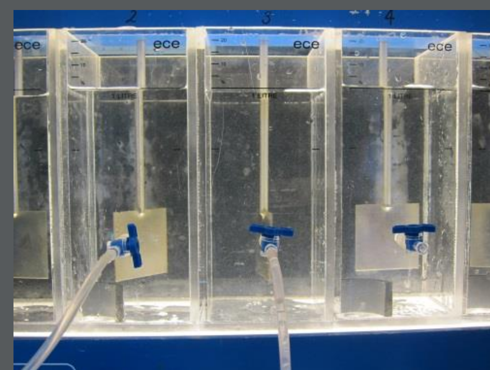
URBAN systems

REPORT



District of Peachland
Bench and Pilot Scale Testing

304 - 1353 Ellis Street, Kelowna, BC V1Y 1Z9 | T: 250.762.2517

January 2015

File: 0655.0170.11

January 29, 2015 File: 0655.0170.11

District of Peachland
5806 Beach Avenue
Peachland, B.C.V0H 1X7

Attention: Joe Mitchel, P. Eng. Director of Operation

RE: Bench and Pilot Scale Testing

Urban Systems is pleased to submit the Final Bench and Pilot Scale Testing Report for the Peachland Lake and Peachland Creek sources.

Please feel free to contact any of the undersigned should you wish to discuss any aspect of this report.

Sincerely,

URBAN SYSTEMS LTD.

Cristina Fonseca, Ph.D., P.Eng.
Process Engineer

Reviewed by,

Peter Gigliotti, P.Eng.
Senior Water Resources Engineer

Executive Summary

Urban Systems Ltd (Urban) was retained by the District of Peachland (District) to evaluate treatment options at bench- and pilot-scale targeting the removal of turbidity, colour, total organic carbon (TOC), and ultraviolet (UV) absorbing compounds (with consequent increase in UV transmittance (UVT)), from its Peachland Lake and Peachland Creek sources.

Urban collaborated with the District and Corix Water Systems (Corix) during July and August of 2014 to mobilize bench- and pilot-scale equipment to the lower dam site. Testing took place between August 15 and October 23 of 2014. During testing, the District Operators were responsible for the pilot-scale skid day-to-day monitoring tasks, supported by Urban. Samples were also sent to Caro Analytical Services (Caro) for analysis. The objective of the bench- and pilot-scale testing was to:

- Confirm the effectiveness of dissolved air flotation (DAF) in removing turbidity, colour, TOC and increasing UVT for both Peachland Lake and Peachland Creek waters,
- Evaluate media filtration performance for three different configurations and different hydraulic loading rates for Peachland Creek water, and
- Test direct filtration as a possible treatment alternative to DAF followed by filtration for Peachland Creek water.

Below is a summary of key findings based on data collected by District Operators, Corix, and reported by Caro.

- Pilot-scale testing suggests that treating Peachland Creek water with coagulation / flocculation and DAF or direct filtration can successfully reduce colour, TOC, DOC and increase UVT. Improved organic matter removal and UVT increase was obtained with DAF than with direct filtration.
- Bench-scale testing suggests that treating Peachland Lake with coagulation / flocculation and DAF can successfully reduce colour, TOC, DOC and increase UVT.
- The deep sand / anthracite media filter performed better than the standard (depth) sand / anthracite and / or the deep anthracite media filters.
- Additional bench-scale testing is recommended for both sources, to screen for additional coagulant and coagulant aids.
- A better understanding of Peachland Lake and Peachland Creek sources potential to form trihalomethanes and haloacetic acids is required, as that will impact treatment selection.

As part of the District's approach to supplying safe water to its consumers both sources should be considered as options during the next evaluation phases. To meet Interior Health's 4-3-2-1-0 Objective (Drinking Water Treatment Objectives (microbiological) for Surface Water Supplies in British Columbia, May 2012; DWTO) the treatment options indicated below can be considered for Peachland Lake and Peachland Creek.

1. **Peachland Lake:**
   I. UV disinfection followed by chlorine disinfection.

   Based on historical water quality data Peachland Lake meets the criteria set by IH to operate without filtration. The installation of UV and chlorine disinfection will allow the District to meet all 4-3-2-1-0 Objectives. However, this treatment option requires confirmation that the level or organic matter present in the raw water does not lead to the formation of disinfection by-products (DBP). Moreover, true colour values must be confirmed.

   II. Direct filtration followed by chlorine disinfection or coagulation, flocculation and DAF, followed by filtration and chlorine disinfection.

   If organic matter removal is required to meet DBP limits in the treated water then pre-treatment followed by filtration is required. The installation of a clarification process is optional and dependent on water quality. It is likely that direct filtration is adequate to treat Peachland Lake. However, a better understanding of coagulation doses required to remove DBP precursor materials is required prior to finalizing the treatment approach.

2. **Peachland Creek:**
   I. Coagulation, flocculation and DAF, followed by filtration and chlorine disinfection. Direct filtration should also be considered as an alternative treatment option.

   Similarly to Peachland Lake, the level of treatment required depends on the source potential to form DBP after reaction with chlorine. Depending on the water reactivity more or less treatment may be required.

Additionally, other treatment technologies are known to treat water of similar quality to Peachland Lake and Peachland Creek, such as membrane filtration, ozone, and activated carbon. These should be investigated in future phases.

