 24, 2017	Full-Scale	UVA @254nm, Unfiltered (/cm)	Bench			0.067	0.068									0.025
		UVT @ 254nm, Unfiltered (%T)	Bench			85.7	85.5									94.5
October 25, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		150.8	176.3	178.2	177.7	178.1	176.9	177.1	176.5	176	176.1	178.6	177
		DO (mg/L)	Bench		9.7	10.5	11.4	10.8	10.7	10.9	10.8	10.7	10.7	10.4	10.7	10.2
		Manganese, Total (mg/L)	Bench		0.017	0.024	0.026	0.016	0.019	0.016	0.017	0.02	0.019	0.018	0.016	0.019
		Oxi-Red Potenital (ORP) (mV)	Bench		196.3	231.1	236.9	294.2	293.5	289.3	285.3	279.9	285.6	293.8	287.4	257.6
		pH	Bench		7.44	5.99	5.98	6	6.01	6.01	5.98	5.96	5.94	5.95	5.96	5.98
		Temperature (ºC)	Bench		9.8	9.7	10.1	10.4	10.5	10.6	10.7	10.7	10.8	10.7	10.8	10.2
		Turbidity (NTU)	Bench		1.13	1.82	1.44	0.47	0.19	0.17	0.19	0.12	0.19	0.12	0.13	0.2
		UVA @254nm, Unfiltered (/cm)	Bench		0.132	0.151	0.159	0.046	0.042	0.041	0.04	0.036	0.036	0.033	0.035	0.039
		UVT @ 254nm, Unfiltered (%T)	Bench		73.8	70.6	69.4	90	90.8	90.9	91.1	92.1	92	92.7	92.3	91.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			184.2	183.8									187.9
		DO (mg/L)	Bench			9.6	11.2									9.8
		Manganese, Total (mg/L)	Bench			0.042	0.043									0.028
		Oxi-Red Potenital (ORP) (mV)	Bench			294	337.3									340.2
		pH	Bench			5.64	5.68									5.44
		Temperature (ºC)	Bench			9.7	10									9.9
		Turbidity (NTU)	Bench			0.52	0.56									0.36
		UVA @254nm, Unfiltered (/cm)	Bench			0.073	0.067									0.025
		UVT @ 254nm, Unfiltered (%T)	Bench			84.5	85.6									94.4
October 26, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		74	9	10	11	11	11	11	12	12	12	12	11
		Aluminum, Dissolved (mg/L)	Lab			0.007	0.007	0.004	0.004	0.004	0.005	0.003	0.005	0.003	0.003	0.004
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.011	0.011	0.005	0.004	0.004	0.004	0.003	0.003	0.003		0.004
				N/D at <0.003	G/N										G/N	
		Antimony, Dissolved (mg/L)	Lab		0.00096	0.0008	0.00061	0.00087	0.00073	0.0008	0.00074	0.0008	0.00117	0.00082	0.0007	0.0008
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.0007	0.00041	0.00042	0.00036	0.00034	0.00034	0.00036	0.00039	0.00039	0.00033	0.00036	0.00035
		Arsenic, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		19.2	19.2	19.7	19.4	19.9	19.7	19.8	20.1	20.1	20.2	20.3	19.8
		Calcium, Total (mg/L)	Lab		19.1	19.3	19.1	20	19.8	19.5	19.8	20.3	20.3	20.5	20.1	19.6
		Chromium, Dissolved (mg/L)	Lab									0.00006	0.00005			
				N/D at <0.00003	G/N	G/N	G/N	G/N	G/N	G/N	G/N			G/N	G/N	G/N
		Chromium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		11	1.5	1.5	1	0.5	1	0.5	0.5	1	1.5	1	0.5
		Conductivity Total (µS/cm)	Bench		150	178	181.3	182.1	181.1	179.7	182.6	183.1	183.4	185.4	183.9	181.3
			Lab		159	189	190	191	192	191	191	193	193	193	196	192
		Copper, Dissolved (mg/L)	Lab		0.0016	0.0002	0.0003	0.0003	0.0004	0.0007	0.0003	0.0005	0.0005	0.0004	0.0004	0.0011
		Copper, Total (mg/L)	Lab		0.002											
				N/D at <0.001		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		10.4	10.5	11.7	10.7	11.3	11	10.8	10.6	10.7	10.9	11	11
		DOC Total (mg/L)	Lab		22.3	6.5	5.8	6	6.1	6	6.1	6.4	6.1	6.5	6.5	6.1
		Iron, Dissolved (mg/L)	Lab		0.005	0.147	0.169	0.003	0.015	0.004	0.116	0.003		0.003	0.003	0.003
				N/D at <0.003									G/N			
		Iron, Total (mg/L)	Lab		0.03	2.15	2.09	0.42	0.3	0.15	0.19	0.03	0.03	0.03	0.03	0.07
		Lead, Dissolved (mg/L)	Lab		0.00004	0.00002	0.00001	0.00004	0.00002	0.00002	0.00001	0.00006	0.00006	0.00002	0.00001	0.00001
		Lead, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.786	5.851	5.938	5.868	6.032	6.049	6.068	5.924	5.957	6.01	6.058	5.951
		Magnesium, Total (mg/L)	Lab		5.84	6.08	5.8	6.11	6.07	6.15	5.91	6.19	6.05	6.09	6.01	5.9
		Manganese, Dissolved (mg/L)	Lab		0.00091	0.0117	0.0117	0.0132	0.0133	0.013	0.0132	0.0126	0.0131	0.0127	0.0126	0.0131
		Manganese, Total (mg/L)	Bench		0.019	0.028	0.031	0.017	0.017	0.02	0.022	0.019	0.019	0.02	0.017	0.018
			Lab		0.011	0.0127	0.0125	0.0136	0.0132	0.0132	0.0134	0.0133	0.0129	0.013	0.0127	0.013
		Nickel, Dissolved (mg/L)	Lab		0.00021	0.00225	0.00234	0.00256	0.00255	0.00269	0.00252	0.00258	0.00255	0.00243	0.00245	0.0025
		Nickel, Total (mg/L)	Lab			0.0022	0.0023	0.0025	0.0025	0.0025	0.0025	0.0027	0.0025	0.0026	0.0024	0.0025
				N/D at <0.0005	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		194.7	252.1	237.9	249.4	233.3	289.4	293.6	287.1	288.1	278	273.1	261.4
		pH	Bench		7.46	5.69	5.75	5.81	5.79	5.85	5.83	5.85	5.85	5.85	5.84	5.82
			Lab		5.93	5.76	5.76	5.87	5.94	5.88	5.86	5.89	5.94	5.9	5.96	6.03
		Potassium, Dissolved (mg/L)	Lab		1.18	1.13	1.16	1.13	1.14	1.14	1.13	1.14	1.14	1.13	1.14	1.14
		Potassium, Total (mg/L)	Lab		1.17	1.12	1.11	1.15	1.14	1.12	1.13	1.15	1.13	1.14	1.12	1.13
		Sodium, Dissolved (mg/L)	Lab		2.308	2.221	2.225	2.179	2.272	2.273	2.247	2.21	2.293	2.257	2.228	2.184
		Sodium, Total (mg/L)	Lab		2.2	2.23	2.25	2.23	2.24	2.24	2.23	2.24	2.2	2.19	2.18	2.14

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 26, 2017	Pilot-Scale	TDSwq (mg/L)	Lab		116	124	130	132	127	126	126	131	131	133	120	126
		Temperature (ºC)	Bench		8.9	9.1	9.7	10	9.9	10.1	10	10	10.2	10.2	10.2	9.5
			Lab		8.9	9.1	9.7	10	9.9	10.1	10	10	10.2	10.2	10.2	9.5
		TSScalc Total (mg/L)	Lab		96	46	70	34	23	18	58	13	15	3	4	4
		TSwv Total (mg/L)	Lab		212	170	200	166	150	144	184	144	146	136	124	130
		Turbidity (NTU)	Bench		1.1	1.27	1.36	0.42	0.23	0.17	0.21	0.1	0.1	0.09	0.14	0.15
			Lab		1.1	1.56	1.48	0.37	0.22	0.17	0.2	0.06	0.06	0.05	0.06	0.16
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.127	0.133	0.148	0.04	0.036	0.032	0.035	0.026	0.025	0.024	0.026	0.031
		UVT @ 254nm, Filtered (/cm)	Lab		75.7	91.6	91.7	93.1	93.4	93.3	93.1	93.6	93.7	93.8	93.5	93.4
		UVT @ 254nm, Unfiltered (%T)	Bench		74.6	73.6	71.1	91.4	92	93	92.2	94.1	94.4	94.5	94.1	93.2
		Zinc, Dissolved (mg/L)	Lab		0.0016				0.001	0.001	0.001	0.0014	0.0013	0.0015	0.0016	
				N/D at <0.0009		G/N	G/N	G/N								G/N
		Zinc, Total (mg/L)	Lab		0.0017											
				N/D at <0.0009		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			10	11									8
		Aluminum, Dissolved (mg/L)	Lab			0.004	0.003									0.007
		Aluminum, Total (mg/L)	Lab			0.004	0.003									0.008
		Antimony, Dissolved (mg/L)	Lab			0.00073	0.00089									0.00082
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00047	0.00036									0.00035
		Arsenic, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			19	18.8									18.8
		Calcium, Total (mg/L)	Lab			18.7	19									19.1
		Chromium, Dissolved (mg/L)	Lab			0.00004	0.00017									0.00013
		Chromium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Colour, True	Lab			1	1									0.5
		Conductivity Total (µS/cm)	Bench			185.5	183.9									179.6
			Lab			194	193									196
		Copper, Dissolved (mg/L)	Lab			0.0044	0.0049									0.0023
		Copper, Total (mg/L)	Lab			0.005	0.006									0.002
		DO (mg/L)	Bench			11.3	11.7									12.1
		DOC Total (mg/L)	Lab			6.4	6.4									6.2
		Iron, Dissolved (mg/L)	Lab			0.106	0.011									0.026
		Iron, Total (mg/L)	Lab			0.5	0.61									0.07
		Lead, Dissolved (mg/L)	Lab			0.00001	0.00003									0.00001
		Lead, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.766	5.743									5.71
		Magnesium, Total (mg/L)	Lab			5.65	5.8									5.85
		Manganese, Dissolved (mg/L)	Lab			0.0374	0.0148									0.0221
		Manganese, Total (mg/L)	Bench			0.046	0.039									0.028
			Lab			0.0365	0.0355									0.0253
		Nickel, Dissolved (mg/L)	Lab			0.00194	0.00179									0.00171
		Nickel, Total (mg/L)	Lab			0.0018	0.0018									0.0018
		Oxi-Red Potenital (ORP) (mV)	Bench			257.9	296.4									239.6
		pH	Bench			5.69	5.79									5.55
			Lab			5.58	5.8									5.49
		Potassium, Dissolved (mg/L)	Lab			1.15	1.1									1.1
		Potassium, Total (mg/L)	Lab			1.09	1.1									1.13
		Sodium, Dissolved (mg/L)	Lab			2.164	2.096									2.323
		Sodium, Total (mg/L)	Lab			2.18	2.23									2.29
		TDSwq (mg/L)	Lab			129	135									133
		Temperature (ºC)	Bench			8.8	9.3									8.7
			Lab			8.8	9.3									8.7
		TSScalc Total (mg/L)	Lab			87	29									37
		TSwv Total (mg/L)	Lab			216	164									170
		Turbidity (NTU)	Bench			0.57	0.61									0.35
			Lab			0.49	0.6									0.14
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D <0.0006		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.063	0.062									0.028

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location											
					Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 26, 2017	Full-Scale	UVT @ 254nm, Filtered (/cm)	Lab			91.4	93.9									95
		UVT @ 254nm, Unfiltered (%T)	Bench			86.5	86.8									93.8
		Zinc, Dissolved (mg/L)	Lab			0.003	0.0022									0.0018
		Zinc, Total (mg/L)	Lab			0.0017	0.0009									0.001
October 27, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		75	10	10	11	11	11	11	11	11	11	12	11
		Aluminum, Dissolved (mg/L)	Lab		0.002		0.008	0.004	0.004	0.003	0.005	0.005	0.004	0.004	0.004	0.004
		Aluminum, Total (mg/L)	Lab		0.003	0.011	0.012	0.007	0.006	0.007	0.006	0.004	0.004	0.004	0.004	0.005
		Antimony, Dissolved (mg/L)	Lab		0.00101	0.00137	0.00069	0.0007	0.00056	0.00083	0.00058	0.00062	0.00043	0.00075	0.00096	0.00074
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00073	0.00039	0.00043	0.00037	0.00037	0.00037	0.00036	0.00035	0.00034	0.00035	0.00036	0.00038
		Arsenic, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		20.4	19.7	19.8	19.7	19.9	19.9	19.7	20.3	20	20.6	20.1	20.5
		Calcium, Total (mg/L)	Lab		20.3	19.8	20.1	20	20.2	20.1	19.9	20	20.3	20.5	20.6	19.7
		Chloride (mg/L)	Lab		2.4											2.3
		Chromium, Dissolved (mg/L)	Lab				0.00003	0.00005			0.00003				0.00004	
				N/D at <0.00003	G/N	G/N			G/N	G/N		G/N	G/N	G/N		G/N
		Chromium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		10	18	30	0.5	1	1	1.5	1	1	0.5	1	2.5
		Conductivity Total (µS/cm)	Bench		150.4	183.3	180.9	182	181	181.3	179.8	180.7	182.1	183.1	180.7	178.1
			Lab		160	188	189	189	189	189	189	190	190	190	190	189
		Copper, Dissolved (mg/L)	Lab		0.0005	0.002	0.0003	0.0004	0.0004	0.0003	0.0004	0.0004	0.0013	0.0017	0.0015	0.001
		Copper, Total (mg/L)	Lab										0.001	0.002	0.001	
				N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N				G/N
		DO (mg/L)	Bench		10.7	11.5	11.5	11.2	11.2	11.3	11.1	11	11.3	11.2	11.3	11.1
		DOC Total (mg/L)	Lab	Data not recv	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		dTot, Hardness (mg/L CaCO3)	Lab		75.7											73.2
		HaaBCAA ion(Fe+2)(ug/L)	Lab		0.8											0.9
		HaaDBAA ion(Fe+2)(ug/L)	Lab	Data not recv	G/N											G/N
		HaaDCAA ion(Fe+2)(ug/L)	Lab		9.8											12.8
		HaaMBAA ion(Fe+2)(ug/L)	Lab	Data not recv	G/N											G/N
		HaaMCAA ion(Fe+2)(ug/L)	Lab	Data not recv	G/N											G/N
		HaaTCAA ion(Fe+2)(ug/L)	Lab		4.2											15.5
		HaaTotal, calc_(ug/L)	Lab		15											29
		Iron, Dissolved (mg/L)	Lab		0.004	0.256	0.622	0.007	0.29	0.006	0.382	0.004	0.004	0.017	0.005	0.006
		Iron, Total (mg/L)	Lab		0.03	2.25	2.44	1.09	1	1.9	1.04	0.03	0.03	0.03	0.03	0.6
		Lead, Dissolved (mg/L)	Lab		0.00003	0.00013		0.00002	0.00001	0.00001	0.00003		0.00002	0.00002	0.00004	0.00002
				N/D at <0.003			G/N					G/N				
		Lead, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		6.162	5.82	6.027	5.814	6.142	5.966	5.959	6.061	5.813	6.25	6.127	6.172
		Magnesium, Total (mg/L)	Lab		6.09	5.82	6.17	6.14	6.1	6.11	5.82	5.97	6.01	6.31	6.09	5.84
		Manganese, Dissolved (mg/L)	Lab		0.00062	0.0118	0.0138	0.0122	0.014	0.0123	0.013	0.0125	0.0126	0.0131	0.0129	0.0124
		Manganese, Total (mg/L)	Bench		0.02	0.029	0.031	0.027	0.029	0.029	0.023	0.022	0.024	0.022	0.02	0.026
			Lab		0.0111	0.013	0.0151	0.0129	0.0145	0.0137	0.0133	0.0124	0.013	0.0129	0.0131	0.0126
		Nickel, Dissolved (mg/L)	Lab		0.00022	0.00213	0.00229	0.00266	0.00235	0.00244	0.00243	0.00253	0.00248	0.00266	0.00255	0.00253
		Nickel, Total (mg/L)	Lab			0.0021	0.0023	0.0024	0.0025	0.0024	0.0025	0.0026	0.0026	0.0026	0.0026	0.0025
				N/D at <0.0005	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		209.1	243.2	265.4	317.3	315.1	313.9	315.7	314.2	295.9	292.7	282.6	267.5
		pH	Bench		7.31	5.74	5.78	5.85	5.85	5.83	5.77	5.77	5.78	5.75	5.75	5.78
			Lab		7.93	5.88	5.74	5.96	5.98	6.02	5.92	5.94	5.98	5.94	5.96	5.95
		Potassium, Dissolved (mg/L)	Lab		1.19	1.13	1.14	1.15	1.14	1.13	1.13	1.14	1.11	1.19	1.13	1.2
		Potassium, Total (mg/L)	Lab		1.15	1.13	1.17	1.13	1.13	1.14	1.12	1.12	1.14	1.15	1.16	1.12
		Sodium, Dissolved (mg/L)	Lab		2.467	2.267	2.289	2.371	2.349	2.25	2.22	2.296	2.31	2.341	2.362	2.388
		Sodium, Total (mg/L)	Lab		2.27	2.25	2.3	2.27	2.27	2.32	2.25	2.28	2.29	2.36	2.33	2.29
		Sulfate (mg/L)	Lab													73
		TDSwq (mg/L)	Lab		88	115	106	120	129	119	124	123	117	132	120	125
		Temperature (ºC)	Bench		8.5	9.1	8.8	9.1	9.3	9.3	9.3	9.3	9.4	9.3	9.3	8.5
			Lab		8.5	9.1	8.8	9.1	9.3	9.3	9.3	9.3	9.4	9.3	9.3	8.5
		ThmBDCM Total(ug/L)	Lab		0.7											2.7
		ThmCHCl3 Total(ug/L)	Lab		9.4											38.2
		ThmTotal,calc_ Total(ug/L)	Lab		10											41
		TSScalc Total (mg/L)	Lab		42	37	62	44	23	53	44	103	49	30	20	23
		TSwv Total (mg/L)	Lab		130	152	168	164	152	172	168	226	166	162	140	148

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

					Sample Location											
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Combined Filtrate**
October 27, 2017	Pilot-Scale	Turbidity (NTU)	Bench		1.11	1.49	1.58	0.85	0.75	0.67	0.81	0.1	0.09	0.1	0.09	0.47
			Lab		1.04	1.66	1.76	0.94	0.73	1.43	0.85	0.07	0.08	0.07	0.08	0.51
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D <0.0006		G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
				N/D at <0.0006	G/N		G/N									
		UVA @254nm, Unfiltered (/cm)	Bench		0.137	0.153	0.151	0.08	0.076	0.068	0.084	0.024	0.028	0.026	0.026	0.046
		UVT @ 254nm, Filtered (/cm)	Lab		75.9	77.9	70.4	92.3	92.8	92.9	93	93.1	93.4	93.1	92.4	92.6
		UVT @ 254nm, Unfiltered (%T)	Bench		73	70.4	70.8	83.3	83.9	85.4	82.4	94.6	93.7	94.4	94.1	89.9
		Zinc, Dissolved (mg/L)	Lab		0.0017	0.0018			0.0013		0.0009	0.0011	0.0014	0.0029	0.001	0.0019
				N/D at <0.0009			G/N	G/N		G/N						
		Zinc, Total (mg/L)	Lab		0.0012							0.0012		0.0013		
				N/D at <0.0009		G/N	G/N	G/N	G/N	G/N	G/N		G/N		G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			10	12									9
		Aluminum, Dissolved (mg/L)	Lab			0.003	0.007									0.004
		Aluminum, Total (mg/L)	Lab			0.004	0.004									0.007
		Antimony, Dissolved (mg/L)	Lab			0.00091	0.00093									0.00073
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00033	0.00037									0.00047
		Arsenic, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			19	19.7									19.2
		Calcium, Total (mg/L)	Lab			19.3	19.4									19.9
		Chloride (mg/L)	Lab													17
		Chromium, Dissolved (mg/L)	Lab			0.00016	0.00045									
				N/D at <0.00003												G/N
		Chromium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Colour, True	Lab			1.5	1									2
		Conductivity Total (µS/cm)	Bench			185.1	185.5									182.2
			Lab			196	192									196
		Copper, Dissolved (mg/L)	Lab			0.0028	0.0022									0.0026
		Copper, Total (mg/L)	Lab			0.003	0.003									0.002
		DO (mg/L)	Bench			11.4	12.2									12
		DOC Total (mg/L)	Lab	Data not recv		G/N	G/N									G/N
		dTot, Hardness (mg/L CaCO3)	Lab													74.9
		HaaBCAA ion(Fe+2)(ug/L)	Lab													0.9
		HaaDBAA ion(Fe+2)(ug/L)	Lab													1.8
		HaaDCAA ion(Fe+2)(ug/L)	Lab													7.8
		HaaMBAA ion(Fe+2)(ug/L)	Lab	Data not recv												G/N
		HaaMCAA ion(Fe+2)(ug/L)	Lab	Data not recv												G/N
		HaaTCAA ion(Fe+2)(ug/L)	Lab													6.6
		HaaTotal, calc_(ug/L)	Lab													17
		Iron, Dissolved (mg/L)	Lab			0.011	0.013									0.074
		Iron, Total (mg/L)	Lab			0.54	0.62									0.06
		Lead, Dissolved (mg/L)	Lab				0.00002									
				N/D at <0.003		G/N										G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.742	5.986									5.824
		Magnesium, Total (mg/L)	Lab			5.8	5.78									6.15
		Manganese, Dissolved (mg/L)	Lab			0.02	0.0236									0.0372
		Manganese, Total (mg/L)	Bench			0.048	0.041									0.028
			Lab			0.0381	0.0371									0.0258
		Nickel, Dissolved (mg/L)	Lab			0.00171	0.00192									0.0017
		Nickel, Total (mg/L)	Lab			0.0017	0.0017									0.0019
		Oxi-Red Potenital (ORP) (mV)	Bench			285.4	314.5									317.5
		pH	Bench			5.67	5.72									5.35
			Lab			5.73	5.92									5.72
		Potassium, Dissolved (mg/L)	Lab			1.08	1.12									1.09
		Potassium, Total (mg/L)	Lab			1.08	1.1									1.12
		Sodium, Dissolved (mg/L)	Lab			2.297	2.538									2.325
		Sodium, Total (mg/L)	Lab			2.29	2.29									2.48
		Sulfate (mg/L)	Lab													48
		TDSwq (mg/L)	Lab			119	124									121
		Temperature (ºC)	Bench			8.5	9.1									8.1

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 27, 2017	Full-Scale	Temperature (ºC)	Lab			8.5	9.1									8.1
		ThmBDCM Total(ug/L)	Lab													2.6
		ThmCHCl3 Total(ug/L)	Lab													23.9
		ThmTotal,calc_ Total(ug/L)	Lab													27
		TSScalc Total (mg/L)	Lab			33	46									35
		TSwv Total (mg/L)	Lab			152	170									156
		Turbidity (NTU)	Bench			0.57	0.59									0.22
			Lab			0.45	0.61									0.14
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D <0.0006		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.062	0.063									0.019
		UVT @ 254nm, Filtered (/cm)	Lab			91.7	94									94.5
		UVT @ 254nm, Unfiltered (%T)	Bench			86.7	86.5									95.7
		Zinc, Dissolved (mg/L)	Lab			0.001	0.0028									0.0021
		Zinc, Total (mg/L)	Lab			0.0014										0.0009
				N/D at <0.0009			G/N									
October 28, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		150.7	183.4	181.2	183.5	182.8	184.2	183.4	181.2	183	183.6	185.7	183.9
		DO (mg/L)	Bench		11	11.7	11.3	11.4	11.5	11.6	11.5	11.2	11.2	11.3	11.2	11.5
		Manganese, Total (mg/L)	Bench		0.023	0.022	0.024	0.017	0.015	0.02	0.017	0.018	0.017	0.02	0.017	0.017
		Oxi-Red Potenital (ORP) (mV)	Bench		214.9	255.3	272.6	328.5	324.9	324.4	323.2	313.7	306.1	320.3	309.3	291.1
		pH	Bench		7.3	5.72	5.74	5.83	5.84	5.82	5.83	5.87	5.87	5.86	5.87	5.9
		Temperature (ºC)	Bench		7.9	7.9	8	8.3	8.5	8.4	8.4	8.5	8.7	8.7	8.6	8.4
		Turbidity (NTU)	Bench		1.13	1.47	1.03	0.2	0.18	0.14	0.09	0.09	0.1	0.11	0.1	0.14
		UVA @254nm, Unfiltered (/cm)	Bench		0.122	0.106	0.093	0.025	0.023	0.026	0.025	0.021	0.02	0.02	0.021	0.022
		UVT @ 254nm, Unfiltered (%T)	Bench		75.5	78.4	80.8	94.5	94.8	94.1	94.5	95.2	95.5	95.4	95.2	95
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.4	184									181.2
		DO (mg/L)	Bench			11.8	12.1									12.4
		Manganese, Total (mg/L)	Bench			0.049	0.048									0.028
		Oxi-Red Potenital (ORP) (mV)	Bench			300.1	329									296.2
		pH	Bench			5.88	6.05									5.56
		Temperature (ºC)	Bench			7.8	8.3									8
		Turbidity (NTU)	Bench			0.62	0.78									0.35
		UVA @254nm, Unfiltered (/cm)	Bench			0.066	0.069									0.028
		UVT @ 254nm, Unfiltered (%T)	Bench			86	95.4									93.8
October 29, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		151.8	185.2	181.6	182.8	182.2	183.4	183.2	184.6	183.9	184.6	187	185.1
		DO (mg/L)	Bench		11.1	11.7	11	11.1	11.2	11.2	10.8	10.9	10.9	11.1	11.4	11.5
		Manganese, Total (mg/L)	Bench		0.022	0.019	0.017	0.018	0.017	0.014	0.015	0.012	0.017	0.014	0.015	0.016
		Oxi-Red Potenital (ORP) (mV)	Bench		209.2	251.9	259.2	309.3	304.1	295	311.2	309.1	308.7	300.6	284.3	274.6
		pH	Bench		7.25	5.69	5.72	5.76	5.76	5.76	5.74	5.74	5.71	5.72	5.7	5.7
		Temperature (ºC)	Bench		7.7	7.9	8	8.1	8.1	8.2	8.3	9.1	9.1	8.8	8.8	8.3
		Turbidity (NTU)	Bench		1.29	0.96	0.78	0.16	0.12	0.13	0.11	0.11	0.14	0.13	0.14	0.13
		UVA @254nm, Unfiltered (/cm)	Bench		0.126	0.091	0.066	0.02	0.019	0.019	0.022	0.015	0.015	0.015	0.015	0.016
		UVT @ 254nm, Unfiltered (%T)	Bench		75	81.2	85.8	95.3	95.6	95.7	95	96.6	96.7	96.5	96.7	96.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			189	187.9									189
		DO (mg/L)	Bench			11.6	10.7									12.9
		Manganese, Total (mg/L)	Bench			0.051	0.041									0.031
		Oxi-Red Potenital (ORP) (mV)	Bench			285.7	321.1									320.2
		pH	Bench			5.59	5.61									5.41
		Temperature (ºC)	Bench			7.9	8									7.9
		Turbidity (NTU)	Bench			0.55	0.79									0.28
		UVA @254nm, Unfiltered (/cm)	Bench			0.051	0.055									0.011
		UVT @ 254nm, Unfiltered (%T)	Bench			88.9	88.1									97.1
October 30, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		151.1	184.2	182.9	183.5	184.3	185.1	184.3	182.6	181.7	184	181.1	182.3
		DO (mg/L)	Bench		11.5	12	12	12.1	11.6	11.9	11.8	11.5	11.5	11.8	11.7	12.4
		Manganese, Total (mg/L)	Bench		0.02	0.021	0.024	0.023	0.022	0.021	0.02	0.019	0.018	0.018	0.016	0.021
		Oxi-Red Potenital (ORP) (mV)	Bench		220.8	265.6	283.8	332.5	325.5	322	316.2	315.9	316.4	306.1	300.3	285.3
		pH	Bench		7.3	5.73	5.77	5.82	5.83	5.83	5.84	5.83	5.82	5.84	5.82	5.8
		Temperature (ºC)	Bench		6.6	7.3	7.2	7.9	7.6	7.7	7.9	7.8	7.9	7.8	7.6	7.3
		Turbidity (NTU)	Bench		1.22	0.99	0.81	0.16	0.13	0.13	0.08	0.09	0.09	0.11	0.13	0.12
		UVA @254nm, Unfiltered (/cm)	Bench		0.128	0.109	0.08	0.03	0.028	0.028	0.029	0.029	0.027	0.028	0.027	0.028
		UVT @ 254nm, Unfiltered (%T)	Bench		74.5	77.8	83.2	93.4	93.8	93.9	93.6	93.5	94.1	93.7	94	93.8
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.6	184									191.9
		DO (mg/L)	Bench			12.2	12.4									12.7
		Manganese, Total (mg/L)	Bench			0.05	0.046									

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

					Sample Location											
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Combined Filtrate**
October 30, 2017	Full-Scale	Oxi-Red Potenital (ORP) (mV)	Bench			283.4	297.7									294.8
		pH	Bench			5.74	5.79									5.69
		Temperature (ºC)	Bench			6.7	7.7									6.9
		Turbidity (NTU)	Bench			0.56	0.7									0.29
		UVA @254nm, Unfiltered (/cm)	Bench			0.077	0.071									0.027
		UVT @ 254nm, Unfiltered (%T)	Bench			83.7	85									93.9
October 31, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		75	10	10	10	10	10	9	9	8	9	8	9
		Aluminum, Dissolved (mg/L)	Lab			0.01	0.01	0.005	0.005	0.006	0.005	0.006	0.006	0.007	0.007	0.005
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.011	0.011	0.006	0.006	0.007	0.006	0.005	0.005	0.005	0.005	0.005
				N/D at <0.003	G/N											
		Antimony, Dissolved (mg/L)	Lab		0.00165	0.00115	0.0011	0.00095	0.00079	0.00178	0.00137	0.00081	0.00076	0.00097	0.00163	0.00121
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00064	0.00039	0.00035	0.00032	0.00032	0.00033	0.00033	0.00032	0.00031	0.00031	0.00033	0.00033
		Arsenic, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		21	20.9	20.9	19.8	19.6	19.8	19.7	19.2	19.3	19	19.1	19.3
		Calcium, Total (mg/L)	Lab		21.1	21.1	20.6	19.8	19.6	20.3	19.3	19.6	19.5	19.4	19.3	19.3
		Chloride (mg/L)	Lab		2.7											2.5
		Chromium, Dissolved (mg/L)	Lab		0.00008	0.0001	0.00004					0.0001	0.00003	0.00007	0.00007	
				N/D at <0.00003				G/N	G/N	G/N	G/N					G/N
		Chromium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		13	2	2	1.5	1	1	1.5	1	1.5	1	1.5	2
		Conductivity Total (µS/cm)	Bench		156	182.3	180.8	180.4	182.5	181.4	179.9	181.5	179.1	177.5	177.3	183.8
			Lab		160	189	189	189	190	189	189	188	188	188	187	189
		Copper, Dissolved (mg/L)	Lab		0.0008	0.0005	0.0006	0.0006	0.0005	0.0008	0.0006	0.0007	0.0006	0.0009	0.0009	0.0005
		Copper, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		11.6	11.6	11.4	11.4	12.1	11.9	11.4	11.6	11.5	11.4	11.2	12
		DOC Total (mg/L)	Lab		26.6	8.3	8.3	7.8	7.9	7.9	7.5	6.6	7.7	7.3	6.9	11
		dTot, Hardness (mg/L CaCO3)	Lab		77.8											74
		HaaBCAA ion(Fe+2)(ug/L)	Lab		0.5											0.7
		HaaDBAA ion(Fe+2)(ug/L)	Lab	Data not recv	G/N											G/N
		HaaDCAA ion(Fe+2)(ug/L)	Lab		12											6.2
		HaaMBAA ion(Fe+2)(ug/L)	Lab	Data not recv	G/N											G/N
		HaaMCAA ion(Fe+2)(ug/L)	Lab	Data not recv	G/N											G/N
		HaaTCAA ion(Fe+2)(ug/L)	Lab		7.7											6.8
		HaaTotal, calc_(ug/L)	Lab		20											14
		Iron, Dissolved (mg/L)	Lab		0.007	0.474	0.141	0.004	0.004	0.005	0.007	0.007	0.005	0.006	0.032	0.004
		Iron, Total (mg/L)	Lab		0.03	1.71	1.83	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		Lead, Dissolved (mg/L)	Lab		0.00003	0.00002	0.00002	0.00015	0.00007	0.00006	0.00004	0.00003	0.00002	0.00005	0.00009	0.00002
		Lead, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.864	6.095	5.956	6.362	6.295	6.329	6.271	6.202	6.208	6.134	6.246	6.228
		Magnesium, Total (mg/L)	Lab		6.07	6.01	6	6.34	6.26	6.49	6.28	6.23	6.41	6.38	6.27	6.3
		Manganese, Dissolved (mg/L)	Lab		0.00203	0.0108	0.0108	0.0113	0.0109	0.0109	0.0114	0.0108	0.0109	0.011	0.0111	0.011
		Manganese, Total (mg/L)	Bench		0.019	0.021	0.022	0.016	0.016	0.015	0.015	0.013	0.014	0.017	0.016	0.014
			Lab		0.0112	0.0123	0.0116	0.0112	0.0109	0.0114	0.0114	0.0109	0.0111	0.0112	0.011	0.011
		Nickel, Dissolved (mg/L)	Lab		0.00038	0.00217	0.00214	0.00235	0.00238	0.00246	0.00237	0.00246	0.00233	0.00243	0.00252	0.00241
		Nickel, Total (mg/L)	Lab			0.0022	0.0022	0.0024	0.0023	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
				N/D at <0.0005	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		201	255.3	274.8	324.5	323.4	322.2	311.7	311	307	302.4	296.9	279.1
		pH	Bench		7.43	5.7	5.73	5.77	5.76	5.76	5.74	5.74	5.74	5.74	5.75	5.76
			Lab		7.8	5.97	5.83	5.8	5.88	5.87	5.82	5.81	5.44	5.8	5.82	5.84
		Potassium, Dissolved (mg/L)	Lab		1.16	1.15	1.18	1.18	1.16	1.21	1.17	1.15	1.17	1.22	1.18	1.15
		Potassium, Total (mg/L)	Lab		1.15	1.14	1.12	1.17	1.16	1.2	1.16	1.17	1.17	1.17	1.15	1.14
		Sodium, Dissolved (mg/L)	Lab		2.297	2.27	2.373	2.512	2.445	2.484	2.432	2.461	2.492	2.61	2.459	2.404
		Sodium, Total (mg/L)	Lab		2.25	2.27	2.27	2.42	2.36	2.43	2.39	2.46	2.39	2.38	2.42	2.36
		Sulfate (mg/L)	Lab													77
		TDSwq (mg/L)	Lab		98	116	115	116	112	116	116	118	120	118	117	117
		Temperature (ºC)	Lab		6.6	7.1	7.1	7.5	7.5	7.5	7.6	8	8	7.7	7.8	6.9
		ThmBDCM Total(ug/L)	Lab		1.5											2.5
		ThmCHCl3 Total(ug/L)	Lab		28											25.4
		ThmTotal,calc_ Total(ug/L)	Lab		30											28
		TSScalc Total (mg/L)	Lab		12	4	17	14	16	16		4		4	13	13

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 31, 2017	Pilot-Scale	TSScalc Total (mg/L)	Lab	N/D at <3							G/N		G/N			
		TSwv Total (mg/L)	Lab		110	120	132	130	128	132	118	122	122	122	130	130
		Turbidity (NTU)	Bench		1.01	1.58	1.19	0.32	0.1	0.13	0.14	0.13	0.1	0.08	0.12	0.1
			Lab		0.79	1.4	1.47	0.17	0.05	0.09	0.06	0.07	0.06	0.06	0.07	0.06
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.13	0.128	0.11	0.03	0.029	0.027	0.03	0.026	0.026	0.024	0.024	0.026
		UVT @ 254nm, Filtered (/cm)	Lab		77.4	92.6	93.9	94.7	95	95.1	95	95.1	95.3	95.5	95.5	95.3
		UVT @ 254nm, Unfiltered (%T)	Bench		74.1	74.4	77.6	93.4	93.5	94	93.4	94.3	94.2	94.5	94.5	94.3
		Zinc, Dissolved (mg/L)	Lab		0.0009	0.0012	0.0025	0.0009		0.0018	0.0017	0.0013		0.0041	0.0023	
				N/D at <0.0009					G/N				G/N			G/N
		Zinc, Total (mg/L)	Lab	N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			8	10									8
		Aluminum, Dissolved (mg/L)	Lab			0.004	0.004									0.006
		Aluminum, Total (mg/L)	Lab			0.004	0.004									0.01
		Antimony, Dissolved (mg/L)	Lab			0.00119	0.00066									0.00095
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00039	0.00034									0.00032
		Arsenic, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			19.1	19.4									18.8
		Calcium, Total (mg/L)	Lab			19.5	18.6									19.2
		Chloride (mg/L)	Lab													18
		Chromium, Dissolved (mg/L)	Lab			0.00005	0.00014									0.00015
		Chromium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Colour, True	Lab			2	2									1.5
		Conductivity Total (µS/cm)	Bench			189.1	181.5									177.2
			Lab			195	193									196
		Copper, Dissolved (mg/L)	Lab			0.0027	0.0044									0.0021
		Copper, Total (mg/L)	Lab			0.003	0.005									0.002
		DO (mg/L)	Bench			11.7	12									12.5
		DOC Total (mg/L)	Lab	Data not recv		G/N	G/N									G/N
		dTot, Hardness (mg/L CaCO3)	Lab													73.2
		HaaBCAA ion(Fe+2)(ug/L)	Lab													0.7
		HaaDBAA ion(Fe+2)(ug/L)	Lab													1.7
		HaaDCAA ion(Fe+2)(ug/L)	Lab													4.3
		HaaMBAA ion(Fe+2)(ug/L)	Lab	Data not recv												G/N
		HaaMCAA ion(Fe+2)(ug/L)	Lab	Data not recv												G/N
		HaaTCAA ion(Fe+2)(ug/L)	Lab													4.2
		HaaTotal, calc_(ug/L)	Lab													11
		Iron, Dissolved (mg/L)	Lab			0.117	0.015									0.02
		Iron, Total (mg/L)	Lab			0.52	0.59									0.06
		Lead, Dissolved (mg/L)	Lab			0.00003	0.00002									0.00001
		Lead, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			6.269	6.252									6.12
		Magnesium, Total (mg/L)	Lab			6.2	5.98									6.15
		Manganese, Dissolved (mg/L)	Lab			0.039	0.0185									0.0238
		Manganese, Total (mg/L)	Bench			0.042	0.038									0.028
			Lab			0.0397	0.0363									0.0268
		Nickel, Dissolved (mg/L)	Lab			0.00188	0.0018									0.00172
		Nickel, Total (mg/L)	Lab			0.0018	0.0017									0.0017
		Oxi-Red Potenital (ORP) (mV)	Bench			289	315.4									299.1
		pH	Bench			5.59	5.72									5.52
			Lab			5.59	5.82									5.6
		Potassium, Dissolved (mg/L)	Lab			1.13	1.21									1.11
		Potassium, Total (mg/L)	Lab			1.16	1.11									1.15
		Sodium, Dissolved (mg/L)	Lab			2.402	2.535									2.626
		Sodium, Total (mg/L)	Lab			2.4	2.37									2.66
		Sulfate (mg/L)	Lab													50
		TDSwq (mg/L)	Lab			112	104									117
		Temperature (ºC)	Lab			6.3	6.1									6.5
		ThmBDCM Total(ug/L)	Lab													2.3
		ThmCHCl3 Total(ug/L)	Lab													15.9

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Fall
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
October 31, 2017	Full-Scale	ThmTotal,calc_ Total(ug/L)	Lab													19
		TSScalc Total (mg/L)	Lab			20	20									3
		TSwv Total (mg/L)	Lab			132	124									120
		Turbidity (NTU)	Bench			0.53	0.57									0.14
			Lab			0.47	0.59									0.15
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.062	0.061									0.023
		UVT @ 254nm, Filtered (/cm)	Lab			93.3	95.2									96
		UVT @ 254nm, Unfiltered (%T)	Bench			86.6	86.8									94.9
		Zinc, Dissolved (mg/L)	Lab			0.0045	0.0017									0.0019
		Zinc, Total (mg/L)	Lab			0.0015										0.0013
				N/D at <0.0009			G/N									

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary - Pilot DAF Float Sludge Sample Only

Season: Fall

Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location DAF Sludge
October 21, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		218
		TSSwv Total (mg/L)	Lab		3150
		TSwv Total (mg/L)	Lab		3370
October 26, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		16
		Temperature (ºC)	Lab		10.5
		TSSwv Total (mg/L)	Lab		7000
		TSwv Total (mg/L)	Lab		7020
October 27, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		236
		Temperature (ºC)	Lab		12.3
		TSSwv Total (mg/L)	Lab		6700
		TSwv Total (mg/L)	Lab		6940
October 31, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		468
		Temperature (ºC)	Lab		9.1
		TSSwv Total (mg/L)	Lab		4850
		TSwv Total (mg/L)	Lab		5320

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter keeps DAF Sludge. The Piloting_Season filter keeps Fall. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

APPENDIX

G

TM NO. 7

WINTER PILOTING SESSION # 2 (NOVEMBER 17 – DECEMBER 7, 2017)

TECHNICAL MEMORANDUM NO. 7

PROJECT: Pilot Testing an Alternative Coagulant for the Winnipeg Water Treatment

TO: Heather Buhler, City of Winnipeg

FROM: Maika Pellegrino (WSP), Justin Rak-Banville (WSP), Charles Goss (WSP)

SUBJECT: Winter #2 Piloting Session (November 17 – December 7, 2017) - Rev. 04

DATE: September 24, 2018

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1 OVERVIEW

Technical Memorandum No. 7 (TM No. 7) evaluates the piloting results for the alternative coagulant, ferric sulphate ($Fe_2(SO_4)_3$), under cold water/winter conditions (less than 4°C). Typically, the technical memorandum would commence by presenting the results of the benchmarking period, when the pilot-scale system was operated under the same conditions as the full-scale system, followed by the results of the transition period to ferric sulphate to demonstrate stability, and finally the results of the alternative coagulant piloting session. However, there was a deviation in piloting during this second Winter piloting session (Winter #2). The pilot-scale system was not transitioned back to ferric chloride following the completion of the Fall piloting session for two reasons:

1. The limited time between Fall and Winter #2 piloting sessions; and
2. The pilot-scale system required maintenance to address the occurrence of discoloured water in the Post-DAF as discussed in Technical Memorandum No. 6 (TM No. 6).

After the Fall piloting session, the stability of the pilot-scale system was monitored by the City to verify the system had returned to normal operation prior to the commencement of the Winter #2 piloting session. Once stability in the pilot-scale system was achieved, the Winter #2 piloting session of ferric sulphate was conducted. Following the completion of the Winter #2 piloting session, the pilot-scale system was transitioned back to ferric chloride and the Winter #2 benchmarking period between the full-scale and pilot-scale systems was completed.

This technical memo reports the results for the Winter #2 transition period, the Winter #2 piloting session using ferric sulphate as an alternative coagulant, and the subsequent hard transition to ferric chloride, followed by the Winter #2 benchmarking period. Table 1-1 provides a summary of the Winter #2 piloting session events which commenced on November 9th, 2017. The alternative coagulant piloting was conducted for 21 days from November 17th to December 7th, 2017. Following this period, the pilot-scale coagulant was returned to ferric chloride for benchmark testing for a total of 28 days, from December 12th to December 21st, 2017 and January 2nd to January 19th, 2018.

Table 1-1: Winter #2 piloting session schedule.

WINTER #2 PILOTING SESSION (<4ºC)	DURATION	START DATE	END DATE
1. Winter #2 Transition Period	8 days	November 9, 2017	November 16, 2017
2. Winter #2 Piloting Session	21 days	November 17, 2017	December 7, 2017
3. Winter #2 Mid-Point Progress Meeting	1 day	November 29, 2017	November 29, 2017
4. Winter #2 Benchmarking Period	28 days	December 12, 2017	January 19, 2018

2 WINTER #2 TRANSITION PERIOD

The Winter #2 transition period was carried out by the City from November 9th to November 16th, 2017. From November 1st to November 9th, the pilot-scale system was offline for maintenance to address the occurrence of discoloured water in the Post-DAF effluent, reported during the Fall piloting session (TM No. 6). Details about the maintenance conducted by the City during this period were reported in TM No. 6. On November 9th, 2017, the pilot-scale system was placed back online and allowed to stabilize for approximately 4 days (November 9th to November 12th). The raw water temperature during the transition period ranged from 1.6 to 2.0°C and had an average turbidity of approximately 1.1 NTU.

From November 13th to November 15th, 2017, the City operated the pilot-scale system with an increasing ferric sulphate dose, ranging from 34 to 48 mg/L, to monitor the operation and performance of the pilot-scale DAF system. The pH controller was not active during this period and the sulphuric acid dose was set to 42 mg/L throughout the evaluation of the coagulant dose. Only Post-DAF turbidity and pH were measured during the Winter #2 transition period.

Table 2-1 presents the results for Post-DAF turbidity and pH at increasing doses of ferric sulphate. The results illustrate that the Post-DAF turbidity decreased with increasing coagulant dose up to a dose of 42 mg/L. Subsequent increases in coagulant dose exceeding 42 mg/L resulted in an increase in Post-DAF turbidity. As expected, the pH decreased with increasing coagulant dose due to the acidity of ferric sulphate.

Table 2-1: Post-DAF turbidity and pH at increasing Ferric Sulphate dose during the Winter #2 transition period. Data originates from benchtop analyses using a Thermo Scientific Orion Star A325 pH probe.

Ferric Sulphate Dose (mg/L)	Recorded pH	Recorded Turbidity (NTU)
34	5.63	1.90
36	5.43	1.80
38	5.32	1.78
40	5.20	1.77
42	5.30	1.68
44	5.15	1.77
46	5.06	1.98
48	5.03	2.02

From the results presented in Table 2-1, the lowest turbidity was 1.68 NTU when operating at a coagulant dose of 42 mg/L and pH of 5.30. The intent of this transition period was to evaluate the pilot-scale DAF system's operation and response to change, and not to establish the correct optimal dose for ferric sulphate in cold water conditions.

It is important to point out that on November 16th, the City identified a problem regarding the addition of sulphuric acid. The problem was the result of a calibration issue with the 4-20 milliamp setting on the sulphuric acid pump, which occurred following the replacement of the sulphuric acid pump head during the Fall piloting session (TM No. 6). The calibration issue did not affect the Fall piloting session results as the pH controller was operating and compensated for the calibration error in the sulphuric acid pump. The

City corrected this calibration issue on November 16th, prior to the commencement of the Winter #2 piloting session.

Table 2-2 presents the Post-DAF turbidity and pH at the optimal ferric sulphate dose of 42 mg/L for two sulphuric acid doses, 39 mg/L and 40 mg/L, respectively. The sulphuric acid dose of 39 mg/L resulted in a pH of 5.75 and Post-DAF turbidity of 1.46 NTU. Comparatively, the sulphuric acid dose of 40 mg/L caused a slightly lower pH of 5.65 and a higher Post-DAF turbidity of 1.53 NTU.

Table 2-2: Post-DAF turbidity and pH at varying doses of sulphuric acid during the Winter #2 transition period.

Ferric Sulphate Dose (mg/L)	Sulphuric Acid Dose (mg/L)	Recorded pH	Recorded Turbidity (NTU)
42	40	5.65	1.53
42	39	5.75	1.46

Overall, the major focus of the Winter #2 transition period was to monitor the performance and stability of the pilot-scale system following maintenance to address the occurrence of discoloured water at the end of the Fall piloting session. The City did not observe any discoloured water in the pilot-scale system during the Winter #2 transition period and reported that the pilot-scale system appeared to have returned to normal operation.

A noted improvement to the pilot-scale DAF operation during the Winter #2 transition period occurred when the City reduced the raw water flow from 3.0 L/s to 2.75 L/s. At a raw water flow rate of 3.0 L/s, there is a retention time in the DAF tank of approximately 6 minutes. The reduction in raw water flow increased the retention time in the DAF tank by approximately 30 seconds, allowing more time for the microbubbles in the DAF tank to push more floc to the surface, improving DAF effluent water quality. Comparatively, the retention time in the full-scale DAF system during normal operation is approximately 33 minutes. Lower water temperatures reduce chemical kinetics and increase the solubility of dissolved gases; thereby, requiring a longer retention time in the DAF tank to achieve maximum efficiency. The City informed WSP that the reduced raw water flow rate was to be used for further piloting in cold water conditions.

3 WINTER #2 PILOTING SESSION ACTIVITY

WSP operated the pilot-scale system from November 17th to December 7th, 2017, inclusive. The specific activities and test conditions that were investigated during this period are outlined in Table 3-1. The results of the analytical work on the piloting samples, completed by the City's Analytical Services Branch (here on referred to as the Lab), are provided in Appendix A. The daily operational logs, which detail observations and specific daily datum, are provided in Appendix B. A detailed description of the piloting work was previously outlined in TM No. 2.

Table 3-1: Summary of the Test Conditions for the Winter #2 Piloting Session

DATE	COAGULANT DOSE (mg/L)	PILOT pH	COAGULANT-AID DOSE (mg/L)	SAMPLE SCHEDULE	COMMENTS
November 17, 2017	40	5.7	No coagulant-aid		
November 18, 2017	40	5.7			
November 19, 2017	41	5.7			
November 20, 2017	41	5.7			
November 21, 2017	42	5.7			
November 22, 2017	42	5.7			
November 23, 2017	43	5.7			
November 24, 2017	43	5.7			
November 25, 2017	44	5.7			
November 26, 2017	44	5.7			
November 27, 2017	41	5.7		[1]Type 1	Best Coagulant
November 28, 2017	41	5.8			
November 29, 2017	41	5.8			
November 30, 2017	-	-		-	OFFLINE
December 1, 2017	41	5.9			
December 2, 2017	41	5.9			
December 3, 2017	41	6.0			
December 4, 2017	41	6.0			
December 5, 2017	41	5.8			Best Conditions/ Filter Bank Flow Test
December 6, 2017	41	5.8		[2]Type 2	Best Conditions
December 7, 2017	41	5.8		Type 1	Best Conditions

[1] Type 1 sampling included: metals (dissolved and total): aluminum, arsenic, boron, calcium, cadmium, chromium, copper, iron, potassium, magnesium, manganese, sodium, nickel, lead, antimony, silver, uranium, zinc, and zirconium. In addition, dissolved organic carbon (DOC), total dissolved solids (TDS), total solids (TS), total suspended solids (TSS), true colour, UV-Transmittance, alkalinity, conductivity, pH and turbidity.

[2] Type 2 sampling included all of Type 1, and threshold odour number, total trihalomethane (T-THM), total haloacetic acids (T-HAA), sulphate, chloride, and hardness. T-THM and T-HAA formation potential were only tested in the raw water and filter effluent of the full-scale and pilot-scale systems.

Process samples were collected from the pilot-scale system on a daily basis at the following locations:

- Raw;
- Post-DAF (via the DAF overflow piping to the overflow tank);
- Post-Ozone (from the combined ozone column piping feeding the Ozone Contact Tank);
- Individual filter effluents (Filters 1 through 8); and
- Combined filter effluent.

Samples were also collected from the full-scale system at the following locations for comparison purposes:

- Post-DAF;
- Post-Ozone (i.e. combined ozone from both tanks); and
- Post Filter Combined

Samples were tested on a daily basis using the available bench-scale apparatus. Lab analyses were planned based on the schedule provided in Table 3-1.

During the Winter #2 piloting session, the raw water flow rate was between 2.5 L/s and 2.70 L/s, and the DAF recycle flow was approximately 0.4 L/s. The flow rates for filter Bank A (Filters 1 – 4) and filter Bank B (Filters 5 – 8) were 0.6 L/s and 0.3 L/s, respectively.

At the City's request, coagulant-aid was not added during the Winter #2 piloting session. Previous technical memos determined that the addition of coagulant-aid significantly increased the need for cleaning and maintenance of the pilot-scale system, due to a rapid buildup of residual coagulant and/or coagulant-aid within the DAF tanks and pilot-scale piping, and decreased the unit filter run volumes (UFRV) observed from the pilot-scale filters. Although previous technical memorandums reported slightly improved water quality with the addition of the coagulant-aid, the gains observed were not significant enough to warrant the additional maintenance and reduced UFRVs observed when the pilot-scale system was operated with coagulant-aid.

Deviations from the original program presented in TM No. 2 were as follows:

- Raw water analysis was taken from the pilot-scale system intake;
- Backwash performance evaluation was not performed as per recommendations in TM No. 3;
- Total Organic Carbon (TOC) analysis was conducted on the raw water and combined filter effluent samples from the full-scale system;
- Optimal coagulant dose was determined without the addition of coagulant-aid;
- Optimal pH was determined without the addition of coagulant-aid;
- Optimal coagulant and pH testing was conducted in duplicate;
- No coagulant-aid dose was tested;
- Pilot-scale raw water flow rate was maintained below 2.75 L/s; and
- Individual filter flow testing was conducted on Filters 1 - 8 (December 5th, 2017).

4 WINTER #2 PILOTING SESSION RESULTS

This section summarizes the operational parameters and the water quality analyses for the Winter #2 piloting session from November 17th to December 7th, 2017, inclusive. Confirmatory laboratory analyses were performed by the Lab and WSP staff performed the daily benchtop analyses. Data was also collected from the pilot-scale system SCADA for comparison between benchtop and online instrumentation.

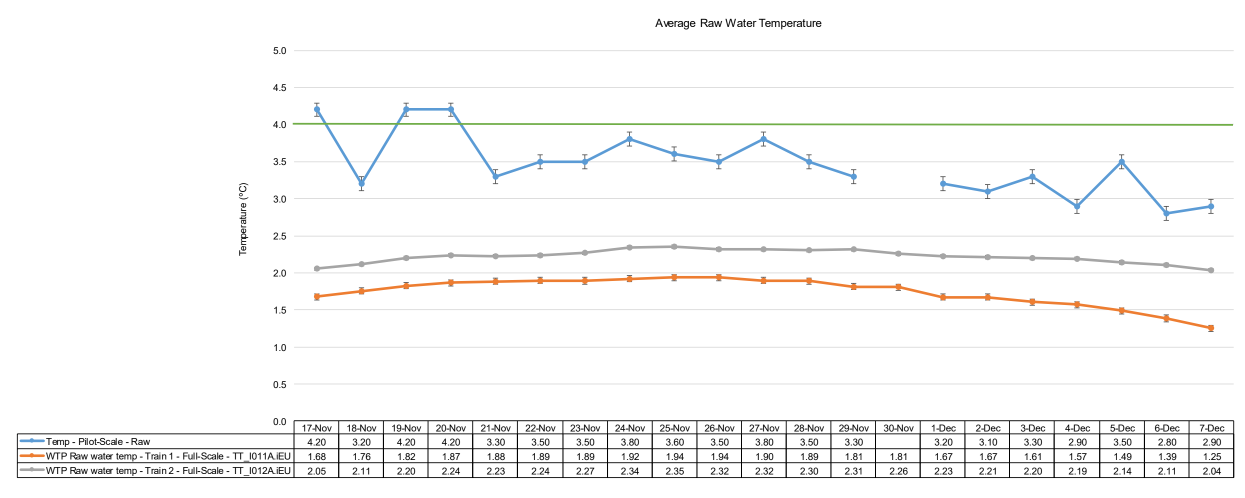
The ozone in the pilot-scale system was not operational on November 18th and 19th. The ozone generator was turned off by City technicians unintentionally on Friday November 17th, following the daily pilot-scale system sample collection, in order to calibrate the pilot-scale system online pH meters. The City technician failed to reinitiate ozone generation following the completion of the pH calibration. Onsite WSP personnel were unaware the ozone generator was not active until Monday November 20th. City technicians reinitiated ozone generation on November 20th, prior to daily filter backwashing.

On November 21st, the pilot-scale system ozone was not operational for approximately 1 hour (11:30am to 12:30pm). This was due to an elevated ozone alarm in the pilot-scale system, which exceeded the minimum ozone level threshold, causing an emergency safety system shut-off of the ozone generator. Investigation into the reason for the elevated ozone in the pilot-scale system was conducted by City engineers and technicians; however, a cause could not be determined. Ozone operation was reinitiated following the investigation by City personnel and no further elevated ozone alarms were experience for the duration of the Winter #2 piloting session.

On November 28th, WSP personnel discovered that there was an airlock in the filter-aid pump feeding Bank A (Filters 1 - 4). City technicians were able to clear the airlock in the line by running the filter-aid pump at an increased rate (increased from 0.01 L/s to 0.014 L/s). The filter-aid addition to Filter Bank A was not operational for approximately 2 hours before daily sample collection. The minor interruption to the filter-aid addition to Filter Bank A did not appear to affect water quality at the time of sampling.

4.1 Raw Water Temperature

The criteria for testing in the Winter #2 conditions (cold water) was that the raw water temperature be less than 4°C (green-line denotes 4°C; Figure 4-1). Raw water temperature for the full-scale system was measured by two online temperature sensors (Train 1 and 2). Pilot-scale raw water temperature was measured using a hand-held digital thermometer on grab samples collected from the pilot-scale system raw water intake.



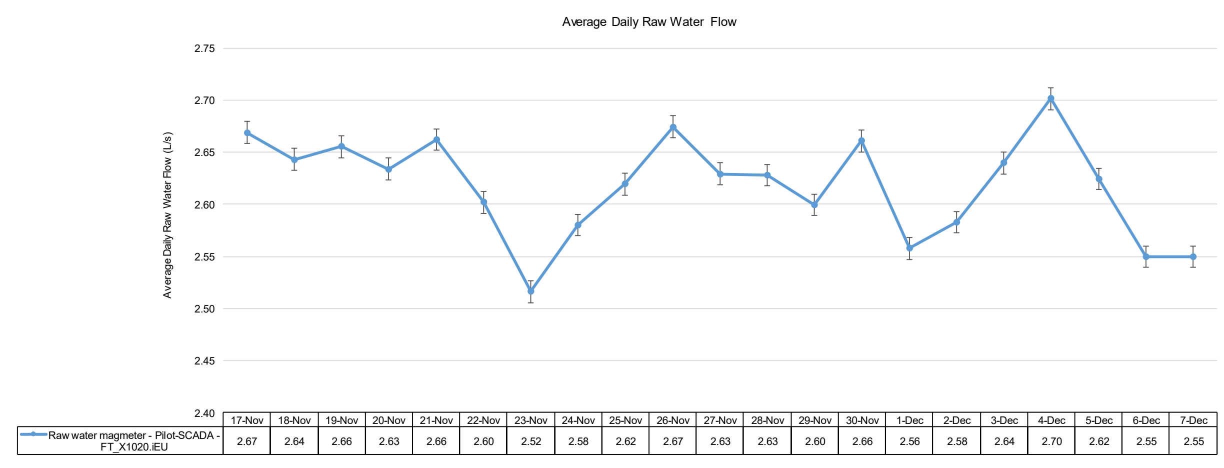
	17-Nov	18-Nov	19-Nov	20-Nov	21-Nov	22-Nov	23-Nov	24-Nov	25-Nov	26-Nov	27-Nov	28-Nov	29-Nov	30-Nov	1-Dec	2-Dec	3-Dec	4-Dec	5-Dec	6-Dec	7-Dec
Temp - Pilot-Scale - Raw	4.20	3.20	4.20	4.20	3.30	3.50	3.50	3.80	3.60	3.50	3.80	3.50	3.30		3.20	3.10	3.30	2.90	3.50	2.80	2.90
WTP Raw water temp - Train 1 - Full-Scale - TT_I011A.iEU	1.68	1.76	1.82	1.87	1.88	1.89	1.89	1.92	1.94	1.94	1.90	1.89	1.81	1.81	1.67	1.67	1.61	1.57	1.49	1.39	1.25
WTP Raw water temp - Train 2 - Full-Scale - TT_I012A.iEU	2.05	2.11	2.20	2.24	2.23	2.24	2.27	2.34	2.35	2.32	2.32	2.30	2.31	2.26	2.23	2.21	2.20	2.19	2.14	2.11	2.04

Figure 4-1: Average daily raw water temperature for the full-scale and pilot-scale systems during the Winter #2 piloting session. The green-line represents the upper temperature limit for cold water conditions (4°C). Pilot-scale system data originates from benchtop analysis and full-scale system data originates from SCADA data.

The results in Figure 4-1 illustrate that the full-scale system raw water temperature ranged from 1.3°C to 1.9°C for Train 1, and 2.0°C to 2.4°C for Train 2, during the Winter #2 piloting session. The raw water temperature measured in the pilot-scale system was approximately 1-2°C warmer than the raw water measured by the full-scale system temperature sensors. This slight increase in temperature has been noted in previous piloting sessions (TM No. 3-6) and is attributed to the movement of raw water within the water treatment plant. Pilot-scale system raw water temperature exceeded the 4.0°C on November 17th, 19th, and 20th, with all three days having a temperature of 4.2°C. It is believed that this minor exceedance in temperature would not likely cause a significant change in raw water quality at the pilot-scale system. Therefore, the raw water met the criteria for cold water conditions during the Winter #2 piloting session.

4.2 Pilot-Scale System Raw Water Flow (SCADA)

The average pilot-scale system raw water flow is presented in Figure 4-2. During the Winter #2 transition period, the City observed a significant decline in Post-DAF effluent water quality when the raw water flow rate exceeded 2.75 L/s. Therefore, the raw water flow rate was maintained below 2.75 L/s for the entirety of the Winter #2 piloting session. Onsite WSP personnel observed periodic fluctuations in the pilot-scale system raw water flow rate during the Winter #2 piloting session; typically reporting a decline in flow rate over time. However, sudden increases in the raw water flow were also observed. Reductions in the pilot-scale system raw water flow rate have been reported in previous technical memo's and have been attributed to buildup of chemical (coagulant/acid) within the raw water line feeding the pilot-scale system. It is unclear if a buildup of chemical within the pipe caused the fluctuations in raw water flow during Winter #2 piloting session; however, it is recommended that a maintenance procedure be implemented to properly address, or prevent, the buildup of chemicals within the raw water line, in order to maintain a stable raw water flow.



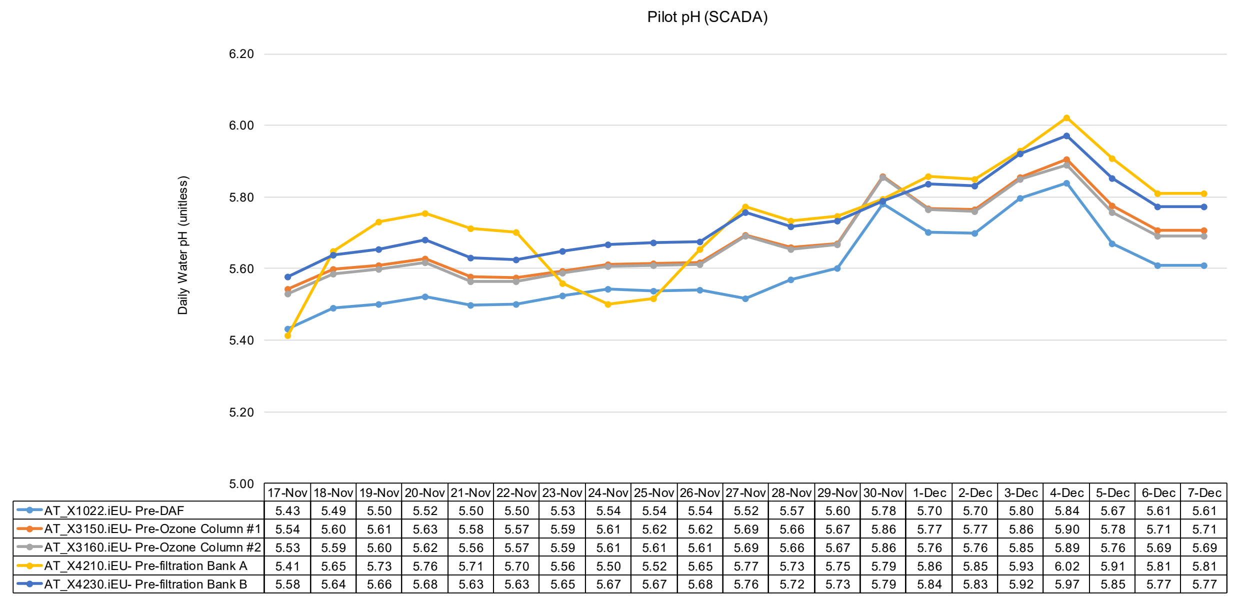
	17-Nov	18-Nov	19-Nov	20-Nov	21-Nov	22-Nov	23-Nov	24-Nov	25-Nov	26-Nov	27-Nov	28-Nov	29-Nov	30-Nov	1-Dec	2-Dec	3-Dec	4-Dec	5-Dec	6-Dec	7-Dec
Raw water magmeter - Pilot-SCADA - FT_X1020.iEU	2.67	2.64	2.66	2.63	2.66	2.60	2.52	2.58	2.62	2.67	2.63	2.63	2.60	2.66	2.56	2.58	2.64	2.70	2.62	2.55	2.55

Figure 4-2: Average daily raw water flow rate during the Winter #2 piloting session. Data originates from online pilot-scale SCADA data.

Throughout the Winter #2 piloting session, the daily average raw water flow rate ranged between 2.52 L/s to 2.70 L/s, meeting the City's request to operate the raw water flow at less than 2.75 L/s.

4.3 pH Monitoring of the Pilot-Scale System (SCADA)

The pH was constantly monitored by the pilot-scale system SCADA. Figure 4-3 illustrates the daily average pH during the Winter #2 piloting session for the following locations: Pre-DAF, Pre-Ozone (columns #1 and #2), and Pre-Filtration (Bank A and Bank B).



	17-Nov	18-Nov	19-Nov	20-Nov	21-Nov	22-Nov	23-Nov	24-Nov	25-Nov	26-Nov	27-Nov	28-Nov	29-Nov	30-Nov	1-Dec	2-Dec	3-Dec	4-Dec	5-Dec	6-Dec	7-Dec
AT_X1022.iEU- Pre-DAF	5.43	5.49	5.50	5.52	5.50	5.50	5.53	5.54	5.54	5.54	5.52	5.57	5.60	5.78	5.70	5.70	5.80	5.84	5.67	5.61	5.61
AT_X3150.iEU- Pre-Ozone Column #1	5.54	5.60	5.61	5.63	5.58	5.57	5.59	5.61	5.62	5.62	5.69	5.66	5.67	5.86	5.77	5.77	5.86	5.90	5.78	5.71	5.71
AT_X3160.iEU- Pre-Ozone Column #2	5.53	5.59	5.60	5.62	5.56	5.57	5.59	5.61	5.61	5.61	5.69	5.66	5.67	5.86	5.76	5.76	5.85	5.89	5.76	5.69	5.69
AT_X4210.iEU- Pre-filtration Bank A	5.41	5.65	5.73	5.76	5.71	5.70	5.56	5.50	5.52	5.65	5.77	5.73	5.75	5.79	5.86	5.85	5.93	6.02	5.91	5.81	5.81
AT_X4230.iEU- Pre-filtration Bank B	5.58	5.64	5.66	5.68	5.63	5.63	5.65	5.67	5.67	5.68	5.76	5.72	5.73	5.79	5.84	5.83	5.92	5.97	5.85	5.77	5.77

Figure 4-3: Average daily pH during the Winter #2 piloting session. Data originates from online pilot-scale system SCADA data.

During the Winter #2 transition period, the DAF pH controller was not active as City engineers reported that instability in the controller was causing fluctuations in Post-DAF pH. On November 17th (Winter #2 piloting session Day #1), onsite WSP personnel operated the pilot-scale system without the use of the pH controller. The pH was controlled by setting the dose rate for sulphuric acid and monitoring changes in Post-DAF pH. Following discussion between onsite WSP personnel and a City technician, modifications were made to the pH controller logic to address the instability in the controller observed by the City during the Winter #2 transition period.

On November 18th, the DAF pH controller was activated prior to daily filter backwashing. The Post-DAF pH was monitored via grab samples every 30 to 60 minutes and compared to the pH set-point of the controller. No instability in the pH controller was observed; however, the controller did require an offset of -0.2 pH units to account for pH changes within the DAF tank. The pH offset of the pH controller was adjusted daily as needed, and the correction was determined by monitoring pH changes in the Post-DAF effluent via grab samples. Overall, the pilot-scale system pH was stable during the Winter #2 piloting session according to the online instrumentation.

4.4 Pilot-Scale System Filter Operation (SCADA)

During the Winter #2 piloting session, Bank A operated at an average flow of 0.6 L/s and Bank B operated at an average flow of 0.3 L/s. The standard procedure was to backwash the filters daily at approximately at the same time. The differential pressure values reported by the pilot-scale system SCADA were evaluated on an average hourly basis to determine the following:

- the filter run times;
- the UFRV values;
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter; and
- the rate of head loss increase of each filter.

The calculations were performed as described in Section 2.4 of TM No. 3. The filter's operational data were compared against the filter effluent turbidity measured by the benchtop analysis, which was sampled approximately 4 hours from the start of the filtration cycle. The summary of the filter operation data obtained during the Winter #2 piloting session is provided in Appendix B. Figure 4-4 illustrates the average daily UFRV values.

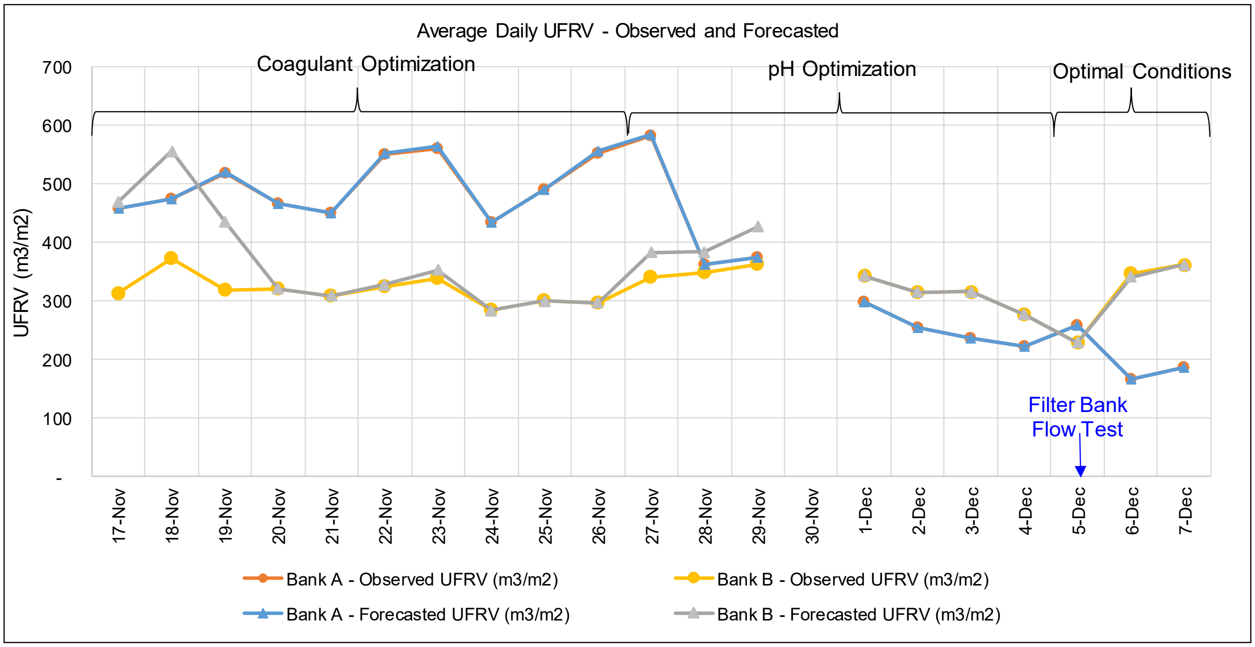


Figure 4-4: Average UFRV values of the pilot-scale system Bank A at an average flow of 0.6 L/s and Bank B at an average flow of 0.3 L/s during the Winter #2 piloting session. UFRV = Filter Run Volume/Filter Surface Area. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset. Note that no data is available for November 30th since the pilot-scale system was offline.

Table 4-1 provides a tabulation of the average filter run times and average UFRV values for the entire Winter #2 piloting session, while also considering overall operation cycles and those cycles which have not failed based on sampled turbidity.

Table 4-1: Average observed and forecasted filter run times and UFRV values during the Winter #2 piloting session.

	UFRV (m^3/m^2)	**FILTER RUN TIME (h)**		**UFRV (m^3/m^2)**		
		Bank A	**Bank B**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	13.1	20.2	397	321	359
	Only cycles with turbidity ≤ 0.1 NTU	12.5	19.7	273	320	316
	Only cycles with turbidity ≤ 0.3 NTU	12.9	20.2	390	321	347
Forecasted Values	Overall Cycles	13.1	20.2	398	352	374
	Only cycles with turbidity ≤ 0.1 NTU	12.5	19.7	273	331	326
	Only cycles with turbidity ≤ 0.3 NTU	12.9	20.2	391	352	366

From the filter operation data, the following observations were made:

→ During the Winter #2 piloting session, the individual filters typically overflowed before the daily backwash each time; however, none of the filters in Bank B (Filters 5-8) overflowed between November 17th to 19th, on November 23rd and between November 27th to 29th. Individually, Filter 6 did not overflow on November 26th, Filter 7 did not overflow from November 17th to November 29th, and Filter 8 did not overflow on November 22nd.

- The turbidity levels of the filters exceeded the City's operational guideline of 0.1 NTU 96% of the time for Bank A and 57% of the time for Bank B, while the turbidity levels have exceeded the full-scale system operating license of 0.3 NTU 39% of the time for Bank A and never for Bank B.
- For Bank A, the observed overall average filter run was 13.1 h and the observed overall average UFRV was 397 m^3/m^2. When discarding the operation cycles where turbidity exceeded 0.1 NTU when sampled, the observed UFRV value drops to 273 m^3/m^2. No substantial difference was observed when comparing the overall average observed UFRV value for all cycles (397 m^3/m^2) with the observed UFRV value for filters which have not presented turbidity above 0.3 NTU (390 m^3/m^2). No substantial difference was observed when comparing the observed UFRV values with the forecasted UFRV values for Bank A.
- For Bank B, the observed overall average filter run was 20.2 h and the observed overall average UFRV was 321 m^3/m^2. No substantial difference was observed when comparing the overall average observed UFRV value for all cycles (321 m^3/m^2) with the observed UFRV values when discarding the cycles that sampled turbidity levels were above 0.1 NTU or 0.3 NTU (320 and 321 m^3/m^2, respectively). The forecasted UFRV values were approximately 10% higher than the observed UFRV values for Bank B.
- The rate of head loss increase ranged from 1.1 to 5.6 kPa/h, with an average of 2.2 kPa/h for Bank A operating at 0.6 L/s, while the rate of head loss increase ranged from 0.6 to 1.4 kPa/h, with an average of 1.1 kPa/h for Bank B operating at 0.3 L/s. Low variability was observed among Bank B filters on the same day, and for each filter of Bank B. Higher variability was observed among Bank A filters on the same day, and for each filter of Bank A.
- When considering Bank A, operating at 0.6 L/s, 18% of the time the bank filters exceeded the typical rate of head loss increase of 3.1 kPa/h, but never the maximum rate of head loss increase of 7.1 kPa/h. (The typical and maximum rate of head loss increase for filter bank operating at 0.6 L/s, are based on the historical averages of the full-scale system. Refer to Table 5-2 of TM No. 3 for additional details).
- In comparison, Bank B filters did not exceed the typical rate of head loss increase of 1.7 kPa/h. (The typical and maximum rate of head loss increase for filter bank operating at 0.3 L/s, 1.7 kPa/h and 3.7 kPa/h, respectively, are based on historical averages of the full-scale system. Refer to Table 5-2 of TM No. 3 for additional details).

In comparing the daily averages as shown in Figure 4-4, a decrease in performance was observed in Bank A after November 27th, when the pH was increased to 6.0 as part of the pH optimization trials. The UFRV for Bank A gradually decreased until it fell behind that of Bank B. Bank B performance was relatively constant during coagulation and pH optimizations.

The loss of performance of Bank A could have been caused by the issues with the filter aid pump feeding Bank A, which were discovered on November 28th. It is possible that the media became clogged and subsequent backwashes were not enough to recover the filter run time. The pH increase could also have influenced the performance of Bank A. However, it is not believed that the pH increase is the main factor for two reasons: (1) the influence of pH on the URFV values for Bank B were significantly smaller, and (2) a decrease of this magnitude associated with an increase in the pH was not observed in the previous piloting sessions for Bank A. The influence of pH in the URFV values are further discussed in Section 4.6.2.

The filter operation from December 5th, when the individual filters flow rates were modified, is presented in Section 4.7. The effects of coagulant dose, pH, and coagulant-aid dose, are further discussed in Section 4.6. Additional evaluation regarding UFRV also is presented in Section 4.9.

4.5 DAF Sludge Production of the Pilot-Scale System

Figure 4-5 illustrates the total suspended solids (TSS) results for the residual generation from the DAF unit.

