Human health risks associated with surface water impacts after a wildfire: Problem formulation

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Contact

Health Protection Branch
Public Health and Compliance
Alberta Health
23rd Floor, ATB Place North
10025 Jasper Avenue NW
Edmonton, Alberta, T5J 1S6 Canada
Facsimile: 780-427-1470
Telephone: 780-427-4518 in Edmonton
or to be connected toll-free inside Alberta, dial 310-0000
Email: health.ephs@gov.ab.ca

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List of abbreviations

AEP – Alberta Environment and Parks

AHS – Alberta Health Services

AO - aesthetic objectives

BAER - burned area emergency rehabilitation

BCAN - bromochloroacetonitrile

CDBM - chlorodibromomethane

CDW - Committee on Drinking Water

CHE - Committee on Health and the Environment

CM – conceptual model

COPC – chemical of potential concern

CPL - Cache la Poudre

DBAA - dibromoacetic acid

DBAN- dibromoacetonitrile

DBP - disinfection by-products

DCAA - dichloroacetic acid

DCAN - dichloroacetonitrile

DCBM - bromodichloromethane

DOC - dissolved organic carbon

HAA_5 - haloacetic acids

HAN_4 -haloacetonitriles

Hatfield - Hatfield Consultants

HpCDD - heptachlorodibenzodioxin

HxCDD - hexachlorodibenzodioxin

HxCDF - hexachlorodibenzofuran

MAC - maximum allowable concentration

MBAA - bromoacetic acid

MCAA - chloroacetic acid

MEMS - Millennium EMS Solutions Ltd

N – nitrogen

NMR - nuclear magnetic resonance spectroscopy

OCDD - octachlorodibenzodioxin

OG - operational guideline

P – phosphorus

PAC - polycyclic aromatic compounds

PAH - polycyclic aromatic hydrocarbons

PCDDs - polychlorinated dibenzo-p-dioxins

PCDFs - polychlorinated dibenzofurans

POP - persistent organic pollutants

TCAA - trichloroacetic acid

TCAN - trichloroacetonitrile

TCDF - tetrachlorodibenzofuran

TDS - total dissolved solids

TP - total phosphorus

TSS - total suspended solids

TTHM - total trihalomethanes

UK - United Kingdom

US EPA - United States Environmental Protection Agency

USA - United States of America

UV – ultraviolet

UWMN - United Kingdom Upland Waters Monitoring Network

1.0 Executive summary

Alberta Health retained Millennium EMS Solutions Ltd., in collaboration with Hatfield Consultants, to complete a problem formulation for human health risks associated with surface water impacts after a wildfire. The main goal of the work was to better understand and assess potential human health risks from the Horse River Wildfire on surface water bodies that serve as drinking and recreational water sources and apply learnings to future wildfires. The current work used information from published literature in conjunction with water monitoring data made available during the 2016 Horse River Wildfire. Health Canada guidance was used to develop the problem formulation, including the identification of chemicals of potential concern (COPC), potentially operative exposure pathways and receptors, which were illustrated in a conceptual model.

The first task of the problem formulation involved a literature review to identify water quality constituents resulting from wildfires that have implications for human health, specifically in recreational and drinking water sources. The literature review demonstrated that the impact of wildfires on surface water can range substantially from minimal to significant impacts on the quality, quantity, and availability of water. The severity of impact depends on a number of factors including fire severity, timing, intensity of major storms following the fire, forest composition, and fuel types. The primary constituents of interest were categorized as total suspended solids/turbidity, nutrients, major ions, trace metals, polycyclic aromatic hydrocarbons (PAHs), dioxins/furans, fire retardants and disinfection by-products (DBP).

A jurisdictional review of available drinking water guidelines was completed; preference was given to Canadian guidance followed by the United States Environmental Protection Agency (US EPA), and then other international jurisdictions or state agencies. Where a guideline was available from Health Canada, no further review was conducted.

Human receptors and exposure scenarios to surface waters potentially impacts due to wildfires were identified based on potential surface water use including drinking domestic use (e.g., drinking water) and recreational use (e.g., swimming). Domestic and recreational users of impacted surface water may be exposed to water contaminants via ingestion, dermal absorption, and inhalation.

Surface water and drinking water data were available from Alberta Environment and Parks. A water constituent was retained as a COPC if the maximum measured concentration exceeded the available drinking water or recreational water guidelines. Few COPC were retained based on an exceedance of health-based screening guidelines for either drinking and recreational water use; instead the majority were retained on a provisional basis as they were either identified in the literature but not measured in the monitoring data or had no available guideline.

One main difference with respect to recreational water use versus drinking water use, was the bacterial load (*Escherichia coli*, total coliforms), which, although a biological concern for river water, was considered to be of low concern to overall health. The acute risk from surface water impacts after a wildfire was expected to be low for drinking water use versus recreational water use, based on the low relative solubility of a number of provisionally retained COPC and the expectation that water treatment processes would remove many of the COPC identified.

There is a significant introduction of nutrients to surface water following wildfires, the composition and magnitude of which are unique to wildfire disturbance and have potential longer-term implications on the ecology of aquatic systems, with secondary outcomes of potential concern to human health. Elevated nutrient levels, including dissolved organic carbon (DOC), can persist in surface water following a wildfire. Increased nutrient loads can promote biofilm growth interfering with water treatment and are associated with elevated DBP in treated drinking water.

Many of the provisionally retained COPC are not part of standard water analysis suites, possibly in part because a number of these compounds are relatively insoluble. One such compound, retene, is a major product of conifer tree combustion and has been noted in the literature as a chemical indicator of wildfires.

Published literature indicates that wildfire related COPC can impact surface water but the magnitude of impact depends on many factors specific to each scenario. A review of wildfire surface water health impact mitigation was completed. Literature was categorized and focused on forest biomass or fuel management, source water protection techniques, and water treatment emergency preparedness.

Five recommendations were provided, including a review of facilities in Alberta that are most susceptible to wildfire associated surface water risk and generation of a small suite of key indicator compounds to help notify water users of the wildfire related impacts to water.

2.0 Introduction

Alberta Health retained Millennium EMS Solutions Ltd. (MEMS), in collaboration with Hatfield Consultants (Hatfield), to complete a problem formulation for human health risks associated with surface water impacts after a wildfire. The problem formulation is the first step in a risk assessment that identifies chemicals of potential concern (COPC), potentially operative exposure pathways and receptors – leading to the development of a conceptual model (CM) that graphically illustrates this information. A problem formulation does not estimate exposure or quantify risk but is often used to qualitatively discuss health risk.

The current work used surface water chemistry data made available during the 2016 Horse River Wildfire along with published literature. The 2016 Horse River Wildfire was first detected on May 1 in a forested area seven km southwest of Fort McMurray, Alberta. By May 2, the burned or burning area was ~2,600 hectares and growing rapidly. While the rate and spread of the wildfire reduced by mid-May, it was not declared under control until July 4, 2016. The final burned area was estimated at 589,552 hectares, including parts of the urban service area of Fort McMurray (MNP, 2017).

Drinking water for Fort McMurray is sourced from the Athabasca River and treated in a Class IV water treatment plant (RMWB, 2017). In Alberta, water and wastewater facilities are classified based on the population served and the degree of difficulty in operating the facility as defined by Alberta Environment and Parks (Alberta Government, 2020). The significant burned area that drains into the Athabasca River, including approximately 50 km adjacent to the river upstream from the treatment facility intake, made this a unique situation to evaluate potential human health risk from wildfire impacted surface water.

The scope of work and problem formulation methodology are presented below, followed by the literature overview organized by chemical group (section 3) which was the basis for identifying wildfire constituents of interest in the problem formulation (section 4). An overview of the surface water and drinking water data that was screened to identify chemicals of potential concern, along with receptors and exposure pathway follow in the problem formulation. The health implications of identified chemicals of potential concern and Alberta drinking water guidelines are presented as sections 5 and 6, respectively. Methods to mitigate impacts to water following a wildfire are presented in section 7, following by conclusions and recommendations. Figures are provided in Appendix A, the literature review methodology and summary of key papers are provided in Appendix B, and Appendix C presents the water data, jurisdictional guidelines, and chemical screening.

2.1 Goals

The overall goals of this work were:

1. utilizing analytical surface water data from the Horse River Wildfire and scientific literature, identify constituents that could present or promote chemical or biological human health risks from drinking and recreational water sources; and
2. to apply the findings from goal 1 to future wildfire events in Alberta.

2.2 Objectives

The following objectives were developed to help guide the work:

1. identify chemicals in surface water for which exposure through drinking or recreational activities could pose a potential risk to human health following a wildfire;
2. provide a comparison of jurisdictional guidelines to measured surface water quality data after the Horse River wildfire, discuss guideline applicability to human health, and discuss emergency guidelines (acute exposure limits);
3. address community concerns regarding the quality of waters residents may use for activities such as swimming, bathing and other sports, and the connection of water quality to human health;
4. inform and/or enable government agencies to more effectively prepare and respond to potential impacts that wildfires may have on surface water used as drinking water and for recreational purposes;
5. provide insight into the next steps for human health risk assessment by highlighting relevant exposure pathways, COPC, and receptors; and
6. support the needs of all departments/agencies as they make policy and operational decisions regarding surface water quality.

2.3 Scope of work

The scope of work for the problem formulation included:

- review of literature regarding impacts of wildfire to water quality in relation to drinking water (supply, storage, or treatment) and recreational use;
- review of water quality guidelines relevant to human health protection in Alberta;
- selection of chemicals related to wildfires;
- screening of surface water analytical data against health-based guidelines to identify COPC;
- identification of relevant human receptors;
- identification of relevant exposure pathways;
- development of a conceptual model; and
- discussion of prevention/mitigation strategies for COPCs, receptors and pathways.

2.3.1 Out of scope items

1. The impact of surface water on fish populations and habitat, fish tissue quality or the quantity and quality of other traditional food sources is not within the scope of this activity.
2. Swimming pools (with treated water) in homes or community recreational centers are not classified as recreational water for the purposes of this activity.
3. Consideration of the impacts of wildfire to groundwater and latent discharge of groundwater into surface water was beyond the scope of this activity.

3.0 Problem formulation methodology

The overall methodology for the problem formulation followed guidance presented in Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (Health Canada, 2012a). The components of a problem formulation include:

- identification of potential wildfire related chemicals;
- chemical screening to identify COPC;
- identification and description of potential human receptors;
- identification of operable exposure pathways; and
- conceptual model development indicating sources, pathways, and receptors.

3.1 Key questions

Throughout the development of the problem formulation, the following five key questions were used to help focus the work.

1. What impact do wildfires have on surface water quality?
2. What are the chemicals of interest to human health in surface water impacted by wildfires?
3. What are the surface water-related human health impacts due to wildfire?
4. How can wildfire impacts on water quality be prevented, mitigated, or otherwise minimized before, during, and after wildfires?
5. In the absence of drinking water and surface water guidelines (with respect to human health) applied in Alberta, are health-based guidelines available from other jurisdictions?

4.0 Literature search and review

A literature review was completed to identify chemicals that could impact water quality and human health following a wildfire. Prevention and/or mitigation measures for water quality impacts were also reviewed.

A detailed literature search methodology and summaries of the selected articles are presented in Appendix B. The methodology involved:

- Planning and search - A total of four key questions (1-4 listed above) and 37 primary search terms were selected and searched in Google Scholar, Science Direct and PubMed. Articles were selected that presented effects of wildfire and fire-retardant use on surface water, drinking water and recreation water quality.
- Narrowing search results - primary search terms were combined to find specific articles directly related to key questions, the review focused primarily on the past 10 years of published articles and grey-literature reports.
- Document screening - A high-level review of all retrieved documents was conducted, and 75 documents identified in the literature search were thoroughly reviewed to identify information relevant to the key questions.
- Data analysis and reporting - 36 articles were identified for inclusion in the review. Each article was summarized in terms of study objectives, high level methodology, key results/trends, along with conclusion/recommendations, if appropriate.

The following preliminary conceptual model of wildfire related impacts on water quality (Figure A, page 11) was used to guide the literature review.

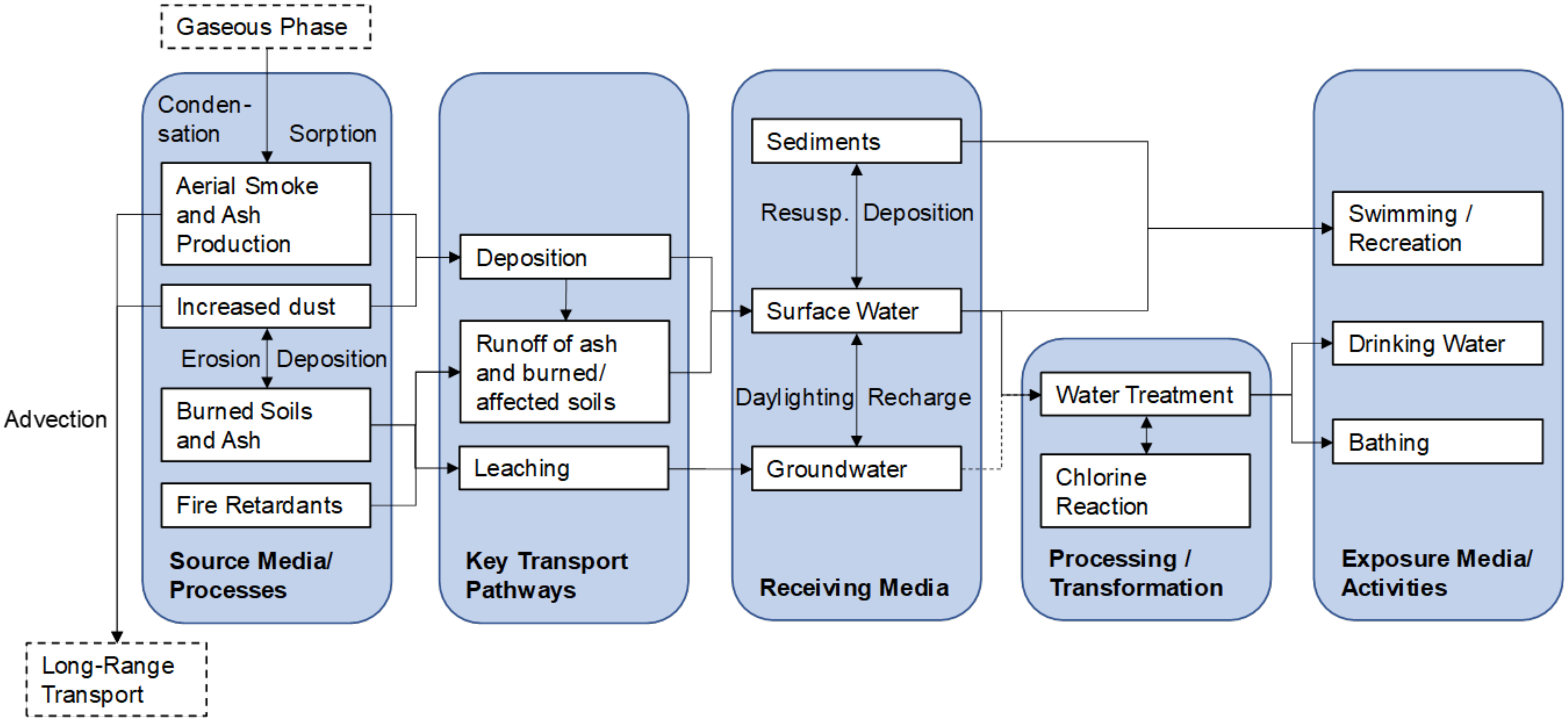

FIGURE A **PRELIMINARY CONCEPTUAL MODEL SHOWING THE SOURCES, TRANSPORT PATHWAYS, RECEIVING MEDIA, PROCESSING/TRANSFORMATION ACTIONS AND EXPOSURE MEDIA/ACTIVITIES FOR CONSTITUENTS OF INTERESTED IN THE WATER QUALITY AFTER A WILDFIRE.**

Dashed arrow – secondary pathway, not the focus of this review.

4.1 Impact of wildfires on surface water quality

4.1.1 Overview

The literature review demonstrated that wildfires can impact the quality, quantity, and availability of surface water downstream of the fire. A number of factors including fire fuel, seasonal timing and weather intensity can influence the severity of impact.

Fire severity has been defined by the degree of destruction (consumption) of above ground and below ground fuels (Chafer 2008; Santín et al., 2015); and is divided into the five following classes:

Low: ground and understory (<0.5m high) fuels burnt, canopy unaffected;
Moderate: ground and understory (<4m high) fuels burnt, canopy unaffected;
High: ground and understory (<4m high) fuels burnt, canopy scorched;
Very high: all available fuels consumed, including stems <0.5cm thick; and
Extreme: all available fuels consumed, including stems <1cm thick.

Many communities rely upon forested watersheds as a domestic water source. Forest biomass is composed of many elemental substances, including but not limited to carbon, nitrogen, phosphorous, trace metals, and a diverse range of organic compounds. When wildfires burn biomass, detritus and soil organic matter, ash is produced. Ash contains minerals and oxidized organic substances (Santín et al., 2015). The lighter weight of ash (relative to dust) makes it highly mobile, able to be transported by wind, water erosion, and surface runoff to surface depressions, foot-slopes, streams, lakes, and reservoirs (Bodi et al., 2014).

Ash composition and character are variable and dependent upon a range of factors, including for example combustion temperatures, fire fuel types, and fire severity. In the case of fire temperatures less than 450°C, the combustion of organic substances is largely incomplete, and the remaining ash is organic-rich, with organic carbon being the main component (Bodi et al., 2014). At temperatures exceeding 450°C, most organic carbon is fully combusted and lost as carbon dioxide, producing mineral ash which has an elevated pH when in solution. This mineral ash is composed primarily of inorganic carbonates of calcium, magnesium, sodium, potassium, silicon, and phosphorous; while temperatures exceeding 580°C produce inorganic oxides of these metals and metalloids (Bodi et al., 2014). Depending on burn severity, the organic carbon released from some types of wildfire ash can have significantly increased aromaticity (i.e., presence of benzene-like rings) (Wang et al., 2015).

Wildfire increases surface water runoff and peak flow in rivers and streams by removing vegetation that could retard surface transport, decreasing transpiration, and increasing soil hydrophobicity (Robichaud et al., 2000; Stavi et al., 2017). Increases in runoff and peak flow are largest in the first year following the wildfire. Elevated concentrations of suspended solids, trace metals, and other inorganic and organic constituents in surface water coincide with peak discharge in post-fire runoff (Khan et al., 2015).

The following sections summarize the chemicals or chemical mixtures of interest in surface water following a wildfire as highlighted in the literature.

4.1.2 Total suspended solids

Total suspended solids (TSS) are a complex chemical mixture comprised of various particulate components which become suspended in solution. Wildfires generally increase sediment yields, resulting in increased TSS concentrations that can lead to problems for water treatment plants and potable water supplies (Emelko et al., 2011; Cawley et al., 2018), resulting in temporary plant closures or treatment plant upgrades to deal with increased TSS loads (Smith et al., 2011).

Runoff and peak flow increase following severe fires due to removal of vegetation which decreases interception and transpiration processes, resulting in erosion and sediment transport. Reported increases in runoff are site-specific and variable, but surface runoff can increase by over 70 per cent per cent compared to pre-fire (Robichaud et al., 2000). Increases in runoff and peak flow are largest in the first year following fire.

Increased post-fire sediment erosion is caused by increases to flow, erodibility of combustion by products, and loss sediment holding root architecture (Emelko et al., 2011; Smith et al., 2011). Increases in TSS are particularly large during extreme precipitation events post-fire. During post-fire precipitation events, large areas of a watershed can become hydrologically connected to rivers with burned portions of the catchment delivering sediment and ash. Fire can also increase susceptibility to mass wasting (slope movement) which can greatly increase sediment influx. The potential for debris avalanches can increase in watersheds with sufficient slope, when availability of debris increases and slope stability decreases post-fire (Robichaud et al., 2000).

Post-fire TSS concentrations have increased up to ten-fold compared to pre fire, depending on the size and severity of the fires (AEP 2018; Burke et al., 2013; Jensen et al., 2017). Reported first year post-fire suspended sediment exports varied from 0.017 to 50 tons/ha/year across a large range of catchment sizes (0.021 to 1,655km^2). This represented an estimated increase of 1 to 1,459 times unburned exports. Maximum reported concentrations of total suspended solids in streams in North America and Australia for the first year after fire ranged from 11 to 500,000 mg/L (AEP 2018; Smith et al., 2011). It has been reported that TSS needed three years or more to be returned to pre-fire levels (Smith et al., 2012).

High levels of TSS can shield pathogens from the effects of disinfection chemicals in drinking water (BCMOE 1997). The organic portion of TSS can act as a source of nutrients for microorganisms, thereby promoting their growth (Singleton 1985). Many trace metals, organic compounds, and nutrients are adsorbed or associated with TSS and thus correlated with concentration increases (Smith et al., 2011).

4.1.3 Nutrients

Elevated concentrations of nutrients, most notably nitrogen and phosphorus, are commonly reported post-wildfire (Bladon et al., 2008; Emelko et al., 2011; Smith et al., 2011). Wildfires have been shown to increase watershed nitrogen and phosphorus exports by 0.3 to 921-fold higher than unburned watershed, with maximum recorded exports of 27 kg/ha of total nitrogen and 3.2 kg/ha of total phosphorous. Variable such as fire size, severity, watershed area and geographical location influence nutrient loading rates (Lane et al., 2008; Smith et al., 2011; Stein et al., 2012). Nutrients transported as particulate matter dominate the post-fire years. Particulates have been found to transport 69 per cent of the total nitrogen and 94 per cent of the total phosphorus over the first year, and 68 per cent of the total nitrogen and 86 per cent of the total phosphorous over the first three years (Lane et al., 2008).

Bladon et al., (2008) studied all nitrogen species in burned and unburned watersheds in the southwestern Rocky Mountains of Alberta after the 2003 Lost Creek wildfire. Concentrations of inorganic nitrogen species including nitrate (500 µg/L) and ammonium (9 µg/L) were 6.5 and 1.5 times greater in severely burned watersheds than in unburned watersheds during the first year post-fire. At the same time, total nitrogen (1,074 µg/L) and dissolved organic nitrogen (528 µg/L) in severely burned watersheds were 5.3 and 4.1 times greater, respectively, relative to unburned watersheds.

Although a rapid decline in mean concentrations and production of most of the nitrogen species was observed in the burned watersheds over the three years after the fire, nitrate, total dissolved nitrogen, and total nitrogen concentrations remained elevated during snowmelt freshet and following precipitation events during this time. Stein et al., (2012) reported two- to four-fold higher nitrate+nitrite concentrations from burned areas (approximately 2.4 mg/L) after a wildfire in southern California compared to unburned natural areas. Writer and Murphy (2012) reported nitrate concentrations of 1.3 mg/L during the first flush storm after the Fourmile Creek fire (California) and as much as 9 mg/L during the summer thunderstorms, coinciding with higher sediment transport.

The mean total phosphorus (TP) concentrations in streams draining the burned watersheds are reported to be an order of magnitude higher than in streams draining unburned watersheds, ranging from 1 to 42 mg/L TP in the burned watersheds (Emelko et al., 2011; Stein et al., 2012; Hohner et al., 2016).

The increase in dissolved organic carbon (DOC) concentrations and exports due to wildfire are reported to be one to two orders of magnitude higher than unburned watersheds, concentrations being ranged from 1 to 70 mg/L in the burned watersheds and remained elevated in the first two years post-fire (Emelko et al., 2011; Writer and Murphy 2012). In contrast, some studies reported that there were negligible differences in DOC concentrations between burned and unburned watersheds (e.g., Smith et al., 2011; Writer et al., 2014; Jensen et al., 2017;) mainly due to low severity of the fires.

Persistent elevated concentrations of nitrogen and phosphorus promotes algal and cyanobacterial blooms, resulting in production of algal toxins or microcystins (Emelko et al., 2011; Khan et al., 2015). Increased concentrations of bioavailable carbon and phosphorus can increase microbial growth and activity in distribution systems and prolong the survival of culturable *Escherichia coli* and other coliform bacteria in water.

DOC leached from wildfire ash may change the formation of drinking water disinfection by-products (see later Section 3.1.9), compared to unburned forest floor detritus. For example, it was reported that organic matter leached from wildfire ash led to reduced production of trihalomethanes and haloacetic acids, but elevated formation of haloacetonitrile following chlorination, and N-nitrosodimethylamine following chloramination (Wang et al., 2015; Hohner et al., 2016;).

4.1.4 Major ions

Elevated concentrations of both negatively charged ions (anions) (e.g., chloride, sulphate, fluoride, nitrate, and bicarbonate) and positively charged ions (cations) (e.g., calcium, magnesium, sodium, and potassium) have been measured in streams receiving runoff from wildfire-affected areas.

Concentrations of these major anion and cation concentrations were 1.5 to 4.7 times the pre-fire concentrations soon after a fire (Rhoades et al., 2011; McCleskey et al., 2012; Burke et al., 2013; Costa et al., 2014; Mansilha et al., 2017). Burke et al., (2013) reported two, three, and four times higher post-fire concentrations for magnesium, calcium, and potassium than pre-fire concentrations, respectively but no differences were noted for sodium concentrations. McCleskey et al., (2012) reported similar degree of differences for these cation concentrations due to Fourmile Canyon fire in Colorado. They also reported two times higher sodium, 1.5 times higher fluoride, 4.5 times higher sulphate, and 2.8 times higher chloride concentrations in water samples in burned watershed, compared to water samples in unburned watershed. These constituents may have leached from burnt plant litter and ash deposits (Smith et al., 2011). Combustion may also increase sulphate concentrations through oxidation of sulfur in soil organic matter. The ion concentrations observed in the articles listed above were influenced by drought conditions, rainwater infiltration, and/or groundwater mineralization and dilution. However, in almost all cases, increased ion concentrations attenuated within one year following the wildfire to guidelines closer to pre-fire conditions.

These major ions listed above contribute to the total dissolved solids (TDS). A common issue with elevated TDS concentrations is with aesthetics (taste), which could impair the use of waters as a drinking water source. An additional effect of some cations (in particular sodium and magnesium) can be scaling of pipes over the long-term.

4.1.5 Trace metals

Forest biomass acts as a sink for regional urban pollutants, including metallic components of air pollutants. Consequently, wildfires may liberate large quantities of contaminants, leading to elevated concentrations of substances, including arsenic, aluminum, barium, cadmium, chromium, copper, iron, lead, mercury, nickel, manganese, and zinc in sediment and water in local streams. The increase in concentrations and loads of these trace metals from pre-fire to post-fire has been observed to range from one order of magnitude to 150-fold (Emelko et al., 2011; Smith et al., 2011; McCleskey et al., 2012; Bladon et al., 2014; Costa et al., 2014; Abraham et al., 2017; Mansilha et al., 2017;). The peak metal concentrations generally occurred within the first year of the wildfire followed by gradual attenuation in the subsequent years depending on rainstorm events. Examples of significant impacts of metals to source surface waters for the drinking water quality include:

- the 2003 eastern Victorian Alpine Fire (Australia) which generated debris flow in the upper Buckland River in which recorded maximum iron, arsenic, chromium, and lead concentrations were respectively 2,467, 40, 18, and 98 times the respective Australian drinking water guidelines (Leak et al., 2003 cited in Abraham et al., 2017);
- the Lost Creek wildfire in Alberta – two years after the fire, total mercury concentrations were higher in discharge from post-fire salvage-logged watersheds than in discharge from the reference watershed and exceeded both the American and Canadian drinking water guidelines of 2 µg/L and 1 µg/L, respectively (Emelko et al., 2011);
- the Fourmile Canyon wildfire (data provided by McCleskey et al., 2012 as an appendix) for which the most affected metals included manganese (151 times the reference watercourse), followed by aluminum (71 times), iron (50 times), cobalt (38 times), nickel (24 times), cadmium (19 times), chromium (10 times), and barium (7 times); and
- a case in Portugal, where it was estimated that approximately 350g manganese per hectare of burnt forest were released to waterways (Costa et al., 2014).

Increased wildfire frequency combined with intensified post-fire rainfall may increase metal concentrations in surface water.

4.1.6 Polycyclic Aromatic Hydrocarbons

Polycyclic Aromatic Hydrocarbons (PAHs) are a unique class of organic pollutants containing two or more fused aromatic rings of carbon and hydrogen atoms. Recent studies indicate that wildfires are one of the contributors for elevated PAHs in wildfire-affected surface waters (Vila-Escalé et al., (2007); Stein et al., 2012; Ahad et al., 2015; Mansilha et al., 2017).

Following wildfire, the total PAH concentration was 1.2 to 4.0 times higher in the burnt watersheds than in the unburnt control watershed (Stein et al., 2012; Mansilha et al., 2017). For the Caramulo Mountain fire (Central Portugal, August 2013), Mansilha et al., (2017) reported that the most detected PAHs in water samples from surface waters and springs affected by wildfires included naphthalene (25 per cent), benzo(ghi)perylene (17.6 per cent), indeno(1,2,3-cd)pyrene (13.6 per cent), benzo(b)fluoranthene (9.4 per cent), benzo(a)pyrene (6.8 per cent), and benzo(k)fluoranthene (6.5 per cent). Benzo(a)pyrene concentrations exceeded the drinking water guideline (European Union Council Directive 98/83/EC), up to five months after this wildfire with overall PAH concentrations declining to non-burned levels eight months after the fire. Fingerprinting analysis by Mansilha et al., (2017) attributed the PAH inputs to combustion, suggesting a wildfire source.

Vila-Escalé et al., (2007) reported that dissolved PAH concentrations after a fire positively correlated with precipitation, runoff, and leaching. Particulate PAHs PAH concentrations approached background levels 15 months after the fire. The rate of elimination of fire-derived PAHs depended mainly on the intensity and frequency of precipitation indicating that the time of the year a wildfire takes place has implication on the timing of mass movement into aquatic systems (Vila-Escalé et al., 2007; Stein et al., 2012;).

Ahad et al., (2015) investigated the possible sources of PAHs in surface sediments in four Saskatchewan lakes influenced by both oil-sands mining activities and wildfires. They concluded that the boreal wildfires were the principal source of PAHs, especially retene.

The United States Environmental Protection Agency (US EPA) has identified 16 PAHs as priority pollutants due to potential human health and ecological hazards. Seven carcinogenic PAHs were identified in a watershed receiving wildfire runoff and accounted for 45 per cent of the total PAHs concentration (Mansilha et al., 2017).

4.1.7 Dioxins and furans

Dioxins and furans are a group of over 200 chemicals that are produced from combustion. Although wildfires are known to be a potential source of dioxins and furans to the atmosphere (Environment Canada and Health Canada 1990), the literature identifying dioxins/furans in surface waters affected by wildfires is limited.

Gabos et al., (2001) investigated dioxins and furans in sediments in northern Alberta where extensive wildfires occurred. The low concentrations of dibenzo-*p*-dioxin and dibenzofurans (PCDD/F) and the similar profiles of these chemicals among sampling sites suggested that the contributing sources were background atmospheric deposition rather than an influence of specific wildfires.

Salamanca et al., (2016) investigated whether the observed peaks in PCDD/F concentrations recorded during a long-term monitoring program in the coastal area (Bio-Bio Region) of central Chile were related to wildfires. The recorded peak PCDD/F concentrations coincided with a major wildfire in the Bio-Bio Region. Dioxin and furan concentrations in the system recovered to local background concentrations within less than a year, suggesting that episodic increases in these chemicals generated by wildfires do not persist for the long-term.

However, based on their chemical properties, dioxins and furans are believed to persist in the environment due to low solubility, lipophilic properties, long half-lives, and a considerable resistance to biological and chemical degradation (Gabos et al., 2001). They are slowly eliminated from aquatic organisms resulting in a high potential for food chain bioaccumulation resulting in potentially elevated concentrations in fish and other aquatic organisms consumed by people (Gabos et al., 2001).

4.1.8 Fire retardants

Fire suppressants or retardants are often applied to reduce the spread or severity of wildfires by starving the fire of fuel. Typically, the fire retardants are water (90 per cent) formulations that contain a variety of chemical constituents, including ammonia, phosphorus, and cyanide.

The chemicals typically found in fire retardants (ammonia, phosphorus, and cyanide) are also reported to be detected in wildfire ash as well as sediment and water in recently burnt watersheds (see review of Smith et al., 2011); meaning that their presence cannot be linked only to fire retardant applications.

Crouch et al., (2006) evaluated ammonia, phosphorus, and cyanide data from four wildfires that were fought with fire retardant to determine whether these chemicals originated primarily from fire or from retardant use. Their findings suggested no difference in ammonia, phosphorus, and total cyanide concentrations in streams in burned areas where retardant was not used, compared to areas where retardant was applied. These results suggest that the application of wildfire retardant had minimal effects on surface water quality.

While the use of fire retardants could result in increases in of ammonium salts and ferro-cyanides in receiving surface waters, the magnitude of this increase would be related to the specific use pattern of the fire-retardant in the watershed. The majority constituents of these products are water soluble, with potential for overland transport during rain events.

4.1.9 Disinfection By-products (DBPs)

Disinfection by-products (DBPs) are a group of chemicals formed during drinking water treatment when disinfectants (typically chlorine) react with organic and inorganic material in the source water. DBPs formed during water treatment are divided into two groups based on their composition: carbonaceous DBPs including total trihalomethanes (TTHM) and haloacetic acids (HAA5), and nitrogenous DBPs including haloacetonitriles (HAN4) and chloropicrin.

Wildfire increases DOC concentrations in surface waters (discussed in Section 3.1.3 above) and this increased DOC may lead to increased DBP formation during water treatment. n a recent study, Cawley et al., (2018) reported DBP concentrations in wildfire-affected sediment leachate in relation to DOC. All sediment leachates showed consistently higher nitrogen based HAN4 and chloropicrin concentrations compared to background river water. It was concluded that the leachates of the sediments containing burned material have different characteristics.

Wang et al., (2016) reported that an increase in leaching after wildfire due to precipitation resulted in increased DOC reactivity in surface water to form carbonaceous TTHM and HAA_5, but not for nitrogenous base haloketones, HAN_4 or N-nitrosodimethylamine. Writer et al., (2014) also reported increased DOC and DBP concentrations in the Cache la Poudre river watershed due to post-fire thunderstorms and spring snowmelt, relative to base-flow conditions.

Drinking water guidelines include health-based thresholds for DBP (Health Canada, 2017), wildfires increase the quantity and change the nature of the DOC that enters treatment plants effecting the quantity and composition of DBPs formed.

4.2 Jurisdictional guidelines search

4.2.1 Drinking water guidelines

The Health Canada Guidelines for Canadian Drinking Water Quality (2017) were used as the primary reference to for drinking water quality guidelines. Where no drinking water quality guideline was available from Health Canada, a jurisdictional guideline search was completed to identify an appropriate drinking water quality guideline for the parameter.

In the absence of guidance, the following regulatory agencies were reviewed to identify health-based drinking water guidelines:

- Alberta Environment and Parks (AEP)
- United States Environmental Protection Agency (US EPA)
- California Environmental Protection Agency
- World Health Organization
- Japan Water Works Association
- European Environment Commission
- Water Quality Australia
- British Columbia Ministry of Environment and Climate Change
- Ontario Environment and Energy
- Quebec Ministry of Environment
- Michigan Department of Environment

The lowest available screening guideline from the above sources was applied. The results of the jurisdictional guideline review are listed in Table C.3 in Appendix C.

4.2.2 Recreational water quality guidelines

The Health Canada Guidelines for Canadian Recreational Water Quality (2012) and the AEP Environmental Quality Guidelines for Alberta Surface Waters (2018) were used as the primary references for recreational water quality guidelines. Where no guideline was available a jurisdictional guideline search was completed to identify a recreational water quality guideline. Recreational water quality guidelines protective of human health were the focus of the search.

Regulatory agencies reviewed to identify recreational water guidelines included: the US EPA, the World Health Organization, the European Environment Commission, and Water Quality Australia. Regulatory agencies in California and Japan were reviewed who did have published recreational water quality guidelines. The results of the search are listed in Table C.4 in Appendix C.

A cursory review indicated that acute exposure limits were not identified for recreational water quality guidelines, rather published guidelines are considered to be applicable to chronic exposure.

5.0 Problem formulation

5.1 Identification of wildfire-related constituents of interest in water

As discussed above, wildfires have been documented in the scientific literature to impact water quality. The major water quality wildfire-related constituents of interest that may influence drinking water quality are listed in Table 1 (page 19). Some constituents may not be relevant to human health (e.g., dissolved oxygen) or may be indicators of other constituents (e.g., conductivity as an indicator of TDS); for completeness, these constituents were retained.

5.1.1 Constituents of interest measured in surface water

Surface water data from grab samples from three Athabasca River monitoring stations, collected during the Horse River Wildfire were provided from Alberta Environment and Parks (AEP). The data were statistically evaluated, comparing background and wildfire impacted surface water collected during the Horse River Wildfire (Appendix C, Table C.1). Data from three stations were provided, including one background location - Station No. AB07CC0130 located at Grand Rapids (Appendix A, Figure 1).

Regarding the background station, in an email sent on October 23, 2018, Government of Alberta water quality scientist Dr. Craig Emmerton noted that this location did experience some smoke exposure; however, the impact of fire-related deposition is expected to be low. A multivariate statistical assessment of the polycyclic aromatic compound signatures at this location relative to ash and bitumen signatures indicated an ash related signature at the beginning of May, before returning to the more typical bitumen signature. Therefore, the data from the beginning of May was omitted and data from May 18 through August 30, 2016 were selected for inclusion in the data set and is thought to reflect natural background chemistry from that same time-period with an expected low influence of any wildfire impacts.

Data from two monitoring stations within the wildfire impacted area were also provided (Appendix A, Figure 1). Station AB07CC0030 is close to the intake for the Fort McMurray water treatment plant but is upstream from much of the urban burn area. Data from a second monitoring station AB07DA0062 further downstream was also provided. The second station is located downstream from much of the burned urban area and after the confluence with the Clearwater River; the drainage of which was also heavily impacted by wildfire. The maximum from both wildfire impacted stations was used for screening; however, it is noteworthy that the majority of the maximums were measured at the station close to the drinking water plant intake.

Those compounds that had not been identified in the literature but were measured and determined to be statistically higher in wildfire impacted surface water compared to the background location, were added to the constituent list. This process ensured that all compounds found to be elevated both in the literature and statistically elevated in surface water were included. Added constituents included: *Escherichia coli*, total coliforms, total alkalinity (Calcium Carbonate), boron, cobalt, strontium, uranium, petroleum hydrocarbon fractions F2 through F4, and naphthalene. Surface water from this region of the Athabasca River is known to contain a signature of naturally occurring PAHs sourced from bitumen. In some cases, a statistical significance was driven by an elevated background concentration. Compounds were not considered if their mean concentration in background water was higher than their mean concentration in wildfire impacted water.

5.2 Contaminant screening

5.2.1 Drinking water contaminants of potential concern

Drinking water data from two separate sampling events (May and June 2016) were provided from AEP (Appendix C, Table C.2). In an email sent on November 22, 2018, drinking water operations specialist Ryan Vettorazzo indicated the earlier sampling data from late May was collected from various locations in the distribution system during the fire including reservoirs, the water treatment plant and the Northern Light Regional Health Centre. The later dates in June represent sampling of the distribution system after each of the listed reservoirs was drained, cleaned, and re-filled, whereas the May data represents water during the period when the distribution system was considered untreated.

Table 1 - Wildfire related constituents of interest in water

Group	Constituents of interest	References
TSS/ Turbidity	turbidity total suspended solids (TSS) pH Conductivity dissolved oxygen	Emelko *et al*., 2011; Smith *et al*., 2012; Burke *et al*., 2013; Costa *et al*., 2014; Hohner *et al*., 2016; AEP 2018.
Major nutrients	ammonia/ammonium nitrate/nitrate total nitrogen total phosphorus dissolved organic carbon	Crouch *et al*., 2006; Bladon *et al*., 2008 and 2014; Emelko *et al*., 2011; Smith *et al*., 2011 and 2012; Santín *et al*., 2015; Hohner *et al*., 2016; Cawley *et al*., 2018.
Major ions	sodium calcium potassium magnesium chloride fluoride sulphate total dissolved solids (TDS)	Smith *et al*., 2011, 2012; McCleskey *et al*., 2012; Burke *et al*., 2013; Costa *et al*., 2014; Santín *et al*., 2015
Metals	arsenic aluminum barium cadmium chromium copper Iron lead manganese mercury nickel silicon zinc	Emelko *et al*., 2011; Smith *et al*., 2011; Burke *et al*., 2013; Bladon *et al*., 2014; Santín *et al*., 2015; Abraham *et al*., 2017; Jensen *et al*., 2017; Mansilha *et al*., 2017.
PAHs	benzo(a)pyrene and other PAHs *Other PAHs include:* anthracene dibenzothiophene chrysene fluoranthene fluorene phenanthrene perylene pyrene retene (major fingerprint indicator of forest fire) benzo[a]anthracene benzo[b]fluoranthene benzo[k]fluoranthene benzo[e]pyrene benzo[ghi]perylene benzo[ghi]perylene indeno[1,2,3-cd]pyrene dibenz[a,h]anthracene substituted PAHs	Vila-Escalé *et al*., 2007; Stein *et al*., 2012; Ahad *et al*., 2015; Mansilha *et al*., 2017.
Dioxins/furans	2,3,7,8-TCDD and other PCDD/Fs	Gabos *et al*., 2001; Salamanca *et al*., 2016
Fire retardants	ammonium sulphate ammonium phosphate ammonium polyphosphate diammonium phosphate sodium hexacyanoferrate sodium-ferrocyanide cyanide	Angeler *et al*., 2004; Crouch *et al*., 2006; Song *et al*., 2014
Disinfection By-products (drinking water only)	trihalomethanes haloacetonitriles haloacetic acids halonitromethanes nitrosamines chloral hydrate	Writer *et al*., 2014; Hohner *et al*., 2016; Wang *et al*., 2016; Cawley *et al*., 2018

Constituents were retained as a COPC if maximum measured concentrations exceeded available drinking water guidance; only the June data was screened for COPC as treated drinking water. Preference was given to Canadian guidance followed by the United States Environmental Protection Agency (US EPA), and then other international jurisdictions or state agencies. If a guideline was available from Health Canada, no further jurisdictional review was conducted. Typically, the screening process would include comparison to background; however, several constituents of interest were not measured and, since water chemistry varies considerably within seasons and over years, comparing to background data from other years would not be defensible. Although, total organic carbon and turbidity measurements prior to the fire (2015 Annual Report -Fort McMurray Waterworks System) were above drinking water guidelines. Further discussion on the assessment of turbidity is presented below.