Contents

Tables

Photos

Appendices

1.0 Introduction

Urban Systems Ltd (Urban) was retained by the District of Peachland (District) to evaluate treatment options at bench- and pilot-scale targeting the removal of turbidity, colour, total organic carbon (TOC), and ultraviolet (UV) absorbing compounds (with consequent increase in UV transmittance (UVT)), from its Peachland Lake and Peachland Creek sources.

Urban collaborated with the District during July and August of 2014 to mobilize bench- and pilot-scale equipment to the lower dam site. Corix Water Systems (Corix) was retained to supply bench- and pilot-scale equipment, install and commission pilot-scale testing equipment, and provide technical support throughout the testing period. Testing took place between August 15 and October 23 of 2014.

During testing, the District Operators were responsible for the pilot-scale skid day-to-day monitoring tasks, supported by Urban. Cristina Fonseca (Urban) was on-site on August 20, 2014 to verify pilot-scale equipment installation, confirm monitoring sites, and work with District Operators on bench-scale testing protocols.

The objective of the bench- and pilot-scale testing was to:

- Confirm the effectiveness of dissolved air flotation (DAF) in removing turbidity, colour, TOC and increasing UVT for both Peachland Lake and Peachland Creek waters,
- Evaluate media filtration performance for three different configurations and different hydraulic loading rates for Peachland Creek water, and
- Test direct filtration as a possible treatment alternative to DAF followed by filtration for Peachland Creek water.

This report summarizes the testing protocols, data collected and significant findings obtained for all bench- and pilot-scale tests performed.

2.0 Background

The District of Peachland (District) currently treats Peachland Creek water at its chlorination facility. Water from the upper dam (which forms Peachland Lake) flows into Peachland Creek and travels approximately 14 Km to a raw water storage pond. Water is supplied from this lagoon directly to the distribution system after disinfection with chlorine gas.

As part of ongoing discussions with Interior Health (IH) the District requested to amend their water master plan and to draw water directly from Peachland Lake with the following objectives:

- Defer filtration based on on-going water quality monitoring.
- Use the available head to generate power during water transport from the upper dam to the water treatment plant.

After reviewing the initial set of water quality data, discussions ensued around ultraviolet transmittance (UVT) values, which were perceived to be low. In the sequence of these discussions IH requested the District to test treatment at pilot-scale targeting colour removal and UVT increase. As part of the approach to meeting IH requirements the following testing was planned and executed during August 15 and October 23 of 2014:

- Peachland Creek water: Pilot-sale testing of dissolved air flotation (DAF) followed by media filtration.
- Peachland Lake water: Bench-scale testing of coagulation / flocculation and DAF using a jar testing apparatus.

The decision to pilot test Peachland Creek instead of Peachland Lake was due to logistic constraints at the upper dam site, namely the remoteness of the location and lack of power availability. It was also assumed that, apart from turbidity, water at the lower intake (raw water storage lagoon) would be similar or slightly worse than at Peachland Lake. The underlying assumption being that while flowing through the creek the organic content of the water would either remain the same or increase. Therefore, pilot testing at the lower intake would provide the District with meaningful information regarding impact of treatment on water UVT.

3.0 Bench and Pilot-Scale Testing Protocols

3.1 Bench-Scale Testing

Peachland Lake and Peachland Creek water treatment was evaluated at bench-scale using a Jar Test apparatus (**Photo 3.1**). The Jar Tester simulates rapid mix, flocculation and sedimentation / DAF processes and allows for screening of different coagulants. At the coagulant doses tested for both Peachland Lake and Peachland Creek the flocs formed after flocculation tended to float more than they tended to settle, and thus DAF was selected instead of sedimentation.

Photo 3.1 – Jar Test Apparatus Used for Bench-Scale Testing

Table 3.1 summarizes the Jar Test mixing conditions used during chemicals screening. A mixing energy graph correlating rpm with G-values is available in **Appendix A**. Bench-scale testing was done at the Corix Laboratory in Langley, by David MacKay, and on-site by Ms. Fonseca (Urban) and District Operators.

Table 3.1 - Jar Test Mixing Conditions Reported by Corix1

Parameter	Flash Mixing	Flocculation	
		Stage 1	Stage 2
RPM	575	70	35
Time (sec)	60	600	600
G (sec^{-1})[3]	>1,000	100	35
G x t	>6.0×10^4	6.0×10^4	2.1×10^4

1. Operated with and without air injection. Air injection set to simulate 10 percent recycle rate.
2. G-values reported for water at 15ºC using the mixing energy graph (Appendix A).

3.1.1 *Peachland Lake Jar Testing*

Because pilot-scale testing was not possible at the Upper Dam site, Peachland Lake water was tested at bench-scale. The Jar Test apparatus was used in DAF mode to evaluate whether this treatment option can effectively remove turbidity, colour, TOC, and UV absorbing compounds (with a consequent increase in UVT). Different coagulants and doses were tested and a preferred condition identified. For this condition, raw and treated water samples were submitted to Caro Analytics (Caro) for analysis. **Table 3.2** summarizes the parameter submitted to Caro for analysis. Potential treatment efficacy was evaluated based on these results.

During screening testing at Corix Laboratories a variety of chemicals were tested, including alum, ClearPAC (from Cleartech), and ferric chloride. Of the coagulants tested by Corix, ClearPAC was the recommended one. Optimal ranges varied between 25 mg/L and 50 mg/L.

Chemicals tested on-site included ClearPAC and ISOPAC (from Klearwater). Doses tested ranged between 20 mg/L and 80 mg/L. Material safety data sheets (MSDS) for all chemicals used are available in **Appendix B**.