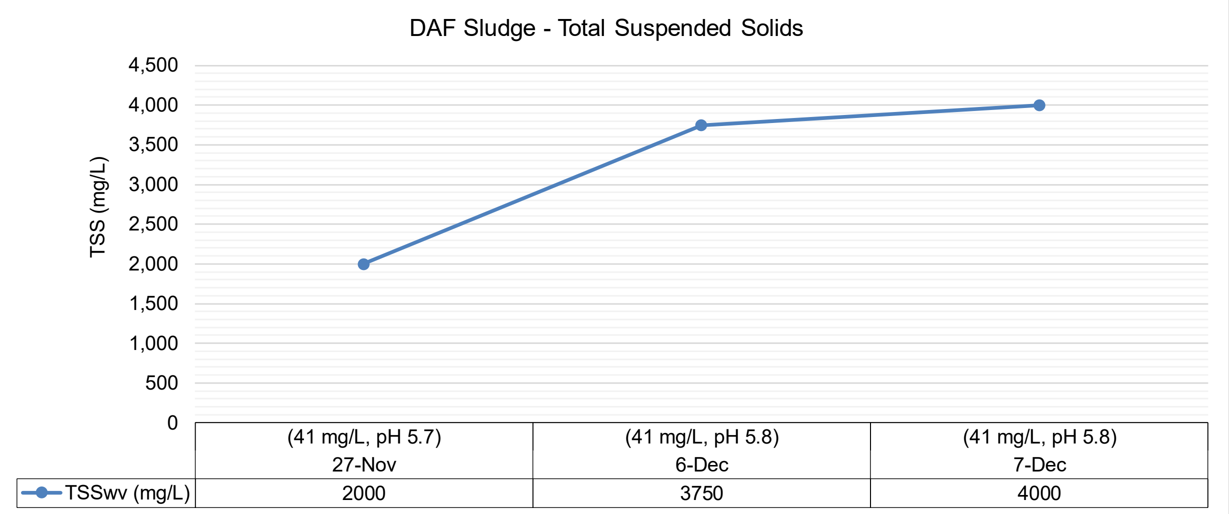


Figure 4-5: TSS results for DAF sludge in the pilot-scale system during the Winter #2 piloting session. Data originates from Lab analysis.

Similar to the Spring and Summer piloting sessions, the TSS concentration increases with increasing pH. When comparing the TSS results from the current Winter #2 piloting session with the residual TSS measured in the previous Winter #1 piloting session (TM No. 3), there is 30% lower TSS measured at the optimal coagulant dose used in the current piloting period, compared to the Winter #1 piloting session. There are two notable causes for the differences in residual production between the two Winter piloting sessions. First, there was a higher concentration of coagulant applied during the Winter #1 piloting session of 46 mg/L, compared to 41 mg/L used in the Winter #2 piloting session. Secondly, there was 0.02 mg/L coagulant-aid (LT-22S) dosed during flocculation in the Winter #1 piloting session; whereas, no coagulant-aid was applied in the Winter #2 piloting session. When evaluating the TSS from the Winter #1 piloting session with the Winter #2 piloting session, at similar coagulant doses (Winter #1 (April 4th and 5th): coagulant of 42 mg/L and coagulant-aid of 0.01 mg/L; Winter #2: coagulant of 41 mg/L and no coagulant-aid), there is approximately 22% more TSS produced when coagulant-aid is applied. This indicates the likelihood of increased sludge handling if coagulant-aid were to be used in conjunction with ferric sulphate.

It should be noted, that the sludge sampling from the pilot-scale DAF is a rudimentary process, and is subject to incomplete scrapper collection and/or variances in the scrapper level affecting the sludge blanket movement.

4.6 Optimization of Alternative Coagulant and pH

4.6.1 Optimization of the Ferric Sulphate Dose

The optimal dose testing for ferric sulphate in cold water conditions was conducted from November 17th to November 26th. The optimal dose range tested was between 40 – 44 mg/L, at a pH of 5.70. Due to the limited range in coagulant dose tested during the Winter #2 piloting session, it was determined that each coagulant dose would be tested in duplicate, and averaged, to allow for better comparison between coagulant doses. The optimal chemical dose was based on daily grab samples that were tested using various benchtop analyses for the following critical parameters: turbidity, UV-transmittance (UVT), UV-absorbance, and total manganese.

Samples were collected daily from the following locations in the pilot-scale system:

- Raw;
- Post-DAF (via the DAF overflow piping to the overflow tank);
- Post-Ozone (from the combined ozone column piping feeding the Ozone Contact Tank);
- Individual filter effluents (Filters 1 - 8); and
- Combined filter effluent.

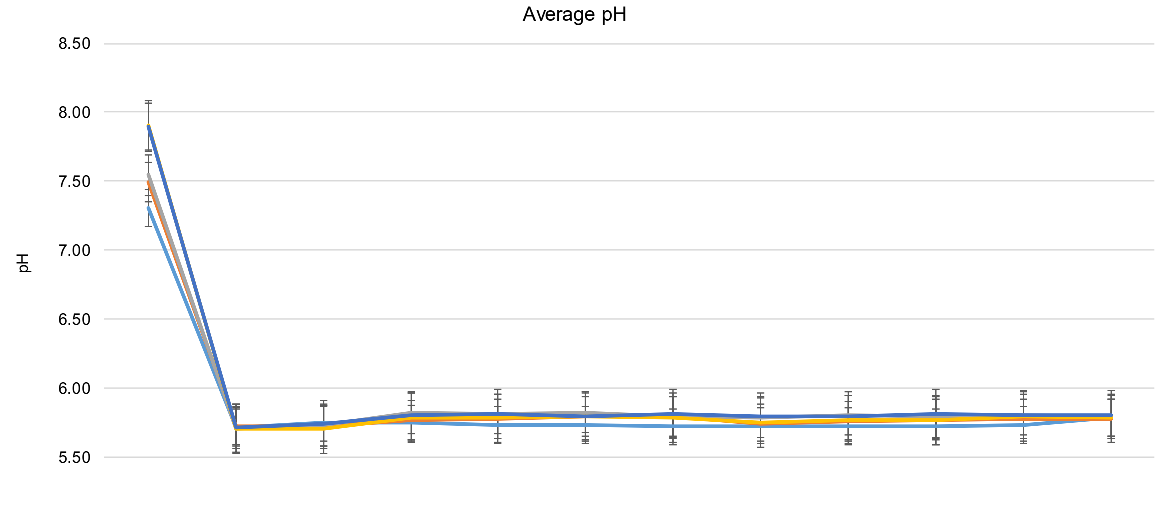
Samples were also collected and tested using benchtop analyses for the critical parameters listed above from the full-scale system at the following locations:

- Post-DAF;
- Post-Ozone (i.e. combined ozone from both tanks); and
- Post Filter Combined.

It is important to note that no coagulant-aid was added during the optimization of the ferric sulphate dose. The UFRV at the different coagulant doses was also noted.

- pH

During the optimization of the ferric sulphate dose, the Post-DAF pH was maintained at 5.70 based on optimal conditions determined during the Fall piloting session (TM No. 6). Figure 4-6 shows that the pH was well maintained throughout the optimization of the ferric sulphate dose, with an average Post-DAF pH of 5.70±0.01. As noted in previous piloting sessions, there was little change in pH between Post-DAF, Post-Ozone, and filter effluent samples.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
40 mg/L, pH 5.70	7.31	5.72	5.75	5.75	5.73	5.73	5.72	5.73	5.73	5.72	5.73	5.79
41 mg/L, pH 5.70	7.50	5.72	5.72	5.77	5.78	5.80	5.79	5.74	5.76	5.77	5.78	5.78
42 mg/L, pH 5.70	7.54	5.71	5.73	5.82	5.81	5.82	5.79	5.79	5.80	5.79	5.81	5.80
43 mg/L, pH 5.70	7.91	5.70	5.70	5.79	5.78	5.79	5.79	5.75	5.77	5.77	5.79	5.78
44 mg/L, pH 5.70	7.90	5.71	5.74	5.80	5.81	5.80	5.81	5.79	5.80	5.81	5.81	5.81

Figure 4-6: Average pH levels during ferric sulphate optimization at pH 5.7 during the Winter #2 piloting session. pH was measured with a Thermo Scientific Orion Star A325 pH probe.

→ Turbidity

The turbidity results for coagulant optimization are presented in Figure 4-7. One important note was that condensation was observed on the turbidity sample cell during turbidity testing due to the cold temperature of the samples. The formation of condensation on the sample vial caused an error during turbidity measurement (increased turbidity). Following discussion with the City Analytical Services Lab Manager[1], it was determined that this error could be minimized if the samples were warmed to room temperature, typically in a hot water bath. On November 17th (Winter #2 piloting session Day #1), samples were warmed on the benchtop, as no hot water bath was available in the pilot-scale system lab. This practice improved turbidity; however, an extended period was needed allow the samples to reach room temperature. Therefore, a hot water bath was improvised by using a plastic bucket filled with warm tap water, reducing the time require to reach room temperature. The improvised hot water bath was used from November 18th to the remainder of the Winter #2 piloting session. One concern with warming the samples was the impact on dissolved oxygen testing. As the samples warmed, the solubility of dissolved oxygen would be reduced, subsequently causing a lower DO reading. This issue was addressed by taking DO measurements prior to warming the samples for turbidity measurement.

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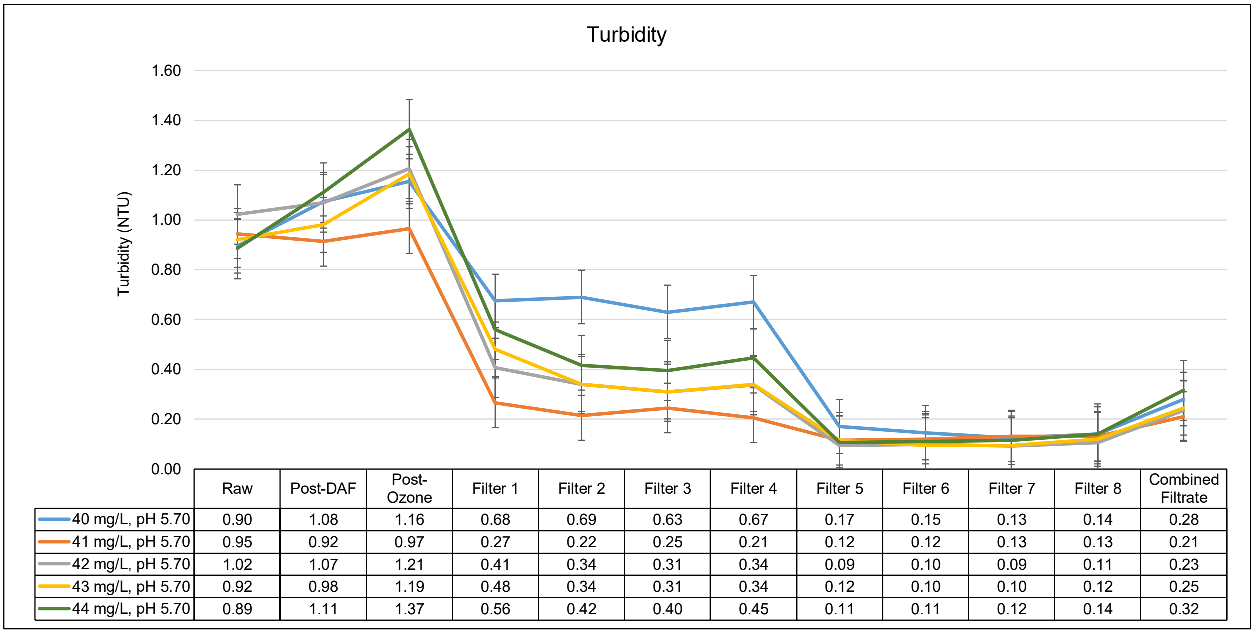
[1] Brock Bradford; personal communication, November 17th, 2017



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
40 mg/L, pH 5.70	0.90	1.08	1.16	0.68	0.69	0.63	0.67	0.17	0.15	0.13	0.14	0.28
41 mg/L, pH 5.70	0.95	0.92	0.97	0.27	0.22	0.25	0.21	0.12	0.12	0.13	0.13	0.21
42 mg/L, pH 5.70	1.02	1.07	1.21	0.41	0.34	0.31	0.34	0.09	0.10	0.09	0.11	0.23
43 mg/L, pH 5.70	0.92	0.98	1.19	0.48	0.34	0.31	0.34	0.12	0.10	0.10	0.12	0.25
44 mg/L, pH 5.70	0.89	1.11	1.37	0.56	0.42	0.40	0.45	0.11	0.11	0.12	0.14	0.32

Figure 4-7: Average turbidity levels following pilot-scale system processes for the determination of the optimal dose of ferric sulphate during the Winter #2 piloting session. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.

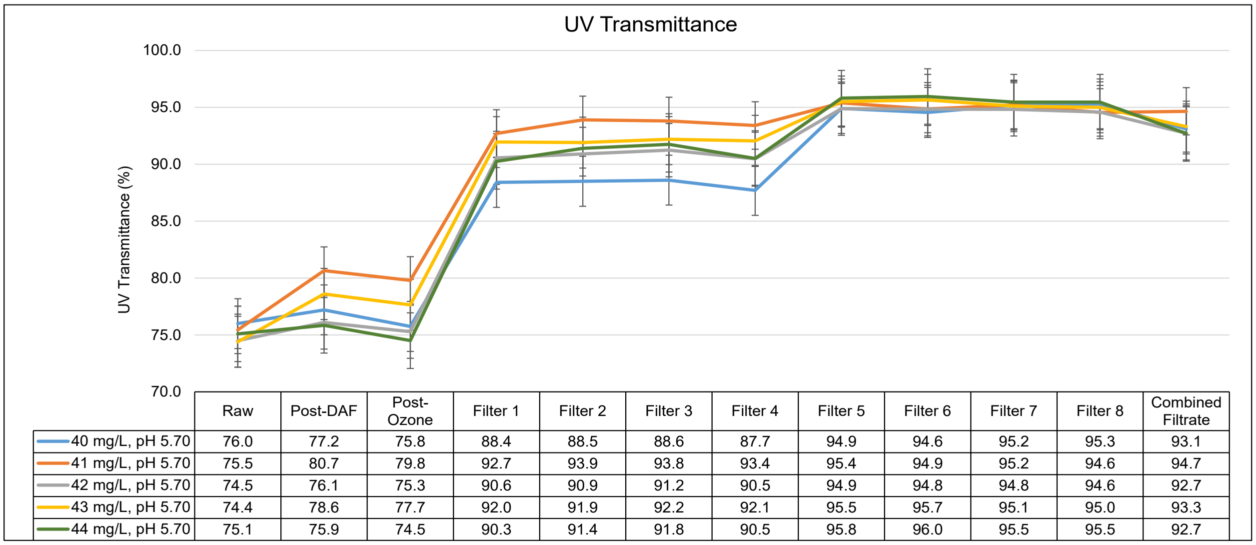
For the coagulant doses tested, turbidity increased in Post-DAF samples, except for the ferric sulphate dose of 41 mg/L, where the turbidity was slightly reduced following DAF treatment. Similarly, the turbidity was found to increase following ozonation for all coagulant doses tested. The turbidity was reduced by filtration for all coagulant doses tested with the ferric sulphate dose of 41 mg/L having the lowest combined filter turbidity of 0.21 NTU, equating to a 78% reduction in raw water turbidity.

It should be noted that Filter Bank B (Filters 5 - 8) consistently outperformed Filter Bank A (Filters 1 - 4) during the Winter #2 piloting session. The discrepancy between Banks A and B has been noted in previous technical memo's. Although the cause of the difference in performance between the two filter banks will require an additional dedicated study, it is speculated that the filter bank flow rates, inconsistency in the filter-aid addition, as well as mechanical differences in the piping and filter arrangement, contribute to the variance in performance between the two banks. The differences in Bank A and B are further discussed in Section 4-6.

The optimal dose for ferric sulphate, according to the turbidity results, was 41 mg/L, due to the reduction in turbidity observed in the Post-DAF samples, as well as having the lowest combined filter turbidity of the coagulant doses tested.

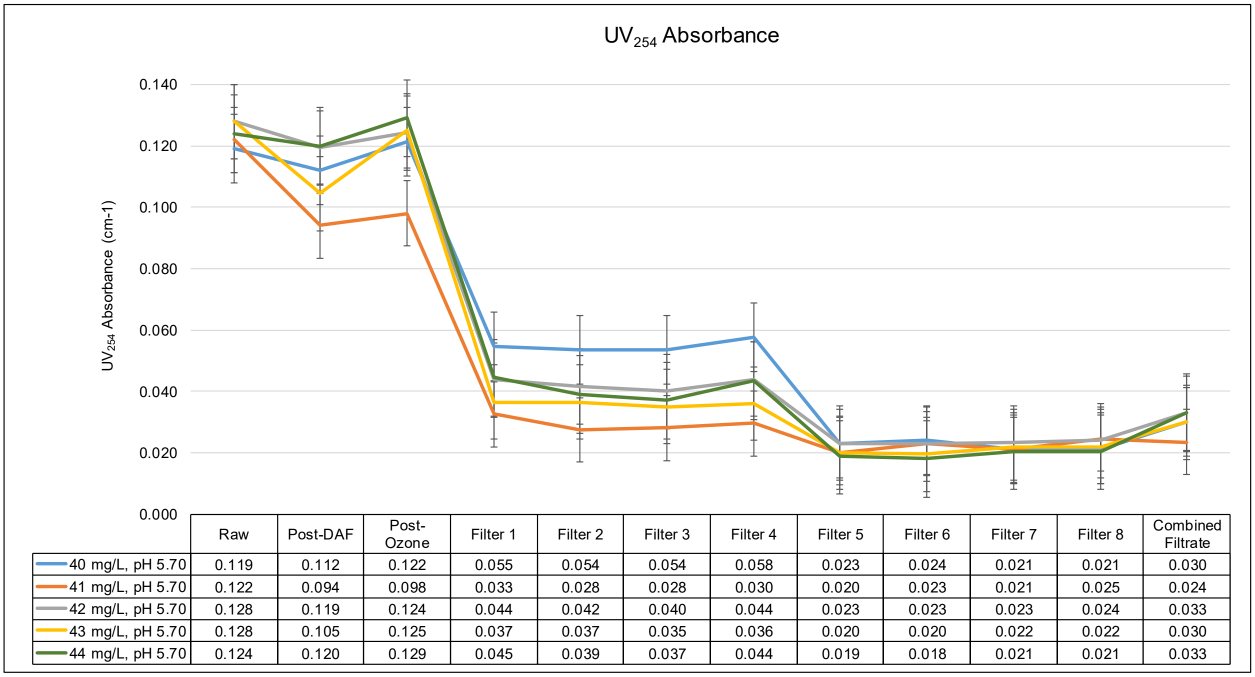
→ UV-Transmittance and Absorbance

The UVT and absorbance measured during coagulant dose optimization are presented in Figure 4-8 and Figure 4-9. For all coagulant doses tested, there was an improvement in both UVT and absorbance following coagulation and DAF treatment, with the greatest improvement occurring at a ferric sulphate dose of 41 mg/L. Following ozonation, water quality was found to slightly decline with regards to UVT and absorbance, for all coagulant doses tested. This is likely due to ozonation forming organic compounds which absorb more radiation at 254nm. Filtration significantly improved both UVT and absorbance for all ferric sulphate doses tested. Similar to the turbidity results, Filter Bank B outperformed Filter Bank A in the reduction of UV absorbing species. When comparing the combined filtrate effluent, the ferric sulphate dose of 41 mg/L had the highest UVT and lowest absorbance of 94.7% and 0.024 cm^{-1}, respectively.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
40 mg/L, pH 5.70	76.0	77.2	75.8	88.4	88.5	88.6	87.7	94.9	94.6	95.2	95.3	93.1
41 mg/L, pH 5.70	75.5	80.7	79.8	92.7	93.9	93.8	93.4	95.4	94.9	95.2	94.6	94.7
42 mg/L, pH 5.70	74.5	76.1	75.3	90.6	90.9	91.2	90.5	94.9	94.8	94.8	94.6	92.7
43 mg/L, pH 5.70	74.4	78.6	77.7	92.0	91.9	92.2	92.1	95.5	95.7	95.1	95.0	93.3
44 mg/L, pH 5.70	75.1	75.9	74.5	90.3	91.4	91.8	90.5	95.8	96.0	95.5	95.5	92.7

Figure 4-8: Average UVT measured following pilot-scale system processes for the determination of the optimal dose of ferric sulphate during the Winter #2 piloting session. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

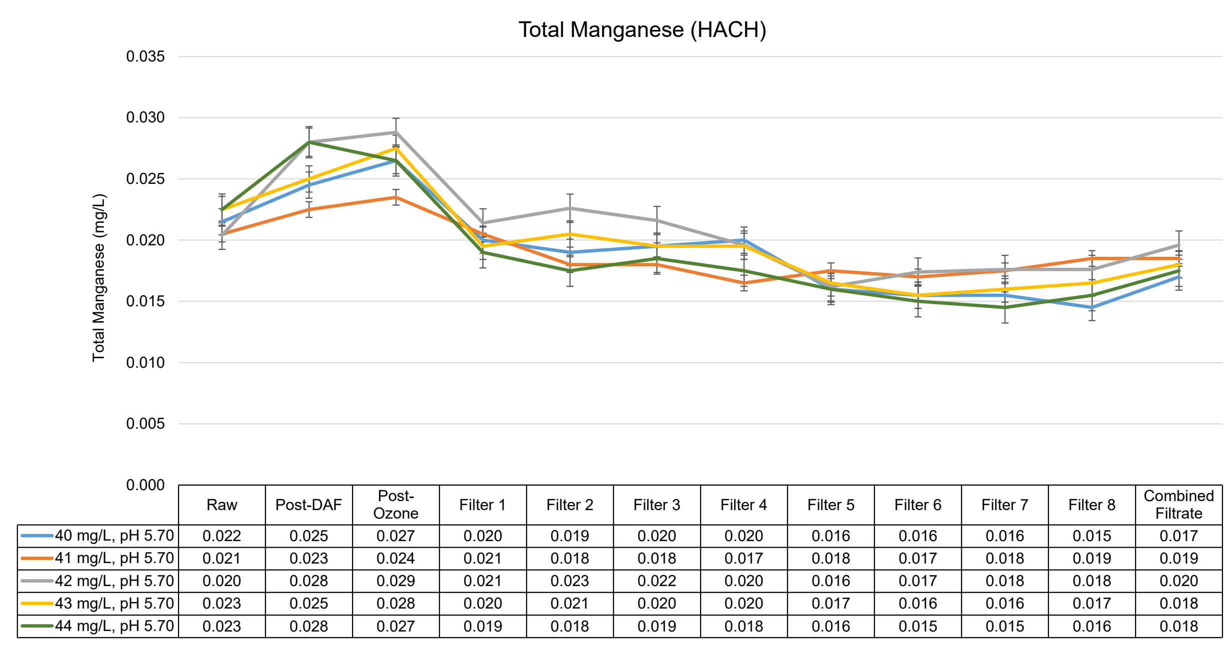


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
40 mg/L, pH 5.70	0.119	0.112	0.122	0.055	0.054	0.054	0.058	0.023	0.024	0.021	0.021	0.030
41 mg/L, pH 5.70	0.122	0.094	0.098	0.033	0.028	0.028	0.030	0.020	0.023	0.021	0.025	0.024
42 mg/L, pH 5.70	0.128	0.119	0.124	0.044	0.042	0.040	0.044	0.023	0.023	0.023	0.024	0.033
43 mg/L, pH 5.70	0.128	0.105	0.125	0.037	0.037	0.035	0.036	0.020	0.020	0.022	0.022	0.030
44 mg/L, pH 5.70	0.124	0.120	0.129	0.045	0.039	0.037	0.044	0.019	0.018	0.021	0.021	0.033

Figure 4-9: Average absorbance measured following pilot-scale system processes for the determination of the optimal dose of ferric sulphate during the Winter #2 piloting session. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ Total Manganese

The reduction in total manganese by the pilot-scale system during coagulant dose optimization is reported in Figure 4-10. An increase in total manganese was measured following coagulation and DAF treatment for all coagulant doses tested, due to the presence of residual manganese in the ferric sulphate. There was no change in manganese concentration following ozonation. The total manganese in the combined filtrate ranged from 0.017 to 0.020 mg/L, with the lowest total manganese concentration occurring at a coagulant dose of 40 mg/L. It should be noted that the total manganese concentration measured during the optimization of the ferric sulphate dose is at the low end of the detection limit for the HACH DR6000. Given the minor differences in total manganese measured in the combined filtrate for each coagulant dose, it is difficult to determine if there is a significant difference in total manganese in the combined filter effluent between the coagulant doses tested using the HACH spectrophotometer.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
40 mg/L, pH 5.70	0.022	0.025	0.027	0.020	0.019	0.020	0.020	0.016	0.016	0.016	0.015	0.017
41 mg/L, pH 5.70	0.021	0.023	0.024	0.021	0.018	0.018	0.017	0.018	0.017	0.018	0.019	0.019
42 mg/L, pH 5.70	0.020	0.028	0.029	0.021	0.023	0.022	0.020	0.016	0.017	0.018	0.018	0.020
43 mg/L, pH 5.70	0.023	0.025	0.028	0.020	0.021	0.020	0.020	0.017	0.016	0.016	0.017	0.018
44 mg/L, pH 5.70	0.023	0.028	0.027	0.019	0.018	0.019	0.018	0.016	0.015	0.015	0.016	0.018

Figure 4-10: Total Manganese measured following pilot-scale system processes for the determination of the optimal dose of ferric sulphate during the Winter #2 piloting session. Data originates from benchtop analyses using a HACH DR6000 UV-VIS spectrophotometer.

→ UFRV

Figure 4-11 illustrates the average observed and forecasted UFRV values obtained for each coagulant dose for Bank A and Bank B. Most of Bank A filters overflowed on all the cycles during the coagulant optimization tests, except one or two individual filters at each dose. Bank B did not overflow in both days at coagulant doses of 40 mg/L, and only one day at coagulant doses of 41 and 43 mg/L. All individual filters of Bank A failed based on turbidity (> 0.1 NTU) at all coagulant doses tested, while most of the filters presented turbidity measurements above 0.3 NTU at ferric sulphate doses of 40, 43 and 44 mg/L. Most individual filters in Bank B failed based on turbidity (> 0.1 NTU) at all coagulant doses tested. More precisely, 25% of the individual filters did not presented turbidity breakthrougth at ferric sulphate doses of 41 and 44 mg/L, while 63% of them did not presented turbidity breakthrougth at ferric sulphate doses of 42 and 43 mg/L.

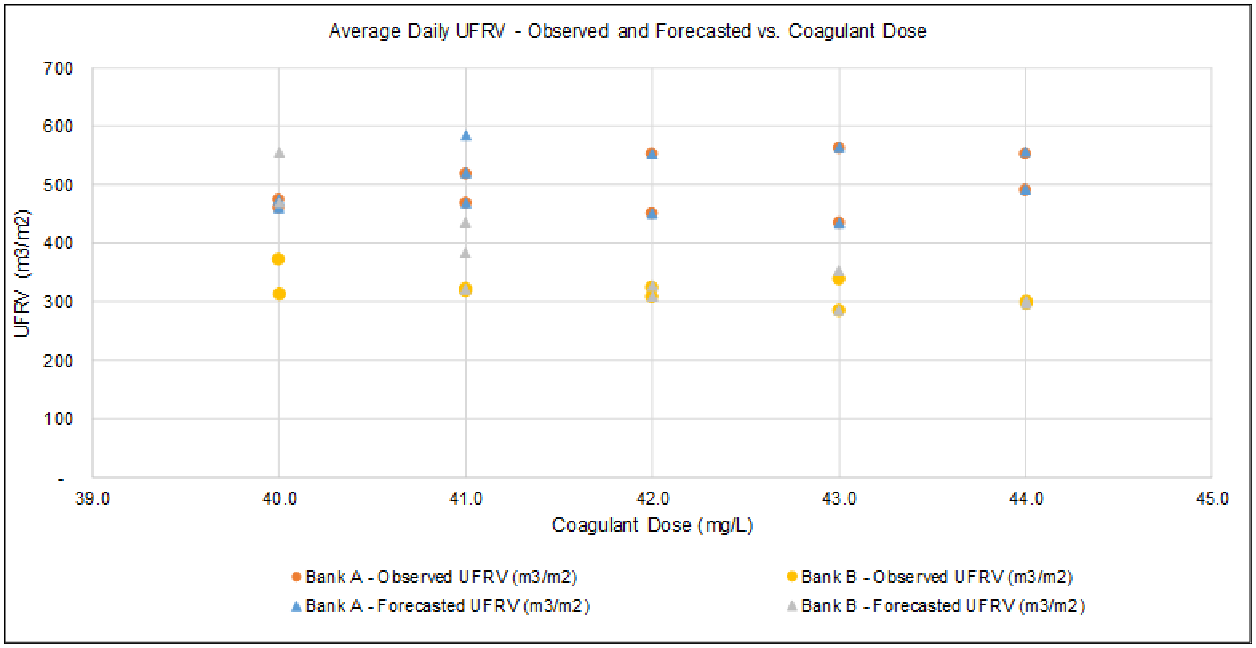


Figure 4-11: Average UFRV values of the pilot-scale system Bank A at 0.6 L/s and Bank B at 0.3 L/s during optimisation of ferric sulphate during the Winter #2 piloting session. The pilot system pH was maintained at pH 5.7 with no addition of coagulant aid. Note the observed and forecasted UFRV values may overlap. Data originates from the pilot's SCADA dataset.

No pattern between the coagulant dose and the UFRV values could be identified. Considering the averages of observed UFRV values at each coagulant dose, the highest UFRV values (521 and 343 m^3/m^2 for Bank A and Bank B, respectively) were obtained at coagulant dose of 44 mg/L for Bank A and 40 mg/L for Bank B. However, all Bank A filters and none of the Bank B filters failed based on turbidity measurements above 0.3 NTU at 44 mg/L dose, while 100% of Bank A filters and 75% of Bank B filters failed based on turbidity measurements above 0.1 NTU at 40 mg/L dose.

Considering Bank B results, since its operational parameters are closer to the full-scale system operational parameters, among the coagulant doses which less filters failed in turbidity, the highest UFRV value (316 m^3/m^2) was obtained at the coagulant dose of 42 mg/L and is considered to be the optimal coagulant dose. Given the UFRV values in the full-scale are expected to be twice as high due to the higher head loss available for filtration and only 63% of Bank B filters did not present turbidity breakthrough at this dose, the dose of 42 mg/L is also deemed a viable for full-scale operation.

The observed UFRV value was 320 m^3/m^2 for Bank B at 41 mg/L of ferric sulphate. Although this value is similar to the UFRV value at the dose of 42 mg/L (316 m^3/m^2), only 25% of the Bank B filters did not present turbidity breakthrough at this dose.

- → Summary of Ferric Sulphate Optimization

According to turbidity, UVT and absorbance results, the optimal dose for ferric sulphate in cold water conditions was determined to be 41 mg/L. Total manganese measured using the Hach equipment in the combined filtrate did not present a significant difference between dosages. The UFRV analysis performed following the Winter #2 piloting session did not confirmed the same optimal dose and indicated that the preferred coagulant dose was 42 mg/L based on filter performance.

4.6.2 Optimization of pH

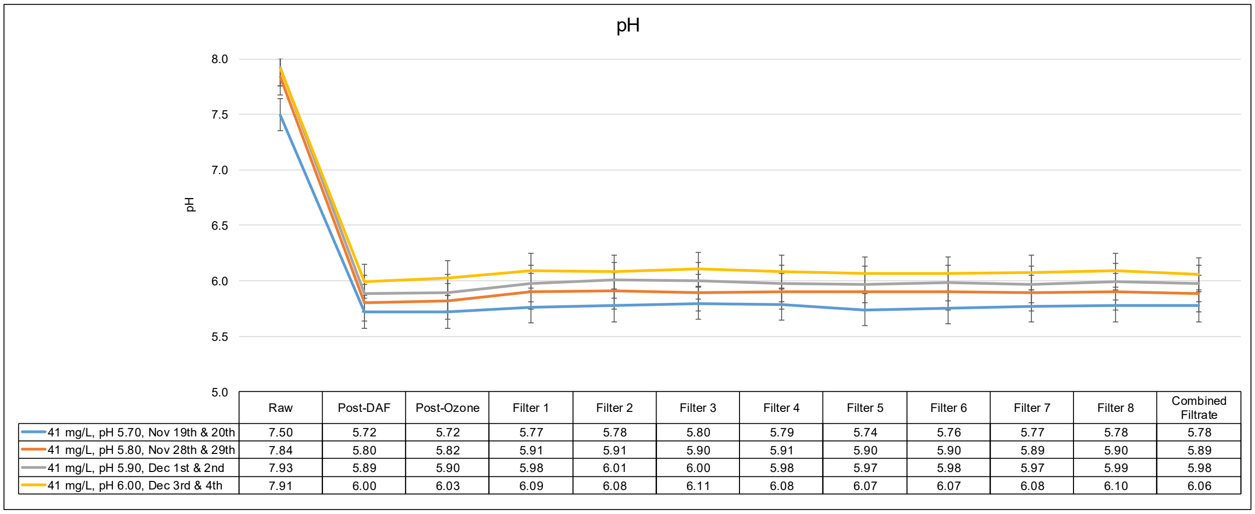
Optimal pH testing was conducted on November 19th and 20th, and from November 28th to December 4th, 2017 (Note: the data set does not include results for November 30th as no samples were collected on that day due to shut-down of the pilot-scale system). An analogous approach to the optimization of the coagulant dose was taken in determining the optimum pH. The optimal ferric sulphate dose of 41 mg/L was used during pH optimization. The target Post-DAF pH tested ranged from 5.70 to 6.00 (Table 4-2), based on previous piloting sessions indicating the optimal pH was between 5.60 and 5.95. Testing at a pH of 5.60 was not conducted based on the City's request that pH below 5.70 be avoided, as it is believed the acidic water increases the rate of deterioration of concrete structures in the full-scale system.

Table 4-2: Comparison of target and measured pH in the Post-DAF for pH optimization during the Winter #2 piloting session. Error is presented as standard deviation from the mean.

Date	Target Post-DAF pH	Measured Post-DAF pH (2 Day Average)
November 19th & 20th	5.70	5.72 ± 0.01
November 28th & 29th	5.80	5.80 ± 0.00
December 1st & 2nd	5.90	5.89 ± 0.01
December 3rd & 4th	6.00	6.00 ± 0.01

From the results reported in Table 4-2, the target Post-DAF pH was well maintained during pH optimization.

Figure 4-12 illustrates the changes in the pilot-scale pH following treatment. A significant reduction in raw water pH was measured in the Post-DAF samples, as expected. Little change in pH was found following ozonation and only a slight increase in pH (<0.1 pH) was observed in the filter effluent samples. Overall, the target Post-DAF pH was well met and there were no significant variations in pH following treatment.

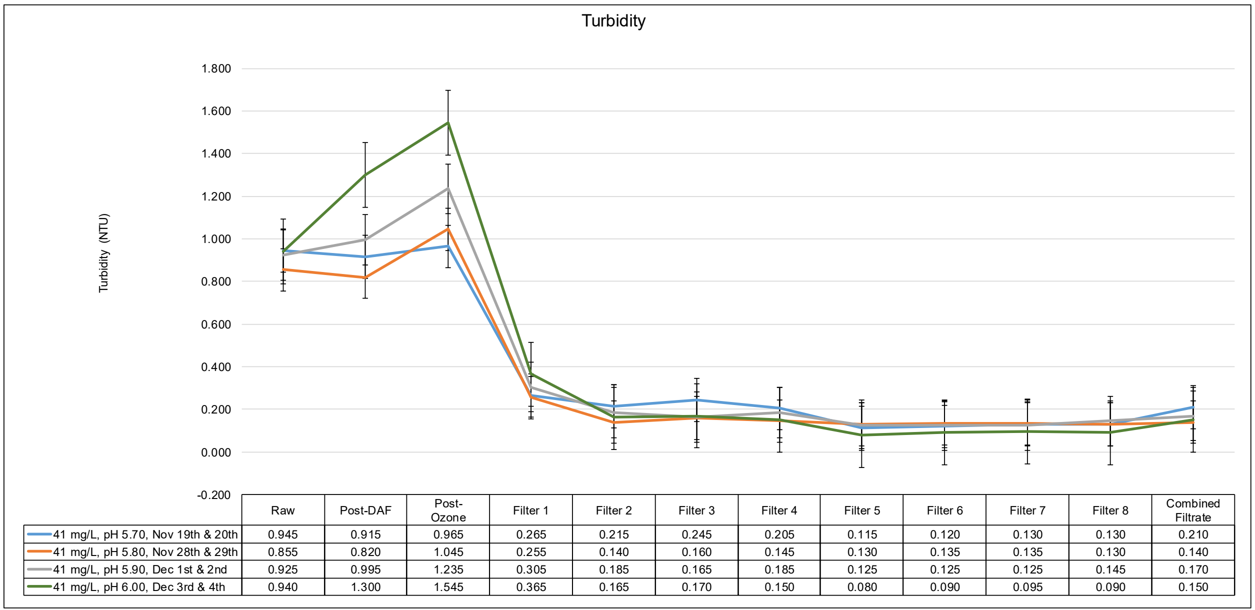


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
41 mg/L, pH 5.70, Nov 19th & 20th	7.50	5.72	5.72	5.77	5.78	5.80	5.79	5.74	5.76	5.77	5.78	5.78
41 mg/L, pH 5.80, Nov 28th & 29th	7.84	5.80	5.82	5.91	5.91	5.90	5.91	5.90	5.90	5.89	5.90	5.89
41 mg/L, pH 5.90, Dec 1st & 2nd	7.93	5.89	5.90	5.98	6.01	6.00	5.98	5.97	5.98	5.97	5.99	5.98
41 mg/L, pH 6.00, Dec 3rd & 4th	7.91	6.00	6.03	6.09	6.08	6.11	6.08	6.07	6.07	6.08	6.10	6.06

Figure 4-12: Average pH levels following the pilot-scale system processes for the determination of the optimal pH for coagulation using ferric sulphate during the Winter #2 piloting session. pH was measured with a Thermo Scientific Orion Star A325 pH probe.

→ Turbidity

The turbidity results presented in Figure 4-13 indicate that raw water turbidity was reduced following coagulation for pH 5.70 and 5.80; however, for pH 5.90 and 6.00 there was an increase in turbidity in the Post-DAF samples. The turbidity increased following ozonation for all pH value tested. This increase is attributed to an increase in solubility for dissolved gases in cold waters. A significant reduction in turbidity was observed following filtration for all pH tested, ranging from 0.14 to 0.21 NTU (combined filter effluent). Although the lowest turbidity was measured at a pH of 5.80, the results demonstrate that turbidity is effectively reduced across all pH values tested. The second lowest turbidity (0.15 NTU) was measured at a pH of 6.0. This suggests that a higher pH could be applied during coagulation, preventing the deterioration of concrete structures, while still meeting effluent guidelines.



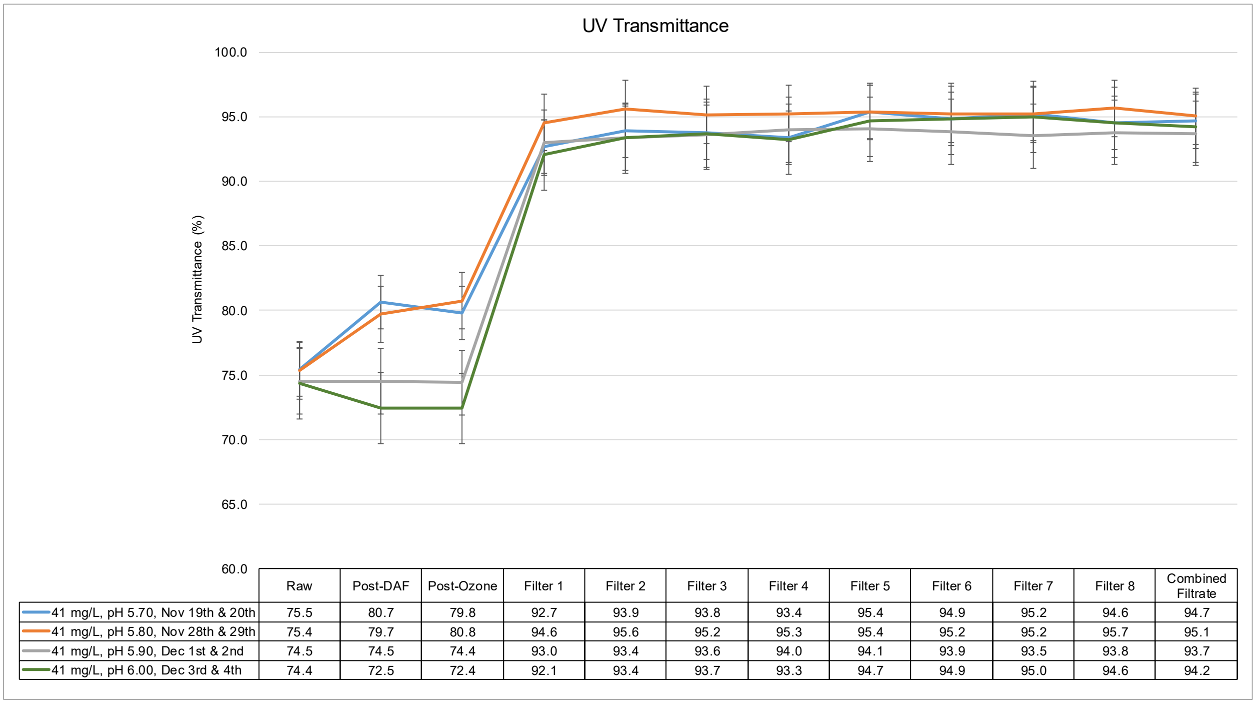
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
41 mg/L, pH 5.70, Nov 19th & 20th	0.945	0.915	0.965	0.265	0.215	0.245	0.205	0.115	0.120	0.130	0.130	0.210
41 mg/L, pH 5.80, Nov 28th & 29th	0.855	0.820	1.045	0.255	0.140	0.160	0.145	0.130	0.135	0.135	0.130	0.140
41 mg/L, pH 5.90, Dec 1st & 2nd	0.925	0.995	1.235	0.305	0.185	0.165	0.185	0.125	0.125	0.125	0.145	0.170
41 mg/L, pH 6.00, Dec 3rd & 4th	0.940	1.300	1.545	0.365	0.165	0.170	0.150	0.080	0.090	0.095	0.090	0.150

Figure 4-13: Average turbidity levels following the pilot-scale system processes for the determination of the optimal pH for coagulation using ferric sulphate during the Winter #2 piloting session. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.

According to the turbidity results, the optimal pH for coagulation using ferric sulphate in cold water was determined to be 5.80.

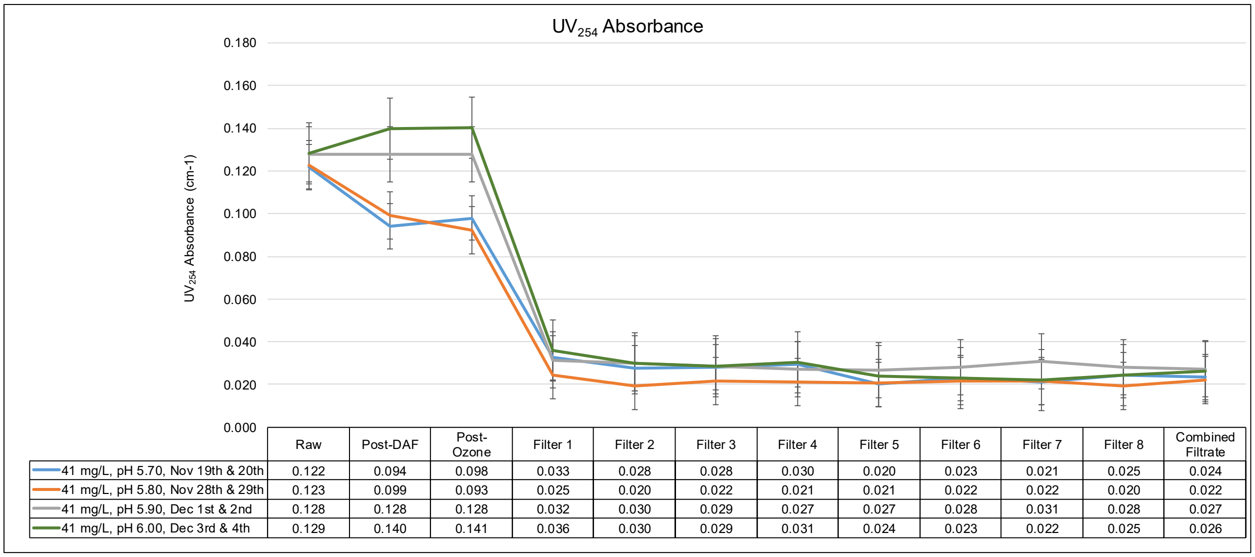
→ UV-Transmittance and Absorbance

The UVT and absorbance results (Figure 4-14 and Figure 4-15) illustrate that as the pH increased from 5.70 to 6.00, there was a steady decline in UVT and increase in absorbance in the Post-DAF samples. There was little change in the UVT or absorbance following ozone treatment; however, a significant improvement in UVT and absorbance was measured in the filter effluent and combined filter effluent across the range of pH tested. Combined filter effluent UVT and absorbance ranged from 93.7% to 95.1%, and 0.022 cm^{-1} to 0.027 cm^{-1}, respectively. Again, suggesting that a wider range of pH can be applied while still meeting finished water quality targets. Overall, the optimal pH according to the UVT and absorbance data was 5.80.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
41 mg/L, pH 5.70, Nov 19th & 20th	75.5	80.7	79.8	92.7	93.9	93.8	93.4	95.4	94.9	95.2	94.6	94.7
41 mg/L, pH 5.80, Nov 28th & 29th	75.4	79.7	80.8	94.6	95.6	95.2	95.3	95.4	95.2	95.2	95.7	95.1
41 mg/L, pH 5.90, Dec 1st & 2nd	74.5	74.5	74.4	93.0	93.4	93.6	94.0	94.1	93.9	93.5	93.8	93.7
41 mg/L, pH 6.00, Dec 3rd & 4th	74.4	72.5	72.4	92.1	93.4	93.7	93.3	94.7	94.9	95.0	94.6	94.2

Figure 4-14: Average UVT measured following the pilot-scale system processes during pH optimization for ferric sulphate during the Winter #2 piloting session. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
41 mg/L, pH 5.70, Nov 19th & 20th	0.122	0.094	0.098	0.033	0.028	0.028	0.030	0.020	0.023	0.021	0.025	0.024
41 mg/L, pH 5.80, Nov 28th & 29th	0.123	0.099	0.093	0.025	0.020	0.022	0.021	0.021	0.022	0.022	0.020	0.022
41 mg/L, pH 5.90, Dec 1st & 2nd	0.128	0.128	0.128	0.032	0.030	0.029	0.027	0.027	0.028	0.031	0.028	0.027
41 mg/L, pH 6.00, Dec 3rd & 4th	0.129	0.140	0.141	0.036	0.030	0.029	0.031	0.024	0.023	0.022	0.025	0.026

Figure 4-15: Average absorbance measured following the pilot-scale system processes during pH optimization for ferric sulphate during the Winter #2 piloting session. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ Total Manganese

The total manganese results (Figure 4-16) illustrate that the change in pH had little impact on total manganese in Post-DAF and Post-Ozone samples. Filtration reduced total manganese concentrations in the Post-Ozone by 21-41% (combined filter effluent) for all pH values tested. When comparing combined filter effluent total manganese concentrations, the lowest total manganese was measured at a pH of 5.80.

	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
41 mg/L, pH 5.70, Nov 19th & 20th	0.021	0.023	0.024	0.021	0.018	0.018	0.017	0.018	0.017	0.018	0.019	0.019
41 mg/L, pH 5.80, Nov 28th & 29th	0.021	0.022	0.022	0.012	0.013	0.012	0.012	0.014	0.012	0.012	0.014	0.013
41 mg/L, pH 5.90, Dec 1st & 2nd	0.022	0.022	0.022	0.016	0.013	0.016	0.015	0.016	0.015	0.015	0.015	0.015
41 mg/L, pH 6.00, Dec 3rd & 4th	0.019	0.022	0.024	0.019	0.016	0.016	0.016	0.018	0.016	0.016	0.017	0.017

Figure 4-16: Total manganese measured following pilot-scale treatment processes during pH optimization for ferric sulphate during the Winter #2 piloting session. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ UFRV

Figure 4-17 illustrates the average observed and forecasted UFRV values obtained for each pH for Bank A and Bank B. Of the two Banks, Bank A overflowed on all the days during the pH optimization tests, whereas Bank B did not overflow on one day at a pH of 5.7 and two days at a pH of 5.8. All individual filters in Bank A failed based on turbidity (> 0.1 NTU) at all pH levels tested. For Filter Bank B the filters all failed on turbidity (> 0.1 NTU) at a pH of 5.7, 5.8 and the first day at 5.9. The second day of a pH of 5.9 and the two subsequent days at a pH of 6.0 the filters in Filter Bank B all had turbidities of 0.1 NTU or less.

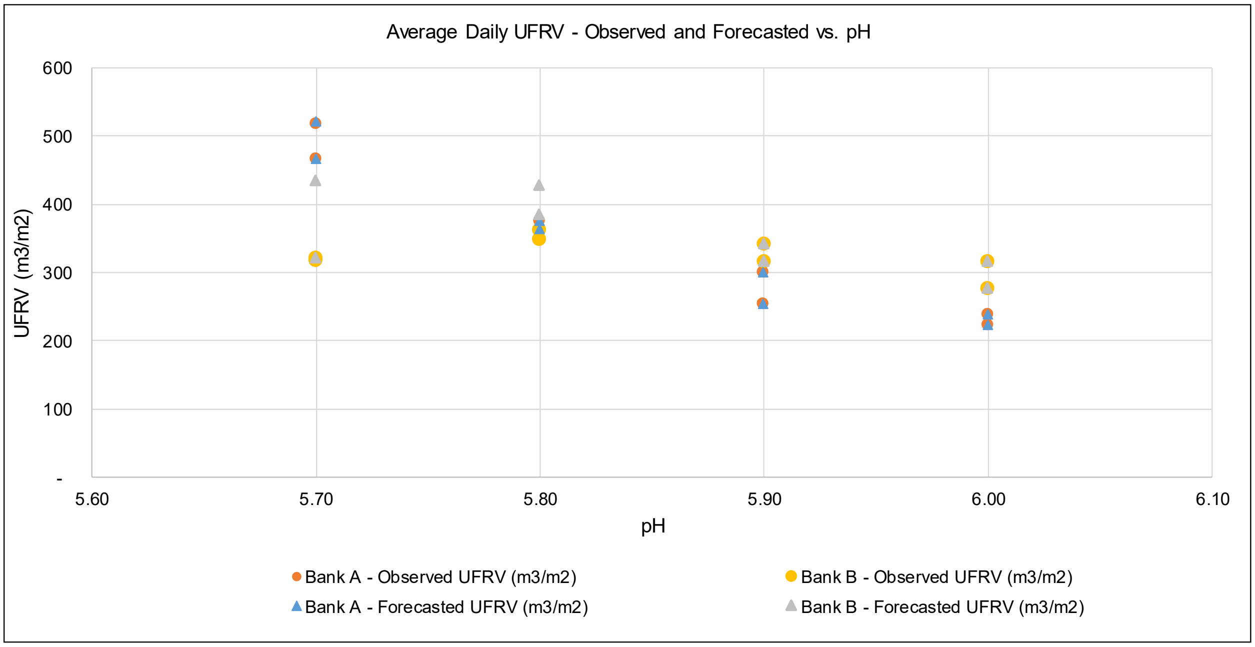


Figure 4-17: Average UFRV values of pilot-scale system Bank A (at 0.6 L/s) and Bank B (at 0.3 L/s) during the pH optimization during the Winter #2 piloting session. The pilot system coagulant dose was maintained at 41 mg/L with no addition of coagulant aid. Note the observed and forecasted UFRV values may overlap. Data originates from the pilot-scale's SCADA dataset.

It was observed that UFRV values decreased with the increase of pH for Bank A. For Bank B, the average UFRV increased as the pH values increased up to 5.80, whereas a decrease in UFRV values was observed at a pH higher than 5.90.

When considering Bank B results, as operational parameters are closer to the full-scale system, the highest UFRV value (356 m^3/m^2) was obtained at a pH of 5.8. However, all individual filters failed based on turbidity measurements above 0.1 NTU at these pH's, subsequently the expected UFRV values would be smaller.

Although the smallest average observed UFRV value (297 m^3/m^2) was found at pH of 6.0, all individual filters of Bank B were able to meet the operational limit of 0.1 NTU at this pH. Given the UFRV values in the full-scale are expected to be twice as high due to the higher head loss available for filtration, the pH of 6.0 is considered the optimal pH and it is also deemed a viable for full-scale system operation.

- Summary of pH Optimization

Overall, based on turbidity, UV parameters and total manganese the optimal pH is 5.80. However, the result indicated a wider pH range could be used while still meeting treated water quality objectives.

The UFRV analysis performed following the piloting session did not confirm the same optimal pH and indicated that the preferred pH was 6.0 based on filter performance. As a result, additional chemical optimization may be required to confirm if this combination of coagulant dose and pH can be used in the full-scale system.

4.7 Individual Filter Performance Testing

There has been noted differences in the filter effluent water quality produced by the pilot-scale system filter Bank A and Bank B during the entirety of this project to date. During the Winter #1 piloting session (TM No. 3), Bank A and Bank B were operated at maximum and minimum flow rates of 0.3 L/s and 0.6 L/s, respectively. The results in the Winter #1 piloting session indicated that Bank B was producing better quality water compared to Bank A. These results were counterintuitive, as it was expected that better filter operation would occur at slower flow rates (i.e. Bank A should have produced better water compared to Bank B). It was hypothesized that possible physical or mechanical differences between the two banks were contributing to the differences in water quality. However, this was only speculative as the results could not identify an exact cause for the deviation between the two banks.

Technical Memo No. 4 (TM No. 4) attempted to clarify the cause for the difference in water quality produced by operating Bank B at the slower flow rate of 0.3 L/s and Bank A at the maximum flow rate of 0.6 L/s. The results presented in TM No. 4 suggested that both flow and mechanical differences were likely impacting combined filter effluent quality from Bank A and Bank B. This was based on the fact that changing the flow rates between Banks A and B did not impact the water quality between the two banks (i.e., Bank B again outperformed Bank A). Again, much of the conclusions regarding the cause for different filter bank performance were merely speculative, suggesting that further testing is required to further identify the causes for the differences in filter effluent quality produced by Bank A and Bank B.

During the Summer and Fall piloting sessions (TM No. 5 and 6), the filter banks were operated in the same manner as in TM No. 4, where Bank A was operated at 0.6 L/s and Bank B at 0.3 L/s. The results presented in TM No. 5 and 6 again found differences in effluent quality from the two banks, with Bank B generally outperforming Bank A.

Following discussion with the City on November 1st, 2017 (Fall mid-piloting meeting), the City proposed that the individual filter flow (Filters 1-8) could be adjusted to operate at either high or low flow rates in an attempt to establish a reason for differences in key parameters measured in filter effluent. Figure 4-18 illustrates the normal filter bank flow rates used during the Spring, Summer and Fall piloting sessions (TM No. 4-6) and the proposed alternative individual filter bank flow conducted during the Winter #2 piloting session (current Technical Memo).

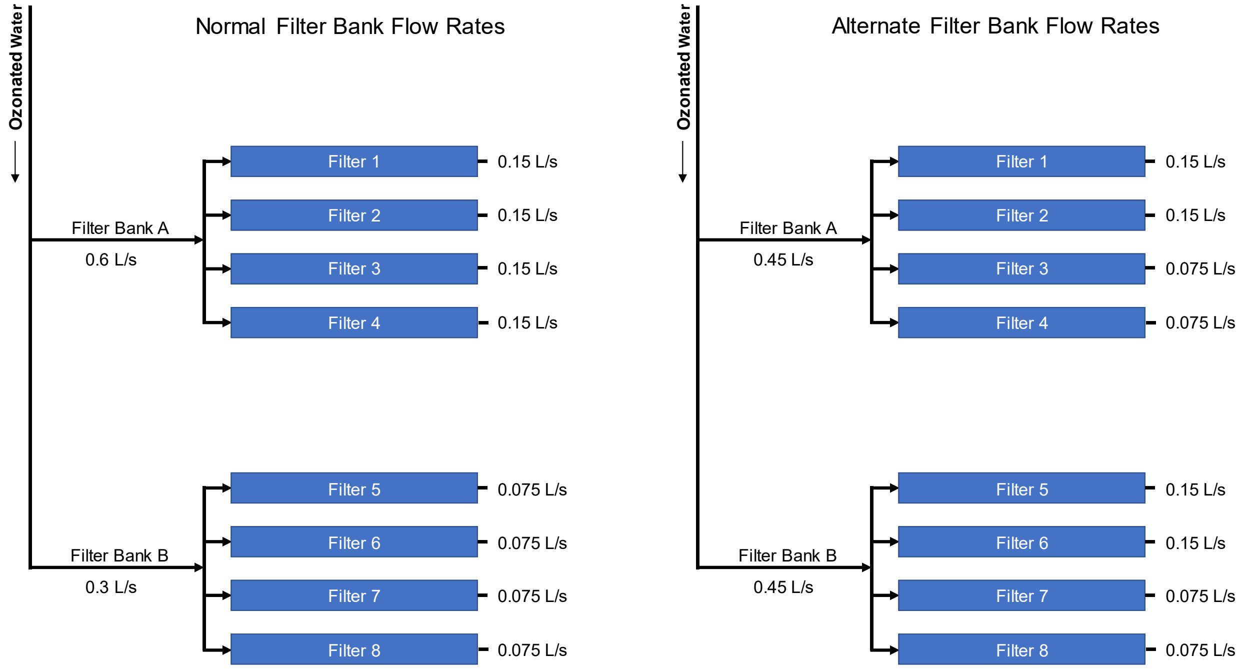


Figure 4-18: Normal pilot-scale filter bank flow rates and alternative individual filter flow rates used during piloting of ferric sulphate.

On December 5th, 2017, WSP tested the individual filter performance using the alternative flow rates presented in Figure 4-18. It should be noted that the data collected during individual filter performance testing was not included in the results for the optimization of coagulant or pH conducted during the Winter #2 piloting session, as it was imperative that consistent flow rates (i.e., normal filter bank flow rates; Figure 4-18) be used during the optimized testing in order to compare the results to previous piloting sessions. Therefore, the following section only compare individual filter performance based on water quality results collected on December 5th, 2017.

The individual filter flow rates were set by manually adjusting of the flow control valves located on each filter (Filters 1 - 8). Onsite WSP personnel visually monitored the filter flow rate during the testing and observed only minor fluctuations in filter flow rates of approximately 0.005 to 0.01 L/s, indicating that the individual filter flow rates could be achieved and that the flow rate was well maintained.

The comparison between individual filter performances was made using benchtop analysis of the following key parameters: turbidity, UVT, absorbance, and effluent total manganese concentration. The coagulant concentration and pH expected to be used during individual filter performance testing were the optimized conditions (i.e., ferric sulphate at 41 mg/L; Post-DAF pH of 5.80) determined during the optimal coagulant and pH testing period. However, the target Post-DAF pH of 5.80 was not met due to a sudden increase in raw water flow rate to 3.2 L/s approximately 1 to 2 hours prior to sample collection, resulting in a Post-DAF pH of 5.90. Since the comparisons made are only between the individual filter performances, and not compared to other Winter #2 piloting session results, the water quality prior to filtration does not impact the interpretation of the results pertaining to individual filter bank performance. As such, Raw, Post-DAF, and Post-Ozone water quality are excluded from the interpretation of the results, with focus solely given to the individual filter performance.

→ Turbidity

The turbidity measured in the filter effluent for Filters 1 to 8 is presented in Figure 4-19. In this figure, orange bars indicate the filters operated at the higher flow rate of 0.15 L/s, while blue bars indicate the filters operated at the lower flow rate of 0.075 L/s. The turbidity results clearly indicate there is a significant reduction in filter performance at higher flow rates in both Bank A and B. Furthermore, significant differences between Bank A and B are noted at higher flow rates, where Filters 1 and 2 produced higher turbidity water compared to Filters 5 and 6, even though all four filters operated at the same flow of 0.15 L/s. Alternatively, when comparing Filters 3 and 4 with Filters 7 and 8, which operated at a flow of 0.075 L/s, the results show similar turbidity removal by all four filters.

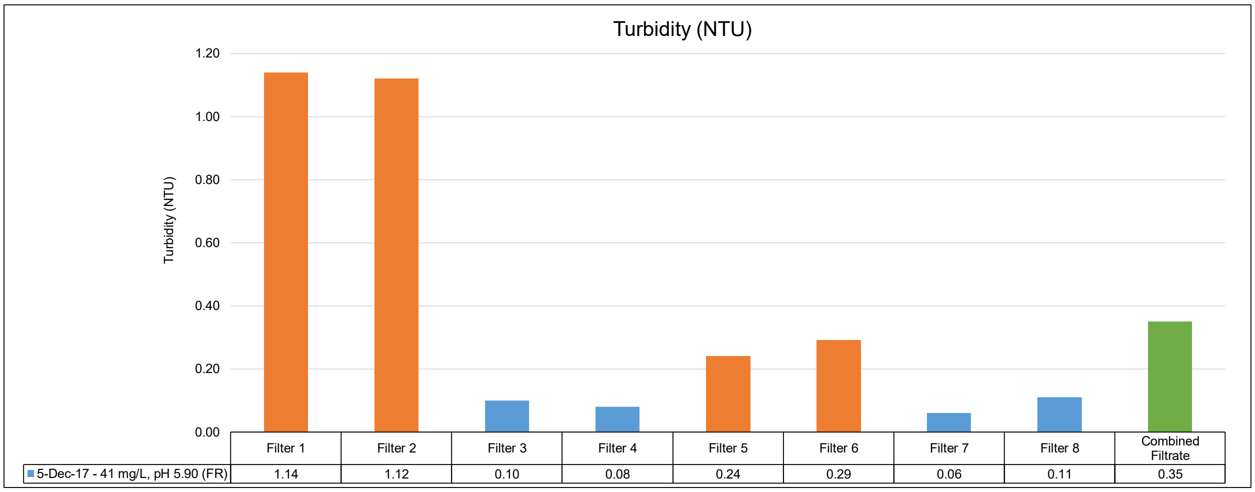


Figure 4-19: Turbidity results for the individual filter performance testing at high flow rate (High flow rate of 0.15 L/s; orange) and low flow rate (Low flow rate of 0.075 L/s; blue). Green bar indicates the combined filter effluent from Filters 1-8. Data originates from benchtop analysis using a Hach 2100Q turbidimeter.

Overall, the turbidity results indicate that there are differences between individual filter performance within, and between, Bank A and Bank B. It is strongly believed that physical, mechanical, and chemical differences are contributing to the filter performance.

Chemical differences which could be affecting filter performance include a filter-aid (LT 22S), which is applied to improve filter function and is introduced to the treatment stream prior to filtration. When considering the relative distance from the filter-aid injection point to the individual filters, it is conceivable that a shorter reaction time and potentially reduced turbulence and mixing time is subsequently impacting the efficacy of polymerization for water entering Filters 1 and 2, in particular when compared to the remaining filter turbidity levels. The shorter reaction time would result in lower polymerization within the water entering the first two filters, equating to the formation of smaller polymers which would not be as easily filtered by the GAC media. Thus, resulting in the higher turbidity measured in Filters 1 and 2.

Filters 5 and 6 operated at the same flow rate as Filter 1 and 2; however, they are further away from the filter-aid injection point and therefore allow for greater polymerization leading to lower turbidity. Filters 3, 4, 7, and 8 operated at the lower flow rate of 0.075 L/s equating to both slower movement through the GAC media, as well as longer time for the filter-aid to polymerize, equating to similar turbidity in the filter effluent for Filters 3 – 4 (Bank A) and Filters 7 – 8 (Bank B).

Physical and mechanical differences, pipe length, and/or pipe orientation could also cause increased loading to Filters 1 and 2, leading to significant decline in filter effluent quality. The combination of physical, mechanical and chemical differences could aggravate the discrepancies observed in the filter effluent water quality and filter operation among the filters.

→ UV-Transmittance, Absorbance, and Total Manganese

The UVT, absorbance and total manganese results collected during the evaluation of filter performance can be found in Figure 4-20, Figure 4-21 and Figure 4-22, respectively. The results from these three key parameters mirror the results reported for turbidity. As such, the same conclusions can be drawn to explain the differences in individual filter performance.

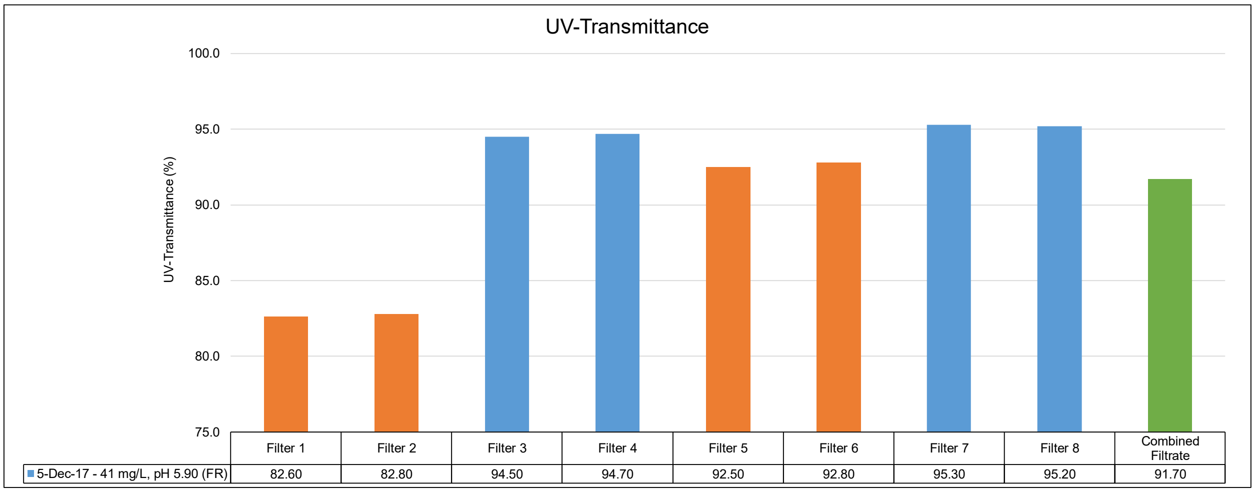


Figure 4-20: UVT results for the individual filter performance testing at high flow rate (High flow rate of 0.15 L/s; orange) and low flow rate (Low flow rate of 0.075 L/s; blue). Green bar indicates the combined filter effluent from Filters 1-8. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

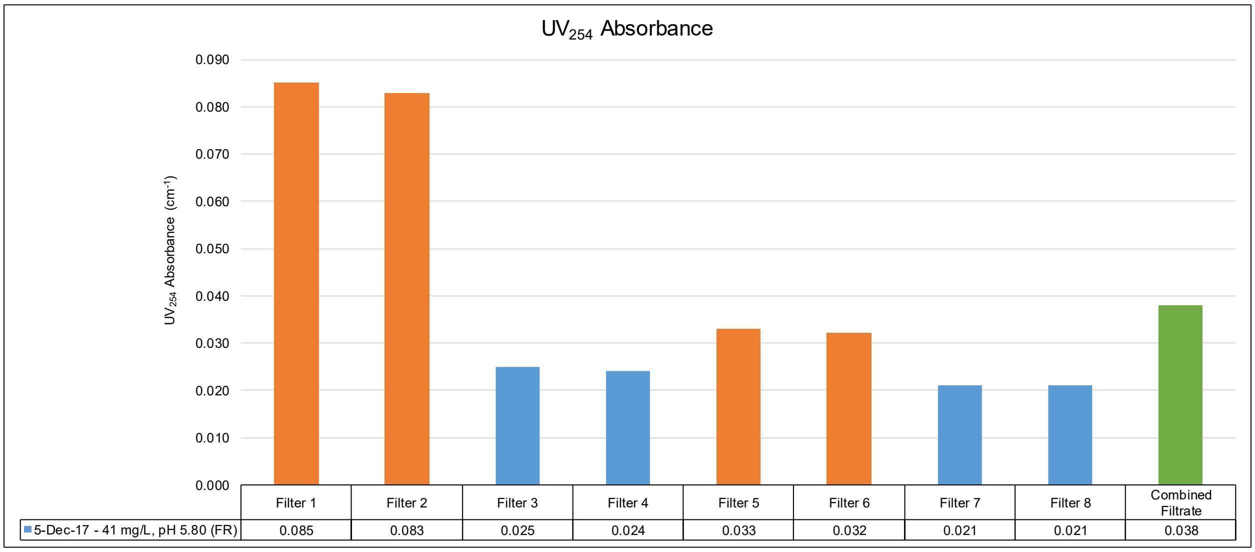


Figure 4-21: Absorbance results for the individual filter performance testing at high flow rate (High flow rate of 0.15 L/s; orange) and low flow rate (Low flow rate of 0.075 L/s; blue). Green bar indicates the combined filter effluent from Filters 1-8. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

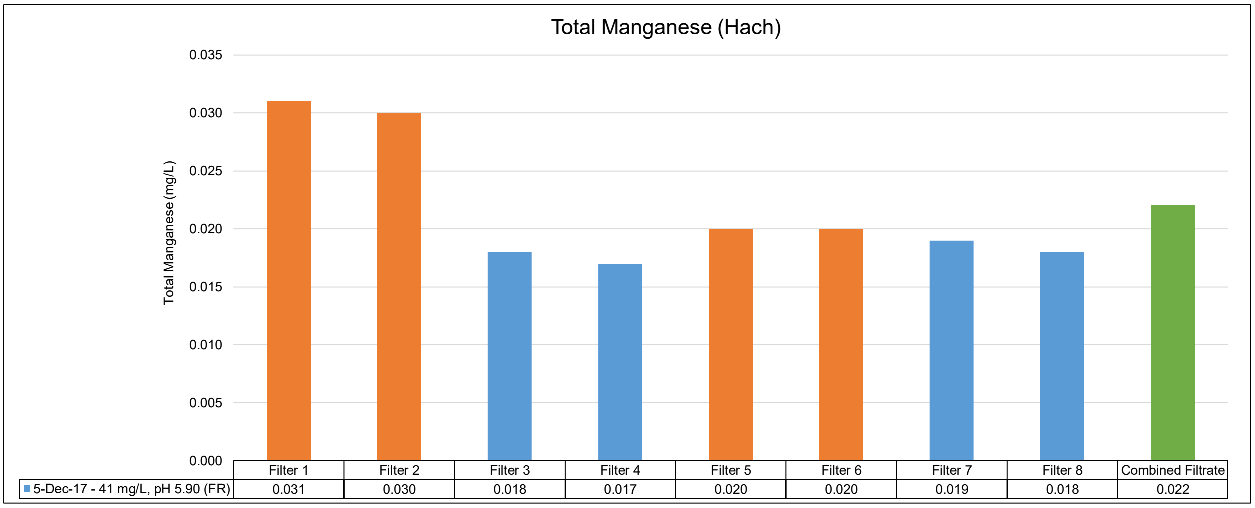


Figure 4-22: Total manganese results for the individual filter performance testing at high flow rate (High flow rate of 0.15 L/s; orange) and low flow rate (Low flow rate of 0.075 L/s; blue). Green bar indicates the combined filter effluent from Filters 1-8. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ UFRV

The UFRV values obtained for Filters 1 to 8 are presented in Figure 4-23. The UFRV values indicate that there is a significant reduction in filter performance at higher flow rates in both Bank A and B (approximately 25%). Furthermore, significant differences between Bank A and Bank B are noted at both flow rates, where UFRV values for Filters 1, 2 and 4 were approximately 15% are higher than that of Filters 5, 6, 7 and 8. Note: Filter 3 differential pressure data was not recorded in the pilot-scale system SCADA system.

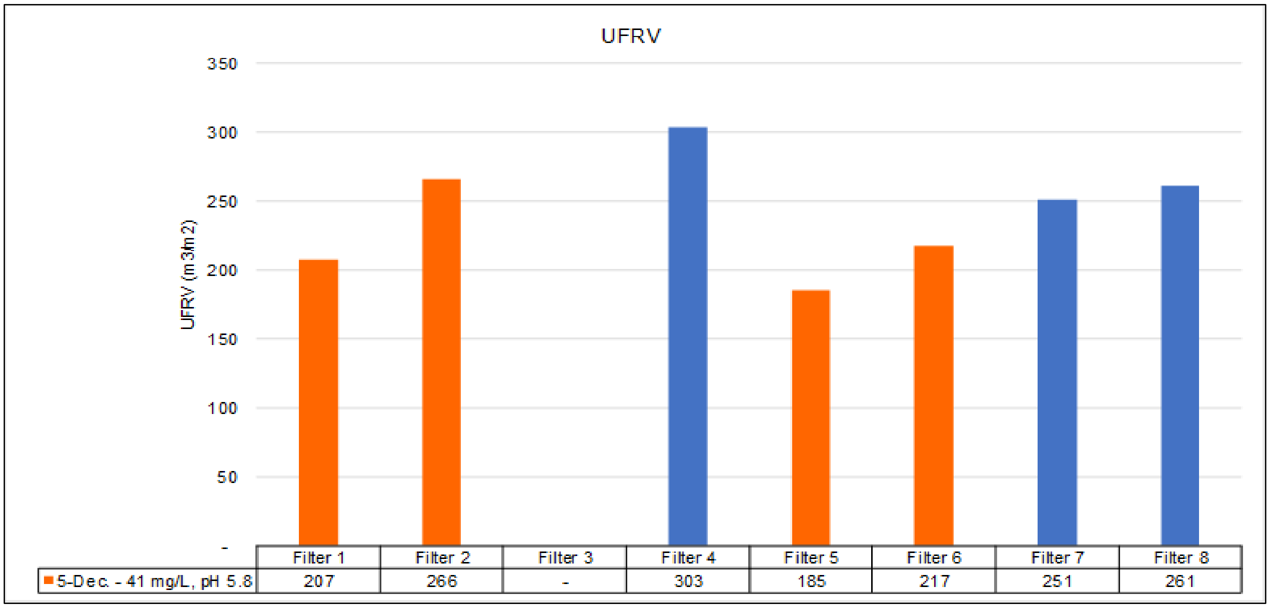


Figure 4-23: UFRV results for the individual filter performance testing at high flow rate (High flow rate of 0.15 L/s; orange) and low flow rate (Low flow rate of 0.075 L/s; blue). Data originates from the pilot-scale's SCADA dataset. Note: Filter 3 data was not consistent and it was discarded.

Overall, the individual filter performance testing was successful in providing some insight into the cause for differences seen in individual filter effluent quality. However, this test was conducted once, and it is suggested that further testing be conducted to fully determine the cause for variations in filter performance. Testing could include duplicating the current alternative filter flow presented in Figure 4-18 to allow for improved statistical comparisons. It is also suggested that additional individual filter flows be tested (i.e., operate Filters 1, 2, 5 and 6 at the lower flow rate of 0.075 L/s and Filter 3, 4, 7 and 8 at the higher flow rate of 0.15 L/s). Additional individual filter flow testing could be used to compare the results and determine if the removal trends remain consistent. Furthermore, it is recommended that testing of the filter performance be conducted without the addition of filter-aid, in order to remove the potential chemical influence.

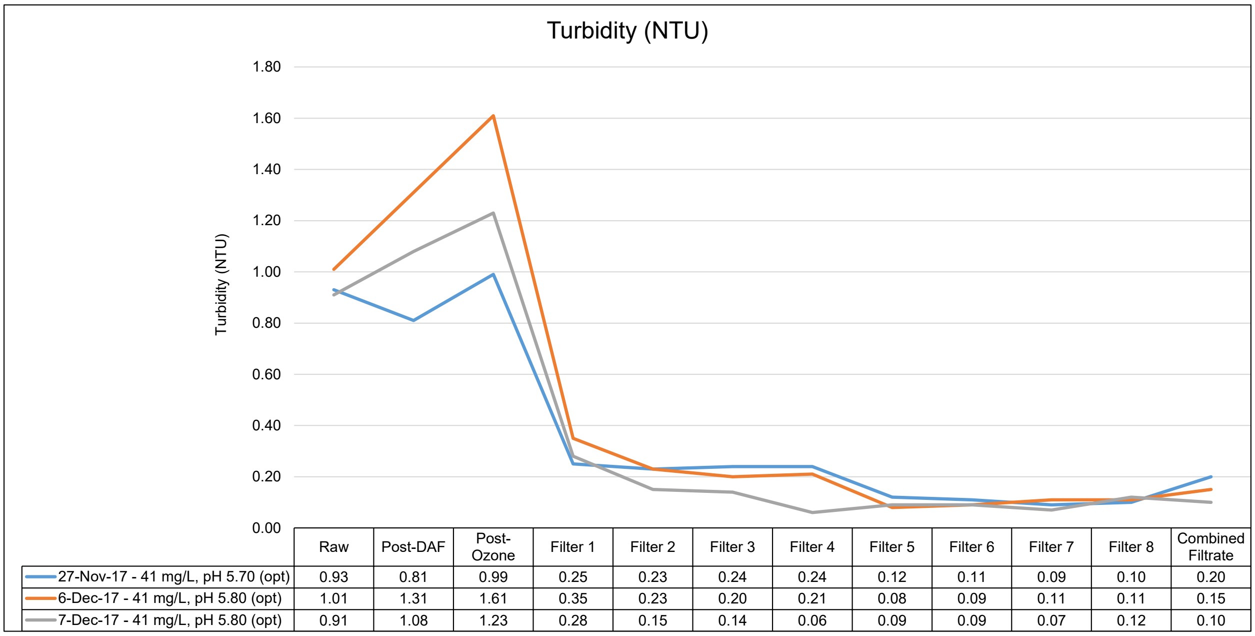
4.8 Optimized Condition Results

This section presents the results for the optimum conditions found during the Winter #2 piloting session. Note: optimal testing on November 27th was conducted using the optimal coagulant dose only as the optimal pH was undetermined at this point in time. The parameters turbidity, UVT, absorbance, manganese (total and dissolved), DOC, iron (total and dissolved), true colour, and UFRV values were evaluated on the specific test dates and the conditions are as follows:

- November 27th with 41 mg/L ferric sulphate and pH 5.70 (prior to pH optimization)
- December 6th and 7th with 41 mg/L ferric sulphate and pH 5.80

→ Turbidity

The change in turbidity during the testing of ferric sulphate under optimized conditions is presented in Figure 4-24. The optimized condition tests compared the difference in coagulant performance at pH 5.70 and at the optimal pH of 5.80.