The screening process for drinking water COPC is presented in Appendix C, Table C.3, and summarized in Table 2 below. The COPC identified were:

- measured above a drinking water guideline;
- without an applicable screening guideline; or
- identified as a constituent of interest in the literature search but not measured in drinking water.

Table 2 - Selected COPC for treated drinking water

COPC	Measured above screening guideline	No available screening guideline	Not measured
Total suspended solids		√	
Turbidity	√		
Total organic carbon	√		
Aluminum	√		
Silicon		√	
Benzo(e)pyrene		√	√
C1-C3-chrysenses/benzo(a)anthracene		√	√
C1-C4-fluoranthes/pyrenes		√	√
C1-C3-fluorenes		√	√
C1-C4-phenanthrenese/anthracenes		√	√
Dibenzothiophene		√	√
Perylene		√	√
Retene		√	√
Tetrachlorodibenzodioxin			√
Ammonium phosphate		√	√
Ammonium polyphosphate		√	√
Ammonium sulphate		√	√
Diammonium phosphate		√	√
Sodium ferrocyanide		√	√
Sodium hexacyanoferrate		√	√
Chloral hydrate		√	√
Haloacetonitriles		√	√
Halonitromethanes		√	√

5.2.2 Recreational water contaminants of potential concern

The refined constituent of interest list (Table 1) was also carried to screen for recreational COPC (Table 3) using the maximum concentration measured in surface water collected from the wildfire exposed stations of the Athabasca River. The screening process for recreational water COPC is presented in Appendix C, Table C.4, and summarized in Table 3 below. The COPC identified were:

- measured above a recreational guideline; or
- above a drinking water guideline (if no recreational guideline available); or
- without an applicable screening guideline; or
- identified as a constituent of interest in the literature search but not measured in surface water.

Disinfection by-products do not apply to untreated river water and were not carried as constituents of interest in the recreational exposure scenario. Additions to Table 3 below for recreational COPC include: *Escherichia coli*, total coliforms, fluoride, iron, manganese, and cyanide (not measured but retained). More constituents of interest were measured in surface water compared to drinking water.

Table 3 - Selected COPC for recreational water use

COPC	Measured above screening guideline	No available screening guideline	Not measured
Escherichia coli[1]	√		
Total coliforms[1]	√		
Total suspended solids		√	
Turbidity	√		
Total organic carbon	√		
Aluminum	√		
Fluoride			√
Silicon		√	√
Benzo(e)pyrene		√	
C1-C3-chrysenses/benzo(a)anthracene		√	
C1-C4-fluoranthes/pyrenes		√	
C1-C3-fluorenes		√	
C1-C4-phenanthrenese/anthracenes		√	
Dibenzothiophene		√	
Perylene		√	
Retene		√	
2,3,7,8-TCDD and other PCDD/Fs			√
Tetrachlorodibenzodioxin		√	√
Ammonium phosphate		√	√
Ammonium polyphosphate		√	√
Ammonium sulphate		√	√
Cyanide			√
Diammonium phosphate		√	√
Sodium ferrocyanide		√	√
Sodium hexacyanoferrate		√	√

5.3 Identification of receptors

Human receptors and exposure scenarios were identified based on potential surface water use including surface water that is used for drinking or domestic purposes, and surface water used for recreation (e.g., swimming).

Domestic users of surface water would be assumed to experience daily, year-round exposure. Potential domestic receptors include all age groups (infants, toddlers, children, teens, and adults), consuming water according to their age-specific water ingestion rates (Health Canada, 2012a).

Recreational users of surface water include any leisure activity where a person may be exposed to the surface water. Receptors include all age groups: infants, toddlers, children, teens, and adults. Recreational users could include both transient and more permanent users like nearby residents and Indigenous groups. Health Canada considers recreational receptors in their guidance but does not define exposure scenarios for these receptors; therefore, published Canadian and US human activity factors were reviewed to define an exposure scenario for this receptor (Richardson, 2013; US EPA, 2017). A potential worst-case exposure scenario, based on professional opinion, was a recreational user who may be exposed to surface water during one dermal contact event every day for two weeks (e.g., daily swimming during recreational camping).

A list of potential human receptors for each exposure scenario is presented in Table 4.

Table 4 - Potential human receptors

Scenario	Receptors
Recreational surface water users	Infants, toddlers, children, teens and adults
Domestic users of surface water	Infants, toddlers, children, teens and adults

5.4 Identification of exposure pathways

Domestic and recreational users of surface water are exposed to contaminants in the water via ingestion, dermal absorption, and inhalation.

5.4.1 Ingestion

Available data and published literature indicate that wildfire related COPC can impact surface water. Surface water is used for domestic purposes including a drinking water source by many Albertans, particularly in the north of the province where groundwater supply may not meet domestic needs. Ingestion of contaminants in surface water could occur via incidental ingestion while bathing or swimming and the use of surface water for drinking for both domestic and recreational water users.

5.4.2 Dermal absorption

Dermal absorption is the transport of COPC from the outer surface of skin into systemic circulation. Select COPC have the potential to be absorbed by the body when contacting skin. Receptors could be exposed to COPC any time skin comes in contact with water (i.e., bathing, swimming). While dermal absorption is an identified exposure pathway, it represents a small contribution to overall exposure and a more likely health effect from dermal contact is skin irritation (Health Canada, 2012b).

5.4.3 Inhalation

Inhalation of sprays, aerosols or volatile COPC could occur during both domestic and recreational activities. Inhalation is noted to be an important recreational exposure pathway for bacterial pathogens that can occur in waters, but inhalation is expected to represent a small contribution to overall exposure (Health Canada, 2012b).

5.5 Conceptual model

Within a risk assessment, the conceptual model provides the basis for the connection between COPC and the receptor. A pictorial of the conceptual model for wildfire associated COPC exposure via surface and drinking water is presented in Appendix A, Figure 2.

This Figure illustrates a variety of physical processes, including deposition, leaching, erosion and groundwater transport, that may bring wildfire associated contaminants into surface water bodies depending in part on their physical-chemical properties. A number of compounds listed in Tables 2 and 3 have relatively low solubility limits. For example, polycyclic aromatic compound benzo(b&j)fluoranthene has a solubility limit of 0.00375 mg/L at 25°C (CCME, 2008), and has been measured at a maximum concentration of 0.00928 mg/L – indicating that some of the measured mass would not be present in the water column in the dissolved phase but rather in solid form and solids eventually deposit to sediment. Contaminants removed from the water column via sedimentation, while important ecologically, are less of a direct human health concern.

6.0 Potential human health impacts associated with selected COPC

6.1 Drinking water use

Drinking water quality guidelines protective of human health were the focus of the search and a compound specific health-based rationale was compiled for each guideline (Table C.3 Appendix C).

Aluminum, turbidity, and total organic carbon were measured above their respective drinking water screening guideline. The guideline for aluminum is operational, meaning it is meant to be protective of operational water treatment considerations as a running annual average rather than a health-based guideline. Health Canada notes that there is no consistent convincing evidence that aluminum in drinking water causes adverse health effects (Health Canada, 2017). The health risk from exposure to aluminum at concentrations relevant to water is therefore expected to be low.

Turbidity and total organic carbon (TOC) are indicator parameters, qualifying the water with respect to disinfection interference and potential for DBP formation, respectively. These parameters themselves do not represent a health risk, and the parameters of primary concern (trihalomethane, *Escherichia coli* and total coliforms) are directly measured. Total suspended solids, which have no screening guideline, is also an indicator parameter, for which associated risk would be addressed through the determination of *Escherichia coli* and coliforms. No directly linked health concern is predicted from exposure to turbidity, TOC or total suspended solids measured above their screening guidelines.

The remaining COPC are primarily PAHs, fire retardants and DBP. These constituents were provisionally carried because they were either not measured, or had no drinking water screening guidelines, and therefore could not be screened out. Qualitative discussion related to the potential health risk from these compounds is not possible without measured concentrations. However, many of these compounds would be considered emerging contaminants and the toxicology for a number of these compounds is in development. Concentrations of the organic COPC were measured in surface water and with further investigation into the toxicology of these compounds may enable a risk determination. As noted, risk assessment is an iterative process and the problem formulation presented herein is only the first stage.

During the 2016 Horse River Wildfire the Fort McMurray water treatment plant remained operational; however, the facility was substantially compromised. Significant water volume was used for fire suppression activities and rehabilitation work for the Fort McMurray and Anzac distribution systems (RMWB, 2017), these increased supply demands pulled volume from storage reservoirs to augment the water supply (fire flow). For 11 days, chemical disinfection of raw water was switched from chloramines to free chlorine, and a boil water order was issued. During this period, rehabilitation activities took place in the distribution system including draining, cleaning, and re filling water reservoirs, and flushing the distribution system.

On November 9, 2018, MEMS communicated via phone with Dr. Lyndon Gyurek, Director of Drinking Water and Wastewater/Stormwater Provincial Programs and Ms. Debra Long, Municipal Water Program Specialist regarding health concerns related to drinking water during the fire. Potential impacts due to changes in surface water due to the wildfire were not identified as a high priority. Of high priority were risks related to loss of pressure at distribution periphery, as well as potential backflow of contaminants into the distribution (i.e., flooded basements), potentially exposing the distribution to biological introduction. Introductions of this nature are guarded against in part through the Plumbing Code Regulation, as well as in-distribution monitoring. While this type of risk is hard to quantify for the population base, in an emergency event pathogenic contamination of the drinking water supply clearly represents a more immediate risk to human health versus exposure to fire related COPC.

6.2 Recreational water use

A key feature to recreational water quality was the high bacterial load (*Escherichia coli*, total coliforms), compared to drinking water. A higher bacterial load in untreated water is reasonably expected; bacterial count numbers in background surface water were not available.

Recreational water data were screened against drinking water guidelines, which is thought to be highly conservative as only incidental ingestion of river water is expected in a recreational exposure scenario. The recreational water and drinking water COPC were similar. Many of the organics measured in recreational water were retained as COPC on the basis of no screening guidelines.

The health concerns associated with exposure to recreational water COPC is thought to be low and is aligned with drinking water COPC, including turbidity, total organic carbon, and aluminum.

7.0 Alberta drinking water guideline review

Within Canada, drinking water is under provincial and territorial jurisdiction, and therefore each province and territory is responsible for the regulation of drinking water. Alberta Environment and Parks (AEP) regulates drinking water for the province of Alberta through several regulations under the Environmental Protection and Enhancement Act (EPEA). Specific regulations under EPEA include the Potable Water Regulation, and the Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems, which describes minimum design and monitoring standards (AEP 2019). The AEP regulates drinking water for approximately 80 per cent of Alberta's population including the approval of public waterworks systems that require health related treatment of raw water (AEP, 2009). Unapproved public systems (those below a threshold service size) are regulated by Alberta Health under the Public Health Act, including water systems that do not require health related treatment of raw water (i.e., private water systems), and service roughly 20 per cent of Alberta's population (AEP, 2009).

Based on the EPEA, water from regulated waterworks systems in Alberta must meet health regulated parameters of the Guidelines for Canadian Drinking Water Quality (Health Canada, 2017). Alberta Health also utilizes this Health Canada guidance for unapproved systems or private water sources; with the exception of First Nations who fall under federal jurisdiction (AEP, 2009). Additionally, the Public Health Act provides provisions to address any condition that may give rise to unsafe drinking water. Treated water past the service connection for a residence is governed by Municipal Affairs, including the Plumbing Code Regulation, aimed to prevent pollutants from contaminating treated water.

The Guidelines for Canadian Drinking Water Quality and the Guideline Technical Documents are developed by the Federal-Provincial-Territorial Committee on Drinking Water (CDW) and have been published by Health Canada since 1968 (Government of Canada, 2018). The guidelines are developed to be protective of human health, including the most vulnerable members of the population such as children and the elderly. The guidelines include microbiological, chemical, and radiological quality guidelines for protection of human health which are presented as maximum allowable concentration (MAC) guidelines. The guidelines also include aesthetic and operational guidelines for parameters which do not pose human health risks, but which may affect consumer acceptance of drinking water such as taste, odour, and colour. Aesthetic or operation guidelines may affect processes at a treatment plant or within the drinking water distribution system; these are presented as aesthetic objectives (AO) and operational guideline (OG) guidelines.

Health Canada provides scientific and technical expertise to the CDW and coordinates its activities for the development of the drinking water guidelines in Canada. The CDW meets twice a year and is composed of voting and non-voting members; the voting members include a representative from each jurisdiction in Canada including the ten provinces, three territories, and the federal government. When a new guideline is under consideration technical documents are reviewed by the CDW and external experts, and they undergo a public consultation. Once all jurisdictions are satisfied with the guideline and supporting documents the guideline may be approved and sent to the CDW's governing authority, the Federal-Provincial-Territorial Committee on Health and the Environment (CHE), for final approval and publication.

8.0 Human health impact mitigation

Health impact mitigation strategies available from published literature were reviewed and presented below. Published literature indicates that wildfire related COPC can impact surface water but the magnitude of impact depends on many factors specific to each scenario. Presented information below takes a broad perspective to wildfire health impact mitigation from surface water exposure and is not specifically speaking to the 2016 Horse River Wildfire response.

8.1 Research and monitoring

Despite the well-documented effects of wildfire on downstream water quality, the magnitude, persistence, and relative contribution of potential effects from post-fire, relative to other sources (e.g., urban runoff or non post-fire runoff) is poorly understood (Stein and Brown 2009). Research and monitoring efforts are required to better understand the effects of wildfires on utilities' source water quality and quantity, and to develop effective wildfire mitigation and management plans (Sham et al., 2013; Bladon et al., 2014).

Climate change and its relationship to wildfire will likely impact the provision of water for domestic, agricultural, industrial, and ecological needs in some regions. Drinking water utility staff were better able to identify serious wildfire risks and develop mitigation plans once they were informed about the risks within their watershed (Emelko and Sham 2014). Therefore, conducting wildfire hazard assessments in the watersheds have been suggested as an important first step to reducing and mitigating the effects of wildfire in the drinking water utilities (Adam 2013; Bladon et al., 2014).

Stein and Brown (2009) identified the following factors responsible for the lack of a coordinated post fire monitoring program:

- there is no procedure for post-fire water quality monitoring that identifies a standard set of constituents and monitoring protocols appropriate for assessing water quality after wildfires;
- resources are often scarce after wildfires making coordination difficult;
- there is no regional entity responsible for coordinating post-fire sampling, compiling the resulting data, and disseminating the information back to resource managers; and
- as wildfires occur unexpectedly, there is often insufficient available funding to conduct post fire sampling.

A concerted effort involving a range of stakeholders to implement a monitoring plan following a wildfire may help remove some of these factors in a proactive way.

8.2 Forest biomass/fuel management

Biomass/fuel management is recommended in the scientific literature as a best management practice to limit the size, frequency, and severity of future wildfires and thus mitigate the wildfire impacts on downstream water supplies (Adam 2013; Emelko and Sham 2014). Adam (2013) argued that forest fuels can build up, either through policies of fire suppression or failure to implement sufficient fuel reduction, resulting in dramatic increase in wildfire frequency and intensity. He suggested that standard forest management practices such as landscape level thinning can mitigate the extent of large-scale, high intensity fires - especially for temperate forests. Common fuel-reduction techniques include mechanical vegetation treatment (thinning harvest through grazing or other means), prescribed/controlled burns, and clear cutting (Abraham et al., 2017; Sham et al., 2013; Townsend and Douglas 2004). Emelko and Sham (2014) reported that historical fire-suppression efforts have resulted in a buildup of fuel in some parts of North America, including Alberta and increasing the risk of more intense and severe wildfires. The authors emphasized that the wildfire mitigation efforts on forest/landscape management should be conducted in coordination with a range of stakeholders.

8.3 Source water protection

Generally, increased runoff, increased peak flow, increased total suspended solids (TSS) and increased sediment erosion and transport occur after a wildfire. This is especially true during large and intense precipitation events, and in the first year after the wildfire. Post-fire mitigations of these hydrological effects are known as source water protection or rehabilitation treatments and as described by Robichaud et al., (2000) aim to:

- minimize threats to life and property;
- reduce erosion and soil productivity;
- reduce loss of water control; and
- minimize water quality deterioration.

The most appropriate rehabilitation treatment(s) following wildfires vary, depending on:

- the downstream environmental values to be protected or preserved;
- burn severity and extent;
- length of time since the fire occurred. Some treatments are most effective immediately after an area is burned, others require years to become effective;
- cost and availability of mitigation measure;
- effectiveness/performance of mitigation (i.e., the amount of runoff and erosion mitigation); and
- hydroclimatic and physiographic factors including climate, soil, topography, and hydrology.

Impacts from wildfire on water quality and quantity are greatest in the year following the wildfire and decrease greatly three years post-fire (Robichaud et al., 2000). Therefore, the discussion below focuses on treatments applied within three years post-fire. This discussion subdivides the rehabilitation treatments into those that are applied: on the landscape ("hillslope treatments"), within channels, and to roads.

8.3.1 Hillslope treatments

8.3.1.1 Seeding

Seeding has a long history, is widely applied, and is generally effective to help mitigate erosion following a wildlife. Seeding is typically applied by aircraft. Seed mixes can include:

- native or non-native plants (typically grasses);
- legumes to increase available nitrogen following a post-fire nutrient flush;
- annuals for quick cover and perennials to establish longer-term protection; and
- fertilizers to increase initial cover.

In the first wet season following a fire, seeding generally has a low probability of success for erosion reduction (Beyers 2009; Robichaud 2009). However, annual grains have a better chance of providing first-year protection compared to perennials, and do not interfere with later regeneration of natural vegetation.

8.3.1.2 Mulching

Mulch consists of shredded woody organic material applied to the soil surface to protect soil from erosion due to rain impacts and overland flow. Straw is generally considered the most effective mulch and is relatively inexpensive; however, it has the potential to introduce weeds and non-native plants if 'weed-free' varieties are not used. Mulch is typically applied in the first year following wildfire. Natural mulching may occur in coniferous stands when significant trees remain post-fire (Bautista et al., 2009).

8.3.1.3 Erosion barriers

Erosion barriers are designed to provide a physical barrier to overland flow, promote infiltration, and trap sediment. Barriers typically consist of straw wattles and logs placed parallel to hill contours. Straw wattles are compressed cylinders consisting of mesh webbing and are typically filled with straw or hay. Contour-felled logs are often backfilled, anchored, and trenched upslope to retard sediment.

Barriers are generally effective, especially when rainfall intensities and runoff are low to moderate but in some cases can disturb the ground further and promote erosion.

8.3.2 Within-channel treatments

Within-channel treatments often consist of check dams, which are small structures placed in low order channels, designed to decrease flow velocities and store sediment. Check dams can be constructed of straw-bales, logs, or rock cages. Within-channel treatments can also include debris basins to trap large amounts of sediment (Robichaud et al., 2000; Robichaud 2009).

Straw-bale dams, consisting of bales of straw or hay, are generally considered effective when installed correctly, are easy to install and are inexpensive but intended for short-term mitigation. They are generally effective at trapping only small amounts of sediment. Guidelines are available for maximum upstream area, maximum flow, and maximum water height (Robichaud et al., 2000).

Log check dams are generally effective and have a longer life expectancy than straw-bale dams but are more expensive and more labor-intensive to install. Well-built log check dams can be 70 to 80 per cent effective in trapping sediment and last for 15 to 30 years.

Rock dams and rock cage dams (consisting of ‘gabions’: a wire basket filled with rock) are highly effective at reducing erosion but are expensive. They need to be anchored to the stream bed to prevent movement during stormflow. Used in conjunction with other mitigation measures, they can reduce erosion by 80 per cent and sediment concentrations by 95 per cent.

Other types of within-channel treatments include armoring and debris basins. Debris basins can consist of excavated pits or ephemeral channels designed to trap sediment. They need to be periodically cleared and are relatively expensive but can be effective for trapping large amounts of sediment.

8.3.3 Road treatments

Road treatments typically consist of armoring, flow directors, and water passage structures. In burned areas, the size or extent of the treatment might be increased to cope with increased post-fire flows, sediment, debris, and erosion- aiming to keep sediment mass from entering water sources (Robichaud et al., 2000; Robichaud 2009).

Armoring around roads generally consists of adding rock or gravel to surfaces that might have water running over them, including the fill slopes and sides of roads, the inlets and outlets of culverts, and ditches. Grading and sloping the road can avoid channeling flow on the road surface and the creation of ruts and gullies. Culverts are sometimes moved or resized following wildfires to allow passage of increased flows and discourage sedimentation. Structures can be built at the inlet of culverts to allow the passage of water, while trapping large debris.

8.4 Water utilities emergency preparedness

Water utilities can mitigate the impacts of wildfire on water treatment through emergency preparedness and response plans/strategies. Rapid changes in raw water quality due to wildfires pose the most difficult treatment scenarios for water providers due to requirement of (1) robust infrastructure to treat a wide range of raw water quality conditions, (2) continuous raw water quality data to enable the appropriate response, and (3) highly trained operators who are capable of rapidly optimizing treatment process performance as raw water quality changes (Emelko and Sham et al., 2014).

Emergency preparedness and response plans should be considered by water utilities especially those identified as at high risk of threat from wildfires. Sham et al., (2013) suggested the following actions under the emergency preparedness and response plans:

- identification of potential alternate sources of water;
- anticipation of the range of potential impacts of wildfire on water quality including the potential for long term sediment production, storage, and downstream transport;
- identification of additional drinking water treatment infrastructure and/or analytical capacity for water quality tests;
- development of treatment plant technological and operational response options (including focused operator training); and
- adoption of a knowledge mobilization strategy to ensure that local stakeholders and those affected by wildfire effects on water supplies understand the risks and actions that may be required in the event of a wildfire, and the implicit costs associated with water utility preparedness.

Wildfire impacts on source waters can affect drinking water treatment process. These impacts documented in the literature range from essentially minimal to large-scale impacts. The wildfire impacts on drinking water treatment are dependent on the following factors (Emelko and Sham 2014):

- how water quality, quantity, and availability are impacted by wildfire;
- proximity of the treatment plant intake to the burned watershed along with influence of unburned source water regions;
- available treatment infrastructure and operational capacity; and
- treatment plant preparedness.

Most existing drinking water treatment plants with surface water supplies utilize several physicochemical processes to produce safe drinking water. Conventional treatment processes typically include coagulation, flocculation, clarification, granular media filtration, and disinfection (Emelko and Sham 2014; Writer et al., 2014). Regardless of the exact configuration, design of the drinking water treatment processes is driven by current and anticipated untreated “raw” water quality.

As identified in Section 3.1, increased loads, and concentrations of TSS/turbidity, associated elevated nutrients, DOC and associated colour and odour, and DBPs in the raw/source waters are important water quality concerns that should guide the selection and design of general drinking water treatment processes.

Real-time modifications may be required by water utilities in response to wildlife water quality or supply impacts. For example, the Fort Collins water treatment facility responded to the High Park wildfire in Colorado by using multiple water supplies, constructing a pre-sedimentation basin, and increasing environmental monitoring to effectively deliver high-quality drinking water to its customers in the year following the fire (Writer et al., 2014). In this facility, alum coagulation effectively reduced DOC concentrations by 30 to 60 per cent and total trihalomethanes (DBP) formation by 60 to 80 per cent at a dose of 50 mg/L.

In another study, Hohner et al., (2016) reported that the conventional treatment of post-fire water samples was effective at a 10 mg/L higher average alum dose than reference samples. However, several after fire post-rainstorm samples pose treatment challenges, even a high alum dose (65 mg/L) removed <10 per cent of DOC.

These water treatment challenges may result in important economic and operational obstacles for water treatment for most of the drinking water suppliers.

8.5 Stakeholder collaboration

Collaboration and policy development inclusive of a variety of stakeholders, followed by implementation can promote effective wildfire risk mitigation activities and leverage funding for mitigation efforts (Sham et al., 2013). Some considerations for stakeholder collaboration include:

- using partnerships with other organizations or drinking water utilities to evaluate wildfire risks and implement a comprehensive strategy for protecting critical watersheds;
- building collaborative forest management groups to educate about wildfire risk and employ mitigation techniques;
- partnering with landowners, federal, provincial/territorial, local, and private stakeholders to implement more effective and comprehensive wildfire monitoring and mitigation activities; and
- working with regulatory agencies in land use planning activities, gain approval for mitigation activities in critical watersheds, or enforcement of best management practices.

9.0 Findings and conclusions

Constituents of interest were identified from published literature and available monitoring data. A statistical comparison of wildfire exposed surface water relative to background confirmed many of the constituents identified in the literature were statistically elevated in surface water as a result of the 2016 Horse River Wildfire. Few COPC were retained based on a comparison to health-based screening guideline; the majority of COPC were retained on a provisional basis as they were either: identified in the literature but not measured in the monitoring data; or had no available screening guideline. As a group, guidelines applicable to recreational exposure are particularly lacking. The lack of health-base guidelines with to screen COPC, introduces uncertainty into the list of COPC that have been identified for people drinking of recreationally using wildfire impacted water.

As documented from the literature, wildfires can result in increased nutrient levels (nitrogen, phosphorus, and DOC) in surface water. Nutrient introductions of this composition and magnitude are unique to wildfire disturbance and have longer-term implications on the ecology of aquatic systems, with secondary outcomes of potential concern to human health. Elevated carbon and nutrient levels increase the primary ecological output of the system, including algal and bacterial biofilm production. The polymer and bacterial matrix of biofilms are a well-documented problem for modern drinking water treatment and distribution systems (Schwartz et al., 1998); influencing the production of DBP, harbouring pathogens and accelerating corrosion (Wingender and Flemming, 2011; Abokifa et al., 2016). While biofilm formation may be a secondary effect as a result of wildfire impacted surface water, the potential health implications of biofilms on water treatment are well documented.

Understanding nutrient levels specific to biofilm proliferation and disinfection requirements is a developing science and expected to vary on a situational basis. However, biofilm proliferation and architecture changes that interfere with disinfection are documented from increased nutrient loads (Rice et al., 2005). Reducing nutrient levels, notably DOC, is a technique employed to limit biofilm growth and improve the effectiveness of chemical disinfection (Chandy and Angles, 2001). When looking specifically at surface water data in weeks following the Horse River Wildfire, dissolved TOC and DOC were not found to be statistically higher in the wildfire impacted surface water; however, elevated concentrations organic carbon has been found to persist for two years post wildfire (Emelko et al, 2011). Evaluation of nutrient levels over a longer time scale would help determine if concentrations have changed as result of the Horse River Wildfire. The overall implications of elevated nutrient levels are expected to be more significant for smaller water treatment systems, with less advanced filtration where flow may be significantly reduced as a result of biofilm formation.

The introduction and harbouring of pathogens within biolfilms of the water distribution system may pose additional challenges for wildfire exposed systems. Data following the Horse River Wildlife indicates that no coliforms or Esherichia coli were measured above health-base limits in treated drinking water in the available data. Required water monitoring ensures that drinking water meets disinfection regulations and it was communicated to MEMS that additional biological monitoring within the distribution is not typically conducted in emergency events (Dr. L Gyurek, personal communication, November 9). The Horse River Wildfire was an extreme scenario with respect to fire flow or water volume withdrawal, and a typical wildfire scenario would not be expected to challenge the distribution in the same way. However, distribution systems in less extreme scenarios may be challenged biologically from increased nutrient inputs, resulting in biofilm proliferation and associated challenges while trying to maintain system integrity.

As indicated in the literature, wildfire ash composition varies depending on the fuel source as well as the fire severity. The PAH retene, a major product of conifer tree combustion, has been noted in the literature as a chemical indicator of wildfire (Gabos et al., 2001; Ahad et al., 2015). Retene was statistically elevated in the wildfire exposed surface water and was provisionally retained as a COPC with no identified screening guideline. Retene has a relatively low solubility and would be expected to primarily partition to sediments – meaning this compound would be best measured as total (rather than dissolved) and sampled in well mixed water.

To summarize, the main findings identified in the problem formulation are:

1. Constituents that were measured, compared against an appropriate screening guideline, and retained as COPC were thought to represent a low concern for human health.
2. Some COPC were identified as provisional that could not be screened in the problem formulation due to lack of jurisdictional guidelines.
3. Elevated nutrient levels, including DOC, can persist in surface water following a wildfire. Increased nutrient loads can promote biofilm growth interfering with disinfection and are associated with elevated DBP in treated drinking water.
4. Bacterial risks to human health via drinking water may occur from operational limitations and secondary outcomes as a result of wildfire impacted surface water.
5. Retene was identified as a potential indicator chemical for wildfire surface water contamination.

10.0 Recommendations

Many of the provisionally retained COPC are not part of standard water analysis suites, possibly in part because a number of these compounds are relatively insoluble. To evaluate the likelihood the retained provisional COPC may pose a potential risk to human health, a more detailed toxicological review for each COPC and their physical chemical properties would be required. Based on the low relative solubility of a number of provisionally retained COPC and considering water treatment processes would be expected to remove many constituents, recreational exposure is thought to represent higher risk from acute exposure to surface water COPC.

Alberta Innovates is supporting a research project on the best practices and policy related to post wildfire water treatment titled, *Drinking Water Supply after Severe Wildfire in Alberta: Assessing Initial Risks and Treatment Technology Resilience*. This work is being led by Dr. Monica Emelko, Professor of Civil and Environmental Engineering and the Director of the University of Waterloo's Water Science, Technology and Policy group. Dr. Emelko was engaged during the Horse River wildfire response and is a leading researcher with respect the wildfire and drinking water implications. Her research will be valuable for any future work on the assessment of human health risks related to water impacts from the Horse River wildfire.

The following items are recommended based on the results of this problem formulation:

1. The completion of the next steps of the risk assessment for recreational water use for the provisionally retained COPC. This would include determination of potential exposure for the identified receptors, a detailed toxicological review of available information and, if possible, the determination of a risk metric.
2. Evaluation of retene as a potential fire indicator, along with other compounds that could comprise a small suite of wildfire impact indicators to help inform resource managers.
3. Communication and solicitation of additional data from wildfire and water quality experts to refine the risk evaluation.
4. A review of water treatment practices and determination of water treatment types and facilities that are most susceptible to wildfire surface water related risk.
5. Assessment of surface water nutrient loading during freshet in the years before and since the Horse River Wildfire, along with a review of DBP formation and heterotrophic bacterial data (if available) in treated drinking water to determine a possible correlation between nutrient persistence and loading and potential health risk.

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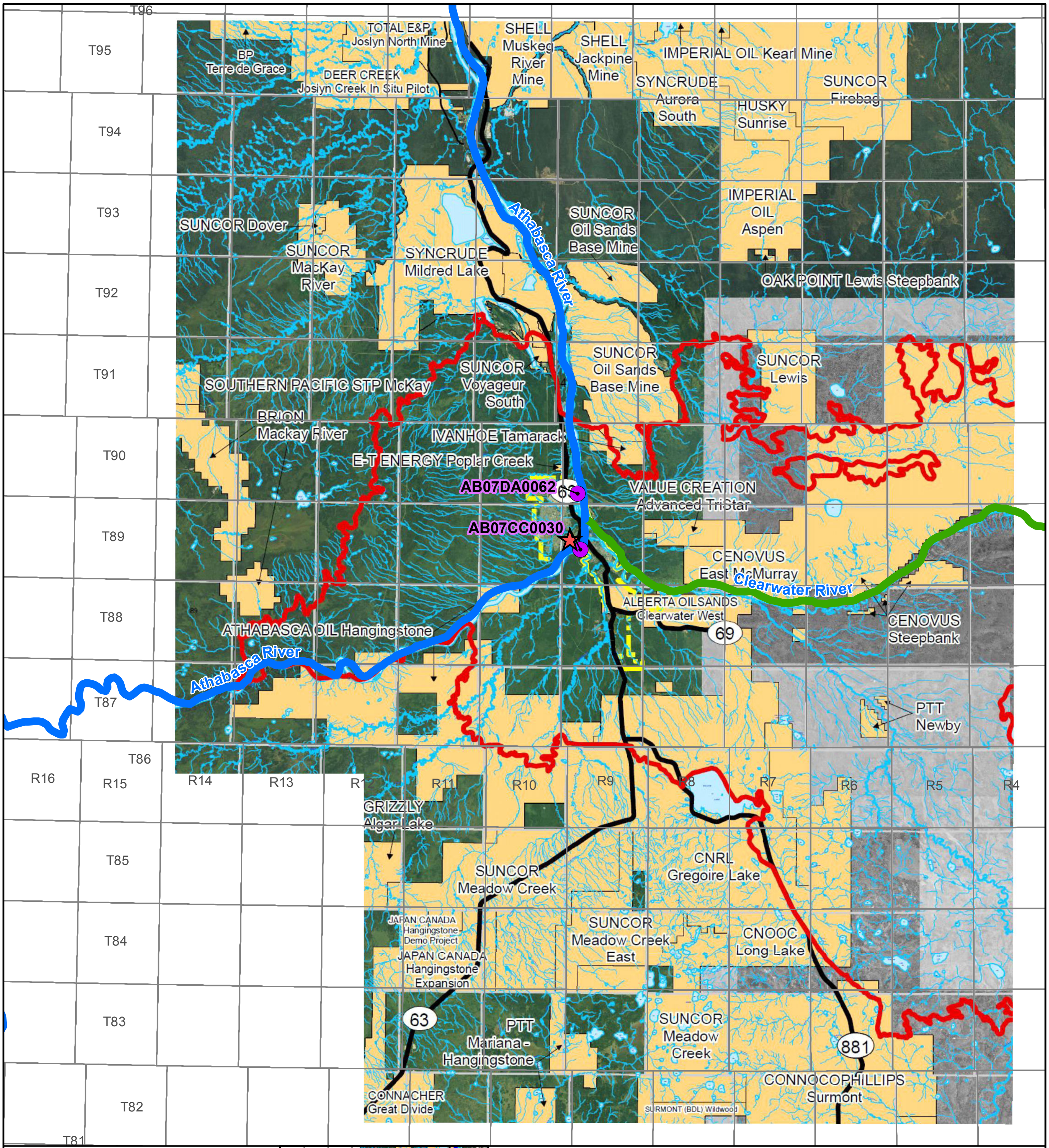
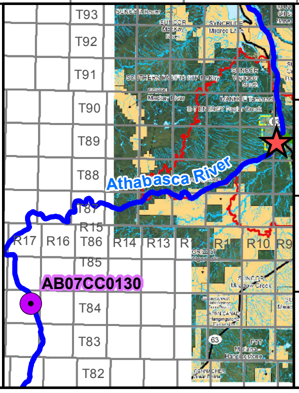
APPENDIX A: FIGURES



LEGEND

- ✱ Monitoring Station
- ★ Fort Mcmurray Water Treatment Plant
- ● Monitoring Station
- ▬ Clearwater River
- ▬ Athabasca River
- ▬ Primary Highway
- ▭ Urban Service Area
- ▭ Extent of Wildfire
- ▭ Oil Sands Project Boundaries (2015)



Alberta Government

HORSE RIVER FIRE RESPONSE FORT MCMURRAY AND ANZAC, RMWB

HORSE RIVER WILDFIRE BOUNDARY (RED OUTLINE) AND OIL SANDS OPERATIONS

MILLENNIUM EMS Solutions Ltd.

Alberta GOV., 2018; MEMS, 2018;

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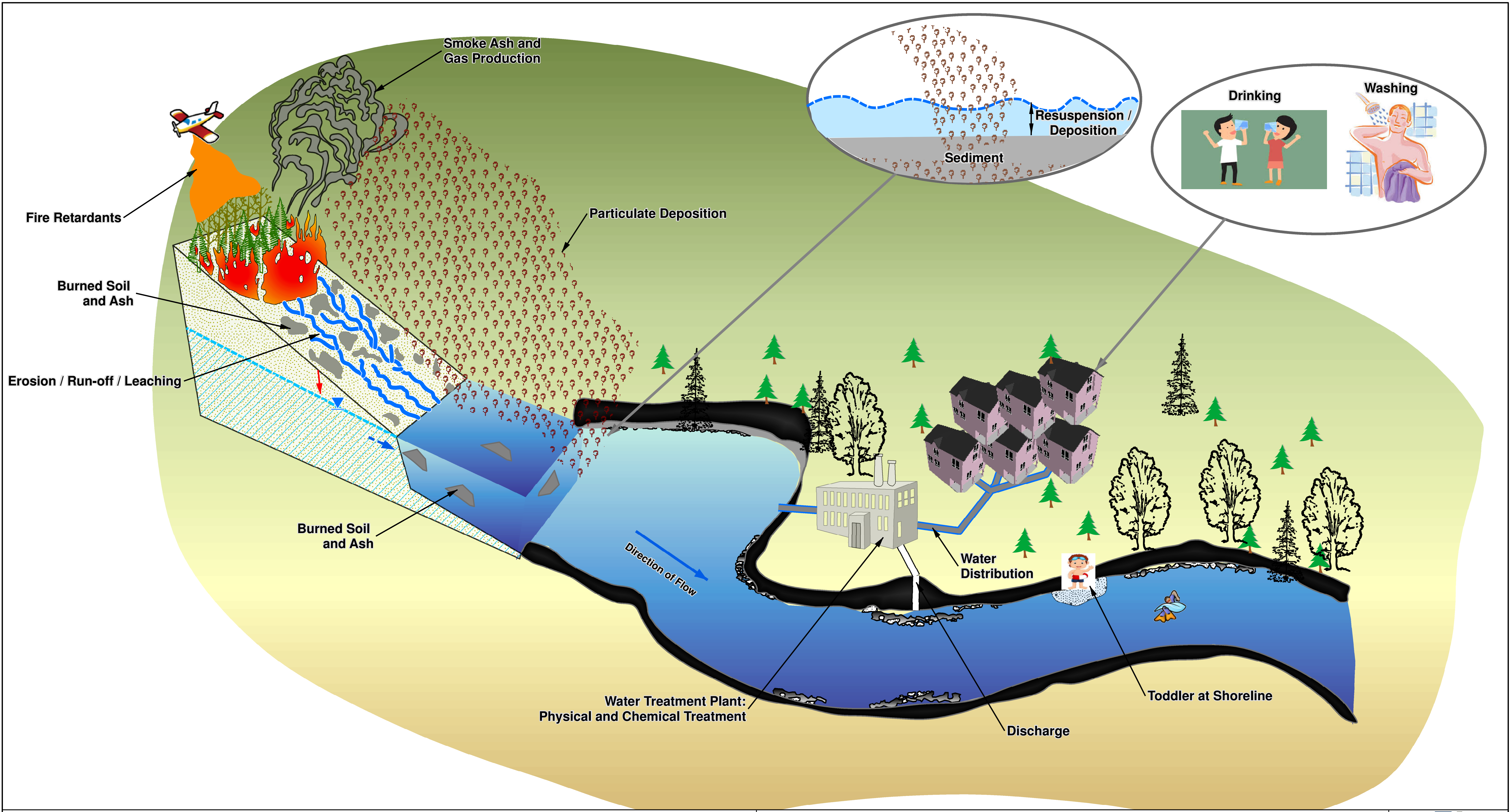

LEGEND

- ▼ Groundwater Level
- — Erosion / Run-off / Leaching
- ➤ Groundwater Flow Direction
- - - Groundwater Table
- → Infiltration
- ▭ Aerial Smoke Ash and Gas Production
- 🟧 Fire Retardants
- 🟥 Wildfire
- ▬ Burned Soil and Ash
- Deposition
- Recreational Swimmer
- Toddler

Alberta Health

ALBERTA HEALTH ACTIVITY 6

CONCEPTUAL MODEL

MEMS, 2018;

SCALE NA

MILLENNIUM
EMS Solutions Ltd.

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APPENDIX B: LITERATURE REVIEW METHODOLOGY AND SUMMARY

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1.0 SEARCH METHODS STEPS

An on-line step-by-step search method was employed to identify water quality constituents of interest in surface waters resulting from surrounding wildfires, with a special emphasis on wildfires in Alberta.

Articles and reports were identified in both the published and the grey literature, with the search method involving the following four overall steps:

Step 1- Planning and search;
Step 2- Narrowing search results;
Step 3- Document screening; and
Step 4- Data analysis and reporting.

The step-by-step literature search methodology is summarized in Figure 1 and discussed below.

1.1 Step 1 – Planning and Search

The purpose of the first step of the literature search was to gain an understanding of the quantity and quality of information available for individual and/or combinations of search terms under different key questions. At this step, important concepts were determined through evaluation of the key questions, and a list of primary and secondary search terms were identified for each concept. A total of four different questions and 37 primary search terms were selected and searched.

The literature search was performed using three different databases:

- Google standard search engine and Google Scholar;
- Science Direct database; and
- PubMed literature search system at the National Library of Medicine (NLM).

Table 1 displays the primary search terms and secondary search terms related to each key question, and the number of articles/results available in each database that was queried. Secondary search terms were combined with the primary search terms to develop refined search strings focussed on identifying jurisdictional best practices and guidance.

Eligibility criteria were determined for the selection of literature as follows:

- articles that directly presented wildfire effects on surface water quality including one or more water quality variables;

- articles that had drinking water quality and recreational water quality implications due to wildfire including source water protection, treatment, and mitigation; and
- articles that presented effects of fire retardants and disinfection by-products on surface water quality.