Table 3.2 - Coagulation Optimization Monitoring Plan

Parameter	Analysis	Raw	Settled
Turbidity (NTU)	District / Caro	√	√
pH (-)	District / Caro	√	√
Temperature (°C)	District	√	-
Alkalinity ($mgCaCO_3/L$)	Caro	√	√
Hardness (mg/L)	Caro	√	√
$N\text{-}NH_3$ (mg/L)	Caro	√	-
TOC (mg/L)	Caro	√	√
DOC (mg/L)	Caro	√	√
UV Absorbance @ 254 nm (cm^{-1})	Caro	√	√
Apparent Colour (C.U.)	District / Caro	√	√
True Colour (C.U.)	Caro	√	√

3.1.2 *Peachland Creek Jar Testing*

For Peachland Creek, jar testing was used to identify the starting point at which to start operating the pilot-scale skid. During pilot-scale testing it was also used to optimize pilot-skid performance. Various chemicals and doses can be efficiently tested within a relatively short period of time at bench-scale. Only those conditions that show promising results are then tested at pilot-scale.

Optimal operating conditions were measured based on floc size and colour, turbidity and colour removal, as well as UVT increase. No samples were sent to Caro for analysis for tests done at bench-scale.

3.2 Pilot-Scale Testing

Peachland Creek water treatment was evaluated at pilot-scale at the Lower Dam site. Treatment consisted of rapid mix / flocculation and DAF followed by media filtration. **Photos 3.2** and **3.3** show the pilot-skid installation at the lower Dam site. **Photo 3.2** shows the chemical injection (3.2-a) and DAF (3.2-b) skids. **Photo 3.3** shows the filter skid, comprised of three filter columns. **Tables 3.3** and **3.4** summarize the pilot-skid testing configurations. Additional pilot-scale skids technical information is available in **Appendix C**.

Direct filtration was also tested for this source; water was pumped directly from the second flocculation stage to the filters, without undergoing DAF. The objective was to test whether the water could be treated without the flotation step, thus reducing the required treatment footprint.

a) Chemical injection and DAF skids. **b) DAF skid**

Photo 3.2– Chemical Injection and Rapid Mix / Flocculation / DAF Skids

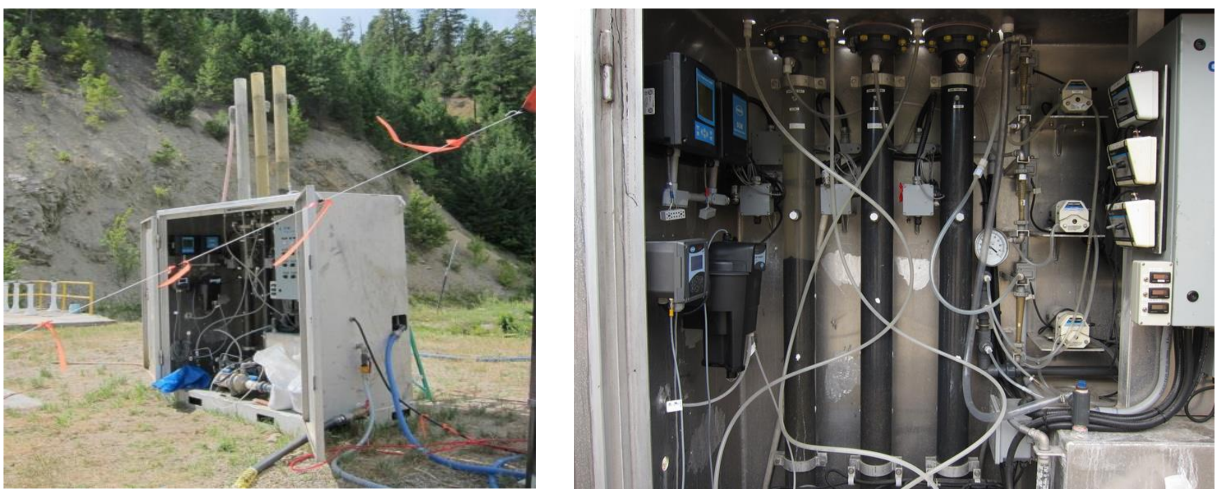


Photo 3.3 – Filter Skid

Table 3.3 - Pilot-Scale Test Variables

Parameter	Conditions	Comments
Flocculation time (min)	15 - 30	Raw water flow range between 55 L/min and 70 L/min.
Coagulant Type (-)	ClearPAC / ISOPAC	Additional coagulants (i.e., alum and ferric chloride) tested at bench-scale by Corix. Only those with good results were tested at pilot-scale.
Filtration Rate (m/h)	7.5 - 12	Upper limit set by maximum filter influent pump rate. Filter influent water ranged in flow between 1.0 L/min and 1.6 L/min.

Table 3.4– Media Filter Configurations Tested at Pilot-Scale

Column	Filter Media	Depth (mm)	Effective Size (mm)
1	Sand Anthracite	450 450	0.45 -0.55[1] 1.0-1.2[2]
2	Sand Anthracite	300 1,350	0.5 – 0.75[1] 1.0-1.45[2]
3	Anthracite	1,800	1.0-1.45[2]

1. Sand Uniformity Coefficient (UC): 1.45
2. Anthracite UC: 1.5

During pilot-scale testing, samples were collected daily by District Operators for monitoring purposes. When operating conditions met the set operating goals, samples were collected along the treatment train and submitted to Caro for analysis. **Table 3.5** summarizes the sampling schedule carried during testing. Treatment performance was evaluated based on these results.