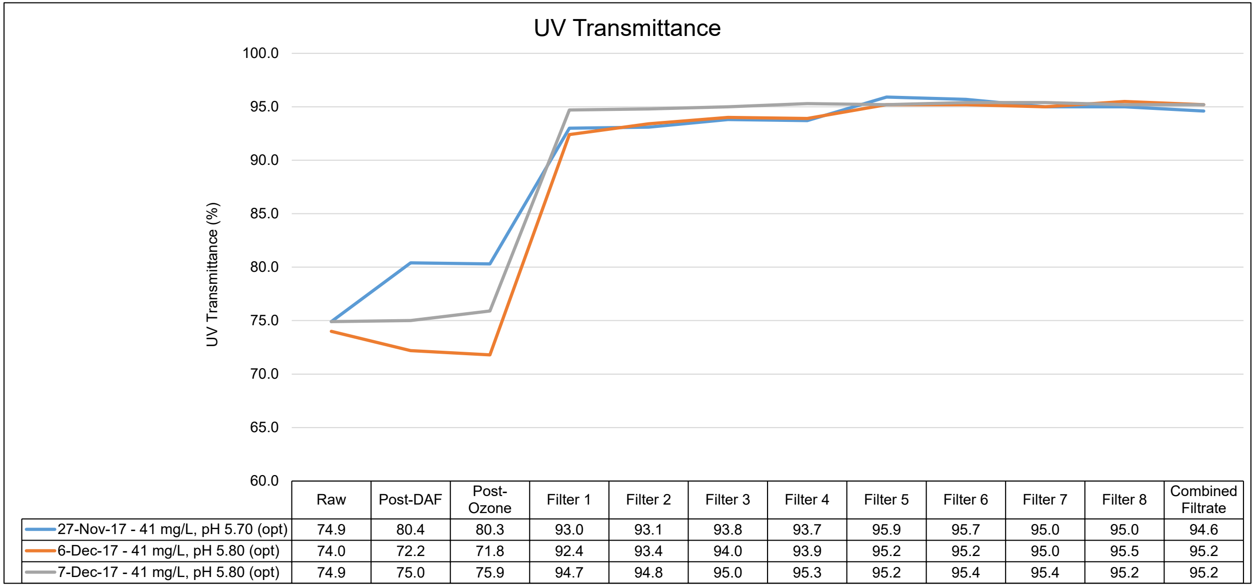
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
27-Nov-17 - 41 mg/L, pH 5.70 (opt)	0.93	0.81	0.99	0.25	0.23	0.24	0.24	0.12	0.11	0.09	0.10	0.20
6-Dec-17 - 41 mg/L, pH 5.80 (opt)	1.01	1.31	1.61	0.35	0.23	0.20	0.21	0.08	0.09	0.11	0.11	0.15
7-Dec-17 - 41 mg/L, pH 5.80 (opt)	0.91	1.08	1.23	0.28	0.15	0.14	0.06	0.09	0.09	0.07	0.12	0.10

Figure 4-24: Turbidity levels during optimal conditions testing using a ferric sulphate dose of 41 mg/L at pH 5.70 and 5.80 during the Winter #2 piloting session. Data originated from benchtop analyses using a HACH 2100Q Turbidimeter.

The results in Figure 4-24 show that there was lower turbidity for DAF and ozone samples at pH of 5.70, compared to 5.80. Conversely, there was better removal of turbidity by filtration at a Post-DAF pH of 5.80, particularly on December 7th. The lower turbidity in the combined filter effluent on December 7th is attributed to the removal observed in Bank A, namely Filters 2, 3 and 4. If only Bank B is considered, there does not appear to be a significant difference in turbidity between pH 5.70 and 5.80, suggesting that a higher operating pH for coagulation can be used to meet water quality objectives. Operating at a slightly higher pH will also reduce the impact of acidic water on the concrete structures in the full-scale system. Furthermore, operating at a slightly higher pH will reduce the amount of sodium hydroxide needed for pH adjustment prior to entering the distribution system.

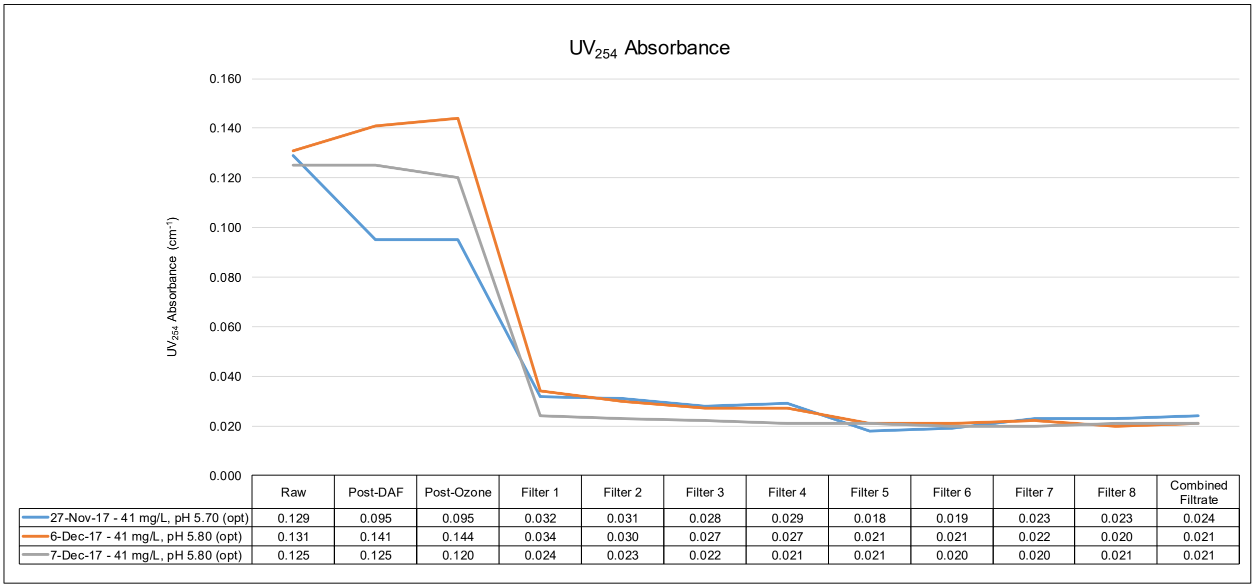
→ UV-Transmittance and Absorbance

The UVT and absorbance results for the optimized ferric sulphate dose at pH 5.70 and 5.80 are presented in Figure 4-25 and Figure 4-26. The UVT and absorbance results demonstrate a similar trend to the turbidity results, where better water quality was measured in the Post-DAF and Post-Ozone at pH 5.70 compared to 5.80. However, the combined filtrate samples a very minor improvement in UVT and absorbance at pH 5.80. As with turbidity, the results suggest that there is a wide range of operation pH that will meet water quality targets, provided the optimal coagulant dose is applied.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
27-Nov-17 - 41 mg/L, pH 5.70 (opt)	74.9	80.4	80.3	93.0	93.1	93.8	93.7	95.9	95.7	95.0	95.0	94.6
6-Dec-17 - 41 mg/L, pH 5.80 (opt)	74.0	72.2	71.8	92.4	93.4	94.0	93.9	95.2	95.2	95.0	95.5	95.2
7-Dec-17 - 41 mg/L, pH 5.80 (opt)	74.9	75.0	75.9	94.7	94.8	95.0	95.3	95.2	95.4	95.4	95.2	95.2

Figure 4-25: UVT measured during optimal conditions testing using a ferric sulphate dose of 41 mg/L at pH 5.70 and 5.80 during the Winter #2 piloting session. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

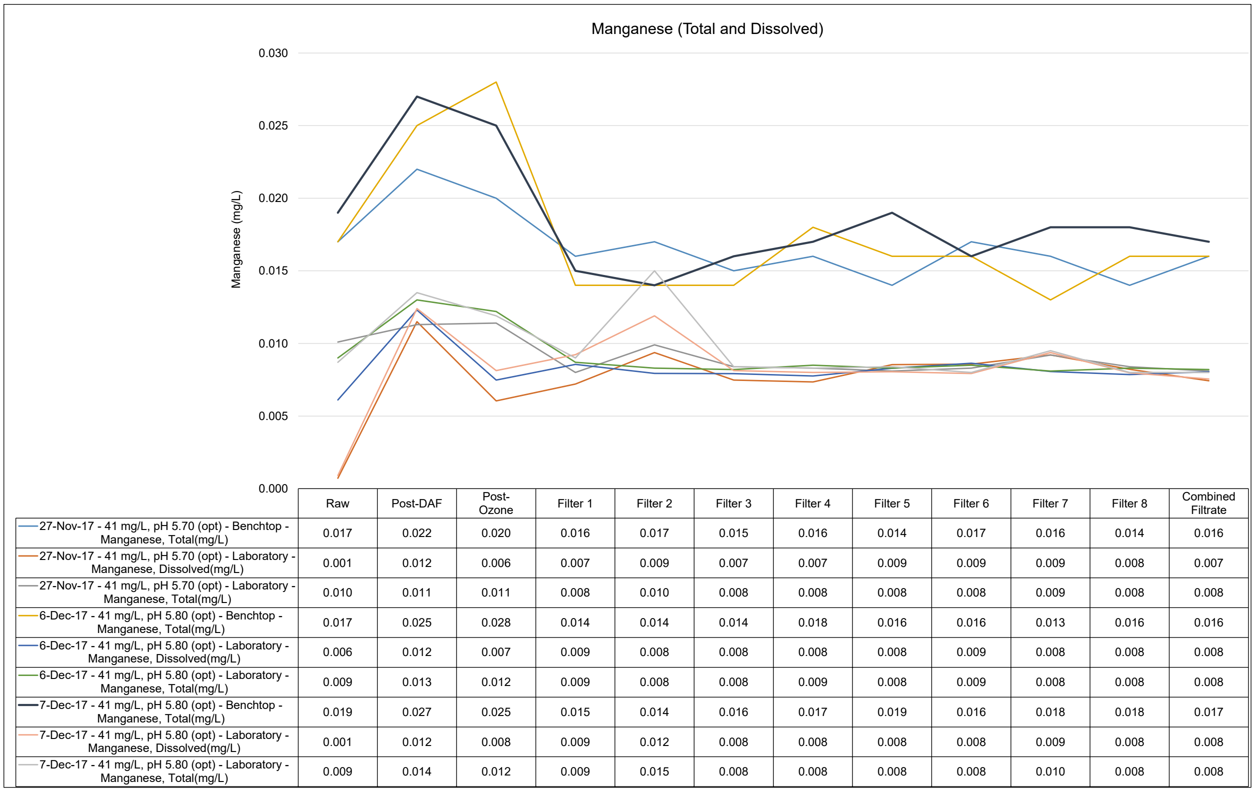


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
27-Nov-17 - 41 mg/L, pH 5.70 (opt)	0.129	0.095	0.095	0.032	0.031	0.028	0.029	0.018	0.019	0.023	0.023	0.024
6-Dec-17 - 41 mg/L, pH 5.80 (opt)	0.131	0.141	0.144	0.034	0.030	0.027	0.027	0.021	0.021	0.022	0.020	0.021
7-Dec-17 - 41 mg/L, pH 5.80 (opt)	0.125	0.125	0.120	0.024	0.023	0.022	0.021	0.021	0.020	0.020	0.021	0.021

Figure 4-26: Absorbance measured during optimal conditions testing using a ferric sulphate dose of 41 mg/L at pH 5.70 and 5.80 during the Winter #2 piloting session. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

→ Total and Dissolved Manganese

Figure 4-27 presents the total manganese results during optimized ferric sulphate dose testing at pH 5.70 and 5.80 for both benchtop testing using the Hach DR6000, as well as the total and dissolved manganese measured by the Lab using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). As noted in previous technical memo's, total manganese concentrations measured by the Lab are consistently lower than those measured by the benchtop Hach instrument due to the high sensitivity and low detection limit with ICP-MS.



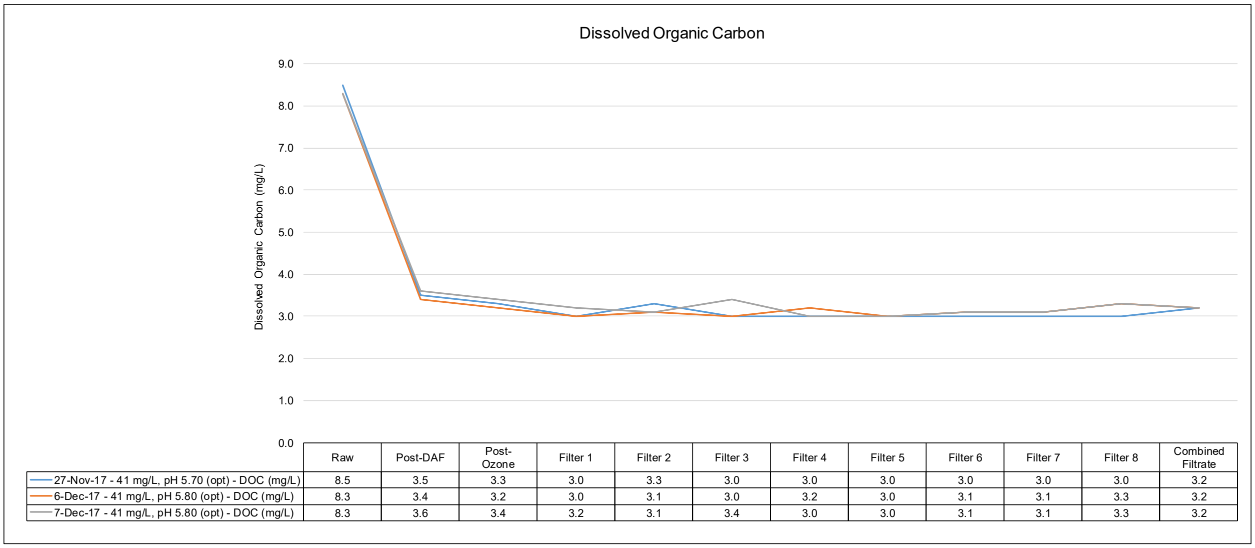
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
27-Nov-17 - 41 mg/L, pH 5.70 (opt) - Benchtop - Manganese, Total(mg/L)	0.017	0.022	0.020	0.016	0.017	0.015	0.016	0.014	0.017	0.016	0.014	0.016
27-Nov-17 - 41 mg/L, pH 5.70 (opt) - Laboratory - Manganese, Dissolved(mg/L)	0.001	0.012	0.006	0.007	0.009	0.007	0.007	0.009	0.009	0.009	0.008	0.007
27-Nov-17 - 41 mg/L, pH 5.70 (opt) - Laboratory - Manganese, Total(mg/L)	0.010	0.011	0.011	0.008	0.010	0.008	0.008	0.008	0.008	0.009	0.008	0.008
6-Dec-17 - 41 mg/L, pH 5.80 (opt) - Benchtop - Manganese, Total(mg/L)	0.017	0.025	0.028	0.014	0.014	0.014	0.018	0.016	0.016	0.013	0.016	0.016
6-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Manganese, Dissolved(mg/L)	0.006	0.012	0.007	0.009	0.008	0.008	0.008	0.008	0.009	0.008	0.008	0.008
6-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Manganese, Total(mg/L)	0.009	0.013	0.012	0.009	0.008	0.008	0.009	0.008	0.009	0.008	0.008	0.008
7-Dec-17 - 41 mg/L, pH 5.80 (opt) - Benchtop - Manganese, Total(mg/L)	0.019	0.027	0.025	0.015	0.014	0.016	0.017	0.019	0.016	0.018	0.018	0.017
7-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Manganese, Dissolved(mg/L)	0.001	0.012	0.008	0.009	0.012	0.008	0.008	0.008	0.008	0.009	0.008	0.008
7-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Manganese, Total(mg/L)	0.009	0.014	0.012	0.009	0.015	0.008	0.008	0.008	0.008	0.010	0.008	0.008

Figure 4-27: Manganese levels (total and dissolved) during optimal conditions testing using a ferric sulphate dose of 41 mg/L at pH 5.70 and 5.80 for the Winter #2 piloting session. Data originated from benchtop analyses using a HACH DR6000 UV-VIS spectrophotometer (benchtop) or the Lab analyses.

The results in Figure 4-27 illustrate that there is an increase in manganese levels following coagulation due to the presence of residual manganese in ferric sulphate. The manganese is reduced following ozonation, and further removed by filtration with final manganese concentration in the combined filtrate of 0.008 mg/L (Lab results; total and dissolved). Overall, based on the Lab results, the total manganese concentration in the final combined filter effluent is below the target of 0.015 mg/L at pH 5.70 and 5.80, again indicating a wider operating range at optimal dose conditions.

- Dissolved Organic Carbon

The reduction of DOC by the pilot-scale system using the optimized ferric sulphate dose is presented in Figure 4-28. The raw water DOC concentration ranged between 8.3 mg/L and 8.5 mg/L during the optimized Winter #2 piloting session. The DOC concentration was reduced by approximately 59% following DAF for both pH tested. Ozone and filtration did not appear to significantly reduced DOC. The final combined effluent DOC concentration for both pH tested was 3.2 mg/L. Again, the results demonstrate that the system can be operated at a slightly higher pH (not exceeding pH 6.0) and still meet effluent water quality targets.

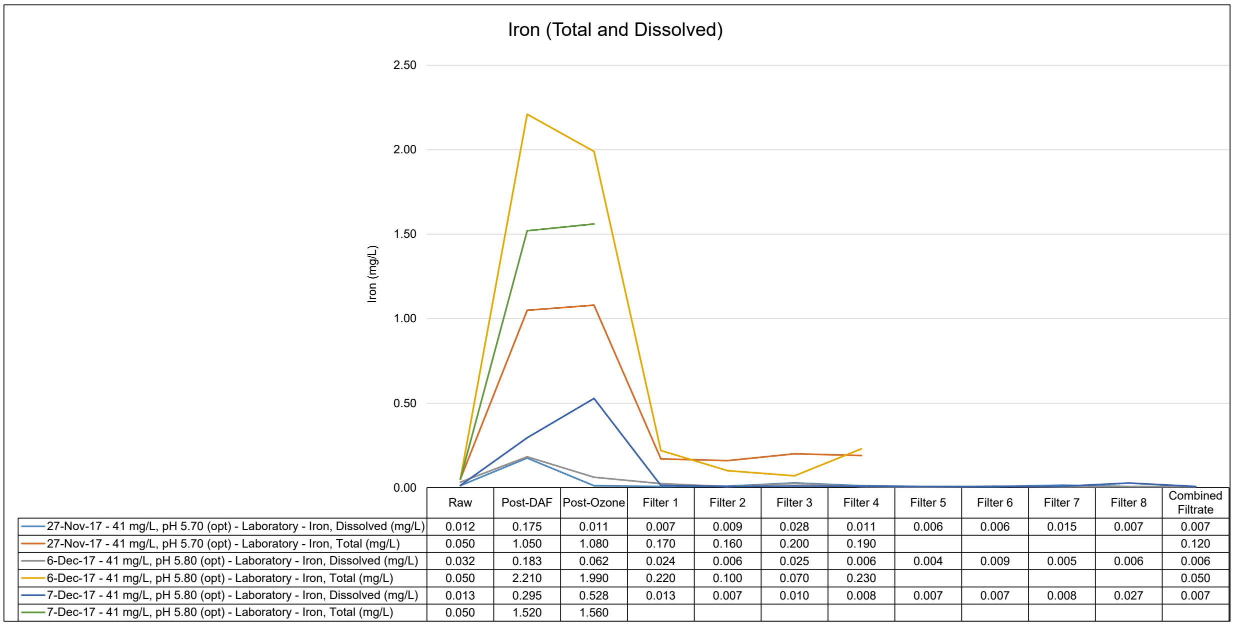


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
27-Nov-17 - 41 mg/L, pH 5.70 (opt) - DOC (mg/L)	8.5	3.5	3.3	3.0	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.2
6-Dec-17 - 41 mg/L, pH 5.80 (opt) - DOC (mg/L)	8.3	3.4	3.2	3.0	3.1	3.0	3.2	3.0	3.1	3.1	3.3	3.2
7-Dec-17 - 41 mg/L, pH 5.80 (opt) - DOC (mg/L)	8.3	3.6	3.4	3.2	3.1	3.4	3.0	3.0	3.1	3.1	3.3	3.2

Figure 4-28: DOC levels during optimal conditions testing using a ferric sulphate dose of 41 mg/L at pH 5.70 and 5.80 for the Winter #2 piloting session. Data originates from City Lab analyses.

→ Total and Dissolved Iron

The total and dissolved iron results during the optimized testing of ferric sulphate are presented in Figure 4-29. The results illustrate that total and dissolved iron concentration increases following coagulation due to the addition of a ferric based coagulant. There was a reduction in dissolved iron following ozonation on November 27th and December 6th; however, there was an increase in dissolved iron following ozonation on December 7th. The cause for the increase measured in the Post-Ozone sample on December 7th is unclear but could be the result of residual buildup of ferric sulphate within the DAF and ozone system.



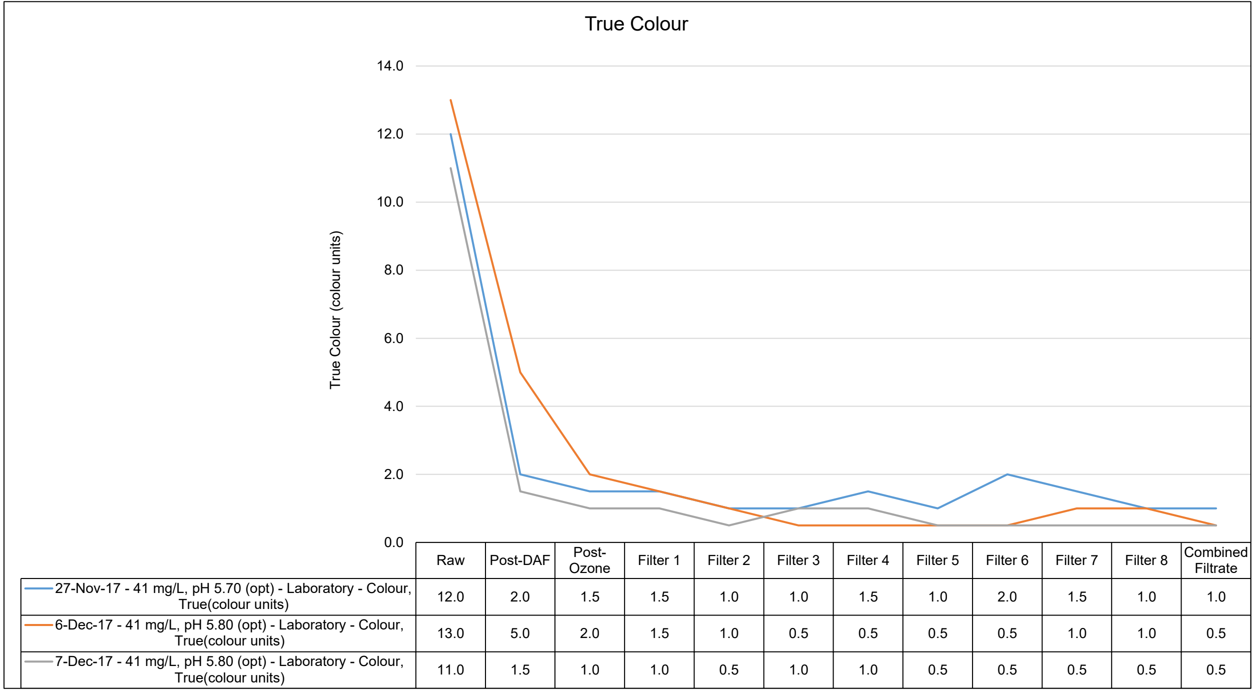
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
27-Nov-17 - 41 mg/L, pH 5.70 (opt) - Laboratory - Iron, Dissolved (mg/L)	0.012	0.175	0.011	0.007	0.009	0.028	0.011	0.006	0.006	0.015	0.007	0.007
27-Nov-17 - 41 mg/L, pH 5.70 (opt) - Laboratory - Iron, Total (mg/L)	0.050	1.050	1.080	0.170	0.160	0.200	0.190					0.120
6-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Iron, Dissolved (mg/L)	0.032	0.183	0.062	0.024	0.006	0.025	0.006	0.004	0.009	0.005	0.006	0.006
6-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Iron, Total (mg/L)	0.050	2.210	1.990	0.220	0.100	0.070	0.230					0.050
7-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Iron, Dissolved (mg/L)	0.013	0.295	0.528	0.013	0.007	0.010	0.008	0.007	0.007	0.008	0.027	0.007
7-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Iron, Total (mg/L)	0.050	1.520	1.560									

Figure 4-29: Total and dissolved iron levels during optimal conditions testing using a ferric sulphate dose of 41 mg/L at pH 5.70 and 5.80 for the Winter #2 piloting session. Data originates from City Lab analyses.

The final combined filter effluent dissolved iron concentration ranged between 0.006 to 0.007 mg/L. The results show the residual dissolved iron from ferric sulphate was adequately removed by the filter media. Furthermore, there is no statistical difference between pH 5.70 and 5.80 with regards to dissolved iron in the combined filter effluent. The results suggest that higher pH can be used when coagulating with ferric sulphate while still meeting treated water quality objectives.

→ True Colour

The true colour results are presented in Figure 4-30. The results illustrate the raw water true colour was 12.0±1.0 TCU during optimized ferric sulphate testing. DAF reduced raw water true colour by 62 - 86% for both pH tested. Ozonation further reduced true colour by 25 – 60%. Better true colour removal following filtration was observed for samples coagulated at pH 5.80, compared to 5.70.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
27-Nov-17 - 41 mg/L, pH 5.70 (opt) - Laboratory - Colour, True(colour units)	12.0	2.0	1.5	1.5	1.0	1.0	1.5	1.0	2.0	1.5	1.0	1.0
6-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Colour, True(colour units)	13.0	5.0	2.0	1.5	1.0	0.5	0.5	0.5	0.5	1.0	1.0	0.5
7-Dec-17 - 41 mg/L, pH 5.80 (opt) - Laboratory - Colour, True(colour units)	11.0	1.5	1.0	1.0	0.5	1.0	1.0	0.5	0.5	0.5	0.5	0.5

Figure 4-30: True colour during optimal conditions testing using a ferric sulphate dose of 41 mg/L at pH 5.70 and 5.80 for the Winter #2 piloting session. Data originates from City Lab analyses.

Ferric sulphate was found to adequately remove true colour at both pH 5.70 and 5.80, with true colour in the final combined filter effluent of 1.0 TCU and 0.5 TCU, respectively.

→ Filter Operation

Table 4-2 tabulates the average UFRV values for optimal conditions of 41 mg/L and pH of 5.8 during the Winter #2 piloting session, while also considering overall operation cycles and those which have not failed based on sampled turbidity.

Table 4-2: Average observed and forecasted UFRV values for the optimal conditions of Winter #2 piloting session.

UFRV (m^3/m^2)		OPTIMAL DAYS OF WITNER #2 PILOTING SESSION		
		Bank A	**Bank B**	**All Filters**
Observed Values	Overall Cycles	273	355	312
	Only cycles with turbidity ≤ 0.1 NTU	204	394	362
	Only cycles with turbidity ≤ 0.3 NTU	283	355	321
Forecasted Values	Overall Cycles	273	379	326
	Only cycles with turbidity ≤ 0.1 NTU	204	394	362
	Only cycles with turbidity ≤ 0.3 NTU	283	379	334

N/R: No results

For Bank A, all individual filters failed based on turbidity (> 0.1 NTU), except Filter 4 once, and the observed overall average UFRV was 273 m^3/m^2 during the optimal conditions of the Winter #2 piloting session. When considering the only cycle where the turbidity levels were below 0.1 NTU when sampled, the observed UFRV value was 204 m^3/m^2. The average rate of head loss increase for Bank A was 3.0 kPa/h, similar to the typical rate of head loss increase for filter bank operating at 0.6 L/s (3.1 kPa/h, Refer to Table 5-2 of TM No. 3).

For Bank B, 69% of the individual filters failed based on turbidity (> 0.1 NTU) and the observed overall average UFRV was 355 m^3/m^2 during the optimal conditions of the Winter #2 piloting session. When considering the only cycle where the turbidity levels were below 0.1 NTU when sampled, the observed UFRV value increased to 394 m^3/m^2. The average rate of head loss increase for Bank B was 1.1 kPa/h, 35% lower than the typical rate of head loss increase for filter bank operating at 0.3 L/s (1.7 kPa/h, Refer to Table 5-2 of TM No. 3).

It is believed that the observed UFRV values obtained for Bank B would likely be doubled in the full-scale system, where the head loss available for filtration (48.9 kPa) is twice that of the available head loss at the pilot-scale system filters (23.9 kPa) as explained in Section 2.4 of TM No. 3. Based on the comparable rate of head loss increase between the pilot-scale and full-scale systems, it is anticipated that the pilot-scale system would be able to achieve UFRVs comparable to the full-scale system at average flow rate of filtration.

The filter effluent turbidity measured by the Lab is plotted against the differential pressure at 4 hours after start of filter cycle (or approximate sampling time) of each individual filter for the December 5th at optimal conditions, as shown on Figure 4-31. This illustration also highlights the City's operational filter turbidity limit of 0.1 NTU, the full-scale system operating licence limit of 0.3 NTU, and the expected differential pressures at the sampling time per flow rate to match the full-scale system's performance. The expected differential pressures of 6.8 kPa for filters at average flow rate and 12.4 kPa for filters at maximum flow rate are based on the historical benchmarking values of the full-scale system filters (average head loss of 48.9 kPa and average filter run of 28.9 h per Table 2-2 of TM No. 1). The differential pressures at 4 hours after start of filter cycle (ranging from 16.3 – 21.8 kPa) were nearly double that of the expected differential pressure (12.4 kPa) for maximum flow rate for Filters 1, 2, 5 and 6. The differential pressures at 4 hours after start of filter cycle (5.7 – 9.3 kPa) were similar to the expected differential pressure (6.8 kPa) for average flow rate for Filters 3, 7, and 8, but almost 50% for Filter 4.

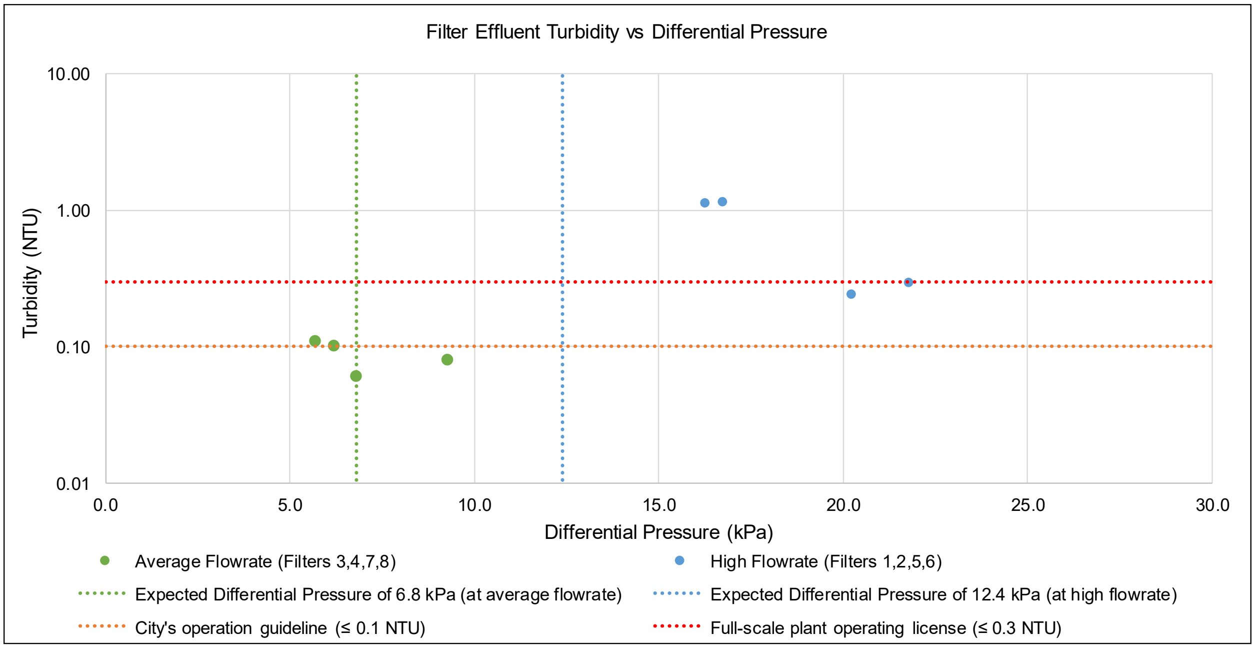


Figure 4-31: Filter effluent turbidity versus differential pressure at sampling time for each individual filter for the optimal conditions of the Winter #2 piloting session. Note the turbidity levels (y-axis) are displayed in a logarithmic scale to improve visualization.

→ Summary of Optimal Conditions

Overall, the water quality results indicate both pH values of 5.7 and 5.8 are deemed satisfactory. The data shows higher turbidity removal, lower UVT and higher UV_{254nm} absorbance levels at pH of 5.7. On the other hand, the data shows lower true colour levels at pH of 5.8, but similar levels of total manganese, dissolved iron and DOC at these two pH values. The UFRV analysis performed following the Winter #2 piloting session indicated that better filter performance was achieved with pH of 5.8 than with pH of 5.7.

5 WINTER #2 BENCHMARKING PERIOD

5.1 Overview of Hard Transition and Benchmarking Activity

The transition from ferric sulphate to ferric chloride in the pilot-scale system occurred on December 7th, immediately following the completion of the final daily sample collection for Winter #2 piloting session. The transition to ferric chloride can be viewed as a hard transition, meaning there was no cleaning of the pilot-scale system (i.e., draining and cleaning of the DAF tank, or flushing of the lines). The City wanted to investigate if there were any potential concerns with transitioning between the two coagulants without first cleaning the system. There was no sample collection during the hard transition and only visual observations of the pilot-scale system were made by the City. Following the hard transition to ferric chloride, the pilot-scale system was shutdown for cleaning and maintenance (December 8th to 11th) before the commencement of the Winter #2 benchmarking period.

The Winter #2 benchmarking period occurred from December 12th, 2017 to January 19th, 2018, immediately following the Winter #2 piloting session of ferric sulphate. The objective of the benchmarking period is to compare the full-scale and pilot-scale systems operation using the same chemical additions, and to facilitate comparisons between the treatment processes. Evaluations for benchmarking between the full-scale and pilot-scale systems are made by comparing the following parameters: pH, turbidity, total manganese, and TOC.

The pilot-scale system samples were collected daily from the following locations:

- Post-DAF (via the DAF overflow pipe to the overflow tank);
- Post-Ozone (from the combined ozone column piping feeding the Ozone Contact tank); and
- Individual filter effluents (Filters 1 through 8).

The full-scale samples were collected from the following locations:

- Raw water;
- Post-DAF;
- Post Ozone (i.e. combined ozone from both tanks);
- Individual filter effluents (Filters 1 through 8); and
- Post Filter Combined.

Note: the raw water was only recorded for the full-scale system, as testing during the Winter #1 piloting session found nominal quantitative differences between the raw water for both full-scale and pilot-scale systems. This excludes a temperature increase of approximately 1°C to 2°C. As such, for the purposes of this study, differences in the raw water quality at the full-scale and pilot-scale systems are assumed to be negligible.

Table 5-1 outlines the pilot-scale system operation during the Winter #2 benchmarking period including chemical doses for ferric chloride and sulphuric acid. The standard protocol for a piloting session, where benchmarking was completed prior to the transition and piloting periods, was altered due to scheduling and pilot-scale system maintenance concerns. Another important difference in the Winter #2 benchmarking period was that the pilot-scale system was not shut-down and cleaned prior to the transition from ferric sulphate to ferric chloride. If the full-scale system were to be transitioned from ferric chloride to ferric sulphate, a complete system shutdown and cleaning of the full-scale system would not be possible.

Table 5-1: Outline of pilot-system system operation and sampling during hard transition to ferric chloride and the Winter #2 benchmarking period.

Date	Ferric Chloride Dose (mg/L)	Sulphuric Acid Dose (mg/L)	Event Details
07-Dec-17	N/A	N/A	Hard transition from ferric sulphate to ferric chloride
08-Dec-17	N/A	N/A	Pilot offline - cleaning and maintenance; no sample collection
09-Dec-17	N/A	N/A	Pilot offline - cleaning and maintenance; no sample collection
10-Dec-17	34.51	33.08	No samples collected
11-Dec-17	32.90	33.87	Pilot offline - cleaning and maintenance; no sample collection
12-Dec-17	29.99	33.87	Winter #2 benchmarking period started; normal operation; sample collection
13-Dec-17	31.60	33.00	Normal operation; sample collection
14-Dec-17	31.60	38.30	Normal operation; sample collection
15-Dec-17	31.60	36.80	Normal operation; sample collection
16-Dec-17	31.60	36.80	No coagulant added ~24 hours; no sample collection in pilot-scale system
17-Dec-17	31.60	36.80	Coagulant pump maintenance; sample collection
18-Dec-17	31.60	36.80	Normal operation; sample collection
19-Dec-17	26.80	41.70	Normal operation; sample collection
20-Dec-17	27.40	40.70	Normal operation; sample collection
21-Dec-17	27.40	40.70	Normal operation; sample collection
22-Dec-17	27.40	40.70	Normal operation; sample collection
23-Dec-17	N/A	N/A	Normal operation; No sample collection
24-Dec-17	N/A	N/A	Normal operation; No sample collection
25-Dec-17	N/A	N/A	Normal operation; No sample collection
26-Dec-17	N/A	N/A	Normal operation; No sample collection
27-Dec-17	N/A	N/A	Normal operation; No sample collection
28-Dec-17	29.40	39.20	Normal operation; No sample collection
29-Dec-17	N/A	N/A	Normal operation; No sample collection
30-Dec-17	N/A	N/A	Normal operation; No sample collection
31-Dec-17	N/A	N/A	Normal operation; No sample collection
01-Jan-18	29.40	39.20	Normal operation; No sample collection
02-Jan-18	29.40	39.20	Normal operation; sample collection
03-Jan-18	31.60	38.50	Normal operation; sample collection
04-Jan-18	33.20	37.70	Ozone stopped; sample collection
05-Jan-18	32.70	38.20	Normal operation; sample collection
06-Jan-18	32.25	38.20	Normal operation; sample collection
07-Jan-18	32.25	38.20	Normal operation; sample collection
08-Jan-18	32.25	38.20	Normal operation; sample collection
09-Jan-18	32.25	38.20	Normal operation; sample collection
10-Jan-18	32.25	38.20	Normal operation; sample collection
11-Jan-18	32.25	38.20	Normal operation; sample collection
12-Jan-18	35.16	36.76	Normal operation; sample collection
13-Jan-18	28.87	41.17	Normal operation; sample collection
14-Jan-18	29.35	41.17	Normal operation; sample collection
15-Jan-18	29.35	41.17	Normal operation; sample collection
16-Jan-18	29.35	41.17	Interruption in flow to Bank A and filter-aid; sample collection
17-Jan-18	29.35	41.17	Interruption in flow to Bank A and filter-aid; sample collection
18-Jan-18	29.35	41.17	Normal operation; sample collection
19-Jan-18	29.35	41.17	Normal operation; sample collection

On December 7th, immediately following the final Winter #2 piloting session sample collection (approximately 1:00pm), City engineers hard transitioned the pilot-scale system coagulant from ferric sulphate to ferric chloride, without cleaning the DAF or flushing chemical lines. After 24 hours of operation there were no noticeable effects to the pilot-scale system DAF operation using ferric chloride, and turbidity levels appeared to remain stable at 1.36 NTU following the hard transition. The observed minimal impact of the sudden switch to ferric chloride suggest that if the full-scale system were to be hard transitioned to ferric sulphate there would be little to no interruption in the full-scale system operation. Further study of this in different seasons is warranted.

On December 8th, 2017, the pilot-scale system was taken offline for cleaning and maintenance including calibrating online pH meters and replacement of the dew point monitor in the ozone system. Once the maintenance was completed the pilot-scale system was brought back online; however, the following day (December 9th) it was discovered the flocculation mixers were not started when the pilot-scale system was placed back online. Therefore, the floc tanks were drained and cleaned to remove any buildup of coagulant in the tanks, after which the pilot-scale system was reinitiated.

On December 10th, there were fluctuations in the raw water flow feeding the pilot-scale system causing high water levels in the pilot-scale system DAF tank. City technicians adjusted the DAF overflow weir to compensate for the high-water level in the DAF tank. The pilot-scale system DAF underwent another shutdown and cleaning on December 11th, 2017 due to high Post-DAF turbidity. The elevated Post-DAF turbidity observed on December 11th could have been a result of the fluctuations in raw water flow and the resulting weir adjustment the day prior. On December 12th, the pilot-scale system returned to normal operation.

On December 16th, the City reported a fault in the coagulant dosing pump resulting in no coagulant being dosed for 24 hours. On December 17th, the faulty pump was reset and recalibrated and the pilot-scale system was returned to normal operation.

From December 22nd, 2017 to January 2nd, 2018, the pilot-scale system was operated in a normal manner (i.e., coagulant addition and daily backwashing); however, no samples were collected for analysis due to limited personnel onsite.

On January 4th, the ozone systems in both the full-scale and pilot-scale systems were taken offline for annual maintenance and inspection. The ozone systems were not brought back online for the remainder of the Winter #2 benchmarking period.

January 16th, 2018, the City reported a fault in the pump for Filter Bank A (P_X401) which interrupted filter operation (Bank A only) and filter-aid addition for approximately 1-hour (12:30pm – 1:30pm). Filter-aid addition was not initiated for approximately 3 hours (3:30pm).

On January 17th, 2018, there was an interruption to the filter-aid pump feeding Filter Bank A (P_X505) for approximately 2 hours (1:30pm – 3:30pm).

5.2 Raw Water Flow Rate

The pilot-scale system daily average raw water flow rate is presented in Figure 5-1. During the Winter #2 transition period and piloting session, the City requested that the raw water flow be reduced to less than 2.75 L/s to improve Post-DAF turbidity. During the Winter #2 benchmarking period, the City further reduced the raw water flow to between 2.3 – 2.5 L/s, reporting the Post-DAF turbidity further improved ranging from 0.8 – 1.0 NTU. The City noted similar fluctuations in raw water flow as reported by WSP during the Winter #2 piloting session. However, maintenance to address the unstable flow rate was not conducted and a cause for the fluctuations was not determined.

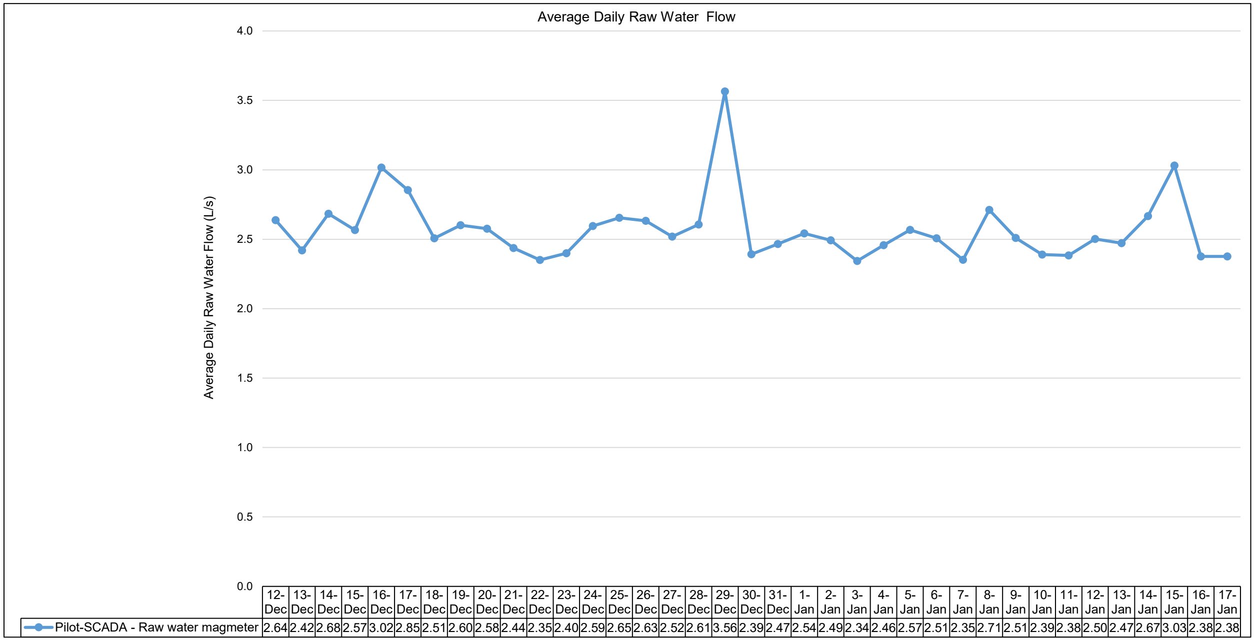


Figure 5-1: Raw water flow rate during Winter #2 benchmarking period (December 12th, 2017 to January 17th, 2018). Data originates from the pilot-scale system's SCADA dataset.

5.3 Filters Operation (SCADA)

Both filter banks were operated at an average flow of 0.3 L/s to represent the full-scale system average flow rate during the 35 days of the Winter #2 benchmarking period. The standard procedure was to backwash the filters daily approximately at the same time. The differential pressure values reported by the pilot-scale system SCADA were evaluated on an average hourly basis to determine the following:

- the filter run times,
- the UFRV values,
- if individual filters overflowed prior to the subsequent cycle based on the typical overflow pressures of each individual filter, and
- the rate of head loss increase of each filter.

The calculations were as described in Section 2.4 of TM No. 3. The filters operational data was compared against the filters effluent turbidity measured by the Lab, which was sampled approximately 4 hours from the start of the filtration cycle. A summary of the filters operational data during the Winter #2 benchmarking period is provided in Appendix A. Figure 5-2 illustrates the average daily UFRV values.

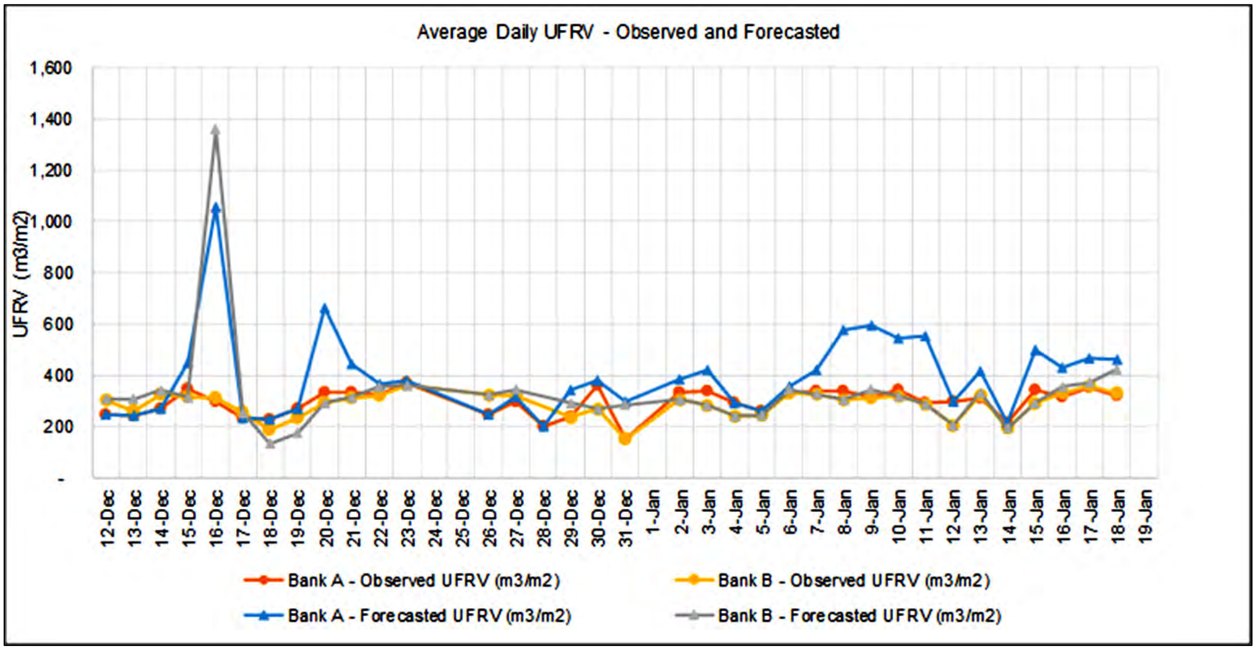


Figure 5-2: Average UFRV values of pilot-scale system Bank A and Bank B at an average flow rate of 0.3 L/s during the Winter #2 benchmarking period. UFRV = Filter Run Volume/Filter Surface Area. Note: Observed and forecasted UFRV values may overlap. Data originates from the pilot-scale system's SCADA dataset.

Table 5-2 tabulates the average filter run times and average UFRV values for the entire Winter #2 benchmarking period, while also considering overall operation cycles and those which have not failed based on sampled turbidity.

Table 5-2: Average observed and forecasted filter run times and UFRV values during the Winter #2 benchmarking period.

	UFRV (m^3/m^2)	**FILTER RUN TIME (h)**			**UFRV (m^3/m^2)**		
		Bank A	**Bank B**	**All Filters**	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	19.5	18.6	19.0	295	287	291
	Only cycles with turbidity ≤ 0.1 NTU	19.4	18.6	19.0	292	289	290
	Only cycles with turbidity ≤ 0.3 NTU	19.5	18.5	19.0	294	287	291
Forecasted Values	Overall Cycles	23.9	19.1	21.5	361	295	328
	Only cycles with turbidity ≤ 0.1 NTU	26.0	21.7	23.6	391	336	360
	Only cycles with turbidity ≤ 0.3 NTU	26.0	21.6	23.8	392	334	363

From the filter operation data, the following observations were made:

- During the Winter #2 benchmarking period, there were a total of 24 cycles that Bank A did not overflow before the daily backwash, versus 26 cycles where Bank B did not overflow.
- The average Post-Ozone turbidity feeding the filters was 1.44 NTU and the average combined filter turbidity was 0.10 NTU during the Winter #2 benchmarking period.

- The turbidity levels of Bank A filters exceeded the City's operational guideline of 0.1 NTU eight days out of 35 days of the Winter #2 benchmarking period, while Filter 8 on Bank B exceeded the guideline only once.
- Filter 1 exceeded the full-scale system's operating license limit of 0.3 NTU four times, while Filter 2, Filter 3 and Filter 4 exceeded the license limit only once.
- The average observed filter run time was 19 hours and the average observed UFRV was 291 m^3/m^2, and both filter banks presented similar results.
- No difference was observed when comparing the overall average UFRV values (291 m^3/m^2) with the UFRV values that considered filters not exceeding either 0.1 or 0.3 NTU (290 and 291 m^3/m^2, respectively). The forecasted UFRV values were approximately 13% higher than the observed UFRV values.
- The rate of head loss increase ranged from 0.5 to 2.2 kPa/h, with an average of 1.1 kPa/h. No substantial variability was observed for each filter during the Winter #2 benchmarking period. The filters exceeded the typical rate of head loss increase of 1.7 kPa/h only 7% of the time, and the maximum rate of head loss increase of 3.7 kPa/h was never exceeded. The typical and maximum rate of head loss increase (1.7 kPa/h and 3.7 kPa/h) are based on historical averages of the full-scale system (Refer to Table 5-2 of TM No. 3 for additional details).

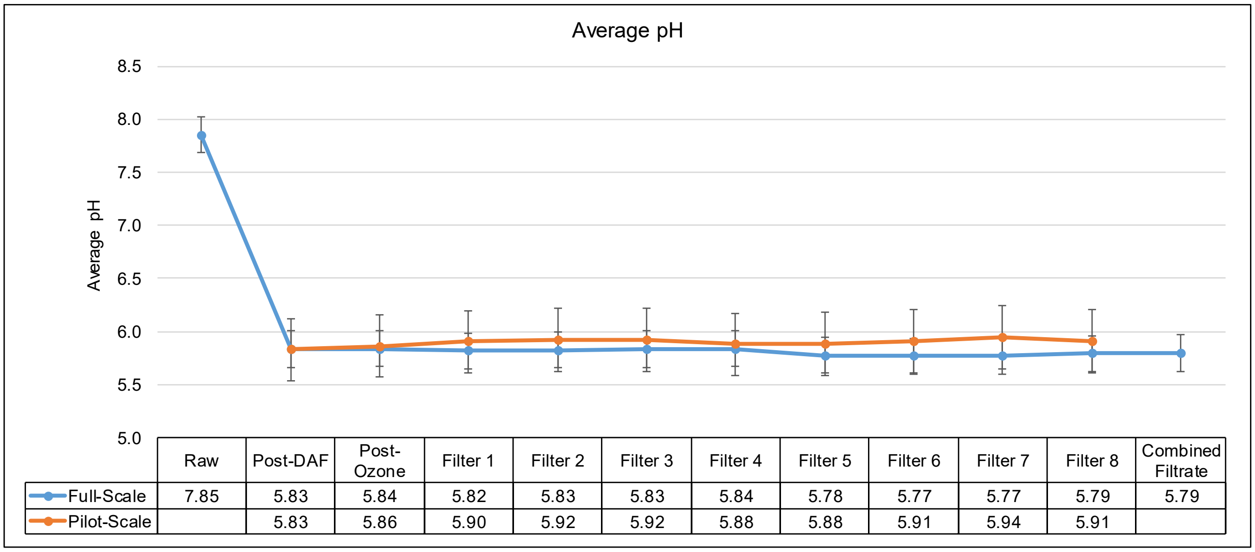
Both banks exhibit similar filter runs and UFRV values, as expected since both filter banks were operated at an average flow rate of 0.3 L/s during the Winter #2 benchmarking period, which emphasises the differences seen in the individual filters performance are much less visible at average flow rate conditions.

Based on full-scale historical benchmarking, the five-year average UFRV value is 495 m^3/m^2 with an average rate of head loss increase of 1.7 kPa/h and an average post-ozone turbidity of 0.79 NTU (see Table 2-1 and Table 2-2 of TM No. 1). The Winter #2 benchmarking period presented a UFRV value 40% smaller than the full-scale system historical value but had a rate of head loss increase lower than the full-scale system, averaging 1.1 kPa/h. However, the UFRV values cannot be directly compared since the head loss available in full-scale system is nearly double that of the available head loss in the pilot-scale system filters as explained in Section 2.4 of TM No. 3. The pilot-scale system filter run times and UFRV values are likely one-half that of the full-scale system values at the same rate of head loss increase. Therefore, some correlation between the two systems is observed and the performance of pilot-scale system filters was deemed similar to the full-scale system.

5.4 Key Parameters

- pH

Figure 5-3 presents the average pH for the full-scale and pilot-scale systems during the Winter #2 benchmarking period. There is little difference in pH between the full-scale and pilot-scale system Post-DAF and Post-Ozone samples. The pilot-scale system had a slightly higher pH in the filter effluent compared to the full-scale system; however, the difference is negligible. Overall, in terms of pH, both systems showed strong similarity during the Winter #2 benchmarking period.

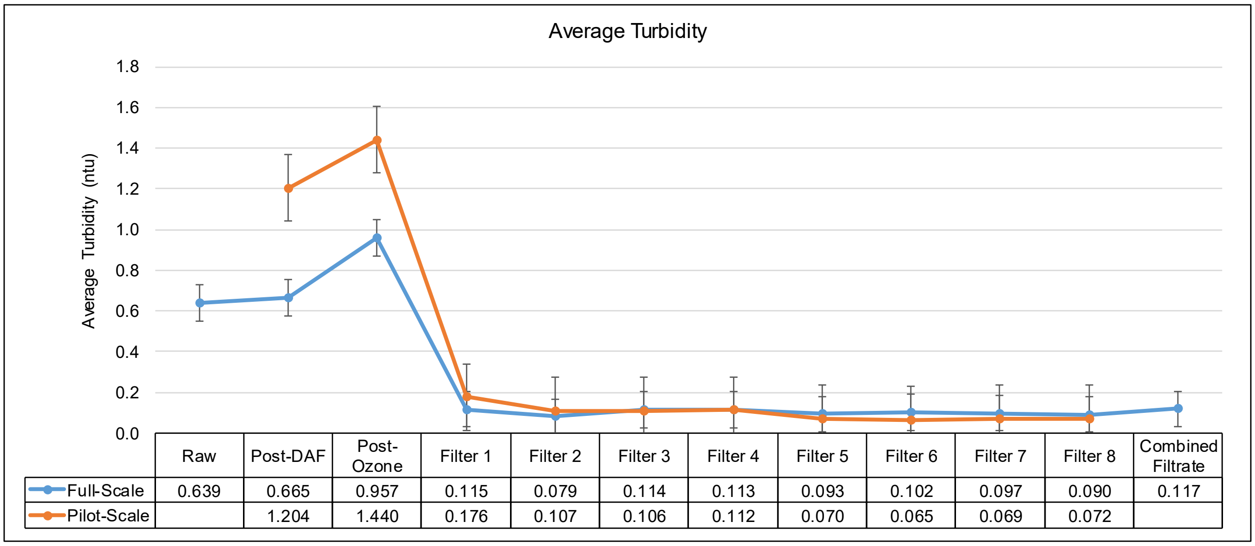


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full-Scale	7.85	5.83	5.84	5.82	5.83	5.83	5.84	5.78	5.77	5.77	5.79	5.79
Pilot-Scale		5.83	5.86	5.90	5.92	5.92	5.88	5.88	5.91	5.94	5.91	

Figure 5-3: Average pH levels in the full-scale and pilot-scale systems during the Winter #2 benchmarking period. Data originates from Lab analyses.

→ Turbidity

The comparison of turbidity levels for the full-scale and pilot-scale systems during the Winter #2 benchmarking period is presented in Figure 5-4. The pilot-scale system had significantly higher Post-DAF and Post-Ozone turbidity compared to the full-scale system. Higher Post-DAF turbidity has been observed in the pilot-scale system throughout the project and has been attributed to several likely factors such as scaling differences between full-scale and pilot-scale DAF systems and retention time in the pilot-scale system DAF. However, the City also noted that the fluctuation in the raw water flow significantly affected the Post-DAF turbidity in the pilot-scale system. This can be seen in the large error bars for Post-DAF and Post-Ozone samples (Figure 5-4) collected from the pilot-scale system compared to the full-scale system.



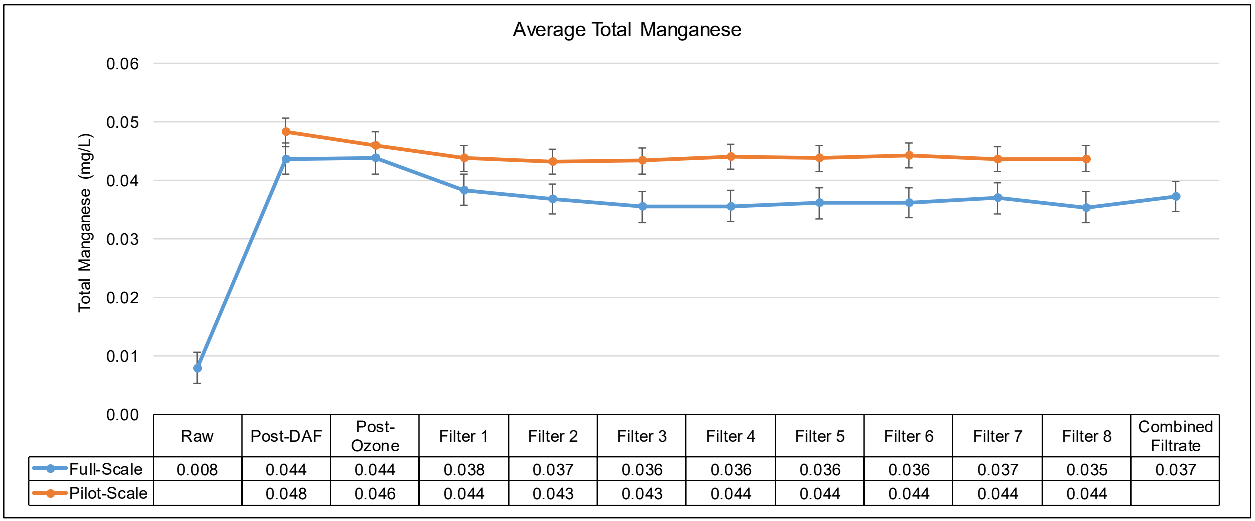
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full-Scale	0.639	0.665	0.957	0.115	0.079	0.114	0.113	0.093	0.102	0.097	0.090	0.117
Pilot-Scale		1.204	1.440	0.176	0.107	0.106	0.112	0.070	0.065	0.069	0.072	

Figure 5-4: Average turbidity levels in the full-scale and pilot-scale systems during the Winter #2 benchmarking period. Data originates from Lab analyses.

The filter effluent samples showed strong comparison between both systems, with a final combined filter effluent turbidity in the full-scale and pilot-scale systems of 0.14 NTU and 0.17 NTU, respectively (reported as the average of individual filter effluent turbidity).

→ Total Manganese

The total manganese results for the Winter #2 benchmarking period are presented in Figure 5-5. There was a significant increase in manganese in both systems following the addition of ferric chloride; however, slightly higher manganese concentrations were measured in the pilot-scale system Post-DAF samples. The elevated manganese in the pilot-scale system Post-DAF samples may be due to the fluctuation in pilot-scale system raw water flow causing poor floc formation and carry-over of residual manganese following DAF treatment.



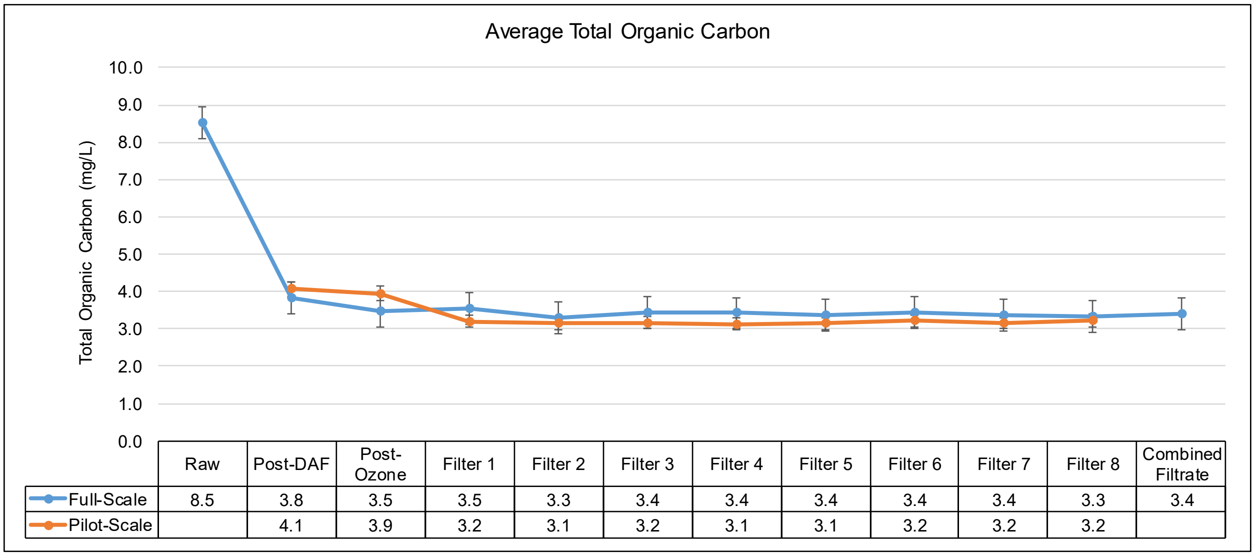
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full-Scale	0.008	0.044	0.044	0.038	0.037	0.036	0.036	0.036	0.036	0.037	0.035	0.037
Pilot-Scale		0.048	0.046	0.044	0.043	0.043	0.044	0.044	0.044	0.044	0.044	

Figure 5-5: Average total manganese concentration measured in the full-scale and pilot-scale systems during the Winter #2 benchmarking period. Data originates from Lab analyses.

Both systems show only a minor reduction in total manganese following filtration with final combined effluent total manganese concentration of 0.038 mg/L and 0.044 mg/L for the full-scale and pilot-scale systems, respectively.

→ Total Organic Carbon

The final parameter tested during the Winter #2 benchmarking period was TOC removal (Figure 5-6). Comparison between the full-scale and pilot-scale systems found that there was better TOC removal by the full-scale system following DAF and ozone treatment compared to the pilot-scale system.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Full-Scale	8.5	3.8	3.5	3.5	3.3	3.4	3.4	3.4	3.4	3.4	3.3	3.4
Pilot-Scale		4.1	3.9	3.2	3.1	3.2	3.1	3.1	3.2	3.2	3.2	

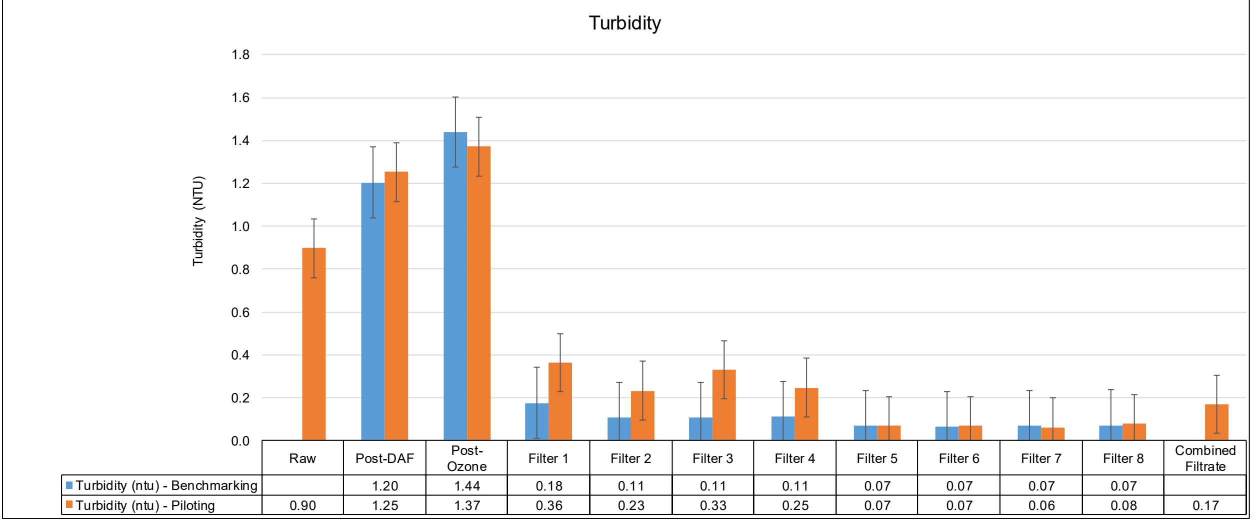
Figure 5-6: Average TOC concentration measured in the full-scale and pilot-scale systems during the Winter #2 benchmarking period. Data originates from Lab analyses.

The final filter effluent TOC concentrations were slightly lower in the pilot-scale system compared to the full-scale system; however, the difference between the two systems is within standard error and was deemed negligible.

Aside from minor differences noted with regards to the pilot-scale system Post-DAF turbidity and total manganese, the full-scale and pilot-scale systems showed strong similarities during the Winter #2 benchmarking period. The results indicate the pilot-scale system can closely match the full-scale system when operated in the same manner (i.e. chemical dose and flow). Therefore, the data obtained during Winter #2 piloting session provides a good indication of how the full-scale system would operate if transitioned to ferric sulphate from ferric chloride.

5.5 Comparison Between the Winter #2 Benchmarking Period and the Winter #2 Piloting Session of the Pilot-System

Figure 5-7 and Figure 5-8 present a comparison between coagulants, ferric chloride and ferric sulphate, used in the pilot-scale system operation during the Winter #2 benchmarking period and the Winter #2 piloting session. Figure 5-7 illustrates a comparison between the average turbidity seen in the pilot-scale system Winter #2 benchmarking period and the Winter #2 piloting session.

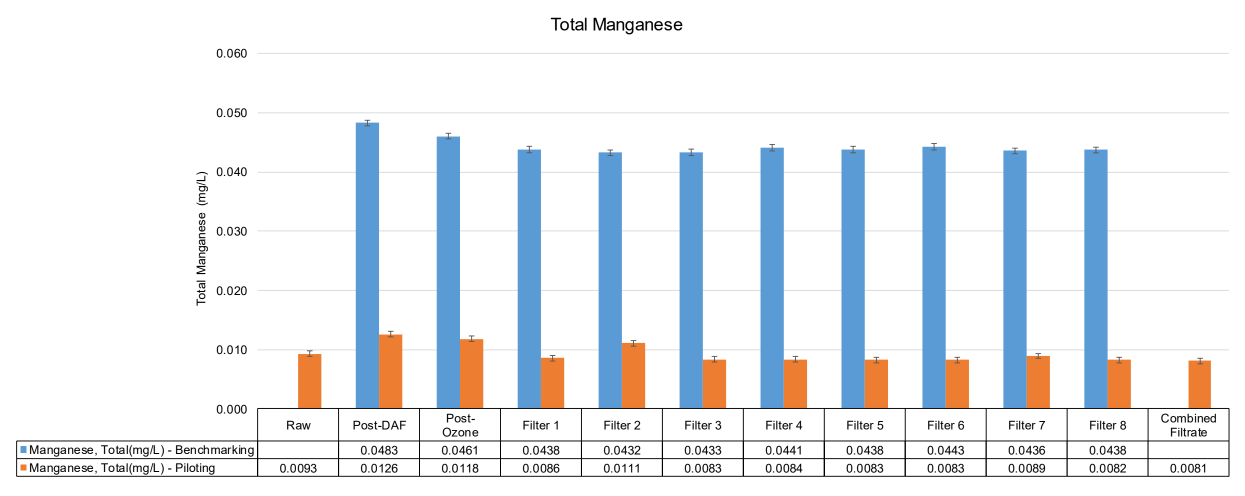


	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
🟦 Turbidity (ntu) - Benchmarking		1.20	1.44	0.18	0.11	0.11	0.11	0.07	0.07	0.07	0.07	
🟧 Turbidity (ntu) - Piloting	0.90	1.25	1.37	0.36	0.23	0.33	0.25	0.07	0.07	0.06	0.08	0.17

Figure 5-7: Comparison of average turbidity between the pilot-scale system Winter #2 benchmarking period (average values from December 7th, 2017 to January 19th, 2018) and the pilot-scale system Winter #2 piloting session (average of optimal conditions from November 27th and December 6th and 7th, 2017). Data originated from Lab analyses.

As observed in Figure 5-7, there was a lower Post-DAF turbidity measured during the Winter #2 benchmarking period using ferric chloride. This may indicate that the floc formed using ferric chloride is more readily removed by DAF treatment compared to the floc formed with ferric sulphate. Effluent turbidity of Bank B was similar for both periods, while Bank A showed a lower turbidity during the Winter #2 benchmarking period, which could be explained by the lower flow rate to Bank A during the Winter #2 benchmarking period.

Results presented in Figure 5-8 confirm that the total manganese concentration in the filter effluent is significantly lower (approximately 2 to 3 times) when using ferric sulphate as the coagulant.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
🟦 Manganese, Total(mg/L) - Benchmarking		0.0483	0.0461	0.0438	0.0432	0.0433	0.0441	0.0438	0.0443	0.0436	0.0438	
🟧 Manganese, Total(mg/L) - Piloting	0.0093	0.0126	0.0118	0.0086	0.0111	0.0083	0.0084	0.0083	0.0083	0.0089	0.0082	0.0081

Figure 5-8: Comparison of average total manganese between the pilot-scale system Winter #2 benchmarking period (average values from December 7th, 2017 to January 19th, 2018) and the pilot-scale system Winter #2 piloting session (average of optimal conditions from November 27th and December 6th and 7th, 2017). Data originated from Lab analyses.

Table 5-3 tabulates the average filter run times and average UFRV values for the Winter #2 benchmarking period and the optimal days of the Winter #2 piloting session, while also considering overall operation cycles and those cycles which have not failed based on sampled turbidity.

Table 5-3: Average observed and forecasted UFRV values for the Winter #2 benchmarking period and the optimal conditions of the Winter #2 piloting session.

UFRV (m^3/m^2)		**WINTER #2 BENCHMARKING PERIOD**	**OPTIMAL DAYS OF WINTER #2 PILOTING SESSION**		
		All Filters	**Bank A**	**Bank B**	**All Filters**
Observed Values	Overall Cycles	291	273	355	312
	Only cycles with turbidity ≤ 0.1 NTU	290	204	394	362
	Only cycles with turbidity ≤ 0.3 NTU	291	283	355	321
Forecasted Values	Overall Cycles	328	273	379	326
	Only cycles with turbidity ≤ 0.1 NTU	360	204	394	362
	Only cycles with turbidity ≤ 0.3 NTU	363	283	379	334

During the Winter #2 benchmarking period with ferric chloride, Bank A exceeded 0.1 NTU 94% of the time and Bank B exceeded 0.1 NTU once. At optimal conditions with ferric sulphate during Winter #2 piloting session, Bank A exceeded 0.1 NTU 94% of the time and Bank B exceeded 0.1 NTU 69% of the time.

In terms of filter operation, the overall average observed UFRV for Banks A and B was 291 m^3/m^2 during the Winter #2 benchmarking period, while the overall average observed UFRV during the optimal conditions of the Winter #2 piloting session was 273 m^3/m^2 and 355 m^3/m^2 for Bank A and Bank B, respectively. When considering operating cycles where turbidity observations exceeded 0.1 NTU, Bank A and Bank B presented average UFRV values relatively close with ferric sulphate to that of ferric chloride (204 m^3/m^2 and 394 m^3/m^2 respectively).

Banks A and B (both operating at a flowrate of 0.3 L/s) during the Winter #2 benchmarking period and Bank B (operating at a flowrate of 0.3 L/s) during Winter #2 piloting session at optimal conditions presented an average rate of head loss increase (1.1 kPa) lower than the typical value of the full-scale system (1.7 kPa), implying improved filter performance and potentially longer run times could be achieved in the pilot-system. Bank A (operating at a flowrate of 0.6 L/s) during Winter #2 piloting session at optimal conditions presented an average rate of head loss increase (3.0 kPa) similar to the typical value of the full-scale system (3.1 kPa).

When comparing the pilot-scale system filter banks operating at the same flowrate, UFRV values and head loss increase rates appear to be better when using ferric sulphate verses ferric chloride. However, almost all of the filters failed based on turbidity when dosing ferric sulphate. As such, it is concluded that the pilot-scale system seems to be able to achieve better overall filter performance with ferric chloride than with ferric sulphate. Should the full-scale plant transition to ferric sulphate, post filter turbidity will have to be monitored closely and increased backwash frequency may be required to prevent high turbidity levels.