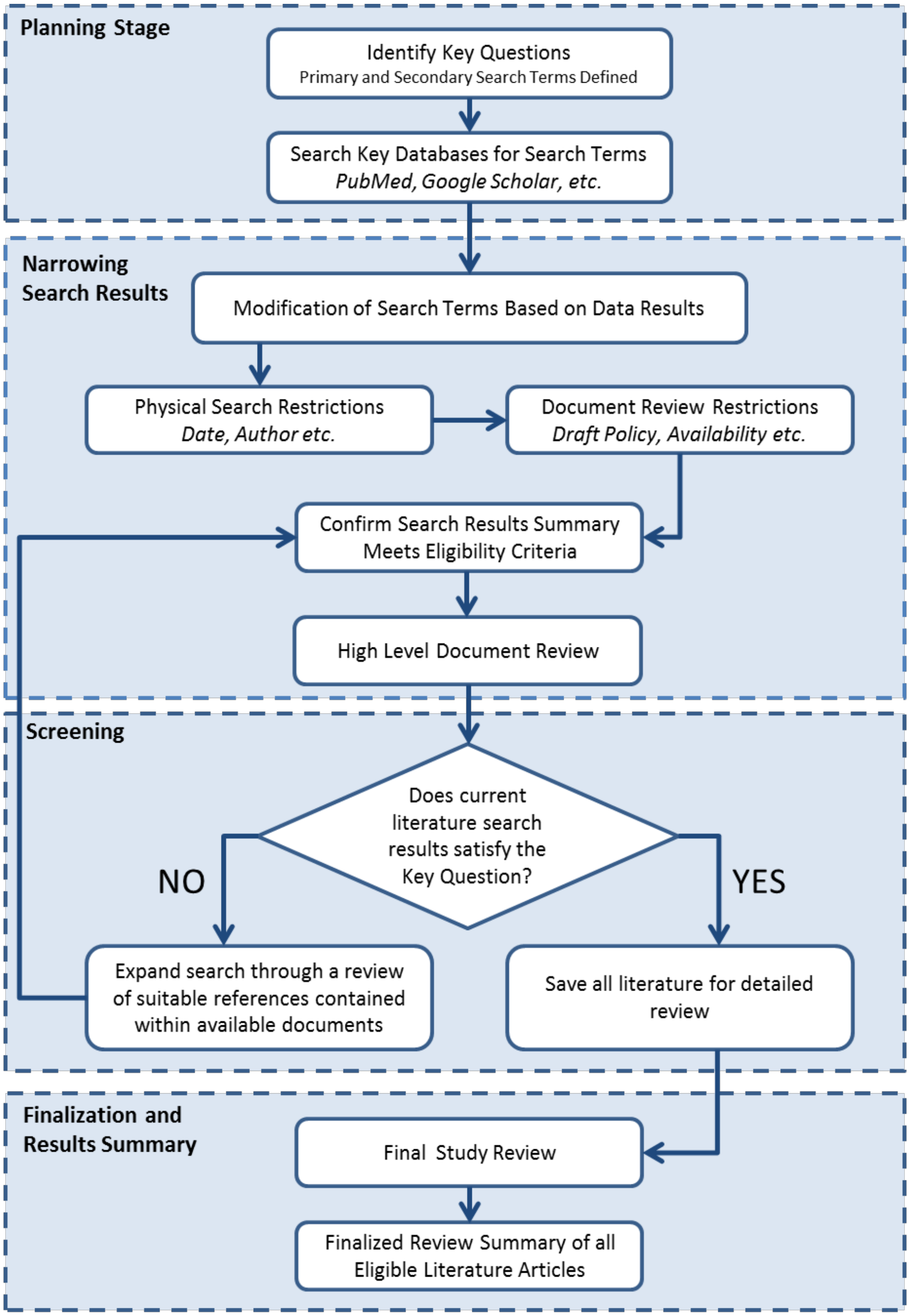

Figure 1 Literature Search Methodology (4-step process).

Table 1 Key Questions, Related Primary and Secondary Search Terms and Number of Results

Questions	Key Words	Google Scholar		PubMed Central		Science Direct	
		Anytime	Last 10 Years	Anytime	Last 10 Years	Anytime	Last 10 Years
What impact do wildfires have on surface water quality?	Wildfire	231,000	49,300	3,459	2,949	2,851	2,247
	Forestfire	15,900	13,700	9,911	8,022	5,434	3,473
	Bushfire	32,100	16,400	277	254	112	63
	Wildfire and Water Quality	25,000	16,700	220	207	87	71
	Wildfire and Surface Water Quality	1,680	1,140	16	16	21	16
	Wildfire and Sediment Quality	501	351	7	5	9	9
	Wildfire and Suspended Sediment	5,460	3,310	8	7	23	17
	Wildfire and Water Pollution	7,250	4,780	36	30	22	18
	Wildfire and Water Contamination	1,960	1,480	44	36	12	11
	Wildfire and Eutrophication	4,910	3,460	5	3	7	5
	Wildfire and Canada	63,900	21,800	120	101	154	122
	Wildfire and USA	88,200	27,400	603	477	236	191
	Wildfire and Australia	48,600	19,500	211	195	246	193
	Wildfire and Alberta	15,000	9,100	39	33	34	24
	Wildfire and British Columbia	29,100	16,600	27	22	32	22
	Wildfire and Fort McMurray	240	377	10	10	5	4
	Wildfire and California	75,000	24,500	241	197	180	146
	Wildfire and New Mexico	21,900	14,000	42	32	29	24
	Wildfire and Florida	28,300	15,700	26	20	22	13

Table 1 Key Questions, Related Primary and Secondary Search Terms and Number of Results

Questions	Key Words	Google Scholar		PubMed Central		Science Direct	
		Anytime	Last 10 Years	Anytime	Last 10 Years	Anytime	Last 10 Years
What are the surface water related human health impacts due to wildfires?	Wildfire effects	3,990	2,720	553	469	46	36
	Wildfire and Drinking Water Quality	19,400	14,200	10	9	9	9
	Wildfire and Recreational Water	21,500	14,100	0	0	4	3
	Wildfire and Water Supply	20,600	14,900	17	22	31	29
	Wildfire and Water Treatment	5,240	3,860	30	26	74	59
	Wildfire and Human Health	329	254	236	194	43	39
	Wildfire and Contaminants	10,700	7,580	13	11	16	16
	Wildfire and Chemicals	16,000	10,200	30	21	209	160
	Wildfire and Toxicity	10,600	7,110	49	36	27	20
What are the water quality constituents of interest to human health in surface water associated with wildfires?	Wildfire and Surface Water and Aerial Deposition	164	106	0	0	2	0
	Wildfire and Surface Water and Ash Composition	104	85	0	0	5	4
	Wildfire and Total Suspended Solids	1,620	1,140	4	4	3	3
	Wildfire and Turbidity	5,400	3,340	5	5	10	8
	Wildfire and Surface Water and Nutrients	7,770	5,080	5	4	12	10
	Wildfire and Surface Water and Metals	4,050	2,790	7	4	2	2
	Wildfire and Surface Water and Ions	2,340	1,580	9	7	1	1
	Wildfire and Surface Water and Hydrocarbons	2,530	1,770	4	4	4	4
	Wildfire and Surface Water and Polycyclic aromatic hydrocarbons (PAHs)	2,340	1,680	2	2	4	4
	Wildfire and Volatile Organic Compounds	13,700	10,200	9	8	16	14

Table 1 Key Questions, Related Primary and Secondary Search Terms and Number of Results

Questions	Key Words	Google Scholar		PubMed Central		Science Direct	
		Anytime	Last 10 Years	Anytime	Last 10 Years	Anytime	Last 10 Years
What are the water quality constituents of interest to human health in surface water associated with wildfires? (Cont'd.)	Wildfire and Surface Water and Volatile Organic Compounds	2,180	1,460	0	0	0	0
	Wildfire and Surface Water and Polychlorinated biphenyls (PCBs)	1,780	1,170	0	0	0	0
	Wildfire and Dioxins	1,860	1,290	1	1	0	0
	Wildfire and Furans	1,160	864	0	0	3	3
	Wildfire and Surface Water and Dioxins	1,610	1,030	0	0	0	0
	Wildfire and Fire Retardants	286	164	7	4	5	2
	Wildfire and Disinfection by-products	40	23	2	2	2	2
How can adverse impacts of wildfires on water quality be prevented or mitigated before, during and after wildfires?	Wildfire and Surface Water and Mitigation	7,760	5,790	0	0	4	4
	Wildfire and Source Water Protection	315	253	1	1	1	1
	Wildfire and Surface Water and Adaptation	11,300	9,720	0	0	1	1

1.2 Step 2 – Narrowing search results

The following techniques were used to refine search results while answering the key questions:

- Primary search terms were combined to find specific articles directly related to key questions (*e.g.*, wildfire and nutrients) whereas secondary search terms were chosen to identify jurisdictional best practices and guidance (*e.g.*, wildfire and Alberta);
- Boolean operators (*e.g.*, and, or, " ", brackets) were used to connect and define relationships between search terms; and
- The review focussed on the past 10 years of published articles and grey-literature reports with the intent on identifying the most current understanding of wildfire impacts. Separate queries were conducted for the most recent 10 years for all databases that were searched but special care was taken not to exclude important and most relevant articles beyond this 10 years timeframe. Older articles with a high degree of relevance were identified by scanning the databases as well as examining the key articles cited in the more recent literature.

The results were categorized for each key question against each search terms and/or combination of search terms. All documents under the most relevant search terms and/or combination of search terms were downloaded. In many instances, the same documents were identified in different databases and with different search strings. Care was taken to retrieve all common documents as well as unique documents available in specific databases, in particular from ScienceDirect and PubMed.

A high-level review of all retrieved documents was conducted. In this step, a total of 75 documents including published scientific articles and grey literature (government and agency reports, workshop and conference proceedings and web-based resources) were retained for detailed review (Step 3, below).

1.3 Step 3 – Document Screening

All 75 documents retained under Step 2 were thoroughly reviewed to identify information relevant to the key questions. An additional search was completed for new relevant references identified within these documents especially in the recently published articles. Bibliographies of publications that met the eligibility criteria were also downloaded and screened for inclusion in the review. After meticulous review of all these articles, 28 journal articles and eight scientific/workshop reports/book chapter were retained for inclusion in the literature review report (See Appendix B1 for summaries of these 36 articles and reports).

1.4 Data Analysis and Reporting

Once the documents screening steps were completed, 36 articles/reports were identified for inclusion in the review. Each article/report was reviewed and the following contents were summarized:

- study objectives;
- high level methodology;
- key results/trends; and
- conclusion/recommendations, if appropriate.

Document summaries regarding constituents of interest are presented in Appendix B1, Table B1.1, and regarding mitigation are presented in Appendix B, Table B1.2. For articles that covered both constituents of interest and mitigation, duplicate summaries are provided in each table (to allow for use of the Appendix tables for quick reference).

APPENDIX B1: SUMMARY OF LITERATURE

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
Abraham, J., Dowling, K., Florentine, S. (2017). Risk of Post-Fire Metal Mobilization into Surface Water Resources: A Review. *Science of The Total Environment,* [online] 599–600, pp.1740–1755. Available at: https://doi.org/10.1016/j.scitotenv.2017.05.096 [Accessed 19 Oct. 2018].	2017	Journal Article	This review article presented the current status of scientific understanding on the risk of post-fire mobilization of the metals into surface water resources. It also discussed the preparation of suitable management plans and policies during and after fire events in order to maintain potable water quality in a cost-effective manner. The human health risks of metals including arsenic, mercury, lead, cadmium, chromium, copper, manganese, nickel, and zinc have been summarized (in Table 1 of original article). A conceptual model depicting the sources of metals to the forest watershed, transport of these post-fire metals to water resources, and pathways of exposure was also presented and discussed. Concentrations of selected metals were compared between pre- and post-fire events as well as between different times after the fires. The conceptual model indicated that the metals from various natural and anthropogenic sources including wildfires may reach aquatic ecosystems and eventually deposit and reside in the sediments, where they can adversely affect the ecosystem, especially benthic communities. Hydrological changes may trigger the exchange of sediment metals back into water and transport them further downstream. Macrophytes and plankton may absorb these potentially-toxic metals leading to an increase in metal availability to all aspects of the food chain. This results in multiple potential impacts to organisms including humans. Apart from this food chain dynamic, human and other terrestrial organisms are also able to absorb metals from the environment through direct ingestion of soils and sediments and dust inhalation. The review findings indicated that forest fires play a significant role in the release of metals usually sequestered in soil organic matter and vegetation, *via* increase soil erosion rate (by 2 to 100-fold) which allows rapid transport of these metals to downstream land and water resources through surface runoff and wind. The authors concluded that the authorities and organizations responsible for watershed and water management should take the following actions to reduce the negative impacts of fire: (i) construction and management of fuel breaks around the water watershed areas, (ii) regular conduct of controlled burning in fire-prone areas to reduce the chance and severity of natural wildfires, and (iii) avoiding the use of fire retardants near waterways and riparian zones in case of fire.				✓						✓	Medium
Ahad, J., Jautzy, J., Cumming, B., Das, B., Laird, K., Sanei, H. (2015). Sources of Polycyclic Aromatic Hydrocarbons (PAHs) to Northwestern Saskatchewan Lakes East of the Athabasca Oil Sands. Organic *Geochemistry*, [online] 80, pp.35–45. Available at: https://doi.org/10.1016/j.orggeochem.2015.01.001 [Accessed 19 Oct. 2018].	2015	Journal Article	This research investigated the possible sources of polycyclic aromatic hydrocarbons (PAHs) in surface sediments in four Saskatchewan lakes influenced by both oil-sands mining activities and wildfires. The lakes were situated 100 to 220 km east–northeast of the main area of bitumen mining in the Athabasca Oilsands Regions.					✓						High

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
			The co-variation between fluxes of the main PAH groups, molecular diagnostic ratios, compound specific $\delta^{13}C$ signatures of individual PAHs and Rock-Eval 6 analysis were used to identify the sources. Concentrations and fluxes of both parent and alkylated PAHs were reported to be low and showed considerable variability over the past 70–100 years. Coincident with the rapid growth of oil-sands production, a small but discernible increase in PAH concentrations and fluxes had occurred over the past 30 years. Based on the multiple lines of evidence, it was concluded that the boreal wildfires are the principal source of PAHs (specifically retene and refractory carbon) in the region over the past several decades.											
Alberta Environment and Parks. (2018). *Variable Responses to the 2016 Horse River Wildfire and Precipitation Events in Large Rivers near Fort McMurray, Alberta.* [Draft Technical Report] Edmonton, AB: Environmental Monitoring and Science Division, Alberta Environment and Parks.	2018	Technical Report	In May and June 2016, the Horse River wildfire burned a total of 590,000 ha near Fort McMurray, Alberta. Following the fire, a series of four large precipitation events occurred, several of which were historically significant. Fluvial responses to these events were investigated using records of discharge, conductivity, turbidity, and total suspended solids (TSS). Much of the data collected from 2016 were from a high-resolution network of continuously-recording data sondes (automated data logger) and analytical water quality samples established in response to the wildfire. Data were presented here from three closely paired discharge and data sonde sites in burned watersheds, and one discharge/sonde location in a nearby 'reference' watershed. Rainfall-generated runoff produced large responses in conductivity, turbidity, TSS, and sediment loads. However, spatial variability in the magnitude and intensity of precipitation event was large, which led to large variability in river responses between watersheds. Conductivity and turbidity were generally lowest in the Ells River, the unburned reference watershed but runoff responses to precipitation events were generally smallest in this river, making it difficult to unambiguously attribute responses to wildfire. Conductivity generally increased for several days following precipitation events, and it is hypothesized that part of this response represents transport of ash from the landscape to rivers. Turbidity also increased in response to precipitation, but responses lasted for weeks to a month. It is hypothesized that within-channel (bank and bed) sediment production continued long after precipitation and remained elevated when discharge was elevated. Responses to precipitation events were largest shortly after the wildfire, and responses were smaller and more variable months after the fire, indicating that availability of ash may have decreased later in the season. Ash transport from the landscape to river was minimal between precipitation events when hydrologic connectivity was low. Ash transport occurred primarily during and shortly following precipitation events when rivers were hydrologically	✓	✓									

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
			connected with the landscape. By the following freshet, transport of ash was low, even during a large precipitation event. This is indicative of exhaustion of readily transportable ash in the year following the wildfire.											
Angeler, D., Rodríguez, M., Martín, S., Moreno, J. (2004). Assessment of Application-rate Dependent Effects of a Long-term Fire Retardant Chemical (Fire Trol 934R) on *Typha domingensis* germination. *Environment International*, [online] 30, pp.375– 381. Available at: https://www.sciencedirect.com/science/article/pii/S0160412003001934 [Accessed 19 Oct. 2018].	2004	Journal Article	This paper presented dose-specific effects of a fire retardant (Fire Trol 934®) on the water quality and seed germination of a macrophyte (*Typha domingensis*) in laboratory-based microcosm experiments. The ultimate objective of this research was to use the results in field conditions in temporal Mediterranean wetlands. The results indicated that application of 1 or 3 liter per m^2 fire retardant can impact *Typha* germination rates in the short-term *via* indirect fire retardant-mediated effects on water quality. Application of fire retardants resulted in increased nutrient concentrations, water color, and electrical conductivity, and, decreased oxygen concentrations.			✓						✓		Low
Bladon, K., Emelko, M., Silins, U., Stone, M. (2014). Wildfire and the Future of Water Supply. *Environmental Science & Technology*, [online] 48, pp.8936–8943. Available at: https://doi.org/10.1021/es500130g [Accessed 19 Oct. 2018].	2014	Journal Article	This review paper presents an overview of wildfire impacts on water quality, hydrology, and ecosystem and public health and provided outlook of water supply in the context of wildfires on a global aspect. The review concluded that wildfire can result in increased solids, nutrients, heavy metals, and temperature which may have significant impact on drinking water treatment cost, property values, recreation, and ecosystem and public health. It also concluded that a major challenge remains to provide actionable science and reliable capacity to predict impacts of wildfire on these water values. In particular, the future of water supply is changing because of climate and its relationship to wildfire. This will likely impact the provision of water for domestic, agricultural, industrial, and ecological needs in some regions. The authors suggested the natural resource managers and agencies will increasingly need to anticipate and prepare for these effects.		✓	✓	✓	✓		✓	✓		✓	Moderate
Bladon, K., Silins, U., Wagner, M., Stone, M., Emelko, M., Mendoza, C., Devito, K., Boon, S. (2008). Wildfire Impacts on Nitrogen Concentration and Production from Headwater Streams in Southern Alberta's Rocky Mountains. *Canadian Journal of Forest Research*, [online] 38, pp. 2359–2371. Available at: https://doi.org/10.1139/X08-071 [Accessed 19 Oct. 2018].	2008	Journal Article	This paper presented the initial effects of the 2003 Lost Creek wildfire on concentrations and production of various nitrogen species and explored the recovery of these effects within the first three years after the fire. The Lost Creek wildfire occurred in southwestern Rocky Mountains of Alberta during July to September and burned more than 21,000 ha in the Crowsnest Pass. The study design consisted of three burned watersheds (Lynx Creek, Drum Creek, and South York Creek) and two unburned/reference watersheds (Star Creek and North York Creek). During the first post-fire year, concentrations of nitrate (NO_3^-), total nitrogen (TN), dissolved organic nitrogen (DON), total particulate nitrogen (TPN), and ammonium (NH_4^+) in severely burned watersheds were 6.5-, 5.3-, 4.1-, 3.0-, and 1.5-times greater, respectively than in unburned watersheds. Although a rapid decline in mean concentrations and production of NO_3, DON, total dissolved nitrogen			✓								High

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
			(TDN), and TN was observed from burned watersheds over the three years after the fire, elevated NO_3^-, TDN, and TN concentrations were still evident during the snowmelt freshet and following precipitation events after three years.											
Burke, M., Hogue, T., Kinoshita, A., Barco, J., Wessel, C., Stein, E. (2013). Pre- and Post-Fire Pollutant Loads in an Urban Fringe Watershed in Southern California. *Environmental Monitoring and Assessment*, [online] 185, pp.10131–10145. Available at: https://doi.org/10.1007/s10661-013-3318-9 [Accessed 19 Oct. 2018].	2013	Journal Article	The research focused on the Station Fire (2009) and compared post-fire water quality with pre-fire baseline data collected in order to better understand the impacts of wildfire on mass loading in highly impacted, urban fringe landscapes. The Station Fire occurred in the upper Arroyo Seco watershed located adjacent to the Greater Los Angeles (California), an area that had not been burned for over 60 years before the 2009 wildfire event. Water quality sampling was conducted prior to (October through March 2009) and immediately following (October through March 2010) the fire, covering four storm events in each year over the rainy seasons. Samples were analyzed for basic cations, total recoverable metals, and total suspended solids. The loss of vegetation and changes in soil properties from the fire increased the magnitude of storm runoff, resulting in 10-fold greater median total suspended solids (TSS) concentration (259 mg/L) than pre-fire median concentration (23 mg/L). Median metal concentrations from pre-fire to post-fire increased over two orders of magnitude in lead and cadmium, over one order of magnitude in aluminum, manganese and zinc, and nine-fold, six-fold, and four-fold in copper, nickel, and iron, respectively. A lesser degree of increase was observed for median concentrations of arsenic (less than two-fold), and selenium (slightly) in the post-fire samples. The median post-fire magnesium, calcium, and potassium concentrations were two, three, and four times higher than the pre-fire concentrations, respectively. The results emphasized the significance of sediment delivery as a primary mechanism for post fire contaminant transport and suggested that traditional management practices that focus on treating only the early portion of storm runoff may be less effective following wildfire. The authors also suggested that watersheds impacted by regional urban pollutants have the potential to pose a significant risk for downstream communities and ecosystems after fire.	✓	✓		✓							Moderate
Cawley, K., Hohner, A., McKee, G., Borch, T., Omur-Ozbek, P., Oropeza, J., Rosario-Ortiz, F. (2018). Characterization and Spatial Distribution of Particulate and Soluble Carbon and Nitrogen from Wildfire-Impacted Sediments. *J Soils Sediments*, [online] 18, pp.1314–1326. Available at: https://doi.org/10.1007/s11368-016-1604-1 [Accessed 19 Oct. 2018].	2018	Journal Article	The purpose of this study on the High Park wildfire (2012) was to characterize burned sediment and its soluble compounds collected from the heavily forested Cache la Poudre (CLP) watershed in northern Colorado (USA). The High Park wildfire began on June 9, 2012, burned 35,300 ha, and was fully contained by July 2, 2012. Ash-affected sediment samples were collected from five sites upstream of the City of Fort Collins drinking water intake of CLP river. At each site, samples were collected from three locations: (1) the edge of the bank adjacent to the water edge			✓	✓				✓			Moderate

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
			(downbank), (2) 1 m upslope of location 1 (midbank), and (3) 2 m upslope of location 1 (upperbank). All sediment samples were analyzed for elemental composition, and a subset of sediment samples were analyzed with ^{13}C solid-state nuclear magnetic resonance spectroscopy (NMR). Sediments were also mixed with the background CLP river water collected from upstream of the wildfire and allowed to leach for 6 and 24 h to determine the quantity and quality of water-soluble constituents. Filtered samples were analyzed for dissolved organic carbon (DOC), iron, manganese, inorganic nutrient concentrations, and disinfection byproducts (DBPs). The results indicated that the percent carbon and nitrogen contents of the solid sediments were accurate predictors of leachate DOC concentration. Mean fluorescence index (an optical parameter used to understand the dissolved organic carbon precursors and chemical characteristics) was higher for wildfire-impacted sediment leachates (1.50) compared to the background CLP river water (1.37), which may be due to changes in DOM molecular weight and oxidation of organic matter. All sediment leachates showed consistently higher haloacetonitrile and chloropicrin yields (nitrogen-based DBPs) compared to background CLP river water, whereas trihalomethanes and haloacetic acids (carbonaceous DBPs) did not show any differences. It was concluded that the leachates of the sediments containing burned material have different characteristics compared to the background CLP river water. This finding indicated that drinking water utilities may need to alter their treatment processes to address increased sediment loads and elevated nutrient and DOC concentrations, and also to control production of nitrogen-based DBPs.											
Costa, M., Calvão, A., Aranha, J. (2014). Linking Wildfire Effects on Soil and Water Chemistry of the Marão River Watershed, Portugal, and Biomass Changes Detected from Landsat Imagery. *Applied Geochemistry*, [online] 44, pp.93–102. Available at: https://doi.org/10.1016/j.apgeochem.2013.09.009 [Accessed 19 Oct. 2018].	2014	Journal Article	The purpose of this study was to assess changes in the chemical composition of soils and surface water as a result of a 2006 wildfire that burned 255 ha in the Marão Mountains, NE Portugal. It compared pre- and post-fire hydro-chemical data and burned/unburned soil data, examined the recovery of vegetation over time using Landsat TM imagery. Samples of ash, soil and water, from within and outside the burned area, were collected for chemical analyses five months and one year after the fire (sampling between November 2006 and December 2008). Landsat TM images were processed into a vegetation index, in order to analyze landcover dynamics and to calculate biomass. Wildfire effects on water quality of the Marão River included an increase in the pH and the total mineralization of water. Conductivity five months after the wildfire was about 56% higher than pre-fire values and remained higher one year after the fire. Increased pH and conductivity was attributed to ash and nutrients transported from the burned slope. Calcium, sodium, magnesium, and manganese		✓								✓	Low

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			showed the greatest increase five months after the fire with this increase attributed to movement of ash to the watercourses. Within one year following the fire, these increases attenuated to values closer to pre-fire concentrations except for concentrations of manganese and silicon that were still rising one year after the fire. Concentration of manganese in ash samples were up to five times greater than values found in underlying soils – transport of manganese in the ash to the stream and followed by solubilization could explain the high concentration in river water. The higher concentrations of silica in receiving waters between five months and one year after the wildfire suggest increased rate of dissolution of silicate minerals from bedrock that was caused by the removal of the overlying ash and soil and the hydrolysis of silicate minerals from the bedrock. One year after the wildfire, almost all the burned area had recovered with herbaceous vegetation and patches of shrub vegetation. The authors estimated 1194.7 dry tons of biomass burnt in this wildfire contributing approximately 350 g/ha of manganese as a result of the fire. It was suggested that this type of biomass assessment can be conducted before a fire to help resource managers understand worst-case scenarios for changes in water quality that have the potential to affect aquatic biotic and the suitability of water for drinking water purposes and agriculture.											
Crouch, R., Timmenga, H., Barber, T., Fuchsman, P. (2006). Post-Fire Surface Water Quality: Comparison of Fire Retardant *versus* Wildfire-Related Effects. *Chemosphere*, [online] 62, pp.874–889. Available at: https://doi.org/10.1016/j. chemosphere.2005.05.031 [Accessed 19 Oct. 2018].	2006	Journal Article	This article reports evaluated ammonia, phosphorus, and cyanide concentrations observed from four wildfires that were fought with airdrops of fire retardant. It focused on determining whether these chemicals originated primarily from the fire or from retardant use. Measured concentrations in streams draining areas where fire retardant was applied were compared with concentrations in streams draining areas where retardant was not used. Correlations between the constituents of interest (ammonia, phosphorus, and cyanide) and calcium were also used to further explore chemical source attribution because correlations with calcium provide an additional line of evidence as calcium concentrations in ash are much higher than in retardant (*e.g.*, if calcium is better correlated with the ammonia, phosphorus, and cyanide, it can be assumed that the elevated ammonia, phosphorus, and cyanide are originated from wildfire ash, not from retardant). The results indicate no difference in ammonia, phosphorus, and total cyanide concentrations between streams in burned areas where retardant was not used and areas where retardant was applied. Concentrations of weak acid dissociable cyanide were generally non-detected or very low, regardless of whether fire retardant was applied in the watershed. Cyanide concentrations in post-fire stormwater runoff were related to pyrogenic sources including wildfire and did not appears affected by the presence of ferrocyanide in the retardant formulas. The			✓				✓		✓		Moderate

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Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
			authors concluded that the application of wildfire retardant had minimal effects on nearby surface water quality.											
Emelko, M., Silins, U., Bladon, K., Stone, M. (2011). Implications of Land Disturbance on Drinking Water Treatability in a Changing Climate: Demonstrating the Need for 'Source Water Supply and Protection' Strategies. *Water Research*, [online] 45, pp.461–472. Available at: https://doi.org/10.1016/j.watres.2010.08.051 [Accessed 19 Oct. 2018].	2011	Journal Article	This article discusses the potential implications of changing climate and wildfire on source water protection and drinking water treatment, with specific reference to the 2003 Lost Creek Wildfire in Alberta (Canada). During July-September 2003, the Lost Creek wildfire burned more than 21,000 ha in the headwaters of the Castle and Crowsnest rivers. The study covered three burned watersheds (South York, Lynx, and Drum Creeks), two unburned/reference watersheds (Star and North York Creeks) prior to the first post-fire spring snowmelt in March-April 2004, as well as two additional burned and salvage-logged watersheds (Lyons Creek East and West) established in January 2005. Four years of hydrology and water quality data from seven watersheds were evaluated and synthesized to assess the implications of wildfire and post-fire intervention (salvage-logging) on downstream drinking water treatment. The 95th percentile turbidity and dissolved organic carbon (DOC) were elevated in streams draining burned watersheds (15.3 NTU, 4.6 mg/L, respectively) and salvage-logged (18.8 NTU, 9.9 mg/L) watersheds, compared to concentrations in streams draining unburned watersheds (5.1 NTU, 3.8 mg/L, respectively). The authors suggested that these constituents could deleteriously impact water treatment by contributing to increased dependency on and/or difficulty in maintaining efficiency of solids removal processes such as coagulation/flocculation/sedimentation, sludge production, and oxidant demand. Concentrations of dissolved organic nitrogen (DON) were higher in discharge from the burned (95th percentile: 756.6 mg/L)) and post-fire salvage-logged (95th percentile: 409.7 mg/L) watersheds, relative to unburned watersheds (358.5 mg/L), even four years after the fire. The authors suggested that elevated DOC and DON due to wildfire and salvage-logging may increase water utility challenges associated with providing adequate disinfection while limiting residual chlorine, balancing chlorine to ammonia ratios, and minimizing disinfectant byproduct (DBP) formation. The 95th percentile total phosphorus (TP) concentrations over the four post-fire years were 10 to 17 times higher in streams draining the burned (121.0 mg/L) and salvage-logged (210.0 mg/L) watersheds, compared to concentrations in streams draining unburned watersheds (12.4 mg/L). The authors discussed that persistent elevated concentrations of TP are of concern because they have been frequently linked with the presence of microcystins produced by Cyanobacteria, elevated levels of which have been associated with gastroenteritis and, in some cases, liver toxicity and death. Increased concentrations of bioavailable phosphorus can increase microbial growth in distribution systems and also prolong the survival of		✓	✓	✓				✓		✓	High

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			culturable *Escherichia coli* in water and biofilms which can also act as a reservoir for microorganisms in drinking water distribution systems. Coagulation, flocculation, and sedimentation (or other clarification processes) may be necessitated for phosphorus and mercury removal. Total mercury, chlorophyll *a*, and A*ctinobacteria*-like microbial concentrations were also higher in the fire affected discharges than in discharge from the reference watersheds. The authors concluded that persistent increases in turbidity, nutrients, heavy metals, and other biological contaminants in discharge from burned and salvage-logged watersheds present important economic and operational challenges for water treatment; most notably, a potential increased dependence on solids and DOC removal processes. They also indicated that many traditional source water protection strategies would fail to adequately identify and evaluate many of the significant wildfire- and post-fire management-associated implications to drinking water "treatability". Therefore, it was recommended that "source water supply and protection strategies" should be developed to consider a suppliers' ability to provide adequate quantities of potable water to meet demand by addressing all aspects of drinking water "supply" (*i.e.,* quantity, timing of availability, and quality) and their relationship to "treatability" in response to land disturbance.											
Evans, C., Malcolm, I., Shilland, E., Rose N., Turner, S., Crilly, A., Norris, D., Granath G., Monteith, D. (2017). Sustained Biogeochemical Impacts of Wildfire in a Mountain Lake Catchment. *Ecosystems,* [online] 20, pp.813–829. Available at: https://doi.org/10.1007/s10021-016-0064-1 [Accessed 19 Oct. 2018].	2017	Journal Article	This article evaluated the impact of wildfire on the water chemistry especially nutrients and their implication to drinking water supply of a mountain lake in the United Kingdom (UK). Water quality data were collected from Blue Lough, draining a moorland watershed (Northern Ireland, UK) which experienced a major wildfire in 2011 that burned over 10,000 ha of land. Long term data (25 years) collected from 22-sites including pre- and post-fire and reference watersheds under the UK Upland Waters Monitoring Network (UWMN) were presented. The main water-quality response to the wildfire was a five times increase in nitrate concentrations (average 82 μeq/L with a peak of 111 μeq/L) relative to pre-fire concentrations. This elevated nitrate concentrations also had secondary effects of increased acidity and aluminum concentrations. In contrast to other studies, a clear reduction in DOC concentrations were observed. However, data from a downstream water supply reservoir indicated a fire-induced change in DOC quality towards more soil-derived aromatic organic compounds, and lake sediment data suggested a large increase in particulate organic carbon. It was concluded that the biogeochemical responses to wildfire in moorland watershed were broadly similar to those observed in forest ecosystems elsewhere, but that historically high nitrogen deposition has made the ecosystem particularly susceptible to nitrate leaching and (re-)acidification.			✓								Low

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Gabos, S., Ikonomou, M., Schopflocher, D., Fower, B., White, J., Prepas, E., Prince, D., Chen, W. (2001). Characteristics of PAHs, PCDD/Fs and PCBs in Sediment following Forest Fires in Northern Alberta. *Chemosphere*, [online] 34, pp.709-719. Available at: https://www.ncbi.nlm.nih.gov/pubmed/11372856 [Accessed 19 Oct. 2018].	2001	Journal Article	This paper examined natural and anthropogenic influences, including wildfires, on the concentration profiles of PAHs, PCDD/Fs and PCBs in sediment samples in northern Alberta. Field sediment collection was carried out in September 1998 at three sites including a partially burned site (Sakwatamau river), a totally burned site (Freeman river), and a reference site (Little Smoke river). The results indicate that alkylated PAH derivatives dominated over parent PAHs at the burned and reference sites. While naturally derived PAHs were abundant in all sites, a high proportion and concentration of retene (an indicator of wildfire influence) was observed at the totally burned sites. The low concentrations of PCDD/Fs and PCBs and the similarities of among profiles of these organochlorine compounds from all sampling sites suggested that the contributing sources is non-point source atmospheric deposition rather than an influence of episodic wildfires.					✓	✓					High
Hohner, A., Cawley, K., Oropeza, J., Summers, R., Rosario-Ortiz, F. (2016). Drinking Water Treatment Response Following a Colorado Wildfire. *Water Research*, [online] 105, pp.187–198. Available at: https://doi.org/10.1016/j.watres.2016.08.034 [Accessed 19 Oct. 2018].	2016	Journal Article	The goal of this study was to assess the impact of a wildfire on drinking water quality and treatability in a watershed serving as a direct drinking water supply for several communities. It was conducted for the High Park wildfire that occurred on June 9, 2012 and burned 35,300 ha land of northern Colorado watershed. A water treatment intake within the burned area and a site upstream of the burned area were monitored during the first snowmelt season (2013) and rainstorm events (water intake only) following the fire. Monitoring was also conducted in 2012 immediately following the fire (which is reported in Writer *et al*. 2014, see later in this table for summary). Four years of pre-fire water quality data from the City of Fort Collins drinking water intake and reference site were used for comparison to post-fire monitoring results. Turbidity, nutrients (total phosphorus, total nitrogen, total organic carbon), dissolved organic matter (DOM) character, coagulation treatability, and disinfection byproduct (DBP) formation were evaluated and compared to pre-fire data. Mean concentrations of turbidity (35 NTU), nitrogen (0.66 mg/ L), and phosphorus (0.058 mg/L) were an order of magnitude higher at post-fire water intake site, compared to pre-fire water intake site as well as a post-fire reference site. Fluorescence index (FI) values were significantly higher at the intake site compared to the reference site and higher than pre-fire years, suggesting the wildfire altered the DOM character of the river. DBP formation including total trihalomethane (TTHM) and haloacetonitrile (HAN) formation at the intake were also higher than the reference site. Conventional treatment of post-fire water was effective at a 10 mg/L higher average alum dose than reference samples. The intake was also monitored following rainstorms. Post-rainstorm samples showed further increase in the FI values (max 1.52), HAN4 (max 3.4 µg/mg C) and	✓		✓					✓		✓	Moderate

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
			chloropicrin formation yields (max 3.6 µg/mg C). However, TTHM and haloacetic acid yields did not respond to rainstorm events. Several post-rainstorm samples presented treatment challenges, and even at high alum doses (65 mg/L), showed minimal dissolved organic carbon removal (<10%). The degraded water quality of the post-rainstorm samples is likely attributed to the combined effects of runoff from precipitation and greater erosion following wildfire. The results suggest that the wildfire may have consequences for influent water quality, coagulant dosing, and DBP speciation.											
Jensen, A., Scanlon, T., Riscassi, A. (2017). Emerging Investigator Series: The Effect of Wildfire on Streamwater Mercury and Organic Carbon in a Forested Watershed in the Southeastern United States. *Environmental Science: Processes & Impact*, [online] 19, pp.1505–1517. Available at: https://doi.org/10.1039/C7EM00419B [Accessed 19 Oct. 2018].	2017	Journal Article	This study investigated the coupled transport of mercury and carbon at Twomile Run, a headwater stream located in the forested mountains of Shenandoah National Park (United States of America (USA)), in the year following a low-severity wildfire (Rocky Mount Fire). The Rocky Mount Fire occurred in April and May 2016, and burned over 4,000 ha of mountain laurel, pine, and oak forest including the Twomile Run watershed. Weekly baseflow samples and bi-hourly high-flow storm samples were collected at Twomile Run from June 2016 through May 2017 and analyzed for dissolved and particulate mercury, dissolved organic carbon (DOC), ultraviolet (UV) absorbance at 254 nm (UV_{254}, surrogate for DOC quantity and character), and total suspended solids (TSS). Reference data collected from 2008–2010 at a nearby unburned watershed (Paine Run) were used for comparison with data collected from burned watershed. The results indicated that streamwater dissolved mercury, DOC concentrations and corresponding UV_{254}, were similar between the burned watershed and the unburned watershed for all flow conditions. TSS concentrations were relatively higher in burned watershed but overall differences were small and likely attributable to site differences rather than fire effects. However, the particulate mercury per unit of TSS at the burned watershed was an order of magnitude higher than the unburned watershed (2.66 and 0.13 ng Hg per mg TSS, respectively) for 8 months following the fire, after which there was a rapid return to unburned conditions. Streamwater total mercury fluxes roughly doubled (0.55 to 1.04 mg/m^2 /year) as a consequence of the fire, indicating that in addition to changing atmospheric and terrestrial mercury cycling, fires can rapidly and significantly alter streamwater mercury dynamics which has implication for downstream ecosystems. This research showed that in the year following a low-severity wildfire, newly available mercury can be rapidly transported downstream during the post-first-flush period even in the absence of significant changes to TSS, DOC, or dissolved mercury concentrations observed in surface water monitoring.	✓	✓		✓							Moderate

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				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
Lane, P., Sheridan, G., Noske, P., Sherwin, C. (2008). Phosphorus and Nitrogen Exports from SE Australian Forests Following Wildfire. *Journal of Hydrology*, [online] 361, pp.186–198. Available at: https://doi.org/10.1016/j.jhydrol.2008.07.041 [Accessed 29 Oct. 2018].	2008	Journal Article	This article examined the magnitude and temporal distribution of nitrogen (N) and phosphorus (P) loads in the dissolved and suspended solid forms from two former research watersheds (136 and 244 ha) in the East Kiewa valley, Victoria (Australia) after a wildfire that burnt over 1 million hectares of forested land in early 2003. Discharge, suspended sediment, bedload and N and P were measured for 3 years post-fire. The nutrient data consisted of 15-minute estimation of particulate P and total Kjeldahl N *via* a regression with turbidity, and dissolved forms of P and N estimated from over 1,100 water samples. Total P and N exports were around 5–6-fold higher due to wildfire, peaking at 1.6 kg/ha of total P and 15.3 kg/ha of total N. Nutrients transported as particulate matter dominated the post-fire years, with particulates transporting 94% of total P and 69% of total N over the first post-fire, and 86% of the total P and 68% of the total N over the three post-fire years. Concentrations and loads of P and N exhibited a rapid recovery to unburnt levels during the second post-fire year and particulate forms declined sharply through a reduction in sediment delivery. Nitrate had the slowest reduction time, possibly due to a persistent subsurface source and nitrification. The authors concluded that particulate N and P were the dominant sources of total post-fire loads, and therefore ignoring the particulate component of both N and P can result in a very significant underestimation of nutrient exports.			✓								
Mansilha, C., Duarte, C., Melo, A., Ribeiro, J., Flores, D., Marques, J. (2017). Impact of Wildfire on Water Quality in Caramulo Mountain Ridge (Central Portugal). *Sustainable Water Resources Management*, [online]. Available at: https://doi.org/10.1007/s40899-017-0171-y [Accessed 19 Oct. 2018].	2017	Journal Article	This study evaluated the impact of a large wildfire on surface water and groundwater quality by examining various constituents of concern including major ions, trace metals, and polycyclic aromatic hydrocarbons (PAHs) in Caramulo Mountain (Central Portugal). The wildfire occurred in August 2013 and affected a wide area corresponding to forest (5,844 ha), woods and pastures (3,097 ha) and agriculture (400 ha). Water samples from burnt and unburnt areas were collected in eight sampling points, over five sampling events from September 2013 to March 2015. The results reveal a wide range of wildfire effects on the levels of various physical and chemical constituents in water from springs and streams from Caramulo Mountain. In many cases, the most evident effects were observed in the January 2014 campaign, during the first important post-fire wet period. After this peak, most effects were considerably attenuated within 1 year. The major findings of this article included: Mean values of water pH, alkalinity, electrical conductivity, and turbidity increased during post-fire conditions, relative to the pre-fire and unburned conditions; Concentrations of major ions including magnesium, chloride, and sulphate were 1.5 to 4.5 times over unburned control;	✓	✓	✓	✓	✓						Low

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			The first-year post-fire nitrate concentrations were 27 to 104 times higher than the unburnt control values, whereas nitrite and ammonia concentrations were low in all samples during the entire study period; Metal concentrations increased between 1 and 8 months after the wildfire, especially iron (2 to 13 times over the unburned control), manganese (8 to 68 times), and lead (1 to 7 time). Other metals showed negligible concentration changes regarding the unburnt control; and The total polycyclic aromatic hydrocarbons (∑PAHs) concentration was 1.2–4.0 times higher than in the unburnt control samples, where a minor influence of rainfall was observed. The most detected PAHs in water samples collected were naphthalene (25%), benzo(ghi)perylene (17.6%), indeno(1,2,3-cd)pyrene (13.6%), benzo(b)fluoranthene (9.4%), benzo(a)pyrene (6.8%), and benzo(k)fluoranthene (6.5%). The seven carcinogenic PAHs with high molecular weights (benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzo(ah)anthracene) accounted for 45% of the total PAHs concentration. Benzo(a)pyrene concentrations exceeded the drinking water guideline, 5 months after the wildfire, probably associated with precipitation events. PAHs concentrations decreased 8 months after the fire, possibly to their degradation by atmospheric agents, such as temperature and humidity, and adsorption on particles. Diagnostic ratios suggest that PAHs can be largely attributed to combustion, revealing the inputs of the pyrogenic material.											
McCleskey, R., Writer, J., Murphy, S. (2012). *Water Chemistry of Surface Waters Affected by the Fourmile Canyon Wildfire, Colorado, 2010–2011*. [PDF, Open-File Report 2012–1104]. Reston, Virginia: U.S. Department of the Interior, U.S. Geological Survey (USGS), pp. 1-11. Available at: https://pubs.usgs.gov/of/2012/1104/OF12-1104.pdf [Accessed 19 Oct. 2018].	2012	Technical Report	This report provides water quality data collected from Fourmile Creek affected by the Fourmile Canyon fire in September 2010. Data were collected from three burned sites and two unburned reference sites along Fourmile Creek starting within a month post-fire and continuing until November 2011. Monitoring frequency was monthly during base flow, biweekly during snowmelt runoff, and more frequently during storm events. Mean concentrations of various water quality variables between burned and reference sites are compared below: TSS and turbidity: TSS (29 mg/L) and turbidity (14 NTU) in burned sites were 4,000 and 1,000 times higher than the concentrations recorded in reference sites; Major ions: Mean concentrations of magnesium (11 mg/L), calcium (31 mg/L), potassium (4 mg/L), and sodium (7 mg/L) were 3.5, 4.5, 5.0, and 2.0 times higher in burned sites than in reference sites. Similarly, anions concentrations including sulphate (42 mg/L), chloride (11 mg/L), and fluoride (0.2 mg/L) were 4.5, 2.8, and 1.5 times higher in burned sites than in unburned sites, respectively; Nutrients: Ammonium (0.48 mg/L) and nitrate (0.61 mg/L) concentrations were 5 and 3 times higher in burned sites than in reference sites, whereas total phosphorus	✓	✓	✓	✓							Moderate

