

**Burgoyne Water Works
13-028**

**2019 Operation and Maintenance
Annual Report
January 2020**



**Prepared for:
Municipality of Arran-Elderslie
PO Box 70, 1925 Bruce Road 10
Chesley, ON N0G 1L0**

**Prepared By:
GSS Engineering Consultants Ltd.
Unit 104D, 1010 – 9th Ave, W.
Owen Sound, ON
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1.0 INTRODUCTION AND BACKGROUND

The purpose of the 2019 Annual Report is to document the operation of the Burgoyne Drinking Water System. This is in accordance with O. Reg 170/03, and could be reviewed by the Ministry of Environment, Conservation & Parks (MECP).

The system was taken over by the Municipality of Arran-Elderslie as directed by the MECP in June of 2018.

The system was registered as a Small Municipal Residential system on December 5th, 2018 with the MECP. The Ministry notified the Municipality on December 17th, 2018, that system registration had been completed. After that, Municipal staff immediately went door to door in Burgoyne and issued a “Precautionary Boil Water Advisory issued by the Municipality” as no water treatment was available.

The system currently has 21 connections, including a church and a restaurant and serves a population of about 45 people.

During the reporting period, system was operated by the following certified operators from the Municipality of Arran-Elderslie:

- a) Mark O’Leary, Water & Wastewater Foreman and the back-up Overall Responsible Operator (ORO) who holds a Class II Water Treatment License, and Class III Water Distribution and Supply;
- b) Trevor Sweiger who holds a Class I Water Treatment and Class I Water Distribution and Supply License;
- c) Chris Legge who holds a Class I Water Treatment and a Class II Water Distribution and Supply License;
- d) Ted Knapp who holds a Class II Water Treatment License and a Class II Water Distribution and Supply License;
- e) Owen Scott who holds OIT licenses for both Water Treatment and Water Distribution and Supply;

- f) Scott McLeod who holds a Class II Water Treatment License and a Class IV Water Distribution and Supply License and is also the back-up ORO.

ORO Services are provided by GSS Engineering's staff, Rakesh Sharma, P. Eng., who holds a Class IV License for both Water Treatment and Water Distribution and Supply.

The report includes sample analysis results collected by the previous operator.

The operating authority for the plant is:

Municipality of Arran-Elderslie

P.O. Box 70, 1925 County Road #10
Chesley, ON N0G 1L0
Telephone: 519-363-3039
Fax: 519-363-2203

ORO service is provided by:

GSS Engineering Consultants Ltd.
Unit 104D, 1010 9th Ave. W.
Owen Sound, ON N4K 5R7
Telephone: 519-372-4828

2.0 DESCRIPTION OF WATER SYSTEM

The Burgoyne Distribution System is comprised of small diameter polyethylene water main. The pipe size is believed to be 50 mm \varnothing . Each household has individual curb-stops. The South West Quadrant of the system contains a blow-off for sampling and flushing purposes.

2.1 Well Site

The Burgoyne Well Site is located on an un-opened road allowance at #4870 Bruce Road #3 in the Hamlet of Burgoyne. The address is a shared driveway with the property owner to the south.

The system is Drinking Water Untreated (DW-UT), and provides no treatment.

The pump-house is cinder block building with approximate dimensions of 3 m x3 m and includes a small tunnel (about .3 m x 1 m) providing room for piping from well casing. The casing is accessed by removing a cement lid located right above the well head, from the exterior of the building and used for pump removal.

The pump house comprises of:

- ❖ One groundwater well,
- ❖ One Submersible well pump,
- ❖ 25 mm ø water meter to monitor flows,
- ❖ Two pressure tanks with associated gauges, and
- ❖ A sample point to collect raw water samples.

The Burgoyne Well was drilled in June 1967 and has a well record number of #5357. The record shows a total depth of 284 feet and includes a 250 foot well casing. The well was drilled by Durham Well Drilling Enterprises Ltd.

At the time of drilling the well, it was tested at 20 igpm for step testing purposes and the pumping rate was recommended at 15 igpm.

3.0 SUMMARY OF WATER QUALITY AND MONITORING

3.1 Turbidity

In 2019 Raw turbidity samples were taken at the Burgoyne well site sixty-four (64) times with turbidity readings ranging from 0.28 NTU to 2.80 NTU. Refer to **Table 1**.

In 2019 Distribution turbidity samples were taken fifty-six (56) times, with readings ranging from 0.19 NTU to 3.71 NTU.

3.2 Microbiological Sampling

3.2.1 Raw Water Samples

The Burgoyne Raw Water Supply was sampled weekly and fifty-five (55) samples were collected, which also included re-samples.

E. Coli was not detected in any of the (55) fifty-five samples taken in 2019.

A single grab sample taken Monday, September 23, 2019 had an adverse count of eleven (11) total coliform. All re-sampling results for samples taken at the well site after the adverse results were acceptable.

Table 1
 Summary Water Usage and Raw Water Turbidity
 Burgoyne Water Works

Month	Total Flow m3	Min. Raw NTU	Max. Raw NTU
January	99m3	0.46	0.64
February	406m3	0.36	0.67
March	202m3	0.31	0.4
April	486m3	0.46	0.81
May	494m3	0.28	0.9
June	280m3	0.83	1
July	515m3	0.66	0.92
August	430m3	0.58	0.99
September	466m3	0.66	1.41
October	353m3	0.78	2.8
November	254m3	0.55	0.69
December	267m3	0.61	0.75
Yearly	4252m3	.28 NTU	2.80 NTU
Monthly Average	354m3		
Min Month January	99m3		
Max Month July	515m3		
Monthly Average Per Household	16.9m3		
Daily Usage Per Household	.55m3		

3.2.2 Distribution Samples

The Burgoyne Distribution System has limited sampling locations. Most samples were therefore collected at the restaurant, church, or blow-off depending upon weather conditions. In 2019, a total of seventy-one (71) samples and re-samples were collected.

Initial samples taken on Monday, September 23, 2019 at the Burgoyne Restaurant had an adverse reading of one (1) total coliform. Re-samples at blow off and taken on Wednesday, September 25, 2019 had adverse reading of two (2) total coliform, and a reading of NDOGT (No Data Overgrown) at the Burgoyne Restaurant. Subsequently, the Grey-Bruce Health Unit, issued a Boil Water Advisory. The Municipality completed chlorination of the well, and distribution system by following the guidelines set out in the “Procedure for Corrective Action for Systems not Currently Using Chlorine”. Re-samples taken on September 28th, 29th and 30th were all acceptable.

On Monday, October 21, 2019, an adverse sample with one (1) total coliform reading was detected at the Burgoyne Restaurant. Re-samples taken on October 23, 2019 at the Restaurant again had adverse readings of two (2) total coliform, and one (1) total coliform at the blow-off. As per MECP’s directive, staff disinfected the well and distribution system. Re-samples taken October 27th and 29th had acceptable test results.

3.3 Lead

The Burgoyne Water System was sampled for lead parameters in both the spring and fall as set-out by the MECP guidelines. Five (5) residential, one (1) non-residential, and one (1) distribution sample were completed both in spring and fall.

Spring sampling was completed on April 5, 2019. An adverse sample of 12.5ug/L was received at the Burgoyne Church. Re-sampling completed on April 23rd, had a concentration of 0.46ug/L.

Staff notified the property owner and followed adverse result procedure.

Fall samples were conducted on October 8, 2019 and all test results were below 1ug/L.

A copy of the lab report is included in **Appendix A**.

3.4 Chlorine Residuals (POE & Distribution), TTHM & HAA

The water system does not provide chlorination of water, and therefore no samples for chlorine residuals were tested in the 2019 calendar year.

In August 2018, in partnership with the Walkerton Clean Water Centre (WCWC) a pilot study was undertaken to try and determine water quality and treatment issues for the Burgoyne Water System. In the pilot study it was determined that the raw water supply has natural ammonia in the water. An average concentration of 0.43 mg/L was detected. The study indicated a breakpoint chlorination of around 6-6.8 mg/L. The WCWC sampled THM's & HAA parameters for the breakpoint chlorination levels. THM's was 18 ug/L and 19 ug/L, while HAA's were not detectable.

3.5 Walkerton Clean Water Centre Pilot Project

Other findings from the WCWC pilot project are provided in the report which is appended (**Appendix B**) to this report for information and reference purposes only.

3.6 Inorganics/Organics/Nitrite/Nitrate/Sodium/Flouride

None of these parameters were tested for in the 2019 calendar year.

4.0 WATER USAGE

A summary of water supplied to the distribution system is included in **Table 1** included in Section 3.0.

5.0 NON-COMPLIANCE DURING THE REPORTING PERIOD

The Burgoyne Water System had (3) Water Quality Incidents as follows:

5.1 April 5, 2019

The Burgoyne Church had an adverse lead result. The reading was 12.5 ug/L and was reported to the Grey-Bruce Health Unit, Ministry of Environment, Conservation and Parks and Spills Action Centre. Re-sample result was acceptable.

5.2 Monday September 23, 2019

Samples taken at the Burgoyne Restaurant had an adverse reading of one (1) total coliform. And the sample taken at the Burgoyne Well site had a reading of eleven (11) total coliform. Re-samples taken on Wednesday, September 25, 2019 had adverse reading at the blow-off with a total coliform count of two (2), and a reading of NDOGT (No Data Overgrown) at the Burgoyne Restaurant. The raw water sample at the well however had zero (0) total coliform reading. The Grey-Bruce Health Unit issued a Boil Water Advisory. Under the direction of MECP, the Municipality undertook chlorination of the well and distribution system in accordance with the guidelines set out in the Procedure for Corrective Action for Systems not Currently Using Chlorine.

Re-samples on September 28th, 29th and 30th tested negative for coliform. The Grey-Bruce Health Unit lifted boil water advisory on Thursday October 3rd. Municipal staff again went door to door to notify the users, however the Municipal precautionary boil water advisory was not lifted.

AWQI Numbers of 148213 & 148214 were created for the Adverse Incident.

5.3 October 21, 2019

Sample at the Burgoyne Restaurant had a reading of one (1) total coliform count. Re-samples taken on October 23, 2019 again had adverse readings two (2) total coliform at the Burgoyne Restaurant, and (1) one total coliform at the blow-off. As per direction of the MECF, staff disinfected the well and distribution system. Re-samples taken October 27th and 29th tested negative for coliform.

AWQI Numbers of 148696, 148741 & 148742 were created for the Adverse Incident.

6.0 IMPROVEMENTS AND MAINTENANCE COMPLETED ON SYSTEM

The following maintenance/improvements steps were undertaken in 2018 and 2019:

August 2018 Arran-Elderslie entered into agreement with Walkerton Clean Water Centre to undertake a pilot project on treatment options for the Burgoyne Water Supply.

December 2018 Arran-Elderslie issued a Precautionary Boil Water Advisory, to water customers after registration of the system with MECF. Staff also circulated a Cross Connection Survey to residents in order to collect as much information as possible about other wells that could possibly be connected to the drinking water system.

January 2019 Operators installed a new 25 mm dia. water meter on raw water supply piping to monitor flows. It was suspected that the old water meter was inaccurate as it was indicating high consumption. However, it was determined that the old water meter was accurate.

The Burgoyne Water System has high water consumption per customer, higher than any another A&E water system.

February 2019 Door lock was changed.

- March 2019** Water meter was taken apart, cleaned and put back into service.
- April 2019** Lead sampling was completed on April 5th. Notification were provided to the Burgoyne Church on April 17th in regard to an adverse reading. It was re-sampled on April 23rd with acceptable results.
- Installed signage on the door to notify public emergency contact numbers.
- International Water Supply (IWS) completed a step test which indicated a 2.25m drawdown over a 30 minute test. Static water level is 17m below TOC. IWS also performed CCTV camera inspection. The well casing was found to be in rough condition indicating areas with spiral cracks. Video logging was stopped at the 42.6 m depth. A plumb utilized for pumping test was unable to get lower than 53.3 m. The lower portions of the well may have blockage or some other issue preventing plumb from going deeper.
- May 2019** On May 28th on-duty operator received a call from a water customer, in regard to “no water” at home. Nickason Plumbing and Heating arrived and installed new one and one-half horsepower (1½ hp) well pump and control box. The system was chlorinated, pumped to waste, and put back online.
- September 2019** Adverse sample result was noted on September 23rd as noted in the Non-Compliance Section.
- October 2019** Staff improved the seal around cement access hatch that provides access to the well head.
- The adverse sample result on October 23rd, as noted in the Non-Compliance Section.
- On Site, October 26th Nickason Electric replaced the damaged wire on the well pump.
- December 2019** The blow-off was winterized.

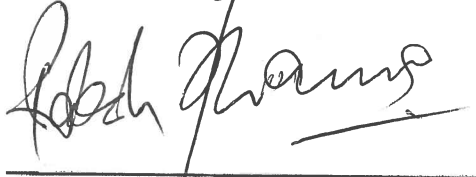
**7.0 MINISTRY OF THE ENVIRONMENT, CONSERVATION AND PARKS INSPECTION
AND REGULATORY ISSUES**

The Burgoyne Water System was not inspected in the 2019 calendar year

- a) The Burgoyne Water Committee consisting of several interested parties continue to work towards a suitable option for getting potable water for the residents of Burgoyne.
- b) The current Certificate of Approval for the Burgoyne Water System expires July 31, 2020.
- c) Consideration will have to be given to testing the aquifer for Inorganics/organics/Sodium/Flouride/Nitrite/Nitrate.

Respectfully submitted:

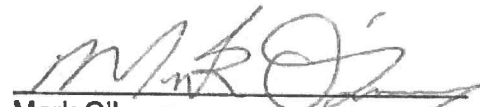
GSS Engineering Consultants Ltd.



Rakesh Sharma, P. Eng., M.A.Sc.
Operator, Class IV WT, Class IV WD

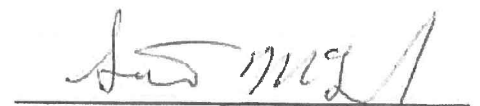
Prepared by:

Municipality of Arran-Elderslie



Mark O'Leary
Water/Sewer Foreman
Operator, Class II WT & Class III WD
Backup ORO

Municipality of Arran-Elderslie



Scott McLeod, Public Works Manager
Class II WT & Class IV WD,
Backup ORO

APPENDIX A

LEAD ANALYSIS REPORTS



Works #: 220008818

SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

15-April-2019

Mun of Arran Elderslie (Burgoyne Water Association)
Attn : Mark O'Leary

Date Rec. : 08 April 2019
LR Report: CA30122-APR19

1925-10 Bruce Rd, PO Box 70
Chesley, ON
N0G 1L0, Canada

Copy: #1

Phone: 519-363-3039 ext:122
Fax:519-363-9337

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Temperature upon Delivery @ London Lab °C	Field pH	Alkalinity mg/L as CaCO3	Lead ug/L
1: Analysis Start Date		---	---	11-Apr-19	15-Apr-19
2: Analysis Start Time		---	---	15:11	11:04
3: Analysis Completed Date		---	---	12-Apr-19	15-Apr-19
4: Analysis Completed Time		---	---	15:37	11:41
5: MAC		---	---	---	10
6: AO/OG		---	---	30-500	---
7: MDL		---	---	2	0.01
8: TAP-PR Kitchen Tap #4855 Bruce Rd #3 1st	05-Apr-19 11:55	14.3	6.88	---	0.12
9: TAP-PR Kitchen Tap #4855 Bruce Rd #3 2nd	05-Apr-19 11:55	14.3	6.88	---	0.07
10: TAP-PR Kitchen Tap #4830 Bruce Rd #3 1st	05-Apr-19 10:35	14.3	7.15	---	0.08
11: TAP-PR Kitchen Tap #4830 Bruce Rd #3 2nd	05-Apr-19 10:35	14.3	7.15	---	0.04
12: TAP-PR Kitchen Tap #4852 Bruce Rd #3 1st	05-Apr-19 10:45	14.3	6.83	---	1.70
13: TAP-PR Kitchen Tap #4852 Bruce Rd #3 2nd	05-Apr-19 10:45	14.3	6.83	---	0.21
14: TAP-PR Kitchen Tap #4854 Bruce Rd #3 1st	05-Apr-19 10:50	14.3	6.40	---	0.01 <MDL
15: TAP-PR Kitchen Tap #4854 Bruce Rd #3 2nd	05-Apr-19 10:50	14.3	6.40	---	0.01 <MDL
16: DW Sample Tap Blow Off 1st	05-Apr-19 11:25	14.3	6.72	---	0.03
17: DW Sample Tap Blow Off 2nd	05-Apr-19 11:25	14.3	6.72	179	---
18: TAP-PR Kitchen Tap #4862 Bruce Rd #3 1st	05-Apr-19 11:30	14.3	6.84	---	0.02
19: TAP-PR Kitchen Tap #4862 Bruce Rd #3 2nd	05-Apr-19 11:30	14.3	6.84	---	0.12
20: TAP-NR Sample Tap Church 1st	05-Apr-19 11:45	14.3	6.88	---	12.5 MAC
21: TAP-NR Sample Tap Church 2nd	05-Apr-19 11:45	14.3	6.88	---	0.47

MAC - Maximum Acceptable Concentration
AO/OG - Aesthetic Objective / Operational Guideline
MDL - SGS Method Detection Limit

Method Descriptions

Parameter	Description	SGS Method Code
Alkalinity	Alkalinity by Titration	ME-CA-[ENV]EWL-LAK-AN-006
Lead	Lead by ICP-MS Drinking Water	ME-CA-[ENV]SPE-LAK-AN-006



Works #: 220008818

SGS Canada Inc.