5.6 Comparison Between the Pilot-Scale and Full-Scale Systems During the Winter #2 Piloting Session

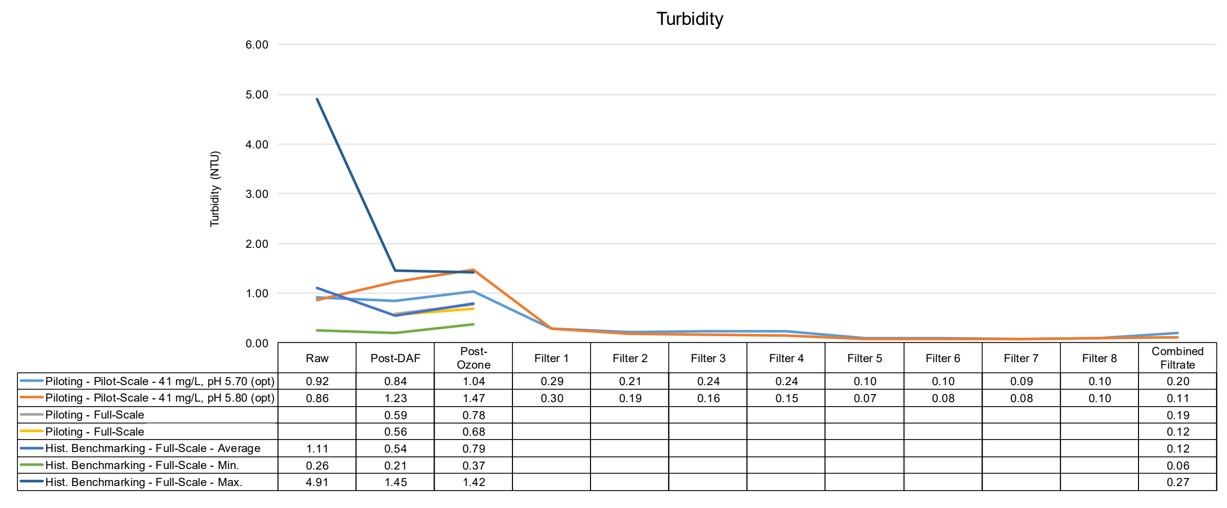
The following section compares the full-scale system operating with ferric chloride, both during the Winter #2 piloting session and the historical benchmark, to the pilot-scale system at optimum condition testing of ferric sulphate during the Winter #2 piloting session. For the Winter #2 piloting session, the Post-DAF, Post-Ozone and combined filter effluent samples were collected from the full-scale system for comparison to the pilot-scale system. During the Winter #2 piloting session the full-scale system dosed ferric chloride ranging from approximately 29 to 34 mg/L, with a Post-DAF pH ranging from approximately 5.7 to 5.9 (Note: pH range determined from grab samples collected from the full-scale DAF effluent during daily sample collection by WSP).

Historical benchmarking for the full-scale system is an average of 5 years of data. The following sections provide a comparison based on key parameters such as turbidity, total manganese, total iron, DOC, and true colour.

5.6.1 Key Parameters

→ Turbidity

Turbidity comparisons between full-scale system, pilot-scale system and historical trends (full-scale system) are presented in Figure 5-9. The results show that raw water turbidity during optimized testing of ferric sulphate was similar to the historical 5-year average. The strong similarity to the historical averages allows for an accurate comparison between the current operation of the full-scale and pilot-scale systems. Samples collected from the pilot-scale system Post-DAF and Post-Ozone had higher turbidity compared to both the full-scale system and historical data.



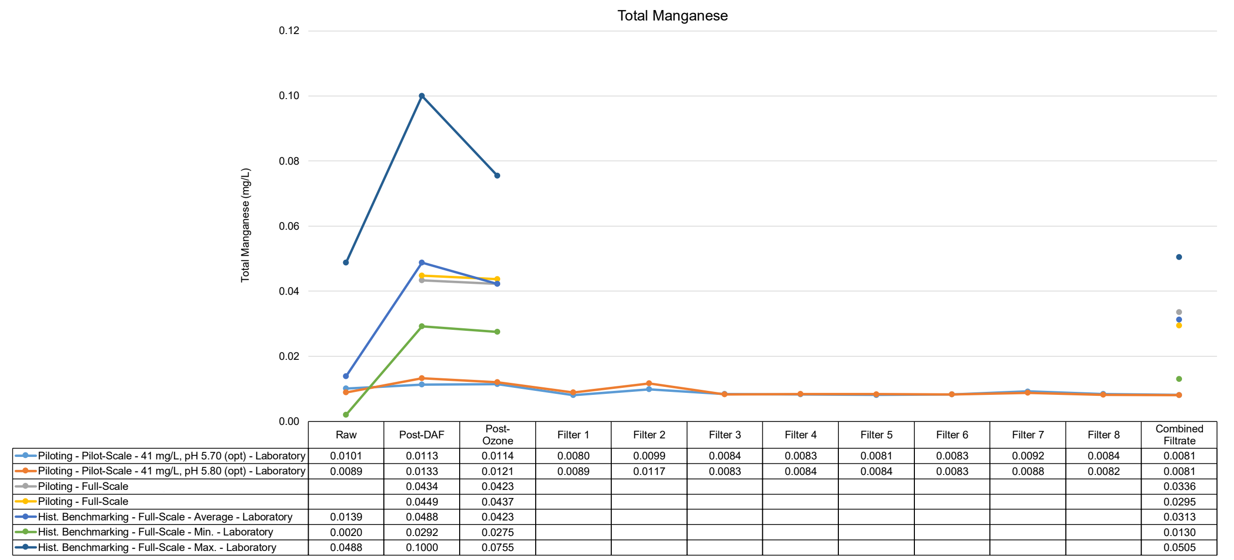
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - Pilot-Scale - 41 mg/L, pH 5.70 (opt)	0.92	0.84	1.04	0.29	0.21	0.24	0.24	0.10	0.10	0.09	0.10	0.20
Piloting - Pilot-Scale - 41 mg/L, pH 5.80 (opt)	0.86	1.23	1.47	0.30	0.19	0.16	0.15	0.07	0.08	0.08	0.10	0.11
Piloting - Full-Scale		0.59	0.78									0.19
Piloting - Full-Scale		0.56	0.68									0.12
Hist. Benchmarking - Full-Scale - Average	1.11	0.54	0.79									0.12
Hist. Benchmarking - Full-Scale - Min.	0.26	0.21	0.37									0.06
Hist. Benchmarking - Full-Scale - Max.	4.91	1.45	1.42									0.27

Figure 5-9: Comparison of turbidity levels between the average historical full-scale system, the full-scale system during the Winter #2 piloting session and the pilot-scale system during the Winter #2 piloting session operating at optimum ferric sulphate conditions: 41 mg/L ferric sulphate, pH 5.7 or 5.8. Data originates from the benchtop analysis using a HACH DR6000 UV-VIS spectrophotometer.

Elevated turbidity has been consistently observed in pilot-scale system Post-DAF and Post-Ozone samples throughout this project, particularly in cold water conditions (TM No. 3). When comparing the turbidity in the combined filter effluent, Figure 4-31, the results indicate that ferric sulphate, at pH 5.80, is removing more turbidity than the full-scale system. Furthermore, the pilot-scale system combined filter effluent turbidity at pH 5.80 is similar to the historical average of 0.12 NTU. This implies ferric sulphate at optimal conditions is comparable to the historical trends for turbidity removal by the full-scale system.

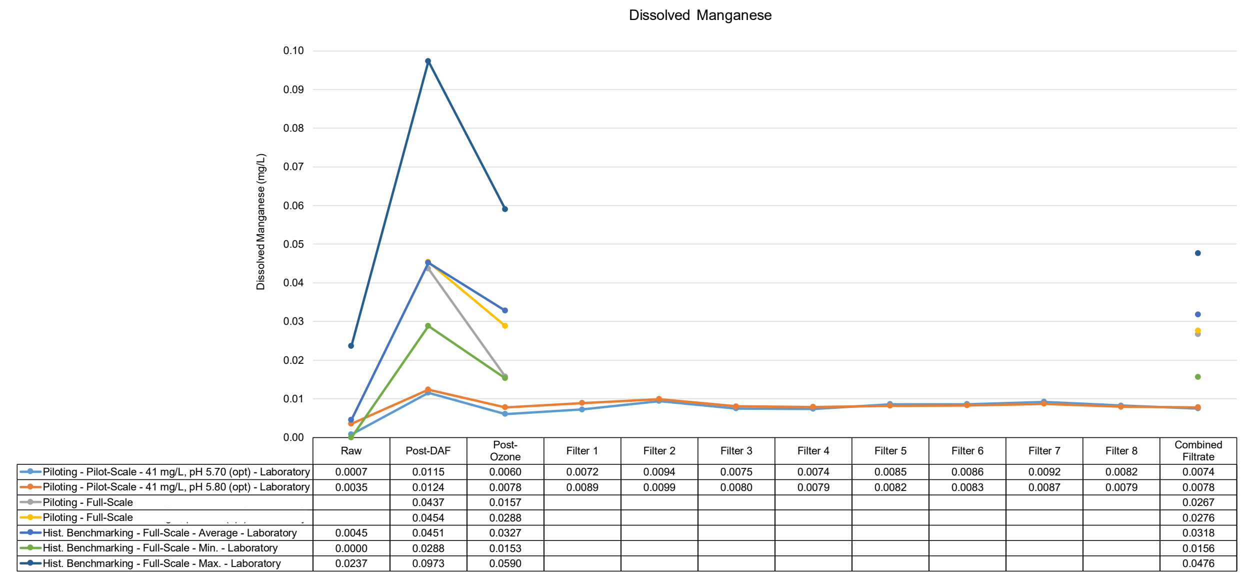
→ Total and Dissolved Manganese

Figure 5-10 and Figure 5-11 provides a comparison of the total and dissolved manganese concentrations for the full-scale and pilot-scale systems. Raw water total manganese concentration during the Winter #2 piloting session was slightly lower than the historical average of 0.0139 mg/L.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - Pilot-Scale - 41 mg/L, pH 5.70 (opt) - Laboratory	0.0101	0.0113	0.0114	0.0080	0.0099	0.0084	0.0083	0.0081	0.0083	0.0092	0.0084	0.0081
Piloting - Pilot-Scale - 41 mg/L, pH 5.80 (opt) - Laboratory	0.0089	0.0133	0.0121	0.0089	0.0117	0.0083	0.0084	0.0084	0.0083	0.0088	0.0082	0.0081
Piloting - Full-Scale		0.0434	0.0423									0.0336
Piloting - Full-Scale		0.0449	0.0437									0.0295
Hist. Benchmarking - Full-Scale - Average - Laboratory	0.0139	0.0488	0.0423									0.0313
Hist. Benchmarking - Full-Scale - Min. - Laboratory	0.0020	0.0292	0.0275									0.0130
Hist. Benchmarking - Full-Scale - Max. - Laboratory	0.0488	0.1000	0.0755									0.0505

Figure 5-10: Comparison of total manganese levels between the average historical full-scale system, the full-scale system during the Winter #2 piloting session and the pilot-scale system during the Winter #2 piloting session operating at optimum ferric sulphate conditions: 41 mg/L ferric sulphate, pH 5.7 or 5.8. Data originates from City Lab analyses.



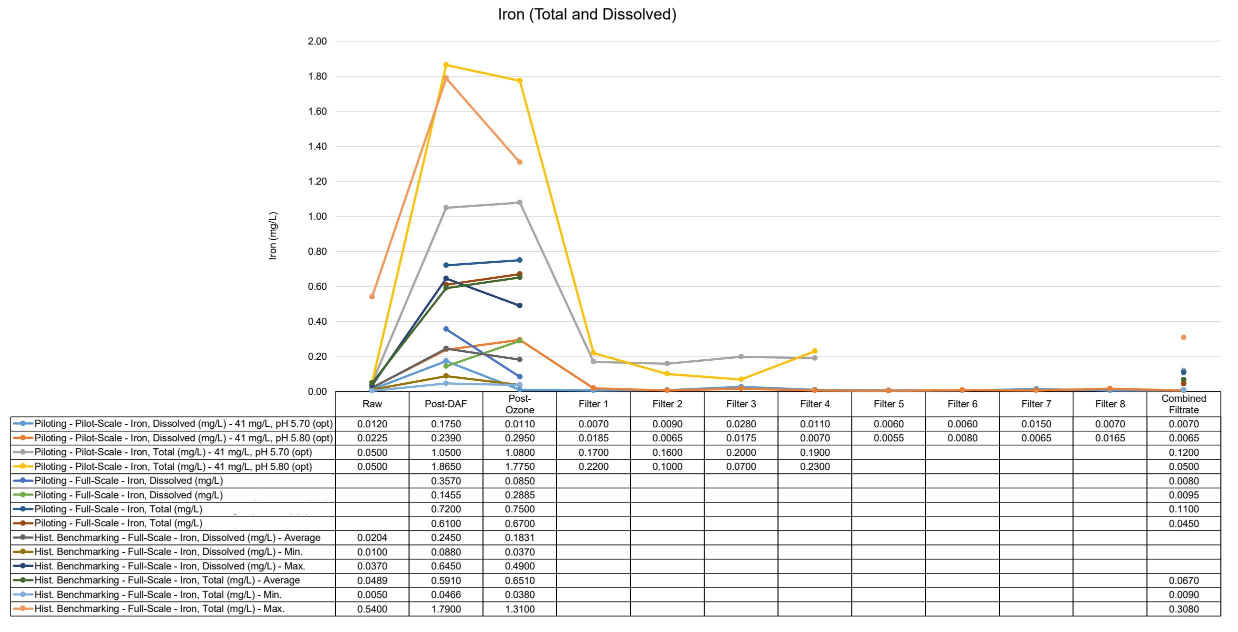
	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - Pilot-Scale - 41 mg/L, pH 5.70 (opt) - Laboratory	0.0007	0.0115	0.0060	0.0072	0.0094	0.0075	0.0074	0.0085	0.0086	0.0092	0.0082	0.0074
Piloting - Pilot-Scale - 41 mg/L, pH 5.80 (opt) - Laboratory	0.0035	0.0124	0.0078	0.0089	0.0099	0.0080	0.0079	0.0082	0.0083	0.0087	0.0079	0.0078
Piloting - Full-Scale		0.0437	0.0157									0.0267
Piloting - Full-Scale		0.0454	0.0288									0.0276
Hist. Benchmarking - Full-Scale - Average - Laboratory	0.0045	0.0451	0.0327									0.0318
Hist. Benchmarking - Full-Scale - Min. - Laboratory	0.0000	0.0288	0.0153									0.0156
Hist. Benchmarking - Full-Scale - Max. - Laboratory	0.0237	0.0973	0.0590									0.0476

Figure 5-11: Comparison of dissolved manganese levels between the average historical full-scale system, the full-scale system during the Winter #2 piloting session and the pilot-scale system during the Winter #2 piloting session operating at optimum ferric sulphate conditions: 41 mg/L ferric sulphate, pH 5.7 or 5.8. Data originates from City Lab analyses.

When comparing the total and dissolved manganese (Figure 5-10 and Figure 5-11) concentration in the Post-DAF and Post-Ozone samples for the full-scale and pilot-scale systems, the full-scale system samples (Winter #2 piloting session and historical data) are approximately 4-times higher than the manganese concentrations (total and dissolved) measured in the pilot-scale system Post-DAF and Post-Ozone samples during the Winter #2 piloting session. Combined filter effluent total manganese concentrations in the pilot-scale system were 0.0081 mg/L during optimization testing of ferric sulphate, which is approximately 4-times lower than filter effluent samples collected from the full-scale system and historical data, respectively. These results indicate that using ferric sulphate as an alternative coagulant to ferric chloride would have a significant positive impact on both total and dissolved manganese concentrations entering the distribution system.

→ Total and Dissolved Iron

The comparison for total and dissolved iron concentrations between the full-scale and pilot-scale systems is presented in Figure 5-12. Raw water total iron concentration during the Winter #2 piloting session was, on average, 0.0500 mg/L and the dissolved iron ranged from 0.0120 mg/L to 0.0225 mg/L, which are within typical iron concentrations reported in the historical data.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - Pilot-Scale - Iron, Dissolved (mg/L) - 41 mg/L, pH 5.70 (opt)	0.0120	0.1750	0.0110	0.0070	0.0090	0.0280	0.0110	0.0060	0.0060	0.0150	0.0070	0.0070
Piloting - Pilot-Scale - Iron, Dissolved (mg/L) - 41 mg/L, pH 5.80 (opt)	0.0225	0.2390	0.2950	0.0185	0.0065	0.0175	0.0070	0.0055	0.0080	0.0065	0.0165	0.0065
Piloting - Pilot-Scale - Iron, Total (mg/L) - 41 mg/L, pH 5.70 (opt)	0.0500	1.0500	1.0800	0.1700	0.1600	0.2000	0.1900					0.1200
Piloting - Pilot-Scale - Iron, Total (mg/L) - 41 mg/L, pH 5.80 (opt)	0.0500	1.8650	1.7750	0.2200	0.1000	0.0700	0.2300					0.0500
Piloting - Full-Scale - Iron, Dissolved (mg/L)		0.3570	0.0850									0.0080
Piloting - Full-Scale - Iron, Dissolved (mg/L)		0.1455	0.2885									0.0095
Piloting - Full-Scale - Iron, Total (mg/L)		0.7200	0.7500									0.1100
Piloting - Full-Scale - Iron, Total (mg/L)		0.6100	0.6700									0.0450
Hist. Benchmarking - Full-Scale - Iron, Dissolved (mg/L) - Average	0.0204	0.2450	0.1831									
Hist. Benchmarking - Full-Scale - Iron, Dissolved (mg/L) - Min.	0.0100	0.0880	0.0370									
Hist. Benchmarking - Full-Scale - Iron, Dissolved (mg/L) - Max.	0.0370	0.6450	0.4900									
Hist. Benchmarking - Full-Scale - Iron, Total (mg/L) - Average	0.0489	0.5910	0.6510									0.0670
Hist. Benchmarking - Full-Scale - Iron, Total (mg/L) - Min.	0.0050	0.0466	0.0380									0.0090
Hist. Benchmarking - Full-Scale - Iron, Total (mg/L) - Max.	0.5400	1.7900	1.3100									0.3080

Figure 5-12: Comparison of total and dissolved iron levels between the average historical full-scale system, the full-scale system during the Winter #2 piloting session and the pilot-scale system during the Winter #2 piloting session operating at optimum ferric sulphate conditions: 41 mg/L ferric sulphate, pH 5.7 or 5.8. Data originated from Lab analyses.

A significant increase in both total and dissolved iron was measured in the pilot-scale system Post-DAF samples, compared to Post-DAF samples collected from the full-scale system. The increased iron content can be attributed to the higher iron dose in ferric sulphate based on a mass equivalence (See TM No. 6 Section 5.7.1). Ozone did not significantly affect total or dissolved iron concentrations. There was a significant reduction in total and dissolved iron measured in the combined filter effluent collected from the pilot-scale system, for samples coagulated at pH 5.80.

Although there was higher total and dissolved iron in the pilot-scale system Post-DAF samples, compared to the full-scale system, the pilot-scale final combined filter effluent had lower total and dissolved iron showing the pilot-scale system filters were able to remove the additional iron. Both full-scale and pilot-scale systems are within range of the historical 5-year trend for iron concentrations.

→ Total and Dissolved Organic Carbon

Figure 5-13 presents the comparison for organic carbon removal (total and/or dissolved) by the pilot-scale system using the optimized conditions, the full-scale system and the full-scale historical trend. It should be noted that the results in Figure 5-13 for the Winter #2 piloting session (full-scale and pilot-scale systems) are measured as DOC, while historical trending data is reported as TOC. In most cases, TOC and DOC are not comparable as typical surface waters have DOC concentrations closer to 50% of the TOC concentration[2]. However, the City has found that the organic matter concentration in Shoal Lake

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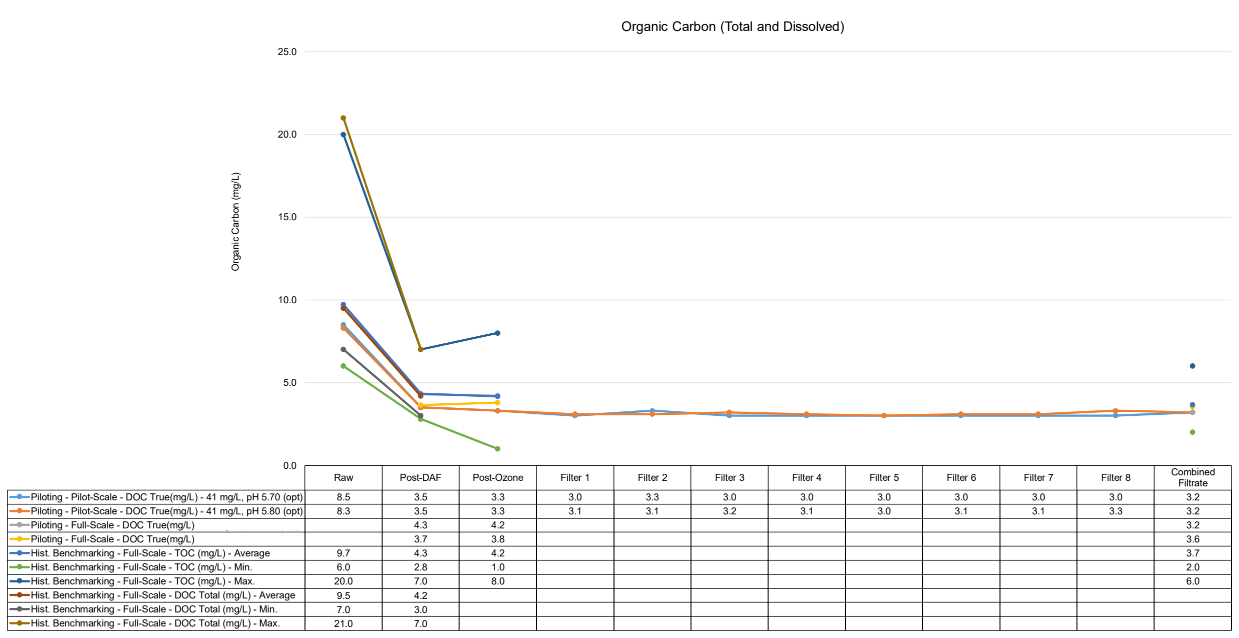
[2] Aiken, G. R., D. M. McKnight, et al. (1985). Humic Substances in Soil, Sediment, and Water. Geochemistry, Isolation, and Characterization. New York, John Wiley & Sons.

(raw water source) is dominated by DOC, and TOC and DOC are essentially equivalent[3]. Therefore, direct comparison between TOC and DOC data is acceptable in this case.



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - Pilot-Scale - DOC True(mg/L) - 41 mg/L, pH 5.70 (opt)	8.5	3.5	3.3	3.0	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.2
Piloting - Pilot-Scale - DOC True(mg/L) - 41 mg/L, pH 5.80 (opt)	8.3	3.5	3.3	3.1	3.1	3.2	3.1	3.0	3.1	3.1	3.3	3.2
Piloting - Full-Scale - DOC True(mg/L)		4.3	4.2									3.2
Piloting - Full-Scale - DOC True(mg/L)		3.7	3.8									3.6
Hist. Benchmarking - Full-Scale - TOC (mg/L) - Average	9.7	4.3	4.2									3.7
Hist. Benchmarking - Full-Scale - TOC (mg/L) - Min.	6.0	2.8	1.0									2.0
Hist. Benchmarking - Full-Scale - TOC (mg/L) - Max.	20.0	7.0	8.0									6.0
Hist. Benchmarking - Full-Scale - DOC Total (mg/L) - Average	9.5	4.2										
Hist. Benchmarking - Full-Scale - DOC Total (mg/L) - Min.	7.0	3.0										
Hist. Benchmarking - Full-Scale - DOC Total (mg/L) - Max.	21.0	7.0										

Figure 5-13: Comparison of DOC levels between the average historical full-scale system, the full-scale system during the Winter #2 piloting session and the pilot-scale system during the Winter #2 piloting session operating at optimum ferric sulphate conditions: 41 mg/L ferric sulphate, pH 5.7 or 5.8. Note: Historical Benchmarking is reported as TOC. Data originates from City Lab analyses.

The raw water DOC concentration in Figure 5-13 range between 8.3 and 8.5 mg/L during the optimized testing of ferric sulphate which is within the range for historical benchmarking. The pilot-scale system had similar DOC removal compared to both the full-scale system and the average removal in the historical benchmarking. Individual filter effluent DOC or TOC are not available for the full-scale system, or historical benchmarking; however, combined filter effluent DOC concentration was lower in the pilot-scale system samples, compared to full-scale system or historical benchmarking.

The results suggest that ferric sulphate under optimized conditions will have comparable reductions in DOC as ferric chloride.

- → True Colour

Figure 5-14 compares the removal of colour causing compounds (reported as True Colour) by the full-scale and pilot-scale systems. The raw water true colour measured during the Winter #2 piloting session exceeded the historical maximum by 50%. Both the full-scale and pilot-scale DAF systems significantly reduced the raw water true colour by 73-83%, which was further reduced by an additional 25-75% following ozonation. Although raw water true colour exceeded historical maximums during the Winter #2 piloting session; both the full-scale and pilot-scale system combined filter effluent was within historical true colour removal trends.

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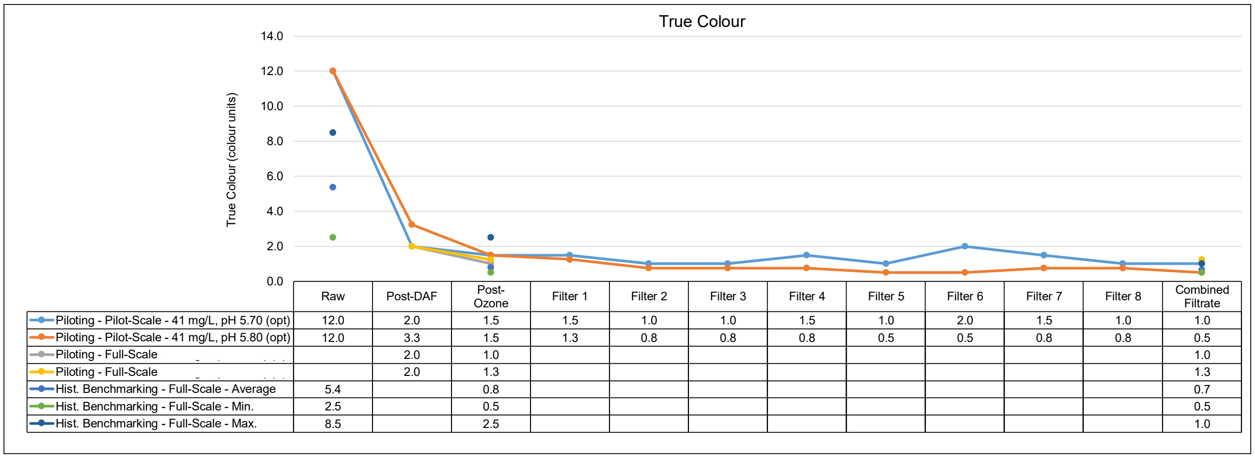
[3] Personal communication: Heather Buhler and Courtney Diduck, January 18th, 2017



	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
Piloting - Pilot-Scale - 41 mg/L, pH 5.70 (opt)	12.0	2.0	1.5	1.5	1.0	1.0	1.5	1.0	2.0	1.5	1.0	1.0
Piloting - Pilot-Scale - 41 mg/L, pH 5.80 (opt)	12.0	3.3	1.5	1.3	0.8	0.8	0.8	0.5	0.5	0.8	0.8	0.5
Piloting - Full-Scale		2.0	1.0									1.0
Piloting - Full-Scale		2.0	1.3									1.3
Hist. Benchmarking - Full-Scale - Average	5.4		0.8									0.7
Hist. Benchmarking - Full-Scale - Min.	2.5		0.5									0.5
Hist. Benchmarking - Full-Scale - Max.	8.5		2.5									1.0

Figure 5-14: Comparison of true colour levels between the average historical full-scale system, the full-scale system during the Winter #2 piloting session and the pilot-scale system during the Winter #2 piloting session operating at optimum ferric sulphate conditions: 41 mg/L ferric sulphate, pH 5.7 or 5.8.

→ UFRV

The pilot-scale system UFRV was 204 m^3/m^2 and 394 m^3/m^2 for Bank A and Bank B, respectively, during the optimal conditions of the Winter #2 piloting session when considering cycles that turbidity levels were below 0.1 NTU (Appendix A). These results are less than the historical average of the full-scale system UFRV value of 495 m^3/m^2. However, given the UFRV values at the full-scale system are expected to be twice as high due to the higher head loss available for filtration, and that filter recovery is not anticipated to be an issue, ferric sulphate is anticipated to be a viable coagulant for full-scale system operation under cold water conditions.

5.6.2 Disinfection By-Product Formation Potential

The disinfection by-product formation potential (DBPFP) test was conducted to determine the extent at which trihalomethanes (THM) and haloacetic acids (HAA) form following disinfection of finished (filter effluent) water using sodium hypochlorite. Samples were collected from the raw water intake located in the pilot-scale system, as well as the full-scale and pilot-scale system combined filter effluents on December 6th, 2017.

The chemical doses (coagulant and pH) used for DBPFP are outlined in Table 5-4. Samples from each location were prepared onsite by WSP personnel for both THM formation potential (THMFP) and HAA formation potential (HAAFP) tests using the protocol outlined in TM No. 4. The temperature for the 7-day reaction period was maintained at approximately 4°C to mimic cold-water conditions. The DBPFP results are presented in Table 5-4 and Table 5-5.

Table 5-4: THMFP results for December 6th, 2017.

Location	BDCM (µg/L)	CHBr3 (µg/L)	CHCl3 (µg/L)	DBCM (µg/L)	Total THM (µg/L)
Raw	2.4	<0.2	52.2	<0.4	55
Combined (Full)	1.8	<0.2	17.2	<0.4	19
Combined (Pilot)	1.5	<0.2	18	<0.4	20

Table 5-5: HAAFP results for December 6th, 2017.

Location	BCAA (µg/L)	DBAA (µg/L)	DCAA (µg/L)	MBAA (µg/L)	MCAA (µg/L)	TCAA (µg/L)	Total HAA (µg/L)
Raw	1.8	<0.3	17	0.9	1.4	19.3	40
Combined (Full)	1.8	<0.3	5.8	1.1	1.7	7.4	18
Combined (Pilot)	1.7	2.6	6.2	1.2	1.6	8.7	22

The results indicate that the raw water generally has a low DBPFP, as the total THMs and HAAs formed are below provincial standards. The full-scale system, using ferric chloride as a coagulant, reduced THMFP and HAAFP by 65% and 53%, respectively. Similar reduction in THMFP and HAAFP was measured in the pilot-scale system combined filter effluent, using ferric sulphate, with reductions in THMFP and HAAFP of 64% and 45%, respectively.

Overall, both ferric chloride and ferric sulphate reduce the formation of THM and HAA, and final concentrations are well below provincial standards.

5.6.3 Corrosive Indices

The degree of corrosion is typically determined primarily by the characteristics of various metals and water quality parameters, i.e. alkalinity. Previous Technical Memos have highlighted some factors that can influence the corrosivity of drinking water.

Table 5-6 tabulates the corrosive indices observed in the raw water and combined filtrate for both pilot-scale and full-scale systems during the key sampling dates of the Winter #2 piloting session. The indices are calculated from laboratory results of samples taken the same day from the full-scale system post filtration and prior to pH adjustment with sodium hydroxide and the pilot-scale system post-filtration operating under optimal conditions. A comparison between the full-scale system and the pilot-scale system is made under the provision that samples taken from their respective sources on the same day share identical raw water quality. Furthermore, as these indices are of a strict predicative nature (the development of a general index is inherently difficult due to the multiple roles of chemical species in potable water), and do not necessarily correlate between theoretical and actual conditions, only a relative comparison is made.

Table 5-6: Corrosive Indices in the Raw Water and Combined Filtrate for the pilot-scale and full-scale systems.

TEST CONDITION	CSMR[1]	LSI[2]	RSI[3]	ALKALINITY (mg/L as $CaCO_3$)[4]
Best coagulant dose (41 mg/L), at pH of 5.70 (November 27th)				
Raw	No chloride or sulphate analyzed	-0.65	9.06	77.00
Pilot-Scale Combined Filtrate		-3.53	12.86	9.00
Full-Scale Combined Filtrate		-3.41	12.61	13.00
Best coagulant dose (41 mg/L), at best pH of 5.8 (December 6th)				
Raw	Sulphate not detected by lab	-0.43	8.83	74.00
Pilot-Scale Combined Filtrate	0.03	-3.35	12.62	10.00
Full-Scale Combined Filtrate	0.49	-3.51	12.78	11.00
Best coagulant dose (41 mg/L), at best pH of 5.8 (December 7th)				
Raw	No chloride or sulphate analyzed	-0.45	8.87	76.00
Pilot-Scale Combined Filtrate		-3.24	12.38	14.00
Full-Scale Combined Filtrate		-3.46	12.68	12.00

[1] Greater than 0.5 indicates a tendency to increase galvanic corrosion of lead solder connected to copper pipes.

[2] At 0, water is under saturated with respect to calcium carbonate. Tendency will be to remove existing calcium carbonate protective coatings.

[3] Values > 8.5, water is very aggressive towards corrosion.

[4] Reported as mg/L $CaCO_3$, very low values << 100 are corrosive & values > 200 result in possible scaling

On November 27th, operating the pilot-scale system at a ferric sulphate dose of 41 mg/L and the DAF operating at a pH of approximately 5.7, the LSI and RSI indices both suggest similar corrosive tendencies at the full-scale and pilot-scale systems. These indices suggest that the water is likely to dissolve calcium carbonite coatings within the distribution network, an attribute likely exacerbated by the observed low alkalinity concentrations of the combined filtrate.

Maintaining the same coagulant dose and increasing the pH to 5.8 appears to slightly improve both LSI and RSI indices. Specifically, on December 6th and 7th (acting as duplicate trials), the LSI is increased, and the RSI is decreased. This observed adjustment to these indices suggest a minor reduction in corrosive tendencies with an increase in pH.

With a laboratory detection limit of less than 2 mg/L for sulphate and a chloride concentration of 2.7 mg/L, the raw water CSMR value is expected to exceed 0.5 and contribute to the galvanic corrosion of lead solder connected to copper pipes. Similar data for the pilot-scale and full-scale system filtrate from December 6th suggests that the pilot-scale system is, theoretically, not expected to increase galvanic corrosion rates, whereas, the full-scale system is considerably close to the CSMR index midpoint of 0.5, suggesting galvanic corrosion remains conceivable.

These results support the continued need to increase alkalinity post-filtration, as performed in the full-scale system.

6 CONCLUSIONS AND RECOMMENDATIONS

From the results presented above, the following may be concluded:

- Cold water conditions were maintained during all of the testing as the raw water temperature was below 4°C for the entirety of the transition, the majority of the Winter #2 piloting session (except for November 17th, 19th, and 20th recorded at the pilot-scale system), and the Winter #2 benchmarking period.

- The Winter #2 transition period was carried out by the City from November 9th to November 16th, 2017. The intention of this period was to monitor the operation and stability of the pilot-scale DAF system following maintenance to address the formation of discoloured water. The City tested a range of coagulant doses at varying pH and reported the DAF system was responding as expected, and appeared to have returned to normal, stable operation. The City did not observe discoloured water in the pilot-scale system during the Winter #2 transition period.

- A noted improvement to pilot-scale system DAF operation during the Winter #2 transition period occurred when the raw water flow was reduced from 3.0 L/s to between 2.52 and 2.70 L/s. The City indicated that the longer retention time at lower flow rates improved DAF effluent water quality.

- WSP operated the pilot-scale system from November 17th to December 7th, 2017 (inclusive), without coagulant-aid. Bank A operated at an average flow of 0.6 L/s, and Bank B operated at an average flow of 0.3 L/s, and within each bank, there was minimal variability in the differential pressures among the filters in the same bank.

- Bank B had an average filter run time of approximately 75% longer than that of the average of filter run time for Bank A. As such, the UFRV values for Bank A and Bank B were also relatively similar. In comparing the daily averages, it was observed that there was a decrease in Bank A performance, in particular after November 27th (this day operated with a coagulant dose of 41 mg/L and at pH 5.7).

- An optimal dose for the ferric sulfate coagulant was evaluated in the pilot-scale system from November 17th to November 26th, 2017 and under a fixed target pH of 5.70. The optimal dose was found to be 41 mg/L, based on turbidity, UVT and absorbance results. The optimal coagulant dose was then repeated on November 27th, 2017.

- The UVT, absorbance, and total manganese concentration indicated the optimal pH was 5.80 for ferric sulphate in cold water conditions. However, based on filter performance the optimum pH was 6.00. It should be noted that the difference in water quality measured between pH 5.70 and 5.80 during optimal testing was minimal and indicates that a wider operational pH can be used while still meeting water quality objectives, provided the optimal coagulant dose is applied.

- There have been noted differences in the filter effluent water quality produced by the pilot-scale system filter Bank A and Bank B during the entirety of the project to date. On December 5th, each individual filter flow (Filters 1-8) were adjusted to operate at either high or low flow rates in an attempt to establish differentiating reasons. The individual filter performance testing was successful in providing some insight regarding the differences observed in individual filter effluent quality. It is presumed that multiple variables are contributing to this observation, including flow rate, pipe length, pipe orientation, relative location of the filter-aid injection, and possible inconsistencies in the delivery rate of filter-aid to each bank.

- The optimized condition results demonstrate both pH values of 5.7 and 5.8 are deemed satisfactory. The data shows higher turbidity removal, lower UVT and higher UV_{254nm} absorbance levels at pH of 5.7. On the other hand, the data shows lower true colour levels at pH of 5.8, but similar levels of total manganese, dissolved iron and DOC at these two pH values. The UFRV analysis performed following the Winter #2 piloting session indicated that better filter performance was achieved with pH of 5.8 than with pH of 5.7.

- When comparing the Winter #2 piloting session results during optimum condition testing to the full-scale system historical average dataset using ferric chloride, the pilot-scale system filter effluent with ferric sulphate yielded turbidity, iron (total and dissolved), DOC, and true colour results within the values associated with the historical trends.

- Reductions in THMFP (65%) and HAAFP (53%) were comparable the pilot-scale system when compared to the full-scale system removals of THMFP (64%) and HAAFP (45%). The THM and HAA concentrations were well below provincial standards indicating that THMs or HAAs would not be of significant concern when using ferric sulphate.

- For the Winter #2 piloting session, the CSMR corrosive indices suggest that the quality of the treated water is not expected to increase galvanic corrosion. Although the LSI and RSI of the pilot-scale system were slightly better, the difference is considered marginal and there is a likelihood that the treated water may dissolve calcium carbonite coatings in the distribution system.

- During the Winter #2 benchmarking period, the full-scale and pilot-scale systems demonstrated strong similarities, aside from minor differences noted with regards to the pilot-scale system Post-DAF turbidity and the total manganese concentration. These results suggest the pilot-scale system can closely match the full-scale system when operated in the same manner.

- Ferric sulphate was hard transitioned to ferric chloride during the Winter #2 benchmarking period, without cleaning or flushing of the pilot-scale system. The hard transition did not appear to interrupt the pilot-scale system's operation. Considering that cleaning the full-scale system prior to a transition from ferric chloride to ferric sulphate would not be possible; the results indicate that the full-scale system should be able to transition between the two coagulants without major interruption to the system. However, the hard transition in the pilot-scale system was only operated for a short period following the change in coagulant and therefore it is recommended that additional testing be conducted to evaluate the long-term impacts to the major components of the system (i.e. DAF, ozone, and filters) following a hard transition to ferric sulphate.

Recommendations regarding the future piloting sessions are as follow:

- → Due to low temperature kinetics, exploring DAF operation at relatively slower raw water flows during the cold-water season is warranted to potentially improve operation.
- → Maintain the reversed flow configuration of the filter banks to offset potential performance shortcomings arising from the mechanical differences between the pilot-scale system filter banks during the piloting sessions. It should be noted there was limited difference between Bank A and Bank B during the Winter #2 benchmarking period when both filter banks were running at same the flow rate.
- → Investigate individual filter performance by testing additional individual filter flows. For example, operating Filters 1, 2, 5 and 6 at the lower flow rate of 0.075 L/s and Filter 3, 4, 7 and 8 at the higher flow rate of 0.15 L/s. Also, test the filter performance without filter-aid, in order to abstract the chemical influence, focusing on the mechanical differences.
- → Maintain sampling of both full-scale and pilot-scale systems on the same day for laboratory testing, to allow a valid comparison of coagulants between the two systems under the same raw water conditions.
- → Verify the calibration of filter-aid pumps periodically and before each piloting sessions (as performed) to confirm polymer dosage accuracy and their influence on the filters performance. Furthermore, since the pumps operate at the low end of their range, dilution of the filter-aid supply would allow the pumps to operate in a more ideal range.

Piloting Results Database Summary

Season: Winter #2
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
December 12, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.045	0.0448	0.0143	0.0145	0.015	0.0156	0.0147	0.0154	0.015	0.0161		
				Avg. of filters 1 to 8												0.01508	
		pH	Lab			5.95	5.96	6.17	6.1	6.07	6.02	6	6.06	6.42	6.16		
				Avg. of filters 1 to 8												6.125	
		TOC, Total (mg/L)	Lab			4.6	4.1	3	2.9	3	2.9						
				Avg. of filters 1 to 8												2.95	
		Turbidity (NTU)	Lab			1.45	1.69	0.09	0.07	0.07	0.06	0.07	0.07	0.08	0.07		
				Avg. of filters 1 to 8												0.0725	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0084	0.047	0.0476	0.03		0.0309	0.03	0.0304	0.0305		0.0313		0.0309
				O/L					G/N					G/N			
		pH	Lab		7.92	5.88	5.86	5.9		6.04	6.16	5.9	5.83		5.73		5.92
				O/L					G/N								
		TOC, Total (mg/L)	Lab		7.8	3.5	3.5	3.2		3	3.1						3.1
		Turbidity (NTU)	Lab		0.73	0.68	0.86	0.12		0.11	0.11	0.09	0.13		0.09		0.14
				O/L					G/N					G/N			
December 13, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab	Avg. of filters 1 to 8												0	
				System Offline		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		
		pH	Lab	Avg. of filters 1 to 8												0	
				Offline		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		
		TOC, Total (mg/L)	Lab	Avg. of filters 1 to 8												0	
		Turbidity (NTU)	Lab	Avg. of filters 1 to 8												0	
				Offline		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		
	Full-Scale	Manganese, Total (mg/L)	Lab	System Offline	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		pH	Lab	Offline	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
		Turbidity (NTU)	Lab	Offline	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N
December 14, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0458	0.0442	0.0148	0.0149	0.0149	0.0151	0.0153	0.0155	0.0156	0.0161		
				Avg. of filters 1 to 8												0.01528	
		pH	Lab			5.74	5.75	5.96	5.9	5.86	5.87	5.9	5.92	6.15	5.99		
				Avg. of filters 1 to 8												5.94375	
		TOC, Total (mg/L)	Lab			3.4	3.5	2.3	2.4	2.4	2.4						
				Avg. of filters 1 to 8												2.375	
		Turbidity (NTU)	Lab			1.44	1.54	0.08	0.06	0.06	0.07	0.06	0.06	0.06	0.06		
				Avg. of filters 1 to 8												0.06375	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0091	0.0459	0.0468	0.0281	0.0281		0.0272	0.0291	0.0289		0.0297		0.0291
				O/L						G/N				G/N			
		pH	Lab		8.03	5.81	5.7	5.91	5.98		5.8	5.64	5.63		5.74		5.66
				O/L						G/N				G/N			
		TOC, Total (mg/L)	Lab		7.6	3.1	2.9	2.7	2.6		2.6						2.5
		Turbidity (NTU)	Lab		0.73	0.91	1.08	0.08	0.1		0.08	0.06	0.09		0.07		0.11
				O/L						G/N				G/N			
December 15, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0471	0.0476	0.0151	0.0152	0.0144	0.0149	0.015	0.0149	0.0153	0.0154		
				Avg. of filters 1 to 8												0.01503	
		pH	Lab			5.99	5.98	5.99	6	5.99	6	6.01	6.05	6.14	6.04		
				Avg. of filters 1 to 8												6.0275	
		TOC, Total (mg/L)	Lab			3.4	3.4					2.7		2.7	2.8		
				Avg. of filters 1 to 8												2.73333	
		Turbidity (NTU)	Lab			1.04	1.1	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.07		
				Avg. of filters 1 to 8												0.065	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.007	0.0407	0.0483		0.0249	0.0227	0.0229	0.026		0.0252	0.0273		0.0271
				O/L				G/N					G/N				
		pH	Lab		7.84	5.97	6.07		5.92	5.9	5.82	5.84		5.92	5.85		5.8
				O/L				G/N					G/N				
		TOC, Total (mg/L)	Lab		8	3.5	3.2					2.7		2.9	2.8		2.7
		Turbidity (NTU)	Lab		0.76	0.86	1.06		0.07	0.08	0.12	0.08		0.08	0.09		0.11
				O/L				G/N					G/N				
December 16, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab	Avg. of filters 1 to 8												0	
				O/L		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		
		pH	Lab	Avg. of filters 1 to 8												0	
				O/L		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		
		TOC, Total (mg/L)	Lab	Avg. of filters 1 to 8												0	
		Turbidity (NTU)	Lab	Avg. of filters 1 to 8												0	
				O/L		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N		
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0069	0.0464	0.0479	0.0269	0.0257	0.0248	0.0278		0.0301	0.0277			0.0299
				O/L								G/N			G/N		
		pH	Lab		7.88	5.68	5.71	5.74	5.75	5.73	5.67		5.67	5.63			5.7
				O/L								G/N			G/N		
		TOC, Total (mg/L)	Lab		7.7	3.2	3.1	2.7	2.7	2.8	2.7						2.7

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
December 16, 2017	Full-Scale	Turbidity (NTU)	Lab		0.79	0.72	0.95	0.07	0.07	0.1	0.07		0.07	0.08			0.15
				O/L								G/N			G/N		
December 17, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0461	0.0467	0.0271	0.0273	0.0276	0.0283	0.032	0.0303	0.0265	0.0317		
				Avg. of filters 1 to 8												0.02885	
		pH	Lab			5.86	5.82	6.21	6.14	6.13	6.03	6.09	6.13	6.1	6.08		
				Avg. of filters 1 to 8												6.11375	
		TOC, Total (mg/L)	Lab			3.6	3.6					2.7	2.7	2.7	2.7		
				Avg. of filters 1 to 8												2.7	
		Turbidity (NTU)	Lab			1.36	1.42	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.08		
				Avg. of filters 1 to 8												0.065	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0082	0.0434	0.0443	0.0238		0.0267	0.0246	0.026	0.0266	0.028	0.0283		0.0254
				O/L					G/N								
		pH	Lab		7.88	5.86	5.82	5.71		5.84	5.72	5.56	5.62	5.7	5.79		5.93
				O/L					G/N								
		TOC, Total (mg/L)	Lab		7.7	3.2	3.1					2.8	2.6	2.8	2.6		2.7
		Turbidity (NTU)	Lab		0.74	0.87	1.08	0.09		0.07	0.09	0.07	0.13	0.09	0.07		0.11
				O/L					G/N								
December 18, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.046	0.0487	0.0426	0.039	0.0383	0.041	0.0414	0.0421	0.0426	0.0418		
				Avg. of filters 1 to 8												0.0411	
		pH	Lab			5.8	5.81	6.12	6.07	6.07	6.05	6.12	6.08	6.05	6.18		
				Avg. of filters 1 to 8												6.0925	
		TOC, Total (mg/L)	Lab			4.7	4.5	3.1	2.8	2.7	2.7						
				Avg. of filters 1 to 8												2.825	
		Turbidity (NTU)	Lab			2.43	2.5	0.5	0.14		0.06	0.07	0.06	0.07	0.06		
				Avg. of filters 1 to 8												0.13714	
				O/L						G/N							
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0092	0.0503	0.0466		0.0256	0.0245		0.024	0.0272	0.0262	0.0258		0.0278
				O/L				G/N			G/N						
		pH	Lab		8.06	5.76	5.79		5.78	5.77		5.76	5.7	5.7	5.69		5.78
				O/L				G/N			G/N						
		TOC, Total (mg/L)	Lab		8.7	3.7	3.7		2.8	2.8							3.1
		Turbidity (NTU)	Lab		0.76	0.94	1.18		0.09	0.11		0.14	0.1	0.12	0.11		0.11
				O/L				G/N			G/N						
December 19, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0424	0.0408	0.0411	0.0411	0.0435	0.0438	0.0424	0.0437	0.0425	0.0437		
				Avg. of filters 1 to 8												0.04273	
		pH	Lab			5.9	6	6.03	6.06	6.11	5.96	6.03	6.15	5.98	6		
				Avg. of filters 1 to 8												6.04	
		TOC, Total (mg/L)	Lab			4.1	4					2.8	2.7	2.8	2.7		
				Avg. of filters 1 to 8												2.75	
		Turbidity (NTU)	Lab			2.16	2.09	0.3	0.19	0.19	0.28	0.07	0.07	0.1	0.1		
				Avg. of filters 1 to 8												0.1625	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0083	0.039	0.039	0.0245	0.0248	0.0272	0.0244	0.0256	0.0257	0.0242			0.0265
				O/L											G/N		
		pH	Lab		7.89	5.85	5.76	5.83	5.79	5.82	5.76	5.62	5.67	5.72			5.8
				O/L											G/N		
		TOC, Total (mg/L)	Lab		7.8	3.5	3.2					2.9	2.8	2.8			2.9
		Turbidity (NTU)	Lab		0.65	0.73	0.96	0.1	0.11	0.19	0.11	0.1	0.12	0.13			0.15
				O/L											G/N		
December 20, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0385	0.0379	0.0399	0.0388	0.04	0.0388	0.0368	0.0402	0.0382	0.0408		
				Avg. of filters 1 to 8												0.03919	
		pH	Lab			5.79	5.71	5.87	5.91	6.05	6.02	5.98	5.97	5.94	5.94		
				Avg. of filters 1 to 8												5.96	
		TOC, Total (mg/L)	Lab			3.7	3.8	3.2	3.2	3.1	3.1						
				Avg. of filters 1 to 8												3.15	
		Turbidity (NTU)	Lab			0.97	0.96	0.09	0.08	0.08	0.09	0.08	0.08	0.09	0.07		
				Avg. of filters 1 to 8												0.0825	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0112	0.0353	0.0336	0.0269		0.0272	0.0252	0.0247	0.0238		0.0231		0.0245
				O/L					G/N					G/N			
		pH	Lab		7.83	6.1	5.93	6.13		6.06	6.07	5.98	5.92		5.83		5.89
				O/L					G/N					G/N			
		TOC, Total (mg/L)	Lab		7.7	3.6	4.1	4.2		4.3	4.3						3.7
		Turbidity (NTU)	Lab		0.79	0.77	1.09	0.5		0.46	0.52	0.16	0.19		0.11		0.29
				O/L					G/N					G/N			
December 21, 2017	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0453	0.0446	0.0428	0.0428	0.0406	0.0425	0.0435	0.0432	0.0404	0.0407		
				Avg. of filters 1 to 8												0.04206	
		pH	Lab			5.99	5.97	6.03	6.09	6.07	6.12	6.04	6.05	6.14	5.98		
				Avg. of filters 1 to 8												6.065	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2

Phase: Benchmarking

					Sample Location												
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Filter Effluent Average**	**Combined Filtrate**
December 21, 2017	Pilot-Scale	TOC, Total (mg/L)	Lab			4.1	4.3					3.3	3.4	3.4	3.4		
				Avg. of filters 1 to 8												3.375	
		Turbidity (NTU)	Lab			0.89	0.9	0.07	0.07	0.07	0.08	0.08	0.07	0.07	0.07		
				Avg. of filters 1 to 8												0.0725	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0092	0.0407	0.0411		0.0258	0.0249	0.0236	0.0251	0.0265	0.0255	0.025		0.0244
				O/L				G/N									
		pH	Lab		7.98	5.89	5.87		5.97	5.93	5.86	5.87	5.86	5.75	5.78		5.86
				O/L				G/N									
		TOC, Total (mg/L)	Lab		9	4	3.6					3.5	3.6	3.5	3.5		3.3
		Turbidity (NTU)	Lab		0.65	0.53	0.8		0.1	0.12	0.16	0.11	0.11	0.11	0.11		0.13
				O/L				G/N									
January 2, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0475	0.0461	0.0453	0.0454	0.0434	0.045	0.0456	0.0448	0.0443	0.046		
				Avg. of filters 1 to 8												0.04498	
		pH	Lab			5.93	5.91	6.01	6.04	6.05	6	5.93	5.91	5.94	5.99		
				Avg. of filters 1 to 8												5.98375	
		TOC, Total (mg/L)	Lab			3.9	3.6	3.1	3.1	3.4	3.2						
				Avg. of filters 1 to 8												3.2	
		Turbidity (NTU)	Lab			0.86	0.87	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.07		
				Avg. of filters 1 to 8												0.0625	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0094	0.0409	0.0449	0.0253		0.0265	0.0248	0.025	0.0248		0.0241		0.0268
				O/L					G/N					G/N			
		pH	Lab		7.86	5.95	5.92	5.87		5.88	5.87	5.85	5.88		5.82		5.84
				O/L					G/N					G/N			
		TOC, Total (mg/L)	Lab		8.6	4.1	4.1	3.7		3.8	3.7						3.6
		Turbidity (NTU)	Lab		0.64	0.69	0.78	0.12		0.11	0.13	0.13	0.18		0.14		0.15
				O/L					G/N					G/N			
January 3, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0535	0.051	0.0509	0.0501	0.0498	0.0504	0.0515	0.0506	0.0505	0.0476		
				Avg. of filters 1 to 8												0.05018	
		pH	Lab			5.84	5.91	6.02	5.98	5.92	5.89	5.92	5.95	5.99	5.79		
				Avg. of filters 1 to 8												5.9325	
		TOC, Total (mg/L)	Lab			4.4	3.9					3.5	3.3	3.2	3.2		
				Avg. of filters 1 to 8												3.3	
		Turbidity (NTU)	Lab			1.03	1.11	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08		
				Avg. of filters 1 to 8												0.0725	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0095	0.0409	0.0416	0.0267	0.0271	0.0268		0.0254		0.0267	0.0255		0.0275
				O/L							G/N		G/N				
		pH	Lab		7.82	5.73	5.79	5.75	5.71	5.73		5.81		5.82	5.79		5.77
				O/L							G/N		G/N				
		TOC, Total (mg/L)	Lab		9.1	4.1	3.6					3.4		3.6	3.4		3.7
		Turbidity (NTU)	Lab		0.62	0.54	0.69	0.07	0.08	0.09		0.12		0.12	0.12		0.1
				O/L							G/N		G/N				
January 4, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0539	0.0542	0.0505	0.0519	0.0519	0.0542	0.0539	0.0576	0.0556	0.0494		
				Avg. of filters 1 to 8												0.05313	
		pH	Lab			5.75	5.67	5.72	5.76	5.81	5.74	5.81	5.8	5.85	5.79		
				Avg. of filters 1 to 8												5.785	
		TOC, Total (mg/L)	Lab			4.5	4.7	3.5	3.5	3.5	3.4						
				Avg. of filters 1 to 8												3.475	
		Turbidity (NTU)	Lab			1.59	1.66	0.07	0.05	0.06	0.06	0.06	0.06	0.06	0.06		
				Avg. of filters 1 to 8												0.06	
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0086	0.0495	0.0542	0.0448	0.0477		0.0486	0.0493	0.0474	0.0414			0.0467
				O/L						G/N					G/N		
		pH	Lab		7.8	5.75		5.83	5.77		5.77	5.73	5.75	5.72			5.69
				O/L			G/N			G/N					G/N		
		TOC, Total (mg/L)	Lab		9.2	3.5		3.6	3.3		3.6						3.8
		Turbidity (NTU)	Lab		0.62	0.57		0.07	0.07		0.07	0.09	0.08	0.08			0.09
				O/L			G/N			G/N					G/N		
January 5, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0528		0.0526	0.0522	0.0522	0.052	0.0506	0.0508	0.0519	0.0523		
				Avg. of filters 1 to 8												0.05183	
		pH	Lab			5.81		5.86	5.95	5.95	5.83	5.83	5.84	5.88	5.85		
				Avg. of filters 1 to 8												5.87375	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4.5						3.2	3.2	3.5	3.6		
				Avg. of filters 1 to 8												3.375	
		Turbidity (NTU)	Lab			1.44		0.59	0.2	0.2	0.23		0.05	0.05	0.05		
				Avg. of filters 1 to 8												0.19571	
				O/L			G/N					G/N					
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0077	0.0476		0.0435		0.0479	0.0469	0.0466	0.0444		0.0445		0.0483

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Benchmarking

					Sample Location												
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Filter Effluent Average**	**Combined Filtrate**
January 5, 2018	Full-Scale	Manganese, Total (mg/L)	Lab	O/L			G/N		G/N					G/N			
		pH	Lab		7.73	5.76		5.9		5.84	5.97	5.76	5.77		5.73		5.66
				O/L			G/N		G/N					G/N			
		TOC, Total (mg/L)	Lab		8.3	4.4						3.7	3.6		3.6		3.6
		Turbidity (NTU)	Lab		0.62	0.66		0.07		0.05	0.06	0.08	0.07		0.06		0.07
				O/L			G/N		G/N					G/N			
January 6, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0479		0.0507	0.0514	0.0514	0.0508	0.0512	0.0515	0.0523	0.0498		
				Avg. of filters 1 to 8												0.05114	
				O/L			G/N										
		pH	Lab			5.82		5.82	5.79	5.79	5.9	5.83	5.83	5.8	5.84		
				Avg. of filters 1 to 8												5.825	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4.3		3.3	3.5	3.5	3.3						
				Avg. of filters 1 to 8												3.4	
		Turbidity (NTU)	Lab			0.94		0.08	0.06	0.06	0.08	0.07	0.07	0.06	0.06		
				Avg. of filters 1 to 8												0.0675	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.007	0.0461		0.0595	0.0449	0.0484		0.0445		0.0459	0.0458		0.0451
				O/L			G/N				G/N		G/N				
		pH	Lab		7.84	5.78		5.84	5.84	5.84		5.85		5.81	5.88		5.87
				O/L			G/N				G/N		G/N				
		TOC, Total (mg/L)	Lab		9	4.4		4.3	3.5	3.6							3.7
		Turbidity (NTU)	Lab		0.58	0.58		0.45	0.07	0.19		0.13		0.18	0.1		0.09
				O/L			G/N				G/N		G/N				
January 7, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0534		0.0515	0.0525	0.0525	0.054	0.0541	0.055	0.051	0.0502		
				Avg. of filters 1 to 8												0.0526	
				O/L			G/N										
		pH	Lab			5.89		5.91	5.88	5.88	5.89	5.9	6	5.95	5.96		
				Avg. of filters 1 to 8												5.92125	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4.3						3.6	3.6	3.4	3.5		
				Avg. of filters 1 to 8												3.525	
		Turbidity (NTU)	Lab			0.87		0.08	0.06	0.06	0.07	0.06	0.06	0.08	0.07		
				Avg. of filters 1 to 8												0.0675	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0085	0.0508		0.0488	0.0469		0.0445	0.0444	0.0495	0.0487			0.0492
				O/L			G/N			G/N					G/N		
		pH	Lab		7.89	5.86		5.8	5.85		5.83	5.77	5.78	5.74			5.8
				O/L			G/N			G/N					G/N		
		TOC, Total (mg/L)	Lab		9.9	4.4						3.9	3.7	3.8			4
		Turbidity (NTU)	Lab		0.58	0.66		0.07	0.07		0.06	0.06	0.08	0.08			0.11
				O/L			G/N			G/N					G/N		
January 8, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0491		0.0519	0.0506	0.0506	0.0517	0.052	0.0511	0.0497	0.0502		
				Avg. of filters 1 to 8												0.05098	
				O/L			G/N										
		pH	Lab			5.72		5.71	5.81	5.81	5.74	5.82	5.82	5.81	5.85		
				Avg. of filters 1 to 8												5.79625	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4		3.3	3.3	3.3	3.4						
				Avg. of filters 1 to 8												3.325	
		Turbidity (NTU)	Lab			1.3		0.4	0.29	0.29	0.25	0.07	0.06	0.07	0.06		
				Avg. of filters 1 to 8												0.18625	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab			0.0479		0.0425		0.0452	0.0432	0.0439	0.045	0.0462	0.0434		0.0503
				O/L			G/N		G/N								
		pH	Lab		7.9	5.87		5.81		5.88	5.82	5.77	5.74	5.76	5.8		5.74
				O/L			G/N		G/N								
		TOC, Total (mg/L)	Lab		8.6	3.7		3.5		3.3	3.4						3.6
		Turbidity (NTU)	Lab		0.56	0.64		0.08		0.07	0.07	0.07	0.08	0.06	0.06		0.08
				O/L			G/N		G/N								
January 9, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0528		0.0539	0.0535	0.0535	0.0532	0.0517	0.0532	0.0545	0.0536		
				Avg. of filters 1 to 8												0.05339	
				O/L			G/N										
		pH	Lab			5.66		5.76	5.76	5.76	5.72	5.7	5.86	5.85	5.78		
				Avg. of filters 1 to 8												5.77375	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4						3.3	3.3	3.2	3.2		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Benchmarking

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
January 9, 2018	Pilot-Scale	TOC, Total (mg/L)	Lab	Avg. of filters 1 to 8												3.25	
		Turbidity (NTU)	Lab			0.9		0.11	0.1	0.1	0.09	0.08	0.06	0.06	0.06		
				Avg. of filters 1 to 8												0.0825	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0073	0.0495		0.048	0.0469	0.0484		0.0477		0.0483	0.0474		0.048
				O/L			G/N				G/N		G/N				
		pH	Lab		7.85	5.76		5.76	5.76	5.78		5.68		5.68	5.65		5.73
				O/L			G/N				G/N		G/N				
		TOC, Total (mg/L)	Lab		8.6	3.9						3.5		3.4	3.3		3.5
		Turbidity (NTU)	Lab		0.6	0.65		0.07	0.06	0.08		0.08		0.07	0.08		0.11
				O/L			G/N				G/N		G/N				
January 10, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0532		0.0528	0.0538	0.0538	0.0523	0.0536	0.0527	0.0539	0.053		
				Avg. of filters 1 to 8												0.05324	
				O/L			G/N										
		pH	Lab			5.68		5.76	5.8	5.8	5.79	5.77	5.76	5.76	5.86		
				Avg. of filters 1 to 8												5.7875	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			3.8		3.3	3.1	3.1	3.1						
				Avg. of filters 1 to 8												3.15	
		Turbidity (NTU)	Lab			0.9		0.1	0.14	0.14	0.18	0.07	0.05	0.06	0.06		
				Avg. of filters 1 to 8												0.1	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0071	0.0457		0.0479	0.0472		0.0484	0.0467	0.0467	0.0479			0.0481
				O/L			G/N			G/N					G/N		
		pH	Lab		7.81	5.77		5.82	5.78		5.86	5.76	5.78	5.76			5.81
				O/L			G/N			G/N					G/N		
		TOC, Total (mg/L)	Lab		8.6	3.8		3.5	3.5		3.9						3.3
		Turbidity (NTU)	Lab		0.58	0.63		0.07	0.07		0.08	0.07	0.07	0.09			0.09
				O/L			G/N			G/N					G/N		
January 11, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0526		0.0511	0.0524	0.0524	0.0521	0.0508	0.0509	0.0512	0.0522		
				Avg. of filters 1 to 8												0.05164	
				O/L			G/N										
		pH	Lab			5.89		5.85	5.92	5.92	5.87	5.78	5.85	5.85	5.77		
				Avg. of filters 1 to 8												5.85125	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4.1						2.9	3.3	3	3.5		
				Avg. of filters 1 to 8												3.175	
		Turbidity (NTU)	Lab			1.14		0.07	0.11	0.11	0.12	0.08	0.07	0.07	0.07		
				Avg. of filters 1 to 8												0.0875	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0068	0.0453		0.0455		0.0444	0.0442	0.0453	0.045		0.0437		0.0448
				O/L			G/N		G/N					G/N			
		pH	Lab		7.88	5.83		5.81		5.79	5.78	5.74	5.79		5.78		5.84
				O/L			G/N		G/N					G/N			
		TOC, Total (mg/L)	Lab		8.4	3.6						3.4	3.6		3.6		3.4
		Turbidity (NTU)	Lab		0.59	0.59		0.08		0.07	0.08	0.07	0.08		0.07		0.08
				O/L			G/N		G/N					G/N			
January 12, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0543		0.0564	0.0519	0.0519	0.0542	0.0544	0.0593	0.0534	0.0548		
				Avg. of filters 1 to 8												0.05454	
				O/L			G/N										
		pH	Lab			5.7		5.7	5.72	5.72	5.72	5.71	5.69	5.72	5.72		
				Avg. of filters 1 to 8												5.7125	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4.1		3.3	2.8	2.8	3						
				Avg. of filters 1 to 8												2.975	
		Turbidity (NTU)	Lab			2.25		0.2	0.14	0.14	0.16	0.08	0.07	0.08	0.18		
				Avg. of filters 1 to 8												0.13125	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0074	0.0424		0.0445	0.0434	0.044		0.0419		0.0424	0.043		0.0415
				O/L			G/N				G/N		G/N				
		pH	Lab		7.8	5.79		5.77	5.82	5.8		5.81		5.81	5.8		5.69
				O/L			G/N				G/N		G/N				
		TOC, Total (mg/L)	Lab		8.4	3.7		3.4	3.3	3.2							3.2
		Turbidity (NTU)	Lab		0.57	0.58		0.06	0.05	0.06		0.07		0.07	0.07		0.14
				O/L			G/N				G/N		G/N				
January 13, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0486		0.0527	0.0529	0.0529	0.0531	0.052	0.0519	0.0526	0.0524		
				Avg. of filters 1 to 8												0.05256	

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Benchmarking

Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
					Sample Location												
January 13, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab	O/L			G/N										
		pH	Lab			5.85		5.81	5.87	5.87	5.78	5.83	5.8	5.83	5.86		
				Avg. of filters 1 to 8												5.83125	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			3.9						3.2	3.3	3.2	3.3		
				Avg. of filters 1 to 8												3.25	
		Turbidity (NTU)	Lab			0.94		0.07	0.09	0.09	0.07	0.07	0.07	0.07	0.07		
				Avg. of filters 1 to 8												0.075	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0065	0.0399		0.0419	0.041	0.0421	0.0412		0.0412	0.0416	0.0432		0.0421
				O/L			G/N					G/N					
		pH	Lab		7.85	5.79		5.81	5.95	5.85	5.88		5.86	5.84	5.93		5.76
				O/L			G/N					G/N					
		TOC, Total (mg/L)	Lab		8.8	4							3.6	3.6	3.5		3.6
		Turbidity (NTU)	Lab		0.57	0.59		0.08	0.07	0.09	0.09		0.08	0.09	0.11		0.12
				O/L			G/N					G/N					
January 14, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0493		0.0483	0.0491	0.0491	0.0484	0.0483	0.0483	0.0485	0.0487		
				Avg. of filters 1 to 8												0.04859	
				O/L			G/N										
		pH	Lab			5.91		5.91	6.02	6.02	5.89	5.83	5.83	5.95	5.88		
				Avg. of filters 1 to 8												5.91625	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			3.7		3.2	3.2	3.3	3						
				Avg. of filters 1 to 8												3.175	
		Turbidity (NTU)	Lab			0.7		0.09	0.06	0.06	0.06	0.06	0.06	0.05	0.05		
				Avg. of filters 1 to 8												0.06125	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0073	0.0413		0.0412	0.0412		0.0412	0.041	0.0403		0.0403		0.0398
				O/L			G/N			G/N				G/N			
		pH	Lab		7.82	5.86		5.78	5.8		5.78	5.75	5.8		5.81		5.84
				O/L			G/N			G/N				G/N			
		TOC, Total (mg/L)	Lab		8.5	3.9		3.6	3.5		3.5						3.5
		Turbidity (NTU)	Lab		0.54	0.64		0.08	0.09		0.08	0.08	0.08		0.09		0.09
				O/L			G/N			G/N				G/N			
January 15, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0477		0.0483	0.0462	0.0462	0.0467	0.0467	0.0471	0.0466	0.0475		
				Avg. of filters 1 to 8												0.04691	
				O/L			G/N										
		pH	Lab			6.01		5.99	6.02	6.02	6.01	6.07	6.08	6.09	6.07		
				Avg. of filters 1 to 8												6.04375	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4.2						3.2	3.3	3.3	3.2		
				Avg. of filters 1 to 8												3.25	
		Turbidity (NTU)	Lab			1.31		1	0.31	0.31	0.37	0.09	0.07	0.07	0.07		
				Avg. of filters 1 to 8												0.28625	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0081	0.0435			0.0395	0.0398	0.0396	0.0401		0.0394	0.0389		0.0416
				O/L			G/N	G/N					G/N				
		pH	Lab		7.76	5.85			5.8	5.81	5.88	5.88		5.9	5.91		5.94
				O/L			G/N	G/N					G/N				
		TOC, Total (mg/L)	Lab		8.2	3.8						3.5		3.5	3.4		3.5
		Turbidity (NTU)	Lab		0.64	0.58			0.07	0.08	0.11	0.1		0.09	0.08		0.11
				O/L			G/N	G/N					G/N				
January 16, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0449		0.0461	0.0411	0.0438	0.0466	0.0411	0.046	0.0429	0.0441		
				Avg. of filters 1 to 8												0.04396	
				O/L			G/N										
		pH	Lab			5.72		5.76	5.81	5.81	5.77	5.73	5.81	5.79	5.78		
				Avg. of filters 1 to 8												5.7825	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			3.9		3.2	3.3	3.3	3.4						
				Avg. of filters 1 to 8												3.3	
		Turbidity (NTU)	Lab			1.03		0.08	0.07	0.07	0.08	0.07	0.07	0.07	0.07		
				Avg. of filters 1 to 8												0.0725	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.007	0.0459		0.0411	0.0408	0.0415	0.0411		0.041	0.0407			0.0403
				O/L			G/N					G/N			G/N		
		pH	Lab		7.71	5.82		5.71	5.73	5.7	5.71		5.7	5.71			5.73
				O/L			G/N					G/N			G/N		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Benchmarking

					Sample Location												
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter Effluent Average	Combined Filtrate
January 16, 2018	Full-Scale	TOC, Total (mg/L)	Lab		8.7	3.9		3.5	3.4	3.4	3.4						3.6
		Turbidity (NTU)	Lab		0.65	0.57		0.09	0.09	0.1	0.1		0.11	0.11			0.1
				O/L			G/N					G/N			G/N		
January 17, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.045		0.046	0.0443	0.0454	0.0452	0.0471	0.0464	0.047	0.0464		
				Avg. of filters 1 to 8												0.04598	
				O/L			G/N										
		pH	Lab			5.79		5.88	5.84	5.84	5.77	5.74	5.76	5.82	5.8		
				Avg. of filters 1 to 8												5.80625	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4						3.3	3.3	3.3	3.5		
				Avg. of filters 1 to 8												3.35	
		Turbidity (NTU)	Lab			0.83		0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06		
				Avg. of filters 1 to 8												0.06375	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0065	0.0381		0.0423		0.0402	0.0395	0.0397	0.0413		0.0396		0.0425
				O/L			G/N		G/N					G/N			
		pH	Lab		7.91	5.88		5.79		5.73	5.77	5.71	5.73		5.73		5.73
				O/L			G/N		G/N					G/N			
		TOC, Total (mg/L)	Lab		8.5	4.1						3.6	3.7		3.6		3.7
		Turbidity (NTU)	Lab		0.54	0.6		0.09		0.07	0.08	0.08	0.1		0.08		0.09
				O/L			G/N		G/N					G/N			
January 18, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0465		0.0462	0.0445	0.0456	0.0474	0.0461	0.0439	0.0467	0.0477		
				Avg. of filters 1 to 8												0.04601	
				O/L			G/N										
		pH	Lab			5.77		5.82	5.83	5.83	5.8	5.78	5.85	5.87	5.89		
				Avg. of filters 1 to 8												5.83375	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			4.7		3.8	3.8	3.8	3.8						
				Avg. of filters 1 to 8												3.8	
		Turbidity (NTU)	Lab			0.81		0.08	0.06	0.06	0.06	0.07	0.07	0.06	0.06		
				Avg. of filters 1 to 8												0.065	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0068	0.0379		0.0393	0.0394	0.0385		0.038		0.037	0.0385		0.0389
				O/L			G/N				G/N		G/N				
		pH	Lab		7.8	5.86		5.76	5.81	5.79		5.79		5.82	5.78		5.82
				O/L			G/N				G/N		G/N				
		TOC, Total (mg/L)	Lab		10	4.6		4.2	4.3	4.2							4.2
		Turbidity (NTU)	Lab		0.51	0.56		0.07	0.07	0.08		0.09		0.08	0.09		0.09
				O/L			G/N				G/N		G/N				
January 19, 2018	Pilot-Scale	Manganese, Total (mg/L)	Lab			0.0468		0.0462	0.047	0.0461	0.0491	0.0471	0.0449	0.0449	0.0456		
				Avg. of filters 1 to 8												0.04636	
				O/L			G/N										
		pH	Lab			5.78		5.81	5.78	5.78	5.7	5.77	5.78	5.85	5.82		
				Avg. of filters 1 to 8												5.78625	
				O/L			G/N										
		TOC, Total (mg/L)	Lab			3.7						3.2	3.2	3.3	3.3		
				Avg. of filters 1 to 8												3.25	
		Turbidity (NTU)	Lab			0.73		0.09	0.09	0.09	0.07	0.07	0.08	0.08	0.08		
				Avg. of filters 1 to 8												0.08125	
				O/L			G/N										
	Full-Scale	Manganese, Total (mg/L)	Lab		0.0063	0.0391		0.0396	0.039	0.0386	0.0395		0.038	0.0392			0.0383
				O/L			G/N					G/N			G/N		
		pH	Lab		7.74	5.78		5.77	5.88	5.83	5.81		5.87	5.85			5.84
				O/L			G/N					G/N			G/N		
		TOC, Total (mg/L)	Lab		8.4	3.9							3.6	3.6			3.7
		Turbidity (NTU)	Lab		0.63	0.61		0.07	0.1	0.12	0.11		0.09	0.12			0.15
				O/L			G/N					G/N			G/N		

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Benchmarking. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
November 17, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		153.6	191	176.7	184.4	185.6	182	183	185.1	188	185.5	186.6	189.4
		DO (mg/L)	Bench		11.9	12.7	12.8	12.3	11.8	11.5	11.5	11.6	11.8	11.4	11.8	12.7
		Manganese, Total (mg/L)	Bench		0.023	0.025	0.028	0.02	0.019	0.021	0.021	0.014	0.012	0.015	0.014	0.015
		Oxi-Red Potenital (ORP) (mV)	Bench		181.9	226.9	238.4	288.8	292.8	292	286.8	280.5	280.6	285.2	280.5	262.5
		pH	Bench		7.27	5.73	5.76	5.76	5.74	5.75	5.74	5.76	5.77	5.77	5.8	5.86
		Temperature (ºC)	Bench		4.2	5.9	4.9	5.7	5.7	5.7	5.8	5.9	5.9	5.8	5.9	5.2
		Turbidity (NTU)	Bench		0.88	0.95	1.13	0.99	1.06	0.89	1.02	0.18	0.16	0.11	0.15	0.35
		UVA @254nm, Unfiltered (/cm)	Bench		0.112	0.109	0.122	0.065	0.064	0.065	0.071	0.015	0.013	0.013	0.013	0.026
		UVT @ 254nm, Unfiltered (%T)	Bench		77.3	77.7	75.8	86.4	86.5	86.4	85	96.6	96.7	97	97.1	93.8
	Full-Scale	Conductivity Total (µS/cm)	Bench			194.5	192.4									202.6
		DO (mg/L)	Bench			13.4	14.2									13.8
		Manganese, Total (mg/L)	Bench			0.051	0.048									0.033
		Oxi-Red Potenital (ORP) (mV)	Bench			276.8	313.7									231.2
		pH	Bench			5.8	5.8									5.7
		Temperature (ºC)	Bench			3.2	3.3									3.3
		Turbidity (NTU)	Bench			0.58	0.67									0.19
		UVA @254nm, Unfiltered (/cm)	Bench			0.056	0.059									0.015
		UVT @ 254nm, Unfiltered (%T)	Bench			87.8	87.3									96.7
November 18, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		155.5	191.3	193.5	183.4	183.4	183.4	183.5	183	189.6	181.6	187.6	174.7
		DO (mg/L)	Bench		11.4	11.5	11.6	11.5	11.5	11.7	11.5	11.6	11.9	11.8	11.8	11.8
		Manganese, Total (mg/L)	Bench		0.02	0.024	0.025	0.02	0.019	0.018	0.019	0.018	0.019	0.016	0.015	0.019
		Oxi-Red Potenital (ORP) (mV)	Bench		174.8	224.1	229.2	292.5	290.2	287.6	288.6	284.2	279.4	278.2	281.3	259.7
		pH	Bench		7.34	5.7	5.73	5.73	5.72	5.71	5.7	5.69	5.68	5.67	5.66	5.71
		Temperature (ºC)	Bench		3.2	4.4	4.8	5.1	5.1	5.2	5.1	5.3	5.3	5.2	5.2	4.6
		Turbidity (NTU)	Bench		0.91	1.2	0.18	0.36	0.32	0.37	0.32	0.16	0.13	0.14	0.13	0.21
		UVA @254nm, Unfiltered (/cm)	Bench		0.126	0.115	0.121	0.044	0.043	0.042	0.044	0.031	0.035	0.029	0.029	0.034
		UVT @ 254nm, Unfiltered (%T)	Bench		74.7	76.7	75.7	90.4	90.5	90.8	90.4	93.2	92.4	93.4	93.5	92.4
	Full-Scale	Conductivity Total (µS/cm)	Bench			182.8	186.9									186.5
		DO (mg/L)	Bench			13.1	13.4									13
		Manganese, Total (mg/L)	Bench			0.055	0.048									0.034
		Oxi-Red Potenital (ORP) (mV)	Bench			264.6	293									292.7
		pH	Bench			5.58	5.6									5.35
		Temperature (ºC)	Bench			3.2	2.8									3.1
		Turbidity (NTU)	Bench			0.56	0.68									0.15
		UVA @254nm, Unfiltered (/cm)	Bench			0.066	0.069									0.019
		UVT @ 254nm, Unfiltered (%T)	Bench			86	85.4									95.8
November 19, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		178.2	187.6	187.8	188.1	188.3	187	188.6	187	190.5	189.4	190.3	190.4
		DO (mg/L)	Bench		12	12.2	11.9	12.1	11.6	11.7	11.6	11.8	11.7	11.8	11.8	12.2
		Manganese, Total (mg/L)	Bench		0.02	0.023	0.025	0.02	0.018	0.018	0.016	0.017	0.017	0.016	0.016	0.017
		Oxi-Red Potenital (ORP) (mV)	Bench		154	227.4	254	275.9	304.4	295.3	288.4	282.7	279	273.9	264.8	249.1
		pH	Bench		7.16	5.71	5.72	5.72	5.74	5.76	5.75	5.72	5.73	5.75	5.75	5.77
		Temperature (ºC)	Bench		4.2	4.2	5.2	5.4	5.4	5.5	5.5	5.7	5.8	5.8	5.7	4.9
		Turbidity (NTU)	Bench		0.94	0.91	0.92	0.24	0.19	0.23	0.19	0.1	0.12	0.1	0.11	0.2
		UVA @254nm, Unfiltered (/cm)	Bench		0.122	0.095	0.102	0.041	0.03	0.031	0.032	0.021	0.023	0.022	0.025	0.025
		UVT @ 254nm, Unfiltered (%T)	Bench		75.5	80.4	79.1	90.9	93.4	93.2	92.9	95.2	94.9	95	94.5	94.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			195.2	191.7									196.3
		DO (mg/L)	Bench			13.5	13.7									14.1
		Manganese, Total (mg/L)	Bench			0.054	0.048									0.033
		Oxi-Red Potenital (ORP) (mV)	Bench			255.6	258.1									248
		pH	Bench			5.73	5.78									5.69
		Temperature (ºC)	Bench			3.5	3.3									3.3
		Turbidity (NTU)	Bench			0.55	0.71									0.2
		UVA @254nm, Unfiltered (/cm)	Bench			0.061	0.065									0.015
		UVT @ 254nm, Unfiltered (%T)	Bench			86.8	86.1									96.5
November 20, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		153.1	188.3	185.7	185.4	182.9	187.2	196.4	187.6	188.2	182.6	187.8	184.9
		DO (mg/L)	Bench		11.5	12.1	11.8	11.9	11.6	11.8	11.7	11.6	11.7	11.8	11.9	12
		Manganese, Total (mg/L)	Bench		0.021	0.022	0.022	0.021	0.018	0.018	0.017	0.018	0.017	0.019	0.021	0.02
		Oxi-Red Potenital (ORP) (mV)	Bench		172.2	241.7	288.3	285.6	280.9	281.7	269	290.2	281	293.7	287.8	290.2
		pH	Bench		7.83	5.73	5.72	5.81	5.81	5.83	5.83	5.76	5.78	5.79	5.8	5.78
		Temperature (ºC)	Bench		4.2	3.7	4.5	4.9	4.9	5	5.1	5.4	5.4	5.5	5.4	5.3
		Turbidity (NTU)	Bench		0.95	0.92	1.01	0.29	0.24	0.26	0.22	0.13	0.12	0.16	0.15	0.22
		UVA @254nm, Unfiltered (/cm)	Bench		0.122	0.093	0.094	0.024	0.025	0.025	0.027	0.019	0.023	0.02	0.024	0.022
		UVT @ 254nm, Unfiltered (%T)	Bench		75.4	80.9	80.5	94.5	94.4	94.4	93.9	95.6	94.8	95.4	94.6	95
	Full-Scale	Conductivity Total (µS/cm)	Bench			190.1	194.7									191.5