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			(0.84 mg/L) and silica (17.6 mg/L) concentrations at burned sites were 14 and 1.8 times the reference sites; and Trace metals: The most affected total metals due to wildfire included manganese (151 times the reference sites), followed by aluminum (71 time), iron (50 times), cobalt (38 times), nickel (24 times), cadmium (19 times), chromium (10 times), and barium (7 times), respectively. Mercury concentrations did not vary between burned and reference sites.											
Pappa, A., Tzamtzis, N., Koufopoulou, S. (2008). Nitrogen Leaching from a Forest Soil Exposed to Fire Retardant with and without Fire: A Laboratory Study. *Annals of Forest Science*, [online] 65, pp.210–210. Available at: https://doi.org/10.1051/forest:2007093 [Accessed 19 Oct. 2018].	2008	Journal Article	This article investigated the leaching of the nitrogen constituent of a long-term fire retardant – Fire-Trol 931 (ammonium polyphosphates based, broadly used in the Mediterranean countries) – from a typical Mediterranean forest soil at the laboratory scale. The leaching of nitrate (NO_3^-) and ammonium (NH_4^+) from pots with Fire-Trol 931 treated and untreated forest soil and pine seedlings (*Pinus halepensis*) from Mount Penteli (close to Athens, Greece), was studied alone and in combination with fire. The results indicated that up to 30% of the total nitrogen in the retardant was lost to leaching, primarily as NO_3^-.							✓		✓		Low
Rhoades, C., Deborah, A., Entwistle, D., Butler, D. (2011). The Influence of Wildfire Extent and Severity on Streamwater Chemistry, Sediment and Temperature following the Hayman Fire, Colorado. *International Journal of Wildland Fire*, [online] 20, pp.430–442. Available at: https://www.fs.fed.us/rm/pubs_other/rmrs_2011_rhoades_c001.pdf [Accessed 19 Oct. 2018].	2011	Journal Article	This article presents stream chemistry, temperature, and turbidity data collected before the fire and at monthly intervals for 5 years after the Hayman wildfire in Colorado. The Hayman Fire was ignited on 8 June 2002 after a period of prolonged drought in the Colorado Front Range and burned an area of 55,800 ha. The results indicate that the average summer water temperature was 4.08 °C higher in burned streams than in unburned streams, possibly sufficient temperature change to alter suitability of aquatic habitat. However, winter temperatures remained similar between burned and unburned streams. Basins burned with high severity wildfire had twice the streamwater nitrate and four times the turbidity, relative to basins burned to a lower extent. Maximum post-fire calcium concentrations were double the mean summer maximum concentration (56 mg/L) of pre-fire streams and post-fire unburned streams (23 mg/L).	✓	✓	✓								Moderate
Robichaud, P. (2009). *Post-fire stabilization and rehabilitation*. In: Cerda, A, Robichaud, P, eds., Fire Effects on Soils and Restoration Strategies, 1st ed. Boca Raton, FL: CRC Press. pp. 303–324.	2009	Book chapter	This book chapter summarizes post-fire treatment techniques and their effectiveness, including treatments applied to hillslopes, roads, and channels. The decision of where and when to use post-fire stabilization treatments requires a site-specific evaluation. In many cases, it is justifiable and cost-effective to not apply any treatment. Treatments should only be applied if unacceptable levels of flooding, erosion, and/or sedimentation are expected. Mulching appears to generally be both inexpensive and effective. Monitoring the effectiveness treatments is essential.										✓	

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
Santín, C., Doerr, S., Otero, X., Chafer, C. (2015). Quantity, Composition and Water Contamination Potential of Ash Produced under Different Wildfire Severities. *Environmental Research,* [online] 142, pp.297–308. Available at: https://doi.org/10.1016/j.envres.2015.06.041 [Accessed 19 Oct. 2018].	2015	Journal Article	This article investigated the amount and characteristics of ash generated under different wildfires, with the specific objective of examining the role of fire severity (*i.e.,* degree of destruction of vegetation and ground fuels) in determining (i) total ash loads (ii) ash chemical composition for constituents relevant to water quality, and (iii) the associated risks for water contamination. In October 2013, the Balmoral wildfire burned over 16,000 ha including 12,694 ha of dry, shrubby sclerophyll eucalypt forests in the water supply watersheds managed by Water NSW. It affected parts of the greater Sydney drinking water supply watershed area including the Nepean and adjacent watersheds. Sampling sites were selected along a ridge typical of the region (presented in Figure 1 of this article) with a relatively homogeneous fuel load. Fire severity was defined as the degree of destruction (consumption) of above ground and ground fuels, based on the classification established for this region. Three fire severities were studied: (1) low fire severity: ground and understory (<0.5 m high) fuels burnt, canopy unaffected; (2) high fire severity: ground and understory (<4 m high) fuels burnt, canopy scorched; and (3) extreme fire severity: all available fuels consumed, including stems <1 cm thick. The wildfire produced substantial ash loads that increased with fire severity, with 6, 16 and 34 Mg/ha found in areas affected by low, high, and extreme fire severities, respectively. Ash bulk density was also positively related to fire severity. The increase in the total load and bulk density of the ash generated with fire severity was attributed to a combination of increasing total fuel affected by fire and contribution of 'burnt mineral soil' to the ash layer (which increased with increasing fire severity). Total concentrations of metals and nutrients in ash were mostly unrelated to fire severity and relatively low compared to values reported for wildfire ash in other environments (*e.g.,* 4.0–7.3 mg/kg arsenic, 2.3–4.1 mg/kg boron, 136–154 mg/kg phosphorus). Solubility of the elements analyzed was low – less than 10% of the total concentration – for all elements except for boron (6–14%) and sodium (30–50%). This lower solubility may have been related to a partial loss of soluble components by leaching and/or wind erosion before the ash sampling (10 weeks after the fire and before major ash mobilization by water erosion). Overall total ash loads suggested a potential for substantial water quality impacts including contaminant effects and increases in turbidity when ash reaches the reservoir as suspended solids.	✓		✓	✓						✓	Low

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Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
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Salamanca, M., Chandía, C., Hernández, A. (2016). Impact of Forest Fires on the Concentrations of polychlorinated Dibenzo-p-Dioxin and Dibenzofurans in Coastal Waters of Central Chile. *Science of The Total Environment*, [online] 573, pp.1397–1405. Available at: https://doi.org/10.1016/j.scitotenv.2016.07.113 [Accessed 19 Oct. 2018].	2016	Journal Article	This research investigated whether the observed peaks in polychlorinated Dibenzo-p-Dioxin and Dibenzofurans (PCDD/F) concentrations recorded during a long-term monitoring program (PROMNA) in the coastal area (Bio-Bio Region) of central Chile were related to wildfires. During January 2012, a large fire burned about 32,000 ha of forest plantations, agricultural land, and native forests in the Bio-Bio Region. A total of 2006 water samples were collected quarterly (February, May, August, and November) between May 2006 and August 2014 and analyzed for PCDD/F. Peak PCDD/F concentrations were recorded in February of 2007 and 2012 and coincided with major wildfires in the Bio-Bio. The fires resulted in short-term increase in medium toxicity furan-type congeners concentrations (TCDF, PCDF and HxCDF) associated with atmospheric transport. Six months later the fire, an increase in low toxicity dioxin-type congeners concentrations was observed (OCDD, HpCDD, and HxCDD) associated with maximum winter river flow. These results suggested that forest fires near the coastal zone were responsible for increases in PCDD/F concentration observed in the study area. The images and the statistical analysis strongly suggested that the high concentrations of PCDD/F identified in 2012 were caused by the fire. The system was able to return to local background concentrations within less than a year, so the episodic high PCDD/F concentrations that are generated by wildfires do not appear to persist in the aquatic environment.						✓					Moderate
Smith, H., Hopmans, P., Sheridan, G., Lane, P., Noske, P., Bren, L. (2012). Impacts of Wildfire and Salvage Harvesting on Water Quality and Nutrient Exports from Radiata Pine and Eucalypt Forest Catchments in South-Eastern Australia. *Forest Ecology and Management*, [online] 263, pp.160–169. Available at: https://doi.org/10.1016/j.foreco.2011.09.002 [Accessed 19 Oct. 2018].	2012	Journal Article	This article investigated nutrient losses following post-wildfire salvage harvesting of a radiata pine plantation watershed compared to an adjacent natural eucalypt forest watershed that was also burnt but not harvested. The study watersheds form part of the long-term Cropper Creek Hydrology Project (established in 1975) that is situated in south-eastern Australia. Post-fire monitoring (2007–2009) involved collection of both weekly and flow proportional water samples that were compared with previously reported data from samples collected prior to the fire (1997–2003). Major findings are summarized below: Median values of total suspended solids (TSS) and turbidity returned to pre-fire levels within three years in both watersheds, whereas maximum levels during storm events in the harvested pine watershed continued to exceed the eucalypt watershed. This reflected a previously reported large increase in post-fire sediment exports from the harvested pine watershed that was at least 180 times the eucalypt watershed over the study period; The impact of harvesting on nutrients (nitrate, phosphorus, and Sulphur) and major ions (chloride, sodium, potassium, calcium, and magnesium) concentrations was minor and most ions returned to pre-fire levels within two to three years in both watersheds. Nutrient exports from the pine watershed exceeded the eucalypt	✓	✓	✓	✓							

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
			watershed by 102 times for particulate phosphorus associated with suspended material compared to 1.9 to 4 times for ions; The post-fire changes in ion concentrations were generally similar for both watersheds and the increase in solute exports was largely a result of greater discharge after the fire and harvesting compared to the burnt eucalypt watershed; and The post-fire loss of particulate phosphorus in suspended sediment and bedload from the pine watershed was estimated at a minimum of 11 kg/ha and together with the estimated loss of phosphorus from burning and the removal of the pines represented approximately 6% of the total phosphorus in surface soil and fertilizer applied to the plantation.											
Smith, H., Sheridan, G., Lane, P., Nyman, P., Haydon, S. (2011). Wildfire Effects on Water Quality in Forest Catchments: A Review with Implications for Water Supply. *Journal of Hydrology*, [online] 396, pp.170–192. Available at: https://doi.org/10.1016/j.jhydrol.2010.10.043 [Accessed 19 Oct. 2018].	2011	Journal Article	This paper reviewed changes to exports and concentrations of key physical and chemical constituents in water that may occur after wildfire in forest watersheds, with a particular focus on burned forest environments in south-eastern Australia. The purpose of this review was to provide an indication of the potential for water supply contamination by different constituents following wildfires. The main findings of this review were: First year post-fire suspended sediment exports ranged from 0.017 to 50 ton ha^{-1} year^{-1} across a large range of watershed sizes from 0.021 to 1,655 km^{2}. This represented an estimated increase of 1 to 1,459 times, relative to unburned exports. Maximum reported concentrations of total suspended solids (TSS) in streams ranged from 11 to 500,000 mg/L; Post-fire stream exports of total nitrogen (1.1 to 27 kg/ha/year) and total phosphorus (0.03 to 3.2 kg/ha/year) were 0.3 to 431 times higher in burned watersheds, relative to unburned watershed, while nitrate exports (0.04 to 13.0 kg/ha/year) were 3 to 250 times higher in burned watershed than in unburned watershed. Concentrations of inorganic nitrogen species including nitrate, nitrite, and ammonia in streams and lakes or reservoirs may increase after wildfire but appear to present a generally low risk of exceeding drinking water guidelines; The limited observations of trace elements indicated that the concentrations of iron, manganese, arsenic, chromium, aluminum, barium, and lead were well over water quality guidelines after wildfire, whereas concentrations of copper, zinc, and mercury were below or only slightly above the guideline values; Elevated sodium, chloride, and sulphate yields have been recorded soon after fire, but the reported concentrations of these constituents were well below the guideline values;		✓	✓	✓	✓		✓				Moderate

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
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			Reported wildfire effects on dissolved organic carbon (DOC) were generally minor and the concentrations were largely similar to background concentrations; Available cyanide in small streams are reported to approach to concentrations of concern soon after the fire, but increases are likely to be of short duration; and Post-fire concentrations of polycyclic aromatic hydrocarbons (PAHs) in streams have been found to increase but remained within the recommended guidelines. Large increases in exports and concentrations of some constituents after wildfire indicate the potential for impacts on water supply from forest watersheds. Finally, it was concluded that various water treatment measures may be required in response to the wildfire impacts on water quality, otherwise water supplies may be vulnerable to disruption.											
Stein, E. and Brown, J. (2009). Effects of Post-fire Runoff on Surface Water Quality: Development of a Southern California Regional Monitoring Program with Management Questions and Implementation Recommendations. [PDF, Technical Report 598] Costa Mesa, CA: Southern California Costal Water Research Project, pp.1–37. Available at: ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/598_SoCalRegionalFireMonitoringPlan.pdf [Accessed 15 Oct. 2018].	2012	Journal Article	The goal of this study was to assess regional patterns of runoff and contaminant loading from wildfires in urban fringe areas of southern California (USA). Stormwater runoff samples were collected from five wildfires between 2003 and 2009. These wildfires burned between 11,500 and 65,800 ha of natural open space in southern California(USA). Two to five storm events were sampled per site within first two years following the fires and analyzed for basic constituents, metals, nutrients, total suspended solids, and polycyclic aromatic hydrocarbons (PAHs). Water quality results were compared to data from 16 unburned natural areas and six unburned urban sites. The major findings are summarized below: Total phosphorus flux was up to 921-fold higher compared to unburned natural areas. Nitrate+nitrite concentrations are reported to be two- to four-fold higher from burned areas compared to unburned natural areas; Mean fluxes (kg/km^2) of copper, lead, and zinc were 112- to736-fold higher in burned watersheds than in unburned natural areas; and PAHs flux was also four times greater from burned areas than from adjacent urban areas. Elevated concentration and flux values decreased mainly due to precipitation. It was concluded that contaminant loading from burned landscapes has the potential for substantial contribution to the total annual load to downstream areas in the first several years following fires.			✓	✓	✓						Moderate

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
Townsend, S., Douglas, M. (2004). The Effect of a Wildfire on Stream Water Quality and Catchment Water Yield in a Tropical Savanna Excluded from Fire for 10 Years (Kakadu National Park, North Australia). *Water Research*, [online] 38, pp.3051–3058. Available at: https://doi.org/10.1016/j.watres.2004.04.009 [Accessed 19 Oct. 2018].	2004	Journal Article	In this paper, the effect of an early dry season wildfire (occurred in May 1998 and burned 627 ha area) on the water quality of a seasonally flowing stream (December–June) was examined for a lowland savanna forest in Kakadu National Park (northern Australia) which had remained unburnt for 10 years. Pre-fire water quality was assessed over the three wet seasons (1992/1993, 1993/1994, and 1994/1995), by collecting discrete water samples during storm. After the watershed was burnt in 1998, water quality was assessed using an automated water sampler collecting composite samples. Post-fire concentrations and the total mass transports of the six water quality parameters tested (total suspended sediment, total phosphorus, total Kjeldahl nitrogen, total iron, and total manganese) were within the 95% confidence interval of pre-fire concentrations, suggesting no major differences between pre- and post-fire stream water quality, except for slightly higher nitrogen concentrations in post-fire samples. The lack of effect on water quality was attributed primarily to the timing of the wildfire and the low intensity relative to fires later in the dry season (September). It was further attributed to the retention of canopy cover and the accumulation of leaf litter following the wildfire, and the watershed's gently undulating terrain. It was concluded that the early dry season-controlled fires appear to be a viable management option for reducing accumulated fuel loads and hence reducing the risk of destructive wildfires later in the dry season.			✓	✓							
Vila-Escalé, M., Vegas-Vilarrúbia, T., Prat, N. (2007). Release of Polycyclic Aromatic Compounds into a Mediterranean Creek (Catalonia, NE Spain) after a Forest Fire. *Water Research*, [online] 41, pp.2171–2179. Available at: https://doi.org/10.1016/j.watres.2006.07.029 [Accessed 19 Oct. 2018].	2007	Journal Article	This paper presented the distribution and persistence of polycyclic aromatic compounds (PACs) including 16 priority PAH pollutants in the Gallifa creek located in Catalonia (NE Spain) after a wildfire. On 11 August 2003, a fire burned 4,500 ha of forest affecting the Gallifa streamlet and the riparian zone. Water and sediment samples were collected from depositional pond located at the downstream limit of the burned area. Samples were taken 12 and 45 days after the fire after the first autumn rainfall. Samples for total suspended solids (TSS), dissolved organic carbon (DOC), total organic carbon (TOC), absorption coefficients, and fluorescence determinations were collected biweekly or monthly for 22 months. Collection of reference samples began three months after the fire and continued simultaneously in both streams. Samples for PAH analysis from Gallifa were collected during the first four months after the fire and at the end of sampling, and background PAH samples were collected only 445 and 662 days after the fire. From day 12 after the fire, individual and $\Sigma PAH_{16/18}$ concentrations of the dissolved, particulate, and sediment phases were low and did not represent toxicological hazard. All PAH concentrations approached background levels 15 months after the fire.					✓						Low

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			The rate of elimination of fire-derived PAH depended mainly on the intensity and frequency of precipitation. This indicated that the time of the year a wildfire takes place affects the potential toxicity and ecological effects of PAHs. For example, a wildfire at the beginning of the summer is more likely to favor PAH concentration, adsorption, and bioaccumulation due to water evaporation and drought conditions. Elimination of PAHs from the stream was not linear over time. Concentrations decreased quickly with the first rains after the fire, but new inputs occurred from the burnt area with post-fire precipitation events. These recurrent inputs are unpredictable and might persist until recovery of the basin.											
Wang, J., Dahlgren, R., Erşan, M., Karanfil, T., Chow, A. (2016). Temporal Variations of Disinfection Byproduct Precursors in Wildfire Detritus. *Water Research*, [online] 99, pp.66–73. Available at: https://doi.org/10.1016/j.watres.2016.04.030 [Accessed 19 Oct. 2018].	2016	Journal Article	This article investigated the characteristics and chlorine reactivity of water extractable dissolved organic matter (DOM) in surface deposits with white ash (indicator of high burn severity) and black ash (indicator of moderate burn severity) from conifer and chaparral vegetation within the 2013 Rim Fire perimeter in California. The Rim Fire started in August 2013 and became the third largest wildfire in California history consuming 104,131 ha of forested watersheds that were the drinking water source for 2.6 million residents in the San Francisco Bay area. This study used two approaches to evaluate the variation of disinfection byproducts (DBPs) precursors with increased leaching in surface ash/soil extracts: 1) temporal sampling of AS samples that were exposed to natural precipitation, biological activity, and other environmental factors for a one-year period; and 2) a laboratory sequential leaching of the AS (high burnt *vs* moderate burnt; conifer *vs* chaparral) collected before any precipitation events. Increased cumulative precipitation in the field or number of extractions in the lab leaching experiment resulted in a significant decrease in specific conductivity, DOC, and DBP formation, but an increase in DOM aromaticity (reflected by specific UV absorbance). Increasing cumulative precipitation and related leaching after fire led to an increase in dissolved organic carbon (DOC) aromaticity as well as reactivity to form trihalomethanes, haloacetic acids, and chloral hydrate, but not for haloketones, haloacetonitrile, or N-nitrosodimethylamine, which were more related to the original burn severity. However, the lab sequential leaching failed to capture the increase of the NO_x^--N/NH_4^+-N ratio and the decrease in pH and DOC/nitrogen ratio of ash/soil extracts.								✓			Moderate

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Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
Writer, J., Hohner, A., Oropeza, J., Schmidt, A., Cawley, K., Rosario-Ortiz, F. (2014). Water Treatment Implications after the High Park Wildfire, Colorado. *Journal - American Water Works Association*, [online] 106, pp.E189–E199. Available at: https://doi.org/10.5942/jawwa.2014.106.0055 [Accessed 19 Oct. 2018].	2014	Journal Article	This study evaluated effects of the 2012 High Park Wildfire in the Cache la Poudre (CLP) river watershed in Colorado (USA) on source water quality and water treatment. The High Park wildfire began burned 35,300 ha, from June 9 to July 2, 2012. Water samples were collected from the CLP river over a range of hydrologic conditions that included base flow, spring snowmelt, and storm-event sampling. Water quality analysis included measurement of inorganic constituents, organic carbon (total and dissolved organic carbon [DOC] and ultraviolet absorbance at 254 nm), and nitrogen species (total dissolved nitrogen, nitrate, nitrite, ammonium). Untreated surface water samples were chlorinated at bench scale to assess the potential formation of disinfection byproducts (DBPs) under conditions representative of an average drinking water treatment plant. Additionally, the efficacy of alum coagulation at reducing organic matter concentrations and corresponding DBP formation following chlorination was evaluated using laboratory bench-scale experiments. Finally, the experiences of the Fort Collins Water Treatment Facility in addressing water treatment challenges caused by the 2012 wildfires were evaluated. Post-wildfire DOC and DBP concentrations were higher in thunderstorms and spring snowmelt condition, relative to base-flow conditions. Alum coagulation effectively reduced DOC concentrations by 30 to 60% and total trihalomethanes (DBP) formation by 60 to 80% at a dose of 50 mg/L. The Fort Collins water treatment facility responded to the High Park wildfire by increasing environmental monitoring, using multiple water supplies, and constructing a pre-sedimentation basin to effectively deliver high-quality drinking water to its customers in the year following the fire. It was concluded that despite potentially large short-term effects on source water quality (primarily during storm events), conventional water treatment processes effectively reduce elevated organic matter concentrations and subsequent DBP formation.			✓					✓			✓
Writer, J., Murphy, A. (2012). *Wildfire Effects on Source-Water Quality—Lessons from Fourmile Canyon Fire, Colorado, and Implications for Drinking-Water Treatment*. [PDF, Fact Sheet 2012–3095] Denver, Colorado: US Geological Survey. Available at: https://pubs.usgs.gov/fs/2012/3095/FS12-3095.pdf [Accessed 19 Oct. 2018].	2012	Technical Report (fact sheets)	Technical report summarizing a study to evaluate the effects of wildfire on water quality and downstream ecosystems in the Colorado Front Range after the 2010 Fourmile Canyon fire near Boulder, Colorado. Involved frequent sampling of Fourmile Creek at monitoring sites upstream and downstream of the burned area to study water-quality changes during hydrological conditions such as base flow, spring snowmelt, and summer thunderstorms. Stream discharge and nitrate concentrations increased downstream of the burned area during snowmelt runoff – the authors suggested that the increases were probably within the treatment capacity of most drinking-water plants. During and after high-intensity thunderstorms turbidity, dissolved organic carbon, nitrate and some metals increased by 1 to 4 orders of magnitude within and downstream of the burned area (detailed water quality results are summarized in McCleskey *et al*. 2012	✓		✓	✓						✓	Moderate

Table B1.1 Summary of Literature Regarding Constituents of Interest.

Reference	Publication Year	Publication Type	Summary	Identification of Constituents of Interest										Geographic Relevance to Alberta*
				Turbidity/TSS	Major Ions	Nutrients	Metals	PAHs	Dioxins/PCBs	Cyanide	DBPs	Fire Retardants	Mitigation	
			below). The authors indicated that increases of such magnitude can pose problems for water-supply reservoirs, drinking-water treatment plants, and downstream aquatic ecosystems. Document summary gives the following overview of fire effects: "*Burned watersheds are prone to increased flooding and erosion, which can impair water-supply reservoirs, water quality, and drinking-water treatment processes. Limited information exists on the degree, timing, and duration of the effects of wildfire on water quality, making it difficult for drinking-water providers to evaluate the risk and develop management options.*" The authors listed the following problems related to drinking water quality management due to wildfires: Increased sediment loading of water-supply reservoirs, shortened reservoir lifetime, and increased maintenance costs; Increased nutrient loading of reservoirs, which may promote algal blooms and associated disagreeable taste and odor; Increased turbidity or increased metal concentrations, which may produce larger volumes of sludge and increase chemical treatment requirements, both of which would increase operating costs; and Increased dissolved organic carbon concentrations, which during disinfection may help form unwanted by-products (*e.g.,* regulated carcinogens such as chloroform and trihalomethanes).											

Table B1.2 Summary of Literature Regarding Mitigation.

Reference	Publication Year	Publication Type	Summary	Geographic Relevance to Alberta*
Abraham, J., Dowling, K., Florentine, S. (2017). Risk of Post-Fire Metal Mobilization into Surface Water Resources: A Review. *Science of The Total Environment*, [online] 599–600, pp.1740–1755. Available at: https://doi.org/10.1016/j.scitotenv.2017.05.096 [Accessed 19 Oct. 2018].	2017	Journal Article	This review article presented the current status of scientific understanding on the risk of post-fire mobilization of the metals into surface water resources. It also discussed the preparation of suitable management plans and policies during and after fire events in order to maintain potable water quality in a cost-effective manner. The human health risks of metals including arsenic, mercury, lead, cadmium, chromium, copper, manganese, nickel, and zinc have been summarized (in Table 1 of original article). A conceptual model depicting the sources of metals to the forest watershed, transport of these post-fire metals to water resources, and pathways of exposure was also presented and discussed. Concentrations of selected metals were compared between pre- and post-fire events as well as between different times after the fires. The conceptual model indicated that the metals from various natural and anthropogenic sources including wildfires may reach aquatic ecosystems and eventually deposit and reside in the sediments, where they can adversely affect the ecosystem especially benthic communities. Hydrological changes may trigger the exchange of sediment metals back into water and transport them further downstream. Macrophytes and plankton may absorb these potentially-toxic metals leading to an increase in metal availability to all aspects of the food chain. This results in multiple potential impacts to organisms including humans. Apart from this food chain dynamic, human and other terrestrial organisms are also able to absorb metals from the environment through direct ingestion of soils and sediments and dust inhalation. The review findings indicated that forest fires play a significant role in the release of metals usually sequestered in soil organic matter and vegetation, *via* increase soil erosion rate (by 2 to 100-fold) which allows rapid transport of these metals to downstream land and water resources through surface runoff and wind. The authors concluded that the authorities and organizations responsible for watershed and water management should take the following actions to reduce the negative impacts of fire: (i) construction and management of fuel breaks around the water watershed areas, (ii) regular conduct of controlled burning in fire-prone areas to reduce the chance and severity of natural wildfires, and (iii) avoiding the use of fire retardants near waterways and riparian zones in case of fire.	Medium
Bladon, K., Emelko, M., Silins, U., Stone, M. (2014). Wildfire and the Future of Water Supply. *Environmental Science & Technology*, [online] 48, pp.8936–8943. Available at: https://doi.org/10.1021/es500130g [Accessed 19 Oct. 2018].	2014	Journal Article	This review paper presents an overview of wildfire impacts on water quality, hydrology, and ecosystem and public health and provided outlook of water supply in the context of wildfires on a global aspect. The review concluded that wildfire can result in increased solids, nutrients, heavy metals, and temperature which may have significant impact on drinking water treatment cost, property values, recreation, and ecosystem and public health. It also concluded that a major challenge remains to provide actionable science and reliable capacity to predict impacts of wildfire on these water values. In particular, the future of water supply is changing because of climate and its relationship to wildfire. This will likely impact the provision of water for domestic, agricultural, industrial, and ecological needs in some regions. The authors suggested the natural resource managers and agencies responsible for water or land will need to anticipate and prepare for these effects.	Moderate
Cawley, K., Hohner, A., McKee, G., Borch, T., Omur-Ozbek, P., Oropeza, J., Rosario-Ortiz, F. (2018). Characterization and Spatial Distribution of Particulate and Soluble Carbon and Nitrogen from Wildfire-Impacted Sediments. *J Soils Sediments*, [online] 18, pp.1314–1326. Available at: https://doi.org/10.1007/s11368-016-1604-1 [Accessed 19 Oct. 2018].	2018	Journal Article	The purpose of this study on the High Park wildfire (2012) was to characterize burned sediment and its soluble compounds collected from the heavily forested Cache la Poudre (CLP) watershed in northern Colorado (USA). The High Park wildfire began on June 9, 2012, burned 35,300 ha, and was fully contained by July 2, 2012. Ash-affected sediment samples were collected from five sites upstream of the City of Fort Collins drinking water intake of CLP river. At each site, samples were collected from three locations: (1) the edge of the bank adjacent to the water edge (downbank), (2) 1 m upslope of location 1 (midbank), and (3) 2 m upslope of location 1 (upperbank). All sediment samples were analyzed for elemental composition, and a subset of sediment samples were analyzed with ^{13}C solid-state nuclear magnetic resonance spectroscopy (NMR). Sediments were also mixed with the background CLP river water collected from upstream of the wildfire and allowed to leach for 6 and 24 h to determine the quantity and quality of water-soluble constituents. Filtered samples were analyzed for dissolved organic carbon (DOC), iron, manganese, inorganic nutrient concentrations, and disinfection byproducts (DBPs). The results indicated that the percent carbon and nitrogen contents of the solid sediments were accurate predictors of leachate DOC concentration. Mean fluorescence index (an optical parameter used to understand the dissolved organic carbon precursors and chemical characteristics) was higher for wildfire-impacted sediment leachates (1.50) compared to the background CLP river water (1.37), which may be due to changes in DOM molecular weight and oxidation of organic matter. All sediment leachates showed consistently higher haloacetonitrile and chloropicrin yields (nitrogen-based DBPs) compared to background CLP river water, whereas trihalomethanes and haloacetic acids (carbonaceous DBPs) did not show any differences.	Moderate

Table B1.2 Summary of Literature Regarding Mitigation.

Reference	Publication Year	Publication Type	Summary	Geographic Relevance to Alberta*
			It was concluded that the leachates of the sediments containing burned material have different characteristics compared to the background CLP river water. This finding indicated that drinking water utilities may need to alter their treatment processes to address increased sediment loads and elevated nutrient and DOC concentrations, and also to control production of nitrogen-based DBPs.	
Costa, M., Calvão, A., Aranha, J. (2014). Linking Wildfire Effects on Soil and Water Chemistry of the Marão River Watershed, Portugal, and Biomass Changes Detected from Landsat Imagery. *Applied Geochemistry*, [online] 44, pp.93–102. Available at: https://doi.org/10.1016/j.apgeochem.2013.09.009 [Accessed 19 Oct. 2018].	2014	Journal Article	The purpose of this study was to assess changes in the chemical composition of soils and surface water as a result of a 2006 wildfire that burned 255 ha in the Marão Mountains, NE Portugal. It compared pre- and post-fire hydro-chemical data and burned/unburned soil data, examined the recovery of vegetation over time using Landsat TM imagery. Samples of ash, soil and water, from within and outside the burned area, were collected for chemical analyses five months and one year after the fire (sampling between November 2006 and December 2008). Landsat TM images were processed into a vegetation index, in order to analyze landcover dynamics and to calculate biomass. Wildfire effects on water quality of the Marão River included an increase in the pH and the total mineralization of water. Conductivity five months after the wildfire was about 56% higher than pre-fire values and remained higher one year after the fire. Increased in pH and conductivity was attributed to ash and nutrients transported from the burned slope. Calcium, sodium, magnesium, and manganese showed the greatest increase five months after the fire with this increase attributed to movement of ash to the watercourses. Within one year following the fire, these increases attenuated to values closer to pre-fire concentrations except for concentrations of manganese and silicon that were still rising one year after the fire. Concentration of manganese in ash samples were up to five times greater than values found in underlying soils – transport of manganese in the ash to the stream and followed by solubilization could explain the high concentration in river water. The higher concentrations of silica in receiving waters between five months and one year after the wildfire suggest increased rate of dissolution of silicate minerals from bedrock that was caused by the removal of the overlying ash and soil and the hydrolysis of silicate minerals from the bedrock. One year after the wildfire, almost all the burned area had recovered with herbaceous vegetation and patches of shrub vegetation. The authors estimated 1194.7 dry tons of biomass burnt in this wildfire contributing approximately 350 g/ha of manganese as a result of the fire. It was suggested that this type of biomass assessment can be conducted before a fire to help resource managers understand worst-case scenarios for changes in water quality that have the potential to affect aquatic biotic and the suitability of water for drinking water purposes and agriculture.	Low
Emelko, M., Sham, C. (2014). *Wildfire Impacts on Water Supplies and the Potential for Mitigation: Workshop Report*. [Web Report #4529] Canadian Water Network and Water Research Foundation, pp.1-25. Available at: http://cwn-rce.ca/assets/resources/pdf/Wildfire-Impacts-on-Water-Supplies-and-the-Potential-for-Mitigation_Workshop-Report.pdf [Accessed 19 Oct. 2018].	2014	Technical Report	This document summarizes the findings of an experts' workshop in Kananaskis, Alberta (September 18-19, 2013), to assess the state of knowledge with respect to wildfires, water supplies, and the potential for mitigation of the impacts of wildfire on the provision of safe drinking water. The workshop examined what leading-edge science exists to explain trends in wildfire occurrence and risks, the impacts of wildfires on water supply and treatment, and the evidence supporting the effectiveness of forest and water management techniques to mitigate the impacts of wildfires on drinking water supplies and treatment. Key messages generated at the workshop were as follows: 1. It is common that wildfires in forested regions adversely impacts drinking water source quality; 2. The timing and magnitude of rainstorm or snowmelt events after wildfire are key factors influencing changes in water quality, making effects more variable and difficult to predict and separate from wildfire effects; 3. The short-term significant fluctuations in water quality (*e.g.*, peak values of turbidity, dissolved organic carbon, nutrients, or heavy metals) that may often be anticipated resulted from severe wildfire can cause a major challenge for drinking water treatment, as the source water quality often exceeds existing treatment and/or operational capacities. Treating drinking water to minimize wildfire impacts on water quality requires additional and costly treatment capacity (infrastructure and/or operational); 4. Historical fire suppression efforts have resulted in a buildup of fuel in some parts of North America, including some areas of Alberta and increases the risk of more intense and severe wildfires; 5. Appropriate forest management and water treatment strategies are required to reduce wildfire risks to water supply and treatment facilities; and 6. Mitigation of the impacts of wildfire on drinking water supplies requires an approach combining: a) assessment of wildfire risks based on the desired values to be protected, such as protection of drinking water supplies, b) strategic fuel/forest management for the protection of	High

Table B1.2 Summary of Literature Regarding Mitigation.

Reference	Publication Year	Publication Type	Summary	Geographic Relevance to Alberta*
			source water supplies, and c) preparedness of the drinking water supplier in the case of adverse effects (*i.e.*, enhancements to infrastructure).	
Emelko, M., Silins, U., Bladon, K., Stone, M. (2011). Implications of Land Disturbance on Drinking Water Treatability in a Changing Climate: Demonstrating the Need for 'Source Water Supply and Protection' Strategies. *Water Research*, [online] 45, pp.461–472. Available at: https://doi.org/10.1016/j.watres.2010.08.051 [Accessed 19 Oct. 2018].	2011	Journal Article	This article discusses the potential implications of changing climate and wildfire on source water protection and treatment for drinking water, with specific reference to the 2003 Lost Creek Wildfire in Alberta (Canada). During July-September 2003, the Lost Creek wildfire burned more than 21,000 ha in the headwaters of the Castle and Crowsnest rivers. The study covered three burned watersheds (South York, Lynx, and Drum Creeks), two unburned/reference watersheds (Star and North York Creeks) prior to the first post-fire spring snowmelt in March-April 2004, as well as two additional burned and salvage-logged watersheds (Lyons Creek East and West) established in January 2005. Four years of hydrology and water quality data from seven watersheds were evaluated and synthesized to assess the implications of wildfire and post-fire intervention (salvage-logging) on downstream drinking water treatment. The 95th percentile turbidity and dissolved organic carbon (DOC) were elevated in streams draining burned watersheds (15.3 NTU, 4.6 mg/L, respectively) and salvage-logged (18.8 NTU, 9.9 mg/L) watersheds, compared to concentrations in streams draining unburned watersheds (5.1 NTU, 3.8 mg/L, respectively). The authors suggested that these constituents could deleteriously impact water treatment by contributing to increased dependency on and/or difficulty in maintaining efficiency of solids removal processes such as coagulation/flocculation/sedimentation, sludge production, and oxidant demand. Concentrations of dissolved organic nitrogen (DON) were higher in discharge from the burned (95th percentile: 756.6 mg/L)) and post-fire salvage-logged (95th percentile: 409.7 mg/L) watersheds, relative to unburned watersheds (358.5 mg/L), even four years after the fire. The authors suggested that elevated DOC and DON due to wildfire and salvage-logging may increase water utility challenges associated with providing adequate disinfection while limiting residual chlorine, balancing chlorine to ammonia ratios, and minimizing DBP formation. The 95th percentile total phosphorus (TP) concentrations over the four post-fire years were 10 to 17 times higher in streams draining the burned (121.0 mg/L) and salvage-logged (210.0 mg/L) watersheds, compared to concentrations in streams draining unburned watersheds (12.4 mg/L). The authors discussed that persistent elevated concentrations of TP are of concern because they have been frequently linked with the presence of microcystins produced by Cyanobacteria, elevated levels of which have been associated with gastroenteritis and, in some cases, liver toxicity and death. Increased concentrations of bioavailable phosphorus can increase microbial growth in distribution systems and also prolong the survival of culturable *Escherichia coli* in water and biofilms which can also act as a reservoir for microorganisms in drinking water distribution systems. Coagulation, flocculation, and sedimentation (or other clarification processes) may be necessitated for phosphorus and mercury removal. Total mercury, chlorophyll *a*, and A*ctinobacteria*-like microbial concentrations were also higher in the fire affected discharges than in discharge from the reference watersheds. The authors concluded that persistent increases in turbidity, nutrients, heavy metals, and other biological contaminants in discharge from burned and salvage-logged watersheds present important economic and operational challenges for water treatment; most notably, a potential increased dependence on solids and DOC removal processes. They also indicated that many traditional source water protection strategies would fail to adequately identify and evaluate many of the significant wildfire- and post-fire management-associated implications to drinking water "treatability". Therefore, it was recommended that "source water supply and protection strategies" should be developed to consider a suppliers' ability to provide adequate quantities of potable water to meet demand by addressing all aspects of drinking water "supply" (*i.e.*, quantity, timing of availability, and quality) and their relationship to "treatability" in response to land disturbance.	High
Hohner, A., Cawley, K., Oropeza, J., Summers, R., Rosario-Ortiz, F. (2016). Drinking Water Treatment Response Following a Colorado Wildfire. *Water Research*, [online] 105, pp.187–198. Available at: https://doi.org/10.1016/j.watres.2016.08.034 [Accessed 19 Oct. 2018].	2016	Journal Article	The goal of this study was to assess the impact of a wildfire on drinking water quality and treatability in a watershed serving as a direct drinking water supply for several communities. It was conducted for the High Park wildfire that occurred on June 9, 2012 and burned 35,300 ha land of northern Colorado watershed. A water treatment intake within the burned area and a site upstream of the burned area were monitored during the first snowmelt season (2013) and rainstorm events (water intake only) following the fire. Monitoring was also conducted in 2012 immediately following the fire (which is reported in Writer *et al*. 2014, see later in this table for summary). Four years of pre-fire water quality data from the City of Fort Collins drinking water intake and reference site were used for comparison to post-fire monitoring results. Turbidity, nutrients (total phosphorus, total nitrogen, total organic carbon), dissolved organic matter (DOM) character, coagulation treatability, and disinfection byproduct (DBP) formation were evaluated and compared to pre-fire data.	Moderate

Table B1.2 Summary of Literature Regarding Mitigation.

Reference	Publication Year	Publication Type	Summary	Geographic Relevance to Alberta*
			Mean concentrations of turbidity (35 NTU), nitrogen (0.66 mg/ L), and phosphorus (0.058 mg/L) were an order of magnitude higher at post-fire water intake site, compared to pre-fire water intake site as well as a post-fire reference site. Fluorescence index (FI) values were significantly higher at the intake site compared to the reference site and higher than pre-fire years, suggesting the wildfire altered the DOM character of the river. DBP formation including total trihalomethane (TTHM) and haloacetonitrile (HAN4) formation at the intake were also higher than the reference site. Conventional treatment of post-fire water was effective at a 10 mg/L higher average alum dose than reference samples. The intake was also monitored following rainstorms. Post-rainstorm samples showed further increase in the FI values (max 1.52), HAN4 (max 3.4 μg/mg C) and chloropicrin formation yields (max 3.6 μg/mg C). However, TTHM and haloacetic acid yields did not respond to rainstorm events. Several post-rainstorm samples presented treatment challenges, and even at high alum doses (65 mg/L), showed minimal dissolved organic carbon removal (<10%). The degraded water quality of the post-rainstorm samples is likely attributed to the combined effects of runoff from precipitation and greater erosion following wildfire. The results suggest that the wildfire may have consequences for influent water quality, coagulant dosing, and DBP speciation.	
Khan, S., Deere, D., Leusch, F., Humpage, A., Jenkins, M., Cunliffe, D. (2015). Extreme Weather Events: Should Drinking Water Quality Management Systems Adapt to Changing Risk Profiles? *Water Research*, [online] 85, pp.124–136. Available at: https://doi.org/10.1016/j.watres.2015.08.018 [Accessed 19 Oct. 2018].	2015	Journal Article	This literature review focused on water quality impacts of extreme weather events including heavy rainfall and floods, cyclones, droughts, heatwaves, extreme cold, and wildfires, and provided practical guidance for drinking water managers. The authors listed a range of wildfire impacts on surface waters including increased magnitude of storm runoff and suspended solids, increased nutrient and contaminant loads, increased organic carbon, elevated risks of algal and cyanobacterial blooms, elevated microbial activity and dissolved organic carbon (DOC) transformation, and presence of fire-fighting chemicals. Many water quality impacts from wildfire may be successfully managed provided that the treatment plants have been adequately designed and operated for the local circumstances. However, such impacts may impose additional burdens on treatment facilities, requiring additional power consumption, chemical use, maintenance or waste production and additional management activities including monitoring, by water utilities, regulators, and others to protect public health. It is recommended that future revisions of drinking water management guidelines pay particular attention to the management of water quality impacts associated with extreme weather events including wildfires. The mitigation measures for wildfire impacts recommended in this paper included (1) diversifying water sourcing options, (2) additional filtration in early stages of drinking water production, (3) careful monitoring and application of disinfectant, (4) additional monitoring of contaminants, and (5) prevention of particulate matter entering water-courses (*e.g.*, straw bales, construction of swales).	Moderate
Robichaud, P. (2009). *Post-fire stabilization and rehabilitation*. In: Cerda, A, Robichaud, P, eds., Fire Effects on Soils and Restoration Strategies, 1st ed. Boca Raton, FL: CRC Press. pp. 303–324.	2009	Book chapter	This book chapter summarizes post-fire treatment techniques and their effectiveness, including treatments applied to hillslopes, roads, and channels. The decision of where and when to use post-fire stabilization treatments requires a site-specific evaluation. In many cases, it is justifiable and cost effective to not apply any treatment. Treatments should only be applied if unacceptable levels of flooding, erosion, and/or sedimentation are expected. Mulching appears to generally be both inexpensive and effective Monitoring the effectiveness treatments is essential.	
Robichaud, P., Beyers, J., Neary, D. (2000). *Evaluating the Effectiveness of Postfire Rehabilitation Treatments*. [PDF, Gen Tech Rep RMRS-GTR-63] Fort Collins: US Department of Agriculture, Forest Service, Rocky Mountain Research Station, pp. 1-63. Available at: https://www.fs.usda.gov/treesearch/pubs/23617 [Accessed 19 Oct. 2018].	2000	Technical Report	In a review of burned area emergency rehabilitation (BAER) reports from the western United States, it was found that existing literature on treatment effectiveness is limited. Assessment of post-fire treatments found that: 1. The amount of protection provided by any treatment is small; 2. Contour-felled logs provide some immediate watershed protection, especially during the first post-fire year; 3. Seeding has a low probability of reducing the first season erosion because most of the benefits of the seeded grass occurs after the initial damaging runoff events; 4. Road treatments such as rolling dips, water bars, and culvert reliefs can reduce damage; and 5. Hillslope erosion control is more effective than sediment storage in channels. Increased monitoring for treatment effectiveness is recommended.	