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Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

LR Report : CA30122-APR19

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety



Works #: 220008818

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2H0
Phone: 705-652-2000 FAX: 705-652-6365

30-April-2019

Mun of Arran Elderslie (Burgoyne Water Association)
Attn : Mark O'Leary

Date Rec. : 25 April 2019
LR Report: CA30327-APR19

1925-10 Bruce Rd, PO Box 70
Chesley, ON
N0G 1L0, Canada

Copy: #1

Phone: 519-363-3039 ext:122
Fax:519-363-9337

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Temperature Upon Receipt °C	Field pH no unit	Lead ug/L
1: Analysis Start Date		---	---	29-Apr-19
2: Analysis Start Time		---	---	09:36
3: Analysis Completed Date		---	---	30-Apr-19
4: Analysis Completed Time		---	---	13:40
5: MAC		---	---	10
7: MDL		---	---	0.01
8: RESAMPLE TAP-PR Outside Tap-Burgoyne Church #1 1st	23-Apr-19 10:45	6.0	6.77	0.46
9: RESAMPLE TAP-PR Outside Tap-Burgoyne Church #2 2nd	23-Apr-19 10:45	6.0	6.77	0.17

MAC - Maximum Acceptable Concentration
MDL - SGS Method Detection Limit

Method Descriptions

Units	Description	SGS Method Code
ug/L	Lead by ICP-MS Drinking Water	ME-CA-[ENV]SPE-LAK-AN-006


Carrie Greenlaw
Project Specialist,
Environment, Health & Safety



Works #: 220008818

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P.O. Box 4300 - 185 Concession St.
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Phone: 705-652-2000 FAX: 705-652-6365

18-October-2019

Mun of Arran Elderslie (Burgoyne Water Association)

Attn : Mark O'Leary

Date Rec. : 10 October 2019
LR Report: CA30185-OCT19

1925-10 Bruce Rd, PO Box 70
Chesley, ON
N0G 1L0, Canada

Copy: #1

Phone: 519-363-3039 ext:122
Fax:519-363-9337

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Temperature upon Delivery @ London Lab °C	Field pH	Lead ug/L
1: Analysis Start Date		---	---	16-Oct-19
2: Analysis Start Time		---	---	09:27
3: Analysis Completed Date		---	---	16-Oct-19
4: Analysis Completed Time		---	---	14:08
5: MAC		---	---	10
7: MDL		---	---	0.01
8: TAP-PR Kitchen 4858 Bruce Rd #3 1st	08-Oct-19 14:15	17.1	6.87	0.33
9: TAP-PR Kitchen 4858 Bruce Rd #3 2nd	08-Oct-19 14:15	17.1	6.87	0.12
10: TAP-PR Kitchen 4830 Bruce Rd #3 1st	08-Oct-19 14:35	17.1	6.88	0.49
11: TAP-PR Kitchen 4830 Bruce Rd #3 2nd	08-Oct-19 14:35	17.1	6.88	0.16
12: TAP-NR Outside 4845 Bruce Rd #3 1st	08-Oct-19 14:40	17.1	6.88	0.16
13: TAP-NR Outside 4845 Bruce Rd #3 2nd	08-Oct-19 14:40	17.1	6.88	0.15

MAC - Maximum Acceptable Concentration
MDL - SGS Method Detection Limit

Method Descriptions

Units	Description	SGS Method Code
ug/L	Lead by ICP-MS Drinking Water	ME-CA-[ENV]SPE-LAK-AN-006


 Carrie Greenlaw
 Project Specialist,
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Works #: 220008818

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18-October-2019

Mun of Arran Elderslie (Burgoyne Water Association)
Attn : Mark O'Leary

Date Rec. : 10 October 2019
LR Report: CA30186-OCT19

1925-10 Bruce Rd, PO Box 70
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N0G 1L0, Canada

Copy: #1

Phone: 519-363-3039 ext:122
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CERTIFICATE OF ANALYSIS Final Report

Sample ID	Sample Date & Time	Temperature upon Delivery @ London Lab °C	Field pH	Alkalinity mg/L as CaCO3	Lead ug/L
1: Analysis Start Date		---	---	11-Oct-19	16-Oct-19
2: Analysis Start Time		---	---	15:30	09:27
3: Analysis Completed Date		---	---	15-Oct-19	16-Oct-19
4: Analysis Completed Time		---	---	16:03	14:08
5: MAC		---	---	---	10
6: AO/OG		---	---	30-500	---
7: MDL		---	---	2	0.01
8: TAP-PR Outside Tap 4834 Bruce Rd 3 1st	08-Oct-19 13:50	17.1	7.16	---	0.57
9: TAP-PR Outside Tap 4834 Bruce Rd 3 2nd	08-Oct-19 13:50	17.1	7.16	---	0.52
10: TAP-PR Kitchen 4851 Bruce Rd 3 1st	08-Oct-19 14:10	17.1	7.21	---	0.24
11: TAP-PR Kitchen 4851 Bruce Rd 3 2nd	08-Oct-19 14:10	17.1	7.21	---	0.12
12: TAP-PR Outside Tap 4835 Bruce Rd 3 1st	08-Oct-19 14:25	17.1	7.27	---	0.19
13: TAP-PR Outside Tap 4835 Bruce Rd 3 2nd	08-Oct-19 14:25	17.1	7.27	---	0.22
14: DW Sample Tap South Blow Off	08-Oct-19 14:45	17.1	7.15	178	0.06

MAC - Maximum Acceptable Concentration
AO/OG - Aesthetic Objective / Operational Guideline
MDL - SGS Method Detection Limit

Method Descriptions

Units	Description	SGS Method Code
mg/L as CaCO3	Alkalinity by Titration	ME-CA-[ENV]EWL-LAK-AN-006
ug/L	Lead by ICP-MS Drinking Water	ME-CA-[ENV]SPE-LAK-AN-006



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LR Report : CA30186-OCT19

Carrie Greenlaw
Carrie Greenlaw
Project Specialist,
Environment, Health & Safety

APPENDIX B

**REPORT ENTITLED “REDUCTION OF IRON AND HYDROGEN SULFIDE
FROM A WELL SYSTEM USING OXIDATION AND FILTRATION”
– MUNICIPALITY OF ARRAN-ELDERSLIE,
BY WALKERTON CLEAN WATER CENTRE**



**Municipality of Arran-Elderslie Draft Final Report:
Reduction of iron and hydrogen sulfide from a well system using
oxidation and filtration**

Walkerton Clean Water Centre

Research & Technology Institute

August 22nd, 2018

Disclaimer

The pilot testing project report is presented solely for information purposes and is not intended to provide specific advice or recommendations in any circumstances. This pilot testing project report may include information from different sources and such information has not been independently confirmed for correctness or completeness. The information provided does not imply on the part of the Government of Ontario, the Walkerton Clean Water Centre (Centre) or its employees, any endorsement or guarantee of any of the information. The Government of Ontario, the Centre and its employees, do not assume and are not responsible for any liability whatsoever for any information, interpretation, comments or opinions expressed in the pilot testing project report.

Abstract

The well water supply is a year round residential system that serves 21 residences. The purpose of this study was to reduce iron and hydrogen sulfide below the aesthetic objectives using economical oxidation and filtration technologies. The water quality was monitored for iron, sulfide, sulfate, disinfection by-product formation, ammonia, turbidity, pH, chlorine residual, UV transmittance, and manganese to assess the efficacy of the proposed treatment.

The concentration of iron was reduced from ~1.5 mg/L to below Ontario's aesthetic objective (AO) with a series of surface pleated cartridge filters. A 1 µm filter was necessary to achieve the desired reduction of iron, while the 3-5 µm monomedia sand filter was not able to reduce the concentration of iron below the AO. The series of 50-5 µm and 25-1 µm dual gradient nominal depth filters followed by a 0.35 µm surface pleated nominal filter was capable of reducing the concentration of iron near or below the detection limit for the duration of the treatment.

The sulfide odour was detected at ~0.08 mg/L in the untreated well water. Passive aeration and ventilation was not effective at reducing the odour, while oxidation using chlorination and ventilation qualitatively reduced the sulfide odour in the finished water. This was not confirmed quantitatively due to underestimates in detection from volatility.

Two doses of sodium hypochlorite were tested due to the presence of ammonia. An average of ~4 mg/L represented the chloramination dose and an average of ~7 mg/L represented the free chlorination dose. Haloacetic acids (HAAs) were not detected while trihalomethanes (THMs) and N-nitrosodimethylamine (NDMA) were detected, but below the maximum acceptable concentration in Ontario for both doses used.

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1. Introduction

The community of Burgoyne is located on the border of the Municipality of Arran-Elderslie and the Town of Saugeen Shores. The Burgoyne water supply is a year round residential system that serves 21 residences each with their own private septic. The system consists of one 280 foot drilled well that has not been confirmed as true groundwater by a hydrogeological study. Although samples have not indicated any microbiological contamination, the well must be assumed to be groundwater under the direct influence of surface water (GUDI) until proven otherwise. The concentration of iron found in the well was ~ 1.5 mg/L, above the aesthetic objective (AO) of 0.3 mg/L (Ontario, 2006), in addition to an offensive sulfide (hydrogen sulfide) odour. No analytical data was previously collected on the level of sulfate or sulfide concentrations so it was investigated in this pilot. It was reported by the Burgoyne Water Association that the turbidity was < 0.1 NTU immediately after sampling from the well; however, if the sample was allowed to sit or was taken near the end of the distribution system, the turbidity was recorded ~13 NTU.

The Municipality of Arran-Elderslie is investigating the potential of implementing a treatment system for the community of Burgoyne. They expressed interest to conduct a pilot experiment to collect information that may assist in determining the most practical and efficient way to remove iron and the sulfide gas odour from the source. The proposed treatments include a combination of aeration and/or chlorine (sodium hypochlorite) oxidation followed by various filtration options.

2. Rationale

Turbidity is an important parameter that represents the clarity of water and measures the suspended particulate and colloidal matter of a water sample, expressed as nephelometric turbidity units (NTU). An instrument that measures this parameter sends a beam of incandescent light through the water sample and measures the amount of light scattered at 90° from the light source. Turbidity readings with a low NTU have a low amount of scattered light, meaning they have fewer suspended particles and are clearer. The Province of Ontario's AO for turbidity in the distribution system is 5 NTU (Ontario,

2006). AOs are established for parameters that may impair the taste, odour and/or colour but will not produce adverse health effects.

Iron was measured at ~1.5 mg/L which is above the AO of 0.3 mg/L (Ontario, 2006). Iron is common in groundwater due to the natural mineral deposits found in aquifers. The iron ion usually exists in a soluble state as Fe^{2+} in aquifers due to the low level of oxygen deep in the ground (Dvorak et al, 2007). Iron that is dissolved in water cannot be seen, does not produce any colour, and won't scatter light when measuring turbidity. As iron approaches the surface it readily combines and precipitates with oxygen and sulfur compounds to form oxides, hydroxides, carbonates, and sulfides (WHO, 2008). In concentrations above the AO, iron visually produces a brown or rust colour (Dvorak et al, 2007), and will scatter light on a turbidity meter. This explains why the water is initially low in turbidity and increases with time in the distribution system. It is common for elevated levels of iron to impart colour and unpleasant tastes in the water, stain fixtures and laundered materials, and precipitate in the distribution system which may promote the growth of iron bacteria in pipes. Based on the level of iron (<10 mg/L) and pH (>7.5), weak oxidants such as air and chlorine are effective at precipitating iron prior to filtration with the appropriate contact time (Dvorak et al, 2007).

Sulfur was reported at the well head as hydrogen sulfide gas, as the gas is volatile and produces offensive odours. Sulfide gas can be present naturally in the ground, but can also be a metabolic byproduct of sulfur reducing bacteria. Sulfates are comprised of sulfur and oxygen and occur naturally in soil and rock formations that contain groundwater (WRC 2014). Sulfur reducing bacteria use sulfates as an energy source and are the main producers of hydrogen sulfide gas, a byproduct of its metabolism and is the cause of the offensive rotten egg or sulfur smell (WRC, 2014). These bacteria are found living in low oxygen environments such as deep wells and often thrive in hot water plumbing and heaters (WRC, 2014). Samples of sulfate and sulfide from the well revealed the average sulfate concentration was 1300 mg/L which is above the AO of 500 mg/L; and sulfide was detected in one sample at 0.08 mg/L which is above the AO of 0.05 mg/L. Sulfide results were mostly non-detected, but was likely underestimated due to the volatility of sulfide gas.

There are a few options to address elevated concentrations of iron and sulfur. Sulfide can be treated using the same aeration and chlorination approach as used for iron (WSC & EPA, 2007). Sulfate, which in high concentrations can impart a bitter or astringent taste and have a laxative effect on some individuals, cannot be addressed using oxidation and filtration (Ontario, 2006; MDH, 2018). It is likely that regular consumers develop a tolerance to the laxative effect, but visitors, new residents or people with sensitivities may experience some symptoms. Although the concentration of sulfates cannot be treated using the identified approach, sulfates can be addressed by controlling sulfur reducing bacteria with the maintenance of a chlorine residual to prevent the metabolism and conversion of sulfate to hydrogen sulfide in the distribution system (WSC & EPA, 2007). Additionally, high levels of sulfate may also corrode metallic plumbing such as copper; therefore, plastic polyvinylchloride (PVC) or cross-linked polyethylene (PEX) pipe is often used because it is more resistant to corrosion. Methods that can be used to remove sulfate from water include reverse osmosis, distillation, and ion exchange; however, these methods are not economical in most cases (MDH, 2018) and outside the scope of this project

3. Objectives

The overall purpose of this study is to reduce iron below the aesthetic objective and reduce the unpleasant sulfide gas odour. Specific objectives to be investigated are listed as follows:

3.1 Bench Scale

1. Conduct water quality analysis of untreated well water
2. a) Determine dose(s) and contact time(s) for effective chlorine oxidation of iron
b) Monitor pH variation for operational guideline
3. Determine appropriate chlorine dose(s) to establish a typical chlorine residual
4. Sample for potential disinfection byproduct formation (specifically THMs, HAAs, and NDMA)

3.2 Pilot Scale

1. a) Reduce iron below the AO using cartridge and media filters
b) Provide filtered particle size exclusion analysis
2. Monitor filter pressure performance for operation and maintenance
3. Reduce sulfide gas odour in finished water
4. Maintain a free chlorine or chloramine residual after filtration
5. Monitor water quality parameters:
 - a) UV transmittance
 - b) pH
 - c) Turbidity

Note- Items outside the scope of this project are listed as follows:

- Treatment technologies necessary for the proper disinfection of water.
- The calculation of the CT (concentration x time)
- Chlorine residuals of the actual distribution system
 - Values will be underestimated due to distribution material, detention time, maintenance and other pre-existing conditions in comparison to that of the pilot system.
- Treatment necessary for the removal of sulfate
- This pilot project does not address primary disinfection. If the community is interested in chloramination it is important to note that primary disinfection must be met prior to establishing a combined chlorine residual.

4. Methods

4.1 Bench Scale

The purpose of objective 1 was to better understand the source water and identify parameters that could affect the finished quality and the proposed treatment (Table 1). The analysis was completed onsite, or offsite at the WCWC lab or external lab dependent on the parameter being analyzed. Sulfide can be measured with Method 8131 using a spectrophotometer in the range of 0.005 to 0.80 mg/L. Sulfates can be measured with Method 8051 between 2 to 70 mg/L SO_4^{2-} and both methods that measure forms of sulfur have hazardous reagents which must be collected from reacted samples and disposed of according to local, state and federal regulations (APHA, 2012). Sulfate and sulfide samples were shipped to an external lab to limit the risk of handling and storing hazardous chemicals on site due to facility limitations. Ammonia can be measured with Method 8155 using a benchtop spectrophotometer or a portable handheld 'key' instrument; however, iron at any level and sulfate at levels above the AO are interferences that could impact the results. Ammonia samples were shipped to an external lab and Method 4500-NH₃ G was used to compare the results to determine if interferences impacted the results.

The experiment for objective 2 examined the iron composition (dissolved and precipitated) in the well immediately and over time as it would appear in the distribution system with no chlorination; followed by the addition of chlorine doses of 1, 2, 3 and 4 mg/L. The sample containers were amber glass bottles that were treated to be chlorine demand free to eliminate external sources of demand. Five samples were prepared with their corresponding chlorine doses. Samples were filtered with a 0.45 µm (micron) polyethersulfone (PES) membrane filter prior to iron analysis. Method 8008 measured total iron, including both dissolved and precipitated iron, using a spectrophotometer; therefore, filtration with a 0.45 µm filter was used to differentiate between dissolved and precipitated iron. It is widely accepted that iron particles smaller than 0.45 µm are considered dissolved (APHA et al, 2012). This information was used to gauge the most appropriate chlorine dose and contact time for the pilot. Samples that met the iron

minimum detection limit (MDL) at the chlorine dose and contact time were sampled once more to verify the analyzed MDL value. The pH was analyzed once per chlorine dose to ensure it was within the operational guideline of 6.5-8.5 (Ontario, 2006).

The experiment that addressed objective 3 showed how the well water reacted with chlorine immediately and over time for the respective chlorine dosages. The doses were chosen based on the level of ammonia found in the raw water and the amount of measured free and total chlorine residual needed to demonstrate a breakpoint curve (Figure 6 and 7). Chlorine residuals were measured immediately after dosing, after 30 minutes, and after 24 hours of contact time (Table 5).

Objective 4 was completed to gauge potential disinfection by-product formation of N-nitrosodimethylamine (NDMA), trihalomethanes (THMs) and haloacetic acids (HAAs) using a simulated distribution system method. A typical chloramination dose (~ 4.0 mg/L), and chlorination dose (~ 8 mg/L) were selected for testing, relative to the source water quality at the time (Table 7). This test confirmed if the concentrations of disinfection by-products formed meet the Ontario Regulation 169/03, Ontario Drinking Water Quality Standards. Samples were taken in duplicate for quality assurance and control.