Samples were sent to Caro corresponding to two treatment approaches: i) pre-treatment / DAF and media filtration, and ii) direct filtration. Results and discussion are summarized in Sections 4 and 5.

Table 3.5 - Pilot-Scale Testing Water Quality Monitoring

Parameter	Monitoring	Location[1]	Frequency
Temperature (°C)	On-Site	Raw, CE, FE	Daily
pH (-)	On-Site / Lab	Raw, CE	Daily / 1x/Test
Turbidity (NTU)	On-Site	Raw, CE, FE	Continuously[2]
Alkalinity (mg$CaCO_3$/L)	On-Site/Lab	Raw, CE	Daily
Hardness (mg$CaCO_3$/L)	Lab	Raw, CE	1x/Test
Ammonia (mgN-NH_3/L)	Lab	Raw	1x/Test
True Colour (C.U.)	On-Site/Lab	Raw, CE, FE	1x/Test
Apparent Colour (C.U.)	On-Site/Lab	Raw, CE, FE	1x/Test
UV transmittance (cm^{-1})[3]	On-Site/Lab	Raw, CE, FE	Daily / 1x/Test
DOC (mg/L)	Lab	Raw, CE, FE	1x/Test
TOC (mg/L)	Lab	Raw, CE, FE	1x/Test

1. CE – Coagulation/Flocculation Effluent; FE – Filter Effluent.
2. FE turbidity measured continuously for Filter #1 and rotated through Filters #2 and #3 daily, for skid monitoring.
3. UV transmittance was measured before and after filtration through a 0.45 μm filter.

4.0 Results and Discussion

4.1 Bench-Scale Testing

4.1.1 *Peachland Lake*

One of the objectives of the bench-scale trials was to evaluate the potential for DAF and / or conventional pre-treatment to improve Peachland Lake water quality, namely remove turbidity, colour, and organic matter, and increase UVT. Conventional treatment includes sedimentation rather than flotation, and is preferred when flocs tend to settle rather than float.

The flocs formed during jar testing trials tended to float more than they tended to settle and thus DAF was selected as the preferred technology. The jar test conditions simulated a DAF with a 10 percent recycle air saturated stream. ISOPAC was tested on-site using different doses. Optimal results were obtained with an ISOPAC concentration of 46 mg/L. **Table 4.1** summarizes the water quality reported by Caro for raw and treated water.

On-site raw water turbidity, pH and temperature were 0.74 NTU, 7.7 pH units, and 12.6 ^{o}C, respectively.

Table 4.1 – Peachland Lake Caro Laboratory Results[1]

Parameter	Units	RW[2]	DAF[2]	Removal (%)
Turbidity	NTU	0.6	0.5	17
pH	-	7.4	7.1	-
Alkalinity	$mgCaCO_3/L$	43	30	30
Hardness	$mgCaCO_3/L$	50.6	45.3	10
Apparent Colour	CU	12	5	58
True Colour	CU	10	<5	75
TOC	mg/L	3.9	2.1	46
DOC	mg/L	3.6	1.9	47
UVT[3]	%	80.5	92.8	-
UV Abs (Calc.)	cm^{-1}	0.094	0.032	66
N-Ammonia	mg-N/L	<0.020	0.052	-

1. Coagulant used was ISOPAC at a dose of 46 mg/L.

2. RW: Raw Water; DAF: DAF Treated Sample - 10 percent recycle saturated air / water stream simulated.

3. UVT samples were measured after filtration through 0.45µm pore filter.

The results reported indicate that coagulation / flocculation and DAF successfully removed colour, organic matter (measured as TOC and DOC) and improved UVT. Treatment performance was good with organic matter removal around 50 percent and 12 percentage points increase in UVT. True colour was removed below the aesthetic objective (AO) of 5 colour units (CU). The low turbidity of the DAF sample indicates the flocs tendency to float thus confirming the suitability of DAF as a potential treatment alternative.

Another potential treatment alternative is direct filtration, where water undergoes coagulation and flocculation prior to filtration. No settling or DAF step is involved in this approach. Due to logistical difficulties this option was tested for Peachland Creek but not for Peachland Lake. A summary of the results obtained is provided in Section 4.2.

ISOPAC was used as a coagulant as it was the one available on site. This coagulant is in use in various water treatment plants in the Okanagan. However, other products are available that should be tested on this source with the goal of identifying the most appropriate product to meet treatment targets. Screening can easily be done at bench-scale. For direct filtration coagulation and filter aids can also be tested. These chemicals have shown to improve performance at different WTP in B.C., such as Salmon Arm and Seymour-Capilano Filtration Plant, Vancouver.

4.1.2 *Peachland Creek*

Prior to pilot-scale testing, Corix performed a series of tests in their lab in Langley, B.C. evaluating the potential for DAF as a suitable treatment alternative for Peachland Creek. A sample was shipped by the District to Corix on July 25, 2014 and tested July 29, 2014. The coagulant used was ClearPAC. Two sets of results were reported (**Table 4.2**). Pin flock detected in the 25 mg/L range with progressive increase in size and consistency (reported as “fluffier”) as doses approached and surpassed 40 mg/L. Best results were reported between 25 and 40 mg/L. The UVT values reported by Corix (**Table 4.2**) are considerable lower than those reported by the District. However, within the context of the bench-scale test the key finding was the relative UVT increase with treatment.