Table B1.2 Summary of Literature Regarding Mitigation.

Reference	Publication Year	Publication Type	Summary	Geographic Relevance to Alberta*
Santín, C., Doerr, S., Otero, X., Chafer, C. (2015). Quantity, Composition and Water Contamination Potential of Ash Produced under Different Wildfire Severities. *Environmental Research,* [online] 142, pp.297–308. Available at: https://doi.org/10.1016/j.envres.2015.06.041 [Accessed 19 Oct. 2018].	2015	Journal Article	This article investigated the amount and characteristics of ash generated under different wildfire with the specific objective examining the role of fire severity (*i.e.,* degree of destruction of vegetation and ground fuels) in determining (i) total ash loads (ii) ash chemical composition for constituents relevant to water quality, and (iii) the associated risks for water contamination. In October 2013, the Balmoral wildfire burned over 16,000 ha including 12,694 ha of dry, shrubby sclerophyll eucalypt forests in the water supply watersheds managed by Water NSW. It affected parts of the greater Sydney drinking water supply watershed area including the Nepean and adjacent watersheds. Sampling sites were selected along a ridge typical of the region (presented in Figure 1 of this article) with a relatively homogeneous fuel load. Fire severity was defined as the degree of destruction (consumption) of above ground and ground fuels, based on the classification established for this region. Three fire severities were studied: (1) low fire severity: ground and understory (<0.5 m high) fuels burnt, canopy unaffected; (2) high fire severity: ground and understory (<4 m high) fuels burnt, canopy scorched; and (3) extreme fire severity: all available fuels consumed, including stems <1 cm thick. The wildfire produced substantial ash loads that increased with fire severity, with 6, 16 and 34 Mg/ha found in areas affected by low, high, and extreme fire severities, respectively. Ash bulk density was also positively related to fire severity. The increase in the total load and bulk density of the ash generated with fire severity was attributed to a combination of increasing total fuel affected by fire and contribution of 'burnt mineral soil' to the ash layer (which increased with increasing fire severity). Total concentrations of metals and nutrients in ash were mostly unrelated to fire severity and relatively low compared to values reported for wildfire ash in other environments (*e.g.,* 4.0–7.3 mg/kg arsenic, 2.3–4.1 mg/kg boron, 136–154 mg/kg phosphorus). Solubility of the elements analyzed was low – less than 10% of the total concentration – for all elements except for boron (6–14%) and sodium (30–50%). This lower solubility may have been related to a partial loss of soluble components by leaching and/or wind erosion before the ash sampling (10 weeks after the fire and before major ash mobilization by water erosion). Overall total ash loads suggested a potential for substantial water quality impacts including contaminant effects and increases in turbidity when ash reaches the reservoir as suspended solids.	Low
Sham, C. Tuccillo, M., Rooke, J. (2013). *Report on the Effects of Wildfire on Drinking Water Utilities and Effective Practices for Wildfire Risk Reduction and Mitigation*. [PDF, Workshop Report #4482] Washington, DC: Water Research Foundation and U.S. Environmental Protection Agency, pp.1-96. Available at: http://www.waterrf.org/PublicReportLibrary/4482.pdf [Accessed 19 Oct. 2018].	2013	Technical Report	This report, focused on developing a comprehensive understanding of wildfires, their effects, and effective practices available for mitigating the risks on water utilities, presented 1) current information on the impacts from wildfires on drinking water utilities and 2) lessons learned and recommendations for future research that were discussed during the Wildfire Readiness and Response Workshop held in Denver, Colorado in April, 2013. The information in this report combines: 1) a comprehensive review of literature on wildfire risk mitigation, effects of wildfire on watershed and water systems, and post-fire rehabilitation, 2) the findings of a survey administered to drinking water utilities that experienced or were at risk of experiencing effects from wildfire, and 3) materials presented and discussion among experts during a workshop. These efforts. The report recommended steps to prepare for wildfires including: assessment of the vulnerability of the watershed to wildfire; assessment of the vulnerability of the drinking water system; and, development of emergency response plans. Findings of this survey are summarized below: 1. Drinking water utility staff indicated that they were better able to identify serious wildfire risks and develop mitigation plans once they were informed about the risks within their watershed. Therefore, conducting wildfire hazard assessments in the watersheds was an important first step to reducing and mitigating the effects of wildfire in the drinking water utilities; 2. Survey participants reported that collaboration with other drinking water systems, landowners, non-profit organizations, and local, state/provincial, and federal government agencies was a critical aspect of wildfire mitigation. Collaboration among the stakeholders helped to conduct more effective and comprehensive wildfire mitigation activities, expand their knowledge base, and leverage financial resources; 3. The survey indicates that drinking water utilities have several tools available to them to develop and conduct wildfire risk reduction/mitigation activities as well as to build partnerships and leverage funding to carry out such activities. Some recommended source water protection measures include establishment of buffer strips, hazardous fuels reduction at the wildland/urban interface (online LANDFIRE.gov and a U.S. Forest Service GIS-based decision support tools are available to help establish hazardous fuels), community wildfire protection plans, and acquiring funding sources; and	

Table B1.2 Summary of Literature Regarding Mitigation.

Reference	Publication Year	Publication Type	Summary	Geographic Relevance to Alberta*
			4. This project also identified a range of research topics to better understand the effects of wildfires on utilities' source water quality and quantity, and to develop effective wildfire management plans.	
Stein, E. and Brown, J. (2009). Effects of Post-fire Runoff on Surface Water Quality: Development of a Southern California Regional Monitoring Program with Management Questions and Implementation Recommendations. [PDF, Technical Report 598] Costa Mesa, CA: Southern California Costal Water Research Project, pp.1–37. Available at: ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/598_SoCalRegionalFireMonitoringPlan.pdf [Accessed 15 Oct. 2018].	2009	Technical Report	This technical report provides a description of a regional post-fire water quality monitoring program. The program goal was to address information gaps by providing agreed upon regional post-fire water qualify sampling procedures and implementation plan. The lack of coordinated monitoring is particularly problematic in southern California because water sheds affected by fire often drain to waterbodies that support sensitive resources. Concentrations of nutrients, metals, and certain organic pollutants reported to be elevated in post-fire runoff (relevant literature to support this is sourced); the receiving waters downstream of burned areas can also be affected. Recommended analysis constituents are listed in Table 3 of the original report. The post-fire monitoring program was organized around three priority management questions: 1. How does post-fire runoff affect contaminant flux? 2. What is the effect of post-fire runoff on downstream receiving waters? 3. What are the factors that influence how long post-fire runoff effects persist?	
Writer, J., Murphy, A. (2012). *Wildfire Effects on Source-Water Quality—Lessons from Fourmile Canyon Fire, Colorado, and Implications for Drinking-Water Treatment*. [PDF, Fact Sheet 2012–3095] Denver, Colorado: US Geological Survey. Available at: https://pubs.usgs.gov/fs/2012/3095/FS12-3095.pdf [Accessed 19 Oct. 2018].	2012	Technical Report (fact sheets)	Technical report summarizing a study to evaluate the effects of wildfire on water quality and downstream ecosystems in the Colorado Front Range after the 2010 Fourmile Canyon fire near Boulder, Colorado. Involved frequent sampling of Fourmile Creek at monitoring sites upstream and downstream of the burned area to study water-quality changes during hydrological conditions such as base flow, spring snowmelt, and summer thunderstorms. Stream discharge and nitrate concentrations increased downstream of the burned area during snowmelt runoff – the authors suggested that the increases were probably within the treatment capacity of most drinking-water plants. During and after high-intensity thunderstorms turbidity, dissolved organic carbon, nitrate and some metals increased by 1 to 4 orders of magnitude within and downstream of the burned area (detailed water quality results are summarized in McCleskey *et al*. 2012 below). The authors indicated that increases of such magnitude can pose problems for water-supply reservoirs, drinking-water treatment plants, and downstream aquatic ecosystems. Document summary gives the following overview of fire effects: "*Burned watersheds are prone to increased flooding and erosion, which can impair water-supply reservoirs, water quality, and drinking-water treatment processes. Limited information exists on the degree, timing, and duration of the effects of wildfire on water quality, making it difficult for drinking-water providers to evaluate the risk and develop management options.*" The authors listed the following problems related to drinking water quality management due to wildfires: 1. Increased sediment loading of water-supply reservoirs, shortened reservoir lifetime, and increased maintenance costs; 2. Increased nutrient loading of reservoirs, which may promote algal blooms and associated disagreeable taste and odor; 3. Increased turbidity or increased metal concentrations, which may produce larger volumes of sludge and increase chemical treatment requirements, both of which would increase operating costs; and 4. Increased dissolved organic carbon concentrations, which during disinfection may help form unwanted by-products (*e.g.*, regulated carcinogens such as chloroform and trihalomethanes).	Moderate

APPENDIX C: TABLES

Table C.1. Alberta Environment and Parks Athabasca River Water Quality Monitoring Data

Station on the Athabasca River	Sample Date	TEMPERATURE AIR deg C	TEMPERATURE WATER deg C	REDOX POTENTIAL mV	OXYGEN DISSOLVED (FIELD METER) mg/L	OXYGEN DISSOLVED (FIELD QC) mg/L	PH (FIELD) pH units	PH (LAB) pH units	SPECIFIC CONDUCTANCE (FIELD) uS/cm	SPECIFIC CONDUCTANCE (LAB) uS/cm	COLOUR TRUE rel units	TURBIDITY NTU	COLIFORMS FECAL No/100 mL	ESCHERICHIA COLI No/100 mL	ALKALINITY TOTAL CACO3 mg/L	ALKALINITY PHENOLPHTHALEIN CACO3 mg/L	HARDNESS TOTAL (CALCD_) CACO3 mg/L	TOTAL DISSOLVED SOLIDS (CALCD_) mg/L	RESIDUE FILTERABLE mg/L	RESIDUE NONFILTERABLE mg/L	IONIC BALANCE (CALCD_) meq/L	SUM OF CATIONS meq/L	SUM OF ANIONS meq/L
Station No. AB07CC0130	18-May-16 12:30	18.00	17.2	223	9.3	9.52	8.14	7.87	281.1	280	33	6.2			100	<0.5	120	160	180	17	1	2.9	2.9
	28-Jun-16 14:30	26.00	21.89	206	8.55		7.69	7.92	210	200	140	80			74	<0.5	90	120	140	150	1.1	2.3	2.1
	05-Jul-16 09:40		19.17	192	8.5	8.54	7.92	7.92	230.7	220	110	92			81	<0.5	110	130	160	180	1.1	2.5	2.3
	12-Jul-16 13:30	24.70	21.03	345	8.5	8.53	7.91	7.97	215.2	210	110	45			80	<0.5	110	120	170	90	1.2	2.6	2.2
	19-Jul-16 12:30	28.00	22.56	190	8.19	8.17	7.91	8.02	257.6	260	65	37			96	<0.5	120	140	170	100	1.1	2.9	2.7
	26-Jul-16 12:15	25.00	21.24	181	8.82		8.01	8.27	273	270	53	21			110	<0.5	130	150	170	46	1	2.9	2.9
	02-Aug-16 13:00	23.00	21.54	159	8.61		8.24	8.15	277	270	58	13			100	<0.5	130	150	170	23	1.1	3	2.7
	09-Aug-16 12:00	23.40	20.43	236	8.58	8.65	8.29	8.15	269.5	260	45	13			100	<0.5	120	150	210	25	0.99	2.8	2.8
	16-Aug-16 12:45	23.40	21.41		8.37	8.32	8.13	8.01	267.1	260	58	31			100	<0.5	120	150	180	61	1	2.9	2.8
	23-Aug-16 12:15	22.00	17.9	329	9.44	9.37	8.31	8.21	284.1	280	47	7.8			110	<0.5	130	160	160	18	1.1	3.2	2.9
	30-Aug-16 12:00	17.80	16.02	196	9.09		8.02	8.12	240.9	240	99	90			99	<0.5	110	140	160	180	1.1	2.7	2.5
Station No. AB07CC0030	11/May/16 18:15		13.72	247	10.4	10.43	8.26	8.2	313.9	300	21	12			120	<0.5	140	170	200	87	1		
	19-May-16 12:00												<10	<10									
	24-May-16 14:45	22.00	18.41	167	11.48	10.8	8.42	8.39	323.7	310	12	5			120	0.86	140	180	170	9.5	1	3.4	3.3
	31-May-16 13:15	16.00	16.31	197	9.49	9.34	7.97	8.15	257.8	260	57	210			100	<0.5	110	140	170	440	0.98	2.6	2.7
	01-Jun-16 13:35												60	60									
	08-Jun-16 12:15		18.88	297	8.83		7.97	8.08	255	250	59	56			100	<0.5	120	150	160	140	1.1	2.9	2.7
	10-Jun-16 10:50		17	174	9.22		7.91	7.9	270.5	260	110	190	90	82	100	<0.5	120	160	180	480	1.1	3	2.9
	15/Jun/16 09:30		17.5	179	8.82		8.11	7.87	236	230	65	200	55	36	85	<0.5	110	130	150	390	1		
	15-Jun-16 12:30	15.00	17.48	220	8.87		8.02	8.03	236.7	240	93	220	1100	840	89	<0.5	110	130	140	430	1	2.5	2.5
	21-Jun-16 12:15	28.00	18.92	165	9.29	9.16	7.95	8.06	236	230	67	76			90	<0.5	110	130	150	170	1.1	2.5	2.4
	28-Jun-16 17:15	30.00	24.59	201	8.62	8.5	8.12	8.15	257	240	73	37			100	<0.5	110	140	160	70	1	2.8	2.6
	05-Jul-16 12:00		20.18	164	8.79		8.15	8.04	277.1	270	62	24			110	<0.5	130	160	180	70	1.1	3.1	2.9
	12-Jul-16 15:30	24.00	23.31	303	8.77		8.22	8.14	248.7	240	69	30			95	<0.5	110	150	180	58	0.87	2.6	3
	13/Jul/16 08:50	19.00	20.17	183	8.85	8.92	8.01	8.14	248.5	250	63	8.8	30	30	95	<0.5	120	140	170	59	1.1		
	19-Jul-16 15:00	29.00	24.9	180	8.38		8.2	8.09	261.1	260	51	35			98	<0.5	130	170	170	94	0.9	2.9	3.3
	26-Jul-16 14:45	26.00	22.55	143	8.9		8.24	8.29	275.6	270	41	33			110	<0.5	140	160	170	69	1.1	3.1	2.9
	02-Aug-16 15:15		22.96	155	8.87		8.35	8.24	297.9	290	47	17			110	<0.5	140	160	180	35	1	3.2	3.1
	09-Aug-16 14:45		21.99	209	8.95		8.37	8.26	283.4	270	24	8.4			110	<0.5	130	160	160	22	1.1	3.1	2.9
	16-Aug-16 14:50	23.00	22.6	192	8.99		8.41	8.23	290.8	280	30	12			110	<0.5	140	160	180	40	1.1	3.1	3
	16/Aug/16 15:00	23.00	22.6	192	8.99	8.92	8.41	8.27	290.8	280	30	7.9	20	20	120	<0.5	130	160	130	45	1		
	23-Aug-16 14:20	22.00	19.9	286	10		8.43	8.36	284.9	280	25	5.5			110	<0.5	140	160	170	18	1.1	3.2	3
	30-Aug-16 14:50	20.00	17.56	189	9.36		8.19	8.17	260.5	250	65	100			110	<0.5	120	150	160	160	1.1	2.9	2.8
Station No. AB07DA0062	12/May/16 10:30							8.24		310	20	13			120	<0.5	140	170	160	70	1.1	3.2	3.4
	19-May-16 11:15	8.00	13.31		9.47		8.12	8.08	250	280	19	9	<10	<10	100	<0.5	120	160	140	25	1	2.9	2.9
	25-May-16 09:25	19.00	15.65	140	9.95	9.58	8.16	8.09	268	260	50	6	30	30	73	<0.5	74	140	150	15	0.98	2.6	2.6
	01-Jun-16 09:30	12.00	16.08	156	9.02	9.01	7.95	8.1	256	250	38	43	27	20	83	<0.5	82	130	160	120	1	2.5	2.5
	09-Jun-16 09:00		18.68	195	8.25		7.96	7.91	225.8	220	43	17	36	10	71	<0.5	77	120	130	74	1.1	2.4	2.2
	10-Jun-16 14:30		19.2	128	9.17		8.23	8.04	264.3	250	49	65	36	18	100	<0.5	120	150	160	170	1.1	2.9	2.7
	10-Jun-16 14:50		19.46	138	9.13		8.23	8	264.2	250	47	56	30	<10	100	<0.5	120	150	160	170	1.1	2.9	2.7
	10-Jun-16 15:30		17.88	153	8.75		8	7.78	272	260	56	170	155	91	78	<0.5	86	150	160	230	1	2.8	2.7
	16-Jun-16 09:30	14.00	16.14	206	8.54	8.56	7.85	7.84	182.1	180	83	130	27	20	62	<0.5	72	96	160	270	1.2	2.1	1.7
	21-Jun-16 14:00	29.00	18.1	155	8.98		7.62	7.85	168	160	88	47	10	10	61	<0.5	70	88	120	160	1.2	1.9	1.6
	29-Jun-16 08:50	23.00	21.18	202	8.18		7.9	7.84	169	190	72	39	40	40	65	<0.5	69	100	130	83	1.1	2.1	1.8
	06-Jul-16 08:20		18.34	167	8.08	8.15	7.75	7.78	220.6	210	150	260	82		70	<0.5	77	120	180	380	1.1	2.3	2.1
	13-Jul-16 08:00	20.00	20.62	203	8.08	8.16	7.68	7.93	202.3	200	110	34	20	10	74	<0.5	78	110	150	73	1.2	2.4	2
	20-Jul-16 08:30		22.01	198	7.9	7.89	7.86	7.97	241.5	240	84	14	50	18	73	<0.5	79	120	160	55	1.1	2.5	2.3
	27-Jul-16 09:45	24.00	20.76	130	8.42	8.37	8	8.1	257.4	250	72	13	<10	<10	79	<0.5	87	130	120	54	1.1	2.7	2.5
	03-Aug-16 08:30		19.38	174	8.49	8.44	7.92	7.96	297.9	270	84	30	20	20	84	<0.5	89	140	160	85	1.1	2.8	2.7
	10-Aug-16 07:15		20.02	190	8.25	8.36	8.01	8	255.1	250	65	7	20	20	76	<0.5	79	130	140	37	1	2.5	2.4
	17-Aug-16 07:40	23.00	19.65	178	8.31		8.11	7.96	263.9	260	64	15	20	10	82	<0.5	83	140	160	26	1	2.7	2.6
	24-Aug-16 08:00		16.94	249	8.97	9	8.06	8.08	277.3	280	54	8	10	10	82	<0.5	88	150	190	23	1.1	2.9	2.7
	31-Aug-16 09:10	16.00	15.03	166	9.33	9.56	8.1	8.1	258.3	250	62	21	20	10	85	<0.5	91	140	150	40	1.1	2.8	2.6
Station No. AB07CC0130	Maximum	28	22.56	**345**	9.44	9.52	8.31	8.27	284.1	280	140	92	0	0	110	0	130	160	210	180	1.2	3.2	2.9
	Mean	23.13	20.04	225.70	8.72	8.73	8.05	8.06	255.11	250.00	74.36	39.64	NC	NC	95.45	NC	117.27	142.73	170.00	80.91	1.07	2.79	2.62
Station No. AB07CC0030	Maximum	**30.00**	**24.90**	303.00	**11.48**	**10.80**	**8.43**	**8.39**	**323.70**	**310.00**	110.00	220.00	**1100.00**	**840.00**	**120.00**	**0.86**	**140.00**	**180.00**	**200.00**	**480.00**	1.10	**3.40**	3.30
	Mean	22.85	20.08	202.15	9.19	9.44	8.19	8.15	270.30	263.00	53.20	64.38	225.83	178.00	104.10	0.86	125.00	153.00	166.50	144.33	1.04	2.93	2.88
Station No. AB07DA0030	Maximum	29.00	22.01	249.00	9.95	9.58	8.23	8.24	297.90	**310.00**	**150.00**	**260.00**	155.00	91.00	**120.00**	0.00	**140.00**	170.00	190.00	380.00	**1.20**	3.20	**3.40**
	Mean	18.80	18.34	173.78	8.70	8.64	7.97	7.98	241.77	241.00	65.50	49.85	37.24	22.47	80.90	NC	89.05	131.70	152.00	108.00	1.08	2.60	2.44
95% Background Value		27.1	22.225	337.8	9.37	NC	8.3	8.24	282.6	280	125	91	NC	NC	110	NC	130	160	195	180	1.15	3.1	2.9
T-test p-value		0.203	0.318	0.104	0.166	0.414	0.647	0.795	0.896	0.843	0.205	0.250	NC	NC	0.519	NC	0.060	0.945	0.090	0.117	0.636	0.629	0.914

Station on the Athabasca River	Sample Date	SODIUM TOTAL (NA) mg/L	SODIUM DISSOLVED/FILTERED mg/L	MAGNESIUM TOTAL mg/L	MAGNESIUM DISSOLVED/FILTERED mg/L	POTASSIUM TOTAL mg/L	POTASSIUM DISSOLVED/FILTERED mg/L	CALCIUM TOTAL mg/L	CALCIUM DISSOLVED/FILTERED mg/L	MANGANESE DISSOLVED mg/L	IRON DISSOLVED mg/L	BICARBONATE (CALCD_) mg/L	CARBONATE (CALCD_) mg/L	HYDROXIDE (CALCD_) mg/L	CHLORIDE DISSOLVED mg/L	SULPHATE DISSOLVED mg/L	SULPHIDE mg/L	HYDROGEN SULPHIDE H2S mg/L	CARBON TOTAL ORGANIC (TOC) mg/L	CARBON DISSOLVED ORGANIC mg/L	PHOSPHORUS TOTAL (P) mg/L	PHOSPHORUS TOTAL DISSOLVED mg/L	PHOSPHATE DISSOLVED ORTHO mg/L	NITROGEN, NITRATE mg/L	NITROGEN NITRITE mg/L	NITROGEN NO3 & NO2 mg/L
Station No. AB07CC0130	18-May-16 12:30	10	10	10	10	1.3	1.2	34	33	<0.004	0.15	120	<0.5	<0.5	2	39	0.0031		6.2	5.7	0.035	0.007	0.004	<0.003	<0.003	<0.005
	28-Jun-16 14:30	9.4	9.4	7.3	6.8	1.6	1	26	25	0.014	0.48	90	<0.5	<0.5	1.7	28	0.012	0.013	21	22	0.15	0.02	0.019	0.0089	<0.003	0.0089
	05-Jul-16 09:40	8.4	8.2	8.6	8.1	1.7	1.1	32	29	0.012	0.47	99	<0.5	<0.5	1.9	32	0.019	0.02	19	17	0.19	0.016	0.019	0.021	<0.003	0.021
	12-Jul-16 13:30	8.2	8.3	8.6	8.5	1.5	1.1	30	29	0.0074	0.47	98	<0.5	<0.5	1.6	26	0.0058		15	16	0.096	0.024	0.019	0.0088	<0.003	0.0088
	19-Jul-16 12:30	7.2	8.1	9.4	9.7	1.4	1.2	32	34	0.0091	0.29	120	<0.5	<0.5	12	22	0.0033	0.004	11	11	0.1	0.016	0.014	0.0054	<0.003	0.0054
	26-Jul-16 12:15	7.9	7.6	11	10	1.3	1.1	38	35	<0.004	0.25	130	<0.5	<0.5	2	31	0.0033	0.004	9.5	9.9	0.043	0.01	0.01	0.014	<0.003	0.014
	02-Aug-16 13:00	9.1	8.9	10	10	1.3	1.1	36	34	<0.004	0.27	120	<0.5	<0.5	1.5	31	0.0033	0.004	9	9	0.033	0.011	0.011	<0.003	<0.003	<0.005
	09-Aug-16 12:00	8.5	8.5	9.9	9.6	1.2	1.1	35	32	<0.004	0.2	130	<0.5	<0.5	2.1	33	<0.0019	<0.002	8.4	7.9	0.035	0.01	0.008	<0.003	<0.003	<0.005
	16-Aug-16 12:45	8.8	8.7	10	9.2	1.6	1.1	37	34	0.0043	0.29	130	<0.5	<0.5	2.1	30	0.018		10	11	0.051	0.012	0.009	<0.003	<0.003	<0.005
	23-Aug-16 12:15	9.8	11	9.5	11	1.1	1.1	34	37	0.0045	0.19	130	<0.5	<0.5	2.2	36	<0.0019	<0.002	9.3	9	0.025	0.006	0.004	<0.003	<0.003	<0.005
	30-Aug-16 12:00	9.4	9.3	9.5	8.3	2.2	1.6	36	31	0.0052	0.32	120	<0.5	<0.5	2.5	24	0.0025	0.003	15	16	0.14	0.014	0.014	0.041	<0.003	0.041
Station No. AB07CC0030	11/May/16 18:15		12		11		1.4		37	0.014	<0.06	140	<0.5	<0.5	2.9	38			6.3	6.2	0.065	0.003	<0.003	<0.003	<0.003	<0.005
	19-May-16 12:00																									
	24-May-16 14:45	13	13	11	11	1.4	1.2	39	38	<0.004	<0.06	140	1	<0.5	3.8	42	<0.0019		5.4	4.8	0.021	0.005	<0.003	<0.003	<0.003	<0.005
	31-May-16 13:15	11	10	12	8	2	1.3	52	30	<0.004	0.12	130	<0.5	<0.5	1.7	27	<0.0019	<0.002	13	12	0.33	0.011	0.006	0.079	0.0049	0.084
	01-Jun-16 13:35																									
	08-Jun-16 12:15	9.5	9.3	10	9.2	1.9	1.4	39	34	<0.004	0.13	130	<0.5	<0.5	2.1	28	0.019	0.02	11	11	0.11	0.011	0.006	0.059	<0.003	0.059
	10-Jun-16 10:50	15	15	15	10	3	1.8	39	30	0.0097	0.37	130	<0.5	<0.5	2.6	34	0.015	0.016	15	16	0.43	0.022	0.016	<0.003	<0.003	<0.005
	15/Jun/16 09:30		7.7		8.6		1.1		29	<0.004	0.14	100	<0.5	<0.5	1.2	31			10	12	0.31	0.017	0.015	0.086	0.0076	0.094
	15-Jun-16 12:30	8.4	8.1	13	8.8	2.3	1.1	45	29	<0.004	0.15	110	<0.5	<0.5	1.4	31	0.016	0.017	9.6	10	0.34	0.015	0.014	0.091	0.0068	0.098
	21-Jun-16 12:15	7.9	7.6	10	8.6	1.7	1.1	36	30	<0.004	0.15	110	<0.5	<0.5	1.1	28	0.0054	0.006	11	12	0.14	0.012	0.009	0.038	<0.003	0.038
	28-Jun-16 17:15	9.6	9.8	8.8	8.6	1.5	1.2	34	32	<0.004	0.19	120	<0.5	<0.5	1.8	28	0.0023	0.002	17	16	0.069	0.008	0.004	0.0034	<0.003	<0.005
	05-Jul-16 12:00	10	11	10	10	1.5	1.3	37	36	<0.004	0.17	130	<0.5	<0.5	2	34	<0.0019	<0.002	15	12	0.075	0.009	0.007	<0.003	<0.003	<0.005
	12-Jul-16 15:30	9.5	8.5	9.8	9.1	1.4	1.1	34	30	<0.004	0.19	120	<0.5	<0.5	27	16	<0.0019		13	12	0.05	0.011	0.032	<0.003	<0.003	<0.005
	13/Jul/16 08:50		9.2		9.8		1.2		33	<0.004	0.2	120	<0.5	<0.5	1.2	29			12	13	0.047	0.011	0.006	<0.003	<0.003	<0.005
	19-Jul-16 15:00	7.3	8.3	9.6	9.9	1.4	1.2	32	34	<0.004	0.13	120	<0.5	<0.5	25	28	0.0025	0.003	9.3	11	0.085	0.008	0.005	<0.003	<0.003	<0.005
	26-Jul-16 14:45	7.6	7.8	11	11	1.4	1.1	40	38	<0.004	0.11	130	<0.5	<0.5	1.7	30	<0.0019	<0.002	9.1	10	0.05	0.006	0.005	0.03	<0.003	0.03
	02-Aug-16 15:15	11	10	12	11	1.4	1.2	39	36	<0.004	0.12	140	<0.5	<0.5	1.3	36	<0.0019	<0.002	9.8	10	0.033	0.007	0.004	<0.003	<0.003	<0.005
	09-Aug-16 14:45	8.8	8.8	11	11	1.2	1.1	36	35	<0.004	0.083	130	<0.5	<0.5	2.1	34	<0.0019	<0.002	6.6	6.3	0.026	0.004	0.003	<0.003	<0.003	<0.005
	16-Aug-16 14:50	9	9.1	11	10	1.3	1.1	39	37	<0.004	0.08	140	<0.5	<0.5	1.9	31	0.0067		6.9	7	0.038	0.003	0.003	<0.003	<0.003	<0.005
	16/Aug/16 15:00		9.1		10		1.1		37	<0.004	0.075	140	<0.5	<0.5	1.6	32			7.5	7.3	0.037	0.003	<0.003	<0.003	<0.003	<0.005
	23-Aug-16 14:20	9.1	9.2	10	11	1.1	1.1	37	37	<0.004	<0.06	140	<0.5	<0.5	2.4	33	<0.0019	<0.002	6.9	6.8	0.014	0.003	<0.003	<0.003	<0.003	<0.005
	30-Aug-16 14:50	9.4	9.3	10	9.3	1.9	1.3	39	34	<0.004	0.22	130	<0.5	<0.5	2.4	26	0.013	0.013	13	13	0.13	0.009	0.006	0.013	<0.003	0.013
Station No. AB07DA0062	12/May/16 10:30							40.1				140	<0.5	<0.5	2.5	39	<0.0019		7	7.6	0.045	0.004	<0.003	<0.003	<0.003	<0.005
	19-May-16 11:15	18	12	8.1	10	1.3	1.1	26	32	<0.004	<0.06	120	<0.5	<0.5	6.9	34	<0.0019		4.2	4	0.047	0.005	<0.003	<0.003	<0.003	<0.005
	25-May-16 09:25	26	25	6.2	6.1	1.4	1.2	20	19	<0.004	0.13	89	<0.5	<0.5	33	13	0.0038		7.2	6.7	0.032	0.008	<0.003	<0.003	<0.003	<0.005
	01-Jun-16 09:30	22	20	7.5	6.7	1.5	1.3	27	22	<0.004	0.1	100	<0.5	<0.5	22	13	0.0038	0.004	9.9	9.9	0.15	0.0098	0.006	0.042	<0.003	0.042
	09-Jun-16 09:00	19	19	6.4	6.3	1.3	1.1	20	20	0.004	0.21	87	<0.5	<0.5	21	8.4	<0.0019	<0.002	10	8.9	0.093	0.015	0.011	0.0072	<0.003	0.0072
	10-Jun-16 14:30	9.5	9.2	12	9.9	2	1.4	40	33	<0.004	0.1	120	<0.5	<0.5	1.9	30	0.0069	0.007	10	11	0.16	0.011	0.006	0.031	0.0036	0.035
	10-Jun-16 14:50	9.3	9.3	12	10	1.9	1.4	40	33	<0.004	0.1	120	<0.5	<0.5	2.1	31	0.01	0.011	10	10	0.16	0.008	0.005	0.013	0.0033	0.016
	10-Jun-16 15:30	25	25	11	7.8	2.6	1.4	27	22	0.0054	0.25	95	<0.5	<0.5	26	22	0.02	0.021	11	11	0.28	0.015	0.012	0.0096	<0.003	0.0096
	16-Jun-16 09:30	13	13	7.9	6	1.9	1.1	22	19	0.013	0.41	75	<0.5	<0.5	12	7.9	0.018	0.02	14	14	0.28	0.021	0.02	0.023	0.0037	0.027
	21-Jun-16 14:00	11	11	6.5	5.7	1.4	0.96	19	18	0.0077	0.36	75	<0.5	<0.5	9.7	4.4	0.0092	0.01	15	16	0.16	0.023	0.017	0.014	0.0034	0.018
	29-Jun-16 08:50	15	15	6.2	5.7	1.2	0.87	20	18	0.0043	0.37	79	<0.5	<0.5	16	3.9	0.011	0.011	16	16	0.12	0.02	0.019	0.02	0.0055	0.025
	06-Jul-16 08:20	17	16	9.4	6.3	2.8	1.4	26	20	0.0078	0.58	85	<0.5	<0.5	15	12	0.019	0.02	23	22	0.37	0.025	0.023	0.051	0.0037	0.054
	13-Jul-16 08:00	16	17	6.6	6.6	1.2	1.1	20	20	<0.004	0.55	90	<0.5	<0.5	17	2.6	<0.0019		17	18	0.057	0.029	0.025	0.017	<0.003	0.017
	20-Jul-16 08:30	16	20	5.6	6.7	0.88	0.95	17	21	0.0054	0.55	89	<0.5	<0.5	24	7.9	0.0042	0.004	15	15	0.09	0.02	0.022	<0.003	<0.003	<0.005
	27-Jul-16 09:45	21	21	7.5	7.5	1.1	0.98	23	22	0.0045	0.53	96	<0.5	<0.5	25	9.2	<0.0019	<0.002	13	13	0.076	0.017	0.017	<0.003	<0.003	<0.005
	03-Aug-16 08:30	24	23	8.7	7.6	1.6	1.2	25	23	0.0063	0.49	100	<0.5	<0.5	28	8.8	0.0075	0.008	15	15	0.077	0.02	0.02	<0.003	<0.003	<0.005
	10-Aug-16 07:15	21	21	7.1	6.9	1.1	1	21	20	0.0051	0.48	93	<0.5	<0.5	27	7.6	<0.0019	<0.002	13	13	0.069	0.019	0.017	<0.003	<0.003	<0.005
	17-Aug-16 07:40	23	22	7.3	7	1.2	1.1	22	22	0.0042	0.46	100	<0.5	<0.5	27	8.5	0.0058		14	14	0.04	0.021	0.019	<0.003	<0.003	<0.005
	24-Aug-16 08:00	25	26	7	7.5	1.1	1.1	22	23	0.0074	0.4	100	<0.5	<0.5	31	9.3	0.005	0.005	12	12	0.048	0.012	0.014	0.014	<0.003	0.014
	31-Aug-16 09:10	21	22	7.4	7.7	1.3	1.1	24	24	0.007	0.49	100	<0.5	<0.5	24	7.8	<0.0019	<0.002	13	14	0.052	0.015	0.018	0.01	0.0044	0.015
Station No. AB07CC0130	Maximum	10	11	11	**11**	2.2	1.6	38	37	0.014	0.48	130	0	0	12	39	0.019	0.02	21	**22**	0.19	0.024	0.019	0.041	0	0.041
	Mean	8.79	8.91	9.44	9.20	1.47	1.15	33.64	32.09	0.01	0.31	117.00	NC	NC	2.87	30.18	0.01	0.01	12.13	12.23	0.08	0.01	0.01	0.02	NC	0.02
Station No. AB07CC0030	Maximum	15.00	15.00	**15.00**	**11.00**	**3.00**	**1.80**	**52.00**	**38.00**	0.01	0.37	140.00	**1.00**	0.00	27.00	**42.00**	0.02	0.02	17.00	16.00	**0.43**	0.02	0.03	**0.09**	**0.01**	**0.10**
	Mean	9.76	9.64	10.89	9.80	1.65	1.22	38.56	33.80	0.01	0.15	127.50	1.00	NC	4.36	30.80	0.01	0.01	10.37	10.42	0.12	0.01	0.01	0.05	0.01	0.06
Station No. AB07DA0030	Maximum	**26.00**	**26.00**	12.00	10.00	2.80	1.40	40.10	33.00	0.01	**0.58**	140.00	0.00	0.00	**33.00**	39.00	0.02	0.02	**23.00**	**22.00**	0.37	0.03	0.03	0.05	**0.01**	0.05
	Mean	18.52	18.24	7.92	7.26	1.51	1.15	25.06	22.68	0.01	0.36	97.65	NC	NC	18.56	14.02	0.01	0.01	12.47	12.56	0.12	0.02	0.02	0.02	0.00	0.02
95% Background Value		9.9	10.5	10.5	10.5	1.95	1.4	37.5	36	NC	0.475	130	NC	NC	7.25	37.5	NC	NC	20	19.5	0.17	0.022	0.019	NC	NC	NC
T-test p-value		0.0000031	0.000010	0.740	0.170	0.410	0.602	0.168	0.019	0.551	0.335	0.428	NC	NC	0.000082	0.003	0.474	0.380	0.653	0.648	0.125	0.661	0.790	0.064	NC	0.028

Notes:

1 - Above Grande Rapids, location experienced some ash deposition but expected to be low. Ash related signatures during the first couple of samples in May, prior to that bitumen signature as normal.