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2

Phase: Piloting

					Sample Location										
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
November 20, 2017	Full-Scale	DO (mg/L)	Bench			12.7	13.4									13.6
		Manganese, Total (mg/L)	Bench			0.054	0.049									0.037
		Oxi-Red Potenital (ORP) (mV)	Bench			277	286.5									266.9
		pH	Bench			5.78	5.86									5.64
		Temperature (ºC)	Bench			4	3.4									3.4
		Turbidity (NTU)	Bench			0.52	0.69									0.22
		UVA @254nm, Unfiltered (/cm)	Bench			0.068	0.069									0.022
		UVT @ 254nm, Unfiltered (%T)	Bench			85.5	85.3									95
November 21, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		154.5	188.3	187.2	187.3	184.6	183.6	182.4	185.9	186	191.3	193.6	192.2
		DO (mg/L)	Bench		11.5	12.2	11.9	11.3	10.9	10.7	11.2	11.1	11.3	11.7	12.2	11.8
		Manganese, Total (mg/L)	Bench		0.023	0.023	0.028	0.025	0.024	0.021	0.021	0.016	0.016	0.018	0.02	0.02
		Oxi-Red Potenital (ORP) (mV)	Bench		217.8	259.5	268.9	381.4	382.4	379.4	379.8	374.8	371.9	364.1	353.6	345.9
		pH	Bench		7.86	5.71	5.69	5.8	5.81	5.79	5.82	5.79	5.82	5.82	5.85	5.81
		Temperature (ºC)	Bench		3.3	3.9	4.9	4.7	4.7	4.9	5.1	5.1	5.2	5.4	5.2	5.1
		Turbidity (NTU)	Bench		0.92	1.03	1.22	0.29	0.3	0.34	0.28	0.1	0.14	0.1	0.11	0.19
		UVA @254nm, Unfiltered (/cm)	Bench		0.128	0.123	0.133	0.041	0.04	0.043	0.041	0.026	0.026	0.027	0.029	0.036
		UVT @ 254nm, Unfiltered (%T)	Bench		74.5	75.3	73.6	91	91.2	90.5	91	94.3	94.1	94	93.5	92.2
	Full-Scale	Conductivity Total (µS/cm)	Bench			190.4	190.5									201.4
		DO (mg/L)	Bench			12.9	13.7									13.7
		Manganese, Total (mg/L)	Bench			0.049	0.049									0.043
		Oxi-Red Potenital (ORP) (mV)	Bench			343.6	371									355.4
		pH	Bench			5.75	5.83									5.71
		Temperature (ºC)	Bench			3.5	3.5									3.2
		Turbidity (NTU)	Bench			0.52	0.71									0.48
		UVA @254nm, Unfiltered (/cm)	Bench			0.069	0.069									0.025
		UVT @ 254nm, Unfiltered (%T)	Bench			85.4	85.3									94.3
November 22, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		155.2	187.1	184.4	187.1	186.6	186.8	184.5	186.1	184.6	186	186.6	191.3
		DO (mg/L)	Bench		11	12.2	11.7	11.6	11.9	11.8	11.7	11.6	11.5	11.6	11.5	11.8
		Manganese, Total (mg/L)	Bench		0.023	0.028	0.031	0.018	0.016	0.015	0.014	0.009	0.012	0.011	0.012	0.011
		Oxi-Red Potenital (ORP) (mV)	Bench		213.2	261.7	350	347	347.4	345.6	346.1	340	333.7	329.3	314.9	307.5
		pH	Bench		7.85	5.7	5.7	5.8	5.79	5.83	5.77	5.75	5.78	5.76	5.81	5.78
		Temperature (ºC)	Bench		3.5	3.7	4.2	5.4	5.4	5.4	5.5	5.7	5.8	5.7	5.8	5.3
		Turbidity (NTU)	Bench		0.87	0.94	1.23	0.33	0.28	0.26	0.3	0.09	0.09	0.08	0.11	0.28
		UVA @254nm, Unfiltered (/cm)	Bench		0.124	0.105	0.109	0.032	0.03	0.031	0.034	0.014	0.011	0.014	0.013	0.026
		UVT @ 254nm, Unfiltered (%T)	Bench		75.2	78.6	77.8	93	93.2	93.1	92.7	96.9	97.4	96.8	97	94.2
	Full-Scale	Conductivity Total (µS/cm)	Bench			193.6	192.2									185.4
		DO (mg/L)	Bench			12.3	12									11.9
		Manganese, Total (mg/L)	Bench			0.046	0.044									0.028
		Oxi-Red Potenital (ORP) (mV)	Bench			310.6	346									325.5
		pH	Bench			5.82	5.84									5.67
		Temperature (ºC)	Bench			3.3	3.5									3.4
		Turbidity (NTU)	Bench			0.54	0.71									0.16
		UVA @254nm, Unfiltered (/cm)	Bench			0.064	0.063									0.021
		UVT @ 254nm, Unfiltered (%T)	Bench			86.3	86.5									95.2
November 23, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		153.3	194.1	187.6	187.1	188	185.2	189.5	186.5	186.3	188.3	187.3	190.7
		DO (mg/L)	Bench		11.4	12.4	13	11.8	11.5	11.7	11.4	11.4	11.6	11.5	11.4	11.7
		Manganese, Total (mg/L)	Bench		0.021	0.026	0.028	0.018	0.019	0.019	0.02	0.017	0.017	0.016	0.017	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		217.8	251.9	319.1	314.2	310.8	314.5	311.1	308.3	297.4	293.8	286.8	279.9
		pH	Bench		7.9	5.69	5.68	5.8	5.76	5.81	5.78	5.77	5.78	5.77	5.8	5.8
		Temperature (ºC)	Bench		3.5	3.5	4	5.1	5.2	4.9	5	5.6	5.6	5.4	5.5	5.1
		Turbidity (NTU)	Bench		0.87	0.9	1.17	0.43	0.26	0.24	0.26	0.13	0.1	0.09	0.11	0.2
		UVA @254nm, Unfiltered (/cm)	Bench		0.129	0.102	0.106	0.031	0.031	0.029	0.034	0.02	0.02	0.02	0.021	0.025
		UVT @ 254nm, Unfiltered (%T)	Bench		74.2	79	78.4	93.2	93	93.4	92.4	95.4	95.5	95.5	95.2	94.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			193.2	193.5									183.7
		DO (mg/L)	Bench			13.3	13.2									14
		Manganese, Total (mg/L)	Bench			0.052	0.048									0.039
		Oxi-Red Potenital (ORP) (mV)	Bench			286.7	306.3									293.8
		pH	Bench			5.73	5.83									5.68
		Temperature (ºC)	Bench			3.5	3.3									3.5
		Turbidity (NTU)	Bench			0.54	0.65									0.14
		UVA @254nm, Unfiltered (/cm)	Bench			0.073	0.072									0.024
		UVT @ 254nm, Unfiltered (%T)	Bench			84.6	84.7									94.7
November 24, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		190.8	190.4	184.8	184	186.5	184.6	188.2	185.6	186.1	190.7	185.5	185
		DO (mg/L)	Bench		11.7	12.5	12.4	12.1	12	12.3	12.4	12.1	12.4	12.2	12.2	12.6

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
November 24, 2017	Pilot-Scale	Manganese, Total (mg/L)	Bench		0.024	0.024	0.027	0.021	0.022	0.02	0.019	0.016	0.014	0.016	0.016	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		153.4	223.9	344.8	335.8	338.5	340.8	336	338.2	321	319.4	306.6	291.2
		pH	Bench		7.91	5.71	5.72	5.77	5.8	5.77	5.79	5.73	5.76	5.77	5.78	5.76
		Temperature (ºC)	Bench		3.8	5.4	5	5.7	5.6	5.7	5.7	5.7	5.8	6	6.1	5.8
		Turbidity (NTU)	Bench		0.97	1.06	1.2	0.53	0.42	0.38	0.42	0.1	0.09	0.1	0.13	0.29
		UVA @254nm, Unfiltered (/cm)	Bench		0.127	0.107	0.144	0.042	0.042	0.041	0.038	0.02	0.019	0.024	0.023	0.035
		UVT @ 254nm, Unfiltered (%T)	Bench		74.6	78.2	76.9	90.7	90.8	91	91.7	95.6	95.8	94.7	94.8	92.3
	Full-Scale	Conductivity Total (µS/cm)	Bench			194.9	192.8									181.9
		DO (mg/L)	Bench			12.9	13.3									13.4
		Manganese, Total (mg/L)	Bench			0.053	0.053									0.043
		Oxi-Red Potenital (ORP) (mV)	Bench			291.8	320.8									313
		pH	Bench			5.8	5.9									5.71
		Temperature (ºC)	Bench			4.2	4									4.2
		Turbidity (NTU)	Bench			0.51	0.66									0.18
		UVA @254nm, Unfiltered (/cm)	Bench			0.072	0.074									0.011
		UVT @ 254nm, Unfiltered (%T)	Bench			84.7	84.3									97.4
November 25, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		152	186.3	179.7	184.5	186.2	185.6	190.6	185.4	186.8	189.7	191	188
		DO (mg/L)	Bench		12.1	12.2	11.8	12	11.9	11.9	12	12	11.9	12.2	12	11.5
		Manganese, Total (mg/L)	Bench		0.022	0.026	0.023	0.02	0.016	0.017	0.017	0.014	0.016	0.014	0.015	0.017
		Oxi-Red Potenital (ORP) (mV)	Bench		224.2	249.6	384.9	382.3	380.5	377.8	373.1	412.2	432.2	428.2	459.9	454.8
		pH	Bench		7.88	5.71	5.72	5.79	5.8	5.77	5.81	5.79	5.8	5.81	5.81	5.81
		Temperature (ºC)	Bench		3.6	3.6	4.7	5.2	5.2	5.5	5.5	5.7	5.6	5.8	5.9	5.4
		Turbidity (NTU)	Bench		0.85	1.01	1.31	0.65	0.37	0.38	0.4	0.11	0.12	0.11	0.14	0.28
		UVA @254nm, Unfiltered (/cm)	Bench		0.123	0.117	0.129	0.044	0.036	0.034	0.039	0.017	0.017	0.021	0.02	0.032
		UVT @ 254nm, Unfiltered (%T)	Bench		75.3	76.3	74.3	90.3	92	92.4	91.4	96.2	96.3	95.4	95.6	92.9
	Full-Scale	Conductivity Total (µS/cm)	Bench			184.4	188.8									197.1
		DO (mg/L)	Bench			12.4	13.9									12.5
		Manganese, Total (mg/L)	Bench			0.049	0.049									0.032
		Oxi-Red Potenital (ORP) (mV)	Bench			443.2	473.5									463.6
		pH	Bench			5.73	5.92									5.73
		Temperature (ºC)	Bench			4	3.5									5.6
		Turbidity (NTU)	Bench			0.62	0.65									0.14
		UVA @254nm, Unfiltered (/cm)	Bench			0.071	0.07									0.023
		UVT @ 254nm, Unfiltered (%T)	Bench			85	84.9									94.8
November 26, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		154	186.4	186.3	187.5	187.7	186.9	186.1	182.2	185.5	187.4	185.1	188.2
		DO (mg/L)	Bench		12.1	11.6	12.1	11.8	11.9	11.9	12	12.2	12.4	12.1	12.1	11.9
		Manganese, Total (mg/L)	Bench		0.023	0.03	0.03	0.018	0.019	0.02	0.018	0.018	0.014	0.015	0.016	0.018
		Oxi-Red Potenital (ORP) (mV)	Bench		220.6	254.5	329.9	326.7	328.2	326.2	318.9	322.7	320.7	312.7	312.2	299.1
		pH	Bench		7.91	5.71	5.75	5.81	5.82	5.82	5.81	5.79	5.79	5.81	5.8	5.8
		Temperature (ºC)	Bench		3.5	4	5.3	5.4	5.4	5.5	5.5	5.6	5.7	5.7	5.7	5.5
		Turbidity (NTU)	Bench		0.92	1.21	1.42	0.47	0.46	0.41	0.49	0.1	0.1	0.12	0.14	0.35
		UVA @254nm, Unfiltered (/cm)	Bench		0.125	0.123	0.129	0.045	0.042	0.04	0.048	0.021	0.019	0.02	0.021	0.034
		UVT @ 254nm, Unfiltered (%T)	Bench		74.9	75.4	74.7	90.2	90.8	91.1	89.6	95.4	95.6	95.5	95.3	92.5
	Full-Scale	Conductivity Total (µS/cm)	Bench			196	196.5									185.4
		DO (mg/L)	Bench			12.9	13.7									12.5
		Manganese, Total (mg/L)	Bench			0.053	0.05									0.035
		Oxi-Red Potenital (ORP) (mV)	Bench			291.2	327.7									313.1
		pH	Bench			5.86	5.94									5.77
		Temperature (ºC)	Bench			3.4	3.4									3.5
		Turbidity (NTU)	Bench			0.62	0.72									0.15
		UVA @254nm, Unfiltered (/cm)	Bench			0.076	0.075									0.025
		UVT @ 254nm, Unfiltered (%T)	Bench			84	84.2									94.3
November 27, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		77	9	8	9	9	8	9	9	9	9	9	9
		Aluminum, Dissolved (mg/L)	Lab			0.013	0.013	0.01	0.011	0.012	0.011	0.009	0.009	0.009	0.009	0.01
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.015	0.014	0.011	0.01	0.01	0.011	0.01	0.009	0.008	0.009	0.018
				N/D at <0.003	G/N											
		Antimony, Dissolved (mg/L)	Lab		0.00044	0.00037	0.0004	0.00044	0.0006	0.00114	0.00041	0.00046	0.00059	0.00031	0.00044	0.00067
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00064	0.00033	0.00027	0.00026	0.00025	0.0004	0.00026	0.00026	0.00026	0.00027	0.00026	0.00026
		Arsenic, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		20.2	19.8	20.2	20.7	20.6	20.3	20.2	20.1	20.2	19.9	20	19.8

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
November 27, 2017	Pilot-Scale	Calcium, Total (mg/L)	Lab		20	19.5	19.7	20.1	19.9	19.9	20	20		19.8	20.3	19.7
		Chromium, Dissolved (mg/L)	Lab									0.00006	0.00006		0.00003	0.00003
				N/D at <0.00003	G/N	G/N	G/N	G/N	G/N	G/N	G/N			G/N		
		Chromium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		12	2	1.5	1.5	1	1	1.5	1	2	1.5	1	1
		Conductivity Total (µS/cm)	Bench		154.8	183.5	185.2	182.8	197.4	181.6	182.2	179.1	180.6	183.5	183.7	183.9
			Lab		165	197	197	196	196	196	196	197	197	197	197	196
		Copper, Dissolved (mg/L)	Lab		0.0004	0.0018	0.0003	0.0005	0.0003	0.0005	0.0003	0.0003	0.0004	0.0004	0.0005	0.0012
		Copper, Total (mg/L)	Lab			0.001										0.002
				N/D at <0.001	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		11.7	11.7	11.2	11.3	11.3	11.8	11.7	11.4	11.4	11.9	11.6	12
		DOC Total (mg/L)	Lab		8.5	3.5	3.3	3	3.3	3	3	3	3	3	3	3.2
		Iron, Dissolved (mg/L)	Lab		0.012	0.175	0.011	0.007	0.009	0.028	0.011	0.006	0.006	0.015	0.007	0.007
		Iron, Total (mg/L)	Lab		0.05	1.05	1.08	0.17	0.16	0.2	0.19					0.12
				N/D at <0.03								G/N	G/N	G/N	G/N	
		Lead, Dissolved (mg/L)	Lab		0.00002	0.00001		0.00001	0.00001	0.00003	0.00001		0.00002	0.00001	0.00002	0.00002
				N/D at <0.003			G/N					G/N				
		Lead, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		5.951	5.877	6.065	6.119	6.076	6.002	6.073	5.944	5.958	5.856	6.005	6.1
		Magnesium, Total (mg/L)	Lab		5.99	5.74	5.83	5.96	5.95	5.87	5.89	5.86	5.93	5.99	5.99	5.85
		Manganese, Dissolved (mg/L)	Lab		0.00072	0.0115	0.00604	0.0072	0.00937	0.00748	0.00735	0.00854	0.00857	0.00921	0.00822	0.00743
		Manganese, Total (mg/L)	Bench		0.017	0.022	0.02	0.016	0.017	0.015	0.016	0.014	0.017	0.016	0.014	0.016
			Lab		0.0101	0.0113	0.0114	0.008	0.0099	0.0084	0.0083	0.0081	0.0083	0.0092	0.0084	0.0081
		Nickel, Dissolved (mg/L)	Lab		0.0002	0.00289	0.00267	0.00284	0.00282	0.00299	0.0028	0.00298	0.00296	0.00284	0.00284	0.00275
		Nickel, Total (mg/L)	Lab			0.0026	0.0026	0.0028	0.0027	0.0027	0.0028	0.0028	0.0028	0.0028	0.0029	0.0022
				N/D at <0.0005	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		196.2	253.8	325.1	324.2	326.3	305	303.5	301.9	300.5	284.5	268.1	253
		pH	Bench		7.75	5.7	5.73	5.82	5.78	5.83	5.8	5.78	5.79	5.81	5.8	5.81
			Lab		8	5.93	5.92	6.07	6.05		6.05	5.99	5.98	6.03	6	6.08
		Potassium, Dissolved (mg/L)	Lab		1.13	1.12	1.12	1.14	1.14	1.13	1.12	1.1	1.12	1.11	1.1	1.1
		Potassium, Total (mg/L)	Lab		1.1	1.08	1.08	1.11	1.1	1.1	1.1	1.1	1.09	1.09	1.1	1.08
		Sodium, Dissolved (mg/L)	Lab		2.313	2.346	2.295	2.272	2.311	2.284	2.313	2.223	2.291	2.26	2.227	2.254
		Sodium, Total (mg/L)	Lab		2.23	2.16	2.2	2.2	2.22	2.2	2.22	2.18	2.2	2.22	2.22	2.38
		TDSwq (mg/L)	Lab		96	119	123	122	109	111	109	102	118	107	118	118
		Temperature (ºC)	Bench		3.8	3.3	5.6	5.7	5.7	5.8	5.8	5.7	5.8	5.8	5.9	5.4
			Lab		3.8	3.3	5.6	5.7	5.7	5.8	5.8	5.7	5.8	5.8	5.9	5.4
		TSScalc Total (mg/L)	Lab			5		4	3	5		16	14	7	6	6
				N/D at <3	G/N		G/N				G/N					
		TSwv Total (mg/L)	Lab		98	124	124	126	112	116	110	118	132	114	124	124
		Turbidity (NTU)	Bench		0.93	0.81	0.99	0.25	0.23	0.24	0.24	0.12	0.11	0.09	0.1	0.2
			Lab		0.9	0.87	1.09	0.32	0.19	0.24	0.24	0.07	0.08	0.08	0.1	0.19
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.129	0.095	0.095	0.032	0.031	0.028	0.029	0.018	0.019	0.023	0.023	0.024
		UVT @ 254nm, Filtered (/cm)	Lab		77	94.5	96.4	96	96.2	96.4	96.6	96.8	96.9	96.9	96.8	96.6
		UVT @ 254nm, Unfiltered (%T)	Bench		74.9	80.4	80.3	93	93.1	93.8	93.7	95.9	95.7	95	95	94.6
		Zinc, Dissolved (mg/L)	Lab			0.0034		0.0014				0.0014	0.0021		0.0012	
				N/D at <0.0009	G/N		G/N		G/N	G/N	G/N			G/N		G/N
		Zinc, Total (mg/L)	Lab									0.0014				0.0044
				N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			15	16									13
		Aluminum, Dissolved (mg/L)	Lab			0.016	0.012									0.016
		Aluminum, Total (mg/L)	Lab			0.017	0.018									0.01
		Antimony, Dissolved (mg/L)	Lab			0.00041	0.00085									0.00053
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00038	0.00028									0.00028
		Arsenic, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			19.5	19.6									20
		Calcium, Total (mg/L)	Lab			19.5	19.7									20
		Chromium, Dissolved (mg/L)	Lab			0.00016	0.00021									0.00031
		Chromium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Colour, True	Lab			2	1									1

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2

Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
November 27, 2017	Full-Scale	Conductivity Total (µS/cm)	Bench			188.7	194									197.1
			Lab			200	200									203
		Copper, Dissolved (mg/L)	Lab			0.0031	0.0056									0.0024
		Copper, Total (mg/L)	Lab			0.003	0.006									
				N/D at <0.001												G/N
		DO (mg/L)	Bench			12.6	14									13.1
		DOC Total (mg/L)	Lab			4.3	4.2									3.2
		Iron, Dissolved (mg/L)	Lab			0.357	0.085									0.008
		Iron, Total (mg/L)	Lab			0.72	0.75									0.11
		Lead, Dissolved (mg/L)	Lab			0.00002										
				N/D at <0.003			G/N									G/N
		Lead, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			5.839	5.889									5.982
		Magnesium, Total (mg/L)	Lab			5.79	5.96									5.96
		Manganese, Dissolved (mg/L)	Lab			0.0437	0.0157									0.0267
		Manganese, Total (mg/L)	Bench			0.052	0.045									0.03
			Lab			0.0434	0.0423									0.0336
		Nickel, Dissolved (mg/L)	Lab			0.00211	0.00217									0.00226
		Nickel, Total (mg/L)	Lab			0.0022	0.0021									0.0028
		Oxi-Red Potenital (ORP) (mV)	Bench			246.8	259.7									250.8
		pH	Bench			5.9	6.04									5.79
			Lab			6.03	6.15									5.96
		Potassium, Dissolved (mg/L)	Lab			1.09	1.1									1.1
		Potassium, Total (mg/L)	Lab			1.08	1.08									1.11
		Sodium, Dissolved (mg/L)	Lab			2.252	2.233									2.539
		Sodium, Total (mg/L)	Lab			2.17	2.25									2.24
		TDSwq (mg/L)	Lab			122	120									120
		Temperature (ºC)	Bench			3.9	3.4									3.1
			Lab			3.9	3.4									3.1
		TSScalc Total (mg/L)	Lab			18	10									4
		TSwv Total (mg/L)	Lab			140	130									124
		Turbidity (NTU)	Bench			0.59	0.76									0.19
			Lab			0.59	0.8									0.18
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.074	0.074									0.025
		UVT @ 254nm, Filtered (/cm)	Lab			93.7	96									96.5
		UVT @ 254nm, Unfiltered (%T)	Bench			84.3	84.2									94.5
		Zinc, Dissolved (mg/L)	Lab			0.0011	0.0019									0.0052
		Zinc, Total (mg/L)	Lab			0.001	0.001									
				N/D at <0.0009												G/N
November 28, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		154.1	183.5	182	187.3	184.4	184.4	183.6	186	185.2	185.6	190.2	185.2
		DO (mg/L)	Bench		12.1	12.4	12.1	11.7	11.4	11.5	11.7	11.7	11.7	11.6	11.4	11.4
		Manganese, Total (mg/L)	Bench		0.02	0.025	0.024	0.011	0.012	0.011	0.013	0.013	0.01	0.012	0.015	0.012
		Oxi-Red Potenital (ORP) (mV)	Bench		208.8	253.6	309.6	312.7	311.4	307.8	301.4	295.5	295.4	297.3	293.1	285.5
		pH	Bench		7.8	5.8	5.84	5.91	5.91	5.9	5.9	5.9	5.9	5.91	5.91	5.88
		Temperature (ºC)	Bench		3.5	3.9	4.3	5.1	4.9	5.1	5	5.6	5.6	5.8	5.9	5.4
		Turbidity (NTU)	Bench		0.87	0.82	1.03	0.33	0.15	0.16	0.14	0.11	0.13	0.14	0.12	0.13
		UVA @254nm, Unfiltered (/cm)	Bench		0.124	0.104	0.098	0.028	0.022	0.023	0.022	0.021	0.021	0.021	0.02	0.021
		UVT @ 254nm, Unfiltered (%T)	Bench		75.2	78.7	79.7	93.9	95.1	94.8	95	95.3	95.4	95.3	95.5	95.2
	Full-Scale	Conductivity Total (µS/cm)	Bench			192.2	188.6									186.4
		DO (mg/L)	Bench			13.1	14.1									13.4
		Manganese, Total (mg/L)	Bench			0.05	0.046									0.033
		Oxi-Red Potenital (ORP) (mV)	Bench			288.8	246.7									328.9
		pH	Bench			5.85	5.9									5.76
		Temperature (ºC)	Bench			3.5	3.5									4.2
		Turbidity (NTU)	Bench			0.63	0.72									0.12
		UVA @254nm, Unfiltered (/cm)	Bench			0.074	0.069									0.022
		UVT @ 254nm, Unfiltered (%T)	Bench			84.3	85.4									95.1
November 29, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		152.7	183.2	180.6	183	184.2	184	184.7	179.4	185.4	182.7	187.2	187.7
		DO (mg/L)	Bench		12.2	11.7	11.8	12	11.8	11.7	11.6	11.7	11.5	11.6	11.8	11.8
		Manganese, Total (mg/L)	Bench		0.022	0.019	0.019	0.012	0.013	0.013	0.01	0.014	0.013	0.012	0.012	0.013
		Oxi-Red Potenital (ORP) (mV)	Bench		226.7	261	317.9	317.3	315.3	312.7	311.3	307.6	305.3	303.7	298.7	285.7
		pH	Bench		7.88	5.8	5.79	5.9	5.91	5.89	5.91	5.9	5.9	5.87	5.89	5.89

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
November 29, 2017	Pilot-Scale	Temperature (ºC)	Bench		3.3	3.5	4.6	6	6.1	5.8	5.8	5.9	6	6	6.1	5.8
		Turbidity (NTU)	Bench		0.84	0.82	1.06	0.18	0.13	0.16	0.15	0.15	0.14	0.13	0.14	0.15
		UVA @254nm, Unfiltered (/cm)	Bench		0.122	0.094	0.087	0.021	0.017	0.02	0.02	0.02	0.022	0.022	0.019	0.023
		UVT @ 254nm, Unfiltered (%T)	Bench		75.5	80.7	81.8	95.2	96.1	95.5	95.5	95.5	95	95.1	95.8	94.9
	Full-Scale	Conductivity Total (µS/cm)	Bench			196.5	193									200.1
		DO (mg/L)	Bench			12.8	13.5									13.5
		Manganese, Total (mg/L)	Bench			0.059	0.051									0.038
		Oxi-Red Potenital (ORP) (mV)	Bench			279	348.1									335
		pH	Bench			5.9	5.96									5.79
		Temperature (ºC)	Bench			3.1	3.3									3.7
		Turbidity (NTU)	Bench			0.64	0.82									0.19
		UVA @254nm, Unfiltered (/cm)	Bench			0.079	0.077									0.026
		UVT @ 254nm, Unfiltered (%T)	Bench			83.4	83.8									94.2
December 1, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		154.4	180.9	181.5	181.4	189	184.9	180.9	183.1	182.3	181.7	181.3	186.2
		DO (mg/L)	Bench		12.3	11.8	12.2	11.8	13.1	12.3	12.3	12	11.6	12	11.8	12.1
		Manganese, Total (mg/L)	Bench		0.023	0.02	0.02	0.015	0.012	0.017	0.013	0.017	0.014	0.014	0.013	0.015
		Oxi-Red Potenital (ORP) (mV)	Bench		226.7	267.7	307	307.4	309.1	309.6	298.9	299.7	296.7	294.6	287.4	279.6
		pH	Bench		7.9	5.89	5.9	5.98	6.05	6.01	5.98	5.98	6	5.96	6	5.97
		Temperature (ºC)	Bench		3.2	3.5	4.2	5.9	5.8	5.5	5.8	5.7	5.9	5.9	5.8	5.5
		Turbidity (NTU)	Bench		0.94	1	1.11	0.32	0.18	0.22	0.25	0.16	0.17	0.18	0.2	0.21
		UVA @254nm, Unfiltered (/cm)	Bench		0.132	0.124	0.117	0.033	0.034	0.034	0.031	0.032	0.034	0.037	0.034	0.033
		UVT @ 254nm, Unfiltered (%T)	Bench		73.8	75.2	76.2	92.6	92.5	92.4	93.1	92.8	92.5	92.7	92.5	92.6
	Full-Scale	Conductivity Total (µS/cm)	Bench			191.4	190.6									198.2
		DO (mg/L)	Bench			13.2	14.4									14.7
		Manganese, Total (mg/L)	Bench			0.056	0.052									0.038
		Oxi-Red Potenital (ORP) (mV)	Bench			280.3	318.9									336
		pH	Bench			5.91	5.95									5.83
		Temperature (ºC)	Bench			3	3									3.5
		Turbidity (NTU)	Bench			0.65	0.79									0.26
		UVA @254nm, Unfiltered (/cm)	Bench			0.08	0.082									0.028
		UVT @ 254nm, Unfiltered (%T)	Bench			83.2	82.8									93.8
December 2, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		156.8	181	182.7	181.3	183.3	182.3	186.1	181.8	183.4	197.4	188.8	184.9
		DO (mg/L)	Bench		12.4	11.8	11.9	11.7	11.8	11.6	11.7	11.6	11.6	11.8	12	12.8
		Manganese, Total (mg/L)	Bench		0.02	0.023	0.024	0.016	0.013	0.015	0.016	0.015	0.016	0.015	0.016	0.015
		Oxi-Red Potenital (ORP) (mV)	Bench		221.3	255.4	298	293	291.9	289.2	283.6	282.3	277.2	272	257	292
		pH	Bench		7.95	5.88	5.89	5.97	5.96	5.99	5.97	5.96	5.96	5.97	5.98	5.98
		Temperature (ºC)	Bench		3.1	3.1	5.3	5.7	5.7	5.4	5.8	5.8	5.9	5.8	5.8	5
		Turbidity (NTU)	Bench		0.91	0.99	1.36	0.29	0.19	0.11	0.12	0.09	0.08	0.07	0.09	0.13
		UVA @254nm, Unfiltered (/cm)	Bench		0.124	0.132	0.139	0.03	0.026	0.023	0.023	0.021	0.022	0.025	0.022	0.021
		UVT @ 254nm, Unfiltered (%T)	Bench		75.2	73.8	72.6	93.4	94.2	94.8	94.9	95.3	95.2	94.3	95.1	94.8
	Full-Scale	Conductivity Total (µS/cm)	Bench			188.5	191.2									189.4
		DO (mg/L)	Bench			13.2	13.7									14.3
		Manganese, Total (mg/L)	Bench			0.054	0.053									0.038
		Oxi-Red Potenital (ORP) (mV)	Bench			292.7	348									344
		pH	Bench			5.79	5.88									5.69
		Temperature (ºC)	Bench			3.8	3.1									3.3
		Turbidity (NTU)	Bench			0.51	0.7									0.17
		UVA @254nm, Unfiltered (/cm)	Bench			0.071	0.073									0.031
		UVT @ 254nm, Unfiltered (%T)	Bench			84.9	84.6									93.4
December 3, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		153.1	180	180.8	181	180.8	179.9	181.2	182.5	179.1	180.3	181.3	182.1
		DO (mg/L)	Bench		12.7	12.4	12.5	12.4	12.4	12.2	12.2	12	12.8	12.4	12.4	12.7
		Manganese, Total (mg/L)	Bench		0.016	0.019	0.02	0.018	0.016	0.014	0.013	0.017	0.014	0.015	0.016	0.017
		Oxi-Red Potenital (ORP) (mV)	Bench		214	255.8	321.3	316	317	316.8	310.7	310.4	313.3	303.2	301.5	300.7
		pH	Bench		7.92	6	6.02	6.07	6.06	6.11	6.08	6.09	6.04	6.07	6.12	6.08
		Temperature (ºC)	Bench		3.3	3.5	4.9	5.9	5.9	5.8	5.8	5.9	5.9	6	6	5.5
		Turbidity (NTU)	Bench		0.92	1.31	1.63	0.39	0.2	0.22	0.23	0.09	0.1	0.1	0.09	0.19
		UVA @254nm, Unfiltered (/cm)	Bench		0.125	0.15	0.145	0.038	0.033	0.032	0.036	0.021	0.022	0.021	0.024	0.027
		UVT @ 254nm, Unfiltered (%T)	Bench		75	70.8	71.7	91.6	92.7	92.9	92.1	95.2	95.1	95.2	94.7	94
	Full-Scale	Conductivity Total (µS/cm)	Bench			185.3	190									182.8
		DO (mg/L)	Bench			12.2	14									12.7
		Manganese, Total (mg/L)	Bench			0.047	0.045									0.032
		Oxi-Red Potenital (ORP) (mV)	Bench			304.9	324.6									315.6
		pH	Bench			5.86	5.94									5.73
		Temperature (ºC)	Bench			3.1	3.1									3.5

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
December 3, 2017	Full-Scale	Turbidity (NTU)	Bench			0.61	0.76									0.15
		UVA @254nm, Unfiltered (/cm)	Bench			0.08	0.076									0.025
		UVT @ 254nm, Unfiltered (%T)	Bench			83.2	83.9									94.4
December 4, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		153.8	182	180.1	181.7	182	181.4	184.2	183	182.3	181.2	182.5	180.6
		DO (mg/L)	Bench		12.7	12.8	13.1	11.9	12	11.8	12	12	11.6	11.6	12	12.5
		Manganese, Total (mg/L)	Bench		0.021	0.024	0.027	0.02	0.016	0.017	0.018	0.019	0.018	0.016	0.017	0.017
		Oxi-Red Potenital (ORP) (mV)	Bench		218	250.9	319.3	316	314.8	312	311.8	312.4	310.7	309	306.9	301.5
		pH	Bench		7.9	5.99	6.03	6.11	6.1	6.1	6.08	6.04	6.09	6.08	6.07	6.03
		Temperature (ºC)	Bench		2.9	4	5.6	4.6	4.7	4.4	4.7	4.8	4.7	4.7	4.7	4.2
		Turbidity (NTU)	Bench		0.96	1.29	1.46	0.34	0.13	0.12	0.07	0.07	0.08	0.09	0.09	0.11
		UVA @254nm, Unfiltered (/cm)	Bench		0.132	0.13	0.136	0.034	0.027	0.025	0.025	0.027	0.024	0.023	0.025	0.025
		UVT @ 254nm, Unfiltered (%T)	Bench		73.7	74.1	73.1	92.5	94	94.4	94.4	94.2	94.6	94.8	94.4	94.4
	Full-Scale	Conductivity Total (µS/cm)	Bench			194	187.5									183.6
		DO (mg/L)	Bench			13.3	13									13.4
		Manganese, Total (mg/L)	Bench			0.054	0.053									0.038
		Oxi-Red Potenital (ORP) (mV)	Bench			310.7	317.3									300.2
		pH	Bench			5.85	5.91									5.75
		Temperature (ºC)	Bench			2.8	3.1									3.1
		Turbidity (NTU)	Bench			0.77	0.68									0.21
		UVA @254nm, Unfiltered (/cm)	Bench			0.076	0.073									0.025
		UVT @ 254nm, Unfiltered (%T)	Bench			84	84.5									94.3
December 5, 2017	Pilot-Scale	Conductivity Total (µS/cm)	Bench		161.8	193.9	179.5	184.9	186.6	185.5	188.6	183.7	185.5	185.2	189.3	188.7
		DO (mg/L)	Bench		12.8	12.9	12.4	12.2	12.3	12.2	12.4	12.1	12.5	11.9	12.4	12.8
		Manganese, Total (mg/L)	Bench		0.024	0.027	0.027	0.031	0.03	0.018	0.017	0.02	0.02	0.019	0.018	0.022
		Oxi-Red Potenital (ORP) (mV)	Bench		220.2	253.1	322.4	319.9	322.8	315.8	318.6	320.7	317.2	315.6	312.8	310
		pH	Bench		7.89	5.9	5.91	6.02	6.02	6.06	6.03	5.96	5.97	6	5.98	5.98
		Temperature (ºC)	Bench		3.5	4	4.7	4.9	4.8	4.9	5.1	5.1	5.3	5.3	5.5	4.7
		Turbidity (NTU)	Bench		1.11	1.34	1.73	1.14	1.12	0.1	0.08	0.24	0.29	0.06	0.11	0.35
		UVA @254nm, Unfiltered (/cm)	Bench		0.126	0.135	0.152	0.085	0.083	0.025	0.024	0.033	0.032	0.021	0.021	0.038
		UVT @ 254nm, Unfiltered (%T)	Bench		74.6	73.3	70.5	82.6	82.8	94.5	94.7	92.5	92.8	95.3	95.2	91.7
	Full-Scale	Conductivity Total (µS/cm)	Bench			194.1	190									194.1
		DO (mg/L)	Bench			13.5	13.6									14.1
		Manganese, Total (mg/L)	Bench			0.059	0.053									0.037
		Oxi-Red Potenital (ORP) (mV)	Bench			316.5	344									346.5
		pH	Bench			5.84	5.94									5.73
		Temperature (ºC)	Bench			2.9	2.8									3.5
		Turbidity (NTU)	Bench			0.64	0.74									0.14
		UVA @254nm, Unfiltered (/cm)	Bench			0.074	0.076									0.025
		UVT @ 254nm, Unfiltered (%T)	Bench			84.4	83.9									94.4
December 6, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		74	10	10	11	11	11	11	11		11	10	10
		Aluminum, Dissolved (mg/L)	Lab			0.007	0.006	0.008	0.007	0.007	0.006	0.005	0.006	0.005	0.005	0.006
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.015	0.013	0.008	0.007	0.007	0.007	0.054	0.007	0.005	0.005	0.006
				N/D at <0.003	G/N											
		Antimony, Dissolved (mg/L)	Lab		0.0014	0.00103	0.00096	0.00053	0.00046	0.00124	0.00105	0.00063	0.00187	0.0005	0.00067	0.00083
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00071	0.00033	0.00027	0.00029	0.00026	0.00028	0.00026	0.00111	0.00029	0.00027	0.00028	0.00027
		Arsenic, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		21.8	21.9	20.1	21.3	22.9	22.2	20.9	20.3	22.1	22.1	22	21.8
		Calcium, Total (mg/L)	Lab		22.4	21.7	20.4	21.7	21.6	22.1	21.6	20.6		22.2	22.4	22.1
		Chloride (mg/L)	Lab		2.7											2.5
		Chromium, Dissolved (mg/L)	Lab		0.00003			0.00102		0.00004		0.00004	0.00005	0.00004	0.00004	
				N/D at <0.00003		G/N	G/N		G/N		G/N					G/N
		Chromium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		13	5	2	1.5	1	0.5	0.5	0.5	0.5	1	1	0.5
		Conductivity Total (µS/cm)	Bench		157.6	183.1	183.5	186.3	184.3	184.5	187.1	184.5	184.3	184.8	187.2	190.5
			Lab		163	194	193	194	194	194	194	194	194	194	195	195
		Copper, Dissolved (mg/L)	Lab		0.0004	0.0003	0.0003	0.0004	0.0003	0.0003	0.0003	0.0043	0.0004	0.0004	0.0004	0.0005
		Copper, Total (mg/L)	Lab									0.004				
				N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N
		DO (mg/L)	Bench		11.8	12.1	12.6	12.4	12.5	12.5	12.2	12.2	12.2	12.3	12	12.3
		DOC Total (mg/L)	Lab		8.3	3.4	3.2	3	3.1	3	3.2	3	3.1	3.1	3.3	3.2

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
December 6, 2017	Pilot-Scale	dTot, Hardness (mg/L CaCO3)	Lab													82
		HaaBCAA ion(Fe+2)(ug/L)	Lab		1.8											1.7
		HaaDBAA ion(Fe+2)(ug/L)	Lab													2.6
				Data not recv	G/N											
		HaaDCAA ion(Fe+2)(ug/L)	Lab		17											6.2
		HaaMBAA ion(Fe+2)(ug/L)	Lab		0.9											1.2
		HaaMCAA ion(Fe+2)(ug/L)	Lab		1.4											1.6
		HaaTCAA ion(Fe+2)(ug/L)	Lab		19.3											8.7
		HaaTotal, calc_(ug/L)	Lab		40											22
		Iron, Dissolved (mg/L)	Lab		0.032	0.183	0.062	0.024	0.006	0.025	0.006	0.004	0.009	0.005	0.006	0.006
		Iron, Total (mg/L)	Lab		0.05	2.21	1.99	0.22	0.1	0.07	0.23					0.05
				N/D at <0.03								G/N	G/N	G/N	G/N	
		Lead, Dissolved (mg/L)	Lab		0.00003	0.00002	0.00003	0.00001		0.00002	0.00002		0.00004	0.00001	0.00005	0.00003
				N/D at <0.003					G/N			G/N				
		Lead, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		6.211	6.193	5.817	6.347	6.377	6.464	6.366	6.3	6.51	6.512	6.246	6.367
		Magnesium, Total (mg/L)	Lab		6.3	6.29	6.07	6.28	6.26	6.45	6.3	6.29	6.49	6.59	6.51	6.49
		Manganese, Dissolved (mg/L)	Lab		0.00611	0.0123	0.00748	0.00856	0.00794	0.00792	0.00776	0.00829	0.00864	0.00807	0.00786	0.00805
		Manganese, Total (mg/L)	Bench		0.017	0.025	0.028	0.014	0.014	0.014	0.018	0.016	0.016	0.013	0.016	0.016
			Lab		0.009	0.013	0.0122	0.0087	0.0083	0.0082	0.0085	0.0083	0.0085	0.0081	0.0083	0.0082
		Nickel, Dissolved (mg/L)	Lab		0.00021	0.00268	0.00255	0.00277	0.00271	0.00263	0.00266	0.0025	0.00267	0.00257	0.00251	0.0026
		Nickel, Total (mg/L)	Lab			0.0027	0.0026	0.0027	0.0026	0.0026	0.0027	0.0025	0.0027	0.0025	0.0025	0.0025
				N/D at <0.0005	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		222.1	260.1	332.4	330.7	329.6	330.1	327.1	327	324.2	322.1	319	318.5
		pH	Bench		7.96	5.8	5.83	5.86	5.9	5.88	5.91	5.91	5.89	5.9	5.93	5.91
			Lab		8.01	5.82	5.81	5.89	5.94		6.01	5.92	5.95	5.96	6	5.95
		Potassium, Dissolved (mg/L)	Lab		1.25	1.23	1.13	1.25	1.26	1.28	1.31	1.17	1.33	1.32	1.27	1.26
		Potassium, Total (mg/L)	Lab		1.19	1.25	1.15	1.24	1.27	1.2	1.28	1.2	1.27	1.26	1.32	1.25
		Sodium, Dissolved (mg/L)	Lab		2.432	2.382	2.254	2.53	2.51	2.573	2.597	2.528	2.645	2.701	2.6	2.514
		Sodium, Total (mg/L)	Lab		2.46	2.38	2.29	2.4	2.51	2.53	2.61	2.43	2.53	2.55	2.53	2.6
		Sulfate (mg/L)	Lab													78
				N/D <2	G/N											
		TDSwq (mg/L)	Lab		101	119	119	121	121	121	116	119	119	122	128	124
		Temperature (ºC)	Bench		2.8	3	4.3	4	4.1	4	4.1	4.1	4.7	4.5	4.5	3.7
			Lab		2.8	3	4.3	4	4.1	4	4.1	4.1	4.7	4.5	4.5	3.7
		ThmBDCM Total(ug/L)	Lab		2.4											1.5
		ThmCHCl3 Total(ug/L)	Lab		52.2											18
		ThmTotal,calc_ Total(ug/L)	Lab		55											20
		TSScalc Total (mg/L)	Lab		9	33	3			21	16	5	3			
				N/D at <3				G/N	G/N					G/N	G/N	G/N
		TSwv Total (mg/L)	Lab		110	152	122	122	122	142	132	124	122	124	128	126
		Turbidity (NTU)	Bench		1.01	1.31	1.61	0.35	0.23	0.2	0.21	0.08	0.09	0.11	0.11	0.15
			Lab		0.72	1.48	1.69	0.33	0.28	0.21	0.24	0.06	0.08	0.06	0.08	0.1
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.131	0.141	0.144	0.034	0.03	0.027	0.027	0.021	0.021	0.022	0.02	0.021
		UVT @ 254nm, Filtered (/cm)	Lab		75.9	92.6	94.3	94.6	94.9	94.1	94.4	94.3	94.8	94.8	95.1	94.7
		UVT @ 254nm, Unfiltered (%T)	Bench		74	72.2	71.8	92.4	93.4	94	93.9	95.2	95.2	95	95.5	95.2
		Zinc, Dissolved (mg/L)	Lab						0.0011			0.0017	0.0025	0.0045		0.0026
				N/D at <0.0009	G/N	G/N	G/N	G/N		G/N	G/N				G/N	
		Zinc, Total (mg/L)	Lab						0.001							
				N/D at <0.0009	G/N	G/N	G/N	G/N		G/N	G/N	G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			13	14									11
		Aluminum, Dissolved (mg/L)	Lab			0.003	0.004									0.007
		Aluminum, Total (mg/L)	Lab			0.004	0.004									0.006
		Antimony, Dissolved (mg/L)	Lab			0.00106	0.00075									0.00044
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00039	0.0004									0.00028
		Arsenic, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			20.5	20.6									21.8
		Calcium, Total (mg/L)	Lab			20.3	20.4									21
		Chloride (mg/L)	Lab													22

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2

Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
					Sample Location											
December 6, 2017	Full-Scale	Chromium, Dissolved (mg/L)	Lab			0.0002	0.00023									0.00047
		Chromium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Colour, True	Lab			2.5	2									2
		Conductivity Total (µS/cm)	Bench			188	182.2									190.8
			Lab			198	198									201
		Copper, Dissolved (mg/L)	Lab			0.0035	0.0075									0.0025
		Copper, Total (mg/L)	Lab			0.004	0.008									0.002
		DO (mg/L)	Bench			12.6	12.5									12.1
		DOC Total (mg/L)	Lab			3.6	3.9									3.6
		dTot, Hardness (mg/L CaCO3)	Lab													77.2
		HaaBCAA ion(Fe+2)(ug/L)	Lab													1.8
		HaaDBAA ion(Fe+2)(ug/L)	Lab	Data not recv												G/N
		HaaDCAA ion(Fe+2)(ug/L)	Lab													5.8
		HaaMBAA ion(Fe+2)(ug/L)	Lab													1.1
		HaaMCAA ion(Fe+2)(ug/L)	Lab													1.7
		HaaTCAA ion(Fe+2)(ug/L)	Lab													7.4
		HaaTotal, calc_(ug/L)	Lab													18
		Iron, Dissolved (mg/L)	Lab			0.241	0.551									0.01
		Iron, Total (mg/L)	Lab			0.59	0.68									0.05
		Lead, Dissolved (mg/L)	Lab			0.00002	0.00003									0.00004
		Lead, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			6.091	6.035									6.366
		Magnesium, Total (mg/L)	Lab			6.05	6.16									5.98
		Manganese, Dissolved (mg/L)	Lab			0.045	0.0401									0.0278
		Manganese, Total (mg/L)	Bench			0.054	0.054									0.04
			Lab			0.0442	0.0443									0.0301
		Nickel, Dissolved (mg/L)	Lab			0.00234	0.00232									0.00231
		Nickel, Total (mg/L)	Lab			0.0023	0.0023									0.0023
		Oxi-Red Potenital (ORP) (mV)	Bench			315.8	350.7									348.2
		pH	Bench			5.92	6.02									5.75
			Lab			5.88	6									5.84
		Potassium, Dissolved (mg/L)	Lab			1.19	1.2									1.2
		Potassium, Total (mg/L)	Lab			1.19	1.19									1.22
		Sodium, Dissolved (mg/L)	Lab			2.486	2.5									2.705
		Sodium, Total (mg/L)	Lab			2.41	2.37									2.61
		Sulfate (mg/L)	Lab													45
		TDSwq (mg/L)	Lab			116	123									126
		Temperature (ºC)	Bench			3.5	2.6									2.6
			Lab			3.5	2.6									2.6
		ThmBDCM Total(ug/L)	Lab													1.8
		ThmCHCl3 Total(ug/L)	Lab													17.2
		ThmTotal,calc_ Total(ug/L)	Lab													19
		TSScalc Total (mg/L)	Lab			10	9									6
		TSwv Total (mg/L)	Lab			126	132									132
		Turbidity (NTU)	Bench			0.54	0.72									0.17
			Lab			0.53	0.67									0.12
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.072	0.074									0.025
		UVT @ 254nm, Filtered (/cm)	Lab			91.3	94.3									94.8
		UVT @ 254nm, Unfiltered (%T)	Bench			85.1	84.4									94.4
		Zinc, Dissolved (mg/L)	Lab			0.002										0.0018
				N/D at <0.0009			G/N									
		Zinc, Total (mg/L)	Lab													0.0018
				N/D at <0.0009		G/N	G/N									
December 7, 2017	Pilot-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab		76	11	10	11	10	10	10	11		11	11	14
		Aluminum, Dissolved (mg/L)	Lab			0.011	0.013	0.007	0.007	0.008	0.007	0.007	0.006	0.006	0.008	0.006
				N/D at <0.002	G/N											
		Aluminum, Total (mg/L)	Lab			0.013	0.012	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.006	0.006
				N/D at <0.003	G/N											
		Antimony, Dissolved (mg/L)	Lab		0.00048	0.00112	0.00105	0.00136	0.00047	0.00102	0.00067	0.00056	0.00055	0.00055	0.00052	0.00065
		Antimony, Total (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Arsenic, Dissolved (mg/L)	Lab		0.00064	0.00036	0.00031	0.00026	0.00027	0.00026	0.00027	0.00025	0.00025	0.00027	0.00028	0.00025
		Arsenic, Total (mg/L)	Lab	N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2

Phase: Piloting

					Sample Location											
Sample Date	**System**	**Analysis**	**Source**	**General Notes (G/N)**	**Raw**	**Post-DAF**	**Post-Ozone**	**Filter 1**	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**	**Combined Filtrate**
December 7, 2017	Pilot-Scale	Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Calcium, Dissolved (mg/L)	Lab		21.8	21.1	21.5	21.3	22	21.4	21.6	21.8	20.9	21.8	21	20.8
		Calcium, Total (mg/L)	Lab		21	21.1	20.7	21.3	21.9	21.8	21.8	21.7		20.8	21.2	20.5
		Chromium, Dissolved (mg/L)	Lab		0.00004	0.0001	0.00023	0.00004	0.00003	0.00006	0.00008	0.00014	0.00009	0.00004	0.00007	0.00007
		Chromium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Colour, True	Lab		11	1.5	1	1	0.5	1	1	0.5	0.5	0.5	0.5	0.5
		Conductivity Total (µS/cm)	Bench		154.7	183.9	184.6	183.1	183	181.4	181.3	182.9	187.3	184.1	180	189.7
			Lab		164	194	194	193	193	193	193	194	194	194	194	194
		Copper, Dissolved (mg/L)	Lab		0.0004	0.0008	0.0007	0.0004	0.0003	0.0007	0.0003	0.0004	0.0003	0.0003	0.0005	0.0013
		Copper, Total (mg/L)	Lab													0.001
				N/D at <0.001	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	
		DO (mg/L)	Bench		11.6	12.5	12.5	12.1	12.1	12.2	12.2	12.2	12.1	12.1	12.2	12.5
		DOC Total (mg/L)	Lab		8.3	3.6	3.4	3.2	3.1	3.4	3	3	3.1	3.1	3.3	3.2
		Iron, Dissolved (mg/L)	Lab		0.013	0.295	0.528	0.013	0.007	0.01	0.008	0.007	0.007	0.008	0.027	0.007
		Iron, Total (mg/L)	Lab		0.05	1.52	1.56									
				N/D at <0.03				G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Lead, Dissolved (mg/L)	Lab		0.00002	0.00003	0.00002	0.00003		0.00002	0.00002	0.00001			0.00002	0.00001
				N/D at <0.003					G/N				G/N	G/N		
		Lead, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Magnesium, Dissolved (mg/L)	Lab		6.402	6.279	6.145	6.441	6.387	6.372	6.395	6.387	6.236	6.44	6.281	6.105
		Magnesium, Total (mg/L)	Lab		6.07	6.35	6.36	6.38	6.4	6.73	6.29	6.39	6.28	6.31	6.24	6.21
		Manganese, Dissolved (mg/L)	Lab		0.0009	0.0124	0.00813	0.00923	0.0119	0.00813	0.008	0.00805	0.00793	0.00937	0.00798	0.00755
		Manganese, Total (mg/L)	Bench		0.019	0.027	0.025	0.015	0.014	0.016	0.017	0.019	0.016	0.018	0.018	0.017
			Lab		0.0087	0.0135	0.0119	0.009	0.015	0.0084	0.0083	0.0084	0.008	0.0095	0.008	0.008
		Nickel, Dissolved (mg/L)	Lab		0.00019	0.00263	0.00278	0.00273	0.00263	0.0027	0.00261	0.00258	0.00254	0.00254	0.00263	0.00253
		Nickel, Total (mg/L)	Lab			0.0025	0.0027	0.0026	0.0026	0.0026	0.0026	0.0026	0.0025	0.0025	0.0026	0.0026
				N/D at <0.0005	G/N											
		Oxi-Red Potenital (ORP) (mV)	Bench		214.7	250.7	307.4	306.7	305.3	302.4	300.9	296.9	296.7	284.1	279.9	265
		pH	Bench		7.95	5.82	5.82	5.89	5.9	5.91	5.91	5.9	5.91	5.92	5.9	5.9
			Lab		8.05	6	5.7	6.01	5.97		5.93	6	6.02	5.99	6.07	6.02
		Potassium, Dissolved (mg/L)	Lab		1.26	1.3	1.26	1.29	1.3	1.3	1.25	1.25	1.26	1.28	1.25	1.21
		Potassium, Total (mg/L)	Lab		1.22	1.21	1.23	1.25	1.26	1.28	1.3	1.26	1.23	1.25	1.22	1.25
		Sodium, Dissolved (mg/L)	Lab		2.512	2.561	2.49	2.555	2.623	2.675	2.487	2.619	2.563	2.495	2.547	2.474
		Sodium, Total (mg/L)	Lab		2.44	2.49	2.47	2.52	2.52	2.62	2.5	2.58	2.53	2.53	2.46	2.55
		TDSwq (mg/L)	Lab		97	124	122	126	122	131	129	120	129	122	128	117
		Temperature (ºC)	Bench		2.9	3.3	4.8	4.5	4.9	5	5	5.1	5	5.2	5.3	4
			Lab		2.9	3.3	4.8	4.5	4.9	5	5	5.1	5	5.2	5.3	4
		TSScalc Total (mg/L)	Lab		15	16	34	26	32	23	3	18		4	14	15
				N/D at <3									G/N			
		TSwv Total (mg/L)	Lab		112	140	156	152	154	154	132	138	130	126	142	132
		Turbidity (NTU)	Bench		0.91	1.08	1.23	0.28	0.15	0.14	0.06	0.09	0.09	0.07	0.12	0.1
			Lab		0.79	1.06	1.34	0.22	0.1	0.09	0.07	0.06	0.07	0.06	0.09	0.08
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
		UVA @254nm, Unfiltered (/cm)	Bench		0.125	0.125	0.12	0.024	0.023	0.022	0.021	0.021	0.02	0.02	0.021	0.021
		UVT @ 254nm, Filtered (/cm)	Lab		74.8	92	93.7	94.7	94.9	94.5	94.5	94.8	94.8	94.9	94.5	94.1
		UVT @ 254nm, Unfiltered (%T)	Bench		74.9	75	75.9	94.7	94.8	95	95.3	95.2	95.4	95.4	95.2	95.2
		Zinc, Dissolved (mg/L)	Lab			0.0012	0.0015	0.001		0.001					0.0011	
				N/D at <0.0009	G/N				G/N		G/N	G/N	G/N	G/N		G/N
		Zinc, Total (mg/L)	Lab	N/D at <0.0009	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N	G/N
	Full-Scale	AlkTotal-pH4_5 (mg/L CaCO3)	Lab			11	14									12
		Aluminum, Dissolved (mg/L)	Lab			0.003	0.003									0.006
		Aluminum, Total (mg/L)	Lab			0.004	0.005									0.006
		Antimony, Dissolved (mg/L)	Lab			0.00074	0.00066									0.00078
		Antimony, Total (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Arsenic, Dissolved (mg/L)	Lab			0.00038	0.00029									0.00029
		Arsenic, Total (mg/L)	Lab	N/D at <0.001		G/N	G/N									G/N
		Cadmium, Dissolved (mg/L)	Lab	N/D at <0.00005		G/N	G/N									G/N
		Cadmium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Calcium, Dissolved (mg/L)	Lab			20.7	20.6									20.5
		Calcium, Total (mg/L)	Lab			20.5	19.8									20.9
		Chromium, Dissolved (mg/L)	Lab			0.00004	0.0002									0.00019
		Chromium, Total (mg/L)	Lab				0.0007									

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary

Season: Winter #2
Phase: Piloting

					Sample Location											
Sample Date	System	Analysis	Source	General Notes (G/N)	Raw	Post-DAF	Post-Ozone	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined Filtrate
December 7, 2017	Full-Scale	Chromium, Total (mg/L)	Lab	N/D at <0.0006		G/N										G/N
		Colour, True	Lab			1.5	0.5									0.5
		Conductivity Total (µS/cm)	Bench			191.3	188.4									187.3
			Lab			198	197									201
		Copper, Dissolved (mg/L)	Lab			0.0035	0.0072									0.0025
		Copper, Total (mg/L)	Lab			0.004	0.008									0.002
		DO (mg/L)	Bench			12.6	14.2									13.1
		DOC Total (mg/L)	Lab			3.7	3.7									3.5
		Iron, Dissolved (mg/L)	Lab			0.05	0.026									0.009
		Iron, Total (mg/L)	Lab			0.63	0.66									0.04
		Lead, Dissolved (mg/L)	Lab			0.00001	0.00002									0.00001
		Lead, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		Magnesium, Dissolved (mg/L)	Lab			6.22	5.935									6.098
		Magnesium, Total (mg/L)	Lab			6	5.98									6.16
		Manganese, Dissolved (mg/L)	Lab			0.0457	0.0175									0.0274
		Manganese, Total (mg/L)	Bench			0.056	0.054									0.04
			Lab			0.0455	0.043									0.0288
		Nickel, Dissolved (mg/L)	Lab			0.00236	0.00229									0.00226
		Nickel, Total (mg/L)	Lab			0.0023	0.0024									0.0022
		Oxi-Red Potenital (ORP) (mV)	Bench			268.7	273.1									265.2
		pH	Bench			5.88	5.98									5.76
			Lab			5.96	6.11									5.91
		Potassium, Dissolved (mg/L)	Lab			1.22	1.24									1.18
		Potassium, Total (mg/L)	Lab			1.18	1.23									1.2
		Sodium, Dissolved (mg/L)	Lab			2.493	2.496									2.687
		Sodium, Total (mg/L)	Lab			2.42	2.54									2.57
		TDSwq (mg/L)	Lab			115	115									123
		Temperature (ºC)	Bench			2.5	1.9									2.9
			Lab			2.5	1.9									2.9
		TSScalc Total (mg/L)	Lab			23	25									19
		TSwv Total (mg/L)	Lab			138	140									142
		Turbidity (NTU)	Bench			0.62	0.65									0.1
			Lab			0.56	0.68									0.09
		Uranium, Dissolved (mg/L)	Lab	N/D at <0.0005		G/N	G/N									G/N
		Uranium, Total (mg/L)	Lab	N/D at <0.0006		G/N	G/N									G/N
		UVA @254nm, Unfiltered (/cm)	Bench			0.078	0.072									0.023
		UVT @ 254nm, Filtered (/cm)	Lab			91.3	93.9									94.4
		UVT @ 254nm, Unfiltered (%T)	Bench			83.6	84.8									94.8
		Zinc, Dissolved (mg/L)	Lab			0.001										
				N/D at <0.0009			G/N									G/N
		Zinc, Total (mg/L)	Lab				0.001									
				N/D at <0.0009		G/N										G/N

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter excludes DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

Piloting Results Database Summary - Pilot DAF Float Sludge Sample Only

Season: Winter #2
Phase: Piloting

Sample Date	System	Analysis	Source	General Notes (G/N)	Sample Location DAF Sludge
November 27, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		2280
		Temperature (ºC)	Lab		7.5
		TSSwv Total (mg/L)	Lab		2000
		TSwv Total (mg/L)	Lab		4280
December 6, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		92
		TSSwv Total (mg/L)	Lab		3750
		TSwv Total (mg/L)	Lab		3840
December 7, 2017	Pilot-Scale	TDScalc (mg/L)	Lab		246
		TSSwv Total (mg/L)	Lab		4000
		TSwv Total (mg/L)	Lab		4250

Average of Result broken down by Sample Location vs. Piloting_Season, Piloting_Phase, Sample Date, Treatment_System, System, Analysis, Data_Source, Source, General Notes (G/N) and General Notes. The view is filtered on Analysis, Sample Location, Piloting_Season, Piloting_Phase, General Notes and General Notes (G/N). The Analysis filter excludes TimeSpled (hrs). The Sample Location filter keeps DAF Sludge. The Piloting_Season filter keeps Winter #2. The Piloting_Phase filter keeps Piloting. The General Notes filter excludes Not analyzed. The General Notes (G/N) filter excludes No data.

APPENDIX

H

TM No. 8

REVIEW AND UPDATE OF FRONT END CHEMICAL DOSE PROCEDURE

TECHNICAL MEMORANDUM NO.8

PROJECT: Pilot Testing an Alternative Coagulant for the Winnipeg Water Treatment Plant

TO: Heather Buhler, City of Winnipeg

FROM: Maika Pellegrino (WSP), Justin Rak-Banville (WSP)

SUBJECT: Review and Update of Front End Chemical Dose Procedure (Document WI-OG-001) – Final

DATE: August 20, 2018

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1. OVERVIEW

Technical Memorandum No. 8 (TM No. 8) provides the content required to update the No. WI-OG-001 Rev. 1 - Front End Chemical Dose Procedure for the alternative coagulant, ferric sulphate ($Fe_2(SO_4)_3$). The existing guidance document WI-OG-001 Rev. 01 provides a primer intended to develop an early understanding of how modifying the existing coagulant, ferric chloride, and acid doses affect the plant's individual treatment processes. The general effects of temperature swings and transitions on the dose adjustments are described within. Furthermore, stepwise cursory cause and effect observations are provided for the raw water, flocculation chambers, DAF float, Post-DAF, ozone, filters, UV reactor, and disinfection by-products (DBPs).

2. REVISED WI-OG-001 FOR FERRIC SULPHATE:

1 Location

a WI: Raw Water Pumping Station at the Water Treatment Plant

2 Objectives

a Provide operating guidance on front end chemical dosing, which includes the adjustment of the ferric sulphate (coagulant) and sulphuric acid (acid) dosages.

b This is a general guideline based on available literature and the observations made using ferric sulphate and sulphuric acid in the pilot-scale plant between February 2017 and January 2018.

c A process change record is to be completed detailing the reasons for adjusting either the ferric sulphate or sulphuric acid dosages.

3 Warning

a All relevant safety procedures should be followed.

b Refer to relevant O&M documents, SWP, and others.

c Review SDS for ferric sulphate and sulphuric acid.

4 Personnel Qualifications

a Knowledge required for operating WTP and the concept of pH control.

b Experience in operating the WTP SCADA.

5 Discussion

a Decisions around quality of the treated water always prevail, in light of adjusting the front end chemical doses.

b The performance of the DAF process is primarily dependent on efficient chemical pre-treatment for the generation of stable flocs, in particular coagulant dose and pH. Particle destabilization is more important than floc size. Chemical dosing (coagulant and pH) is oftentimes more significant than the physical flocculation in achieving desired performance.

c An understanding of how ferric sulphate and sulphuric acid adjustments effect water chemistry will allow operators to make sensible pre-screening decisions and let him/her focus on optimizing the treatment process to achieve the treatment goals.

6 Hazards

a Consult the coagulant SDS for additional information.

b Consult sulphuric acid SDS for additional information.

c Refer to relevant O&M documents, SDS, SWP, and others.

7 Abbreviations

a DAF, dissolved air floatation

b DBPS, Deacon booster pumping station

c SDS, safety data sheet

d O&M, operation & maintenance

e SCADA, supervisory control and data acquisition

f SWP, safe work procedures

g UV, ultraviolet

h WTP, water treatment plant

8 Equipment and Supplies

a 93% sulphuric acid (typical)

b 12% (Fe^{3+}) ferric sulphate (typical)

9 Preparation

a Refer to relevant plant protocols.

10 Procedure

a Pilot-scale Plant Temperature and Dose Observations

The original water treatment plant design anticipated the use of the coagulant ferric chloride and sulphuric acid for pH adjustment. However, the ferric chloride was replaced by ferric sulphate as the coagulant. These two chemicals are dosed at the front end of the plant.

Temperature is known to affect flocculation and filter performance, specifically floc formation is slower at lower temperatures for ferric based coagulants. Whereas breakage, in terms of floc size reduction, is greater for higher temperatures, typically suggesting a weaker floc. It should be noted the transitional seasons are short, and can display characteristics from both extremes. Table 2-1 tabulates the findings from the alternative coagulant piloting testing program performed in 2017.

Table 2-1: Findings from the five sessions of the alternative coagulant piloting testing with ferric sulphate.

Water Quality Season	Cold Water (< 4ºC)	Cool Water (4 to 14 ºC)	Warm Water (> 14 ºC)	Cool Water (4 to 14 ºC)	Cold Water (< 4ºC)
Piloting Session Reference	Winter #1	Spring	Summer	Fall	Winter #2
Piloting Session Dates (2017)	March 15 to April 5	May 11 to May 31	July 24 to August 17	October 16 to October 31	November 17 to December 7
Temperature Range (°C)	2.8 - 4.2	11.0 - 14.0	21.1 - 23.1	4.0 - 11.4	1.3 - 2.4
Ferric Sulphate Optimal Dose (mg/L)	46.0	42.0	38.0	42.0	41.0
Sulphuric Acid Dose (mg/L)	42.2	26.2 – 30.0	34.0	26.0	42.0
Post-DAF Operating Target pH	No target	6.1	5.8	5.7	5.8
Coagulant-aid Optimal Dose (mg/L)	0.02	0.2	0.1	0.07	Not evaluated

During the above piloting sessions of ferric sulphate, coagulant doses ranging from 25 mg/L to 52 mg/L were investigated while varying the addition of sulphuric acid (and subsequently adjusting pH), and varying the doses of coagulant-aid Magnafloc LT-22S to the pilot DAF process.

Optimized dosing conditions were guided by the total manganese concentration, UV-absorbance at 254 nm, and turbidity. The following dose conditions (Table 2-2) were determined to be the optimal conditions resulting from the piloting efforts. Table 2-2 tabulates the coagulant dosages, sulphuric acid dosages, and subsequent target pH values.

Table 2-2: Optimal conditions for ferric sulphate under varying seasonal conditions.

Optimal Conditions	Cold Water (< 4ºC)	Cool Water (4 to 14 ºC)	Warm Water (> 14 ºC)
Ferric Sulphate Dose (mg/L)	41 - 46	42	38
Sulphuric Acid Dose (mg/L)	42	26 – 30	34
Post-DAF Operating Target pH	5.8	5.7 – 6.1	5.8

b Corrosion Considerations and the Effect on Water Quality

Internal corrosion can impact water quality, infrastructure performance, scaling, and re-equilibrium issues, inclusive of discolouration and taste and odour concerns. These problems are typically the result of corrosion of metal pipe surfaces, pipe solder, and plumbing fixtures or dissolution of existing pipe scales.

The degree of corrosion is determined primarily by the characteristics of various metals and water, and nature and duration in which the two are in contact with each other. Table 2-3 highlights some factors that can influence the corrosiveness of drinking water and selected corrosion indicators.

Table 2-3: Potential corrosion vectors and corrosion indicators.

Corrosion Vector	General Effects
pH	Lowering the pH generally accelerates corrosion. It should be noted that low pH induces chloride attack and spalling of concrete surfaces (due to concrete being a highly alkaline material). When process water in contact with the concrete surface of the plant is between a pH of 5.5 and 6.5, the water is aggressive to the integrity of the concrete, increasing porosity and subsequently impacting integrity.
Dissolved Oxygen	Higher rates of DO typically induces corrosion, particularly in ferrous and copper materials.
Alkalinity and Buffering Capacity	Low or insufficient alkalinity reduce the ability to buffer corrosion activities. Literature suggests that to benefit from corrosively buffering by alkalinity, a total alkalinity and calcium concentration should be at least 50 to 100 mg/L $CaCO_3$. In general, elevated concentration of alkalinity and calcium improve the water's capacity for corrosion retardation, yet too much can promote scale formation (alkalinity >200 mg/L $CaCO_3$).
Total Dissolved Solids and Conductivity	High concentrations of dissolved salts often increase conductivity and subsequently can stimulate corrosive tendencies.
Various Metals	The types of corrosion products present depends on the metals availability and their oxidation state. For example, copper can increase corrosion of downstream materials within distribution networks.
Chloride-to-Sulphate Mass Ratio (CSMR)	The magnitude of galvanic corrosion between lead and copper is largely governed by the relative concentration of chloride to sulphate. As such, the CSMR serves to explain this effect. A CSMR above 0.5 is considered to increase galvanic corrosion of lead solder connected to copper pipe, as evidenced by increased galvanic voltage measurements first detailed by Walker and Oliphant (1983)[1] and Gregory (1990)[2].
Langelier Saturation Index (LSI)	The LSI indicates scale or corrosion forming tendencies based on the hardness, alkalinity, dissolved solids, and pH of the water. The ideal index value is zero, indicative of a minimal tendency to form scale or be corrosive, whereas when greater than zero, the LSI suggests that scale will form, and less than zero indicates the water to be corrosive.
Ryznar Stability Index (RSI)	The RSI is used to consider pitting corrosion depth, as it is a measure of the amount of calcium carbonate in saturation compared to the actual amount present. Like the RSI, is used to calculate scale and corrosion tendencies in water and distribution networks. If the index is above 6, the indices suggest there is a tendency for pitting to occur.

Internal corrosion issues are typically associated with discoloured water problems[3]. The corrosion of cast-iron piping, including the dissolution of pre-existing scales within said piping can contribute a rust colour to the bulk water due to suspension of ferric iron (Fe^{3+}). Furthermore, under reduced dissolved oxygen concentrations (a low oxygen reduction potential, ORP), iron can contribute a yellow or black colour due to the presence of ferrous iron (Fe^{2+}). Equally, black and brown colours may also arise from the result of manganese (Mn^{4+}) found in manganese dioxide, whereas corrosion of galvanized piping can produce a turbid milky appearance from zinc (Zn^{2+}) found in zinc hydroxide.

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[1] Walker, R. and Oliphant, R., 1983. A cell to study corrosion of materials in the water industry. *Jour. Water Engrs and Scientists*, *32*(2), pp.143-150.

[2] Gregory, R., 1990. Galvanic corrosion of lead solder in copper pipework. *Water and Environment Journal*, *4*(2), pp.112-118.

[3] Kirmeyer, G. J. (2000). Guidance manual for maintaining distribution system water quality. American Water Works Association.

Internal corrosion contributes to the suspension and transport of loose small corrosion deposits. This concept is intensified from changes arising in the magnitude or the direction of flow, serving to release various metal ions at the surface, followed by the subsequent oxidation of these metals and precipitation into the bulk water contributing to colour. As such, ample literature [4,5,6] and a 2015 third party review of discoloured water complaints recommend preventing internal corrosion in order to reduce the propensity for discoloured water.

Throughout the alternative coagulant piloting testing in 2017, ferric sulphate doses ranged between 38 to 46 mg/L with sulphuric acid doses between 26 to 42 mg/L on optimal testing days giving rise to a CSMR consistently of 0.03 in the filtrate. Increasing either the coagulant or sulphuric acid dose reduces the CSMR (due to increasing sulphate content). The formulation of both coagulant and acid result in lower CSMR, further reducing the risk of lead corrosion observed when CSMR value is above of 0.5.

Regarding the LSI, RSI and alkalinity values, reducing the pH with the addition of sulphuric acid will also reduce the alkalinity. Further worsening this, is the addition of ferric sulphate, for each milligram per litre used, 0.53 mg/L of alkalinity is consumed. This ratio is based the following equation:

$$Fe_2SO_4 + 9H_2O + 3Ca(HCO_3)_2 \rightarrow 2Fe(OH)_3 + 3CaSO_4 + 6CO_2 + 9H_2O$$

Given this relationship, as a rule of thumb, some literature suggests[7] that half the alkalinity of the amount of ferric sulphate coagulant dose be present when adding the coagulant. For example, if a dose of 60 mg/L of ferric sulphate is needed, then the alkalinity must be at least 30 mg/L $CaCO_3$. At minimum, a concentration of 20 to 30 mg/L $CaCO_3$ of alkalinity should remain after coagulation. The adjustment of ferric sulphate and sulfuric acid doses and their subsequent effect on select corrosion indices is tabulated in Table 2-4.

Table 2-4: Effects of chemical dose adjustments on corrosion indicators.

Parameter	Relationship to $Fe_2(SO_4)_3$ Dose	Relationship to H_2SO_4 Dose
CSMR	Inversely related. As dose is reduced, the CSMR increases	Inversely related. As dose is reduced, the CSMR increases
LSI	Inversely related. As dose is reduced, the LSI increases	Inversely related. As dose is reduced, the LSI increases
RSI	Inversely related. As dose is reduced, the RSI increase	Inversely related. As dose is reduced, the RSI increases
Alkalinity	Inversely related. As dose is reduced, the alkalinity increases	Inversely related. As dose is reduced, the alkalinity increases
pH	Inversely related. As dose is reduced, the pH increases	Inversely related. As dose is reduced, the pH increases

c Dose Changes and Subsequent Verification of Results

The following sections provide an outline of possible response factors for operator consideration should there be a front end chemical dose adjustment or change. When reviewing this information, operators are reminded of the lag time which exists when the change starts, and when the response is observed within the plant's various processes. Between three to four hours pass from when raw water enters the plant and when it finally leaves as treated water. As a result of this lead and lag timeframe, several hours are needed to verify the conditions described in the following sections from the initial dose change.