Table 1. Bench Scale: Sampling and Laboratory Analysis

Objective	No. of Samples	No. of Parameters	Sampling Conditions	In-House Parameters	Out-Sourced Parameters
1	1	41	Untreated	<ul style="list-style-type: none"> • Turbidity (nephelometric) • Iron (Method 8008) • Filtered iron (Method 8008) • Alkalinity (Method 8203) • pH (Method 8156) • UV transmittance (Method 10054) • Dissolved organic carbon (persulphate-UV oxidation) • Manganese (Method 8149) • Ammonia (Method 8155) 	<ul style="list-style-type: none"> • Manganese (Method 200.8 ICP-MS) • Sulfate (Method 300.1 Ion chromatography) • Sulfide (Method SM 4500-S2 segmented flow colourimetry) • Ammonia (Method 4500-NH3 G)
2	5	35	Chlorinated	<ul style="list-style-type: none"> • Filtered iron (Method 8008) • pH (Method 8156) 	
3	8	36	Chlorinated	<ul style="list-style-type: none"> • Free chlorine (Method 8201) • Total chlorine (Method 8201) 	
4	4	28	Chlorinated	<ul style="list-style-type: none"> • Free chlorine (Method 8201) • Total chlorine (Method 8201) 	<ul style="list-style-type: none"> • THMs (Method SW-846, SM 8260C) • HAAs (Method EPA 552.3) • NDMA (Method SM 6410B)

4.2 Pilot Scale

From the utility line, a backflow prevention device was installed to protect the residents from experiencing water quality changes during experimental testing (Figure 1). Phase 1 included a passive aeration venturi and hydro-pneumatic tank to oxidize and purge sulfide. Following the tank, a peristaltic pump dosed chlorine with an injector prior to a static mixer. A sample port located immediately following chlorination measured iron and chlorine residuals to either confirm bench scale results or allow for adjustments in the process. A chlorination dose of ~6.5 -7 mg/L was used to run the system with a free chlorination residual of ~1.2-1.5 mg/L following the filters. Sample ports and pressure gauges followed each filter to monitor performance over time. The two proposed methods for the removal of precipitated iron were monomedia sand filtration, housed in a pressure vessel with a nominal rating of 3-5 μm and as series of surface pleated cartridge filtration with nominal ratings of 50, 20, 10, 5, and 1 μm .

Phase 2 omitted aeration from the process and chlorination was added upstream of the hydro-pneumatic tank to increase the chlorine contact time (Figure 2). This was done to determine if the sulfide odour could be reduced and if the size of the iron particles increased with time under the same filtration conditions.

Phase 3 experimented with a different configuration of cartridge filters and removed the monomedia sand filter due to the results from the first two phases (Figure 3). A configuration of a 50-5 μm and 25-1 μm dual gradient depth nominal filters and a 0.35 μm surface pleated nominal filter were used in series for iron removal with a chlorine dose of ~4 mg/L to achieve a combined chlorine residual.

Online analyzers were connected to continuously monitor the quality of water throughout the pilot and measured turbidity, pH, UV transmittance and free chlorine residuals. Turbidity is an important parameter to monitor as it can negatively affect UV and chlorine disinfection. The pH was monitored to ensure the operational guideline was maintained. UV transmittance was used to gauge the effectiveness of UV disinfection should it be implemented and chlorine residual was monitored to confirm the estimated dose applied and collect data relating to secondary disinfection.

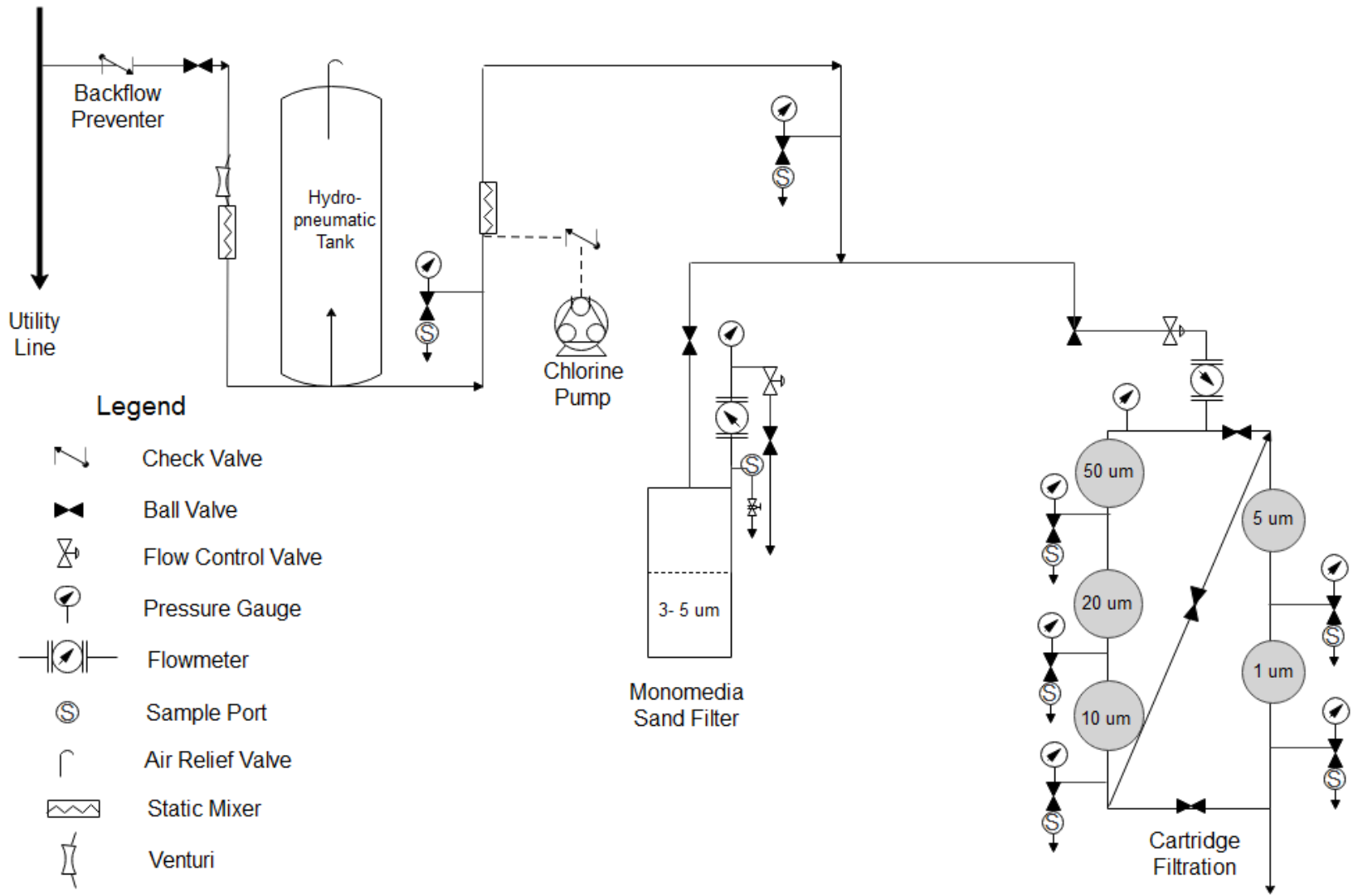


Figure 1. Pilot: Phase 1 Process Flow

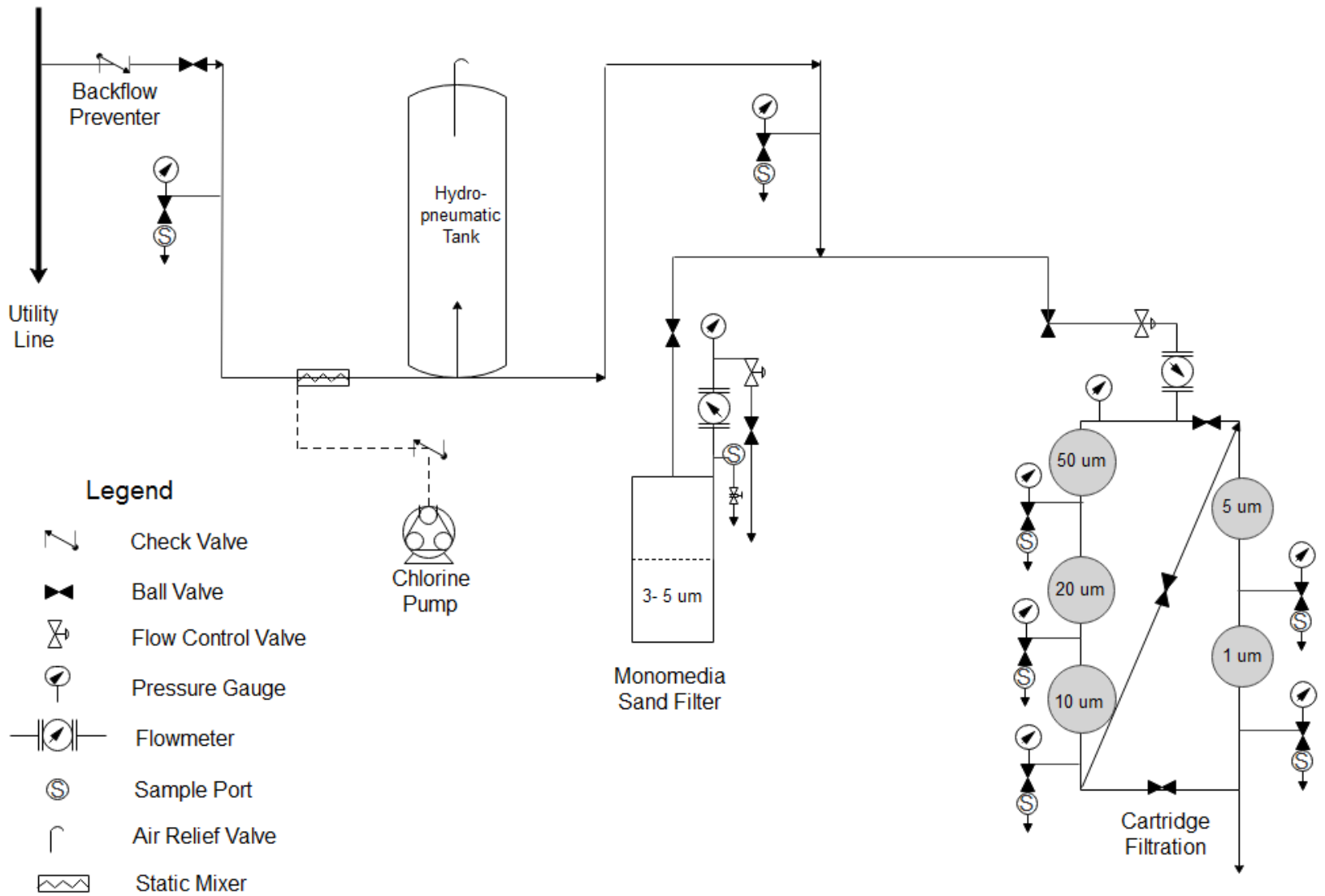


Figure 2. Pilot: Phase 2 Process Flow

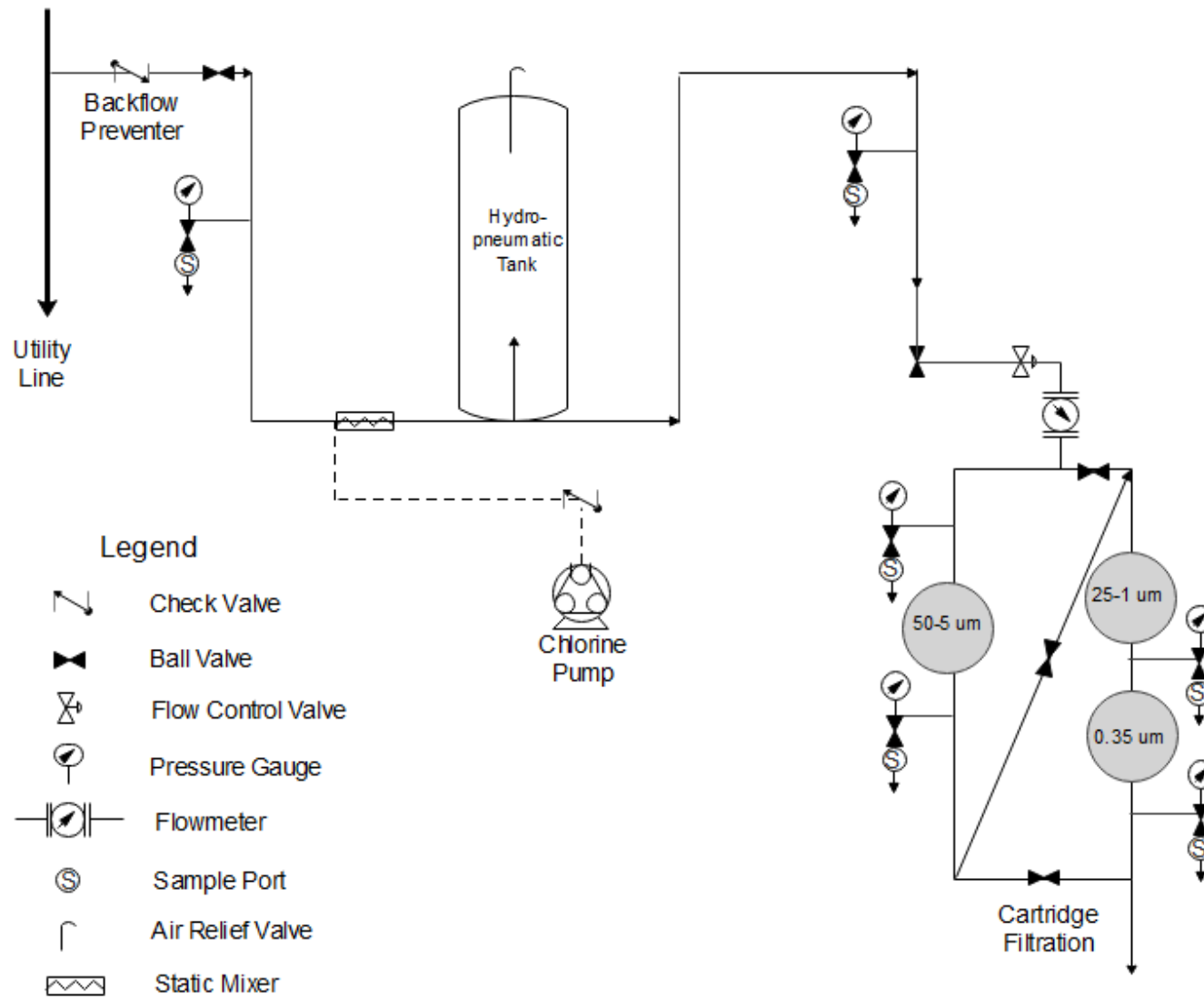
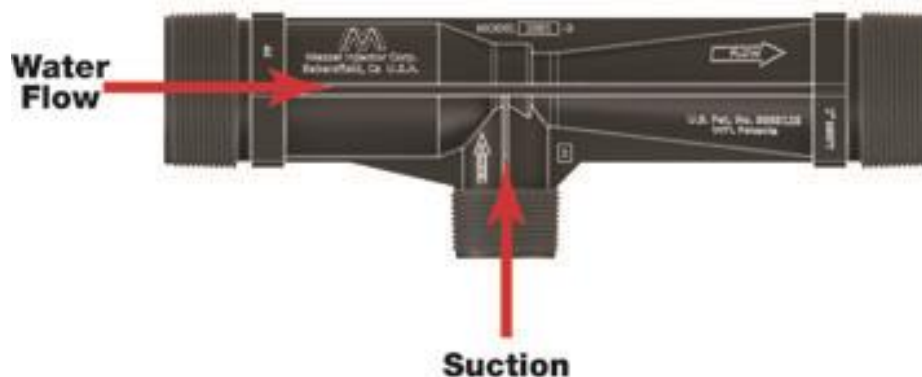


Figure 3. Pilot: Phase 3 Process Flow

4.2.1 Oxidation

Passive aeration is a term used for an air injection system that does not require energy, such as a blower or compressor. Instead, water flows in line where the diameter of the pipe narrows abruptly, increasing the velocity, known as a venturi (Figure 4). The increase in velocity creates a vacuum adjacent to a check valve that allows air to be drawn into the pipe but does not let air or water out. The amount of air being drawn into the pipe varies and is controlled by the water flow, pressure, the pipe diameter, and a bypass valve. The system only injects air when water is flowing so there is no need for automation and controls. The system passively injects air because there is no additional energy to the amount of air being applied. Flow meters are available to quantify the air being drawn into the system and specifications are available for sizing units during design. A bypass valve can be used to control the water flow through or around the venturi, thereby allowing the adjustment of air flow through the suction.

Figure 4. Pilot: Phase 1 Passive (Venturi) Aeration



(Source: http://mazzei.net/venturi_injectors/)

The operation and maintenance of this technology is simple, inexpensive, and can be effective; however, the flexibility of the aeration dose is limited. Since aeration is a weak oxidant, conditions such as temperature, contact time, and pH are important for the successful use of aeration as an oxidant. For small applications where chlorine will also be applied as an oxidant, passive aeration is an option. Passive aeration occurs in a closed and pressurized application followed by a hydro-pneumatic tank that controls the amount of air in the system using a float and air relief valve.

Chlorine is a commonly used oxidant for iron precipitation and is favourable due to the fact that this system will likely be dosing chlorine for secondary disinfection. This simplifies the design, operation and maintenance of the system with relatively low capital, operation and maintenance expenses. Chlorine is a stronger oxidant than air and is able to precipitate iron and sulfide with less contact time. In certain cases, chlorine will oxidize iron with very little contact time needed prior to filtration, which is dependent on iron concentration, chlorine dosage, pH, and temperature. Chlorination is appropriate for both small and large oxidation applications and will reduce the overall footprint when comparing it to aeration alone due to the reduced contact time. Chlorine can also be used to prevent the growth of sulfur reducing bacteria (WSC & EPA, 2007). There is flexibility with the dosage and concentration of chlorine residual in the water provided the system meets its CT disinfection requirements.