2 - Upstream from Fort McMurray water treament intake, 100 m above the confluence with Horse River - left bank

3 - Downstream from Fort McMurray water treatment intake, influence of Clearwater River present on water chemistry

NC = could not calculate

Bold indicates maximum

Grey shading indicates the background concentration was the maximum

A p-value equal to, or less than, 0.05 indicates a statistically significant difference between background concentrations and wildlife exposure area

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.1. Alberta Environment and Parks Athabasca River Water Quality Monitoring Data

Station on the Athabasca River	NITROGEN TOTAL KJELDAHL (TKN) mg/L	NITROGEN DISSOLVED KJELDAHL mg/L	AMMONIA TOTAL mg/L	NITROGEN TOTAL (CALCD_) mg/L	METHYL MERCURY ng/L	DISSOLVED METHYL MERCURY ng/L	MERCURY TOTAL ng/L	MERCURY DISSOLVED ng/L	ALUMINUM TOTAL RECOVERABLE ug/L	ALUMINUM DISSOLVED (AL) ug/L	ANTIMONY TOTAL RECOVERABLE ug/L	ANTIMONY DISSOLVED (SB) ug/L	ARSENIC TOTAL RECOVERABLE ug/L	ARSENIC DISSOLVED ug/L	BARIUM TOTAL RECOVERABLE ug/L	BARIUM DISSOLVED ug/L	BERYLLIUM TOTAL RECOVERABLE ug/L	BERYLLIUM DISSOLVED ug/L	BISMUTH TOTAL RECOVERABLE ug/L	BISMUTH DISSOLVED ug/L	BORON TOTAL RECOVERABLE ug/L	BORON DISSOLVED ug/L	CADMIUM TOTAL RECOVERABLE ug/L	CADMIUM DISSOLVED ug/L	CALCIUM TOTAL RECOVERABLE mg/L	CALCIUM DISSOLVED mg/L	CHLORINE TOTAL RECOVERABLE mg/L	CHLORINE DISSOLVED mg/L	CHROMIUM TOTAL RECOVERABLE ug/L	CHROMIUM DISSOLVED ug/L	COBALT TOTAL RECOVERABLE ug/L	COBALT DISSOLVED ug/L	COPPER TOTAL RECOVERABLE ug/L	COPPER DISSOLVED ug/L	IRON TOTAL RECOVERABLE ug/L	IRON DISSOLVED ug/L	LEAD TOTAL RECOVERABLE - PB ug/L	LEAD DISSOLVED ug/L	LITHIUM TOTAL RECOVERABLE ug/L	LITHIUM DISSOLVED ug/L	MANGANESE TOTAL RECOVERABLE ug/L	MANGANESE DISSOLVED ug/L	MOLYBDENUM TOTAL RECOVERABLE ug/L	MOLYBDENUM DISSOLVED ug/L	NICKEL TOTAL RECOVERABLE ug/L	NICKEL DISSOLVED ug/L	SELENIUM TOTAL RECOVERABLE ug/L	SELENIUM DISSOLVED ug/L	SILVER TOTAL RECOVERABLE ug/L	SILVER DISSOLVED ug/L	STRONTIUM TOTAL RECOVERABLE ug/L
Station No. AB07CC0130	0.27	<0.05	<0.05	0.27	0.103	0.066	1.54	0.78	228	15.3	0.086	0.085	0.73	0.493	52.5	46.2	0.042	0.023	0.007	<0.003	27.1	26.3	0.051	0.032	30.3	30.1	2.85	2.82	0.14	0.1	0.347	0.15	1.25	0.9	667	137	0.345	0.066	7.46	7.1	46.8	1.96	0.812	0.802	2.46	2.12	0.33	<0.04	0.023	0.018	252
	0.89	0.65	<0.05	0.9	0.317	0.225	6.72	2.81	1860	61.8	0.089	0.088	1.8	0.695	79.1	40.9	0.149	0.024	0.029	0.005	37.1	34	0.074	0.034	23.8	23.7	1.4	1.38	2.26	0.4	1.49	0.198	4.04	2.27	3400	457	2.27	0.34	10.8	8.82	102	9.82	0.361	0.356	5.21	3.28	0.12	<0.04	0.03	0.005	155
	0.82	0.52	<0.05	0.84	0.306	0.181	7.7	2.58	1750	80.3	0.102	0.129	2.01	0.758	91.8	44.1	0.165	0.026	0.028	0.006	33.7	31.7	0.089	0.022	29.7	28.8	1.89	1.47	2.2	0.4	1.83	0.195	4.22	1.68	3560	446	2.73	0.199	9.47	7.87	156	10.6	0.518	0.477	5.81	2.76	0.25	0.26	0.033	0.006	248
	0.54	0.42	<0.05	0.55	0.253	0.21	5.73	2.26	874	140	0.081	0.08	1.4	0.785	65.8	46.6	0.086	0.029	0.025	0.004	25	24.9	0.046	0.017	27.3	26.8	1.55	1.53	1.37	0.6	0.923	0.238	2.74	1.9	2530	648	1.47	0.317	7.52	6.89	73.7	10.5	0.538	0.531	3.48	2.08	0.12	<0.04	0.016	0.004	173
	0.49	0.37	<0.05	0.49	0.206	0.143	8.6	1.51	913	21.5	0.087	0.086	1.39	0.705	81.1	51.7	0.079	0.01	0.018	0.003	19.7	19.1	0.147	0.018	31.6	30.1	1	0.99	1.62	0.6	0.99	0.058	2.76	1.39	2250	221	1.45	0.098	7.26	6.16	92.2	2.76	0.649	0.641	3.46	1.77	<0.06	<0.04	0.019	0.003	223
	0.39	0.37	<0.05	0.4	0.165	0.108	4.04	1.18	611	22.4	0.079	0.078	0.989	0.64	69.7	53.8	0.043	<0.009	0.011	<0.003	18.6	18.2	0.033	0.012	34.1	31.3	0.82	0.81	0.97	0.4	0.646	0.054	2.04	1.16	1450	203	0.882	0.082	6.35	5.68	59	2.39	0.73	0.722	2.74	1.58	0.31	0.26	0.01	0.002	222
	0.35	0.37	<0.05	0.35	0.134	0.103	2.61	1.14	371	27.7	0.068	0.076	0.971	0.707	60.8	52.5	0.041	0.019	0.013	0.01	28.5	28.3	0.032	0.025	36	34.9	1.37	1.35	0.55	0.1	0.442	0.109	1.55	0.94	1080	246	0.438	0.054	8.7	8.36	46.9	2.8	0.794	0.784	2.16	1.5	0.28	0.23	0.007	0.002	240
	0.37	0.32	<0.05	0.37	0.114	0.094	2.16	0.87	331	21.9	0.121	0.12	0.815	0.64	57.7	49.8	0.066	0.065	0.024	0.019	19.7	19.5	0.058	0.057	35.4	33.2	0.88	0.87	0.49	0.2	0.375	0.26	1.39	1	825	185	0.458	0.15	6.36	5.95	40	2.19	0.824	0.814	1.86	1.35	0.17	0.17	0.049	0.049	263
	0.33	0.38	<0.05	0.33	0.146	0.144	5.35	1.68	2220	37.8	0.096	0.095	1.31	0.656	86.4	54.2	0.098	0.012	0.019	0.005	24.8	22	0.043	0.018	35.1	32.2	1.01	1	2.75	0.7	0.804	0.078	2.78	1.29	2500	210	1.19	0.094	8.64	6.4	67.2	2.01	0.694	0.685	3.01	1.21	0.14	0.13	0.032	0.009	231
	0.29	0.28	<0.05	0.29	0.098	0.08	2.32	1.14	309	29.3	0.068	0.067	0.817	0.632	54.2	48.4	0.032	0.013	0.007	<0.003	26.5	25.4	0.028	0.013	36	35.9	1.15	1.14	0.52	0.2	0.386	0.159	1.57	1.17	911	234	0.363	0.052	7.79	7.63	45	3.17	0.818	0.816	2.16	1.6	0.13	<0.04	0.007	0.003	242
	0.82	0.48	<0.05	0.86	0.275	0.145	9.74	2.27	2670	28.4	0.123	0.122	1.4	0.615	97.1	50.3	0.15	0.018	0.036	0.004	24.4	21.5	0.076	0.016	29.6	27.4	1.83	1.81	3.17	0.1	1.66	0.077	4.08	1.96	4410	319	2.55	0.177	9.3	6.91	191	2.85	0.552	0.545	4.91	1.61	0.15	0.14	0.041	0.004	186
Station No. AB07CC0030	0.42		<0.05	0.42	0.232	0.07	5.32	0.76	758	7.39	0.087	0.086	0.978	0.448	83	60.6	0.062	0.019	0.016	<0.003	27.3	25	0.043	0.025	40.2	34.8	1.53	1.44	1.23	0.1	1.26	0.256	2.62	1.16	1830	41.1	1.17	0.061	8.2	6.61	219	7.32	0.665	0.657	2.94	1.46	0.3	0.24	0.011	0.011	293
	0.26	0.24	<0.05	0.26	0.119	0.055	1.73	0.72	897	34.7	0.078	0.077	0.596	0.475	66.8	55.5	0.052	0.047	0.027	0.027	32.7	32.3	0.046	0.045	36.5	36.2	3.12	3.08	0.93	0.2	0.378	0.197	1.27	0.94	718	25.6	0.322	0.07	8.12	7.89	49.2	3.64	0.791	0.781	1.67	1.35	0.24	0.19	0.01	0.006	337
	1.2	0.55	<0.05	1.3	0.815	0.175	13.68	1.93	3020	34.9	0.147	0.145	1.76	0.463	154	53.9	0.22	<0.009	0.047	0.004	23	22	0.144	0.014	34	26.1	1.71	1.69	3.93	0.1	3.08	0.081	6.54	2.1	7880	145	5.01	0.15	9.74	5.92	305	1.79	0.45	0.444	8.22	1.29	<0.06	<0.04	0.058	0.002	193
	0.61	0.42	<0.05	0.66	0.325	0.143	6.9	1.76	2670	29.3	0.13	0.128	1.24	0.535	100	56.3	0.121	<0.009	0.03	<0.003	22.9	22.5	0.06	0.013	29.4	28.1	1.04	1.03	3.04	0.3	1.4	0.052	3.98	1.73	3530	104	2.18	0.099	7.23	5.46	122	1.96	0.583	0.575	4.76	1.44	0.24	0.24	0.033	0.002	199
	1.4	0.69	<0.05	1.4	0.477	0.14	20.78	1.87	4420	50.2	0.165	0.155	1.73	0.563	112	41.3	0.234	0.01	0.048	0.006	62.5	61.7	0.091	0.009	26.2	24.5	1.61	1.59	5.3	0.2	3.29	0.147	6.08	1.91	8710	329	5.39	0.227	14.2	9.01	247	4.71	0.328	0.324	9	1.49	0.22	0.15	0.085	0.007	193
	0.92		<0.05	1	0.476	0.126	13.85	1.77	4130	37.5	0.117	0.115	2.24	0.59	133	44.7	0.217	0.009	0.046	<0.003	28.8	28.6	0.121	0.008	34.1	27.3	0.56	0.55	3.95	<0.1	3.4	0.115	6.86	1.78	7910	133	4.82	0.115	10.3	6.07	209	2.59	0.417	0.412	8.61	2.27	0.2	0.2	0.06	0.005	195
	0.97	0.5	<0.05	1.1	0.514	0.133	12.74	1.47	6920	86.4	0.151	0.122	2.33	0.466	159	42.4	0.322	0.016	0.074	0.004	36.2	32.6	0.142	0.019	23.5	19.8	0.9	0.88	7	0.1	3.15	0.121	6.58	1.32	24000	156	5.81	0.145	14.3	6.9	262	3.95	0.598	0.59	8.51	1.88	<0.06	0.06	0.093	0.092	190
	0.68	0.43	<0.05	0.71	0.258	0.137	8.14	2.19	1410	40.5	0.115	0.114	1.48	0.588	88.2	49.9	0.143	0.019	0.028	0.006	27.8	25.9	0.07	0.024	33.6	27.3	0.68	0.67	2.19	<0.1	1.55	0.096	4.04	1.62	3470	154	2.44	0.114	8.67	6.35	116	3.13	0.52	0.513	4.93	1.85	<0.06	<0.04	0.034	0.008	197
	0.59	0.52	<0.05	0.59	0.233	0.166	5.68	2.12	1010	38.3	0.101	0.1	1.16	0.686	71.7	52.8	0.08	0.013	0.017	0.005	34.3	33.1	0.043	0.043	30.6	29.7	1.81	1.79	1.38	0.2	0.718	0.105	2.95	2.26	1980	332	1.11	0.641	9.13	8.08	58.5	3.14	0.341	0.337	3.17	3.13	0.15	<0.04	0.012	0.005	189
	0.53	0.47	<0.05	0.53	0.238	0.154	5.26	2.01	853	49	0.086	0.12	1.16	0.661	69.6	52.6	0.058	0.013	0.012	0.003	40.6	39.4	0.032	0.017	35.5	33.9	2.09	2.17	1.38	0.3	0.73	0.094	2.45	1.49	1480	247	0.979	0.127	9	8.01	71.9	4.34	0.492	0.421	2.85	1.64	0.24	0.29	0.012	0.004	317
	0.51	0.45	<0.05	0.51	0.282	0.149	4.97	1.79	815	20.8	0.086	0.085	1.08	0.641	64.5	47	0.069	0.024	0.018	0.007	30.5	29.8	0.039	0.038	31.6	30.3	1.3	1.28	1.52	0.4	0.774	0.097	2.45	1.38	1700	151	1.09	0.122	7.25	6.23	59.5	1.97	0.493	0.487	2.55	1.15	0.19	0.05	0.02	0.014	192
	0.51		<0.05	0.51	0.206	0.142	4.86	1.64	663	24.8	0.082	0.081	1.14	0.631	64.7	48.9	0.06	<0.009	0.01	<0.003	30.1	29.3	0.03	0.009	32.8	30.9	1.38	1.36	1.05	0.3	0.676	0.112	2.32	1.7	1590	173	0.972	0.105	7.25	6.29	57.8	2.34	0.431	0.425	2.32	1.06	0.2	0.2	0.012	0.003	207
	0.47	0.36	<0.05	0.47	0.185	0.161	6.13	1.41	984	17.3	0.092	0.09	1.32	0.586	82.7	54.6	0.086	<0.009	0.012	<0.003	19.8	19	0.041	0.014	32.5	30.6	1.06	1.05	1.53	0.7	0.98	0.038	2.86	1.46	2000	104	1.29	0.073	7.02	5.92	83.5	1.35	0.473	0.467	3.12	1.51	0.3	0.13	0.014	0.001	229
	0.42	0.34	<0.05	0.45	0.269	0.147	3.72	1.23	937	19.8	0.088	0.087	1.08	0.572	78.6	57.9	0.061	<0.009	0.017	<0.003	17.6	17.4	0.038	0.016	35.4	32.1	0.78	0.77	1.31	0.3	0.768	0.034	2.52	1.44	1880	85.5	1.04	0.135	6.08	5.03	66.5	1.33	0.628	0.621	2.87	1.46	0.23	0.23	0.013	0.002	227
	0.44	0.39	<0.05	0.44	0.169	0.12	3.51	1.35	905	18.3	0.073	0.072	1.12	0.619	67.2	53.6	0.052	<0.009	0.01	0.003	40.4	39.8	0.022	0.016	38.1	37.1	1.49	1.47	1.2	<0.1	0.622	0.059	1.94	1	1410	119	0.655	0.647	9.7	8.73	50	1.45	0.62	0.613	1.84	1.01	0.26	0.25	0.009	0.003	257
	0.32	0.25	<0.05	0.32	0.096	0.062	1.88	0.99	311	15.9	0.08	0.079	0.668	0.557	60.6	53.6	0.034	0.022	0.012	0.007	20.9	20.9	0.018	0.017	37.6	36.5	0.96	0.95	0.44	0.1	0.314	0.073	1.32	0.86	706	65.5	0.524	0.063	5.87	5.5	37.7	1.13	0.659	0.651	1.5	0.911	0.15	0.12	0.015	0.015	259
	0.32	0.22	<0.05	0.32	0.116	0.06	3.94	1	1180	47.2	0.087	0.086	0.954	0.551	74.6	57.9	0.063	<0.009	0.01	<0.003	21.2	20	0.031	0.018	39.2	37.2	1.12	1.11	1.58	0.2	0.598	0.078	2.19	1.09	1490	160	0.746	0.064	7.62	6.33	53	2.68	0.704	0.695	2	0.934	0.37	0.1	0.019	0.006	265
	0.33		<0.05	0.33	0.124	0.056	3.14	0.92	618	15.4	0.076	0.075	0.926	0.596	69.9	56.4	0.032	<0.009	0.01	<0.003	19.4	18.3	0.028	0.015	36.4	34.8	0.96	0.94	0.91	0.1	0.532	0.057	1.86	1.12	1110	59.3	0.662	0.06	6.14	5.52	47.9	1.58	0.626	0.618	1.37	0.532	0.27	0.21	0.012	0.003	257
	0.32	0.31	<0.05	0.32	0.082	0.057	1.95	0.87	201	14.1	0.067	0.066	0.685	0.538	58.8	54	0.019	<0.009	0.005	<0.003	17.5	17.1	0.018	0.012	37	37	1.19	1.17	0.38	0.2	0.244	0.068	1.39	1.14	567	59	0.312	0.035	5.83	5.59	31	1.25	0.721	0.712	1.25	0.825	0.3	0.11	0.004	0.002	254
	0.88	0.49	<0.05	0.89	0.253	0.111	11.16	2.31	2430	24.7	0.123	0.122	1.5	0.563	101	52.2	0.147	0.013	0.032	0.004	23.2	19.3	0.068	0.016	32.6	29.6	1.8	1.78	3.01	0.2	1.67	0.072	4.03	1.62	4350	210	2.48	0.151	9.24	6.6	192	2.45	0.534	0.528	4.51	1.32	0.23	0.22	0.031	0.004	209
Station No. AB07DA0062	0.36	0.26	<0.05	0.36	0.153	0.056	3.77	0.73	552	7.32	0.075	0.074	0.772	0.36	75.4	61.1	0.035	<0.009	0.011	<0.003	22.5	21.6	0.035	0.016	40.1	39.5	1.22	1.21	0.85	0.2	0.751	0.193	1.86	1.11	1260	41.1	0.742	0.041	7.39	6.75	70.4	0.6	0.784	0.775	2.4	1.26	0.11	0.11	0.007	<0.001	308
	0.45	0.18	<0.05	0.45	0.088	0.021	1.47	0.46	152	5.87	0.038	0.037	0.483	0.283	35	29.3	0.021	0.017	0.002	<0.003	31.2	29.9	0.015	0.015	21	20.5	10.6	10.5	0.13	0.1	0.254	0.073	0.92	0.62	761	158	0.251	0.048	6.5	6.21	78.5	6.68	0.415	0.41	1.21	0.899	0.22	0.18	0.004	0.004	163
	0.41	0.35	<0.05	0.41	0.072	0.029	1.68	0.64	943	37.2	0.063	0.062	0.821	0.489	31.9	23.5	0.077	0.076	0.042	0.041	41.9	41.4	0.067	0.067	19.8	19.3	19	18.8	0.93	0.3	0.376	0.161	0.89	0.62	1180	181	0.391	0.131	8.45	8.04	67.9	5.04	0.414	0.409	1.13	0.686	0.62	0.25	0.015	0.015	139
	0.75	0.45	<0.05	0.79	0.241	0.075	6.3	0.92	1000	34.7	0.063	0.062	0.947	0.408	53.6	28.7	0.07	<0.009	0.018	<0.003	35.9	35.4	0.036	0.007	19.1	18.3	15.2	15	1.14	<0.1	1	0.073	2.5	1.11	3010	140	1.4	0.107	8.21	7.35	117	3.12	0.4	0.395	2.36	0.302	0.2	0.13	0.015	0.001	117
	0.62	0.39	<0.05	0.63	0.141	0.063	3.06	0.85	846	18.1	0.047	0.046	0.9	0.438	38.2	22.7	0.051	<0.009	0.013	<0.003	31.5	30.9	0.022	0.005	17.1	16.7	15.6	15.4	1.1	0.1	0.713	0.031	1.88	1.04	2100	159	0.898	0.088	6.97	6.14	159	2.48	0.325	0.321	1.97	0.677	0.24	0.2	0.011	0.001	100
	0.65	0.4	<0.05	0.69	0.262	0.118	9.36	1.54	1760	27.3	0.12	0.118	1.09	0.479	96.4	56.4	0.11	<0.009	0.03	<0.003	21.5	20.6	0.059	0.012	28.7	27.1	1.71	1.69	2.28	0.1	1.39	0.049	3.08	1.2	3240	113	2.32	0.085	7.32	5.52	139	1.18	0.55	0.543	4.23	1.13	0.2	0.19	0.037	0.003	216
	0.7	0.39	<0.05	0.72	0.323	0.112	8.69	1.55	1560	24.2	0.122	0.12	1.12	0.419	96.1	57	0.11	<0.009	0.026	<0.003	20.5	19.3	0.063	0.012	29.2	27	1.77	1.75	2.03	0.1	1.42	0.047	3.04	1.22	3250	99.9	2.31	0.084	7.08	5.39	146	1.13	0.531	0.524	4.27	1.07	0.22	0.17	0.037	0.004	217
	1	0.56	<0.05	1	0.214	0.069	6.7	1.12	4010	51.4	0.097	0.096	1.31	0.442	68.4	25.1	0.206	<0.009	0.043	<0.003	49.4	48.8	0.06	0.004	17.9	17.6	18.7	18.5	4.37	0.1	2.37	0.046	3.91	0.82	6400	184	3.93	0.108	12.9	9.02	248	1.78	0.239	0.236	5.98	0.921	0.21	0.15	0.065	0.004	128
	1	0.65	<0.05	1	0.196	0.074	8.09	1.64	1460	57.9	0.075	0.075	1.59	0.693	63.8	25.2	0.131	0.022	0.044	0.019	31.5	31.1	0.043	0.026	17.8	16.8	4.07	3.13	3.13	0.2	2.74	0.095	4.33	1.05	5970	374	2.99	0.2	8.61	7.21	244	4.41	0.258	0.185	6.2	1.54	<0.06	0.17	0.036	0.02	77.5
	0.75	0.61	<0.05	0.77	0.185	0.103	5.06	1.7	1520	77.1	0.063	0.062	1.48	0.77	53.2	23.8	0.133	0.026	0.024	0.009	34.1	34	0.044	0.016	17.3	16.8	3.97	3.92	2.81	0.2	1.62	0.116	2.99	1.02	4200	407	1.98	0.161	8.76	6.55	177	9.61	0.274	0.27	3.74	1.3	0.18	0.18	0.033	0.014	84.6
	0.79	0.61	<0.05	0.81	0.183	0.12	4.17	1.43	1230	38.7	0.048	0.048	1.3	0.748	39.5	21.5	0.084	<0.009	0.016	0.004	36.7	36.6	0.027	0.011	17.2	17	11.9	11.7	1.61	0.2	0.91	0.03	1.98	1.07	2690	390	1.08	0.164	8.34	6.93	126	3.35	0.041	0.041	2.2	1.06	0.21	0.18	0.012	0.003	85.2
	1.2	0.66	<0.05	1.3	0.314	0.123	12.08	2.33	4620	96.9	0.078	0.112	2.18	0.767	81.4	23.7	0.311	0.014	0.046	0.003	64.7	63	0.074	0.006	21.8	20.3	12.9	15.1	6.85	1.1	3.75	0.119	6.48	1.52	10000	384	5.11	0.186	15.9	9.16	333	5.98	0.128	0.125	8.19	1.54	0.15	0.14	0.06	0.005	148
	0.71	0.62	<0.05	0.73	0.209	0.156	5.56	1.79	714	44	0.043	0.043	1.16	0.655	33	19.8	0.059	0.009	0.016	0.003	35.4	34.8	0.017	0.003	18.8	18.4	13.6	13.4	1.6	0.4	0.848	0.063	1.82	1.09	2200	475	0.99	0.126	7.16	6.14	98.5	4.8	0.218	0.215	2.07	0.731	0.2	0.16	0.014	0.004	92.2
	0.68	0.49	<0.05	0.68	0.175	0.151	3.6	1.29	444	21.1	0.037	0.036	1.06	0.698	34.7	24.9	0.041	<0.009	0.008	<0.003	34.2	33.8	0.016	0.006	20	19.4	14.1	13.9	1.05	0.6	0.549	0.03	1.39	0.84	1740	488	0.665	0.089	7.18	6.72	81.3	3.4	0.301	0.297	1.7	0.872	0.22	0.21	0.006	0.002	119
	0.64	0.51	<0.05	0.64	0.147	0.091	2.84	1.14	454	16.5	0.039	0.038	1.13	0.778	33.1	24	0.037	<0.009	0.011	<0.003	34.5	34.1	0.014	0.006	20	19.6	14.7	14.5	0.81	0.3	0.556	0.034	1.43	0.67	1820	470	0.66	0.082	7.14	6.7	77.2	3.12	0.313	0.31	1.73	0.856	0.25	0.2	0.01	0.003	118
	0.61	0.58	<0.05	0.61	0.149	0.12	5.15	1.78	1120	28.7	0.051	0.05	1.3	0.745	38.3	23.8	0.072	<0.009	0.013	0.004	49.7	48.5	0.025	0.008	24.4	23.7	19.9	19.7	1.76	0.2	0.974	0.088	2.3	0.75	2900	527	1.05	0.105	11	9.37	86.1	4.7	0.241	0.238	2.46	0.936	0.24	0.24	0.013	0.001	127
	0.56	0.54	<0.05	0.56	0.123	0.078	2.64	1.12	321	12.7	0.039	0.038	0.887	0.685	27.2	20.7	0.023	<0.009	0.007	<0.003	35.1	34.7	<0.002	<0.002	21.4	21.1	14.9	14.7	0.57	0.1	0.401	0.035	1.04	0.54	1350	417	0.434	0.054	6.88	6.6	68.4	3.7	0.297	0.293	1.18	0.556	0.11	0.11	0.006	0.002	119
	0.42	0.47	<0.05	0.42	0.11	0.082	2.79	1.08	588	20	0.038	0.037	1.04	0.734	31.6	23.4	0.034	<0.009	0.006	0.004	38.5	37.7	0.013	0.004	20.7	20.4	13.8	13.6	0.86	0.1	0.42	0.052	1.15	0.53	1460	390	0.464	0.061	8.16	7.46	59.5	2.83	0.279	0.276	1.26	0.561	0.28	0.21	0.007	0.002	125
	0.4	0.44	<0.05	0.42	0.092	0.075	2.27	0.88	266	14.4	0.03	0.03	0.818	0.63	25.2	21	0.018	<0.009	0.007	<0.003	39.3	38.5	0.006	0.005	22.1	22	16	15.8	0.47	0.2	0.316	0.056	1	0.6	1200	480	0.33	0.046	7.76	7.49	55.2	3.99	0.303	0.299	0.82	0.461	0.26	0.24	0.006	0.002	129
	0.43	0.49	<0.05	0.45	0.126	0.084	3.36	1.12	455	11.3	0.037	0.037	0.82	0.547	30.8	22	0.038	<0.009	0.007	<0.003	42.5	39.2	0.016	0.004	20.8	20	19.2	19	0.66	0.1	0.442	0.057	1.2	0.9	1660	465	0.557	0.098	8.59	8	61.2	4.69	0.298	0.294	1.13	0.421	0.21	0.2	0.008	0.002	121
Station No. AB07CC0130	0.89	0.65	0	0.9	0.317	**0.225**	9.74	**2.81**	2670	**140**	0.123	0.129	2.01	**0.785**	97.1	54.2	0.165	0.065	0.036	0.019	37.1	34	0.147	0.057	36	35.9	2.85	2.82	3.17	0.7	1.83	0.26	4.22	**2.27**	4410	**648**	2.73	0.34	10.8	8.82	191	**10.6**	**0.824**	**0.816**	5.81	**3.28**	0.33	0.26	0.049	0.049	263
	0.51	0.42	NC	0.51	0.19	0.14	5.14	1.66	1103.36	44.22	0.09	0.09	1.24	0.67	72.38	48.95	0.09	0.02	0.02	0.01	25.92	24.63	0.06	0.02	31.72	30.40	1.43	1.38	1.46	0.35	0.90	0.14	2.58	1.42	2143.91	300.55	1.29	0.15	8.15	7.07	83.62	4.64	0.66	0.65	3.39	1.90	0.20	0.20	0.02	0.01	221.36
Station No. AB07CC0030	**1.40**	**0.69**	0.00	**1.40**	**0.82**	0.18	**20.78**	2.31	**6920.00**	86.40	**0.17**	**0.16**	**2.33**	0.69	**159.00**	60.60	**0.32**	0.05	**0.07**	0.03	62.50	61.70	**0.14**	0.05	**40.20**	37.20	3.12	3.08	**7.00**	0.70	3.40	**0.26**	**6.86**	2.26	**24000.00**	332.00	**5.81**	**0.65**	14.30	9.01	305.00	7.32	0.79	0.78	**9.00**	3.13	0.37	**0.29**	**0.09**	**0.09**	**337.00**
	0.61	0.41	NC	0.63	0.27	0.12	6.97	1.51	1756.60	31.32	0.10	0.10	1.26	0.57	88.00	52.31	0.11	0.02	0.02	0.01	28.84	27.70	0.06	0.02	33.84	31.19	1.35	1.34	2.16	0.24	1.31	0.10	3.31	1.46	3915.55	142.65	1.95	0.16	8.54	6.60	116.93	2.71	0.55	0.54	3.90	1.43	0.24	0.18	0.03	0.01	232.95
Station No. AB07DA0030	1.20	0.66	0.00	1.30	0.32	0.16	12.08	2.33	4620.00	96.90	0.12	0.12	2.18	0.78	96.40	**61.10**	0.31	**0.08**	0.05	**0.04**	**64.70**	**63.00**	0.07	**0.07**	40.10	**39.50**	**19.90**	**19.70**	6.85	**1.10**	**3.75**	0.19	6.48	1.52	10000.00	527.00	5.11	0.20	**15.90**	**9.37**	**333.00**	9.61	0.78	0.78	8.19	1.54	**0.62**	0.25	0.07	0.02	308.00
	0.66	0.48	NC	0.67	0.18	0.09	4.93	1.26	1200.75	32.27	0.06	0.06	1.11	0.59	49.34	28.88	0.08	0.03	0.02	0.01	36.53	35.70	0.03	0.01	21.76	21.08	12.14	12.07	1.75	0.25	1.09	0.07	2.26	0.92	2919.55	317.15	1.43	0.10	8.52	7.14	124.66	3.83	0.33	0.32	2.81	0.89	0.23	0.18	0.02	0.00	136.68
95% Background Value	0.855	0.5915	NC	0.88	0.3115	0.2175	9.17	2.695	2445	110.15	0.122	0.1255	1.905	0.7715	94.45	54	0.1575	0.0488	0.0325	NC	35.4	32.85	0.118	0.0455	36	35.4	2.37	2.315	2.96	0.65	1.745	0.249	4.15	2.115	3985	552.5	2.64	0.3285	10.135	8.59	173.5	10.55	0.821	0.815	5.51	3.02	0.321	NC	0.045	0.0335	257.5
T-test p-value	0.143	0.384	NC	0.131	0.352	0.080	0.458	0.250	0.294	0.310	0.207	0.138	0.702	0.008	0.599	0.004	0.664	0.736	0.598	0.598	0.010	0.005	0.191	0.089	0.030	0.011	0.000025	0.000023	0.228	0.184	0.195	0.028	0.645	0.146	0.096	0.198	0.283	0.660	0.497	0.580	0.069	0.254	0.0007	0.00088	0.955	0.0031	0.275	0.472	0.957	0.654	0.022

Notes:

1 - Above Grande Rapids, location experienced some ash deposition but expected to be low. Ash related signatures during the first couple of samples in May, prior to that bitumen signature as normal.

2 - Upstream from Fort McMurray water treament intake, 100 m above the confluence with Horse River - left bank

3 - Downstream from Fort McMurray water treatment intake, influence of Clearwater River present on water chemistry

NC = could not calculate

Bold indicates maximum

Grey shading indicates the background concentration was the maximum

A p-value equal to, or less than, 0.05 indicates a statistically significant difference between background concentrations and wildlife exposure area

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.1. Alberta Environment and Parks Athabasca River Water Quality Monitoring Data

Station on the Athabasca River	STRONTIUM DISSOLVED ug/L	THALLIUM TOTAL RECOVERABLE ug/L	THALLIUM DISSOLVED ug/L	THORIUM TOTAL RECOVERABLE ug/L	THORIUM DISSOLVED ug/L	TIN TOTAL RECOVERABLE ug/L	TIN DISSOLVED ug/L	TITANIUM TOTAL RECOVERABLE ug/L	TITANIUM DISSOLVED ug/L	URANIUM TOTAL RECOVERABLE ug/L	URANIUM DISSOLVED ug/L	VANADIUM TOTAL RECOVERABLE ug/L	VANADIUM DISSOLVED ug/L	ZINC TOTAL RECOVERABLE ug/L	ZINC DISSOLVED ug/L	F1, HYDROCARBONS (C6-C10)- BTX ug/L	BENZENE ug/L	TOLUENE ug/L	ETHYLBENZENE ug/L	M- + P-XYLENE ug/L	O-XYLENE ug/L	F2, HYDROCARBONS (C10-C16) ug/L
Station No. AB07CC0130	244	0.0315	0.0196	0.0665	0.0305	0.056	0.047	5.47	1.03	0.481	0.457	0.69	0.2	2.4	0.78	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	154	0.0499	0.0129	0.626	0.0806	0.035	0.013	29.1	5.25	0.613	0.373	4.4	0.5	11.8	1.65	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	247	0.0638	0.0122	0.655	0.0723	0.026	0.004	17.8	4.53	0.692	0.429	4.58	0.62	13.4	1.31	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	172	0.0362	0.0082	0.411	0.123	0.033	0.03	11.4	3.04	0.471	0.395	2.28	0.55	7.1	1.9	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	219	0.0422	0.0087	0.33	0.0288	0.027	0.027	18.6	2.05	0.529	0.404	2.74	0.37	10.1	0.89	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	215	0.0243	0.0068	0.193	0.028	0.016	0.016	10.4	1.8	0.469	0.413	1.87	0.33	4.1	0.62	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	233	0.0213	0.0157	0.0978	0.0227	0.005	0.005	4.71	1.2	0.505	0.47	1.22	0.4	3.2	0.97	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	261	0.0568	0.0561	0.229	0.134	0.013	0.013	5.04	1.24	0.424	0.399	0.96	0.35	4.5	1.48	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	225	0.0417	0.0092	0.357	0.0383	0.084	0.058	56.7	2.05	0.493	0.384	5.18	0.38	7.1	0.79	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	242	0.0105	0.0016	0.0624	0.0194	0.018	0.013	7	1.17	0.481	0.467	0.92	0.28	3.2	1.23	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	185	0.0669	0.0249	0.594	0.0323	0.07	0.005	56.3	2.08	0.606	0.396	5.67	0.4	10.1	0.75	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
Station No. AB07CC0030	292	0.0332	0.0328	0.208	0.0196	0.016	0.016	10.1	0.82	0.606	0.508	2.55	0.23	5.9	0.87							
	330	0.0332	0.0328	0.127	0.0634	0.06	0.06	11.7	0.81	0.548	0.534	2.11	0.39	3.1	0.62	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	191	0.096	0.0091	1.11	0.0533	0.037	0.006	48.5	4.86	0.916	0.49	8.12	0.51	16.3	0.44	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	198	0.053	0.0066	0.674	0.0427	0.037	0.034	54.9	3.51	0.581	0.409	5.5	0.43	9.8	0.65	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	186	0.0801	0.0063	1.07	0.0728	0.054	0.02	70.6	8	0.817	0.42	9.29	0.62	15.7	0.8	<10	<0.1	<0.1	<0.1	<0.1	<0.1	11
	194	0.0911	0.0074	1.42	0.0439	<0.003	<0.003	20.6	2.14	0.852	0.439	8.48	0.52	19.6	0.86							
	189	0.139	0.0115	2.37	0.0598	0.046	<0.003	57.4	5.05	1.01	0.467	13.5	0.41	19.6	0.56	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	196	0.0548	0.0133	0.624	0.0546	0.021	0.009	28.9	4.25	0.615	0.39	4.57	0.41	9.3	0.72	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	188	0.0341	0.0093	0.244	0.0503	0.018	0.018	12.9	3.11	0.464	0.389	2.59	0.46	6	5.96	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	315	0.0231	0.0088	0.222	0.0466	0.018	0.004	8.48	2.74	0.485	0.414	2.64	0.51	5.4	0.98	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	191	0.0405	0.04	0.29	0.0393	0.018	0.018	14.1	1.83	0.435	0.352	2.58	0.36	5.2	1.3	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	206	0.0247	0.007	0.18	0.0221	0.014	0.014	10.3	1.71	0.432	0.364	2.17	0.32	5	0.99							
	221	0.0358	0.0072	0.243	0.025	0.027	0.021	16.5	2.1	0.489	0.4	2.89	0.32	7.4	0.78	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	227	0.0266	0.0073	0.281	0.0245	0.024	0.024	12.9	1.85	0.47	0.4	2.62	0.34	5.6	1.66	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	251	0.0195	0.0097	0.176	0.0138	0.017	0.017	14.9	1.49	0.491	0.422	2.52	0.44	4.1	0.6	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	257	0.0277	0.0274	0.147	0.0529	0.015	0.015	4.83	1.16	0.442	0.396	1.05	0.22	3.2	0.8	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	264	0.0247	0.0053	0.23	0.0217	0.038	0.012	29.1	1.83	0.493	0.417	2.98	0.44	4.9	0.83	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	253	0.0179	0.0084	0.136	0.0097	0.017	0.011	15.3	1.02	0.454	0.396	1.91	0.34	3.9	0.63							
	253	0.0118	0.0037	0.045	0.0146	0.013	0.006	3.95	0.91	0.46	0.44	0.78	0.27	2.4	0.75	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	209	0.0606	0.0123	0.589	0.0388	0.054	0.012	51.1	2.1	0.638	0.442	5.55	0.34	9.9	0.82	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
Station No. AB07DA0062	305	0.0226	0.0058	0.109	0.0122	0.023	0.023	9.71	0.56	0.582	0.506	1.9	0.21	3.8	0.09							
	160	0.0086	0.0084	0.0338	0.0191	0.021	0.021	4.54	0.99	0.225	0.215	0.64	0.18	2.2	0.51	<10	0.2	<0.1	<0.1	<0.1	<0.1	<5
	138	0.0554	0.0547	0.162	0.0869	0.074	0.073	12.4	1.67	0.208	0.205	2.13	0.41	2.2	0.4	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	117	0.0297	0.0052	0.317	0.0366	0.013	0.004	20.5	2.54	0.293	0.189	2.93	0.3	6	0.57	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	100	0.02	0.0028	0.245	0.028	0.023	0.022	20.7	2.08	0.177	0.1	2.42	0.28	4.3	1.56	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	213	0.0451	0.007	0.431	0.0385	0.029	<0.003	37.4	3.8	0.605	0.425	3.93	0.38	7.5	0.25	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	213	0.043	0.007	0.336	0.0372	0.024	0.005	37.7	3.57	0.6	0.426	3.52	0.39	7.3	0.28	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	125	0.0617	0.0052	0.874	0.0476	0.076	<0.003	101	6.98	0.552	0.204	7.17	0.33	10.6	0.2	<10	<0.1	<0.1	<0.1	1.1	<0.1	<5
	72.1	0.0555	0.0188	0.839	0.0729	0.024	0.016	51.8	6.2	0.357	0.135	6.46	0.56	11.3	0.44	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	84	0.0491	0.0094	0.59	0.0669	0.038	0.009	53.9	6.38	0.274	0.098	5.17	0.67	8.2	0.68	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	84.4	0.0238	0.0058	0.276	0.0503	0.016	0.016	23.3	3.98	0.18	0.088	3.16	0.44	5.9	1.07	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	152	0.0788	0.0061	1.53	0.0801	0.071	0.009	45.6	9.55	0.551	0.165	10.7	1	17.9	0.89	<10	<0.1	<0.1	<0.1	<0.1	<0.1	18
	91.5	0.0239	0.0051	0.271	0.0429	0.016	0.016	14.9	4.34	0.161	0.085	2.6	0.49	4.9	0.9	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	116	0.0154	0.0042	0.137	0.0255	0.02	0.02	10.6	2.42	0.184	0.12	1.73	0.45	3.4	0.88	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	117	0.0159	0.0033	0.146	0.0211	0.018	0.018	10.9	2.35	0.181	0.128	1.76	0.41	3.4	0.52	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	126	0.0187	0.0062	0.292	0.026	0.009	0.009	13.6	3.19	0.221	0.139	3.44	0.54	6.7	0.88	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	119	0.0113	0.0055	0.121	0.0344	0.008	0.007	7.82	1.74	0.14	0.112	1.26	0.35	2.4	0.53	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	125	0.0144	0.0075	0.123	0.0318	0.01	<0.003	13.1	2.46	0.16	0.122	1.83	0.42	3	0.34	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	129	0.005	<0.0004	0.0671	0.0173	0.019	0.007	8.64	2.12	0.144	0.12	1	0.3	3	0.53	<10	<0.1	<0.1	<0.1	<0.1	<0.1	<5
	119	0.0177	0.0034	0.127	0.0187	0.024	0.013	9.22	1.43	0.164	0.123	1.26	0.24	2.6	0.61	<10	<0.1	<0.1	<0.1	<0.1	<0.1	14
Station No. AB07CC0130	261	0.0669	**0.0561**	0.655	**0.134**	**0.084**	0.058	56.7	5.25	0.692	0.47	5.67	0.62	13.4	1.9	0	0	0	0	0	0	0
	217.91	0.04	0.02	0.33	0.06	0.03	0.02	20.23	2.31	0.52	0.42	2.77	0.40	7.00	1.12	NC	NC	NC	NC	NC	NC	NC
Station No. AB07CC0030	**330.00**	**0.14**	0.04	**2.37**	0.07	0.06	0.06	70.60	8.00	**1.01**	**0.53**	**13.50**	0.62	**19.60**	**5.96**	0.00	0.00	0.00	0.00	0.00	0.00	11.00
	230.55	0.05	0.01	0.52	0.04	0.03	0.02	24.85	2.56	0.58	0.42	4.22	0.39	8.12	1.08	NC	NC	NC	NC	NC	NC	11.00
Station No. AB07DA0030	305.00	0.08	0.05	1.53	0.09	**0.08**	**0.07**	**101.00**	**9.55**	0.61	0.51	10.70	**1.00**	17.90	1.56	0.00	**0.20**	0.00	0.00	**1.10**	0.00	**18.00**
	135.30	0.03	0.01	0.35	0.04	0.03	0.02	25.37	3.42	0.30	0.19	3.25	0.42	5.83	0.61	NC	0.20	NC	NC	1.10	NC	16.00
95% Background Value	254	0.06535	0.0405	0.6405	0.1285	0.077	0.0525	56.5	4.89	0.6525	0.4685	5.425	0.585	12.6	1.775	NC	NC	NC	NC	NC	NC	NC
T-test p-value	0.025	0.789	0.337	0.304	0.227	0.428	0.538	0.481	0.219	0.061	0.000082	0.197	0.862	0.984	0.146	NC	NC	NC	NC	NC	NC	NC