Table 4.2 – Peachland Creek Corix Results

Parameter	Units	RW	ClearPAC Dose (mg/L)					
			25	30	35	40	45	50
July 29, 2014								
Turbidity	NTU	11	1	0	0	0	-	-
pH	-	8.0	7.6	-	-	-	-	-
True Colour	CU	25	*46*	*43*	*35*	*38*	-	-
UVT	%	63.8	80.9	82.5	79	82.9	-	-
July 31, 2014								
Turbidity	NTU	11	-	2	2	2	2	2
True Colour	CU	25	-	8	0	0	0	0
UVT	%	63.8	-	90.2	90.9	92.2	93.1	93.7

Tests were also done on-site with Isopac to screen dose ranges to use at pilot-scale. Doses ranging between 20 mg/L and 40 mg/L were tested and a dose of approximately 30 mg/L selected. During Corix's September site visit on September 16 – 18, 2014 after the DAF skid hydraulic loading rate and air saturated recycle water loop were optimized, the recommended dose was changed to 37.5 mg/L.

The UVT values shown in **Table 4.2** are significantly lower than historically reported, i.e., ranging between 80 and 85 percent. However, for the purpose of this test the objective was to evaluate a relative improvement with treatment. The data shown in the table indicates a relative increase in UVT after treatment.

Jar tests done with both ClearPAC and Isopac resulted in considerable increase in UVT and turbidity reduction. The initial colour results obtained with ClearPAC were suspicious because of considerable increase in the treated samples. These results were attributed to malfunction of the bench-top colour meter.

4.2 Pilot-Scale Testing

4.2.1 *Operator Reported Data*

District Operators monitored the pilot-scale skid on a daily basis for most of the test duration. Only during the first two weeks of October the pilot-skid was not run due to Operator workload and equipment malfunction.

Until the first week of October the pilot-skid plant was operated to simulate rapid mix / flocculation, DAF followed by media filtration. During David Mackay's (Corix) site visit on October 8 to 10 the skid was converted to operate using a direct filtration process, i.e., rapid mix / flocculation followed by filtration. Normally, the pilot-scale skid was started in the morning and sampled at the end of the day. During the direct filtration trial the skid operated continuously during week days. A summary of the values reported by the Operators is available in **Appendix D**.

A considerable number of issues were reported during pilot-skid operation, associated with equipment and operational deficiencies:

- The DR-890 hand-held meter was unreliable and was returned to Corix. Colour monitoring was continued with the District's unit.
- The hand-held turbidity meter was not operational throughout the duration of the pilot-scale test.
- The on-line DAF effluent turbidity meter was not operational until October. On October 1 a sample was collected and submitted to Caro for analysis, to verify the on-line meter reading. The on-line and lab values were 2.6 and 2.0, respectively.
- Often the saturator malfunctioned leading to bursts of air into the DAF area. In summary, issues associated with the saturator instrumentation led to only air (instead of air saturated water) being released in the DAF area. These bursts impacted the flotation process leading to high turbidity values in the DAF effluent, and floc overloading of the media filters. Operators reported a layer of brownish chemical precipitates on top of the media.

- The initial operating conditions set for the DAF were found to be sub-optimal, namely the raw water flow was identified as too high and the recycle air saturated loop too low. At this time no float was observed at the top of the DAF. On September 16 - 19 David MacKay visited the site and optimized DAF operations. The raw water was adjusted to 55 L/min, chemical dosing to 37 mg/L and the recycle loop to approximately 12 percent. Mr. MacKay reported that although floc formation was still challenging, a small floating layer accumulating at the top was observed by the time he left the site. **Photo 4.1** shows the layer formed.

Photo 4.1 – Optimized DAF Float (September 19, 2014)

The following is a summary of the data reported by District Operators when Peachland Creek was treated using coagulation, flocculation, DAF and media filtration:

- DAF effluent turbidity values, ranging between 1.5 NTU and 3.0 NTU, were considerably higher than expected. Normally, values below 1 NTU are expected by Corix. However, as mentioned in Section 4.2.2 the DAF used for this study was not as deep as Corix's standard units and that may have led to higher than expected turbidity levels.
- Pre-treatment and DAF successfully removed UV absorbing compounds, resulting in higher UVT in the clarified water. UVT values (after filtration through 0.45 μm filter) increased from approximately 83 to 92 percent.
- Treatment successfully reduced colour below the AO level of 5 C.U.
- Filtration effectively removed particulate matter at standard filtration rates (i.e., 10 m/h) during the initial stages of a filter run. However, it is unclear how long the filter ran until filtered water turbidity rose above 0.3 NTU. The short duration of the filtration runs is attributed to the high turbidity levels in the DAF effluent water.
- Higher filtration rates (i.e., 13 to 14 m/h) were tested without much success due to the elevated turbidity values in the DAF effluent. As expected, the deeper filters (i.e., Filter #2 and #3) were capable of dealing with higher turbidity levels as well as higher filtration rates better than Filter #1.