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[4] Vreeburg, I. J., & Boxall, J. B. (2007). Discolouration in potable water distribution systems: A review. Water research, 41(3), 519-529.

[5] Boxall, J. B., and A. J. Saul. "Modeling discoloration in potable water distribution systems." *Journal of Environmental Engineering* 131.5 (2005): 716-725.

[6] Vreeburg, Joannes Henricus Gerardus. "Discolouration in drinking water systems: a particular approach." Delft University of Technology, Delft, The Netherlands (2007).

[7] Engelhardt, T.L. (2010). Coagulation, Flocculation and Clarification of Drinking Water. Drinking water sector, Hach Company

i Raw Water

Figure 2-1 summarizes the daily temperatures recorded from the full-scale WTP SCADA (tags TT_I011A and TT_I012A) on a monthly average basis during the alternative coagulant piloting testing from February 2017 to January 2018. In addition, monthly average raw water turbidity measurements are illustrated.

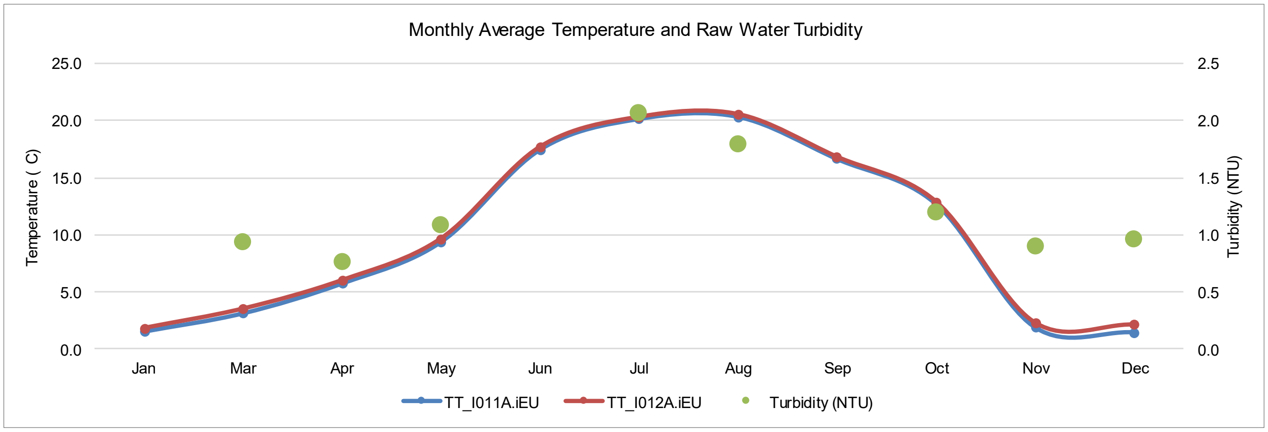


Figure 2-1: Monthly average raw water temperatures as recorded by full-scale SCADA system (Train 1, TT_I011A.iEU, in blue and Train 2, TT_I012A.iEU, in red) and monthly average raw water turbidity levels (in green) during ferric sulphate piloting as measured by a Hach 2100Q turbidimeter.

This figure demonstrates that the raw water being fed into the plant from the Deacon reservoirs experiences a great deal of change throughout the seasons, primarily identifiable by the increases or decreases in raw water temperature, subsequently observable as changes in water quality (i.e. turbidity). It should be noted that temperature changes can also be observed throughout the day, especially in spring and in summer.

Table 2- tabulates key parameters for consideration when adjusting the chemical feed dosage in regard to the incoming raw water conditions. It should be noted that these observations are highly simplified, and that the raw water can change, further complicating the application of the general observation tabulated below.

Table 2-5: Effects of coagulant and acid dose adjustments based on raw water condition.

Raw Water Parameter	Relationship to $Fe_2(SO_4)_3$ Dose	Relationship to H_2SO_4 Dose
Online Temperature	Inversely related. As temperature increases, the dose is reduced	Inversely related. As temperature increases, the dose is reduced
Online pH	pH adjustment to be controlled by the acid dose for coagulant pH target	Directly related. As pH increases, the dose is increased
Online Turbidity	Directly related. As turbidity increases, the dose is increased	Directly related. As turbidity increases, the dose is increased
UVT **(Tested every 12 hr)**	Directly related. As UVT increases, the dose is increased	Inversely related. As UVT decreases, the dose is increased

ii Coagulation and Flocculation

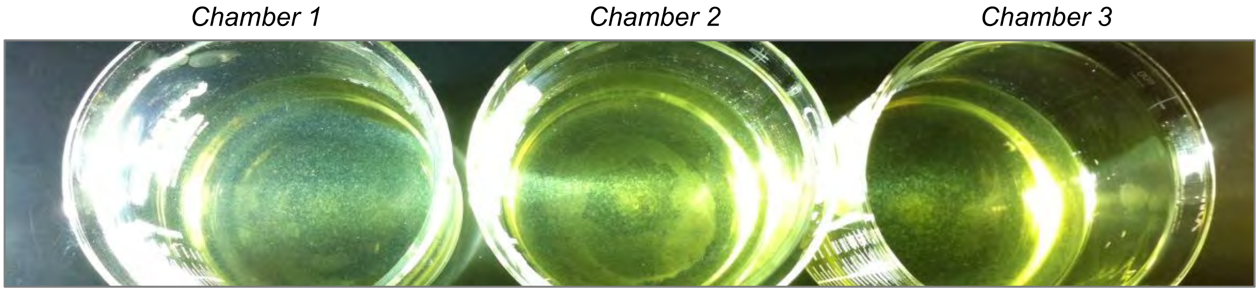
Coagulation and flocculation occurs in successive steps, allowing particle collision and growth of floc. If coagulation is incomplete, flocculation step will be unsuccessful, and if flocculation is incomplete, suspended solids removal will be unsuccessful. Improvement on their effectiveness and efficiency will provide a significant influence on the overall process.

Flocculation is a gentle mixing step utilized to increase the particle size from submicroscopic micro-floc to visible suspended particles by inducing collisions which bind particles together and producing larger visible flocs (i.e. pin-flocs). Floc sizes can continue to increase with additional collisions and the adding of polymers or coagulant-aids (such as Magnafloc LT-22S), leading to macro-flocs through bridging, binding, and strengthening of the floc.

Figure 2-2 and Figure 2-3 illustrate a visual inspection of flocculation chambers demonstrating growth to the formation of visible suspended particles. Successful flocculation occurs in successive steps. First is the initial mixing stage to increase particle sizes from submicroscopic floc to visible suspended particles (Chamber 1). The second step is the result of the microfloc particle collisions, causing them to bond to produce larger, visible flocs called pinflocs (Chamber 2). Lastly, once the pinflocs are formed, their removal from the bulk volume is needed and achieved through the introduction of a highly saturated pressurized stream of air lifting the pinflocs and other suspended particulate matter to the surface of the DAF chamber (ultimately forming the DAF float). However similar the samples may appear in Figure 2-3, the objective is to demonstrate the initial appearance of the pinfloc (Chamber 1) and the macroscopic agglomeration of the floc (Chamber 2) and the eventual suspension in solution (Chamber 3).

Chamber 1 *Chamber 2* *Chamber 3*

Figure 2-2: Typical particle settling by flocculation chambers, chambers 1 to 3, from left to right.



Chamber 1 *Chamber 2* *Chamber 3*

Figure 2-3: Samples taken from each flocculation chamber, chambers 1 to 3, from left to right.

Observable flocculation is variable dependent upon seasons, water temperatures, water quality (turbidity, organics, etc.), among other influences. Small samples were collected from each flocculation chamber and placed into individual beakers. Figure 2-2 and Figure 2-3 above exhibits the typical particle suspension pattern and subsequent progression of solids separation for each chamber. The samples were acquired during the month of June when the water temperature was approximately 18ºC.

As noted above, the amount of floc collisions significantly impacts the efficacy of flocculation. With changes in raw water quality, such as increases in turbidity, organic carbon, temperature, pH, and the subsequent adjustment to the ferric sulphate coagulant dose, the need to re-evaluate floc formation arises. As such, mixer speeds can be increased to decrease the floc size as desired to optimize this process.

iii DAF Basin

Floated matter, referred to as the DAF "float" is created by the release of micro-bubbles which adhere to suspended matter, causing it to float and concentrate at the water's surface. Figure 2-4 details the float at various locations of the DAF process. This float ultimately becomes the waste stream, specifically a sludge for disposal.

Figure 2-4: Visual inspection of a DAF basin top.

Because the sludge concentration in a DAF system is dependent upon the interaction between the rising air bubbles and the floc particles, on a routine and continuous basis, operators observe the DAF float for its colour, consistency, and apparent thickness. It should be noted that these are qualitative and subjective observations which are to be considered in conjunction with empirical data collected from other processes within plant. As such, the float is affected by season, water temperature, organics levels, and other quality parameters. Throughout an operating shift, observations of the float help to guide the front end chemical dose as follows.

Table 2- tabulates the relationship of key DAF float parameters and the subsequent ferric sulphate and sulfuric acid dose interpretation.

Table 2-6: DAF float observations and the subsequent chemical dose interpretation.

Float Parameter	Relationship to $Fe_2(SO_4)_3$ Dose	Relationship to H_2SO_4 Dose
Float Colour	Directly related. As a dark colour increases, the dose is high	pH adjustment to be controlled by the acid dose for coagulant pH target
Float Consistency	Directly related. As binding increases, the dose high	Inversely related. As binding increases, the dose is low
Float Thickness	Directly related. As thickness increases, the dose is high	pH adjustment to be controlled by the acid dose for coagulant pH target

The DAF process is controlled by the selection of either the small or large diameter air saturated recycle streams. These streams are designed to provide the same volumetric air requirement, under differing recycle ratios and/or temperatures. Typically, in the cold-water season, the small diameter recycle stream is selected and in the warm-water season, the large diameter recycle stream is selected. As well, the speed of skimmers can be adjusted as required to remove the waste stream effectively.

Table 2-7 tabulates the general relationship of key Post-DAF effluent water quality parameters and the interpretation of ferric sulphate and sulfuric acid doses.

Table 2-7: Post-DAF effluent quality observation and chemical dose adjustment interpretation.

Post-DAF Effluent Parameter	Relationship to $Fe_2(SO_4)_3$ Dose	Relationship to H_2SO_4 Dose
Online pH and Laboratory pH	Directly related. A high pH, increase the dose	Directly related. A high pH, increase the dose
Online Turbidity	Directly related. A high turbidity, increase the dose	Inversely related. A high turbidity, reduce the dose
Online UVT and Laboratory UVT	Directly related. A high UVT, increase the dose	Inversely related. A high UVT, reduce the dose
Total Iron Concentration (Tested every 12 hours and after coagulant dose changes)	Inversely related. A high iron content, reduce the dose	Inversely related. A high iron content, reduce the dose

iv Ozone

No significant relationship was observed between ferric sulphate dose adjustments and ozonation during the alternative coagulant piloting testing in 2017. As such, with respect to the front end chemical dose, the ozonation parameters are not generally of strong consideration.

v Filtration

Filtration is used to remove suspended particles not removed by the DAF process. During filtration, most of the suspended particles are removed in the top portion of the filter media. The full-scale plant backwashes on a time basis, to dislodge and remove particles trapped within the filter bed, to reduce head loss (pressure build up), and to keep the filter media clean.

The filter run time describes the length of time between filter backwashes during which a filter is in production mode. The filter run time is not only an indicator of the effectiveness of prior treatment (for example, the ability of the coagulation and clarification steps to remove suspended solids), but contributes to the general efficiency of the filter itself. Filter performance, particularly with regards to particulate contaminants, is often poorest immediately following a backwash. As the filter run time increases and the concentration of suspended particles and solids in the media increases, the filtration process often performs better with regards to particulate contaminant removal.

The clarity of the water above the filter media is an indication of successful combination upstream treatment processes (Figure 2-5). The dynamic nature of the treatment process calls upon an operator's training, judgement, and experience in troubleshooting chemical dosing adjustment.

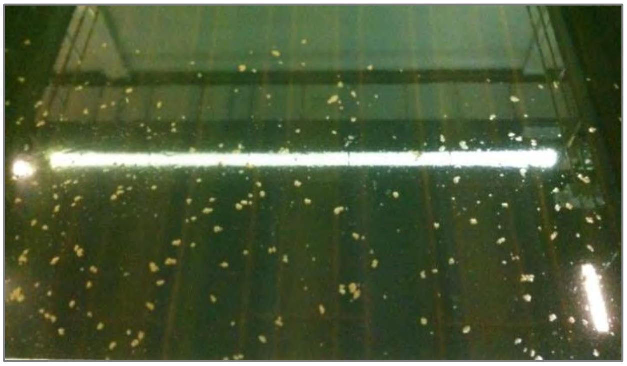


Figure 2-5: Visual inspection of a filter top. Note the solids on the water surface are not a concern.

Should adjustment of dosing conditions not resolve these concerns, it is prudent to review the maintenance aspects of the elements in the upstream DAF system, and that maintenance is conducted in accordance with the manufacturer's recommendations, or more frequently where actual experience shows it to be necessary.

Table 2- tabulates the relationship of the key parameters in regard to the filtration system operation to help guide the chemical doses because the quality of the filter effluent is largely governed by the efficacy of the upstream processes, including the ferric sulphate and sulfuric acid dosages (i.e. the dosages guide the filter effluent quality).

Table 2-8: Effect of chemical dose adjustments on filtration.

Post-DAF Effluent Parameter	Relationship to $Fe_2(SO_4)_3$ Dose	Relationship to H_2SO_4 Dose
Online Filter Effluent Turbidity	Directly related. High turbidity, increase the dose	Directly related. As turbidity increases, increase the dose
Online Filter Effluent Particle Counts	Directly related. High total particles counts, increase the dose	Inversely related. High total particles counts, reduce the dose
Observed Headloss	Inversely related. Large headloss, reduce the dose	Inversely related. Large headloss, reduce the dose
Observed UFRV	Directly related. Low UFRV, reduce the dose	Inversely related. Low UFRV, increase the dose
Observed Run Time	Directly related. Short run time, reduce the dose	Inversely related. Short run time, increase the dose
Observed Filter Flows	Inversely related. Low filter flows, reduce the dose	Inversely related. Low filter flows, increase the dose

vi Ultraviolet Disinfection

Historic records correlated an increase in the need for UV reactor cleaning with the transitional seasons, specifically those seasons associated with a rapid increase or decrease in temperature. In response to these rapid changes during the transitional seasons, the front end chemical doses are adjusted in response to varying water quality conditions.

These cleanings have now been integrated into scheduled maintenance routines and are performed on a scheduled basis regardless of the amount of cleaning generated by dose adjustment and system operation. As such, the front end chemical doses do not significantly influence the UV cleaning routine, the UV reactor run time, or the ability to meet the required UV dose.

vii Deacon Booster Pumping Station

Table 2- tabulates the relationship of the key parameters in regard to the Deacon Booster Pumping Station (DBPS) to help guide the chemical doses.

Table 2-9: Effect of chemical dose adjustments on finished water.

DBPS Parameter	Relationship to $Fe_2(SO_4)_3$ Dose	Relationship to H_2SO_4 Dose
Online UVT and UVT tested every 12 hours and after chemical dose changes	Directly related. As UVT increases, increase the dose	Inversely related. As UVT increases, reduce the dose
Iron concentration as tested every 12 hours and after dose changes	Inversely related. As iron content increases, reduce the dose	Directly related. As iron content increases, increase the dose

viii Chlorination and Disinfection By-Products

Disinfection by-products is a term used to describe a group of organic and inorganic compounds formed during the disinfection, typically using hypochlorite. These by-products are largely formed by the reactions between disinfectants (i.e. chlorination) and natural organic matter (NOM) in water. Accordingly, there is a relationship between coagulant dose at the front end, their effect on the removal of NOM, and the subsequent potential to form these disinfection by-products. However, this relationship is complicated and can be influenced by a large amount of process interaction (NOM removal efficiencies), thermodynamics (temperature, redox conditions, etc.), and water quality (availability of specific molecules and dose of disinfectant). UVT can serve as a continuous surrogate measurement for NOM, and thus the relationship between UVT and coagulant dose can be interpreted. Table 2- tabulates the relationship of coagulant dose and UVT.

11 Facility Equipment/Parts Numbers

a None applicable

12 Related Procedures

a For reference, this document has been adapted from WI-OG-001 Rev. 1, May 13, 2015.

13 Environmental

a None applicable.

14 References

Boxall, J. B., and A. J. Saul. "Modeling discolouration in potable water distribution systems." Journal of Environmental Engineering 131.5 (2005): 716-725.

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Water Treatment Plant Operations Manual.

APPENDIX

I

DAILY PILOTING DATASET

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, March 15, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.63	443.1	196.8	10.40	0.010	69.3	0.160	0.84		
Post-DAF	5.93	372.3	222.7	10.70	0.007	74.0	0.129	1.46		
Post-Ozone	5.97	445.5	229.6	10.40	0.012	75.6	0.123	2.18		
Filter 1	6.09	407.3	1308	9.40	0.015	11.2	0.949	1.01		
Filter 2	6.16	442.3	239.9	10.40	0.014	91.8	0.037	0.20		
Filter 3	6.15	443.1	253.8	10.40	0.015	82.0	0.036	0.96		
Filter 4	6.13	455.9	235.1	10.40	0.009	93.7	0.028	0.61		
Filter 5	6.06	453.1	249.8	10.50	0.012	92.4	0.034	0.69		
Filter 6	6.07	455.8	234.9	10.50	0.016	95.8	0.028	0.26		
Filter 7	6.06	457.4	234.6	10.30	0.021	93.9	0.027	0.94		
Filter 8	6.03	474.2	245.2	10.60	0.012	93.8	0.028	0.34		
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Mid-testing per schedule; standard backwashing procedures: 10 min air, 5 min air and water, 10 min water.
- Sampling started at 13:23hrs.
- All bench top instruments calibrated at time of sampling.
- Filter 1 DO sample shaken causing drop in DO, lower than it should be.
- UVT Filter 1 is very low but visually did not look turbid or cloudy.
-No Ozone online

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, March 16, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.66	300.5	206.5	10.90	0.011	69.1	0.161	0.95	14:29	4.3
Post-DAF	5.92	250.6	228.0	12.10	0.015	77.7	0.109	1.65	14:28	4.8
Post-Ozone	5.95	293.0	259.1	12.40	0.018	77.3	0.112	1.43	14:29	5.2
Filter 1	6.12	320.2	210.4	10.90	0.012	94.5	0.024	0.44	14:27	6.0
Filter 2	6.08	344.8	210.1	10.70	0.013	94.5	0.025	0.98	14:26	6.0
Filter 3	6.09	345.9	211.4	10.70	0.016	94.7	0.026	0.17	14:26	5.9
Filter 4	6.09	345.8	209.7	10.60	0.010	94.5	0.024	0.19	14:25	6.1
Filter 5	5.99	345.9	215.3	11.40	0.008	94.5	0.025	0.36	14:26	5.9
Filter 6	6.07	356.0	213.7	10.80	0.009	94.6	0.024	0.16	14:23	5.9
Filter 7	6.02	354.3	213.0	11.20	0.013	94.8	0.023	0.21	14:23	6.1
Filter 8	5.99	352.7	213.0	11.00	0.014	93.8	0.028	0.88	14:22	6.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
-At 10:10hrs second ozone pump was brought online.
-After backwashing flows ran at 0.15 L/s for 30 mins, prior to 0.3 and 0.6 L/s per train. Began altered backwash times per AHA document.
-10:30hrs when ramping up Filter bank B to 0.6 L/s, observed slug of ferric at top of filters. Has slowed moved down and dissipated.
-Ozone operating 29%, 185W.
-Ozone just above 0 mg/L is now online

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, March 17, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.71	251.8	164.1	9.30	0.015	68.5	0.164	1.74	14:15	5.9
Post-DAF	5.93	258.9	202	10.60	0.019	71.0	0.149	1.54	14:16	5.4
Post-Ozone	5.92	281.1	200.7	11.30	0.016	71.3	0.147	1.77	14:16	5.4
Filter 1	6.09	289.9	204	10.00	0.013	92.8	0.033	0.23	14:20	6.3
Filter 2	6.03	300.6	211.8	11.10	0.012	92.8	0.032	0.40	14:22	6.5
Filter 3	6.01	308.5	211.9	10.70	0.012	93.3	0.030	0.46	14:22	6.5
Filter 4	6.01	316.7	203.9	10.90	0.014	93.5	0.029	0.22	14:21	5.9
Filter 5	5.96	325.7	203.6	10.70	0.014	92.5	0.032	0.39	14:21	6.3
Filter 6	5.94	329.9	210	11.30	0.012	93.5	0.029	0.38	14:22	6.4
Filter 7	5.96	331.4	205.3	11.30	0.014	93.1	0.031	0.21	14:22	6.2
Filter 8	5.95	334	201.6	10.80	0.023	93.2	0.031	0.62	14:22	6.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
-Today samples were taken yesterday afternoon to accommodate Analytical Service submission.
-Ozone at 29%, 185W
-Both Rosemount turbidimeters on the combined filter effluents were dissembled and cleaned in the PM.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Saturday, March 18, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.71	278.7	188.3	10.60	0.013	70.8	0.150	1.770	14:00	4.9
Post-DAF	5.98	277.7	205.4	10.60	0.018	72.5	0.141	1.640	14:00	4.3
Post-Ozone	5.92	356.2	206.5	11.10	0.016	73.7	0.133	1.700	14:01	5.3
Filter 1	6.06	350.2	214.8	11.60	0.009	96.4	0.016	0.160	14:02	6.0
Filter 2	6.04	350.5	212.0	11.30	0.011	95.2	0.021	0.160	14:02	5.9
Filter 3	6.06	347.4	209.7	11.20	0.009	95.2	0.021	0.150	14:03	6.0
Filter 4	6.04	346.9	208.1	11.60	0.011	95.3	0.021	0.120	14:03	6.0
Filter 5	5.96	350.1	223.0	11.90	0.011	95.3	0.021	0.110	14:03	5.8
Filter 6	6.00	348.6	211.3	11.30	0.012	95.0	0.023	0.090	14:03	5.7
Filter 7	5.97	346.9	210.4	11.40	0.010	94.9	0.022	0.110	14:04	5.7
Filter 8	5.95	339.6	213.0	11.40	0.013	94.6	0.024	0.110	14:04	5.7
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
-Polymer dose in DAF was observed to be empty in the morning.
-Right ozone rotameter had small bubbles in it.
-Right rotameter sweating (not normally observed).
-Raw flow appeared to have slightly increased to 3.3 L/s, was turned down closer to 3L/s.
-Ozone at 31%, 189W

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, March 19, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.78	300.8	172.6	10.50	0.011	69.5	0.158	1.30	13:45	4.2
Post-DAF	5.93	264.8	204.3	10.70	0.021	75.7	0.119	1.20	13:45	4.1
Post-Ozone	5.91	304.5	204.4	11.70	0.020	75.9	0.120	1.38	13:47	4.9
Filter 1	6.06	318.8	213.4	10.70	0.012	94.8	0.023	0.14	13:49	5.7
Filter 2	6.05	326.2	211.1	10.50	0.017	94.8	0.023	0.15	13:49	5.8
Filter 3	6.07	328.4	203.5	10.00	0.012	94.6	0.024	0.13	13:50	5.7
Filter 4	6.05	331.3	204.2	10.00	0.012	94.5	0.025	0.14	13:51	5.8
Filter 5	6.04	335.4	207.2	10.30	0.012	93.7	0.029	0.13	13:52	5.7
Filter 6	5.99	340.9	208.7	10.40	0.014	93.0	0.032	0.13	13:52	5.6
Filter 7	6.01	336.8	207.4	10.00	0.013	93.1	0.031	0.14	13:53	5.6
Filter 8	5.98	342.6	209.4	10.60	0.013	92.9	0.033	0.10	13:54	5.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
-Right ozone rotameter had small bubbles in it.
-Right rotameter sweating (not normally observed).
-Ozone at 31%, 189W
-Polymer remained filled overnight.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, March 20, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.70	230	174.8	10.90	0.014	68.5	0.164	1.11	13:58	5.2
Post-DAF	6.14	242.6	203.4	10.80	0.018	59.4	0.226	2.31	13:58	5.4
Post-Ozone	6.18	326	201.2	10.60	0.018	66.8	0.176	2.11	13:59	5.4
Filter 1	6.07	320.6	208.4	10.60	0.011	93.1	0.031	0.14	13:59	6.0
Filter 2	6.05	317.8	207.6	10.80	0.015	93.1	0.031	0.15	14:00	6.1
Filter 3	6.02	311.3	211.1	11.20	0.015	93.2	0.031	0.14	14:00	6.1
Filter 4	6.02	319.9	207.6	10.60	0.011	93.1	0.031	0.12	14:01	6.1
Filter 5	6.02	313.1	208.8	10.90	0.013	92.8	0.032	0.16	14:01	6.1
Filter 6	5.98	306.3	211.5	11.60	0.013	93.0	0.032	0.10	14:02	6.1
Filter 7	6.02	299.2	207.4	11.10	0.012	92.9	0.032	0.10	14:02	6.0
Filter 8	5.96	283.5	208.6	10.60	0.014	92.8	0.033	0.1	14:02	6.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
-Right ozone rotameter had small bubbles in it.
-Right rotameter sweating (not normally observed).
-Coagulant drum was swapped in the PM. This may explain why there is a unusual reduced UVT observed Post-DAF.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, March 21, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.79	263.2	185.6	10.10	0.013	68.0	0.168	0.67	13:29	5.9
Post-DAF	5.91	245.8	202.1	10.90	0.017	73.0	0.138	1.55	13:29	4.9
Post-Ozone	5.9	293.5	204.3	11.90	0.019	74.4	0.128	1.67	13:30	5.7
Filter 1	6.1	300.4	207	10.80	0.011	93.0	0.032	0.28	13:31	3.1
Filter 2	6.12	308.8	205.2	1.80	0.011	93.1	0.031	0.12	13:31	3.1
Filter 3	6.06	321.1	207.5	10.90	0.014	92.6	0.034	0.15	13:32	3.0
Filter 4	6.04	326.4	207.4	10.90	0.016	93.3	0.030	0.12	13:32	6.2
Filter 5	5.99	333.6	207.4	10.90	0.017	92.3	0.035	0.17	13:33	5.7
Filter 6	5.94	340	207.6	10.60	0.014	92.6	0.033	0.15	13:33	5.8
Filter 7	6.01	333.1	215.7	10.90	0.013	92.3	0.035	0.15	13:33	5.9
Filter 8	5.98	328	208.3	10.70	0.013	92.4	0.035	0.20	13:33	5.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Ozone 31%, 193W
-Sulfuric acid barrel changed out in the PM.
-Right rotameter has some bubbles.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, March 22, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.80	307.4	169.1	10.70	0.017	70.0	0.155	0.86	13:37	6.2
Post-DAF	5.92	251.6	203.0	10.50	0.023	76.1	0.118	1.36	13:37	5.8
Post-Ozone	5.88	288.7	206.2	10.90	0.025	75.8	0.121	1.72	13:38	7.2
Filter 1	6.09	301.4	213.1	11.10	0.016	94.8	0.023	0.10	13:44	6.5
Filter 2	6.03	305.0	211.9	11.60	0.015	95.8	0.019	0.09	13:44	6.4
Filter 3	6.09	307.7	211.8	11.30	0.016	95.0	0.022	0.09	13:43	6.6
Filter 4	6.06	313.3	210.9	11.50	0.015	95.5	0.020	0.13	13:43	6.5
Filter 5	5.95	317.3	216.0	11.80	0.012	95.5	0.020	0.08	13:40	6.1
Filter 6	5.93	321.9	215.3	11.80	0.012	94.7	0.024	0.10	13:40	6.5
Filter 7	5.96	325.1	215.6	11.80	0.016	95.2	0.021	0.13	13:40	6.7
Filter 8	5.96	327.3	212.7	10.70	0.012	95.7	0.019	0.11	13:40	6.7
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Ozone rotameter has visible bubbles.
- Full sample set for lab collected today.
- Ozone at 31%, 189W.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, March 23, 2017
Season: Winter

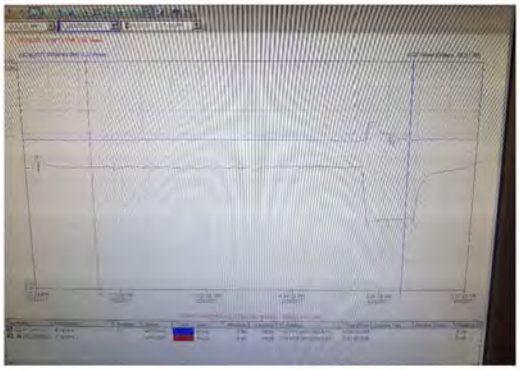
	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.86	215.0	173.3	11.30	0.016	69.0	0.161	0.68	14:38	5.6
Post-DAF	5.98	253.5	203.1	10.40	0.024	73.1	0.138	1.09	14:40	6.0
Post-Ozone	5.95	369.8	204.4	11.40	0.022	73.4	0.130	1.67	14:41	6.0
Filter 1	6.10	364.3	203.0	10.80	0.014	93.7	0.028	0.15	14:45	6.5
Filter 2	6.10	363.9	172.2	10.90	0.017	92.9	0.032	0.15	14:46	6.6
Filter 3	6.07	367.7	194.0	10.40	0.016	93.5	0.029	0.14	14:47	6.6
Filter 4	6.05	338.6	197.3	10.80	0.016	93.4	0.030	0.12	14:48	6.7
Filter 5	6.00	334.8	158.9	10.90	0.016	93.2	0.031	0.11	14:49	6.3
Filter 6	5.95	329.6	199.2	10.50	0.014	93.2	0.030	0.11	14:50	6.3
Filter 7	5.95	327.7	220.4	11.10	0.015	93.8	0.032	0.17	14:51	6.3
Filter 8	5.98	321.0	204.8	11.70	0.012	93.0	0.032	0.09	14:52	6.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Ozone at 29%, 189W
- Last day of AHA modified backwashing.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, March 24, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw					0.008	68.5	0.164	0.75	13:50	6.0
Post-DAF					0.014	75.5	0.121	1.16	13:50	5.6
Post-Ozone					0.014	74.1	0.130	1.81	13:51	5.9
Filter 1					0.013	94.1	0.028	0.08	13:50	6.3
Filter 2					0.013	93.0	0.031	0.09	13:50	6.6
Filter 3					0.014	93.0	0.028	0.09	13:53	6.5
Filter 4					0.013	88.0	0.055	0.12	13:53	6.6
Filter 5					0.010	93.0	0.032	0.15	13:54	6.3
Filter 6					0.018	93.2	0.038	0.15	13:54	6.2
Filter 7					0.013	90.8	0.034	0.08	13:55	6.2
Filter 8					0.013	92.0	0.036	0.09	13:55	6.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- First day of coagulant dose variation. Coagulant dose reduced to 34 mg/L after sampling.
- Particle counters were calibrated today by Hach. Hach rep noted previous calibration was poor.
- Main plant shut down occurred between 7:30-8:00 am, as a result flow stopped to the pilot. This caused the pH to drop and the DO and coagulant concentration to rise. Samples did not show proper values. pH/ORP/Conductivity/DO were not sampled, they were erroneous.
- Ozone at 29%, 189W.



Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Saturday, March 25, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.81	237.2	176	10.90	0.011	70.7	0.150	0.80	13:33	5.7
Post-DAF	6.05	276.7	211.6	11.40	0.021	71.0	0.148	1.22	13:34	5.2
Post-Ozone	6.06	376.2	210.3	11.90	0.014	73.2	0.134	1.35	13:36	5.7
Filter 1	6.10	376.2	206.4	11.20	0.007	92.7	0.033	0.22	13:37	6.4
Filter 2	6.09	376	207.5	11.10	0.009	92.5	0.034	0.20	13:37	6.5
Filter 3	6.08	375.7	207.4	11.20	0.009	92.7	0.033	0.23	13:38	6.5
Filter 4	6.05	375	209	11.00	0.009	92.6	0.034	0.18	13:38	6.5
Filter 5	6.02	373.8	209.7	11.40	0.010	93.0	0.032	0.13	13:40	6.3
Filter 6	6.07	374.3	211.4	11.60	0.010	92.8	0.032	0.14	13:40	6.2
Filter 7	6.04	376.2	209.5	11.40	0.010	92.7	0.033	0.18	13:42	6.2
Filter 8	6.00	369.8	199.4	11.60	0.009	92.3	0.035	0.16	13:42	6.2
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Coagulant dose remains at 34 mg/L
- Poly 0.01 mg/L
- Standard backwashing cycle, 10-5-10
- Ozone 29%, 191W

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, March 26, 2017
Season: Winter

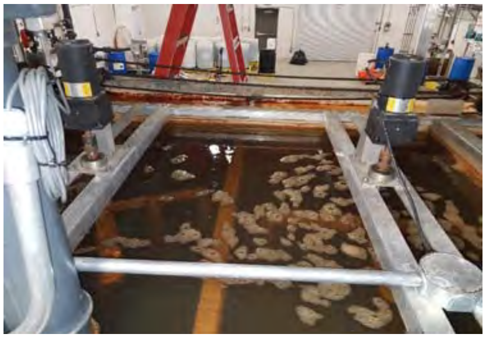
	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.81	248.4	175.3	11.00	0.007	69.0	0.162	0.74	13:30	5.6
Post-DAF	6.03	283.5	207.1	11.30	0.014	70.7	0.151	1.21	13:30	4.9
Post-Ozone	6.04	348.5	203.9	11.30	0.015	72.3	0.141	1.36	13:32	5.6
Filter 1	6.17	339.7	204.8	11.10	0.008	91.0	0.041	0.26	13:33	6.5
Filter 2	6.16	338.7	205.6	11.10	0.007	91.4	0.039	0.25	13:33	6.6
Filter 3	6.15	337.6	207.6	11.30	0.009	91.3	0.039	0.24	13:34	6.7
Filter 4	6.12	330.1	207.8	11.50	0.008	91.1	0.040	0.28	13:34	6.6
Filter 5	6.08	329.0	206.5	11.40	0.009	92.1	0.036	0.13	13:35	6.5
Filter 6	6.07	324.2	211	11.60	0.008	92.7	0.033	0.13	13:35	6.4
Filter 7	6.08	316.4	210.3	11.30	0.008	92.4	0.034	0.14	13:37	6.4
Filter 8	6.08	306.8	200.7	11.70	0.009	92.4	0.034	0.14	13:38	6.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Coagulant dose remains at 34 mg/L
- Poly 0.01 mg/L
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s (B seems better based on UVT, abs, and turb)
- Ozone rotameter still has bubbles. Ozone operating at 29%, 191W
- Coagulant dose increased to 38 mg/L after sampling at 3pm.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, March 27, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.82	321.3	167.1	10.00	0.011	67.3	0.172	0.73	13:51	5.7
Post-DAF	5.97	258.8	209.3	10.70	0.017	72.1	0.143	1.22	13:52	5.4
Post-Ozone	5.93	286.5	208.4	11.40	0.020	74.8	0.127	1.42	13:53	5.8
Filter 1	6.15	288.4	210.3	10.40	0.012	92.0	0.036	0.28	13:51	6.5
Filter 2	6.13	295.8	255.5	10.30	0.011	92.0	0.036	0.22	22:11	6.4
Filter 3	6.11	297.8	209.4	10.70	0.008	92.3	0.035	0.21	13:52	6.7
Filter 4	6.09	302.8	206.7	10.20	0.011	91.6	0.038	0.32	13:52	6.9
Filter 5	6.02	310.5	205.2	10.60	0.008	92.6	0.033	0.25	13:54	6.7
Filter 6	5.96	313	208.4	10.80	0.009	93.1	0.031	0.13	13:54	6.6
Filter 7	6.03	316.7	207.2	10.60	0.010	93.3	0.030	0.17	13:55	6.5
Filter 8	5.98	317.8	208.3	10.10	0.010	93.0	0.031	0.11	13:55	6.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Coagulant dose remains at 38 mg/L
- Poly 0.01 mg/L
- Standard backwashing cycle, 10-5-10
- Bank A: 0.289L/s, Bank B: 0.564L/s (Jeff reduced because ozone break tank was getting low) (B appears to be operating better)
- Ozone rotameter still has bubbles. Ozone operating at 29%, 189W



Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, March 28, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.69	294.2	166.7	10.10	0.013	69.1	0.162	0.74	13:46	6.1
Post-DAF	5.66	270.6	208.8	10.50	0.019	74.8	0.125	1.23	13:46	5.4
Post-Ozone	5.60	292.2	208.0	10.00	0.018	73.2	0.131	1.88	13:47	5.7
Filter 1	5.81	298.9	21.7	10.60	0.014	93.1	0.030	0.15	13:48	6.6
Filter 2	5.78	316.0	209.0	10.50	0.014	93.3	0.030	0.12	13:48	6.7
Filter 3	5.83	324.7	208.1	10.00	0.016	93.3	0.030	0.12	13:50	6.6
Filter 4	5.77	331.1	207.5	10.60	0.014	93.1	0.031	0.18	13:50	6.6
Filter 5	5.65	337.0	210.4	10.40	0.014	93.3	0.030	0.11	13:52	6.5
Filter 6	5.60	341.4	212.0	11.00	0.011	93.3	0.030	0.09	13:52	6.5
Filter 7	5.60	349.5	210.8	10.90	0.014	93.7	0.028	0.14	13:53	6.4
Filter 8	5.67	352.4	211.4	11.10	0.015	93.9	0.030	0.11	13:53	6.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Coagulant dose at 42 mg/L
- Poly 0.01 mg/L
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s.
- No bubbles in ozone rotameter. Screen at ozone columns was cleaned to improve flow to filters.
- Ozone operating at 29%, 189W
- Coagulant dose increased to 46 mg/L after sampling at 1:55 pm.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, March 29, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.80	281.4	174.6	10.8	0.009	69.3	0.16	0.76	13:58	5.2
Post-DAF	5.70	277.0	207.6	11.0	0.130	75.1	0.12	1.23	13:59	5.2
Post-Ozone	5.76	297.3	211.8	11.7	0.016	74.6	0.13	1.55	13:59	5.9
Filter 1	5.93	305.6	210.8	10.4	0.011	94.5	0.03	0.11	14:00	6.4
Filter 2	5.87	311.4	210.2	10.8	0.016	93.7	0.03	0.10	14:00	6.6
Filter 3	5.93	314.3	209.0	10.7	0.012	94.3	0.03	0.10	14:00	6.6
Filter 4	5.90	328.8	209.9	10.8	0.013	94.8	0.02	0.11	14:00	6.5
Filter 5	5.80	334.8	212.3	11.1	0.013	94.3	0.03	0.11	14:02	6.3
Filter 6	5.79	336.3	212.2	11.1	0.014	95.0	0.02	0.11	14:02	6.2
Filter 7	5.79	340.3	214.1	11.0	0.015	95.1	0.02	0.08	14:02	6.2
Filter 8	5.83	339.2	212.4	11.0	0.015	94.9	0.02	0.10	14:02	6.3
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Coagulant dose at 46 mg/L
- Poly 0.01 mg/L
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s.
- Ozone operating at 29%, 189W
- Coagulant dose increased to 50 mg/L after sampling at 2:05 pm.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, March 30, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.82	312.0	174.2	10.9	0.011	68.6	0.163	0.73	13:31	5.2
Post-DAF	5.58	356.9	214.5	11.1	0.017	75.3	0.124	1.22	13:33	5.2
Post-Ozone	5.60	412.5	210.0	11.5	0.015	76.2	0.117	1.35	13:34	5.6
Filter 1	5.80	399.3	213.3	11.3	0.012	93.5	0.029	0.12	13:37	6.4
Filter 2	5.80	400.0	211.5	10.8	0.012	94.0	0.027	0.09	13:37	6.5
Filter 3	5.77	401.4	214.3	10.6	0.014	94.2	0.027	0.10	13:38	6.5
Filter 4	5.75	400.6	213.2	10.4	0.016	93.6	0.028	0.11	13:38	6.4
Filter 5	5.62	404.1	213.9	10.8	0.017	93.5	0.029	0.12	13:39	6.4
Filter 6	5.62	400.7	212.0	10.7	0.014	93.5	0.029	0.07	13:40	6.3
Filter 7	5.65	396.1	212.2	10.9	0.011	92.8	0.032	0.07	13:41	6.4
Filter 8	5.64	393.0	210.5	11.0	0.010	93.7	0.028	0.09	13:41	6.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Coagulant dose at 50 mg/L
- Poly 0.01 mg/L
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s.
- Full Type I sample collection day.
- Raw water flow at 2.75 L/s, cannot increased to 3 L/s for some reason (valve fully open).
- Ozone operating at 29%, 189W
- Coagulant dose reduced to 42 mg/L at 3pm.

Double Backwash Day Schedule:
7:00am – Begin first backwash
9:30am – First backwash completed and system initiated
11:30pm – Sample collection for benchtop analysis (after approximately 2 hours runtime)
12:00pm – Shut down filters and ozone pumps to clean DAF tank of residual coagulant buildup
1:30pm – Begin second backwash
3:30pm – Second backwash competed; increase polymer pump to dose at 0.05 mg/L

NOTE**:** During shutdown, raw water will remain flowing however the system will be altered to divert water from the DAF tank to the DAF overflow tank (waste). This will prevent water with residual coagulant/polymer that is being removed from the side of the DAF tank during the cleaning process from entering the filter columns and potential overloading the filters with heavy sludge. Once the tank is cleaned the second backwash will begin. Following the second backwash the system will be monitored for a short time to ensure there is not concerns with increasing the polymer.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, March 31, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.88	263.3	210.6	10.8	0.009	69.4	0.159	0.77	11:29	5.6
Post-DAF	5.81	299.9	205.4	11.0	0.014	74.6	0.128	1.19	11:29	5.6
Post-Ozone	5.86	367.9	205.6	11.2	0.017	75.4	0.120	1.36	11:30	5.8
Filter 1	6.02	379.8	207.0	10.6	0.016	93.7	0.028	0.27	11:30	6.7
Filter 2	6.00	381.8	206.9	10.5	0.013	93.8	0.028	0.24	11:31	6.8
Filter 3	6.01	383.1	203.6	10.2	0.012	94.2	0.026	0.34	11:32	6.8
Filter 4	5.99	380.6	205.2	10.3	0.008	94.0	0.027	0.22	11:32	6.9
Filter 5	5.90	381.0	207.1	10.5	0.011	93.7	0.028	0.20	11:33	6.8
Filter 6	5.88	390.8	205.8	10.3	0.010	93.6	0.029	0.23	11:33	6.8
Filter 7	5.89	392.4	207.6	10.5	0.009	93.8	0.028	0.23	11:34	6.6
Filter 8	5.88	389.9	207.1	10.6	0.008	93.3	0.030	0.22	11:34	6.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- NB Polymer is flow paced off of raw
- Polymer flow turned up to 0.05 mg/L at 4pm.
- Coagulant dose at 42 mg/L
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s.
- Note raw water flow was at 2.45 L/s in the morning of March 31 at 7am, however at 7:30am the flow increased to 3.85 L/s which was reduced to 3 L/s to match typical flow rates.
- Ozone operating at 29%, 189W
- Double backwash day.
- **Note** at 6am mud balls were seen in the polymer tank. As a result, the polymer aid was scaled back to 0.02 mg/L, tank was cleaned once more.

The system underwent two backwashes at 7am and 230pm
Bench testing was conducted approximately 2 hours after the 1st backwash
The coagulant/floc tanks, polymer tank, and DAF tank were cleaned of residual coagulant on the sides and any mud-balls that were floating in the polymer tank were removed prior to the second backwash
Following completion of the second backwash the polymer dose was increased to 0.05mg/L as per schedule. Increase occurred at 4pm
The system was monitored (visual inspections of tanks and filters) for 2 hours (6pm) after which significant accumulation of polymer floc (mud-balling) was found on the surface of the polymer tank
It was decided that the polymer concentration was exceeding optimal operating conditions at 0.05 mg/L and was reduced to 0.02mg/L at 6pm.
Prior to the polymer reduction the polymer tank was cleaned again to remove polymer buildup
Visual inspection of the DAF tank on April 1st at 630am found some mud-balling occurred; however, the amount of polymer buildup on the surface was minimal

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Saturday, April 01, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.80	205.9	170.1	10.7	0.014	69.9	0.16	0.69	13:39	5.9
Post-DAF	5.73	268.2	206.6	11.2	0.017	68.9	0.16	1.53	13:42	5.6
Post-Ozone	5.79	337.7	203.3	10.8	0.019	69.4	0.16	1.72	13:43	5.7
Filter 1	5.98	335.6	207.2	11.0	0.014	91.6	0.04	0.20	13:45	6.9
Filter 2	5.96	336.2	202.3	11.3	0.011	91.6	0.04	0.12	13:45	6.9
Filter 3	5.94	337.2	207.1	11.0	0.014	90.8	0.04	0.25	13:47	6.8
Filter 4	5.94	336.9	206.6	11.0	0.014	90.3	0.05	0.27	13:47	6.8
Filter 5	5.86	337.2	206.1	10.7	0.013	93.6	0.03	0.06	13:49	6.8
Filter 6	5.84	332.0	202.9	11.0	0.011	93.8	0.03	0.06	13:49	6.6
Filter 7	5.83	328.4	24.3	10.9	0.011	93.8	0.03	0.07	13:52	6.6
Filter 8	5.79	323.5	217.9	10.7	0.012	93.5	0.03	0.07	13:52	6.7
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Coagulant dose at 42 mg/L
- Poly 0.02 mg/L
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s.
- Mud balling build-up in polymer DAF tank section, cleaned prior to increase in polymer to 0.03 mg/L.
- Ozone operating at 29%, 189W
- Polymer increased to 0.03 mg/L at 2:50pm

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, April 02, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.78	217.0	168.1	10.5	0.016	69.6	0.16	0.69	13:32	6.1
Post-DAF	5.97	287.8	207.7	11.1	0.022	70.5	0.15	1.43	20:13	5.7
Post-Ozone	5.80	394.5	208.2	11.6	0.023	71.6	0.15	1.53	13:34	5.9
Filter 1	6.01	395.1	206.9	10.8	0.018	93.2	0.03	0.16	13:36	6.6
Filter 2	5.98	394.6	206.5	10.9	0.018	93.5	0.03	0.12	13:38	6.9
Filter 3	5.99	393.4	211.2	10.9	0.016	93.7	0.03	0.10	13:40	6.9
Filter 4	5.95	390.4	209.6	10.7	0.016	93.4	0.03	0.10	13:40	6.9
Filter 5	5.90	388.7	208.8	11.1	0.016	93.4	0.03	0.06	13:43	6.9
Filter 6	5.87	386.2	205.0	10.7	0.014	93.5	0.03	0.05	13:43	6.8
Filter 7	5.82	379.9	208.0	10.8	0.015	93.9	0.03	0.09	13:45	6.8
Filter 8	5.86	367.6	206.7	10.9	0.013	94.0	0.03	0.07	13:45	6.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Coagulant dose at 42 mg/L
- Poly 0.03 mg/L
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s.
- Some mud balling is observable at 0.03 mg/L
- Ozone operating at 29%, 189W
- Polymer reduced to 0.01 mg/L at 3:30pm

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, April 03, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.92	257.0	171.2	10.8	0.011	69.1	0.154	0.85	11:40	6.0
Post-DAF	5.73	249.8	211.2	10.9	0.023	70.0	0.156	1.70	11:41	5.8
Post-Ozone	5.74	288.8	215.7	11.4	0.021	71.1	0.148	1.90	11:41	6.2
Filter 1	5.95	292.9	206.8	10.7	0.013	94.1	0.026	0.17	11:43	7.2
Filter 2	5.90	307.7	204.5	10.4	0.013	94.3	0.025	0.10	11:43	7.2
Filter 3	5.89	312.3	204.4	10.5	0.015	93.0	0.029	0.15	11:44	7.2
Filter 4	5.89	320.1	205.7	10.6	0.012	94.1	0.026	0.19	11:44	7.1
Filter 5	5.82	334.5	505.5	10.9	0.016	94.4	0.025	0.07	11:44	7.0
Filter 6	5.83	335.9	203.9	10.7	0.014	94.2	0.026	0.08	11:44	7.1
Filter 7	5.75	335.6	203.2	10.4	0.015	94.2	0.026	0.13	11:46	7.1
Filter 8	5.80	337.7	205.0	10.3	0.011	94.0	0.027	0.08	11:46	6.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Double backwash day
- Filter aid addition was changed to a submerged pipe installation. City installed pipe to add polymer to DAF tank #3 approximately half way down into DAF.
- Optimal conditions deemed to be 46 mg/L and 0.02 mg/L polymer
- Conditions set at 2 pm.
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s.
- Ozone operating at 29%, 189W

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, April 04, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.83	232.8	174.4	10.7	0.012	69.2	0.160	0.95	14:34	6.4
Post-DAF	5.63	282.8	210.0	10.3	0.020	72.1	0.142	1.53	14:36	5.9
Post-Ozone	5.67	372.2	210.0	11.0	0.019	72.5	0.140	2.12	14:38	6.2
Filter 1	5.86	378.1	209.8	10.8	0.013	93.1	0.032	0.26	14:41	6.6
Filter 2	5.84	380.2	211.1	10.8	0.014	92.9	0.032	0.26	14:42	6.9
Filter 3	5.82	381.4	211.5	10.4	0.017	93.8	0.028	0.30	14:43	6.9
Filter 4	5.81	383.3	210.8	10.2	0.015	92.5	0.034	0.29	14:45	7.2
Filter 5	5.68	387.1	211.2	10.8	0.013	95.0	0.022	0.12	14:47	6.8
Filter 6	5.73	367.9	212.2	10.8	0.014	95.6	0.021	0.12	14:49	6.7
Filter 7	5.72	365.4	210.2	10.8	0.012	95.0	0.023	0.12	14:50	6.7
Filter 8	5.70	360.5	201.6	10.6	0.014	95.4	0.020	0.08	14:51	6.6
Combined Filter	5.83	349.1	230.6	10.3	0.012	93.7	0.028	0.09	14:30	7.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Optimal conditions deemed to be 46 mg/L and 0.02 mg/L polymer
- Standard backwashing cycle, 10-5-10
- No polymer buildup in DAF tank (a result of modified injection)
- THM/HAA collected in clear unpreserved bottles
- Type II sample day with samples collected from pilot and main plant
- Bank A: 0.3L/s, Bank B: 0.6L/s.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, April 05, 2017
Season: Winter

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp
Raw	7.88	210.9	171.6	10.80	0.018	70.7	0.150	0.622	13:58	6.2
Post-DAF	5.67	267.6	207.0	10.40	0.029	72.7	0.138	1.510	13:59	6.0
Post-Ozone	5.64	340.4	206.1	11.00	0.025	73.2	0.136	3.040	14:01	6.3
Filter 1	5.85	343.9	208.3	10.60	0.016	92.5	0.033	0.397	13:58	7.3
Filter 2	5.81	342.4	207.1	10.10	0.016	92.0	0.036	0.391	13:58	7.3
Filter 3	5.86	341.5	208.5	10.10	0.017	93.9	0.028	0.205	14:01	7.1
Filter 4	5.82	341.7	208.5	10.60	0.017	94.3	0.025	0.227	14:01	7.1
Filter 5	5.59	342.5	212.3	10.80	0.016	95.2	0.022	0.041	14:03	7.0
Filter 6	5.70	338.1	209.0	10.60	0.019	95.6	0.019	0.040	14:05	6.9
Filter 7	5.77	334.1	210.9	11.10	0.012	95.5	0.020	0.046	14:06	6.9
Filter 8	5.65	329.2	207.7	10.90	0.013	95.1	0.021	0.057	14:02	7.0
Combined Filter	5.78	305.9	216.1	11.30	0.017	94.7	0.230	0.179	13:51	7.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Daily Notes:
- Optimal conditions (duplicate) tested today.
- Optimal conditions deemed to be 46 mg/L and 0.02 mg/L polymer (using revised polymer injection into water column)
- Pilot plant turbidity meter (Hach 2100Q) lost calibration, as such, turbidity measurements were taken using Analytical Service's turbidity meter (Hach 2100N)
- Type II sample day with samples collected from pilot and main plant
- Standard backwashing cycle, 10-5-10
- Bank A: 0.3L/s, Bank B: 0.6L/s.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, May 11, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	8.34	273.5	157.1	10.10	0.012	73.4	0.134	1.07	13:00	11.7
Post-DAF	6.03	227.4	187.1	10.30	0.024	59.9	0.228	2.47	13:00	11.4
O3-Combined	6.02	267.5	185.3	11.10	0.024	61.5	0.210	2.40	13:01	11.8
Filter 1	6.01	285.2	186.0	10.40	0.013	88.9	0.050	0.49	13:01	12.1
Fitler 2	6.01	293.7	185.2	10.50	0.012	89.3	0.049	0.42	13:02	11.9
Filter 3	6.04	299.8	185.8	10.40	0.012	88.9	0.052	0.47	13:02	12.0
Filter 4	6.04	305.7	185.1	10.30	0.012	88.9	0.051	0.44	13:03	12.1
Filter 5	5.95	311.4	184.8	10.10	0.008	92.8	0.032	0.19	13:03	12.3
Filter 6	5.89	322.8	183.7	10.00	0.010	93.4	0.030	0.17	13:04	12.5
Filter 7	5.92	327.9	183.1	10.10	0.010	92.1	0.036	0.22	13:04	12.3
Filter 8	5.96	340.5	181.0	10.10	0.011	92.2	0.035	0.23	13:05	12.3
Combined Pilot Filtrate	5.98	336.3	184.5	10.20	0.013	91.5	0.038	0.31	13:05	12.0
Plant Post-DAF	5.62	284.4	193.6	11.00	0.043	88.2	0.055	0.37	12:51	12.1
Plant O3-Combined	5.79	374.5	195.1	12.10	0.039	88.5	0.053	0.64	12:52	11.3
Plant Filtrate Combined	5.44	292.6	198.8	11.30	0.031	95.7	0.019	0.65	12:55	11.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 a.m.
Backwash End Time:	8:30 a.m.
Plant Raw Water Temp (SCADA):	

*30 min. delay on start due to pump maintenance - start @ 9:00 am

6:00 am - 4:00 pm * plus 1 hr. for meeting

Comments:
Coag. - 32 mg/L
Poly - 0.01 mg/L
(Normal) Bank A → 0.3 L/S reversed today only
B → 0.6 L/S due to pump maintenance
Acid - 43 mg/L ~so B = 0.3 A = 0.6

Daily Notes:
pHc DAF - pilot → see pictures by Charles

*Coag Dose changed to 35 mg/L @ 3:15 pm
- H_2S_{o4} increased to 45 mg/L @ 3:00 pm but pH dropped too low so decreased to 44 mg/L @ 3:45 pm

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, May 12, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	8.30	313.1	156.9	10.10	0.017	74.3	0.129	1.22	13:00	11.7
Post-DAF	5.83	270.5	189.5	10.40	0.027	61.4	0.212	2.11	13:00	11.6
O3-Combined	5.82	299.5	189.5	10.70	0.031	64.2	0.192	2.24	13:01	11.8
Filter 1	5.88	313.0	188.2	10.00	0.014	95.5	0.020	0.15	13:01	12.5
Fitler 2	5.89	327.5	189.5	10.00	0.015	95.8	0.018	0.17	13:02	12.3
Filter 3	5.88	330.3	189.1	9.80	0.016	95.9	0.018	0.16	13:02	12.6
Filter 4	5.87	335.3	190.1	9.90	0.014	96.0	0.017	0.13	13:03	12.5
Filter 5	5.82	337.3	189.2	10.00	0.015	96.3	0.016	0.11	13:03	12.5
Filter 6	5.81	344.5	190.7	10.30	0.020	96.3	0.016	0.11	13:04	12.5
Filter 7	5.81	348.1	190.6	10.30	0.015	94.4	0.025	0.12	13:04	12.6
Filter 8	5.81	336.8	191.1	10.40	0.016	95.3	0.021	0.16	13:05	12.5
Combined Pilot Filtrate	5.84	344.7	189.8	9.80	0.016	94.7	0.023	0.16	13:05	12.3
Plant Post-DAF	5.48	305.3	195.5	10.20	0.044	88.0	0.056	0.44	12:51	11.7
Plant O3-Combined	5.76	361.7	193.5	11.50	0.040	87.3	0.059	0.57	12:52	11.2
Plant Filtrate Combined	5.44	373.7	197.3	11.80	0.029	96.6	0.015	0.22	12:55	11.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 a.m.
Backwash End Time:	8:30 a.m.
Plant Raw Water Temp (SCADA):	

6:00 am - 5:30 pm

Comments:
Coag. - 35 mg/L
Poly - 0.01 mg/L
Acid - 44 mg/L
Bank A - 0.3 L/s
Bank B - 0.6 L/s

Daily Notes:
Coagulant dose changed to 38 mg/L @ 4 pm

Meeting with Maika, Mora and Justin and City crew - May 15/17
No AMA
- Two days TM to be delivered.
- Varation blt pilot / WTP
- Winter started to bench opt.
- Last week good aeration. Start March 15.
- Just captured winter → Pilot warmer doesn't change quality.
- DAF ↓ Mn 1/5 full
- Filt - 1-4 → 0.3 L/s
  5-8 → 0.6 L/s
- Overtime filter pressure ↓ after 10 days
- Pressure from SCADA for benchmark
  Fe: Bench same for Fe B/+ 1-4 and 5-8
- Chloride fill scale
(Linda question) Bench vs. pilot during the benchmark period during winter.
  - Add section for TN3
- April 7th → pressure 1-4 for transition xxxxxxx request.
- Swich Banks → Break for Naoh o/n → 3 per THM/HAA

Title:	Winnipeg Alternative Coagulant Piloting Lab Data
Date:	Saturday, May 13, 2017
Season:	Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	8.42	233.4	159.0	10.10	0.23	71.7	0.146	1.08	14:01	12.2
Post-DAF	5.74	279.0	189.4	10.20	0.33	60.3	0.221	2.51	14:01	12.3
O3-Combined	5.78	364.5	189.9	10.30	0.37	64.4	0.193	2.46	14:05	12.6
Filter 1	5.90	366.0	190.3	9.80	0.15	94.4	0.025	0.13	14:05	13.0
Fitler 2	5.87	372.9	190.6	9.70	0.12	94.2	0.026	0.08	14:06	13.0
Filter 3	5.87	370.5	190.8	10.00	0.17	94.6	0.024	0.10	14:06	13.0
Filter 4	5.84	373.2	190.6	10.10	0.16	94.4	0.025	0.13	14:08	13.0
Filter 5	5.76	369.2	191.0	10.10	0.19	90.4	0.045	0.44	14:08	12.7
Filter 6	5.76	377.8	191.6	10.20	0.11	90.2	0.045	0.38	14:09	12.9
Filter 7	5.76	411.3	191.1	9.90	0.15	91.2	0.040	0.52	14:09	12.7
Filter 8	5.74	408.7	193.9	10.30	0.21	91.5	0.039	0.52	14:10	12.9
Combined Pilot Filtrate	5.78	413.1	192.2	9.50	0.20	93.5	0.029	0.38	14:14	12.7
Plant Post-DAF	5.58	346.2	192.2	10.30	0.43	85.7	0.068	0.40	15:13	11.9
Plant O3-Combined	5.61	434.5	196.0	12.60	0.41	87.2	0.060	0.50	15:17	12.0
Plant Filtrate Combined	5.55	346.5	221.2	11.80	0.31	93.7	0.028	0.52	15:01	12.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 a.m.
Backwash End Time:	8:30 a.m.
Plant Raw Water Temp (SCADA):	

6:00 am - 11:30 am

Comments:
Coag. - 38 mg/L
Poly - 0.01 mg/L
Acid - 44 mg/L
Bank A - 0.3 L/s
Bank B - 0.6 L/s
Saturator: 0.7681 L/s

Daily Notes:
Coagulant dose changed @ 4:11 to 42 mg/L

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, May 14, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	8.40	365.0	156.2	9.30	0.014	72.2	0.141	1.12	12:44	12.5
Post-DAF	5.59	277.9	190.0	10.00	0.028	67.9	0.169	1.84	12:45	12.5
O3-Combined	5.58	332.8	188.8	10.20	0.033	66.8	0.177	2.28	12:47	12.8
Filter 1	5.75	355.6	190.0	9.60	0.015	95.9	0.018	0.08	12:50	13.3
Fitler 2	5.73	362.9	192.4	9.80	0.015	95.8	0.019	0.08	12:51	13.4
Filter 3	5.77	371.5	191.7	9.70	0.016	95.4	0.021	0.11	12:52	13.4
Filter 4	5.72	373.8	190.5	9.70	0.015	96.4	0.016	0.08	12:53	13.4
Filter 5	5.64	376.7	190.6	9.90	0.014	95.9	0.018	0.12	12:54	13.3
Filter 6	5.66	373.1	192.7	10.00	0.015	96.3	0.016	0.10	12:55	13.3
Filter 7	5.65	372.0	193.2	10.00	0.014	94.9	0.024	0.10	12:57	13.3
Filter 8	5.65	366.7	192.8	10.10	0.013	96.2	0.017	0.10	12:58	13.2
Combined Pilot Filtrate	5.66	362.2	192.8	9.90	0.013	95.2	0.021	0.10	13:04	12.9
Plant Post-DAF	5.58	322.0	195.6	10.10	0.044	86.6	0.062	0.46	12:30	12.7
Plant O3-Combined	5.80	308.2	195.3	10.10	0.039	87.7	0.057	0.66	12:32	12.0
Plant Filtrate Combined	5.59	332.1	195.6	10.90	0.034	94.1	0.026	0.20	12:35	12.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	5:50 AM
Backwash End Time:	7:58 AM
Plant Raw Water Temp (SCADA):	

10:30 am - 4:00 pm

Comments:
Fiter Bank A - 0.3 L/s
Fiter Bank B - 0.6 L/s
Coag - 42 mg/L
Acid - 44 mg/L
Poly - 0.01 mg/L
Flow Ramp Up - 8:30 am
Saturator - 0.77 L/s @ 64 psi

Daily Notes:
Coagulant increased to 45 mg/L @ 3 pm

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, May 15, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	8.24	419.1	156.6	10.00	0.010	72.0	0.143	1.15	13:17	12.8
Post-DAF	5.40	364.9	191.5	9.90	0.028	66.4	0.176	2.11	13:18	12.4
O3-Combined	5.50	485.3	191.0	10.40	0.027	67.4	0.170	2.37	13:19	12.5
Filter 1	5.62	432.6	190.7	9.70	0.160	94.8	0.023	0.24	13:20	13.5
Fitler 2	5.59	451.0	193.0	9.70	0.120	94.8	0.023	0.16	13:20	13.3
Filter 3	5.60	453.2	193.4	9.70	0.160	95.3	0.021	0.12	13:21	13.5
Filter 4	5.56	456.2	193.5	9.70	0.130	94.9	0.023	0.14	13:21	13.5
Filter 5	5.44	453.1	193.4	9.80	0.200	86.7	0.060	0.97	13:22	13.4
Filter 6	5.50	448.8	194.8	10.10	0.210	88.4	0.052	0.67	13:22	13.3
Filter 7	5.50	451.6	194.6	10.10	0.210	88.0	0.055	0.67	13:23	13.4
Filter 8	5.50	447.6	194.2	9.80	0.200	86.6	0.062	0.74	13:23	13.3
Combined Pilot Filtrate	5.52	440.4	194.0	9.80	0.180	90.7	0.042	0.51	13:25	13.6
Plant Post-DAF	5.53	390.0	195.1	9.80	0.480	87.2	0.059	0.54	13:06	12.4
Plant O3-Combined	5.73	449.7	193.2	11.20	0.460	88.9	0.051	0.51	13:07	12.1
Plant Filtrate Combined	5.56	459.2	196.9	11.20	0.400	94.2	0.026	0.18	13:10	12.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:30 AM
Plant Raw Water Temp (SCADA):	

6:00 am - 4:30 pm

Comments:
Fiter Bank A - 0.3 L/s
Fiter Bank B - 0.6 L/s
Coag - 45 mg/L
Acid - 44 mg/L
Poly - 0.01 mg/L

Daily Notes:
* After completion of bench, F5 was rerun for UVT / ABS to see if it was still high. It was 83.1 and 0.078. Meaning it ↑ since original scope.
* ↑ coag. to 48 mg/L @ 4 pm
4 pm - ↑ flow to 100% massive plug came off Bank A only.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, May 16, 2017
Season: Spring

	pH	**ORP**	**Conducutivity**	**DO**	**Hach Mn**	**UVT**	**Abs**	**Turb**	**Time**	**Temp °C**
Raw	8.24	372.1	151.1	9.30	0.014	73.2	0.135	0.96	12:40	13.4
Post-DAF	5.61	265.4	188.6	9.40	0.030	66.2	0.179	2.03	12:44	13.5
O3-Combined	5.55	316.2	189.6	10.00	0.029	70.1	0.154	2.08	12:45	13.7
Filter 1	5.53	340.4	188.8	9.70	0.019	91.5	0.038	0.48	12:46	13.7
Fitler 2	5.53	345.8	190.2	9.70	0.018	92.1	0.033	0.40	12:46	14.0
Filter 3	5.52	352.2	190.2	9.70	0.015	93.1	0.031	0.39	12:47	14.2
Filter 4	5.46	361.5	189.1	9.60	0.017	93.5	0.029	0.40	12:47	14.0
Filter 5	5.42	366.2	189.3	9.40	0.014	96.2	0.017	0.10	12:48	14.2
Filter 6	5.43	368.6	188.7	9.30	0.015	95.8	0.019	0.13	12:48	14.1
Filter 7	5.42	374.2	189.2	9.40	0.013	94.5	0.025	0.14	12:49	14.4
Filter 8	5.43	375.6	189.2	9.40	0.014	95.7	0.019	0.14	12:49	14.3
Combined Pilot Filtrate	5.47	374.1	190.0	9.40	0.016	92.6	0.034	0.30	12:51	14.6
Plant Post-DAF	5.55	332.4	194.2	9.70	0.480	86.0	0.066	0.47	12:31	13.2
Plant O3-Combined	5.75	340.3	192.9	10.50	0.460	88.3	0.054	0.56	12:32	13.3
Plant Filtrate Combined	5.51	351.8	195.0	10.70	0.034	94.8	0.023	0.15	12:38	13.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:30 AM
Plant Raw Water Temp (SCADA):	

6:00 am - 4:30 pm

Comments:
Coag - 48 mg/L
Acid - was 44 mg/L from day 5 - 6, but was reduced to 41 mg/L prior to start of run. * Pic. after pH change.
Poly - 0.01 mg/L

Daily Notes:
* Bank A flow changed to 0.6 L/s } Todays
  Bank B flow changed to 0.3 L/s } Run

* pH was ↓ to 40 mg/L after sampling, due to ↓ pH

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, May 17, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	8.21	314.4	152.9	9.30	0.019	72.2	0.141	1.03	12:42	12.9
Post-DAF	5.40	249.2	189.9	9.80	0.038	57.4	0.241	3.08	12:42	12.7
O3-Combined	5.30	317.9	190.5	10.20	0.040	61.7	0.211	3.04	12:43	13.1
Filter 1	5.35	326.3	192.8	10.10	0.027	82.0	0.085	1.28	12:44	13.3
Fitler 2	5.32	333.4	193.1	10.00	0.024	82.3	0.086	1.18	12:44	13.4
Filter 3	5.32	340.1	192.9	9.90	0.026	84.7	0.073	1.04	12:45	13.4
Filter 4	5.30	339.1	192.7	9.80	0.025	83.6	0.077	1.23	12:45	13.5
Filter 5	5.30	350.9	191.0	9.60	0.019	96.5	0.015	0.11	12:46	13.5
Filter 6	5.32	359.9	191.1	9.60	0.021	96.7	0.014	0.12	12:46	13.8
Filter 7	5.31	366.5	192.3	9.60	0.020	96.6	0.015	0.11	12:47	13.6
Filter 8	5.30	370.0	192.7	9.50	0.017	96.6	0.015	0.08	12:47	13.9
Combined Pilot Filtrate	5.30	363.8	192.8	9.70	0.017	91.0	0.039	0.43	12:50	13.7
Plant Post-DAF	5.49	323.0	193.5	9.90	0.050	87.6	0.058	0.51	12:31	12.7
Plant O3-Combined	5.66	324.5	191.2	10.40	0.039	88.6	0.053	0.58	12:32	12.5
Plant Filtrate Combined	5.49	339.6	192.6	10.90	0.034	95.1	0.022	0.22	12:38	12.8
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:05 AM
Backwash End Time:	8:40 AM
Plant Raw Water Temp (SCADA):	

6:00 am - 6:30 pm + 2 hrs. waiting

Comments:
Coag - 52 mg/L
Acid - 40.25 mg/L (was ↑ to bring up pH ~ 5.6)
Poly - 0.01 mg/L
Bank A - 0.6L/s
Bank B - 0.3 L/s

Daily Notes:
* @ 4:30 pm 2nd fill backwash on both filters b/c of the way ↑ turbs found in Bank A.
Optional dose is 42 mg/L ↓ tub, UVT and Abs with lower Mn
Change to strength @ 6:30; Acid @ 40 mg/L @ 6:30

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, May 18, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw										
Post-DAF										
O3-Combined										
Filter 1										
Fitler 2										
Filter 3										
Filter 4										
Filter 5										
Filter 6										
Filter 7										
Filter 8										
Combined Pilot Filtrate										
Plant Post-DAF										
Plant O3-Combined										
Plant Filtrate Combined										
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6 a.m.
Backwash End Time:	
Plant Raw Water Temp (SCADA):	

6:00 am - 11:30 pm

Comments:
Coag - 42 mg/L
Acid
Backwash - 6
Poly - 0.01 mg/L
Bank A - 0.6L/s
Bank B - 0.3 L/s

Daily Notes:
Checked F3 and F6 in the morning.
F3 → 1.50 Turb; UVT / ABS 78.2 / 0.106
F7 → 0.30 Turb; UVT / ABS 93.11 / 0.031

Day not completed. Water Post-DAF was yellow. Heather wants to clean system.
* Double backwash completed to attempt to clean filters and remove colour post-filler.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: 21/05/2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	8.04	316.4	164.1	9.50	0.015	74.1	0.130	0.98	12:55	12.9
Post-DAF	5.75	269.5	188.5	10.00	0.022	79.8	0.098	1.13	12:57	12.3
O3-Combined	5.68	284.6	187.5	10.50	0.250	73.8	0.106	1.35	12:59	13.3
Filter 1	5.95	293.8	194.8	10.10	0.020	85.9	0.066	0.73	13:01	13.3
Fitler 2	5.97	300.6	194.6	9.90	0.017	86.8	0.061	0.65	13:01	13.5
Filter 3	5.98	309.8	194.5	10.00	0.016	89.2	0.050	0.55	13:02	13.4
Filter 4	5.95	312.6	194.8	10.00	0.017	88.3	0.053	0.61	13:02	13.5
Filter 5	6.04	316.8	196.0	9.80	0.012	95.5	0.020	0.08	13:03	13.6
Filter 6	6.08	320.0	196.4	9.70	0.014	95.8	0.019	0.06	13:03	13.5
Filter 7	6.09	323.6	196.8	9.70	0.013	95.5	0.020	0.06	13:04	13.4
Filter 8	6.13	323.4	196.9	9.70	0.015	95.5	0.020	0.09	13:04	13.5
Combined Pilot Filtrate	6.05	330.6	194.5	9.80	0.014	93.8	0.029	0.25	13:10	14.0
Plant Post-DAF	5.54	317.5	195.8	10.40	0.050	87.1	0.060	0.38	12:40	12.3
Plant O3-Combined	5.76	316.3	192.2	10.70	0.050	87.9	0.056	0.69	12:42	12.2
Plant Filtrate Combined	5.50	320.6	196.7	11.00	0.033	96.1	0.018	0.26	12:47	12.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 a.m.
Backwash End Time:	8:50 a.m.
Plant Raw Water Temp (SCADA):	

6:00 am -
<u>Comments:</u>
Coag - 42 mg/L
Acid - 39.5 mg/L
Backwash - 6
Poly - 1.01 mg/L
Bank A - 0.6L/s
Bank B - 0.3 L/s

<u>Daily Notes:</u>
Yellow Water Post-DAF in morning.
- see Charles pic.
- Fiters appeared to remove it a bit.
Type 1 sample day.
Both banks @ 0.3 L/s May 20th → May 21st
Acid ↓ 39.25 @ 4 pm
Poly ↑ 0.03 mg/L @ 4 pm
IMPORTANT!!
- DAF recirculation ~ 0.44 after cleaning of system by City on 19th
- pH DAF req's offset reading low ~5.05; actual = 5.50 pH xxxx in lab.
Morning Test
Bank A - 0.5 Turb; 91 UVT
Bank B - 0/6 Turb; 87 UVT
Post AAF - > Turb; 39.1 UVT
* Justin said continue on
Polymer and to DAF not on half the time.
* Took pic of A/B filters

Title:	Winnipeg Alternative Coagulant Piloting Lab Data
Date:	Sunday, May 21, 2017
Season:	Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	8.08	368.8	155.5	9.20	0.014	73.2	0.135	0.93	12:37	12.9
Post-DAF	5.79	287.9	187.1	9.80	0.021	80.2	0.096	1.01	12:37	13.2
O3-Combined	5.72	303.9	187.3	10.30	0.020	79.8	0.098	1.43	12:38	13.0
Filter 1	5.85	312.1	190.5	9.90	0.018	93.7	0.028	0.18	12:39	13.5
Fitler 2	5.83	318.4	191.1	9.90	0.014	94.1	0.026	0.13	12:39	13.6
Filter 3	5.88	320.5	191.1	9.70	0.012	94.5	0.024	0.13	12:41	13.5
Filter 4	5.84	325.8	191.6	9.90	0.013	94.2	0.026	0.12	12:41	13.7
Filter 5	5.90	328.9	189.1	9.60	0.013	94.8	0.023	0.08	12:42	13.6
Filter 6	5.94	330.7	190.2	9.50	0.012	94.9	0.023	0.07	12:42	13.8
Filter 7	5.95	326.9	190.5	9.50	0.013	94.8	0.023	0.08	12:43	13.8
Filter 8	5.97	331.0	190.6	9.40	0.015	94.6	0.024	0.09	12:43	13.8
Combined Pilot Filtrate	5.90	336.0	190.6	9.50	0.015	94.7	0.024	0.13	12:35	13.8
Plant Post-DAF	5.45	348.6	195.0	9.60	0.050	87.8	0.057	0.40	12:31	13.0
Plant O3-Combined	5.66	403.8	191.7	10.40	0.049	88.3	0.054	0.50	12:31	12.5
Plant Filtrate Combined	5.38	373.4	196.4	10.60	0.037	95.7	0.019	0.11	12:35	12.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:30 AM
Plant Raw Water Temp (SCADA):	

Comments:
Polymer optimization (Day 1) → 0.01 mg/L previous data
Coag - 42 mg/L
* Poly - .03 mg/L
H_2S_{o4} = 39.25 mg/L
Bank A - 0.6L/s
Bank B - 0.3 L/s

Daily Notes:
Filters had ~ 1 inch flow on top in morning before backwash (see pic.)
- Post-DAF colour is clear, no visible yellow
- may have been A in pH doing shutdown, waiting to stabilize after cleaning on Friday, May 19.