Station on the Athabasca River	F3, HYDROCARBONS (C16-C34) ug/L	F4, HYDROCARBONS (C34-C50) ug/L	Naphthalene ng/L	C1-Naphthalenes ng/L	C2-Naphthalenes ng/L	C3-Naphthalenes ng/L	C4-Naphthalenes ng/L	Biphenyl ng/L	C1-Biphenyls ng/L	C2-Biphenyls ng/L	Acenaphthylene ng/L	Acenaphthene ng/L	C1-Acenaphthenes ng/L	Fluorene ng/L	C1-Fluorenes ng/L	C2-Fluorenes ng/L	C3-Fluorenes ng/L	Anthracene ng/L	Phenanthrene ng/L	C1 Phenanthrenes/Anthracenes ng/L	C2 Phenanthrenes/Anthracenes ng/L	C3-Phenanthrenes/Anthracenes ng/L
Station No. AB07CC0130	<20	<20	13.3	3.02	1.66	1.62	1.2	0.451	1.43	4.81	<0.049	<0.118	<0.072	<0.051	8.33	1.83	1.68	<0.033	1.13	1.19	1.35	1.05
	<20	<20	1.75	1.5	2.59	2.88	1.9	0.443	1.08	3.4	<0.057	0.392	<0.126	0.099	0.519	0.86	1.93	<0.098	1.29	1.8	1.83	2.08
	<20	<20	2.6	1.9	4.13	5.67	3.66	0.632	1.04	2.89	<0.138	<0.368	0.162	0.178	0.895	1.91	4.05	<0.098	1.97	3.22	2.74	3.36
	<20	<20	1.79	1.57	2.56	3.12	1.59	0.785	1.06	2.17	<0.048	0.325	<0.103	<0.133	0.741	0.899	2.11	<0.067	1.71	2.35	2.38	2.41
	<20	<20	1.42	2.35	4.23	3.21	2.23	1.15	2.1	5.48	<0.086	<0.288	<0.07	<0.158	0.591	1.4	2.23	0.145	2.15	2.84	2.45	1.77
	<20	<20	2.17	4.05	6.01	3.55	2.4	1.7	3.16	6.85	<0.1	<0.142	<0.123	<0.316	1.12	3.29	3.66	<0.136	3.01	4.59	3.34	2
	<20	<20	1.61	1.67	1.64	1.98	0.927	0.763	1.41	3.92	<0.059	0.149	<0.053	0.26	0.506	0.811	0.967	<0.095	1.3	1.65	1.22	0.671
	<20	<20	1.98	1.7	2.14	2.8	1.39	0.845	0.978	1.96	<0.063	<0.138	<0.046	0.252	0.953	1.26	1.34	0.125	1.64	2.03	1.29	0.972
	<20	<20	3.16	9.6	18	16.7	9.68	1.88	2.92	2.99	<0.068	0.277	<0.07	0.732	2.65	5.42	5.74	0.238	6.22	13.7	9.67	5.84
	<20	<20	2.23	1.78	2.54	1.72	0.896	0.594	0.97	2.02	<0.079	<0.186	<0.107	0.291	0.831	0.501	0.668	0.114	1.45	1.75	0.963	0.551
	<20	<20	2.8	5.64	10.5	8.64	3.61	1.86	2.78	3.46	<0.072	0.448	<0.099	0.866	2.04	4.08	5.38	0.296	4.69	8.15	5.47	4.19
Station No. AB07CC0030																						
	<20	<20	34.5	11.3	8.82	8.68	4.09	14.4	2.93	6.61	1.21	0.639	<0.044	1.7	5.28	4.77	3.25	<0.14	9.64	5.59	4.92	3.89
	49	<20	3.29	8.59	16.3	19	22.3	3.07	6.23	11.4	0.195	1.22	0.199	1	4.54	11.7	14.6	0.797	8.67	18.9	19.3	21.1
	<20	<20	4.1	5.04	9.02	10.3	9.74	1.62	3.89	8.52	0.187	0.539	<0.08	0.452	1.69	3.86	5.57	<0.165	4.27	7.36	7.91	8.48
	708	388	3.78	3.33	8.08	93.3	232	1.43	1.63	5.56	<0.663	12	2.64	4.19	24.1	146	165	<0.537	<5.37	10.8	73.8	154
	32	<20	3.13	9.66	18	23.8	35.1	3.37	6.47	9.56	0.168	1.66	0.324	1.24	5.18	18.4	29.1	<0.735	9.51	22.7	27	36.8
	<20	<20	2.35	5.3	10.8	10.6	10.9	1.85	2.68	3.19	<0.126	0.755	<0.195	0.438	1.85	7.27	9.76	0.256	4.71	9.85	10.9	11.8
	<20	<20	<4.21	<1.65	<6.19	3.99	3.38	<1.42	3.52	12	<1.27	<1.81	<2.5	<0.825	<1.32	<1.37	<2.37	<0.847	2.37	1.38	4.12	6.1
	<20	<20	3.55	2.28	4.65	15.3	30.6	0.919	1.04	2.72	0.209	0.768	<0.212	0.352	2.97	8.99	15.3	<0.232	2.94	10.3	14	17.4
	<20	<20	2	1.96	3.12	4.51	4.84	1.02	1.16	2.11	<0.06	<0.297	<0.08	0.222	1.4	3.02	4.97	<0.149	2.42	4.32	5.87	6.63
	<20	<20	2.01	2.42	3.92	4.16	5.56	1.02	1.63	3.91	<0.053	0.277	<0.105	0.154	0.964	3.71	5.15	<0.078	2.29	3.66	5.82	6.54
	<20	<20	2.94	5.59	10	7.71	7.12	2.27	4.19	7.43	<0.063	<0.219	<0.121	0.428	2.09	6.74	7.16	0.201	4.57	9.09	8.06	7.52
	<20	<20	2.27	2.26	3.38	4.02	5.36	0.682	1.36	3.85	<0.077	0.235	<0.085	0.341	1.12	3.28	3.97	<0.076	1.79	3.58	5.12	6.23
	<20	<20	2.01	1.68	2.76	4.73	6.35	0.729	1.16	2.85	<0.031	0.242	<0.059	0.334	1.33	2.86	5.39	<0.089	1.61	3.23	4.42	5.6
	<20	<20	1.68	2.47	5.45	6	5.84	0.974	1.09	1.02	<0.044	0.26	0.072	0.456	1.51	4.17	6.01	<0.157	2.68	5.42	6.59	6.33
	<20	<20	1.79	2.03	3.24	2.55	2.55	0.802	0.972	2.06	<0.095	0.232	<0.116	0.404	0.868	1.41	2.61	<0.085	1.92	2.87	2.75	2.81
	<20	<20	2.03	4.42	8.96	10.3	11.2	14.2	2.68	3.16	<0.069	0.471	<0.162	0.704	2.21	5.76	8.53	<0.224	4.29	9.26	9.83	10.9
Station No. AB07DA0062																						
	<20	<20																				
	<20	<20	42.1	11.4	8.48	8.83	5.69	13	2.04	3.87	1.51	0.763	<0.096	1.41	9.23	7.03	5.92	0.203	7.62	4.68	6.71	8.56
	52	<20	7.44	5.15	7.02	7.55	10.2	2.88	3.34	8.22	<0.601	0.737	0.125	0.864	2.96	7.32	13.2	<0.308	5.19	8.17	12.6	20.9
	<20	<20	9.86	3.61	2.87	4.29	9.76	2.24	2.05	6.17	0.481	0.455	0.089	0.533	1.14	3.88	8.75	<0.176	2.93	3.54	8.26	16.6
	56	60	2.49	4.51	8.54	27.2	59.3	1.39	2.95	5.93	<0.186	2.22	0.565	1.05	5.89	32.5	51.7	<0.322	5.01	11.5	23.4	43.5
	67	48	5.73	3.54	4.3	38	91.7	1.49	1.7	5.45	0.754	2.88	1.13	1.42	9.75	41.8	64.2	<0.362	5.54	26.5	71	104
	124	60	2.9	4.95	8.7	25.9	60.4	1.47	2.98	6.35	<0.162	1.73	0.455	0.9	5.73	33.5	42.5	<0.289	4.78	11.2	21.3	39
	126	46	2.68	2.32	3.47	10.4	33.9	0.835	1.81	5.77	0.27	0.939	0.238	0.521	2.74	19.1	39.5	<0.224	3.16	14.2	36	70.5
	40	<20	2.54	2	1.99	7.58	23.2	0.501	0.698	1.49	0.205	0.56	0.195	<0.072	1.49	8.86	18.6	<0.373	2	8.27	16.2	27.1
	78	<20	2.39	1.56	1.47	3.34	14.6	0.466	0.939	3.96	0.162	0.394	<0.141	0.173	1.3	7.62	18.9	<0.346	1.4	5.94	14.5	32.5
	201	61	2.55	2.11	2.95	17	70.5	1.27	0.892	3.08	<0.311	1.2	0.419	<0.136	3.22	25.8	53.5	<1.05	4.02	18.4	40.4	85.8
	<20	<20	1.91	1.17	1.73	4.91	9.19	0.715	0.695	2.2	<0.117	<0.338	<0.216	0.181	0.898	5.71	12.5	<0.175	1.4	0.522	7.11	20.4
	<20	<20	2.57	2.01	1.51	2.3	4.56	0.899	1.72	6.46	<0.078	<0.239	<0.136	0.114	0.575	3.01	5.3	<0.12	1.15	1.53	3.92	7.33
	22	34	2.09	1.86	1.31	2.19	7.08	0.53	0.756	1.63	<0.14	<0.224	<0.096	0.128	0.725	7.03	15.3	<0.169	1.53	4.36	10.9	22.9
	<20	54	6.84	4.03	3.31	15.2	51.1	0.843	0.898	3.17	0.572	0.929	0.299	0.527	3.91	24.9	65	<0.233	2.77	13	39	104
	<20	<20	3.34	1.84	2.24	3.87	7.6	0.719	0.595	1.41	<0.126	0.288	<0.15	0.254	1.43	3.68	8.09	<0.091	1.3	2.87	5.23	11.9
	<20	<20	2.03	2.88	5.02	4.59	4.54	0.703	0.777	0.733	0.086	0.201	<0.054	0.373	1.07	3.14	4.56	0.091	2.09	2.96	4.91	6.56
	<20	<20	3.75	2.89	1.82	1.72	2.25	0.46	0.645	1.54	<0.131	0.176	<0.111	0.255	0.439	0.919	2.66	<0.112	1.04	1.43	2.2	5.09
	92	44	2.26	1.77	2.4	2.37	3.56	0.558	0.76	1.36	0.116	0.23	<0.084	0.271	0.524	1.88	3.93	<0.083	1.24	2.07	3.09	6.09
Station No. AB07CC0130	0	0	13.3	9.6	**18**	16.7	9.68	1.88	3.16	6.85	0	0.448	0.162	0.866	8.33	5.42	5.74	0.296	6.22	13.7	9.67	5.84
	NC	NC	3.16	3.16	5.09	4.72	2.68	1.01	1.72	3.63	#DIV/0!	0.32	0.16	0.38	1.74	2.02	2.71	0.18	2.41	3.93	2.97	2.26
Station No. AB07CC0030	**708.00**	**388.00**	34.50	11.30	**18.00**	**93.30**	**232.00**	**14.40**	**6.47**	**12.00**	1.21	**12.00**	**2.64**	**4.19**	**24.10**	**146.00**	**165.00**	**0.80**	**9.64**	22.70	**73.80**	**154.00**
	263.00	388.00	4.76	4.56	7.77	14.31	24.81	3.22	2.66	5.37	0.39	1.48	0.81	0.83	3.81	15.46	19.09	0.42	4.25	8.02	13.15	19.51
Station No. AB07DA0030	201.00	61.00	**42.10**	**11.40**	8.70	38.00	91.70	13.00	3.34	8.22	**1.51**	2.88	1.13	1.42	9.75	41.80	65.00	0.20	7.62	**26.50**	71.00	104.00
	85.80	50.88	5.86	3.31	3.84	10.40	26.06	1.72	1.46	3.82	0.46	0.91	0.39	0.56	2.95	13.20	24.12	0.15	3.01	7.84	18.15	35.15
95% Background Value	NC	NC	8.23	7.62	14.25	12.67	6.67	1.87	3.04	6.165	NC	NC	NC	NC	5.49	4.75	5.56	NC	5.455	10.925	7.57	5.015
T-test p-value	NC	NC	0.238	0.432	0.754	0.022	0.0040	0.046	0.410	0.192	NC	0.052	NC	0.096	0.132	0.011	0.0015	0.379	0.085	0.017	0.00022	0.00019

Notes:

1 - Above Grande Rapids, location experienced some ash deposition but expected to be low. Ash related signatures during the first couple of samples in May, prior to that bitumen signature as normal.

2 - Upstream from Fort McMurray water treament intake, 100 m above the confluence with Horse River - left bank

3 - Downstream from Fort McMurray water treatment intake, influence of Clearwater River present on water chemistry

NC = could not calculate

Bold indicates maximum

Grey shading indicates the background concentration was the maximum

A p-value equal to, or less than, 0.05 indicates a statistically significant difference between background concentrations and wildlife exposure area

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.1. Alberta Environment and Parks Athabasca River Water Quality Monitoring Data

Station on the Athabasca River	C4-Phenanthrenes/Anthracenes ng/L	Retene ng/L	Fluoranthene ng/L	Pyrene ng/L	C1-Fluoranthenes/Pyrenes ng/L	C2-Fluoranthenes/Pyrenes ng/L	C3-Fluoranthenes/Pyrenes ng/L	C4-Fluoranthenes/Pyrenes ng/L	Benz[a]anthracene ng/L	Chrysene ng/L	C1-Benzo[a]anthracenes/Chrysenes ng/L	C2-Benzo[a]anthracenes/Chrysenes ng/L	C3-Benzo[a]anthracenes/Chrysenes ng/L	C4-Benzo[a]anthracenes/Chrysenes ng/L	Benzo[b]fluoranthene ng/L	Benzo[j,k]fluoranthenes ng/L	Benzo[e]pyrene ng/L	Benzo[a]pyrene ng/L	C1-Benzofluoranthenes/Benzopyrenes ng/L	C2-Benzofluoranthenes/Benzopyrenes ng/L	Dibenz[a,h]anthracene ng/L	Perylene ng/L	Benzo[ghi]perylene ng/L	Indeno[1,2,3-cd]pyrene ng/L	Dibenzothiophene ng/L	C1-Dibenzothiophenes ng/L	C2-Dibenzothiophenes ng/L	C3-Dibenzothiophenes ng/L	C4-Dibenzothiophenes ng/L
Station No. AB07CC0130	2.2	0.668	0.554	0.471	1.49	1.94	0.617	<0.088	0.124	0.368	0.736	0.649	<0.07	<0.064	0.241	<0.105	<0.275	<0.125	0.302	<0.123	<0.087	1.55	<0.23	<0.161	0.16	0.342	1.77	1.55	1.89
	7.18	4.86	0.856	1.03	5.92	7.04	3.09	2	0.163	0.983	1.9	2.04	<1.03	<0.072	0.902	0.241	0.949	0.472	3.01	0.657	0.155	13.8	0.642	0.473	<0.138	<0.152	0.704	1.71	1.29
	13.7	4.16	1.46	1.8	11.3	17.1	8.48	4.92	<0.278	1.99	4.48	4.82	1.07	<0.155	1.77	0.608	1.63	0.69	6.42	1.88	<0.238	24.2	1.42	1.01	<0.251	0.93	3.27	5.6	4.99
	9.62	4.48	0.925	0.999	6.01	7.46	4.83	0.79	<0.218	1.1	2.44	2.23	0.654	<0.067	0.984	<0.279	0.878	<0.497	2.83	0.67	<0.166	12.2	0.77	<0.438	<0.184	0.284	1.97	2.51	2.31
	5.66	3.53	0.925	0.888	4.78	5.47	2.87	1.94	0.185	1.06	1.94	1.72	0.319	<0.063	0.684	<0.32	0.645	0.276	2.05	0.538	<0.147	9.7	0.477	<0.288	0.239	0.284	1.32	1.08	0.834
	3.82	2.17	0.761	0.701	3.55	4.92	1.96	0.799	<0.166	1.08	1.72	1.29	0.417	<0.079	0.642	<0.092	0.577	0.165	1.4	0.622	<0.109	4.36	0.365	<0.177	<0.266	0.576	1.37	1.05	0.708
	1.91	1.19	0.566	0.505	1.79	1.7	0.805	0.435	0.125	0.511	0.706	0.719	<0.07	<0.065	<0.341	<0.146	<0.411	<0.162	0.726	0.135	<0.127	2.77	0.553	<0.209	<0.15	0.177	0.524	0.411	0.321
	2.55	1.07	0.722	0.461	2.02	2.61	<0.117	1.04	0.095	0.521	1.2	0.942	<0.089	<0.078	0.324	<0.082	<0.248	<0.11	1.94	0.488	<0.202	2.48	<0.212	<0.07	<0.162	0.445	0.485	0.866	0.414
	11.9	3.62	1.3	1.65	9.92	11.9	4.44	1.35	0.336	2.69	3.94	3.09	0.679	<0.046	1.31	<0.222	2.01	0.35	4.28	1.76	0.178	5.17	1.06	<0.293	<0.544	1.98	3.91	2.94	3.5
	1.69	0.711	0.602	0.427	1.53	1.76	0.595	1.22	0.084	0.423	0.61	0.482	<0.108	<0.084	0.197	<0.073	0.217	<0.124	0.386	<0.114	<0.069	1.92	0.223	<0.102	<0.149	<0.18	0.535	0.532	0.434
	14.2	6.78	1.38	1.72	9.85	12.6	4.59	2.56	0.382	2.16	3.89	3.16	0.499	<0.092	1.65	0.389	1.5	0.651	5.85	1.21	<0.225	16.4	1.07	<0.597	<0.549	1.42	2.63	2.93	2.28
Station No. AB07CC0030																													
	17.2	12.7	1.45	1.22	3.19	3.14	1.45	<0.192	<0.074	0.631	0.792	0.902	<0.073	<0.072	0.195	<0.1	0.39	<0.126	<0.163	<0.113	<0.078	1.02	0.641	<0.155	0.242	0.573	2.8	4.04	3.48
	62.6	18.8	2.58	3.84	26	39.5	24.6	10.2	0.683	5.49	11.5	13.8	4.51	1.02	3	0.915	3.43	1.15	10.7	4.11	<0.4	29	2.01	1.07	<1.03	1.58	22.2	33.2	38.3
	22.8	7.46	1.32	1.98	11.1	14.3	7.89	2.04	<0.26	2.33	4.12	4.39	1.34	<0.121	1.35	<0.453	1.6	<0.36	3.81	0.924	<0.172	12.3	1.09	<0.498	0.417	1.41	7.28	10.2	8.87
	376	22.6	3.15	7.56	101	205	159	62.5	2.27	17.9	52.7	85.5	33.3	12.3	4.38	<1.49	7.11	2.41	32.3	20.6	<0.833	15.4	3.68	2	<4.78	45.6	412	533	386
	98.6	21.9	3.16	5.14	43.5	70.7	53.2	18.7	<0.841	7.6	19.5	23.7	8.64	3.64	3.91	<1.19	4.6	1.58	17.2	7.18	<0.568	41.5	2.9	1.51	<1.15	6.78	47	68.7	68.6
	29	6.76	1.42	2.2	15.1	23.6	11.5	5.52	0.376	2.86	6.31	7.44	1.74	1	1.61	0.406	1.77	0.51	5.96	2.21	<0.283	17	1.08	0.604	0.533	2.61	16.1	21.9	16.1
	10.6	3.45	0.905	1.31	6.61	7.46	1.8	<0.986	0.817	1.47	2.16	2.48	<0.595	<0.508	0.84	<0.44	0.98	<0.578	<1.52	<1.16	<0.667	5.19	0.56	0.532	<0.566	<0.898	4.74	10.1	<1.84
	34.6	5.05	1.03	1.57	10.9	18.2	11.5	5.68	<0.276	2.38	4.52	6.02	1.32	<0.207	0.947	<0.391	1.37	<0.573	4.08	1.69	<0.445	6.72	1.07	0.46	<0.414	6.08	32.6	46.4	25.8
	15.2	3.2	1.14	1.31	6.35	8.95	6.09	1.9	0.388	1.56	3.45	2.58	0.984	<0.073	<0.801	<0.25	<0.921	<0.368	2.6	1.18	<0.194	5.54	0.545	<0.311	<0.352	1.42	9.29	13.5	11
	18.3	5.49	1.03	1.28	8.79	12.2	7.07	3.34	0.226	1.7	3.14	4.08	1.79	<0.194	0.987	<0.311	1.06	<0.375	2.99	1.16	<0.132	8.01	0.63	<0.398	<0.279	1.46	8.12	12.8	13.8
	22	5	1.02	1.52	10.6	15.9	10.3	4.07	0.298	2.42	4.1	4.86	1.91	0.561	1.02	<0.246	1.17	0.284	3.42	1.87	<0.126	6.31	0.602	<0.299	0.539	2.28	7.78	11.1	11.9
	11.9	1.93	0.85	0.948	5.22	7.89	6	2.36	<0.107	1.02	1.9	2.9	1.29	0.114	0.405	<0.113	<0.542	<0.148	1.33	0.544	<0.09	1.88	0.57	<0.306	<0.301	<0.289	10.5	13.3	11.9
	17	1.79	0.72	0.965	5.72	9.3	3.95	2.2	0.12	1.16	2.26	2.82	1.42	<0.071	0.429	<0.094	<0.448	<0.161	0.961	0.417	<0.083	2.31	0.259	<0.182	<0.227	1.57	7.12	12.7	10.8
	17.4	2.68	0.935	1.34	8.32	12.4	7.96	4.09	<0.188	1.82	3.33	4.36	1.98	<0.087	0.695	<0.154	0.889	0.299	3.2	1.61	<0.118	3.96	0.484	<0.251	<0.32	2.05	8.13	12.3	12.3
	7.07	0.967	0.581	0.639	3.29	4.59	1.94	1.59	0.119	0.753	1.16	1.46	<0.099	<0.09	0.269	<0.09	0.311	<0.12	0.986	0.258	<0.143	1.43	0.201	<0.167	<0.271	0.676	4.21	6.44	4.23
	30.6	9.61	1.38	2	14.6	19.3	10.9	4.03	0.396	2.83	5.52	6.3	1.2	<0.162	1.52	0.56	1.73	0.614	5.42	1.82	<0.452	14.4	1.18	0.607	<0.513	2.96	15.1	23.7	19.7
Station No. AB07DA0062																													
	38.7	19.3	1.43	2.05	9.77	15.2	10	3.71	<0.253	1.62	3.31	5.14	2.05	<0.144	<0.45	<0.221	0.823	<0.202	1.99	1.02	<0.119	1.88	0.464	<0.306	0.22	0.84	7.18	13.9	14.8
	72.3	17	1.66	2.81	22.3	41	30.4	8.84	0.427	4.4	10.6	16.3	6.99	1.37	<1.97	<0.686	2.62	<0.804	9.81	4.01	<0.33	13.7	1.53	0.978	<0.452	0.662	15.5	27.3	40.1
	58.9	12	1.08	2.11	14.8	32.1	24.5	6.96	<0.353	2.83	7.3	11.9	4.46	0.64	<1.18	0.543	1.67	<0.629	6	2.48	<0.215	7.8	1.29	0.84	<0.165	0.849	16.7	30.4	31.9
	134	13.5	2.48	4.93	49.5	87.8	64.4	21.3	<0.846	7.94	20.2	33.9	14.6	4.68	<2.89	<0.709	4.12	<1.31	16.4	9.15	<0.509	17.7	2.31	1.12	<1.43	12.2	99.6	131	120
	208	20.5	2.54	5.08	56.9	118	87.5	40.7	1.36	9.98	33.3	51.4	20.5	8.18	<4.8	<1.79	6.24	2.5	30.2	16	<0.953	30.2	4.92	3.59	<0.789	15	148	219	172
	101	13	1.81	3.9	39.5	71.3	55.3	21.6	<0.681	6.58	16.2	26.2	9.63	3.3	<2.53	<0.636	3.14	<1.01	12.6	6.7	<0.4	15.3	1.78	0.992	<1.19	15	85.8	115	96.1
	169	20.8	1.8	3.94	46.5	95.5	74.2	27.5	<0.718	7.58	26.6	39.9	14.9	6.17	<3.89	<1.74	5.04	<2.23	24.4	10.7	<0.787	30.9	3.83	2.97	<0.289	<0.248	56.4	132	130
	65	7.06	1.16	2.65	23.3	48.4	36.4	16.4	<0.74	3.78	10.7	17	4.49	2.35	2.27	0.924	2.49	1.14	13.6	5.79	<0.678	15.4	2.07	1.73	0.228	0.906	29	60.2	59
	68.7	12.4	0.873	2.21	23	28	29.9	14.8	<0.421	3.32	9.92	15.6	4.3	1.66	1.47	<0.519	1.79	0.762	8.09	3.7	0.407	8.56	1.34	1.07	<0.634	<0.682	20.5	66.8	60.8
	170	23	2.83	6.37	53.1	94	70.6	33.2	<1.49	9.82	30.2	35.6	11.1	5.57	6.28	3	7.09	2.92	30.1	9.16	<2.47	42.5	6.14	4.92	<1.03	<1.45	81.3	177	125
	60.5	17.6	0.801	1.93	15	31.6	29.5	12.2	<0.24	2.68	7.47	10.2	6.52	1.16	<1.31	<0.551	1.39	<0.699	6.93	3.37	<0.301	8.46	1.17	<0.898	<0.127	<0.24	14.7	40	45
	27.4	6.7	0.565	1.33	9.95	17	12.9	4.27	0.166	1.76	4.35	6.04	3	0.783	0.719	<0.297	0.861	0.338	3.36	1.68	<0.138	4.84	0.591	0.396	<0.328	<0.247	6.97	16.5	19.9
	53.7	4.62	0.662	1.83	16	19.8	24.7	10.2	<0.305	3.02	8	11.5	6.38	1.38	1.23	<0.374	1.55	0.501	6.14	3.73	0.245	6.46	1.03	0.798	<0.328	<0.521	27.6	70.6	85.6
	221	<14.6	1.75	3.69	45.5	103	92.5	34.6	<1.23	8.02	28	45.7	25.3	2.75	<2.68	<1.5	<3.93	<1.94	19.5	11	<0.901	14.7	2.89	1.98	<0.542	<0.838	76.6	189	200
	37.5	2.83	0.753	1.63	10.9	22.6	11.9	5.85	0.27	2.01	5.11	6.95	3.47	<0.121	0.738	<0.286	<1.15	<0.388	2.45	1.48	<0.174	4.07	<0.73	<0.5	<0.112	0.41	11.4	28.3	31.3
	20.8	2.18	0.737	1.36	<9.29	15.4	10.1	3.7	0.182	1.82	3.79	4.61	2.33	0.571	<0.695	<0.219	1.02	0.257	<2.64	<1.39	0.121	3.13	<0.619	0.341	0.169	0.622	6.93	14.1	14
	16.8	1.75	0.455	0.9	6.81	11.9	7.03	3.68	<0.162	1.35	2.8	3.73	0.639	<0.127	0.461	<0.116	0.573	0.271	2.4	0.81	0.145	2.79	0.528	0.39	<0.13	0.163	4.91	15.1	15.4
	17.2	2.47	0.561	1.02	8	13.8	7	3.89	0.123	1.33	3.12	4.91	0.997	<0.11	0.613	0.222	0.753	0.272	3.09	1.15	<0.161	4.2	0.61	0.393	<0.131	0.619	6.2	15.5	12.3
Station No. AB07CC0130	14.2	6.78	1.46	1.8	11.3	17.1	8.48	4.92	0.382	2.69	4.48	4.82	1.07	0	1.77	0.608	2.01	0.69	6.42	1.88	0.178	24.2	1.42	1.01	0.239	1.98	3.91	5.6	4.99
	6.77	3.02	0.91	0.97	5.29	6.77	3.23	1.71	0.19	1.17	2.14	1.92	0.61	NC	0.87	0.41	1.05	0.43	2.65	0.88	0.17	8.60	0.73	0.74	0.20	0.72	1.68	1.93	1.72
Station No. AB07CC0030	**376.00**	22.60	**3.16**	**7.56**	**101.00**	**205.00**	**159.00**	**62.50**	**2.27**	**17.90**	**52.70**	**85.50**	**33.30**	**12.30**	4.38	0.92	**7.11**	2.41	**32.30**	**20.60**	0.00	41.50	3.68	2.00	**0.54**	**45.60**	**412.00**	**533.00**	**386.00**
	49.43	8.09	1.42	2.18	17.52	29.53	20.32	9.16	0.57	3.37	7.90	10.85	4.72	3.11	1.44	0.63	2.03	0.98	6.78	3.26	#DIV/0!	10.75	1.09	0.97	0.43	5.50	38.44	52.09	42.85
Station No. AB07DA0030	221.00	**23.00**	2.83	6.37	56.90	118.00	92.50	40.70	1.36	9.98	33.30	51.40	25.30	8.18	**6.28**	**3.00**	7.09	**2.92**	30.20	16.00	**0.41**	**42.50**	**6.14**	**4.92**	0.23	15.00	148.00	219.00	200.00
	85.58	11.57	1.33	2.76	26.52	48.13	37.71	15.19	0.42	4.44	12.83	19.25	7.87	2.90	1.72	1.17	2.57	1.00	11.59	5.41	0.23	12.92	2.03	1.50	0.21	4.30	39.74	75.65	70.73
95% Background Value	13.95	5.82	1.42	1.76	10.61	14.85	6.8375	3.858	NC	2.425	4.21	3.99	NC	NC	1.716	NC	NC	NC	6.135	NC	NC	20.3	NC	NC	NC	NC	3.59	4.27	4.245
T-test p-value	0.000073	0.000018	0.0083	0.000040	0.00011	0.00013	0.00010	0.00014	0.041	0.00018	0.00023	0.00017	0.00020	NC	0.076	0.201	0.0049	0.033	0.00051	0.00038	0.406	0.268	0.0054	0.196	0.108	0.036	0.0058	0.00095	0.00022

Notes:

1 - Above Grande Rapids, location experienced some ash deposition but expected to be low. Ash related signatures during the first couple of samples in May, prior to that bitumen signature as normal.

2 - Upstream from Fort McMurray water treament intake, 100 m above the confluence with Horse River - left bank

3 - Downstream from Fort McMurray water treatment intake, influence of Clearwater River present on water chemistry

NC = could not calculate

Bold indicates maximum

Grey shading indicates the background concentration was the maximum

A p-value equal to, or less than, 0.05 indicates a statistically significant difference between background concentrations and wildlife exposure area

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.2 - Post-cleaning, Confirmatory Drinking Water Quality

Client Sample ID				POST-CW	POST-LTS	POST-BH	POST-RES-1	POST-RES-2	POST - ABA	POST - RES 4	POST - RES 5	POST - RES 3	POST - RES 6	TW1	HOSP	RES1	RES 2	RES 3	RES 4	RES 5	RES 6	
Location				Clearwell at Water Treatment Plant	Lower Townsite Reservoir	Beacon Hill Reservoir	Thickwood Reservoir	Timberlea Reservoir	Abasands Reservoir	Mackenzie Park Reservoir	Southeast Pump House	Parsons Creek Reservoir	Anzac Reservoir	Water Treatment Plant	Northern Lights Regional Health Centre	Thickwood Reservoir	Timberlea Reservoir	Parsons Creek Reservoir	Mackenzie Park Reservoir	Southeast Pump House	Anzac Reservoir	Maximum
Date Sampled				7-Jun-2016	7-Jun-2016	7-Jun-2016	7-Jun-2016	7-Jun-2016	27-Jun-2016	27-Jun-2016	28-Jun-2016	30-Jun-2016	30-Jun-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	27-May-2016	27-May-2016	
Parameter	GCDWQ MAC	Lowest Detection Limit	Units	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Bacteriological results																						
E. Coli	0/100mL	NA	NA		All bacterological tests have been taken in accordance with the drinking water system approval and all have passed									All bacterological tests have been taken in accordance with the drinking water system approval and all have passed								
Total coliforms	0/100mL	NA	NA		All bacterological tests have been taken in accordance with the drinking water system approval and all have passed									All bacterological tests have been taken in accordance with the drinking water system approval and all have passed								
Physical Tests (Water)																						
Color, True		2.0	C.U.	<2.0	<2.0	<2.0	<2.0	<2.0	2.7	<2.0	<2.0	<2.0	2.2	<2.0	2.3	<2.0	<2.0	<2.0	<2.0	2.6	5.0	5
Total Suspended Solids		3.0	mg/L	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	6.6	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	6.6
Total Dissolved Solids		10	mg/L	215	201	214	211	219	182	188	192	200	230	218	214	208	209	221	212	194	251	251
Turbidity		0.10	NTU	<0.10	0.13	0.13	0.15	0.11	0.16	0.22	0.30	0.15	1.50	0.12	0.38	0.28	0.22	0.52	0.28	0.18	0.55	1.5
Anions and Nutrients (Water)																						
Alkalinity, Total (as CaCO3)		2.0	mg/L	101	102	104	96.7	100	82.3	79.0	79.4	89.0	101	103	101	103	103	105	104	105	131	131
Ammonia, Total (as N)		0.050	mg/L	0.513	0.489	0.500	0.476	0.471	0.478	0.461	0.472	0.513	0.519	0.436	0.397	0.372	0.381	0.107	0.394	0.387	0.415	0.519
Bicarbonate (HCO3)		5.0	mg/L	123	125	127	118	122	100	96.4	96.9	109	102	126	123	126	126	128	127	124	151	151
Bromate	0.01	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Carbonate (CO3)		5.0	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	0
Chlorate	1	0.010	mg/L	0.268	0.254	0.256	0.262	0.257	0.216	0.226	0.221	0.271	0.258	0.233	0.234	0.196	0.197	0.217	0.207	0.165	0.171	0.271
Chloride (Cl)		0.50	mg/L	25.6	25.1	25.3	25.3	25.4	29.4	30.5	30.2	27.6	28.0	24.9	25.8	24.4	24.4	24.2	24.8	24.1	24.5	30.5
Chlorite	1	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Conductivity (EC)		2.0	uS/cm	350	356	356	352	351	317	319	319	329	367	371	373	366	366	380	369	368	442	442
Fluoride (F)	1.5	0.020	mg/L	0.040	0.040	0.040	0.042	0.039	<0.020	0.056	0.059	0.026	0.034	0.045	0.049	0.045	0.044	0.051	0.044	0.047	0.053	0.059
Hardness (as CaCO3)			mg/L	131	135	133	129	135	118	118	121	127	146	132	129	131	128	134	133	135	155	155
Hydroxide (OH)		5.0	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	0
Ion Balance			%	101	102	101	103	104	108	109	111	108	110	101	100	99.5	97.6	103	100	107	106	111
Nitrate and Nitrite (as N)	10	0.022	mg/L	0.031	<0.022	0.026	0.029	0.025	0.059	0.058	0.061	0.044	0.086	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	0.112	0.112
Nitrate (as N)	10	0.020	mg/L	0.031	0.021	0.026	0.029	0.025	0.059	0.058	0.061	0.044	0.086	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.112	0.112
Nitrite (as N)	1	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
pH		0.10	pH	8.15	8.15	8.15	8.16	8.13	8.01	7.63	7.67	7.99	8.20	8.06	8.08	8.02	8.01	7.98	8.03	7.91	7.96	8.2
TDS (Calculated)			mg/L	187	190	190	183	188	169	167	169	178	201	191	189	189	187	195	191	194	238	238
Sulfate (SO4)		0.30	mg/L	33.9	36.0	35.3	34.3	35.3	27.2	26.6	26.9	30.7	42.1	36.6	36.4	36.6	36.3	37.6	36.2	35.8	49.0	49
Sulphide (as S)		0.0015	mg/L	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	0
Cyanides (Water)																						
Cyanide, Total	0.2	0.0020	mg/L	<0.020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0026	<0.0020	<0.0020	<0.0020	0.0026
Organic / Inorganic Carbon (Water)																						
Dissolved Organic Carbon		1.0	mg/L	6.9	7.6	7.2	7.7	6.6		6.0	6.0	7.3	5.7	5.1	4.9	4.6	4.6	5.5	5.1	4.4	3.4	7.7
Total Organic Carbon		1.0	mg/L	3.8	3.6	3.8	3.8	3.7	4.7	4.8	4.6	4.8	4.1	3.8	3.9	3.7	3.7	4.7	4.1	4.4	3.3	4.8
Inorganic Parameters (Water)																						
Chlorine, Free		0.10	mg/L	0.89	<0.10	0.16	0.13	0.15	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.11	<0.10	0.23	0.12	0.21	0.89
Chlorine, Total		0.10	mg/L	1.99	1.86	1.89	2.00	2.09	1.63	1.56	1.58	1.25	0.71	1.86	1.72	2.20	2.22	0.35	1.08	1.95	0.81	2.22
Total Metals (Water)																						
Aluminum (Al)-Total		0.0030	mg/L	0.0396	0.0462	0.0506	0.0417	0.0407	0.0369	0.0281	0.0307	0.0474	0.0635	0.0433	0.0495	0.0431	0.0524	0.216	0.0567	0.0502	0.0439	0.216
Antimony (Sb)-Total	0.006	0.00010	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011
Arsenic (As)-Total	0.01	0.00010	mg/L	0.00023	0.00025	0.00022	0.00022	0.00023	0.00018	0.00020	0.00019	0.00023	0.00021	0.00027	0.00024	0.00026	0.00026	0.00025	0.00025	0.00023	0.00018	0.00027
Barium (Ba)-Total	1	0.000050	mg/L	0.0598	0.0598	0.0601	0.0596	0.0597	0.0563	0.0578	0.0568	0.0572	0.0370	0.0564	0.0540	0.0574	0.0564	0.0554	0.0559	0.0602	0.0583	0.0602
Beryllium (Be)-Total		0.00010	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0
Bismuth (Bi)-Total		0.000050	mg/L	<0.000050	0.000084	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000084
Boron (B)-Total	5	0.010	mg/L	0.028	0.029	0.030	0.029	0.030	0.042	0.041	0.042	0.036	0.091	0.027	0.027	0.028	0.029	0.029	0.028	0.028	0.031	0.091
Cadmium (Cd)-Total	0.005	0.0000050	mg/L	0.0000110	0.0000140	0.0000117	0.0000115	0.0000118	0.0000062	0.0000075	0.0000084	0.0000143	0.0000062	0.0000111	0.0000136	0.0000103	0.0000129	0.0000130	0.0000115	0.0000156	0.0000165	0.0000165
Calcium (Ca)-Total		0.050	mg/L	36.4	37.4	37.4	36.6	37.0	35.1	33.8	34.7	36.6	22.6	36.4	35.6	34.7	36.7	37.0	35.2	38.3	43.6	43.6
Cesium (Cs)-Total		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000011	<0.000010	<0.000010	0.000013	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000013
Chromium (Cr)-Total	0.05	0.00010	mg/L	0.00011	0.00011	0.00013	0.00010	0.00012	<0.00010	<0.00010	<0.00010	<0.00010	0.00020	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010	<0.00010	<0.00010	0.0002
Cobalt (Co)-Total		0.00010	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	0.00010	0.00010	0.00010	0.00010	0.00015	0.00010	0.00011	0.00015	0.00015
Copper (Cu)-Total		0.00050	mg/L	0.0608	0.0411	0.0133	0.00455	0.00154	0.00223	0.00841	0.00214	0.0586	0.0682	0.0437	0.00257	0.00416	0.00166	0.0733	0.00658	0.00119	0.0759	0.0759
Iron (Fe)-Total		0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.014	0.011	<0.010	0.035	<0.010	0.038	<0.010	<0.010	0.013	<0.010	<0.010	0.034	0.038
Lead (Pb)-Total	0.01	0.000050	mg/L	0.000203	0.00110	0.000111	<0.000050	<0.000050	0.000078	0.000068	0.000076	0.000059	0.000187	0.000086	0.000229	<0.000050	<0.000050	0.000141	<0.000050	0.000059	0.000171	0.0011
Lithium (Li)-Total		0.0010	mg/L	0.0064	0.0067	0.0066	0.0066	0.0065	0.0066	0.0062	0.0064	0.0065	0.0200	0.0065	0.0064	0.0064	0.0065	0.0077	0.0064	0.0069	0.0085	0.02
Magnesium (Mg)-Total		0.0050	mg/L	10.7	11.2	10.9	10.8	11.0	8.30	8.11	8.33	10.1	23.1	10.1	10.1	10.2	10.2	9.91	9.97	10.2	11.6	23.1
Manganese (Mn)-Total		0.00010	mg/L	0.00052	0.00052	0.00079	0.00054	0.00067	0.00183	0.00309	0.00227	0.00080	0.00188	0.00024	0.00150	0.00036	0.00046	0.00137	0.00070	0.00206	0.00713	0.00713
Mercury (Hg)-Total	0.001	0.0000050	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0
Molybdenum (Mo)-Total		0.000050	mg/L	0.000588	0.000609	0.000609	0.000598	0.000596	0.000608	0.000588	0.000624	0.000731	0.000719	0.000680	0.000703	0.000690	0.000714	0.000725	0.000684	0.000737	0.000801	0.000801
Nickel (Ni)-Total		0.00050	mg/L	0.00102	0.00107	0.00116	0.00100	0.00098	0.00095	0.00115	0.00132	0.00114	0.00141	0.00087	0.00091	0.00082	0.00088	0.00112	0.00081	0.00093	0.00094	0.00141
Phosphorus (P)-Total		0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0
Potassium (K)-Total		0.050	mg/L	1.44	1.52	1.45	1.43	1.47	1.42	1.39	1.41	1.56	1.80	1.37	1.41	1.41	1.41	1.84	1.42	1.52	2.13	2.13
Rubidium (Rb)-Total		0.00020	mg/L	0.00120	0.00126	0.00121	0.00120	0.00118	0.00116	0.00114	0.00113	0.00134	0.00155	0.00094	0.00112	0.00104	0.00105	0.00127	0.00102	0.00111	0.00155	0.00155
Selenium (Se)-Total	0.05	0.000050	mg/L	0.000152	0.000117	0.000122	0.000132	0.000135	0.000145	0.000146	0.000125	0.000181	0.000140	0.000128	0.000131	0.000111	0.000113	0.000161	0.000135	0.000120	0.000152	0.000181
Silicon (Si)-Total		0.050	mg/L	1.07	0.831	0.924	1.01	0.908	1.83	1.90	1.87	1.90	1.40	0.758	0.878	0.779	0.773	1.21	0.816	0.943	1.90	1.9
Silver (Ag)-Total		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000026	0.000020	0.000028	0.000025	<0.000010	0.000021	<0.000010	<0.000010	0.000028

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.2 - Post-cleaning, Confirmatory Drinking Water Quality

Client Sample ID				POST-CW	POST-LTS	POST-BH	POST-RES-1	POST-RES-2	POST - ABA	POST - RES 4	POST - RES 5	POST - RES 3	POST - RES 6	TW1	HOSP	RES1	RES 2	RES 3	RES 4	RES 5	RES 6	
Location				Clearwell at Water Treatment Plant	Lower Townsite Reservoir	Beacon Hill Reservoir	Thickwood Reservoir	Timberlea Reservoir	Abasands Reservoir	Mackenzie Park Reservoir	Southeast Pump House	Parsons Creek Reservoir	Anzac Reservoir	Water Treatment Plant	Northern Lights Regional Health Centre	Thickwood Reservoir	Timberlea Reservoir	Parsons Creek Reservoir	Mackenzie Park Reservoir	Southeast Pump House	Anzac Reservoir	Maximum
Date Sampled				7-Jun-2016	7-Jun-2016	7-Jun-2016	7-Jun-2016	7-Jun-2016	27-Jun-2016	27-Jun-2016	28-Jun-2016	30-Jun-2016	30-Jun-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	27-May-2016	27-May-2016	
Parameter	GCDWQ MAC	Lowest Detection Limit	Units	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Sodium (Na)-Total		0.050	mg/L	19.3	19.8	19.6	19.0	19.7	19.8	19.0	19.6	20.9	26.7	19.0	19.8	18.2	18.3	20.7	19.3	19.4	27.7	27.7
Strontium (Sr)-Total		0.00020	mg/L	0.274	0.280	0.284	0.272	0.275	0.247	0.232	0.246	0.272	0.154	0.261	0.258	0.257	0.268	0.261	0.257	0.278	0.340	0.34
Sulfur (S)-Total		0.50	mg/L	12.4	12.9	12.9	12.4	12.8	9.91	9.67	9.80	15.0	15.3	12.5	12.9	12.6	12.7	13.2	12.4	12.5	17.2	17.2
Tellurium (Te)-Total		0.00020	mg/L	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0
Thallium (Tl)-Total		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0
Thorium (Th)-Total		0.00010	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0
Tin (Sn)-Total		0.00010	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0
Titanium (Ti)-Total		0.00030	mg/L	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00142	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00142
Tungsten (W)-Total		0.00010	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0
Uranium (U)-Total	0.02	0.000010	mg/L	0.000048	0.000052	0.000050	0.000047	0.000050	0.000034	0.000027	0.000028	0.000044	0.000028	0.000058	0.000072	0.000058	0.000057	0.000117	0.000068	0.000087	0.000119	0.000119
Vanadium (V)-Total		0.00050	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0
Zinc (Zn)-Total		0.0030	mg/L	0.0077	0.0096	0.0042	<0.0030	<0.0030	<0.0030	0.0055	<0.0030	<0.0030	0.0071	0.0034	<0.0030	<0.0030	<0.0030	0.0072	<0.0030	<0.0030	0.0204	0.0204
Zirconium (Zr)-Total		0.00030	mg/L	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0
Volatile Organic Compounds (Water)																						
Benzene	0.005	0.00050	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0
Tetrachloromethane	0.005	0.00050	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0
Chlorobenzene	0.08	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
1,2-Dichlorobenzene	0.2	0.00050	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.0015	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0
1,4-Dichlorobenzene	0.005	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
1,2-Dichloroethane	0.005	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	<0.0010	<0.0010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0010	<0.0010	0.0011
1,1-Dichloroethene	0.014	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Dichloromethane	0.05	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Ethylbenzene	0.14	0.00050	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0
Tetrachloroethene	0.01	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Toluene	0.06	0.00050	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0
Trichloroethene	0.005	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Vinyl chloride	0.002	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
o-Xylene		0.00050	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0
m+p-Xylene		0.00050	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0
Xylenes	0.09	0.00071	mg/L	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	0
F1(C6-C10)		0.10	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
F1-BTEX		0.10	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Hydrocarbons (Water)																						
F2 (>C10-C16)		0.10	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
F3 (C16-C34)		0.25	mg/L	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0
F4 (C34-C50)		0.25	mg/L	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0
Polycyclic Aromatic Hydrocarbons (Water)																						
Acenaphthene		0.000020	mg/L	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0
Acenaphthylene		0.000020	mg/L	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0
Anthracene		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0
Benzo(a)anthracene		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0
Benzo(a)pyrene	0.00001	0.0000050	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0
Benzo(b&j)fluoranthene		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0
Benzo(g,h,i)perylene		0.000020	mg/L	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0
Benzo(k)fluoranthene		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0
Chrysene		0.000020	mg/L	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0
Dibenzo(a,h)anthracene		0.0000050	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0
Fluoranthene		0.000020	mg/L	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.000075	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.000075
Fluorene		0.000020	mg/L	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0
Indeno(1,2,3-cd)pyrene		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0
Naphthalene		0.000050	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0
Phenanthrene		0.000050	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000182	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000182
Pyrene		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000014	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000014
B(A)P Total Potency Equivalent		0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0
Trihalomethanes (Water)																						
Bromodichloromethane		0.0010	mg/L	0.0013	0.0015	0.0015	0.0013	0.0014	0.0021	0.0016	0.0013	0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0015	<0.0010	0.0015	0.0019	0.0021
Bromoform		0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Dibromochloromethane		0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Chloroform		0.0010	mg/L	0.0384	0.0387	0.0410	0.0395	0.0341	0.0461	<0.0010	0.0388	0.0368	0.0308	0.0265	0.0292	0.0182	0.0188	0.0485	0.0241	0.0428	0.0265	0.0485
Total THMs	0.1	0.0050	mg/L	0.0397	0.0402	0.0425	0.0408	0.0355	0.0482	<0.005	0.0401	0.0381	0.0308	0.0265	0.0292	0.0182	0.0188	0.05	0.0241	0.0443	0.0284	0.05