The following is a summary of the data reported by District Operators when direct filtration was used to treat Peachland Creek water:

- Turbidity after the second flocculation unit ranged between 1.5 and 2.3 NTU.
- Direct filtration successfully removed UV absorbing compounds, resulting in higher UVT in the clarified water. UVT values (after filtration through 0.45 μm filter) increased by approximately six percentage points. The lower removals (when compared to DAF) can be attributed to the lower coagulant doses used in the trial.
- Treatment reduced true colour to levels <5 NTU.
- Filtered water turbidity was reduced to values below 0.3 NTU after backwashing. It was not possible to evaluate turbidity breakthrough cycles based on the data collected on site. However, normally, direct filtration process rely on the addition of coagulant and filter aids to prolong filter run lengths.
- Based on data collected at the end of the test trial and submitted to Caro (**Table 4.5**) the dual-sand / anthracite media filter reported better turbidity removals than the anthracite media alone.

4.2.2 *Corix Reported Data*

During pilot-scale testing Corix was on site three times; during start-up and commissioning (Mr. Daniel Tyczkowski), September 16 -19 (Mr. David MacKay) and October 8 – 10 (Mr. David MacKay). Formal data reporting was done only for the third visit.

During the second visit Mr. MacKay went to site with the objective of improving DAF effluent turbidity, which had been consistently above 2 NTU. Operators also reported poor floc (if any) formation. Mr. MacKay tested different chemical doses both at bench- and pilot-scale, as well as adjusting the hydraulic loading rate of the skid (by reducing the raw water flow). The third site visit objectives are outlined below.

- Optimize DAF operation to reduce DAF effluent turbidity. It was reported that the lowest turbidity values that could be obtained were around 1.5 NTU.
- Confirm filter performance (i.e., headloss build-up and filter effluent turbidity) after DAF optimization.
- Convert pilot-scale skid operation from a DAF to a direct filtration process.

A report with Mr. MacKay's findings is available in **Appendix E**. A summary of key results are listed below:

- Floc formation was reported as challenging for most doses tested.
- DAF performance was evaluated for Isopac doses ranging between 5 mg/L and 25 mg/L. The best results were obtained for concentrations above 20 mg/L with the recycle flow set at 8.3 percent.
- Isopac dose between 15 and 20 recommended as a starting point for the direct filtration trial.

Corix reported that the pilot-skid unit installed at Peachland was shallower than its standard DAF units which may have led to lower performance than expected; normally, DAF effluent turbidity values lower than 1 NTU are expected for these units. However, it is not uncommon for raw water sources with extremely low turbidity values, such as Peachland Creek, to be extremely difficult to treat with chemical pre-treatment. The low particulate matter present in the water matrix makes it difficult for particles to coalesce and form flocs.

4.2.3 *Caro Reported Data*

Initially, the objective was to evaluate up to four different treatment scenarios at pilot-scale. The approach was to have District Operators monitor treatment performance on a daily basis until stable operation for a particular treatment scenario was achieved. At this stage, samples were collected across the treatment train (refer to **Table 3.5**) and sent to Caro for analysis. The treatment scenarios evaluated were:

1. Rapid mix / flocculation, DAF followed by media filtration (September 10, 2014)
2. Rapid mix / flocculation followed by media filtration; direct filtration (October 21, 2014)

Table 4.3 summarizes testing conditions for both trials. **Tables 4.4** and **4.5** summarize the data reported for the DAF and direct filtration trials.

Table 4.3– Pilot-Scale Test Conditions During Sampling Events (Samples Sent to Caro)

Parameter	Value
DAF / Media Filtration	
Raw Water Flow, L/min	70
ISOPAC Dose, mg/L	36
Flocculation Time, min	24
DAF HLR, m/h	12
Filter Influent Flow, L/min	1.2
Filter HLR, m/h	9.2
Direct Filtration	
Raw Water Flow, L/min	65
ISOPAC Dose, mg/L	14
Flocculation Time, min	20
Filter Influent Flow, L/min	1.0
Filter HLR, m/h	7.6

Table 4.4 – DAF Pilot Scale Test Caro Results

Parameter	Units	Reported Values					Performance (%)			
		RW	DAF	F1	F2	F3	DAF	F1	F2	F3
Turbidity	NTU	0.5	0.8	0.2	0.2	<0.1	-	60	60	>80
pH[1]	-	7.97	7.63	-	-	-	-	-	-	-
Alkalinity	mg $CaCO_3$/L	100	88	-	-	87	12	-	-	13
Hardness	mg $CaCO_3$/L	112	112	113		110	-	-	-	-
True Colour	CU	11	<5	<5	<5	<5	>77	>77	>77	>77
Apparent Colour	CU	15	15	-	-	-	-	-	-	-
TOC	mg/L	3.5	2.4	2.3	2.2	2.1	31	34	37	40
DOC	mg/L	3.2	2.1	2.1	2.1	2.1	34	34	34	34
UVT	%	83.6	91.1	91.7	91.5	91.7	-	-	-	-
UV Abs (Calc.)	cm^{-1}	0.078	0.040	0.038	0.039	0.038	48	52	50	52
N-Ammonia	mg N-NH_3/L	<0.020	-	-	-	-	-	-	-	-
Aluminum[2]	mg/L	<0.05	-	**0.24**	-	0.07	-	-	-	-