4.2.2 Filtration

There are two types of preferred filtration techniques that can be used for particulate removal that produce similar results but vary in capital, operational, and maintenance expenses. Generally, media based filtration will have more capital but less operational and maintenance costs compared to cartridge filtration.

The most common media options for particulate removal are either a monomedia comprised of sand or anthracite, or a dual media usually comprised of anthracite and sand or granular activated carbon and sand. The media is housed in a pressure vessel with a strainer system. In residential and commercial applications, a control valve is mounted at the head to provide a control interface for the operator. Some interface functions include the ability to initiate backwashes using capacity, runtime, or a manual setting, and some can monitor the stages of the backwash cycle. The Centre has previously used a monomedia sand filter with a nominal rating of 3-5 μm for precipitated iron particulate removal and found it was able to reduce the concentration of iron to near or below the MDL for a water source. Media based filtration is a reusable technology because of the backwash feature and is commonly adopted in residential to municipal scale potable water systems. A capital and maintenance consideration is the

management of backwash waste that must be collected and disposed of in accordance with local and provincial regulations.

Cartridge filtration is applicable for residential, commercial and small municipal systems and has a variety of options when considering particulate removal. Cartridges are made from cellulose or synthetic based materials and are either surface pleated (filter at the surface) or depth (filter throughout the depth of the filter's radius). Many filters are rated nominal for filtration efficiency for a specified pore size (example: 99.7% removal of 5 μm), but some are absolute for a specified size and will not allow any particles that size or larger to pass (example: 100% removal of $\geq 1 \mu\text{m}$). There are many pore sizes available for both surface and depth filters that include but are not limited to 100, 50, 25, 20, 10, 5, 1, 0.35 μm . Some depth filters are dual gradient and include two filtration ratings across the gradient of the depth (example: 25- 1 μm), which may further reduce the system's design footprint.

The cartridge filtration system in phases 1 and 2 housed five surface pleated filters in series with nominal ratings of decreasing micron sizes (Figure 1 & 2.). The largest was 50 μm followed by 20 μm , 10 μm , 5 μm and 1 μm . The nominal surface filters used were 10" in length by 4.5" in diameter, made from thin cellulose and pleated to increase surface area. Water entered the filter housing and passed from the outside to the inside of the filter where particles of the specified size range were collected at the surface based on efficiency.

In phase 3, the filtration system was comprised of three cartridge filters. Two were dual gradient nominal depth with a 50-5 μm and 25-1 μm rating followed by one 0.35 μm surface pleated nominal filter (Figure 3). The dual gradient depth filters used were also 10" in length by 4.5" in diameter and made with a thick cellulose layer. Filtration also occurred from the outside in, and is based on particulate size efficiency similar to surface pleated; however, the size of the particulate rating decreased as the water traveled through the depth of the filter.

5. Results and Discussion

5.1 Bench Scale

5.1.1 Objective 1: Untreated Well Water Quality

The results for the untreated well water sampling and analysis can be found in Table 2. Noted parameters were iron, sulfide, sulfate, and ammonia. The composition of iron was mostly dissolved when analyzed immediately, in agreement with the turbidity and UV transmittance immediately after sampling. The offensive odour caused by sulfide was noticeable in the untreated water and was measured at 0.08 mg/L. Sulfate, which is a source of food for sulfur reducing bacteria and the probable cause for the production of sulfide gas, was detected at 1,300 mg/L.

The ammonia concentration was recorded at an average of 0.43 mg/L and was expected to influence chlorination (Figure 6 and 7). Two ammonia tests were completed internally with an onsite portable instrument (HACH SL1000) and at the WCWC lab with a colourimetric method that produced similar results. The two methods are affected by iron and sulfate interferences; therefore, ammonia samples were sent to an external lab for confirmation which also produced similar results. The range of ammonia was recorded from 0.35 mg/L up to 0.58 mg/L.

Manganese was originally recorded above the AO using Method 8149; however, the sample contained levels of hardness that could interfere with the result. Grab samples were sent to an external lab and confirmed an average concentration of approximately 15.0 µg/L which is below the AO of 50 µg/L. This suggested that manganese should not be targeted for removal during this study.

Table 2. Bench: Objective 1

Untreated Well Water Quality			
Parameter	Concentration	AO/OG	MDL
Turbidity	0.23 NTU	5	0.01
(Total) Iron	1.36 mg/L	0.3 mg/L	0.02 mg/L
(Dissolved) Iron	1.36 mg/L		
Alkalinity	181 mg/L	30- 500 mg/L	-
Ammonia	0.43 mg/L	n/a	0.01 mg/L
Dissolved Organic Carbon	0.668 mg/L	5 mg/L	0.03 µg/L
pH	6.69	6.5-8.5	-
UV transmittance	96.1 %	75%	-
Sulfate	1300 mg/L	500 mg/L	0.04 mg/L
Sulfide	<0.006 mg/L	0.05 mg/L	0.006 mg/L
Manganese	~15.1 µg/L	50 µg/L	0.01 µg/L

5.1.2 Objective 2: Iron Precipitation and Filtration

Iron was oxidized and filtered out to below the aesthetic objective with a dose of 2 mg/L of chlorine, and reached the method's minimum detection limit with a dose of 3 mg/L (Table 3). The reaction appeared to be instantaneous and similar results were obtained over the 5 minutes of contact time for each corresponding dose as the slope of each plotted line is fairly horizontal (Figure 5). The pH remained within the operational guideline for all chlorine dose treatments.

Filtered Iron Concentrations (mg/L): Chlorine Dose and Contact Time Matrix

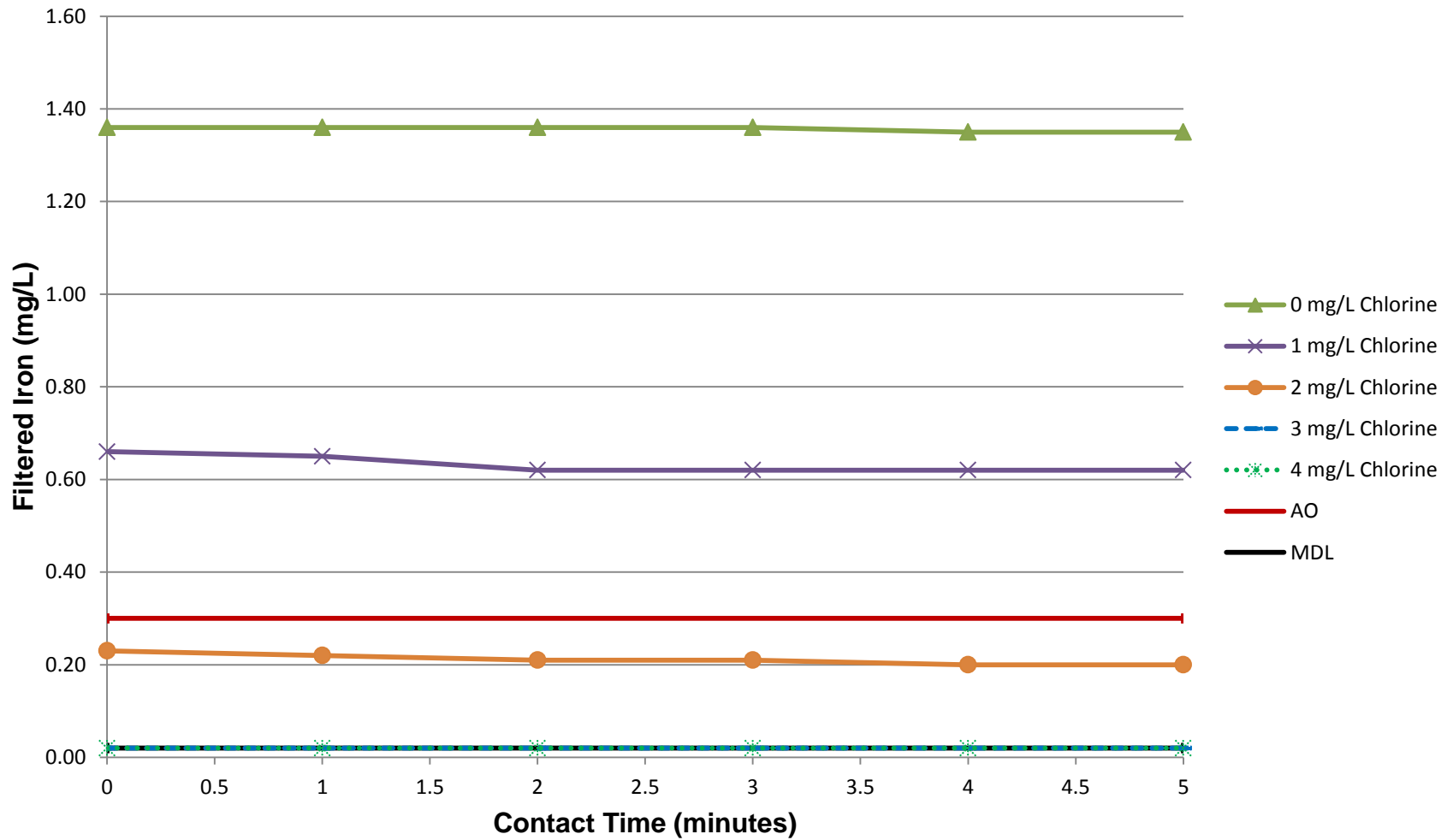


Figure 5. Bench: Objective 2a

5.1.3 Objective 3: Chlorine Dose, Residual and Contact Time

The presence of ammonia at an average of 0.43 mg/L appears to affect the dose of chlorine based on the results from Tables 5 and 6, illustrated in Figures 6 and 7. A chlorine breakpoint curve was observed as it follows the typical relationship when graphed.

As the graph suggests, ammonia reacts with the chlorine dose to form chloramines between doses of ~1-4 mg/L and ~1-5 mg/L as indicated in Figures 6 and 7 respectively. As the chlorine dose increases beyond the formation stage, the combined residual decreases due to the destruction of chloramines. Breakpoint was achieved at doses of ~6 mg/L and ~6.8 mg/L as indicated in Figures 6 and 7 respectively, where the combined residual and free residual intersect and begin to increase in difference. This graph can be used to understand the demands present in the source water and can assist in planning a disinfection strategy for the system. .

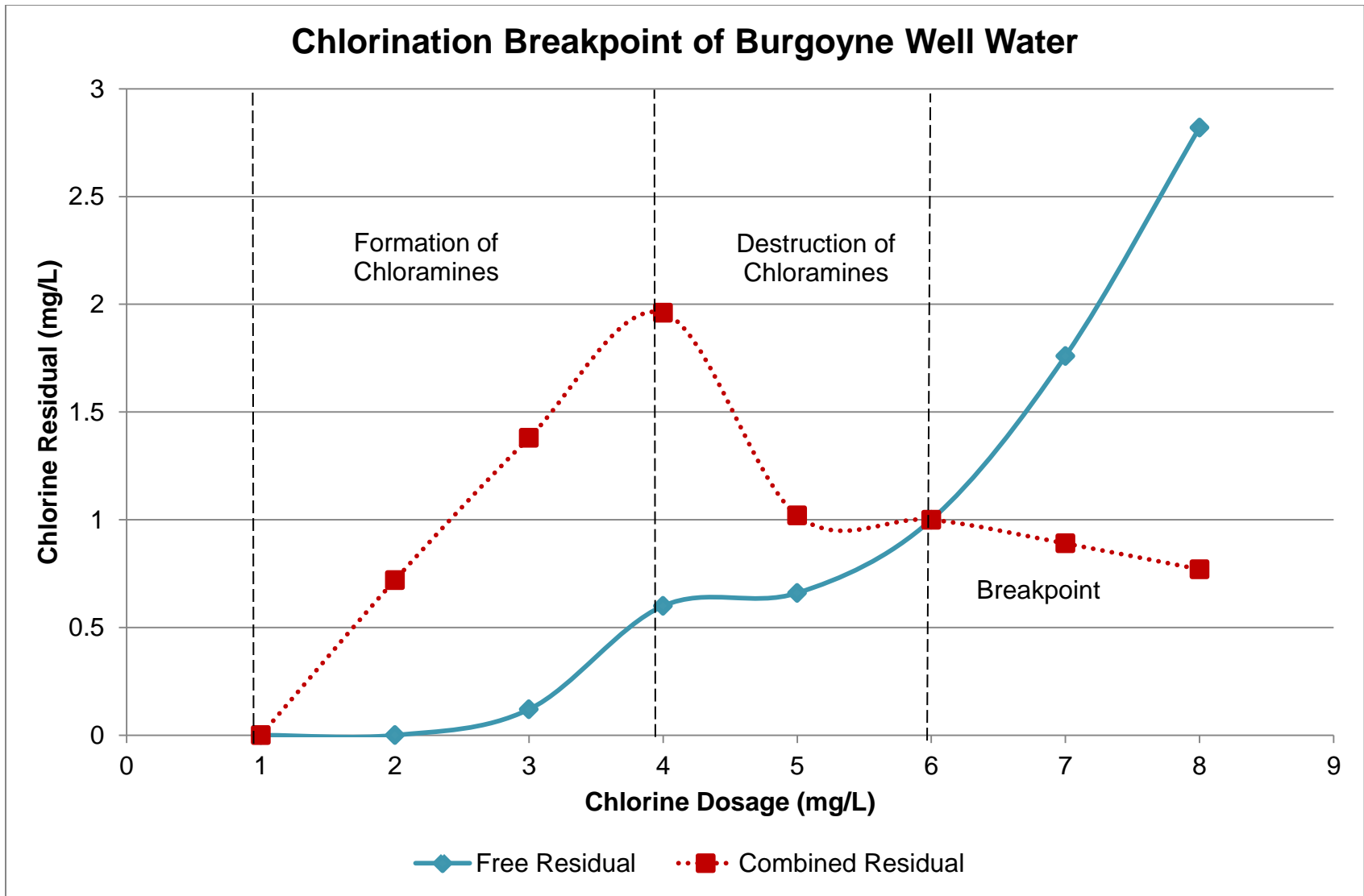


Figure 6. Bench: Objective 3 (Rep. 1)

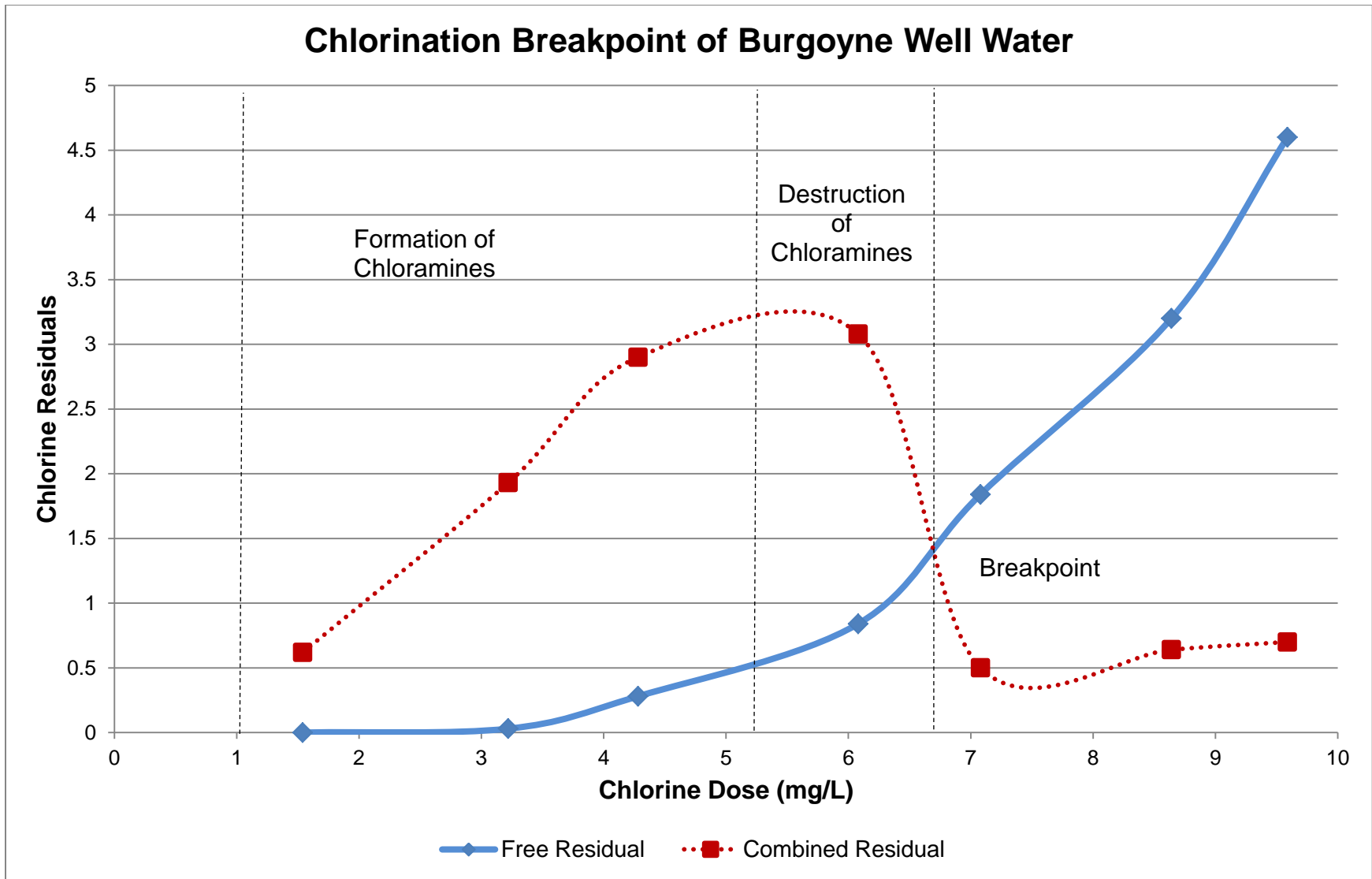


Figure 7. Bench: Objective 3 (Rep 2)

5.1.4 Objective 4: Disinfection By-Product Formation

Disinfection by-product formation potential was assessed by subjecting the finished water to a simulated distribution system which estimated distribution system's storage time. Haloacetic acids were not detected in any of the samples for both chlorine doses. Trihalomethanes were detected in all of the samples and were approximately three times higher in samples subjected to the higher dose of chlorine; however, the highest values obtained were 18 µg/L and 19 µg/L, and are below 20% of the maximum acceptable concentration (MAC). N-nitrosodimethylamine was detected in all of the samples, but was also reported at 20% of the MAC. If the water quality and system conditions were to remain similar year-round, both doses of chlorine should not produce a level of disinfection by-products that would cause concern for the community.