Poly ↑ 0.05 @ 3 pm

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, May 22, 2017
Season: Spring

	pH	**ORP**	**Conducutivity**	**DO**	**Hach Mn**	**UVT**	**Abs**	**Turb**	**Time**	**Temp °C**
Raw	8.01	227.4	156.4	9.60	0.014	74.6	0.127	0.93	12:31	12.9
Post-DAF	5.67	284.1	187.8	10.00	0.017	81.5	0.088	1.06	12:31	12.5
O3-Combined	5.70	359.1	187.5	9.90	0.017	82.9	0.081	1.17	12:31	13.1
Filter 1	5.81	355.5	189.9	9.80	0.010	94.4	0.025	0.08	12:32	13.2
Fitler 2	5.82	359.7	189.4	9.90	0.010	94.4	0.025	0.07	12:32	13.4
Filter 3	5.83	358.9	189.4	9.80	0.015	94.2	0.026	0.07	12:33	13.2
Filter 4	5.83	359.1	190.3	9.90	0.013	94.5	0.025	0.07	12:33	13.5
Filter 5	5.87	360.0	189.0	9.70	0.012	94.5	0.025	0.07	12:34	13.4
Filter 6	5.87	356.0	189.6	9.70	0.011	94.4	0.025	0.10	12:34	13.7
Filter 7	5.84	354.6	189.3	9.70	0.012	94.4	0.025	0.07	12:35	13.6
Filter 8	5.85	347.8	189.7	9.60	0.009	94.6	0.024	0.07	12:35	13.7
Combined Pilot Filtrate	5.79	342.5	190.3	9.70	0.010	94.2	0.026	0.08	12:30	13.4
Plant Post-DAF	5.40	353.6	196.1	10.30	0.050	87.4	0.058	0.39	12:25	12.7
Plant O3-Combined	5.64	411.6	192.7	10.90	0.048	87.1	0.060	0.71	12:25	12.4
Plant Filtrate Combined	5.41	377.4	197.1	10.80	0.030	94.6	0.024	0.18	12:28	12.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	5:50 AM
Backwash End Time:	8:15 AM
Plant Raw Water Temp (SCADA):	

<u>Comments:</u>
Polymer optimization (Day 2)
Coag - 42 mg/L
Poly - .05 mg/L
Acid - 39.25 mg/L
Bank A - 0.6L/s
Bank B - 0.3 L/s

<u>Daily Notes:</u>
Coagulat and ↑ to 0.10 @ 2 pm

Title:	Winnipeg Alternative Coagulant Piloting Lab Data
Date:	Tuesday, May 23, 2017
Season:	Spring

	pH	**ORP**	**Conducutivity**	**DO**	**Hach Mn**	**UVT**	**Abs**	**Turb**	**Time**	**Temp °C**
Raw	8.01	276.6	156.0	9.80	0.015	73.4	0.134	0.89	12:36	12.7
Post-DAF	5.64	276.6	188.4	9.70	0.024	83.7	0.080	0.91	12:36	12.6
O3-Combined	5.69	322.1	187.0	10.50	0.021	86.7	0.065	0.90	12:37	12.9
Filter 1	5.80	313.4	191.9	9.80	0.016	94.8	0.023	0.09	12:40	13.1
Fitler 2	5.78	306.2	192.3	9.70	0.016	94.8	0.023	0.08	12:40	13.3
Filter 3	5.81	314.8	192.6	9.90	0.018	95.3	0.021	0.10	12:41	13.2
Filter 4	5.74	303.4	191.9	10.00	0.016	95.5	0.020	0.08	12:41	13.4
Filter 5	5.78	277.7	192.5	9.70	0.018	95.5	0.020	0.07	12:42	13.5
Filter 6	5.81	336.2	192.5	9.70	0.017	95.3	0.021	0.10	12:42	13.6
Filter 7	5.79	329.3	193.0	9.70	0.015	95.5	0.020	0.08	12:43	13.6
Filter 8	5.79	318.6	193.2	9.80	0.014	95.6	0.019	0.09	12:43	13.8
Combined Pilot Filtrate	5.73	307.9	193.9	9.90	0.018	95.1	0.022	0.09	12:33	13.4
Plant Post-DAF	5.44	320.0	195.6	10.70	0.055	88.1	0.056	0.35	12:30	12.5
Plant O3-Combined	5.61	348.8	192.8	10.90	0.053	87.6	0.058	0.60	12:30	12.7
Plant Filtrate Combined	5.36	323.1	191.0	10.50	0.034	95.0	0.022	0.15	12:33	12.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:30 AM
Plant Raw Water Temp (SCADA):	

Comments:

Polymer optimization (Day 2)
Coag - 42 mg/L
Poly - .10 mg/L
Acid - 39.25 mg/L
Bank A - 0.6L/s
Bank B - 0.3 L/s

Daily Notes:

* @ ~ 11:15 - 11:20 am Main plant pump shut down ↓ flow to pilot and ↓ pH
- pH returned to normal after 20 min.
* Nelson off-set pH probe (A tank) + 0.6 pH
Poly ↑ 0.20 @ 3 pm

Title:	Winnipeg Alternative Coagulant Piloting Lab Data
Date:	Wednesday, May 24, 2017
Season:	Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	7.98	214.7	157.4	9.40	0.014	74.6	0.127	0.82	12:50	13.5
Post-DAF	5.75	269.5	187.9	9.50	0.016	86.7	0.061	0.78	12:50	13.3
O3-Combined	5.70	338.3	187.6	10.00	0.016	89.9	0.049	0.81	12:52	13.6
Filter 1	5.84	338.0	189.8	9.70	0.013	95.9	0.018	0.11	12:54	13.8
Fitler 2	5.82	335.3	189.8	9.60	0.012	96.1	0.017	0.10	12:54	13.9
Filter 3	5.85	331.5	189.9	9.50	0.010	95.4	0.020	0.11	12:55	13.8
Filter 4	5.81	323.0	190.2	9.70	0.013	95.8	0.019	0.10	12:55	14.0
Filter 5	5.82	307.3	189.3	9.50	0.014	95.7	0.019	0.10	12:56	14.1
Filter 6	5.83	302.2	190.7	9.50	0.016	95.5	0.020	0.10	12:56	14.3
Filter 7	5.82	303.9	188.9	9.50	0.014	95.0	0.022	0.09	12:58	14.1
Filter 8	5.81	299.1	189.3	9.50	0.015	95.6	0.020	0.08	12:58	14.4
Combined Pilot Filtrate	5.83	289.3	191.1	9.40	0.014	95.5	0.020	0.10	12:46	14.3
Plant Post-DAF	5.43	300.2	196.1	9.50	0.052	87.6	0.056	0.37	12:40	13.3
Plant O3-Combined	5.65	348.4	192.3	10.20	0.052	88.8	0.052	0.57	12:40	12.9
Plant Filtrate Combined	5.46	339.0	200.5	9.60	0.029	96.2	0.017	0.10	12:45	13.3
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:30 AM
Plant Raw Water Temp (SCADA):	

Comments:
Coag - 42 mg/L
Poly - 0.2 mg/L
Acid - 39.25 mg/L
Bank A - 0.6 L/s
Bank B - 0.3 L/s

Daily Notes:
raw water just after pH probe = 5.96
* NB = Used ultra high purety water for UVT/ABS

Optimal polymer is 0.20 mg/L for MN & UVT
Turb is ~ some for 0.10 and 0.20 mg/L; 0.2 bit better
ABS: is better 0.20 also → 0.20 optimal, however, some build-up on DAF - strains, so caution is taken exceeding 0.2 mg/L

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: 25/05/2017 (Optimal Day)
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	7.84	208.2	156.3	9.40	0.018	73.7	0.133	0.92	12:55	14.3
Post-DAF	5.60	265.5	187.4	9.50	0.026	85.8	0.066	0.55	12:59	14.2
O3-Combined	5.59	278.4	187.9	9.50	0.027	89.4	0.049	0.35	12:59	14.0
Filter 1	5.70	326.4	191.3	9.40	0.027	93.8	0.030	0.29	13:01	14.2
Fitler 2	5.67	321.6	190.5	9.40	0.024	93.6	0.029	0.14	13:01	14.1
Filter 3	5.69	338.1	190.2	9.30	0.027	93.7	0.028	0.15	13:02	14.3
Filter 4	5.68	338.6	190.0	9.40	0.019	93.7	0.028	0.13	13:02	14.4
Filter 5	5.72	330.8	190.9	9.30	0.026	93.6	0.029	0.13	13:03	14.4
Filter 6	5.72	328.8	190.7	9.20	0.027	93.7	0.028	0.13	13:03	14.6
Filter 7	5.72	338.2	192.9	9.10	0.030	93.7	0.029	0.11	13:05	14.6
Filter 8	5.72	329.5	195.5	9.20	0.030	94.1	0.026	0.10	13:05	14.6
Combined Pilot Filtrate	5.70	309.2	191.2	9.40	0.021	93.6	0.029	0.11	12:40	14.4
Plant Post-DAF	5.44	311.6	194.9	9.90	0.062	86.6	0.062	0.38	12:35	13.3
Plant O3-Combined	5.67	349.2	189.1	10.60	0.057	87.5	0.058	0.55	12:37	13.5
Plant Filtrate Combined	5.37	346.6	184.5	10.50	0.046	93.9	0.027	0.20	12:50	14.0
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:15 AM
Plant Raw Water Temp (SCADA):	

<u>Comments:</u>
Coag - 42 mg/L
Poly - 0.2 mg/L
Acid - 39.50 mg/L @ 9:45 a.m. pH = 5.55 - * 39.00 reduced @ 9:45 to ↑ pH
Bank A - 0.6 L/s
Bank B - 0.3 L/s

<u>Daily Notes:</u>
Type II today
Chlorination of TMN / HAA @ 4°C.
* @ 2 p.m. Nelson found 0_3 not on since ~ 9 a.m.
Chlorination for THM / HAA FP
Buffo → 6.81 g potassium dihydrogen phos.
1.17 g NaOH

NACIO solution
stock = 0.87 = 8000 mg/L
diluted by 10x
= > 0.08% = 800 mg/L

$$x= \frac{(2mg/L)\ (0.250\ L)}{(800\ mg/L)}$$

x= 0.625 Ml NaC10

* 5mll buffer → 250 ml bottle to 0.625 ml NaC10

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, May 26, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	7.66	214.7	214.7	9.50	0.018	73.4	0.135	1.07	12:54	14.1
Post-DAF	6.06	232.2	181.2	9.80	0.022	86.6	0.064	0.53	12:54	14.2
O3-Combined	6.07	323.6	181.4	10.10	0.018	89.4	0.049	0.80	12:56	14.7
Filter 1	6.06	320.8	178.3	9.60	0.011	93.7	0.028	0.12	12:54	14.6
Fitler 2	6.02	325.0	178.6	9.50	0.014	93.8	0.028	0.10	12:54	14.6
Filter 3	6.02	320.9	179.2	9.50	0.013	93.7	0.028	0.14	12:55	14.5
Filter 4	6.00	315.4	178.9	9.50	0.015	93.8	0.028	0.11	12:55	14.7
Filter 5	5.89	301.1	174.4	9.30	0.011	94.2	0.026	0.09	12:56	14.5
Filter 6	5.83	277.7	174.8	9.50	0.010	93.5	0.029	0.10	12:56	14.6
Filter 7	5.78	298.5	173.4	9.59	0.013	93.6	0.028	0.13	12:59	14.7
Filter 8	5.74	275.4	178.9	9.43	0.012	83.8	0.028	0.12	12:59	14.7
Combined Pilot Filtrate	6.19	275.0	181.8	9.40	0.011	93.6	0.028	0.11	1:00	14.5
Plant Post-DAF	5.47	337.4	195.2	9.80	0.054	87.6	0.058	0.46	1:11	13.5
Plant O3-Combined	5.63	374.8	240.4	10.90	0.058	87.7	0.057	0.58	1:15	13.7
Plant Filtrate Combined	5.50	340.0	195.8	11.20	0.044	95.4	0.020	0.13	1:25	13.8
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:05 AM
Backwash End Time:	8:45 AM
Plant Raw Water Temp (SCADA):	

Comments:
pH adjustment @ opt. coag./poly
pH: 5.95 ~ Observed at FAF overflow (Dosed at 29 mg/L) @ 9:30 am ~ pH 5.98
Coag - 42 mg/L
Poly - 0.2 mg/L (DAF), Filter Aid: 0.01 mg/L

Daily Notes:
F8 DO → 9:40
* seems like best day
Note: DC's only read 1 column/day.
Not every hour as before.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Saturday, May 27, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	7.70	241.3	154.3	9.40	0.019	72.9	0.137	1.08	12:31	14.7
Post-DAF	6.21	245.5	179.5	9.80	0.021	84.5	0.072	0.50	12:33	14.1
O3-Combined	6.23	351.5	179.1	10.30	0.019	89.3	0.049	0.75	12:33	14.5
Filter 1	6.26	353.0	178.4	9.60	0.012	93.1	0.031	0.10	12:35	15.0
Fitler 2	6.25	350.2	178.0	9.50	0.012	91.4	0.040	0.10	12:35	15.1
Filter 3	6.25	346.4	178.3	9.50	0.008	92.9	0.032	0.11	12:34	14.9
Filter 4	6.20	342.9	180.0	9.60	0.008	92.7	0.033	0.18	12:34	15.1
Filter 5	6.16	336.7	259.9	9.50	0.010	92.5	0.034	0.29	12:35	14.8
Filter 6	6.11	326.0	174.8	9.40	0.005	93.1	0.031	0.25	12:36	15.1
Filter 7	6.04	307.1	176.7	9.40	0.006	92.9	0.032	0.10	12:36	14.9
Filter 8	5.86	346.0	175.5	9.00	0.012	93.1	0.032	0.17	12:37	15.0
Combined Pilot Filtrate	6.46	283.6	177.6	9.40	0.008	93.0	0.030	0.11	12:40	14.8
Plant Post-DAF	5.50	292.2	193.7	9.60	0.057	88.3	0.054	0.30	12:52	14.1
Plant O3-Combined	5.79	316.7	191.0	10.90	0.052	88.8	0.052	0.47	12:52	14.0
Plant Filtrate Combined	5.50	333.3	195.1	11.30	0.041	95.2	0.021	0.14	12:45	14.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:07 AM
Backwash End Time:	8:20 AM
Plant Raw Water Temp (SCADA):	

<u>Comments:</u>
pH - 6.25
Coag - 42 mg/L
Poly - 0.2 mg/L
Acid - 23.65 mg/L → Post DAF pH of 6.23 @ 7:14 a.m.; 6.25 @ 7:33 a.m.; 6.24 @ 8:15 a.m.
Bank A - 0.6 L/s
Bank B - 0.3 L/s

<u>Daily Notes:</u>
- Calibrated pH probe at 6:10 am
- At restart, large slug of orange coag. observed in both banks.
** Note: Bank B slug appeared w large floc/particulate when compared to Bank A. Largest slug is in Filters 5/6.
- pH before DAF: 6.01, after DAF 6.25 - D??

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, May 28, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	7.52	172.4	161.8	9.20	0.025	72.6	0.139	1.13	1:09	14.5
Post-DAF	6.65	191.6	172.9	9.70	0.026	79.2	0.102	0.77	1:09	14.1
O3-Combined	6.63	233.1	173.6	10.20	0.024	82.2	0.083	0.87	1:10	14.7
Filter 1	6.62	237.6	170.2	9.60	0.011	91.2	0.040	0.14	1:10	14.7
Fitler 2	6.64	249.2	170.7	9.80	0.010	91.4	0.039	0.11	1:10	14.5
Filter 3	6.65	256.0	169.6	9.40	0.011	91.0	0.041	0.17	1:11	14.7
Filter 4	6.63	253.7	169.9	9.40	0.009	91.5	0.038	0.11	1:11	14.7
Filter 5	6.60	264.5	166.2	9.50	0.005	91.1	0.041	0.12	1:11	14.7
Filter 6	6.58	270.0	164.1	9.30	0.007	91.2	0.040	0.14	1:12	14.8
Filter 7	6.59	278.5	164.5	9.20	0.009	91.2	0.040	0.13	1:12	14.8
Filter 8	6.57	278.8	164.0	9.30	0.009	90.9	0.041	0.14	1:12	14.7
Combined Pilot Filtrate	6.61	279.5	168.5	9.30	0.009	91.3	0.040	0.12	1:15	14.7
Plant Post-DAF	5.54	303.7	193.5	9.40	0.059	88.4	0.054	0.35	1:29	14.1
Plant O3-Combined	5.73	298.9	196.5	10.70	0.056	89.0	0.051	0.45	1:28	14.0
Plant Filtrate Combined	5.49	321.7	196.0	10.70	0.039	95.7	0.019	0.14	1:25	14.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:15 AM
Backwash End Time:	8:55 AM
Plant Raw Water Temp (SCADA):	

Comments:

pH - 6.55 → 6.51 @ 7:31 am, 6.53 @ 8:30 am, 6.55 @ 8:45 am, 6.55 @ 8:55 am
Coag - 42 mg/L
Poly - 0.2 mg/L
Acid - 10 mg/L

Notes:
- Good stg.

Title:	Winnipeg Alternative Coagulant Piloting Lab Data
Date:	Monday, May 29, 2017
Season:	Spring

	pH	**ORP**	**Conducutivity**	**DO**	**Hach Mn**	**UVT**	**Abs**	**Turb**	**Time**	**Temp °C**
Raw	7.74	175.9	155.2	9.50	0.016	73.0	0.136	1.14	12:39	14.3
Post-DAF	6.80	231.9	168.2	9.80	0.030	74.6	0.128	1.03	12:40	14.2
O3-Combined	6.83	339.7	167.3	10.30	0.028	78.5	0.104	1.08	12:41	14.5
Filter 1	6.83	339.6	165.8	9.70	0.011	90.8	0.041	0.20	12:43	14.8
Fitler 2	6.82	338.0	166.8	9.70	0.010	90.9	0.041	0.18	12:43	14.5
Filter 3	6.82	340.6	165.0	9.80	0.012	90.3	0.044	0.13	12:44	14.6
Filter 4	6.78	341.8	165.4	9.70	0.008	90.6	0.043	0.15	12:44	14.8
Filter 5	6.76	346.7	160.4	9.40	0.005	89.8	0.047	0.13	12:45	14.7
Filter 6	6.75	352.1	159.3	9.40	0.003	90.7	0.042	0.13	12:45	14.9
Filter 7	6.77	351.6	160.1	9.40	0.005	90.5	0.043	0.15	12:46	14.8
Filter 8	6.76	350.3	160.6	9.40	0.005	90.7	0.042	0.17	12:46	14.8
Combined Pilot Filtrate	6.79	349.9	164.2	9.60	0.011	90.7	0.042	0.16	12:37	14.6
Plant Post-DAF	5.47	376.0	193.3	10.10	0.056	89.0	0.050	0.36	12:30	14.3
Plant O3-Combined	5.62	385.2	191.3	10.70	0.052	89.6	0.047	0.48	12:31	14.0
Plant Filtrate Combined	5.30	344.7	197.2	10.90	0.038	97.5	0.019	0.29	12:35	14.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:30 AM
Plant Raw Water Temp (SCADA):	

6 a.m. - 3 p.m.

Comments:
Coag - 42 mg/L
Poly - 0.2 mg/L pH Dose
Acid - 6.85 mg/L @ 6:20 am = 6.40 acid = 10 mg/L
7:00 am = 6.55 acid = 7 mg/L
7:45 am = 6.60 acid = 1 mg/L
8:50 am = 6.70 acid = 0.10 mg/L
9:10 am = 6.75 acid = 0 mg/L
Bank A - 0.6 L/s
Bank B - 0.3 L/s

Daily Notes:
No H_2S_{04} added → Highest pH available.
No Type I → changed to Tuesday, May 30.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, May 30, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw	7.80	312.6	157.9	9.40	0.021	73.4	0.135	1.54	12:38	14.4
Post-DAF	6.16	281.1	182.3	9.70	0.023	81.5	0.089	0.82	12:37	13.5
O3-Combined	6.25	398.3	181.5	10.00	0.025	86.1	0.066	0.70	12:38	14.1
Filter 1	6.30	402.0	186.7	9.80	0.018	94.1	0.027	0.15	12:40	14.2
Fitler 2	6.30	405.2	184.8	9.70	0.013	94.1	0.026	0.12	12:40	14.3
Filter 3	6.27	403.6	185.3	9.80	0.014	94.1	0.026	0.11	12:42	14.1
Filter 4	6.25	398.4	184.8	9.70	0.015	94.2	0.026	0.10	12:42	14.4
Filter 5	6.30	401.0	185.1	9.50	0.015	93.7	0.028	0.09	12:44	14.5
Filter 6	6.32	396.5	185.9	9.40	0.009	92.9	0.032	0.08	12:44	14.6
Filter 7	6.25	402.3	187.0	9.50	0.011	93.3	0.030	0.12	12:47	14.5
Filter 8	6.27	403.5	186.4	9.30	0.008	94.0	0.027	0.13	12:47	14.6
Combined Pilot Filtrate	6.13	396.4	187.7	9.90	0.011	93.9	0.027	0.14	12:35	13.6
Plant Post-DAF	5.36	381.9	197.7	10.10	0.055	88.0	0.056	0.55	12:31	13.5
Plant O3-Combined	5.47	381.1	194.8	10.66	0.050	90.3	0.045	0.47	12:30	13.3
Plant Filtrate Combined	5.36	294.0	202.0	10.70	0.036	95.5	0.020	0.32	12:34	14.2
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:30 AM
Plant Raw Water Temp (SCADA):	

6 a.m. - 3:30 p.m.

Comments:
Optimal pH cond.
Coag - 42 mg/L (opt.)
Poly - 0.2 mg/L (opt.)
Acid - 25 mg/L → pH = 5.97 (opt.) - checked @ 8 a.m.
Bank A - 0.6 L/s
Bank B - 0.3 L/s

Daily Notes:
Type I sample day.
* pH ↑ than expected.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, May 31, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw		182.0	156.6	9.40	0.018	74.7	0.127	1.64	12:54	14.2
Post-DAF	6.01	216.6	184.0	9.60	0.025	84.3	0.073	0.81	12:52	14.1
O3-Combined	5.98	236.6	183.5	9.80	0.021	90.5	0.043	0.50	12:50	14.7
Filter 1	6.10	300.4	189.4	9.30	0.014	94.6	0.024	0.36	12:48	15.3
Fitler 2	6.07	296.1	189.8	9.30	0.010	95.0	0.022	0.38	12:46	14.7
Filter 3	6.08	286.6	188.9	9.40	0.012	95.1	0.022	0.35	12:44	14.7
Filter 4	6.08	272.4	188.9	9.20	0.014	95.0	0.022	0.14	12:42	15.0
Filter 5	6.09	291.1	191.2	9.40	0.012	94.5	0.025	0.12	12:40	15.3
Filter 6	6.10	282.0	192.3	9.30	0.015	94.1	0.026	0.12	12:37	15.0
Filter 7	6.12	290.4	189.1	9.30	0.007	94.2	0.026	0.13	12:39	15.2
Filter 8	6.03	283.8	189.7	9.90	0.009	94.4	0.025	0.12	12:36	15.0
Combined Pilot Filtrate	5.95	261.5	190.8	9.40	0.011	94.5	0.024	0.30	12:44	14.4
Plant Post-DAF	5.37	346.9	199.1	9.90	0.042	90.2	0.044	0.57	12:35	13.9
Plant O3-Combined	5.55	346.4	195.2	10.50	0.054	91.4	0.039	0.68	12:36	13.8
Plant Filtrate Combined	5.46	296.8	196.5	10.70	0.054	95.4	0.021	0.30	12:40	15.2
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	6:00 AM
Backwash End Time:	8:30 AM
Plant Raw Water Temp (SCADA):	

5:50 a.m. - 3:15 p.m.

Comments:
Optimal Day
Coag - 42 mg/L
Poly - 0.2 mg/L
Acid - 28 mg/L → 5.90 @ 6:43 a.m.
28 mg/L → 5.98 @ 7:10 a.m.
↑ 28.5 mg/L → 6.00 @ 7:40 a.m.
↑ 29.0 mg/L → 5.97 @ 8:15 a.m.
30.0 mg/L → 5.89 @ 10:15 a.m.
29.5 mg/L → 5.96 @ 11:10 a.m.
* pH supposed to be @ 5.95
Bank A - 0.6 L/s
Bank B - 0.3 L/s

Daily Notes:
Type II sample day.
Sludge - 12:30 - 16.2°C

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, June 01, 2017
Season: Spring

	pH	ORP	Conducutivity	DO	Hach Mn	UVT	Abs	Turb	Time	Temp °C
Raw										
Post-DAF										
O3-Combined										
Filter 1										
Fitler 2										
Filter 3										
Filter 4										
Filter 5										
Filter 6										
Filter 7										
Filter 8										
Combined Pilot Filtrate										
Plant Post-DAF										
Plant O3-Combined										
Plant Filtrate Combined										
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	Hrs	C

Backwash Start Time:	
Backwash End Time:	
Plant Raw Water Temp (SCADA):	

8:00

Comments:
THN Day # 1st Type II

Sample	pH THN	pH-MAA
Raw	7.12	7.15
WTP Comb	7.02	6.98
Pilot Comb	6.97	6.99

* pH maintained between
→ 6.97 - 7.15

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, July 24, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.73	308.8	148.5	8.30	0.042	73.1	0.136	1.99	22.7
Post-DAF	6.04	313.5	174.4	8.40	0.043	61.6	0.214	1.58	23.0
Post-Ozone	6.07	337.5	174.3	8.40	0.041	60.9	0.215	1.57	22.8
Filter 1	6.10	411.8	177.4	8.30	0.015	78.8	0.103	0.67	23.2
Filter 2	6.08	409.2	177.0	8.20	0.021	78.7	0.104	0.65	23.4
Filter 3	6.06	409.9	176.8	8.10	0.020	78.0	0.108	0.66	23.3
Filter 4	6.10	403.9	176.6	8.30	0.018	77.3	0.112	0.65	23.3
Filter 5	6.06	404.0	176.3	7.80	0.013	76.8	0.115	0.70	23.3
Filter 6	6.04	406.3	176.0	7.90	0.016	77.6	0.110	0.70	23.2
Filter 7	6.01	400.1	176.5	8.20	0.018	79.2	0.101	0.67	23.1
Filter 8	5.99	391.0	176.4	8.00	0.013	79.4	0.100	0.68	23.1
Pilot-Combined	5.92	388.5	176.7	8.10	0.015	79.4	0.100	0.69	23.0
Full-Scale Post-DAF	5.37	387.2	188.8	8.50	0.062	93.9	0.027	0.24	22.4
Full-Scale Post-Ozone	5.51	418.6	187.0	9.70	0.060	94.7	0.024	0.49	22.5
Full-Scale Combined	5.32	417.0	193.3	9.30	0.043	96.1	0.017	0.23	22.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Summer Pilot - Day #1 (5:50 am - 2:50 pm)
Coag - 25 mg/L Bank A = 0.6 L/S
Poly - 0 Bank B = 0.3 L/S
Acid - 42 mg/L - 5.84 @ 6 am
*Note: Acid Dose Used in
Backwash @ 6:00 am - 8:20 am
Sampling @ 12:50 pm
pH tested @ 6:40 am - 42 mg/L = 5.84 5.82 (41.5)
@ 7:20 am - 41.5 mg/L = 5.92 5.85 (41.0)
@ 8:05 am - 41.0 mg/L = 5.96 5.85
@ 8:45 am - 41.0 mg/L = 6.00

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, July 25, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.52	214.4	148.7	8.40	0.040	72.9	0.138	2.07	21.8
Post-DAF	6.00	242.8	175.1	8.50	0.033	67.5	0.170	1.30	21.7
Post-Ozone	5.99	271.9	175.2	8.40	0.027	68.1	0.166	1.22	22.0
Filter 1	6.09	319.3	177.5	8.30	0.006	83.2	0.080	0.47	21.9
Filter 2	6.07	311.9	178.1	8.40	0.007	83.6	0.079	0.45	22.1
Filter 3	6.05	318.8	176.8	8.30	0.008	83.2	0.080	0.47	22.0
Filter 4	6.05	314.7	177.4	8.20	0.011	83.5	0.078	0.46	22.0
Filter 5	6.03	313.4	176.5	8.00	0.004	83.5	0.078	0.48	22.2
Filter 6	6.06	307.5	176.3	8.00	0.008	83.8	0.077	0.46	22.1
Filter 7	6.04	303.6	176.1	7.90	0.006	83.3	0.079	0.49	22.2
Filter 8	6.02	298.7	176.3	8.00	0.003	83.6	0.078	0.47	22.1
Pilot-Combined	6.00	294.3	176.6	8.20	0.003	83.7	0.077	0.46	22.0
Full-Scale Post-DAF	5.27	242.1	187.4	8.10	0.055	90.4	0.044	0.32	21.7
Full-Scale Post-Ozone	5.45	287.2	187.5	10.10	0.059	91.5	0.038	0.56	21.9
Full-Scale Combined	5.31	304.7	190.5	9.60	0.037	96.0	0.018	0.11	22.0
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #2 (6:00 am - 3:30 pm)
Coag - 28 mg/L Bank A @ 0.6 L/S
Poly - 0.0 mg/L Bank B @ 0.3 L/S
Acid - 41 mg/L
Backwash @ 6:00 am - 8:40 am
Sample @ 1:00 pm
Acid = @ 41.0 - 5.89 @ 7:30 am (↓40.5 mg/L)
@ 40.5 - 5.92 @ 8:20 am (↓40.25 mg/L)
@ 40.25 @ 9:30 am

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, July 26, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.62	194.5	149.2	8.30	0.053	72.8	0.138	1.97	22.1
Post-DAF	5.95	221.7	176.7	8.50	0.037	76.0	0.119	1.13	22.0
Post-Ozone	5.97	242.5	176.2	8.40	0.039	76.7	0.115	1.13	22.3
Filter 1	6.06	335.9	179.0	8.20	0.017	90.0	0.460	0.36	22.0
Filter 2	6.05	336.1	178.7	8.10	0.016	90.6	0.043	0.35	22.3
Filter 3	6.05	331.8	178.7	8.10	0.012	90.7	0.043	0.35	22.2
Filter 4	6.04	331.0	179.5	8.10	0.013	91.0	0.041	0.32	22.3
Filter 5	6.03	324.2	179.1	7.80	0.008	88.8	0.053	0.32	22.4
Filter 6	6.05	319.4	179.0	8.00	0.010	89.2	0.049	0.32	22.4
Filter 7	6.02	315.8	178.5	7.70	0.006	90.5	0.043	0.37	22.3
Filter 8	6.01	308.3	178.7	7.90	0.008	89.5	0.048	0.31	22.4
Pilot-Combined	5.96	300.5	178.9	8.00	0.010	89.6	0.048	0.28	22.1
Full-Scale Post-DAF	5.32	314.1	190.5	8.60	0.075	91.0	0.041	0.65	22.0
Full-Scale Post-Ozone	5.50	319.2	187.7	9.50	0.069	89.5	0.048	0.62	22.2
Full-Scale Combined	5.34	316.8	190.1	8.80	0.057	96.1	0.017	0.36	22.3
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #3 (6:00 am - 3:00 pm)   @9 shutdown
Coag = 32 mg/L   No O3 still
Poly = 0   * NB Nelson cleaned lines
Acid = 40.25 mg/L   Online no good today
Backwash - 6:00 am - 8:00 am
PH @ 7:30 am - (40.25 mg/L = 5.88) acid ↓ 40 mg/L
PH @ 8:00 am - (40 mg/L = 5.90) acid ↓ 39.75 mg/L
PH @ 9:00 am - (39.75 mg/L = 5.91) acid ↓ 39.50 mg/L ↓

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, July 27, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.54	192.8	149.2	8.30	0.052	71.7	0.144	2.18	22.8
Post-DAF	5.95	229.9	176.4	8.50	0.038	80.0	0.097	0.79	22.5
Post-Ozone	5.93	255.8	176.1	8.30	0.042	78.3	0.103	0.71	22.5
Filter 1	6.06	347.8	178.3	8.10	0.014	91.5	0.039	0.25	22.9
Filter 2	6.04	345.9	177.8	8.10	0.014	91.7	0.037	0.23	22.6
Filter 3	6.06	356.8	177.4	8.00	0.012	91.3	0.040	0.25	22.6
Filter 4	6.05	347.4	178.2	8.10	0.014	91.3	0.040	0.27	23.1
Filter 5	6.02	346.3	177.5	7.90	0.013	90.1	0.046	0.24	22.6
Filter 6	6.00	354.7	177.7	7.70	0.011	90.8	0.042	0.23	22.8
Filter 7	5.96	342.4	176.5	7.70	0.008	91.4	0.039	0.27	22.7
Filter 8	6.00	339.8	177.0	7.70	0.011	91.6	0.038	0.25	22.9
Pilot-Combined	5.98	330.9	177.8	8.00	0.014	91.6	0.038	0.23	22.5
Full-Scale Post-DAF	5.24	307.8	189.6	8.60	0.070	90.1	0.045	0.55	22.6
Full-Scale Post-Ozone	5.41	351.4	187.3	9.70	0.065	89.8	0.047	0.70	22.2
Full-Scale Combined	5.29	329.7	189.2	9.20	0.050	96.5	0.015	0.33	22.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #4 (6:00 am - 3:00 pm)
Coag = 35 mg/L
Poly = 0
Acid = 39.25
Backwash = 6:00 am - 8:30 am
7:00 am - PH @ 39.25 mg/L = 5.77 ↓ 38.75 mg/L
8:00 am - PH @ 38.75 mg/L = 5.86 ↓ 38.25 mg/L
9:00 am - PH @ 38.25 mg/L = 5.88 ↓ 38.00 mg/L
10:00 am - PH @ 38.00 mg/L = 5.90 ↓ 37.75 mg/L
11:00 am - PH @ 37.75 mg/L = 5.86?? ↓ 37.25 mg/L
12:00 pm - PH @ 37.25 mg/L = 5.88 ↓ 37.00 mg/L

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, July 28, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.49	186.8	148.7	8.20	0.058	71.7	0.144	2.07	22.6
Post-DAF	6.06	225.1	174.8	8.30	0.037	80.1	0.096	0.77	22.5
Post-Ozone	6.06	259.5	174.3	8.40	0.045	78.0	0.108	0.87	22.7
Filter 1	6.10	326.0	175.6	8.00	0.015	91.0	0.040	0.25	22.5
Filter 2	6.15	323.1	175.8	8.10	0.013	91.0	0.041	0.27	22.7
Filter 3	6.16	319.2	175.2	8.00	0.014	91.4	0.039	0.27	22.6
Filter 4	6.14	316.7	176.4	8.00	0.012	92.2	0.035	0.26	22.7
Filter 5	6.12	312.7	174.6	7.70	0.013	91.4	0.039	0.27	23.0
Filter 6	6.10	308.6	175.0	7.80	0.009	91.6	0.038	0.20	22.8
Filter 7	6.10	304.0	174.0	7.80	0.009	92.5	0.034	0.20	23.0
Filter 8	6.08	298.3	173.8	7.70	0.008	91.5	0.039	0.23	22.9
Pilot-Combined	6.04	289.0	175.4	8.10	0.012	92.3	0.035	0.23	22.6
Full-Scale Post-DAF	5.27	307.2	189.3	8.60	0.069	90.6	0.043	0.55	22.5
Full-Scale Post-Ozone	5.42	324.9	188.1	9.40	0.063	89.4	0.048	0.78	22.3
Full-Scale Combined	5.26	294.1	188.6	9.00	0.045	97.0	0.013	0.29	22.3
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #5 (6:00 am - 2:45 pm)
Coag - 38 mg/L
Poly - 0
Acid - 32 mg/L * Nelson PH controller
Backwash - 6:00 am - 8:30 am
PH check @ 7:00 am = 6.01
PH check @ 11:00 am = 5.96

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Saturday, July 29, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.79	252.2	222.8	7.90	0.072	70.2	0.153	2.13	22.4
Post-DAF	6.01	242.4	173.8	8.20	0.044	81.8	0.085	0.65	22.5
Post-Ozone	6.01	211.5	174.9	8.30	0.046	79.8	0.099	0.84	22.6
Filter 1	6.10	239.6	176.4	8.10	0.017	89.7	0.047	0.88	22.7
Filter 2	6.16	250.0	176.3	8.10	0.015	90.3	0.044	0.55	22.8
Filter 3	6.12	258.7	176.0	8.10	0.012	88.5	0.053	0.88	22.8
Filter 4	6.16	297.1	176.2	8.00	0.017	89.7	0.047	0.35	22.7
Filter 5	6.13	302.6	176.3	7.90	0.011	89.9	0.046	0.67	22.9
Filter 6	6.15	303.3	175.9	7.70	0.009	89.8	0.047	0.64	22.9
Filter 7	6.13	306.7	174.8	7.80	0.008	90.6	0.043	0.54	22.9
Filter 8	6.18	309.7	175.0	7.90	0.009	89.9	0.046	0.44	22.9
Pilot-Combined	6.15	311.0	176.5	8.10	0.018	90.3	0.043	0.52	22.7
Full-Scale Post-DAF	5.36	317.5	190.0	8.10	0.080	88.3	0.055	0.89	22.5
Full-Scale Post-Ozone	5.42	304.8	187.9	9.70	0.070	88.0	0.056	0.92	22.5
Full-Scale Combined	5.27	320.2	188.7	9.20	0.055	93.7	0.029	0.46	22.8
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #6
Coag = 42 mg/L
Poly = 0
Acid = controller (Nelson)
Backwash = 5:00 am - 7:30 am
PH @ 6:30 am = 5.98
PH @ 8:00 am = 6.01
* There does not appear to be coagulant overflow in DAF

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, July 30, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.62	230.5	148.8	7.60	0.074	71.8	0.144	1.92	22.7
Post-DAF	6.10	272.4	173.2	8.20	0.047	79.5	0.100	0.89	23.0
Post-Ozone	6.10	287.1	173.8	8.20	0.054	77.8	0.109	1.02	22.8
Filter 1	6.22	367.2	174.8	8.00	0.018	92.2	0.035	0.19	23.2
Filter 2	6.21	365.3	174.3	8.00	0.016	92.1	0.036	0.19	23.4
Filter 3	6.20	362.4	175.1	7.90	0.015	92.3	0.035	0.16	23.3
Filter 4	6.15	360.9	174.7	7.90	0.012	92.3	0.035	0.20	23.3
Filter 5	6.14	359.9	174.5	7.60	0.011	92.5	0.034	0.20	23.3
Filter 6	6.13	350.1	174.7	7.50	0.009	92.4	0.034	0.22	23.2
Filter 7	6.10	340.7	173.7	7.80	0.010	92.6	0.033	0.22	23.1
Filter 8	6.11	333.3	173.7	7.90	0.012	92.4	0.034	0.19	23.1
Pilot-Combined	6.07	321.8	175.1	8.10	0.013	92.6	0.033	0.20	23.0
Full-Scale Post-DAF	5.43	339.5	186.5	8.40	0.083	86.0	0.066	1.03	22.4
Full-Scale Post-Ozone	5.62	345.0	184.8	9.10	0.074	88.0	0.055	0.65	22.5
Full-Scale Combined	5.48	347.8	185.1	8.70	0.053	95.1	0.022	0.23	22.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #7
*OPT TYPE 1 * Particle counter error today @ 6:15 am
Coag = 38
PH = controller @ 6.0
Poly = 0
Backwash = 6:10 am - 8:45 am
PH check @ 8:10 am = 6.03
NB - WTP-Post DAF & O3 - Yellow + coag in it

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, July 31, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.48	164.1	148.7	7.60	0.065	72.2	0.142	2.16	23.1
Post-DAF	5.71	215.9	175.9	8.10	0.037	83.4	0.079	0.60	22.8
Post-Ozone	5.80	240.1	176.9	8.00	0.038	83.7	0.077	0.67	22.9
Filter 1	6.03	312.0	181.9	7.80	0.015	93.0	0.031	0.21	23.2
Filter 2	6.02	311.7	181.8	7.80	0.015	93.8	0.028	0.17	23.0
Filter 3	6.03	308.3	181.7	7.80	0.013	92.8	0.033	0.20	23.4
Filter 4	6.02	309.0	182.5	7.70	0.014	93.1	0.031	0.23	23.3
Filter 5	6.07	306.5	184.0	7.50	0.004	93.0	0.032	0.23	23.2
Filter 6	6.07	304.4	184.5	7.60	0.006	93.2	0.031	0.17	23.4
Filter 7	6.06	301.4	185.3	7.50	0.005	92.7	0.033	0.18	23.2
Filter 8	6.00	286.7	183.5	7.70	0.003	92.0	0.036	0.18	23.2
Pilot-Combined	5.90	275.3	183.1	7.90	0.010	93.0	0.031	0.20	23.2
Full-Scale Post-DAF	5.33	288.3	188.1	8.10	0.073	87.6	0.058	0.36	22.7
Full-Scale Post-Ozone	5.48	287.2	186.3	9.40	0.071	88.8	0.052	0.75	22.5
Full-Scale Combined	5.30	263.4	188.2	9.00	0.045	94.9	0.023	0.36	22.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #8 (6:00 am - 3:00 pm)
pH optimization
Coag = 38 mg/L
Poly = 0
pH = 5.65 - controller * Nelson ↓pH @ 8:00 am
pH check @ 9:30 am = 5.85
pH check @ 10:20 am = 5.78
pH check @ 11:00 am = 5.66

* some fluctuations in pH meter on DAF
- SCADA shows on x1022

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, August 01, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.66	178.7	148.7	7.30	0.078	71.0	0.149	1.94	22.8
Post-DAF	5.99	222.9	172.0	8.00	0.049	78.6	0.105	0.84	22.6
Post-Ozone	5.98	250.3	174.4	8.20	0.051	77.0	0.113	0.91	22.8
Filter 1	6.07	285.8	176.7	8.10	0.020	91.3	0.039	0.17	22.7
Filter 2	6.10	282.7	176.6	8.00	0.021	91.6	0.038	0.12	22.7
Filter 3	6.09	279.2	176.8	7.90	0.019	91.3	0.040	0.13	22.9
Filter 4	6.08	271.8	176.8	7.80	0.022	91.9	0.037	0.11	22.9
Filter 5	6.11	274.6	176.9	7.70	0.012	91.6	0.038	0.13	23.0
Filter 6	6.07	270.0	176.7	7.70	0.013	91.1	0.040	0.14	22.9
Filter 7	6.04	265.9	175.4	7.60	0.012	91.1	0.040	0.14	23.0
Filter 8	6.00	260.8	174.5	7.90	0.010	91.0	0.041	0.17	22.9
Pilot-Combined	6.09	222.4	175.3	7.70	0.015	90.9	0.042	0.15	22.7
Full-Scale Post-DAF	5.34	273.7	188.8	8.20	0.092	88.6	0.052	0.44	22.6
Full-Scale Post-Ozone	5.46	266.9	186.6	9.30	0.089	87.9	0.056	0.89	22.4
Full-Scale Combined	5.33	264.9	191.1	9.20	0.060	95.3	0.021	0.27	22.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #9 (6:00 am - 3:00 pm)
Coag = 38 mg/L
pH = 5.95 (controller on @ 2:00 pm July 31)
Poly = 0
* Nelson improved pH control
ave ± 0.02
pH check @ 6:50 am = 5.98
pH check @ 7:30 am = 5.96

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, August 02, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.54	223.7	148.6	7.00	0.082	73.1	0.136	2.12	22.7
Post-DAF	6.27	240.7	170.0	8.10	0.056	72.0	0.143	1.22	22.8
Post-Ozone	6.25	262.7	169.2	8.10	0.055	70.8	0.150	1.41	22.9
Filter 1	6.33	286.1	171.4	7.90	0.019	90.9	0.041	0.28	22.8
Filter 2	6.32	285.5	171.3	7.80	0.021	90.4	0.044	0.27	22.9
Filter 3	6.31	284.7	170.9	7.80	0.015	90.9	0.041	0.29	22.9
Filter 4	6.29	283.3	171.2	7.80	0.015	90.6	0.043	0.31	23.0
Filter 5	6.30	281.4	169.7	7.80	0.008	88.5	0.053	0.32	22.8
Filter 6	6.29	279.7	169.5	7.60	0.010	88.6	0.052	0.31	23.0
Filter 7	6.26	277.3	168.8	7.60	0.011	87.5	0.058	0.29	22.9
Filter 8	6.25	273.2	168.0	7.70	0.011	87.4	0.059	0.30	23.1
Pilot-Combined	6.22	266.0	170.4	8.00	0.012	88.6	0.052	0.30	23.1
Full-Scale Post-DAF	5.32	287.7	187.1	7.90	0.088	90.2	0.045	0.46	22.7
Full-Scale Post-Ozone	5.47	288.1	186.8	9.40	0.079	91.7	0.038	0.81	22.8
Full-Scale Combined	5.21	272.3	188.3	9.00	0.056	97.0	0.013	0.29	22.8
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #10 (6:00 am - 3:00 pm)
pH opt
Coag = 38 mg/L
Poly = 0
Acid = 6.25 pH controller
6:45 am pH check = 6.23
8:40 am pH check = 6.27
* Neslon cleaned DAF turb meters @ 11:30 am and post-filter turbs @ 10:00 am

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, August 03, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.58	172.7	149.2	7.40	0.077	74.0	0.131	1.89	22.5
Post-DAF	5.83	212.0	178.2	8.60	0.046	80.4	0.094	0.77	22.7
Post-Ozone	5.82	256.2	178.3	8.60	0.043	81.7	0.088	0.86	22.8
Filter 1	5.99	295.8	181.0	8.10	0.022	94.0	0.027	0.18	22.5
Filter 2	5.98	293.2	180.8	8.30	0.023	94.2	0.026	0.15	22.8
Filter 3	5.97	289.0	180.9	8.10	0.022	94.4	0.025	0.15	22.5
Filter 4	5.97	285.9	180.8	7.90	0.024	94.7	0.024	0.14	22.6
Filter 5	6.00	279.7	181.0	7.70	0.016	94.1	0.026	0.15	22.6
Filter 6	5.98	275.5	180.7	7.90	0.017	94.4	0.025	0.15	22.7
Filter 7	5.93	273.0	180.7	7.70	0.014	94.4	0.025	0.17	22.6
Filter 8	5.93	267.9	180.0	7.80	0.016	94.7	0.024	0.18	22.6
Pilot-Combined	5.98	256.3	181.0	8.00	0.019	94.6	0.024	0.16	22.9
Full-Scale Post-DAF	5.34	269.1	188.9	8.50	0.085	92.4	0.034	0.39	22.5
Full-Scale Post-Ozone	5.52	319.8	187.3	9.60	0.082	90.4	0.044	0.82	22.6
Full-Scale Combined	5.21	314.0	189.5	9.40	0.060	95.2	0.021	0.30	22.7
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #11 (6:00 am - 3:00 pm + 1 h evening)
Coag = 38 mg/L
Poly = 0
Acid = pH of 5.80
pH check @ 7:20 am = 5.80
pH check @ 9:40 am = 5.82

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, August 04, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.78	171.8	149.4	8.2	0.046	72.7	0.139	1.90	22.7
Post-DAF	5.85	218.5	177.2	8.5	0.035	82.5	0.083	0.63	22.8
Post-Ozone	5.84	244.3	177.1	8.2	0.034	82.8	0.081	0.57	22.5
Filter 1	5.99	298.8	178.9	8.0	0.020	91.8	0.037	0.22	22.9
Filter 2	5.98	296.7	179.3	8.0	0.018	92.3	0.035	0.19	23.0
Filter 3	5.97	290.7	179.5	8.0	0.018	92.1	0.036	0.15	23.0
Filter 4	5.94	288.0	179.4	8.0	0.019	92.1	0.036	0.17	23.0
Filter 5	5.95	282.2	178.8	7.8	0.012	92.4	0.035	0.16	23.1
Filter 6	5.93	278.0	179.2	7.8	0.013	92.1	0.036	0.19	23.1
Filter 7	5.91	268.5	178.0	7.7	0.013	92.1	0.036	0.18	23.1
Filter 8	5.87	262.9	177.5	8.1	0.010	92.5	0.034	0.17	23.0
Pilot-Combined	5.88	241.1	178.4	8.2	0.016	91.6	0.045	0.16	22.9
Full-Scale Post-DAF	5.42	252.8	188.5	8.5	0.079	89.0	0.051	0.35	22.8
Full-Scale Post-Ozone	5.62	309.5	186.3	9.5	0.076	88.9	0.052	0.65	22.4
Full-Scale Combined	5.33	291.5	188.8	9.1	0.053	95.8	0.018	0.32	22.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #12 (5:50 am - 3:50 pm)
pH opt day - type II
Coag = 38
pH = 5.80
Poly = 0
pH check @ 6:30 am = 5.82
pH check @ 10:00 am = 5.83

* HAA / THM @ raw intake in plant
* DBP @ 20° or @ room temp.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Saturday, August 05, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.53	182.6	151.0	7.9	0.063	71.8	0.144	1.88	22.3
Post-DAF	5.80	216.2	178.7	8.2	0.036	83.3	0.079	0.64	22.2
Post-Ozone	5.86	250.8	177.7	8.2	0.037	83.8	0.077	0.69	22.4
Filter 1	6.01	291.1	179.0	8.0	0.024	91.2	0.044	0.20	22.5
Filter 2	6.01	288.3	178.8	8.0	0.021	90.2	0.045	0.19	22.5
Filter 3	6.00	286.6	178.6	8.0	0.018	90.3	0.044	0.18	22.6
Filter 4	5.99	282.4	178.4	7.9	0.018	91.8	0.037	0.16	22.6
Filter 5	6.01	280.6	177.5	7.6	0.012	90.1	0.045	0.19	22.6
Filter 6	6.00	274.9	177.7	7.7	0.016	90.0	0.046	0.19	22.5
Filter 7	5.97	272.3	176.7	7.8	0.014	92.2	0.035	0.18	22.5
Filter 8	5.98	268.1	176.2	7.7	0.015	91.8	0.037	0.20	22.5
Pilot-Combined	5.95	256.0	178.1	8.0	0.022	91.5	0.039	0.19	22.5
Full-Scale Post-DAF	5.29	273.2	190.7	8.6	0.080	88.9	0.046	0.42	22.3
Full-Scale Post-Ozone	5.48	294.0	187.2	9.4	0.075	88.2	0.055	0.66	22.3
Full-Scale Combined	5.37	273.4	190.9	9.1	0.064	94.5	0.024	0.35	22.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #13 (6:00 am - 4:00 pm)
Coag = 38 mg/L * Poly set at 3:00 pm August 4th
Acid = pH = 5.80 (pH controller not accounting for polymer addition - offset to 5.70 - DID NOT WORK)
Poly = 0.05
pH check @ 6:30 am = 5.88
pH check @ 8:30 am = 5.90
* small fluctuation @ 8:00 am 5.56 - 5.8

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, August 06, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.77	291.9	149.3	8.3	0.047	71.8	0.144	1.84	22.8
Post-DAF	5.83	273.7	179.2	8.3	0.038	84.4	0.072	0.64	22.7
Post-Ozone	5.80	257.1	178.4	8.2	0.036	85.1	0.069	0.56	22.7
Filter 1	5.92	264.4	180.0	8.0	0.023	93.9	0.028	0.18	22.7
Filter 2	5.89	266.1	180.1	8.0	0.021	95.5	0.020	0.18	22.9
Filter 3	5.91	266.3	180.0	8.0	0.020	95.6	0.019	0.14	22.7
Filter 4	5.90	266.4	179.8	7.8	0.019	94.1	0.027	0.12	22.7
Filter 5	5.91	265.5	178.6	7.8	0.017	93.9	0.027	0.15	22.8
Filter 6	5.91	166.6	177.8	7.8	0.018	93.8	0.028	0.14	22.8
Filter 7	5.90	267.2	177.6	7.7	0.016	95.7	0.019	0.12	22.7
Filter 8	5.91	264.6	177.2	7.9	0.016	95.3	0.021	0.13	22.8
Pilot-Combined	5.89	258.7	183.2	8.1	0.019	95.1	0.022	0.15	22.8
Full-Scale Post-DAF	5.41	276.8	188.4	8.8	0.063	91.2	0.040	0.36	22.7
Full-Scale Post-Ozone	5.59	275.1	187.9	9.5	0.060	89.9	0.046	0.68	22.4
Full-Scale Combined	5.30	269.9	189.1	9.4	0.046	97.5	0.011	0.24	23.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #14 (6:00 am -)
Coag = 38 mg/L
Acid & pH = 5.80 (not controlleer) manual pump
Poly = 0.10
*ORP measured in RMV - ORP used so - 198.8 mu offset
pH check @ 6:15 am = 5.65 @ 4.10 RPM

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, August 07, 2017
Season: Summer

	pH	**ORP**	**Conductivity**	**DO**	**Hach Mn**	**UVT**	**Abs**	**Turb**	**Temp**
Raw	7.61	395.5	149.7	8.2	0.047	72.5	0.140	1.70	22.7
Post-DAF	5.83	423.3	177.2	8.1	0.035	90.6	0.042	0.63	22.8
Post-Ozone	5.78	445.0	177.8	8.2	0.035	91.2	0.040	0.32	22.9
Filter 1	5.90	534.0	179.2	8.0	0.020	93.0	0.032	0.16	23.0
Filter 2	5.88	532.9	178.5	7.8	0.021	94.5	0.025	0.14	22.9
Filter 3	5.88	530.3	177.8	7.8	0.019	94.1	0.027	0.14	22.0
Filter 4	5.87	529.8	177.9	7.9	0.020	93.1	0.031	0.14	23.0
Filter 5	5.90	527.6	178.0	7.7	0.012	93.5	0.029	0.15	23.0
Filter 6	5.91	523.3	177.7	7.7	0.016	93.6	0.029	0.16	23.0
Filter 7	5.89	526.1	177.4	7.9	0.016	94.0	0.027	0.14	23.0
Filter 8	5.84	526.0	176.9	7.8	0.013	94.4	0.025	0.14	23.0
Pilot-Combined	5.82	521.6	178.6	7.7	0.018	94.0	0.027	0.14	22.0
Full-Scale Post-DAF	5.22	548.7	189.3	8.4	0.060	89.8	0.047	0.43	22.0
Full-Scale Post-Ozone	5.48	545.2	186.5	9.3	0.053	88.9	0.046	0.65	22.0
Full-Scale Combined	5.31	529.4	191.3	9.2	0.047	97.5	0.011	0.18	22.0
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #15 (6:00 am -)
Coag = 38 mg/L
Acid = 5.80 manual control
Poly = 0.15 mg/L (started @ 6:00 am August 7th)
* ORP - RMV offset = 197.8 mv - not manually applied to values
pH check @ 7:50 am = 5.77 @ 3.9 RPM
pH check @ 8:50 am = 5.80 @ 3.8 RPM

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, August 08, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.73	394.3	149.1	7.9	0.055	72.2	0.141	2.12	22.9
Post-DAF	5.79	417.7	177.4	8.3	0.031	85.2	0.070	0.64	23.0
Post-Ozone	5.83	423.8	178.0	8.2	0.028	90.6	0.044	0.26	23.0
Filter 1	6.00	535.6	176.1	8.0	0.020	93.0	0.044	0.11	23.1
Filter 2	5.99	535.4	176.7	7.9	0.015	92.1	0.036	0.13	23.1
Filter 3	5.96	536.5	177.4	8.1	0.018	92.1	0.036	0.10	23.1
Filter 4	5.95	531.8	176.7	7.8	0.017	91.6	0.038	0.10	23.1
Filter 5	5.95	529.7	173.6	7.8	0.014	91.7	0.038	0.13	23.1
Filter 6	5.97	522.3	173.5	7.7	0.014	91.8	0.037	0.15	23.2
Filter 7	5.94	517.2	173.1	7.7	0.013	92.4	0.034	0.14	23.2
Filter 8	5.97	516.9	173.0	7.6	0.015	92.7	0.033	0.17	23.1
Pilot-Combined	5.95	513.7	174.2	8.0	0.018	91.8	0.037	0.12	23.1
Full-Scale Post-DAF	5.30	520.3	188.8	8.6	0.059	89.6	0.047	0.36	22.9
Full-Scale Post-Ozone	5.53	532.9	186.1	9.5	0.061	86.1	0.064	0.68	22.8
Full-Scale Combined	5.27	513.4	187.7	8.9	0.046	94.7	0.024	0.25	22.8
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #16 (5:15 am - 4:30 pm)
Coag = 38 mg/L
pH = 5.80 (manual)
Poly = 0.20 mg/L
* ORP - +197.8 mv offset applied by intrument calibration
pH check @ 6:30 am = 5.81 @ 3.8 RPM
pH check @ 7:40 am = 5.83 @ 3.8 RPM
pH check @ 11:00 am = 5.99 - controller

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, August 09, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.67	364.9	149.7	8.1	0.059	72.1	0.141	1.96	22.5
Post-DAF	5.81	416.8	177.3	8.4	0.037	84.5	0.073	0.73	22.5
Post-Ozone	5.82	427.6	177.3	8.5	0.033	89.1	0.050	0.36	22.6
Filter 1	5.94	545.8	178.2	7.2	0.019	91.9	0.036	0.20	22.8
Filter 2	5.95	545.2	178.0	7.5	0.017	92.6	0.033	0.22	22.8
Filter 3	5.94	544.0	178.6	7.5	0.014	92.9	0.032	0.21	22.8
Filter 4	5.92	542.1	177.9	7.5	0.019	93.0	0.032	0.26	22.8
Filter 5	5.92	539.2	177.6	7.9	0.017	92.4	0.034	0.18	22.7
Filter 6	5.91	537.8	177.3	7.7	0.021	92.4	0.034	0.16	22.8
Filter 7	5.89	531.9	176.3	7.8	0.019	92.6	0.033	0.17	22.8
Filter 8	5.84	524.0	170.1	7.9	0.018	91.4	0.039	0.17	22.7
Pilot-Combined	5.89	503.7	176.8	7.4	0.017	91.6	0.038	0.19	22.8
Full-Scale Post-DAF	5.30	534.0	188.8	8.7	0.065	88.3	0.054	0.40	22.4
Full-Scale Post-Ozone	5.51	543.5	186.2	9.3	0.067	85.8	0.067	0.66	22.4
Full-Scale Combined	5.33	535.6	189.4	8.8	0.046	94.0	0.027	0.22	22.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #17 (5:15 am -)
Coag = 38 mg/L
pH = 5.80 - controller
Poly = 0.25 mg/L - turned on @ 5:30 am
* ORP - 1978 offset applied
pH check @7:00 am = 5.83
pH check @10:30 am = 5.78
* some coagulant / poly carryover in last DF chamber

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, August 14, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.40	181.6	148.9	7.6	0.037	72.6	0.139	1.29	22.5
Post-DAF	5.89	213.7	175.8	8.0	0.028	83.4	0.079	0.64	22.8
Post-Ozone	5.90	310.2	175.5	8.7	0.029	87.5	0.058	0.54	22.9
Filter 1	5.81	313.6	178.2	8.0	0.167	92.5	0.034	0.19	23.4
Filter 2	5.83	310.2	179.0	8.0	0.183	93.1	0.031	0.19	23.5
Filter 3	5.82	307.8	179.2	7.9	0.154	93.4	0.030	0.19	23.5
Filter 4	5.83	304.6	178.8	7.7	0.137	93.3	0.030	0.20	23.4
Filter 5	5.99	297.2	184.2	7.5	0.031	93.1	0.031	0.17	23.4
Filter 6	5.97	294.7	185.5	7.5	0.026	93.1	0.031	0.19	23.3
Filter 7	5.96	295.8	184.6	7.3	0.027	92.7	0.033	0.20	23.3
Filter 8	5.93	296.0	184.6	7.4	0.021	93.7	0.028	0.16	23.2
Pilot-Combined	5.85	283.4	195.2	7.6	0.152	93.0	0.032	0.17	23.3
Full-Scale Post-DAF	5.46	300.6	185.1	8.4	0.064	84.4	0.074	0.54	22.5
Full-Scale Post-Ozone	5.60	296.8	183.5	9.4	0.060	83.6	0.078	0.76	22.6
Full-Scale Combined	5.24	288.3	185.8	8.9	0.046	93.8	0.028	0.29	22.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #18 (6:00 am - 6:15 pm)
Best of all 3 * backwash started @8:00 am - 11:00 am after filter overflow
Coag = 38 mg/L
Acid = 5.80 with controller
Poly = 0.1 mg/L (started at 8:25 am)
* Type II Testing
pH controller offset to 5.70 with polymer addition
O3 on @ 2:00 pm

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, August 15, 2017
Season: Summer

	pH	**ORP**	**Conductivity**	**DO**	**Hach Mn**	**UVT**	**Abs**	**Turb**	**Temp**
Raw	7.42	230.5	149.0	7.5	0.042	70.9	0.149	1.74	22.5
Post-DAF	5.86	267.6	175.6	8.0	0.029	82.1	0.086	0.70	22.5
Post-Ozone	5.94	388.7	175.3	8.7	0.026	87.5	0.058	0.72	22.8
Filter 1	6.00	388.9	181.7	8.0	0.030	93.6	0.029	0.25	22.7
Filter 2	5.99	392.9	181.1	8.0	0.025	93.8	0.028	0.21	22.8
Filter 3	5.99	401.3	181.2	8.0	0.023	94.0	0.027	0.19	22.8
Filter 4	5.97	406.8	181.7	7.8	0.021	94.2	0.026	0.21	22.8
Filter 5	5.97	400.4	182.6	7.9	0.016	94.0	0.027	0.21	23.0
Filter 6	5.96	400.3	182.6	7.6	0.019	93.9	0.027	0.17	23.0
Filter 7	5.94	402.3	182.5	7.5	0.015	94.4	0.025	0.19	23.0
Filter 8	5.94	397.8	182.1	7.6	0.018	94.3	0.025	0.18	22.9
Pilot-Combined	5.91	371.5	182.3	8.0	0.022	94.3	0.025	0.20	22.8
Full-Scale Post-DAF	5.40	384.3	185.8	8.3	0.056	84.0	0.076	0.59	22.0
Full-Scale Post-Ozone	5.55	386.1	184.4	9.3	0.051	81.3	0.090	0.80	22.0
Full-Scale Combined	5.40	384.6	195.4	9.1	0.044	91.5	0.039	0.30	22.0
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Pilot Day #19 (6:00 am - 7:45 pm)
Coag = 38 mg/L
Poly = 0.1 mg/L
pH = 5.80
Backwash @ 11:30 am - 1:50 pm
*Filters 8 and 6 were not overflowing in the morning
pH offset @5.70
pH check @ 7:30 am = 5.85

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, August 16, 2017
Season: Summer

	pH	**ORP**	**Conductivity**	**DO**	**Hach Mn**	**UVT**	**Abs**	**Turb**	**Temp**
Raw	7.25	208.8	149.0	7.2	0.037	73.7	0.133	1.42	22.3
Post-DAF	5.91	214.0	175.6	7.8	0.031	82.7	0.082	0.69	22.4
Post-Ozone	5.93	276.6	175.7	8.0	0.032	86.0	0.066	0.51	22.4
Filter 1	6.00	425.3	181.9	7.6	0.031	92.5	0.034	0.22	22.6
Filter 2	5.99	426.8	181.8	7.5	0.028	92.8	0.032	0.19	22.6
Filter 3	6.01	435.0	182.0	7.6	0.023	92.4	0.034	0.17	22.6
Filter 4	6.00	453.8	182.1	7.6	0.027	92.1	0.036	0.18	22.6
Filter 5	5.98	457.0	182.2	7.5	0.015	93.0	0.032	0.16	22.7
Filter 6	5.98	461.3	182.9	7.4	0.018	93.0	0.032	0.18	22.7
Filter 7	5.96	465.8	182.5	7.3	0.011	92.5	0.034	0.70	22.6
Filter 8	5.93	472.5	182.5	7.4	0.015	92.5	0.034	0.20	22.6
Pilot-Combined	5.88	454.9	182.5	7.6	0.023	92.7	0.033	0.22	22.6
Full-Scale Post-DAF	5.36	450.4	184.8	8.0	0.066	83.9	0.076	0.71	22.3
Full-Scale Post-Ozone	5.55	455.2	182.5	9.1	0.052	82.5	0.084	0.80	22.3
Full-Scale Combined	5.24	457.4	184.6	8.8	0.046	92.1	0.036	0.33	22.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:
-No UFRV ran today due filter head loss during run and fire drill.

Pilot Day #20 (9:00 am - 10:00 pm)
Coag = 38 mg/L
Poly = 0.1 mg/L
pH = 5.80 - 5.70 offset to account for polymer in pH
Backwash @ 12:00 pm - 2:30 pm
Sample @ 6:30 pm
* pH a bit high - reduced offset

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, August 17, 2017
Season: Summer

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.38	219.4	149.4	7.5	0.037	76.0	0.119	1.44	22.5
Post-DAF	5.82	257.3	176.3	7.6	0.027	87.9	0.056	0.64	22.4
Post-Ozone	5.80	292.6	176.6	7.8	0.032	90.0	0.046	0.52	22.6
Filter 1	5.94	413.7	182.9	7.6	0.032	95.1	0.022	0.38	22.7
Filter 2	5.91	416.9	182.7	7.5	0.030	95.0	0.022	0.20	22.8
Filter 3	5.91	417.9	183.1	7.5	0.026	95.0	0.022	0.18	22.8
Filter 4	5.88	418.5	181.7	7.5	0.027	95.4	0.020	0.17	22.8
Filter 5	5.91	416.5	184.4	7.3	0.016	95.8	0.019	0.17	22.8
Filter 6	5.88	412.9	185.3	7.2	0.018	95.8	0.019	0.15	22.8
Filter 7	5.87	408.3	183.9	7.1	0.017	95.7	0.019	0.17	22.8
Filter 8	5.88	407.1	184.6	7.3	0.017	95.8	0.019	0.16	22.8
Pilot-Combined	5.88	373.4	185.2	7.9	0.025	95.3	0.021	0.16	22.8
Full-Scale Post-DAF	5.42	370.2	184.4	8.2	0.062	86.1	0.065	0.65	22.3
Full-Scale Post-Ozone	5.58	370.7	182.9	8.9	0.061	83.1	0.080	0.83	22.4
Full-Scale Combined	5.23	345.4	186.5	8.5	0.053	95.1	0.022	0.33	22.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:
-No UFRV ran today due filter head loss during run and fire drill.

Pilot Day #21 (9:45 am)
Coag = 38 mg/L
Poly = 0.1 mg/L
pH = 5.80 - 5.60 offset @ 11:50 am

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, October 16, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.26	271.3	149.3	10.1	0.020	74.7	0.126	1.52	10.4
Post-DAF	5.93	244.6	179.2	9.4	0.025	69.8	0.156	1.70	10.5
Post-Ozone	5.96	326.3	177.2	10.9	0.030	70.2	0.155	1.58	11.0
Filter 1	6.05	448.6	178.9	10.7	0.027	86.8	0.061	0.56	11.4
Filter 2	6.04	447.6	178.9	10.7	0.028	87.1	0.060	0.65	11.4
Filter 3	6.02	452.4	178.6	10.8	0.021	86.6	0.062	0.70	11.3
Filter 4	6.00	441.6	178.8	10.5	0.023	85.6	0.067	0.69	11.4
Filter 5	5.98	444.6	180.8	10.6	0.029	87.4	0.058	0.48	11.4
Filter 6	5.96	448.6	180.3	10.3	0.018	87.5	0.058	0.49	11.5
Filter 7	5.96	446.4	181.1	10.5	0.018	87.8	0.056	0.46	11.5
Filter 8	5.98	445.6	181.0	10.6	0.018	87.7	0.057	0.49	11.6
Pilot-Combined	5.99	443.2	179.4	10.6	0.015	87.1	0.060	0.56	11.5
Full-Scale Post-DAF	5.51	456.3	187.8	11.0	0.051	89.1	0.050	0.54	10.2
Full-Scale Post-Ozone	5.63	513.9	184.9	12.7	0.047	90.3	0.044	0.58	10.3
Full-Scale Combined	5.60	349.4	186.2	10.1	0.041	94.9	0.023	0.41	10.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Observations - Yellow colour observed in filter head volume following initiation of second ozone contactor pump. Likely due to residual buildup.
pH is not chaning at post-DAF with ↓ of H2SO4.
* pH in DAF tank #1 is 5.83 when pH probe (raw) is set to 5.40.