1. On-site raw water turbidity, pH and temperature were 0.48 NTU, 8.35, and 9.9°C, respectively.

Table 4.5 – Direct Filtration Pilot Scale Test Caro Results

Parameter	Units	Reported Values				Performance (%)		
		RW	Floc	F2	F3	Floc	F1	F2
Turbidity	NTU	0.5	1.4	0.1	0.2	-	80	60
pH[1]	-	7.6	7.72	-	-	-	-	-
Alkalinity	mg $CaCO_3$/L	94	92	-	-	-	-	-
Hardness	mg $CaCO_3$/L	110	116	112	111	-	-	-
True Colour	CU	20	20	-	-	-	-	-
Apparent Colour	CU	12	7	6	6	42	50	50
TOC	mg/L	5.0	4.7	3.1	3.9	6.0	38	22
DOC	mg/L	4.8	4.6	2.9	3.1	4.2	40	35
UVT	%	82.6	87.1	88.1	87.8	-	-	-
UV Abs (Calc.)	cm^{-1}	0.083	0.060	0.055	0.057	28	34	32
N-Ammonia	mg N-NH_3/L	<0.020	-	-	-	-	-	-
Aluminum[2]	mg/L	<0.05	-	**0.17**	**0.23**	-	-	-

1. On-site raw water turbidity, pH and temperature were 0.44 NTU, 8.6, and 10.8°C, respectively.
2. MAC is 0.1 mg/L for WTP using alum-based coagulants.

5.0 Conclusions and Recommendations

Based on the data collected during bench-scale testing Peachland Lake water is characterized by low turbidity, alkalinity, hardness, and colour, moderate TOC, DOC and UVT (**Table 4.1**). The pH value is close to neutral. The turbidity, colour and UVT values reported during this study are within the historical values measured during the last two years. Compared to Peachland Creek, Peachland Lake shows lower alkalinity and hardness (i.e., approximately 50 percent), pH, and slightly lower colour levels. Data reported for TOC and DOC showed Peachland Lake values within the range reported for Peachland Creek. Two samples were collected for Peachland Creek, both after the sample collected for Peachland Lake (**Tables 4.4** or **4.5**). The second sample was collected after a rain event and might have led to slightly elevated TOC and DOC levels.

Chemical pre-treatment with Isopac followed by DAF successfully removed colour, TOC, DOC and UV absorbing compounds from the water. Approximately 50 and 75 percent removal was obtained for TOC / DOC and colour, respectively. UVT increased by approximately 12.5 percent. Based on these preliminary results Peachland Lake water is likely amenable to treatment with DAF technology. Moreover, based on the water quality and tests done with Peachland Creek water (refer to Section 4.2) it is likely that direct filtration could be a treatment option for this source. However, additional testing will be required to further screen this treatment approach, namely:

- Lower coagulant doses will be required and should be tested at bench-scale
- Coagulant aid should be tested at bench-scale
- The use of filter aid should be considered during the detailed design phase. A summary survey of what local WTPs are doing would be useful in evaluating this option. Discussions with Metro Vancouver about their operations strategy indicated that the use of filter aids increased filter runs considerably.

Although normally more expensive and costly to operate, membrane filtration can also be considered as a treatment option for Peachland Lake.

The water quality collected for Peachland Creek during pilot-scale testing indicates moderate alkalinity, hardness TOC, DOC and UV absorbing compounds (**Tables 4.4** and **4.5**). The pH value was neutral to slightly basic (i.e., ranging between 7.6 and 8.0). As mentioned previously Peachland Creek showed higher alkalinity and hardness compared to Peachland Lake as well as a slight increase in water pH. The organic content of the water was lower than Peachland Lake during the DAF trial and higher during the direct filtration trial. Differences in water quality should be confirmed as further data is collected. Although it rained during the pilot-test trial it is not clear whether the differences in water quality were due to the rain or just natural water quality variability in the lake and creek.

The data collected indicated that pre-treatment with coagulation / flocculation and DAF can successfully reduce colour, TOC, DOC and increase UVT. Although turbidity increased after pre-treatment, compared to the raw water, it was reduced below GCDWQ limits (i.e., 0.3 NTU) after filtration. Coagulant doses ranging between 30 mg/L and 50 mg/L appeared to be the most suited to achieve treatment goals with DAF treatment. Nevertheless, floc formation was reported as difficult and it is recommended that other coagulants also be tested to evaluate their potential for better floc formation. The challenges faced during piloting did not allow for a thorough investigation of filter run times and headloss development under optimal treatment conditions. Nevertheless, based on the data gathered during testing, it is assumed that standard design criteria can be used to size full-scale filters.

The TOC and DOC values obtained after DAF and filtration are still slightly elevated and may lead to the formation of disinfection by-products (DBP), especially during periods of higher raw water temperatures. Bench-scale simulated distribution system tests could be done to further evaluate this concern.

The data collected during the direct filtration trial suggests that this technology has potential to be implemented at full-scale. However, because of the lower coagulant doses required for direct filtration lower organics removal are obtained with the potential for increased formation of DBP. TOC and DOC removals were calculated between 22 and 40 percent, depending on the filter configuration. Colour removal was approximately 50 percent while UVT increased by five percentage points. As for DAF, DBP formation potential must be evaluated for this technology prior to implementation at full-scale.

Challenges reported during the direct filtration trial did not allow for a thorough investigation of filter performance with regards to filter run length and productivity. Moreover, it was not possible to test filtration rates in the 13 to 14 m/h range as it was initially planned. Therefore, design of a full-scale facility should be based on standard design criteria with flexibility to increase filtration rate based on actual performance data.

For both DAF and direct filtration trials an increase in aluminum concentration was observed after treatment. The values measured are above the maximum acceptable concentration (MAC) level of 0.1 mg/L. This indicates sub-optimal coagulant dosing and should be evaluated. Normally, plants operating properly will show low aluminum in the treated water.