Table 3. Bench: Objective 4

Disinfection By-Product Formation												
Chlorine Dose	THM (µg/L)				HAA (µg/L)				NDMA (µg/L)			
	Rep 1	Rep 2	MAC	MDL	Rep 1	Rep 2	MAC	MDL	Rep 1	Rep 2	MAC	MDL
4	6.0	5.8	100 ²	0.37	<5.3	<5.3	80 ^{1, 2}	5.3	0.0018	0.0014	0.009	0.0008
8	18	19			<5.3	<5.3			0.0011	0.0014		

¹ On January 1, 2020, O. Reg. 169/03, Schedule 2 is to be amended by adding a MAC for HAA
² Expressed as a running annual average of quarterly results

5.2 Pilot Scale

5.2.1 Phase 1

The results of phase 1 showed that iron was still detected after every filter and that the 1 micron filter was necessary to reduce the concentration below the AO (Figure 8). The filters were monitored for pressure differential and volume treated which can be used to estimate the life expectancy based on the level of desired performance (Figure 9).

The free chlorine residual target was ~1.2 –1.5 mg/L after filtration and was monitored continuously with free chlorine probes (Figure 15). To achieve this concentration, the target chlorination dose added was approximately ~ 7.0-7.5 mg/L. This value was estimated using a combination of the breakpoint curve (Figure 7) and the point of entry (POE)/unfiltered chlorine residuals (Figure 16) as the sodium hypochlorite stock was diluted and found to vary depending on mixing.

The hydrogen sulfide odour was still noticeable during phase 1 and sulfide was detected at 0.080 mg/L, 0.081 mg/L and 0.081 mg/L for the raw and monosand media and cartridge filter trains respectively, all above the AO of 0.05 mg/L (Table 8).

The pH remained within the OG and was consistent during phase 1 with minimal variation (Figure 18). The turbidity values followed the expected trend as the cartridge filter effluent yielded the lowest turbidity followed by media filtration, raw/untreated, and the highest being post-chlorination oxidation (unfiltered) due to the precipitated iron (Figure 19). UV transmittance followed a similar trend with cartridge filtration, monomedia filtration and raw/untreated being lower than the chlorinated, unfiltered water due to the presence of precipitated iron (Figure 17). Variation in the UV transmittance data for the media filtration train was likely due to the production of air bubbles during aeration that interfered with the analyzer. It also appeared that the filters had a high chlorine demand initially that decreased over time (Figure 15 & 16).

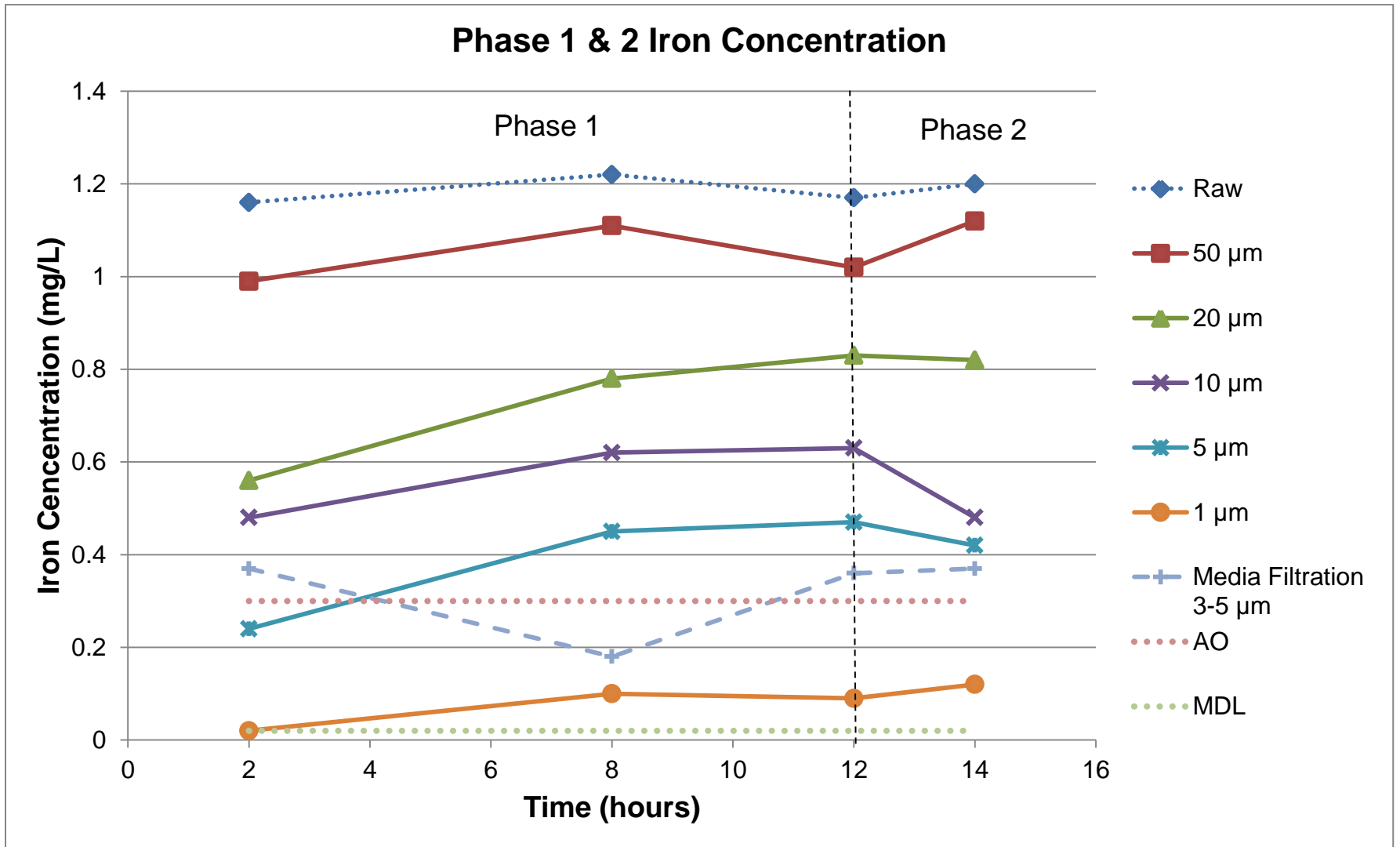


Figure 8. Pilot: Phase 1 & 2 Objective 1a

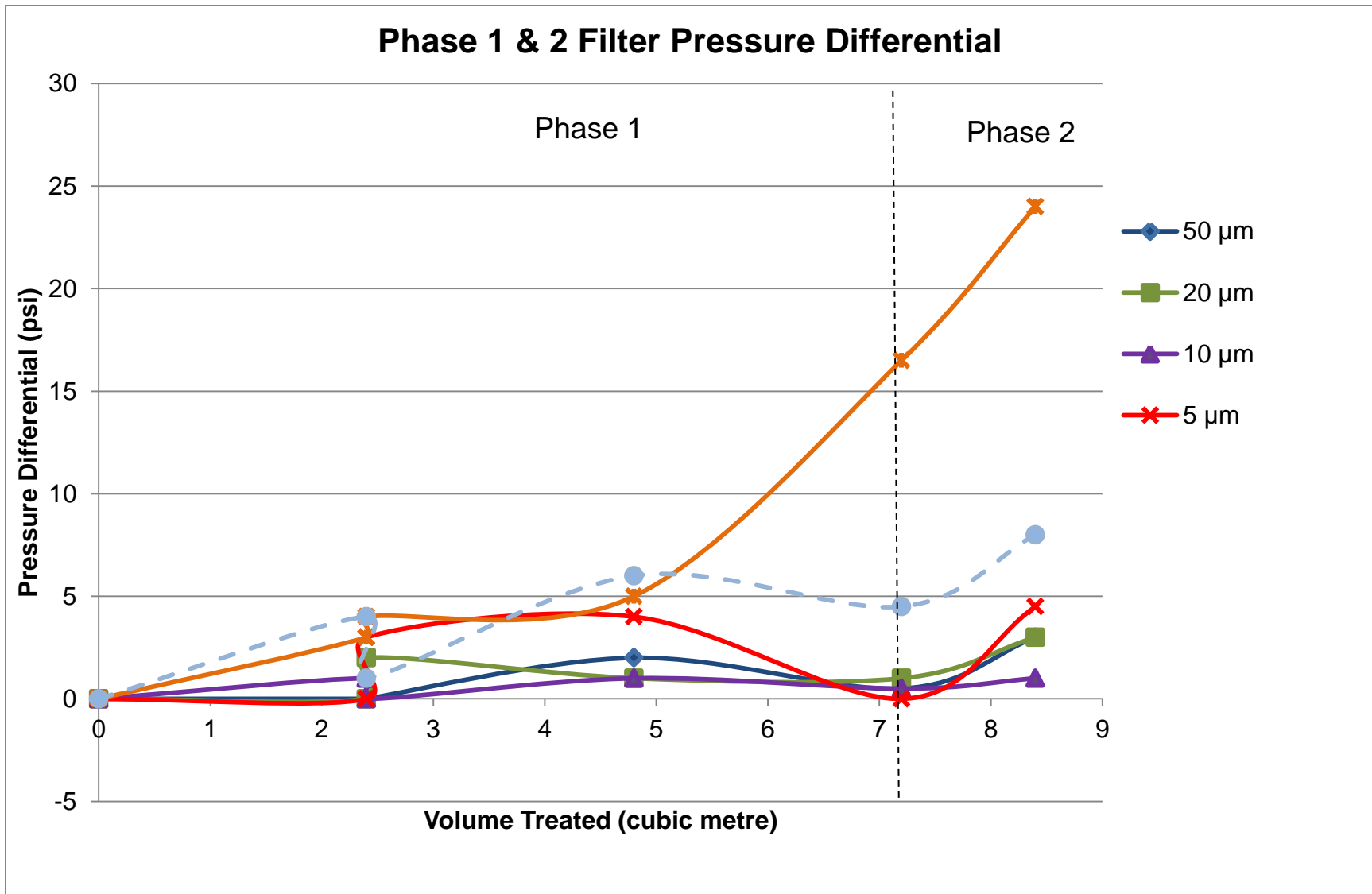


Figure 9. Pilot: Phase 1 & 2 Objective 2

5.2.2 Phase 2

The aeration system was removed from the pilot in phase 2 and chlorine injection was moved upstream of the hydro-pneumatic tank (contact and ventilation) to oxidize sulfide and increase the chlorine contact time prior to filtration. There was no noticeable change in the iron removal of the media or cartridge filters after increasing the contact time (Figure 8). The filters were monitored for pressure differential and volume treated which can be used to estimate the life expectancy based on the level of desired performance (Figure 9). The sulfide odour seemed to be reduced as it was no longer observed by staff members on-site. The dose of chlorine was reduced to maintain a chloramination dose of ~3.5-4.5 mg/L based on the results from the chlorination breakpoint curve (Figure 7). It appeared that the chlorine demand of the filters was reduced when operating with a combined chlorine residual (Figure 13).

The removal of aeration was the probable cause of the stabilization of UV transmittance readings due to air bubble interference presented during media filtration (Figure 15). The pH remained within the OG during phase 2 with minimal variation from phase 1 (Figure 16). The turbidity followed the expected trend as the cartridge filter effluent yielded the lowest turbidity followed by media filtration, raw/untreated, and the highest turbidity being chlorinated-unfiltered due to the precipitated iron (Figure 17).

5.2.3 Phase 3

The 50-5 µm and 25-1 µm dual gradient nominal depth cartridge filters followed by the 0.35 µm surface pleated nominal cartridge filter removed iron below the MDL (Figure 10) during the life of the filters. Additionally, they were able to treat over twice the volume observed in phases 1 and 2 before experiencing a similar loss in pressure performance (Figure 11). The average particle size loading for each filter (Figure 18) can be used to estimate the life expectancy if larger filters are used.

The sulfide odour was suspected to be reduced through staff observation and was not detected in the analyzed samples; it is possible the reported values were underestimated since it was also not detected in the untreated water (Table 11).

The chlorine dose used to maintain a typical combined chlorine residual did not produce disinfection by-products above the MACs (Figure 19).

UV transmittance (Figure 20), pH (Figure 21), and turbidity (Figure 22) were similar to that recorded during the first two phases, further suggesting that precipitated iron is the primary influence in readings of elevated turbidity and reductions in UV transmittance.