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Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.2 - Post-cleaning, Confirmatory Drinking Water Quality

Client Sample ID				POST-CW	POST-LTS	POST-BH	POST-RES-1	POST-RES-2	POST - ABA	POST - RES 4	POST - RES 5	POST - RES 3	POST - RES 6	TW1	HOSP	RES1	RES 2	RES 3	RES 4	RES 5	RES 6	
Location				Clearwell at Water Treatment Plant	Lower Townsite Reservoir	Beacon Hill Reservoir	Thickwood Reservoir	Timberlea Reservoir	Abasands Reservoir	Mackenzie Park Reservoir	Southeast Pump House	Parsons Creek Reservoir	Anzac Reservoir	Water Treatment Plant	Northern Lights Regional Health Centre	Thickwood Reservoir	Timberlea Reservoir	Parsons Creek Reservoir	Mackenzie Park Reservoir	Southeast Pump House	Anzac Reservoir	Maximum
Date Sampled				7-Jun-2016	7-Jun-2016	7-Jun-2016	7-Jun-2016	7-Jun-2016	27-Jun-2016	27-Jun-2016	28-Jun-2016	30-Jun-2016	30-Jun-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	27-May-2016	27-May-2016	
Parameter	GCDWQ MAC	Lowest Detection Limit	Units	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Haloacetic Acids (Water)																						
Bromochloroacetic Acid		0.0010	mg/L	0.0018	0.0017	0.0011	0.0012	0.0021	<0.0010	<0.0010	0.0011	0.0010	<0.0010	0.0022	0.0030	0.0036	0.0042	<0.0010	0.0027	0.0020	0.0013	0.0042
Dibromoacetic Acid		0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.001
Dichloroacetic Acid		0.0010	mg/L	0.0200	0.0213	0.0208	0.0210	0.0195	0.0298	0.0307	0.0304	0.0293	0.0230	0.0254	0.0264	0.0221	0.0226	0.0374	0.0237	0.0282	0.0180	0.0374
Total Haloacetic Acids 5	0.08	0.0054	mg/L	0.038	0.0394	0.0394	0.0411	0.0389	0.055	0.0566	0.0565	0.0544	0.0402	0.0532	0.0497	0.0474	0.0469	0.075	0.0517	0.061	0.0304	0.075
Monobromoacetic Acid		0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Monochloroacetic Acid		0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0059	<0.0050	0.0068	0.0059	<0.0050	0.0074	0.0062	<0.0050	0.0074
Trichloroacetic Acid		0.0010	mg/L	0.0180	0.0180	0.0186	0.0201	0.0184	0.0252	0.0259	0.0261	0.0250	0.0172	0.0219	0.0233	0.0185	0.0185	0.0376	0.0206	0.0266	0.0123	0.0376
Semi-Volatile Organics (Water)																						
N-Nitrosodimethylamine	0.04	0.050	ug/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0
Perfluorinated Compounds (Water)																						
Perfluorobutanesulfonate		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Perfluorohexanesulfonate		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Perfluoro-N-Tridecanoic Acid		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Perfluorooctanesulfonate		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
N-Ethylperfluoro-1-Octanesulfonamide		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
2-(N-ethylPF-1-Octanesulfonamido)-EtOH		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
N-Methylperfluoro-1-Octanesulfonamide		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
2-(N-methylPF-1-Octanesulfonamido)-EtOH		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Perfluoro-1-Heptanesulfonate		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Perfluoro-1-Octanesulfonamide		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Perfluoro Decanesulfonate		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Perfluoro-N-Decanoic Acid		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	0
Perfluoro-N-Dodecanoic Acid		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Perfluoro-n-Heptanoic Acid		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Perfluoro-n-Hexanoic Acid		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Perfluoro-N-Nonanoic Acid		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Perfluoro-N-Octanoic Acid		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Perfluoro-n-Pentanoic Acid		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Perfluoro-N-Tetradecanoic Acid		0.0050	ug/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Perfluoro-N-Undecanoic Acid		0.0010	ug/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0
Perfluoro-n-Butanoic Acid				Results for this parameter were not reliable due to contamination of analytical method blanks at the laboratory										<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0
Organochlorine Pesticides (Water)																						0
Aldrin		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Aldrin + Dieldrin		0.020	ug/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0
alpha-BHC		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
beta-BHC		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
gamma-hexachlorocyclohexane		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
delta-BHC		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
a-chlordane		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Chlordane (Total)		0.030	ug/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0
g-chlordane		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
op-DDD		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
pp-DDD		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
o,p-DDE		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
pp-DDE		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
op-DDT		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0
pp-DDT		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
DDT + metabolites		0.040	ug/L	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0
Dieldrin		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
alpha-Endosulfan		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0
beta-Endosulfan		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0
Endosulfan Sulfate		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Endrin		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Endrin Aldehyde		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Heptachlor		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Heptachlor Epoxide		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Hexachlorobenzene		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Methoxychlor		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Mirex		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Oxychlordane		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	<0.010	<0.010	<0.010	<0.010	0
																						0

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.2 - Post-cleaning, Confirmatory Drinking Water Quality

Client Sample ID				POST-CW	POST-LTS	POST-BH	POST-RES-1	POST-RES-2	POST - ABA	POST - RES 4	POST - RES 5	POST - RES 3	POST - RES 6	TW1	HOSP	RES1	RES 2	RES 3	RES 4	RES 5	RES 6	
Location				Clearwell at Water Treatment Plant	Lower Townsite Reservoir	Beacon Hill Reservoir	Thickwood Reservoir	Timberlea Reservoir	Abasands Reservoir	Mackenzie Park Reservoir	Southeast Pump House	Parsons Creek Reservoir	Anzac Reservoir	Water Treatment Plant	Northern Lights Regional Health Centre	Thickwood Reservoir	Timberlea Reservoir	Parsons Creek Reservoir	Mackenzie Park Reservoir	Southeast Pump House	Anzac Reservoir	Maximum
Date Sampled				7-Jun-2016	7-Jun-2016	7-Jun-2016	7-Jun-2016	7-Jun-2016	27-Jun-2016	27-Jun-2016	28-Jun-2016	30-Jun-2016	30-Jun-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	25-May-2016	27-May-2016	27-May-2016	
Parameter	GCDWQ MAC	Lowest Detection Limit	Units	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Herbicides (Water)																						0
Bromoxynil	5	0.50	ug/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0
2,4-D	100	10	ug/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	0
Dicamba	120	12	ug/L	<12	<12	<12	<12	<12	<24	<24	<24	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	0
Dinoseb		1.0	ug/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0
Glyphosate	280	5.0	ug/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	0
MCPA	100	0.50	ug/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0
Picloram	190	19	ug/L	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	0
2,4,5-T		28	ug/L	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	<28	0
																						0
Carbamate Pesticides (Water)																						0
Aldicarb		0.90	ug/L	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	<0.90	0
																						0
Pesticides (Water)																						0
Alachlor		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Ametryn		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Atrazine		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Atrazine+N-Dealkylated Metabolites	5	0.20	ug/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0
Azinphos-methyl	20	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Bendiocarb		0.50	ug/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0
Benzo(a)pyrene		0.010	ug/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0
Carbaryl	90	0.50	ug/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0
Carbofuran	90	0.50	ug/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0
Chlorpyrifos	90	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Cyanazine		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Diazinon	20	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
2,4-Dichlorophenol	900	0.30	ug/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	0
Dimethoate	20	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Diquat	70	1.0	ug/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0
Diuron	150	15	ug/L	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	0
Atrazine Desethyl		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Parathion	50	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Malathion	190	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Diclofop-methyl	9	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Methyl Parathion		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Metolachlor	50	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Metribuzin	80	1.0	ug/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0
Paraquat	7	1.0	ug/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0
Pentachlorophenol	60	6.0	ug/L	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	0
Phorate	2	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Prometon		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Prometryne		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Propazine		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Simazine	10	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Temephos		1.0	ug/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0
Terbufos	1	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Terbutryn		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
2,3,4,6-Tetrachlorophenol	100	1.0	ug/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0
Triallate		0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
2,4,6-Trichlorophenol	5	0.50	ug/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0
Trifluralin	45	0.10	ug/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0
Organic Parameters (Water)																						
Microcystin	1.5	0.20	ug/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0
Nitrilotriacetic Acid (NTA)	0.4	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0
Miscellaneous (Water)																						
Chloramines	3	0.20	mg/L	1.10	1.78	1.74	1.87	1.94	1.60	0.52	0.54	1.21	0.70	1.87	1.66	2.16	2.11	0.30	0.85	1.83	0.60	2.16

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Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.3 Drinking Water Screening for Chemicals of Potential Concern (COPC)

Parameter	Maximum from Available Drinking Water Data (mg/L, unless noted)	Health Canada (2017)			United States Environmental Protection Agency*	•California Environmental Protection Agency	World Health Organization	•Japan Water Works Association	European Environment Commission	Water Quality Australia	Alberta Environment and Parks	British Columbia Ministry of Environment and Climate Change	Ontario Environment and Energy	Quebec Ministry of Environment	Michigan Department of Environment	Retained as a COPC?
		Maximum Allowable Concentration (mg/L, unless noted)	Health Considerations	Comments	Maximum contaminant level (MCL)	Public Health Goal	Guideline Value (mg/L)	Standard Value	Parametric value	Guideline	Tier 1 Groundwater Remediation Guideline for Potable Groundwater Pathway (mg/L)	Source Drinking Water Quality Guideline (mg/L)	Chemical Standards (mg/L)		Residential Health-Based Drinking Water Criteria (mg/L)	
Bacteriological results																
Escherichia coli	No number provided, noted as passed	MAC of None detectable per 100 mL	The presence of *E. coli* indicates faecal contamination and the potential presence of microorganisms capable of causing gastrointestinal illnesses; pathogens in human and animal faeces pose the most immediate danger to public health.													No
Total coliforms	No number provided, noted as passed	MAC of none detectable/100 mL in water leaving a treatment plant and in non-disinfected groundwater leaving the well	Total coliforms are not used as indicators of potential health effects from pathogenic microorganisms; they are used as a tool to determine how well the drinking water treatment system is operating and to indicate water quality changes in the distribution system. Detection of total coliforms from consecutive samples from the same site or from more than 10% of the samples collected in a given sampling period should be investigated.	In a distribution and storage system, detection of total coliforms can indicate regrowth of the bacteria in biofilms or intrusion of untreated water.												No
Conventional Variables																
CaCO3 (total alkalinity)[1]	131	None required	Hardness may have significant aesthetic effects but a guideline has not been established. Public acceptance of hardness may vary according to the local conditions.	Hardness levels between 80 and 100 mg/L (as CaCO3) provide acceptable balance between corrosion and incrustation.	Not listed	Not listed	No guideline established as parameater not of health concern at levels found in drinking-water	Not listed	Not listed	**Total hardness (as calcium carbonate): 200 mg/L** Guideline derivation based on: • difficulty in obtaining a lather with soap; • water with a total hardness (as calcium carbonate) above 200 mg/L can cause a rapid build-up of undesirable deposits, or scale, in hot water pipes and fittings.	Not listed					No
Conductivity (EC)	442 uS/cm	Not listed			Not listed	Not listed	Not listed	Not listed	**2500 µS/cm at 20 °C Indicator parameter**	Not listed	Not listed					No
Dissolved oxygen	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not Listed	No[5]
pH	8.2	7.0–10.54		The control of pH is important to maximize treatment effectiveness, control corrosion and reduce leaching from distribution system and plumbing components.												No
Total dissolved solids (TDS)	251	AO: ≤ 500		Based on taste; TDS above 500 mg/L results in excessive scaling in water pipes, water heaters, boilers and appliances; TDS is composed of calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate and nitrate. Eelvated select ions can results in transient diarrhea												No
Total suspended solids (TSS)	6.6	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not Listed	Yes[2]
Turbidity	1.5 NTU	Conventional and direct filtration: ≤ 0.3 NTU1 Slow sand and diatomaceous earth filtration: ≤ 1.0 NTU2 Membrane filtration: ≤ 0.1 NTU3	Treated water turbidity target from individual filters of less than 0.1 NTU.	Particles can harbour microorganisms, protecting them from disinfection, and can entrap heavy metals and biocides; elevated or fluctuating turbidity in filtered water can indicate a problem with the water treatment process and a potential increased risk of pathogens in treated water.												Yes
Major Nutrients																
ammonia/ammonium	0.519	None required	Levels of ammonia, either naturally present in the source water or added as part of a disinfection strategy, can affect water quality in the distribution system (e.g., nitrification) and should be monitored.	Guideline not necessary, produced in the body and metabolized in healthy people; no adverse effects at levels found in drinking water.												No
nitrate	0.112	45 as nitrate; 10 as nitrate-nitrogen	Methaemoglobinaemia (blue baby syndrome) and effects on thyroid gland function in bottle-fed infants Other: Classified as possible carcinogen under conditions that result in endogenous nitrosation	Systems using chloramine disinfection or that have naturally occurring ammonia should monitor the level of nitrate in the distribution system. Homeowners with a well should test concentration of nitrate in their water supply.												No
nitrite	0.01[a]	3 as nitrite; 1 as nitrite-nitrogen														No
total nitrogen[1] (TKN)	0.631 (calculated based on measure nitrate + nitrite + total ammonia)	Not listed			**10 mg/L is MCL for nitrate + nitrite (both as N) (US EPA 2018)**	10 mg/L as nitrogen due to risk of hematoxicity (methemoglobinemia). The maximum contribution from nitrite should not exceed 1 mg/L as nitrite-nitrogen.	Combined nitrate plus nitrite: The sum of the ratios of the concentrations of each of nitrate and nitrite to its guideline value should not exceed 1.	For Nitrate and Nitrite: 10 mg/L Nitrogen	Not listed	For Nitrate and Nitrite: The sum of the ratios of the concentration of each of nitrate and nitrite to its guideline value should not exceed 1. The health basis is that nitrate and nitrate have a common toxic effect (methaemoglobinaemia).	Not listed					No
phosphorus	0.05[a]	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	AO: 0.01 mg/L B.C. will continue to use the ENV (1985) SDWQG of 0.01mg/L as Health Canada does not have a drinking water guideline for P. A P guideline is recommended to reduce the risks of algal blooms and impairment of drinking water sources during the growing season.	Not listed	Not listed	**63**	No
total organic carbon	4.8	Not listed			Not listed	Not listed	Not listed	**3 mg/L**	Not listed	Not listed	Not listed	4.0 mg/L Studies iindicate that if the total organic carbon levels remained at or below 4.0 mg/L in drinking water sources, the risk of trihalomethane (THM) formation in treated drinking water would likely remain below the THM guideline of 0.1 mg/L established by Health Canada (2009b).	Not listed	Not listed		Yes

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Table C.3 Drinking Water Screening for Chemicals of Potential Concern (COPC)

Parameter	Maximum from Available Drinking Water Data (mg/L, unless noted)	Health Canada (2017)			United States Environmental Protection Agency*	•California Environmental Protection Agency	World Health Organization	•Japan Water Works Association	European Environment Commission	Water Quality Australia	Alberta Environment and Parks	British Columbia Ministry of Environment and Climate Change	Ontario Environment and Energy	Quebec Ministry of Environment	Michigan Department of Environment	Retained as a COPC?
		Maximum Allowable Concentration (mg/L, unless noted)	Health Considerations	Comments	Maximum contaminant level (MCL)	Public Health Goal	Guideline Value (mg/L)	Standard Value	Parametric value	Guideline	Tier 1 Groundwater Remediation Guideline for Potable Groundwater Pathway (mg/L)	Source Drinking Water Quality Guideline (mg/L)	Chemical Standards (mg/L)		Residential Health-Based Drinking Water Criteria (mg/L)	
Major Ions																
calcium[1]	43.6	No guideline required		Guideline value not necessary, as there is no evidence of adverse health effects from calcium in drinking water; calcium contributes to hardness.												No
chloride[1] - dissolved	30.5	AO: ≤ 250		Based on taste and potential for corrosion in the distribution system.												No
fluoride	0.059	1.5	Moderate dental fluorosis (cosmetic effect)	Beneficial in preventing dental caries.												No
magnesium	23.1	No guideline required		Guideline value not necessary, as there is no evidence of adverse health effects from magnesium in drinking water.												No
potassium	2.13	Not listed			Not listed	Not listed	**No guideline required.** Occurs in drinking-water at concentrations well below those of health concern	Not listed	Not listed	Not listed	Not listed					No
sodium[1]	27.7	AO: ≤ 200		Based on taste; where a sodium-based water softener is used, a separate unsoftened supply for cooking and drinking purposes is recommended.												No
sulphate[1] - dissolved	49	AO: ≤ 500	High levels (above 500 mg/L) can cause physiological effects such as diarrhoea or dehydration	Based on taste; it is recommended that health authorities be notified of drinking water sources containing sulphate concentrations above 500 mg/L.												No
Metals																
aluminium	0.216	Operational guideline: < 0.1 (conventional treatment); < 0.2 (other treatment types)	There is no consistent, convincing evidence that aluminum in drinking water causes adverse health effects in humans.	The operational guideline applies to treatment plants using aluminum-based coagulants; it does not apply to naturally occurring aluminum found in groundwater.												Yes
arsenic[1]	0.00027	0.010 ALARA	Classified as a carinogen: lung, bladder, liver, and skin cancer. Other: Skin, vascular and neurological effects (numbness and tingling of extremities)	Based on treatment achievability; elevated levels associated with certain groundwaters; levels should be kept as low as reasonably achievable.												No
barium[1]	0.0602	1	Increases in blood pressure, cardiovascular disease													No
boron[1]	0.091	5	Health basis of MAC: Reproductive effects (testicular atrophy, spermatogenesis) Other: Limited evidence of reduced sexual function in men	MAC based on treatment achievability.												
cadmium	0.0000165	0.005	Kidney damage and softening of bone													No
chromium	0.0002	0.05	Enlarged liver, irritation of the skin, respiratory and gastrointestinal tracts from chromium (VI) Other: Chromium (III) is an essential element	Protective of health effects from chromium (VI).												No
cobalt[1]	0.00015	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No listed	**0.04**	No
copper	0.0759	AO: ≤ 1.0	Copper is an essential element in human metabolism. Adverse health effects occur at levels much higher than the aesthetic objective	Based on taste, staining of laundry and plumbing fixtures; plumbing should be thoroughly flushed before water is used for consumption.												No
iron	0.038	AO: ≤ 0.3		Based on taste and staining of laundry and plumbing fixtures; no evidence exists of dietary iron toxicity in the general population.												No
lead	0.0011	0.01	Biochemical and neurobehavioural effects in infants and young children (under 6 years). Other: Anaemia, central nervous system effects; in pregnant women, can affect the unborn child; classified as probably carcinogenic to humans.													No
manganese	0.00713	AO: ≤ 0.05		Based on taste and staining of laundry and plumbing fixtures.												No
mercury	0.000005[a]	0.001	Health basis of MAC: Irreversible neurological symptoms	Applies to all forms of mercury; mercury generally not found in drinking water, as it binds to sediments and soil.												No
nickel[1]	0.00141	Not listed			Compound listed with no screening value (US EPA, 2018).	0.012 mg/L Not considered a carcinogen; public health goal based on reproductive toxicity.	0.07 mg/L Allergic contact dermatitis is the most prevalent effect of nickel in the general population.	Not listed	20 ug/L Parametric value	**0.02 mg/L** Long-term exposure may result in effects to the kidney and liver. Increased beta-microglobulin concentrations were reported among electroplating workers exposed to high amounts of nickel. Nickel is known to be a common skin allergen and can cause dermatitis, particularly in younger women.	Not listed					No
selenium	0.000181	0.05	Health basis of MAC: chronic selenosis symptoms in humans following exposure to high levels Other: Hair loss, tooth decay, weakened nails and nervous system disturbances at extremely high levels of exposure	Selenium is an essential nutrient. Most exposure is from food; little information on toxicity of selenium from drinking water. Selenium can be found in non-leaded brass alloy where it is added to replace lead.												No
silicon	1.9	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes[2]
strontium[1]	0.34	5 Bq/L	Cancer of the lung, breast, thyroid, bone, digestive organs and skin; leukaemia												**4.6**	No
zinc	0.0204	AO: ≤ 5.0		AO based on taste; water with zinc levels above the AO tends to be opalescent and develops a greasy film when boiled; plumbing should be thoroughly flushed before water is consumed.												No
uranium[1]	0.000119	0.02	Health basis of MAC: Kidney effects (various lesions); may be rapidly reversible after exposure ceases	Based on treatment achievability; MAC based on chemical effects, as uranium is only weakly radioactive; uranium is rapidly eliminated from the body.												No

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Table C.3 Drinking Water Screening for Chemicals of Potential Concern (COPC)

Parameter	Maximum from Available Drinking Water Data (mg/L, unless noted)	Health Canada (2017)			United States Environmental Protection Agency*	•California Environmental Protection Agency	World Health Organization	•Japan Water Works Association	European Environment Commission	Water Quality Australia	Alberta Environment and Parks	British Columbia Ministry of Environment and Climate Change	Ontario Environment and Energy	Quebec Ministry of Environment	Michigan Department of Environment	Retained as a COPC?
		Maximum Allowable Concentration (mg/L, unless noted)	**Health Considerations**	**Comments**	**Maximum contaminant level (MCL)**	**Public Health Goal**	**Guideline Value (mg/L)**	**Standard Value**	**Parametric value**	**Guideline**	**Tier 1 Groundwater Remediation Guideline for Potable Groundwater Pathway (mg/L)**	**Source Drinking Water Quality Guideline (mg/L)**	**Chemical Standards (mg/L)**		**Residential Health-Based Drinking Water Criteria (mg/L)**	
Organics																
anthracene	0.00001^{a}	Not listed			10 mg/L is DWEL, no published MCL	Not listed	Not listed	Not listed	Not listed	Not listed	No guideline required - calculated value is > solubility or > 1,000,000 mg/L				**0.043** Cancer risk, 1 in 100,000	No
B(a)P Total Potency Equivalent	0.00001	0.00001	Sum of individual carcinogenic PAH, standardized to benzo(a)pyrene potency equivalence factor.		Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		No
benzo[a]anthracene^{1,4}	0.00001^{a}	Assessed as B(a)P total potency equivalents			Listed in US EPA 2018 with no published value	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed					No
benzo(a)pyrene (B(a)P)^{4}	0.000005^{a}	0.00004	Classified as a carcinogen, producing stomach tumours.													No
benzo[b]fluoranthene	Not measured	Not listed			Listed in US EPA 2018 with no published value	Not listed	Not listed	Not listed	No value	Not listed	Not listed	Not listed	Not listed	Not listed		No, see report
benzo(b&j)fluoranthene^{4}	0.00001^{a}	Assessed as B(a)P total potency equivalents			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed				**0.0015** Cancer risk, 1 in 100,000	No
benzo[e]pyrene	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
benzo(ghi)perylene^{1,4}	0.00002^{a}	Assessed as B(a)P total potency equivalents			No value (US EPA, 2018)	Not listed	Not listed	Not listed	No value	Not listed	Not listed					No
benzo(k)fluoranthene^{4}	0.00001^{a}	Assessed as B(a)P total potency equivalents			No value (US EPA, 2018)	Not listed	Not listed	Not listed	No value	Not listed	Not listed					No
biphenyl^{1}	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.3**	No, see report
C1_C3 chrysenses/benzo[a]anthracenes^{1}	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
C1-C4 fluoranthenes/pyrenes^{1}	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
C2-C3 fluorenes^{1}	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
C1-C4 phenanthrenes/anthracenes^{1}	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
chrysene^{1,4}	0.00002^{a}	Assessed as B(a)P total potency equivalents			No value (US EPA, 2018)	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed					No
dibenzo(a,h)anthracene^{4}	0.000005^{a}	Assessed as B(a)P total potency equivalents			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed					No
dibenzothiophene^{1}	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
Hydrocarbon fraction F2 (C10-16)^{1}	0.10^{a}	Not listed			Not listed	Not listed	Not guideline developed as Taste and odour will in most cases be detectable at concentrations below those of health concern, particularly with short-term exposure	Not listed	Not listed	Not listed	**1.1**					No
Hydrocarbon fraction F3 (C16-34)^{1}	0.25^{a}	Not listed			Not listed	Not listed	Not guideline developed as Taste and odour will in most cases be detectable at concentrations below those of health concern, particularly with short-term exposure	Not listed	Not listed	Not listed	Not listed					No, insoluble
Hyfrocarbon fraction F4 (C34-50)^{1}	0.25^{a}	Not listed			Not listed	Not listed	Not guideline developed as Taste and odour will in most cases be detectable at concentrations below those of health concern, particularly with short-term exposure	Not listed	Not listed	Not listed	Not listed					No, insoluble
fluoranthene	0.000075	Not listed			Not listed	Not listed	No guideline required. Occurs in drinking-water at concentrations below those of health concern	Not listed	Not listed	Not listed	No guideline required - calculated value is > solubility or > 1,000,000 mg/L				**0.2**	No
fluorene	0.00002^{a}	Not listed			No value (US EPA, 2018)	Not listed	Not listed	Not listed	Not listed	Not listed	**0.94**					No
indeno(1,2,3-cd)pyrene^{4}	0.00001^{a}	Assessed as B(a)P total potency equivalents			No value (US EPA, 2018)	Not listed	Not listed	Not listed	No value	Not listed	Not listed					No
naphthalene^{1}	0.000050	Not listed			No MAC listed. DWEL is 0.7 mg/L, Life-time is 0.1 mg/L	Not listed	Not listed	Not listed	Not listed	Assessed as B(a)P total potency equivalents	**0.47**					No
perylene	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
phenanthrene	0.000182	Not listed			No value (US EPA, 2018)	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.052**	No
pyrene^{1}	0.000014	Not listed			No value (US EPA, 2018)	Not listed	Not listed	Not listed	Not listed	Not listed	0.71					No
retene^{1}	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
Dioxins/Furans																
2,3,7,8-TCDD (Tetrachlorodibenzodioxin)	Not measured	Not listed			3E-08 mg/L Potential Health Effects from Longterm Exposure above the MCL: Reproductive difficulties; increased risk of cancer (US EPA 2018, 2009)	0.05 picograms/L (pg/L) Health Risk Category: Carcinogenicity	Not listed	Not listed	Not listed	Not listed	Not listed					Yes^{3}
Fire Retardants																
ammonium phosphate	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
ammonium polyphosphate	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
ammonium sulphate	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
Cyanide, Total	0.0026	0.2	No clinical or other changes at the highest dose tested												**0.2**	No
diammonium phosphate	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
sodium-ferrocyanide	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}
sodium hexacyanoferrate	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed		Yes^{3}

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.3 Drinking Water Screening for Chemicals of Potential Concern (COPC)

Parameter	Maximum from Available Drinking Water Data (mg/L, unless noted)	Health Canada (2017)			United States Environmental Protection Agency*	•California Environmental Protection Agency	World Health Organization	•Japan Water Works Association	European Environment Commission	Water Quality Australia	Alberta Environment and Parks	British Columbia Ministry of Environment and Climate Change	Ontario Environment and Energy	Quebec Ministry of Environment	Michigan Department of Environment	Retained as a COPC?
		Maximum Allowable Concentration (mg/L, unless noted)	Health Considerations	Comments	Maximum contaminant level (MCL)	Public Health Goal	Guideline Value (mg/L)	Standard Value	Parametric value	Guideline	Tier 1 Groundwater Remediation Guideline for Potable Groundwater Pathway (mg/L)	Source Drinking Water Quality Guideline (mg/L)	Chemical Standards (mg/L)		Residential Health-Based Drinking Water Criteria (mg/L)	
Disinfection By-Products																
chloral hydrate	Not measured	Concentration warrenting investigation: 0.2 mg/L	Exposure levels in Canada far below concentration that would cause health effects; levels above 0.2 mg/L may indicate a concern for health effects and should be investigated.												Not listed	Yes[3]
haloacetic acids (total)	0.075	0.08	Health basis of MAC: Liver cancer (DCA); DCA is classified as probably carcinogenic to humans Other: Other organ cancers (DCA, DBA, TCA); liver and other organ effects (body, kidney and testes weights) (MCA)	Refers to the total of monochloroacetic acid (MCA), dichloroacetic acid (DCA), trichloroacetic acid (TCA), monobromoacetic acid (MBA) and dibromoacetic acid (DBA); MAC is based on ability to achieve HAA levels in distribution systems without compromising disinfection; precursor removal limits formation.												No
haloacetonitriles (Halogenated acetonitriles)	Not measured	Not listed			Not listed	Not listed	0.07 mg/l (70 µg/l) for Dibromoacetonitrile. Not classifiable as to carcinogencicity in humans. Dichloroacetonitrile and bromochloroacetonitrile have been shown to be mutagenic in bacterial assays.	Not listed	Not listed	Data are inadequate to set guideline values for haloacetonitriles in drinking water	Not listed					Yes[3]
halonitromethanes	Not measured	Not listed			Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Yes[3]
N-Nitrosodimethylamine (NDMA) (nitrosamines)	0.05[a]	0.00004	Health basis of MAC: Liver cancer (classified as probable carcinogen)	MAC takes into consideration all exposures from drinking water, which include ingestion, as well as inhalation and dermal absorption during showering and bathing.; levels should be kept low by preventing formation during treatment.												No
trihalomethanes (total)	0.05	0.1	Health basis of MAC: Liver effects (fatty cysts) (chloroform classified as possible carcinogen) Other: Kidney and colorectal cancers	Refers to the total of chlorodibromomethane, chloroform, bromodichloromethane and bromoform; MAC based on health effects of chloroform.												No

Notes:
a - A concentration could not be mesured and the laboratory method detection limit was used for chemical screening.
1 - compound statistically higher (p value <0.05) in the wildfire exposed area, or not detected in background
2 - compound retained as a COPC with no identified screening value
3 - compound not measured but provisionally retained as a COPC
4 - Assessed as Benzo(a)pyrene total potency equivalents
5 - Dissolved oxygen is a quality indicator parameter, itself having no deleterious health outcomes
CFU = colony forming units
AO = aesthetic objective
Bold indicates selected screening value
*US EPA 2009, 2018, and US HDR 2017-2019

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.4 Recreational Water Screening for Chemicals of Potential Concern (COPC)

Parameter	**Athabasca River Max from Wildfire Exposed Stations (mg/L)**	**Recreational Screening Value**						**Selected Drinking Water Screening Value (mg/L, unless indicated)**	**Retained as a COPC?**
		Alberta Environment and Parks, 2018	**Health Canada, 2012**	**United States Environmental Protection Agency**	**World Health Organization**	**European Union**	**Australia**		
		Guideline for Recreation and Aesthetics	**Recreational Water Quality Guideline**	**Recommendations**	**Guideline**	**Guideline**	**Guideline**		
Bacteriological									
Escherichia coli	840 cfu/ 100 mL	**≤ 100 cfu/100 mL** Geometric Mean (30-d interval). A minimum of weekly samples is recommended.	Geometric mean concentration (minimum 5 samples): ≤ 200 E. coli /100 mL. Single sample maximum concentration: ≤ 400 E. coli /100 mL	*Magnitude Recommendation 1* : Geometric mean of 35 cfu/100 ml and statistic threshold value of 130 cfu/100 ml *Magnitude Recommendation 2*: 30 cfu/100 ml and 110 cfu/110	Not listed (insufficient data for guideline development)	Sufficient for inland waters: 900 cfu/100 ml	Not listed	MAC of None detectable per 100 mL (Health Canada 2017)	Yes
Total coliforms	1100 cfu/ 100 ml	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	MAC of **none detectable**/100 mL in water leaving a treatment plant and in non-disinfected groundwater leaving the well (Health Canada 2017)	Yes
Conventional Variables									
$CaCO_3$ (total alkalinity)[1]	120	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Total hardness (as calcium carbonate): **200 mg/L** (Australian Government 2011)	No
Conductivity	323.7 uS/cm	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**2500 µS/cm** at 20 °C Indicator parameter (European Union 2006)	No
Dissolved oxygen	11.48	Not listed	Not listed	Not listed	Not listed	Not listed	Recreational water should have a dissoved oxygen content > 80%. When considered with colour and turbidity, dissolved oxygen is an indicator of the extent of eutrophication of the water body.	No screening value	No[5]
Hardness Total	140				Not listed	Not listed	Not listed		
Dissolved organic carbon	22	Not listed in AEP 2018	Not listed in HC 2012	Not listed	Not listed	Not listed	Not listed		
pH	8.43	**5.0 to 9.0** For waters used in primary contact recreation.	5.0 to 9.0 For waters used in primary contact recreation.	Not listed	Not listed	Not listed	6.5 to 8.5	7.0–10.54 (Health Canada 2017)	No
Total dissolved solids (TDS)	180	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**AO: ≤ 500** (Health Canada 2017)	No
Total suspended solids (TSS)	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes[3]
Turbidity	260 NTU	**AO: Turbidity should not exceed 50 NTU to satisfy most recreational users.**	AO: 50 NTU To satisfy most recreational uses.	Not listed	Not listed	Not listed	Not listed	Conventional and direct filtration: ≤ 0.3 NTU1 Slow sand and diatomaceous earth filtration: ≤ 1.0 NTU2 Membrane filtration: ≤ 0.1 NTU3 (Health Canada 2017)	Yes
Major Nutrients									
ammonia/ammonium	0	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No guideline required	No
nitrate	0.091	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**45 as nitrate;** 10 as nitrate-nitrogen (Health Canada 2017)	No
nitrite	0.0076	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**3 as nitrite;** 1 as nitrite-nitrogen (Health Canada 2017)	No
total nitrogen[1] (TKN)	1.4	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**10 mg/L** is MCL for nitrate + nitrite (both as N) (US EPA 2018)	No
phosphorus	0.43	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	63	No
total organic carbon	23	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	3 mg/L (Japan 2016)	Yes
Major Ions									
calcium[1]	52	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	None required (Health Canada 2017)	No
chloride[1] - dissolved	33	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**AO: ≤ 250** (Health Canada 2017)	No
fluoride	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**1.5** (Health Canada 2017)	Yes
magnesium	15	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No guideline required	No
potassium	3	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No guideline required	No
sodium[1]	26	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**AO: ≤ 200**	No
sulphate[1] - dissolved	42	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**AO: ≤ 500**	No
Metals									
aluminium	6.92	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**Operational guideline:** **< 0.1 (conventional treatment);** **< 0.2 (other treatment types)**	Yes
arsenic[1]	0.00233	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.010** **ALARA**	No
barium[1]	0.159	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**1**	No
boron[1]	0.0647	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**5**	No
cadmium	0.000147	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.005**	No
chromium	0.007	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.05**	No
cobalt[1]	0.00375	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.04**	No
copper	0.00686	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**AO: ≤ 1.0**	No
iron	24	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.005**	Yes
lead	0.00581	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.05**	No
manganese	0.333	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**AO: ≤ 0.05**	Yes
mercury	0.00002078	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.001**	No
nickel[1]	0.009	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.02**	No
selenium	0.00062	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.05**	No
silicon	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes[2]
strontium[1]	0.337	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**4.6**	No
zinc	0.0196	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**AO: ≤ 5.0**	No
uranium[1]	0.00101	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.02**	No
	0.00596			Not listed	Not listed	Not listed	Not listed		

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Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB

Table C.4 Recreational Water Screening for Chemicals of Potential Concern (COPC)

Parameter	Athabasca River Max from Wildfire Exposed Stations (mg/L)	Recreational Screening Value						Selected Drinking Water Screening Value (mg/L, unless indicated)	Retained as a COPC?
		Alberta Environment and Parks, 2018	Health Canada, 2012	United States Environmental Protection Agency	World Health Organization	European Union	Australia		
		Guideline for Recreation and Aesthetics	Recreational Water Quality Guideline	Recommendations	Guideline	Guideline	Guideline		
Organics									
anthracene	0.000000797	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.043**	No
B(a)P Total Potency Equivalent	0.00000392	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.00001**	No
benzo(a)anthracene^{1,4}	0.00000227	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Assessed as B(a)P total potency equivalents	No
benzo(a)pyrene (B(a)P)^{4}	0.00000292	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.00004**	No
benzo[b]fluoranthene	0.00000628	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.0015** Cancer risk 1 in 100,000	No
Benzo(j&k)fluoranthene^{4}	0.000003	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Assessed as B(a)P total potency equivalents	No
benzo[e]pyrene	0.00000711	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
benzo[ghi]perylene^{1,4}	0.00000614	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Assessed as B(a)P total potency equivalents	No
benzo[k]fluoranthene^{4}	0.000003	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Assessed as B(a)P total potency equivalents	No
biphenyl^{1}	0.0000144	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.3**	No
C1-Benzo[a]anthracenes/Chrysenes^{1}	0.0000527	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C2-Benzo[a]anthracenes/Chrysenes^{1}	0.0000855	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C3-Benzo[a]anthracenes/Chrysenes^{1}	0.0000333	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C4-Benzo[a]anthracenes/Chrysenes^{1}	0.0000123	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C1-Benzofluoranthenes/Benzopyrenes^{1}	0.0000323	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C2-Benzofluoranthenes/Benzopyrenes^{1}	0.0000206	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C1-Fluoranthenes/Pyrenes^{1}	0.000101	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C2-Fluoranthenes/Pyrenes^{1}	0.000205	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C3-Fluoranthenes/Pyrenes^{1}	0.000159	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C4-Fluoranthenes/Pyrenes^{1}	0.0000625	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C2-Fluorenes^{1}	0.000146	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C3-Fluorenes^{1}	0.000165	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C3-Naphthalenes^{1}	0.0000933	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C4-Naphthalenes^{1}	0.000232	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C1 Phenanthrenes/Anthracenes^{1}	0.0000265	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C2 Phenanthrenes/Anthracenes^{1}	0.0000738	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C3-Phenanthrenes/Anthracenes^{1}	0.000154	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
C4-Phenanthrenes/Anthracenes^{1}	0.000376	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
chrysene^{1,4}	0.0000179	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Assessed as B(a)P total potency equivalents	No
dibenz[a,h]anthracene^{4}	0.000000407	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Assessed as B(a)P total potency equivalents	No
dibenzothiophene^{1}	0.000000539	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
Hydrocarbon fraction F2 (C10-16)^{1}	0.018	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**1.1**	No
Hydrocarbon fraction F3 (C16-34)^{1}	0.708	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No guideline required based on very low solubility	No
Hyfrocarbon fraction F4 (C34-50)^{1}	0.388	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No guideline required based on very low solubility	No
fluoranthene^{1}	0.00000316	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.2**	No
fluorene	0.00000419	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.94**	No
indeno[1,2,3-cd]pyrene^{4}	0.00000492	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	Assessed as B(a)P total potency equivalents	No
naphthalene^{1}	0.0000421	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.47**	No
perylene	0.0000425	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
phenanthrene	0.00000964	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.052**	No
pyrene^{1}	0.00000756	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.71**	No
retene^{1}	0.000023	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{2}
Dioxins/Furans									
2,3,7,8-TCDD and other PCDD/Fs	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**3E-08 mg/L**	Yes^{3}
Fire Retardants									
ammonium phosphate	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
ammonium polyphosphate	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
ammonium sulphate	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
cyanide	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	**0.2**	Yes^{3}
diammonium phosphate	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
sodium-ferrocyanide	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
sodium hexacyanoferrate	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
Disinfection by-products									
chloral hydrate	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
haloacetic acids	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	0.08	Yes^{3}
haloacetonitriles	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
halonitromethanes	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	No screening value	Yes^{3}
nitrosamines	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	0.00004	Yes^{3}
trihalomethanes	Not measured	Not listed	Not listed	Not listed	Not listed	Not listed	Not listed	0.1	Yes^{3}

Notes:
Bold indicates selected screening value
1 - compound statistically higher (p value <0.05) in the wildfire exposed area, or not detected in background
2 - compound retained as a COPC with no identified screening value
3 - compound not measured but provisionally retained as a COPC
4 - Assessed as Benzo(a)pyrene total potency equivalents
CFU = colony forming units
AO = aesthetic objective
Concentrations listed as total recoverable, unless otherwise listed

GCDWQ MAC = Guidelines for Canadian Drinking Water Quality Maximum Acceptable Concentration
Chemistry results from ALS Reports L1780541, L1789917, L1791994
Bacteriological results as reported by Alberta Health Services ProvLAB