5.1 Recommendations

Both DAF / filtration and direct filtration are promising treatment options and should be considered during future evaluation phases of this project. However, additional testing is proposed to confirm the findings to date, namely:

- Collect seasonal water quality samples for critical parameters to be agreed with IH and the District.
- Evaluate different coagulants with the objective of identifying those with better floc formation potential in addition to organics and turbidity removal; identify optimal dose ranges.
- Evaluate different coagulant aids and coagulant / coagulant aid combinations; identify optimal dose ranges to use for direct filtration.
- Determine seasonal DBP formation potential and compare to data collected in the District's distribution system.

Based on historical water quality data Peachland Lake meets the criteria set by IH to operate without filtration. The Drinking Water Treatment Objectives (microbiological) for Surface Water Supplies in British Columbia (DWTO, May 2012) allow systems to operate without filtration if they specific criteria (as per Section 4.3). If the levels of DBP formed upon reaction with chlorine / sodium hypochlorite are below the

Guidelines for Canadian Drinking Water Quality (GCDWQ) limits that treatment with UV and chlorine disinfection would be sufficient to meet IH's 4-3-2-1-0 Objective (refer to Section 5.2).

In addition to DAF and direct filtration other treatment options can be considered, including membrane filtration and ozone followed by biological filtration. Once the DBP formation potential is identified the best treatment approach can be better outlined after discussions between the District and IH.

5.2 Next Steps

Moving forward, the District's main objective is to identify the best source water and treatment alternative to meet IH's DWTO, which are based on the British Columbia Drinking Water Act (2001), British Columbian Drinking Water Protection Regulation (2003), and the Guidelines for Canadian Drinking Water Quality (GCDWQ). The treatment objectives set by IH are:

- **4:** 4-log virus disinfection / reduction,
- **3:** 3-log *Cryptosporidium* and *Giardia* inactivation / reduction,
- **2:** treatment barriers,
- **1:** treated water turbidity to be <1 NTU
- **0:** 0 CFU/100mL of total coliform bacteria and *Escherichia coli* detected in the treated water

Additionally, depending on whether filtration is required as part of the treatment train lower turbidity targets will apply, as per the GCDWQ. For rapid sand filtration the treated water turbidity limit is 0.3 NTU.

Therefore, treatment options should be evaluated based on treatment targets, assuming that a phased approach could be adopted by the District in moving towards meeting IH's treatment objectives. **Table 5.1** summarizes common treatment alternatives and corresponding treatment goals.

Table 5.1 - Water Treatment Processes Objectives

Treatment Technology	IH Objectives	Observations
Disinfection with Sodium Hypochlorite	0 and 4	May lead to disinfection by-products (DBP) formation.
Disinfection with UV Light	3	Design impacted by raw water UVT
Pre-Treatment / DAF / Filtration	1 and 3	Reduces colour and organic matter and increases UVT.
Pre-Treatment / Direct Filtration	1	UV disinfection required to fully meet 3-log Crypto and Giardia inactivation
Oxidation with Ozone	3	*Giardia* inactivation, only. Results in colour reduction and UVT increase.
Micro / Ultra Membrane Filtration	1 and 3	Likely requires pre-treatment.
Granular Activated Carbon	none	Removed DBP precursors, limiting DBP formation. Results in colour reduction and UVT increase.

Combination of two or more processes outlined above can be done to achieve IH's treatment objectives, including the presence of two treatment barriers.

As an example, the treatment options indicated below may be considered for Peachland Lake and Peachland Creek.

1. **Peachland Lake:**
    1. UV disinfection followed by chlorine disinfection.

       Based on historical water quality data Peachland Lake meets the criteria set by IH to operate without filtration. The installation of UV and chlorine disinfection will allow the District to meet all 4-3-2-1-0 Objectives. However, this treatment option requires confirmation that the level or organic matter present in the raw water does not lead to the formation of disinfection by-products (DBP). Moreover, true colour values must be confirmed.

    2. Direct filtration followed by chlorine disinfection or coagulation, flocculation and DAF, followed by filtration and chlorine disinfection.

       If organic matter removal is required to meet DBP limits in the treated water then pre-treatment followed by filtration is required. The installation of a clarification process is optional and dependent on water quality. It is likely that direct filtration is adequate to treat Peachland Lake. However, a better understanding of coagulation doses required to remove DBP precursor materials is required prior to finalizing the treatment approach.

2. **Peachland Creek:**
    1. Coagulation, flocculation and DAF, followed by filtration and chlorine disinfection. Direct filtration should also be considered as an alternative treatment option.

       Similarly to Peachland Lake, the level of treatment required depends on the source potential to form DBP after reaction with chlorine. Depending on the water reactivity more or less treatment may be required.

Additionally, other treatment technologies are known to treat water of similar quality to Peachland Lake and Peachland Creek, such as membrane filtration, ozone, and activated carbon. These should be investigated in future phases.
In summary, it is recommended that during the next project phase includes the following:

1. Treatment options based on source water, required treatment level, and treated water quality objectives.
2. Development of conceptual WTP footprint requirements and potential site layout arrangements.
3. Evaluation of treatment approaches based on source-to-tap, environmental, and operational considerations.
4. Project cost evaluation based on capital as well as life-cycle costs.

Appendix A:

Jar Testing Apparatus Technical Specifications

Appendix B:

Material Data Safety Sheets

Appendix C:

Dissolved Air Flotation (DAF)

Pilot-Scale Skid Specifications

Appendix D:

Operator Daily Logs