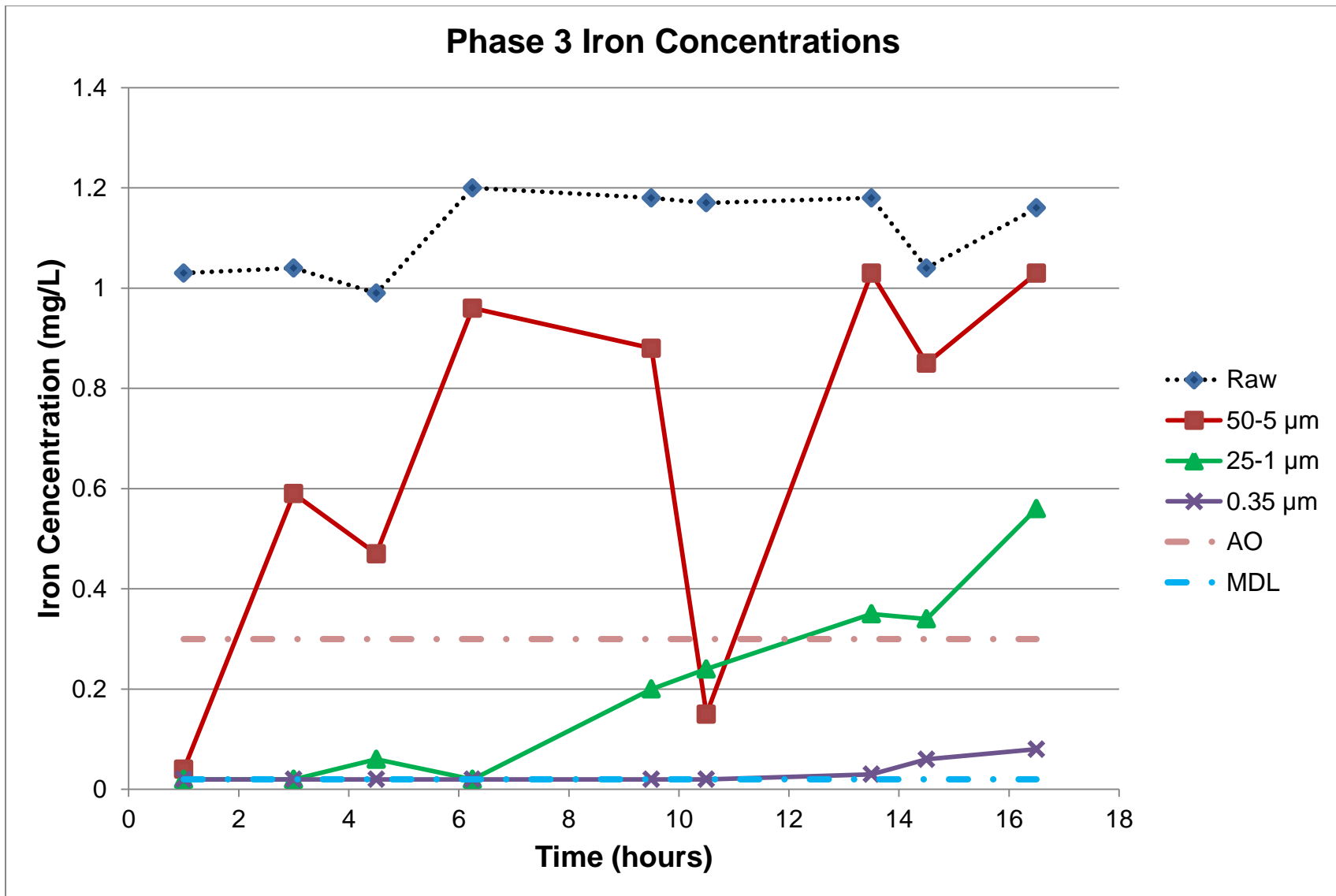


Figure 10. Pilot: Phase 3 Objective 1a

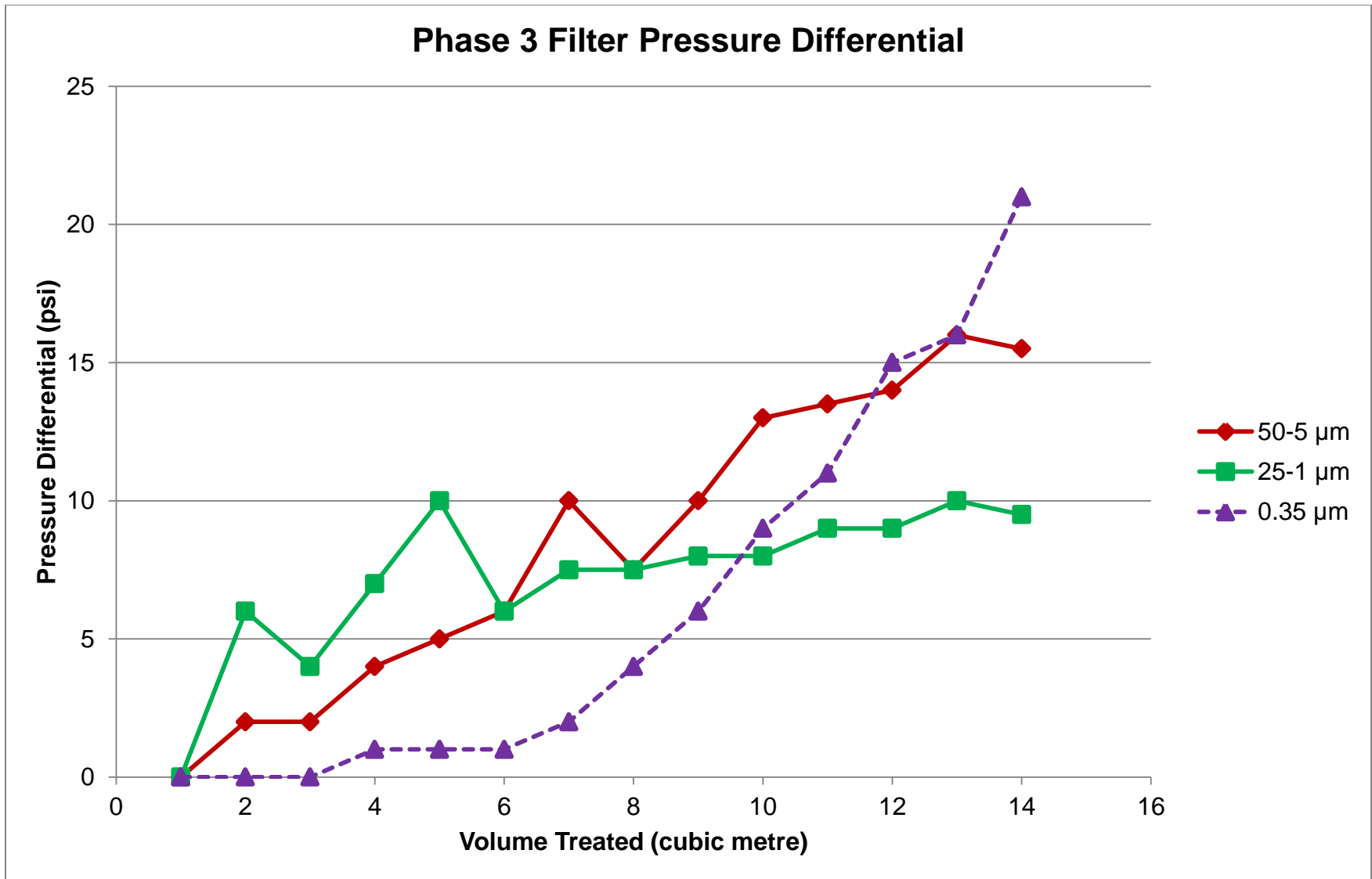


Figure 11. Pilot: Phase 3 Objective 2

6. Conclusions

It was concluded that the untreated well water was above the respective aesthetic objectives for iron, sulfate, and sulfide. Iron was determined to be dissolved in the well and, as it precipitates, was the probable cause for elevated turbidity in the distribution system. Chlorine was an effective oxidant for the precipitation of iron and a filter $\leq 1 \mu\text{m}$ was needed to reduce the concentration of iron below the aesthetic objective. The 3-5 μm monomedia sand filter was ineffective for the removal of iron below the aesthetic objective. The filter performance was measured throughout the study, and the data acquired can enable the community to determine the economic feasibility of iron removal using cartridge filtration. Passive aeration with ventilation was ineffective at oxidizing and venting sulfide at the quantitative and qualitative levels. Although not supported with quantitative data, the reduction in the offensive sulfide gas odour was achieved at the qualitative level using chlorine as an oxidant prior to ventilation. The well water was dosed using typical chlorination and chloramination concentrations to achieve a residual that were within Ontario's guidelines, and disinfection by-product formation was below the respective MAC levels for THMs, HAAs, and NDMA in all samples. The turbidity, pH, and UV transmittance values followed the expected trends and met the provincial aesthetic objectives or operational guidelines.

7. Communication

A final report to summarize the findings from the pilot testing experiments will be submitted to the Municipality of Arran-Elderslie. The Centre will disseminate findings to provide information to other owners and operators of Ontario's drinking water systems. This could include, but is not limited to, conference presentations and case studies used in training materials. ***The anonymity of the Municipality of Arran-Elderslie will be maintained by the Centre in compliance with the Freedom of Information and Protection of Privacy Act (FIPPA).***

8. References

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9. Appendices

Table 4. Bench: Objective 2a

Filtered (Dissolved) Iron Concentrations (mg/L)												
Contact time (minutes)	Chlorine Dose (mg/L)										AO	MDL
	0 mg/L		1 mg/L		2 mg/L		3 mg/L		4 mg/L			
	DI Blank	Sample	DI Blank	Sample	DI Blank	Sample	DI Blank	Sample	DI Blank	Sample		
0	0.02	1.36	0.02	0.66	0.02	0.23	0.02	0.02	0.02	0.02	0.3	0.02
1		1.36		0.65		0.22		0.02		0.02		
2		1.36		0.62		0.21		0.02		0.02		
3		1.36		0.62		0.21		0.02		0.02		
4		1.35		0.62		0.2		0.02		0.02		
5		1.35		0.62		0.2		0.02		0.02		

Table 5. Bench: Objective 2b

pH of Chlorine Doses					
	Chlorine Dose (mg/L)				
	0	1	2	3	4
pH	6.69	6.89	6.78	6.78	6.94

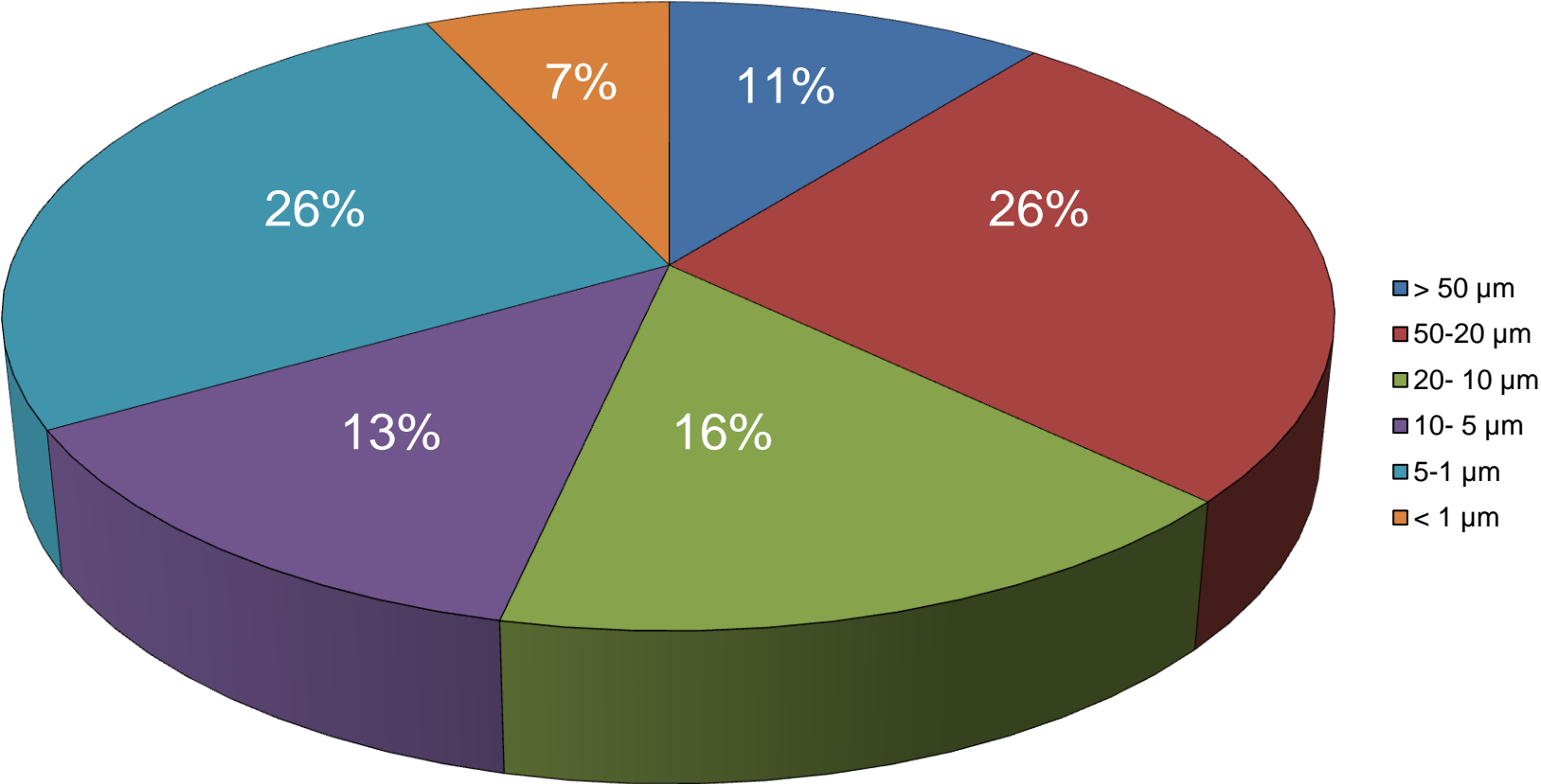
Table 6. Bench: Objective 3 Chlorine Doses, Demand, and Residuals

Chlorine Doses, Demand, and Residuals (mg/L)																
Contact Time (hrs)	1 mg/L		2 mg/L		3 mg/L		4 mg/L		5 mg/L		6 mg/L		7 mg/L		8 mg/L	
	Free	Combined	Free	Combined	Free	Combined	Free	Combined	Free	Combined	Free	Combined	Free	Combined	Free	Combined
0	0	0	0.01	0.71	0.12	1.38	0.6	1.955	0.66	1.02	1.00	1.00	1.76	0.89	2.82	0.77
0.5	N/A						0.225	2.27	0.31	0.34	0.75	0.20	1.69	0.6	2.74	0.59
24							0.265	1.095	0.125	0.04	0.55	0.14	1.69	0.075	2.44	0.3

Table 7. Bench: Objective 3 Residual Chlorine Matrix

Chlorination Matrix (mg/L)								
Chlorine Dosage	1	2	3	4	5	6	7	8
DI Free	1.07	1.87	2.88	4.04	4.9	5.45	7.14	8.32
Free Residual	0	0	0.12	0.6	0.66	1	1.76	2.82
Combined Residual	0	0.72	1.38	1.96	1.02	1	0.89	0.77
Demand	0	1.05	1.79	3.52	4.32	4.6	5.42	5.54
Total Residual	0	0.72	1.5	2.56	1.68	2	2.65	3.59

Phase 1 & 2 Filtered Particle Size Exclusion Analysis



Percents rounded to nearest whole number

Figure 12. Pilot: Phase 1 & 2 Objective 1b

Table 8. Pilot: Phase 1 & 2 Objective 3

External Laboratory Analysis									
Time (hours)	Sulfate (mg/L)			Manganese ($\mu\text{g/L}$)			Sulfide		
	Raw	Cartridge	Media	Raw	Cartridge	Media	Raw	Cartridge	Media
0	1300			0.02			0.006		
6	1300	1200	1200	13.9	3.39	3.3	0.006	0.006	0.006
11	1300	1300	1400	14.3	1.71	9.8	0.08	0.081	0.081