Coag = 36 mg/L @ 630 am	* no ozone dose
Poly = 0 mg/L	ozonator not active
pH = 5.80	Bank A = 0.6 L/S
BW = 6am-830am	Bank B = 0.3 L/S

All Instruments calibrated in AM
pH check Post-DAF - @725am - 5.87 pH with controller at 5.60 pH
- @745am - 5.88 pH with controller at 5.60 pH
  * pH controller ↓ to 5.50 @ 750am
- @9am - 5.85 pH with controller at 5.50 pH
  * pH controller ↓ to 5.45 @ 9am
- @10am - 5.81 pH with controller at 5.4 pH
- @1130am - 5.86 pH with controller at 5.45 pH

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, October 17, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.32	248.2	149.3	10.5	0.022	75.3	0.123	0.108	10.6
Post-DAF	5.89	238.5	178.6	10.4	0.029	75.1	0.124	0.169	10.5
Post-Ozone	5.85	292.0	177.5	10.3	0.024	74.8	0.127	0.146	11.1
Filter 1	6.00	336.5	178.3	10.2	0.021	89.7	0.048	0.36	11.0
Filter 2	5.99	351.8	177.8	10.2	0.017	90.6	0.043	0.35	11.1
Filter 3	5.94	353.0	177.5	10.2	0.016	91.0	0.041	0.37	11.1
Filter 4	5.93	333.0	179.2	10.0	0.019	90.3	0.045	0.36	11.0
Filter 5	5.94	301.0	178.5	10.1	0.017	90.5	0.043	0.32	11.1
Filter 6	5.92	394.6	179.1	10.0	0.020	90.7	0.042	0.38	11.2
Filter 7	5.92	398.8	178.9	10.1	0.021	90.5	0.043	0.37	11.1
Filter 8	5.92	406.1	179.5	10.2	0.018	90.6	0.043	0.40	11.0
Pilot-Combined	5.90	402.2	178.9	10.5	0.016	90.5	0.043	0.33	10.9
Full-Scale Post-DAF	5.55	389.7	188.2	10.7	0.052	89.3	0.049	0.54	10.1
Full-Scale Post-Ozone	5.66	384.6	186.6	11.7	0.047	90.5	0.043	0.57	10.3
Full-Scale Combined	5.63	327.3	188.0	10.9	0.039	96.5	0.015	0.16	10.7
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 38 mg/L   O3 = not active
Poly = 0 mg/L   BW = 6am-830am
pH = 5.80   Flow = A - 0.6 / B - 0.3

pH check - @630am - Controller @ 5.4 pH = 5.91 Post-DAF pH
↑ pH to 5.45 at 640am - to account for ↑ Ferric to 38 mg/L
- @7am - Controller @ 5.45 pH = 5.98 Post-DAF pH
↓ Controller to 5.40 @ 705am
- @8am - Controller @ 5.40 = 5.95 Post-DAF pH
↓ Controller to 5.30 @ 8am
- @10am - Controller @ 5.30 = 5.87 Post-DAF pH
↓ Controller to 5.22 @ 1020am
- @11am - Controller @ 5.22 = 5.70 Post-DAF pH
↑ Controller to 5.35 @ 1110am
- @1130am - Controller @ 5.35 = 5.82 Post-DAF pH
- @12pm - Controller @ 5.35 = 5.95 Post-DAF pH

@ ~ 115 Nelson
- replace pH probe on DAF and will try to stabilize pH Post-DAF
- pH ~ 4 @ 210pm
- Nelson replaced and calulated probe on DAF
* figured out it was acid pump to be issue will replace tomorrow and check
may also do ferric pump tube
*indicates long run times should have pump maintenance

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, October 18, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.18	174.4	150.9	10.8	0.019	75.9	0.120	1.43	10.2
Post-DAF	5.85	197.4	177.6	10.0	0.029	75.0	0.125	1.03	10.3
Post-Ozone	5.91	263.1	184.5	10.8	0.026	73.8	0.133	1.20	10.6
Filter 1	6.05	298.3	174.8	10.7	0.025	92.3	0.034	0.35	10.9
Filter 2	5.99	297.2	175.1	10.7	0.019	92.7	0.033	0.28	11.0
Filter 3	5.98	284.4	175.3	10.8	0.014	93.7	0.028	0.26	10.9
Filter 4	5.96	285.5	176.3	10.7	0.017	93.1	0.031	0.27	11.0
Filter 5	5.94	286.7	172.4	10.4	0.013	94.3	0.025	0.21	11.1
Filter 6	5.91	281.9	175.5	10.4	0.012	94.9	0.023	0.20	11.3
Filter 7	5.92	279.0	172.5	10.5	0.012	94.1	0.027	0.19	11.3
Filter 8	5.93	274.1	172.5	10.6	0.010	93.7	0.028	0.21	11.2
Pilot-Combined	5.89	255.9	173.5	10.9	0.012	92.3	0.025	0.24	10.8
Full-Scale Post-DAF	5.51	261.6	187.6	10.5	0.044	89.5	0.048	0.54	9.9
Full-Scale Post-Ozone	5.63	264.2	188.2	11.20	0.043	97.6	0.057	0.50	10.4
Full-Scale Combined	5.41	272.5	184.4	9.9	0.038	94.4	0.025	0.29	10.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Caoag = 40 mg/L
Poly = 0
pH = 5.8

O3 = not active
BW = 1030-1pm
Flow = same

pH Check -	Controller Set	Actual pH	Time
	5.80	5.86	1630
	5.80	5.80	1815
	5.80	5.85	1900

- Fe and acid pump maintenance completed in AM
- DAF tank cleaned while maintenance on pumps and full-scale shutdown
- * 2 hour equilibration time before 4 hour period prior to sampling
  ie) 6 hours from end of backwash = sampling

BW ended @ 1pm - plant online @ 130pm - plant start up after Post-DAF pH = 5.80 via grab @ 545pm
Sampling will begin @ 945pm

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, October 19, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.26	205.8	147.9	9.1	0.021	76.1	0.119	1.47	10.2
Post-DAF	5.80	247.4	176.8	9.9	0.024	78.2	0.107	1.05	10.3
Post-Ozone	5.83	261.1	177.3	11.0	0.024	78.4	0.106	1.07	11.0
Filter 1	5.91	356.9	177.3	10.3	0.021	93.8	0.028	0.32	11.2
Filter 2	5.90	353.6	176.5	10.1	0.019	93.6	0.029	0.26	11.2
Filter 3	5.90	350.5	179.8	10.2	0.021	93.3	0.030	0.18	11.3
Filter 4	5.86	347.4	179.6	10.5	0.020	94.0	0.027	0.12	11.3
Filter 5	5.87	339.0	180.8	10.2	0.019	94.2	0.026	0.11	11.3
Filter 6	5.87	330.9	182.1	10.0	0.021	94.5	0.025	0.10	11.4
Filter 7	5.86	317.2	181.8	10.1	0.017	94.8	0.023	0.14	11.3
Filter 8	5.88	307.1	179.7	10.4	0.018	94.8	0.023	0.10	11.5
Pilot-Combined	5.86	287.2	180.4	10.7	0.019	94.9	0.023	0.15	10.7
Full-Scale Post-DAF	5.47	276.2	182.5	10.6	0.050	89.9	0.046	0.38	9.9
Full-Scale Post-Ozone	5.56	273.1	181.3	10.8	0.047	87.9	0.056	0.51	10.3
Full-Scale Combined	5.48	284.8	187.5	8.1	0.050	93.1	0.031	0.20	10.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L O3 = not active
pH = 5.80 BW = 9-1130am
Poly = 0 Flow = same

pH Check -	Set Point	Actual	Time
	5.80	5.88	1030am
	* Set point reduced to 5.70 to have Post-DAF closer to 5.80		
	5.70	5.81	1140am
	5.70	5.85	123pm
	* Set point reduced to 5.65 @ 130pm		
	5.65	5.84	300pm

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, October 20, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.34	197.8	149.9	9.7	0.019	76.7	0.115	1.19	10.2
Post-DAF	5.78	230.2	185.1	10.9	0.025	75.9	0.119	1.17	10.5
Post-Ozone	5.81	239.8	175.5	10.2	0.027	77.8	0.109	0.85	11.0
Filter 1	5.92	393.3	176.4	10.1	0.018	90.2	0.045	0.28	11.1
Filter 2	5.91	347.6	176.6	10.2	0.014	91.3	0.040	0.18	11.2
Filter 3	5.89	345.8	177.1	10.4	0.018	91.8	0.038	0.23	11.2
Filter 4	5.86	337.4	178.8	10.3	0.018	92.0	0.036	0.13	1.1
Filter 5	5.85	341.5	178.0	10.1	0.015	92.0	0.036	0.20	11.2
Filter 6	5.88	346.3	179.2	10.1	0.016	92.5	0.034	0.25	11.4
Filter 7	5.87	341.7	179.5	10.2	0.016	92.2	0.035	0.27	11.5
Filter 8	5.84	340.3	178.4	10.1	0.017	91.8	0.037	0.19	11.3
Pilot-Combined	5.83	328.8	176.4	10.3	0.018	90.2	0.045	0.25	10.6
Full-Scale Post-DAF	5.53	330.6	185.1	10.4	0.046	88.4	0.054	0.43	9.8
Full-Scale Post-Ozone	5.70	375.3	186.1	11.9	0.041	88.5	0.053	0.67	10.3
Full-Scale Combined	5.63	323.5	191.3	11.6	0.038	95.4	0.020	0.21	10.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 44 mg/L No O3
pH = 5.80 BW = 6-830am
Poly = 0 Flow = same

pH Check	Time	Set Point	Actual
	730am	5.65	5.82
	800am	5.65	5.82
	1200pm	5.65	5.87
	1215pm	5.65	5.86
	1230pm	5.63	5.83

* Ferric changed caused fluctuation in pH

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Saturday, October 21, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.25	184.7	149.7	10.3	0.021	74.9	0.125	0.108	
Post-DAF	5.82	245.7	180.1	10.4	0.029	81.2	0.090	0.70	
Post-Ozone	5.79	237.7	181.0	11.1	0.027	80.6	0.093	0.74	
Filter 1	5.84	257.9	180.1	10.7	0.019	93.4	0.030	0.20	
Filter 2	5.87	343.2	179.2	10.4	0.018	93.9	0.027	0.08	
Filter 3	5.86	338.6	178.8	10.3	0.016	93.2	0.030	0.08	
Filter 4	5.80	325.7	180.0	10.1	0.019	93.3	0.030	0.08	
Filter 5	5.81	326.5	178.9	9.7	0.018	94.3	0.025	0.09	
Filter 6	5.80	316.1	178.8	9.6	0.019	94.3	0.026	0.10	
Filter 7	5.81	318.8	179.3	9.7	0.014	91.5	0.025	0.12	
Filter 8	5.81	308.5	177.6	9.6	0.016	94.5	0.025	0.13	
Pilot-Combined	5.81	279.8	178.1	9.9	0.015	94.2	0.026	0.12	
Full-Scale Post-DAF	5.60	276.8	184.2	10.2	0.041	86.6	0.063	0.64	
Full-Scale Post-Ozone	5.74	305.7	182.8	11.5	0.036	87.0	0.060	0.55	
Full-Scale Combined	5.51	304.1	187.0	12.4	0.027	95.0	0.022	0.33	
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L No O3
pH = 5.80 Flow = same
Poly = 0 BW = 6-830

Time / Temp = Pic by Charles

Lowest Turb - 42 mg/L
ABS / OVT - 42 mg/L
Mn - 40 mg/L

* Scrapper below surface of water

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, October 22, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.24	212.1	151.3	9.9	0.017	75.2	0.124	1.11	10.6
Post-DAF	5.70	249.5	180.1	10.3	0.032	82.6	0.083	0.62	10.6
Post-Ozone	5.72	265.9	182.1	10.3	0.023	83.1	0.080	0.64	10.9
Filter 1	5.82	342.2	181.1	9.9	0.020	94.1	0.026	0.14	11.5
Filter 2	5.82	341.4	180.8	10.2	0.027	94.2	0.026	0.14	11.4
Filter 3	5.80	334.9	182.1	10.3	0.023	94.2	0.026	0.11	11.4
Filter 4	5.78	333.1	181.9	10.0	0.018	94.1	0.026	0.08	11.5
Filter 5	5.78	346.5	182.4	9.8	0.015	94.5	0.025	0.08	11.8
Filter 6	5.78	341.9	180.6	9.9	0.016	94.6	0.024	0.07	11.7
Filter 7	5.78	342.5	183.5	9.7	0.017	94.4	0.025	0.09	11.8
Filter 8	5.78	334.7	182.7	9.9	0.019	94.2	0.026	0.08	11.8
Pilot-Combined	5.79	314.4	182.5	9.5	0.023	94.1	0.026	0.08	11.1
Full-Scale Post-DAF	5.62	322.2	186.4	10.0	0.048	84.3	0.074	0.45	10.7
Full-Scale Post-Ozone	5.73	365.3	183.0	11.6	0.042	85.0	0.071	0.56	11.0
Full-Scale Combined	5.57	331.8	184.0	9.6	0.036	93.3	0.030	0.25	10.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L
pH = 5.70
Poly = 0

BW = 630-9am
Flow = same
* No O3

pH Check -	Time	Set	Actual	
	730am	5.55	5.76	
	830am	5.55	5.73	
	10am	5.55	5.73	* controller to 5.52
	11am	5.52	5.70	
	12pm	5.52	5.70	

Scrapper is below water level
-chain is loose
-Raw flow ↓ 2.75 L/S to reduce DAF tank level
* After ~ 30 min. water level slightly reduced and not flowing over beach anymore
* M & J will replace shain tomorrow

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, October 23, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.57	180.8	152.2	10.4	0.018	75.0	0.124	1.12	10.9
Post-DAF	5.82	229.6	180.1	10.7	0.027	74.1	0.130	1.11	10.6
Post-Ozone	5.85	258.3	179.0	10.2	0.029	71.7	0.143	1.16	11.1
Filter 1	5.83	328.5	178.3	10.6	0.026	92.1	0.036	0.30	11.3
Filter 2	5.84	323.8	179.1	10.5	0.022	92.8	0.033	0.14	11.4
Filter 3	5.82	320.3	176.9	10.3	0.020	93.1	0.031	0.13	11.4
Filter 4	5.80	317.7	180.5	10.2	0.020	93.0	0.030	0.14	11.5
Filter 5	5.78	310.4	180.6	10.5	0.020	93.8	0.028	0.07	11.6
Filter 6	5.80	305.6	180.4	10.1	0.021	94.2	0.026	0.08	11.9
Filter 7	5.80	301.2	179.5	10.4	0.022	93.7	0.028	0.07	11.7
Filter 8	5.82	286.7	178.6	10.4	0.017	92.9	0.032	0.08	11.5
Pilot-Combined	5.80	272.9	178.3	10.2	0.020	93.3	0.030	0.11	10.9
Full-Scale Post-DAF	5.67	270.1	186.9	10.5	0.045	85.5	0.067	0.42	10.5
Full-Scale Post-Ozone	5.74	283.5	176.2	11.9	0.047	83.7	0.077	0.60	10.6
Full-Scale Combined	5.50	319.8	189.4	9.8	0.040	91.2	0.040	0.47	10.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L No O3
pH = 5.80 Flow = same
poly = 0 BW = same

pH Check -	Time	Set	Actual
	750	5.55	5.78
	1130	5.55	5.81

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, October 24, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.46	190.1	147.9	10.1	0.019	74.8	0.126	1.10	9.9
Post-DAF	5.91	229.3	177.5	10.4	0.033	68.9	0.162	1.51	10.2
Post-Ozone	5.92	249.3	176.5	10.3	0.035	67.9	0.168	1.57	10.3
Filter 1	5.94	323.1	175.9	10.7	0.023	90.3	0.044	0.33	10.5
Filter 2	5.94	322.5	174.6	10.4	0.026	90.7	0.042	0.24	10.6
Filter 3	5.93	317.5	175.1	10.3	0.021	91.7	0.038	0.19	10.7
Filter 4	5.89	318.6	175.4	10.7	0.020	89.2	0.050	0.34	10.7
Filter 5	5.89	317.7	176.5	10.1	0.021	93.5	0.029	0.12	10.7
Filter 6	5.87	313.2	175.5	10.4	0.018	93.8	0.028	0.09	10.8
Filter 7	5.87	314.7	176.9	10.7	0.018	93.7	0.028	0.10	10.8
Filter 8	5.88	305.1	177.1	10.7	0.018	93.4	0.030	0.12	10.7
Pilot-Combined	5.90	286.0	177.9	11.1	0.019	92.2	0.036	0.18	10.1
Full-Scale Post-DAF	5.65	295.9	183.6	11.7	0.044	85.7	0.067	0.47	9.6
Full-Scale Post-Ozone	5.75	331.8	177.8	12.4	0.037	85.5	0.068	0.62	10.0
Full-Scale Combined	5.51	338.0	179.9	11.8	0.033	94.5	0.025	0.35	9.7
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L — No O3
pH = 5.90 — Flow = same
Poly = 0 — BW = same

pH Check:	Time	Set	Actual
	830	5.75	5.91
	1030	5.75	5.89

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Wednesday, October 25, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.44	196.3	150.8	9.7	0.017	73.8	0.132	1.13	9.8
Post-DAF	5.99	231.1	176.3	10.5	0.024	70.6	0.151	1.82	9.7
Post-Ozone	5.98	236.9	178.2	11.4	0.026	69.4	0.159	1.44	10.1
Filter 1	6.00	294.2	177.7	10.8	0.016	90.0	0.046	0.47	10.4
Filter 2	6.01	293.5	178.1	10.7	0.019	90.8	0.042	0.19	10.5
Filter 3	6.01	289.3	176.9	10.9	0.016	90.9	0.041	0.17	10.6
Filter 4	5.98	285.3	177.1	10.8	0.017	91.1	0.040	0.19	10.7
Filter 5	5.96	279.9	176.5	10.7	0.020	92.1	0.036	0.12	10.7
Filter 6	5.94	285.6	176.0	10.7	0.019	92.0	0.036	0.19	10.8
Filter 7	5.95	293.8	176.1	10.4	0.018	92.7	0.033	0.12	10.7
Filter 8	5.96	287.4	178.6	10.7	0.016	92.3	0.035	0.13	10.8
Pilot-Combined	5.98	257.6	177.0	10.2	0.019	91.3	0.039	0.20	10.2
Full-Scale Post-DAF	5.64	294.0	184.2	9.6	0.042	84.5	0.073	0.52	9.7
Full-Scale Post-Ozone	5.68	337.3	183.8	11.2	0.043	85.6	0.067	0.56	10.0
Full-Scale Combined	5.44	340.2	187.9	9.8	0.028	94.4	0.025	0.36	9.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L No O3
pH = 6.0 Flow = same
Poly = 0 BW = 545-815am

pH Check:	Time	Set	Actual
	745	5.85	6.01
	840	5.85	5.98

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Thursday, October 26, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.46	194.7	150.0	10.4	0.019	74.6	0.127	1.10	8.9
Post-DAF	5.69	252.1	178.0	10.5	0.028	73.6	0.133	1.27	9.1
Post-Ozone	5.75	237.9	181.3	11.7	0.031	71.1	0.148	1.36	9.7
Filter 1	5.81	249.4	182.1	10.7	0.017	91.4	0.040	0.42	10.0
Filter 2	5.79	233.3	181.1	11.3	0.017	92.0	0.036	0.23	9.9
Filter 3	5.85	289.4	179.7	11.0	0.020	93.0	0.032	0.17	10.1
Filter 4	5.83	293.6	182.6	10.8	0.022	92.2	0.035	0.21	10.0
Filter 5	5.85	287.1	183.1	10.6	0.019	94.1	0.026	0.10	10.0
Filter 6	5.85	288.1	183.4	10.7	0.019	94.4	0.025	0.10	10.2
Filter 7	5.85	278.0	185.4	10.9	0.020	94.5	0.024	0.09	10.2
Filter 8	5.84	273.1	183.9	11.0	0.017	94.1	0.026	0.14	10.2
Pilot-Combined	5.82	261.4	181.3	11.0	0.018	93.2	0.031	0.15	9.5
Full-Scale Post-DAF	5.69	257.9	185.5	11.3	0.046	86.5	0.063	0.57	8.8
Full-Scale Post-Ozone	5.79	296.4	183.9	11.7	0.039	86.8	0.062	0.61	9.3
Full-Scale Combined	5.55	239.6	179.6	12.1	0.028	93.8	0.028	0.35	8.7
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

OPT pH + Cpag Type I

Coag = 42 mg/L (optimal) No O3
pH = 5.70 (optimal) Flow = same
Poly = 0 BW = 5-730am

pH Check:	Time	Set	Actual
	11am	5.53	5.68

↑ 5.55

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Friday, October 27, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.31	209.1	150.4	10.7	0.020	73.0	0.137	1.11	8.5
Post-DAF	5.74	243.2	183.3	11.5	0.029	70.4	0.153	1.49	9.1
Post-Ozone	5.78	265.4	180.9	11.5	0.031	70.8	0.151	1.58	8.8
Filter 1	5.85	317.3	182.0	11.2	0.027	83.3	0.080	0.85	9.1
Filter 2	5.85	315.1	181.0	11.2	0.029	83.9	0.076	0.75	9.3
Filter 3	5.83	313.9	181.3	11.3	0.029	85.4	0.068	0.67	9.3
Filter 4	5.77	315.7	179.8	11.1	0.023	82.4	0.084	0.81	9.3
Filter 5	5.77	314.2	180.7	11.0	0.022	94.6	0.024	0.10	9.3
Filter 6	5.78	295.9	182.1	11.3	0.024	93.7	0.028	0.09	9.4
Filter 7	5.75	292.7	183.1	11.2	0.022	94.4	0.026	0.10	9.3
Filter 8	5.75	282.6	180.7	11.3	0.020	94.1	0.026	0.09	9.3
Pilot-Combined	5.78	267.5	178.1	11.1	0.026	89.9	0.046	0.47	8.5
Full-Scale Post-DAF	5.67	285.4	185.1	11.4	0.048	86.7	0.062	0.57	8.5
Full-Scale Post-Ozone	5.72	314.5	185.5	12.2	0.041	86.5	0.063	0.59	9.1
Full-Scale Combined	5.35	317.5	182.2	12.0	0.028	95.7	0.019	0.22	8.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

OPT pH + Cpag Type II

Coag = 42 mg/L
pH = 5.70
Poly = 0

No O3
Flow = same
BW = 530-800am

pH Check:	Time	Set	Actual
	11am	5.55	5.73

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Saturday, October 28, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.30	214.9	150.7	11.0	0.023	75.5	0.122	1.13	7.9
Post-DAF	5.72	255.3	183.4	11.7	0.022	78.4	0.106	1.47	7.9
Post-Ozone	5.74	272.6	181.2	11.3	0.024	80.8	0.093	1.03	8.0
Filter 1	5.83	328.5	183.5	11.4	0.017	94.5	0.025	0.20	8.3
Filter 2	5.84	324.9	182.8	11.5	0.015	94.8	0.023	0.18	8.5
Filter 3	5.82	324.4	184.2	11.6	0.020	94.1	0.026	0.14	8.4
Filter 4	5.83	323.2	183.4	11.5	0.017	94.5	0.025	0.09	8.4
Filter 5	5.87	313.7	181.2	11.2	0.018	95.2	0.021	0.09	8.5
Filter 6	5.87	306.1	183.0	11.2	0.017	95.5	0.020	0.10	8.7
Filter 7	5.86	320.3	183.6	11.3	0.020	95.4	0.020	0.11	8.7
Filter 8	5.87	309.3	185.7	11.2	0.017	95.2	0.021	0.10	8.6
Pilot-Combined	5.90	291.1	183.9	11.5	0.017	95.0	0.022	0.14	8.4
Full-Scale Post-DAF	5.88	300.1	188.4	11.8	0.049	86.0	0.066	0.62	7.8
Full-Scale Post-Ozone	6.05	329.0	184.0	12.1	0.048	95.4	0.069	0.78	8.3
Full-Scale Combined	5.56	296.2	181.2	12.4	0.028	93.8	0.028	0.35	8.0
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag and OPT

Coag = 42 mg/L BW = 630-900
pH = 5.70 Ozone = Active
Poly = 0.05 (started @ 630am)

pH Check	Time	Set Point	Actual Post DAF pH
	800am	5.55	5.66
	830am	5.55	5.77
	↓ controller - 5.50 @ 830am		
	11am	5.50	5.69

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Sunday, October 29, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.25	209.2	151.8	11.1	0.022	75.0	0.126	1.29	7.7
Post-DAF	5.69	251.9	185.2	11.7	0.019	81.2	0.091	0.96	7.9
Post-Ozone	5.72	259.2	181.6	11.0	0.017	85.8	0.066	0.78	8.0
Filter 1	5.76	309.3	182.8	11.1	0.018	95.3	0.020	0.16	8.1
Filter 2	5.76	304.1	182.2	11.2	0.017	95.6	0.019	0.12	8.1
Filter 3	5.76	295.0	183.4	11.2	0.014	95.7	0.019	0.13	8.2
Filter 4	5.74	311.2	183.2	10.8	0.015	95.0	0.022	0.11	8.3
Filter 5	5.74	309.1	184.6	10.9	0.012	96.6	0.015	0.11	9.1
Filter 6	5.71	308.7	183.9	10.9	0.017	96.7	0.015	0.14	9.1
Filter 7	5.72	300.6	184.6	11.1	0.014	96.5	0.015	0.13	8.8
Filter 8	5.70	284.3	187.0	11.4	0.015	96.7	0.015	0.14	8.8
Pilot-Combined	5.70	274.6	185.1	11.5	0.016	96.3	0.016	0.13	8.3
Full-Scale Post-DAF	5.59	285.7	189.0	11.6	0.051	88.9	0.051	0.55	7.9
Full-Scale Post-Ozone	5.61	321.1	187.9	10.7	0.041	88.1	0.055	0.79	8.0
Full-Scale Combined	5.41	320.2	189.0	12.9	0.031	97.1	0.011	0.28	7.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 Ozone - Active
Poly = 0.07 BW = 550-

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Monday, October 30, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.30	220.8	151.1	11.50	0.020	74.5	0.128	1.22	6.6
Post-DAF	5.73	265.6	184.2	12.00	0.021	77.8	0.109	0.99	7.3
Post-Ozone	5.77	283.8	182.9	12.00	0.024	83.2	0.080	0.81	7.2
Filter 1	5.82	332.5	183.5	12.10	0.023	93.4	0.030	0.16	7.9
Filter 2	5.83	325.5	184.3	11.60	0.022	93.8	0.028	0.13	7.6
Filter 3	5.83	322.0	185.1	11.90	0.021	93.9	0.028	0.13	7.7
Filter 4	5.84	316.2	184.3	11.80	0.020	93.6	0.029	0.08	7.9
Filter 5	5.83	315.9	182.6	11.50	0.019	93.5	0.029	0.09	7.8
Filter 6	5.82	316.4	181.7	11.50	0.018	94.1	0.027	0.09	7.9
Filter 7	5.84	306.1	184.0	11.80	0.018	93.7	0.028	0.11	7.8
Filter 8	5.82	300.3	181.1	11.70	0.016	94.0	0.027	0.13	7.6
Pilot-Combined	5.80	285.3	182.3	12.40	0.021	93.8	0.028	0.12	7.3
Full-Scale Post-DAF	5.74	283.4	188.6	12.20	0.050	83.7	0.077	0.56	6.7
Full-Scale Post-Ozone	5.79	297.7	184.0	12.40	0.046	85.0	0.071	0.70	7.7
Full-Scale Combined	5.69	294.8	191.9	12.70		93.9	0.027	0.29	6.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L Ozone - Active
Poly = 0.13 mg/L BW = 6-845
pH = 5.70 Flow = same

pH Check	Time	Set	Actual	
	800	5.50	5.68	
	915	5.50	5.68	
	1130	5.50	5.74	* ↓ reduced 5.45

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: Tuesday, October 31, 2017
Season: Fall

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.43	201.0	156.0	11.60	0.019	74.1	0.130	1.01	
Post-DAF	5.70	255.3	182.3	11.60	0.021	74.4	0.128	1.58	
Post-Ozone	5.73	274.8	180.8	11.40	0.022	77.6	0.110	1.19	
Filter 1	5.77	324.5	180.4	11.40	0.016	93.4	0.030	0.32	
Filter 2	5.76	323.4	182.5	12.10	0.016	93.5	0.029	0.10	
Filter 3	5.76	322.2	181.4	11.90	0.015	94.0	0.027	0.13	
Filter 4	5.74	311.7	179.9	11.40	0.015	93.4	0.030	0.14	
Filter 5	5.74	311.0	181.5	11.60	0.013	94.3	0.026	0.13	
Filter 6	5.74	307.0	179.1	11.50	0.014	94.2	0.026	0.10	
Filter 7	5.74	302.4	177.5	11.40	0.017	94.5	0.024	0.08	
Filter 8	5.75	296.9	177.3	11.20	0.016	94.5	0.024	0.12	
Pilot-Combined	5.76	279.1	183.8	12.00	0.014	94.3	0.026	0.10	
Full-Scale Post-DAF	5.59	289.0	189.1	11.70	0.042	86.6	0.062	0.53	
Full-Scale Post-Ozone	5.72	315.4	181.5	12.00	0.038	86.8	0.061	0.57	
Full-Scale Combined	5.52	299.1	177.2	12.50	0.028	94.9	0.023	0.14	
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

OPT Coag + pH + Aid

Coag = 42 mg/L BW = 545-
pH = 5.70 Ozone = Active
Poly = 0.07 mg/L Flow = same

pH Check	Time	Set	Actual
	900	5.52	5.66
	1030	5.55	5.71

Type II

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 17, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.27	181.9	153.6	11.9	0.023	77.3	0.112	0.88	4.2
Post-DAF	5.73	226.9	191.0	12.7	0.025	77.7	0.109	0.95	5.9
Post-Ozone	5.76	238.4	176.7	12.8	0.028	75.8	0.122	1.13	4.9
Filter 1	5.76	288.8	184.4	12.3	0.020	86.4	0.065	0.99	5.7
Filter 2	5.74	292.8	185.6	11.8	0.019	86.5	0.064	1.06	5.7
Filter 3	5.75	292.0	182.0	11.5	0.021	86.4	0.065	0.89	5.7
Filter 4	5.74	286.8	183.0	11.5	0.021	85.0	0.071	1.02	5.8
Filter 5	5.76	280.5	185.1	11.6	0.014	96.6	0.015	0.18	5.9
Filter 6	5.77	280.6	188.0	11.8	0.012	96.7	0.013	0.16	5.9
Filter 7	5.77	285.2	185.5	11.4	0.015	97.0	0.013	0.11	5.8
Filter 8	5.80	280.5	186.6	11.8	0.014	97.1	0.013	0.15	5.9
Pilot-Combined	5.86	262.5	189.4	12.7	0.015	93.8	0.026	0.35	5.2
Full-Scale Post-DAF	5.80	276.8	194.5	13.4	0.051	87.8	0.056	0.58	3.2
Full-Scale Post-Ozone	5.80	313.7	192.4	14.2	0.048	87.3	0.059	0.67	3.3
Full-Scale Combined	5.70	231.2	202.6	13.8	0.033	96.7	0.015	0.19	3.3
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 40 mg/L BW - 6-830 am
pH = 5.70 Flow - A = 0.6 L/s *see note
No coagulant aid B = 0.3 L/s

pH Check	Time	Set	Actual	
	630	5.50	5.70	
	730	5.50	5.71	
	1215	-	5.60	*pH controller not active; using H_2SO_4 dose (H_2SO_4 = 43 mg/L H_2SO_4 = 42 mg/L)

*NOTE: Bank A flow was set at 0.3 L/s for 3.5 hours (9-1230 pm). Norices at 1230 pm and upped to 0.6 L/s.
* pH decreased due to upping flow (raw water) - adjusted at 1230 pm and collection delayed by 30 minutes to allow system to reach pH set point

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 18, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.34	174.8	155.5	11.4	0.020	74.7	0.126	0.91	3.2
Post-DAF	5.70	224.1	191.3	11.5	0.024	76.7	0.115	1.20	4.4
Post-Ozone	5.73	229.2	193.5	11.6	0.025	75.7	0.121	0.18	4.8
Filter 1	5.73	292.5	183.4	11.5	0.020	90.4	0.044	0.36	5.1
Filter 2	5.72	290.2	183.4	11.5	0.019	90.5	0.043	0.32	5.1
Filter 3	5.71	287.6	183.4	11.7	0.018	90.8	0.042	0.37	5.2
Filter 4	5.70	288.6	183.5	11.5	0.019	90.4	0.044	0.32	5.1
Filter 5	5.69	284.2	183.0	11.6	0.018	93.2	0.031	0.16	5.3
Filter 6	5.68	279.4	189.6	11.9	0.019	92.4	0.035	0.13	5.3
Filter 7	5.67	278.2	181.6	11.8	0.016	93.4	0.029	0.14	5.2
Filter 8	5.66	281.3	187.6	11.8	0.015	93.5	0.029	0.13	5.2
Pilot-Combined	5.71	259.7	174.7	11.8	0.019	92.4	0.034	0.21	4.6
Full-Scale Post-DAF	5.58	264.6	182.8	13.1	0.055	86.0	0.066	0.56	3.2
Full-Scale Post-Ozone	5.60	293.0	186.9	13.4	0.048	85.4	0.069	0.68	2.8
Full-Scale Combined	5.35	292.7	186.5	13.0	0.034	95.8	0.019	0.15	3.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 40 mg/L
pH = 5.70 *pH controller activated at 6 am
BW - 545-815 am
Flow - A = 0.6 L/s B = 0.3 L/s
Sampling at 1230 pm

pH Check	Time	Set	Actual	
	600	5.50	5.68	*No controller
	630	5.50	5.70	*Controller on
	730	5.50	5.73	
	800	5.50	5.70	*appears stable
	930	5.50	5.71	

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 19, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.16	154.0	178.2	12.0	0.020	75.5	0.122	0.94	4.2
Post-DAF	5.71	227.4	187.6	12.2	0.023	80.4	0.095	0.91	4.2
Post-Ozone	5.72	254.0	187.8	11.9	0.025	79.1	0.102	0.92	5.2
Filter 1	5.72	275.9	188.1	12.1	0.020	90.9	0.041	0.24	5.4
Filter 2	5.74	304.4	188.3	11.6	0.018	93.4	0.030	0.19	5.4
Filter 3	5.76	295.3	187.0	11.7	0.018	93.2	0.031	0.23	5.5
Filter 4	5.75	288.4	188.6	11.6	0.016	92.9	0.032	0.19	5.5
Filter 5	5.72	282.7	187.0	11.8	0.017	95.2	0.021	0.10	5.7
Filter 6	5.73	279.0	190.5	11.7	0.017	94.9	0.023	0.12	5.8
Filter 7	5.75	273.9	189.4	11.8	0.016	95.0	0.022	0.10	5.8
Filter 8	5.75	264.8	190.3	11.8	0.016	94.5	0.025	0.11	5.7
Pilot-Combined	5.77	249.1	190.4	12.20	0.017	94.3	0.025	0.20	4.9
Full-Scale Post-DAF	5.73	255.6	195.2	13.50	0.054	86.8	0.061	0.55	3.5
Full-Scale Post-Ozone	5.78	258.1	191.7	13.70	0.048	86.1	0.065	0.71	3.3
Full-Scale Combined	5.69	248.0	196.3	14.10	0.033	96.5	0.015	0.20	3.3
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 41 mg/L
pH = 5.70 (controller)
BW - 7-930 am
Flow - same
Sampling at 2 pm

pH Check	Time	Set	Actual
	845	5.50	5.67
	930	5.50	5.69
	1115	5.50	5.72
	1200	5.50	5.73

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 20, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.83	172.2	153.1	11.5	0.021	75.4	0.122	0.95	4.2
Post-DAF	5.73	241.7	188.3	12.1	0.022	80.9	0.093	0.92	3.7
Post-Ozone	5.72	288.3	185.7	11.8	0.022	80.5	0.094	1.01	4.5
Filter 1	5.81	285.6	185.4	11.9	0.021	94.5	0.024	0.29	4.9
Filter 2	5.81	280.9	182.9	11.6	0.018	94.4	0.025	0.24	4.9
Filter 3	5.83	281.7	187.2	11.8	0.018	94.4	0.025	0.26	5.0
Filter 4	5.83	269.0	196.4	11.7	0.017	93.9	0.027	0.22	5.1
Filter 5	5.76	290.2	187.6	11.6	0.018	95.6	0.019	0.13	5.4
Filter 6	5.78	281.0	188.2	11.7	0.017	94.8	0.023	0.12	5.4
Filter 7	5.79	293.7	182.6	11.8	0.019	95.4	0.020	0.16	5.5
Filter 8	5.80	287.8	187.8	11.9	0.021	94.6	0.024	0.15	5.4
Pilot-Combined	5.78	290.2	184.9	12.0	0.020	95.0	0.022	0.22	5.3
Full-Scale Post-DAF	5.78	277.0	190.1	12.7	0.054	85.5	0.068	0.52	4.0
Full-Scale Post-Ozone	5.86	286.5	194.7	13.4	0.049	85.3	0.069	0.69	3.4
Full-Scale Combined	5.64	266.9	191.5	13.6	0.037	95.0	0.022	0.22	3.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 41 mg/L
pH = 5.70
BW = 6-830 am

Values with offset

pH Check	Time	Set	Actual	
	700	5.50	5.65	
	730	5.50	5.77	
	745	5.50	5.72	
	845	5.50	5.73	*New pH probe other one seemed to drift
	930	5.50	5.71	

*NOTE: Collected again at 345 for pH only.

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 21, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.86	217.8	154.5	11.5	0.023	74.5	0.128	0.92	3.3
Post-DAF	5.71	259.5	188.3	12.2	0.023	75.3	0.123	1.03	3.9
Post-Ozone	5.69	268.9	187.2	11.9	0.028	73.6	0.133	1.22	4.9
Filter 1	5.80	381.4	187.3	11.3	0.025	91.0	0.041	0.29	4.7
Filter 2	5.81	382.4	184.6	10.9	0.024	91.2	0.040	0.30	4.7
Filter 3	5.79	379.4	183.6	10.7	0.021	90.5	0.043	0.34	4.9
Filter 4	5.82	379.8	182.4	11.2	0.021	91.0	0.041	0.28	5.1
Filter 5	5.79	374.8	185.9	11.1	0.016	94.3	0.026	0.10	5.1
Filter 6	5.82	371.9	186.0	11.3	0.016	94.1	0.026	0.14	5.2
Filter 7	5.82	364.1	191.3	11.7	0.018	94.0	0.027	0.10	5.4
Filter 8	5.85	353.6	193.6	12.2	0.020	93.5	0.029	0.11	5.2
Pilot-Combined	5.81	345.9	192.2	11.8	0.020	92.2	0.036	0.19	5.1
Full-Scale Post-DAF	5.75	343.6	190.4	12.9	0.049	85.4	0.069	0.52	3.5
Full-Scale Post-Ozone	5.83	371.0	190.5	13.7	0.049	85.3	0.069	0.71	3.5
Full-Scale Combined	5.71	355.4	201.4	13.7	0.043	94.3	0.025	0.48	3.2
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L
pH = 5.70
BW = 6-830 am

pH Check	Time	Set	Actual
	730	5.50	5.71
	815	5.50	5.69
	845	5.50	5.71
	955	5.50	5.71
	1230	5.50	5.70

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 22, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.85	213.2	155.2	11.0	0.023	75.2	0.124	0.87	3.5
Post-DAF	5.70	261.7	187.1	12.2	0.028	78.6	0.105	0.94	3.7
Post-Ozone	5.70	350.0	184.4	11.7	0.031	77.8	0.109	1.23	4.2
Filter 1	5.80	347.0	187.1	11.6	0.018	93.0	0.032	0.33	5.4
Filter 2	5.79	347.4	186.6	11.9	0.016	93.2	0.030	0.28	5.4
Filter 3	5.83	345.6	186.8	11.8	0.015	93.1	0.031	0.26	5.4
Filter 4	5.77	346.1	184.5	11.7	0.014	92.7	0.034	0.30	5.5
Filter 5	5.75	340.0	186.1	11.6	0.009	96.9	0.014	0.09	5.7
Filter 6	5.78	333.7	184.6	11.5	0.012	97.4	0.011	0.09	5.8
Filter 7	5.76	329.3	186.0	11.6	0.011	96.8	0.014	0.08	5.7
Filter 8	5.81	314.9	186.6	11.5	0.012	97.0	0.013	0.11	5.8
Pilot-Combined	5.78	307.5	191.3	11.8	0.011	94.2	0.026	0.28	5.3
Full-Scale Post-DAF	5.82	310.6	193.6	12.3	0.046	86.3	0.064	0.54	3.3
Full-Scale Post-Ozone	5.84	346.0	192.2	12.0	0.044	86.5	0.063	0.71	3.5
Full-Scale Combined	5.67	325.5	185.4	11.9	0.028	95.2	0.021	0.16	3.4
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 42 mg/L
pH = 5.70
BW = 6-830 am

pH Check	Time	Set	Actual
	700	5.50	5.68
	800	5.50	5.70

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 23, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.90	217.8	153.3	11.4	0.021	74.2	0.129	0.87	3.5
Post-DAF	5.69	251.9	194.1	12.4	0.026	79.0	0.102	0.90	3.5
Post-Ozone	5.68	319.1	187.6	13.0	0.028	78.4	0.106	1.17	4.0
Filter 1	5.80	314.2	187.1	11.8	0.018	93.2	0.031	0.43	5.1
Filter 2	5.76	310.8	188.0	11.5	0.019	93.0	0.031	0.26	5.2
Filter 3	5.81	314.5	185.2	11.7	0.019	93.4	0.029	0.24	4.9
Filter 4	5.78	311.1	189.5	11.4	0.020	92.4	0.034	0.26	5.0
Filter 5	5.77	308.3	186.5	11.4	0.017	95.4	0.020	0.13	5.6
Filter 6	5.78	297.4	186.3	11.6	0.017	95.5	0.020	0.10	5.6
Filter 7	5.77	293.8	188.3	11.5	0.016	95.5	0.020	0.09	5.4
Filter 8	5.80	286.8	187.3	11.4	0.017	95.2	0.021	0.11	5.5
Pilot-Combined	5.80	279.9	190.7	11.7	0.018	94.3	0.025	0.20	5.1
Full-Scale Post-DAF	5.73	286.7	193.2	13.3	0.052	84.6	0.073	0.54	3.5
Full-Scale Post-Ozone	5.83	306.3	193.5	13.2	0.048	84.7	0.072	0.65	3.3
Full-Scale Combined	5.68	293.8	183.7	14.0	0.039	94.7	0.024	0.14	3.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 43 mg/L *increased at 630 am
pH = 5.70
BW = 545-820 am
Sample Time = 1230

pH Check	Time	Set	Actual
	800	5.50	5.66
	835	5.50	5.66
	900	5.50	5.64
	920	5.50	5.66
	*pH controller upped to 5.54		
	1030	5.54	5.70

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 24, 2017
Season: Winter #2

	pH	**ORP**	**Conductivity**	**DO**	**Hach Mn**	**UVT**	**Abs**	**Turb**	**Temp**
Raw	7.91	153.4	190.8	11.7	0.024	74.6	0.127	0.97	3.8
Post-DAF	5.71	223.9	190.4	12.5	0.024	78.2	0.107	1.06	5.4
Post-Ozone	5.72	344.8	184.8	12.4	0.027	76.9	0.144	1.20	5.0
Filter 1	5.77	335.8	184.0	12.1	0.021	90.7	0.042	0.53	5.7
Filter 2	5.80	338.5	186.5	12.0	0.022	90.8	0.042	0.42	5.6
Filter 3	5.77	340.8	184.6	12.3	0.020	91.0	0.041	0.38	5.7
Filter 4	5.79	336.0	188.2	12.4	0.019	91.7	0.038	0.42	5.7
Filter 5	5.73	338.2	185.6	12.1	0.016	95.6	0.020	0.10	5.7
Filter 6	5.76	321.0	186.1	12.4	0.014	95.8	0.019	0.09	5.8
Filter 7	5.77	319.4	190.7	12.2	0.016	94.7	0.024	0.10	6.0
Filter 8	5.78	306.6	185.5	12.2	0.016	94.8	0.023	0.13	6.1
Pilot-Combined	5.76	291.2	185.0	12.6	0.018	92.3	0.035	0.29	5.8
Full-Scale Post-DAF	5.80	291.8	194.9	12.9	0.053	84.7	0.072	0.51	4.2
Full-Scale Post-Ozone	5.90	320.8	192.8	13.3	0.053	84.3	0.074	0.66	4.0
Full-Scale Combined	5.71	313.0	181.9	13.4	0.043	97.4	0.011	0.18	4.2
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 43 mg/L
pH = 5.70
BW = 545-815 am
Sampling at 1230

pH Check	Time	Set	Actual
	615	5.54	5.70
	715	5.54	5.69

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 25, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.88	224.2	152.0	12.1	0.022	75.3	0.023	0.85	3.6
Post-DAF	5.71	249.6	186.3	12.2	0.026	76.3	0.117	1.01	3.6
Post-Ozone	5.72	384.9	179.7	11.8	0.023	74.3	0.129	1.31	4.7
Filter 1	5.79	382.3	184.5	12.0	0.020	90.3	0.044	0.65	5.2
Filter 2	5.80	380.5	186.2	11.9	0.016	92.0	0.036	0.37	5.2
Filter 3	5.77	377.8	185.6	11.9	0.017	92.4	0.034	0.38	5.5
Filter 4	5.81	373.1	190.6	12.0	0.017	91.4	0.039	0.40	5.5
Filter 5	5.79	412.2	185.4	12.0	0.014	96.2	0.017	0.11	5.7
Filter 6	5.80	432.2	186.8	11.9	0.016	96.3	0.017	0.12	5.6
Filter 7	5.81	428.2	189.7	12.2	0.014	95.4	0.021	0.11	5.8
Filter 8	5.81	459.9	191.0	12.0	0.015	95.6	0.020	0.14	5.9
Pilot-Combined	5.81	454.8	188.0	11.5	0.017	92.9	0.032	0.28	5.4
Full-Scale Post-DAF	5.73	443.2	184.4	12.4	0.049	85.0	0.071	0.62	4.0
Full-Scale Post-Ozone	5.92	473.5	188.8	13.9	0.049	84.9	0.070	0.65	3.5
Full-Scale Combined	5.73	463.6	197.1	12.5	0.032	94.8	0.023	0.14	5.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 44 mg/L
pH = 5.70
Flow = same
BW = 7-930 am
Sampling at 130 pm

pH Check	Time	Set	Actual
	800	5.54	5.69
	830	5.54	5.70

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 26, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.91	220.6	154.0	12.1	0.023	74.9	0.125	0.92	3.5
Post-DAF	5.71	254.5	186.4	11.6	0.030	75.4	0.123	1.21	4.0
Post-Ozone	5.75	329.9	186.3	12.1	0.030	74.7	0.129	1.42	5.3
Filter 1	5.81	326.7	187.5	11.8	0.018	90.2	0.045	0.47	5.4
Filter 2	5.82	328.2	187.7	11.9	0.019	90.8	0.042	0.46	5.4
Filter 3	5.82	326.2	186.9	11.9	0.020	91.1	0.040	0.41	5.5
Filter 4	5.81	318.9	186.1	12.0	0.018	89.6	0.048	0.49	5.5
Filter 5	5.79	322.7	182.2	12.2	0.018	95.4	0.021	0.10	5.6
Filter 6	5.79	320.7	185.5	12.4	0.014	95.6	0.019	0.10	5.7
Filter 7	5.81	312.7	187.4	12.1	0.015	95.5	0.020	0.12	5.7
Filter 8	5.80	312.2	185.1	12.1	0.016	95.3	0.021	0.14	5.7
Pilot-Combined	5.80	299.1	188.2	11.9	0.018	92.5	0.034	0.35	5.5
Full-Scale Post-DAF	5.86	291.2	196.0	12.9	0.053	84.0	0.076	0.62	3.4
Full-Scale Post-Ozone	5.94	327.7	196.5	13.7	0.050	84.2	0.075	0.72	3.4
Full-Scale Combined	5.77	313.1	185.4	12.5	0.035	94.3	0.025	0.15	3.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 44 mg/L
pH = 5.70
Same conditions
Sampling at 145 pm

pH Check	Time	Set	Actual
	1000	5.54	5.70

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 27, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.75	196.2	154.8	11.7	0.017	74.9	0.129	0.93	3.5
Post-DAF	5.70	253.8	183.5	11.7	0.022	80.4	0.095	0.81	4.0
Post-Ozone	5.73	325.1	185.2	11.2	0.020	80.3	0.095	0.99	5.3
Filter 1	5.82	324.2	182.8	11.3	0.016	93.0	0.032	0.25	5.4
Filter 2	5.78	326.3	197.4	11.3	0.017	93.1	0.031	0.23	5.4
Filter 3	5.83	305.0	181.6	11.8	0.015	93.8	0.028	0.24	5.5
Filter 4	5.80	303.5	182.2	11.7	0.016	93.7	0.029	0.24	5.5
Filter 5	5.78	301.9	179.1	11.4	0.014	95.9	0.018	0.12	5.6
Filter 6	5.79	300.5	180.6	11.4	0.017	95.7	0.019	0.11	5.7
Filter 7	5.81	284.5	183.5	11.9	0.016	95.0	0.023	0.09	5.7
Filter 8	5.80	268.1	183.7	11.6	0.014	95.0	0.023	0.10	5.7
Pilot-Combined	5.81	253.0	183.9	12.0	0.016	94.6	0.024	0.20	5.5
Full-Scale Post-DAF	5.90	246.8	188.7	12.6	0.052	84.3	0.074	0.59	3.9
Full-Scale Post-Ozone	6.04	259.7	194.0	14.0	0.045	84.2	0.074	0.76	3.4
Full-Scale Combined	5.79	250.8	197.1	13.1	0.030	94.5	0.025	0.19	3.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Optimal Day - Type I

Coag = 41 mg/L Changed at 6am
pH = 5.70
Flow = Same
BW = 6-830 am

pH check	Time	Set	Actual
	700	5.50	5.70
	945	5.50	5.71

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 28, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.80	208.8	154.1	12.1	0.020	75.2	0.124	0.87	3.5
Post-DAF	5.80	253.6	183.5	12.4	0.025	78.7	0.104	0.82	3.9
Post-Ozone	5.84	309.6	182.0	12.1	0.024	79.7	0.098	1.03	4.3
Filter 1	5.91	312.7	187.3	11.7	0.011	93.9	0.028	0.33	5.1
Filter 2	5.91	311.4	184.4	11.4	0.012	95.1	0.022	0.15	4.9
Filter 3	5.90	307.8	184.4	11.5	0.011	94.8	0.023	0.16	5.1
Filter 4	5.90	301.4	183.6	11.7	0.013	95.0	0.022	0.14	5.0
Filter 5	5.90	295.5	186.0	11.7	0.013	95.3	0.021	0.11	5.6
Filter 6	5.90	295.4	185.2	11.7	0.010	95.4	0.021	0.13	5.6
Filter 7	5.91	297.3	185.6	11.6	0.012	95.3	0.021	0.14	5.8
Filter 8	5.91	293.1	190.2	11.4	0.015	95.5	0.020	0.12	5.9
Pilot-Combined	5.88	285.5	185.2	11.4	0.012	95.2	0.021	0.13	5.4
Full-Scale Post-DAF	5.85	288.8	192.2	13.1	0.050	84.3	0.074	0.63	3.5
Full-Scale Post-Ozone	5.90	246.7	188.6	14.1	0.046	85.4	0.069	0.72	3.5
Full-Scale Combined	5.76	328.9	186.4	13.4	0.033	95.1	0.022	0.12	4.2
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 41 mg/L
pH = 5.80

pH Check	Time	Set	Actual
	830	5.60	5.82
	1030	5.60	5.79

*pH controller has some larger variations today 5.50-5.70 - Average = 5.60

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: November 29, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.88	226.7	152.7	12.2	0.022	75.5	0.122	0.84	3.3
Post-DAF	5.80	261.0	183.2	11.7	0.019	80.7	0.094	0.82	3.5
Post-Ozone	5.79	317.9	180.6	11.8	0.019	81.8	0.087	1.06	4.6
Filter 1	5.90	317.3	183.0	12.0	0.012	95.2	0.021	0.18	6.0
Filter 2	5.91	315.3	184.2	11.8	0.013	96.1	0.017	0.13	6.1
Filter 3	5.89	312.7	184.0	11.7	0.013	95.5	0.020	0.16	5.8
Filter 4	5.91	311.3	184.7	11.6	0.010	95.5	0.020	0.15	5.8
Filter 5	5.90	307.6	179.4	11.7	0.014	95.5	0.020	0.15	5.9
Filter 6	5.90	305.3	185.4	11.5	0.013	95.0	0.022	0.14	6.0
Filter 7	5.87	303.7	182.7	11.6	0.012	95.1	0.022	0.13	6.0
Filter 8	5.89	298.7	187.2	11.8	0.012	95.8	0.019	0.14	6.1
Pilot-Combined	5.89	285.7	187.7	11.8	0.013	94.9	0.023	0.15	5.8
Full-Scale Post-DAF	5.90	279.0	196.5	12.8	0.059	83.4	0.079	0.64	3.1
Full-Scale Post-Ozone	5.96	348.1	193.0	13.5	0.051	83.8	0.077	0.82	3.3
Full-Scale Combined	5.79	335.0	200.1	13.5	0.038	94.2	0.026	0.19	3.7
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 41 mg/L
pH = 5.80
BW = 550-820 am
Sampling at 1230 pm

pH Check	Time	Set	Actual
	745	5.60	5.80

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: December 1, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.90	226.7	154.4	12.3	0.023	73.8	0.132	0.94	3.2
Post-DAF	5.89	267.7	180.9	11.8	0.020	75.2	0.124	1.00	3.5
Post-Ozone	5.90	307.0	181.5	12.2	0.020	76.2	0.117	1.11	4.2
Filter 1	5.98	307.4	181.4	11.8	0.015	92.6	0.033	0.32	5.9
Filter 2	6.05	309.1	189.0	13.1	0.012	92.5	0.034	0.18	5.8
Filter 3	6.01	309.6	184.9	12.3	0.017	92.4	0.034	0.22	5.5
Filter 4	5.98	298.9	180.9	12.3	0.013	93.1	0.031	0.25	5.8
Filter 5	5.98	299.7	183.1	12.0	0.017	92.8	0.032	0.16	5.7
Filter 6	6.00	296.7	182.3	11.6	0.014	92.5	0.034	0.17	5.9
Filter 7	5.96	294.6	181.7	12.0	0.014	92.7	0.037	0.18	5.9
Filter 8	6.00	287.4	181.3	11.8	0.013	92.5	0.034	0.20	5.8
Pilot-Combined	5.97	279.6	186.2	12.1	0.015	92.6	0.033	0.21	5.5
Full-Scale Post-DAF	5.91	280.3	191.4	13.2	0.056	83.2	0.080	0.65	3.0
Full-Scale Post-Ozone	5.95	318.9	190.6	14.4	0.052	82.8	0.082	0.79	3.0
Full-Scale Combined	5.83	336.0	198.2	14.7	0.038	93.8	0.028	0.26	3.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 41 mg/L
pH - 5.90
BW = 550-820 am
Sampling at 1230 pm

pH Check	Time	Set	Actual	
	~~900~~	~~5.70~~	~~4.27~~	*SEE NOTES - Nov. 30th
	700	5.70	5.85	
	800	5.70	5.88	
	830	5.70	5.90	
	1130	5.70	5.90	

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: December 2, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.95	221.3	156.8	12.4	0.020	75.2	0.124	0.91	3.1
Post-DAF	5.88	255.4	181.0	11.8	0.023	73.8	0.132	0.99	3.1
Post-Ozone	5.89	298.0	182.7	11.9	0.024	72.6	0.139	1.36	5.3
Filter 1	5.97	293.0	181.3	11.7	0.016	93.4	0.030	0.29	5.7
Filter 2	5.96	291.9	183.3	11.8	0.013	94.2	0.026	0.19	5.7
Filter 3	5.99	289.2	182.3	11.6	0.015	94.8	0.023	0.11	5.4
Filter 4	5.97	283.6	186.1	11.7	0.016	94.9	0.023	0.12	5.8
Filter 5	5.96	282.3	181.8	11.6	0.015	95.3	0.021	0.09	5.8
Filter 6	5.96	277.2	183.4	11.6	0.016	95.2	0.022	0.08	5.9
Filter 7	5.97	272.0	197.4	11.8	0.015	94.3	0.025	0.07	5.8
Filter 8	5.98	257.0	188.8	12.0	0.016	95.1	0.022	0.09	5.8
Pilot-Combined	5.98	292.0	184.9	12.8	0.015	94.8	0.021	0.13	5.0
Full-Scale Post-DAF	5.79	292.7	188.5	13.2	0.054	84.9	0.071	0.51	3.8
Full-Scale Post-Ozone	5.88	348.0	191.2	13.7	0.053	84.6	0.073	0.70	3.1
Full-Scale Combined	5.69	344.0	189.4	14.3	0.038	93.4	0.031	0.17	3.3
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 41 mg/L
pH = 5.90
BW = 615-845 am
Sampling at 1 pm

pH Check	Time	Set	Actual
	815	5.70	5.89

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: December 3, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.92	214.0	153.1	12.7	0.016	75.0	0.125	0.92	3.3
Post-DAF	6.00	255.8	180.0	12.4	0.019	70.8	0.150	1.31	3.5
Post-Ozone	6.02	321.3	180.8	12.5	0.020	71.7	0.145	1.63	4.9
Filter 1	6.07	316.0	181.0	12.4	0.018	91.6	0.038	0.39	5.9
Filter 2	6.06	317.0	180.8	12.4	0.016	92.7	0.033	0.20	5.9
Filter 3	6.11	316.8	179.9	12.2	0.014	92.9	0.032	0.22	5.8
Filter 4	6.08	310.7	181.2	12.2	0.013	92.1	0.036	0.23	5.8
Filter 5	6.09	310.4	182.5	12.0	0.017	95.2	0.021	0.09	5.9
Filter 6	6.04	313.3	179.1	12.8	0.014	95.1	0.022	0.10	5.9
Filter 7	6.07	303.2	180.3	12.4	0.015	95.2	0.021	0.10	6.0
Filter 8	6.12	301.5	181.3	12.4	0.016	94.7	0.024	0.09	6.0
Pilot-Combined	6.08	300.7	182.1	12.7	0.017	94.0	0.027	0.19	5.5
Full-Scale Post-DAF	5.86	304.9	185.3	12.2	0.047	83.2	0.080	0.61	3.1
Full-Scale Post-Ozone	5.94	324.6	190.0	14.0	0.045	83.9	0.076	0.76	3.1
Full-Scale Combined	5.73	315.6	182.8	12.7	0.032	94.4	0.025	0.15	3.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coad = 41 mg/L
pH = 6.00

pH Check	Time	Set	Actual
	815	5.83	6.03
	1000	5.80	5.96
	1030	5.84	6.01

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: December 4, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.90	218.0	153.8	12.7	0.021	73.7	0.132	0.96	2.9
Post-DAF	5.99	250.9	182.0	12.8	0.024	74.1	0.130	1.29	4.0
Post-Ozone	6.03	319.3	180.1	13.1	0.027	73.1	0.136	1.46	5.6
Filter 1	6.11	316.0	181.7	11.9	0.020	92.5	0.034	0.34	4.6
Filter 2	6.10	314.8	182.0	12.0	0.016	94.0	0.027	0.13	4.7
Filter 3	6.10	312.0	181.4	11.8	0.017	94.4	0.025	0.12	4.4
Filter 4	6.08	311.8	184.2	12.0	0.018	94.4	0.025	0.07	4.7
Filter 5	6.04	312.4	183.0	12.0	0.019	94.2	0.027	0.07	4.8
Filter 6	6.09	310.7	182.3	11.6	0.018	94.6	0.024	0.08	4.7
Filter 7	6.08	309.0	181.2	11.6	0.016	94.8	0.023	0.09	4.7
Filter 8	6.07	306.9	182.5	12.0	0.017	94.4	0.025	0.09	4.7
Pilot-Combined	6.03	301.5	180.6	12.5	0.017	94.4	0.025	0.11	4.2
Full-Scale Post-DAF	5.85	310.7	194.0	13.3	0.054	84.0	0.076	0.77	2.8
Full-Scale Post-Ozone	5.91	317.3	187.5	13.0	0.053	84.5	0.073	0.68	3.1
Full-Scale Combined	5.75	300.2	183.6	13.4	0.038	94.3	0.025	0.21	3.1
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Coag = 41 mg/L
pH = 6.00

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: December 5, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.89	220.2	161.8	12.8	0.024	74.6	0.126	1.11	3.5
Post-DAF	5.90	253.1	193.9	12.9	0.027	73.3	0.135	1.34	4.0
Post-Ozone	5.91	322.4	179.5	12.4	0.027	70.5	0.152	1.73	4.7
Filter 1	6.02	319.9	184.9	12.2	0.031	82.6	0.085	1.14	4.9
Filter 2	6.02	322.8	186.6	12.3	0.030	82.8	0.083	1.12	4.8
Filter 3	6.06	315.8	185.5	12.2	0.018	94.5	0.025	0.10	4.9
Filter 4	6.03	318.6	188.6	12.4	0.017	94.7	0.024	0.08	5.1
Filter 5	5.96	320.7	183.7	12.1	0.020	92.5	0.033	0.24	5.1
Filter 6	5.97	317.2	185.5	12.5	0.020	92.8	0.032	0.29	5.3
Filter 7	6.00	315.6	185.2	11.9	0.019	95.3	0.021	0.06	5.3
Filter 8	5.98	312.8	189.3	12.4	0.018	95.2	0.021	0.11	5.5
Pilot-Combined	5.98	310.0	188.7	12.8	0.022	91.7	0.038	0.35	4.7
Full-Scale Post-DAF	5.84	316.5	194.1	13.5	0.059	84.4	0.074	0.64	2.9
Full-Scale Post-Ozone	5.94	344.0	190.0	13.6	0.053	83.9	0.076	0.74	2.8
Full-Scale Combined	5.73	346.5	194.1	14.1	0.037	94.4	0.025	0.14	3.5
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Filter Bank Flow Test

Coag = 41 mg/L
pH = 5.80
BW = 615-845 am   Filters on at 915 am

pH Check	Time	Set	Actual
	930	5.65	5.84
	1030	5.65	5.85
	1145	5.60	5.81

*pH off - raw flow increased to 3.2 L/s prior to sampling

USE ONLY FOR FILTER COMPARISON

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: December 6, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.96	222.1	157.6	11.8	0.017	74.0	0.131	1.01	2.8
Post-DAF	5.80	260.1	183.1	12.1	0.025	72.2	0.141	1.31	3.0
Post-Ozone	5.83	332.4	183.5	12.6	0.028	71.8	0.144	1.61	4.3
Filter 1	5.86	330.7	186.3	12.4	0.014	92.4	0.034	0.35	4.0
Filter 2	5.90	329.6	184.3	12.5	0.014	93.4	0.030	0.23	4.1
Filter 3	5.88	330.1	184.5	12.5	0.014	94.0	0.027	0.20	4.0
Filter 4	5.91	327.1	187.1	12.2	0.018	93.9	0.027	0.21	4.1
Filter 5	5.91	327.0	184.5	12.2	0.016	95.2	0.021	0.08	4.1
Filter 6	5.89	324.2	184.3	12.2	0.016	95.2	0.021	0.09	4.7
Filter 7	5.90	322.1	184.8	12.3	0.013	95.0	0.022	0.11	4.5
Filter 8	5.93	319.0	187.2	12.0	0.016	95.5	0.020	0.11	4.5
Pilot-Combined	5.91	318.5	190.5	12.3	0.016	95.2	0.021	0.15	3.7
Full-Scale Post-DAF	5.92	315.8	188.0	12.6	0.054	85.1	0.072	0.54	3.5
Full-Scale Post-Ozone	6.02	350.7	182.2	12.5	0.054	84.4	0.074	0.72	2.6
Full-Scale Combined	5.75	348.2	190.8	12.1	0.040	94.4	0.025	0.17	2.6
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Optimal Day #1 - Type II

Coag = 41 mg/L
pH = 5.80

pH Check	Time	Set	Actual
	630	5.60	5.78
	700	5.60	5.81
	900	5.60	5.80

Title: Winnipeg Alternative Coagulant Piloting Lab Data
Date: December 7, 2017
Season: Winter #2

	pH	ORP	Conductivity	DO	Hach Mn	UVT	Abs	Turb	Temp
Raw	7.95	214.7	154.7	11.6	0.019	74.9	0.125	0.91	2.9
Post-DAF	5.82	250.7	183.9	12.5	0.027	75.0	0.125	1.08	3.3
Post-Ozone	5.82	307.4	184.6	12.5	0.025	75.9	0.120	1.23	4.8
Filter 1	5.89	306.7	183.1	12.1	0.015	94.7	0.024	0.28	4.5
Filter 2	5.90	305.3	183.0	12.1	0.014	94.8	0.023	0.15	4.9
Filter 3	5.91	302.4	181.4	12.2	0.016	95.0	0.022	0.14	5.0
Filter 4	5.91	300.9	181.3	12.2	0.017	95.3	0.021	0.06	5.0
Filter 5	5.90	296.9	182.9	12.2	0.019	95.2	0.021	0.09	5.1
Filter 6	5.91	296.7	187.3	12.1	0.016	95.4	0.020	0.09	5.0
Filter 7	5.92	284.1	184.1	12.1	0.018	95.4	0.020	0.07	5.2
Filter 8	5.90	279.9	180.0	12.2	0.018	95.2	0.021	0.12	5.3
Pilot-Combined	5.90	265.0	189.7	12.5	0.017	95.2	0.021	0.10	4.0
Full-Scale Post-DAF	5.88	268.7	191.3	12.6	0.056	83.6	0.078	0.62	2.5
Full-Scale Post-Ozone	5.98	273.1	188.4	14.2	0.054	84.8	0.072	0.65	1.9
Full-Scale Combined	5.76	265.2	187.3	13.1	0.040	94.8	0.023	0.10	2.9
Units	-	mV	µS/cm	mg/L	mg/L	%	cm^{-1}	NTU	C

Daily Notes:

Optimal Day #2 - Type I

Coag = 41 mg/L
pH = 5.80

pH Check	Time	Set	Actual
	630	5.60	5.78
	730	5.60	5.81

APPENDIX

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FILTER PERFORMANCE

FILTER PERFORMANCE

Session	Date	Parameter	BANK A				BANK B			
			Filter 1	**Filter 2**	**Filter 3**	**Filter 4**	**Filter 5**	**Filter 6**	**Filter 7**	**Filter 8**
		Defined Overflow Pressure (kPa)	22.3	24.2	23.9	27.6	23.8	22.7	24.1	22.5
Winter #1										
Coagulant (mg/L): 46.00		Filter Starting Pressure (Avg Hr, kPA)	0.72	0.54	1.09	0.61	0.00	0.70	0.61	-
Sulphuric (mg/L): 42.00		Filter Ending Pressure (Avg Hr, kPA)	16.31	14.78	15.63	15.12	20.75	22.42	23.89	-
Coag. Aid (mg/L): 0.02		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	22	22	22	22	6	5	6	-
Pre-DAF pH: 5.37		Lab Turbidity at 4hrs After start (NTU)	0.18	0.13	0.12	0.15	0.07	0.05	0.05	0.05
	4-Apr-17	Pressure Reading 4hrs After Start (kPa)	7.35	6.52	7.27	6.84	20.75	25.52	23.89	-
		Average Filter Bank Flow (L/s)	0.30	0.30	0.30	0.30	0.60	0.60	0.60	0.60
		UFRV at Ending Pressure (m^2/m^3)	**319**	**319**	**319**	**319**	**174**	**145**	**174**	**-**
		Estimated Runtime at Overflow Pressure (hrs)	32	39	37	44	O/F	O/F	O/F	O/F
		Forecasted UFRV at Overflow Pressure (m^2/m^3)	**461**	**562**	**534**	**642**				
Coagulant (mg/L): 46.00		Filter Starting Pressure (Avg Hr, kPA)	0.00	0.43	0.56	0.00	0.00	0.00	0.00	0.00
Sulphuric (mg/L): 42.00		Filter Ending Pressure (Avg Hr, kPA)	15.05	13.74	13.06	12.83	19.96	20.84	18.50	0.00
Coag. Aid (mg/L): 0.02		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	25	25	25	25	6	6	4	0
Pre-DAF pH: 5.34		Lab Turbidity at 4hrs After start (NTU)	1.94	2.06	0.59	0.5	<0.05	0.05	0.46	0.06
	5-Apr-17	Pressure Reading 4hrs After Start (kPa)	7.19	6.27	6.37	5.99	19.96	20.84	18.50	0.00
		Average Filter Bank Flow (L/s)	0.30	0.30	0.30	0.30	0.60	0.60	0.60	0.60
		UFRV at Ending Pressure (m^2/m^3)	**362**	**362**	**362**	**362**	**174**	**174**	**116**	**0**
		Estimated Runtime at Overflow Pressure (hrs)	36	43	45	53	O/F	O/F	O/F	O/F
		Forecasted UFRV at Overflow Pressure (m^2/m^3)	**516**	**629**	**659**	**766**				
Spring Piloting Session										
Coagulant (mg/L): 42.00		Filter Starting Pressure (Avg Hr, kPA)	0.00	0.03	0.52	0.07	0.00	0.02	0.00	0.00
Sulphuric (mg/L): 25.00		Filter Ending Pressure (Avg Hr, kPA)	10.09	22.47	23.77	26.72	23.69	22.30	24.07	20.86
Coag. Aid (mg/L): 0.20		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	4	7	5	7	9	9	12	9
Pre-DAF pH: 6.10	30-May-17	Lab Turbidity at 4hrs After start (NTU)	0.22	0.10	0.12	0.09	0.08	0.09	0.09	0.11
		Pressure Reading 4hrs After Start (kPa)	25.48	20.55	26.46	26.30	14.98	15.62	11.97	12.98
		Average Filter Flow (L/s)	0.15	0.15	0.15	0.15	0.08	0.08	0.08	0.08
		UFRV at Ending Pressure (m^2/m^3)	**116**	**203**	**145**	**203**	**130**	**130**	**174**	**130**
Coagulant (mg/L): 42.00		Filter Starting Pressure (Avg Hr, kPA)	0.00	0.13	0.41	0.15	0.00	0.00	0.00	0.00
Sulphuric (mg/L): 29.50		Filter Ending Pressure (Avg Hr, kPA)	13.09	19.86	20.72	22.18	20.87	18.61	14.72	16.77
Coag. Aid (mg/L): 0.20		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	3	4	4	4	6	7	6	6
Pre-DAF pH: 6.10	31-May-17	Lab Turbidity at 4hrs After start (NTU)	0.15	0.08	0.08	0.07	0.08	0.07	0.08	0.09
		Pressure Reading 4hrs After Start (kPa)	27.6	26.3	29.1	27.8	15.9	14.6	11.0	12.7
		Average Filter Flow (L/s)	0.16	0.17	0.14	0.16	0.08	0.08	0.07	0.07
		UFRV at Ending Pressure (m^2/m^3)	**95**	**129**	**112**	**123**	**98**	**104**	**86**	**86**
Summer Piloting Session										
Coagulant (mg/L): 38.00		Filter Starting Pressure (Avg Hr, kPA)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulphuric (mg/L): 31.00		Filter Ending Pressure (Avg Hr, kPA)	21.95	24.05	21.79	27.50	21.05	20.56	21.41	17.84
Coag. Aid (mg/L): 0.00		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	10	14	10	15	21	23	23	19
Pre-DAF pH: 6.00		Lab Turbidity at 4hrs After start (NTU)	0.20	0.11	0.13	0.1	0.13	0.14	0.1	0.11
	30-Jul-17	Pressure Reading 4hrs After Start (kPa)	13.00	9.99	13.21	12.85	2.69	3.77	3.71	4.02
		Average Filter Flow (L/s)	0.17	0.17	0.16	0.16	0.08	0.08	0.08	0.08
		UFRV at Ending Pressure (m^2/m^3)	**319**	**462**	**300**	**459**	**341**	**350**	**352**	**288**
		Estimated Runtime at Overflow Pressure (hrs)	O/F	O/F	O/F	O/F	24	26	26	24
		Forecasted UFRV at Overflow Pressure (m^2/m^3)					**390**	**396**	**402**	**357**
Coagulant (mg/L): 38.00		Filter Starting Pressure (Avg Hr, kPA)	0.00	0.00	0.16	0.25	0.00	0.00	0.14	0.00
Sulphuric (mg/L): 36.30		Filter Ending Pressure (Avg Hr, kPA)	20.39	24.03	21.82	27.60	23.76	21.71	23.14	19.65
Coag. Aid (mg/L): 0.00		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	9.00	13	10	15	22	22	21	19
Pre-DAF pH: 5.80	4-Aug-17	Lab Turbidity at 4hrs After start (NTU)	0.22	0.09	0.12	0.08	0.09	0.09	0.09	0.11
		Pressure Reading 4hrs After Start (kPa)	14.03	10.83	13.97	13.45	2.78	3.76	4.19	0.83
		Average Filter Flow (L/s)	0.17	0.17	0.15	0.16	0.08	0.08	0.08	0.08
		UFRV at Ending Pressure (m^2/m^3)	**289**	**426**	**296**	**457**	**357**	**332**	**320**	**286**
Coagulant (mg/L): 38.00		Filter Starting Pressure (Avg Hr, kPA)	0.00	0.00	0.31	0.06	0.00	0.00	0.00	0.00
Sulphuric (mg/L): 34.00		Filter Ending Pressure (Avg Hr, kPA)	20.45	23.04	22.96	27.58	23.78	20.94	24.06	21.11
Coag. Aid (mg/L): 0.10		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	11.00	20	11	19	15	15	16	14
Pre-DAF pH: 5.80	16-Aug-17	Lab Turbidity at 4hrs After start (NTU)	0.21	0.13	0.12	0.1	0.09	0.1	0.1	0.09
		Pressure Reading 4hrs After Start (kPa)	13.37	10.34	13.84	12.13	3.83	4.92	3.60	1.41
		Average Filter Flow (L/s)	0.15	0.18	0.16	0.16	0.08	0.07	0.08	0.08
		UFRV at Ending Pressure (m^2/m^3)	**320**	**683**	**341**	**598**	**246**	**213**	**247**	**212**
Coagulant (mg/L): 38.00		Filter Starting Pressure (Avg Hr, kPA)	0.00	0.00	1.88	1.88	0.00	0.00	0.00	0.00
Sulphuric (mg/L): 34.00		Filter Ending Pressure (Avg Hr, kPA)	21.94	19.06	22.43	22.74	16.32	14.93	14.47	11.56
Coag. Aid (mg/L): 0.10		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	12	14	13	13	13	14	13	11
Pre-DAF pH: 5.80		Lab Turbidity at 4hrs After start (NTU)	0.20	0.11	0.13	0.1	0.13	0.14	0.1	0.11
	17-Aug-17	Pressure Reading 4hrs After Start (kPa)	12.52	8.00	13.26	13.49	5.03	4.28	3.03	4.54
		Average Filter Flow (L/s)	0.17	0.17	0.15	0.16	0.09	0.08	0.08	0.08
		UFRV at Ending Pressure (m^2/m^3)	**394**	**458**	**389**	**393**	**214**	**211**	**197**	**162**
		Estimated Runtime at Overflow Pressure (hrs)	O/F	17	13	15	18	21	21	20
		Forecasted UFRV at Overflow Pressure (m^2/m^3)		**565**	**400**	**469**	**305**	**314**	**315**	**292**

FILTER PERFORMANCE

Session		Date	Parameter	BANK A				BANK B			
				Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8
			Defined Overflow Pressure (kPa)	22.3	24.2	23.9	27.6	23.8	22.7	24.1	22.5
Fall Piloting Session											
Coagulant (mg/L):	42.00	29-Oct-17	Filter Starting Pressure (Avg Hr, kPA)	0.00	0.00	0.00	0.22	2.57	0.00	0.00	4.02
Sulphuric (mg/L):	26.00		Filter Ending Pressure (Avg Hr, kPA)	17.17	24.11	18.66	27.27	23.51	21.93	24.01	20.08
Coag. Aid (mg/L):	0.07		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	6	8	7	8	8	10	11	6
Pre-DAF pH:	5.70		Lab Turbidity at 4hrs After start (NTU)	0.16	0.12	0.13	0.11	0.11	0.14	0.13	0.14
			Pressure Reading 4hrs After Start (kPa)	17.17	14.02	13.84	17.20	14.70	6.74	8.17	20.08
			Average Filter Flow (L/s)	0.18	0.17	0.14	0.15	0.09	0.08	0.08	0.08
			UFRV at Ending Pressure (m^2/m^3)	**207**	**259**	**191**	**238**	**134**	**147**	**166**	**92**
Coagulant (mg/L):	42.00	31-Oct-17	Filter Starting Pressure (Avg Hr, kPA)	0.00	0.00	1.35	0.00	4.11	0.00	0.08	7.25
Sulphuric (mg/L):	26.00		Filter Ending Pressure (Avg Hr, kPA)	21.52	23.64	19.82	27.48	22.01	20.90	24.09	21.35
Coag. Aid (mg/L):	0.07		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	5.00	6	4	7	6	9	11	6
Pre-DAF pH:	5.70		Lab Turbidity at 4hrs After start (NTU)	0.16	0.17	0.15	0.16	0.08	0.08	0.08	0.08
			Pressure Reading 4hrs After Start (kPa)	24.66	23.64	25.37	27.04	22.01	11.34	13.79	21.35
			Average Filter Flow (L/s)	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1
			UFRV at Ending Pressure (m^2/m^3)	**158**	**193**	**116**	**219**	**91**	**135**	**172**	**94**
Winter #2 Piloting Session											
Coagulant (mg/L):	41.00	27-Nov-17	Filter Starting Pressure (Avg Hr, kPA)	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00
Sulphuric (mg/L):	41.15		Filter Ending Pressure (Avg Hr, kPA)	22.25	24.01	22.98	27.37	23.72	19.49	20.94	18.75
Coag. Aid (mg/L):	0.00		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	16	23	17	23	23	23	23	22
Pre-DAF pH:	5.70		Lab Turbidity at 4hrs After start (NTU)	0.32	0.19	0.24	0.24	0.07	0.08	0.08	0.1
			Pressure Reading 4hrs After Start (kPa)	12.08	10.93	12.03	14.78	4.93	3.05	3.83	3.11
			Average Filter Flow (L/s)	0.17	0.16	0.16	0.16	0.09	0.08	0.08	0.08
			UFRV at Ending Pressure (m^2/m^3)	**513**	**709**	**520**	**709**	**385**	**347**	**345**	**330**
			Estimated Runtime at Overflow Pressure (hrs)	O/F	20	O/F	19	24	28	27	27
			Forecasted UFRV at Overflow Pressure (m^2/m^3)		**618**		**583**	**400**	**416**	**410**	**407**
Coagulant (mg/L):	41.00	5-Dec-17	Filter Starting Pressure (Avg Hr, kPA)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulphuric (mg/L):	42.00		Filter Ending Pressure (Avg Hr, kPA)	20.58	24.05	23.14	27.43	23.10	22.69	21.59	21.86
Coag. Aid (mg/L):	0.00		Estimate Runtime Prior to Overflow Pressure or Backwash (hrs)	7	9	17	19	7	7	16	17
Pre-DAF pH:	5.80		Lab Turbidity at 4hrs After start (NTU)	1.14	1.12	0.1	0.08	0.24	0.29	0.06	0.11
			Pressure Reading 4hrs After Start (kPa)	16.75	16.26	6.19	9.30	20.24	21.80	6.79	5.71
			Average Filter Flow (L/s)	0.15	0.15	0.08	0.08	0.16	0.16	0.08	0.08
			UFRV at Ending Pressure (m^2/m^3)	**207**	**266**	**265**	**303**	**216**	**217**	**236**	**261**
			Estimated Runtime at Overflow Pressure (hrs)	O/F	O/F	O/F	19	O/F	O/F	O/F	O/F
			Forecasted UFRV at Overflow Pressure (m^2/m^3)				**298**				

O/F - Over-flow

APPENDIX

K

CITY OF WINNIPEG – FILTER PERFORMANCE TESTING

Water and Waste Department • Service des eaux et des déchets

July 16, 2018

WSP Canada Inc.
1600 Buffalo Place
Winnipeg, MB R3T 6B8

Attention: Ian McKinnon, P. Eng

Dear Mr. McKinnon,

After the competition of the Winter #2 benchmarking period in January 2018, the City of Winnipeg continued to operate the pilot-scale system to confirm and optimize filter performance with the alternative coagulant, ferric sulphate.

From May 9 to June 26, 2018 the pilot-scale system was operated in a steady state at a raw water flow of 2.20 L/s, filter flows of 0.3 L/s per filter Bank, ferric sulphate dose of 39 mg/L and a pH in the range of 5.7 to 6.0, averaging 5.85. During this period Unit Filter Run Volumes (UFRVs) were monitored daily to confirm filter performance. Filters were generally backwashed daily at 8:00am, with some extended filter runs being completed between June 11 and June 18th. UFRVs and maximum filter run times were calculated based on the differential pressure and turbidity recorded on the SCADA for each filter. An operating limit was set on turbidity at 0.1 NTU for filter performance to match the operating limit currently used in the full-scale system. Filter run times were calculated based on a filter failure due to turbidity over 0.1 NTU or a filter overflow due to pressure. Where filters did not fail on either overflow or turbidity prior to the next scheduled backwash the filter run time was extrapolated to estimate to filter run time at failure.

In general, performance between Bank A and Bank B was comparable throughout this time period with the exception of May 21st through May 24, 2018 when Bank B failed to reach a turbidity of below 0.1 NTU. For comparison, Bank A filters did maintain turbidities below 0.1 NTU and achieved UFRV's ranging from 355-529 m^3/m^2 from May 21st to May24th. The exact cause of the performance difference between the filter Banks on these four days is unknown. Figure 1, illustrates the daily average UFRV for each filter bank.

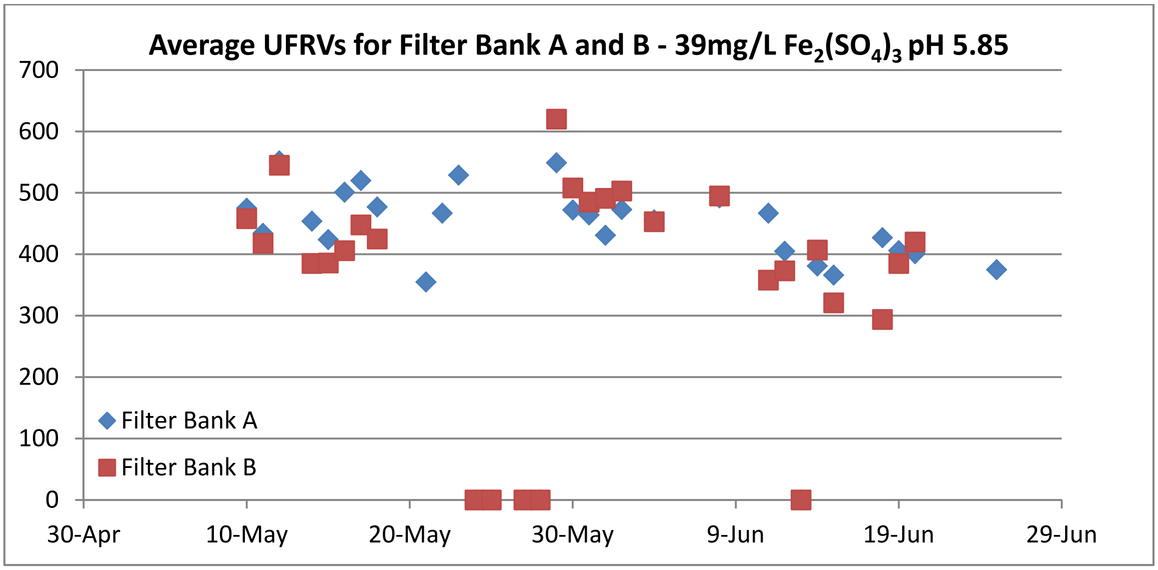

Figure 1: Average UFRVs for Filter Bank A and Filter Bank B dosing 39 mg/L ferric sulphate at an average pH of 5.85
Note: May 24th to May 28, 2018 the filters were offline due to a maintenance issue on the sulphuric acid pump.

From May 10th to June 26th the pilot–scale system Bank A UFRVs ranged from 355 to 552 m^3/m^2, averaging 452 m^3/m^2. Bank B UFRVs ranged from 294 to 620 m^3/m^2, averaging 435 m^3/m^2. Filter run times during this period averaged 30.2 hours for Bank A and 28.6 hours for Bank B. Table 1, provides a summary of the data collected from the pilot-scale system from May 10th to June 26, 2018.

Table 1: Summary of Filter Performance Data for Filter Bank A and Filter Bank B with Ferric Sulphate

	Filter Bank A				Filter Bank B			
	Average UFRV (m^3/m^2)	Average Run Time (hrs)	Average Ripening Time (mins)	Average ΔP Rise (kPa/hr)	Average UFRV (m^3/m^2)	Average Run Time (hrs)	Average Ripening Time (mins)	ΔP Rise (kPa/hr)
	Ferric Sulphate 39 mg/L Average pH 5.85 (May 10-June 26, 2018)							
Average	452	30.2	34	0.87	436	28.6	32	0.92
Maximum	552	42.6	69	1.12	620	40.3	65	1.45
Minimum	355	23.2	16	0.67	294	20.6	15	0.61

For comparison, benchmarking of the pilot-scale system to full-scale system was conducted from February 27th to March 8th as part of a separate study. Ferric chloride was dosed between 30-34 mg/L at a pH of 5.7. During this period the pilot-scale system filters all failed on overflow at run times between 17-21 hours and UFRVs ranged from 260 to 330 m^3/m^2, averaging 289 m^3/m^2 for Bank A and B. This comparison illustrates that the pilot-scale system is capable of achieving higher average UFRVs operating with ferric sulphate when compared to ferric chloride. However, it should be noted that the benchmarking data was collected in February and early March at water temperatures of around 4°C. The trial data was collected from May to June at water temperatures between 12-22°C. Lower water temperatures will affect the efficiency of the coagulation process resulting in a less effective DAF operation and potentially lower filter performance. As such, it is possible that the UFRVs in the pilot-scale system operating with ferric chloride might be higher with warmer water and more comparable to the UFRVs found when dosing ferric sulphate.

For further discussion, the full-scale Water Treatment Plant's historical five-year average UFRV value was 495 m^3/m^2 based on an average 30 hours backwashing schedule (Note: the full-scale system is not run to failure but backwashed based on time). The pilot-scale system, while benchmarking against the full-scale system was only able to achieve average UFRVs of 289m^3/m^2. This is a 42% reduction in filter operation between the pilot-scale and full-scale systems dosing the same coagulant at comparable dose rates and pH. This notable difference is likely related to the scaling differences between the pilot-scale and full-scale system DAF and filters. However, if this difference is directly related to the scaling differences between the systems, it would expected to see a comparable reduction in filter operation between the pilot-scale and full-scale systems operating with ferric sulphate as well. Based on this reasoning, filter UFRVs in the range of 746 to 774 m^3/m^2 may be expected when operating the full-scale system with ferric sulphate.

In addition to the UFRVs and run times, Table 1 provides data on the average pressure increase for each filter bank from May 10th to June 26, 2018. The average pressure increase was 0.87 kPa/h in Bank A and 0.92 kPa/h in Bank B. Comparably, the full-scale system's historical five-year average pressure increase was 1.7 kPa/h. This comparison provides additional support that the full-scale system may expect to see higher filter performance when operating with ferric sulphate, as the pressure increase across the filters is notable lower in the pilot-scale system when dosing ferric sulphate compared to what the full-scale system is historically achieving dosing ferric chloride. The lower pressure rise indicates that the filters are building up pressure at a slower rate and may potentially be able to operate for longer periods of time.

Based on the UFRV and filter pressure data collected in the pilot-scale system from May 10th to June 26, 2018, it has been confirmed that the pilot-scale system while dosing ferric sulphate is capable of achieving UFRVs averaging 436-452 m^3/m^2 which is in line with what has been historically seen from the full-scale system (495 m^3/m^2). The rise of filter pressure in the pilot-scale system over this period was consistently lower than seen in the full-scale system historically. This indicates that the pilot-scale system filters are capable of building up pressure slower with ferric sulphate then the full-scale system filters when dosing ferric chloride. It is anticipate, based on this data, that the full-scale system should be able to achieve comparable filter performance after the transition to coagulation with ferric sulphate.

Yours truly,

Heather Buhler, P. Eng
Engineer SR - Water Planning

HB/ctk