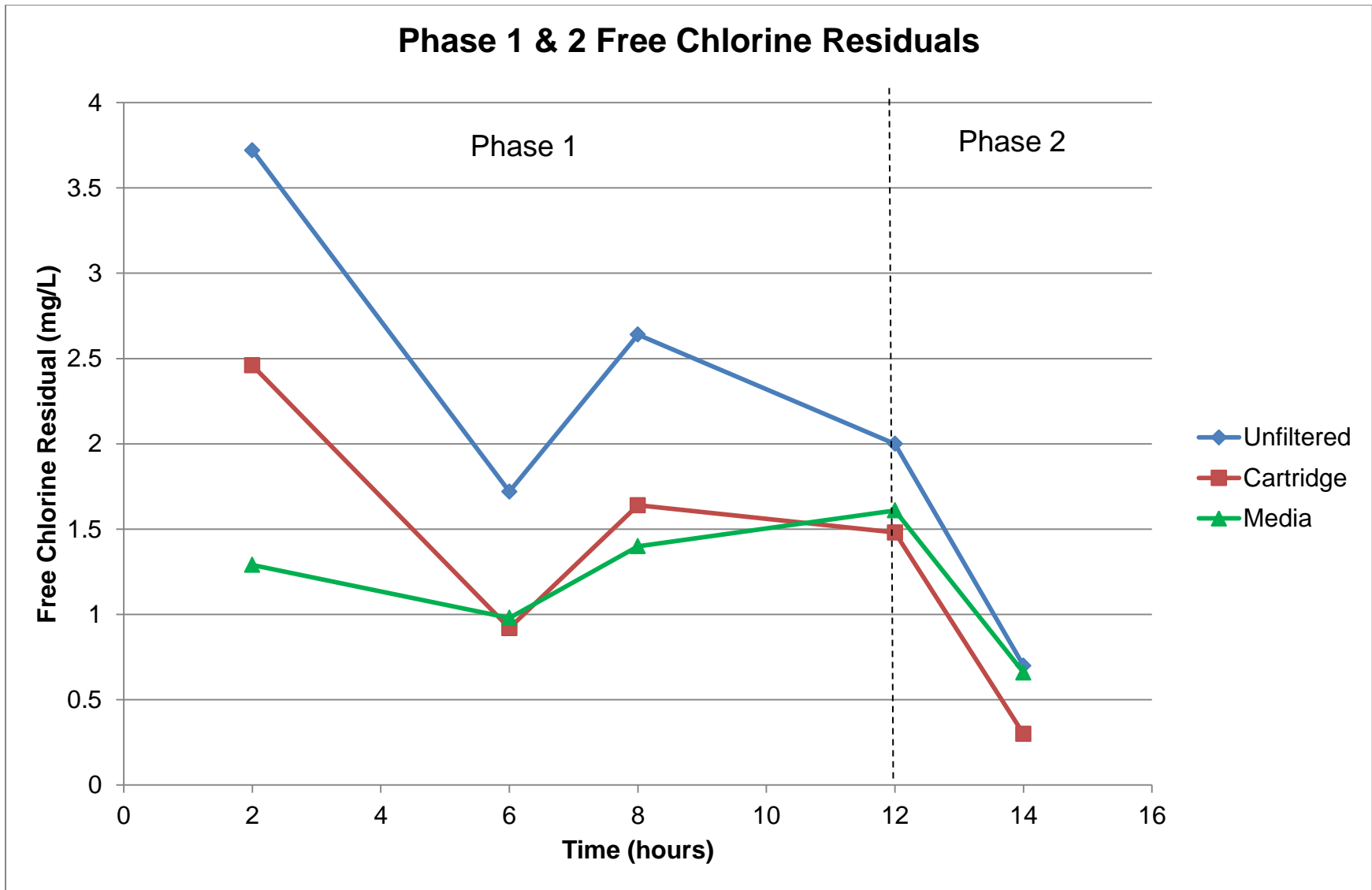


Figure 13. Pilot: Phase 1 & 2 Objective 4 Free Chlorine Residuals

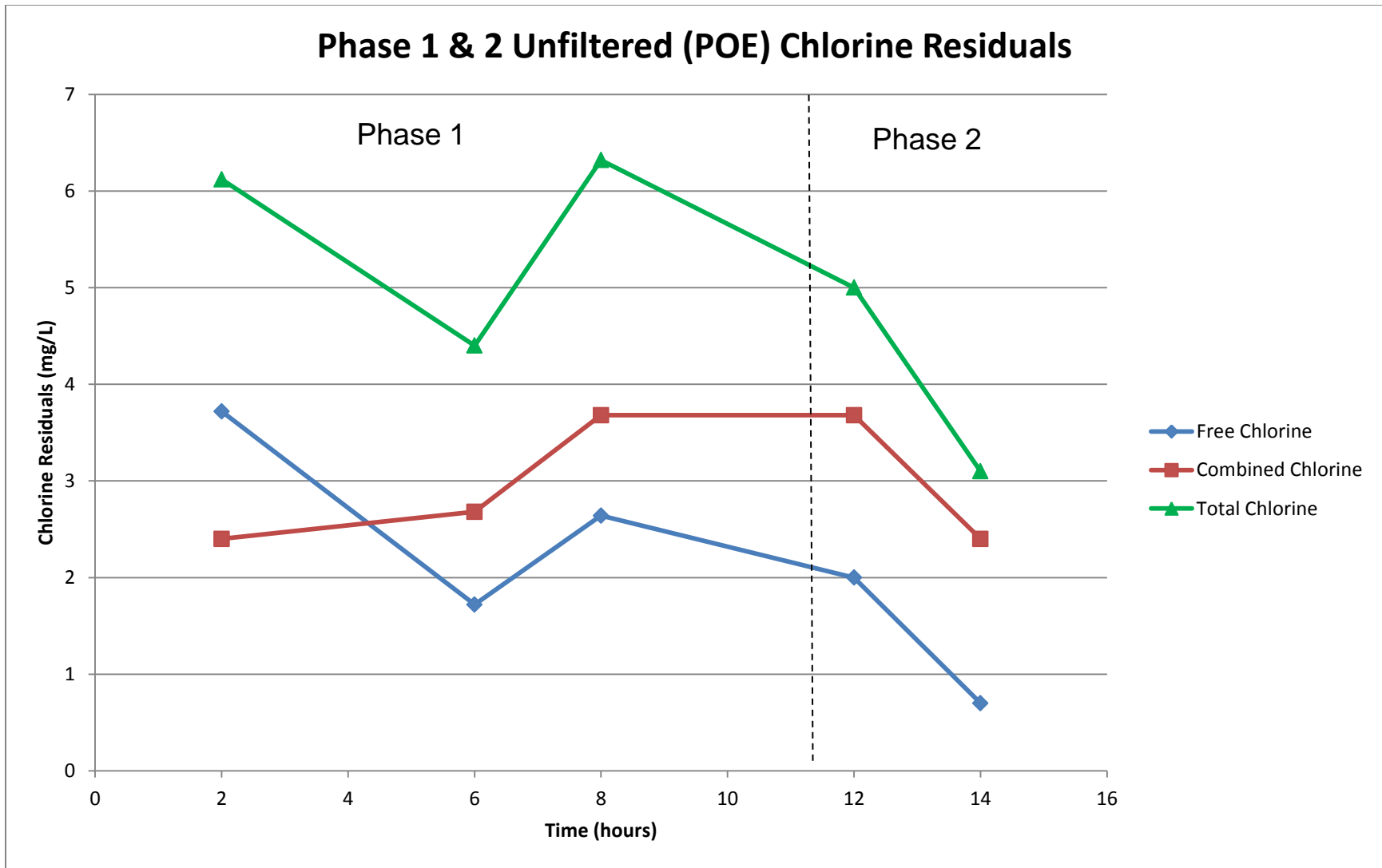


Figure 14. Pilot: Phase 1 & 3 Objective 4 Unfiltered Chlorine Residuals

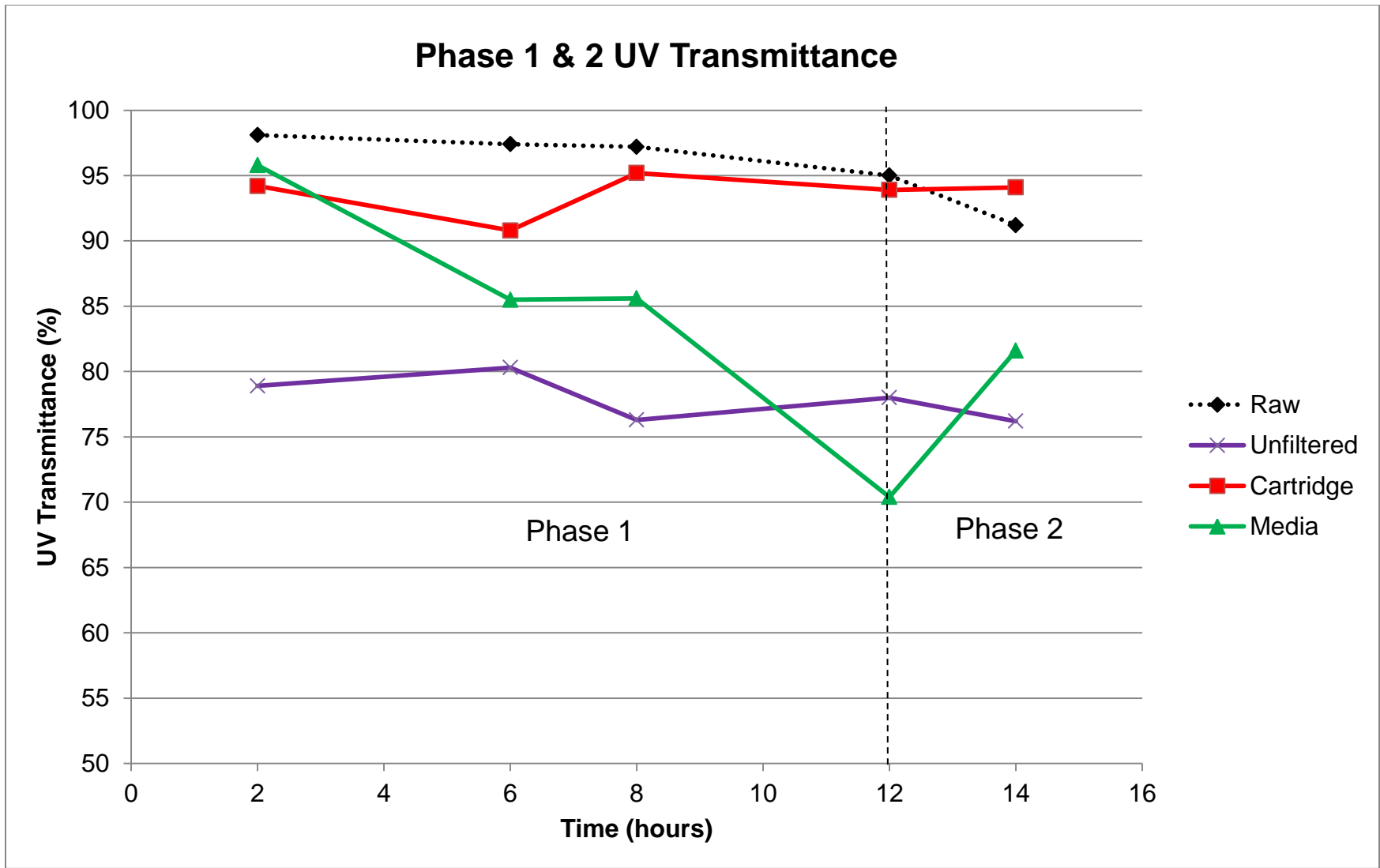


Figure 15. Pilot: Phase 1 & 2 Objective 5a

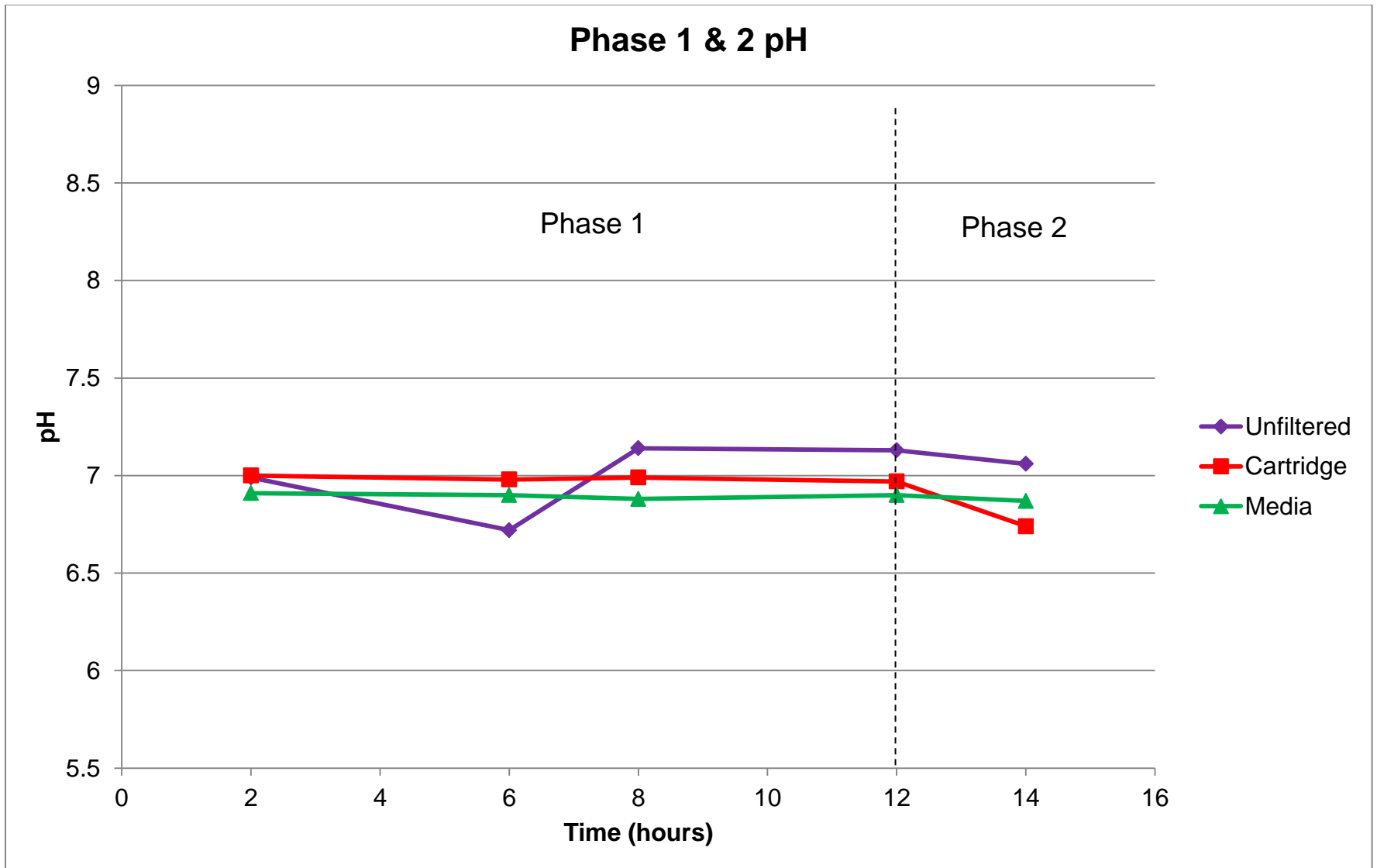


Figure 16. Pilot: Phase 1 & 2 Objective 5b

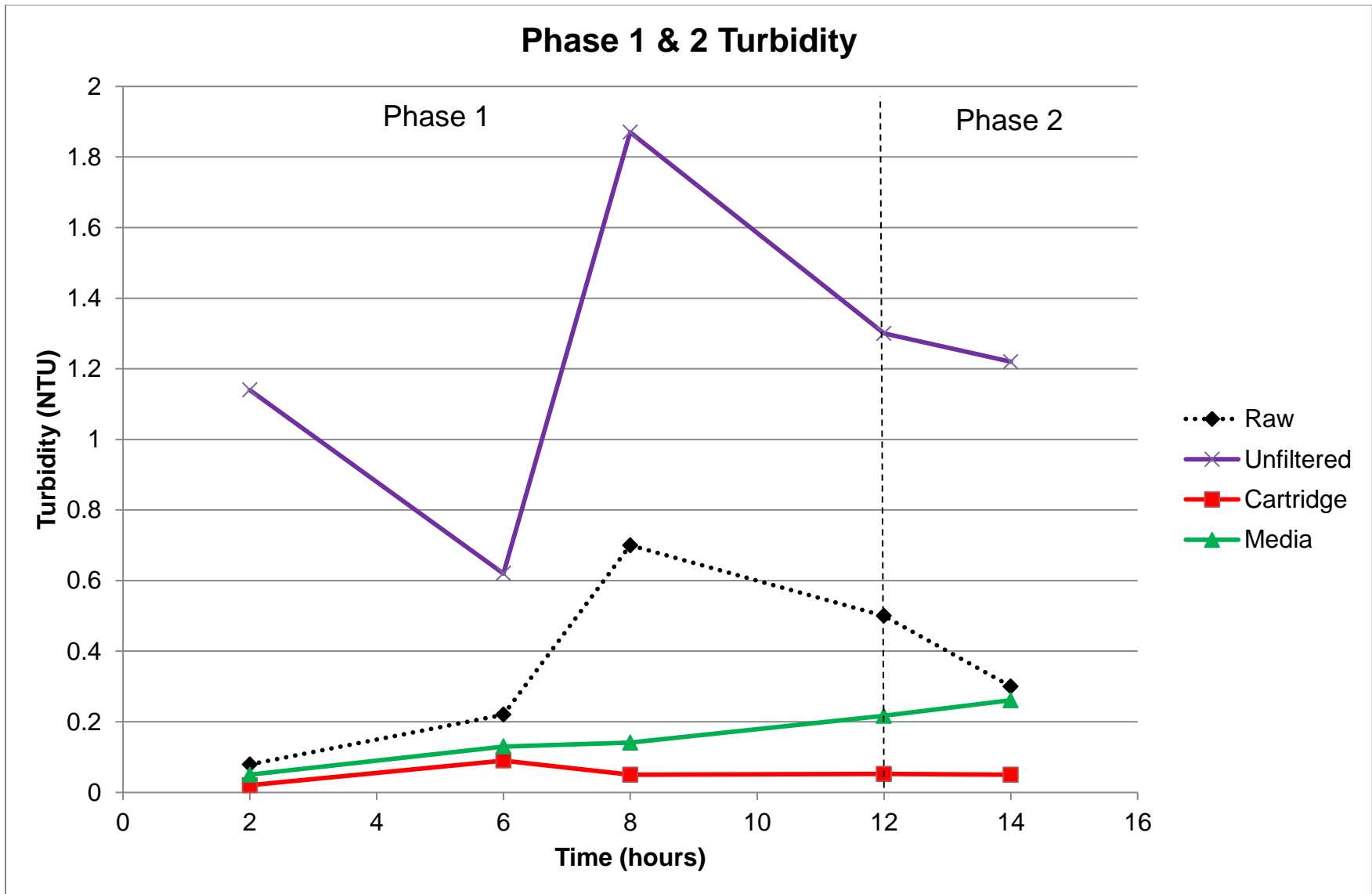


Figure 17. Pilot: Phase 1 & 2 Objective 5c

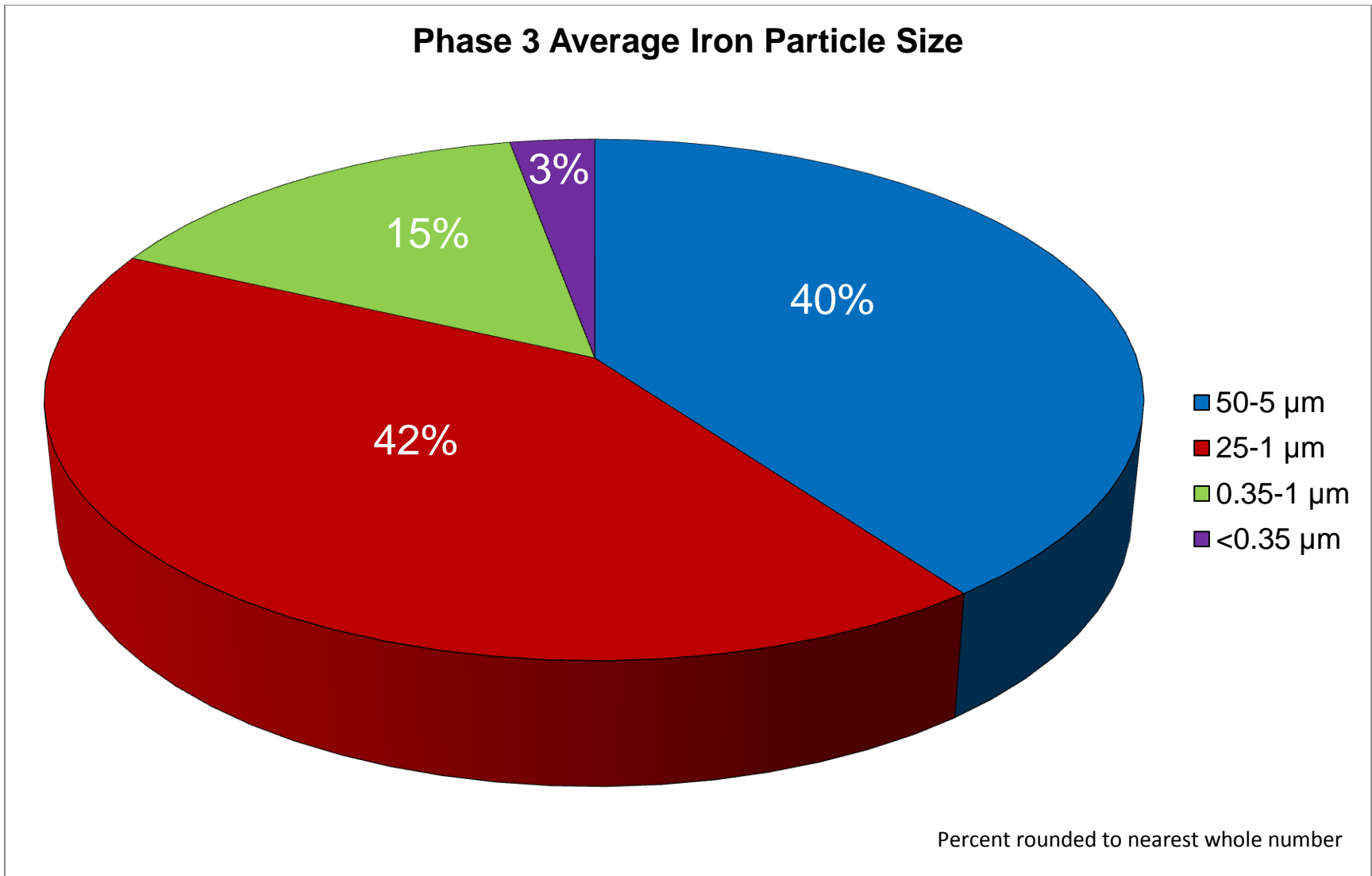


Figure 18. Pilot: Phase 3 Objective 1b

Table 9. Pilot: Phase 3 Objective 1a

Phase 3 Iron Concentrations							
Visit	Time (hours)	Raw	Cartridge Filtration			AO	MDL
			50-5 µm	25-1 µm	0.35 µm		
3-Jul-18	1	1.03	0.04	0.02	0.02	0.3	0.02
	3	1.04	0.59	0.02	0.02	0.3	0.02
	4.5	0.99	0.47	0.06	0.02	0.3	0.02
4-Jul-18	6.25	1.2	0.96	0.02	0.02	0.3	0.02
	9.5	1.18	0.88	0.2	0.02	0.3	0.02
5-Jul-18	10.5	1.17	0.15	0.24	0.02	0.3	0.02
	13.5	1.18	1.03	0.35	0.03	0.3	0.02
	14.5	1.04	0.85	0.34	0.06	0.3	0.02
9-Jul-18	16.5	1.16	1.03	0.56	0.08	0.3	0.02

Table 10. Pilot: Phase 3 Objective 2 Filter Performance

Transient Pressure @ L/min									Pressure Differential		
Visit	Time (hours)	Raw	Cartridge Filtration			Flowrate (L/min)	Volume		Cartridge Filtration		
			50-5 μm	25-1 μm	0.35 μm	Cartridge	Cartridge (L)	Cartridge (m^3)	50-5 μm	25-1 μm	0.35 μm
3-Jul-18	0	0	0	0	0	0	0	0	0	0	0
	1	53	51	45	45	20	1200	1.2	2	6	0
	3	49	47	43	43	20	3600	3.6	2	4	0
	5	57	53	46	45	20	6000	6	4	7	1
4-Jul-18	6	60	55	45	44	20	7200	7.2	5	10	1
	9.5	46	40	34	33	20	11400	11.4	6	6	1
5-Jul-18	10.5	55	45	37.5	35.5	20	12600	12.6	10	7.5	2
	11.5	50	42.5	35	31	20	13800	13.8	7.5	7.5	4
	13	52	42	34	28	20	15600	15.6	10	8	6
	14.25	45	32	24	15	20	17100	17.1	13	8	9
	14.5	49.5	36	27	16	20	17400	17.4	13.5	9	11
	15.5	54	40	31	16	20	18600	18.6	14	9	15
9-Jul-18	16	60	44	34	18	20	19200	19.2	16	10	16
	17	59	43.5	34	13	20	20400	20.4	15.5	9.5	21

Table 11. Pilot: Phase 3 Objective 3

External Laboratory Analysis									
Time (Hours)	Sulfate (mg/L)			Manganese (mg/L)			Sulfide (mg/L)		
	Raw	Cartridge Rep 1	Cartridge Rep 2	Raw	Cartridge Rep 1	Cartridge Rep 2	Raw	Cartridge Rep 1	Cartridge Rep 2
16	1400	1400	1300	14.6	4.5	4.25	<0.006 ¹	<0.006 ²	<0.006 ²
¹ Likely underestimated due to the volatility of the compound ² Accuracy of testing could be underestimated due to the volatility of the compound									

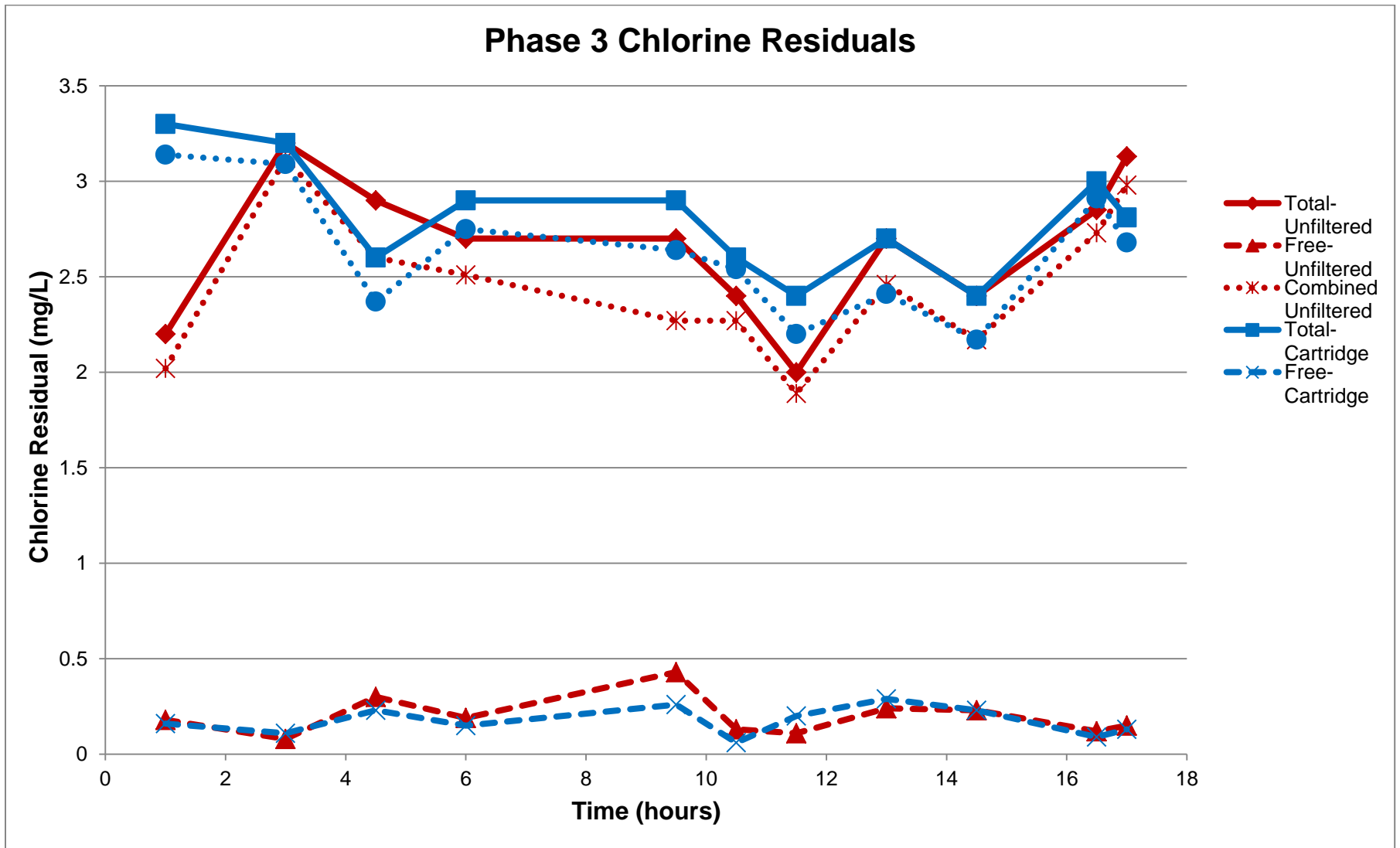


Figure 19. Pilot: Phase 3 Objective 4

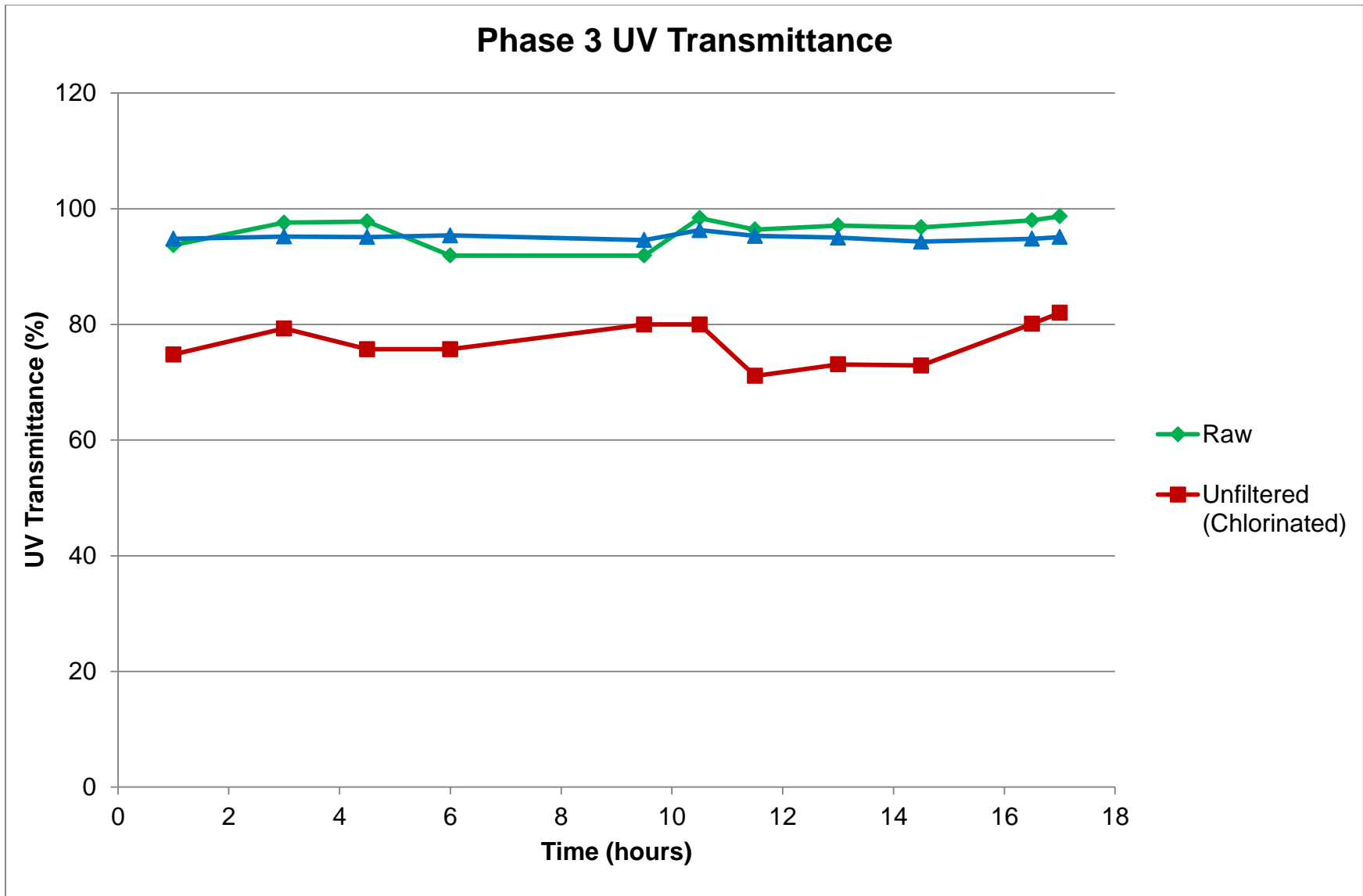


Figure 20. Pilot: Phase 3 Objective 5a

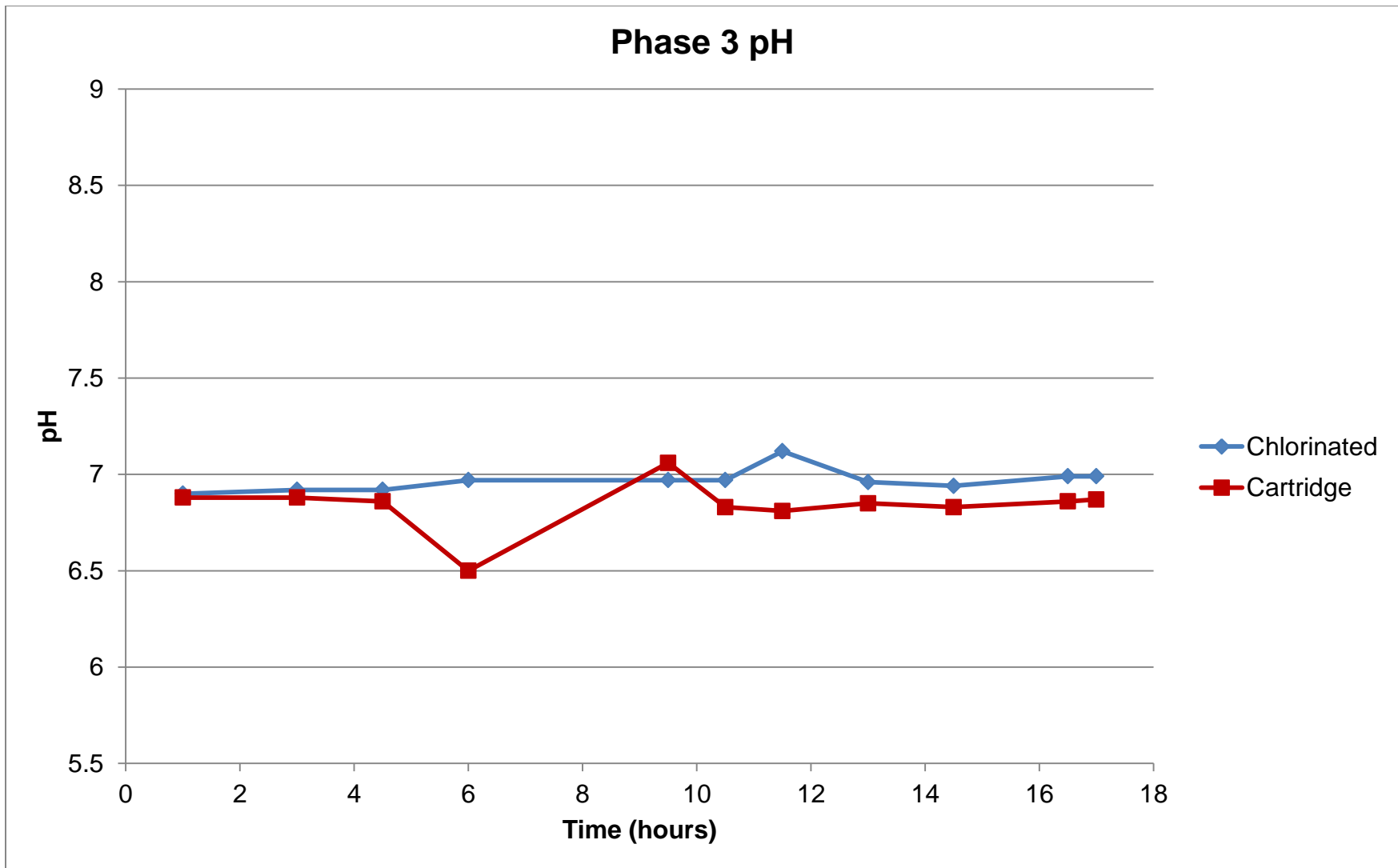


Figure 21 Pilot: Phase 3 Objective 5b

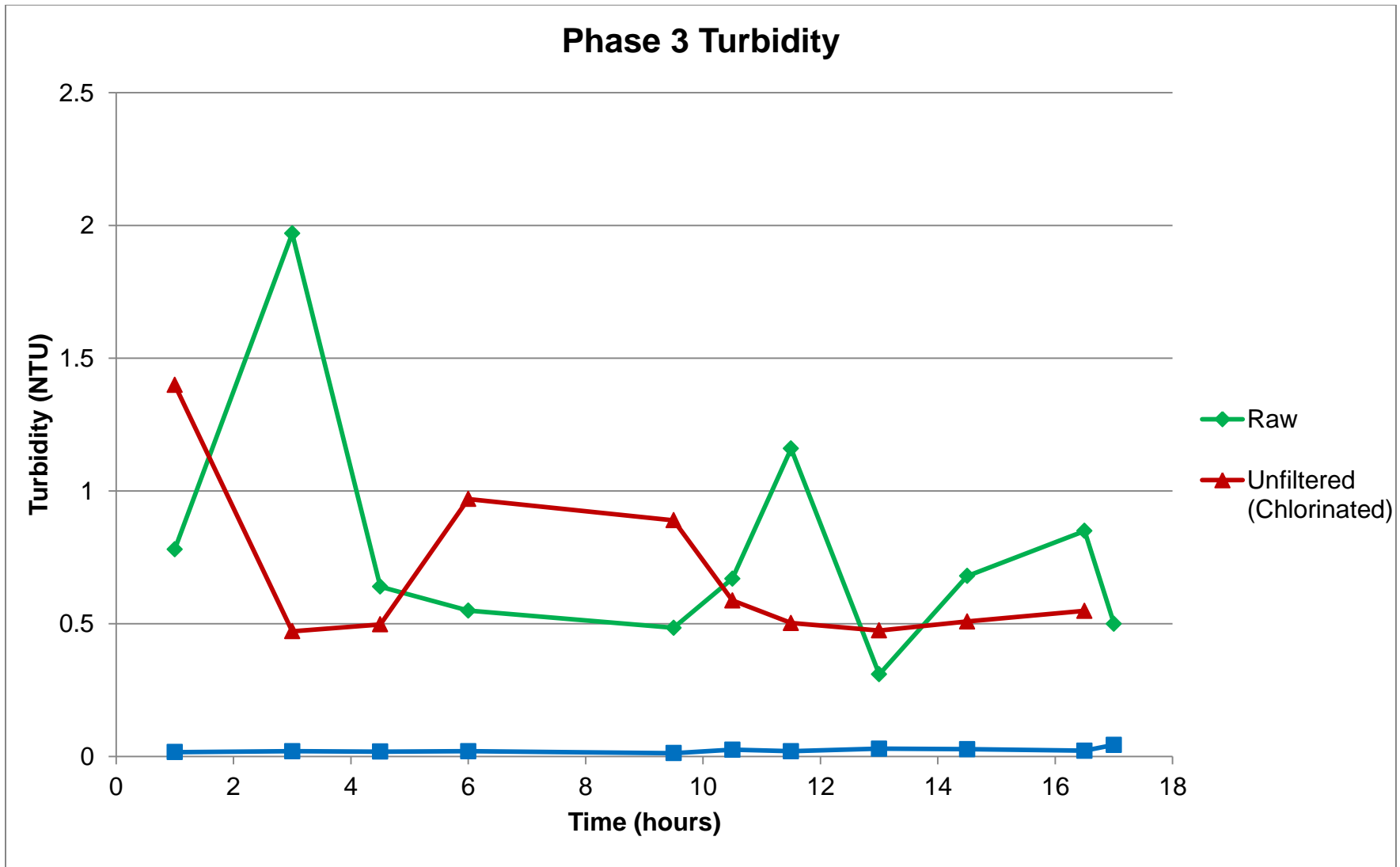


Figure 22. Pilot: Phase 3 Objective 5c